

# **Deep Geologic Repository Conceptual Design**

## **Annex 7**

### **Waste Shaft Hoisting System Used Fuel Container Design**

December 2002

## **NOTICE to the Reader**

“This document has been prepared by CTECH Radioactive Materials Management, a joint venture of Canatom NPM Inc. and RWE Nukem Ltd. (“Consultant”), to update the conceptual design and cost estimate for a deep geologic repository (DGR) for long term disposal of used nuclear fuel. The scope is more fully described in the body of the document. The Consultant has used its professional judgment and exercised due care, pursuant to a purchase order dated October 2001. (the “Agreement”) with Ontario Power Generation Inc. acting on behalf of the Canadian nuclear fuel owners (“the Client”), and has followed generally accepted methodology and procedures in updating the design and estimate. It is therefore the Consultant’s professional opinion that the design and estimate represent a viable concept consistent with the intended level of accuracy appropriate to a conceptual design, and that, subject to the assumptions and qualifications set out in this document, there is a high probability that actual costs related to the implementation of the proposed design concept will fall within the specified error margin.

This document is meant to be read as a whole, and sections or parts thereof should not be read or relied upon out of context. In addition, the report contains assumptions, data, and information from a number of sources and, unless expressly stated otherwise in the document, the Consultant did not verify those items independently. Notwithstanding this qualification, the Consultant is satisfied that the updated conceptual design and cost estimate was carried out in accordance with generally accepted practices in a professional manner .

This document is written solely for the benefit of the Client, for the purpose stated in the Agreement, and the Consultant’s liabilities are limited to those set out in the Agreement.”

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# 1 INTRODUCTION

## 1.1 GENERAL

SNC-LAVALIN are providing engineering services to Ontario Power Generation (OPG) through CANATOM/CTECH to update the conceptual design for a deep geologic repository (DGR) for used nuclear fuel.

JR Morris Engineering is retained to provide specialist engineering services in the area of hoisting, shaft design, and related facilities. A report is to be developed comparing the conceptual designs for hoists, conveyances, and shafts, tabulation of design parameters, sketches of proposed arrangements, description of operating features, and estimates of marginal cost differences. SNC-Lavalin will be assisted in preparing more detailed designs and estimates for a selected base case.

## 1.2 DESIGN PARAMETERS

Spent fuel rod bundles will be received at the repository's surface facility where they will be packaged in special containers for emplacement. The loaded containers, encased in a bentonite jacket and suitably shielded, will be transported underground through the used fuel handling shaft. On the repository's emplacement level they will be transported by rail to the emplacement rooms.

The designs will be of a generic nature, with no specific site selected. The primary design criteria are as follows:

1. Repository depth 1000 m.
2. Used Fuel Container (UFC) 1168 mm diameter x 3867 mm long . Mass 24.7 Mg.
3. UFC encased in bentonite jacket (UFC/BJ), octagonal, 1670 mm over flats, 4380 mm long. Mass 36.7 Mg
4. Shielding cask, round, 2.305 m diameter x 5.0 m long. Mass, including UFC/BJ, 86.5 Mg.
5. Emplacement rate 371 containers/y, maximum 2 containers/d.
6. Preferred container attitude is horizontal during transport. Vertical attitude can be considered.
7. Containers may be transported down the shaft in shielding casks, or alternately without casks, but with shielding provided either by the cage structure or by fixed shielding at loading and unloading areas.
8. Transport of UFC/BJ's in the underground repository will be on railcars.
9. A steel thickness of 150 mm is required for gamma shielding, with the addition of 50 mm of polyethylene for neutron shielding.
10. Shaft and hoisting design will be according to Province of Ontario Occupational Health and Safety Act and Regulations for Mines and Mining Plants.
11. When the repository is decommissioned the shaft will be sealed and backfilled, using clay-based sealing material as used in UFC/BJ emplacement. Removal of

shaft lining will be required prior to backfilling to eliminate possible fluid passages at the concrete/rock interface.

### 1.3 PREVIOUS WORK

The project will be based on previous studies<sup>1, 2</sup>, extending that work to accommodate redesigned fuel emplacement containers, modified storage rate, and other changes to operating concepts.

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<sup>1</sup> Engineering for a Disposal Facility Using the In-Room Emplacement Method, P. Baumgartner, D.M. Bilinsky, Y. Ates, R.S. Read, J.L. Crosthwaite, D.A. Dixon, AECL-11595-96-223, June 1996.

<sup>2</sup> Used Fuel Disposal Centre – A Reference Concept Vol. I, II, III, AECL-CANDU, J.S. Redpath Mining Consultants, Golder Associates, The Ralph M. Parsons Company, April 1992

## 2 SUMMARY

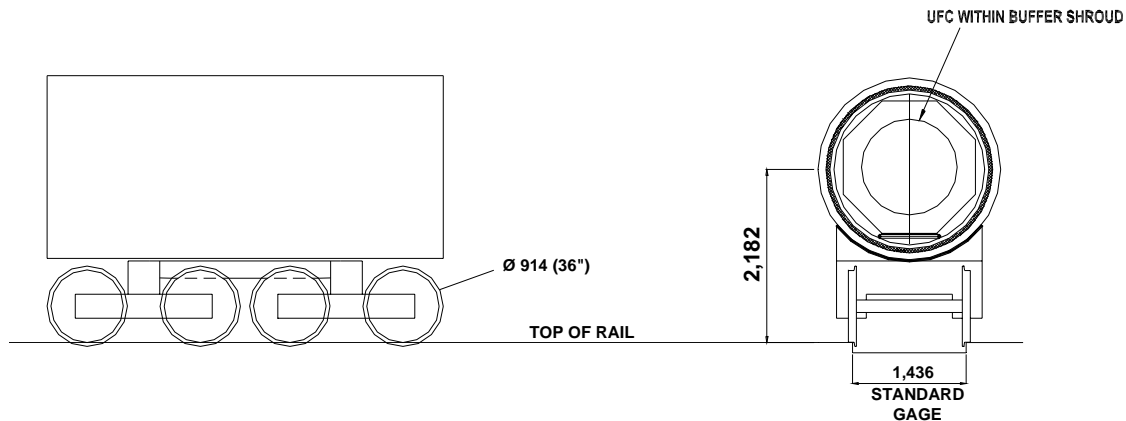
### 2.1 THE FOLLOWING CASES WERE CONSIDERED:

- Case #1 A cask containing a UFC/BJ is loaded on a railcar in the surface packaging plant, moved to the shaft and pushed in the horizontal position into the shaft cage. The railcar with cask is pulled out of the cage on the repository level and moved to the emplacement location. Cage payload including railcar is maximum at 95.2 Mg, with estimated cage mass of 38.1 Mg.
- Case #2 A UFC/BJ is moved to the shaft in a transport cask, then transferred to a lighter unshielded railcar for transit down the shaft. The cage is unshielded, but fixed shielding is installed around the shaft compartment at landings. At the repository level a crane beside the shaft transfers the UFC/BJ to another transport cask for travel to the emplacement location. Payload mass is reduced to 40.4 Mg, with a cage mass of 16.1 Mg.
- Case #3 This is similar to Case #2, except that the shaft cage is shielded so that work around the loaded cage would be possible in case of operating problems. Transfers between a light railcar used in the cage and a cask and railcar used for transport outside the shaft area would still be necessary. Payload remains at 40.4 Mg, but cage mass is increased to 60.0 Mg.
- Case #4 A cask with UFC/BJ is brought to the shaft in horizontal position, then picked up by a large crane beside the shaft, rotated to vertical position, and set on a special railcar for movement in and out of the shaft. On the repository level the procedure is reversed, using another large crane to rotate the cask to horizontal position and load it on another railcar for transport to the emplacement area. Projecting trunnions are needed on the cask for pickup by the crane. Payload is 95.0 Mg, with cage mass of 38.0 Mg.
- Case #5 This is similar to Case #4, except that the cask and cage are designed so that the cask can be picked up and tilted using the main shaft hoist, eliminating the need for additional cranes beside the shaft. No railcar is carried in the cage. Payload is 86.5 Mg, with cage mass of 39.0 Mg.
- Case #1 is recommended as the base case for ongoing studies. This is the most expensive option, but it offers the simplest cask handling procedures. This is expected to result in lowest maintenance requirements and accident frequency. The large shaft diameter offers greater flexibility should plans require handling of larger equipment. The marginal cost difference between this option and the least expensive is approximately C\$4,600,000: this is not significant in the total project cost.
  - The maximum payloads proposed can be handled by a Koepe hoist using currently catalogued hoist ropes.
  - Blair-type drum hoists were briefly considered, but costs are high and the surface structures complex.
  - Hoisting speed is not critical because of the low duty cycle. A speed of 2.5 m/s (7.7 RPM) was used for study purposes. The hoist will be driven through a two-stage reduction gear to obtain this low RPM. Transit time through the shaft will be

