APM Conceptual Design and Cost Estimate Update
Deep Geological Repository Design Report
Crystalline Rock Environment
Copper Used Fuel Container

APM-REP-00440-0001 **August 2011**

SNC-:Lavalin Nuclear Inc.
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Nuclear

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NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

NWMO
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CRYSTALLINE ROCK ENVIRONMENT
COPPER USED FUEL CONTAINER

Submission to

Nuclear Waste Management Organization

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Title

Report
Deep Geological Repository Design – Crystalline Rock, Copper UFC

Project

APM Conceptual Design and Cost Estimate Update

CLIENT: NUCLEAR WASTE MANAGEMENT ORGANIZATION

PROJECT: APM Conceptual Design and Cost Estimate Update

Prepared By: Jonathan Read, P.Eng. _____ **Date** August 2011

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EXECUTIVE SUMMARY

The Nuclear Waste Management Organization (NWMO) is implementing Adaptive Phased Management (APM), Canada's plan for the long-term management of used nuclear fuel. The APM approach encompasses centralized containment and isolation of the used fuel in a Deep Geological Repository (DGR) in a suitable rock formation, such as crystalline rock or sedimentary rock.

In 2009, the NWMO undertook the task to update previously completed conceptual design work related to the APM program. This report on DGR design addresses the present concepts for a used-fuel repository in a crystalline rock environment.

Two used CANDU fuel inventory scenarios are considered: 3.6 million used CANDU fuel bundles (Base Case) and 7.2 million used CANDU fuel bundles (Alternate Case) delivered over 30 and 60 year periods, respectively. A rate of delivery of 120,000 bundles per year for both scenarios has been selected to match the overall operating capacity of the DGR facility. This is equivalent to 333 Used Fuel Containers (UFCs) placed per year. The used fuel will be re-packaged at the DGR's Used Fuel Packaging Plant into baskets which are in turn inserted into UFCs for subsequent placement in the underground repository, as illustrated below.

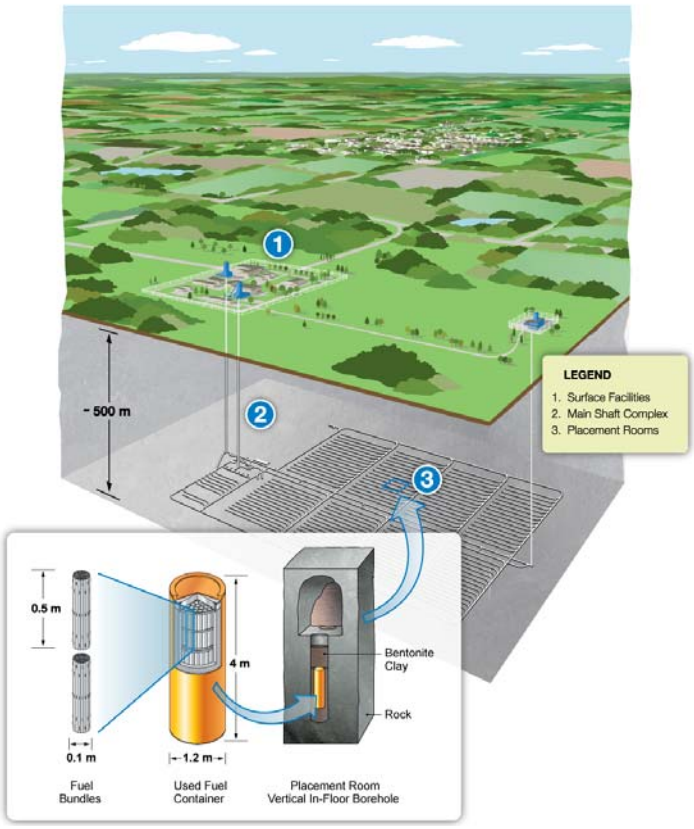


Illustration of APM Deep Geological Repository

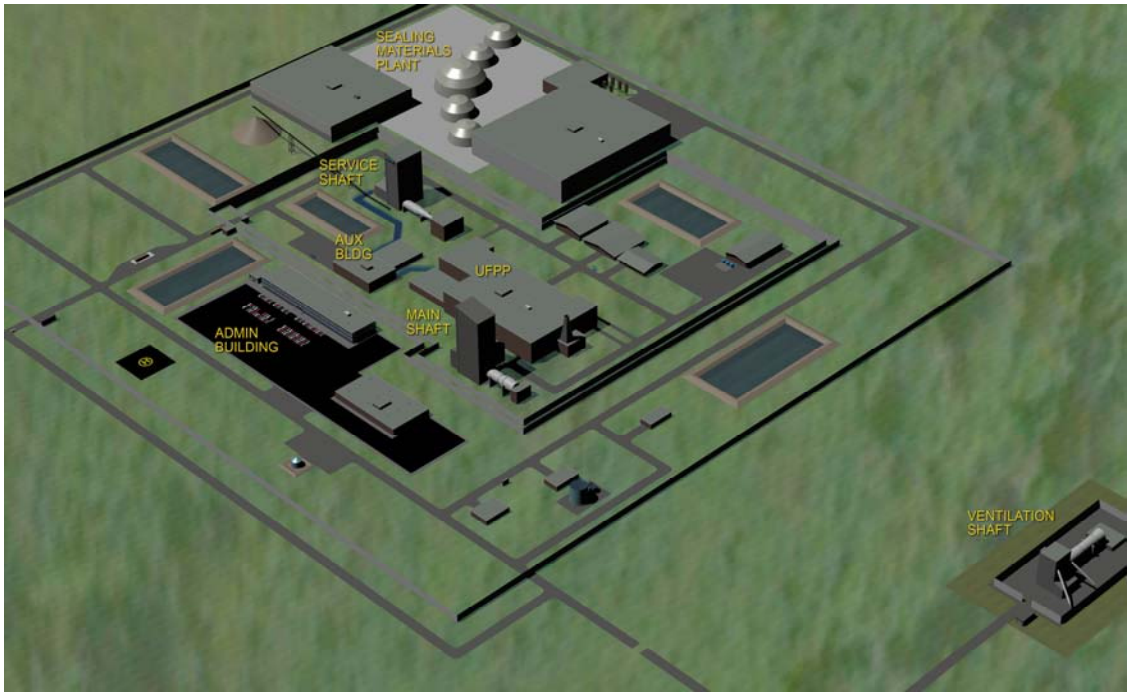
The Base and Alternate Case scenarios are very similar with respect to the core methods and equipment presented for the DGR's operations although the underground layout requirements will double for the Alternate Case. In addition, the longer duration of the Alternate Case will necessitate additional equipment replacement events.

Surface Facilities

The DGR will be a self-contained complex, with facilities provided for operation, maintenance and long-term monitoring. Within this complex, surface facilities are identified as either being in a Protected Area or Balance of Site, the differentiation being that all buildings or activities pertaining to the handling and storage of used nuclear fuel are located in the Protected Area.

Facilities included in the Protected Area comprise, among others, the Used Fuel Packaging Plant, the Main Shaft and Service Shaft complexes, the Auxiliary Building and the Quality Control Offices and Laboratory. Several 'active' waste handling facilities are also found in the Protected Area for the management of liquid and solid residual materials. The remaining significant operations contained in this area include the switchyard, transformer area and powerhouse.

For the Balance of Site, the primary DGR facilities include the Administration Building, Firehall, Security Monitoring Room and Ventilation Shaft complex. Other operations that are part of the Balance of Site include the Sealing Materials Compaction Plant, cafeteria, garage, warehouse, water and sewage treatment plants, and a helicopter pad. Fuel and water storage tanks and an air compressor building are also found in the Balance of Site.



Three Dimensional Perspective of Surface Facilities

External facilities, located outside the DGR's perimeter fences, will further be required for the construction, operation and long-term support of the fuel repository. Such facilities include town and (construction) camp sites, a visitor's centre and a waste rock disposal area.

Used Fuel Packaging Plant (UFPP)

The used nuclear fuel will be received at the DGR from the originating reactor Owners' sites in certified road transportation casks (an Irradiated Fuel Transport Cask or IFTC). The IFTCs will be received at the UFPP where the contained used-fuel bundles will be transferred to the UFCs. The filled UFCs will then be sealed, inspected and dispatched for placement in the underground repository. There will also be provisions for cutting open, emptying and decontaminating any containers that do not fulfill the requirements for long-term disposal.

The UFPP will incorporate two parallel processing lines for receiving and unloading used fuel from the IFTCs and one processing line for handling the UFCs.

Sealing Material Production Plant

Aggregate, concrete batch and sealing materials compaction (SMC) plants are required at the DGR to produce the required repository sealing materials to encapsulate the placed UFCs.

The aggregate plant receives host rock from the waste rock stockpile and produces material for the concrete batch and SMC plants. At the concrete batch plant, aggregate is blended with binders and a water reducing admixture to produce low heat, high performance (LHHP) concrete which is used for the bulkhead seals for the entrances of the filled placement rooms. At the SMC plant, raw materials from the aggregate plant as well as externally sourced lake clay and bentonite are mixed, as appropriate, to produce dense backfill blocks, light backfill, highly compacted bentonite blocks and gap fill. The plant will employ custom designed presses and moulds for manufacturing the compacted bentonite blocks with vacuum suction type lifting devices in place to handle the formed materials.

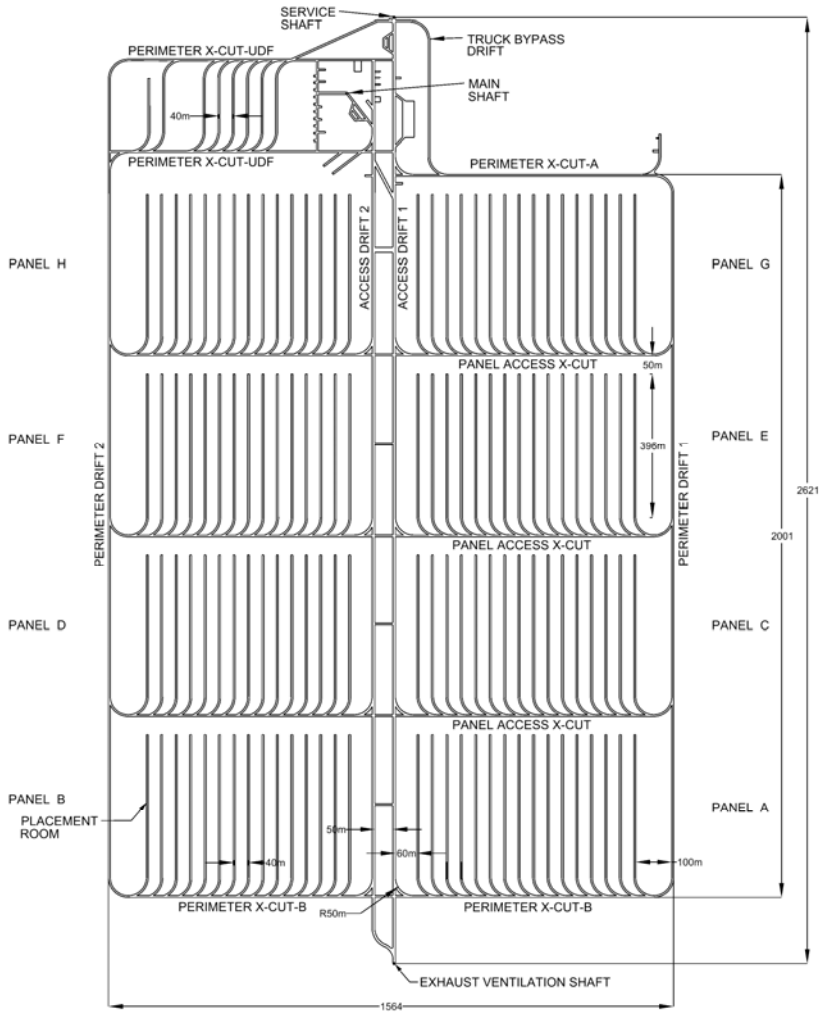
Shafts and Hoists

Three shaft complexes (head frames and hoisting plants) will support the underground development works. The Main Shaft serves as the exclusive conveyance structure for the surface-to-underground transport of the UFCs for placement. Additionally, and when there is a need, the Main Shaft will also accommodate the transfer of any retrieved UFCs to the surface. The Service Shaft is a multi-purpose hoisting facility for the repository, and incorporates the only waste rock handling installation. This combined usage system is set up with five compartments to accommodate two counterbalanced skips, a main service cage and counterweight, and an auxiliary cage for off-shift or secondary egress hoisting. The Ventilation Shaft handles the majority of the repository exhaust and also serves as a secondary means of egress from the underground repository.

Underground Facilities

An Underground Demonstration Facility (UDF) has been designed as a stand-alone testing location near the Main and Service Shafts at one end of the underground repository. The UDF would subsequently expand to encompass the perimeter drifts around the outside of the repository to allow for the study and testing of the host geosphere's rock mass. The UDF would support the long-term demonstration and monitoring of container placement and sealing system tests and provide a potential training area for DGR employees. Test rooms in the UDF can evaluate all important aspects of the underground development.

The following figure illustrates the layout of the underground repository.



UDF and Repository Layout

The UDF development would also provide a range of facilities to support the DGR's operations. Such facilities include:

- Refuge station, offices, washrooms;
- Maintenance shop and warehouse;
- Locomotive charging and maintenance station;
- Fuel bay and equipment/material storage areas;
- Explosives and detonators magazines;
- Main electrical substation; and
- Truck dump equipped with grizzly and rockbreaker.

Development of the UDF would require approximately five years including the perimeter drifts and crosscuts that surround and traverse the used-fuel repository. The test placement rooms would be available for prototype equipment testing five years before the repository is operational.

The intended in-floor placement of UFCs will involve the installation of a single row of UFCs placed in a retreating arrangement within buffer-lined vertical boreholes. Following installation of each individual UFC and buffer within the borehole, the placement rooms are backfilled in a retreating manner towards the entrance of the room.

The basic arrangement of the DGR involves a series of parallel, dead-end placement rooms, organized into panels. All underground openings (access drifts, etc.) will be carried out by controlled drill and blast methods with the exception of the placement boreholes which will be formed with a boring machine. The placement rooms will have an arched shape of nominal dimensions 5.5 m wide by 5.5 m high. Sequencing of the development (excavation) and UFC placement activities will provide for adequate separation of these two major activities from a manpower, ventilation and equipment perspective.

Using, amongst other tools, thermal/mechanical modelling techniques, UFC and room spacings are found to be primarily dictated by requirements to limit the maximum temperature profile of the buffer materials surrounding the UFCs. As presently determined, a proposed UFC spacing of 4.2 m (centre to centre) between placement boreholes and a parallel placement room spacing of 40 m (centre to centre) will be adopted.

On an overall basis, and as illustrated above, the underground repository covers an area of approximately 2,630 m by 1,560 m for the Base Case. For the Alternate Case, this will increase to accommodate the doubled quantities of used fuel bundles.

Underground Ventilation

Three primary airways will be used to ventilate the repository. The Main Shaft will constitute the dedicated fresh air passage and the Service Shaft and Ventilation Shaft will constitute the exhaust air passages. Five primary surface fans will be required to achieve the design flow distribution with a further five underground booster fans in place for adequate flow distribution. A fresh air heating plant, based on a direct-gas-fired heating system using burners placed directly into the airstream will accommodate winter temperatures at surface.

Container Placement and Retrieval

The UFC consists of an outer copper vessel, an inner steel vessel and three steel baskets. The function of the copper vessel is to provide a corrosion-resistant barrier in the repository environment. The inner vessel is designed to withstand any mechanical stresses present in the repository.

The current reference design for the used fuel container, IV-25, holds 360 used-fuel bundles distributed in six layers of 60 bundles per layer. These layers are arranged in baskets that are stacked on top of each other inside the inner vessel (2 layers per basket). To provide structural support, all components are welded together into one integrated basket assembly.

Concepts for the safe transport and placement of the UFCs in the crystalline rock repository have been developed based on a review of similar initiatives and trials actively being pursued by other national radioactive waste management organizations, as well as the practical application of known technologies. The identified concepts, which employ radiation shielding to allow unrestricted movement of personnel, can be refined and demonstrated at mock-up in-floor boreholes at the UDF.

This demonstration work will further encompass the potential retrieval of the UFCs from the repository placement rooms, for subsequent transport to the DGR's surface facilities. The intended retrieval approach allows effective re-use of some of the container placement and mining equipment.

Operational Safety and Radiation Shielding

Both during the operational phase as well as after the last UFC has been placed in the DGR there will be a requirement for monitoring to maintain facility integrity and safety. Key monitoring programs will address:

- Worker occupational health and safety;
- Environmental monitoring at the surface and underground;
- Nuclear material safeguards and radiation protection;
- Site security and emergency response plans; and
- Support systems including fire detection and suppression.

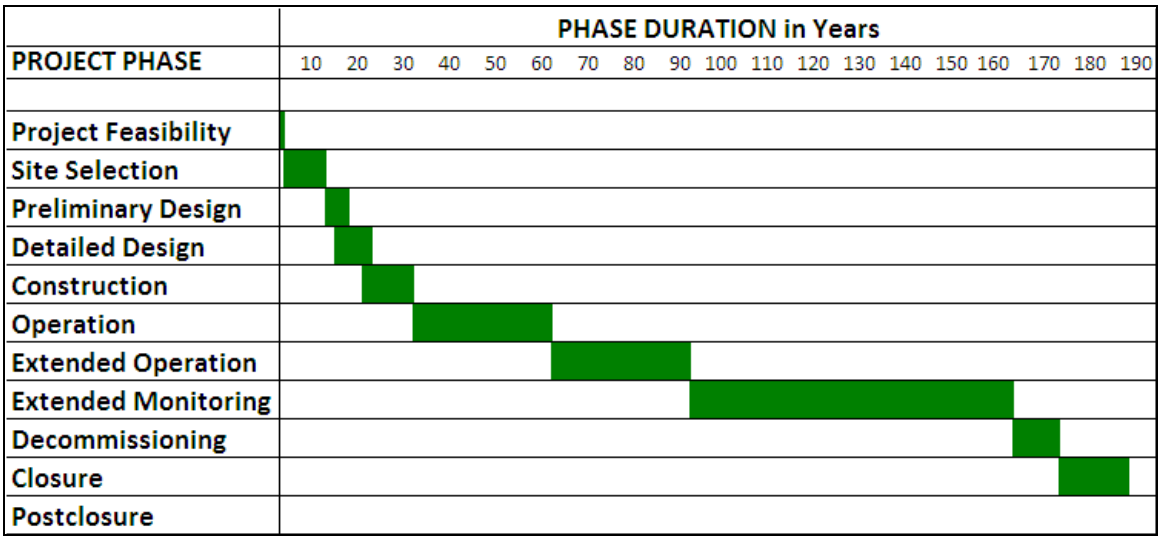
Radiological assessments and scoping calculations have been carried out on selected aspects of the DGR's design elements to help ensure that the potential whole-body dose to facility employees during normal operations at the DGR does not exceed dose limits in the Canadian Nuclear Safety Commission (CNSC) Radiation Protection Regulations. The shielding calculations and analyses were focused on keeping doses As Low As Reasonably Achievable (ALARA) in accordance with CNSC guidance and the most recent recommendations of the International Commission on Radiological Protection.

Decommissioning and Closure

Decommissioning and closure of the facility are the final steps in its active life-cycle, and result in the return of the site to essentially unrestricted surface use. Subsequent to the cessation of used-fuel placement activities for either the Base or Alternate Cases, several stages of post-placement activities will take place, in the following order:

- A 70 year or more extended monitoring period;
- A 10 year decommissioning period;
- A 15 year closure period; and
- A postclosure period.

This sequence of activities is illustrated on the following figure.



Project Lifecycle – Alternate Case

Summary

As presented in this report, the establishment and operation of the DGR's surface works and underground repository is realistic and achievable using currently available technology. The safety of receiving, re-packaging and placing the used nuclear fuel in the repository is well served by the design approaches discussed herein.

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DEFINITIONS AND ACRONYMS

The major terms used in this document are described below:

AECL	Atomic Energy of Canada Ltd.
ALARA	As Low As Reasonably Achievable
ANFO	High impact explosive made of a mixture of ammonium nitrate and fuel oil
APM	Adaptive Phase Management
Backfill	An engineered mixture (solid or loose) designed to infill a void
Basket	Container to maintain the geometry of a used fuel bundle inside a UFC
Bentonite	A clay material used as a sealing material
Borehole	A vertical, horizontal or angled hole drilled into rock
Bulkhead	A concrete stopping / plug
Cage	Shaft conveyance used to move men and material underground
CANDU	Canadian deuterium and uranium
Cask	Mobile container for used-fuel storage or transport (also 'Flask')
CCTV	Closed circuit television
CEAA	Canadian Environmental Assessment Agency
Cluster Drill	Two or more drills combined to establish a larger diameter hole
CNSC	Canadian Nuclear Safety Commission
Collar	The shaft opening at surface and the structure that supports the top of shaft
Crosscut	A tunnel driven at right angles or near right angles to an access tunnel
CRS	Container retrieval system
D&C	Decommissioning and closure
DBF	Dense backfill
DGR	Deep Geological Repository
Drift	Underground tunnel
Drill and Blast	Rock excavation by loading and detonating drill holes with explosive
EBW	Electron beam welding
EDZ	Excavation damage zone
ERT	Emergency Response Team
Flask	Mobile container for used fuel storage or transport
FSW	Friction stir welding
Geosphere	The rock environment the DGR will be located within
GMM	Ground movement monitor
Grizzly	Heavy duty grate to stop oversize rock from falling into a muck pass

HCB	Highly compacted bentonite
Head frame	Tower structure that supports a hoisting operation, situated above the shaft
Heading	A tunnel that is being developed
HEPA	High efficiency particulate air filter
Hoek-Brown	Strength criteria
Hot Cell	Isolated shielded room for radioactive, contaminated material and equipment
HVAC	Heating, ventilation and air conditioning
IAEA	International Atomic Energy Agency
IFTC	Irradiated fuel transport cask
ILW	Intermediate-level waste
Isotropic	Same in all directions
Jumbo	A mechanized drilling machine
kg	Kilogram
kV	Kilovolts
L & ILW	Low and intermediate level waste
LAN	Local area network
LBF	Light Backfill
LHD	Load/haul/dump unit (low-profile version of a surface front end loader)
LHHPC	Low heat high performance concrete
Lifter	Blast hole drilled around the perimeter of the heading
LLW	Low-level waste
Locomotive	Rail mounted diesel or electric vehicle to move transported equipment
m / mm	Metre(s) / millimetre(s)
m^2 / m^3	Square metre(s) / cubic metre(s)
Mbgs	Metres below ground surface
Module	Rack system holding used fuel bundles within a rectangular framework
MPa	Mega pascal (unit of pressure)
MSM	Master slave manipulator for remote handling in radiation shielded areas
Muck	Broken rock
NDT	Non-destructive testing
NEW	Nuclear Energy Worker
NFC	National Fire Code
NFPA	National Fire Protection Agency
NFWA	Nuclear Fuel Waste Act
NWMO	Nuclear Waste Management Organization

OPG	Ontario Power Generation
OSHA	Occupational, Safety and Health Act
OTC	Overhead travelling crane
PA	Protected Area
Permeability	The ability of a rock or soil mass to transport water
Pillar	Rock left in place to separate open areas
Placement Room	Semi-elliptical tunnel used for vertical placement of UFCs in boreholes
PLC	Process logic controller
PPE	Personnel protective equipment
QA/QC	Quality Assurance / Quality Control
Raise	Vertical excavation used for ventilation, or to move personnel via ladders
RDZ	Radiation Defined Zone
RMR	Rock Mass Rating
Rock Bolt	Inserted into a hole and turned to tighten to hold rock around opening in place
Safety Bays	Cut-out in side of tunnel for people to stand when equipment is passing
Scissor lift	Working platform that can be raised and lowered
Shaft	Vertical excavation for the hoisting of personnel, materials and rock
Shotcrete	Concrete sprayed on tunnel surfaces for ground support
SKB-IC	Svensk Kärnbränslehantering AB
SMC	Sealing materials compaction
Swellex	Steel tube pressurized to expand in a drill hole to hold rock in place
TBD	To be determined
TBM	Tunnel boring machine
TC	Transport cask (intra-site)
T-H-M	Thermal-Hydraulic-Mechanical
Transfer Flask	Mobile container enclosing the UFC when transported underground
Trolley	A portable transportation platform used to move equipment on rails
UDF	Underground Demonstration Facility
UFC	Used-fuel container (holds the used-fuel bundles in repository)
UFPP	Used Fuel Packaging Plant
Used Fuel	Irradiated fuel bundles removed from a CANDU nuclear fission reactor
Wi-Fi	Trademark for wide local area network
Working Face	The front end of a tunnel that is being developed
Xactex	Low impact explosive

1. INTRODUCTION

The Nuclear Waste Management Organization (NWMO) is implementing Adaptive Phased Management (APM), Canada's plan for the long-term management of its used nuclear fuel. The APM approach encompasses centralized containment and isolation of the used fuel in a Deep Geological Repository (DGR) in a suitable rock formation, such as crystalline rock or sedimentary rock.

In 2009, the NWMO undertook the task to update the previous conceptual design related to the APM program. This report on the design of the DGR is meant to address concepts for the required facilities and infrastructure needed to safely receive, re-package and place (in an underground repository) the used nuclear fuel as transported from the source reactor storage sites. For the purposes of this report, the repository is assumed to be located in a crystalline rock geosphere.

Two used nuclear fuel inventory scenarios are considered for the conceptual design. Under the Base Case, 3.6 million used CANDU fuel bundles will be delivered to the DGR over a 30 year placement period. The Alternate Case, which assumes (in part) the construction of new nuclear reactors, sees this quantity increased to 7.2 million used CANDU bundles delivered to the DGR over a 60 year period.

Section 3 of this report addresses the proposed surface facilities including the Used Fuel Packaging Plant (UFPP) which is designed to receive and process the incoming used-fuel materials. Section 4 describes the three shafts and hoist systems that will service the underground development. Section 5 provides an overview of this development (test facilities and placement rooms) as well as the supporting ventilation systems. Section 6 deals with the intended procedures to process, re-package and place the used fuel containers (UFCs) into the repository. Section 7 addresses their potential retrieval from the repository. Sections 8 and 9 describe site security features and operational safety and monitoring systems, respectively. Section 10 addresses the issue of decommissioning and closure.

In addition to the main body of this document, two supporting appendices have also been included with this report. Appendix A describes the current plans for the design and manufacturing of the UFCs. Appendix B provides a series of radiation shielding calculations to support the presented design concepts.

1.1 Concurrent Concept Developments in other Countries

At the same time that the NWMO is pursuing the establishment of a repository for used nuclear fuel, several other similar initiatives are also underway in other countries. Organizations in Belgium, Finland, France, Germany, Great Britain, Japan, Sweden, Switzerland and the United States have all made some degree of progress in this regard, all toward the common goal of the safe containment and long-term storage of radioactive waste. The conceptual designs presented in this report have been informed, in part, by the work of these other agencies.

Some of the concepts presently being pursued by the other agencies are described herein.

Andra (France)

The French National Radioactive Waste Management Agency (Andra) has been studying concepts for DGRs since 1991. Primarily targeting low permeability, homogeneous argillaceous clay (shale) deposits at an approximate 500 m depth, secondary studies have also examined repository locations within a granite lithology. Placement room concepts have included the excavation of panels of parallel rooms and horizontally bored tunnels.

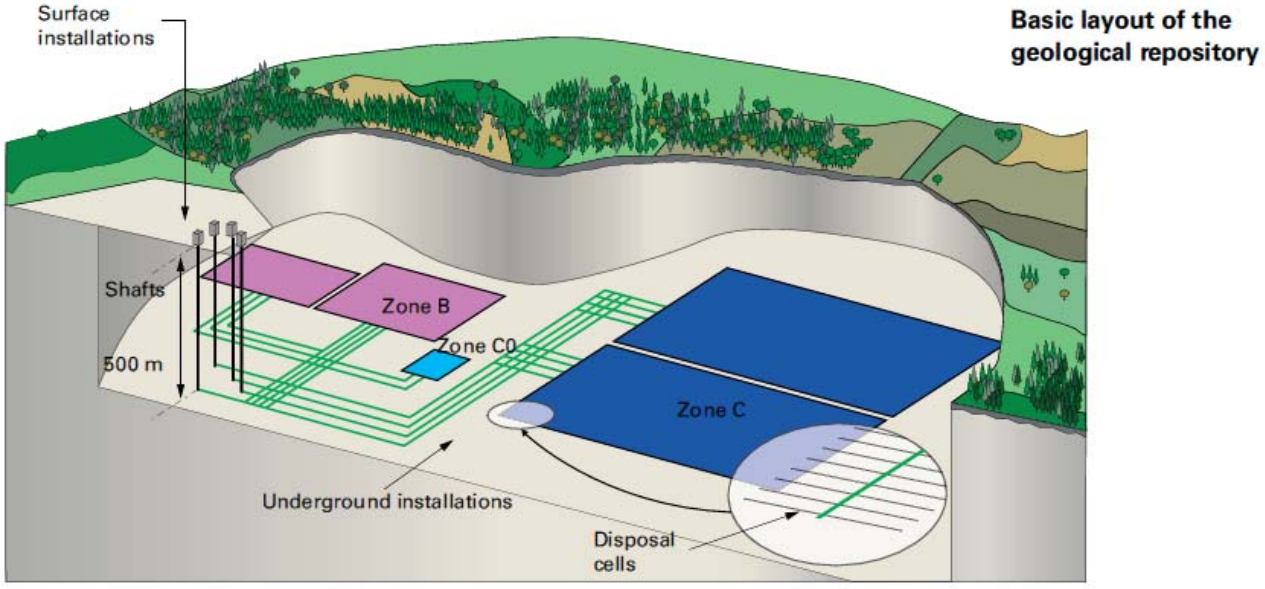


Figure 1: Andra (France) Proposed Repository

Nagra (Switzerland)

The National Cooperative for the Disposal of Radioactive Waste (Nagra) has been carrying out research for the safe disposal of radioactive waste for more than 20 years. Nagra presently operates the Grimsel test site located in granite rock at a depth of about 450 m. Excavations to date have primarily been developed with a full face boring machine. Studies have also been conducted into the feasibility of development within a clay/shale sedimentary lithosphere, accessed by ramp and shaft.

Department of Energy (United States)

The United States Department of Energy began studying Yucca Mountain in 1978 to determine whether it would be suitable for the nation's first long-term geologic repository. In 2002 the site was approved by Congress as a DGR for used fuel and other radioactive waste. The repository, to be constructed at a depth of approximately 300 m within an ignimbrite rock mass, was to be accessed by ramps with shafts developed for ventilation. Waste would be transported by rail underground and placed in a series of parallel rooms.

SKB (Sweden)

Since the 1970's, the Swedish Nuclear Fuel and Waste Management Company (SKB) has had the responsibility for the management and disposal of all radioactive waste from Swedish nuclear power plants. The current disposal concept involves establishing a DGR within a hard rock environment at a 500 m depth. The repository would be accessed by both shafts and ramps and the underground excavations developed by drill and blast methods. The used fuel containers are to be placed within large diameter boreholes either drilled in the floor or side-wall of the repository rooms. In 2009, SKB selected a final site for the DGR.

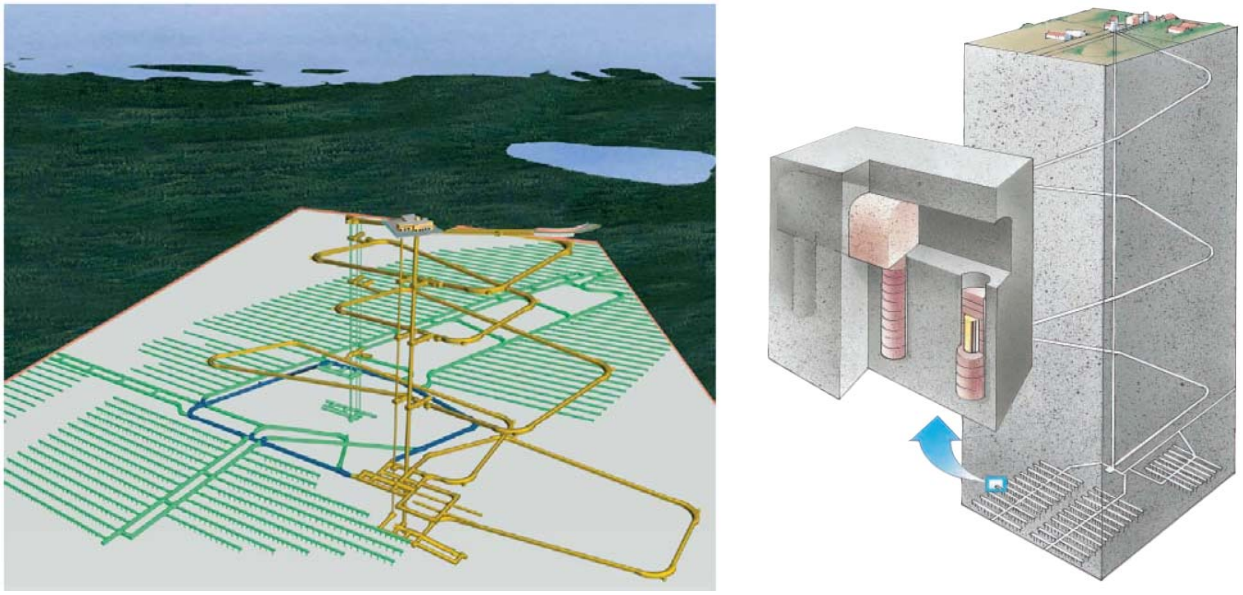


Figure 2: SKB (Sweden) Proposed Repository

NUMO (Japan)

The Nuclear Waste Management Organization of Japan (NUMO), a private consortium, was developed in 2000 to manage the country's current high-level radioactive waste disposal program. NUMO is responsible for carrying out site assessment studies, developing and demonstrating reliable disposal technologies, and obtaining site approval. Repository concepts considered to date include construction at depths greater than 300 m in granite or sedimentary rock environs. Concepts also include shaft access to the DGR with in-floor UFC storage similar to the SKB concept.

NIREX/NDA (Great Britain)

In 1982 the Nuclear Industry Radioactive Waste Management Executive (NIREX) was established with responsibility for disposing of long-lived nuclear waste. In 2006, a Committee on Radioactive Waste Management recommended geologic disposal 200 m to 1,000 m

underground. In recent years, the Nuclear Decommissioning Authority (NDA) has assumed responsibility for the work previously conducted by NIREX and has developed a generic repository concept based on the Swedish (SKB) model but has not yet selected a site.

Posiva Oy (Finland)

Onkalo, Finland is the proposed repository site for the Finnish nuclear industry's waste. Posiva Oy was established in 1995 on behalf of the nuclear waste fuel owners to conduct research into final disposal options for the used fuel and for other nuclear waste management tasks. The present repository design employs a ramp access to a depth of about 500 m. Waste that is transported underground will be placed within bentonite lined boreholes drilled into the floor of storage rooms. In 1999, Poiva Oy selected a final site for a DGR.

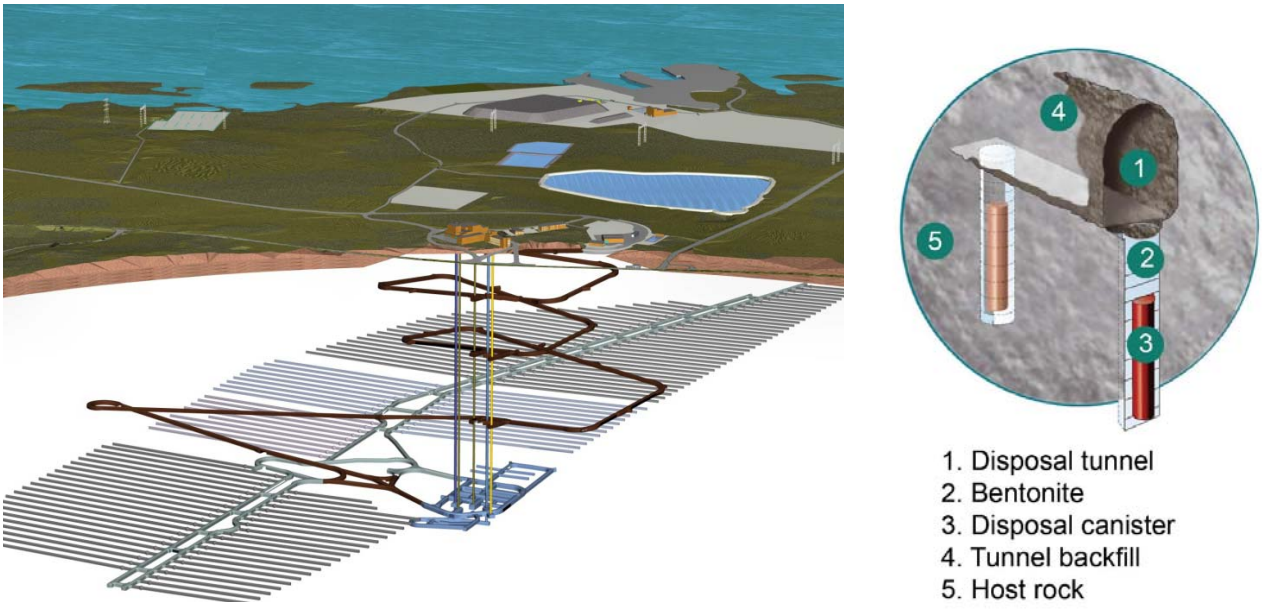


Figure 3: Posiva Oy (Finland) Proposed Repository

ONDRAF/NIRAS (Belgium)

The National Agency for Radioactive Waste and Fissile Materials Management (ONDRAF/ NIRAS) is responsible for the safe management of all radioactive materials in Belgium, including transport, treatment, conditioning, storage and disposal. Belgium's government elected deep geologic disposal in 1998, deciding that deep clay and shale were the most appropriate formations to develop. Generic concepts studied include the construction of a network of concrete lined underground galleries in a poorly indurated layer of clay. Access to the surface would be by shafts.

2. SCOPE AND ASSUMPTIONS

The following sections identify requirements, the main assumptions and design criteria that formed the starting basis for the conceptual design work presented in this document. Battery limits (the scope of analysis) are also discussed.

2.1 Design Requirements

In addition to the numerous technical resources employed (Section 11), various regulations, codes and standards were referenced in the completion of the supporting project work to this report. The primary of such references, which included both domestic and international sources, included the following:

- Nuclear Safety and Control Act (1997, c.9) and associated regulations, Government of Canada;
- Canadian Nuclear Safety Commission (CNSC) (2004). Keeping Radiation Exposures and Doses "As Low as Reasonably Achievable (ALARA)". CNSC G-129 Revision 1;
- CNSC Regulatory Guide G-208 Transportation Security Plans for Category I, II or III Nuclear Material, March 2003 Transport Canada;
- Decommissioning Planning for Licensed Activities (2000). Canadian Nuclear Safety Commission Regulatory Guide G-219;
- International Atomic Energy Agency (IAEA) Safety Reports Series no 45 Standard Format and Content for Safety Related Decommissioning Documents;
- IAEA Safety Standards Series, Regulations for the Safe Transport of Radioactive Material, 1996 Edition (Revised), No. TS-R-1 (ST-1, Revised);
- Transportation of Dangerous Goods Act (1992), including Amendment SOR/2008-34, Department of Transport, Government of Canada;
- Ontario Mining Regulations (Occupational Health and Safety Act, R.R.O. 1990, Regulation 854, Mines and Mining Plants);
- National Fire Code, as set out in the National Building Code and National Fire Protection Association 801;
- Ontario Provincial Standard Specifications (OPSS) for particle size distribution; and
- National Building Code of Canada (2005), National Research Council Canada, http://www.nrc-cnrc.gc.ca/eng/ibp/irc/codes/05-national-building-code.htm.

2.2 Assumptions

The primary assumptions that formed the basis for the conceptual design work included the following:

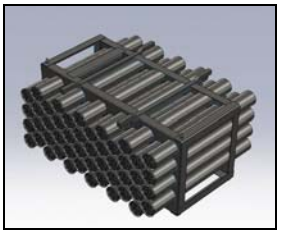
Used-fuel Characteristics

- Two discrete used fuel inventory scenarios are to be accommodated, the Base Case and Alternate Case comprising 3.6 million and 7.2 million used CANDU fuel bundles, respectively;
- Used fuel shipments will occur over 30 years under the Base Case and 60 years under the Alternate Case. All used fuel is to be 30 years out of the reactor prior to shipment;

- The used fuel itself is presented in a used-fuel bundle and transported in storage modules. In the module, 96 fuel bundles are stored in linear pairs in horizontal tubes held in a rectangular framework;



Fuel Bundle



96 Bundle Module

- The used fuel modules are to be transported by road within Irradiated Fuel Transport Casks (IFTCs) to the DGR. IFTCs are discussed in detail in the Transportation Design Report; and
- Each IFTC will hold two used-fuel modules, one stacked on top of the other.

Used-fuel Handling, Packaging and Placement

- A rate of placement equivalent to 120,000 used-fuel bundles per year for both scenarios will be accommodated. This is equivalent to 333 UFCs placed per year (360 used-fuel bundles per UFC);
- The used fuel will be re-packaged at the UFPP into baskets which are in turn inserted into Used Fuel Containers (UFCs) for subsequent placement in the underground repository. Each basket holds 120 used-fuel bundles in two layers of 60 bundles;
- The UFC consists of an outer copper vessel, an inner steel vessel and three UFC baskets;
- Interim storage capacity in the UFPP will be equivalent to six weeks' processing of UFCs (empty and filled) and three months' processing of filled modules;
- Empty modules (used in the delivery of used fuel bundles) will be decontaminated and compacted in a dedicated area within the Used Fuel Packaging Plant (UFPP);
- In the event that filled UFCs are returned from the underground repository (for example as part of a retrieval program), it will be possible to reverse the packaging process in order to cut open and unload the UFCs; and
- The UFPP will be designed with the principle that any anticipated abnormal operational occurrences shall not lead to serious consequences for the environment, personnel or the plant itself.

Used-fuel Repository Setting

- The repository will be located within a high-quality (e.g., sparsely fractured) crystalline rock geosphere;
- The underground development will be constructed at a nominal depth of 500 m below ground surface (shaft bottom allowances for sumps, etc. will be below this elevation);
- The repository's placement rooms and access tunnels will have a minimum stand-off distance to a major fracture of 50 m;
- To the extent practical and necessary, underground openings will be oriented with respect to the in-situ stress fields so as to minimize stress concentration around openings to promote long-term stability and minimize rock support requirements;
- Placement room geometries will be designed to minimize stress levels and excavation damage at the rock surface; and
- Flexibility will be provided in the repository layout so that changes can be implemented if necessary (e.g., due to adverse rock conditions).

Used-fuel Placement and Retrieval

- An in-floor borehole placement method will be utilized for the UFCs in the underground repository;
- Only undamaged, sealed UFCs will be considered for placement and/or retrieval from a borehole location;
- The placement room cross-section will be sized to provide the required clearances for excavation, insertion of sealing materials and UFC placement and retrieval. It will also contribute to excavation stability;
- An in-floor borehole rejection rate of 10% will result from future groundwater seepage ingress rates (increases the number of boreholes required to be drilled);
- UFC placement configurations will ensure that a minimum thickness of 250 mm of bentonite buffer surrounding the UFC does not exceed 100°C;
- Upon completion of each placement room, a seal will be constructed to restrict the potential passage of water via the excavation damage zone (EDZ);
- Open access to the sealed placement room entrances will be available during any UFC retrieval undertaking; and
- Drift access equipment must not mechanically disturb the placed UFCs.

Radiation Shielding

- CNSC Radiation Protection Regulations will be met which prescribe a maximum effective (whole body) dose of 1 mSv/a to a member of the general public and 100 mSv per 5 year dosimetry period (with not more than 50 mSv in any single year) to a Nuclear Energy Worker;
- Permanent and temporary radiation shielding systems will be designed to ensure that doses are maintained As Low As Reasonably Achievable (ALARA) during both normal operations and anticipated abnormal operational occurrences;
- Shielding will be integrated into the design of structures, equipment and containers as required and the use of remote handling techniques will be maximized; and
- In order to simplify construction, maintenance and operations, shielding will be comprised of ordinary materials (e.g., concrete) wherever possible and be designed for easy decontamination of exposed surfaces.

Supporting Operations

- The DGR will be readily accessible by road (within 25 km of a major highway) and within close proximity to power and water sources (within 10 km of a regional power grid);
- A maximum of two UFCs will be placed in the repository per day, being transported in a horizontal position on railcars from the UFPP;
- A hoisting speed of not more than 2.5 m/s will be used for UFC haulage;
- The shaft complexes will provide varying levels and periods of usage both before and after the used-fuel placement period;
- Waste management facilities will be capable of safely and efficiently handling, treating and packaging any generated low and intermediate level (non-fuel) waste prior to final, long-term management off-site;
- Ventilation for the underground repository will provide effective dilution of excavation contaminants (e.g., vehicle exhaust) and dissipation of heat to provide a comfortable working environment, one kept under positive pressure; and

- Raw material inventories will be adequate to compensate for any delivery delays due to adverse weather conditions.

Decommissioning and Closure

- After placement is complete there will be a period of about 70 or more years during which underground access will be maintained and the placement rooms will be monitored;
- During this extended monitoring period, the capability will be maintained to recover the used fuel bundles; and
- Final closure characteristics will be as close to natural conditions as practical with no provision allowed for re-entry underground.

2.3 Battery Limits

The scope of analysis of the Deep Geological Repository Design Report spans the receipt and internment of the used nuclear fuel as transferred from the originating reactor storage sites.

The battery limits for the design work are essentially represented by the DGR's perimeter fence systems, which encompass practically all of the design elements outlined in this report with two minor exceptions. The first exception relates to the external site facilities discussed in Section 3.15 (e.g. the Waste Rock Disposal Area). The second exception relates to some of the radiation shielding calculations presented in Appendix B. Two sets of these calculations are associated with used-fuel transportation functions which are external to the DGR complex.

3. SURFACE FACILITIES AND INFRASTRUCTURE

The DGR is a self-contained complex, with facilities provided for operation, maintenance, and long-term monitoring. Within this complex, surface facilities are identified as either being in a Protected Area or associated with the Balance of Site, the differentiation being that all buildings or activities pertaining to the handling and storage of used nuclear fuel are located in the Protected Area. The two areas, while occupying the same geographic location, are separated for safety and security reasons.

External facilities, located outside the DGR's perimeter fence, are also required for the construction, population and long-term support of the repository. Such facilities include town and (construction) camp sites as well as a visitor's centre.

The following section describes the primary surface facility components with the exception of the underground shafts and the site security features. The three shafts (Main Shaft, Service Shaft and Ventilation Shaft) are discussed in Section 4. Site security measures (fencing, security checkpoints, guardhouses and monitoring rooms) are described in Section 8.

3.1 Site Layout and Staffing

The DGR's site layout is shown in Figure 4 with component facilities identified in Table 1. As illustrated, and as discussed in subsequent sections, the facility is laid out such that all buildings which handle or store used nuclear fuel are located in a Protected Area. This area is separated from other surface facilities by a security fence, equipped with lighting and intruder detection systems. Personnel and vehicular access to the Protected Area will be strictly controlled by way of checkpoints and security gates provided with radiation monitors. Issues regarding site security are addressed in Section 8.

The layout of the buildings provides for the safe and efficient operation of the facility in terms of radiological zoning, material movement, traffic patterns and interaction between the services provided by the different buildings. The Service Shaft, Ventilation Shaft and the Main Shaft are the anchor points for the DGR's layout. The distance between the UFPP and Main Shaft, for example, was kept to a minimum to accommodate the delivery of the UFC transfer casks by way of a trolley and covered rail line. The Auxiliary Building and Sealing Materials Compaction Plant are positioned either inside of, or near to the Protected Area to facilitate the transfer of personnel and materials, primarily to the Service Shaft.

The land required to accommodate the DGR covers an area of approximately 550 m x 600 m. An additional fenced zone needed for the Ventilation Shaft is located about 2 km distant from the main complex (see Figure 4). As the UFPP stack is the only significant potential source of airborne emissions, there are no requirements for an additional exclusion zone.

A three dimensional perspective of the repository is provided as Figure 5.

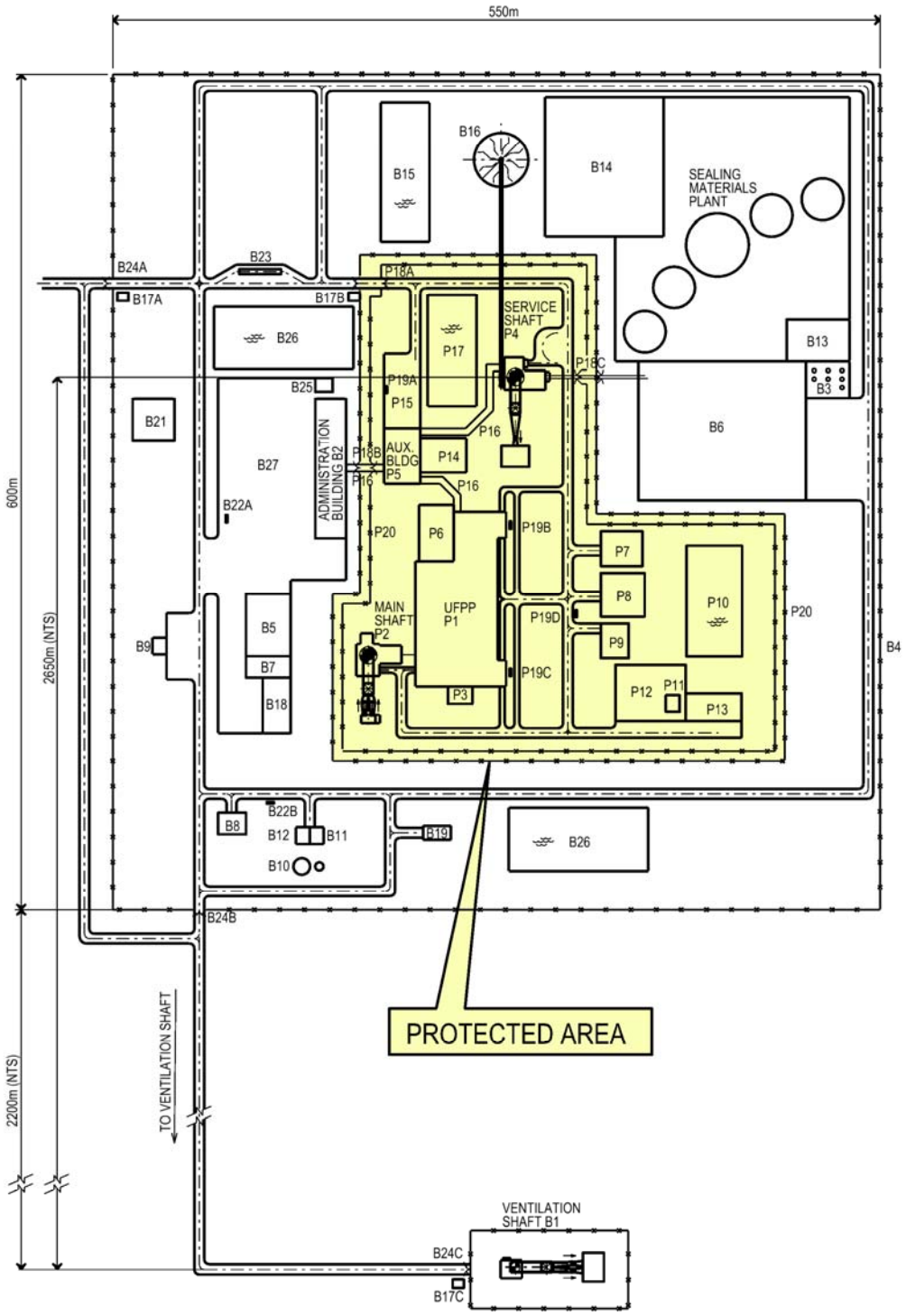


Figure 4: Site Layout Areas

Table 1: Area Number and Description

Area	Protected Area	Area	Balance of Site
P1	Used Fuel Packaging Plant	B1	Ventilation Shaft Complex
P2	Main Shaft Complex	B2	Administration Building including Firehall and Cafeteria
P3	Stack	B3	Sealing Material Storage Bins
P4	Service Shaft Complex	B4	Perimeter Fence
P5	Auxiliary Building	B5	Garage
P6	Active Solid Waste Handling Facility	B6	Sealing Materials Compaction Plant
P7	Waste Management Area	B7	Warehouse and Hazardous Materials Storage Building
P8	Active Liquid Waste Treatment Building	B8	Air Compressor Building
P9	Low-Level Liquid Waste Storage Area	B9	Fuel Storage Tanks
P10	Stormwater Detention Pond	B10	Water Storage Tanks
P11	Switchyard	B11	Water Treatment Plant
P12	Transformer Area	B12	Pump House
P13	Powerhouse	B13	Concrete Batch Plant
P14	Quality Control Offices and Laboratory	B14	Aggregate (Rock Crushing) Plant
P15	Parking Area	B15	Process Water Settling Pond
P16	Covered Corridor / Pedestrian Routes	B16	Waste Rock Stockpile
P17	Mine Dewatering Settling Pond	B17	Guardhouse
P18	Security Checkpoint	B18	Storage Yard
P19	Bus Shelters	B19	Sewage Treatment Plant
P20	Double Security Fence	B20	Not Used
		B21	Helicopter Pad
		B22	Bus Shelters
		B23	Weigh Scale
		B24	Security Checkpoints
		B25	Security Monitoring Room
		B26	Stormwater Detention Ponds
		B27	Parking Area

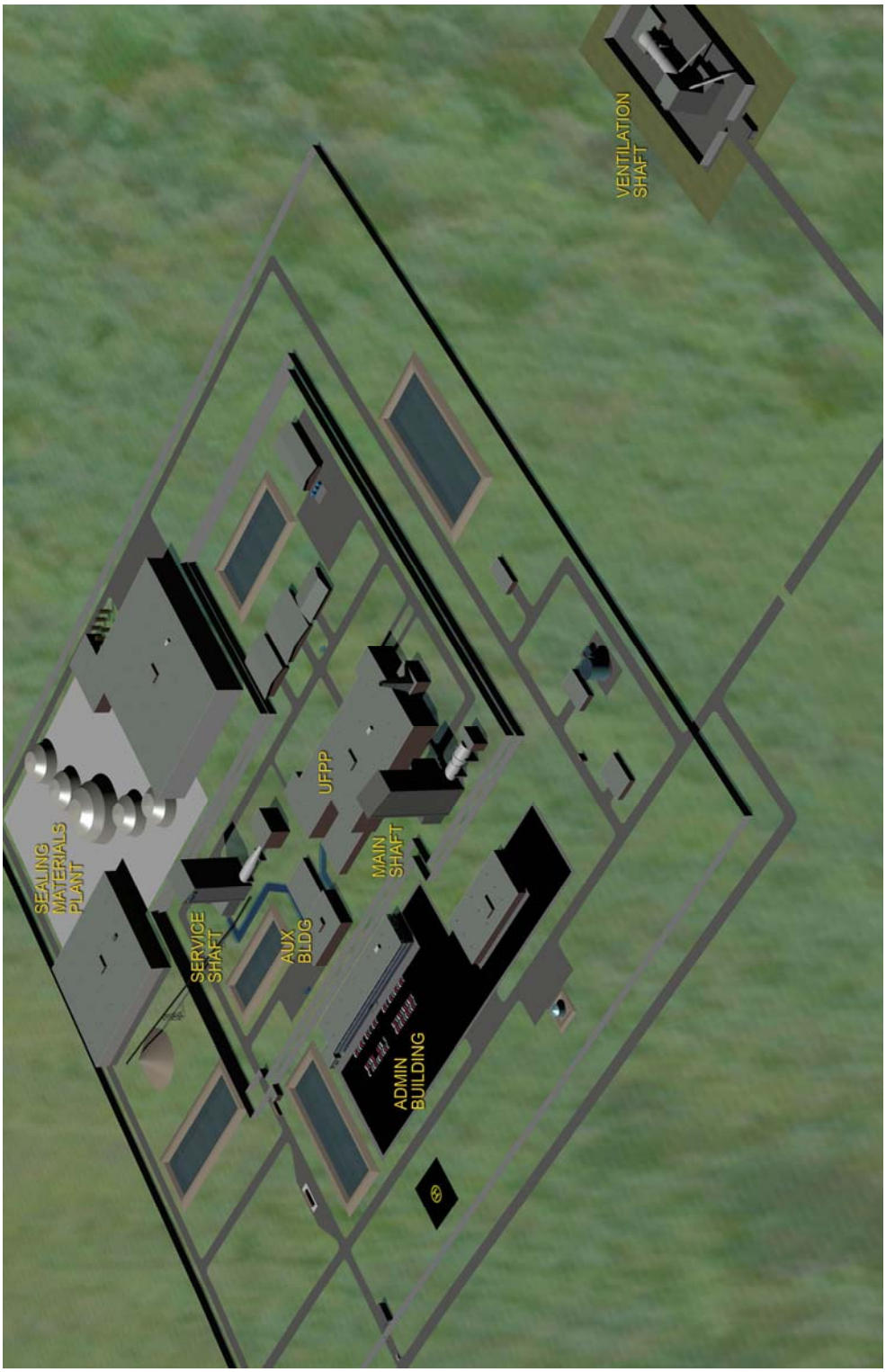


Figure 5: Three Dimensional Perspective

Anticipated staffing levels associated with the operation of the DGR are indicated in Table 2.

