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**Civilian Radioactive Waste Management System
Management & Operating Contractor**

Concept of Operations for Waste Transport, Emplacement, and Retrieval

TDR-WER-ME-000001 REV 00

July 2001

Prepared for:

U.S. Department of Energy
Yucca Mountain Site Characterization Office
P.O. Box 30307
North Las Vegas, Nevada 89036-0307

Prepared by:

Bechtel SAIC Company, LLC
1180 Town Center Drive
Las Vegas, Nevada 89144-6352

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**Civilian Radioactive Waste Management System
Management & Operating Contractor**

Concept of Operations for Waste Transport, Emplacement, and Retrieval

TDR-WER-ME-000061 REV 00

July 2001

Prepared by:

Norman T. Raczka
Norman T. Raczka
Senior Design Engineer

7/2/2001
Date

Checked by:

Homi J. Minwalla
Homi J. Minwalla
Checker

7/2/2001
Date

Approved by:

Bruce T. Stanley
Bruce T. Stanley
Waste Emplacement Engineering Team Lead

7/2/2001
Date

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ACRONYMS

°C	Degrees Celsius
CRWMS	Civilian Radioactive Waste Management System
DOE	U. S. Department of Energy
HEPA	High-Efficiency Particulate Air
kW	kilowatt
kW/m	kilowatt per meter
m ³ /s	cubic meters per second
MGR	Monitored Geologic Repository
M&O	Management and Operations (contractor)
NRC	U.S. Nuclear Regulatory Commission
OMCS	Operations Monitoring/Control System
PLC	Programmable Logic Controller
PWR	pressurized-water reactor
TWP	Technical Work Plan
WHB	Waste Handling Building
WP	Waste Package

1. OBJECTIVE AND SCOPE

The preparation of this technical report has two objectives. The first objective is to discuss the base case concepts of waste transport, emplacement, and retrieval operations and evaluate these operations relative to a lower-temperature repository design. Aspects of the operations involved in waste transport, emplacement and retrieval may be affected by the lower-temperature operating schemes. This report evaluates the effects the lower-temperature alternatives may have on the operational concepts involved in emplacing and retrieving waste. The second objective is to provide backup material for the design description, in a traceable and defensible format, for Section 2 of the Waste Emplacement/Retrieval System Description Document.

For purposes of this report, the following definitions are applicable:

High-Level Radioactive Waste (HLW)—(1) Irradiated reactor fuel; (2) liquid wastes resulting from the operation of the first-cycle solvent extraction system, or equivalent, and the concentrated wastes from subsequent extraction cycles, or equivalent, in a facility for reprocessing irradiated reactor fuel; and (3) solids into which such liquid wastes have been converted (NRC 1998, Section 63.2). It is worth noting that only waste in solid form is destined for storage at the Yucca Mountain repository.

Waste Transport—This operation involves the movement of the Waste Packages (WPs) from the surface facilities, specifically the Waste Handling Building (WHB), to the entrance of the designated emplacement drift.

Waste Emplacement—This operation involves the movement of the WPs from the entrance of the designated emplacement drift to its final placement within the drift.

Waste Retrieval—This operation involves the removal of the WPs from the emplacement drifts and moving them to the facilities located on the surface. Waste retrieval operations can take place under normal or abnormal conditions as further discussed in section 3.3.6.3 of this report.

The scope of this document is limited to discussing the operational concepts of moving a WP from the WHB to its final placement within the emplacement drift. Related to retrieval, this document is limited to discussing the operational concepts of moving a WP from an emplacement drift to facilities located on the surface.

2. QUALITY ASSURANCE

The quality assurance classification of repository structures, systems, and components (SSCs) has been performed in accordance with QAP-2-3, *Classification of Permanent Items*. The equipment involved in the waste emplacement and retrieval operations have Quality Assurance classifications ranging from QL-1 to conventional quality as documented in the *Classification of the MGR Waste Emplacement/Retrieval System* (CRWMS M&O 2001a, Section 7.1).

This technical report has been prepared in accordance with a Technical Work Plan (TWP) (CRWMS M&O 2001b) and M&O procedure AP-3.11Q *Technical Reports*. Included in the TWP is an activity evaluation (CRWMS M&O 2001b, pages A22 and A23), that has determined that this technical report is quality affecting. Therefore, this technical report is subject to the requirements of the *Quality Assurance Requirements and Description* (DOE 2000).

The method used to control the electronic management of data as required by AP-SV.1Q, *Control of the Electronic Management of Information*, was accomplished in accordance with the controls as specified in the TWP (CRWMS M&O 2001b, page B13).

3. TECHNICAL REPORT

3.1 INTRODUCTION

In the base case operating mode of the repository, the high-level waste will be emplaced to create a thermal line loading of 1.45 kW/m within each emplacement drift. The waste packages will be fully loaded and emplaced in the emplacement drifts end-to-end, with a separation between packages of 10 centimeters (CRWMS M&O 2000d, Section 1.2.1.9). The drifts will be ventilated during the 25-year emplacement period, then for an additional 25 years. In this operating mode, the postclosure temperature in the host rock will rise above the boiling point of water.

Because the host rock temperature will be above the boiling point of water, any moisture in the rock within several meters of the emplacement drifts will evaporate and be driven away from the drifts. More than half of the pillar of rock between adjacent drifts will remain below the boiling point, providing a conduit for the evaporated and recondensed water to drain through the repository horizon. This feature should reduce the availability of water near the emplacement drifts, delaying the time at which the water may seep into the emplacement drifts and contact the waste packages.

The U.S. Department of Energy (DOE) is currently evaluating a lower-temperature operating mode that will ensure that the temperature of the host rock remains below the boiling point of water. This mode may mitigate some of the uncertainties that may be related to the coupled processes associated with the boiling point design. In addition, keeping the surface temperatures of the WPs below 85 °C may keep the waste package conditions outside the window of potential susceptibility to localized corrosion.

This report investigates operating the repository in the lower-temperature mode and evaluates the possible effects this will have on the operational concepts of waste emplacement and retrieval. The operations involved in waste transport, emplacement, and retrieval are discussed and the possible effects that a lower-temperature repository may have on the equipment as well as the concept of operations is presented.

3.2 LOWER-TEMPERATURE ALTERNATIVES

Lower-temperature operating modes are currently being investigated to provide options for mitigating some of the potential uncertainties (ie. rock thermal-hydrologic and thermal-mechanical properties, potential corrosion susceptibility of Alloy 22 used in the WP) associated with the base-case, higher-temperature repository design. The following sections present several alternatives of lower-temperature operating scenarios that may be used in the development of the repository. These scenarios are based on information presented in *ANSYS Calculations in Support of Natural Ventilation Parametric Study for SR* (BSC 2001a, Table 6-1) and *Operating a Below-Boiling Repository: Demonstration of Concept* (CRWMS M&O 2000g, Section 5) and are consistent with the scenarios presented within the *Yucca Mountain Science and Engineering Report* (DOE 2001, Section 2.1.5.2). These examples demonstrate the feasibility of various alternatives and provide a basis for understanding the technical trade-offs involved in

implementing a lower-temperature operating mode of the repository. Reports such as this one will evaluate the effects of these alternatives on other aspects of the repository design.

3.2.1 Scenario 1: Increased Waste Package Spacing and Extended Ventilation

In this scenario, fully loaded waste packages would be emplaced at an average of 2 meters apart to create a 1 kW/m drift lineal thermal load. The separation between emplacement drifts would remain at 81 meters. The drifts would be actively ventilated at a rate of 15 m³/s per drift. This active ventilation would be conducted from the start of emplacement to 50 years after the last drift is fully loaded. The repository would then be allowed to ventilate naturally for 250 years.

An implication of this scenario on the waste emplacement and retrieval process is that additional drift excavation will be required to accommodate the more widely spaced waste packages. The total excavated drift length and emplacement area will be larger than the base-case design.

3.2.2 Scenario 2: De-Rated or Smaller Waste Packages

In this scenario, limiting the amount of waste loaded in a package will reduce the thermal output of each of the waste packages. This can be achieved by limiting the quantity of spent nuclear fuel assemblies to less than the waste package design capacity or replacing the larger waste packages with smaller waste packages that have a lower thermal output. All waste packages would be emplaced at an average of 10 centimeters apart to create a 1 kW/m drift lineal thermal load. The separation between emplacement drifts would remain at 81 meters. The drifts would be actively ventilated at a rate of 15 m³/s per drift. This active ventilation would be conducted from the start of emplacement to 50 years after the last drift is fully loaded. The repository would then be allowed to ventilate naturally for 250 years.

An implication of this scenario on the waste emplacement and retrieval process is that additional drift excavation will be required to accommodate the additional quantity of waste packages. The total excavated drift length and emplacement area will be larger than the base-case design.

3.2.3 Scenario 3: Extended Ventilation and Increased Waste Package Spacing

Lower operating temperatures of the repository could also be achieved by emplacing the waste packages an average of 6 meters apart and increasing the period of active ventilation to 100 years after the last drift is fully loaded, without a period of natural ventilation. This scenario would create a drift lineal thermal load of approximately 0.7 kW/m at the time of emplacement.

An implication of this scenario on the waste emplacement and retrieval process is that additional drift excavation will be required to accommodate the more widely spaced waste packages. The total excavated drift length and emplacement area will be larger than the base-case design.

3.2.4 Scenario 4: Extended Surface Aging, Extended Ventilation, and Increased Waste Package Spacing

In this alternative, surface aging of the hotter portion of the commercial spent nuclear fuel, along with spacing the waste packages approximately 2 meters apart, reduces the thermal loading of the drifts to about 0.5 kW/m at the time of emplacement. Surface aging of the hotter wastes would extend the emplacement period from 25 years to approximately 60 years. It is not anticipated that repository operations would be significantly affected because the cooler commercial spent nuclear fuel, along with the naturally cooler DOE waste forms, could be emplaced while the hotter fuel cools through aging. The active ventilation would continue for approximately 65 years after the last drift is fully loaded.

An implication of this scenario on the waste emplacement and retrieval process is that additional drift excavation will be required to accommodate the more widely spaced waste packages. The total excavated drift length and emplacement area will be larger than the base-case design.

3.2.5 Scenario 5: Extended Natural Ventilation

This scenario investigates increasing the period of active ventilation by 50 years and having an indefinite period of natural ventilation. At the end of the active ventilation period, the repository would be closed to access, but ventilation shafts would stay open to allow natural ventilation to circulate cooler, drier air.

This scenario is similar to the base-case design with the same thermal loading, waste package spacing and drift-to-drift spacing and should have no effect on the concepts for waste emplacement and retrieval.

3.2.6 Scenario Summary

Refining the design and the temperature of the operating repository is an ongoing iterative process involving many scientists, engineers, and decision-makers. The goal is to develop a design that works with the natural system to enhance containment and isolation of the high-level waste. Table 1 summarizes the information presented in Sections 3.2.1 through 3.2.5 to which the concept of operations for waste transport, emplacement, and retrieval will be evaluated.