approximately seven minutes. Because of the low speed, electrical drive costs will be a relatively minor part of the total hoisting system and savings through further hoist speed reduction would be negligible.

- The vertical and unshielded UFC/BJ options markedly reduce shaft diameter, at the expense of more complex handling equipment and procedures. Hoist size is also reduced when handling unshielded UFC/BJ's in an unshielded cage. Although the capital cost differential in selecting one of these options is not considered significant at the present stage, these choices might be more attractive should an arrangement be selected which required more cask length.
- The Koepe hoist will be tower mounted in a concrete headframe. Protection against sabotage or terrorist attack should be considered: concrete construction is inherently damage-resistant as compared to steel, and can be easily strengthened to any desired specification by increasing wall thickness.
- Overall height will be approximately 38.0 m to the top of the roof parapet. Installation of the hoist will be done with a mobile crane; an overhead crane capable of maintenance lifts will be installed in the hoistroom.
- The electrical room will be at ground level, attached to the headframe. Reinforced concrete construction is recommended for security reasons.
- Hoist control will be from a central control room at the service shaft.
- The cage will be of steel construction. The floor will be designed as a bridge deck within the cage frame, able to slide vertically to isolate the effects of rope elasticity when landing on banking beams.
- Banking beams at collar will be retractable, while those at repository level will be fixed during operation. Special shock-absorbing systems will be included to handle the heavy loads.
- As this shaft will be sunk after repository access is available through the Service Shaft, excavation by raise-and-slash methods offers more economical sinking and potentially enhanced wall rock conditions compared with the use of pilot-and-slash blasting methods.
- Conventional shaft lining would consist of a nominal 300 mm thickness of concrete. In this shaft intermittent curbs are recommended, located at 5.5 m spacing to support the shaft sets. This will reduce initial cost slightly, and greatly reduce decommissioning work. It is also possible to omit lining entirely, using rock bolts and mesh for ground support; this is particularly appropriate if rope guides are used, eliminating the need for set support. The latter option will reduce the costs of stripping and sealing the shaft to a minimum.
- Additional grouting or other water control measures should be allowed for to ensure a clean working environment.
- The shaft was specified in the original study references as being dedicated to the handling of used fuel. The presently projected duty will require less than one hour per day of shaft time. Alternate uses of this very large payload hoisting system can be considered with no compromise of the primary requirement. These uses might include: transport of heavy excavation equipment: transport of clay-based sealing and other bulk materials from a surface preparation plant. The latter option would greatly simplify the





**FIGURE 1**  
**RAIL CAR USING ARTICULATED RAIL TRUCKS**

underground arrangements, and would permit more flexibility in the block forming of the clay-based sealing material. This would be particularly valuable should extended curing of the blocks prove necessary before emplacement.

## 3 CASK AND RAILCAR ARRANGEMENTS

### 3.1 GENERAL

A single railcar will preferably carry the UFC/BJ from the packaging plant on surface to the emplacement location underground. The details of handling procedures, particularly during emplacement of the UFC/BJ in the repository, are not known at this time

### 3.2 BOGIE DESIGN WITH SEPARATE CASK

#### 3.2.1 Horizontal Cask

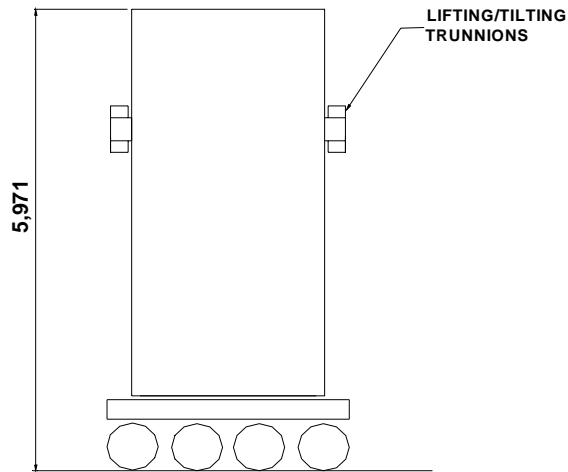
The design shown in Figure 1 is based on conventional railcar design, with a chassis supported on two – four wheeled trucks, or bogies. The chassis pivots on the bogies when traversing curves. Wheel diameter and wheelbase (within each bogie) are reduced from standard railway practice for 100 ton cars to minimize shaft diameter and lower the height of the UFC/BJ. The chassis must be designed to cradle the cask, possibly with retaining catches. Wheel gauge is shown as railway standard, although increased gauge would increase stability and should be considered in final design.

#### 3.2.2 Vertical Cask

The advantage of transporting the UFC vertically in the shaft is that it allows a smaller shaft diameter.

The disadvantages are:

- Additional activities and hoisting equipment are required to stand the cask vertically before entering the cage and to lay it horizontally after leaving the cage for underground transport.
- Trunnions for lifting and tilting the cask will increase width, possibly making the cask less



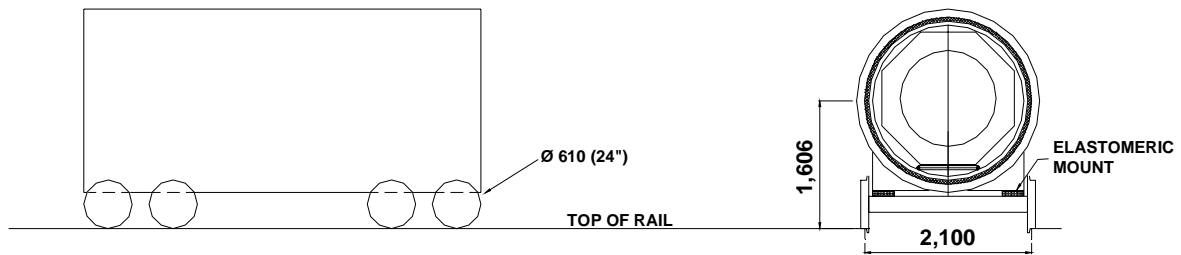
**FIGURE 2**  
**VERTICAL CASK/RAIL CAR DESIGN**

F  
C  
b  
  
A  
k  
e  
s  
l  
i  
v  
c  
a  
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o  
o

### 3.2.3 Integrated Design with Wheels on Cask

Figure 3 shows a car design in which the axles attach directly to the cask structure. The primary purpose of this design is to reduce the height of the cask to reduce excavation requirements. There is also some reduction in overall weight.

The axles are supported on elastomeric pads which accommodate vertical discrepancies in rail elevation so as to share load on the wheels. They also provide lateral flexibility so the wheels can track around curves.