Table 2: Anticipated Site Staffing Levels

Staffing	Direct Operations	In-direct Operations	O&M Operations	Used Fuel Packaging Plant	Underground Development	UFC Transport and Place	Total
Senior Management	8						**8**
Line Management	12	13					**25**
Superintendent/Foremen		6	8		9	6	**29**
Technical (engineers, technicians)	120	22		14	13	6	**175**
Maintenance			20	8	14	6	**48**
Operations				73	18	33	**124**
Administration	10	22	4		2		**38**
Health Services/Safety/Security		124			3		**127**
Site Support		80	30				**110**
Sub-Total	**150**	**267**	**62**	**95**	**59**	**51**	**684**

- Direct Operations includes additional NWMO staffing of 40 persons (to those developed by SNC/Golders);
- In-direct Operations includes conventional safety in the Health Services/Safety/Security totals. Health physics are included in Technical numbers;
- UFC Transport and Place includes all labour for sealing material preparation plus that to place the UFC's.

3.2 Administration Building including Firehall and Cafeteria Area B2

The Administration Building (Area B2 on Figure 4) will be the first building that visitors and most staff will encounter when coming to the DGR. Equipped with full fire protection and monitoring systems, the building will be divided into three main areas: the administrative offices, a cafeteria and the firehall. The two-storey structure will provide for up to 200 full-time staff (see Table 2).

Employees working at the DGR will enter through the parking area adjacent to the building and proceed to their respective locker spaces or to the Auxiliary Building (Section 3.3). Protective clothing (for those working outside of the Protected Area) and civilian clothing will be stored in separate lockers. The lockers will be of sufficient size to accommodate safety hats, boots and overalls. Provision will be made for locker space for site visitors including inspectors and government officials. Showers will also be in place.

The cafeteria will provide sit-down areas with a serviced hot kitchen for continuous full meal services.

The firehall (supported by the Security Monitoring Room - see Section 8.1) will be equipped with detection and monitoring equipment for any fire hazards or smoke from any of the DGR's operations. Firefighters will be on duty each shift with other fire team members on standby in the event of an emergency. Two large municipal fire trucks will be available with telescopic ladders, hoses, pumps and all fire-fighting tools.

The main administrative office area will have offices for senior management and key staff, boardrooms for meetings and training sessions, and cubicles for other supervisory or technical personnel. Offices will have full internal and external communications facilities, as required, including internet, telephone, two-way radio systems and wired networks. Additional facilities at the Administration Building will include:

- Transportation and logistics coordination centre equipped with display monitors for the real time tracking of used-fuel transport trucks;
- Procurement area to serve as the central procurement department for all on-site equipment and consumables;
- IT and communication facilities, connected to a rooftop-mounted satellite dish;
- Health & Safety training room and offices to be used for the training of employees and the orientation of visitors to the DGR; and
- Nursing station and first aid room with consultation rooms and a doctor's office. A full-time nurse practitioner will be on duty for all shifts.

3.3 Auxiliary Building Area P5

The Auxiliary Building is situated adjacent to the border of the Protected Area and provides facilities for surface operations staff who work primarily in the Protected Area. It is connected by covered walkways (Section 3.13) to the UFPP, the Service Shaft complex, and the Administration Building.

This building is located as central as possible to the UFPP and Service Shaft to reduce the distance for personnel to walk, and also to minimize the extent of needed covered walkways. Manpower to be accommodated in the Auxiliary Building will be about 50 to 60 persons, as previously noted in Table 2.

The Auxiliary Building will be a two-storey structure and be equipped with full fire protection and radiation monitoring systems. The building will include the following facilities:

- Operational management areas consisting of offices and meeting rooms equipped with voice, video, and data connections;
- First Aid station to meet all Occupational Health and Safety Act requirements;
- Change rooms, lockers, washrooms and shower facilities for staff and visitors accessing the Protected Area. Lockers will be in place to accommodate safety hats, boots, overalls and protective suits;
- Laundry facilities for all laundry needs exclusive to the Protected Area; and

- Protected Area cafeteria, provided to minimize the movement of personnel into or out of the Protected Area during shifts. This cafeteria will be supported by the main cafeteria in the Administration Building, with foods being prepared and delivered on an as-required basis.

3.4 Used Fuel Packaging Plant (UFPP) Area P1

The used-fuel packaging plant (UFPP) is identified as Area P1 on Figure 4. This multi-storey reinforced concrete structure will include all necessary provisions for receiving empty UFCs, receiving used-fuel bundles in IFTCs, transferring used-fuel bundles from the IFTCs to the UFCs, and sealing, inspecting and dispatching filled containers for placement in the DGR. There are also provisions for cutting open, emptying and decontaminating any UFCs that do not fulfill the requirements for the repository.

Empty containers will be produced off-site at a dedicated UFC factory, with used-fuel loading and final processing to complete an intergrated filled container conducted in the UFPP. Reference should be made to Appendix A for a discussion of the copper/steel UFC's design and fabrication.

The UFPP is a three-storey reinforced concrete structure. All fuel is received in IFTCs that are transported on trailers. Empty UFCs are also transported to the UFPP on trailers, and filled UFCs are dispatched to the repository in shielded casks that are transferred from the plant in a horizontal position on a rail wagon.

There are two parallel processing lines for receiving and unloading IFTCs, and one processing line for UFCs. The processing line for UFCs is designed so that several containers can be in process simultaneously. Key data for the UFPP throughput is provided in Table 3. The UFPP also includes required auxiliary systems, such as ventilation, electrical power systems, a central control room, waste treatment areas, and facilities for personnel and visitors.

Table 3: Key Data for the UFPP Throughput

	Bundles per Unit	Throughput			
		Base Case Total	Alternate Case Total	Annual	Daily
Bundles	1	3,600,000	7,200,000	120,000	522
Modules	96	37,500	75,000	1,250	5.43
IFTC	192	18,750	37,500	625	2.72
UFC	360	10,000	20,000	333	1.45

Several conceptual design sketches, Figures 6, 7 and 8, are provided on the following pages to illustrate the anticipated layout of the UFPP.

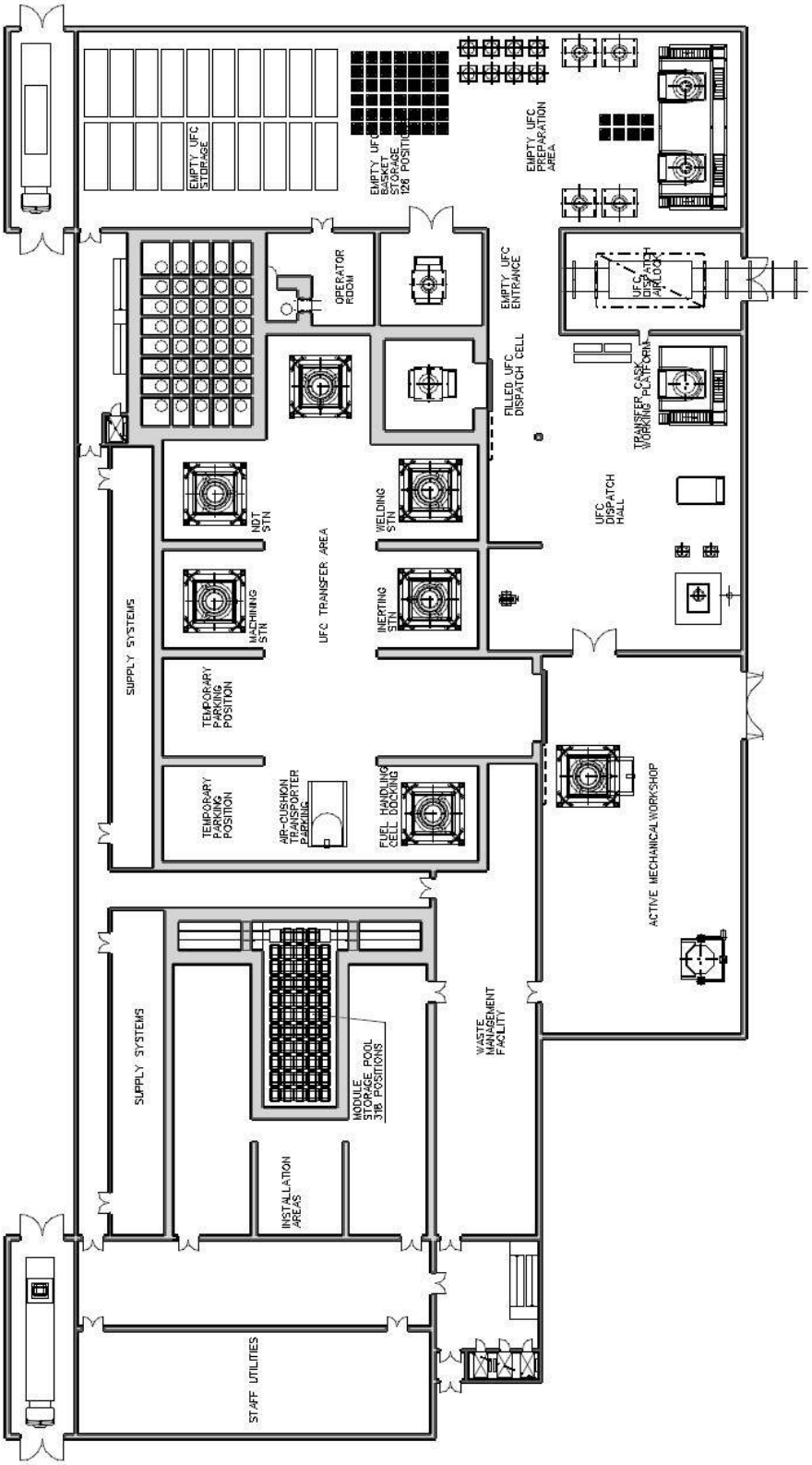


Figure 6: Used Fuel Packaging Plant – Transfer Level

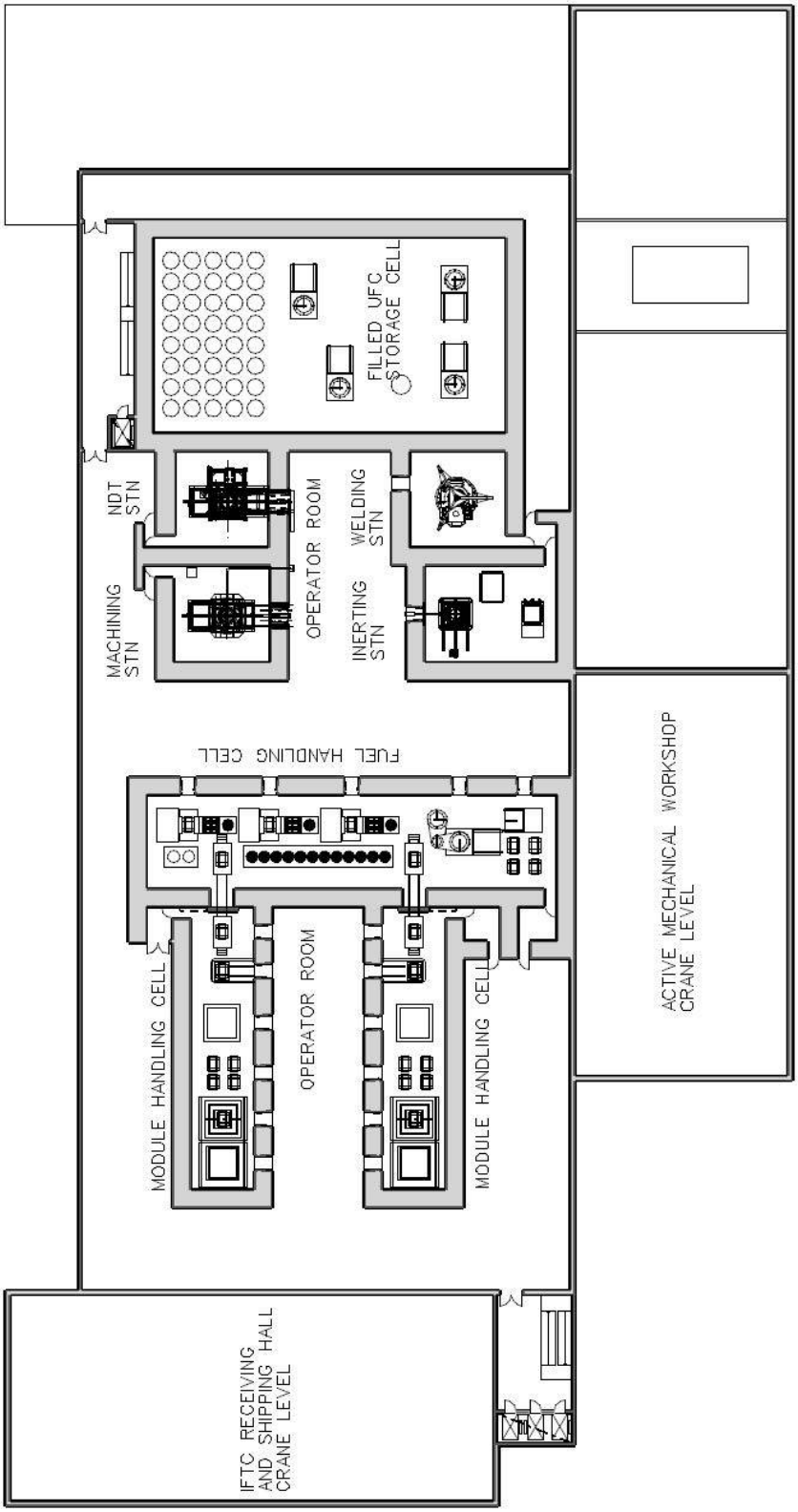


Figure 7: Used Fuel Packaging Plant – Operation Level

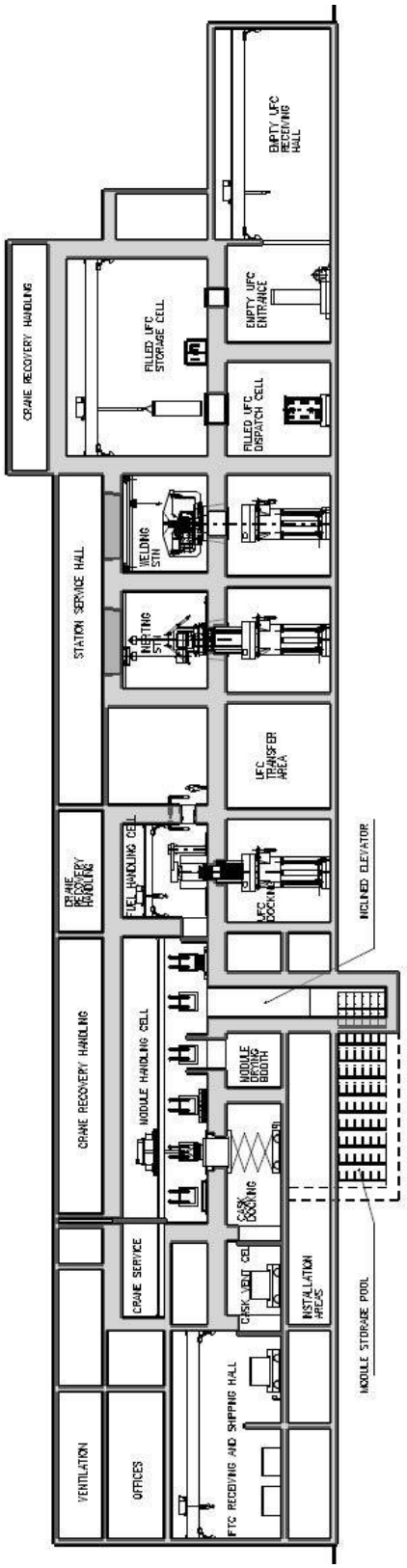


Figure 8: Used Fuel Packaging Plant – Cross-Section

Most steps in the packaging process are remotely operated. However, after removal of the radiation source and remote decontamination, all areas can be accessed by maintenance personnel. Areas and equipment handling used-fuel bundles and filled UFCs are radiation shielded. Docking arrangements to cells and stations include containment hatches and gamma gates that minimize the spread of airborne activity and protect personnel from high radiation fields at all times. The fuel receiving and transfer area will be kept at a negative pressure to prevent the spread of airborne contamination.

3.4.1 Transport Cask (IFTC) Receipt And Unloading

The main areas and equipment for receiving and unloading the IFTCs are described below.

IFTC Receiving and Shipping Hall

The IFTC receiving and shipping hall is a dedicated area with equipment and space for receiving filled IFTCs and dispatching empty IFTC's for return to the reactor sites. The hall is accessed from the outside through a port that leads into a transport airlock, where trailers with IFTCs are parked upon arrival to the plant. The roof of the transport airlock is retractable so that casks can be lifted from the trailer and transferred into the receiving and shipping hall using a 40 tonne overhead travelling crane (OTC). Within the receiving and shipping hall, there are 12 positions for temporary storage of empty or filled casks, and an area for placement of impact limiters during cask unloading operations.

There are two parallel processing lines for handling and unloading transport casks, once they have been lifted out of the airlock. Each processing line begins with a filled cask being lowered onto one of two transfer pallets, either directly from the airlock or from a storage position.

IFTC Transfer Pallets

Two motorized cask transfer pallets, on rails, are used for IFTC transfer. Each pallet is used for transferring casks between: the receiving and shipping hall; a cask vent cell; and, a docking position below a module handling cell. The transfer pallets are equipped with a scissor lift to enable the cask to be raised and docked with the module handling cell.

IFTC Vent Cells

Adjacent to the receiving and shipping hall, there are two parallel, manually operated cask vent cells that are accessed via sliding ports. The purpose of the cask vent cells is to facilitate venting of the IFTCs and removal of the lid bolts as part of the receiving operations. During dispatch of empty casks, the cells are used for replacing and fastening lid bolts, pressure testing lid seals, monitoring for surface contamination and, if necessary, decontaminating casks and transfer pallets. From each cask vent cell, there is also a sliding port to a transfer area located below an adjacent module handling cell.

Module Handling Cells

Two parallel module handling cells are used to unload modules from the IFTCs. The cells are radiation shielded, and all equipment is remotely operated. The cells are also equipped with lead glass windows, master slave manipulators (MSMs) and vacuum cleaners.

To enable unloading of the modules, each cell has a docking port that leads down to a transfer area for the cask transfer pallet. The docking port is equipped with a gamma gate for radiation shielding and an airtight containment door/enclosure that, together with the cask lid, can be remotely lifted into the cell (to minimize the probability of contaminating the outer surface of the IFTC's lid).

Each module handling cell is equipped with a crane for lifting and transferring modules between all applicable positions in the cell. Within the cell, there are four positions for temporary storage of the modules, and one position for placing the containment door and lid during unloading.

Since the fuel must be dried to a level required for long-term safety in the DGR, the module handling cell also includes a drying booth. This is expected to be necessary only for fuel that has been held in the module storage pool (see below).

Module Storage Pool

Between the module handling cells, there is a storage pool for the surge storage of used-fuel bundles in modules. The purpose of the surge storage is to ensure that the packaging process can continue in the event that used-fuel shipments from the reactor sites are interrupted, and to enable the continued receiving of IFTCs if the packaging process is temporarily stopped. Under normal operations, modules would not be transferred via the storage pool.

The storage pool contains stacking frames with a capacity for 318 modules (sufficient for up to three months of processing). Each module handling cell is connected to the storage pool by an inclined elevator with a rail cart that holds one module. Above the pool, there is a gantry crane with handling equipment for lifting and transferring modules between the rail cart and the storage positions. Provisions will be included for cooling and cleaning of the pool water as required.

Module Transfer Cart

There are two parallel lines for module transfer from the module handling cells to the fuel handling cell. Each line is equipped with a remote controlled cart that can transfer one module at a time from a loading position in the module handling cell to an unloading position in the fuel handling cell. The module transfer carts are transferred on rails.

3.4.2 Used-Fuel Container (UFC) Loading and Sealing

The main areas and equipment for loading and sealing UFCs are described in this section.

Empty UFC Receiving Hall

The receiving hall is a dedicated area for receiving and handling empty UFCs. The hall is located at ground floor level and includes storage positions for 40 UFCs and 126 baskets (both stored in their transport frames and packaging to minimize potential damage).

The hall is equipped with a 30 tonne OTC and a UFC preparation platform. The platform contains two parallel positions for inspection, installation of UFCs into sleeves and loading of empty baskets. Adjacent to the preparation platform are eight storage positions for sleeves, eight positions for empty baskets and four positions for pallets with empty UFCs in sleeves, ready for use in the packaging process. The pallets are transferred within the hall using an air-cushion transporter (see below), a design developed by SKB to handle UFCs in Sweden.

Shielded Frames and Air-Cushion Transporters

To enable radiation shielded transfer of filled UFCs within the UFPP, a UFC is first installed into a sleeve, which in turn is installed in a shielded frame. The sleeve has two main functions; it enables lifting and handling of an empty UFC (after removal from the transport frame), and it is equipped with a turntable for rotating UFCs during non-destructive testing.

The shielded frame consists of a transport platform with two telescopic, shielded sections that are vertically mounted on the platform. The bottom section can be raised and lowered by screw jacks, thereby enabling a UFC to be raised and docked with the processing stations. The top section is equipped with a gamma gate and is designed for airtight docking with the stations (to avoid contaminating the outer surface of the UFC and spreading airborne activity from cells).

Shielded frames are transferred between stations using an air-cushion transporter, which consists of a transfer pallet with air cushions mounted on the bottom. The air cushions are shaped like the inner tubes of a tire, with the centre of each tube connected to an air supply. To move the transporter, air is pumped into the centre of each tube, creating an overpressure which in turn creates an air film between the tube and the floor. The transporter is also equipped with steering wheels that remain in contact with the floor, also when it is in the raised position. The air-cushion transporter can be controlled both manually and remotely.



Figure 9: Air-Cushion Transporter with Frame
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UFC Transfer Area

The UFC transfer area is a dedicated area for moving UFCs in shielded frames between the different processing stations. The area is located below the fuel handling cell and subsequent stations for UFC processing. To dock a container to a cell or station, a shielded frame is transferred and parked below the station. Using screw jacks on the frame, the container is raised into position for docking and the gamma gate on the frame is opened. Within the UFC transfer area there are two parking positions for shielded frames and one position for air-cushion transporters.

Fuel Handling Cell

The fuel handling cell is a radiation shielded facility for the transfer of used-fuel bundles from modules to baskets, and the subsequent lowering of baskets into empty UFCs. The cell is equipped with lead glass windows, MSMs and vacuum cleaners. All equipment in the fuel handling cell is remotely operated.

To enable loading of filled baskets into a UFC, the fuel handling cell has a docking port that leads down to the UFC transfer area. The docking port is equipped with a gamma gate for radiation shielding and an airtight containment door/enclosure that, together with the inner vessel lid, can be remotely lifted into the cell (to minimize the probability of contaminating the outer surface of the lid).

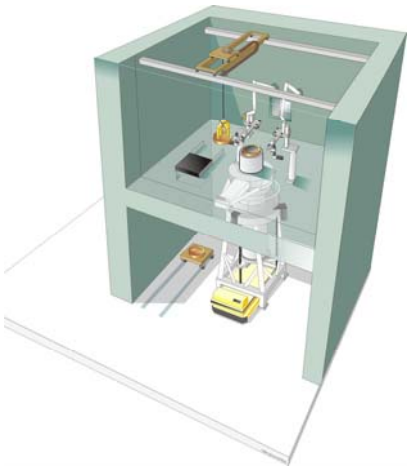
The cell is also equipped with an OTC for lifting modules, baskets and the containment door. Within the cell, there are four positions for the temporary storage of modules, and one position for parking the containment door and inner vessel lid. The cell also has a dedicated area for the temporary storage of 12 filled or empty baskets. In the floor of the fuel handling cell, there is a port with a gamma gate leading to a waste management facility, which includes provisions for the decontamination and compaction of emptied modules.

Fuel Handling Machines

Inside the fuel handling cell, there are three fuel handling machines that can be operated in parallel. The machines are used for the horizontal transfer of used-fuel bundles from a module to a UFC basket. During the transfer operation, the end plates are visually inspected to verify the bundle's identity for safeguard purposes. Provisions will be included for transferring any damaged bundles into storage cans for further treatment and loading into containers purpose-built for the disposal of damaged bundles.

Inerting Station

The inerting station is a radiation shielded station that contains provisions for remotely bolting the lid to the inner vessel. The station also houses equipment for removing air contained in the inner vessel and re-filling it with inert gas. To ensure that personnel are always protected from potentially high radiation levels during maintenance, the docking port is equipped with a gamma gate. The inerting station is further equipped with a hatch and an OTC for importing lids for subsequent placement onto the copper vessels.

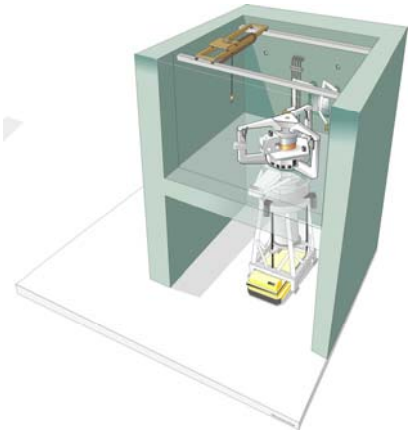


Inerting Station

Welding Station

The welding station contains equipment for seal welding the copper lids to the copper vessels. To ensure personnel protection during maintenance, the docking port is equipped with a gamma gate.

For the current design, the copper vessel is assumed to be seal welded using friction stir welding (FSW). During such a process, the welding head is rotated around the vessel, which is held in a fixed position.

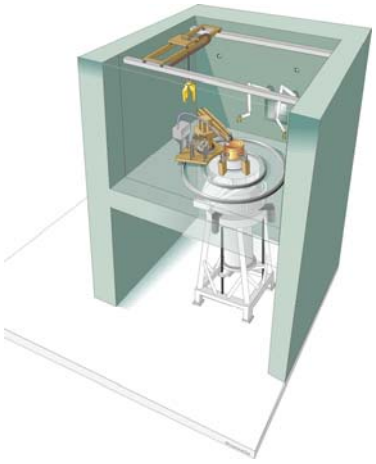


Welding Station

Machining Station

In this station, there is a milling machine with tools for machining the weld area down to a smooth surface. Machining of the surface is required for two reasons: to enable non-destructive testing of the weld; and, to produce a surface that meets the requirements for placement in the DGR. The milling machine can also be equipped with a special tool for cutting open a defective UFC.

During machining, the equipment is rotated and the UFC is held in a fixed position. The docking arrangements in the machining station are the same as in the welding station.

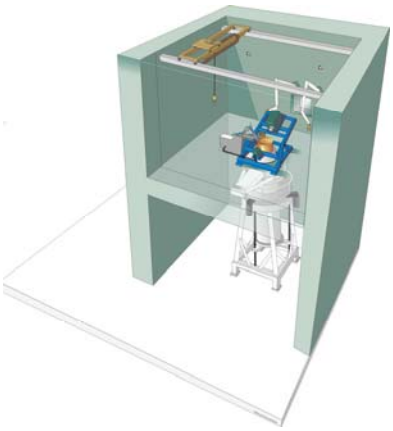


Machining Station

NDT Station

The NDT station contains equipment for non-destructive testing of the copper lid weld, to ensure that the requirements for long-term emplacement of the UFCs are met. The docking arrangements in the NDT station are the same as in the welding station.

During radiographic examination, the NDT equipment is held fixed while the UFC is rotated using the turntable in the shielded frame. During ultrasonic examination, the rotation can be provided either by the ultrasonic equipment or the UFC.



NDT Station

3.4.3 Filled Used-Fuel Container Storage and Dispatch

The following describes the main areas and equipment for the storage and dispatch of UFCs.

Filled UFC Storage Cell

At one end of the UFC transfer area, there is a shielded area for the monitoring and storage of filled UFCs. This storage cell is equipped with a 30 tonne OTC that can lift a filled and sealed UFC. In the floor of the cell, there is a port for the docking of a shielded frame in the UFC transfer area, as well as a docking port for the transfer of filled UFCs to the dispatch hall (see below). Empty UFCs are also lifted into the area through a dedicated port, for transfer and loading into a docked shielded frame in the UFC transfer area. All equipment in the UFC storage cell is remotely operated with MSMs.

Below the storage cell, there are positions for the vertical storage of 40 filled UFCs. A UFC decontamination cell is also located below the filled storage cell, for the monitoring of filled containers and the decontamination of UFCs that evident surface contamination.

UFC Dispatch Hall

Adjacent to the filled UFC storage cell is a dispatch hall for the loading of filled UFCs into shielded transfer casks before removal to the repository. Within the dispatch hall, there is an airlock for transfer casks arriving and departing on a rail wagon.

The UFC dispatch hall is equipped with an 80 tonne OTC and a working platform for inspection and cask lid operations. There is also a dispatch cell, for the lowering of a filled UFC into a transfer cask. The hall is further equipped with an air-cushion transporter and pallet for the transfer of a cask between the working platform and the filled UFC dispatch cell.

Waste Management Facility and Active Mechanical Workshop

The UFPP includes a waste management facility, which is located below the fuel handling cell and is accessed from the cell via a dedicated port with a gamma gate. Equipment in the waste facility includes provisions for the decontamination and compaction of emptied modules.

Adjacent to the waste management facility is an active mechanical workshop. The workshop can be used for maintenance, as well as for the handling, decontamination and monitoring of container components after the opening and unloading of defective UFCs.

3.5 Sealing Materials Production Plants Areas B3, B6, B13 & B14

The sealing material receipt, storage and preparation facilities provide for the production of various concrete and clay based sealing materials that will allow for the encapsulation of UFCs in the underground repository. The facilities comprise an aggregate plant / rock crushing plant (Area B14), a concrete batch plant (Area B13) and a sealing material compaction (SMC) plant with associated material storage bins (Areas B6 and B3, respectively).

The aggregate plant consumes a portion of the excavated rock from the underground workings to manufacture products suitable for the concrete batch plant including concrete sand and concrete stone. Modified granular A and fine sand for the SMC plant are also delivered from the aggregate plant and used as a component of the different clay based sealing materials. Externally sourced raw materials required in the production of the various sealing materials include different binders (cement T50, silica fume and silica flour), bentonite and glacial lake clay.

From the concrete batch plant, two different qualities of low heat, high performance (LHHP) concrete mixes are produced, one for the placement room floor and the other for the bulkhead. The SMC plant produces four different categories of clay based sealing material, dense backfill (DBF) blocks and disks, light backfill (LBF), highly compacted bentonite (HCB) rings and disks, and gap fill.

Only during LHHP bulkhead pouring will the concrete batch plant need to operate continuously to provide the required material. On day-to-day operations, the plant will run on an as-needed basis. Conversely, the high demand for clay based sealing materials and the anticipated high capital cost required for the compaction processes necessitates a three shift, daily operation for the SMC operations.

Aggregate products are stockpiled and stored within the batch plant area. Overhead field conveyors (which will facilitate vehicular travel around the plants) are used to bring finished aggregate product to the concrete batch plant. Overhead conveyors will also be constructed to connect the concrete batch plant to the SMC plant. In all, the aggregate, concrete batch and SMC plants are seen as an interconnected network.

The sealing materials facilities will be situated adjacent to the Protected Area, so as to be located as close as possible to the Service Shaft. This location will minimize the distance materials will need to be transported, help to reduce the footprint of the site, and remove the

need for workers in the compaction plant to enter the Protected Area. The produced products and sealing materials are brought to the Service Shaft for delivery underground.

The following sections initially describe the material requirements at: the aggregate crushing, screening & wash plant; the concrete batch plant; and, the SMC plant. Plant descriptions are then provided.

3.5.1 Aggregate Material Requirements

Table 4 illustrates the different products manufactured by the aggregate plant as well as its design capacity. The noted annual values represent the minimum quantities, as the actual production split of the crushing and screening process may not match the target usage. A 15% production factor is applied to compensate for this difference. A plant designed to operate at 220 tonnes/hour capacity will meet annual production demands running each year over an 11 week period (4 days/week) assuming a plant availability of 90%.

Table 4: Sealing Materials Plant Capacities

Material	Aggregate Plant (tonnes)	Concrete Plant (tonnes)	SMC Plant (tonnes)
Concrete Stone	1,475	1,475	
Concrete Sand	1,270	1,270	
Fine Sand	7,720		7,591
Modified Granular A	49,353		49,353
Cement T50		138	
Silica Fume		138	
Silica Flour		275	
Superplasticizer		15	
Bentonite			19,406
Glacial Lake Clay			17,626
Plant Capacity	**69,000***	**3,311**	**93,976**

*Note: total of above plus production factor allowance

3.5.2 Concrete Material Requirements

There are two different LHHP concrete mix designs, one for bulkhead sealing of the placement room (for the concrete mass poured at the entrance to each placement room to provide a mechanical seal once UFC placement is complete) and one for the placement room floor (for the plinths used to support the installed rail lines).

The demand for LHHP concrete is relatively low on a week to week basis, however, the plant does need to operate year round. Other mixes, such as shotcrete, grout or other concrete uses for areas of the DGR could also place a demand on plant operations. These demands are

currently undefined. The LHHP concrete materials produced are highly specialized, and the binders require extensive on-site testing prior to use. This suggests that externally produced concrete may not be acceptable for use at the DGR.

3.5.3 Clay-Based Sealing Material Requirements

Clay-based sealing material buffer and backfill is required for the in-floor borehole and the placement room. In-floor borehole components comprise HCB buffer rings and buffer disks, DBF disks and, the gap fill. Placement room components entail DBF blocks and the LBF. The resulting raw material and consumption demand for these clay-based sealing materials are depicted in Table 4.

There are two types of LBF required. In the first instance, LBF is used to fill the voids between the DBF blocks and the placement room walls. Secondly, LBF is used to replace the LHHP concrete floor to create a level surface for the DBF blocks (as the UFCs are placed and the placement room is sealed, the LHHP concrete floor and rails will be successively removed). On a weekly basis, the following materials are required:

- In-floor borehole: 56 HCB buffer rings; 28 HCB buffer disks; and, 14 DBF disks; and
- Placement room: 540 DBF blocks of different shapes.

Eighteen different blocks that are 1 m deep are needed to fill in a 1 m deep cross-section of the placement room. A cross-section view of the placement room and borehole layout, Figure 10, illustrates the placement of the UFC and clay based backfill materials.

The annual binder consumption (cement T50, silica fume and silica flour) is relatively small and thus inventory to be held on site should be minimal. In contrast, bentonite and glacial lake clay use is significantly higher, amounting to 373 tonne/week and 339 tonne/week, respectively. Storage silos will inventory approximately two weeks of product.

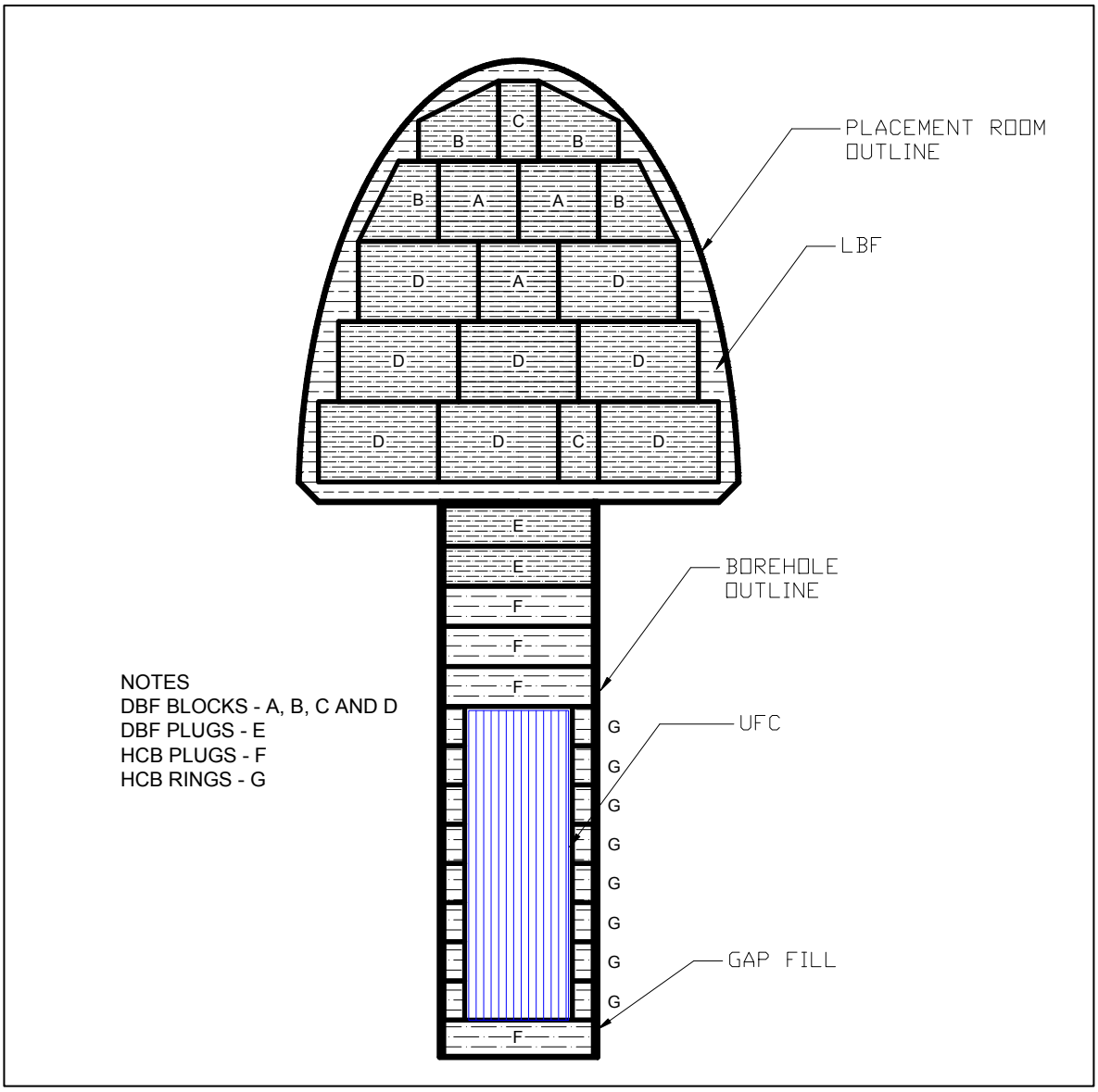


Figure 10: Sealing Material in Placement Room and Borehole

3.5.4 Aggregate Crushing, Screening & Wash Plant Description

The aggregate plant (Area B14 on Figure 4) will consist of three crushing and screening circuits and a wash plant for fines processing. A conceptual plant layout for the aggregate (and concrete batching) operations is provided below as Figure 11.

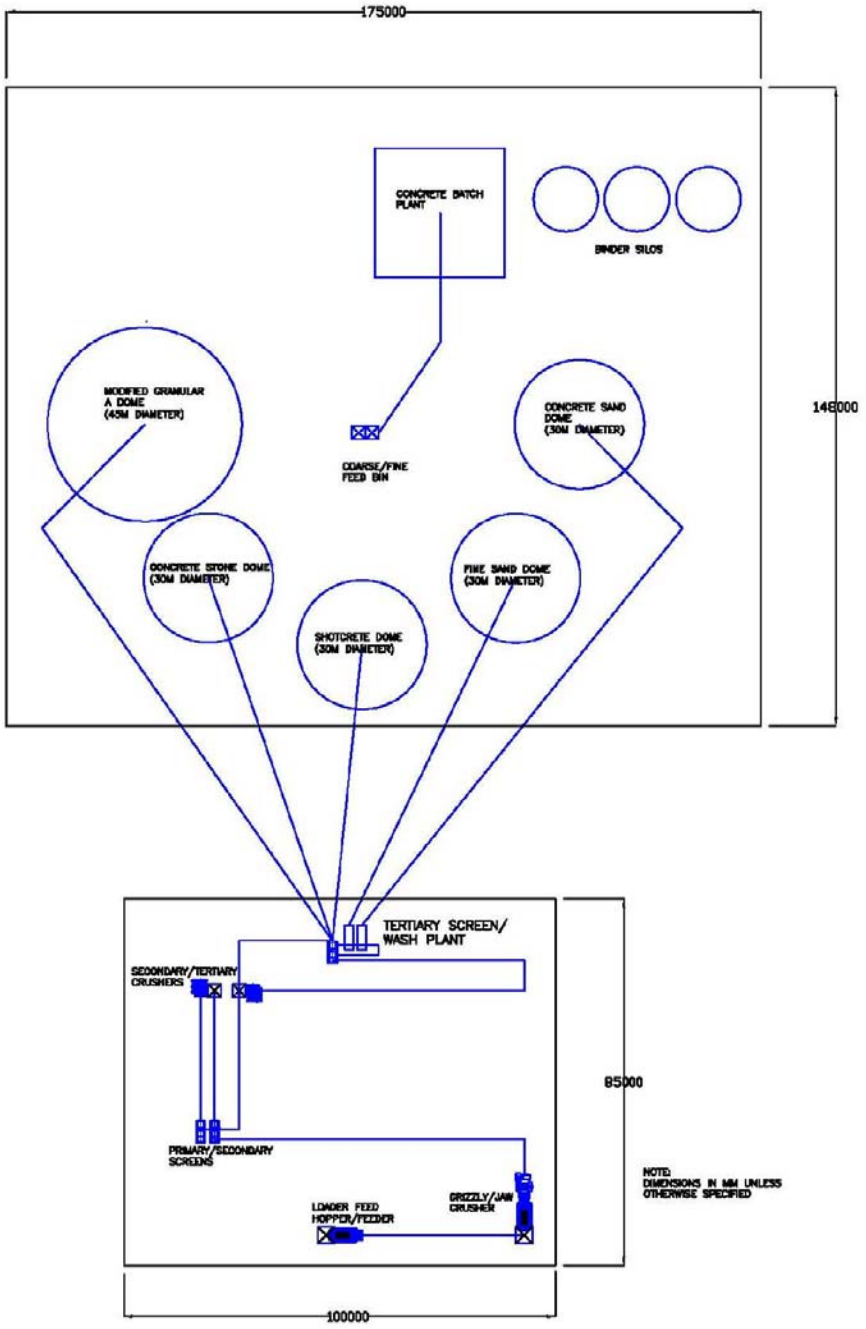


Figure 11: Aggregate and Concrete Batch Plant Layout

A rock stockpile of approximately 6,000 to 8,000 tonnes generated by waste rock from the underground excavations will be available on site (Area B16 on Figure 4) to support the aggregate operations. The balance of the waste rock from the DGR's development will be transferred to the off-site Waste Rock Disposal Area (see Section 3.15.1).

At the start of the crushing circuit, rock will be delivered by front end loader to a primary crusher for initial size reduction with belt magnets or metal detectors installed to prevent tramp metal entry. Material retained on the primary screen is further crushed in a secondary crusher. Streams from the secondary crusher discharge and the fines from the primary screen are combined and brought to the secondary screen for sizing. Aggregate retained on the top deck is re-circulated back to the secondary crusher. Material retained on the middle deck is brought to a tertiary crusher. Fines passing the secondary screen and discharge from the tertiary crusher will be directed to a tertiary screen feed hopper. Fines are further processed in a classifying tank to manufacture concrete sand and for the LBF mix.

For this plant a crew consisting of one supervisor and four staff will manage the plant's daily activities and perform maintenance duties. It is conceivable that personnel at the aggregate plant would work at the concrete batch plant or other parts of the DGR during the rest of the year when the plant is not in operation. For aggregate quality control purposes, gradation analyses will be performed.

Major equipment anticipated for the aggregate operations, all considered readily available and conventional machinery, are identified on Table 5 (left-hand column). As the aggregate plant will only operate during the summer months it will not be enclosed.

Table 5: Major Sealing Materials Equipment List (including standby equipment)

Aggregate Plant	Concrete Batch Plant	SMC Plant
Vibratory Pan Feeder	Cement & Silica Fume Silos (2)	PD Blowers (5)
Vibratory Grizzly Feeder	Silica Flour Silo	Conveyors (2)
Loader Dump Hopper	Binder Hopper	Silos for Clay Materials (10)
Two Deck Screens	Cement Batcher	Modified Granular A Silo
Three Deck Wash Screen	PD Blowers (4)	Fine Sand Silo
Crushers (3)	Hoppers (Coarse and Fine)	Weigh Hoppers (5)
Conveyors (26)	Belt Feeder	Dust Collector
Crusher Feed Hoppers (2)	Conveyors (5)	Mixers (5)
Surge Hopper	Aggregate Hopper	Vacuum Pumps (8)
Classifying Tank	Aggregate Batcher	Bentonite Presses (2)
Dewatering Screws (2)	Hot Water Tank	DBF Presses (6)
Fresh/Wastewater Pumps (2)	Admixture Tanks (4)	Vacuum Handling Devices (6)
Belt Magnet	Domes with Heated Floors (5)	
Metal Detectors (2)	Ready-Mix Trucks (3)	
	Bulkers for Binder Storage (3)	

3.5.5 Concrete Batch Plant Description

The concrete batch plant (designed to produce two different concrete mixes) will be fed by a loader bringing aggregate from the storage dome to a coarse/fine feed bin. The aggregate will be delivered to a batcher where it will be weighed and dispensed into a ready-mix truck. The cement T50, silica fume and silica flour will be delivered via tanker trucks directly to the plant (Area B13 on Figure 4).

As illustrated on Figure 11, cement T50 and silica fume will be stored in 75 tonne silos, with silica flour kept in a 150 tonne silo. These storage capacities are sufficient to supply LHHP concrete for the equivalent of two successive bulkhead pouring campaigns. The binders will be subsequently dispensed into a cement batcher, where they are weighed and discharged into a ready-mix truck (along with water and admixture). At the ready-mix truck, a homogeneous product is formed which is then delivered to the Service Shaft for underground use. The concrete plant will be enclosed where necessary to allow for year round operation (to minimize winter weather impacts).

The plant will produce material constantly during the LHHP concrete bulkhead pours with a required plant capacity of between 9 m^3/hr to 18 m^3/hr. A small, commercially available plant will be employed for this application.

A crew dedicated to the concrete batch plant is not necessary owing to the low demand when bulkhead pours are not being conducted (each year, four bulkhead pouring campaigns are scheduled). Operations to produce LHHP concrete floor material will consist of a trained team gathered from different parts of the DGR.

Each bulkhead pour will take about 309 m^3 of LHHP concrete. Two ready-mix trucks will provide sufficient surface delivery capacity. As binder and aggregate materials are confirmed to meet the target specifications they will be used in the concrete batch plant. Slump and air content will be measured for each load prior to placement.

Major equipment expected at the concrete batch plant, all considered readily available and conventional machinery, are identified on Table 5 (middle column).

3.5.6 SMC Plant Description

The SMC plant will produce four types of clay-based sealing material (HCB, DBF, LBF and gap fill) for delivery to the Service Shaft head frame. The plant and its associated storage bins are identified as Areas B6 and B3, respectively, on Figure 4. With a conceptual layout further detailed as on Figure 12, the SMC plant is divided into two primary sections:

- Raw materials storage, handling and mixing; and
- HCB and DBF material compaction.

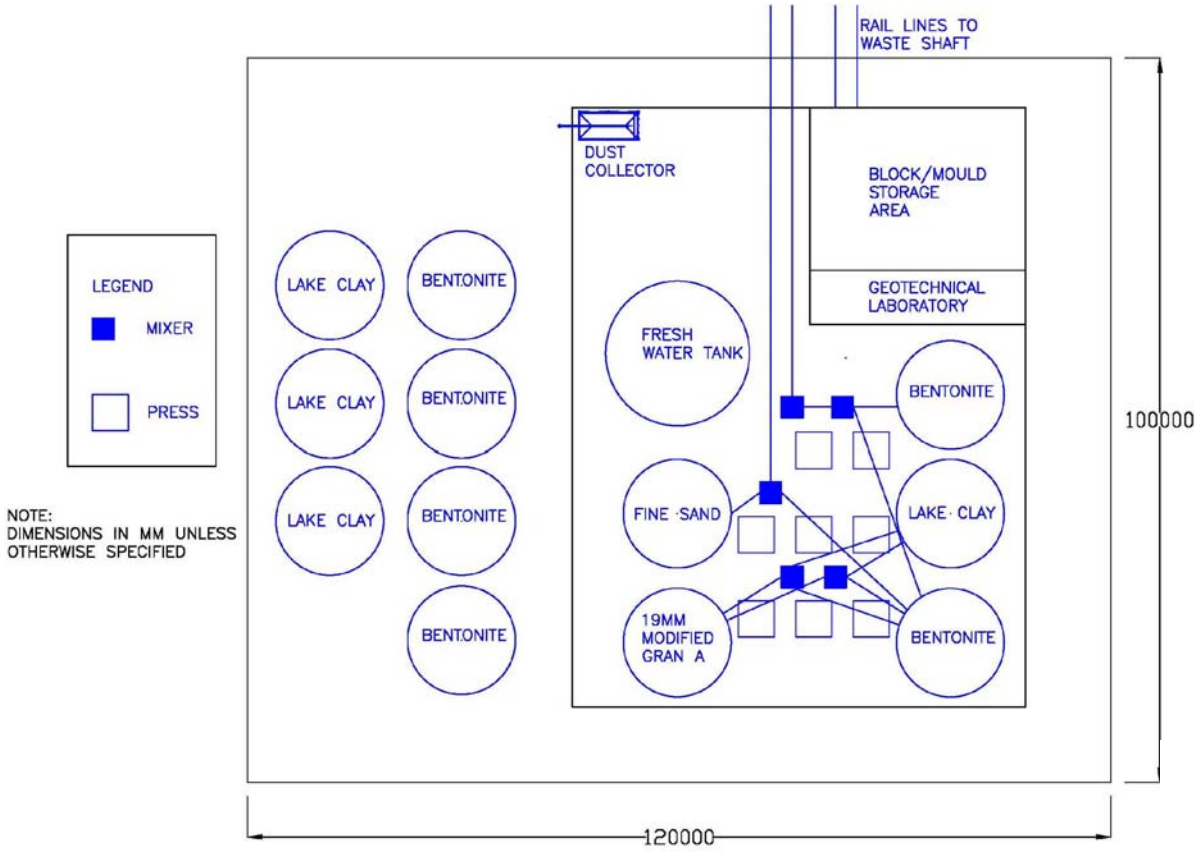


Figure 12: SMC Plant Layout

Bentonite and glacial lake clay will be delivered via tanker trucks to the plant. Seven exterior silos, each of a 150 tonne capacity, will be in place to dispense bentonite and glacial lake clay using rotary valves, day bins and positive displacement blowers. Modified granular A and fine sand, conveyed to their respective 150 tonne and 50 tonne storage silos in the enclosed plant, will be dispensed with the bentonite and glacial lake clay into weigh hoppers and then to a batch mixer. Water is subsequently added to the mixer to produce a homogenous material after blending. The bentonite and glacial lake clay storage silos will accommodate the equivalent of approximately two weeks of material consumption.

Mixed LBF and gap fill materials will be loaded onto tanker style rail cars for transportation to the underground repository or storage. Mixed bentonite and DBF materials will be further processed in a closed forge type hydraulic press to produce the shape, size and characteristic of compacted material suitable for use underground. This compression step will be operated under negative pressure to reduce the infiltration of dust to the surroundings.

The presses that will produce these HCB and DBF materials will be specialized items designed to suit this purpose. They will be hydraulically driven units with custom fabricated moulds to

provide the structure for the HCB and DBF products. Their power requirements will be significant. A depiction of the type of press envisioned for the production of the clay-based blocks is shown in Figure 13 (the equipment illustrated is from the metal forming industry).



Figure 13: Example of Closed-Die Forging Presses

Conservatively, and considering that it will take about one hour to produce a disk, at 80% availability it is estimated that two presses (1 standby) would be required to manufacture the HCB rings and disks needed in this project. Using a similar production rate to produce the DBF blocks and disks, a further estimated six presses (1 standby) would be required.

The capacity of the presses themselves will be different for the production of HCB and DBF materials. To achieve the target dry density of 1.61 t/m^3 for the HCB rings and disks, a compaction pressure in the range of 10 to 20 MPa can be expected. For an HCB disk this equates to 2,800 to 5,600 tonnes of compressive force. The actual press capacity needed will likely be greater. For the compaction of the DBF blocks, a target dry density of 2.12 t/m^3 is required. With its different material mix, however, smaller capacity presses are anticipated.

Specially designed equipment will be used to lift the HCB and DBF products out of the moulds. One example of such an approach is the vacuum suction system illustrated on Figure 14, which is normally attached to an overhead crane. This technique is a non-intrusive yet proven method to safely and effectively handle these types of compacted materials. The SMC plant will be outfitted with a similar system where HCB and DBF materials are to be brought to rail cars and subsequently transported to storage or to the Service Shaft (for delivery underground).



Figure 14: Vacuum Lifting Device

As the SMC plant will be a highly automated facility, a minimal number of highly skilled workers are expected on the plant floor. Such workers are likely to include a plant supervisor and foreman, control room and floor operators, and geotechnical quality control technicians.

The SMC plant and its compacted materials' storage area will be enclosed to maintain climate and humidity control (to minimize moisture absorption and ensure the integrity of the finished products). The exterior silos or storage domes will also have heated concrete floors (as required) to keep stockpiles from freezing. The enclosed structures will further help to prevent wind erosion effects that can cause fugitive dust emissions. A multi-chamber dust collection bag house will be in place to collect any dust generated by the sealing materials operations.

A quality control laboratory and the geotechnical technicians will be housed in the SMC plant (that is, these resources are in addition to those accommodated in the main quality control office and laboratory facility, Area P14). The laboratory will be responsible for materials testing for the aggregate, concrete batch and SMC plants. Each truck load of bentonite and glacial lake clay, for example, will be sampled and tested before being released into the storage silos. Particle size, moisture content, organic content, liquid limit, plastic limit, mineral composition and swelling characteristics are some of the parameters to be confirmed. ASTM tests for fluid loss and hydraulic conductivity may also be completed.

Major equipment expected in the sealing materials operations are identified in Table 5 (right-hand column).

3.6 Quality Control Offices and Laboratory Area P14

The quality control office and laboratory facility, illustrated as Area P14 on Figure 4, will provide space for the DGR's resident quality control specialists and scientists (see Table 2). Such staff will provide quality control, monitoring and testing for such items as groundwater, stormwater, air quality, and radiation-related issues (see Section 9).

The building, envisaged as a single storey structure, will be located in the Protected Area. It will house the quality control offices, laboratories and work stations for the facility's technicians, researchers, quality inspectors, scientists and managers. Work benches, experimental areas and refrigerators (for any chemicals or reagents requiring cool storage conditions) will be in place. Meeting rooms will further be provided.

Fire fighting equipment will be installed near most work areas and outside the laboratories, in addition to the normal sprinkler system in the ceilings.

3.7 Garage / Warehouse / Hazardous Materials Storage Areas B5 & B7

The Garage / Warehouse / Hazardous Materials Storage (single storey) facility will include maintenance shops, repair bays and a warehouse with space allocated for hazardous materials storage.

The garage and warehouse/storage area will be a combined facility externally with a partition wall between the distinct spaces, and a limited-access zone for hazardous materials storage. The garage area and one portion of the storage warehouse will be heated while another section of the warehouse will be unheated. While separate entrances will be provided for the garage and warehouse sections, a wide opening sliding double-door will be provided for off-loading supplies in the main warehouse through the garage. Fire fighting equipment will be available in all rooms. Additional details are as follows:

- Maintenance and Repair Bays – the garage area will have three vehicle maintenance bays as well as benches and extra space for machining, welding, etc. While major vehicle and equipment repairs will generally not be handled at the DGR (instead being carried out at designated and proximate authorized facilities), the maintenance and repair bays will be available to deal with emergency and routine requirements.