Table 1. Summary Comparison of Operational Parameters for Alternative Lower-Temperature Repository Operating Modes

Parameters	Higher-Temperature Operating Mode	Example Scenarios for 70,000 MTHM Inventory				
		1 Increased Waste Package Spacing and Extended Ventilation	2 De-Rated or Smaller Waste Packages	3 Increased Spacing and Duration of Forced Ventilation	4 Extended Surface Aging with Forced Ventilation	5 Extended Natural Ventilation
Variable Parameters						
Waste Package spacing (m)	0.1	2	0.1	6	2	0.1
Maximum waste package thermal loading	11.8 kW	11.8 kW	<11.8 kW	11.8 kW	<11.8 kW	11.8 kW
Linear thermal loading objective (kW/m) at emplacement	1.45	1	1	0.7	0.5	1.45
Years of forced ventilation after start of the emplacement	50	75	75	125	125	75
Years of natural ventilation after forced ventilation period	0	250	250	0	0	>300
Dependent Parameters						
Size of pressurized water reactor waste packages	21 PWR	21 PWR	<21 PWR	21 PWR	21 PWR	21 PWR
Total excavated drift length (km)	~60	~80	~90	~130	~80	~60
Required emplacement area (acres)	~1,150	~1,600	~1,800	~2,500	~1,600	~1,150
Average waste package maximum temperature (°C)	>96	<85	<85	<85	<85	<96

NOTES: PWR = pressurized-water reactor.

(DOE 2001, Table 2-2)

3.3 CONCEPT OF REPOSITORY OPERATIONS

Repository operations will begin when there is sufficient construction of the emplacement drifts to ensure safe operations after the repository has been licensed to receive high-level radioactive waste. The emplacement phase will overlap the construction and monitoring phases, and elements of these phases will occur during operation of the repository.

The following major emplacement activities will occur during the Operations Phase and the concept of operations for each activity are discussed further in this report:

- ◆ Preparatory Surface Operations (Section 3.3.1) to include:
 - Preparation of the emplacement gantry at the surface facilities
 - Preparation of the waste package transporter
 - Engagement of the transport locomotives
 - Loading of the waste package/pallet assembly
 - Travel of the locomotives and waste package transporter to the North ramp
- ◆ Preparatory Subsurface Operations (Section 3.3.2) to include:
 - Transfer of emplacement gantry from the surface to an active emplacement drift
 - Transfer of emplacement gantry from one emplacement drift to another emplacement drift or to the surface facilities
 - Possible maintenance activities involving transport of personnel and equipment
- ◆ Waste Transport Operations (Section 3.3.3) to include:
 - Transport of WP transporter and locomotives from North ramp through the main drifts
 - Arrival at the turnout of the emplacement drift
 - Docking at emplacement drift entrance
 - WP transporter return to surface
- ◆ Waste Emplacement Operations (Section 3.3.4) to include:
 - Transfer of WP from deck of transporter to the emplacement gantry
 - Travel of the emplacement gantry down the emplacement drift
 - Final placement of the WP within the emplacement drift
 - Travel of the emplacement gantry back to the entrance of the emplacement drift to await the next WP

- ◆ Waste Movement Operations (Section 3.3.5) to include:
 - Removing a WP from an emplacement drift
 - Travel of the WP transporter to another emplacement drift
 - Unloading the WP at the different emplacement drift
- ◆ Waste Retrieval Operations (Section 3.3.6) to include:
 - Purpose of waste retrieval
 - Normal retrieval conditions and operations
 - Possible abnormal retrieval conditions and operations

3.3.1 Preparatory Surface Operations

This section of the report discusses preparatory surface operations that are necessary to be completed in support of the waste emplacement process. At the end of this section is an evaluation of the effects of operating the repository at a lower-temperature on the intended concept of operations.

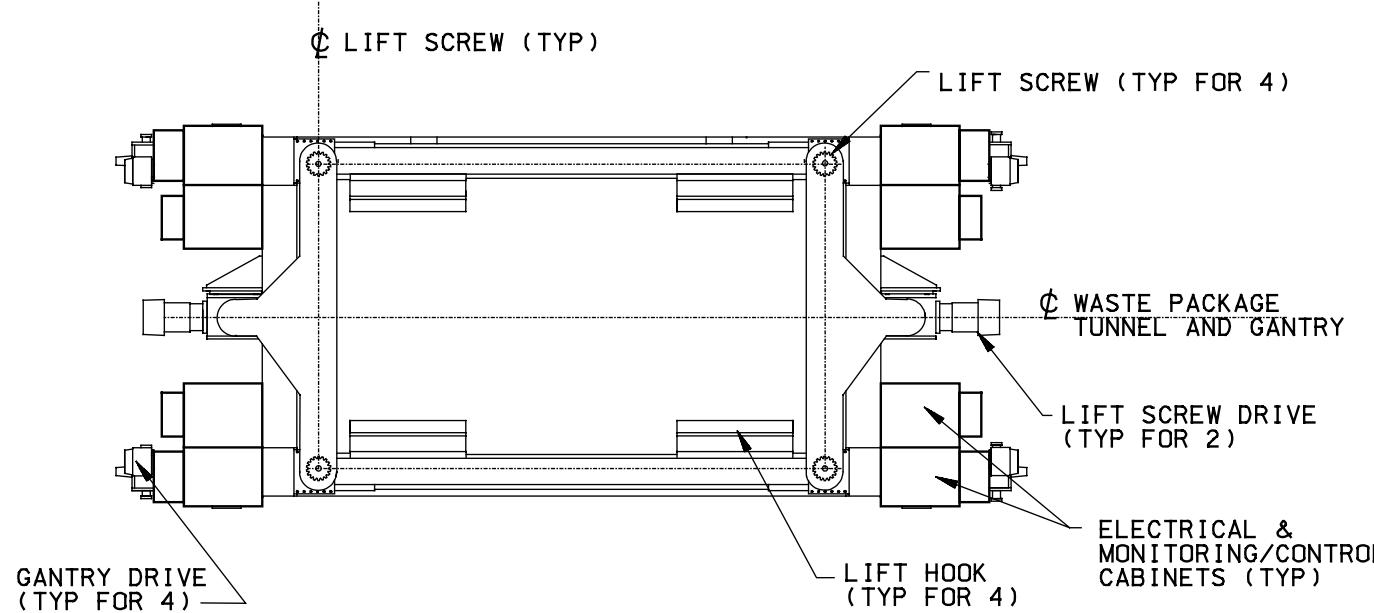
3.3.1.1 Preparation of the Emplacement Gantry

In the current emplacement concept, the emplacement gantry is one of the most critical elements of the overall design. It is essential that this system perform its intended functions in a safe and reliable manner. The emplacement gantry will be designed to operate in the relatively harsh thermal and radiation environment located inside the emplacement drifts. Due to these harsh conditions, human operators located at a remote control station will control the operations of the gantry. The basic purpose of the emplacement gantry is to transport the WPs from the emplacement drift dock area, down the length of the emplacement drift, and place them within the drift. To support movement and normal retrieval of WPs the emplacement gantry will also be capable of reversing these functions.

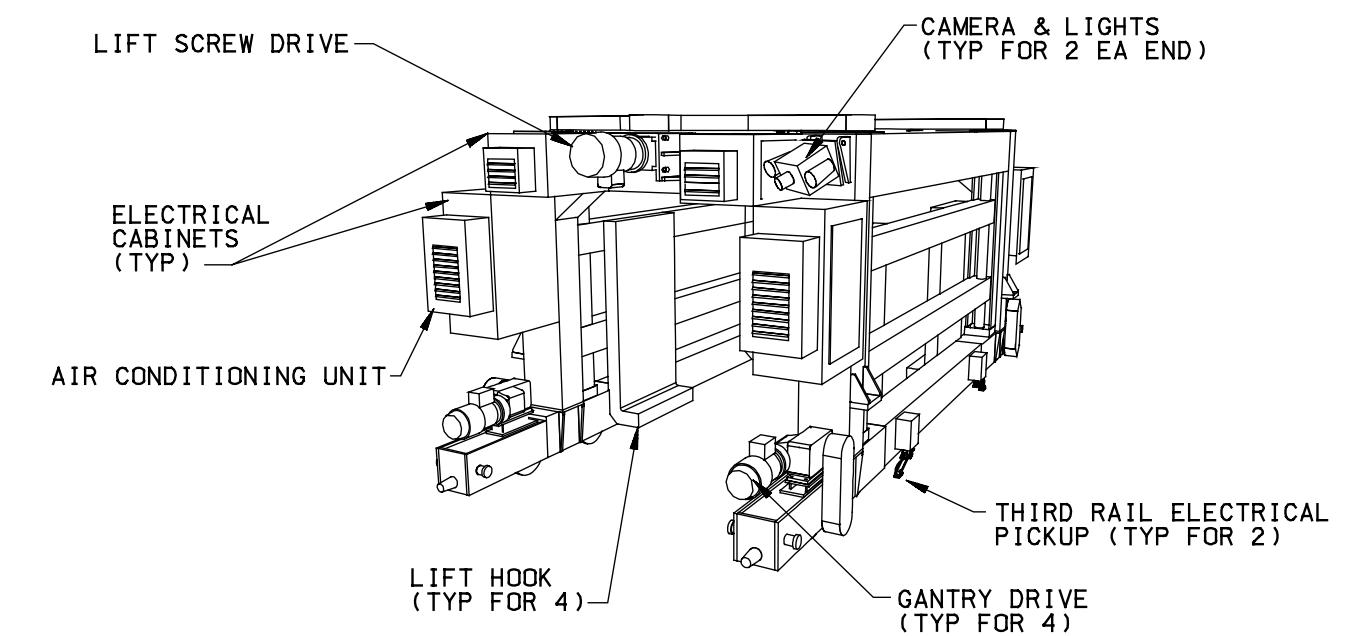
A preliminary design of the emplacement gantry was recently presented in the design analysis *Gantry Structural/Control System Analysis* (BSC 2001b, entire). The basic mechanical configuration of the emplacement gantry is shown in Figure 1.

It is estimated that up to four emplacement gantries will be used at Yucca Mountain. Multiple gantries can be underground at the same time, performing their function of emplacing the waste packages. When the emplacement gantries are not in use underground, it is anticipated that they will be housed in a storage and maintenance facility located on the surface. In this surface facility, routine maintenance will be performed on the emplacement gantries to ensure they remain operational. Large-scale decontamination, that may not be possible in the subsurface environment, although very unlikely, could also be performed within this facility.