**FIGURE 3**  
**UNITIZED CASK/RAIL CAR DESIGN**

## 4 HOISTING PLANT

### 4.1 HOIST SELECTION

#### 4.1.1 General

Even the lightest payload considered is beyond the capacity of a single hoist rope as currently available. The two commonly accepted multi-rope hoisting systems are the Blair drum hoist system, which normally uses two ropes per conveyance, and the Koepe, or friction hoist, system, which can use as many ropes as can be attached in the available space on the conveyance centerline. More than eight ropes are seldom used.

Safety catches are not required by Ontario hoisting regulations when multiple ropes are used.

#### 4.1.2 Drum Hoists

The Blair Multi-Rope (BMR) system provides two winding drums for each conveyance; for counterweighted hoisting this results in four drums connected to two conveyances. These four drums are normally mechanically linked together. Some installations have used electrical interlinking, but the electrical costs become very high. The tensions in the two ropes connected to each conveyance tend to vary because of differences in spooling on the winding drums, or variations in rope elasticity. The tensions must be equalized, normally by a floating headsheave arrangement supported by a hydraulic system linked between the two sheaves.

As in any drum hoist, rope handling is somewhat simpler than with a Koepe system, as all ropes can be wound to surface for changing.

The normal BMR could handle the loads in Case 3, UFC/BJ in unshielded cage, but at a cost probably \$10,000,000 - \$12,000,000 greater than would be needed for a friction hoist of the same capacity.

A four-rope BMR can be visualized, which would have no counterweight. Two mechanically connected drums would be mounted on either side of the shaft, with electrical linking between the two sides. The four ropes could handle the loads in Case 1, but at an additional cost of perhaps \$15,000,000. The principal attraction in this system is that with a single conveyance and no tail ropes, the cage could be designed for pneumatic retardation in case of a runaway. This is a system which has been postulated previously, but has never been implemented; its pursuit cannot be recommended.

#### 4.1.3 Koepe Hoists

The Koepe system leads the multiple ropes (head ropes) over a friction wheel, with a conveyance attached to each end; in this case there will be a cage on one end and a counterweight on the other. The load ratio ( $T_1/T_2$ ) between the two sides of the friction wheel must be kept within certain limits. To assist with this, balance ropes (tail ropes) are hung from the bottom of one conveyance to the bottom of the other to compensate for the changing weights of the head ropes as the conveyances travel up and down the shaft.

Since none of the ropes are attached to the hoist, and tension ratios must always be observed, special procedures must be used for rope installation and changing. Special rope winders are often provided for this service. Although rope handling is more complicated, rope life is normally better than with a drum hoist, where wire damage from multi-layer spooling is common with highly tensioned ropes.

The Koepe hoist is often mounted in a headframe tower immediately over the shaft. All ropes are thus enclosed in the headframe, protected from weather and outside interference. The principal features of the hoists calculated for the various cases are summarized below. Hoist diameters have not been rationalized.

CASE	ROPES Number x diameter, mm x kg/m	HOIST DIAMETER mm	RMS POWER kW
1	6 x 54.0 x 16.16	6210	1420
2	4 x 42.9 x 10.04	4934	510
3	6 x 46.0 x 11.67	5520	560
4	6 X 54.0 X 16.16	6210	1420
5	6 X 52.4 X 15.30	6026	1300

#### 4.1.4 Hoist Control

The hoist will normally operate on automatic control. During shaft inspection and maintenance, while crew are riding on top of the cage, control will be by manual remote radio link. Special operations such as rope installation or changing will be manually controlled from an operating console. This hoist will be installed some years after commissioning of the Service Shaft. Assuming that the Waste Handling Shaft will be relatively close to the Service Shaft, it is anticipated that the control console for both will be located in the Service Shaft hoist control room.

#### 4.1.5 Safety Features

Hoisting safety provisions fall into four main areas:

1. Structural/mechanical strength.

- Regulations require the aggregate breaking strength of the hoist ropes to exceed the total suspended load by a large factor; at a depth of 1000 m the factor, for a Koepe hoist, is approximately 6.3:1.
- Factors for conveyances and headframe structures are expressed differently, but the general principle is that these components of the system are able to survive a rope-breaking incident without catastrophic failure. Some repair of deformed members is accepted in such a case.
- Hoist main shaft and wheel are designed for infinite fatigue life at the specified loads.

2. Mechanical Redundancy

- Multiple hoist ropes on a Koepe hoist provide redundancy, since loss of up to half the ropes would not reduce the total rope breaking strength below the total suspended load. In the case of a single rope drum hoist, safety dogs are required for personnel hoisting, thus providing a redundant support system for the cage in case of a rope failure.
- Braking systems are divided into two halves. Each has a separate brake disk, calipers, and application valves. Each half of the system has the capacity to stop and hold the greatest load to be carried. The brakes may be applied by pneumatic or hydraulic pressure in normal operation, but in an ultimate emergency situation will be applied by springs or weights, which are independent of any outside power source.

3. Control Redundancy

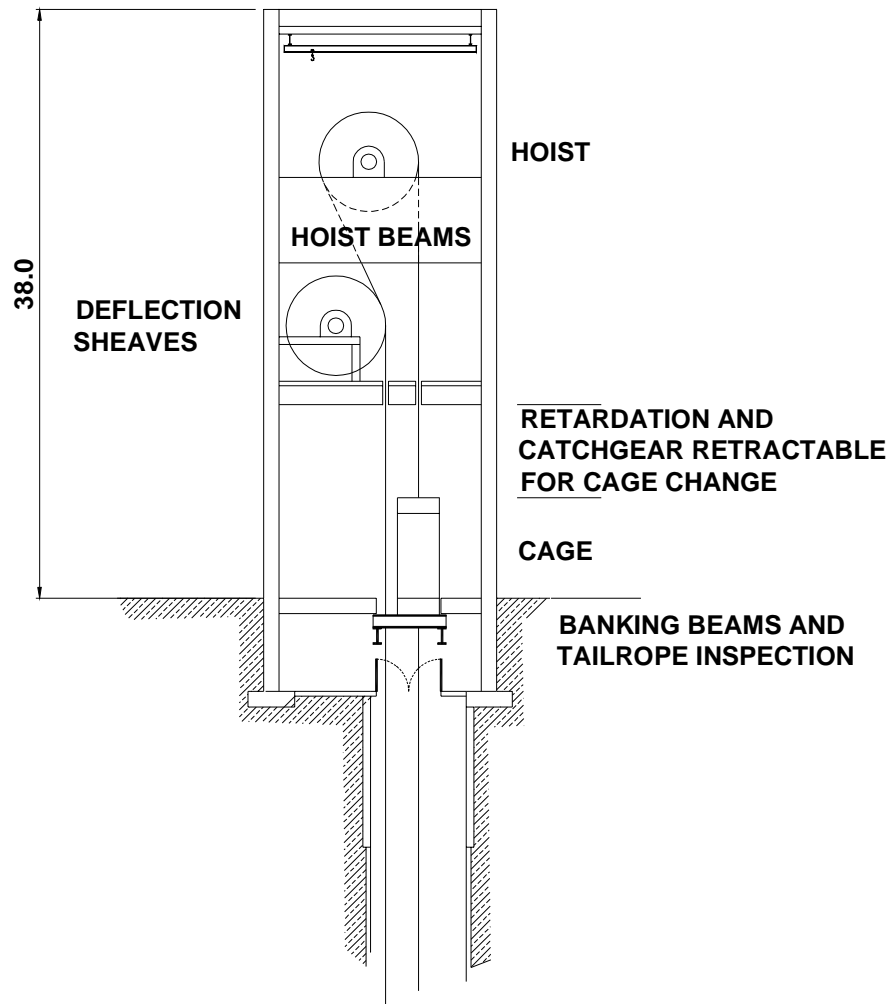
- The primary hoist control provides a speed/position operating envelope within which the hoist must operate. This defines maximum speed, speed limits in specific areas such as when approaching a stopping point, acceleration and deceleration rates, and limits of travel distance. Stopping points are defined by the hoist control, but normally the final stopping point is controlled by a physical position switch in the shaft. The control system will normally have two inputs for critical items, such as dual encoders for conveyance position, or encoder with tachogenerator backup for conveyance speed. Various other items, such as correct release of brakes, correct system voltage, proper brake operating pressure, and motor current limits are fed into the system from external sensors; if these values breach the operating rules an emergency stop is invoked.
- A hoist monitor follows the action of the primary control, providing a second speed/position envelope. If the operating envelope or values are breached an emergency stop is invoked. Modern digital hoist monitors provide many additional functions, such as recording performance during emergency stops.
- Physical limit switches (track limits) in the conveyance travelway provide a third limit to conveyance travel. Additional switches are typically used to synchronize the control system digital position indicator with the actual conveyance position, and to check speed at a particular points in the shaft against the speed envelope at this position.