  The maintenance and repair area will be equipped with all of the tools and small machinery needed including hydraulic jacks, ramps and lifts as well as an overhead crane. An air compressor will be supplied for pneumatic tools and equipment and stored lubricants will be available for routine maintenance;

- Truck Wash Bay – a single bay will be provided for washing buses, trucks and other equipment. Discharged water will collect in a holding pond where suspended particles will settle out. A separator in the pond area will collect oils for containment and removal

before the wastewater is re-used or discharged to the environment. The collected water will be topped up with fresh water as required; and

- Warehouse – a warehouse area, with forklifts, will be provided for the bulk storage of all equipment, parts and items required for the areas of the DGR without their own storage. This warehouse will also be used as a staging area for distribution to other buildings. Warehouse space will be split as further described below:

  - An unheated area for storing bulky items (not associated with used nuclear fuel waste) at the far end of the building;
  - A heated storage area for mechanical and electrical equipment, spare parts, workshop items, benches, jacks and toolkits;
  - A heated area for construction related items including cement, geotextile membranes, pipes, couplings, etc.;
  - A separate and limited-access (fenced-off) heated area for hazardous materials storage including any reagents for water or wastewater treatment, laboratories, etc.

3.8 Switchyard, Transformer Area and Powerhouse Areas P11, P12 & P13

Electrical services will be managed, and back-up emergency power supplied by the Switchyard, Transformer Area and Powerhouse. For security, these facilities are all located in the Protected Area.

3.8.1 Switchyard

The Switchyard (Area P11 on Figure 4) is designated to host all high voltage equipment for circuit-breaking interruption, circuit-making, isolating disconnects, switching, and for the protection of transformers, lines, cables and capacitor banks. All designated equipment mechanisms will be fully enclosed and protected. Positively sequenced operations will be assured regardless of weather conditions. Protection from high winds, rain, sleet and snow will be in place.

The switchyard area will be surrounded by a dyke (or perimeter ditch and sump) to collect any spilled oil. It will be lined, as required, and have a surface comprising a compacted granular sub-base.

3.8.2 Transformer Area

Two step-down transformers each capable of handling a load of 20 MW will be supplied at the sub-station (Transformer Area) with all controls and switchgear housed in an adjacent building. These facilities are identified as Area P12 in Figure 4.

The total electrical power demand for the facility will be less than 40 MW (see Table 6, below). The site's power supply will be received from a high voltage overhead line branching off from the regional power grid within 10 km of the facility. This line is expected to be tower mounted, with towers generally spaced at 200 m intervals for stability.

Table 6: Site Power Requirements

Equipment Description	Net M.V. Run Demand		Net L.V. Run Demand	
	(kW)	(kVA)	(kW)	(kVA)
Used Fuel Packaging Plant			1,553	1,726
Sealing Materials Operations			16,168	17,964
Hoist Motors for 3 Shafts	2,190	2,433	135	150
Ventilation Systems	2,422	2,691	892	1,006
Waste Management Operations			374	416
Underground Demonstration Facility			785	872
Underground Operations			510	567
Other Operations and Surface Facilities			3,585	3,983
Total	4,612	5,124	24,002	26,684
Total demand, MV + LV (values rounded)			28,600 kW	
			31,800 kVA	
Calculated Power Factor (at each voltage)			0.900	
Electrical System Losses, kW (assume ~3% of demand)			860	
Total Peak Running Demand Load, with losses (rounded)			32,800 kVA	
Total Running Demand Load, with losses and 95% Overall Diversity Factor (values rounded)			28,000 kW	
			31,100 kVA	

Note: M.V. and L.V. means medium and low voltage, respectively

After being received at the two transformers, the electrical power will be conveyed via overhead medium voltage (13.8 kV) power lines to the plant distribution level. The power lines will run alongside access roads within the surface facilities to all buildings and terminate at step-down units. Step-down transformer units will provide the needed power for motors, buildings or compressors as per requirements. Areas with obstructions to overhead supply arrangements will utilize underground lines with armoured cable.

The transformer area will be situated within the previously described switchyard. Reinforced concrete platforms will be provided for the transformer units with mounted switches in steel box enclosures and with fire wall separation and fire protection.

3.8.3 Powerhouse

The Powerhouse (Area P13 in Figure 4) will house the emergency power generators and related equipment. Three 1.5 MW diesel generators (one for standby) will be able to provide the emergency power needed at the DGR. In this respect, the primary loads that would be served by the emergency generators are for the underground ventilation systems as well as for the Ventilation Shaft hoist and the Service Shaft auxiliary hoist. As illustrated in Table 7,

allowances have also been made to sustain critical services in the UFPP, and the various other surface and underground operations.

Table 7: Emergency Power Requirements

Applicable Emergency Services	Needed Power (kW)
UFPP Area (allowance)	500
Exhaust and Booster Fans for Underground Ventilation	1,240
Hoists for Ventilation Shaft and Auxiliary Service Shaft	530
Security Control Systems (allowance)	200
Miscellaneous Underground Requirements including Pumps	200
Miscellaneous Surface Requirements	300
Total:	2,970

The diesel generators will be connected to the same switchgear for the step-down transformers as connected to the medium voltage (13.8 kV) power lines from the grid. That is, the switchgear will be compatible for either grid power or diesel generated power. All other controls and switches will be housed in the powerhouse building and be capable of switch-over from the main grid to the diesel generators. A separate storage room for diesel tanks and oil will be provided in the powerhouse building.

Most buildings at the DGR will have connections for emergency power to the key areas, corridors, washrooms and external security lighting, key offices, laboratories and essential services. In an emergency, all security lighting and facilities for monitoring and detection of intrusions will receive full power. The firehall and kitchen will also be provided with full power in essential areas but meal areas (for example) will be on half power.

In addition to the forgoing, uninterrupted power supplies (as per CNSR SOR/2000-209 Paragraph 15.1) will be in place in various facilities to fully ensure the continued functioning of vital computer, instrumentation and security equipment.

3.9 Water Storage, Treatment and Distribution Areas B10, B11 & B12

Raw water for the DGR site will be sourced from a local river or water body. For current purposes the water source is assumed to be up to 5 km distant. The required water supply rate is expected to be approximately 200 m^3/day, sufficient to meet the following demands as listed on Table 8 (Note: water demand for sand production could be reduced with recycling at the sand classifier or by using mine dewatering flows if the quality is acceptable):

Table 8: Surface Facilities Average Water Demand

End Use	Quantity	Unit Rate of Water Required	Daily Demand (m^3/day)
Site Personnel	500 (rounded)	150 litres/person/day	75
Concrete Production	180 tonnes/year	at 10% waste and 10% solids slurry	5
Sand Production	8,990 tonnes/year		102
Truck Wash Make up	N/A	5 m^3/day	5
Dust Control	5,000 gallon truck	1 spray truck/day	15
		Total:	**202**

The sourced raw water will be held at the DGR site in the Water Storage Tanks (Area B10). These tanks will be located adjacent to the Water Treatment Plant and Pump House building (Areas B11 and B12, respectively). The Pump House area will accommodate the potable, fresh and firewater distribution pumps in a single storey engineered structure.

A total fire water demand of 1,020 m^3 is based on a demand duration of 3 hours at 340 m^3/h. This volume will be stored at the site in a shared fresh/fire water tank. The fire water volume will be kept separate from the raw water by using different draw off points from the tank. Fire water pumps will be packaged as a set containing a diesel, electric and jockey pump.

The water will be distributed through pressure pipes (a dedicated fire main) feeding fire hydrants situated at visible and accessible locations within the vicinity of buildings and other facilities exposed to fire hazards as directed by NFPA 20 and 24. Otherwise hydrants will generally be located at 60 m spacings.

Potable water will be produced on site at the Water Treatment Plant using the fresh/fire water tank as a supply source. The water treatment plant will be capable of full treatment to federal and provincial safe drinking water standards with a 24 hr treated supply stored in a potable water tank. The treatment plant will be complete with a filtration and sterilization system, filter backwashing equipment with air blowers, backwash pumps and inter-connecting pipework. The final water quality will be monitored for chlorine residual and turbidity.

A dedicated supply system will distribute potable water to all buildings, kitchen and washroom facilities. The system will be capable of providing a peak flow rate of four times the average daily flow rate. Two duty potable water distribution pumps and one standby unit will be installed. A central operations room in the Pump House will permit remote control of the pumps.

3.10 Sewage Treatment Plant Area B19

Sewage collected from all serviced buildings will be piped to the DGR's Sewage Treatment Plant for treatment to Provincial standards prior to discharge to the environment. The plant

(Area B19 on Figure 4) will be sized to handle 100% of the produced potable water plus a peaking factor of four for shift changes. Sewage waste from below-ground operations will also ultimately be disposed of at the Sewage Treatment Plant.

A packaged sewage treatment unit such as rotating biological contactor (RBC) or similar system will likely be utilized to handle the liquid waste. The RBC technology employs a fixed growth media process whereby bacteria are grown on a media surface that is rotated into and out of the wastewater. The RBC rotor is enclosed in a steel tank and the system also includes a primary clarifier, final clarifier, ultra-violet disinfection system, controls, switchgear and piping.

Such a modular sewage treatment system can accommodate variations in flow and is fully enclosed, eliminating any tanks and unsightly ponds. Organic loading fluctuations are dealt with easily without affecting the treatment process or effluent quality. Sludge accumulated in the plant would periodically be pumped to a mobile sludge tank and taken off-site for further treatment.

Treated effluent from the plant will be monitored for compliance before being discharged to a natural watercourse or for other uses (e.g., dust control). Laboratory tests will be conducted regularly to ensure that the effluent quality is maintained at the design levels.

3.11 Process Water and Stormwater Control Areas P10, P17, B15 & B26

Five pond structures will be established at the DGR, to effect either process water or stormwater control. All of the ponds will be lined over their base and embankments with high density polyethylene (HDPE) for protection and to prevent water infiltration back into the ground. Collected flows will, in all cases, also be quality monitored and potentially treated before being directed to any downstream processes (e.g. aggregate crushing plant) or discharged off the site. With regards to the latter, water quality will be analyzed for compliance with the guidelines set out in Section 9.2.2, before being released to a natural watercourse.

The ponds will de designed to settle out suspended particles with any collected mud and silt deposits cleaned out on a periodic basis to maintain design retention volumes and times. The ponds may be used for the temporary storage of snow and ice removed from the access roads and parking areas during winter months.

Stormwater Detention Pond (Area P10)

A perimeter ditch around the Protected Area will direct falling precipitation to this stormwater detention pond. The runoff collection ditches, conveyance pipes and culverts as well as the storage pond will be designed for the 100 year storm event with the pond discharge weir normally closed.

Mine Dewatering Settling Pond (Area P17)

Mine water pumped from the underground dewatering sumps will be piped to a dewatering settling pond. An estimated 550 m^3/day of groundwater has been assumed to be pumped from the sumps and discharged to the settling pond. The pond will be designed to have a retention period of 5 days. An allowed freeboard and adjustable weirs on the outlet side of the pond will control the discharge rate and retain floating material such as oil residue collected in the underground sumps.

Process Water Settling Pond (Area B15)

Raw water is required at the rock crushing plant for cleaning processed rocks and for use in the classifier in the production of fine sand. The total water demand has been estimated to be 102 m^3/day during crushing operations (see Table 8) which will occur over the summer months. Process water high in suspended solids will be directed to this pond which will be designed for a 7 day retention time.

Stormwater Detention Ponds (Area B26)

Two detention ponds located at opposite ends of the DGR will receive stormwater run-off collected from the Balance of Site. Similar to the stormwater pond in the Protected Area (Area P10), the ponds will be sized for the 100 year storm event. The water will be routed to the ponds through a system of conveyance pipes, ditches and culverts designed for the storm event. The ponds will have a bypass arrangement to directly discharge into the local watercourse if the storm event is continuous, to prevent damage to pond embankments.

3.12 Waste Handling Facilities Areas P6, P7, P8 & P9

This section addresses low and intermediate level waste (L&ILW) management facilities as well as those designed for non-radiological hazardous wastes. The principal subject waste streams, generated in both solid and liquid form, are as follows:

- Low Level Waste (LLW): comprises radioactive waste, in which the concentration or quantity of radionuclides are above CNSC clearance levels. LLW is defined as material with a dose rate of less than 10 mSv/hr measured at a distance of 30 cm;
- Intermediate Level Waste (ILW): comprises radioactive, non-fuel waste containing long-lived radionuclides. ILW is defined as material with a dose rate over 10 mSv/hr measured at 30 cm; and
- Free Release Waste: comprises that in which radionuclides are below CNSC clearance levels. This would include non-radioactive hazardous and non-hazardous materials.

3.12.1 Active Solid Wastes

Figure 15 illustrates the expected primary solid L&ILW streams. As noted thereon, the main sources of active solid wastes are anticipated to be from the UFPP, the Auxiliary Building, and from the active liquid waste treatment processes.

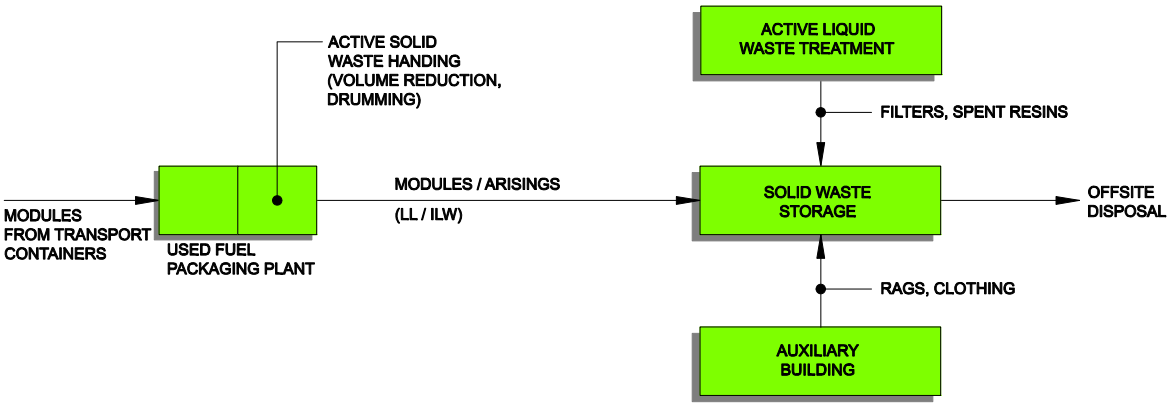


Figure 15: Active Solid Waste Flow Diagram

The modules from the incoming IFTCs will represent the most significant source of active waste. When a module has been emptied of used-fuel bundles, it will be decontaminated to free-release limits to allow shipment to an off-site metals recycling facility. Active waste streams will also include HEPA filters used in ventilation exhaust air units as well as spent filters and/or ion exchange media from the treatment of active liquid wastes.

Other active solid waste streams will include arisings (spent equipment/tools or components thereof) from the maintenance of hot cell equipment. Further, LLW streams will include that from general decontamination activities and/or resulting from incidental contact with loose radioactive material such as cleaning materials and used personal protective equipment (PPE).

Table 9 identifies the quantities of solid L&ILW expected to be generated. In total, approximately 2,000 m^3 of such wastes are anticipated each year.

Table 9: Inventory of Active Solid Wastes

Source	Description	Level	Annual Quantity
UFPP	Modules from IFTCs	L or ILW	330 m^3
UFPP	Arisings from operations and maintenance	ILW	12 drums
		LLW	500 drums
UFPP	Used HEPA filters		
UFPP	Bead IX resins		500 L
UFPP	Powder resins		120 kg
UFPP	HEPA & cartridge filters		285 filters
UFPP	Hot Cell vacuum filters		2 drums
Ventilation Exhausts	Used HEPA filters	LLW	TBD
Aux. Building & other Facilities	Dry swabs, rags, etc.	LLW	TBD
	PPE (clothing, gloves, etc.)	LLW	10,000 kg
Active Liquid Treatment	Spent filters and IX media	L or ILW	100 drums
Various	Miscellaneous	L or ILW	10,000 kg

3.12.2 Active Liquid Wastes

Figure 16 below, identifies the liquid L&ILW streams. Similar to the active solid waste flows, the primary sources are anticipated to be from the UFPP and Auxiliary Building.

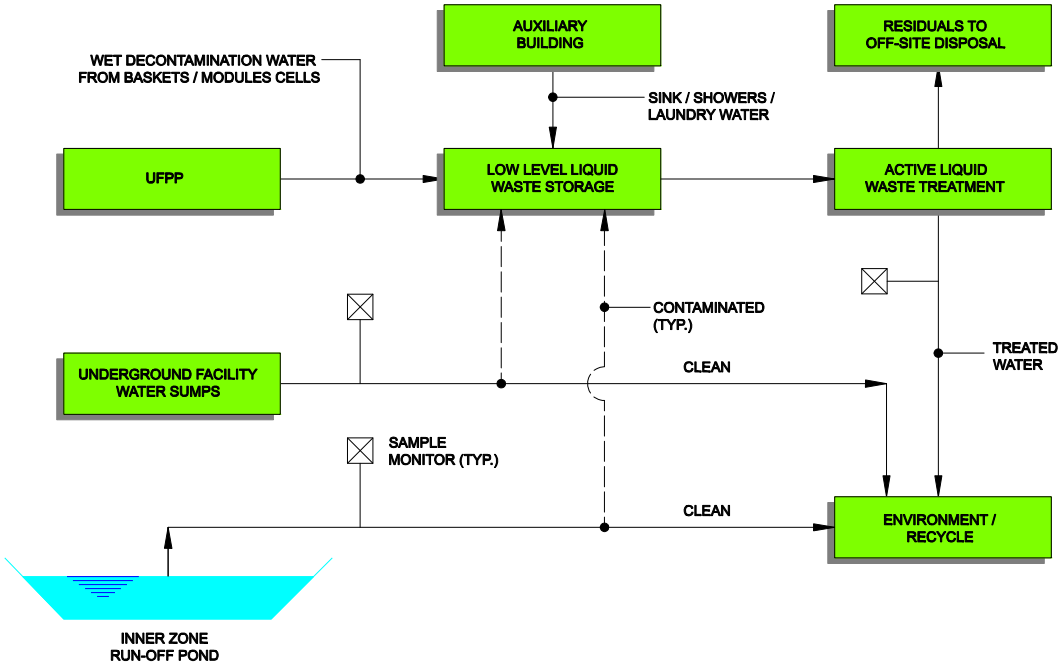


Figure 16: Active Liquid Waste Flow Diagram

Active liquid L&ILW flows from the UFPP will originate from the decontamination of used-fuel modules, cell washdowns, discharges from the wet storage pool, and the wet decontamination of IFTCs and containers. The other primary source of liquid waste flows will include some laundry wash and rinse waters (normally directed to sewage treatment system, only rerouted if indicated by monitoring).

Table 10 identifies all sources and the associated quantities of liquid L&ILW that will be generated. In total, approximately 1,000 drums and 9,000 m^3 of piped active liquid wastes will be produced each year.

Table 10: Inventory of Active Liquid Wastes

Source	Description	Level	Annual Quantity
UFPP	Module decontamination	ILW	1,250 m^3 (piped)
UFPP	Active cell wash down	ILW	10 m^3 / 50 drums
UFPP	Wet storage pool	ILW	Variable (piped)
UFPP	Cask decontamination	ILW	1,600 m^3 (piped)
Lab. & Test Areas	Cleaning and samples	LLW	100 m^3 / 500 drums
Auxiliary Building	Laundry, change rooms	LLW	max. 6,000 m^3 (piped)
Waste Management Area	Cleaning of package exteriors	LLW	25 m^3 / 125 drums
Underground or Surface	Collection sump, ponds	LLW	normally nil (piped)
Active Liquid Waste Treatment	Spent regenerants	LLW	150 - 300 drums

3.12.3 Non-Radiological Hazardous Waste

Various non-radiological, hazardous solid and liquid wastes will also be generated from the ongoing operations. These will include: solvents used in decontamination and cleaning; lubricants and greases; petroleum based fuels; and, explosive residues. The accepted strategy for the management and control of these types of materials is to minimize their use, find less-hazardous replacement materials, provide spill containment and monitoring, and ensure separation of incompatible materials such as organic solvents and inorganic acids.

3.12.4 Non-Radiological Non-hazardous Waste

There will be a number of conventional waste streams generated at the DGR (e.g., office and lunchroom waste, etc.). To the extent possible, the quantity of these wastes will be minimized and segregated by type for recycling. One major waste stream in this regard will be the copper chips generated in the UFPP from the machining of the UFCs (see Appendix A).

3.12.5 Waste Management Approaches

With respect to the waste facilities, four separate operations will be incorporated into the design and operation of the DGR. As discussed in the following sections, these include:

- Active Solid Waste Handling Facility – meant to receive active solid wastes from the UFPP;
- Waste Management Area – which will manage active solid waste materials;
- Active Liquid Waste Treatment Area – a processing point for active liquid waste materials; and
- Low-Level Liquid Waste Storage Area – which will receive low-level liquid waste materials prior to transfer to the treatment area.

General, non-hazardous refuse will be handled as in any other type of industrial setting. Such garbage will be directed to a local municipal landfill or other waste management facility. The approach to handling non-radiological hazardous waste is expected to be similar. The quantity of such materials will be reduced to the maximum extent possible and any collected wastes will be shipped off-site for recycling or long-term management as quickly as possible.

Active Solid Waste Management Systems (Areas P6 & P7)

As previously noted, L&ILW management activities will centre on two on-site operations, the Active Solid Waste Handling Facility and the Waste Management Area (Areas P6 and P7 on Figure 4, respectively).

The Active Solid Waste Handling Facility is associated with and attached to the UFPP and serves as a staging area for solid wastes from that building. It will comprise a used-module size reduction, drumming and export area, a processed waste transfer cell and, an overhead crane. Once received, processed and packaged, the containerized wastes will be directed to the Waste Management Area.

The Waste Management Area incorporates a stand-alone storage building. Racks will be in place to accommodate about 1,000 m^3 of LLW and 300 m^3 of ILW, sufficient for six months of waste generation at the site. Additional storage space will also be available outdoors, under cover. Whether in plastic bags or rigid drums, the wastes will be stored to prevent damage and loss of containment. A baler to consolidate collected material will be provided.

Active solid wastes which are not, or cannot be decontaminated to free-release limits will be placed into ISO transportation containers and shipped off-site to a licensed long-term management facility. As the quantity of waste which is combustible is expected to be limited, incineration for volume reduction will not be pursued.

Active Liquid Waste Management Systems (Areas P8 & P9)

Active liquid waste treatment will be managed through two facilities, a storage building located in the Low-Level Liquid Waste Storage Area (Area P9 on Figure 4), and the Active Liquid Waste Treatment Building (Area P8), a processing point for the wastes.

The storage building, incorporating secondary containment for spills or leaks, will provide for the interim assembly of collected liquids prior to treatment. The building will house storage tanks to receive piped and drummed active liquids as well as an area where drummed liquids would be stored. One tank will be kept empty to provide space for unplanned receipts. Over normal operations, active liquids will be transferred into one of the storage tanks for blending or moved directly to the treatment building.

The Active Liquid Waste Treatment building will house the following equipment:

- Two feed / equalization tanks with feed pumps;
- Two treated water collection and monitoring tanks with transfer pumps;
- Treatment systems comprising filtration to remove particulate contaminants, ion exchange or membrane separation to extract dissolved contaminants and possibly post-treatment filters to allow for recycling of the treated water;
- Three tanks to supply regeneration / cleaning liquids and receive spent regenerant / washwater and concentrate from the membrane separation modules; and
- Pumps to serve the three tanks above.

The treatment of active liquid wastes using particulate filters and ion exchange columns is commonly used in many locations including nuclear power plants. The system will be comprised of three 50% capacity modules, two of which would be operating at any given time with the third unit on stand-by.

Alternatives to this treatment approach include the use of high efficiency evaporative technologies such as multiple effect evaporators and vapour/liquid recompression units. Membrane separation technologies such as ultra-filtration and reverse osmosis are also possible.

3.13 Roads, Parking Areas, Bus Shelters and Covered Pedestrian Routes Areas B27, P15, B22, P19 & P16

Access Roads

The access road to the DGR from the local highway has been assumed to be up to 25 km long. In addition, the facility itself will require a total of 4.8 km of road network within the Protected Area and the Balance of Site as well as an approximate 2 km access road to the Ventilation Shaft complex. Private vehicle traffic allowed into the controlled zones will be kept to a minimum with most DGR employees using the main/primary parking lot, which will also be serviced at regular intervals by buses.

The main access road from the highway will be constructed with a compacted base course and asphaltic surfacing and be provided with shoulders and ditching on both sides. Roads within the facility will also be complete with drainage ditches but without any shoulders. Collected on-site runoff will be directed to the DGR's stormwater ponds. The interior roads and parking pads will be paved.

Parking (Areas B27 & P15)

Parking will be available in several locations at the DGR with the primary parking lot (Area B27) situated adjacent to the Administration Building. This lot will be of sufficient size to accommodate cars, buses and trucks requiring parking services at the DGR. Unobstructed outdoor parking will further be ensured for all fire and security vehicles. An additional parking area (Area P15) will be provided in the Protected Area near the Auxiliary Building and Quality Control Offices and Laboratory for deliveries as well as fire and security vehicles.

Bus Shelters (Areas B22 & P19)

Bus shelters (Areas B22-A&B) will be located in the main parking area adjacent to the Administration Building as well as in the vicinity of the Water Treatment Plant and Air Compressor Building (Areas B11 and B8, respectively). All shelters will be complete with sliding doors, benches and heat to keep the occupants warm during winter. Additonal shelters (Areas P19-A,B,C&D) will be provided in the Protected Area adjacent to the Auxiliary Building as well as in the vicinity of the UFPP and the various waste management facilities.

The bus shelters in the main parking area are expected to be used by staff commuting to the DGR site. The remaining bus shelters are provided to facilitate intra-site employee travel.

Covered Corridor / Pedestrian Routes (Area P16)

Covered corridors or pedestrian routes will be established to facilitate personnel movement between the Administration Building, Auxiliary Building, UFPP and the Service Shaft complex. The covered corridors will allow easy access and movement between buildings during winter and other harsh weather conditions.

Corridors will be located so as to allow vehicle traffic to circulate the facility in an efficient manner. Adequate space will be provided for pedestrians to share the passageways with handcarts. The corridors will be climate controlled (insulated and heated). Windows and doors will be installed as required for safety, and fire protection will be in place along the corridor lengths.

3.14 Other Facilities Areas B8, B9, B18, B21 & B23

Air Compressor Building (Area B8)

Air compressors are required for pressurizing service and breathing air requirements for the surface facilities and underground repository. Service air, to be supplied at a rate of 1 m^3/s, will be delivered using 3 rotary screw compressors (one standby) each with a capacity of 0.5 m^3/s. Breathing air, to be delivered at a rate of 0.15 m^3/s, will be provided using a further 2 compressors (one standby) each with capacity of 0.15 m^3/s.

Fuel Storage Tanks (Area B9)

A fuel storage facility will hold a two week supply of diesel and gasoline for plant site vehicles and equipment including the emergency generators. Fuel will be stored in accordance with the NFPA 30 Flammable and Combustible Liquid Code. Two fuel tanks will be required comprising a diesel fuel tank with a capacity of 105,000 litres and a 25,000 litre gasoline fuel tank. The tanks will be located within a HDPE lined containment area with sufficient capacity to hold the volume of the largest tank plus 10%.

Both tanks will retain in excess of two weeks supply of fuel. Diesel fuel storage is based on an average diesel consumption of 300 litres/day per piece of equipment for 20 units. The back-up generators will require about 1,000 litres/day. Gasoline requirements for light vehicles are estimated at 50 litres/day per vehicle for approximately 30 vehicles. Tanker fuel pumps or dedicated loading pumps will be used to fill the storage tanks and fuel will be dispensed through a metered fuel dispensing station. Card readers will be in place at the dispensing station.

Storage Yard (Area B18)

The Storage Yard will be an open area reserved for the laydown and temporary storage of new and decommissioned equipment and materials. It will have a granular surface and be fenced with lockable access gates.

Helicopter Pad (Area B21)

An area adjacent to the main parking lot will be dedicated for a helicopter landing pad. Based on Ontario's current Sikorsky S76 air ambulances and International Civil Aviation Organization (ICAO) requirements, the helipad's clear area will be 30 m in diameter, capable of receiving a single helicopter while also allowing for parking on the pad. The landing pad will be designed with proper navigational aids and lighting requirements.

Weigh Scale (Area B23)

A Weigh Scale will be provided to properly monitor the receipt of bulk materials to the DGR as well as the shipping of waste rock off site. The scale will be sized to accommodate a fully loaded tractor and double trailer for an overall length of 25 m, using current Ontario Ministry of Transportation regulations. The scale will be supported by fully automatic controls, providing signal lights for traffic management and a motion detection system.

3.15 External Facilities and Operations

This section describes the off-site facilities (i.e. those outside the security boundaries of the DGR), that will be established to support the DGR's development and operations. Such facilities include a waste rock disposal area, a construction camp site, a town site, and a Visitors' Centre.

3.15.1 Waste Rock Disposal Area

The primary waste rock storage facility will be located off-site and is assumed to be located within a 25 km distance of the DGR. It will be fenced but without full time staff.

The disposal area will initially be prepared using dumped crusher wastes to directly fill any low-lying depressions. Additional waste rock will then be placed in layers on the prepared ground surface. Access routes and paths will be prepared for loaders, dumpers and trucks to move around and up the piles easily.

The area will include a stormwater runoff pond to collect and monitor the effluent before being released to the environment. Depending on the composition of the waste rock and its exposure to air, some consideration may need to be given to the potential production of acids in the disposal area runoff.

While the disposal area will receive any waste rock not suitable for concreting, road works or as backfill in the underground operations, it will also hold some rock that will eventually be processed at the DGR's sealing materials operations. As noted in Section 3.5, a small storage area will be located beside the sealing materials' aggregate operations for the provision of the daily needs of the rock crushing plant.

3.15.2 Construction Camp Site

There will be a stand-alone accommodation camp established for construction personnel during the development of the DGR and its associated facilities and infrastructure. While the location of the facility is presently unknown, it is assumed to be approximately 2 km from the DGR site.

Considering manpower needs as related to shaft development, general site works, management and monitoring personnel, etc. the current estimate for camp capacity is almost 600 people (to be confirmed), comprising the following:

- Mine Development – 150;
- Project Management – 10;
- Monitoring / Validation – 20;
- Security – 30;
- Administration – 15;
- Construction, including management – 250;
- Support (administration, first aid, security, catering and housekeeping, and camp operations and maintenance) – 100.

A typical camp layout is provided as Figure 17. As illustrated, a total of three accommodation units are shown, arranged as H-shaped, two storey buildings. Interior layouts for the units will vary depending on the intended occupancy. Some units will feature rooms with larger sleeping quarters and private bathrooms and be intended for management and supervisory personnel. Other units will comprise rooms with one or two beds and shared toilet facilities. Common areas will also be provided.

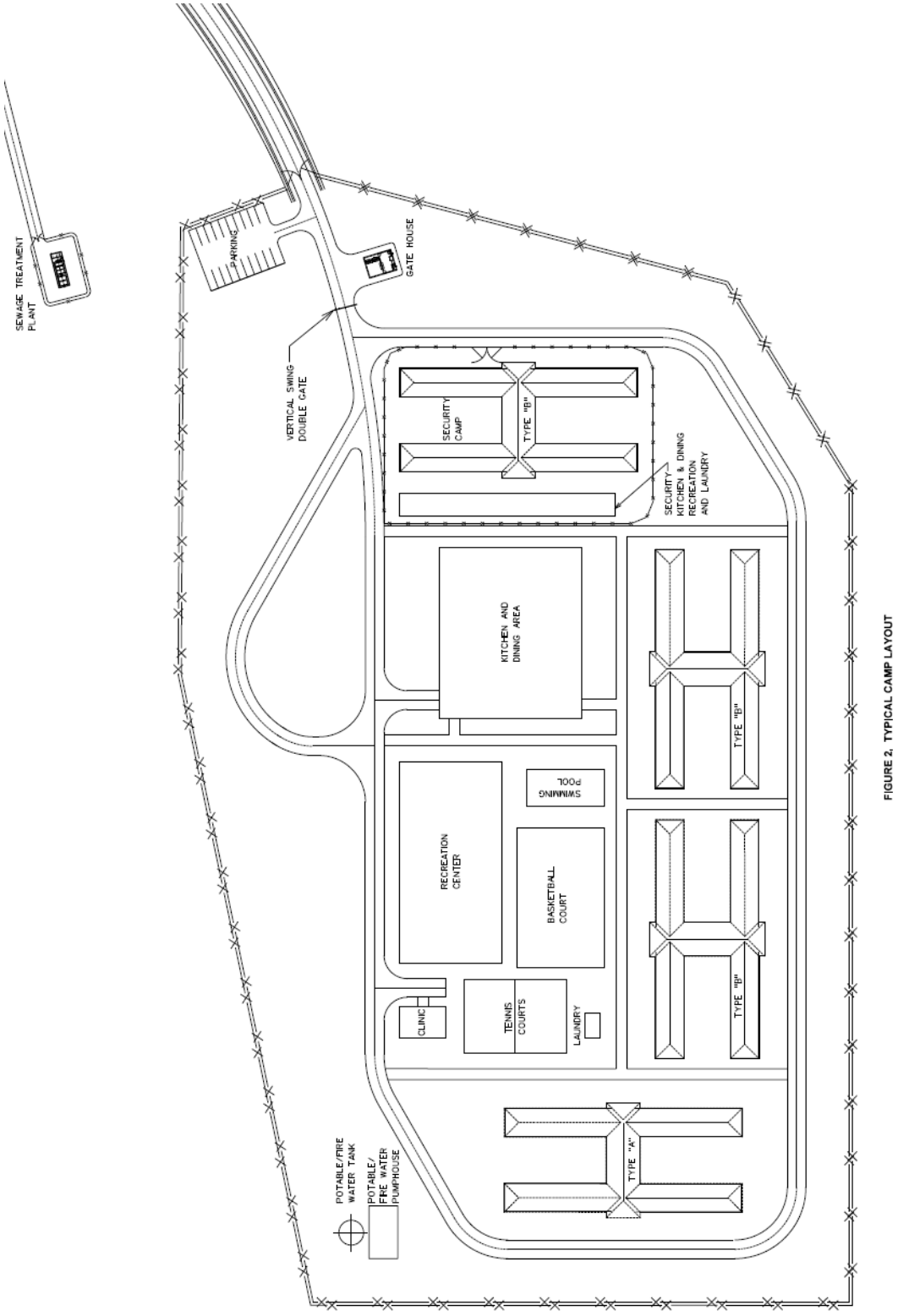


Figure 17: Typical Camp Site

In addition to the camp site's residential structures, required support facilities and systems will include the following:

- Security fencing including access gates around the facility as well as area and security lighting;
- Access roads and parking;
- Power generation and distribution systems (electrical power will initially be supplied by generators) and fuel supply;
- Water, stormwater, sanitary sewage and solid waste facilities as well as a telecommunications system;
- Fire detection and protection systems;
- Kitchen, dining, laundry and recreation facilities; and
- Medical centre (e.g., nursing station).

3.15.3 Town Site

For current purposes it has been assumed that the DGR site, while relatively remote, will be within 30 km of a small existing community of approximately 1,000 people. Also, while some basic infrastructure will be available, it may not be sufficient to support the new influx of 3,000 people anticipated to be either directly or indirectly associated with the development and operation of the DGR. An improvement and expansion in services and infrastructure may be needed, and new infrastructure may be required, subject to discussions between the NWMO and the community.

No assumptions have been taken at this time as to the possible influx of entrepreneurs who will move into the area as the population increases. As any town site development could create private sector opportunities, the strengthened municipal tax base will, in turn, encourage additional self-sustaining growth for the community as a whole.

3.15.4 Visitors' Centre

A Visitors' Centre will be established to provide the public with information about the DGR and its related activities. The Centre will be at or near the town site (see above) in a highly visible and accessible location outside the confines of the DGR facility itself. While bus services may need to be implemented between the Visitors' Centre and the DGR, such a location will benefit from shared services from the town site and its location will be more easily accessible to local area visitors.

As an option to the above, the Centre could be located just outside the primary security gates for the DGR. Such a location will be exceptionally convenient for starting tours of the DGR facilities but may pose potential security concerns with higher traffic levels close to the used fuel repository. Also, and depending on the DGR's final distance from a major highway, such a location may be more inconvenient for 'pass though' travellers.

The Visitors' Centre will provide facilities to accommodate 10,000 people per year. Five or more full time staff are anticipated, supported by 10 or more seasonal staff for the peak touring season. The Centre will include the following facilities:

- Exhibition or display rooms with interactive educational resources;
- Meeting rooms and a presentation theatre;
- Kitchen/dining facilities for staff and visitors; and
- Change rooms and laundry facilities (for DGR tour clothing).

4. SHAFTS AND HOISTS

This section addresses the surface to underground conveyance structures (shaft complexes, head frames and hoisting plants) required to support the construction and operation of the DGR. Three shafts are to be established: the Main Shaft; Service Shaft; and, Ventilation Shaft. Identified as Areas P2, P4 and B1, respectively, on Figure 4, each serves one or several functions such as UFC transport, development rock hoisting, men and materials handling and ventilation.

The location of the shafts relative to one another was initially fixed by the layout of the underground works, discussed in Sections 5.2 and 5.3. The Ventilation Shaft complex, for example, is situated about 2.2 km from the DGR's outer perimeter fence, a location that simplifies the design of underground fresh/return air routes by providing an outlet for exhaust air from one end of the underground development. Its location also allows for multiple commencement points for the initial below-ground development stages (increasing productivity and reducing the construction schedule) and serves as a convenient emergency egress location for persons working at the farthest reaches of the UFC repository.

The shafts will be serviced by a total of five hoists, with three in the Service Shaft, and one each in the Main and Ventilation Shafts.

4.1 Hoisting System Design

The five hoisting systems integrated into the three shaft complexes are described in this section. In several cases, the use of a friction hoist is specified to provide flexibility and durability related benefits to the hoist facilities. Such a hoisting plant will have a life of 100 years or more, assuming the adoption of appropriate preventative maintenance practices and component upgrade schedules.

4.1.1 Main Shaft Hoist

The Main Shaft will serve as the exclusive conveyance structure for the surface-to-underground transport of the UFCs for placement. Additionally, and when there is a need, the Main Shaft will also accommodate the transfer of any retrieved UFCs from the repository level to the surface.

The UFC's anticipated weight and dimensions are fully described in Appendix A. The intended mode of transport for placement in (or retrieval from) the repository, via a rail-based trolley, is outlined in Sections 6.3 and 7.2, respectively.

As presented in these sections, the UFC with its transport trolley and associated shielding is expected to require a lift capacity of 63.5 tonnes. The associated dimensions of the UFC on its trolley are provided in Figure 18 (dimensions are in millimetres).

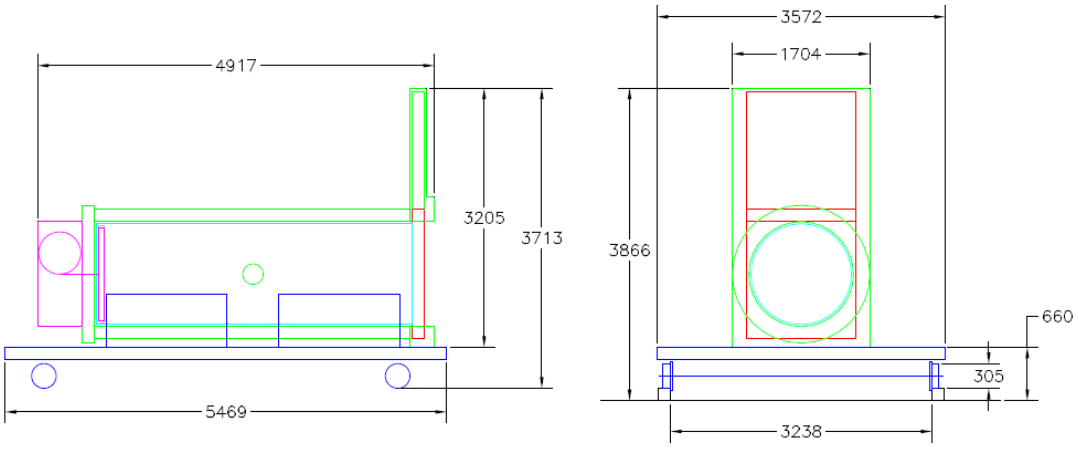


Figure 18: UFC and Transport Trolley Dimensions

The Main Shaft's hoist system, comprising one main cage with a counterweight in balance, would be configured as noted on the following Table 11. In the event of a power loss or other problem when handling UFC's, this balanced system will allow the use of a standby generator to move the conveyance up or down safely.

Table 11: Main Shaft Hoist System

Item	UFC Hoist
Configuration	Friction Hoist
Weights/Payloads	
➢ Tare with Attachments	63,500 kg
➢ Payload	63,500 kg
➢ Counterweight	95,500 kg
Suspended Load	305,500 kg
Hoist Speed	2.5 m/s
Required Motor	1,570 kW

4.1.2 Service Shaft Hoists

The Service Shaft is a multi-purpose hoisting facility for the underground repository, and incorporates the only waste rock handling installation. This combined usage system is set up with five compartments to accommodate two counterbalanced skips, a main service cage and counterweight, and an auxiliary cage for off-shift or secondary egress hoisting.

Waste Rock Hoist

The waste rock or skipping hoist will handle the excavated rock generated by development efforts during the construction of the underground repository. It will comprise two bottom dump skips in a balanced layout. Waste rock or muck will be directed to a grizzly-protected raise that feeds a loading pocket. The loading pocket will consist of two bins or flasks that are weigh-to-meter controlled, that will fill the skips when they are in position.

Service Hoist

The service hoist (one cage with a counterweight in balance) will accommodate personnel and consumables, and will be used to move equipment in and out of the underground repository. It will further be used to move sealing material components such as pre-compacted bentonite rings and disks from the surface to the repository. It will be able to carry up to 50 personnel and handle loads up to 10 tonnes.

Auxiliary Hoist

The auxiliary hoist will additionally be available in the Service Shaft to move personnel on an as-needed basis using an auxiliary cage. Power will be supplied by a diesel-fueled generator set in the event of a power loss or emergency.

The details of the Service Shaft hoist systems are as shown in the following Table 12.

Table 12: Service Shaft Hoist Systems

Item	Waste Rock Hoist	Service Hoist	Auxiliary Hoist
Configuration	Friction Hoist	Friction Hoist	Drum Hoist
Weights/Payloads			
➢ Tare with Attachments	10,000 kg	10,000 kg	2,700 kg
➢ Payload	6,500 kg	10,000 kg	1,600 kg
➢ Counterweight		15,000 kg	
Suspended Load	39,800 kg	48,400 kg	5,900 kg
Hoist Speed	5 m/s	2.5 m/s	2.5 m/s
Required Motor	373 kW	300 kW	186 kW

4.1.3 Ventilation Shaft Hoist

The Ventilation Shaft handles the majority of the repository exhaust and also serves as a secondary means of egress from the underground repository. This is provided via a single drum auxiliary hoist and cage that, like the similar installation in the Service Shaft, will have a diesel-

fueled generator for the provision of motive power in the event of an emergency. The details of the Ventilation Shaft's hoist system are as shown in Table 13.

Table 13: Ventilation Shaft Hoist System

Item	Auxiliary Hoist
Configuration	Drum Hoist
Weights/Payloads	
➢ Tare with Attachments	2,700 kg
➢ Payload	1,600 kg
Suspended Load	5,900 kg
Hoist Speed	2.5 m/s
Required Motor	186 kW

4.2 Shaft System Design

The primary design elements associated with the three required shafts were dictated by ventilation and hoisting requirements for personnel, materials and equipment, emergency egress considerations and services entry needs (air/water/power/communications).

In the first instance, and to allow for the adequate movement of air flows, the installed shafts must be of a sufficient diameter. As discussed later in Section 5.5, these requirements are as follows:

- The Main Shaft must have a diameter of at least 7 m;
- The Service Shaft must have a diameter of at least 3.5 m; and
- The Ventilation Shaft must have a diameter of at least 6.5 m.

Using these minimum diameter requirements, conceptual layouts were undertaken for each of the shafts. For the following discussions, reference should be made to Figures 20, 21 and 22 (all located at the end of Section 4) for the Main Shaft, Service Shaft and Ventilation Shaft, respectively.

All headframes for the three shafts will be of slip-formed concrete construction for a durable and easily maintainable structure, one that will provide a high level of protection against meteorological impacts. Further, all shafts will be concrete lined.

4.2.1 Main Shaft

The Main Shaft (Figure 20) will have a finished diameter of 7 m and have two compartments; one supporting the large cage used to transfer the UFCs and one for the counterweight. As the

hoisting plant will operate at only 2.5 m/s, alignment integrity and guide wear will not be an issue with respect to ongoing maintenance needs.

The Main Shaft's headframe will support the final hoisting plant. The plant will include the head frame and collar house, which will house the loading facility for the UFCs onto the transport cage. The collar house floor will be inset with rails and switches to accommodate these efforts.

The head frame will have 5 floors, consisting of one hoist floor, one power floor, a dump floor (which houses the equipment necessary to dump the sinking buckets), the collar floor and a sub-collar, in descending order.

4.2.2 Service Shaft

The Service Shaft's final finished diameter, as determined by its multiple hoisting requirements, is 6.5 m, which exceeds that needed for ventilation purposes (3.5 m). All conveyances, save the auxiliary cage, will run on steel guides. The auxiliary cage will accommodate the use of a safety 'dog' system, which will arrest the cage in the shaft by automatically deploying blades or 'dogs' into its timber guides, and bringing the cage to a safe and controlled stop in the event that the rope goes slack. The Service Shaft is illustrated in Figure 21.

Installed utilities will include service piping, power and communications cables. Piping will be required for the transmission of compressed air and water, as well as for pumping and concrete slicklines to support the development/construction of underground installations.

The Service Shaft plant will include the head frame, collar house and a bin house for handling development muck brought to surface. The head frame will have 7 floors, consisting of 3 hoist floors, one power floor, one dump floor, the collar floor and a sub-collar, in descending order.

In the shaft, loose rocks from mucking operations will be prevented from falling into the other hoisting compartments using installed panels. At the bottom of the Service Shaft, the loading pocket will have some spillage. A ramp will be developed to the shaft bottom, allowing an LHD (load/haul/dump unit) or scooptram to clean out the shaft bottom on a regular basis.

4.2.3 Ventilation Shaft

The 6.5 m diameter Ventilation Shaft (Figure 22) is the simplest of the three provided installations, with a tower that has a single operating floor to support the drum hoist and generator, plus the collar floor and sub-collar. The collar house will be able to support mine rescue or evacuation efforts and the main exhaust fans will be located adjacent to the headframe.

4.3 Shaft Sinking Requirements

The three shafts will be developed using a conventional controlled drill & blast sinking approach. The use of a raisebore for one or two of the shafts was reviewed and rejected due to schedule and efficiency concerns. It is further envisaged that the three shafts would be sunk utilizing temporary head frames in lieu of using the final head frames. This will reduce wear and tear on the final facilities.

The design of the shaft liner and grouting system (if grouting is required), will be completed after the location of the shaft (and site) is established. The shaft liner typically serves two purposes; first it is a measure of ground support, preventing minor ground shifts or loose rock from falling into the shaft, and it also may help as a means to keep water from the shaft. As will be discussed in Section 5.1, it is expected that the host geosphere for the underground repository will consist of a very good quality rock mass, one that is only moderately to sparsely fractured and with a low permeability.

The shaft sinking process itself involves several steps, which include;

- Collaring or starting the shaft;
- Setting up the equipment needed to sink the shaft;
- Sinking the shaft to its full depth; and
- Dismantling the equipment used for sinking.

4.3.1 Shaft Collaring

Collaring the shaft requires the establishment of the shaft centerline via survey, and usually requires the drilling of a borehole to confirm rock type and quality. The borehole will be drilled within the finished diameter of the planned shaft.

Once the location is confirmed, the shaft excavation will commence. This involves the use of controlled dill & blast techniques to establish the rough diameter of the shaft to an approximate 30 m depth. Removal of waste rock or muck is accomplished using a crane equipped with a bucket, with a small excavator being lowered into the excavation to load the bucket. Once the desired depth is achieved, a set of forms are installed close to the bottom, and the permanent liner for the collar is poured into place using reinforced concrete.

If the shaft is first excavated through overburden, then a similar process takes place, with the excavation through ground being carried out with a small excavator that is captive in the hole until bedrock is reached. During excavations, temporary support of the walls is provided using liner plates and ring beams, which are bolted into place. Once bedrock is reached, a drill is lowered into the hole and a 5 m cut is sunk into the excavation's bottom to act as a water-proof socket for the shaft liner, preventing influx at the rock/overburden interface. With the cut completed, a set of shaft forms are lowered into the hole, and the reinforced concrete collar is poured from the bottom up.

4.3.2 Sinking Plant Set-up

Once the collar is established, the equipping of the sinking plant can commence. The sinking plant has four main elements: the sinking hoist; sinking winches; the sinking headframe; and, Galloway (or sinking stage, see below).

The sinking hoist will be a double drum hoist, equipped with two sinking buckets to both move personnel and material into the shaft excavation, and to remove waste rock from it as it is excavated. The sinking winches (2 to 4 required) are smaller low speed hoists used to raise and lower the Galloway as required during the sinking cycle.

The sinking headframe will be a steel structure that supports the hoist and winches as well as a set of chutes for dumping the excavated shaft muck into a bunker for removal via payloader. The headframe will be approximately 40 m high to accommodate travel room for the hoisting plants, and to allow for the lowering of items like drill jumbos and mobile equipment into the shaft. A temporary enclosure attached to the headframe called a collar house will be in place to shelter workers from the elements, and to temporarily house material and equipment.

The shaft sinking stage or Galloway is a multi-decked structure that is supported by the sinking winches in the shaft. The stage is not attached to or supported by the shaft walls, it hangs independently. It is an integrated development and excavation system, wherein all aspects of the shaft development effort are completed from the one structure including drilling, mucking, ground control and liner installation. It contains all working needs, including small tools, shaft sinking drills or jumbos, and shaft liner forms.

Each deck within the Galloway has a different function, and each Galloway is unique to the shaft under construction. As the shafts in this case are close to the same diameter, utilizing the same design may be possible.

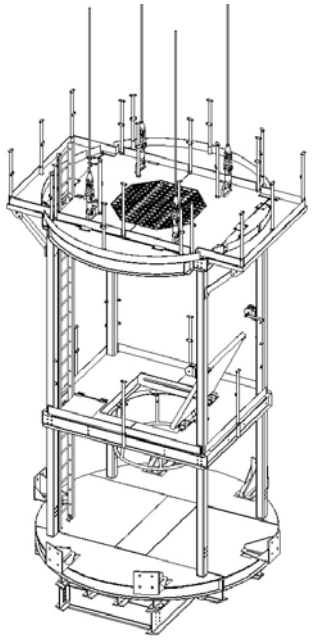


Figure 19: Typical Galloway

4.3.3 Shaft Sinking Operations

The basic process of sinking a shaft is methodical and repetitive, as follows:

- The face (or exposed bottom) of the excavation is cleaned and prepared for drilling;
- The shaft jumbo is lowered to the face and the round is drilled;
- The jumbo is lifted clear and the holes are loaded with explosives;
- The workers are brought to surface, the Galloway is lifted clear to a safe distance and the round is blasted;
- The shaft is ventilated to clear blast gases prior to workers being allowed to re-enter;
- Workers begin excavating the bottom of the shaft and installing ground control (i.e. rockbolts, screen) in the shaft walls. Geological inspections may also be undertaken across the shaft walls and face during this time;
- The shaft liner is formed and poured, extending it down closer to the face; and
- Once the face is cleared of waste rock, the cycle continues.

An average rate of advance for the shafts is between 2.5 m and 3.5 m per day.

4.3.4 Dismantling the Sinking Gear

Once the shaft bottom is reached, the entire sinking system will be dismantled to allow for production equipping. This requires that the shaft sinking stage or Galloway be taken apart and hauled to surface. The shaft sinking buckets are then removed, the various ropes used re-wound and taken off of the headframe, and the headframe removed from the collar. At that point, the permanent headframe can be constructed in its place.

4.4 Shaft Operations and Maintenance

The three shafts have been designed to promote uniformity wherever possible, so that repeat maintenance events will be as similar as practical in terms of the sequence of events, equipment required, and manpower needs.

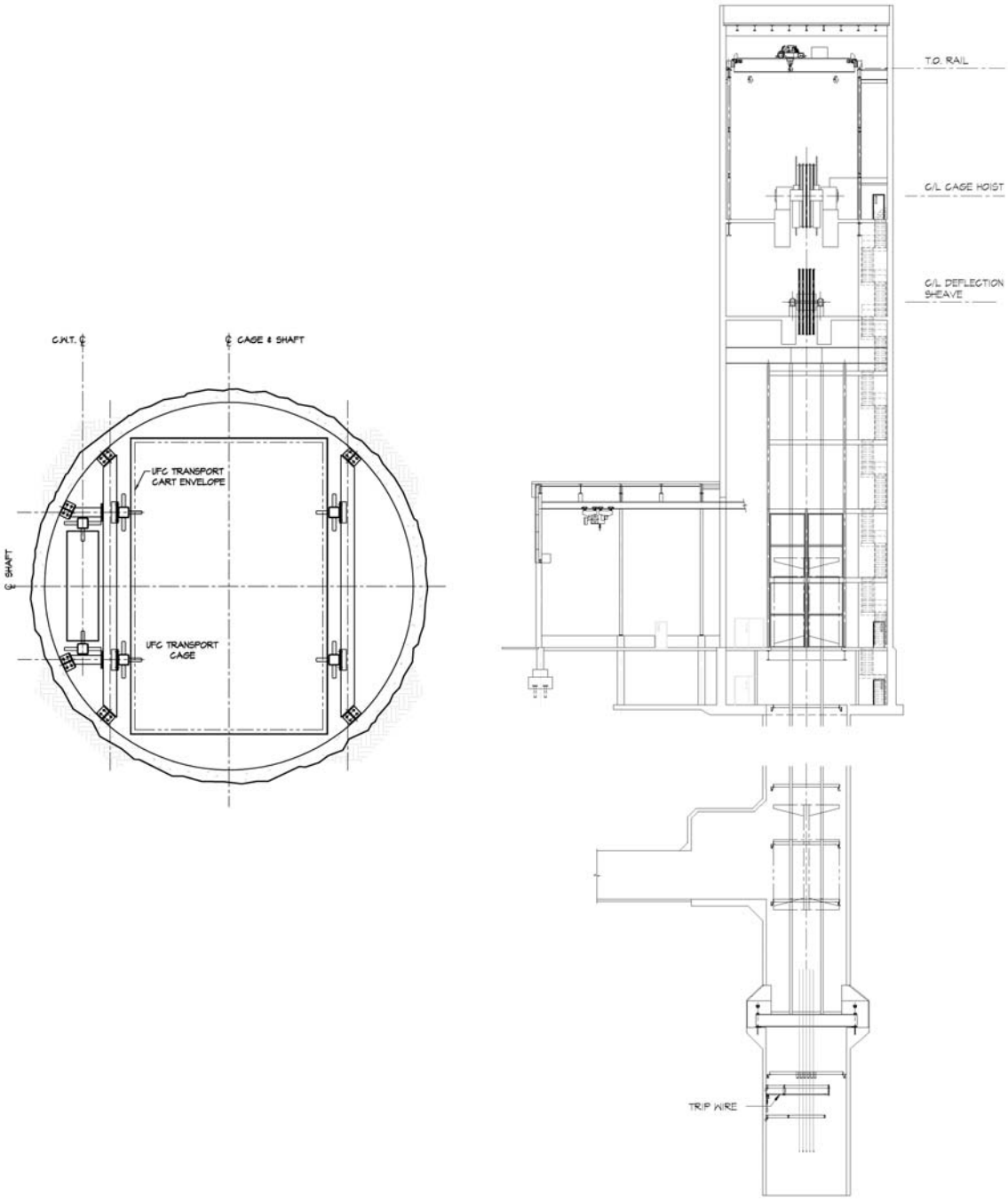
During normal operations, a minimum number of inspections will be carried out each week, as well as regular testing of hoisting plant braking systems. The hoisting plants, including ropes, conveyances and hoisting equipment will also be inspected on a periodic basis to ensure that they are in proper condition and fit for continued use.

Hoist ropes will be periodically changed, and will also be subject to regulatory requirements to have sections cut from the ends for destructive testing. This will require that conveyances be temporarily banked or supported at the collars while head ropes are disconnected for inspection or change-out. Likewise, for the friction hoists, new tail ropes will need to be installed, requiring the use of small tuggers or winches to pull the ropes up the shaft during these operations. The systems will be relatively simple to maintain and change out as required.

The Service Shaft, as a muck-handling facility, will require additional maintenance as compared to the other two installations. A general maintenance/replacement table is included below.