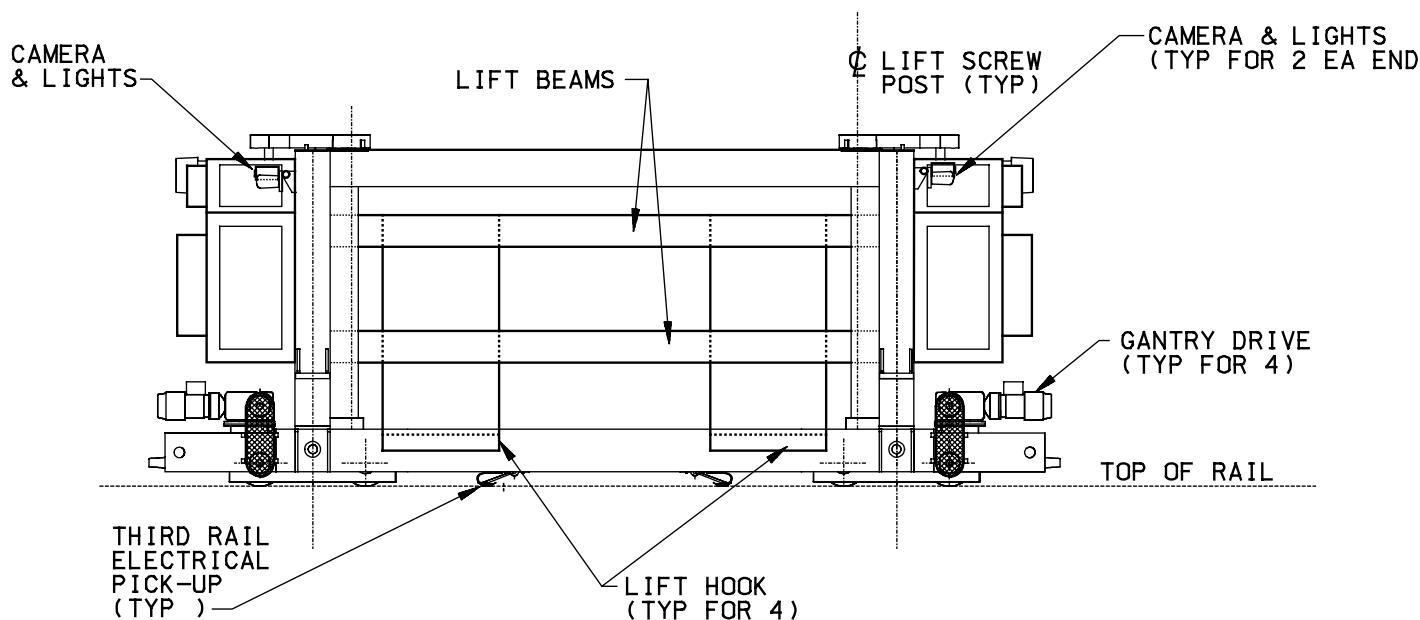
Routine maintenance activities could include: (1) lubrication of ball screws, gear reducers, bearings, etc.; (2) checking motor operation; (3) bogey and drive system maintenance; (4) calibration of instrumentation; and (5) verification of control system operation. These activities



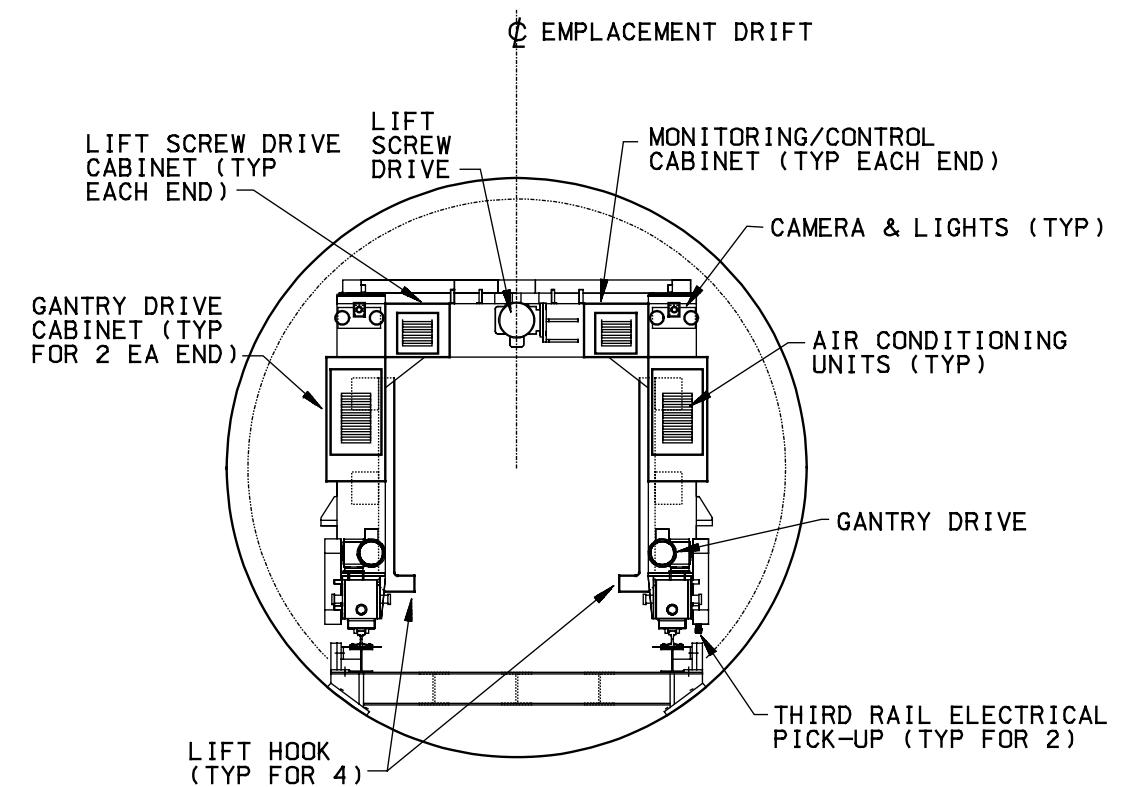
PLAN VIEW



PERSPECTIVE VIEW



ELEVATION VIEW



END VIEW

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Figure 1. Emplacement Gantry

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will be completed on a scheduled basis, determined during the detailed design and fabrication of the emplacement gantries.

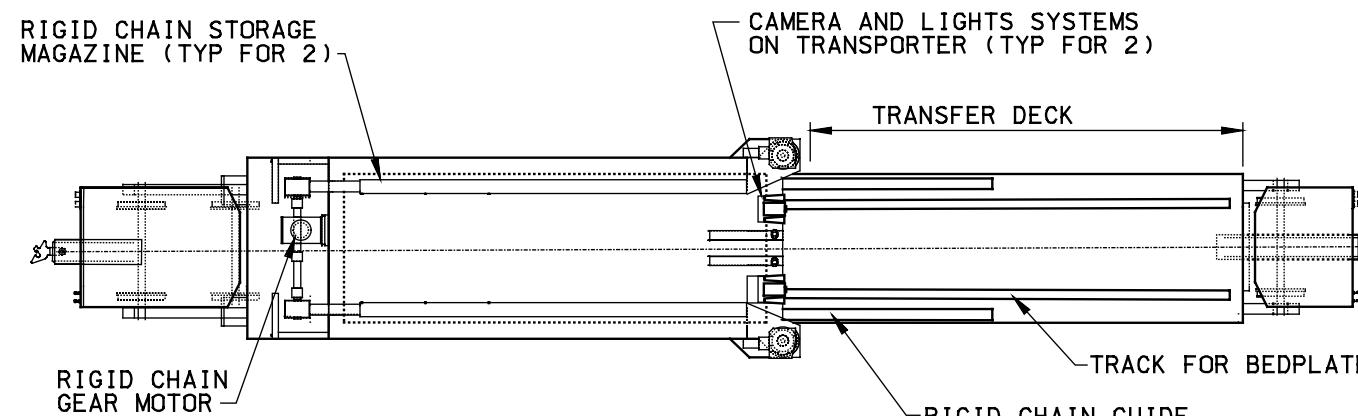
The maintenance facility will contain a dock and rail system, of appropriate rail gauge, similar to the docks located at the entrances of the emplacement drifts. This will allow the gantries to be loaded and unloaded to/from the gantry carrier. Movement of the gantries can be accomplished by using the same wireless methods that will be used in the emplacement drifts or by directly connecting a temporary pendant to the control system of the gantry. Once it is determined that an emplacement gantry is ready for service, it will be moved to the dock and transferred to the gantry carrier. The emplacement gantry carrier is basically a flatbed rail-car device that will be used to shuttle the emplacement gantry from the surface storage and maintenance facility to the drifts underground. The emplacement gantry carrier will also be used to move the emplacement gantry from one drift to another drift. The transport locomotives will move the gantry carrier.

3.3.1.2 Preparation Of The Waste Package Transporter

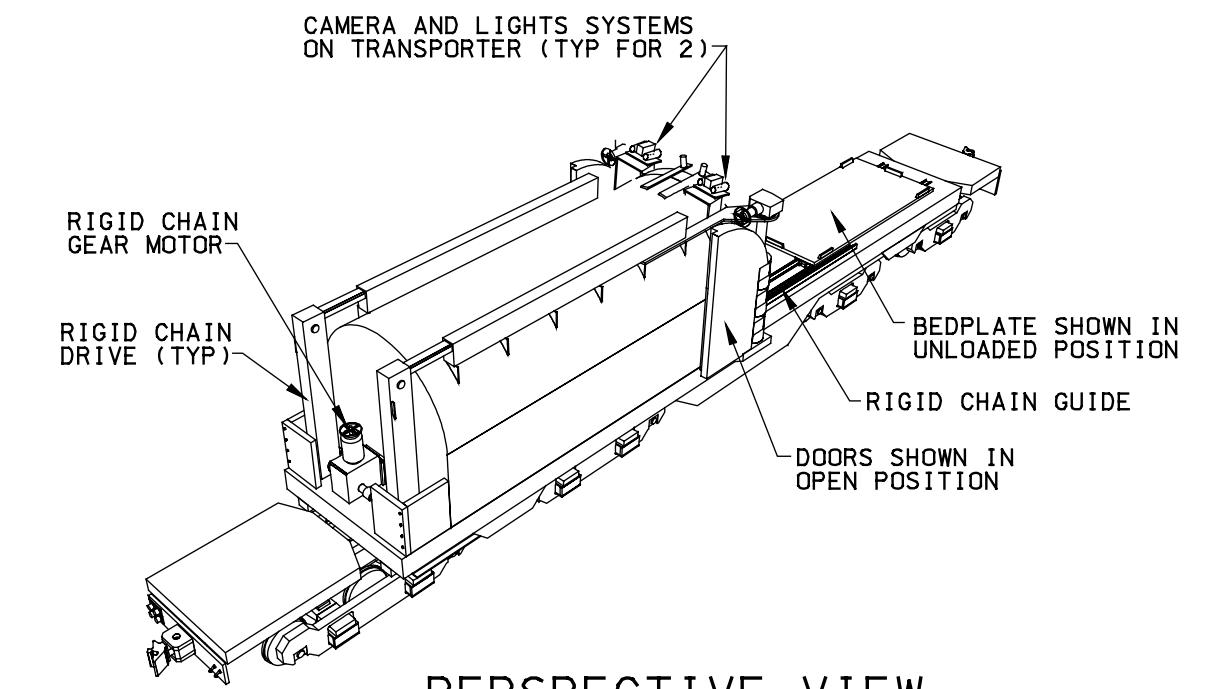
The waste package transporter will be a massive rail car that will be used to transport the WPs in a completely enclosed and shielded enclosure from the Waste Handling Building (WHB) at the surface, down into the emplacement drift area of the potential repository. The waste package transporter will be shielded to protect personnel that may need to work in the area through which the transporter will travel. A preliminary mechanical design for the waste package transporter was presented in the *Waste Package Transport and Transfer Alternatives* design analysis (CRWMS M&O 2000e, section 6) and is shown in Figure 2. In its current design configuration, the shielding used to form the walls, floor, crown and doors of the waste package transporter will be over 260-mm thick. The shielding will be multiple layers of stainless and carbon steels, and a borated polyethylene material.