- The safety circuit, which invokes an emergency stop, consists of several contacts connected in series. Some of these are direct connections to sensors, such as the track limit switches, brake wear switches, position switches and pressure switches, or motor current limit. Others are activated by the hoist control or monitor Programmable Logic Controller (PLC) if the operating envelope or operating rules are breached. All contacts must be in closed condition if the hoist motor is to be energized and the brakes released; the loss of any circuit wiring causes the same result as the opening of a safety contact. Once the hoist is in motion, fault conditions handled through the PLC may invoke either an immediate stop or a preventive stop, in which the hoist is allowed to complete the current trip, but prevented from starting again. A preventive stop might be caused by such things as failure of a hoist motor cooling fan, which will not cause immediate danger or damage to the system.
- Some systems may provide an electrically controlled stop, much less stressful for the equipment than a full mechanically braked emergency stop, for some problems which are not immediately threatening.

## 4.2 HEADFRAME

The headframe can be either of steel or concrete construction; there is little to choose in terms of cost. The concrete tower is usually faster to enclose when weather is a schedule factor. It can also be economically reinforced against sabotage by increasing wall thickness. Concrete is proposed for this project.

Figure 4 is a section through the headframe showing principal features. Since the headframe is relatively low (38.0 m), hoist installation will be done with a mobile crane. A smaller crane will be installed over the hoist for maintenance tasks such as lifting bearing caps and brake units. An electrical room will be built on ground level adjoining the headframe. This would typically be a steel-framed building, but in this case reinforced concrete is recommended.



**FIGURE 4  
HEADFRAME  
VERTICAL SECTION**

## 4.3 END ZONE ARRANGEMENTS

### 4.3.1 Cage Banking Arrangements

The cage must be banked, or landed, on fixed supports when loading and unloading railcars so that the rails on the cage match closely with those on the station. A combination of elastomeric and hydraulic shock absorbers will be used to avoid impact as the cage is landed. The final



landing onto the fixed supports will be done hydraulically, as this can be controlled more precisely than is possible with the hoist.

The payload will cause a rope stretch of approximately 0.7 m when the payload is at the repository level. The head rope tension must be released by an amount equivalent to the payload before the load is removed, otherwise the cage will rise violently as the wheels of the railcar leave the cage. Section 5.1 below describes the cage floor arrangement which will be used to isolate the effects of rope elasticity from the railcar loading/unloading.

Rope stretch is much less when loading at the collar, but is sufficient that, with the loads being considered, banking beams will be required. Collar banking beams must be retractable to let the cage pass. Banking beams at shaft bottom will be fixed in lateral position during operation, but will be retractable to allow the conveyances to be raised above collar level during installation and maintenance.

#### **4.3.2 Retardation and Catchgear System**

Regulations and good practice call for a retardation system at top and bottom of travel capable of stopping a conveyance traveling at full speed, and a catchgear system at the top of travel which will prevent a conveyance falling down the shaft in case of an incident which breaks the hoist ropes.

Because of the low speed in this case less than one meter of retardation distance is needed. Hydraulic retardation is proposed. At shaft bottom the retarder cylinders will support the banking beams, allowing them to sink sufficiently under heavy impact to stop the conveyance at a deceleration rate of approximately 0.9 g.

A similar retardation system will be used in the headframe, and will be incorporated with a catchgear system. The catchgear provides a latching system to engage the conveyance should it travel past the normal stopping point. Although catchgear is designed to minimize fallback of a conveyance, shock absorbers must also be provided to soften the impact of a conveyance dropping onto the latches.

The counterweight will be provided with retarders and catchgear similar to that for the cage.

## 4.4 ALTERNATE TECHNOLOGY

### 4.4.1 Block Hoist System

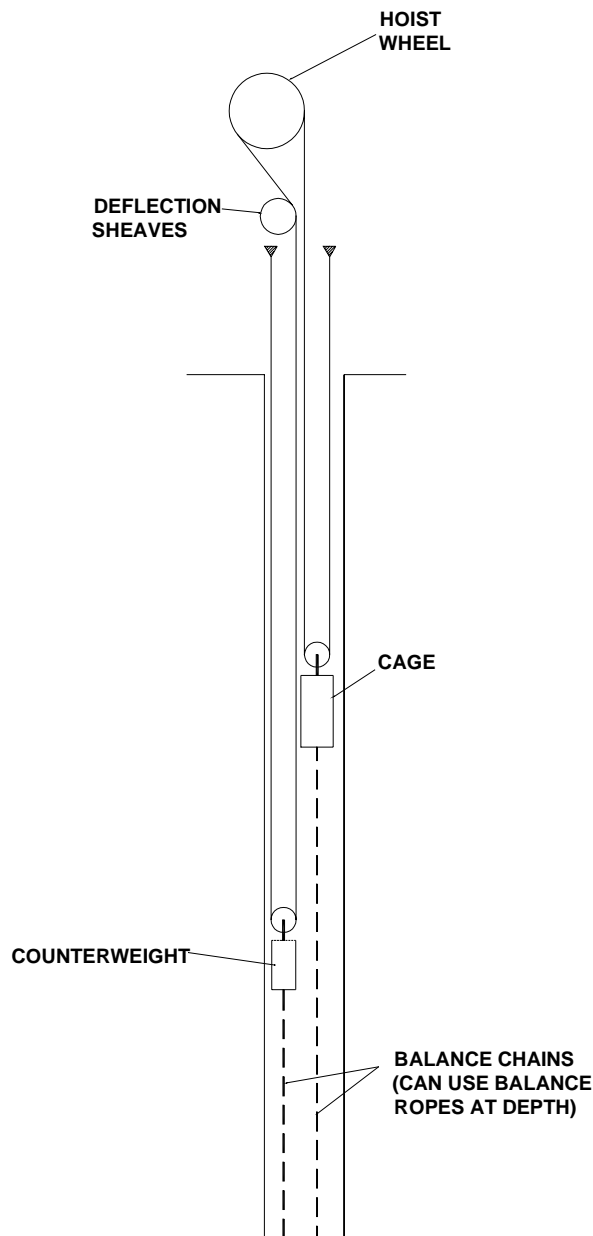
The 'Block Hoist' system has been used several times in South Africa for handling loads of up to 64 tonnes, at depths of over 300 m. It is more complex than an ordinary Koepe hoist, but allows smaller ropes to be used. At shallow depths the hoist wheel can also be smaller, but at the

proposed depth of the repository the hoist diameter is governed by the number of turns required per trip, and would be approximately the same as the largest Koepe hoist being considered.

To maximize the advantages of this system it would be necessary to use stranded ropes rather than Full Locked Coil, which is not usual Canadian practice at the proposed depth. The layout would be improved if permission could be obtained to use sheave diameter:rope diameter (D:d) ratios of less than the 80:1 normally required.