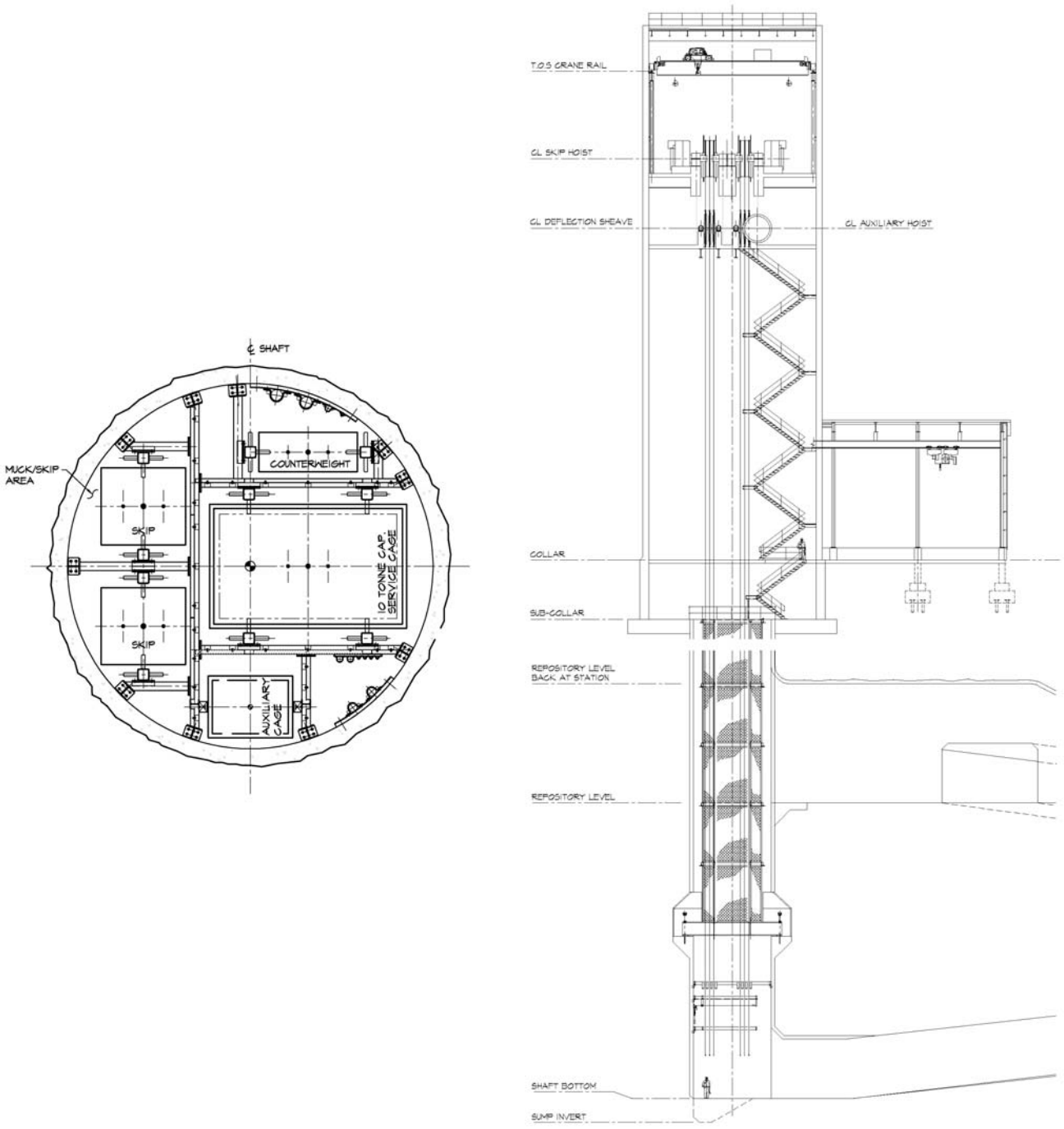
Table 14: Shaft/Hoist General Maintenance Table

Item	Replacement Frequency	Notes
Hoist Ropes	5 to 7 years	Depends on the findings of rope inspections.
Hoist Conveyances	5 years for skips 10 years for cages	If conveyance is not displaying fatigue or wear, it may be used longer.
Hoist Brake Liners	5 years	
Hoist Bearings	25 years	Depends on hoist alignment and balancing. Well balanced and lubricated machines will last longer.
Hoist Motors	25 years	
Hoist Drives	25 years	Will be impacted by obsolescence and availability of spares (may need to replace components sooner).
Hoist Replacement	50 to 100 years	Few hoists have approached 100 years in age. Full hoist replacements assumed in 50 years.



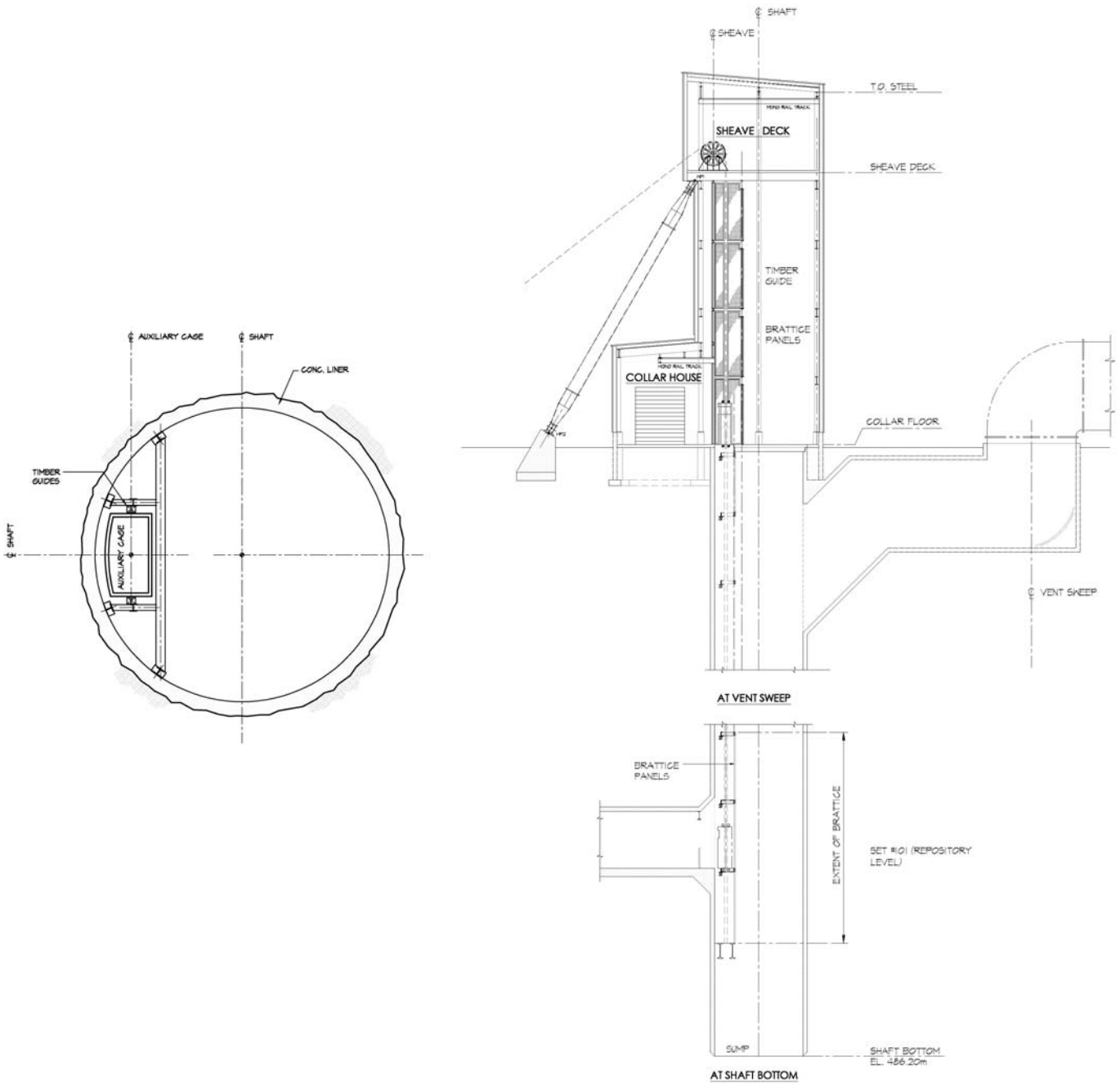
Shaft Plan **Shaft and Headframe Section**

Figure 20: Main Shaft



Shaft Plan **Shaft and Headframe Section**

Figure 21: Service Shaft



Shaft Plan **Shaft and Headframe Section**

Figure 22: Ventilation Shaft

5. UNDERGROUND FACILITIES

There are two main components to the underground operations of the DGR: the Underground Demonstration Facility and the main repository itself that will contain the placed UFCs. These operations are described in this section, following a brief description of the expected geosphere conditions. Additionally, the ventilation system that will be used to support the development of these facets of the DGR is presented.

5.1 Geosphere

Given that a location has not yet been selected for the establishment of the DGR, a hypothetical site setting was postulated for the design of the underground works. This 'reference geosphere' comprises a single material type (granitic gneiss) with attributes that closely match those of a typical Canadian Shield crystalline rock site. The geosphere is assumed to be an elastic, isotropic, homogeneous, undamaged and generally sparsely fractured rock.

The rock mass is assumed to be of a very good quality with an effective mass permeability of 10^{-15} m^2 and a hydraulic conductivity of $1x10^{-13}$ m/s. Its thermal conductivity is assumed to be 3.0 W/m°C.

For the conceptual design work, a discrete fracture network was assumed using a geostatistical fracture propagation procedure, the results of surface lineament analysis and lineament/fracture statistics thought to be typical of a site in the Canadian Shield region. Surface lineaments were extended into a self-consistent set of fractures to depths of 1,500 m using propagation conditions that represent both sensible and geomechanically plausible fracture behaviour.

Thermo-hydraulic-mechanical (elastic) analyses or T-H-M modelling for the crystalline geosphere was then carried out to assess potential changes in time with near-field and far-field conditions. In the modelling, criteria were adopted representing the peak and residual strength of the rock mass with a plastic algorithm in the numerical analyses used to predict potential changes in these characteristics over time. The modelling also took account of the backfill materials that will surround the UFC and fill its placement room.

Excavation-related damage around the in-floor cylindrical placement holes at the design depth (500 m) and associated in situ stress field is inevitable, regardless of the adopted design parameters. Considering, however, that the underground excavations are to be conducted using controlled drill & blast and shaft boring techniques (as discussed later), no or negligible damage to the walls of the created openings is anticipated from the actual excavation work. Thermal considerations for the emplacement of the UFC (i.e. the heat dissipation from the entombed UFCs) are expected to dictate the spacing of the rooms and containers.

As a contingency for this study, it has been assumed that approximately 10% of the in-floor boreholes would not be useable due to unfavourable geotechnical or hydrogeological conditions. The maximum in-floor borehole inflow rate allowable is 0.1 L/min. Flow rates greater than this have been deemed to destabilize the bentonite rings and disks, prior to the placement of the UFC. This contingency will also cover conditions such as encountering unfavourably oriented fractures or ground conditions.

5.2 Underground Demonstration Facility (UDF)

The Underground Demonstration Facility (UDF) is the first area to be developed underground and has been designed to test and confirm the configuration, equipment and methodologies used to develop and operate the DGR. The other main objective of the intended work with the UDF is to assess the characteristics of the geosphere within which the UFC repository will be developed and identify any major geologic discontinuities which could affect its construction and performance. The UDF would operate for several years prior to the commencement of used fuel deposition and could have a continuing role over the life of the underground repository.

5.2.1 Purpose of UDF

The Underground Demonstration Facility (UDF) would be the first stage of the underground operations at the DGR with development beginning upon completion of the rock handling system in the Service Shaft. The UDF includes the area near the Main and Service Shafts that would be used for demonstration tests, as well as the perimeter drifts that will be excavated prior to development of the placement rooms.

The UDF provides an area prior to the full operations phase of the DGR for site-specific testing and demonstration of various aspects of the eventual underground repository. A rigorous experimental program could be carried out and many of these potential areas of investigation have been listed in Table 15. A further elaboration of some of these programs has also been provided in the sections following this table.

The UDF would also further be used for training operating personnel with mockups and actual equipment in a realistic environment. The same training areas can additionally be employed to show visitors the operations of the underground works. Such interactions could be performed with little or no direct effect on the main repository's operation.

As discussed later, this facility can incorporate offices and specialized storage and repair facilities as well as on-site offices for all underground engineering and technical personnel. These facilities can allow technical staff to undertake their support work close to where equipment testing is being performed, thus reducing time in travel to and from the surface.

Table 15: Potential Experimental and Demonstration Programs for the UDF

Programs	Locations	Duration
Rock Mass Characterization		
➢ Geologic mapping of underground excavations ➢ Thermal property tests ➢ Stress state measurements ➢ Displacement monitoring (at underground openings) ➢ Seismic monitoring ➢ Geophysical monitoring	Demonstration rooms, perimeter cross-cuts, shafts and/or boreholes	Throughout UDF development (some tests continuing during operations)
Rock Mechanical Experiments		
➢ 3D stress rotation experiment to support 3D modeling ➢ Large scale strength tests (for spalling and scaling) ➢ Creep tests to determine the time and thermal dependent behaviour ➢ EDZ experiments around the underground spaces	Boreholes, demonstration rooms and perimeter cross-cuts	During drift excavations and throughout UDF development and operations
Hydrogeological Experiments		
➢ Straddle packer hydraulic testing of rock mass and fracture zones if detected ➢ Hydraulic interference and tracer transport experiments in detected fracture zones ➢ Monitoring of hydraulic pressures	Boreholes from perimeter tunnel, demonstration rooms and cross-cuts	Throughout UDF development and operation
Geochemistry Experiments		
➢ Long-term diffusion ➢ Radionuclide retention ➢ Microbial experiments ➢ Monitoring of groundwater chemistry ➢ Matrix pore waters geochemistry	Demonstration rooms and perimeter cross-cut, and/or boreholes	Several years throughout UDF development and operation
Excavation and Mining Engineering		
➢ Optimize drill and blast techniques to minimize EDZ ➢ Optimal geometry of placement rooms ➢ Long-term performance support ➢ Bulkhead Performance (including LHHP concrete interaction with bentonite bulkhead seal) ➢ Mechanical excavation of UFC in-floor borehole	Demonstration rooms	Emphasis during first years of development of UDF and demonstration rooms
Demonstration of Placement and Retrieval Equipment		
➢ Rail bed optimization ➢ Radiation shielding and bentonite sealing systems ➢ UFC placement using specialized equipment ➢ UFC retrieval using dedicated equipment	Demonstration rooms	Throughout operation of UDF
Long-term Full Scale Placement Demonstrations		
➢ Instrumentation and monitoring equipment ➢ Long-term corrosion studies ➢ Performance of heated (empty) UFCs, bentonite sealing systems and near-field rock and groundwater ➢ Placement and long-term assessment of active UFCs ➢ Retrieval of UFCs with dedicated equipment	Demonstration rooms	Throughout operation of UDF

5.2.1.1 Demonstration of Placement and Retrieval of Used Fuel Containers

The UDF can be used to test all aspects of the equipment and associated methodologies for UFC placement and long-term isolation. The evaluation work can be performed in a number of test rooms with each component of the placement cycle undertaken in a location or room dedicated to that particular aspect of future activity. The main components of the UFC placement operations to be tested, demonstrated and evaluated could include:

- Track installation methodologies that minimize the use of concrete in rail support;
- Drilling of the in-floor boreholes;
- Buffer material placement in boreholes (including buffer rings, disks and gap fill pellets);
- UFC transport and placement in borehole; and
- Backfill block and light backfill installations for placement room sealing.

For these and other operational components, a demonstration room set-up can be established and associated equipment (e.g., borehole drilling units) installed. Following initial testing and monitoring, the operational components may be refined and improved with subsequent testing carried out on the undertaken modifications. This process would continue until an optimum approach is identified.

Testing may also focus on the potential automation and monitoring systems required for the underground operations. Test rooms can be provided with the same data, communication and automation support infrastructure that would be installed throughout the repository complex.

Long-term performance demonstrations of UFC, buffer, backfill and geosphere performance over the period of operation of the DGR could be carried out. Tests could include dedicated demonstration rooms for monitoring the performance of both heated non-radioactive UFCs and UFCs containing fuel bundles. A component of this work would also examine the recovery of the buffer and backfill materials for geotechnical analysis, as well as the removal of the UFC for corrosion assessments.

Placement methods for the UFC can be assessed as would extraction/removal operations. The complete retrieval method can eventually be refined and perfected to additionally encompass the removal of the concrete bulkhead, as well as the fully saturated sealing materials.

5.2.1.2 Geosphere Characterization

For areas more remote from the Main / Service Shaft complex, the UDF will be used to assess the host geosphere during development of the perimeter drifts around the outside of the underground repository. While constructing the drifts, geotechnical monitoring and testing instrumentation would be put in place to assess critical site-specific geomechanics, rock properties and other geosphere characteristics which can be used to optimize placement room design and the overall configuration of the repository.

5.2.1.3 Demonstration of Excavation Methods

In order to minimize potential pathways for groundwater movement after closure, and to reduce the use of ground support in the placement rooms and drifts, the blasting damage in the rock surrounding the created openings needs to be minimized. This excavation damage zone (EDZ) can be controlled through the use of careful excavation techniques. Detailed mapping of the rock after excavation, and correlation of the EDZ thickness to the blasthole pattern and blasting techniques (for example) will ensure that the methods adopted meet all requirements. Excavation methodologies for the various required types of underground openings can, therefore, be optimized.

With respect to ground support, there are a number of options available depending on the conditions encountered and the geospheric characteristics. The UDF can allow testing of a variety of systems to optimize the approaches used for the different opening sizes and configurations. Where automated installation equipment (e.g., remote controlled rigs to install rockbolts) is deemed appropriate for quality control, such equipment would be tested and modified to meet the requirements of the DGR.

5.2.1.4 Geosphere Monitoring

In order to assess the in-situ conditions of the geosphere, as well as changes brought about by the process of developing the repository, a testing and monitoring program can be developed and implemented during the UDF phase and will continue throughout the life of the repository.

The baseline in-situ parameters such as rock strength, stress, temperature and permeability will require collection at an early stage of repository development to assess changes brought about by the development work. Such tests can be carried out in virgin ground, away from development activities. Measurements and the collection of representative samples for testing can be carried out through drilled boreholes. Limits on boreholes can be established to minimize potential conduits for the migration of groundwater from the repository.

Once in-situ measurements have taken place, instruments can be installed in the boreholes for the long-term monitoring of changing conditions. Instruments including piezometers to measure pore water pressure and thermistors can be installed and monitored remotely for long-term data collection.

As repository development and placement techniques are refined within the UDF complex, changes in the in-situ parameters can be assessed to confirm predictions of previous studies as well as to allow optimization of excavation techniques and layout. Such activities can include physical measurement, visual observation and remote techniques. Pre-installed stress change measurement and displacement monitoring instrumentation can gauge changes in in-situ conditions as excavations proceed. Pre-drilling and optical logging of observation boreholes through the rock mass in advance of excavations can allow post observation of the same boreholes to examine changes. Remote sensing using, for example, ground penetrating radar, may be employed. Micro-seismic monitoring can also be used to assess the energy imparted by the various excavation techniques.

5.2.2 UDF Life and Expandability

The UDF can be developed prior to the commencement of used fuel receipt into the repository's main placement rooms to pre-test most aspects of the underground operations. The UDF can continue to operate over the complete life of the repository, to demonstrate, monitor and confirm simulated UFC placement results and provide feedback on the effectiveness of the design approaches.

The UDF has been designed to integrate with the overall underground repository but be located so as to be separate from the UFC placement rooms with respect to the test room activities. This will ensure that facilities common to both the UDF and the repository are centrally located to both operations.

For the Base Case 3.6 million fuel bundle scenario, the underground repository's operational life is forecast to be about 30 years, which translates into a 35 year life for the UDF. The additional 5 years allows for test room development and the evaluation of various operational aspects of the underground works before UFC placement activities. For the Alternate Case 7.2 million fuel bundle scenario, the repository's life is forecast to be 60 years, which translates into a 65 year life for the UDF. While the two proposed lifespans for the UDF are very different in scope, they will share common requirements with respect to the core facilities and services adjacent to Main Shaft complex.

The layout envisaged for the UDF design incorporates a test room layout similar to that planned for the main UFC placement rooms. It also incorporates adjacent available undeveloped and unbounded areas sufficient for the development of additional test rooms or facilities should they be required (e.g., if needed for the Alternate Case development).

5.2.3 UDF Location and Configuration

The location of the UDF can be such as to allow for flexibility in the development of the testing rooms while also providing adequate opportunity to assess the overall repository geosphere. It can be located close to the required services for the DGR's on-going operations. As previously described, the UDF would be the first phase of the overall underground project implementation and would operate on a stand-alone basis for about 5 years.

5.2.3.1 Location of Facility

The primary testing area of the UDF would be situated around the Main and Service Shaft complexes (see Figure 23). As illustrated, the test rooms, personnel offices and associated facilities are located on one side of the repository footprint. This area is connected to the shaft complexes and other facilities through the access crosscuts and drifts. The common service facilities for both the UDF and the main repository are on the opposite side of the shafts.

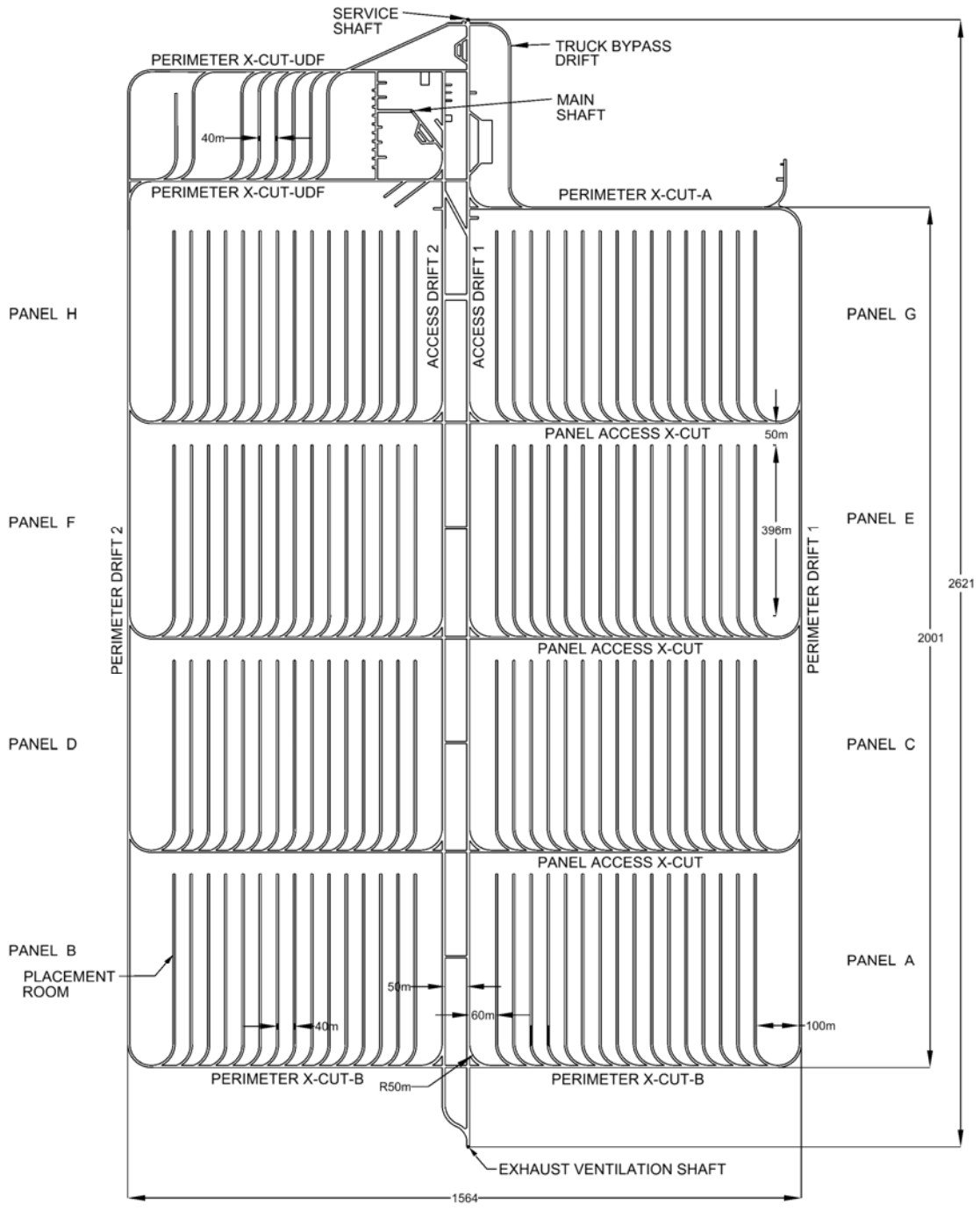


Figure 23: UDF and Repository Layout

The close proximity to the Main and Service Shafts will minimize the initial development required to place the UDF into operation. It also minimizes travel times and materials handling coordination during the initial development.

Figure 24 presents an enlargement of the test rooms and service facilities area. As shown, the configuration of the area provides for additional test rooms to be developed if and as required. The proposed UDF location would allow it to operate independent of the repository activities with minimal interference to the UFC placement operations. The location can further facilitate expanded UDF functions, even after repository operations are finished.

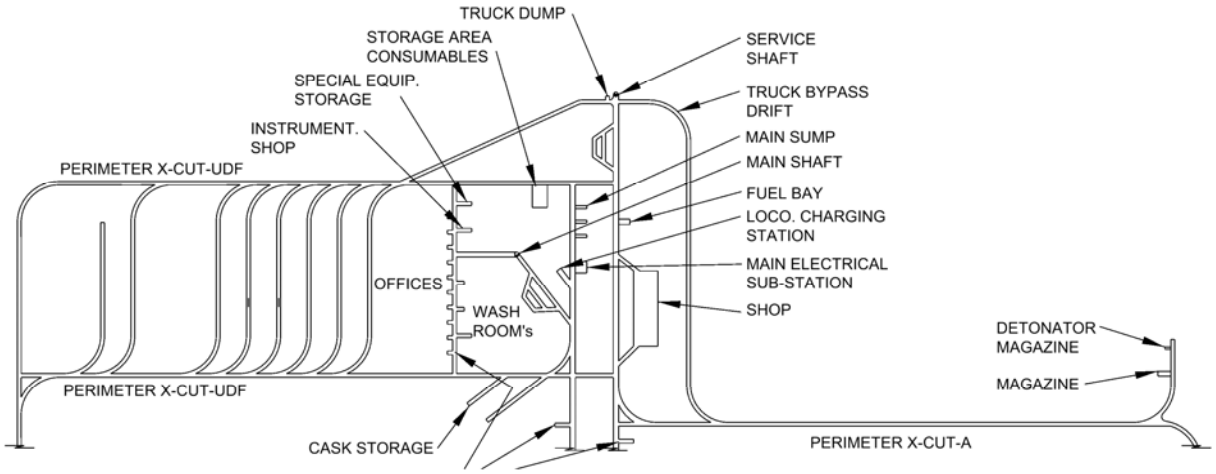


Figure 24: Test Rooms and Service Facilities

As illustrated in Figures 23 and 24, the 'central' UDF area itself would consist of the test rooms, accesses to the rooms, offices and services drifts and associated installations. As further illustrated on Figure 23, and to adequately assess the geosphere characteristics for the repository footprint, the UDF phase also includes drift and crosscut development around the perimeter and through the area of the proposed underground works. The perimeter drifts and crosscuts will be developed with the dimensions required for the UFC placement phase. All assessments of the repository geosphere would be carried out in these perimeter openings and crosscuts. The perimeter drifts would extend approximately 2.6 km from the Main and Service Shafts to the Ventilation (exhaust) Shaft. The perimeter crosscuts would be approximately 1.6 km long and be developed on either side of the central access drifts (i.e. they would extend outwards from the central drifts by about 800 m).

5.2.3.2 Configuration Design

The UDF areas represent, in some respects, a smaller version of the main repository footprint. The main testing areas would be accessed from central Access Drift 2 (see Figure 23) with one crosscut above and one below the testing rooms, interconnecting the rooms. The crosscuts are the same length as the repository panels below it. The first drift off the access crosscuts would include the offices and services drift. Subsequent drifts would contain the testing rooms. The

initial test rooms would demonstrate and refine drilling and blasting techniques intended for the DGR's UFC placement areas.

Subsequent rooms, spaced at 40 m centres, would accommodate testing and evaluation activities for the various placement equipment components. The first such testing room would be assigned to borehole drill evaluations. Borehole drill prototype(s) would be trialled and the production model finalized here. The production machine would then be used to drill a series of boreholes in the subsequent test rooms to facilitate the examination of UFC placement and room backfilling equipment. Rooms would also be provided to test and demonstrate buffer placement in the boreholes, buffer cap placement and backfill blocks placement.

Two additional rooms would be developed at the far end of the UDF and house actual container placement facilities. One room would have empty containers (without actual fuel bundles) to simulate UFC installations. The second room would accommodate the placement of containers with used-fuel bundles to monitor real installation conditions versus the modelled conditions. These two rooms would be isolated from the other test rooms to eliminate the possibility of any heating effect on local ground conditions interfering with ongoing training or equipment testing being performed in the other rooms.

The room spacing, with a 40 m centreline to centreline separation, would be the same as for the main repository footprint (spacing is discussed later in Section 5.3.3).

The test room lengths are designed to provide sufficient lateral area to allow for preliminary placement systems' setups and testing and to accommodate any potential modifications as may be required for the test prototypes. In addition, the test room lengths are envisaged to incorporate sufficient space to allow for a production style operation of the finalized placement equipment configurations. This will ensure that the equipment systems can be successfully transferred from test to actual production conditions while also providing training to initial DGR crews in a near production mode phase.

The UDF would also be connected via the access crosscuts and connection drifts to all required service facilities. Such facilities will be accessed from Central Access Drift 1 (Figure 23).

5.2.3.3 Excavation Profiles

The excavation profiles discussed below for the various drifts, crosscuts and placement rooms have been based on equipment sizing requirements and ventilation air flow criteria.

Central Access Drifts

The central access drifts will be used as the main travelways from the shafts to the repository placement panels. These drifts will be developed with widths to accommodate rail transport and foot traffic simultaneously, without requiring safety bays for people. Rail transport systems require an approximate 5 m width and an additional 2 m has been provided for people on foot (see Figure 25). The height would be 5 m to allow for service placements and equipment travel.

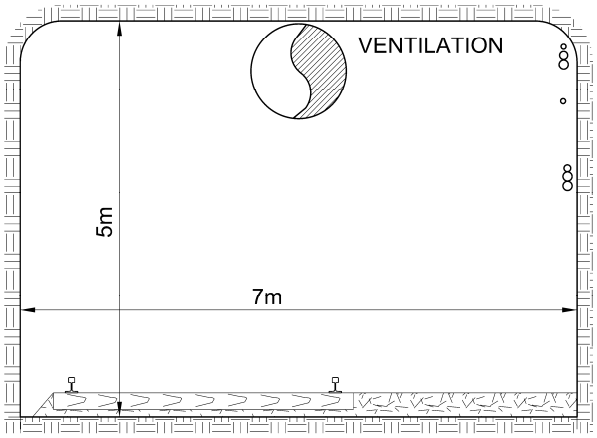


Figure 25: Central Access Drift

As the access drifts are developed, the main services will be installed including compressed air lines, waterlines, drainlines, power cables, blasting cables and ventilation ducting. After drift development has been completed the final rail installation with a concreted track would also be established. The concrete floor will ensure a good long-term track installation and simplify any clean-up operations required. Lighting will be provided for the full length of the drifts to improve visibility and safety.

Panel Access Drifts and Crosscuts, Perimeter Drifts

Panel access drifts, perimeter drifts and crosscuts would be developed similar to the central access drifts except with dimensions of 5 m wide by 5 m high. Track would be installed in the panel access drifts (see Figure 26) and crosscuts but not in the perimeter drifts (Figure 27). As a result, the perimeter drifts would contain a levelled gravel floor only. For these travelways, personnel on foot would stand in room accesses and safety bays along the access routes to avoid passing rail, truck or LHD (load/haul/dump) traffic.

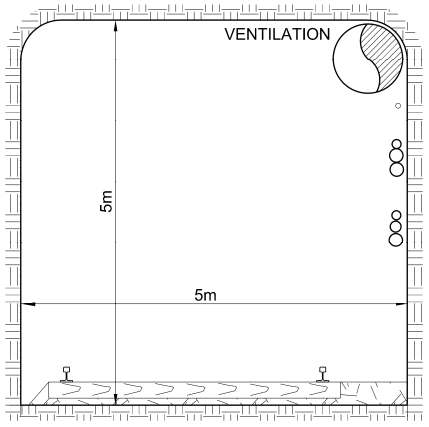


Figure 26: Panel Access Drift

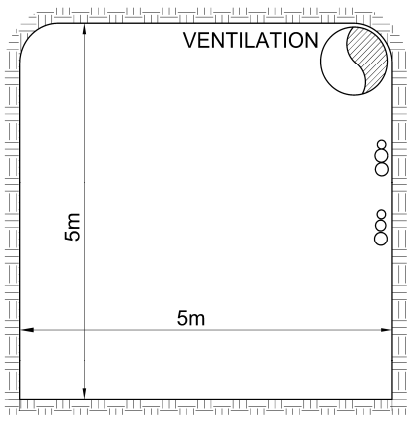


Figure 27: Perimeter Drift

5.2.3.4 UDF Test Rooms

The UDF test rooms would be used to finalize the placement room design. Initially it is anticipated that a half elliptical shape with the long axis in the vertical dimension will be developed. The ellipse on which the shape is based has dimensions of 11 m by 5.5 m. The resulting room would have dimensions of 5.5 m wide at the floor and 5.5 m in height (see Figure 28). The floor width of the test rooms is based on the proposed track gauge for the test placement equipment while also providing for working space on either side of the equipment.

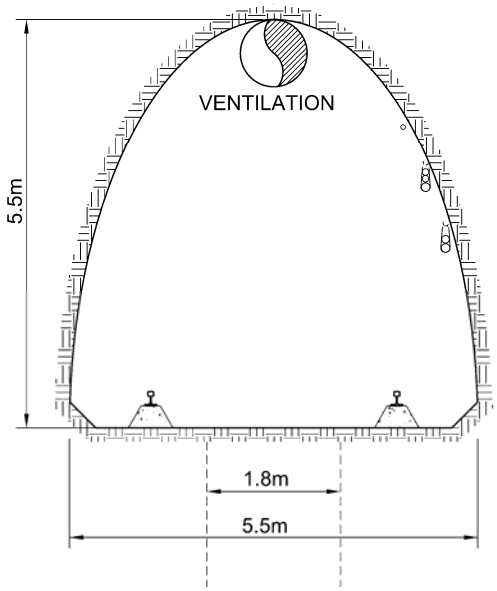


Figure 28: Test Room

The test rooms would be configured identically to that of the repository placement rooms, to simulate as closely as possible all aspects of repository operations. They would also simulate the openings configuration of the repository's placement rooms to assist in monitoring potential rock behaviour before and after UFC placement is completed.

After development of the initial test rooms is completed (demonstrating and refining excavation techniques for the UFC placement areas), track to test prototype placement equipment would be installed. Following tests and evaluations, methods would be modified as required to produce the most effective track installation approach for the placement rooms. After the optimum track configuration has been established, this setup would be employed in all subsequent test room installations.

5.2.4 UDF Services and Support Installations

Most support installations required for the UFC repository would also be required for development and operation of the UDF, before the main repository footprint is developed. Services to support development of both phases would be installed in their permanent configuration during the initial establishment of the UDF.

5.2.4.1 Support Services

The main support (utility) services to be provided for the underground operations are discussed below.

Electrical Distribution

A 13.8 kV feed will be sent underground by two cables, both powered and interlocked so that they are kept 'warm'. Either cable will be able to carry the entire facility load, providing 100% redundancy. Loads on the UDF/repository level will be handled by mobile power centres that will transform power down to 4,160 V and 600 V as required. On surface, the 4,160 V feed will drive the hoists, fans, and other power requirements for the shaft complexes. Lighting panels and welding plugs will be serviced via low-capacity, local transformers and panels.

Compressed Air

Compressed air will be supplied by 3 compressors located on surface near the Main Shaft. Two will operate at any one time with the third on standby. The compressors will supply a main 254 mm compressed air pipeline located in the Main Shaft. This main line will distribute compressed air to the underground distribution system piping.

Service and Potable Water

Total annual service water requirements for drilling and other uses will be approximately 110 million litres, primarily based on estimated equipment and process water needs. Up to 90% of the used water is expected to be recycled. All water pumped to surface will be cleaned of particulate matter in a settling pond for potential re-use.

Water will be sent underground in a 200 mm pipe located in the Main Shaft. This will feed the distribution lines underground. Potable water would be supplied to all lunchrooms/refuge stations and washrooms via a separate potable water pipeline connected to the surface potable water supply. Bottled water may also be used for the supply of drinking water.

Mine Dewatering

Water collection sumps would be located near the office complex and at the midpoint of each perimeter drift of the main repository footprint. Pumps placed in the sumps and dewatering lines will direct water to the main water collection sumps, for settling, recirculation and/or discharge from the mine. All sumps would be periodically cleaned to remove settled slimes. The primary dirty water sumps will be constructed near the Main and Service Shafts.

Central Blasting Control

Excavation blasting will be scheduled at the same time each day with its control centralized close to the Service Shaft. A check-in/check-out procedure will be in place to ensure that active development areas are clear prior to blasting.

Mine Communications and Controls System

A communications and data network will provide voice communications, PLC monitoring and control, data collection and dissemination via an underground computer LAN and video. A fibre optic cable backbone and wireless data and voice system will provide all applications required to operate the mine and undertake data handling and transmission to the surface.

5.2.4.2 Primary Support Facilities

The primary facilities needed to support development and operation of the underground repository are discussed below. Additional works, to that described below, will also be in place (e.g., UFC temporary storage area, materials flat cars parking areas, etc.).

Maintenance Shop

A shop will be in place to perform all maintenance on the mobile trackless mining equipment. The shop will be constructed near the Service Shaft, off Access Drift 1 (Figure 23) with a main shop area for working on larger equipment and satellite bays to service smaller equipment. The maintenance shop will also incorporate a wash bay, welding shop, parts storage warehouse, electrical room, crew meeting room and a supervisors' office (with workstations connected to the mine information management system). Details of the maintenance shop arrangement are presented in Figure 29.

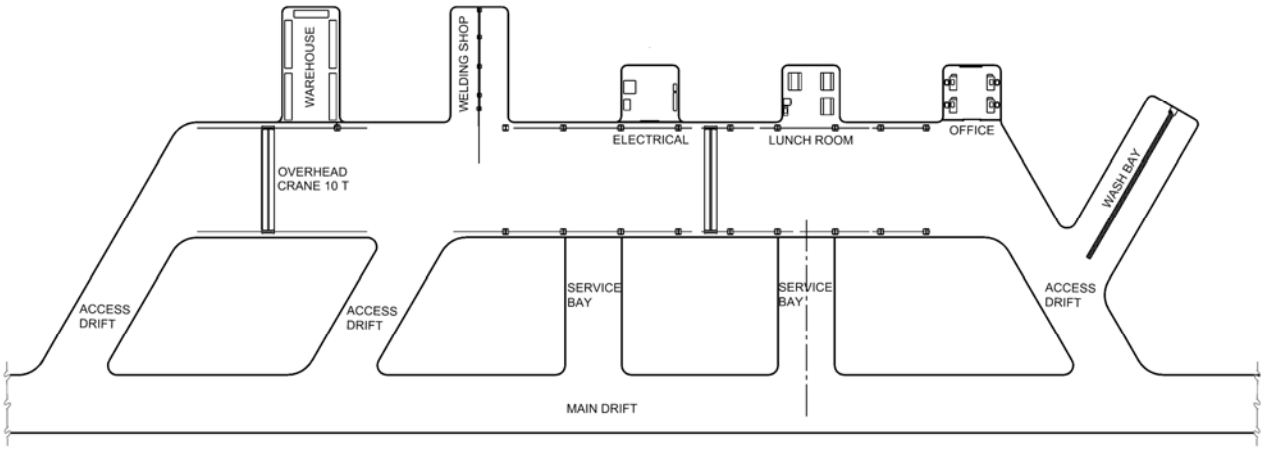


Figure 29: Maintenance Shop

The main shop area which will be approximately 75 m long, 12 m wide and 10 m high. Overhead bridge cranes and an overhead monorail crane will be in place to support the maintenance activities.

Fuel Station

A fuel station will be constructed near the maintenance shop with entry from Access Drift 1. It will be provided with a fire resistant roll-up door at the open end, to separate the fuel bay from other working areas in the event of a fire. The fuel bay will house 2 steel or HDPE fuel tanks and 3 HDPE lube tanks.

Explosives Magazine

An explosives magazine will be located at the end of Perimeter Crosscut A (see Figure 24), to isolate it from the main UDF and UFC repository operations while being readily accessible for trackless explosives loading trucks. The magazine will be fitted with shelving for bulk explosives bags and stick powder and be equipped with a wall mounted jib crane.

Detonator Magazine

The detonator magazine will be located adjacent to the explosives magazine. It will be equipped with shelving for the stacking of detonator boxes.

Charging Station and Locomotive Repair Shop

A battery charging station and repair shop for locomotives will be located near the Main Shaft access drift (see Figure 23). It will be approximately 30 m long, 7 m wide and 6 m high. The station's general arrangement is shown in Figure 30 (next page). Two crane installations will be in place for changing locomotive batteries and for general repair work. Battery racks will also be installed on one side of the station along with battery charger units.

Materials Handling and Storage Area

A large storage area for mining consumables including pipe and fittings, ground support materials, ventilation supplies, etc. will be developed near the Service Shaft. With a 20 m length, 7 m width and 5 m height, the area will include shelving and racking to safely store articles. Rail flat cars will transport bulk shipments from the Service Shaft to the storage areas. Excavation related materials will in turn be distributed to the final working places by service vehicles. Materials for the UFC placement operations would be transported by rail.

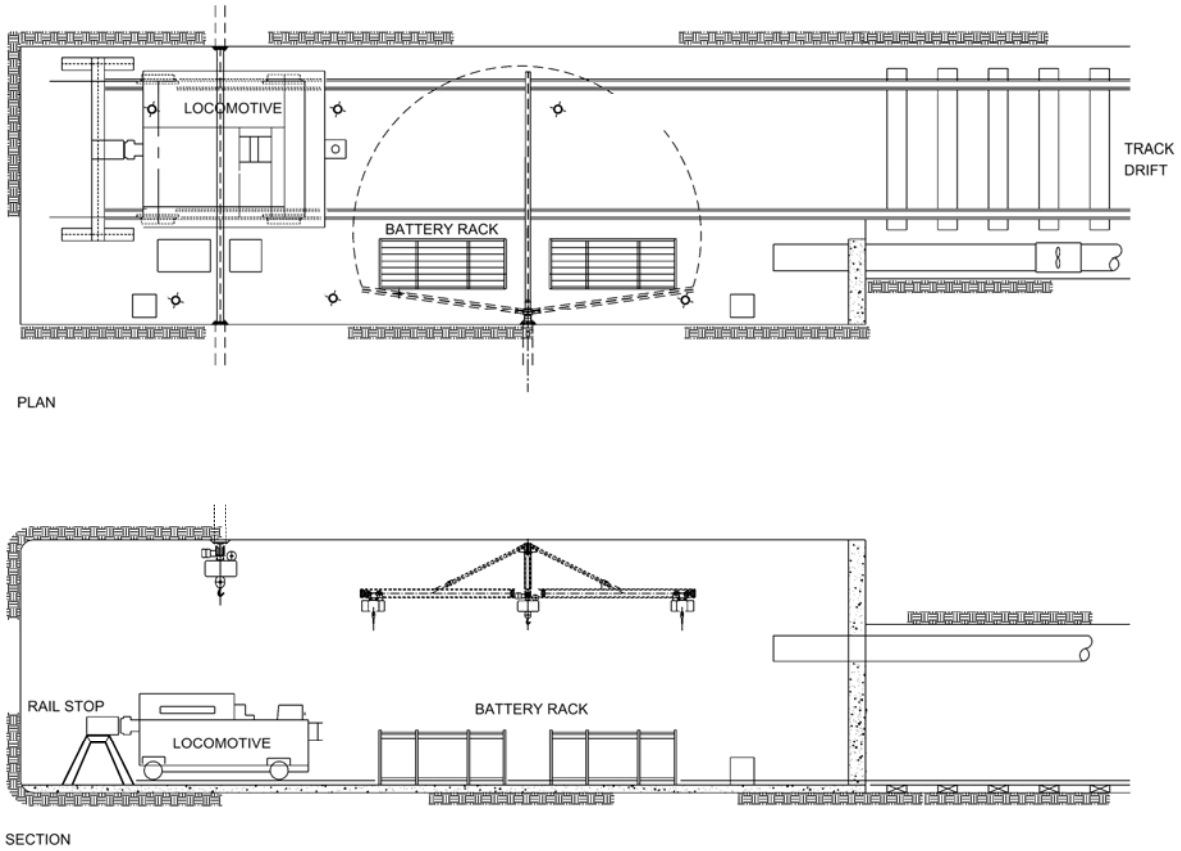


Figure 30: Charging Station and Locomotive Repair Shop

5.2.4.3 Ancillary Support Facilities

The UDF 'central' testing area will also include ancillary facilities for technical staff. Such facilities will include offices, specialized equipment repair areas, washrooms and a combination refuge station/lunchroom (where, in the event of a fire or other emergency, personnel would gather for safety). A drift near the Main Shaft would accommodate the vast majority of these facilities.

Offices

Offices will be developed on an as-required basis in the offices and services drift. Offices will be provided with a computer network connection to the DGR-wide data and control network.

Refuge Station / Lunchroom

A refuge station will be located near the offices. The station will be about 15 m long, 5 m wide and 4 m high. Its general arrangement is shown in Figure 31. The station will have 2 concrete walls with steel doors at one end. It will include a main area for personnel, and an operations

supervisor's office at the back end of the station. The refuge station will be equipped with safety and rescue equipment such as a fire extinguisher, eyewash station, first aid kit, emergency food and drink rations and a stretcher. Under normal operations, the facility will serve as the lunchroom for the underground activities.

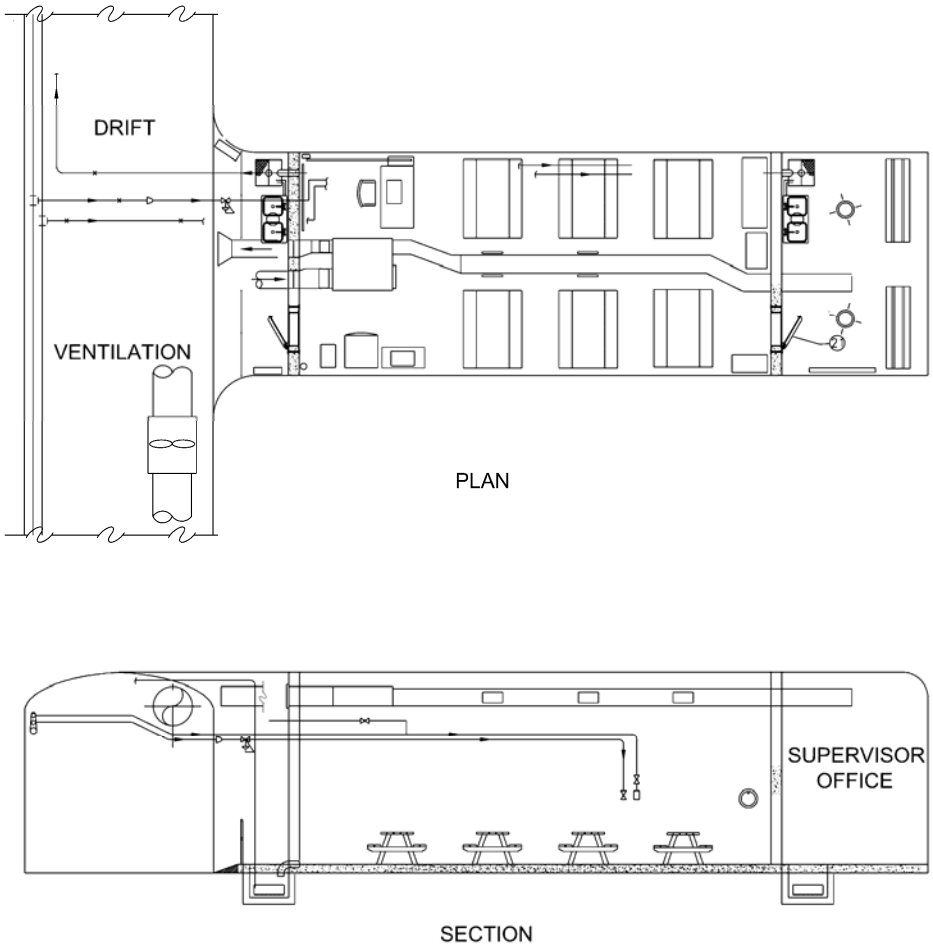


Figure 31: Refuge Station

Two additional (smaller) refuge stations will be established along the main access drifts in the main repository footprint.

Washrooms

Underground toilets (portable mining toilets) will be provided near the offices and refuge station. Wastewater from the washrooms will initially be held in local holding tanks. These tanks would be pumped out on an as-required basis to a larger transport tank for transmission to the surface for treatment. During the subsequent development of the UFC repository, additional portable toilets will be provided in the operational placement room's panel.

Instrumentation Shop

A small underground instrumentation shop will be provided across from the offices to store and repair specialized equipment used in testing activities. The shop will be 30 m long by 5 m wide and 4 m high. It will be equipped with work benches, shelving and repair and calibration tools. Other storage areas for specialized tools and parts used in the UDF testing rooms will be developed across from the offices or near the rooms themselves.

5.3 UFC Repository

As previously described, the UFC repository will be developed at a single horizon along with the various facilities, infrastructure and works that comprise the UDF. The UDF construction would, therefore, provide the infrastructure required for the repository's operating period (truck dump/ rockbreaker, maintenance shop, offices, etc.) and its service facilities including washrooms and refuge station/lunchroom will be used by repository personnel. The following sections examine alternate design arrangements and identify preferred approaches for the development of the repository.

As will be discussed, the UFC placement rooms comprise a series of parallel, single-level excavations. Within the rooms, the UFCs will be lowered into boreholes drilled into the room's floor and surrounded within a mass of sealing materials to impede groundwater contact and facilitate heat dissipation. Following the completion of UFC placement within a particular room, it will be sealed by a bulkhead to contain the sealing materials and inhibit any groundwater flow to or from the room.

The placement density of the UFCs is designed to minimize the areal extent of the DGR, while satisfying established design parameters including heat dissipation and structural integrity. The actual configuration (as will be discussed) will be a function of the characteristics of the rock mass, and particularly the accommodation of any structural discontinuities or other geological features that may be encountered during development.

5.3.1 Placement Room Arrangements

The repository layout is centered across a central access drift connecting the Main Shaft complex to the Ventilation Shaft (see Figure 23). As described in Section 5.2, a perimeter drift outlines the basic repository footprint for initial characterization purposes as well as for long-term access and ventilation uses. Parallel placement rooms are then excavated in a series of panels.

Starting from these basic concepts, alternate arrangements were reviewed for the placement rooms.

5.3.1.1 Dead End vs. Open Rooms

The current design employs dead-ended placement rooms which are backfilled in a retreating manner as the UFCs are entombed. The rooms are established perpendicular to a panel access drift, which is (in turn) oriented perpendicular to the main access drifts connecting the Main and Ventilation Shafts. The panel access connection between the main access drift and

the perimeter drift allows fresh air to enter the panels from the main drifts with waste air exiting to the perimeter drift.

The establishment of a second panel access drift parallel to the main panel access drift at the end of the placement rooms was reviewed. The advantages of such open-ended placement rooms include:

- Two working faces would be available for room excavation, potentially increasing development productivity;
- Continual access to the placement rooms is possible without a dedicated in-room ventilation system (prior to UFC placement);
- Multiple access and ventilation routes would be available during repository construction; and
- If UFC recovery is required, access will potentially be facilitated (i.e. shorter).

Disadvantages of open-ended placement rooms (two parallel panel access drifts) include:

- Additional development required for the second panel access drift and a resulting larger repository footprint;
- Two bulkheads will be required (at the ends of each room, to ultimately seal the room);
- Once the first UFC has been placed and room backfilling commences, the flow through ventilation advantage ceases; and
- The number of connections between the panels and drifts is doubled, providing an alternate route for contaminant flow and making the panels' isolation (should a problem arise) more difficult.

5.3.1.2 Chevron Pattern vs. Panel Layout

As an alternative to the adopted panel configuration, alternate layouts incorporating a chevron room pattern were considered. The main advantage of incorporating a chevron design would be to reduce the change in angle between the drifts and placement rooms to facilitate room access in the transport of the UFCs. When compared to a rectangular type (panel) layout of rooms, however, the chevron-type pattern was found to have some distinct disadvantages including:

- Additional lengths of access drift required for the same areal extent of panel;
- Larger sized intersections and acute angled pillar edges between intersecting chevron drifts, which may lead to stability and support issues;
- A potentially larger overall footprint required for the repository; and
- Potentially more bulkheads required if rooms are twinned off common access drifts.

5.3.2 Placement Room Geometry

While circular cross-sections have also been evaluated, placement room geometry previously focused on the use of an elliptical cross-section, with the main axis aligned parallel to the major axis of the room in the horizontal direction (vertical and horizontal axis dimensions of approximately 4 m and 7 m, respectively). While this geometry can maximize room stability by

minimizing stress concentrations around the perimeter of the room, some disadvantages of this approach as compared to one where the main axis is vertical include the fact that the vertical clearance required for the in-floor borehole and UFC placement/retrieval equipment results in an overall room cross-section much larger than required. This in turn results in much unused lateral space and large backfill requirements.

The repository host geosphere is expected to comprise a good quality rock with high strength and moderate in situ stresses (see Section 5.1). The potentially improved room stability with a horizontally-oriented elliptical geometry will, therefore, not be that important. Accommodating the size of the borehole drilling and UFC placement/retrieval equipment is more critical to the room geometry.

Various room profiles were reviewed that would permit the size of the borehole drilling and UFC handling equipment, while optimizing ground support needs. A geometry incorporating one-half of an ellipse with a vertical height of 5.5 m and a room width of 5.5 m was found to be preferred (Figures 10 and 28).

5.3.3 Placement Room Spacing

Heat will be generated by the UFCs once they are placed. Thermo-mechanical analyses for the crystalline geosphere were carried out examining near-field and far-field conditions to optimize the room and container spacings for the repository.

Excavation-related damage around the in-floor cylindrical placement holes at the 500 m repository depth and its associated in-situ stress field is inevitable, regardless of the proximity of the adopted spacings. Such damage, however, will only be surficial in nature, likely limited to 10 cm or less in the floor of the rooms. The depth of the EDZ will likely be greatest at the junction between the in-floor boreholes and the floor of the rooms and at its lowest level closer to the mid-point between the boreholes.

Heat from the emplaced UFCs and the resulting elevated thermal regime will induce additional thermal stresses resulting in a damage zone, including micro-cracking, extending to about 70 cm below the floor of the rooms along the centreline of the rooms (between containers). This depth of damage decreases from the centre of the rooms to the outer edges, where it is about 10 cm to 20 cm. Such thermal considerations were used to dictate the spacing of the rooms and UFCs.

It should be noted that while the temperature at the surface of the UFC is estimated to peak at 81°C, at 16.5 years after placement, the temperature in the rock between the UFC boreholes at room floor level is expected to reach about 55°C at 60 years after placement. Thereafter, the rock's temperature will continue to marginally rise, peaking only at around 1,000 years before subsiding. Although the blocks and the backfill in the rooms will behave as insulators, slowing the heat flows, they have little impact on the temperature histories for the containers.

From the above, T-H-M numerical modelling was undertaken to assess both temperature and stress/displacement impacts. Considering the requirement that 250 mm of buffer must be at or below 100°C at all times, the results from the thermal analyses indicate the requirement for a room-to-room spacing of 40 m (centre of room to centre of room), and an in-room container-to-

container spacing of 4.2 m (centre of UFC to centre of UFC). This room spacing is further supported by the well established fact that rooms of circular cross-section at spacings greater than three diameters will not interfere with stress conditions between each other. A room-to-room spacing of 40 m is equivalent to 7 to 10 diameters for the proposed room sizes (although it is noted that an elliptical cross-section is to be used).

Figure 23 shows the layout of the repository based on these dimensions.