The waste package transporter will be equipped with its own set of air brakes and a redundant backup set of spring-loaded fail-safe brakes. The waste package transporter will have a set of double doors at one end which will be opened and closed by two heavy-duty gear motors mounted in-line with the axis of the door hinges. Inside the waste package transporter will be WP loading and unloading mechanisms. The loading and unloading mechanisms will consist of two main systems: a bedplate and a rigid-chain drive system, which will be used for extending and retracting the bedplate during loading and unloading activities. Both of these component systems will have multiple positioning sensors and other types of performance feedback sensors. Inside the waste package transporter will be a camera system for remote viewing, along with radiation and thermal monitoring instrumentation. An air exhaust system and external radiation monitor may also be used in the final design of the transporter. This will be used to monitor for airborne contamination inside of the transporter. A positive indication of this would be indicative of either a leaking or contaminated waste package, in which case the transporter would be directed to return to the decontamination facilities located on the surface.

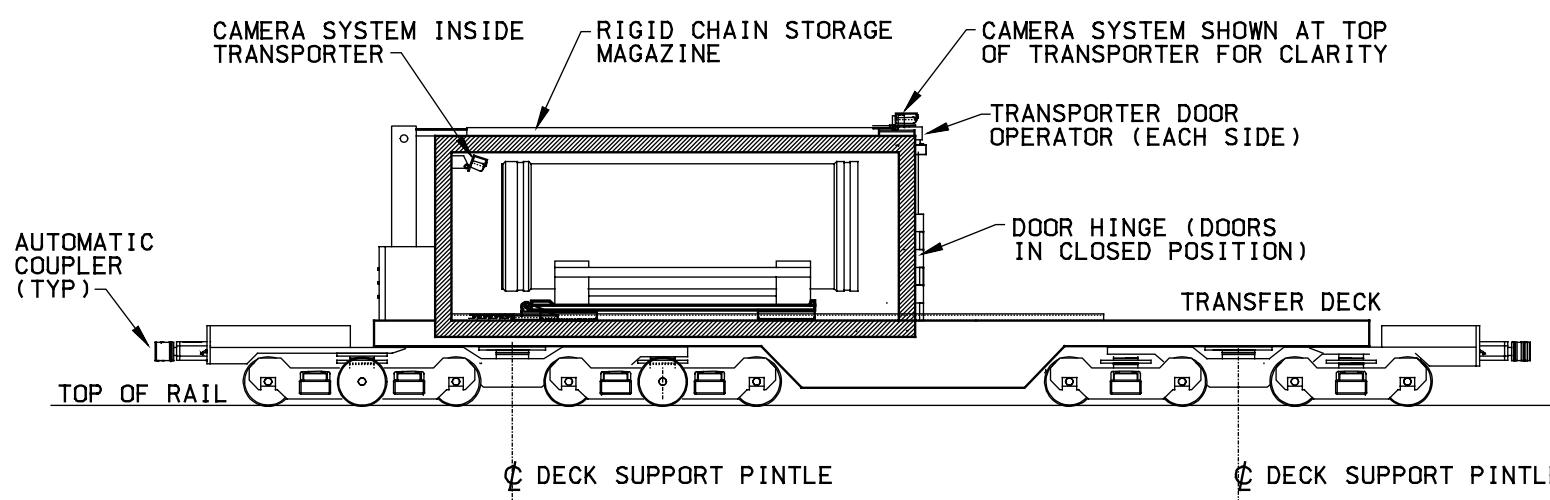
The operation and functions of the WP transporter will be remotely controlled. Control commands will originate either from the operator located on the primary locomotive, or they will originate from operators located at the remote control room. In either case, the control signals will be processed by a Programmable Logic Controller (PLC)-based control system located on



PLAN VIEW

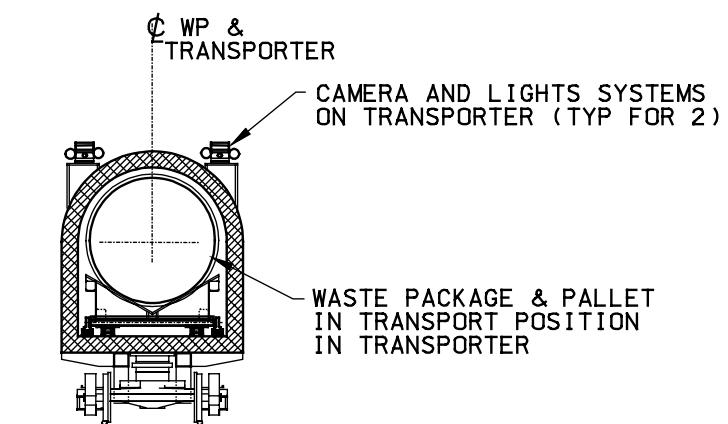


PERSPECTIVE VIEW



LONGITUDINAL SECTION

(SECTIONAL VIEW OF SHIELDED ENCLOSURE)



CROSS SECTION

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the primary transport locomotive, and then transferred to a PLC-based control system located on the WP transporter. The PLC-based control system on the WP transporter would then open-close the doors, extract-retract the bedplate, lock the bedplate during transit, and monitor the interior environment while a WP is present. Interfacing with the surface facilities will therefore be through the transport locomotive control system. The PLC on the primary locomotive will monitor and check all operations and system performance parameters of the WP transporter and relay these signals to operators located at the remote control room.

To meet the peak emplacement rates, it is estimated that there will be two or more waste package transporters used at Yucca Mountain. When the waste package transporters are not in use, it is anticipated that they will be housed in a storage and maintenance facility located on the surface. In this surface facility, routine maintenance will be performed on the waste package transporters to ensure they remain operational. Decontamination, should it be required, could also be performed within this facility.

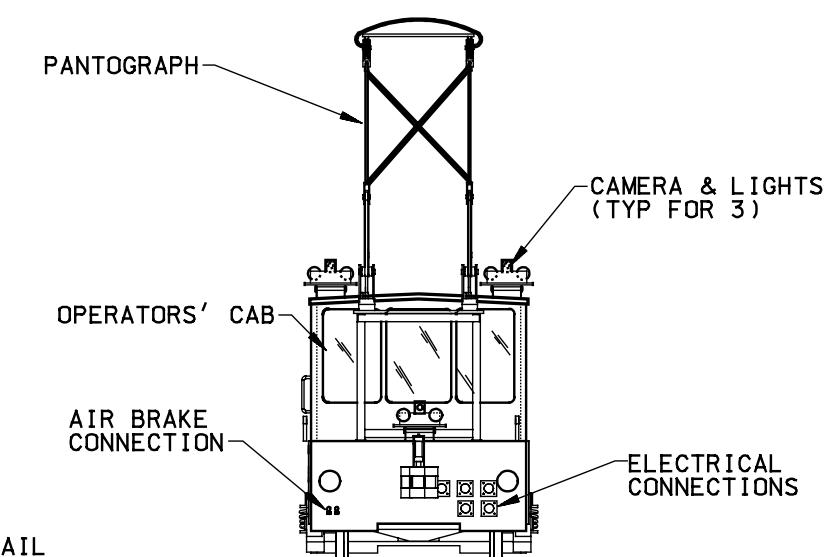
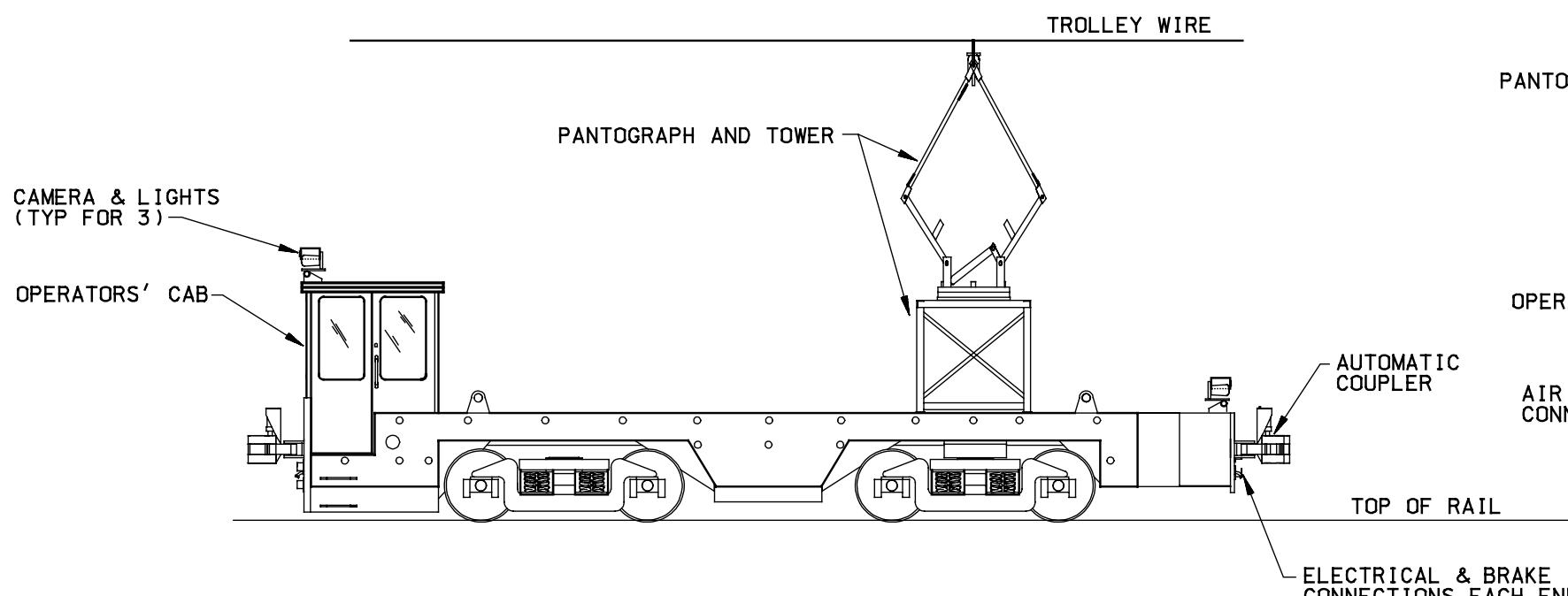
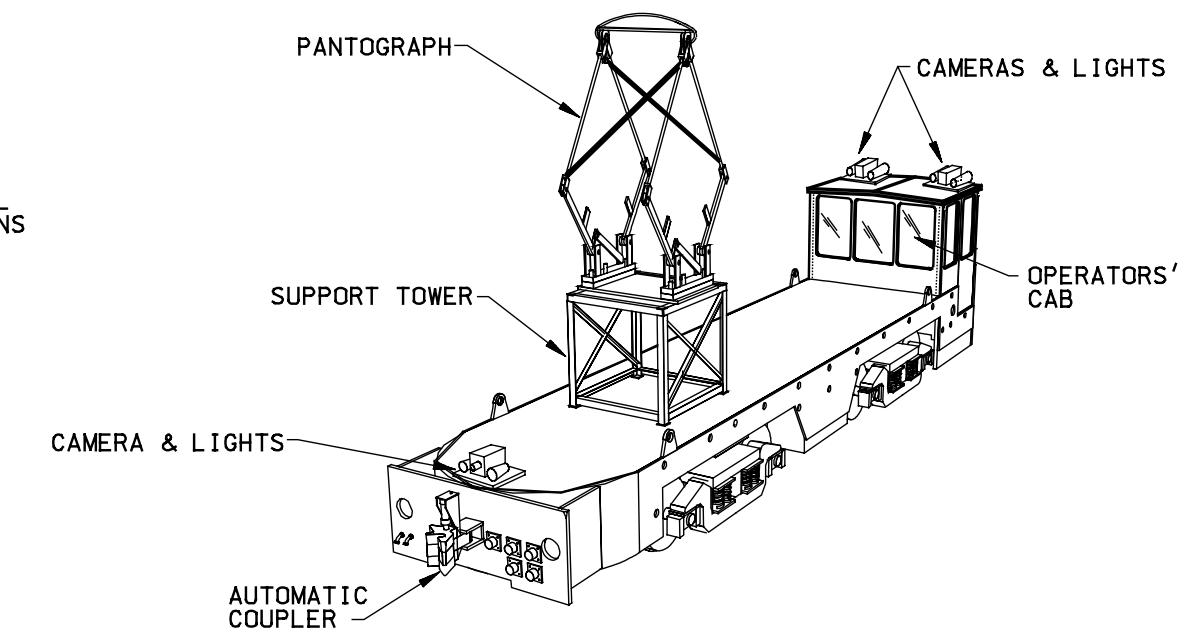
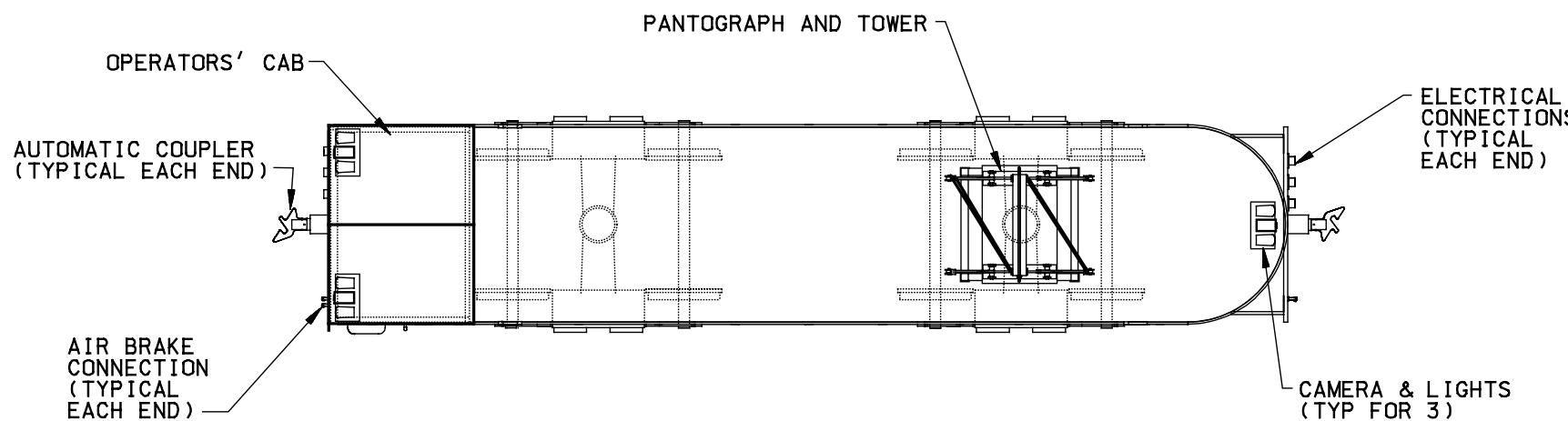
Routine maintenance activities could include: (1) lubrication of unloading mechanism, gear reducers, bearings, etc.; (2) checking door operation and proper sealing; (3) bogey maintenance; and (4) calibration of instrumentation. These activities will be completed on a scheduled basis, determined during the detailed design and fabrication of the waste package transporters.