The system would be a more attractive alternative if the repository was to be located at shallower depth. It is not recommended for the depth being considered.

Figure 5 shows the concept, using a D:d ratio of 60:1 for the sheaves on top of cage and counterweight. Shaft diameter would be approximately 7.0 m with this arrangement.



**FIGURE 5  
BLOCK HOIST SYSTEM  
ARRANGEMENT**

## 5 CAGE

### 5.1 GENERAL

Three principal cage variants are considered, in various dimensions. All but one variant is designed for handling railcars. All cages are designed without doors, with the railcar locked into the cage by means of mechanized rail chocks, except in Case 3 where a door is provided for shielding. The variant without rails carries the cask vertically, suspended from saddles that engage trunnions on the cask.

All cages will have a floor designed as a platform that can slide within the framework of the cage. This allows the payload to be landed on banking beams while the weight of the tail ropes and major part of the cage remains suspended from the head ropes. This removes from the ropes the elastic stretch due to payload, while maintaining an acceptable T1/T2 ratio. It provides a totally static situation while loading and unloading railcars. Other means of handling this problem have been used, but do not provide the simplicity of positively isolating rope tension and proving correct release by means of simple limit switches<sup>3</sup>.

All cages are expected to have some powered devices onboard, such as rail chocks, other load retaining devices, or winches. Power will be provided by bayonet-style contacts that engage sockets on the cage when at loading/unloading position. Energization of the circuit will be controlled by interlocks; no voltage will be present unless the cage is in position and hoist brakes set. The devices will be activated by springs or weights to return to a locked or failsafe condition when power is removed.

### 5.2 HORIZONTAL CASK ATTITUDE

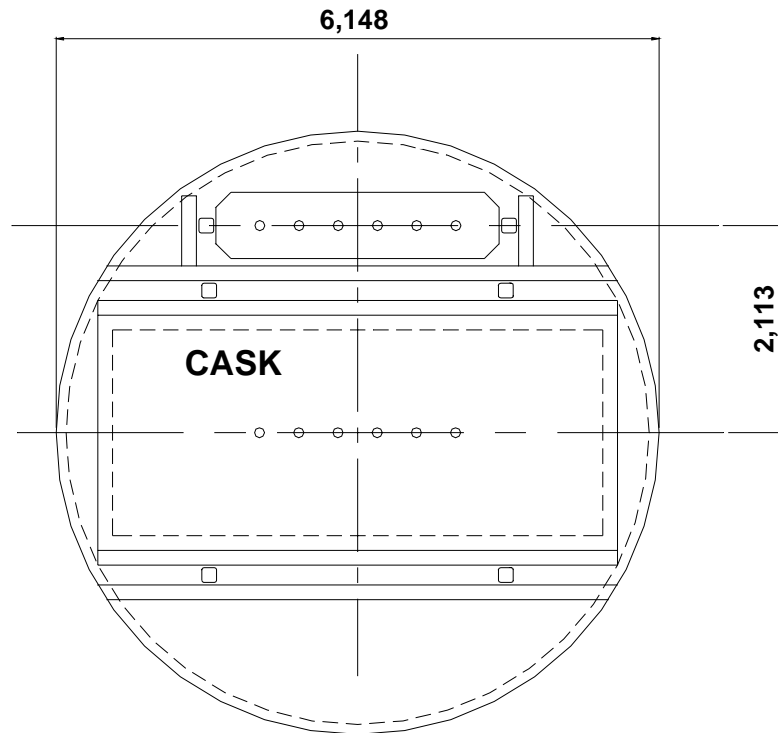
#### 5.2.1 Unshielded Cage

##### 5.2.1.1 Case #1

Figure 6 illustrates a cage sized to accept a cask of specified size and loaded weight. This represents the simplest shaft operating situation, as the load approaches and leaves the shaft in horizontal position and is fully shielded so that crew can work adjacent to a loaded cask in case of any emergency maintenance problem. The price of this convenience is large shaft diameter (6.15 m).

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<sup>3</sup> Englemann, H.J., W. Filbert and C. Schrimpf. 1993. Demonstration tests for the simulation of shaft transfer. In Proceedings of the Symposium on Waste Management (WM'93). Tucson, Arizona. V2 pages 1311-1315.

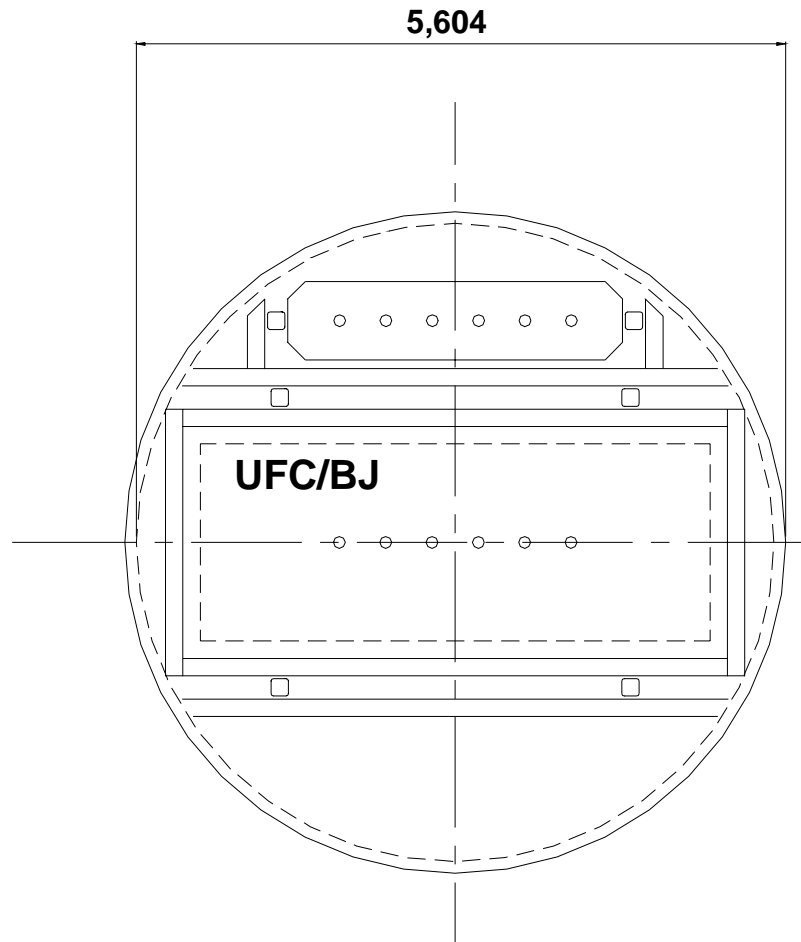


**FIGURE 6**  
**SHAFT PLAN FOR HORIZONTAL CASK TRANSPORT**

#### 5.2.1.2 Case #2

Figure 7a illustrates a cage sized to handle a UFC/BJ without shielding cask. In this case shielding will be provided on all vertical sides of the cage compartment at surface and repository level. Opening the compartment gate, and all subsequent activities until the UFC/BJ was transferred to and enclosed in a transport cask, would be conducted remotely. Note that in this case the number of hoist ropes is reduced because of the lesser payload.

Savings are obtained in shaft, hoist, ropes, and cage at the penalty of increased cost for remote operating devices, more complex handling activities, and limitations on emergency maintenance activities. Large cranes will be needed at shaft side to transfer the UFC/BJ into a shielded railcar. A possible advantage of this system lies in the ability to conveniently use different car styles on surface and underground, should the requirements of packaging and emplacement favor different designs.