5.3.4 Placement Room Design Carried in Present Concept

Based on the preceding reviews, the adopted placement room arrangements will utilize dead-end rooms within a rectangular panel geometry (placement rooms oriented parallel to the principal in-situ stress direction for the host geosphere). A vertically-oriented, elliptical room section geometry with a vertical height of 5.5 m and a room width of 5.5 m was further accepted as the preferred approach. Room-to-room spacings of 40 m and an in-room container-to-container spacing of 4.2 m will also be accommodated in the design.

5.3.5 UFC Repository Layout

The repository complex has been configured with drifts and crosscuts equipped to ensure minimal crossover and interference between development mining equipment and UFC placement equipment. In general the excavation-related equipment will travel in trackless drifts around the outer perimeter of the repository. UFC-related transport is concentrated in the central access drifts and from there directly to the placement rooms. All rock is trucked in the outer perimeter drifts to prevent interference with UFC transport operations.

The general layout for the envisaged repository is illustrated in Figure 23 for the Base Case of 3.6 million used-fuel bundles. Placement room lengths are almost 400 m which will reasonably accommodate development work by limiting ventilation ducting runs to practical lengths. This room length also allows the repository to be divided into a series of stand alone panels with some flexibility in their location to avoid poor geosphere conditions. It will further facilitate room development and UFC placement activities to operate independently of one another. As panel placement activities are completed, the placement rooms will be permanently sealed off with concrete bulkheads.

The repository panels will be interconnected by two parallel and central access drifts running from the Main and Service Shafts area to the exhaust Ventilation Shaft at the opposite end of the facility. Panel access crosscuts will be developed at right angles to the central access drifts with the placement rooms oriented perpendicular to the panel access crosscuts.

Each placement room entrance is developed with a 50 m radius curve to facilitate equipment travel into the rooms. The entrance point from the panel access crosscut to a room is also configured to point away from the central access drifts, to facilitate a locomotive pulling a UFC to a placement room entrance and pushing the UFC along the room to its placement point. This maximizes the travel time spent pulling a UFC (as opposed to pushing it) so that potential hazards along the travelway are more easily seen by the locomotive operator.

The UFC repository is developed immediately adjacent to the UDF testing rooms and service facilities (Figure 23) and is within the area bordered by the perimeter drifts and panel access crosscuts developed during the UDF/characterization phase of the project. All drifts accessing the repository are essentially extensions of the UDF testing area configuration, as both facilities have almost identical placement room configurations.

The various components of the repository layout (central access drifts, panel access drifts, panel access crosscuts and perimeter drifts) were previously described in Section 5.2.3.

5.3.6 Areal Layout Requirements

On an overall basis, the underground repository covers an area approximately 2,630 m in length (Service Shaft to Ventilation Shaft centrelines) and 1,560 m in width, as presented in Figure 23. Each panel of placement rooms requires an area of about 450 m by 700 m.

Using the reference geosphere discussed in Section 5.1 (and considering its assumed scarcity of any significant anomalies), it is expected that the repository layout can be accommodated sufficient distant from any major fault features.

The Alternate Case's used fuel inventory will involve the placement of an additional 3.6 million bundles over a further 30 years of repository life. In order to satisfy the requirement for placement rooms to be at least 50 m away from a major fault, and for the rooms to be aligned in the direction of the host rock mass' major principal stress, an irregular shaped layout (see Figure 32, next page) may be necessary.

As illustrated on Figure 32, the DGR's underground arrangement for the Alternate Case requires an areal extent of approximately 5.8 km by 1.5 km. The repository for the Alternate Case would comprise essentially two 3.6 million bundle repositories connected by a 1 km tunnel and sharing the same Main Shaft. There would not be a requirement to change the size of the Base Case UDF and services facilities placed near the Main Shaft as the two repository areas will be sequentially, and not concurrently, developed.

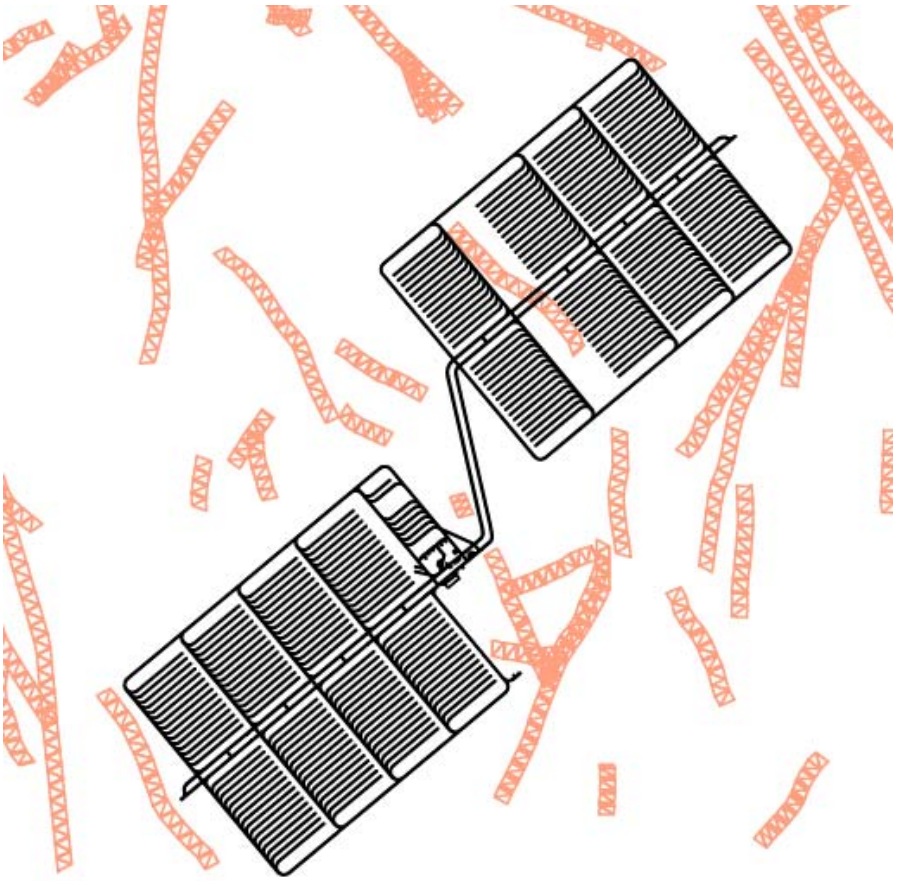


Figure 32: Potential Irregular Shape Layout for Alternate Case

5.4 Development of Underground Repository

All excavations associated with the UDF and support services will be carried out by drilling and controlled blasting techniques. A discussion of alternative excavation methods considered for the underground repository is provided below, in Section 5.4.1. Drilling and blasting in normal mining environments inherently creates a damaged zone in proximity to the opening. This requires that ground support be installed as required to prevent rock failures. Ground support approaches are discussed in Section 5.4.2.

Blasted rock will be removed from the working faces by LHDs and loaded into haulage trucks. Loaded trucks would travel to the truck dump near the Service Shaft. Trucks would discharge at the dump facilities where a hydraulic rockbreaker would break any oversize pieces of rock. Material from the truck dump would flow to a lower loading level for skipping (transfer) to surface in the Service Shaft. Services (compressed air, water, electrical, etc.) would be extended into the development openings as appropriate to the intended use of each area.

Later subsections address the anticipated development schedule, material handling approaches as well as the expected equipment requirements and labour needs.

5.4.1 Excavation Techniques

Three main categories of rock excavation techniques are possible for the development of the DGR's underground work including: drill & blast; mechanical excavation (e.g., tunnel boring machines, mobile miners, horizontal pull / push reaming); and, percussion drilling. A summary of their potential for application in this project is presented below.

5.4.1.1 Drill & Blast

Conventional blasting operations include drilling holes in a converging pattern, placing an explosive and detonator in each hole, detonating the charge, and removing or excavating the waste rock. Hole patterns are such as to minimize the quantity of explosive detonated per volume of rock broken. Boreholes are typically detonated in sequence from the centre of the excavation outwards with each detonation creating an open face for the next volume of rock to break towards.

Between the blasting cycles, fumes are vented, scaling is undertaken to remove loose rock, ground support is applied as required, and the next round of blasting is surveyed. Typical standard drill and blast practices result in a rate of advance in the range of 5 m to 15 m per day based on one crew working multiple headings.

The act of rock fragmentation by explosives creates an excavation damage zone (EDZ) around the perimeter of the created opening. To lessen or mitigate such adverse effects, controlled drilling and blasting techniques can be employed.

Under a controlled drill and blast approach, a closely spaced series of perimeter holes established around all sides of the opening would be loaded with decoupled low impact explosives (such as Xactex) and blasted last. The blasting of these holes would also be timed to ensure that ground movement is minimized in the walls and that minimum energy transfers from the main development round and perimeter hole blasting to the surrounding wall. Electronic blast initiators are utilized to provide maximum accuracy in blasthole initiation.

Hole direction and drill pattern accuracy will be optimized through computer-assisted drill development jumbos. Semi-automation can increase drill pattern accuracy through computer assisted alignment, as well as drill rod alignment and drill operating parameters, to minimize drill hole wander.

5.4.1.2 Mechanical Excavation

During mechanical excavation, high forces are applied to tools (cutters) that are dragged or rolled over the rock surface to produce a groove or kerf in the rock to a depth of a few centimeters. The interaction of the forces produced between the grooves and the natural rock structure produces rock chips. Rolling cutters can either be in the form of discs, such as in the face of a tunnel boring machine (TBM) or buttons as in the face of a raise boring machine.

In the case of road-header machines (Figure 33), picks are installed within the face of the rotating head of the machine and act to rip the rock at the heading face. Mobile miners, such as road-headers are typically used in soft rock environments, such as potash and gypsum mines. The maximum thrust supplied by the machine is provided by their weight, and advance rates will be low in comparison to TBMs in hard rock environments.



Figure 33: Road-Header Machine

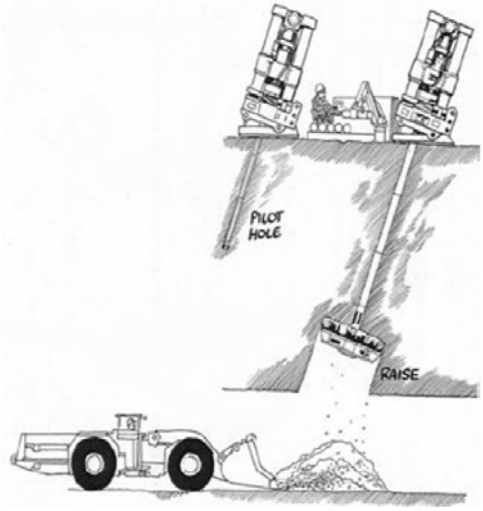


Figure 34: Raise Bore Machine

A raise bore machine is a common application of the mechanical excavation of shafts in a sub-vertical orientation (Figure 34). With this technique, a pilot hole is collared from an upper level and drilled down to an underground opening. Once the pilot bit breaks through it is removed from the drill string and a reaming head attached. The drilling equipment rotates and pulls the reaming head to the collar elevation. Cuttings fall down the shaft and are removed at the bottom.

Horizontal reaming involves the drilling of a pilot hole between two adjacent openings and back reaming with a cutter head. A variation of horizontal reaming is push-reaming, where the reamer is pushed instead and the drill string is supported by stabilizers. The advantage of push reaming is that the work can be drilled blind as no extra service tunnel is required behind to mount the reamer on the drill string. The advance rate is lower for horizontal reaming than for a TBM as less thrust and torque can be applied at the cutters.

For the development of the in-floor boreholes for UFC placement, a boring machine would appear to be the best approach. As illustrated on Figure 35, the drill is operated from a mobile carrier which can function in areas of limited headroom and working space. It has been found to produce acceptable test holes.

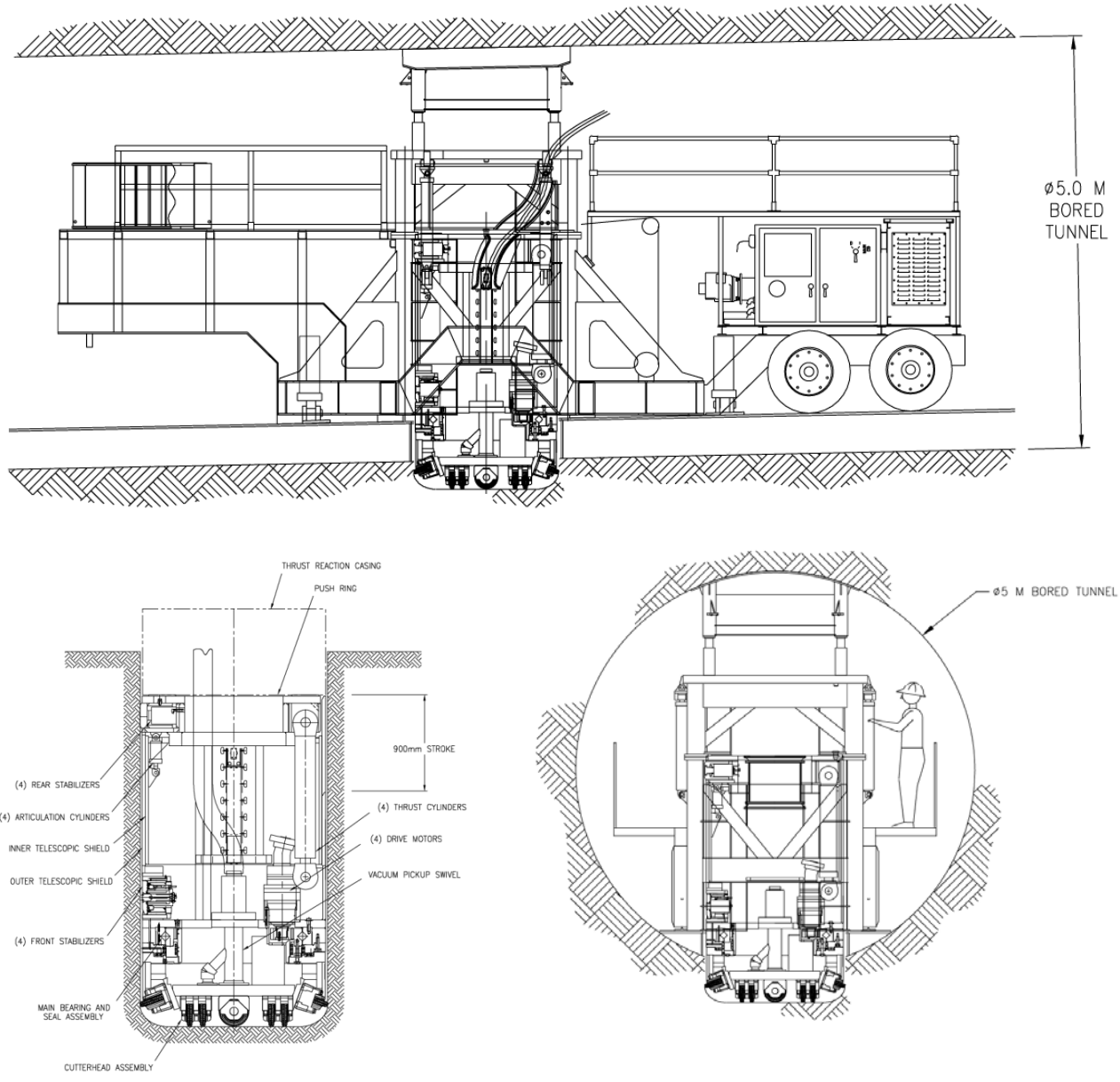


Figure 35: Boring Machine

5.4.1.3 Percussion Drilling

The concept of percussion drilling is a well established and typical method of hard rock borehole drilling. The drill contains a piston that is driven at high pressure by pneumatic or hydraulic power and provides impact to the drill bit. Rock fragments are removed up the drill hole by high pressure compressed air or by water. A variant of this technique would be possible for horizontal drifts wherein a cluster drilling set-up would involve several percussion drills being put together in a frame that slowly rotates to excavate a much larger opening.

5.4.1.4 Preferred Excavation Techniques

Long-term safety would not be impacted by the choice of excavation method assuming that a drill & blast approach is executed to minimize the EDZ (through controlled drill & blasting). The main advantage with drill & blast is flexibility and cost. The method is easily adapted to a range of rock conditions, and customized tunnel shape and blasting design are more readily accommodated to meet particular requirements. Further, the technology is mature and efficient.

The main advantage with mechanical excavation is that the operation is more or less continuous with a constant excavation quality as potential human factor impacts will have less potential to affect work quality. Mechanical approaches, however, suffer somewhat from the perspective of the volumes of generated materials as the created circular shapes with some techniques can result in voids of no use but that still need expensive backfilling. Further, certain mechanical approaches, such as the use of horizontal pull-reaming are not well established for the construction of underground drifts. Other methods, such as the use of a TBM, are more suited to circular profile room geometries, are unable to mine complicated openings and are associated with lower productivities (i.e. low advance rates).

In summary, drill & blast is the only practical method for the large underground openings and irregular shapes that characterize the central UDF area (offices, test areas, storage, etc). A drill & blast excavation technique was also considered to be the most efficient method of repository room development due to the geometry and dimensions of the proposed rooms. In all cases, to minimize the extent of the EDZ, a controlled drill & blast approach appears best.

For the UFC deposition holes, drill & blast is not a possible method due to requirements on final geometry like surface roughness, etc. While a down-reaming approach may be viable in meeting the geometrical requirements, it is not considered an efficient approach. At this time, a shaft boring machine appears to be the favourable method to establish these holes.

5.4.2 Ground Support Requirements

After the broken rock is removed from the area under development, a scissor-bolter-screener unit would install the as-required ground support. In permanent openings development, such as the maintenance shop, refuge station, etc., backs and walls would be shotcreted, in addition to any initial support works established, for long-term integrity.

In the expected good quality rock environment of the host geosphere, it is likely that minimum ground support will be needed within the development and placement rooms. In fact, for spans of 7 m or less, bolting probably would not be required. For the main access drifts of a 7 m span,

which will be open for the duration of the repository life, it is recommended however that systematic bolting be installed on a pattern of 2.5 m x 2.5 m spacing. Patterned bolting will also be required for the intersection of drifts of a 7 m span or greater.

In zones where the development and placement rooms cross zones of poorer ground, additional support will be applied as required. It has been assumed that 10% of the drift lengths will require additional support based on encountered conditions.

Due to the long life of the repository, a monitoring program will be implemented to assess the long-term performance of the established ground support features. Maintenance, or installation of additional support will be carried out as required.

[Note: The presented support recommendations are preliminary only and will need to be revisited after geotechnical characterization of the selected geosphere.]

5.4.3 Development Schedule

The UDF's main testing area would be developed and available approximately 5 years before the UFC repository enters operation. The perimeter drift components of the UDF will also be commissioned about 5 years before the repository is required to ensure adequate time to assess the host geosphere and make any design changes required. The UDF testing area development would proceed simultaneously to that of the support facilities required for both the UDF and full UFC repository.

Once the sinking and equipping of the shafts is completed, they will be utilized to develop the UDF. The fuel bay, sumps and main electrical substation will be completed first in this regard to support ongoing development and testing activities. All other facilities (e.g., test rooms) can then be completed to meet the UDF test work phase. Once the testing areas are available, the support facilities (maintenance shop, explosives magazines, etc.) and perimeter drifts and crosscuts will be developed and equipped.

For the UFC repository, the placement room panels would be developed to retreat from the Ventilation Shaft end of the repository to the Main Shaft end. The first rooms to be developed would be in Panel A in proximity to the exhaust Ventilation Shaft (see Figure 36), with all the rooms developed in each panel before UFC placement operations are commenced. The panel sequence would progress A through H. This panel sequence provides for placement operations to fill and seal areas working back toward the Main Shaft. Retreating towards the Main Shaft ensures that personnel do not have to enter or pass by the completed areas to perform regular daily duties. It also ensures that all ventilation air passing through these areas is routed directly to the exhaust shaft and does not permit reuse of this air.

The panel rooms would be developed to ensure the maximum possible separation between active development and placement activities. This will ensure that secondary vibration of already developed placement rooms, where placement activities are taking place, is minimized until the finished rooms are backfilled and sealed off. Minimizing the impact of ground vibration as a result of development activities will also help prevent increased ground relaxation of the EDZ around openings.

Each placement panel will be completed in its entirety before commencing to the next panel so that panel development is completed prior to placement operations and to ensure that excavation and placement activities are isolated from one another (and excavation and placement equipment do not operate in the same panel simultaneously). Excavation activities will be concentrated in a series of panels on one side of the central access drifts while placement activities are being performed in panels on the opposite side of the access drifts. The sequence is outlined in Figure 36 which also illustrates the separation of activities.

Each placement panel in the DGR would require 3 years for development to be completed. Placement activities in the equivalent panel would require 3.5 to 4 years. Repository development spans 27 years with approximately a one year suspension of development between completion of any one panel and commencing development of the next panel.

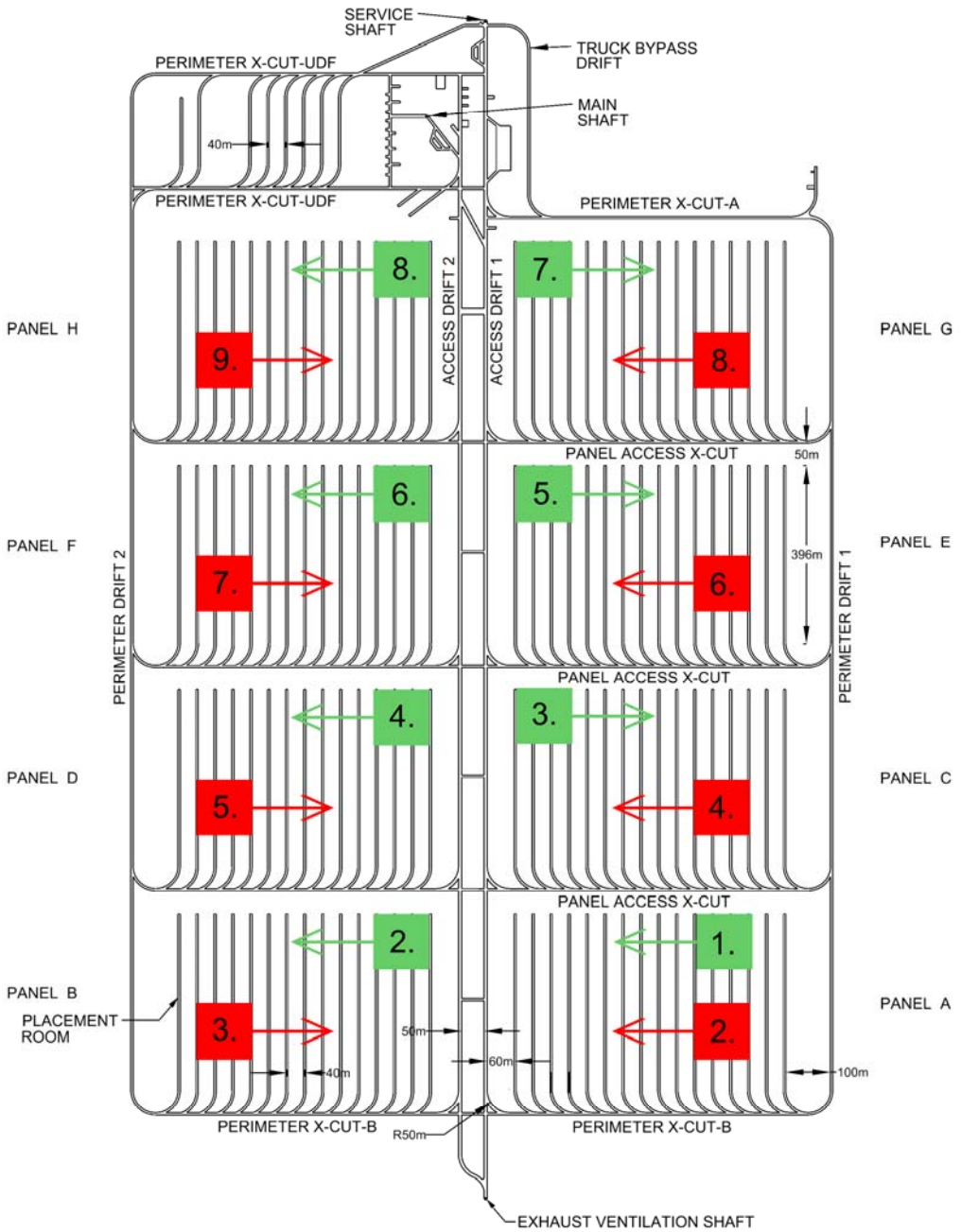
A conceptual longitudinal section of the placement rooms is included in Figure 37. The rooms would be developed to a length of 396 m. The curved entrance to the placement room would be developed at a 50 m centre-line radius (and a 65 m length) to a sectional dimension of 5 m wide by 5 m high. The last 6 m of the curved entrance and the first 12 m of the placement room would also serve as the site of the placement room sealing bulkhead and seals following placement activities. The remaining length of the placement room would be developed to a semi-elliptical profile.

After development of a placement room has been completed, track to operate placement equipment would be installed. Track would be mounted on top of formed and poured concrete plinths. As the UFCs are placed, the track and concrete would be removed and retreat backfilling of the placement rooms would be carried out.

Placement rooms would be filled progressing from the perimeter drift to the central access drifts. Drilling and blasting operations would be a minimum of approximately one panel width (700 m) from placement operations.

Upon completion of placement activities, and backfilling of the placement room, an impermeable seal would be placed within the entrance of the placement room. This would consist of a mechanically excavated slot around the perimeter of the room extending to a depth beyond the EDZ that might develop as a result of room development and future stress loading. Following placement of the EDZ seal, a low heat, high performance concrete bulkhead will be installed at the entrance of the placement room to act as a seal and to contain backfill materials.

For the Alternate Case, which is essentially two Base Case layouts, the repository development will proceed in two major campaigns, with the development of Panels A to H completed first and the second major campaign for preliminary development of Panels I to P completed just prior to year 30 in anticipation of placement of the next 3.6 million bundles. Development of panels and placement of UFCs will retreat from the second Ventilation Shaft towards the Main Shaft complex.



8. ←	Sequence and direction of placement room development	8. →	Simultaneous sequence and direction of UFC placement

Figure 36: Sequencing and Development of UFC Placement

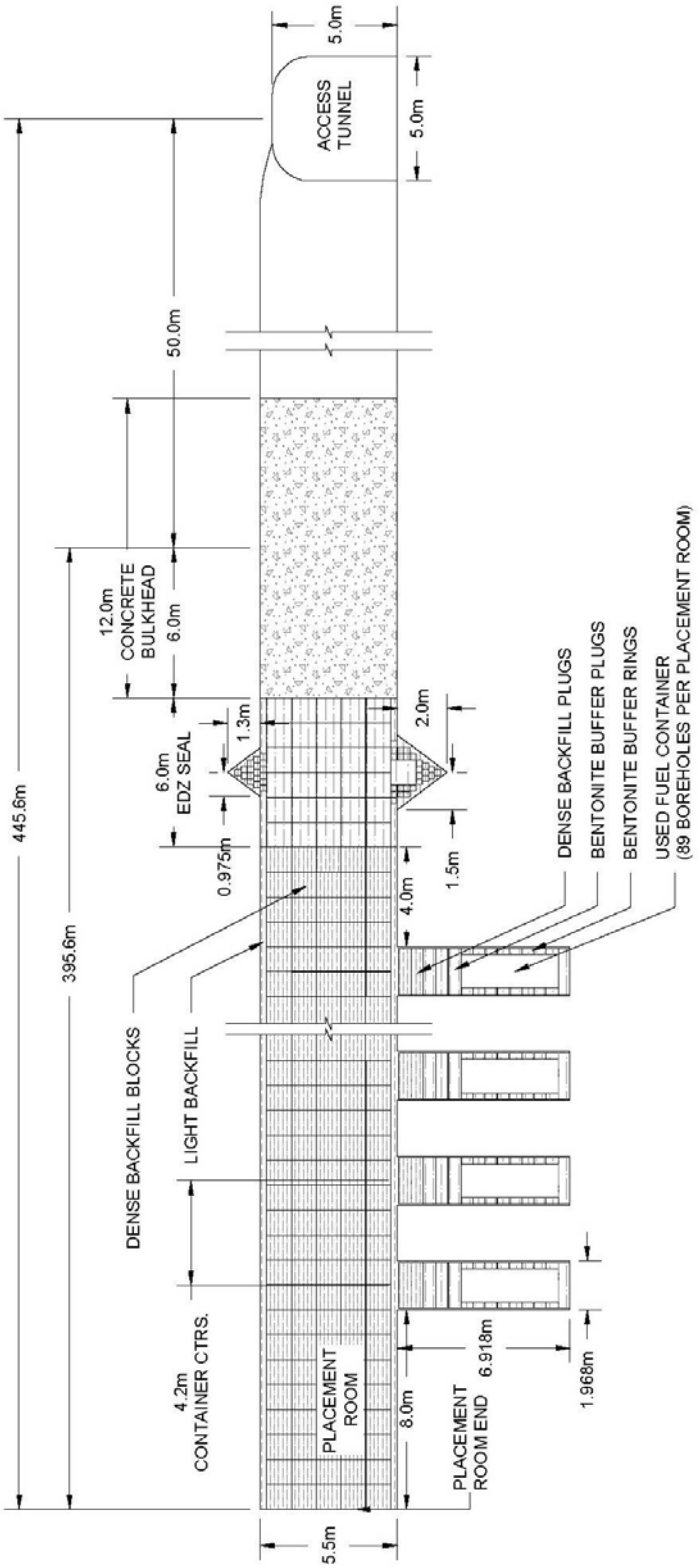


Figure 37: Section Through Placement Room

5.4.4 Material Handling

Rock Handling

Broken rock would be loaded by 6.4 m^3 LHD's into 40 tonne underground haul trucks at the placement room entrances. Loaded trucks would travel along the panel access crosscuts to one of the perimeter drifts and then to an access crosscut. The crosscuts would lead to the truck bypass drift connecting to the truck dump near the Service Shaft. Trucks would dump onto a grizzly, at the dump. A hydraulic rockbreaker would break any oversize left on the grizzly. The rockbreaker would be automated to allow remote operation by the skip tender or by a central control room operator. Material from the dump would flow to the loading pocket level for skipping to surface in the Service Shaft.

The most effective method of drilling and clearing broken rock for large excavation cross-sections in mining projects utilize technologies primarily based on rubber tired equipment. Mobility is more flexible and the need to lay track as part of the development cycle is eliminated. Larger and more efficient equipment can be utilized and the need to maintain temporary track in each heading is eliminated. While rail cars could adequately move the anticipated volumes of broken rock, this would necessitate good track installation and higher maintenance needs. The track will also need to be replaced in advance of UFC placement. Conveyors, while efficient in transporting large volumes of rock along a series of straight lines, do not facilitate any other development activities in the DGR. Further, the volumes of rock requiring handling for the DGR's underground development are not, in a relative sense, large.

Materials Handling

Rock excavation materials (e.g., explosives, rockbolts, pipe, etc.) would be transported on rail-based flatcars and materials cars in the Service Shaft and moved to the main storage area near the UDF using battery operated locomotives. The rail cars would be off-loaded and materials placed in the main storage area. Trackless service vehicles will carry materials from the main storage area to working places throughout the underground development.

UFC Transport

All equipment, parts and materials for UFC placement (with the exception of the UFCs themselves) would be moved by rail in the access drifts, crosscuts and placement rooms using flat cars and materials handling cars. The same battery powered locomotives, as used for excavation materials handling, would be used to move these items.

The UFCs will be placed on specifically designed rail flatcars on surface and transported in the Main Shaft to the underground shaft station. A 15 to 20 tonne battery powered locomotive will pull the UFC flatcar on rail to the temporary cask storage area or directly to a placement room. All UFC flatcars would travel via the central access drifts and panel access crosscuts to the placement rooms.

Tracked-based technology for UFC placement offers enhanced container security during transport from surface to the placement rooms and reduced operational complexity in placing

containers within placement rooms. The track automatically sets the equipment's horizontal location across a placement room width.

5.4.5 Equipment Requirements

As previously described, a combination of tracked and trackless equipment will be used in the development and operation of the UDF and the UFC repository.

The UDF phase of development and construction will utilize trackless rubber tired diesel powered equipment with broken rock trucked to the Service Shaft for hoisting to surface. Rubber tired equipment is very mobile and flexible, the need to lay track as part of the development cycle is eliminated, and larger and more efficient machinery can be utilized. The trackless development environment also facilitates the use of other equipment for ground support installation and services work, as well as flexible transport for personnel.

For the UFC repository, all development will also be undertaken using mobile rubber tired equipment. Materials transport in the Service Shaft and from the Service Shaft to the main storage area would be accomplished using track mounted flat cars and materials and parts transport cars. All UFC placement equipment will operate on rail and move between the Main Shaft and placement rooms by rail. All rail based equipment will be electrically driven. All locomotives will be powered by battery (rechargeable).

UFCs will be transported to the underground repository using the Main Shaft. All men, equipment and development muck will be transported using the Service Shaft (see Section 4).

The use of electrical powered equipment will be maximized to minimize ventilation volume requirements. All rail mounted equipment will operate and travel using electrically powered systems. While the trackless equipment carriers will be powered by diesel, they will use electricity to power on-board systems, such as electric hydraulic drills, electric jacks, etc.

Although the haul trucks and LHD's are available as equivalent electric options, these pose many limitations in development operations. LHD's, for example, can be electrically powered using a trailing cable which reels out behind the vehicle as it travels. The cable length is limited to approximately 150 m (placement rooms and their entrances are over 400 m long) and running over and damaging or cutting the cable in a drift can be a common occurrence. Trucks powered by overhead trolley wires are also applied in mining, but the truck and trolley capital costs and their potential operational problems will negate the positive aspects of electric trucks in this application.

The list of mining equipment and quantities for the both the development of the UDF as well as for the subsequent operation of the full repository is presented in Table 16. Of the listed equipment, those required at the commencement of UDF construction would include a number of the development jumbos, ANFO loaders, LHD units, screener units and scissor lifts as well as various service and transport vehicles.

Table 16: Underground Mobile Equipment List (including standby equipment)

Diesel Equipment	Track Equipment
Load-Haul-Dump Loaders (3)	15 - 20 tonne Locomotives (3)
40 tonne Trucks (3)	5 tonne Locomotives (4)
Development Jumbos (3)	Canister Flat Cars (2)
Scissor Bolters (3)	Flat / Materials Cars (30)
Scissor Lifts (5)	**UFC Placement / Retrieval Equipment**
ANFO Loaders (2)	
Shotcrete Truck	Borehole Shaft Boring Machines (2)
Concrete Truck	Transfer Casks (3)
Grader	Transport Flatbeds (3)
Service & Crew Trucks (3)	Placement/Retrieval Machine & Trolley (2)
Bucket forklifts (2)	Trolleys for Transfer Cask (2)
Utility Vehicles (10)	Temporary Borehole Covers (267)
Miller Carts (2)	Borehole Vacuums (2)
Service Trade Vehicles (4)	Borehole Shielding Barriers (2)
	Bentonite Disk Placement Shields (2)
	Trolleys with Bentonite Pellet Blower (2)

In all, the following concepts for underground equipment will be applied:

- All underground excavations will be carried out by rubber tired equipment (jumbo's, LHD machinery and trucks);
- Rubber tired equipment would be propelled by diesel motors. Semi-stationary equipment such as drill jumbos would be powered by electricity;
- Haulage of development rock to the shaft would be by diesel powered trucks;
- Transport of UFCs to placement rooms would be by rail cars pulled by locomotives powered by rechargeable batteries; and
- Placement activities of UFC's within the placement rooms would be carried out by electrically operated machinery.

5.4.6 Labour Needs

To achieve the development schedule, 3 crews will be active at any one time with initial priorities focusing on the UDF development as well as those related to the establishment of the central access drifts between the Service Shaft and the Ventilation Shaft.

As these headings are completed, crews will be redeployed to complete the testing areas and support facilities and finally to develop the repository perimeter drifts and crosscuts. The development schedule is based on construction work taking place over two 12 hour shifts per day, with each shift seeing the mobilization of three crews (i.e. at total of 6 work crew shifts per

day). The work will be carried out over 350 days per year. One development crew (2 shifts per day) will be required to develop each panel over a four year time frame.

Each construction crew will comprise 3 to 4 persons. Where track installations are required upon finishing a complete length of heading, a track construction crew will then take over and pour the concrete floors and lay the track.

All UDF excavation, support and construction work would be performed by an underground mining contractor who will supply all mining related equipment, direct and indirect development labour, and supervision. Contracted activities would include forming and concrete work, electrical, ventilation and exhaust systems, and the installation of major equipment (e.g., rockbreakers) and furnishings. The contractor would be directed and supported by the DGR's technical and managerial personnel in these activities. All day-to-day operations associated with the test room equipment would be planned, supervised, directed and performed by DGR personnel or DGR service contractors.

Maintenance and services labour for rock excavation related activities are expected to total approximately 200 contractor personnel and 20 DGR personnel. When operational (that is, during the UDF testing and experimental programs), the DGR staffing complement is expected to increase to 60 testing personnel as well as 20 supervisory and technical staff.

As discussed later in Section 5.5, the UDF will be adequately ventilated to include reasonable temperature control. This will allow personnel to work, at all times of year, in normal indoor workwear (coveralls, work boots, etc.) as in a surface factory setting. A direct fired heating system in the ventilation network will be used to maintain working temperatures. Support offices and ancillary facilities will also be kept at temperatures where work can be performed in every day indoor workwear, without the need for heavy clothing.

5.5 Subsurface Ventilation

The ventilation design was based on a rigorous assessment of system performance, employing network modelling techniques to create a three-dimensional model of the repository, and to conduct real time simulations of the ventilation system during excavation and placement activities. Engineering design procedures were used to select and size the primary surface fans and underground booster fans and to develop a safe and reliable ventilation system that will support the underground activities.

5.5.1 General Description of Ventilation Complex

The ventilation system uses the repository's three shaft complexes (see Section 4) and a combination of parallel airways to intake and exhaust the air. Underground booster fans, ventilation doors and stoppings (ventilation control devices used to block off mine openings or airways to prevent air flow) are further used to control the airflow distribution.

The primary repository ventilation system will consist of relatively large airways and the overall circuit can be described as one of relatively low resistance characteristics in a push-pull type network. Two parallel surface fresh air fans will supply air (heated as required) to the Main

Shaft. The fresh air supply will reach the repository level at the Main Shaft station and be split to the UDF and the main repository itself.

Fresh air from the UDF will be boosted by underground fans installed in a parallel configuration at the Main Shaft station. Exhaust air is routed to the Service Shaft by an exhaust booster fan, installed underground at the Service Shaft station. The return air is exhausted to atmosphere by one exhaust fan installed on the surface in the Service Shaft area.

Exhaust air from the repository area will be routed to the Ventilation Shaft by two exhaust booster fans, installed underground in a parallel configuration at the shaft station. Return air is exhausted to atmosphere by two parallel exhaust fans installed on the surface in the Ventilation Shaft area. Air distribution in the repository is promoted through the use of fans and regulators. Fresh air will be distributed to the individual panels through axivane, or axial flow fans.

Individual placement rooms will be ventilated by axivane fans in an exhaust configuration, installed to remove air from the rooms and direct it into the exhaust circuit. Such fans will work with a ducting system to provide, by design, approximately 37.8 m^3/s of air to the room face during room excavation. During UFC placement activities, the required supply flow per room is 14 m^3/s. The exhaust air from these fans will be carried to the panel exhaust drift, and then to underground booster exhaust fans.

The system will be operated to ensure that the underground work is performed in a fresh air supply stream with the exhaust being directed through unoccupied areas, and from low (potential) contamination to greater (potential) contamination areas. A high-efficiency particulate (HEPA) filtration system could be established in the Service Shaft and Ventilation Shaft stations as emergency or stand-by systems which would be activated as air exhaust volumes and conditions demand. The underground ventilation systems could be equipped with air filtration systems that are activated should contamination levels in an area reach a predetermined threshold. For the purpose of this conceptual design, a HEPA filtration system is assumed to be established in the Service Shaft and Ventilation Shaft stations.

Figure 38 provides a simplified schematic of the DGR's ventilation system.

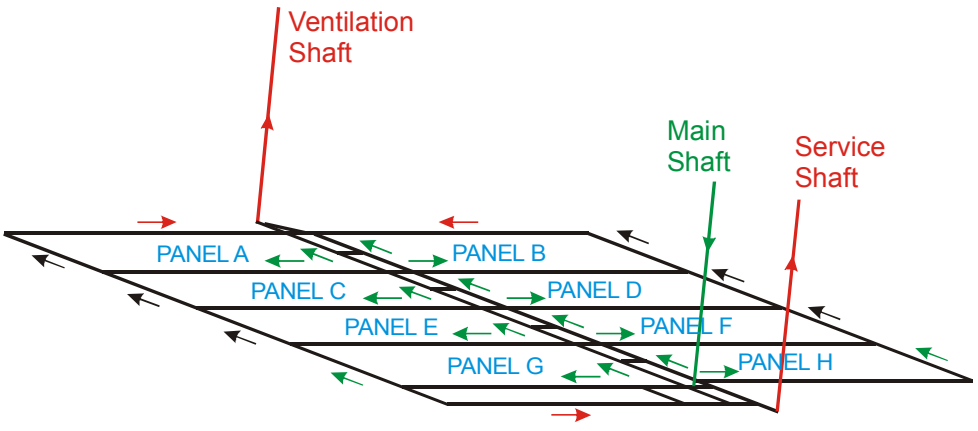


Figure 38: Simplified DGR Ventilation Schematic

5.5.2 Estimation of Air Flow Requirements

Airflow volume requirements were based on that required to provide dilution of the underground diesel equipment fleet contaminants considering projected equipment availability and utilization. Ventilation requirements were further determined so as to provide a comfortable working environment for facility staff, and the operational air quality needs of specific areas and activities.

The underground operations were divided into two areas for the purposes of estimating the total airflow volume requirements: the Main and Service Shafts / UDF complex and, the UFC repository itself. These two areas are ventilated independently. Airflow requirements for the repository were based on the sum of flows needed both for excavation and for placement activities, since the two operations are often performed concurrently.

The primary underground ventilation needs are as follows:

- **Main & Service Shafts / UDF Complex:** A minimum supply of fresh air to this area approximating 56 m^3/s has been estimated. Allowing for a 10% contingency for the purposes of accommodating air leakage, a minimum supply of fresh air approximating 62 m^3/s will be provided;

- **Room Excavation Activities:** When diesel power fleet utilization is considered, a total of 3,493 kW of diesel power would be operating, and airflow requirements would approximate 221 m^3/s. Based on this, and allowing for 20% air leakage, the necessary supply of fresh air to these underground operations is 265 m^3/s; and

- **Placement Activities:** Airflow needs during UFC placement activities were based on the volumes required to dissipate heat and provide a comfortable working environment, as well as to dilute diesel equipment contaminants. During UFC placement, a minimum air velocity of 0.5 m/s in the access tunnels will maintain air temperatures below 27°C. When considering the cross-sectional area of the access tunnels and placement rooms, air volumes of 12.5 m^3/s and 15 m^3/s, respectively, are calculated. Airflow requirements for 5 placement rooms operating simultaneously approximate 75 m^3/s.

Table 17 presents the noted airflow requirements incorporating leakage. Figure 39 provides a simplified schematic of the resulting airflow distribution.

Table 17: Key Subsurface Ventilation Requirements

Location	Leakage	Excavation & Placement	Placement Activities Only
Main & Service Shafts / UDF Complex	10%	62 m^3/s	62 m^3/s
Repository Excavation	20%	265 m^3/s	-
UFC Placement		75 m^3/s	75 m^3/s
Total Air Volume Requirement		**402 m^3/s**	**137 m^3/s**

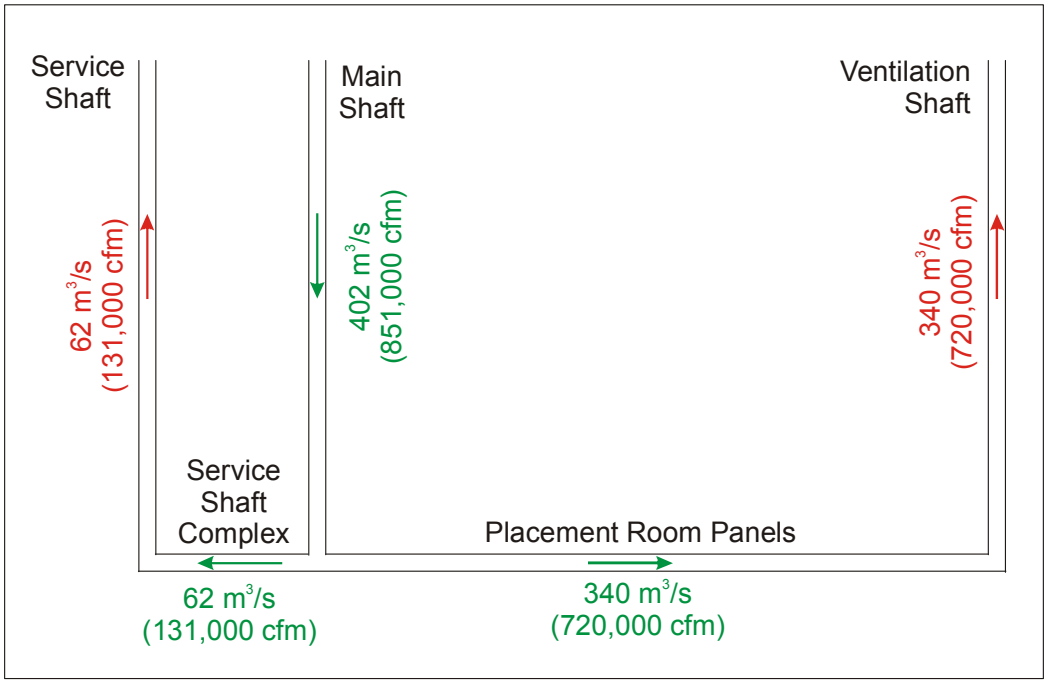


Figure 39: Underground Simplified Flow Distribution

As illustrated, an overall supply of fresh air to the underground operations of 402 m^3/s will be provided. This incorporates anticipated air leakage rates of about 10% for the Main & Service Shafts / UDF Complex and 20% for the UFC placement area.

5.5.3 Main Fan Systems

The following outlines the main fan systems supporting the ventilation network.

Main Shaft Surface Supply Fans

The Main Shaft surface fans are designed to bring fresh air from surface to the shaft-plenum intersection and headframe. The role of the intake fans is to provide flow and pressure influence up to the plenum at the shaft, from that point air is drawn under the influence of the underground fresh air booster fans. The surface intake fans will be supplied with variable frequency drives, necessary to control the balance of pressures and distribution of flows.

The air intake plenum will be 7 m wide and 5.5 m high. The surface fan assemblage will have 2 fans, with an installed power of 373 kW per fan. This will provide for operational flexibility at higher pressures and flows.

The use of an 18 MW direct fired heating plant using burners placed directly into the airstream will also be in place. Direct fired heaters will consist of an intake section, burner section and air

plenum. Integral blower burners (burners with integral, low horsepower fans) will be mounted directly in the airstream.

Service Shaft Surface Exhaust Fan

The role of the exhaust fan is to draw flow and provide pressure influence up to the plenum at the shaft, from that point air is exhausted from the underground under the influence of the subsurface exhaust booster fan(s). The surface exhaust fan will be supplied with a variable frequency drive, necessary to control the balance of pressures and distribution of flows. A single fan will be provided with an installed power of 45 kW. The plenum sizing will be 6.5 m wide and 5.1 m high.

Ventilation Shaft Surface Exhaust Fans

Similar to that above, the Ventilation Shaft exhaust fans will draw flow and provide pressure influence up to the plenum at the shaft. From that point air is exhausted under the influence of the underground booster fans. Two fans will be installed, each with an installed power of 336 kW. This will give the flexibility of operation at higher pressures and flows, in case the total repository exhaust flow must be accommodated (i.e. Service Shaft fan is down). The fans will be supplied with variable frequency drives to control the balance of pressures and the distribution of flows. The plenum will be 6.5 m wide and 5.1 m high.

Underground Booster Fans

As previously noted, incoming fresh air flows are boosted by underground fans installed in a parallel configuration at the Main Shaft station (as part of a push-pull type ventilation system). Two fans will be in place, each with an installed power of 298 kW. Exhaust air routed to the Service Shaft is facilitated by an exhaust booster fan (45 KW), installed underground at the Service Shaft station. Exhaust air directed to the Ventilation Shaft is helped along by two booster fans (298 kW each), installed in a parallel configuration at the subsurface shaft station.

Other Fans

An additional 15 kW fan will be installed to ventilate the truck dump / rockbreaker area.

5.5.4 Ventilation Planning Exercises

Short and long-term ventilation planning was undertaken for the repository in order to confirm that flow requirements are achievable during the life of the project. As discussed, air is to be distributed throughout the repository through the use of regulators and fans. Within a given panel, fresh air will be supplied via the central access drift and exhausted through the perimeter access drift. Fresh air will be distributed to the individual panels through axivane booster fans or regulators, depending on flow requirements. When incorporating leakage, a total fresh air flow supply of 168 m^3/s will be needed to ventilate a single panel during development.

An example of the staged development of the ventilation network is provided in Figure 40. As illustrated thereon, four development headings are under excavation (Panel E) and eight rooms have been dedicated to placement activities (Panel D). The required panel flows are presented

in the figure. The modelled fresh air flow supplies to Panels E and D are 170 m^3/s and 127 m^3/s, respectively. A small booster fan will be used to maintain the required flow to Panel E. Regulators installed in Perimeter Drift E will control flows and recirculation.

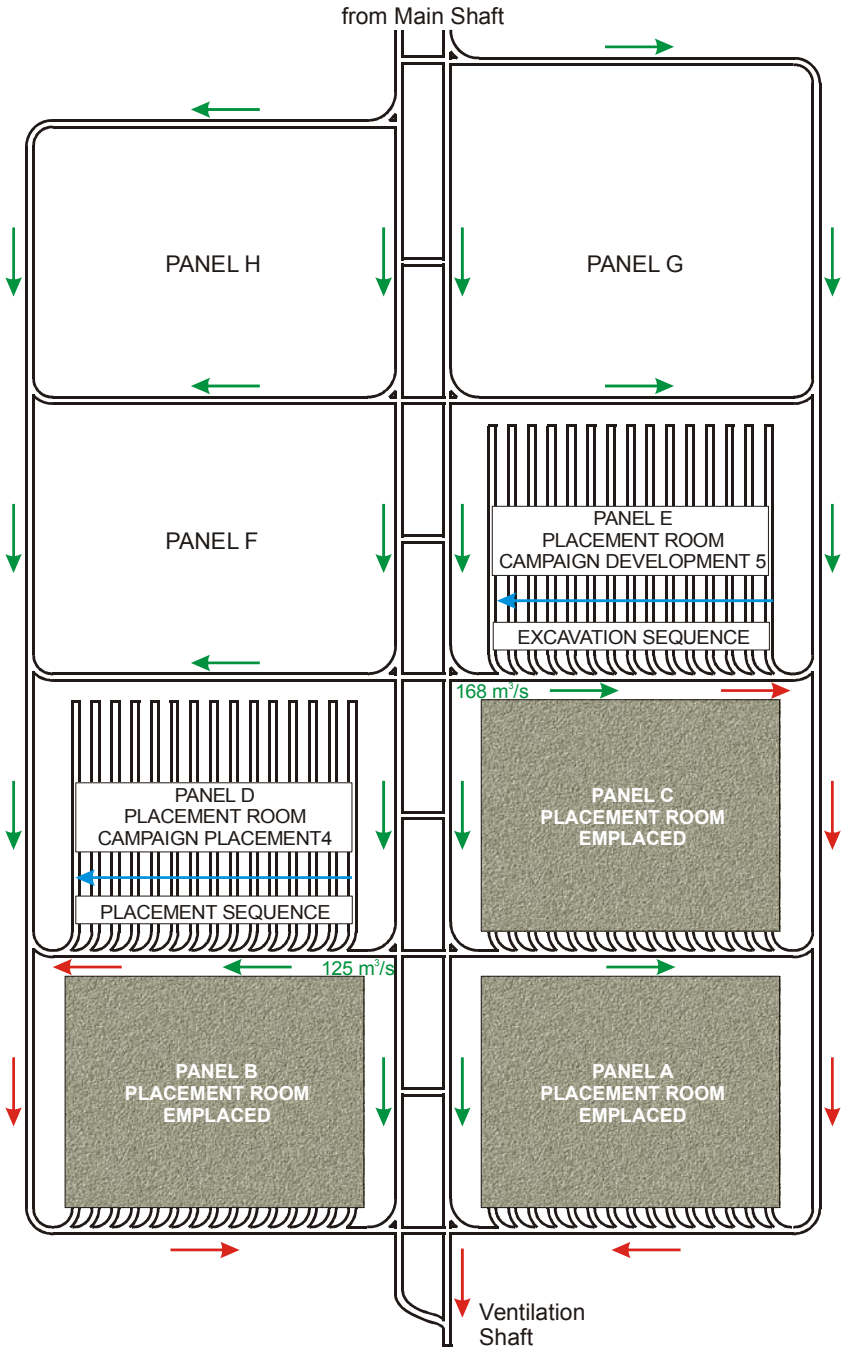


Figure 40: DGR Typical Ventilation Evolution Sequence

HEPA filters will be installed on auxiliary ducts used to ventilate placement rooms during UFC internment activities. During placement operations, a portable HEPA filter will be provided on the exhaust from the placement room where UFC placement is being carried out. Each duct will be equipped with a radiation monitor and bypass damper. Under normal conditions, the HEPA filter will be bypassed. However, upon detection of radioactive contaminants, the damper will be activated, an alarm will be sounded for placement room evacuation, and the air exhaust will be routed through the HEPA filter.

6. USED FUEL HANDLING, PACKAGING AND PLACEMENT

During operation, the used fuel bundles will be received at the UFPP in road transportation casks (IFTCs). Within the UFPP, the fuel bundles will be transferred from the IFTCs into fuel handling cells, from which they will then be transferred and loaded into UFCs. Each UFC will be sealed, inspected and, if it meets specifications, loaded into a shielded UFC cask which will be transferred underground using the Main Shaft. Underground, the UFC will be transferred to either a temporary storage area or directly to a placement room in the repository.

6.1 Receiving and Packaging at UFPP

All used fuel shipments directed to the DGR will be received at the UFPP from the Owners' reactor sites via road transport in IFTCs. At the packaging plant, the used fuel will be transferred into the UFCs intended for underground placement. The following sections describe the associated processes undertaken in the UFPP. The areas referred to herein were previously described and illustrated in the conceptual layouts provided in Section 3.4.

6.1.1 Receiving and Handling of Empty UFCs

The components of the UFCs and the containers themselves will be manufactured and assembled off-site by qualified, external suppliers. Before shipment to the DGR, the container dimensions will be checked to ensure that the UFC meets all quality specifications (as below, only visual inspection and documentation control will be performed in the UFPP). This QA approach minimizes the probability of rejection of empty containers upon receipt in the UFPP, and their subsequent return to the UFC supplier.

Empty UFCs will arrive at the DGR and be transported to the UFPP by road, inside a transport frame that is horizontally placed on a transport trailer. At the UFPP, the trailer will be driven in through a port into the transport airlock where it is parked. Using the 30 tonne OTC in the receiving hall, the transport frame will be lifted to a storage position. From the storage position, the empty vessel will be tilted to vertical position and transferred to the UFC preparation platform where it will be placed on a pallet. Its copper lid will be transferred and imported to the inerting station. Empty baskets will be transported to the plant separately and stored in the empty UFC receiving hall.

At the preparation platform, the UFC will be visually inspected to ensure it has not been damaged during transportation or handling. Its identification marks will be checked against the documentation, and it will be verified that all quality controls have been performed according to procedures. The UFC will then be installed in a sleeve, with the bolts of the inner vessel lid loosened and the lid lifted off. The internal cavity will be inspected and three empty baskets will be inserted into the inner vessel. The inner vessel lid will then be lifted back onto the inner vessel, with the lid bolts left loose. An air-cushion transporter will then transfer the sleeve (with empty container) to the empty UFC entrance position. Using the OTC, the sleeve (with empty container) will be lifted – via the filled UFC storage cell – to a shielded frame parked at the UFC entrance and exit position of the UFC transfer area.

After installation, the shielded frame will be transferred by the air-cushion transporter to the docking port below the fuel handling cell. The container will then be raised and docked with the port. The gamma gate will be opened and, using the in-cell crane, the containment door and inner vessel lid are then removed. The three baskets will be lifted into the fuel handling cell, leaving the empty container ready for the subsequent loading of filled baskets.

6.1.2 Receiving And Unloading of IFTCs

Transport trailers bringing the IFTCs to the UFPP will be received through a port and parked in the airlock by the IFTC receiving and shipping hall. Using the hall's 40 tonne OTC, the IFTCs will be lifted and transferred either to an awaiting transfer pallet or to an empty storage position for transfer to a pallet at a later time.