3.3.1.3 Engagement Of The Transport Locomotives

The transport locomotives will serve as the multi-purpose prime movers of equipment and personnel and will be used in almost every aspect of subsurface operations. During emplacement operations, the transport locomotives will be used to haul WPs in the waste package transporter from the WHB to the entrance of the emplacement drifts. The transport locomotives will also be used to shuttle the emplacement gantry from drift to drift and periodically return it to the surface storage and maintenance facility. The transport locomotives will also be used to move personnel or materials, as needed, within the subsurface operations area.

According to *Mobile Waste Handling Support Equipment* (CRWMS M&O 1998, section 7.3.1), current concepts for the transport locomotives are based on commercially available mining locomotives. The estimated weight of the locomotives is currently being reviewed, but should be in the range between 50 to 90 tons. Power for the locomotives will be provided by an overhead trolley system, and the locomotives will be designed for both direct manual control and wireless remote control (CRWMS M&O 2000a, section 6.7). The current design layout of the transport locomotive is shown in Figure 3.

The transport locomotives will engage with either the emplacement gantry carrier or the waste package transporter by the use of an automatic coupler. These couplers will join automatically and can be released by means of an air cylinder that can be activated from the compressed air system on the locomotive. It is envisioned that the automatic couplers will include the mechanical coupling as well as all other required utilities such as compressed air, electrical power, and connections for the control system. Sensors installed in the coupler can transmit



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Figure 3. Transport Locomotive

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control signals representative of proper engagement to the control system on-board the locomotive.

The transport locomotive will engage with the emplacement gantry carrier in the surface storage and maintenance facility. The gantry will have to be properly orientated on the carrier so that it can be readily unloaded into the emplacement drifts underground. The locomotive and gantry carrier will then travel to the North portal, with the locomotive in the lead position pulling the carrier.

The transport locomotive will also engage with the waste package transporter in the surface storage and maintenance facility. The locomotive will engage to the end of the transporter that has the shielded enclosure, leaving the open deck end uncoupled. Operation of the transporter functions can then be verified. The door could be opened and closed. The bedplate could be extended and retracted. After successful operation of all mechanical functions and verification of all monitoring signals, the locomotive/transporter could then be considered ready for waste transport.

3.3.1.4 Loading Of The Waste Package/Pallet Assembly

The locomotive and transporter will then travel to the Waste Handling Building and dock in the area designed for waste package loading. The door of the transporter will open and the bedplate will be extended on the open deck. The final operation involved in the preparation of a waste package in the Waste Handling Building involves decontamination of the waste package. The waste package will be lifted and rotated to a horizontal position and moved by crane to a separate cell for decontamination. Following decontamination, the waste package will be placed on a pallet and the waste package/pallet assembly will be positioned on the extended bedplate of the waste package transporter. Final identification and verification of the waste package placed onto the transporter will take place at this time. The bedplate of the transporter will retract into the shielded enclosure and the door will close. The locomotive and transporter will then exit the WHB. Because of the relatively high radiation environment surrounding the waste package, all of these operations will be conducted by remote control.

3.3.1.5 Travel Of The Locomotives And Waste Package Transporter To The North Ramp

Outside of the WHB, an operator will get in the cab of the locomotive engaged to the waste package transporter and switch the operating mode of the locomotive to local/manual control. The operator will then drive the locomotive to an area that will allow the engagement of a second locomotive to the open deck end of the waste package transporter. An on-board operator will also drive this second locomotive as it is engaged to the transporter by the automatic couplers. Final readings and operability of the two locomotives connected to the transporter will be confirmed at this time.

Orientation of the WP transporter, prior to entering the repository, is important depending on whether the designated emplacement drift entrance is off of the East or West main. The open deck of the WP transporter must ultimately face the drift docking area for successful transfer of the WP to the emplacement drift. The WP transporter and locomotives cannot rotate or change

the orientation of the WP transporter once they enter the subsurface facility. Upon successfully orienting the WP transporter, the operators then drive the locomotives to the North portal where final readings and inspections can take place.

3.3.1.6 Evaluation of Lower-Temperature Operating Modes on Preparatory Surface Operations

All of the operations previously described in section 3.3.1 take place on the surface of the Geologic Repository Operations Area. These operations are the same as the base-case design and the temperature of the operating mode of the repository, should it be lower, will have no impact on the intended operational concepts.

3.3.2 Preparatory Subsurface Operations

This section of the report discusses the preparatory subsurface operations that will be necessary to be completed in support of the waste emplacement process. At the end of this section is an evaluation of the effects of operating the repository at a lower-temperature on the intended concept of operations.

3.3.2.1 Transfer of Emplacement Gantry from Surface Facilities to an Emplacement Drift

As stated in section 3.3.1.3, the locomotives will engage with the gantry carrier in the surface storage and maintenance facility. The emplacement gantry will be suitably positioned on the carrier for unloading into a designated emplacement drift. An operator in the cab of the locomotive will then drive the locomotive/carrier assembly to the North portal. The locomotive will be in the lead position, pulling the carrier.

After appropriate check-in procedures are completed at the North portal entrance, the operator will continue to drive the locomotive down the North ramp of the repository. Status and positional signals will be continuously transmitted to personnel located in the main control room for remotely monitoring the operation. Video signals from cameras located along the North ramp will also be transmitted to the main control room. The operator will then drive the locomotive down the East or West main, depending on the location of the drift entrance.

The operator would drive the locomotive and gantry carrier to an area near the designated turnout of the emplacement drift to which the gantry is to be unloaded. The operator of the locomotive would then switch the control system to remote, leave the cab of the locomotive, and move to a radiation safe area, avoiding all potentially high radiation areas such as the entrance of the turnout. Exactly how far away the radiation safe area may be will be determined once final calculations can be made regarding the expected dose in the drift turnout with the emplacement drift isolation doors both open and closed. Once in the radiation safe area, the operator would inform personnel in the main control room that it is clear to complete the gantry unloading operation. Control of the locomotive would now be from personnel located in the main control room.

The emplacement drift isolation doors would open and the locomotive would slowly push the carrier into the entrance of the emplacement drift. Video signals along with sensory signals would be conveyed to the personnel in the main control room to allow them to complete the docking of the gantry carrier at the dock of the emplacement drift. After alignment and other appropriate signals signifying correct docking have been received, the gantry would be driven off of the carrier into the emplacement drift under control of operators in the main control room.

Once the gantry is completely off of the carrier, and correct operation is verified, the locomotive/carrier assembly would travel away from the dock and into the emplacement drift turnout. The emplacement drift isolation doors would then be closed. The locomotive/carrier assembly would then be directed to the main drift. At this time, personnel in the main control room would notify the operator in the radiation safe area that it is safe to return to the cab of the locomotive. The operator would then switch control of the locomotive to manual and resume control of the locomotive/carrier assembly. The locomotive/carrier assembly would then return to the surface where the carrier would be uncoupled and stored for the next gantry transfer.