**FIGURE 7b**  
**SHAFT PLAN FOR UFC/BJ TRANSPORT**  
**IN SHIELDED CAGE**

### 5.2.1.3 Case #3 - Shielded Cage

Figure 7b illustrates a cage sized to handle a UFC/BJ without cask, as in 7a. However, in this case the cage structure is constructed of steel plate to provide shielding equivalent to a cask. Overall weight of cage and shielding is less than that of cage plus cask, since the shielding plates form major structural members. However, the hoist must still use six ropes, very nearly equal to the hoist used in case 4. This, together with additional cage length to provide heavy doors, results in a larger shaft than in 7a.

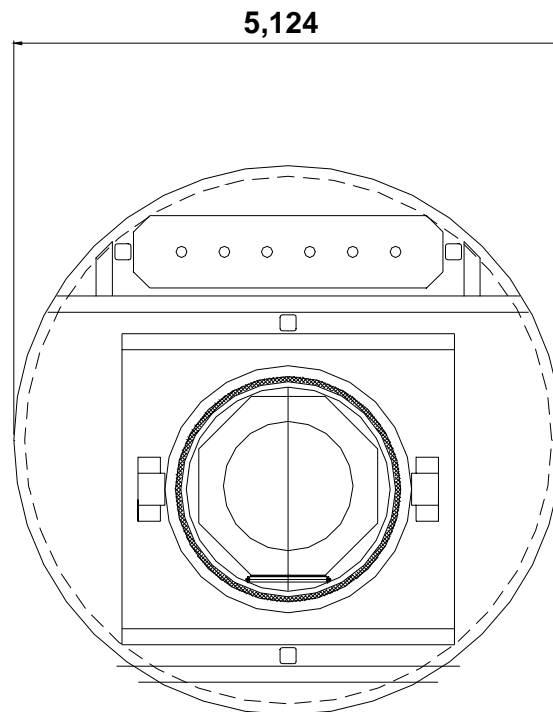
Although it would be possible to work around the shaft station with a loaded cage present, all activities to transfer the UFC/BJ to a transport container would still have to be done by remote operation. As in the previous case, large cranes would be needed at the shaft to transfer UFC/BJ's to and from the cage. The value of this approach as compared to case 7a is questionable.

## 5.3 VERTICAL CASK ATTITUDE

### 5.3.1.1 Case #4 - Cask Tilted Outside Shaft

The UFC/BJ is assumed to arrive at the shaft in horizontal position in a transport cask. The cask would be designed with trunnions, complete with bearings, so that it could be lifted by crane near the shaft, rotated to the vertical position, and set on a short-wheelbase car to be moved into the cage. This special car is visualized to move only a short distance in a straight line to and from the shaft, so that axle design can be very basic. The cage would be equipped with a yoke that lowers around the upper end of the vertical cask to secure it against any lateral impulses.

At the repository level the car would be pulled out of the shaft and the cask transferred to a transport car for the trip into the repository. Another large crane would be needed near the shaft, and additional excavation would be needed to accommodate it. The bentonite jacket on the UFC would experience some mechanical shearing forces during tilting that might be objectionable. The cage arrangement for this option is shown as Figure 8a.

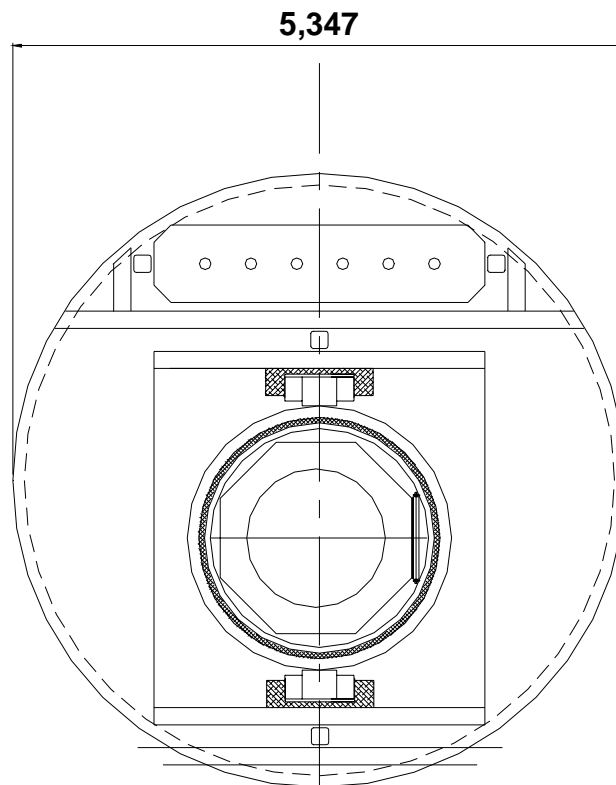


**FIGURE 8a**  
**SHAFT PLAN FOR TRANSPORT OF CASK**  
**LOADED VERTICALLY ON RAILCAR**

### 5.3.1.2 Case #5 - Cask Tilted in Cage

The cage would be designed with saddles to engage the lifting trunnions on the casks. All tilting would be done within the cage using the main hoist. The cage floor would serve as a bridge so a standard car could enter the cage on surface to deliver the cask, and then be removed. The floor would be able to slide downwards a sufficient vertical distance to allow the cask to hang in the trunnions so that the car can be removed. An on-board winch would control cask movement during tilting, and would return the cask to horizontal position at the repository level. On the repository level the cask would be tilted horizontal, a similar car would enter the cage, and the cage would be lowered until the load rested on the car and the trunnions lifted clear of the saddles, at which time the car would be pulled out of the cage.

Figure 8b shows a slightly larger shaft than in 8a, due to the orientation of the cask trunnions. Handling arrangements would be simplified, since no additional major cranes would be needed for tilting the casks. Net rope loads would be slightly less, since the weight of the trunnion saddles is expected to be less than that of a short-wheelbase railcar and no retaining yoke would be needed for the top end of the cask.



**FIGURE 8b**  
**SHAFT PLAN FOR TRANSPORT OF CASK**  
**SUSPENDED VERTICALLY IN CAGE**



## 6 SHAFT

### 6.1 GENERAL

Shaft arrangements have been shown in Figures 6, 7a,b, and 8a,b.

CASE NO.	FINISHED DIAMETER m	EXCAVATED AREA m <sup>2</sup>
1	6.15	35.8
2	5.45	28.7
3	5.61	30.3
4	5.13	25.8
5	5.35	27.8

The shaft is assumed to be in sound rock such that only nominal ground support is needed. Ground water will be controlled primarily by grouting, although short sections of hydrostatic lining might be included in the near surface sections where most water is encountered. A water collection ring will be provided immediately above the repository level; additional water rings could be provided at other shaft locations if needed.

Characterization of the shaft walls will be a significant time element in the sinking schedule. The schedule should allow one shift per day for characterization, with two shifts per day for sinking. Shaft cross-section is controlled by the cage floor plan and the number of hoist ropes needed to support the payload (influences counterweight width). A minimum clearance of 100 mm is allowed between cage and shaft walls.

No permanent pipes are expected in the shaft. Although this will be a rather critical operating system, the conditions in this shaft will be much safer than in any other shaft in the proposed complex, and electrical and communications cables can be routed through here. Communications cables for the hoist controls and cask handling equipment will be carried on the shaft walls. A leaky coaxial cable should be installed for reliable communications during shaft inspection.

### 6.2 SHAFT LINING AND FURNISHING

A concrete lining of 300 mm thickness would be conventional for a shaft of this nature. However, the necessity of sealing the shaft on decommissioning, probably with removal of the lining, may render other approaches more attractive. As the site will be chosen on the basis of good rock quality, continuous concrete lining can be dispensed with, and support provided by rock bolts and mesh, shotcrete, or by concrete curbs at each set location with bolts and mesh between. All these approaches have been previously used in mining shafts. There is a penalty in increased ventilation resistance, but this shaft is not intended to carry large volumes of air. If concrete curbs, one meter high, are installed at 5.0 m intervals, conventional steel sets and guides, as shown in the illustrations, can be readily installed. In planning for decommissioning, the argument could be made that having potential flow paths of one meter length behind the curbs, separated by 4.0 m lengths of clay-based sealing material, will provide sealing substantially equivalent to that which would be accomplished by removal of the curbs. The curbs would serve as excellent bases for the full concrete seals that will possibly be placed at three locations in the shaft.