When the IFTC is positioned on the transfer pallet, the impact limiter will be removed and transferred, using the OTC, to a park position for impact limiters. The pallet will then be transferred into the cask vent cell where the IFTC is inspected and vented, and the lid bolts are removed.

Next, the pallet will be transferred and positioned so that the IFTC is directly below the docking port of the module handling cell. Using the pallet's scissor lift, the cask is raised until its top flange is sealed against the port's gamma gate. The gamma gate will then be opened, which allows the containment door to be lifted into the cell, together with the IFTC's lid.

With the module crane, the top module will be lifted into the module handling cell, where it is placed in one of the storage positions near the port. The bottom module will also be lifted out before the IFTC's lid is lifted back and the cask undocked, for a reversal of the process for receiving IFTCs and subsequent dispatch from the UFPP.

Using the module crane, a module will be transferred to the module transfer cart. The module may also be transferred to the cart of the inclined elevator and lowered into the module storage pool for surge storage. A module that is retrieved from the pool must first be transferred to the drying booth, where the fuel will be dried to the required level, before transfer to the module transfer cart. The module transfer cart is then transferred through a door into the fuel handling cell.

In the fuel handling cell, the module will be lifted by the in-cell crane and transferred to one of the fuel handling machines, along with an empty basket in the horizontal position. In the fuel handling machine, two fuel bundles at a time are pushed from the module into one of the basket's tubes. During the transfer operation, a visual inspection and measurements are performed to verify the fuel for safeguard purposes.

When a module has been emptied of fuel, it will be lifted out of the fuel handling machine and replaced with a full module, thereby allowing the transfer operation to resume. The empty module will be visually inspected (to ensure that no loose fuel pieces are left inside) and transferred to the waste management facility (Sections 3.4 and 3.12) for decontamination and compaction.

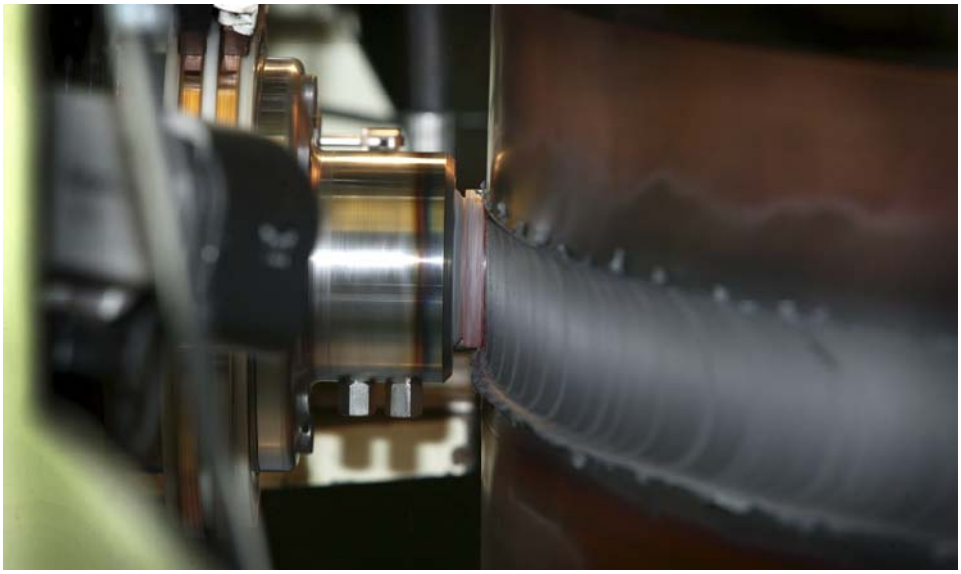
When all 60 tubes of a basket have been filled, the transfer operation stops. The basket will be removed from the fuel handling machine and tilted to the vertical position. Using the in-cell crane, the basket is then transferred and lowered into an awaiting UFC. The filled basket may also be transferred to one of the basket storage positions for subsequent loading.

When three baskets have been loaded into a UFC, the inner vessel lid and containment door will be replaced and the gamma gate closed. The UFC will then be undocked and lowered back into the shielded frame for transfer to the inerting station.

6.1.3 Sealing, Inspection and Dispatch of UFCs

At the inerting station, the UFC will be raised by the shielded frame and docked with the station. The inner vessel lid will be bolted on, with the valve in the lid connected to vacuum pumps and the inert gas supply. The air inside the inner vessel will first be evacuated and then replaced with inert gas. This process will be repeated and the gas content measured to determine if the inner atmosphere fulfills specified requirements or if further gas exchanges are required. During this operation, the tightness of the inner vessel lid can be tested, if needed. When the inerting process is completed, the connection to the valve will be removed. The top surface of the copper tube is then cleaned before the copper lid is placed onto the UFC using the OTC. The container is then undocked and lowered back into the shielded frame for transfer to the welding station.

At the welding station, the UFC will be docked and raised until its top section is inside the station. The UFC is then fixed into position. Using friction stir welding (FSW), the copper lid will be seal welded onto the copper vessel (see Figure 41). When the welding process is completed, the UFC is undocked and lowered back into the shielded frame for transfer to the machining station.



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Figure 41: Friction Stir Welding of a Copper Lid

At the machining station, the UFC will be docked and positioned so that it can be accessed by the station's milling machine with the weld area machined to a smooth surface. The UFC will then be undocked and transferred to the NDT station.

After time has allowed the UFC to cool down, non-destructive testing of the copper lid weld will be performed in the NDT station. The weld quality will be inspected using ultrasonic equipment and, if necessary, radiographic examination. When the NDT process is completed, the container will be undocked and lowered back into the shielded frame.

When a UFC has passed NDT inspection, it will be transferred and parked below the port to the filled UFC storage cell. Using the cell's 30 tonne OTC, the UFC is lifted through the port into the cell. Once inside, the UFC will be transferred to the decontamination cell, where it is monitored to ensure that it has not been contaminated during the packaging process. If contamination swipe results are unacceptable, the UFC will be decontaminated and re-monitored. It is also visually inspected to ensure that it has not been mechanically damaged during the packaging process.

After passing monitoring and visual inspection, the UFC will be positioned above a port down to the filled UFC dispatch cell (or to one of the storage positions for later dispatch). During dispatch, the UFC will be lowered vertically down through the port, into a shielded transfer cask.

The UFC transfer cask will have previously arrived at the UFPP on a rail wagon. The wagon is driven in through a port in the UFC dispatch airlock. Using the OTC, the transfer cask will first be tilted to a vertical position in the airlock and then transferred to a pallet at a working platform in the dispatch hall. At the platform, the transfer cask will be inspected with the lid bolts removed. Using an air-cushion transporter, the pallet with the cask will be moved to the filled UFC dispatch cell. The gamma gate to the filled UFC storage cell will then be opened and, using the OTC, the transfer cask lid is lifted off.

Once a UFC has been lowered into the transfer cask, the cask lid will be lifted back using the 80 tonne OTC. The cask will then be returned to the platform where the lid is bolted and the cask inspected. Next, the cask will be lifted by the OTC and transferred to an awaiting rail wagon in the airlock. During loading onto the rail wagon, the cask will be tilted to a horizontal position.

6.2 UFC Transfer from UFPP to Repository

After final inspection at the UFPP, the transfer cask will be dispatched from the UFPP to the underground repository. The transfer cask and UFC will be moved by rail using the wagon (or trolley) to the Main Shaft. It will then be lowered to the repository and transferred either directly to a placement room or to a temporary storage area to await placement.

6.3 UFC Placement in Repository

As previously described, the UFC's placement entails in-floor borehole placement in elliptically arched rooms. A 0.5 m thick disk of highly compacted bentonite (HCB) buffer material is placed at the bottom of the hole, followed by 8 rings of the same material, totalling about 4 m in height, and creating a cylindrical space for the container. Two gaps of 50 mm are left on both sides of the buffer rings; one annulus between the container and the inner side of the rings; the other

annulus between the rock and the outer side of the rings. These gaps are filled with bentonite gap fill material. This assemblage is then topped by three 0.5 m disks of HCB buffer and two 0.5 m disks of dense backfill (DBF). The floor of the placement room is then levelled with 250 mm of light backfill (LBF) with blocks of dense backfill then placed to take up most of the room volume. After placement of the DBF blocks, the spaces between the blocks and the rock are filled with LBF.

The conceptual UFC placement method is outlined in a storyboard format included as Figure 42 (found at the end of Section 6). The first of these illustrations provides a summary of the required placement equipment. Such equipment, some of which must be developed specifically for this project and its design requirements (e.g., shielding needs, cask weight, etc.) will comprise:

- UFC Transfer Cask and trolley;
- Placement machine;
- Borehole shielding barrier;
- Bentonite pellet blowing equipment;
- Bentonite disk placement shield;
- Temporary borehole cover;
- Bentonite disks and rings; and
- Locomotive.

The placement sequence itself has been broken down into 29 phases as shown on Figure 42. As illustrated within the component phases, the placement procedure involves several discrete major tasks including: preparation of placement room borehole; placement of the UFC; and, installing gap fill and bentonite discs in the borehole. These tasks are more fully described following Figure 42.

Upon backfilling of the borehole, the placement room will be backfilled in a retreating fashion with pre-formed dense backfill blocks and pneumatically placed light backfill.

Following setting up the room for placement of the initial UFC, it has been estimated that the total sequence for placing and backfilling a single UFC will take 23.5 hours, including a 20% contingency.

As approximately two UFCs will be placed per day, at least three placement rooms are expected to be active in some stage of the placement sequence at any one time. This includes two rooms which will be actively involved in UFC placement procedures, with a third room likely undergoing backfilling activities.

6.3.1 Preparation of Placement Borehole

Following completion of excavation of all placement rooms within a panel, and drilling of the placement boreholes, temporary covers will be placed over each borehole and rail will be laid to allow transport of the UFC transfer cask from the Main Shaft to the placement room borehole. Bentonite discs and rings would be transported by rail trolley to the placement machine and

lowered into the borehole to receive the UFC. After the bentonite discs and rings have been placed, a shielding barrier will be moved into place over the borehole.

6.3.2 Placement of UFC

The UFC transfer cask, complete with UFC, will be transported by rail from the shaft area to the active placement room and moved into place beneath the placement machine and over the target borehole. The UFC will be rotated to a vertical position and coupled to the shielding barrier overlying the borehole. Doors from the transfer cask and shielding barrier will be opened and the UFC will be lowered by winch into the borehole, and within the bentonite rings. Once the UFC is in place, the shielding barrier opening to the borehole will be closed and the empty UFC transfer cask will be removed from the placement room.

6.3.3 Backfilling of Placement Borehole

Once the transfer cask has been removed, the bentonite pellet equipment will be moved into place above the shielding barrier. Bentonite pellets will be blown into the annulus between the bentonite disc/rings and borehole wall as well as between the UFC and the bentonite rings. The bentonite blowing equipment will then be removed and three bentonite discs and two dense fill discs, installed within a disc placement shield will be moved into the room and coupled to the shielding barrier. The discs will be lowered onto the borehole to cover the exposed top of the UFC and complete backfilling of the borehole to the placement room floor elevation. The disc placement cask will then be removed, followed by the shielding barrier and the placement machine in preparation for the placement room backfilling.

6.4 Backfilling of Placement Room

Following the preceding activities, the bentonite pellet equipment will be returned to the borehole to fill the annulus between the final bentonite discs and the borehole wall. The section of track straddling the newly placed UFC will then be removed. Light backfill will be placed over the placement room floor and levelled in preparation for the dense backfill blocks. A total of 17 blocks, 1 m deep each, in 4 geometries, will be placed per metre of retreated placement room backfilled. The configuration of the placed blocks was previously shown in Figure 10.

6.5 Handling of Defective UFCs

When non-destructive testing or visual inspection shows defects that do not fulfill requirements for long-term disposal, the UFC will be held in one of the parking positions for shielded frames for subsequent handling. Should a defective container be discovered, the normal packaging process will be stopped to ensure that no additional UFCs are produced with the same defects. The cause of the defects will be investigated and any issues resolved before the packaging process is allowed to resume.

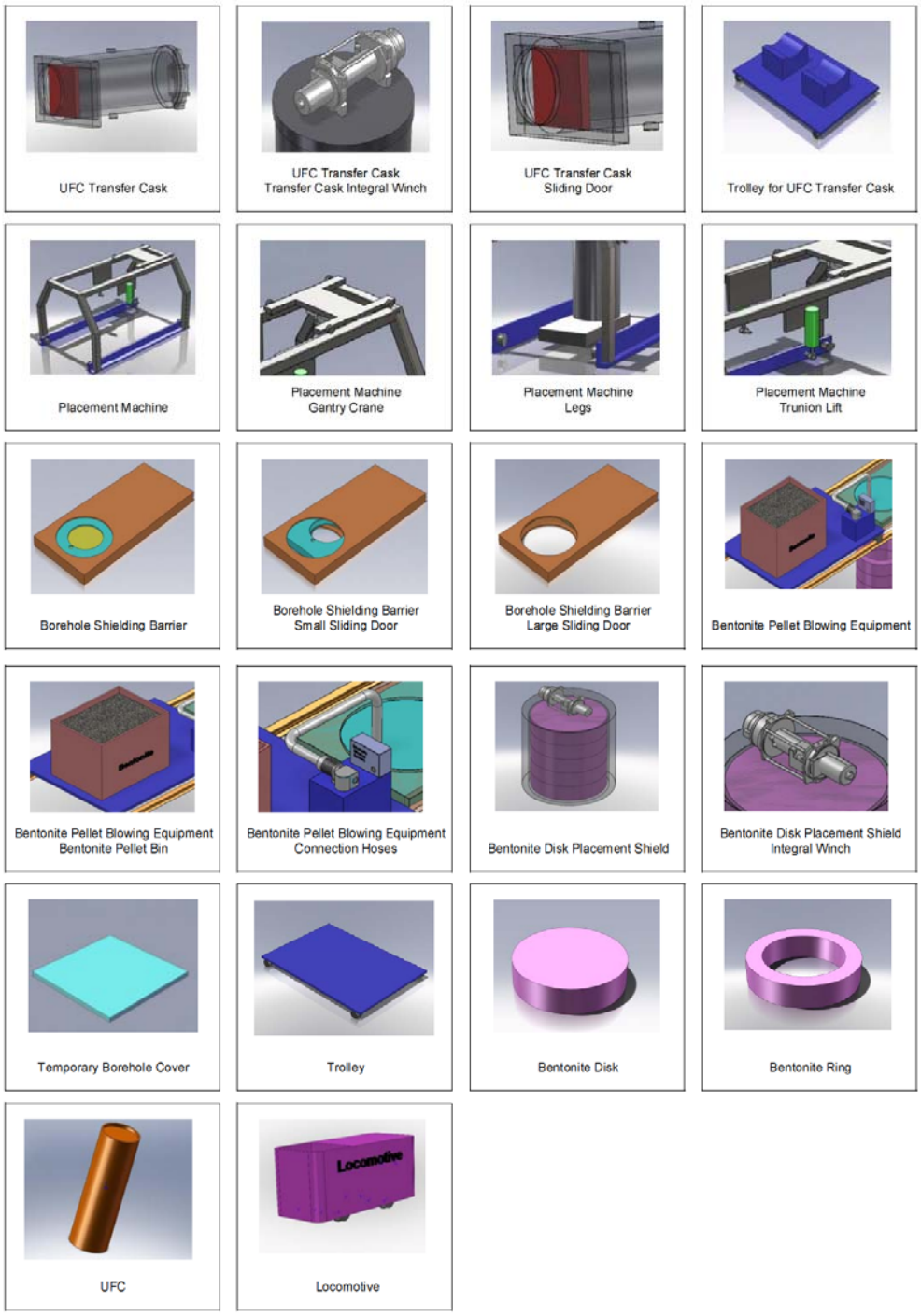
To re-open a defective UFC, the milling machine in the UFPP machining station will first be fitted with a special tool for cutting open the copper lids. The UFC will then be transferred to and docked with the machining station where the copper lid is cut but left on top of the copper vessel. The UFC will then be transferred to the inerting station where the copper lid is lifted off using the station's OTC, and the bolts of the inner steel lid are loosened.

Next, the UFC will be transferred to the fuel handling cell where the steel lid is lifted off, and the baskets lifted out of the container and transferred to storage positions in the fuel handling cell.

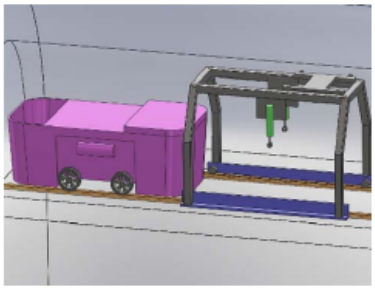
The emptied UFC will be visually inspected, and if any fuel pieces are found at the bottom of the container, they will be removed using vacuum cleaners and MSMs equipped with special tools. The UFC will then be transferred to the active mechanical workshop where it will be decontaminated and packaged for subsequent handling. If possible, the inner vessel will be re-used, while decontaminated copper vessels will be shipped off-site for recycling.

Once the packaging process resumes, a new UFC will be docked to the fuel handling cell. The three filled baskets, from the previous unloading of the defective container, will be loaded into the new UFC for normal processing.

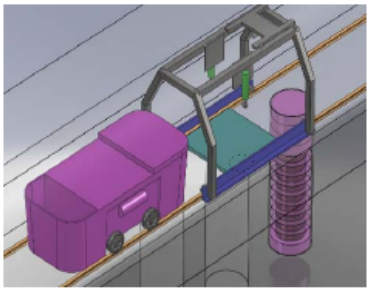
Legend for Vertical Placement Equipment



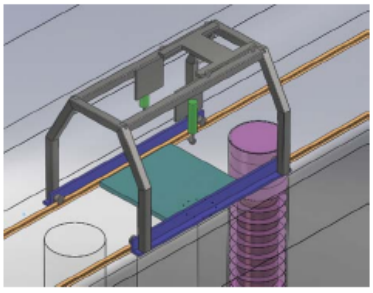
Container Placement - Sequence of Operations



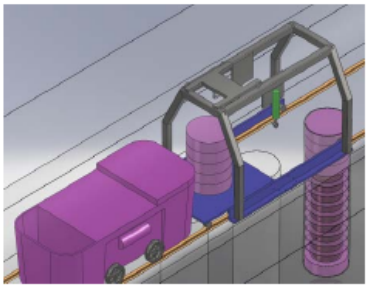
Phase 1
Move Trolley with Placement Machine to Vertical Borehole



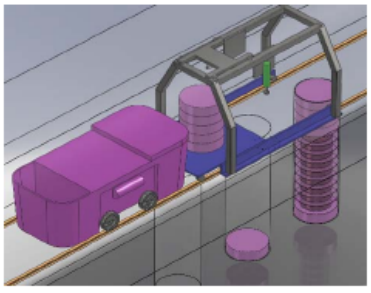
Phase 2
Positioning Placement Machine over Vertical Borehole



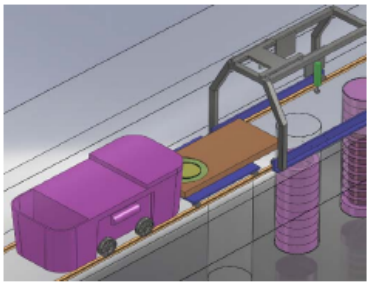
Phase 3
Lower Placement Machine Legs and remove Trolley



Phase 4
Remove Temporary Cover and Positioning Bentonite Trolley under Placement Machine

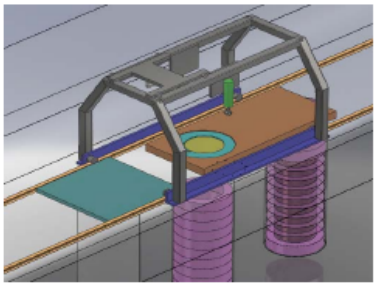


Phase 5
Lower Bentonite Components with Placement Machine into Borehole

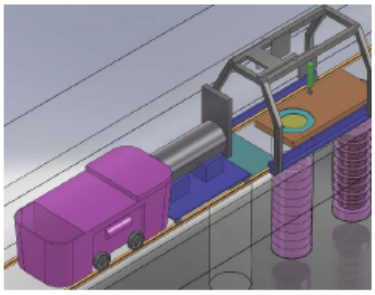


Phase 6
Move Shielding Barrier to Placement Machine over Borehole

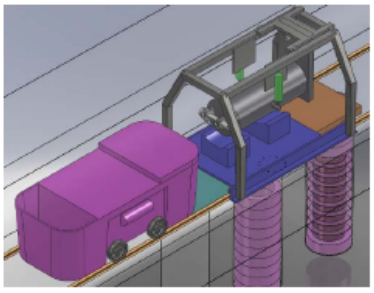
Container Placement - Sequence of Operations



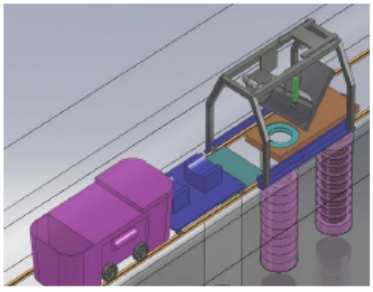
Phase 7
Positioning Shielding Barrier under Placement Machine



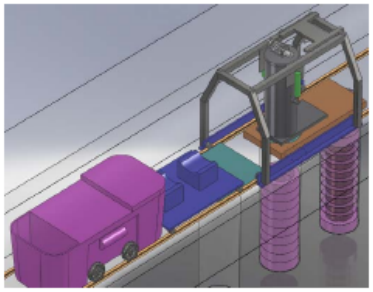
Phase 8
Move Trolley with Filled UFC Transfer Cask to Placement Machine



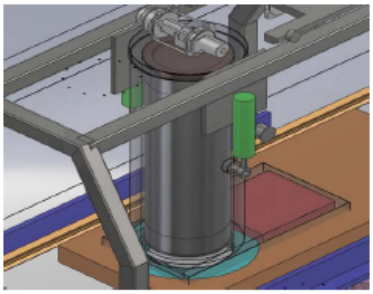
Phase 9
Lift Filled UFC Transfer Cask off Trolley with Placement Machine



Phase 10
Rotate UFC Transfer Cask with Placement Machine

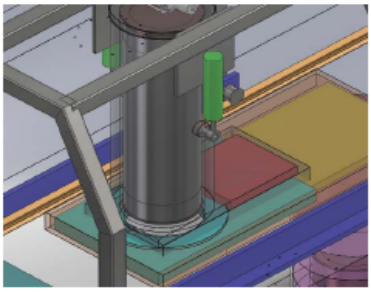


Phase 11
Lower UFC Transfer Cask onto Shielding Barrier using Placement Machine

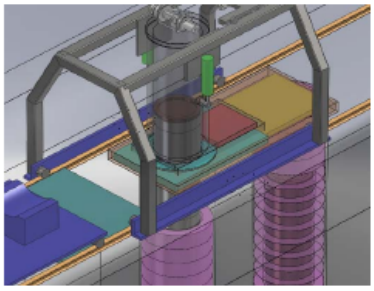


Phase 12
Raise UFC 1" using UFC Transfer Cask Integral Winch

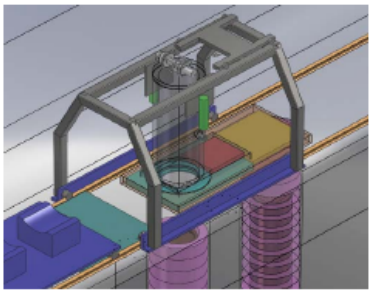
Container Placement - Sequence of Operations



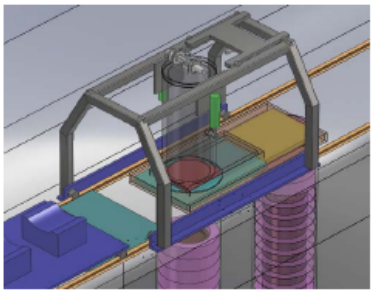
Phase 13
Open Shielding Barrier and UFC Transfer Cask Sliding Door



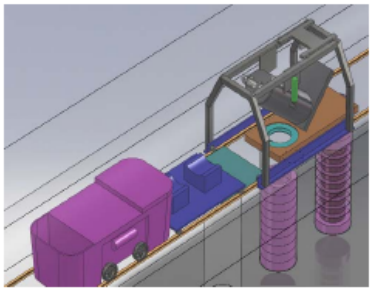
Phase 14
Lower UFC into Borehole



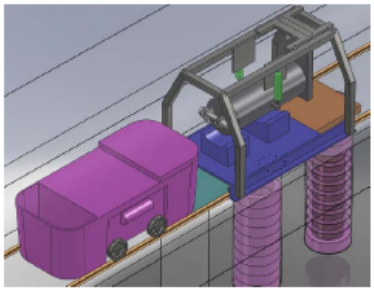
Phase 15
Use Tool to release UFC Clamp and retract UFC Clamp



Phase 16
Close Shielding Barrier and UFC Transfer Cask Sliding Door

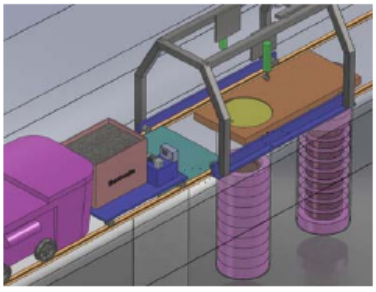


Phase 17
Lift and rotate UFC Transfer Cask with Placement Machine

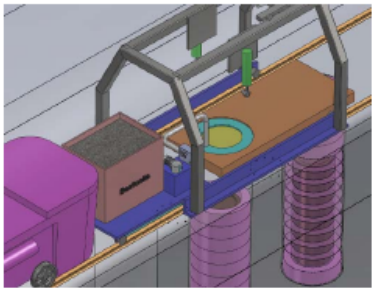


Phase 18
Lower UFC Transfer Cask on Trolley and transport to Storage

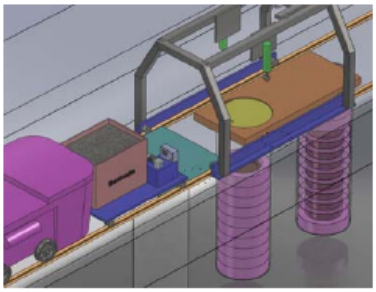
Container Placement - Sequence of Operations



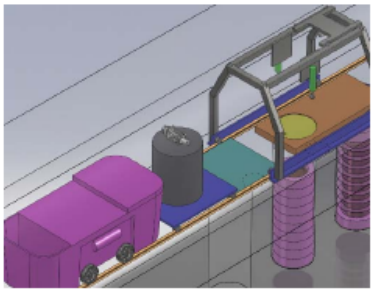
Phase 19
Move Trolley with Bentonite Pellet Blowing Equipment to Placement Machine



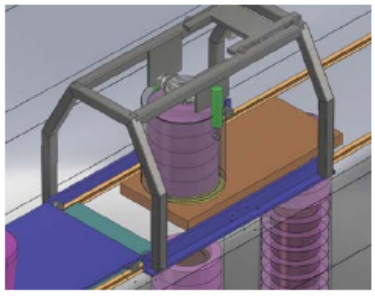
Phase 20
Fill Inner and Outer Gaps with Bentonite Pellets



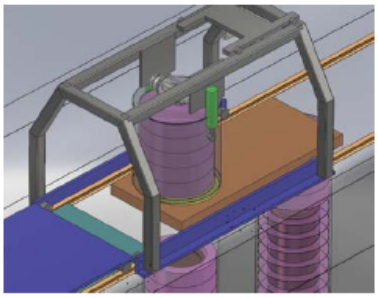
Phase 21
Move Trolley with Bentonite Pellet Blowing Equipment to Storage



Phase 22
Move Trolley with Bentonite Disk Placement Shield and Disk to Placement Machine

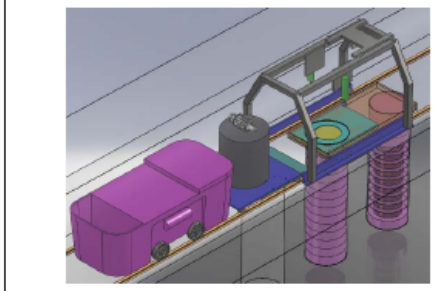


Phase 23
Lift Bentonite Disk Placement Shield onto Shielding Barrier using Placement Machine

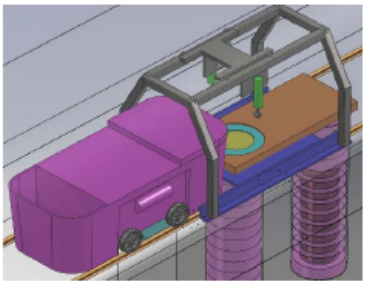


Phase 24
Lower 5 disks using Integral Winch in Disk Placement Shield

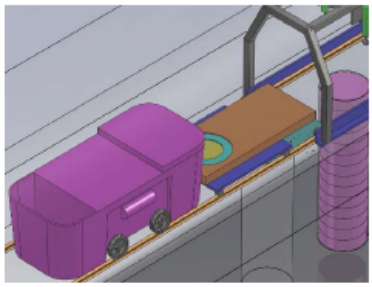
Container Placement - Sequence of Operations



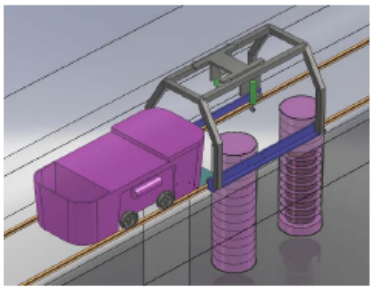
Phase 25
Move Trolley with Bentonite Disk Placement Shield to Storage



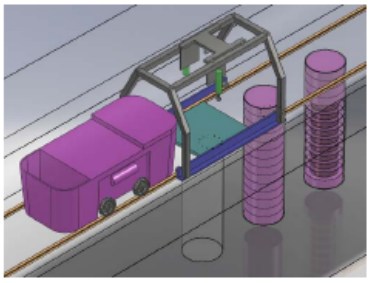
Phase 26
Lift Shielding Barrier with Placement Machine and place onto Trolley



Phase 27
Move Trolley with Shielding Barrier to Storage



Phase 28
Raise Placement Machine legs and Lower onto Trolley



Phase 29
Move Trolley with Placement Machine to the next Borehole and position

Figure 42: Container Placement - Sequence of Operations

7. CONTAINER RETRIEVAL

The following section describes the approach for a container retrieval system (CRS) to safely extract a UFC from its location in the repository for subsequent transport to the DGR surface facilities. There are two major stages in the retrieval operation: providing access to the target borehole; and, retrieving the UFC. The intended approaches for these two stages, discussed below, will be examined and refined as part of the UDF testing program (see Section 5.2.1).

7.1 Gaining Access to Target UFC

Activities related to providing access to the target borehole and UFC will be significantly impacted by the location of the UFC within a particular placement room as well as the length of time that has passed after its placement.

The immediate retrieval of a UFC when the placement room is still open will not have to contend with the light and dense backfill that will be used to seal the placement room. Secondly, and depending upon the extent that the placement room's development has been completed, the room's concrete bulkhead may or may not be in place.

As previously described, bentonite clay is to be used as a primary fill material throughout the UFC repository. It will be used in the form of dense, highly compacted bentonite (HCB) rings, disks and blocks and also in the form of pellets, pneumatically placed to fill any remaining narrow spaces. Of particular importance to the UFC retrieval process are the characteristics of these sealing materials, some of which may have been placed for an extended period of time. Over time, the placed bentonite may evolve from an unsaturated to a saturated condition. Alternatively, the heat produced from the entombed UFCs may cause some of this fill to become dry and hard.

The amount of water saturation that the surrounding bentonite buffer will experience is important for container retrieval. Bentonite swells with moisture becoming a significant barrier to water movement but, more importantly, the swelling will introduce a gripping pressure on the UFC. The net effect of this pressure is that a simple mechanical means of lifting the UFC out of a borehole cannot be performed by extraction equipment until the gripping pressure has been relieved.

The immediate impediments to UFC retrieval (removal of the concrete bulkhead and the light and dense backfill) are discussed below. As noted, in order to minimize mechanical disturbance to the emplaced UFCs from transmitted lateral forces, the reuse of drill & blast techniques previously employed for the development of the repository was not considered to be appropriate (material hauling vehicles, the LHDs and haul trucks, may still be reused).

7.1.1 Concrete Bulkhead Removal

To remove the concrete bulkhead without mechanically disturbing any placed UFCs, a non-explosive expansion agent will be used. Under such an approach, boreholes would be drilled into the concrete bulkhead and loaded with an expansion agent. Commonly available as powder based materials that are mixed with water for activation, such agents can generate a

high expansive stress without the ground vibration that is associated with drill & blast methods. The agent expands as it cures over a period of hours or days generating sufficient pressure to break the concrete (the bulkhead may require some cutting to allow room for expansion). The resulting concrete fragments are then removed through traditional mining material removal techniques.

7.1.2 Bentonite Backfill Removal

The backfill in the placement room is primarily a series of bentonite blocks arranged in a manner to fill the semi-elliptical tunnel. As previously described in Section 3.5, the placement rooms will be filled with these blocks, as well as light backfill (50% bentonite, 50% sand).

Given the nature of the bentonite fill, a controlled demolition chemical agent is again suggested for the removal process. As above, such an approach will minimize any disturbances transferred to the placed UFCs. Further, and recognizing that the needed expansion agents are activated by mixing with water, the presence of any moisture in the saturated bentonite will not deter the demolition process. While not a rapid process of removal for the bentonite, it is assumed that speed will not be a driving factor in the UFC retrieval operation.

7.1.3 In-Floor Bentonite Discs and Rings Removal

Once access has been provided to the target location in the placement room, the borehole HCB discs and rings need to be removed. To effectively carry this out without mechanically disturbing the emplaced UFCs, a vertically applied hydrodynamic method will be employed. The basic premise is to wash away the bentonite with a saline water solution. While potentially time consuming, the reasons for a hydrodynamic technological approach are:

- The vertical borehole provides a controlled operating volume for the process;
- The approach has been demonstrated in other applications as an effective means to eliminate gripping pressures prior to attempting container retrieval;
- Simultaneous chemical and mechanical action on the buffer erodes the compacted bentonite in any state (ranging from dry and hard to fully saturated);
- The method can be applied in a continuous process with little risk of damage to the UFC; and
- No bulky load-bearing or positioning structural parts are needed (compared with equipment that uses some type of mechanical freeing technology).

The method essentially consists of two stages: slurrying of the bentonite buffer; and, dewatering of the generated slurry (which will contain a large volume of water).

Technology is currently available to deal with fine bentonite slurries (a common requirement in many mining applications) and a multi-stage separation process may be employed. The key component technology, however, will be based on the mechanical dehydration of sludge using a common decanter centrifuge process. The principle of operation is based on a high energy centrifuge in a bowl rotating around it's axle. Concentration and evacuation of dehydrated sludge is achieved by a cylindro-conical screw that operates at a variable speed. Figure 43 shows a typical decanter centrifuge.

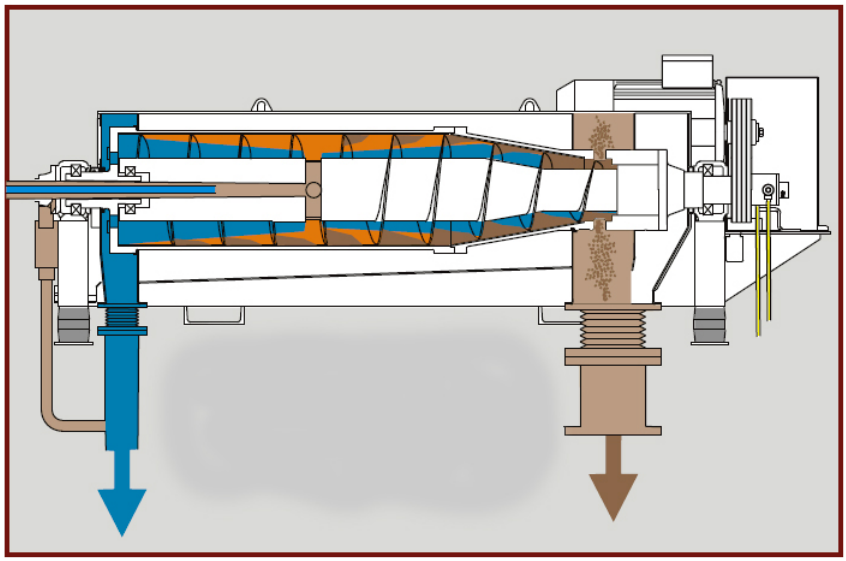


Figure 43: Typical Bentonite Decanting Equipment

In addition to the hydrodynamic method, alternate approaches that have been investigated by others for freeing containers from a bentonite buffer have included:

- Mechanical methods where the bentonite is machined away by boring or drilling;
- Thermal methods where the container's mantle surface is freed by heating or cooling; and
- Electrical methods where the bentonite nearest the container's mantle surface is shrunk by means of an electric current to create a gap between the container and the buffer.

None of these methods have proven as effective as the hydrodynamic approach described above.

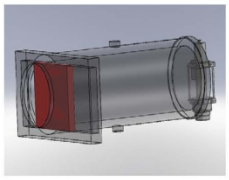
7.2 UFC Extraction and Retrieval

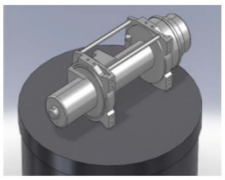
Once the bentonite buffer has been removed, the actual UFC retrieval process can be started. The envisaged process has primarily been influenced by the need to ensure a safe retrieval with continuous radiation shielding to allow unrestricted movement of personnel as well as the effective re-use of container placement equipment. The retrieval methodology has been based, to the extent possible, on the reversal of placement operations.

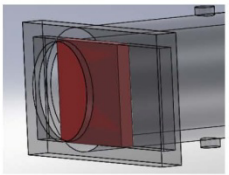
Much of the UFC placement equipment can be re-used for retrieval. Such equipment will include the UFC transfer flask and trolley, the placement machine with its gantry crane and trolley, and the temporary borehole covers. New equipment needed for the retrieval operations will include a revised borehole shielding barrier with sliding door, a UFC clamp tool, slurry vacuum, water sprays, water bladder, spray ring and winch. Further, bentonite recovery equipment (hydrodynamic removal and decanting systems) will need to be assembled.

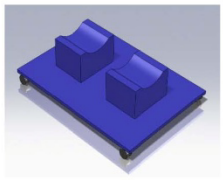
A simplified version of the sequence of the envisaged container retrieval system (CRS) is provided in pictorial storyboard form in Figure 44 over the next 6 pages. The first of these illustrations provides a summary of the required retrieval equipment.

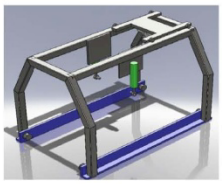
Legend for In-Floor Borehole CRS Equipment

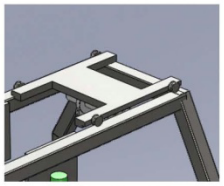

UFC Transfer Cask

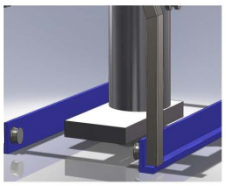

UFC Transfer Cask
Transfer Cask Integral Winch

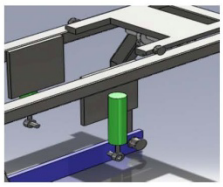

UFC Transfer Cask
Sliding Door

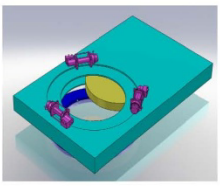

Trolley for UFC Transfer Cask

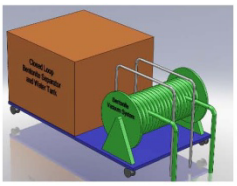

Placement Machine


Placement Machine
Gantry Crane

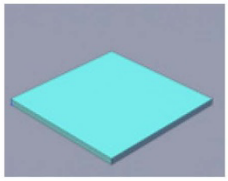

Placement Machine
Legs

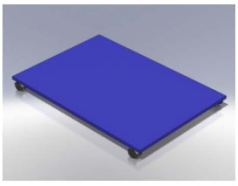

Placement Machine
Trunion Lift


Shielding Barrier with Sliding Door,
Spray Ring

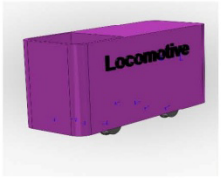

Trolley with Water Tank, Pumps and
Bentonite Separator


Bentonite Separator Equipment


Temporary Borehole Cover

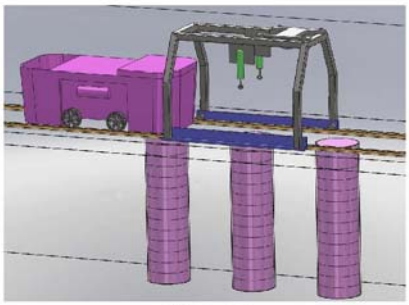

Trolley


UFC

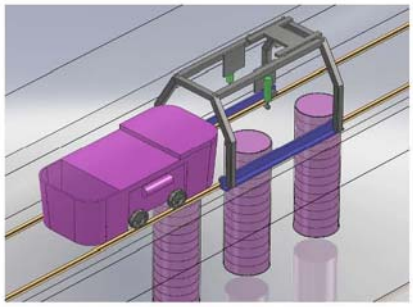


Locomotive

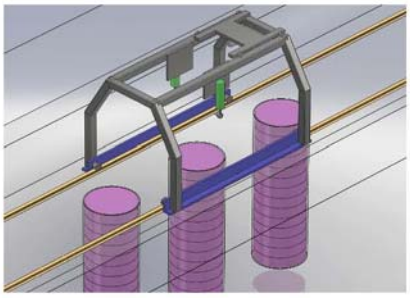
Container Retrieval - Sequence of Operations



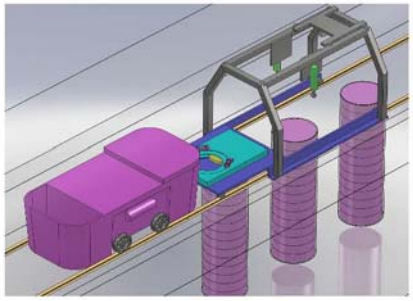
Phase 1
Transport and position Placement Machine over Borehole



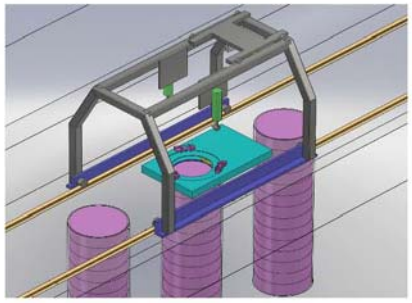
Phase 2
Connect Placement Machine to Services



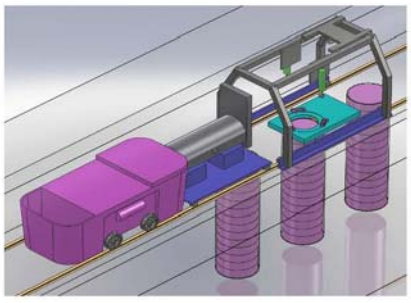
Phase 3
Lower Placement Machine Legs and move Placement Machine Trolley to Storage



Phase 4
Transport Shielding Barrier to Placement Machine

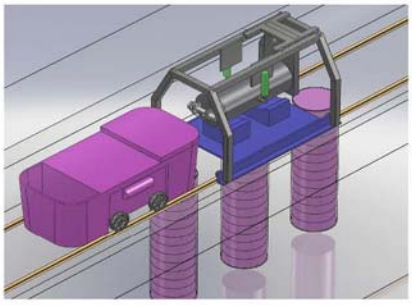


Phase 5
Positioning Shielding Barrier over Borehole

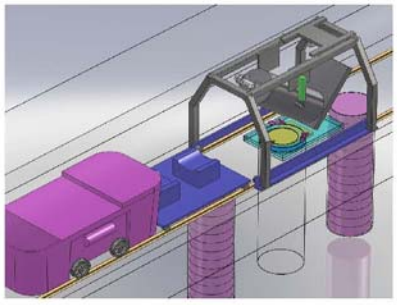


Phase 6
Move Trolley with Empty UFC Transfer Cask to Placement Machine

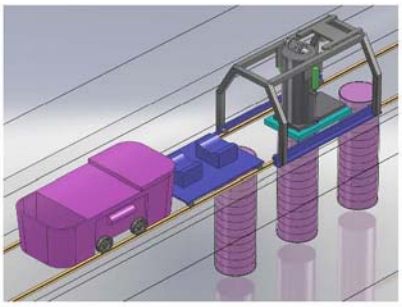
Container Retrieval - Sequence of Operations



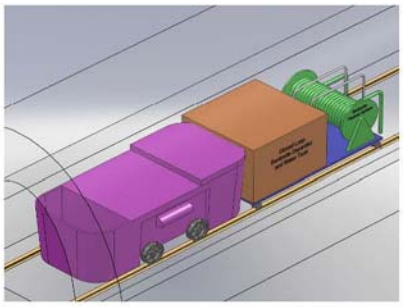
Phase 7
Lift Empty UFC Transfer Cask
using Placement Machine off Trolley



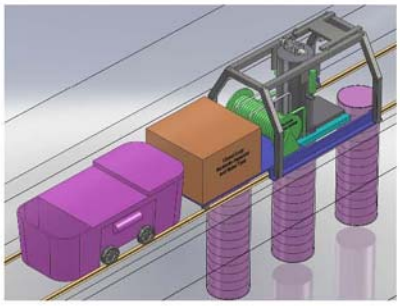
Phase 8
Rotate UFC Transfer Cask with
Placement Machine



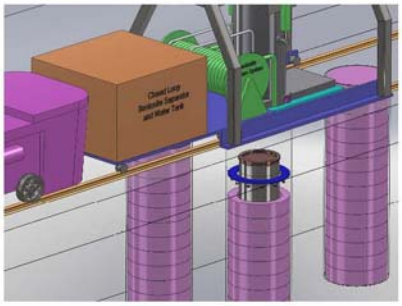
Phase 9
Lower UFC Transfer Cask onto Shielding
Barrier using Placement Machine



Phase 10
Connect Locomotive to Trolley with
Water Tank, Pumps and Bentonite Separator

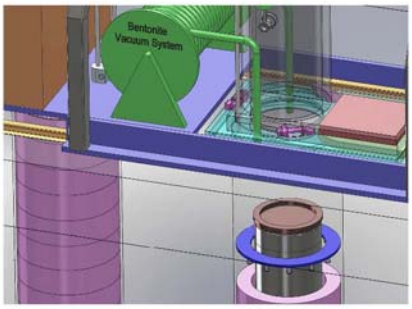


Phase 11
Move Trolley with Water Tank, Pumps and
Bentonite Separator and connect to Services
and Shielding Barrier

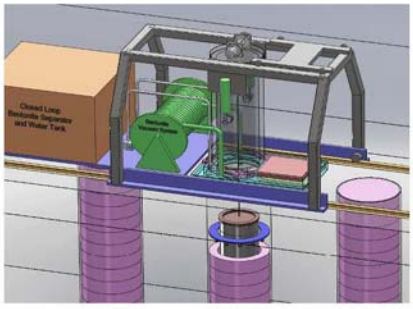


Phase 12
Start Pumps, Slurry Vacuum
and dissolve Bentonite, Continue
until 25% of UFC is Exposed

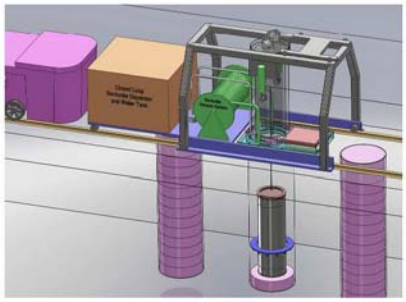
Container Retrieval - Sequence of Operations



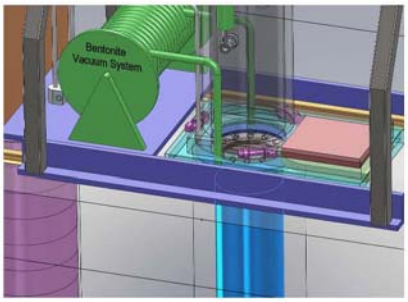
Phase 13
Open Shielding Barrier Sliding Door and UFC Transfer Cask Sliding Door



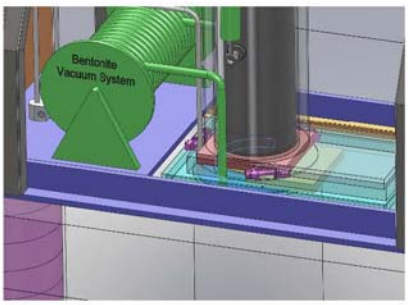
Phase 14
Lower UFC Clamp using Integral Winch in Transfer Cask and connect to UFC



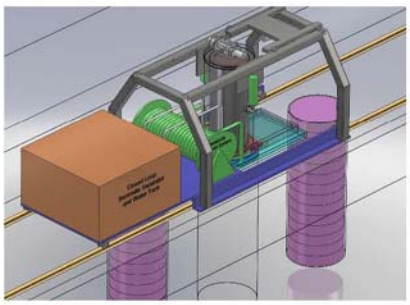
Phase 15
Continue Dissolving Bentonite and Removing Slurry to Expose UFC



Phase 16
Raise Spray Ring to Shielding Barrier and Use Sprays to rinse UFC during Lift

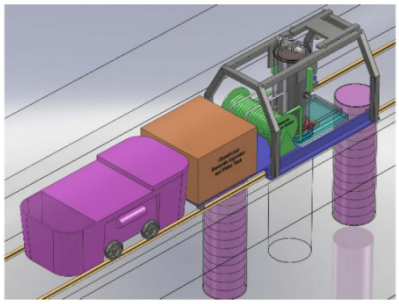


Phase 17
Close UFC Transfer Cask Sliding Door and Shielding Barrier Sliding Door

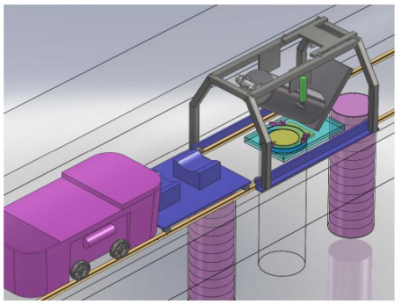


Phase 18
Disconnect Services from Bentonite Separation Equipment, Shielding Barrier and Transfer Cask.

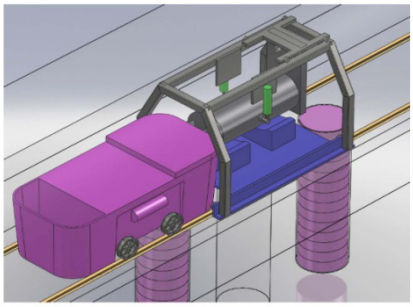
Container Retrieval - Sequence of Operations



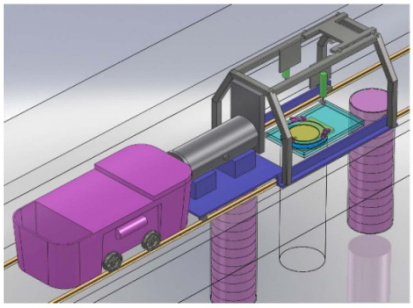
Phase 19
Connect Locomotive to Trolley with Bentonite Separation Equipment and move to Storage



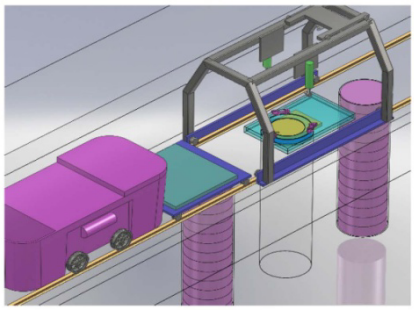
Phase 20
Lift and Rotate UFC Transfer Cask Using Placement Machine



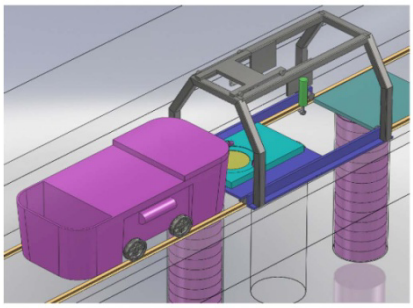
Phase 21
Move UFC Transfer Cask Trolley under UFC Transfer Cask



Phase 22
Lower UFC Transfer Cask onto UFC Transfer Cask Trolley and move to Storage



Phase 23
Move Trolley with Temporary Borehole Cover from Storage to Placement Machine



Phase 24
Lift Shielding Barrier onto Trolley using Placement Machine

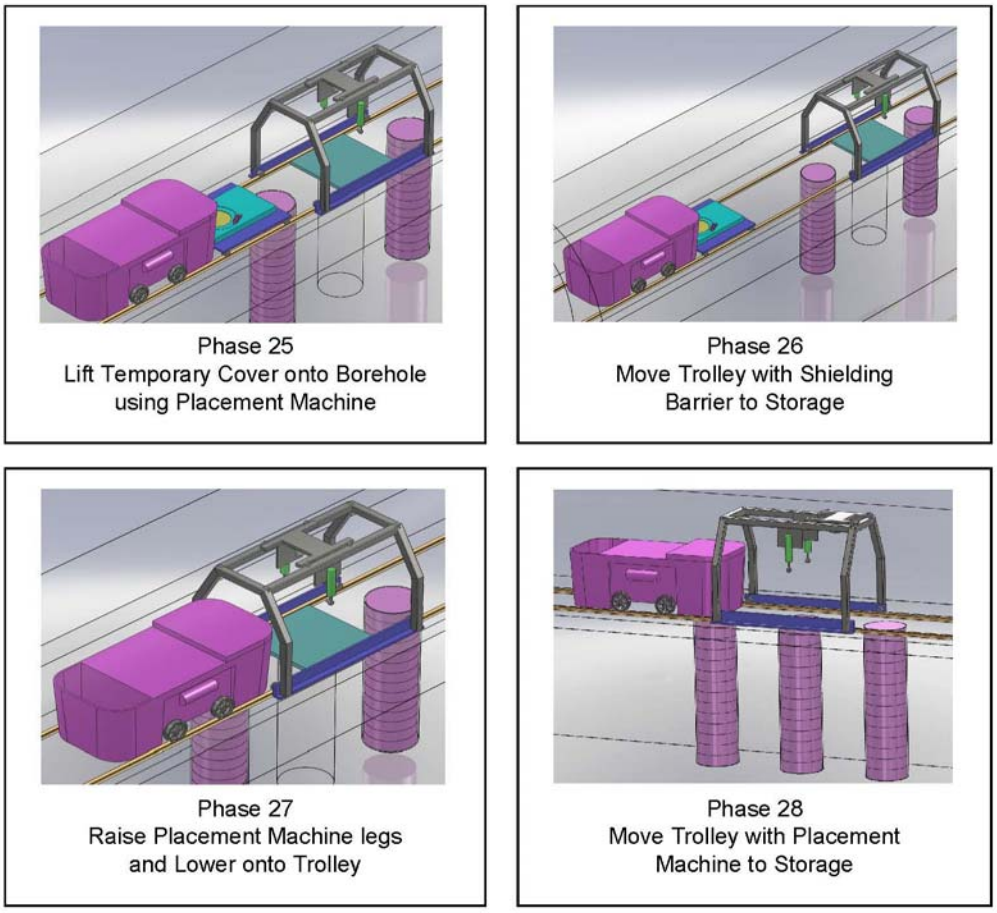


Figure 44: Container Retrieval - Sequence of Operations

8. SITE SECURITY

The interior section of the DGR is considered a Protected Area per current CNSC Nuclear Security Regulations (SOR/2000-209). The Protected Area boundary will consist of a physical protection system, with controlled personnel and vehicle access points. Furthermore, the entire DGR facility will be surrounded by a fence to provide insular vehicular, person or wildlife challenged access to the facility.

The Protected Area's physical protection system will incorporate a perimeter barrier with unobstructed land on both sides of the barrier, consistent with CNSC requirements. In addition, a system of protective elements will be in place to provide multiple layers of delay, detection and assessment that are controlled through a central command post or security monitoring room. The assessment component will enable security personnel to evaluate detected threats and provide the appropriate response. All of these component layers will further be connected to a back-up uninterrupted power supply, located within the Protected Area.

CNSC Nuclear Security Regulation (SOR/2000-209) stipulates that the detection and assessment components must each feature two independent systems. The delay component must have additional capabilities to deny intruders using large vehicles from forcing entry. Consistent with these requirements, the systems established to secure the Protected Area will include:

- A physical barrier to delay intruders for a sufficient period of time to enable effective interdiction by response personnel and provide sufficient time delay at all points around the perimeter of the facility;
- A detection system to identify intruders immediately and alert security and response personnel; and
- An assessment system, with a dedicated lighting network, to allow security personnel to clearly identify and qualify any possible intrusion.