3.3.2.2 Transfer of Emplacement Gantry from One Emplacement Drift to Another Emplacement Drift or to Surface Facilities

When the gantry has completed emplacement operations in an emplacement drift, or maintenance is required, or it is determined that WP emplacement should proceed in another drift, it will be necessary to remove the gantry from the emplacement drift it is currently in. This can be accomplished by reversing the steps described in section 3.3.2.1.

An operator would drive the locomotive/carrier assembly to the drift turnout, switch locomotive control to remote, and proceed to a radiation safe area. The emplacement drift isolation doors would open and the carrier would dock at the entrance of the emplacement drift. The gantry would be driven onto the deck of the gantry carrier. Once the gantry is properly secured to the carrier, the locomotive will back away from the dock and into the drift turnout. The isolation doors would close. The operator would then return to the cab of the locomotive in the main drift and drive the locomotive either to the surface or to the turnout of another emplacement drift. If it goes to another drift turnout, then the unloading sequence as stated in section 3.3.2.1 will be repeated. If it goes to the surface, appropriate checkout routines will be conducted at the North portal. If everything is satisfactory, the gantry would be driven to the surface storage and maintenance facility where storage or required maintenance activities would be conducted.

3.3.2.3 Transport of Personnel and Maintenance Equipment

Maintenance activities need to be periodically performed on the installed equipment located on the emplacement side of the repository. The rail/invert system, electrical distribution system, lighting system, control/monitoring system, and others require adjustment, lubrication, replacement, and/or calibration over the life of the repository. Transport locomotives coupled to flatbed railcars and/or personnel carriers will be used to assist the maintenance personnel with these activities. Onboard operators will manually drive the transport locomotive.

After appropriate check-in procedures are completed at the North portal entrance, the operator will continue to drive the locomotive down the North ramp of the repository. Status and positional signals will be continuously transmitted to the main control room for remotely monitoring the location of the maintenance crew. Video signals from cameras located along the North ramp will also be transmitted to the main control room. Upon completion of the activity, the locomotive and all personnel will return to the North portal where required checkout procedures can be completed.

3.3.2.4 Evaluation of Lower-Temperature Operating Modes on Preparatory Subsurface Operations

This section of the report will evaluate the five scenarios presented in Sections 3.2.1 through 3.2.5 against the operations described in section 3.3.2.

Scenario 1 (Section 3.2.1)—The preparatory subsurface operations take place in the main drifts of the subsurface repository. The main drifts will be maintained to a temperature that will be safe for human occupation as stated in the *Subsurface Ventilation System Description Document* (CRWMS M&O 2000c, Section 1.2.1.3). This scenario has the same number of waste packages as the base case design. Since the waste packages will be spaced 2 meters apart, additional emplacement area will be required to accommodate the emplacement of all packages. The effect this will have on the emplacement equipment is that the equipment will be required to travel longer distances to reach the turnouts to the emplacement drifts. The impacts of the longer haulage and travel distances will not be significant during initial emplacement operations.

Because the equipment will travel longer distances, the cycle time for each trip will increase slightly. Each round trip will take slightly longer, so the equipment will be operating longer. It is anticipated that the maintenance schedules of the equipment will most likely be based on run-hours. Therefore, the equipment may require additional maintenance activities for the number of trips it has made. For example, routine maintenance may be conducted every 40 trips for the base case design. For this scenario, routine maintenance may need to be conducted every 35 or 36 trips. The equipment for waste emplacement will be specified later in the program and exact maintenance impacts can be determined at that time. It is a logical conclusion, though, that additional maintenance will be necessary.

Scenario 2 (Section 3.2.2)— This scenario has more waste packages than the base case design. Even though the waste packages will be spaced 0.1 meters apart, additional emplacement area will be required to accommodate the additional quantity of waste packages. The effect this will have on the emplacement equipment is that the equipment will be required to make additional trips and travel longer distances to reach the turnouts to the emplacement drifts. The impacts of the longer haulage and travel distances will not be significant during initial emplacement operations.

Similar to scenario 1, the equipment will most likely require additional maintenance activities for the number of trips it has made. For example, routine maintenance may be conducted every 40 trips for the base case design. For this scenario, routine maintenance may need to be conducted

every 35 or 36 trips. This scenario will also have more trips than scenario 1, so the maintenance requirements will most likely be more than scenario 1.

Scenario 3 (Section 3.2.3)—This scenario is very similar to scenario 1 except the waste package spacing is three times larger (6 m) and the emplacement area is 55 percent more. Travel distances per trip will increase significantly, as will the equipment maintenance requirements. The maintenance activities for this scenario will most likely be more than scenario 1, and equal to or greater than that anticipated for scenario 2.

Scenario 4 (Section 3.2.4)—This scenario is similar to scenario 1. It is therefore anticipated that this scenario will have the same amount of additional maintenance requirements as scenario 1.

Scenario 5 (Section 3.2.5)—This scenario is functionally identical to the base case, and therefore it is anticipated that there will be no effect on the operational concepts.

3.3.3 Waste Transport Operations

This section of the report describes the operation of moving the WPs from the surface facilities, specifically the North portal, to the entrance of the designated emplacement drift. At the end of this section is an evaluation of the effects of operating the repository at a lower-temperature on the intended concept of operations.

3.3.3.1 Locomotive and WP Transporter Travel through the Main Drifts

After final check-in procedures are completed at the North portal entrance, the WP transporter, sandwiched between two locomotives, will begin travel down the North ramp. Figure 4 depicts the leading locomotive, trailing locomotive, and WP transporter. Status and positional signals will be continuously transmitted to the main control room for remotely monitoring the operation. The operators located in the locomotive cabs will control the locomotives. An override capability will be available to allow the operators located in the main control room to assume control of the locomotives, should such a condition arise. Video signals from cameras located along the North ramp will also be transmitted to the main control room. The operators will then drive the locomotives down the East or West main, depending on the location of the designated emplacement drift.

3.3.3.2 Locomotive and WP Transporter Arrival at Emplacement Drift

In the East or West main, at a location near the designated drift turnout, the locomotives and WP transporter will come to a stop. The locomotive coupled to the open deck end of the WP transporter will then uncouple from the assembly and move away from the WP transporter. The operator of the locomotive still coupled to the WP transporter would then switch the control system to remote, leave the cab of the locomotive, and move to a radiation safe area, avoiding all potentially high radiation areas such as the entrance of the turnout and the WP transporter. Exactly how far away the radiation safe area may be will be determined once final calculations can be made regarding the WP transporter shielding, locomotive shielding, and the expected dose in the drift turnout with the emplacement drift isolation doors both open and closed. Once

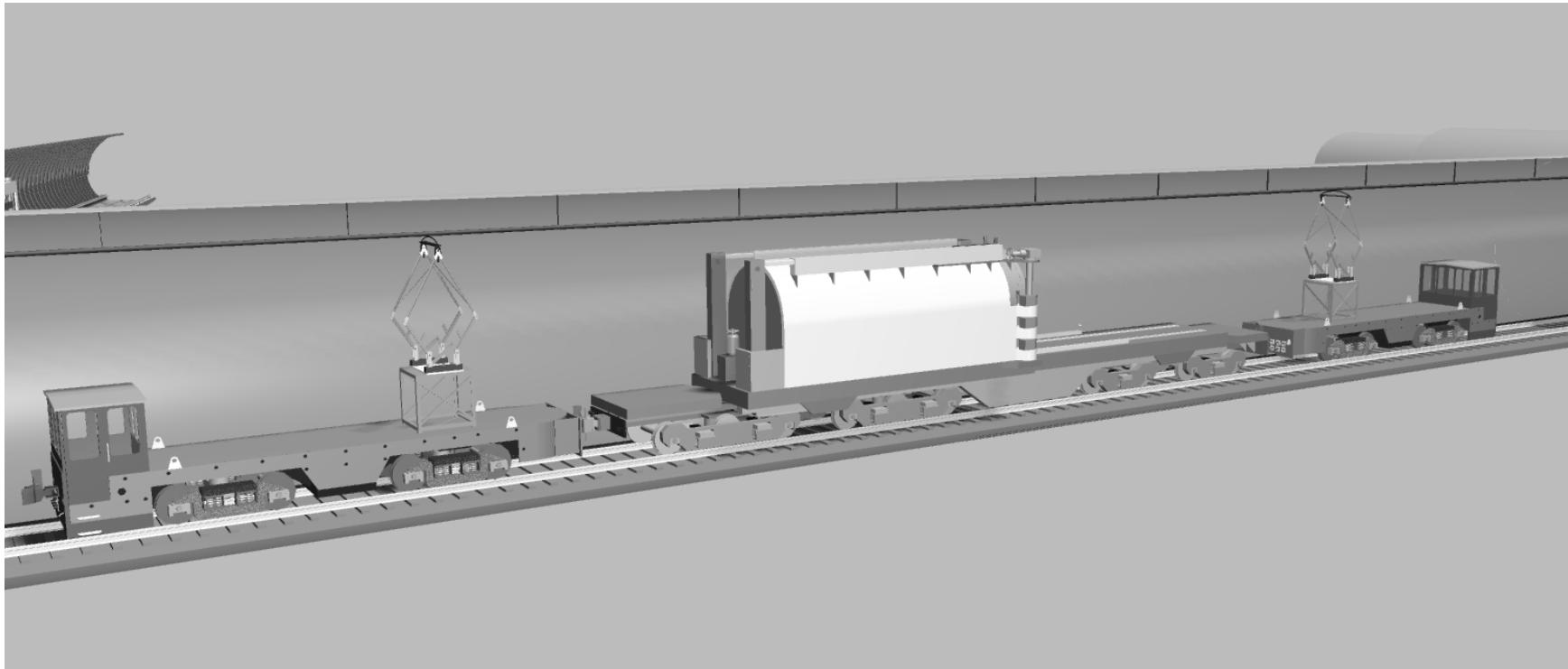


Figure 4. Tandem Locomotives Transporting the Waste Package Transporter

in the radiation safe area, the operators can inform personnel in the main control room that it is clear to complete the WP transporter docking operation. Control of the locomotive coupled to the WP transporter would now be from personnel located in the main control room.

3.3.3.3 Locomotive and WP Transporter Docking at Emplacement Drift

The locomotive, under remote control, pushes the WP transporter, with the open deck end leading, into the emplacement drift turnout to a point outside the isolation doors and stops. The emplacement drift isolation doors and the WP transporter doors would open. Once the operators in the main control room receive verification that all doors are completely open, the locomotive would slowly push the WP transporter into the entrance of the emplacement drift. Video signals along with sensory signals would be conveyed to the personnel in the main control room to allow them to safely complete the docking of the WP transporter at the dock of the emplacement drift as shown in Figure 5. After alignment and other appropriate signals signifying correct docking have been received, the locomotive would be put in a parked mode.

If all conditions are satisfactory, the bedplate with the WP and pallet assembly will extend from the shielded enclosure out onto the open deck. Appropriate sensory and visual equipment will be installed to inform the operators in the main control room that the WP and pallet assembly is ready to be removed from the WP transporter.