Rope guides could be readily used at this depth, although wall clearances would have to be increased to 200 mm. Rope guides, together with an unlined shaft, would reduce excavation volume somewhat since the additional wall clearance needed would be more than offset by the elimination of the 300 mm concrete thickness. Guide rope life in the conditions envisaged in this shaft could exceed 25 years. Inspection and maintenance effort would be reduced as there are no structural connections to be checked within the shaft.

Concrete curbs with conventional steel sets are recommended for this shaft, subject to evaluation of the need for removal of the curbs on decommissioning.

### **6.3 SINKING ARRANGEMENTS**

The Service Shaft will be the first shaft to be sunk, as it must support development of the repository and initial underground characterization. The Waste Handling Shaft and Ventilation Shafts are indicated to be relatively close to the Service Shaft, providing the opportunity to use the more economical raise and slash method for excavating these shafts. The raise and slash method is well suited to the pilot and slash blasting technique that was developed at WNRE. Long slash rounds can be broken to the pilot raise, potentially improving shaft wall conditions and promoting more effective sealing when decommissioning.

The shaft depth is excessive for single-lift raising, but the provision of a mid-shaft access level to support raise development may be justified.

The Koepe hoist could be rigged as a single drum hoist to service the slashing operation, eliminating the cost of installing a temporary sinking hoist.

### **6.4 VENTILATION**

Downcast ventilation in the Canadian climate produces very dry shaft conditions in the winter, when heating is needed. This results in very good maintenance conditions with negligible corrosion. In summer, particularly if the site should be in the southern Precambrian Shield area where high humidity can occur, surface air tends to cool as it meets the shaft walls, and may condense substantial amounts of water. This may occur on relatively few days, depending on location, and under normal circumstances a slight downcast flow would be preferred that potentially could incorporate the use of a dehumidifying plant. However, because of radiological safety concerns, the Waste Shaft should be upcasting. In the event of a radioactive release resulting from an upset condition in the Waste Shaft, the upcast arrangement prevents the underground area from being contaminated.

## 7 ESTIMATES

### 7.1 GENERAL

These estimates are prepared for the purpose of ranking the options considered in this report, and are presented as marginal cost differences for the major cost categories in provision of shaft and hoisting plant. The least cost case for each cost category is assigned a value of zero; marginal cost differences are then calculated from historical factors for the other cases.

For example, the electrical costs associated with a hoist include control systems and area power and lights, which are essentially constant for each option, plus a variable amount for DC converters and motors.

Estimates are in Canadian dollars. Target accuracy is +25%, -50%.

### 7.2 SUMMARY OF MARGINAL COSTS

Amounts in thousands of dollars.

CASE	SHAFT	HOIST	CONVEY'CES	ROPES & ATTACHM'TS	UFC/BJ HANDLING	TOTAL MARGIN	MARGINAL DIFFERENCE
1	4,120	1671	494	460	0	6744	4600
2	1,195	0	0	0	1100 <sup>1</sup>	2145	0
3	1,854	896	685	123	560 <sup>2</sup>	3968	1823
4	0	1668	492	460	460 <sup>3</sup>	3080	936
5	824	1507	481	396	0	3208	1063

Note:

1. Includes shaft side cranes for handling unshielded UFC/BJ's. Includes required surface structure and underground excavation. Allowance for fixed shielding around cage compartment at stations. Includes allowance for isolated control rooms and remote crane operating systems for handling unshielded containers.
2. Includes shaft side cranes for handling unshielded UFC/BJ's. Includes required surface structure and underground excavation. No allowance for fixed shielding as this is included in cage. Includes allowance for isolated control rooms and remote crane operating systems for handling unshielded containers.
3. Includes shaft side cranes for lifting/tilting loaded casks. Includes required surface structure and underground excavation.

## APPENDIX

Hoist Design Calculations

Cost Parameters

JR MORRIS ENGINEERING FRICTION HOIST DESIGN PROGRAM												
CASE:		OGP-DGR, LOWERING UFC/BJ IN UNSHIELDED CAGE						DATE:		02-Jul-02		
REFERENCE NUMBER:		02SNC-a										
SYSTEM TYPE:		Counterweighted Cage										
PRODUCTION RATE	tonnes/hour	400				PRODUCTIVITY FACTOR				1		
HOISTING DISTANCE	m	1000				MINIMUM CONVEYANCE TARE FACTOR				0.4		
SUSPENDED ROPE LENGTH	m	1015				COUNTERWEIGHT FACTOR				0.5		
HOIST DIAMETER	mm	4934				HOIST/ROPE DIAMETER RATIO				115		
EQUIV EQUIPMENT MASS	kg	258				MECHANICAL EFFICIENCY				%		
T1/T2 RATIO, allowable		1.40				TAIL LOOP LENGTH				m		
TOTAL SUSPENDED LOAD	kN	1719				HEADROPE/TAILOPE WT RATIO				1.00		
TREAD PRESSURE	kPa	2030				REVOLUTIONS/TRIP				64.5		
T1/T2 RATIO		1.26				T2/T3				1.35		
SIDE ONE						SIDE TWO						
CONVEYANCE MASS	kg	16148								36333		
PAYLOAD	kg	40370										
HEADROPES						TAILROPES						
NUMBER OF HEADROPES		4				NUMBER OF TAIL ROPES				4		
ROPE TYPE		FLC										
ROPE STRENGTH	kN	1564										
ROPE DIAMETER	mm	42.90										
ROPE UNIT WEIGHT	kg/m	10.04								10.04		
SAFETY FACTOR AT SHEAVE, STATUTORY		6.34										
ACTUAL		6.53										
ROPE LOADS												
	RATE	TIME sec	DISTANCE m	ROPE LOADS				HOIST EFFORT @ROPES kN	POWER kw	T1/T2		
				STATIC SIDE 1 kN	STATIC SIDE 2 kN	ACC'L'N SIDE 1 kN	ACC'L'N SIDE 2 kN					
ACCELERATE TO CREEP	m/s/s	0.25	2.00	0.50	958	760	24	-19	262	785	1.33	
					958	760	24	-19	262	785	1.33	
CREEP	m/sec	0.5	0.00	0.00	958	760			218	653	1.26	
					958	760			218	653	1.26	
ACCELERATE TO RUN	m/s/s	0.25	10.00	17.50	958	760	24	-19	262	785	1.33	
					958	760	24	-19	262	785	1.33	
RUN	m/sec	3	320.67	962.00	958	760			218	653	1.26	
					958	760			218	653	1.26	
DECELERATE TO CREEP	m/s/s	0.25	10.00	17.50	958	760	-24	19	174	522	1.20	
					958	760	-24	19	174	522	1.20	
CREEP	m/sec	0.5	4.00	2.00	958	760			218	653	1.26	
					958	760			218	653	1.26	
DECELERATE TO STOP	m/s/s	0.25	2.00	0.50	958	760	-24	19	174	522	1.20	
					958	760	-24	19	174	522	1.20	
LOAD/UNLOAD			60.00						0			
									0			
TOTAL			408.67	1000.00								
									POWER, fan-cooled		604	
									self-cooled		635	