The various aspects of the site security infrastructure, including those for the Protected Area, are discussed in this section. For illustrative purposes, their individual locations in the DGR complex have been highlighted in the following Figure 45.

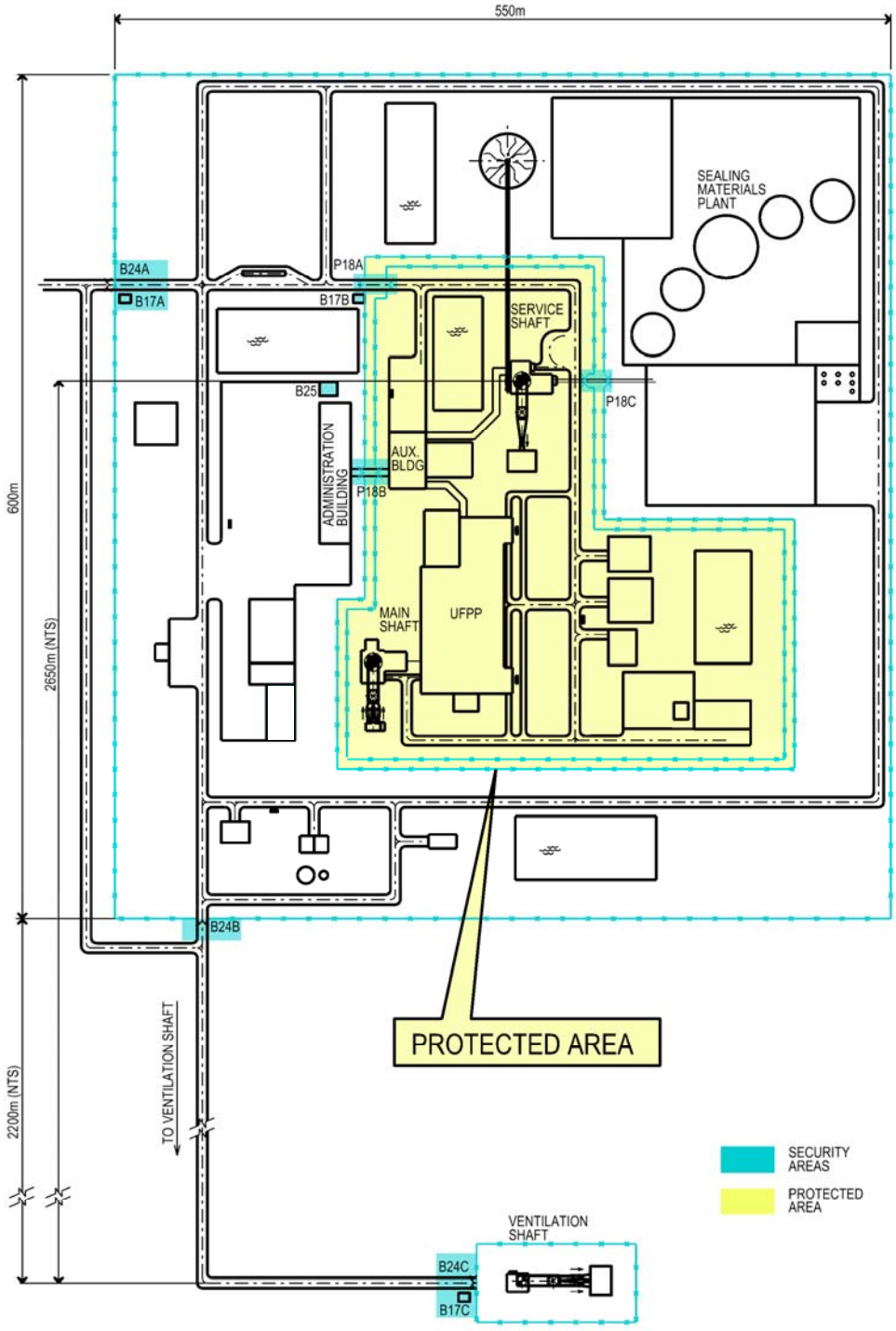


Figure 45: Site Security Components

8.1 Security Monitoring Room Area B25

The main Security Monitoring Room will house monitoring equipment including cameras and closed-circuit TV monitors, and will serve as the central command point for security works serving both the Protected Area and the Balance of Site. The security room (Area B25), located adjacent to the Administration Building, will accommodate four on-duty personnel per shift. Remaining security team members will be on standby in the event of an emergency.

8.2 Physical Barrier Systems

There will be two security fence systems in place at the DGR facility. While a double fence (Area P20) will surround the Protected Area, a separate perimeter fence (Area B4) will act to contain essentially all of the DGR's surface facilities, excluding the separately enclosed Ventilation Shaft Complex (Area B1).

8.2.1 Protected Area Security Fence Area P20

A physical barrier system will be constructed to restrict access to employees and visitors approved to enter the facilities in the Protected Area. As illustrated on Figure 46, there will be two fences; one inner and one outer barrier each 3 m high above grade. The fences will be set 3 m apart with coils of barbed wire placed in between over a gravel surface. Lighting and monitoring will be in place as discussed below. The ground will be cleared to provide an unencumbered setback on either side of the fence to permit visibility as well as to allow for patrol vehicles. Posted signs will identify the restricted access.

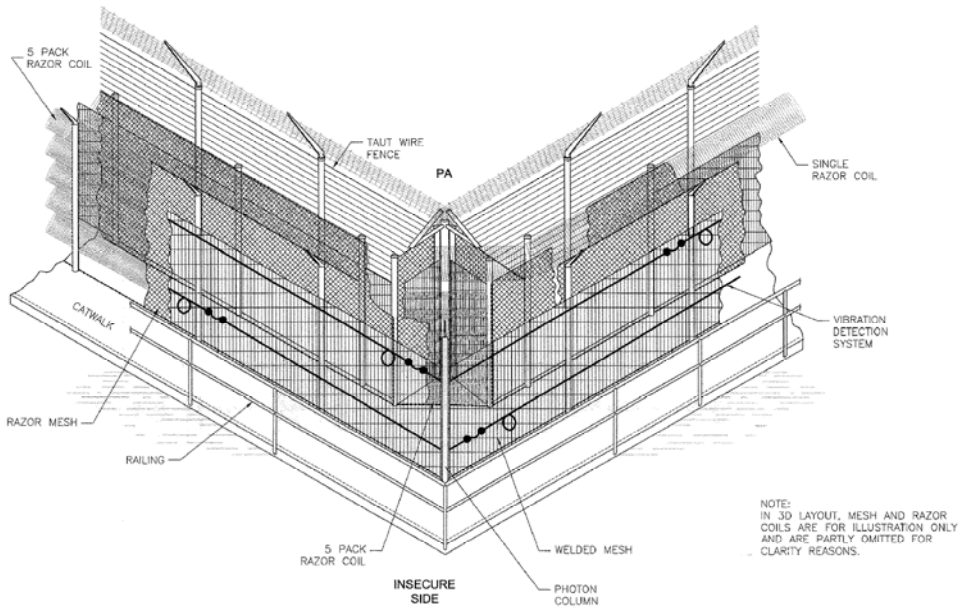


Figure 46: Protected Area Security Fence

In addition, supplementary capabilities will be established to deny intruders using large vehicles access to the Protected Area. While jersey barriers may typically be used for such purposes, a structure similar to that illustrated on Figure 47 will be installed at the vehicle access point. Two pairs of these movable gates will be established, separated by a space (sally port) sufficiently large to accommodate any vehicle entering the Protected Area.



Figure 47: Vehicle Entry Point

Protected Area Detection System

To detect intruders attempting to gain access into the Protected Area the following sensor systems will be established:

- Photon sensors installed immediately outside the outer fence to detect and alert security personnel that an intruder is attempting to climb the fence;
- Shaker sensors installed on the outer fence to detect and alert personnel that an intruder is attempting to climb the fence; and
- A taut wire fence 3 m high and located 4 m away from the main fencing including a guy wire and detectors to alert security that an intruder is attempting to gain access.

Protected Area Assessment System

To assess alarm signals sent by the Protected Area detection system sensors the following will be in place:

- Each sector of the assessment system will have one dedicated CCTV camera installed on a pole. Every two sectors will have a camera with pan, tilt and zoom capabilities;
- Every two sectors will have one dedicated infrared camera to assist security personnel during poor weather and visibility conditions; and
- An auxiliary remote wireless surveillance camera mounted on the highest point of the facility will compensate for any deficiencies of the preceding equipment.

The installed cameras will be supported by a lighting system situated inside of the Protected Area boundary that is capable of providing the required illumination levels. Additionally, secure mobile phones and satellite phones will permit secure lines of communication between security personnel.

The coordination of these security functions will be carried out through the Security Monitoring Room (Section 8.1).

Protected Area Entry Control System

Further to that above, DGR personnel access to the Protected Area will also be controlled. While the ultimate configurations of the entry/egress arrangements are still to be determined, several integrated security features are anticipated. These include entry turnstiles controlled by hand geometry identifiers and exiting turnstiles controlled by a radiation portal monitor. Explosive detectors as well as metal detection devices for personnel and personal articles will additionally be installed. Figure 48 provides an illustrative example of a similar system.



Figure 48: Example Entry Control System

8.2.2 Balance of Site Perimeter Fence Area B4

An additional fence will act as a site demarcation (perimeter) feature for the DGR complex while also providing a barrier/deterrent to intruders, including large animals. Entry through the fence will be by the facility access road from the incoming highway. While free access will be provided through this point, 'cattle grates' may also be incorporated to deter large animal entry. The ground will be cleared to provide an unencumbered setback on either side of the fence to allow for unrestricted visibility and as a route for future maintenance. Signs will be posted on the fence indicating the purpose of the facility, and its restricted access.

The fence will consist of 3 m tall galvanized chain link wire, of heavy gauge construction. Access gates will be of the automatic sliding metal chain link type, with a secondary lift-up barrier. Gates will be controlled by security personnel at the guardhouses (Section 8.3), and be monitored by the main Security Monitoring Room (Section 8.1).

8.3 Security Checkpoints and Guardhouses

Several access control points and guardhouses will be established at the DGR, as illustrated on Figure 45. These are discussed below.

8.3.1 Security Checkpoints Areas P18A, B & C, B24A, B & C

Access to the Protected Area will be strictly controlled, as discussed above. Regular staff will enter through controlled systems and all visitors, after registering with security staff, will be accompanied by authorized staff members when in the Protected Area. The adopted system will be capable of tracking personnel into and out of the Protected Area, and maintaining an electronic list of on-site personnel and their locations.

Three Protected Area access control points are to be established, two of which will allow for vehicular traffic. Identified as Areas P18A through P18C on Figure 45, the access control points are described below:

- Checkpoint P18A – will serve as the main vehicular access point to the Protected Area, and the gate through which the incoming used-fuel shipments will pass. This checkpoint will utilize a manned security booth for traffic control and inspections, and will provide barriers to deny intruder entry using large vehicles;

- Checkpoint P18B – will provide access to the Auxiliary Building (Area P5), and will be considered the primary access point for personnel. This checkpoint will utilize a manned security station, turnstiles and biometric identification systems for personnel control, with an auxiliary access gate for equipment; and

- Checkpoint P18C – will allow access for materials from the Sealing Materials Compaction Plant (Area B6). A manned security booth will be in operation during active

hours for the transport of materials to the Service Shaft complex (Area P4). Personnel access will not generally be through this checkpoint.

Access control points for the Balance of Site will be provided for general security concerns only, such as theft, vandalism, animal intrusion, and general liability (safety). Personnel and vehicular access to the Balance of Site will be controlled through access gates. Three control points are provided, all of which will allow vehicular traffic. Located as indicated on Figure 45, they include:

- Checkpoint 24A – will act as the main access point to the DGR complex. All facility traffic will pass through this point. While the gate will be able to be locked, its status will be controlled by the adjacent guardhouse (Area 17A);

- Checkpoint 24B – will govern access to the roadway leading to the Ventilation Shaft complex (Area B1). Traffic through this area is expected to be minimal, therefore a manned security booth will not be required. Access will be by key and lock; and

- Checkpoint 24C – will provide access to the Ventilation Shaft complex itself. Access will be by key and lock and will be overseen by the adjacent guardhouse (Area B17C).

8.3.2 Guardhouses Areas B17A, B & C

In addition to the checkpoints described above, three Guardhouses will be provided for security personnel for the control, verification and authorization of vehicle and staff movements into and out of the DGR facility.

The first guardhouse will be located at the main entrance to the Balance of Site (Area B17A on Figure 45). A second station will be situated at the entry control point for the Protected Area (Area 17B). Both guardhouses will accommodate a control room and security desk. A secure staging area for vehicles (a sally port) will be provided adjacent to the Area 17B station.

In addition to the above, a third (smaller) guardhouse will be located at the entrance to the Ventilation Shaft complex. This station is identified as Area 17C on Figure 45.

9. OPERATIONAL SAFETY AND MONITORING

The following section addresses operational safety and monitoring initiatives that will be enacted at the DGR. The described initiatives have been identified both from a best-of-practice perspective, as well as to meet the objectives set out in domestic and international regulatory and guidance documents (e.g., Canadian Nuclear Safety Commission, International Atomic Energy Agency, etc.).

Conceptual-level design details are provided herein for radiation detection and monitoring systems, fire detection and suppression, facility environmental and performance monitoring and, emergency response procedures.

9.1 Operational Safety

This section describes the key operational safety concepts consistent with good practice as well as regulatory compliance in line with, among others, CNSC, OSHA and Mines and Aggregate Safety and Health Association requirements.

An occupational health and safety program will be in place and implemented for all periods in the evolution of the DGR when there are workers actively involved. As the project's components involve underground construction and operation, as well as the handling of used nuclear fuel, there are significant industrial and radiological components to the program.

9.1.1 Radiological Detection and Zoning

Radiological detection and monitoring will be addressed with regard to achieving, among other things, As Low As Reasonably Achievable (ALARA) objectives while also maintaining information to support health physics programs. Radiological zoning considers the movement of staff and material, required maintenance activities, regulatory requirements etc. Three radiation hazard zones have been assigned to various areas of the facility, as noted below.

ZONE 1

Zone 1 is considered a "clean" zone. The dose received by an individual from external radiation sources during continuous occupancy of a Zone 1 area is not to exceed the recommended annual limit to the public in one year. Only natural background levels of radioactivity and no radioactive contamination would be present.

Zone 1 space typically includes offices, access corridors, lunch and coffee rooms, and site lands and roadways. In terms of the DGR complex, the identified 'Balance of Site' (that is, all locations outside of the Protected Area with the exception of the fenced-in lands around the Ventilation Shaft complex) would be considered as Zone 1.

ZONE 2

This zone is normally free from contamination and radiation fields. However, contamination and temporary radiation fields may exist. If contamination is found, it will be cleaned up as soon as

detected. Chronic recurrences of contamination in Zone 2 will not be tolerated. Continued occupancy of Zone 2 operations will be restricted to those who have been designated Nuclear Energy Workers, as specified in the Radiation Protection Regulations (Canada 2000).

Generally all operations within the Protected Area, as well as the lands inside of the fenced-in area around the Ventilation Shaft complex will be considered as Zone 2. When UFCs are being moved underground for emplacement, the repository areas would also be considered Zone 2 as the package integrity will prevent the release of radioactivity.

ZONE 3

Zone 3 is for medium-term occupancy by personnel classified as Nuclear Energy Workers with such occupancy subject to continuous management review. The nature of the work would be expected to result in contamination and, therefore, its presence would be tolerated until a work assignment was completed, when the contamination would be cleaned up. The radiation fields might be such that worker exposure times would require monitoring and work might have to be planned in advance in order to maintain doses ALARA. Worker protection in the form of protective clothing would usually be a prerequisite, and respirator protection might also be required.

Depending upon the final design details, the only Zone 3 areas associated with the DGR facility will be within the UFPP. It is currently expected that the radiation hazard zones for this building will be a mixture of Zone 2 and Zone 3 designations.

9.1.2 Radiation Monitoring

As the Protected Area comprises the Zone 2 and Zone 3 operational designations (outside of the small fenced-in area around the Ventilation Shaft), a system will be established to detect, monitor and record any radiation dosage received by personnel or transport entering or leaving the area. The system will be consistent with CNSC regulations and will be implemented with the goal to keep the amount of exposure to ALARA.

In this respect, and again consistent with CNSC requirements, a licensed dosimetry service will be used to measure and monitor any potential impacts received by personnel who have a reasonable probability of facing an effective dose greater than 5 mSv in a one-year period. CNSC radiation protection regulations permit a member of the general public to receive a maximum whole body dose not to exceed 1 mSv/a.

The radiation protection control system will employ multiple measuring devices and continuously analyze for potential concerns, alerting personnel if required. An uninterrupted power supply will be provided for all devices required by the detection and assessment systems (in addition to any associated alarm annunciations).

9.1.3 Radiation Protection

In conjunction with the radiation monitoring program, a protection and control system will also be instituted. This system will incorporate the following features:

- Use of personal dosimeters for all staff or visitors within the Protected Area;
- For personnel leaving a higher level radiation defined zone to a lower defined zone (e.g., going from a Zone 3 to a Zone 2 area) or at each radiation zone transition point, use of hand and foot monitors or whole body monitors is expected;
- A whole body counter for personnel to use annually or quarterly;
- Fixed area gamma monitors located throughout the facility to gauge local dose rates at places routinely occupied by operating personnel;
- Air radiation monitors located throughout the facility; and
- Radiation vehicle monitors (portable and fixed) at entry or unloading areas.

The DGR's on-site laboratory will assist personnel with radiation related issues (e.g., monitoring and analysis).

9.1.4 Fire Detection and Suppression

As the above-ground facilities will be serviced by an on-site fire department, the following discussion focuses on the underground systems to be put in place as related to fire detection and fire safety. An optimum suppression concept that balances worker and nuclear safety will be established.

The aspects of OSHA and Regulation 864/90 that will pertain specifically to the underground development and operations of the DGR require that:

- Suitable fire extinguishing equipment be provided in any fire hazard area;
- Fire extinguishing equipment be provided in the mine entrance and at shaft stations;
- A suitable fire suppression system be available; and
- Refuge stations be located for workers during emergencies. These stations are to have breathing equipment, emergency air systems and communication devices.

All of these measures will be adopted for the DGR's underground repository. In addition, fire detection systems incorporating heat, smoke and carbon monoxide detectors in key points in the facility will be set up. Key points will include all underground infrastructure rooms, the exhaust ventilation air ducts exiting each emplacement room, the intake duct at the exit from the Main Shaft, and at the main exhaust ducts of the upcast Ventilation Shaft. Audible and visual alarms will be activated on detection by any instruments required to do so.

In accordance with OSHA and Regulation 854/90, all underground vehicles will also be fitted with fire detection and suppression equipment. In total, fire suppression will be achieved through the use of a number of systems both for the equipment and the underground environment. Systems will include the following:

- Hand-held foam based fire extinguishers mounted throughout the facility;

- Automatic, foam-based fire suppression systems mounted on all diesel equipment;
- An inert gas generator and a portable foam generator for extinguishing any fires that develop in the emplacement rooms;
- Normal sprinkler and/or fire hose systems for areas where appropriate;
- A water spray deluge system for hazardous environments where fires may spread very quickly or where valuable materials needs to be cooled; and
- A water mist system for areas where appropriate.

Breathing air requirements as prescribed by regulatory guidelines and worker health and safety protocols (as applied to fire fighting, non-nuclear air contamination, etc.) will be followed.

9.1.5 Emergency Response

Procedures for emergency response planning, the notification of releases and incident reporting will meet CNSC requirements and include the utilization of incident command systems to meet the needs of any kind or complexity of situation. For severe incident management (e.g., extreme or violent weather, chemical spills, etc.), various emergency related resources will be available. These will include:

- Pre-planned response procedures (including shutdown protocols);
- Pre-established post-emergency procedures including those for resuming operations;
- Off-site and on-site communications and management protocols, including regulatory notifications and public interaction;
- The services of an Emergency Response Team (ERT); and
- Pre-trained staff that have undergone regular training on emergency response issues.

The primary personnel involved in handling any emergency will reside within an ERT under the direction of a Chief of Security and a Director of Safety for the DGR. These resources would also be supported by on and off-site firemen and first aid attendants as well as the DGR's various superintendents and shift managers. A Communications Manager will further be in place to coordinate and assist in the required incident communications activities.

9.2 Environmental Monitoring Programs

The environmental monitoring program for the DGR facility will initially be oriented towards confirming and supplementing the site investigation data accumulated over the licensing phase of the project. Thereafter, the program will monitor for any changes that may be imposed on the environment to optimize facility performance throughout the life of the project, and to demonstrate regulatory compliance. Extended monitoring requirements for the post-closure period will need to be re-examined as part of the finalized closure plan.

Consistent with CNSC policy as set out in P-223 (Protection of the Environment), the described environmental monitoring program is comprised of the following components:

- Groundwater quality and levels monitoring;
- Monitoring of surface water and stormwater;
- Air quality monitoring;

- Supportive meteorological monitoring; and
- Monitoring of underground systems.

The following sections address each of the program components. The final elements will be developed as part of the formal licensing process for the DGR. The expectation is that the program will provide reliable, accurate and timely data in a fashion that is easily audited.

9.2.1 Groundwater Monitoring

Baseline hydrogeological studies will identify the main hydrostratigraphic units and define the groundwater flow conditions of the various units. From the developed groundwater flow model, features will be identified that should be monitored during the construction and operation of the DGR. Such features will encompass the groundwater regime at the DGR as well as any nearby community or individual water supply wells.

Potential groundwater impacts from the operation of the DGR could include an unwanted influence to local groundwater flow patterns and/or the potential for contamination from, for example, chemical or fuel oil spills. The potential for impact will, as a result, be evaluated on the basis of a monitoring program that will include determinations of both groundwater quality and groundwater levels.

Monitoring well locations will include those established to characterize the baseline conditions of the site and those installed during the construction phase. In total, the monitoring well network is anticipated to be in the order of 100 wells that spatially cover the entire site area as well as extending down-gradient and up-gradient of the facility. The wells will be positioned at strategic locations to monitor potential impacts from on-site operations that may handle or manage potentially contaminated materials (e.g., the waste rock dumps and on-site ponds).

Representative water supply wells for any proximate community as well as strategically positioned points between these and the DGR site will also be included in the program.

The parameters selected for groundwater quality monitoring will build upon the accumulated baseline database and encompass the measurement of physical characteristics, mineral and metals content, nutrients and toxic substances. Groundwater samples will be collected and analyzed on a quarterly basis although if changes in the samples are noted the frequency will be reassessed and modified, if required.

9.2.2 Stormwater / Surface Water Monitoring

Stormwater runoff from the developed site (roads, parking areas and rooftops) can lead to increased flows and downstream erosion. Stormwater management ponds are designed to attenuate the variations in flow conditions while also being designed to detain and settle out sediments associated with runoff. They will also provide detention to allow sampling to confirm effluent limits are met prior to discharge and accommodate some emergency storage in the event effluent limits are exceeded and discharge is not allowed.

The monitoring program will be focused on the measurement of flows and water quality at the pond discharge points to assess the potential environmental loading. In so doing, the ponds'

design requirements can be checked and any needed corrective actions implemented, all to ensure the maintenance of regulatory compliance.

Pond water samples will be analyzed for a full suite of conventional parameters including anions and cations, metals, oil and grease and nutrient compounds. Sediment samples will additionally be collected from each pond and analyzed for trace metals, PCBs, PAHs, organochlorine pesticides, total organic carbon, nutrients, and oil and grease.

Grab samples from the inlet and outlet of each pond will be examined for the identified parameters on a quarterly basis (spring, fall and twice during the summer). Sediment samples will be assessed on an annual basis.

The monitoring program will also encompass surface watercourses and bodies outside the DGR's footprint and at nearby communities. Sampling locations will be selected to characterize water quality and flows both upstream and downstream of the DGR in the local watersheds. Gauging locations will further be established to measure surface water elevations and flows. Flow measurements will be conducted in accordance with established Environment Canada protocols.

Water quality and hydrologic conditions will be monitored using both automatic and manual sampling techniques.

9.2.3 Air Quality Monitoring

Air quality monitoring, particularly in mining and tunnelling applications, is essential for personnel safety. Furthermore, as the repository's ventilation system will be exhausting into the atmosphere, it is also necessary to monitor potential discharge impacts on the local air shed.

The primary contaminants expected to be emitted include the products of combustion of diesel fuel from the operation of mobile equipment. The pollutants of concern to be addressed by the monitoring program, therefore, are anticipated to include particulate matter, nitrogen oxides, sulphur oxides, carbon monoxide, carbon dioxide and total organic compounds.

For the underground repository, several forms of air monitoring equipment will be employed. These will include hand held instruments (see Figure 49) as well as in-situ continuous emission monitoring devices.

For the above-ground environment, ambient air quality monitoring locations will be established both in the predominant downwind direction of the facility (including one at the nearest community) as well as upwind of the site.



Figure 49: Manual Air Quality Monitoring

9.2.4 Meteorological Monitoring

A weather monitoring station will be installed and operational at the DGR. Using tower-mounted instrumentation to meet CNSC requirements, the station will provide site-specific and continuous meteorological data to assist in the ongoing operations of the facility. Real-time measured parameters will include:

- Ambient temperature;
- Relative humidity;
- Dew point;
- Barometric pressure;
- Wind speed;
- Wind direction;
- Rainfall;
- Solar conditions; and
- Nuclear radiation.

9.3 Seismic and Vibration Monitoring

Monitoring approaches related to underground facilities and systems will be in compliance with requirements as set out in CNSC P-223 (Protection of the Environment) as noted above, as well as those associated with industrial occupational health and safety guidelines. Compliance with the latter will be supported by monitoring initiatives established to ensure the integrity of the subsurface environment. Such initiatives will include rock mass and pillar convergence instrumentation, embedded and surface-mounted concrete load cells in the shaft linings, and rock dowel load cells. Seismic monitoring will also be undertaken.

Seismicity, a form of ground vibration or movement, is a commonly examined characteristic of underground mines. While significant seismic events are not anticipated for the DGR's location (considering its site selection criteria which will emphasize geosphere stability) some form of seismicity can be expected as the operations involve the breakage and removal of material. Monitoring will be used in the rock extraction work to lessen the likelihood of causing seismic vibrations.

The seismic monitoring network will, as a result, be aimed at continual improvements to the underground development procedures. The specific seismic and vibration measuring detectors will include:

- **Geophones**: A series of geophones will be grouted into short boreholes drilled into the roof and floor of the repository and into the shaft sidewalls at various elevations. Figure 50 provides an illustration of a typical geophone;



Figure 50: Geophone

- **Ground Movement Monitors**: or single point extensometers will be installed within short boreholes in the roof of the repository (two per placement room) to monitor for roof movement; and

- **Stress Cells**: A series of stress cells will be installed in short boreholes in the roof of the repository (one per placement room) to gauge any rock stress changes as a result of excavation work and/or heating by the UFCs.

A conceptual layout arrangement for the geophones is illustrated on Figure 51. This figure also shows the location for the multiplexers and data loggers which will receive the collected data (such data to eventually be transmitted to surface).

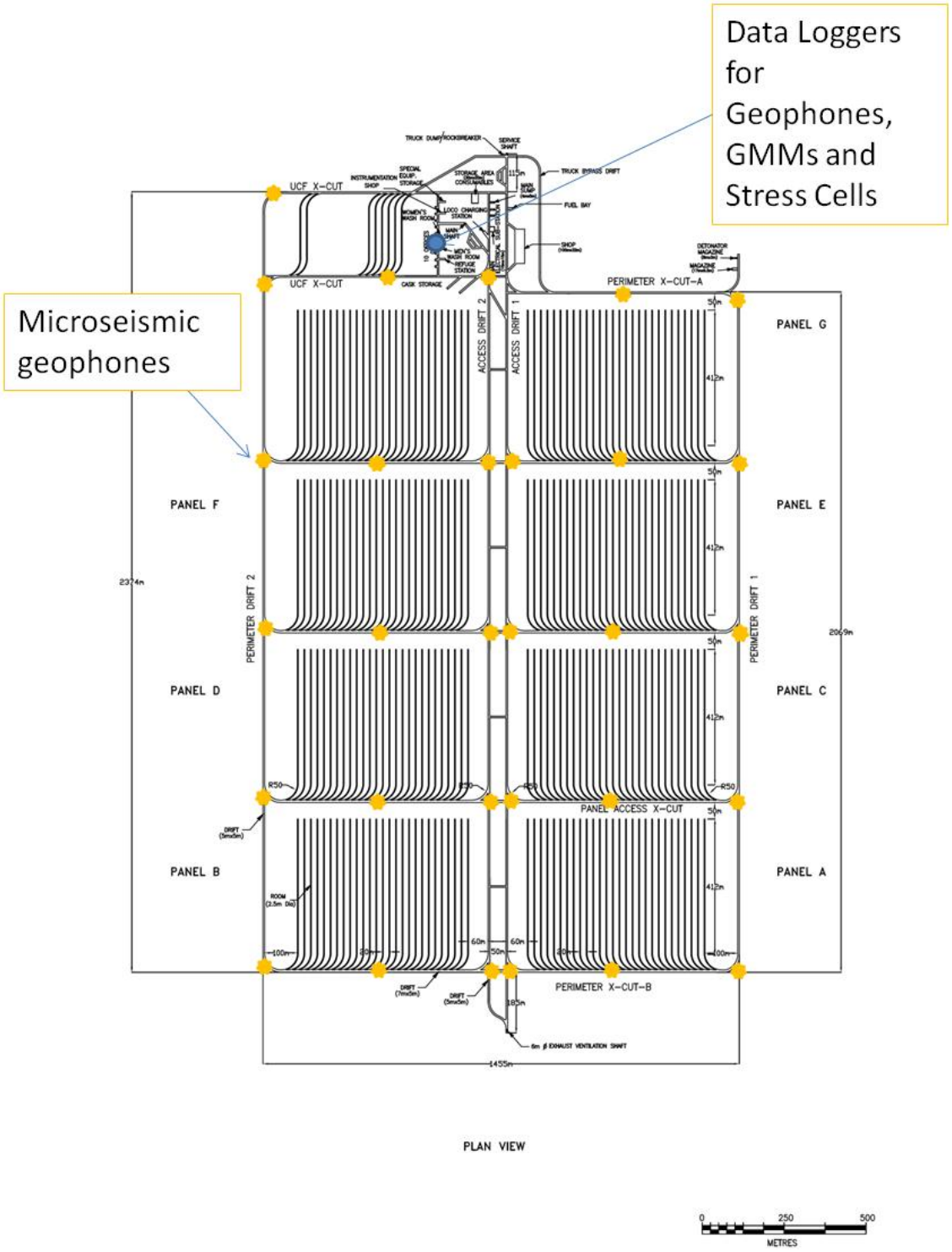


Figure 51: Geophone Layout

9.4 Quality Assurance/Quality Control

Quality assurance/quality control procedures will be implemented throughout the monitoring programs to ensure thoroughness and accuracy of the data. In this regard, the programs will include the following measures (among others) to ensure a high degree of confidence in the collected information:

- Strict adherence to standard protocols for the collection, preservation, storage, handling and shipping of samples and for in situ sampling;
- A field quality control program, including the submission of travel and field blanks and duplicate samples;
- Implementation of a quality control program for the laboratory analyses; and
- Timely review of analytical results to identify areas of concern (including potential impacts).

Annual and quarterly status reports will be prepared to summarize the activities as related to the environmental monitoring program. The results of the ongoing QA/QC activities will be incorporated in these reports.

9.5 Central Tagging System

A central tagging system will be put in place at the DGR to monitor the movements and quickly locate all facility personnel, equipment and tools (including radiation-impacted objects). The system will be coordinated out of a central control area which will receive wireless signals from transmitting/receiving devices assigned to on-duty personnel and installed on each facility vehicle or asset. Conceptually, the tagging system will operate as follows:

- A wireless tag will be provided to a person and/or attached to a piece of equipment when entering the DGR's check in point;
- As the person/item moves through the DGR, the associated tag is read by other multiple wireless readers positioned in various locations in the facility;
- In terms of hard assets, once the item reaches its destination, a tag reader will allow a cross-check to be made to confirm that it is supposed to be at that location;
- Items incorrectly received will be flagged for removal and re-routed; and
- When an item or person leaves the facility the associated wireless tags are read at the exit point.

This tracking system will assist operational personnel and increase worker safety. It will also allow for the remote management of all assets by identifying their exact location.

In the underground environment the collected data will be transmitted using a leaky co-ax and fibre optic system, which will relay information from the source instrument or electronic device to the surface control room. As illustrated on Figure 52, such a system consists of cables running along the tunnels and in shafts which emit and receive digital transmissions. The digital information is transmitted by fibre optic cable as it is resistant to EMI and can carry more data by way of having a larger bandwidth (than copper wire).

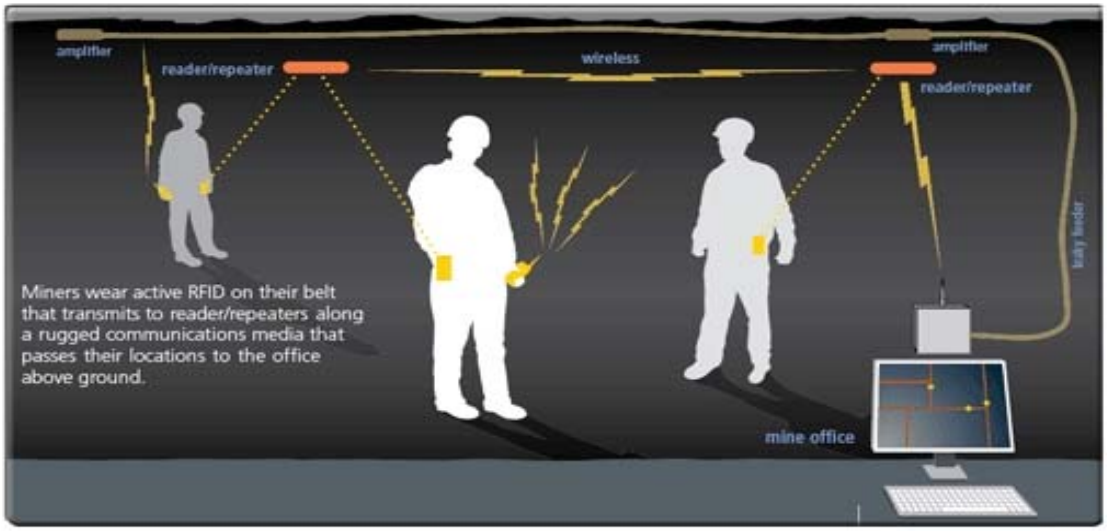


Figure 52: Typical Wi-Fi System

10. DECOMMISSIONING AND CLOSURE

As noted elsewhere, two used nuclear fuel placement scenarios are under consideration in the development of the DGR. Under the Base Case, 3.6 million used fuel bundles will be accommodated in the repository over a 30 year period. The Alternate Case, which assumes (in part) the construction of new nuclear reactors, sees this quantity increased to 7.2 million bundles delivered to the DGR over a 60 year period.

Subsequent to the cessation of used-fuel placement activities for either the Base or Alternate Cases, several stages of post-placement activities will take place, in the following order:

- A 70 or more year extended monitoring period;
- A 10 year decommissioning period;
- A 15 year closure period; and
- A postclosure period.

These activities are the subject of this section, following a brief discussion of certain key issues that will impact upon the decommissioning and closure (D&C) stages of work and the staged, progressive development of the overall supportive D&C planning. As discussed below, such planning will commence with the preparation of a Preliminary Decommissioning Plan structured to meet the requirements of CNSC guidance G-219 and CSA N294-09.

10.1 Key Issues Impacting D&C Activities

Several issues have the potential for a material impact to D&C planning and implementation. Such issues include the final site selection, the status of container retrieval initiatives, the potential for advancements in associated technologies, and the direction received from regulatory bodies. These factors are outlined below.

Site Selection

Actions undertaken during the D&C period will be designed to return the selected site and related facilities to the desired end-state. Given this, the ultimately chosen location for the DGR will have a material influence over the required D&C activities.

Container Retrieval

The possibility for future container retrieval has a potential major impact on the timeframe of the overall repository project and, as a result, the implementation and staging of D&C activities. A decision following completion of placement to forego the possible retrieval of UFCs would, for example, allow a number of surface facilities no longer required to be decommissioned. On the other hand, under the approach that the potential for retrieval remain open, surface and underground facilities will need to be inspected and maintained over the full 70 or more year extended monitoring period (or until a decision has been taken that retrieval will no longer be considered).

Advancements in Associated Technologies

The described initiatives within this document have been identified from, in part, a current best-of-practice perspective. Considering the long time period associated with the DGR's operation through to its postclosure stage (in excess of about 150 years), it is not possible to determine at this time, with certainty, what technical solutions will be available or applied to the period following the placement of used nuclear fuel.

10.2 Planning for Decommissioning and Closure

Given the potential for future material influences on the ultimate implementation of the D&C initiatives, it will be important that comprehensive planning instruments are assembled at an early stage and, following this assembly, continually updated up to the point of action. Such planning will, therefore, commence at the outset of the project work, during the feasibility stage, and continue over the full life-cycle of the project.

Figure 53 represents the proposed timeframe for the project under the Alternate Case scenario, and provides a basic schedule for the D&C planning activities, including:

- Initial preparation of Revision '0' (R0) of the D&C plan - or Preliminary Decommissioning Plan - during the project feasibility stage, to serve as the basis for subsequent revisions and updates;

- Completion of the first material revision to the D&C plan (revision R1) during the site selection stage, incorporating actual site-specific data. This revision will serve as input to the licensing review and approval process, while also providing direction to the detailed design criteria for the other DGR systems;

- Progressive updates to revision R1 (R1.1 through R1.14) over the course of the preliminary and detailed design stages of work as well as for the period of used-fuel placement. The maintained and updated D&C plan will support periodic licence renewals throughout DGR operations based on current codes, regulations and standards and incorporating relevant advances in technology. The plan will evolve throughout this period to continually represent the current as-built status of the facility, and operational and maintenance experience gained during placement;

- Following the period of operations, and at the commencement of the 70 year extended monitoring period, preparation of the second material revision (R2) to the D&C plan. The plans will be subject to a special detailed review at this time in order to finalize requirements for the extended monitoring period. As a significant portion of the effort spent during the extended monitoring is actually focused on facilities needed to support decommissioning and closure, this review will assist in providing directions and recommendations. This revision will be progressively updated (R2.1 through R2.6) over the course of the extended monitoring phase. Any updates would consider experience gained, as well as regulatory or technology updates. The evolving D&C plans will also provide updated directions and recommendations for facility maintenance or even early removal and disposal of component operations, where appropriate;

- Preparation of the third material revision (R3) to the D&C plan prior to the commencement of the 10 year decommissioning period, using information collected during extended monitoring. The resulting Detailed Decommissioning Plan will support the licensing for approval to start decommissioning and closure. The plan will be based on a fully defined methodology and procedures for implementation; essentially the detailed design for D&C. It will form the basis for actually contracting and managing the implementation activities. Progress reports would also be published over the course of the decommissioning stage;

- Assembly of the fourth material revision (R4) to the D&C plan at the start of the 15 year closure period, based on information collected to that point in time and documenting the results of the decommissioning work. Progress reports would also be produced during the closure period; and

- Preparation of a postclosure report documenting the results of decommissioning and closure activities.

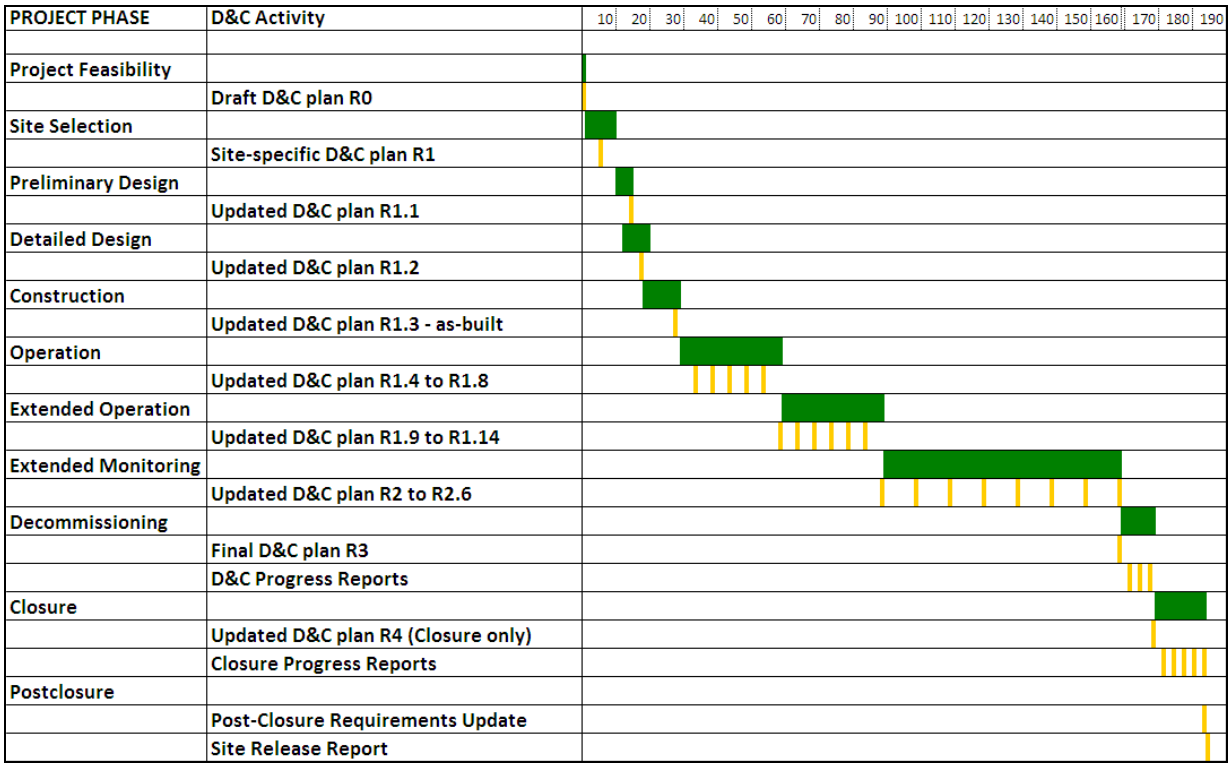


Figure 53: Decommissioning & Closure Planning (Alternate Case)

Regular maintenance of the evolving D&C plans will help ensure that the site programs and designs remain consistent with up-to-date and relevant internal/external decommissioning

experience. It will also act to ensure that licensing and other regulatory requirements are continually met with regards to site safety, security and access control needs.

As previously described, the D&C plans will all be designed, prepared and maintained to achieve the return of the site and related facilities to the desired end-state.

10.3 Decommissioning of Underground Facilities

Following the receipt of regulatory approval and the licence to decommission from the CNSC, underground facilities are expected to be removed first, in parallel with those surface operations not required to support the remaining decommissioning activities.

Decommissioning of underground facilities involves the removal of operational systems and furnishings, the interim installation of temporary services and furnishings, and the repair and preparation of exposed rock surfaces for sealing. As currently envisaged, the decommissioning will be carried out in several stages and will include activities related to support and material handling systems, the sealing of underground horizontal openings, and the decommissioning and sealing of drifts, shafts and boreholes.

10.3.1 Support Systems and Material Handling Systems

During decommissioning, when it is safe to do so, ground support systems including bolting and shotcrete will be removed, and taken to the surface for disposal. Also, all rail system components used for handling material during the development and operation of the facility will be taken up. The removal of ground support systems will be sequenced with the sealing of underground horizontal openings to minimize the time span of unsupported ground.

10.3.2 Sealing of Underground Horizontal Openings

The sealing of underground horizontal openings consists of closing off access drifts and ancillary facilities. Such activities would commence with the removal of instruments from boreholes (and sealing the boreholes) followed by the preparation of exposed rock surfaces and removing loose rock before backfilling and sealing. The central access drifts would then be backfilled, with sealing bulkheads installed at strategic locations where conditions dictate.

The key functional requirements for the employed sealing materials will be as follows:

- Fill the entire excavated volume of each area being sealed (e.g., shafts, access drifts and service areas - except for the volume occupied by the bulkhead seals at placement room entrances and other locations);
- Resist physical and chemical deterioration by the local environment, which includes the pre-closure and post-closure geochemical conditions; and
- Limit the rate of groundwater movement (and any associated contaminant transport) to and from the sealed placement rooms.

Sealing of the underground openings will be achieved by using materials and methodologies similar to that used for the placement rooms. The clay-based fill will be complemented by concrete bulkhead seals that may incorporate highly compacted bentonite blocks to provide a sealing element that will exert a radial load on the walls of the openings being closed off.

The sealing of access drifts will be carried out ensuring that the central drifts are maintained open to provide ventilation to working areas. Therefore, the sequence for tunnel closures will consist of sealing the perimeter and panel tunnels in a retreating manner from the Ventilation Shaft to the Service Shaft while maintaining open a central access tunnel. Local ventilation systems using portable exhaust fans and duct tubing will be exhausted into the flow-through ventilation system. Periodic crossovers between the tunnels will be used to provide flow through ventilation and to draw air from the work areas.

Bulkheads will be installed near access drift intersections and also near intersections with significant zones (as appropriate). The key functional requirements for the bulkheads will be to provide mechanical restraint against the forces exerted by swelling clays or pressures from other repository sealing systems, the surrounding rock mass or other sources. The bulkheads will further act to keep the sealing materials isolated in their intended locations and protected from any adverse conditions that may exist in adjacent unsealed excavations.

10.3.3 Sealing of Shafts

Sealing of the shafts is the last step in the decommissioning of the DGR. This activity starts when the sealing of underground openings and ancillary areas is complete. At that time, the following activities are envisioned:

- Removal of shaft services including compressed air lines, water lines, power supply and lighting cables, and communication cables;
- Removal of instruments from any impacted boreholes and sealing of each borehole;
- Removal of furnishings including all of the shaft guides and sets, steel support brackets, brattice and lower crash beam assemblies from bottom to top while backfilling; and
- Reaming of the shafts (as required) to remove the concrete linings and any wall rock degradation. Thereafter, each shaft will be re-equipped with services and staging, and backfilling will commence with sealing bulkheads installed at strategic locations. At least 0.5 m of rock will be removed to expose the sound rock.

The proposed concepts for a shaft seal system are summarized in Table 18.

Table 18: Proposed Sealing System for Shafts

Depth from Surface	Material
0 – 20 m	Low heat high performance concrete (LHHPC) – concrete cap at surface
20 – 150 m	70/30 bentonite / sand shaft seal compacted in-situ
150 – 170 m	LHHPC for concrete bulkhead keyed into rock / overburden to a distance of 0.5 times the original radius of the shaft
170 – 330 m	70/30 bentonite / sand shaft seal compacted in-situ
330 – 380 m	Asphalt seal
380 – 480 m	70/30 bentonite / sand shaft seal compacted in-situ
480 – 500 m	Concrete monolith – LHHPC

10.3.4 Sealing of Boreholes

The purpose of sealing a borehole (e.g., monitoring boreholes) is to inhibit groundwater movement and contaminant transport along the borehole and in the near-field rock parallel to the borehole axis. Cement-based sealing materials will be installed where required to isolate fractured and highly permeable zones because of their low hydraulic conductivities and their groundwater resistance. Clay-based materials with low permeability and a high swelling potential will be installed in adjacent zones.

Sealing of boreholes is commonly practiced in the construction and resource industries to decommission water and monitoring wells. As the geological features intercepted by each borehole will not be identical, a thorough review will be conducted on all available core and borehole logs and down-hole test results to ascertain the preferred sealing approach for each location.

10.4 Decommissioning of Surface Facilities

Both following and in conjunction with the decommissioning of the underground facilities, the supporting surface facilities will be dismantled and removed from the site, in preparation for the planned 15 year closure period.

The surface facilities and related services will be evaluated and classified in the D&C planning instruments to identify if they are required to support underground decommissioning, the D&C period security, etc. The sequencing described in this section, and suggested in Table 19, is based on an initial evaluation in this respect which resulted in the placement of each component or service in a comparative position on the decommissioning time queue.

In general, and as illustrated on Table 19, the majority of surface facilities will not be decommissioned until the underground operations have been dismantled and removed, with the access tunnels and shafts sealed as planned. These activities will be the primary focus for

concrete and special sealing materials which require an operating surface facility and an underground hoisting operation.

Table 19: Surface Facility Classification for Decommissioning

Area	Protected Area	Primary Function	Comments
P1	Used Fuel Packaging Plant	UFC processing	Decommissioned with U/G facilities. Once no UFC retrieval is contemplated the UFPP can be demolished.
P2	Main Shaft	Provide U/G access	Can be decommissioned as last step of U/G D&C.
P3	Stack	Related to UFPP	Will be decommissioned with the UFPP.
P4	Service Shaft	Provide U/G access	Can be decommissioned as last step of U/G D&C.
P5	Auxiliary Building	Related to U/G access	Can be decommissioned as last step of U/G D&C.
P6	Active Solid Waste Handling Facility	Related to operation and decontamination	Will be decommissioned as part of Protected Area facilities.
P7	Waste Management Area	Related to operation and decontamination	Will be decommissioned as part of Protected Area facilities.
P8	Active Liquid Waste Treatment Building	Related to operation and decontamination	Will be decommissioned as part of Protected Area facilities.
P9	Low-Level Liquid Waste Storage	Related to operation and decontamination	Will be decommissioned as part of Protected Area facilities.
P10	Stormwater Retention Pond	Related to total project	Will be part of closure activity.
P11	Switchyard	Related to total project	Will be part of closure activity.
P12	Transformer Area	Related to total project	Will be part of closure activity.
P13	Powerhouse	Related to total project	Will be part of closure activity.
P14	QC Offices and Laboratory	Related to total project	Will be part of closure activity.
P15	Parking Area	Related to total project	Will be part of closure activity.
P16	Covered Corridor / Pedestrian Routes	Related to total project	Will be decommissioned consistent with connected structures.
P17	Mine Dewatering Settling Pond	Related to decommissioning of U/G	Cannot be decommissioned until U/G decommissioning is complete.
P18	Security Checkpoint	Related to total project	Will be part of closure activity.
P19	Bus Shelters	Related to operation until start of D&C	Will be decommissioned at end of decommissioning period.
P20	Double Security Fence	Related to decommissioning of U/G	Cannot be decommissioned until U/G decommissioning is complete.

Area	Balance of Site	Primary Function	Comments
B1	Ventilation Shaft Complex	Related to U/G access	Can be decommissioned as last step of U/G D&C.
B2	Admin. Building, Firehall, Cafeteria	Related to total project	Will be reconfigured as part of closure activity.
B3	Sealing Material Storage Bins	Related to decommissioning of U/G	Cannot be decommissioned until U/G decommissioning is complete.
B4	Perimeter Fence	Related to total project	Will be part of closure activity, possibly reconfigured.
B5	Garage	Related to total project	Will be part of closure activity.
B6	Sealing Materials Compaction Plant	Related to decommissioning of U/G	Cannot be decommissioned until U/G decommissioning is complete.
B7	Warehouse and Hazardous Mat'ls	Related to operation and decontamination	Will be decommissioned with Protected Area facilities.
B8	Air Compressor Building	Related to total project	Will be part of closure activity.
B9	Fuel Storage Tanks	Related to total project	Will be part of closure activity.
B10	Water Storage Tanks	Related to total project	Will be part of closure activity.
B11	Water Treatment Plant	Related to total project	Will be part of closure activity.
B12	Pump House	Related to total project	Will be part of closure activity.
B13	Concrete Batching Plant	Related to decommissioning of U/G	Cannot be decommissioned until U/G decommissioning is complete.
B14	Rock Crushing Plant	Related to decommissioning of U/G	Cannot be decommissioned until U/G decommissioning is complete.
B15	Process Water Settling Pond	Related to decommissioning of U/G	Cannot be decommissioned until U/G decommissioning is complete.
B16	Waste Rock Disposal Area	Related to total project	Will be part of closure activity.
B17	Guard House	Related to total project	Will be part of closure activity.
B18	Storage Yard	Related to total project	Will be part of closure activity.
B19	Sewage Treatment Plant	Related to total project	Will be part of closure activity.
B21	Helicopter Pad	Related to total project	Will be decommissioned at end of decommissioning period.
B22	Bus Shelters	Related to operation until start of D&C	Will be decommissioned at end of decommissioning period.
B23	Weigh Scale	Related to total project	Will be decommissioned at end of decommissioning period.
B24	Security Checkpoints	Related to total project	Will be part of closure activity.
B25	Security Monitoring Room	Related to total project	Will be part of closure activity.
B26	Stormwater Detention Ponds	Related to total project	Will be part of closure activity.
B27	Parking Area	Related to total project	Will be part of closure activity.

Once the underground works have been decommissioned, the surface decommissioning will proceed generally in the following sequence:

- The UFPP, hoisting systems, and all other facilities in the (formerly) Protected Area will be dismantled, removed, and sent off-site for disposal or recycling;
- Approval will be obtained to remove the Protected Area fencing and security systems, and they will also be subject to disposal or recycling;
- All surface facilities not required for the maintenance of site administration and staff-related purposes (the administration-focused systems) will be dismantled and removed (e.g., process water settling pond, hazardous material storage, etc.);
- At this point the site status will be an administration building supported by electrical utilities, water and sewage treatment, parking, and the perimeter fence; and
- Reconfiguration of the remaining administration facilities and utility services into a suitable package to support the closure period. The balance of site will be rehabilitated to greenfield conditions.

10.4.1 Decontamination

The issue of decontamination during decommissioning is expected to be of potential significance solely from the perspective of radiological matters. After emplacement operations are complete, operations staff will decontaminate the UFPP and other surface facilities except for fixed contamination in the concrete surfaces or equipment which will be addressed during decommissioning. It is expected that proper practices during the DGR's operational period will have effectively eliminated any residual concerns with other forms of hazardous materials.

The strategy adopted for decontamination, therefore, is based on the facility being free of loose surface contamination, with design elements intended to minimize the amount of fixed or exposure-based radioactive waste.

Although the radiological facilities will have been surveyed and loose contamination removed following the end of operations, the first step will be to re-survey and confirm the loose contamination-free status and the current exposure rate levels where fixed contamination or material sources exist. Following the removal, packaging and disposal of any contaminated material or removable equipment found (including any additional wastes generated in addressing concrete surfaces), the initial radiation survey would be repeated to confirm the absence of contamination.

The survey and clean-up activities will be carried out for all appropriate facilities including, as needed, the underground facilities.

10.5 Closure and Postclosure

The minimized administration area will be maintained during the closure period in order to support the post-decommissioning monitoring systems. If at that time it is felt that permanent facilities are no longer required, the monitoring systems could be supported by small enclosures for the electrical equipment, and all other remaining facilities would be removed and the site essentially fully returned to its intended end-state.

The facility's environmental monitoring carried out during the operational and extended monitoring periods as well as throughout the decommissioning stage will further be continued into the closure and postclosure periods. While the level of monitoring will be reduced, it is expected that the program will still address (at a minimum) groundwater and surface water quality issues, to ensure compliance with regulatory requirements.

In addition, safeguards containment / surveillance monitoring (e.g., an acoustic emissions or microseismic network) will be considered on the surface in the rock above and around the DGR to detect any noise that might be associated with an attempt to excavate into the repository. In all respects, inspections and containment / surveillance measures will continue for as long as necessary to ensure the full safeguarding of the sealed DGR.

As the closure period nears its end, the final approval to release the site for public surface use (with underground access excluded) will establish any final postclosure long-term monitoring needs. At that point, the monitoring would be finally configured, fenced and signed as required, and the site released in accordance with the obtained approvals.