3.3.3.4 WP Transporter Return to Surface

After the WP and pallet assembly has been removed from the extended bedplate of the WP transporter, the locomotive will back out of the dock at the entrance of the emplacement drift. Once the locomotive is sufficiently clear of the isolation doors it will stop in the emplacement drift turnout. The bedplate would retract into the shielded enclosure and the isolation doors and WP transporter doors would close. The operators in the main control room, having received verification that all doors are closed, would then direct the locomotive to the main drift. The operators, in the radiation safe area, would be notified that it is safe to return to the area outside the emplacement drift. The second locomotive would couple to the open deck end of the WP transporter. The operators, in the cabs of both locomotives, would then drive the WP transporter back up to the surface facilities.

3.3.3.5 Evaluation of Lower-Temperature Operating Modes on Waste Transport Operations

The waste transport operations will take place in the main drifts of the subsurface repository. The main drifts will be maintained to a temperature that will be safe for human occupation as stated in the *Subsurface Ventilation System Description Document* (CRWMS M&O 2000c, Section 1.2.1.3). The operations presented in this section are very similar to those discussed in Section 3.3.2. The effects of a lower-temperature repository on the waste transport operations will be the same as those presented in Section 3.3.2.4. The major impact is that with a larger emplacement area, the equipment may require additional maintenance because of the longer distances and extended travel times that the equipment must endure as compared to the base case design.

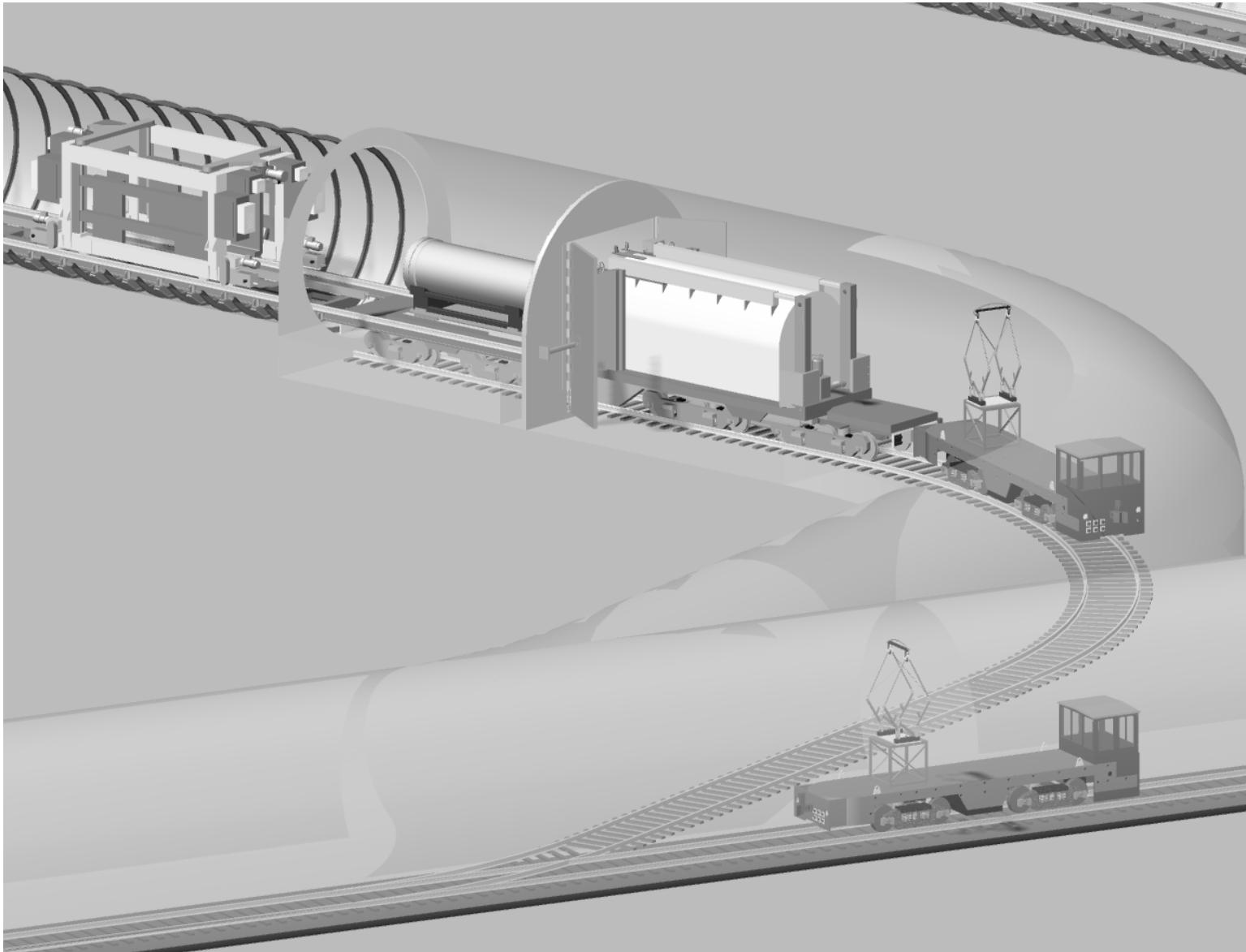


Figure 5. Waste Package Transporter Docked at Emplacement Drift Entrance

3.3.4 Waste Emplacement Operations

This section of the report describes the operation of moving the WPs from the entrance of the designated emplacement drift to its final placement within the drift.

3.3.4.1 Emplacement Gantry Engagement of WP and Pallet Assembly

After the WP and pallet assembly is extended on the bedplate of the WP transporter at the emplacement drift dock, the emplacement gantry will be instructed to move over the WP and pallet, straddling the WP transporters open deck. The lift hooks will be in the lowest position allowing them to move under the pallet. Control of the gantry will be by operating personnel located in the main control room. After successful positioning of the gantry, the drive motors will be put in the locked or parked position and the lift hooks will raise the WP and pallet off of the WP transporter bedplate. Once sufficiently raised, the lift hook hoist motors will be put in the locked or parked position. The drive motors will be unlocked and the gantry, with the WP and pallet assembly, will then be driven down the emplacement drift as shown in Figure 6. The WP transporter would not be allowed to leave the dock area until the gantry has moved the WP and pallet assembly clear of the WP transporter through the use of administrative and mechanical controls.

3.3.4.2 Emplacement Gantry Travel within Emplacement Drift

The gantry will be equipped with visual and other sensory equipment to allow the operators remotely controlling it to know its position within the emplacement drift at all times. The gantry will have a “home” position that will be a short distance into the emplacement drift. It is from this home position that all movement of the gantry will originate. After the gantry has lifted the WP and pallet assembly to clear all obstructions, it will move to the home position. The WP transporter will leave the emplacement drift dock area and the drift isolation doors will close.

Once the emplacement drift isolation doors have been verified in the closed position, the gantry will then be allowed to leave the home position. The base-case repository design consists of line loading the emplacement drifts. This equates to a 10 centimeter spacing between waste packages as they are permanently placed within the emplacement drift. The gantry will then travel the appropriate distance down the emplacement drift to place the WP and pallet assembly 10 centimeters from the previously installed WP. Should the WP be the first one to be installed in the drift, permanent markings or other means will be used so the operators can remotely position the gantry at the correct location to set the WP.

3.3.4.3 Placement of WP within Emplacement Drift

Once the gantry has been verified to be in the correct position to place the WP, the drive motors will be put into the locked or parked position. The lift hook hoist motors will be released from their parked position and they will lower the WP and pallet assembly onto the invert of the emplacement drift. Measurements of the WP spacing would then be made. If a modification to the WP placement is deemed to be necessary, the hoist motors would lift the WP and pallet, the gantry drive motors would creep in the appropriate direction and the WP and pallet would be re-

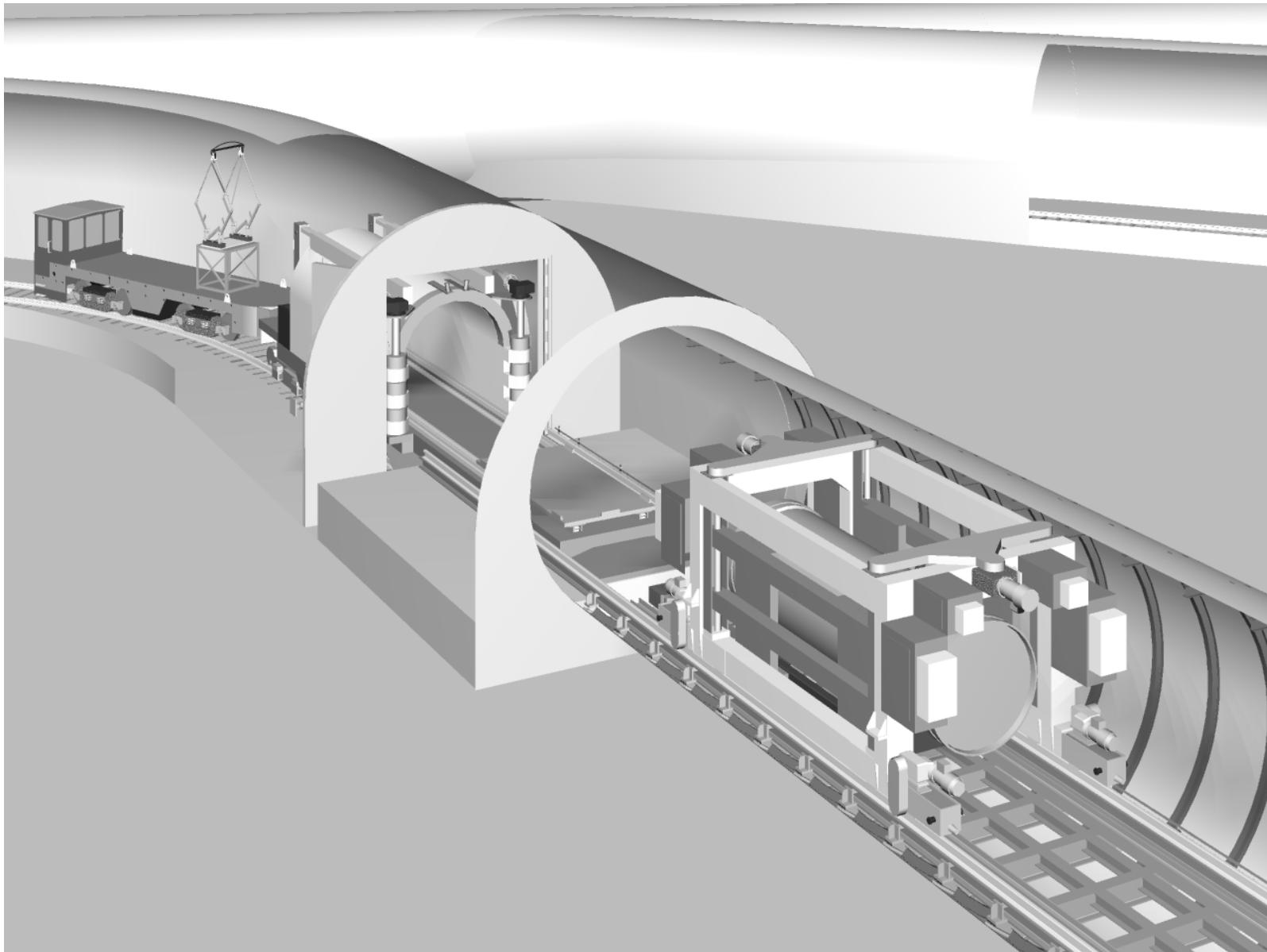


Figure 6. Emplacement Gantry Transporting a Waste Package in the Emplacement Drift

lowered onto the drift invert. The process would be repeated until the placement of the WP is within acceptable limits. Final readings of the WP's placement would then be taken and recorded in the database for future use. After acceptable final placement, the gantry, with the lift hooks in the lowered position, would then be directed to the home position where it would be put in the parked position to await further operating instructions.