JR MORRIS ENGINEERING FRICTION HOIST DESIGN PROGRAM												
CASE:		OGP-DGR LOWERING UFC/BJ IN SHIELDED CAGE						DATE:		02-Jul-02		
REFERENCE NUMBER:		02SNC-b										
SYSTEM TYPE:		CWTTED CAGE				GUIDE MATERIAL:		STEEL				
PRODUCTION RATE	tonnes/hour	NA				PRODUCTIVITY FACTOR		1				
HOISTING DISTANCE	m	1000				MINIMUM CONVEY'CE TARE FACTOR		NA				
SUSPENDED ROPE LENGTH	m	1015				COUNTERWEIGHT FACTOR		0.45				
HOIST DIAMETER	mm	5520				HOIST/ROPE DIAMETER RATIC		120				
EQUIV EQUIPMENT MASS	kg	474				MECHANICAL EFFICIENCY		%		95		
T1/T2 RATIO, allowable		1.40				TAIL LOOP LENGTH		m		10		
TOTAL SUSPENDED LOAD	kN	3160				HEADROPE/TAILOPE WT RA		1.00				
TREAD PRESSURE	kPa	2074				REVOLUTIONS/TRIP		57.7				
T1/T2		1.15				T2/T3		1.14				
SIDE ONE						SIDE TWO						
CONVEYANCE MASS	kg	60000				78167						
PAYLOAD	kg	40370										
HEADROPES						TAILROPES						
NUMBER OF HEADROPES		6				NUMBER OF TAIL ROPES		6				
ROPE TYPE		FLC										
ROPE STRENGTH	kN	1803										
ROPE DIAMETER	mm	46.00										
ROPE UNIT WEIGHT	kg/m	11.67				11.67						
SAFETY FACTOR AT SHEAVE, STATUTO		6.34										
ACTUAL		6.41										
ROPE LOADS												
	RATE	TIME sec	DISTANCE m	ROPE LOADS				HOIST EFFORT @ROPES kN	POWER kw	T1/T2		
				STATIC SIDE 1 kN	SIDE 2 kN	ACC'L'N SIDE 1 kN	SIDE 2 kN					
ACCELERATE TO CREEP	m/s/s	0.25	2.00	0.50	1689	1471	43	-37	318	955	1.21	
					1689	1471	43	-37	318	955	1.21	
CREEP	m/sec	0.5	0.00	0.00	1689	1471			238	713	1.15	
					1689	1471			238	713	1.15	
ACCELERATE TO RUN	m/s/s	0.25	10.00	17.50	1689	1471	43	-37	318	955	1.21	
					1689	1471	43	-37	318	955	1.21	
RUN	m/sec	3	320.67	962.00	1689	1471			238	713	1.15	
					1689	1471			238	713	1.15	
DECELERATE TO CREEP	m/s/s	0.25	10.00	17.50	1689	1471	-43	37	157	472	1.09	
					1689	1471	-43	37	157	472	1.09	
CREEP	m/sec	0.5	4.00	2.00	1689	1471			238	713	1.15	
					1689	1471			238	713	1.15	
DECELERATE TO STOP	m/s/s	0.25	2.00	0.50	1689	1471	-43	37	157	472	1.09	
					1689	1471	-43	37	157	472	1.09	
LOAD/UNLOAD			60.00									
TOTAL			408.67	1000.00								
									POWER, fan-cooled		661	
									self-cooled		694	

JR MORRIS ENGINEERING FRICTION HOIST DESIGN PROGRAM												
CASE: OGP-DGR LOWERING WASTE CASK ON RAIL CAR			DATE: 02-Jul-02									
REFERENCE NUMBER: 02SNC-C												
SYSTEM TYPE: Counterweighted Cage												
PRODUCTION RATE	tonnes/hour		NA	PRODUCTIVITY FACTOR				1				
HOISTING DISTANCE	m		1000	MINIMUM CONVEYANCE TARE FACTOR				0.4				
SUSPENDED ROPE LENGTH	m		1015	COUNTERWEIGHT FACTOR				0.4				
HOIST DIAMETER	mm		6210	HOIST/ROPE DIAMETER RATIO				115				
EQUIV EQUIPMENT MASS	kg		601	MECHANICAL EFFICIENCY				%				
T1/T2 RATIO, allowable			1.40	TAIL LOOP LENGTH				m				
TOTAL SUSPENDED LOAD	kN		4003	HEADROPE/TAILOPE WT RAT				1.00				
TREAD PRESSURE	kPa		1990	REVOLUTIONS/TRIP				51.3				
T2/T3			1.33	T2/T3				1.28				
			SIDE ONE				SIDE TWO					
CONVEYANCE MASS	kg		38060									76120
PAYLOAD	kg		95150									
			HEADROPES				TAILROPES					
NUMBER OF HEADROPES			6	NUMBER OF TAIL ROPES				6				
ROPE TYPE			FLC									
ROPE STRENGTH	kN		2472									
ROPE DIAMETER	mm		54.00									
ROPE UNIT WEIGHT	kg/m		16.16									16.16
SAFETY FACTOR AT SHEAVE, STATUTORY			6.34									
ACTUAL			6.50									
ROPE LOADS												
			STATIC		ACCL'N				HOIST EFFORT @ROPES		POWER	
RATE			TIME	DISTANCE	SIDE 1	SIDE 2	SIDE 1	SIDE 2			T1/T2	
			sec	m	kN	kN	kN	kN	kN		kw	
ACCELERATE TO CREEP	m/s/s	0.25	2.00	0.50	2282	1722	58	-44	709	2127	1.39	
CREEP	m/sec	0.5	0.00	0.00	2282	1722	58	-44	709	2127	1.39	
					2282	1722			607	1820	1.33	
ACCELERATE TO RUN	m/s/s	0.25	10.00	17.50	2282	1722	58	-44	709	2127	1.39	
					2282	1722	58	-44	709	2127	1.39	
RUN	m/sec	3	320.67	962.00	2282	1722			607	1820	1.33	
					2282	1722			607	1820	1.33	
DECELERATE TO CREEP	m/s/s	0.25	10.00	17.50	2282	1722	-58	44	505	1515	1.26	
					2282	1722	-58	44	505	1515	1.26	
CREEP	m/sec	0.5	4.00	2.00	2282	1722			607	1820	1.33	
					2282	1722			607	1820	1.33	
DECELERATE TO STOP	m/s/s	0.25	2.00	0.50	2282	1722	-58	44	505	1515	1.26	
					2282	1722	-58	44	505	1515	1.26	
LOAD/UNLOAD			60.00									
TOTAL			408.67	1000.00								
									POWER, fan-cooled		1683	
									self-cooled		1767	

OPG-DGR Hoisting Tradeoff Estimates  
Marginal Cost Basis  
February  
12,2002

CASE	SHAFT			HOIST ELECTRICAL			HOIST MECHANICAL			HOIST TOTAL	CAGE & CWT			ROPES & ATTACHMENTS			UFC/BJ HANDLING	TOTAL MARGINAL	MARGINAL DIFF
	Area	Unit \$	Marginal Cost \$'000	kw	Unit \$	Marginal Cost \$'000	eem	Unit \$	Marginal Cost \$'000	Weight, kg	Unit \$	Marginal Cost \$'000	Rope wt kg	Unit \$	Marginal Cost \$'000	CRANES, EXCAVATION, STRUCTURE	\$'000	\$'000	
1	35.8	400	4,120	1420	300	273	61215	40	1397520	1671	114180	8	494	223000	5.45	460	0	6744	4600
2	28.7		1,195	510		0	26277		0	0	52480		0	138550		0	950	2145	0
3	30.3		1,854	558		14	48312		881400	896	138167		685	161050		123	410	3968	1823
4	25.8		0	1418		272	61165		1395520	1668	114000		492	223000		460	460	3080	936
5	27.8		824	1291		234	58093		1272640	1507	112600		481	211140		396	0	3208	1063