11. TECHNICAL REFERENCES

Many references were accessed during the course of developing the supporting studies that formed the basis for this design report. The more significant of these references are listed below:

1. American Conference of Governmental Industrial Hygienists (1978). Industrial Ventilation - A Manual of Recommended Practice. ACGIH;

2. Andersson, C.G. (1998). Test Manufacturing of Copper Canisters with Cast Inserts. Swedish Nuclear Fuel and Waste Management Co. Report No. TR-98-09;

3. AECL T-H-M Modelling Report on Horizontal Tunnel Geometry in Crystalline Rock (2009);

4. Backblom, G., R. Christiansson and L. Lagerstedt, (2004). Choice of Rock Excavation Methods for the Swedish Deep Repository for Spent Nuclear Fuel, Swedish Nuclear Fuel and Waste Management Co. Report SKB R-04-62. Stockholm, Sweden;

5. Baumgartner, P., DmM. Bilinsky, C. Onofrei, Y. Ates, F. Bilinsky, J. L. Crosthwaite and G.W. Kuzyk (1995). The In-room Emplacement Method for a Used Fuel Disposal Facility – Preliminary Design Considerations. AECL Technical Record TR-665, COG-94-533;

6. Bromilov, J.G. (1960). The Estimation and Reduction of Aerodynamic Resistance of Mine Shafts. Transactions of the Institution of Mining Engineers. Vol. 119. Part 8;

7. CTECH (CTECH Radioactive Materials Management) (2002). Conceptual Design for a Deep Geological Repository for Used Nuclear Fuel. Report No. 1106-MD-18085-REP-0102;

8. Davison, C.C., A. Brown, R.A. Everitt, M. Gascoyne, E.T. Kozak, G.S. Lodha, C.D. Martin, N.M. Soonawala, D.R. Stevenson, G.A. Thorne and S.H. Whitaker (1994). The Disposal of Canada's Nuclear Fuel Waste: Site Screening and Site Evaluation Technology. Atomic Energy of Canada Limited Report, AECL-10713, COG-93-3;

9. De Bock, C., J.M. Bosgiraud, B. Been, M. Johnson, T Rothfuchs, H. Weber, P. Van Marcke and J. Verstricht (2009). Module 1 (Buffer Construction Technology) Final Report. Engineering Studies and Demonstrations of Repository Designs, Contract No. F16W-CT-2004-5058851;

10. Dixon, D.A., J. Martino and P. Onagi, (2009). Enhance Sealing Project (ESP): Preliminary Design and Construction Plan. Nuclear Waste Management Organization, Report No. DGR-REP-01601-0001;

11. Dixon, D., N. Chandler and P. Thompson, (2001). The Selection of Sealing System Components in AECL's 1994 Environmental Impact Statement. Ontario Power Generation, Report No. 06819-REP-01200-10074-R00;

12. Garisto, F., A. D'Andrea, P. Gierszewski and T. Melnyk, (2004). Third Case Study - Reference Data and Codes. Ontario Power Generation, Nuclear Waste Management Division. 06819-REP-01200-10107-R00, Toronto, Ontario;

13. Gatabin, C. (2008). ESDRED project Module 1 – From Bentonite Powder to Engineering Barriers Units: An Industrial Process. International Technical Conference on Practical Aspects of Deep Radioactive Waste Disposal, in Prague, Czech Republic June 16-18;

14. Gierszewski, P., M. Jensen, P. Maak and Vorauer (2004). Third Case Study Site and Design Description, Report No.06819-REP-01200-10124, Ontario Power Generation, Toronto;

15. Guo, R. (2008). Sensitivity Analysis to Investigate the Influence of the Container Spacing and Tunnel Spacing on the Thermal Response in a Deep Geological Repository, Atomic Energy of Canada Limited. Chalk River, Ontario;

16. Guo, R. (2009). Application of Numerical Modelling in Choosing Container Spacing, Placement-Room Spacing and Placement-Room Shape for a Deep Geological Repository Using the In-Floor Borehole Placement Method, Atomic Energy of Canada Limited. Report No. NWMO TR-2009. Chalk River, Ontario;

17. Hartman, H.L. (1982). Mine Ventilation and Air Conditioning. 2nd. Ed. John Wiley and Sons;

18. Hoek, E. and E.T. Brown (1980). Underground Excavations in Rock, the Institute of Mining and Metallurgy, London;

19. ICRP (2007), The 2007 Recommendations of the International Commission on Radiological Protection. Publication 103;

20. Johanesson, L. E. (1999). Compaction of Full Size Blocks of Bentonite for the KBS-3 Concept – Initial Tests for Evaluating the Technique. Svensk Kambranslehantering AB, Report No. R-99-66;

21. Kuzyk, G.W. and J.B. Martino (2008). URL Excavation Design, Construction and Performance, Atomic Energy of Canada Limited, Pinawa, Manitoba;

22. Maak, P. (1985). Electron Beam Welding of Thick-walled Copper Containers for Nuclear Fuel Waste Disposal – Phase Three B. Ontario Hydro Research Division Report No. 85-125-K;

23. Maak, P. (1986). Electron Beam Welding of a Thick-walled Oxygen-free Copper Pipe Mock-up. Ontario Hydro Research Division Report No. 86-224-K;

24. Maak, P. (2009). Used Fuel Deep Geological Repository and Transportation System – Used Fuel Container Preliminary Design Requirements for the APM Update. NWMO Document No. APM-PDR-01110-0005-R00;

25. McPherson, M.J. (1993). 'Subsurface Ventilation and Environmental Engineering'. Chapman & Hall;

26. National Climate Data and Information Archive http://www.climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html;

27. Noivi, L. (2009). Manufacture of Disposal Canisters. Posiva Report No. 2009-03;

28. NWMO (2009). Scope of Services - Scope for Updating the Conceptual Design and Cost Estimate for Adaptive Phased Management. Toronto, Ontario;

29. Nyström, A. and K. Gillin (2010) Used Fuel Packaging Plant Design Description. SKB International. Nuclear Waste Management Organization Technical Memorandum Revision R0;

30. Poon, G., M. Saiedfar and P. Maak (2001). Selection of a Primary Load-bearing Component Conceptual Design for Used-fuel Containers. Ontario Power Generation, Nuclear Waste Management Division Report No. 06819 REP 01200 10051 R00;

31. Pusch, R. (2001). The Buffer and Backfill Handbook – Part 2: Materials and Techniques. Svensk Kärnbränslehantering AB. Technical Report TR-02-12;

32. Pusch, R. (2002). The Buffer and Backfill Handbook – Part 1: Definitions, Basic Relationships, and Laboratory Methods. Svensk Kärnbränslehantering AB. Technical Report TR-02-20;

33. Raiko, H., I. Meuronen, J. Pitkänen, T. Salonen, N. Wikström and V. Ämmälä (2009). EB-demo – Canister Sealing Demonstration. Posiva Working Report No. 2009-126;

34. RWE Nukem Ltd. (2003). Deep Geological Repository: In-Floor Borehole Emplacement Design Changes from the In-Room Emplacement Concept. Report No. 89125-Rep-02-2003;

35. RWE Nukem Ltd. (2004). Deep Geological Repository: Horizontal Borehole Emplacement Cost Estimate. Report No. 89125-REP-07;

36. Saiedfar, M. and P. Maak (2000). Preliminary Structural Analyses of Used Fuel Disposal Container Geometric Alternatives. Ontario Power Generation. Nuclear Waste Management Division Report No. 06819 REP 01300 10012 R00;

37. Simmons, G.R. (2006). A Framework for the Long-term Monitoring of a DGR for Used Nuclear Fuel, OPG NWMO Report 06819-REP-01300-10119;

38. Simmons, G.R. (2009). Used Fuel Deep Geological Repository and Transportation System - System Requirements for the APM Update. NWMO Document No. APM-PR-01110-0001-R01;

39. Simmons, G.R. (2009). Used Fuel Deep Geological Repository and Transportation System – Placement Room Sealing System - Preliminary Design Requirements for the APM Update. NWMO Document No. APM-PDR-01110-0001-R00;

40. Simmons, G.R. (2009). Used Fuel Deep Geological Repository and Transportation System – Borehole Sealing System - Preliminary Design Requirements for the APM Update. NWMO Document No. APM-PDR-01110-0002-R00;

41. Simmons, G.R. (2009). Used Fuel Deep Geological Repository and Transportation System – Bulkhead Sealing System - Preliminary Design Requirements for the APM Update. NWMO Document No. APM-PDR-01110-0003-R00;

42. Simmons, G.R. (2009). Used Fuel Deep Geological Repository and Transportation System – Access and Service Areas Sealing System - Preliminary Design Requirements for the APM Update. NWMO Document No. APM-PDR-01110-0004-R00;

43. Simmons, G.R. (2009). Used Fuel Deep Geological Repository and Transportation System Used Fuel Container Preliminary Design Requirements for the APM Update. NWMO Document No. APM-PDR-01110-0005-R00;

44. Simmons, G.R. and Baumgartner (1994). The Disposal of Canada's Nuclear Fuel Waste: Engineering for a Disposal Facility. Atomic Energy of Canada Ltd., Report No. AECL-10715, COG-93-5;

45. SKB (2006). Kapsel för använt kärnbränsle – Svetsning vid tillverkning och förslutning. Swedish Nuclear Fuel and Waste Management Co. Report No. R-06-04. (Available in Swedish only.);

46. SKB (2007). RD&D Programme 2007 – Programme for Research, Development and Demonstration of Methods for the Management and Disposal of Nuclear Waste. Swedish Nuclear Fuel and Waste Management Co. Report No. TR-07-12;

47. SKB (2007). Encapsulation Plant at Forsmark. SKB Report No. R-07-36;

48. SKB (2007a). Aspo Hard Rock Laboratory Annual report 2006. SKB Technical Report TR-07-10. Stockholm, Sweden;

49. SKB 2007b. R&D Program 2007, Program for Research, Development and Demonstration of Methods for Management and Disposal of Nuclear Waste. SKB Technical Report TR-07-10. Stockholm, Sweden;

50. SKB (2009). Design Premises for a KBS-3V Repository based on Results from the Safety Assessment SR-Can and Some Subsequent Analyses. Swedish Nuclear Fuel and Waste Management Co. Report No. TR-09-22;

51. Tait, J.C. and S. Hanna (2001). Characteristics and Radionuclide Inventories of Used Fuel from OPG Nuclear Generating Stations (Volumes 1 to 3). Ontario Power

Generation, Nuclear Waste Management Division Report 06819-REP-01200-10029-R00. Toronto, Ontario; and

DOCUMENT END

APPENDIX A

COPPER USED-FUEL CONTAINER DESIGN AND FABRICATION TECHNOLOGY DESCRIPTION

The used-fuel container (UFC) has been designed with an outer copper vessel, an inner steel vessel and three steel baskets. The current reference design for the used-fuel container holds 360 used-fuel bundles, distributed in six layers of 60 bundles per layer. The basis for this conceptual design is to package 120,000 CANDU bundles per year, with operation of relevant facilities during either 30 years (the Base Case of 3.6 million used-fuel bundles) or 60 years (the Alternate Case of 7.2 million used-fuel bundles).

The container design for this conceptual design update is referred to as IV-25 and is based on NWMO's previous development work (several other UFC designs with various geometries and capacities for used fuel are also possible and will be studied as part of the APM design development program). A prerequisite for this reference design has been to use a copper tube with a wall thickness of 25 mm and a radial gap between the inner vessel and the outer vessel of 1 mm. As input to future container design development, a comparison has been made with an IV-25 design that has a copper wall thickness of 50 mm and a radial gap of 1.5 mm.

The function of the copper vessel is to provide a corrosion-resistant barrier in the repository environment. In this conceptual design, the IV-25 copper vessel is manufactured by roll forming copper plates into tube halves that are longitudinally welded together. The copper lid and copper bottom are machined out of pre-formed forged blanks. Friction stir welding is the reference welding method described in this conceptual design for the longitudinal welds, as well as for seal welding of the lid and bottom.

The inner vessel is designed to withstand the mechanical stresses that will be present in the repository. In this conceptual design, the inner vessel is fabricated from steel plates using conventional forming and welding techniques that are used for fabrication of pressure vessels.

To provide structural support and facilitate loading of the used-fuel bundles, the container design includes three baskets that are stacked on top of each other inside the inner vessel. Each basket consists of 60 seamless steel tubes that are supported by outer rings, with all components welded together into one integrated basket assembly.

A.1 UFC Principal Data

The IV-25 UFC design consists of an outer copper vessel (for corrosion resistance), an inner steel vessel (for mechanical strength) and three steel baskets (for support of the used-fuel bundles during loading). An assembly drawing of the reference container design with a copper wall thickness of 25 mm is provided at the end of this appendix. The total number of UFCs that is required is 10,000 in the Base Case and 20,000 in the Alternate Case. With the specified rate of delivery to the DGR, 333 filled containers need to be produced per year.

The principal data of the IV-25 UFC is provided below:

Used-Fuel Container (UFC)	
Total number of used-fuel bundles	360
Total weight of 360 used-fuel bundles	8,640 kg
Number of fuel layers	6
Number of bundles per layer	60
Number of baskets	3
UFC diameter	1,247 mm
Total height of UFC	3,842 mm
Total weight of UFC with fuel	26,700 kg

Outer Copper Vessel	
Height of copper vessel with lid and bottom	3,842 mm
Outer diameter (OD) of copper vessel	1,247 mm
Inner diameter (ID) of copper vessel	1,197 mm
Wall thickness of copper vessel	25 mm
Height of copper lid	110 mm
Minimum copper lid (and bottom) thickness	25 mm
Weight of copper vessel with lid and bottom	4,170 kg

Inner Steel Vessel	
Height of inner vessel with lid and bottom	3,700 mm
Outer diameter (OD) of inner vessel	1,195 mm
Inner diameter (ID) of inner vessel	990 mm
Wall thickness of inner vessel	102.5 mm
Height of steel lid (and bottom)	350 mm
Minimum steel lid (and bottom) thickness	170 mm
Weight of inner vessel with lid and bottom	12,650 kg
Weight of three UFC baskets	1,240 kg

A.2 Design Prerequisites

The components of the UFC will be manufactured separately by suitable, external suppliers. After initial machining, components will be transported to a UFC factory where they will be machined to final dimensions and assembled. The assumption is that the UFC factory will be

located at a separate site, from which the empty containers will be transported to the DGR by road in purpose-built transport frames.

The ultimately contained fuel is assumed to be standard CANDU used-fuel bundles with a nominal length of 495.3 mm, a maximum diameter of 102.3 mm and a weight of 24 kg (see Figure A-1). The used fuel will have decayed in interim storage for at least 30 years before loading into the UFCs.



Figure A-1: Standard CANDU Used-Fuel Bundle

The copper vessel has been designed for seal welding of the copper lid and bottom using friction stir welding. The copper lid shall be designed so that filled containers can be lifted by the lid (using a purpose-built tool) during handling in the UFPP and placement in the DGR. It will also be possible to retrieve containers from the repository and cut them open, as required by the APM approach. The centre of the copper lid will be marked with a unique UFC identification number visible during placement in the DGR.

For design purposes, it is assumed that the quality obtained during packaging will be such that 1 in 100 completed containers will fail inspection in the UFPP and require re-packaging. It is assumed that 1 in 5,000 containers will contain undetected defects that could lead to container failure in the DGR.

The UFC is an integral part of the APM system and shall be compatible with the packaging plant and the system for transfer of filled UFCs to the DGR. The design and fabrication of the UFC will comply with all applicable CNSC regulations and other relevant requirements.

As previously noted, the IV-25 UFC design will hold 360 used-fuel bundles and has a total length of approximately 3.9 m. The wall thickness of the copper vessel has been designed to be 25 mm and the radial gap between the copper vessel and the inner vessel is 1 mm.

The inner steel vessel will be fabricated using conventional forming and welding methods that are used for the fabrication of pressure vessels.

A.3 Outer Copper Vessel

A.3.1 Design and Material

The outer copper vessel of the IV-25 UFC design consists of a 25 mm thick copper tube with a welded copper lid and bottom. The copper lid is designed with a flange to enable lifting of a filled container while the copper bottom has a flat design. The flange on the copper lid is designed with surplus material as required for of the lid (see below).

The copper components are made of pure, oxygen-free copper that has been alloyed with 30 to 70 ppm phosphorous.

A.3.2 Fabrication of Copper Tubes

Three methods are available methods for the fabrication of the UFCs' copper tubes: extrusion; pierce and draw; and, roll forming and longitudinal welding. Through extensive discussions with potential suppliers each approach was assessed with potential limitations noted. Based on this work, roll forming and longitudinal friction stir welding was deemed to be the most promising method for the IV-25 copper container design and was therefore selected as the reference method for this design at this time.

An overview of the three methods is provided below. All fabrication methods require machining to final dimensions.

Roll Forming and Longitudinal Welding

Roll forming is used to transform copper plates into tube halves that are then longitudinally welded together. This is a cold-forming process that is manually controlled and requires skilled operators. Each of the tube halves is formed in stages and the shape is controlled against templates until specified requirements have been fulfilled. After roll forming and the removal (by machining) of surplus materials, milling is undertaken to prepare the surfaces for longitudinal welding.

After final inspection of the container's measurements, the halves are assembled in a fixture, as illustrated on Figure A-2. The seams are then welded together using friction stir welding or, potentially, electron beam welding. Heat treatment for stress relieving will likely be required after welding.



Figure A-2: Assembly of Tube Halves for Longitudinal Welding

Depending upon future developments in copper plate technology, it may also be possible to form a whole copper tube from one large plate (similar to the technology used for producing steel tower sections for the wind power industry).

Pierce and Draw Processing

Pierce and draw processing is a hot-forming method that has been used for fabrication of seamless copper tubes. The process starts with a cylindrical copper ingot which, for a copper tube with IV-25 dimensions, would weigh approximately 21 tonnes.

During pierce and draw, the ingot is first hot formed by upset forging, which generates a shorter piece with larger diameter. The material is then placed vertically in a special tool, where it is pierce-punched by a mandrel, see Figure A-3. The bottom of the material is kept intact to support the piercers in subsequent horizontal forming steps.

The pierce and draw process is continued with alternating steps of expansion and elongation, as illustrated in Figure A-4. For expansion, a mandrel with a diameter that is larger than the tube's inner diameter is pressed into the material against a steel plate (top photo in Figure A-4). In the subsequent elongation step, the steel plate is removed, and the material is pressed by the mandrel through an open ring that has a slightly smaller diameter than the outer diameter of the material (bottom photo in Figure A-4). The expansion and elongation steps are then repeated until the tube has obtained the specified length and diameter. Re-heating of the material is required during and between some of the forming steps.

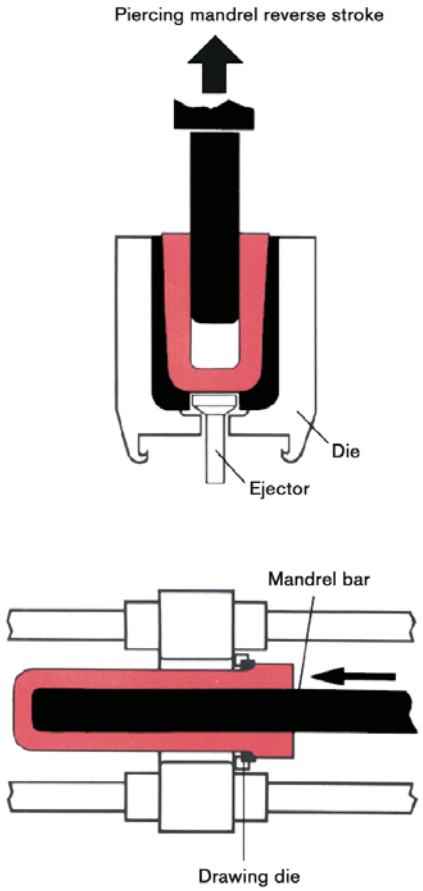


Figure A-3:
Principles of the Pierce and Draw Process

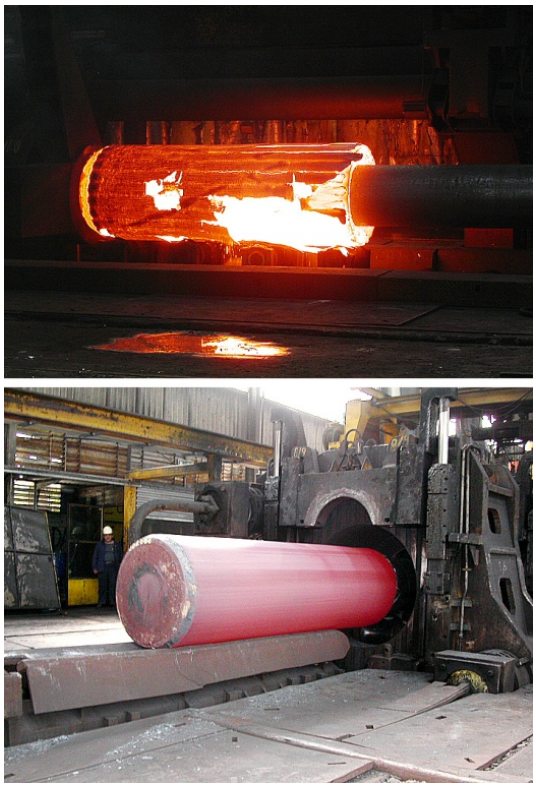
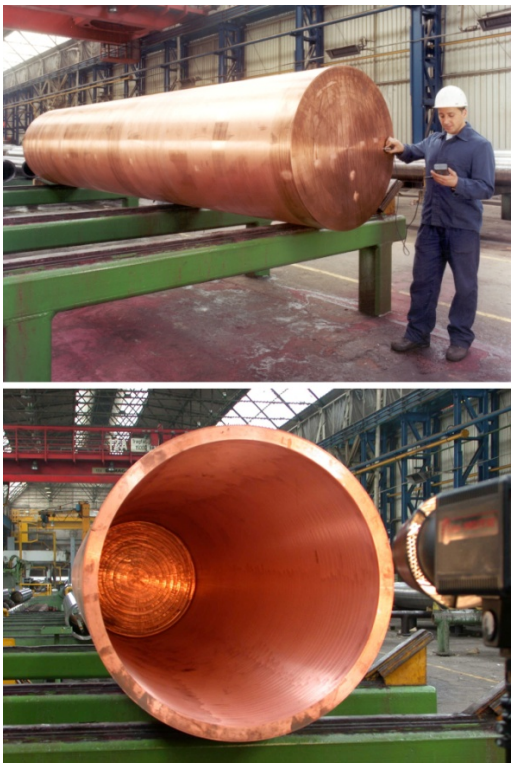


Figure A-4:
Consecutive Expansion and Elongation Steps During Pierce and Draw

After cooling, both ends of the tube are normally cut off to the required length, resulting in a tube that is open at both ends. It has been investigated whether the bottom that is formed as part of the pierce and draw process could be left on the tube and, after machining, become the container bottom. This would require that the bottom is not deformed during the process steps but retains a structure with a grain size that fulfills specifications. Trials have been performed (by others) with promising results, see Figure A-5. It is important to note that the internal machining that would be required for these relatively long tubes with integrated bottoms may be problematic. Further, and given that the minimum wall thickness that can be produced is approximately 80 mm (as the copper is at risk of breakage at hot-forming temperatures), more than 50% of the material would have to be machined off to reach the targeted wall thickness of 25 mm for the IV-25 design.



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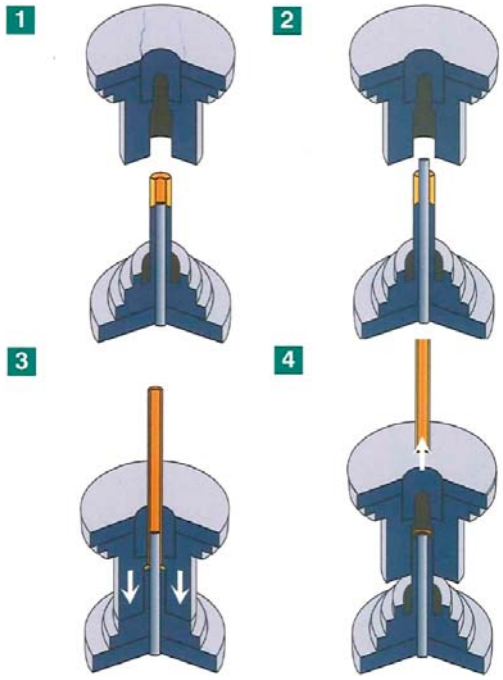
Figure A-5: Machined Copper Tube with Integrated Bottom

An additional issue with pierce and draw processing is the size of the starting cylindrical copper ingot required (approximately 21 tonnes). At present, it is unknown if the size needed for the IV-25 design can be met by existing suppliers.

Extrusion

Extrusion is a hot-forming method that produces seamless copper tubes. As shown in Figure A-6, the main steps in extrusion are: 1) a hollow blank (previously formed by upset forging and punching) is heated and placed below the press tool; 2) an internal mandrel determines the inner diameter of the tube; 3) the large press tool is pushed downwards; and, 4) a tube is formed and pressed upwards in a single, vertical motion.

Currently, extrusion presses are not large enough to form copper tubes with the dimensions required for the IV-25 design.



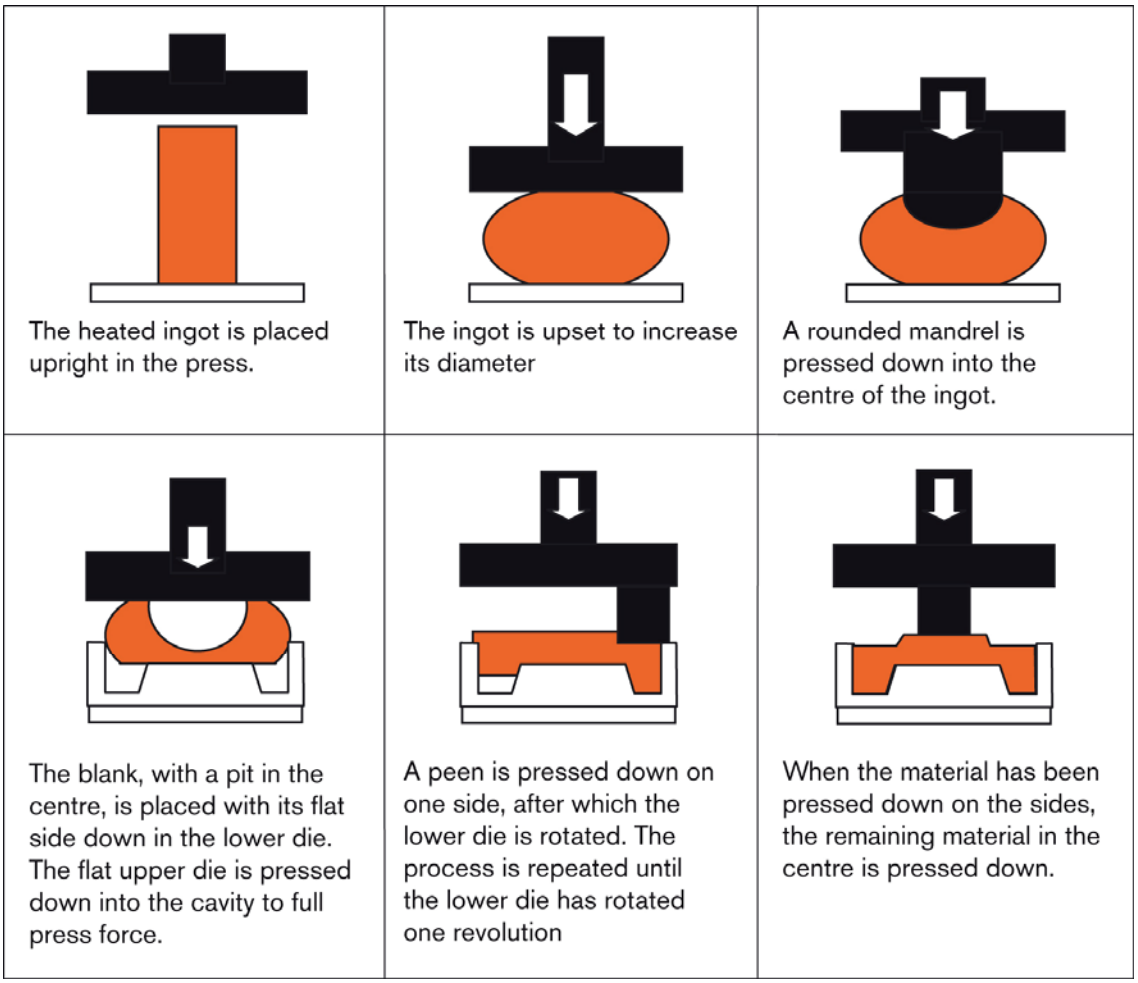
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Figure A-6: Main Steps of Extrusion of Copper Tubes

A.3.3 Fabrication and Seal Welding of Copper Lids and Bottoms

Copper lids and bottoms will be machined to specified dimensions from blanks that have been pre-formed by hot forging. A benefit with forging is that it produces a blank shape that reduces the amount of material that needs to be machined off. The hot-forming process further results in a material that has a homogeneous and fine-grained structure. Forging of copper lids and bottoms can be performed in a conventional forging press, and such presses are available at many companies.

The starting stock for the forging process is a cylindrical copper ingot. After heating, the ingot is stood on end and pressed between flat tools. The forging then takes place in steps in a purpose-built die as illustrated in Figure A-7.



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Figure A-7: Fabrication of Copper Lids and Bottoms

For seal welding of the copper lid (and bottom), the method anticipated in this conceptual design is friction stir welding (FSW). In FSW, a rotating tool is inserted and moved along the joint between the copper lid and the copper tube, and with the heat created from the friction, the parts are joined together while remaining in a solid state. During FSW of the UFC lid, the welding head is rotated around the container, while the container is fixed.

A.3.4 Re-assessment of the Copper Wall Thickness

Initiatives in other jurisdictions have incorporated wall thicknesses for the outer copper vessel of 50 mm, as compared to the 25 mm thickness assumed as part of NWMO's reference UFC. A thicker copper wall may offer some advantages, including:

- A further reduction in the risk of container breach through corrosion should buffer erosion develop in the repository due to the penetration of glacial meltwaters over the very long term (although this risk is already acceptably low);

- Increased tolerances for mechanical damage (e.g., indentations) during machining and handling in the UFPP and DGR;

- For the pierce and draw method (and working with a minimum starting tube wall thickness of approximately 80 mm), a reduction in the amount of surplus material that must be machined off;

- Increased resistance to the copper tube becoming slightly oval with time during storage and transportation (such ovality could cause difficulties during assembly of the inner steel vessel into the copper container, especially with a maximum radial gap of 1 mm);

- Improved tolerances for hidden defects beneath the canister surface in the copper lid weld zone (lifting strengths enhanced); and

- Exploitation of already existing technology for both extrusion and pierce and draw approaches as they are already in place for the fabrication of thicker copper tubes.

Ongoing evaluations will continue to refine the design approach for the copper container.

A.4 Inner Steel Vessel

A.4.1 Design and Material

The inner vessel of the UFC is a pressure-bearing steel vessel that consists of a thick-walled tube with a lid and bottom. Inside the vessel, three steel baskets will be stacked on top of each other, with each basket holding 120 used-fuel bundles in two layers of 60 bundles (see drawing at the end of this appendix).

The inner vessel is designed to withstand an external isotropic pressure of 15 MPa prior to glaciation (as per the ASME Boiler & Pressure Code, Section III, with a prescribed safety factor) and an external post-glaciation isotropic pressure of 45 MPa. The vessel will be constructed from SA 516 Gr. 70 carbon steel plates. The material specified for components of the UFC basket is SA 210.

As an alternative, cast steel may be considered instead of steel plates for the inner vessel tube. This approach would allow for the production of seamless tubes, at a lower cost. Another alternative would see the use of cast nodular iron for the inner vessel tube (for this option, an open tube would be cast with a separate lid and bottom that are bolted to the tube).

It is noted that, for a cast iron insert, the chemical composition can be adjusted, as long as the mechanical properties fulfill the requirements.

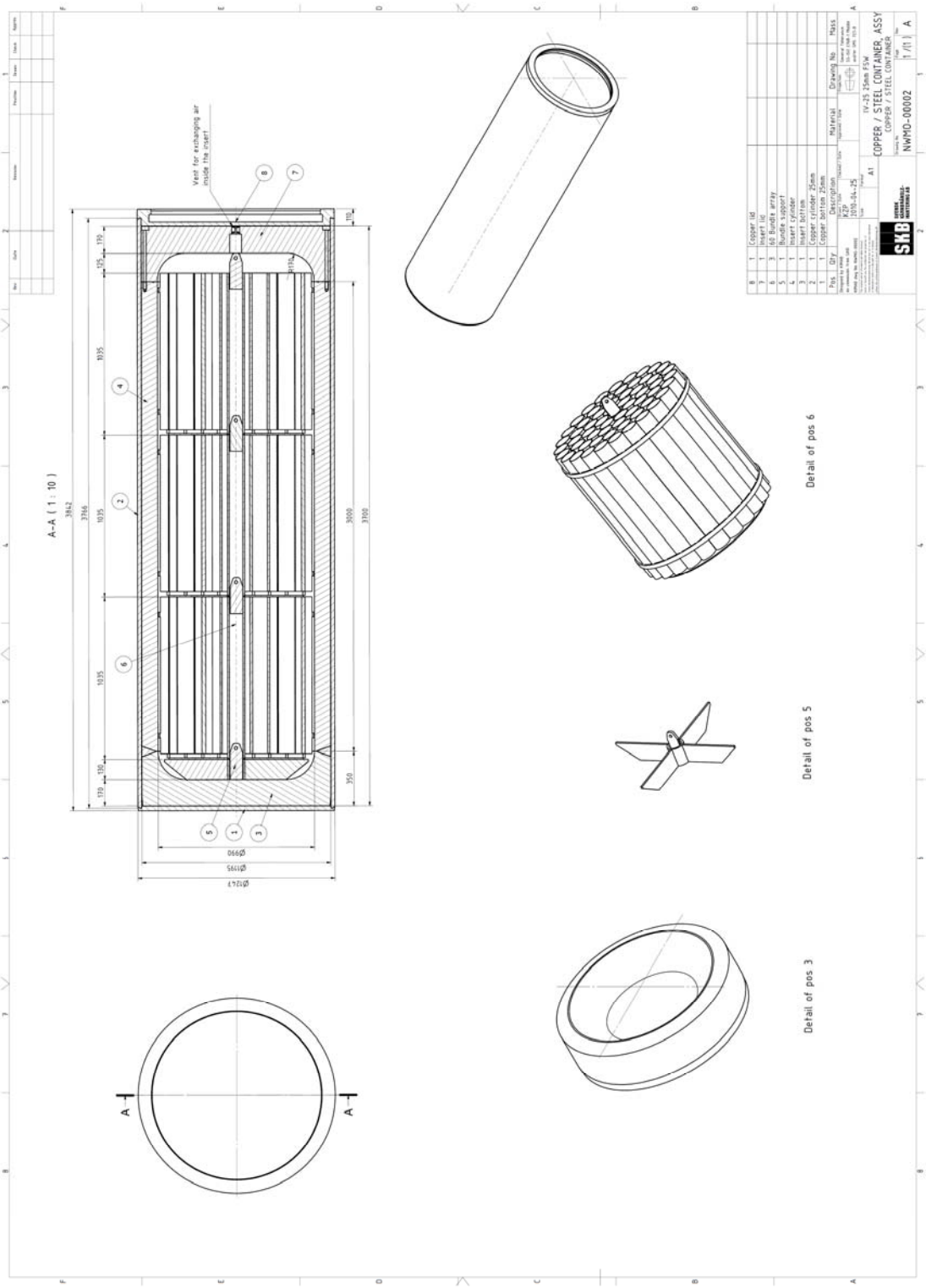
A.4.2 Fabrication

The inner steel vessel, including the baskets, will be fabricated using conventional forming and welding methods. For the inner vessel tube, steel plates will be roll formed and sealed by

longitudinal welding. The lid and bottom will be fabricated by forging. The bottom of the inner vessel is welded to the tube, while a bolted design is used for the lid.

The inner vessel will be fabricated in accordance with ASME Section III, Subsection NC, with the exception that impact testing on material and welds are not required. Welds will be inspected according to NC-5000, and alternate volumetric inspection techniques may be used if radiographic examination is not feasible.

ASSEMBLY DRAWING OF THE IV-25 UFC



APPENDIX B

RADIATION SHIELDING

In order to ensure that the design of the DGR's component operations have been optimized in accordance with the As Low As Reasonably Achievable (ALARA) principle, radiation dose rates have been estimated for a variety of exposure scenarios. The following seeks to provide preliminary dose estimates for the following situations:

- Handling and transport of the Irradiated Fuel Transport Cask (IFTC);
- Receipt and storage of the IFTC at the DGR's UFPP;
- Used-fuel cell shielding at the UFPP;
- Transfer of UFCs using the Intra-site Transport Casks;
- Placement of the UFC within the DGR's placement rooms; and
- UFC retrieval from the placement boreholes.

Each situation was broken up into exposure scenarios and assessed using multiple dose points.

B.1 Dose Assessment Methodology

All dose calculations were based on a reference 37-element CANDU fuel bundle, with an average burn-up value per kilogram uranium (kg-U) of 280 MWh/kg-U, an average bundle power of 455 kW and an age of 30 years.

Throughout the devised exposure scenarios, dose rates were estimated at dose points (DPs) located at 0.01, 0.05, 0.5, 1, 5 and 10 m distances from an accessible operational surface of the source.

MicroShield® (v.7.02), a commercial software package produced by Grove Software Inc, was used to calculate the estimated dose rates at the various assessment locations. MicroShield® is a comprehensive photon/gamma ray shielding and dose assessment program that is widely used in the nuclear industry.

B.2 Handling and Transport of IFTCs to DGR

Table B-1 outlines the typical processes used for loading and unloading the IFTC onto (at the Owner's site) and off of (at the DGR site) the transportation vehicle and their approximate durations. Three workers will complete the required tasks in an average time period of three hours. A contingency allowance was assumed and added to the duration of the processes.

Table B-1: Loading of the IFTC
(similar steps, though reversed, for unloading)

Activity	Components	Duration (hrs)
Load IFTC assembly with impact limiter on transport vehicle with lifting beam and gantry crane	IFTC and impact limiter, gantry crane, lifting beam	0.5
Attach transport vehicle tie-downs to IFTC assembly and tighten	Tie-downs, IFTC assembly	0.5
Post-loading inspection of IFTC assembly and tie-downs		0.25
Test transport vehicle for contaminants	Smear radiation test unit	0.25
Position weather cover on transport vehicle trailer	Weather cover - accordion style	0.25
Final inspection of transport vehicle and supporting systems integrity	Communications, tracking, security systems	0.5
	TOTAL (w/contingency)	**≈ 3.00**

The first exposure scenario relating to the handling/transportation of IFTCs targeted shielding aspects to determine potential doses to operators during loading and unloading of the IFTCs onto and off of the transport trailers (see Table B-1). Dose rates were estimated at various distances from the IFTC's side and end surfaces.

The second exposure scenario involved assessing doses to the driver-escort teams in the vicinity of the IFTC during road transport to the DGR.

Cyclic logistics are provided in the Transportation Design Report for three different return trip distances that cover the various reactor site locations (one way travel distances of 1,000 km, 1,500 km and 2,500 km). A breakdown of the time spent (on-duty and off-duty) per transportation team member in the vicinity of an IFTC for each cycle was developed. The longest combined on-duty and off-duty exposure time was assessed, to present a degree of conservatism in estimating the potential yearly doses.

Results

In terms of the estimated doses for operations related to the loading, handling and transport of the IFTCs, the dose rate limit of 1 mSv/h (near the accessible surfaces of the IFTC) are not exceeded for any of the considered exposure cases.

The annual dose to a worker involved in all related operations was calculated at 1 m away from the IFTC to be between 7-8 mSv, closely approaching the yearly dose limit of 10 mSv. The annual dose to a transport team member situated within the transport tractor cabin was calculated to be approximately 4.7 mSv (47% of the yearly dose limit) for the most conservative transportation case. When considering the tractor cab, none of the occupants were found to be exposed to dose rates in excess of the 10 µSv/h limit.

Conclusions

The adequacy of the IFTC shielding features against the contained used-fuel modules during handling and transportation was verified by the results of the performed analysis.

Estimated dose rates for (radial) dose points with respect to the sides of the IFTC were slightly higher than those estimated at similarly placed (axial) points from its ends. Given that the shielding thickness and construction is uniform throughout the IFTC, this slight difference was considered to be due to the increased level of self-absorption for axially-radiated source photons for the given source geometry.

B.3 IFTC Receipt and Storage at UFPP

As outlined in Section 6.1, receiving, unloading and storage of IFTCs occurs at the UFPP. The exposure scenarios discussed in this section cover dose assessments associated with the IFTC storage area. In order to provide a conservative gamma dose estimate, several assumptions and modelling-related approximations were made, including:

- The UFPP's storage area holds 12 filled IFTCs;
- The IFTCs were modelled as one body exhibiting a rectangular cross-section, holding a source of 24 fully loaded fuel modules (illustrated in Figure B-1);
- The volume occupied by the filled modules consists entirely of uranium; and
- At least one crane operator and two workers are normally involved in the internal storage operations.

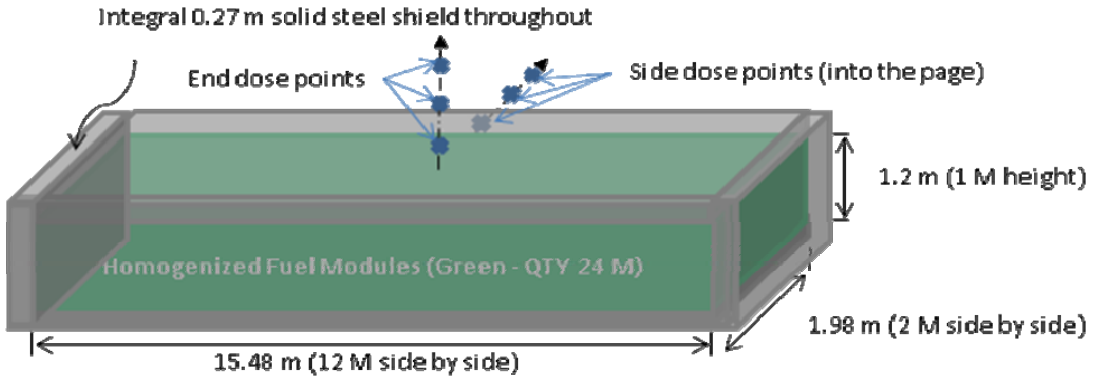


Figure B-1: IFTCs in Storage - As Modelled
(dimensions of homogenized source shown, not to scale)

In the first exposure scenario, the IFTC inventory within the storage area was conservatively modelled with potential doses estimated at the side and end of the self-shielded IFTCs. For the second exposure scenario, the IFTC inventory within storage was modelled with adjacent

concrete shielding structures. Doses were estimated at the side and end of the concrete structures to verify the adequacy and sufficiency of the provided shielding.

Results

Analysis of the exposure scenarios yielded a maximum gamma dose rate of 36 µSv/h at the accessible end surface of the modelled IFTCs. This value constitutes about 4% of the specified limit of 1 mSv/h which confirms the adequacy of the IFTCs' shielding features. As the storage area is not normally occupied, assessment against the hourly dose limit of 10 µSv is not applicable.

Dose assessments yielded a maximum gamma dose rate of 0.85 µSv/hr above the assumed IFTC storage concrete ceiling thickness of 0.25 m. When assessing this dose rate against the 1 mSv/h dose limit at accessible surfaces of shielded structures, it was determined that it constitutes approximately 0.1% of the limiting value. Furthermore, assuming that the office area above the storage ceiling is normally occupied with personnel, the estimated gamma dose rate of 0.78 µSv/h comprises approximately 1% of the prescribed 10 µSv/hr dose rate limit for normally occupied areas. Lastly, the annual dose to a worker located in the receiving and shipping hall, performing internal IFTC transport activities, was calculated to be approximately 2.5% of the 10 mSv annual limit.

Conclusions

Dose estimates based on the utilized conservative inputs and assumptions for the defined IFTC storage area exposure scenarios were lower than the stipulated dose constraints. The shielding capabilities of the concrete storage walls and ceiling confirms that a 0.25 m thickness afforded adequate shielding.

B.4 Used-Fuel Handling Cell Shielding at the UFPP;

This exposure scenario concerns the operating area around the UFPP's fuel handling cell (see Section 3.4). The cell wall thickness required to effectively shield against 12 fully-loaded fuel baskets (1,440 fuel bundles) was established. The source was modeled as a homogenized rectangular volume of uranium (depicted as a dashed line around the baskets shown in Figure B-2).

As the cell shielding is provided by concrete walls and leaded glass viewing ports, the shielding thickness requirements for both materials was determined. In Figure B-2, several DPs, whose heights are measured perpendicularly with respect to the shielding wall, are indicated using stars. The fuel baskets have been placed up against the shielding wall in order to render a conservative shielding thickness.

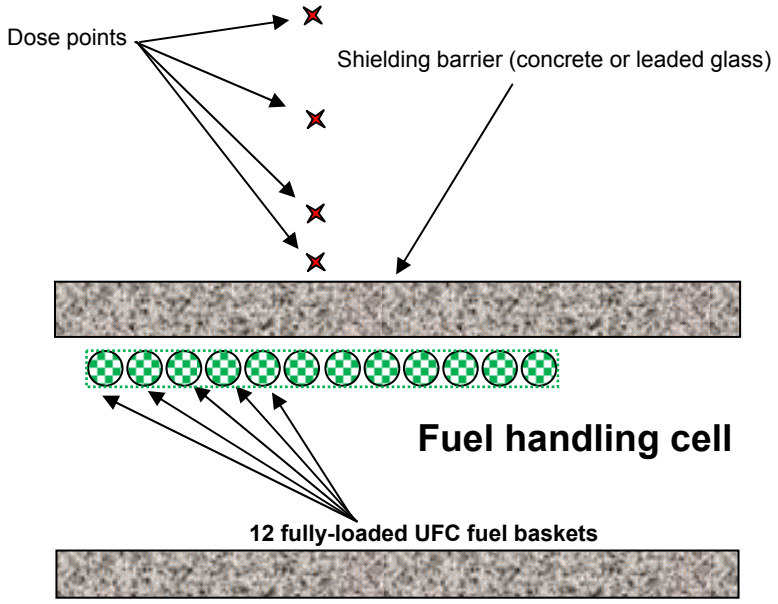


Figure B-2: Fuel Handling Cell: Top View of Modelled Geometry with Dose Points

The first modelled scenario assessed the thickness for the concrete shielding wall in the UFPP's fuel handling cell. The second modelled scenario examined the shielding thickness for the handling cell's leaded glass window. The leaded glass density was adjusted to yield the same shielding as that of 1 m of concrete.

Results

The simulation results indicate that a 1 m thick wall of standard concrete reduces the radiation fields to 3.25 µSv/h on contact (1 cm from the wall) and to 2.30 µSv/h at 1 m from the shielding wall. For the leaded glass, a total shielding thickness of 47 cm is indicated for the 1 m viewing port space.

Shielding requirements dictate dose rates outside the fuel handling cell not exceeding 1 mSv/h on contact and 10 µSv/h at a distance of 1 m from the wall. The modeled thicknesses meet this requirement with an external dose rate at 1 m of 2.30 µSv/h (more than a factor of four below the limit). Considering the unfavourable geometry modelled, with baskets directly against the shielding wall, these results are conservative. Dose rates decrease rapidly with increasing distance from the shielding surface, dropping below 1 µSv/h at a distance of 5 m.

Conclusions

The fuel handling cell was modelled in an effort to conservatively establish shielding needs for both the concrete cell walls and the associated leaded glass viewing ports. It was determined that 1 m of concrete, coupled with viewing ports having an equivalent thickness of 47 cm of leaded glass are sufficient to reduce the radiation fields.

There are other possible exposure pathways. In particular, manipulator ports typically present a pathway for radiation penetration and scatter inside operational areas. It is anticipated that this will not be problematic as many similar hot cells exist at other facilities where such exposure pathways have been successfully reduced and mitigated.

B.5 Transfer of UFCs using Intra-site Transport Casks (TCs)

Filled UFCs are loaded into shielded intra-site transport casks (TCs) in the UFC dispatch hall (see Section 3.4). After a UFC has been lowered into the TC, the cask lid is bolted and the cask inspected. The TCs are then lifted by crane and placed horizontally onto an awaiting rail flatcar. Using a locomotive, the TC is dispatched from the UFPP to the Main Shaft and then to the underground repository. A subsurface locomotive will pull the flatcar to a temporary storage area or directly to the active placement room. During these operations, shielding from the UFC is provided mainly by the TC, which has a solid steel wall.

The first exposure scenario for the intra-site TC stage involved operations performed during the handling and inspection of the TC at the dispatch hall. In this process, the vertically oriented, filled TC is lifted from the working platform in the dispatch hall and placed horizontally onto a rail flatcar in the dispatch airlock. Three persons will be involved in this process at varying distances from the TC. One crane operator and two plant workers (to position and inspect the TC on the flatcar) will be active for a 15 minute duration. Potential exposures are analyzed at the side and end surfaces of the filled TC (see Figure B-3).

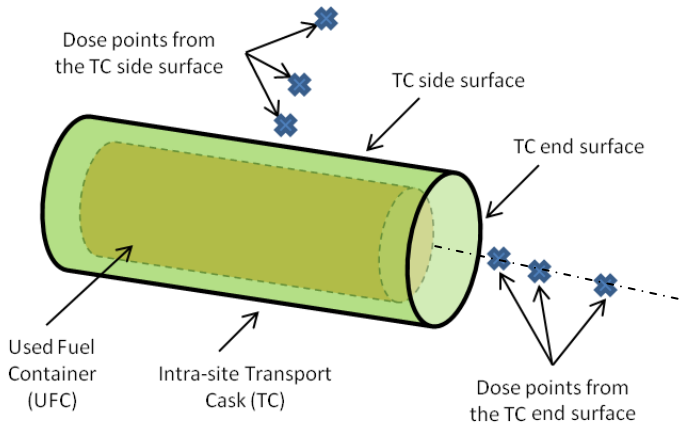


Figure B-3: Illustration of Exposure Cases

The second scenario deals with the potential exposure of the locomotive operator during transport from the UFPP to the Main Shaft, and from the shaft's bottom to the TC's underground destination. It is assumed that one operator is located in the locomotive cabin and that each of the surface and below-ground movements last 15 minutes. As the TC will be in a horizontal orientation, the operator will be exposed to fields emanating from the ends of the TC.

Results

When analyzing the tabulated values, it was determined that the expected dose rates at all points near the side and end of the filled TC are significantly less than the 1 mSv/h limit at the accessible surface of the UFC. Furthermore, for normally occupied areas in the vicinity of a UFC, all exposure cases evidenced hourly doses at a 1 m distance from the UFC at less than 10 µSv.

Using the highest estimated dose rate, the annual dose for a worker involved in handling and inspection activities was calculated to be approximately 143 µSv. Additionally, the annual dose to a locomotive operator transporting filled TCs was calculated to be just over 10 µSv. The annual gamma doses for both scenarios are significantly lower than the limit of 10 mSv/a.

Conclusions

The analysis confirmed the adequacy of the intra-site TC in shielding fields emanating from the UFC. The conservatively estimated dose rates were considerably below the regulated limits. As expected, the estimated dose rates at DPs on the side of the intra-site TC were higher than those at the same distances from its end. This is mainly due to the greater vessel end wall thickness relative to the side wall and, to a lesser extent, due to the increased level of source photon self-absorption inherent to the end field exposure geometry.

This analysis was extended to investigate the dependency of the dose rate on TC wall thickness. It was determined that the intra-site TC steel wall thickness can safely be reduced from 15.2 cm to 10 cm while still providing a sufficient margin of safety with respect to radiation shielding. It is noted, however, that the structural and mechanical stresses inherent in the TC function may impose design constraints which will limit the degree to which shielding reductions can be accommodated.

B.6 Placement of UFC within the DGR

A detailed depiction of the typical UFC placement process is provided in Section 6.3. As noted therein, and as illustrated below in Figure B-4, vertical placement of the UFCs involves the insertion of discs of Highly Compacted Bentonite (HCB) in the receiving boreholes before acceptance of the UFC. After container placement, the borehole is backfilled with additional bentonite discs and pellets. Following placement, the section of track leading to the newly filled borehole is removed and that section of the placement room is backfilled will light and dense bentonite materials.

This exposure scenario assessed the case where a UFC is situated within a borehole. In this scenario, the vertically-placed UFC is completely backfilled with bentonite buffer inside the borehole but the placement room itself has not been progressively filled in. The dose rates are assessed along a vertical line passing through the center of the UFC at various distances above the floor of the drift. This exposure scenario effectively represents one that might apply to a worker in the placement room before room backfilling.

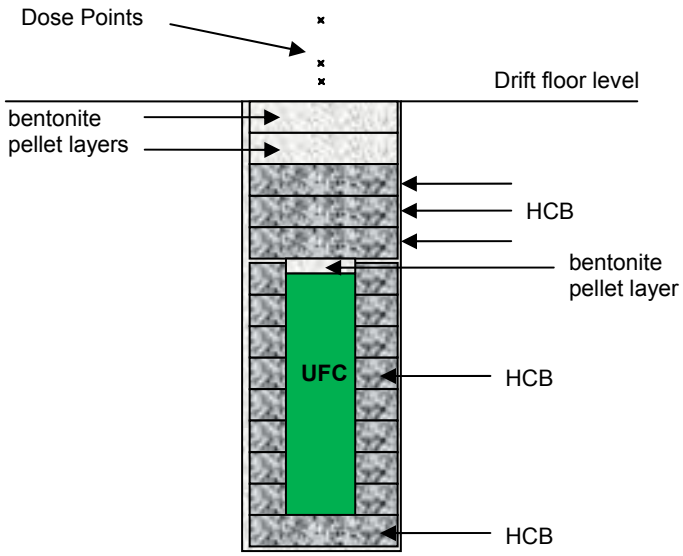


Figure B-4: Geometry of UFC in Placement Borehole
(Dose Points indicated using crosses)

Results

For the situation where a UFC is completely backfilled within a bentonite buffer inside a vertical borehole, transmitted fields through the backfill at positions directly above are reduced to below background levels and are completely negligible from a radiological point of view (<1E-8 μSv/h). They do not contribute materially to occupational dose.

Conclusions

Modelling results demonstrate that external fields are low enough to permit operator activities in the vicinity of the UFC placement boreholes, should such activities be required. The current conceptual design constitutes a safe and effective vertical emplacement.

B.7 UFC Retrieval from Placement Boreholes

UFC retrieval from vertical boreholes does not present any new or unique radiological hazards beyond those encountered during vertical placement. The most significant difference between placement and retrieval may arise due to the additional time spent operating the retrieval equipment in proximity to the UFC. A description of the UFC retrieval process is provided in Section 7.2.

A number of exposure scenarios for several phases of bentonite removal from the borehole were considered. As the de-slurry process begins, the various levels of bentonite buffer material are being dissolved in succession, increasing the dose rate at and above the shielding cover at the target borehole.

In the exposure scenario illustrated in Figure B-5, the dose rate above the drift floor is assessed where the top two layers of bentonite (pellets) have been removed. The dose rates for this and each successive case of bentonite cover removal were evaluated along a vertical line passing through the centre of the UFC at varying distances above the floor of the drift.

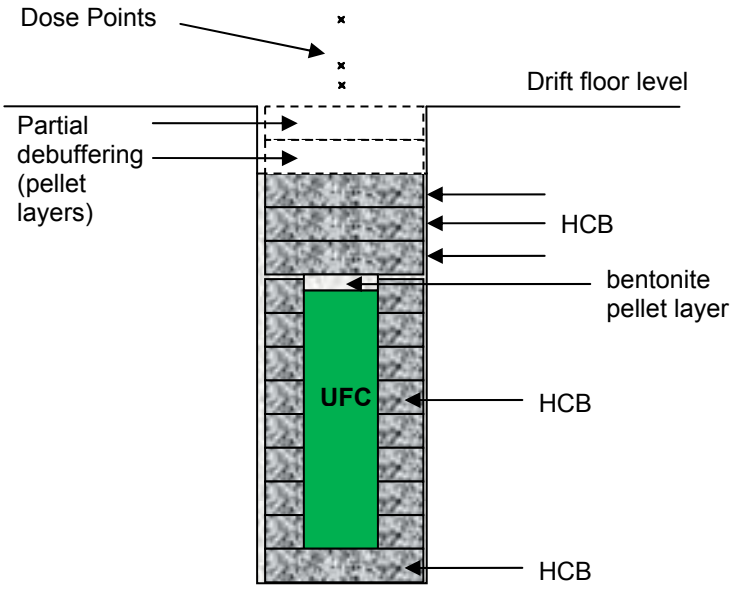


Figure B-5: Geometry of UFC Being Debuffered Within a Borehole (Dose Points indicated using crosses)

Results

Dose rates above the borehole were assessed for the initial / totally-backfilled state progressively through to where only a final thin layer of bentonite pellets remained on top of the UFC. Dose rates were found to be generally quite small (i.e. below 15 μSv/h) regardless of the thickness of the bentonite buffer cover, owing to the depth of the UFC within the borehole.

Conclusions

Estimated dose rates, as measured with respect to the placement room floor and for all stages of debuffering are significantly below the prescribed 10 μSv/h maximum. The highest estimated rate found was 14 μSv/h at 1 cm above the floor and concentric with the borehole. The corresponding figure at a 1 m distance was 8 μSv/h. These rates correspond to the special case where there is effectively little or no buffer material above the UFC, and none of the normally-used secondary shielding is present. With the exception of the final stages of debuffering, where the UFC would be visible from above the borehole, occupational dose rates are typically below the prescribed maximum. For all following retrieval stages, the use of shielding barriers, shielding doors and administrative controls will be essential to mitigate the possibility of subjecting operators to excess fields.