3.3.4.4 Evaluation of Lower-Temperature Operating Modes on Waste Emplacement Operations

This section of the report evaluates the five scenarios presented in Sections 3.2.1 through 3.2.5 against the operations described in section 3.3.4. At the end of this section is an evaluation of the effects of operating the repository at a lower-temperature on the intended concept of operations.

Scenario 1 (Section 3.2.1)—This scenario has the same quantity of waste packages as the base case design. Waste emplacement operations will all take place within the emplacement drifts. The *Subsurface Ventilation System Description Document* states that temperatures within the emplacement drifts shall be maintained to a maximum of 50 °C (CRWMS M&O 2000c, Section 1.2.1.4) during emplacement operations. The waste emplacement operations, for this scenario, will be the same as the base-case design and the temperature of the operating mode of the repository, should it be lower, will have no impact on the intended operational concepts.

Scenario 2 (Section 3.2.2)—This operating scenario will have more waste packages to emplace than the base case design. As in scenario 1, temperatures within the drift will be maintained to a maximum of 50 °C. Because of the additional amount of waste packages, the emplacement gantry will be required to operate for a longer period of time. This extended period of operation would require additional maintenance and possible replacement of the emplacement gantry.

Scenario 3 (Section 3.2.3)—This scenario has the same quantity of waste packages as the base case design. The waste emplacement operations, for this scenario, will be the same as the base-case design and the temperature of the operating mode of the repository, should it be lower, will have no impact on the intended operational concepts

Scenario 4 (Section 3.2.4)—This scenario has the same quantity of waste packages as the base case design. The waste emplacement operations, for this scenario, will be the same as the base-case design and the temperature of the operating mode of the repository, should it be lower, will have no impact on the intended operational concepts

Scenario 5 (Section 3.2.5)—This scenario has the same quantity of waste packages as the base case design. The waste emplacement operations, for this scenario, will be the same as the base-case design and the temperature of the operating mode of the repository, should it be lower, will have no impact on the intended operational concepts.

3.3.5 Waste Movement Operations

This section of the report describes the operation of relocating a WP from one emplacement drift to another emplacement drift located within the subsurface facilities.

3.3.5.1 Removing a WP From an Emplacement Drift

To facilitate the relocation of a WP, the emplacement gantry will need to be unloaded into the emplacement drift that contains the particular WP to be relocated. This unloading operation of the emplacement gantry will be as stated in Section 3.3.2.1. The emplacement gantry will travel to the home position within the drift and wait until the WP transporter is docked at the entrance of the emplacement drift. The docking of the WP transporter will be as described in Section 3.3.3.3. Upon verification that the WP transporter is successfully docked, the emplacement gantry, with the lift hooks in the lowered position, will then travel down the drift until the first WP is encountered.

Once the gantry has been verified to be in the correct position to raise the WP, the drive motors will be put into the locked or parked position. The lift hook hoist motors will be released from their parked position and they will raise the WP and pallet assembly off the invert of the emplacement drift. Once the WP and pallet assembly has been sufficiently raised, the lift hook motors will be put into their locked position and the drive motors will be released. The gantry will then travel to the entrance of the emplacement drift and suitably position itself over the extended bedplate of the WP transporter. Once the gantry has been verified to be in the correct position to lower the WP, the drive motors will be put into the locked or parked position. The lift hook hoist motors will be released from their parked position and they will lower the WP and pallet assembly onto the extended bedplate of the WP transporter.

The gantry will then move to its home position within the emplacement drift, the bedplate of the WP transporter will retract into the shielded enclosure, the transport locomotive will pull the WP transporter away from the dock of the emplacement drift, and all doors (WP transporter and drift isolation) will close.

3.3.5.2 Travel of WP Transporter to Another Emplacement Drift

Under remote control by the operators located in the main control room, the transport locomotive and WP transporter will be directed to the main drift. The operator will then return from the radiation safe area and enter the cab of the locomotive coupled to the WP transporter. The second transport locomotive may couple to the open deck end of the WP transporter at this time, depending on the location of designated emplacement drift for movement of the WP. If the designated drift is off the same main drift, a short distance away, only one transport locomotive may be used. If the designated drift entrance is off the other main drift (East going to West or West going to East), the second locomotive will couple to the WP transporter and the assembly will travel to the surface. This action is necessary to properly orient the WP transporter for WP unloading. The open deck of the WP transporter must ultimately face the drift docking area for successful transfer of the WP to the emplacement drift. Transport locomotive and WP transporter travel through the main drifts will be as discussed in Section 3.3.3.1.

3.3.5.3 Unloading the WP at the Different Emplacement Drift

Unloading a WP at a different emplacement drift will consist of the same operations as initial WP transport and emplacement. These operations are described in Sections 3.3.3 and 3.3.4 of this report.

3.3.5.4 Evaluation of Lower-Temperature Operating Modes on Waste Movement Operations

The waste movement operations will consist of the same operations as those discussed in Sections 3.3.3 and 3.3.4 of this report. The effects of a lower-temperature repository on the waste movement operations will therefore be the same as those presented in Sections 3.3.3.5 and 3.3.4.4. The major impact is that with a larger emplacement area, the equipment may require additional maintenance because of the longer distances and extended travel times that the equipment must endure as compared to the base case design.

3.3.6 Waste Retrieval Operations

This section of the report describes the operation of retrieving the WPs from the emplacement drifts to facilities located on the surface.

3.3.6.1 Purpose of Waste Retrieval

The capability to retrieve all or part of the emplaced high-level nuclear waste is required by law and NRC licensing requirements (NRC 1998, Section 63.111). The design approach to satisfy the retrievability requirement is that nothing in the repository design or in the emplacement procedures shall preclude the retrieval of any or all of the waste packages. While the capability to retrieve the waste packages is a licensing requirement, it will not unduly control the repository design and waste emplacement operations.

There can be two reasons for retrieving all or part of the nuclear waste emplaced at the repository. The first reason is because it has been determined that failure in the site, the waste package, or some other system is causing a possible risk to the public health, waste isolation, or the environment. The second reason is because the DOE has determined that recovery of valuable resources is possible from the emplaced spent nuclear fuel. The need to retrieve will be caused by a change in DOE policy and not by an event or condition known to exist at the time of repository approval to accept spent nuclear fuel.

3.3.6.2 Normal Retrieval Conditions and Operations

Normal retrieval would occur based on the reasons stated above. Conditions within the repository during preclosure would be as expected with no leakage or contamination from any waste package detected. All significant systems, structures, and components that make up the subsurface facility would be operating normally and capable of performing their intended functions. The operational concepts for retrieving the waste packages under normal conditions

would be exactly opposite those executed in the waste emplacement process. The normal retrieval sequence of operations is summarized below:

1. The locomotive and gantry carrier w/gantry travel to the emplacement drift.
2. The drift isolation doors would open.
3. The locomotive and carrier docks at the entrance of the emplacement drift.
4. The gantry moves off of the carrier and the locomotive and carrier leave the area and the drift isolation doors close.
5. The gantry moves to the location of the nearest WP, which will be closest to the drift entrance, engages the pallet assembly, and raises the WP and pallet.
6. The transport locomotives and empty WP transporter travel to the main drift just outside the turnout to the emplacement drift.
7. The secondary locomotive uncouples and the primary locomotive pushes the WP transporter into the drift turnout, all doors open, and the WP transporter docks at the emplacement drift entrance.
8. The bedplate of the WP transporter extends out onto the open deck.
9. The gantry moves over the open deck of the WP transporter and lowers the WP and pallet assembly onto the extended bedplate.
10. The bedplate retracts into the shielded enclosure of the WP transporter.
11. The primary locomotive then moves the WP transporter from the dock, into the drift turnout, all doors close, and then the WP transporter moves into the main drift.
12. The secondary locomotive couples to the WP transporter and the train travels to the surface facilities.

Retrieved WPs that are in good condition will be taken to the surface and staged in a dedicated area within the surface facilities complex. The surface facilities complex for retrieved WPs will have appropriate unloading mechanisms to remove the WP/pallet assembly from the bedplate of the WP transporter. It is anticipated that these unloading mechanisms will be similar to those used to load the WP transporter as stated in Section 3.3.1.4. If a damaged WP or a drift condition preventing normal retrieval is encountered, the sequence will be interrupted, and contingency plans for abnormal retrieval, discussed in section 3.3.6.3, will be implemented.

3.3.6.3 Abnormal Retrieval Conditions and Operations

Abnormal retrieval conditions result when one or more abnormal events occur before or during waste emplacement, caretaking, or normal retrieval operations. Abnormal events may be the result of an unexpected or unplanned process occurring within the repository that would hinder normal operation. An abnormal event refers to subsurface conditions that have deviated or been disturbed in some way to prevent normal operation.

The basic strategy for the mitigation of all abnormal conditions will consist of the following activities:

- Assessing nuclear and non-nuclear safety
- Establishing access control and isolation of the event area from continued operations, if required
- Confining radioactive contamination, if present
- Collecting critical technical data, other than nuclear
- Formulating a mitigation plan
- Designing and providing any additional specialized equipment needed for mitigation
- Implementation of the mitigation plan

This report discusses operational concepts for three worst case abnormal events consisting of (1) an emplacement gantry derailment within the emplacement drift, (2) a rock fall or ground support failure within the emplacement drift, and (3) retrieval of contaminated or breached waste packages. There are numerous abnormal conditions that could occur during the preclosure period of the repository leading to abnormal retrieval operations. The discussion and identification of all possible abnormal events and retrieval scenarios such as a collapsed WP pallet, fire, emplacement equipment failure, drift isolation door failure, rail switch failure or other system failure is considered outside the scope of this report.

3.3.6.3.1 Derailment of Emplacement Gantry

The purpose of this section is to discuss a recovery concept for an abnormal condition that deals with a derailed or otherwise immobilized gantry within an emplacement drift. At the time of the derailment, the gantry may be with or without the load of a WP/pallet assembly.

To accommodate working in an emplacement drift under abnormal conditions, two pieces of retrieval equipment were presented and discussed in the *Retrieval Equipment and Strategy for WP on Pallet* analysis (CRWMS M&O 2000b, Section 6.2.4). These were:

- Emplacement Drift Gantry Carrier, shown in Figure 7 (CRWMS M&O 2000b, Section 6.2.4)
- Multipurpose Hauler, shown in Figure 8 (CRWMS M&O 2000b, Section 6.2.4)

Both pieces of equipment have been conceived to operate on steel rollers and temporary steel plates, which would need to be placed on the invert system between the gantry rails. The

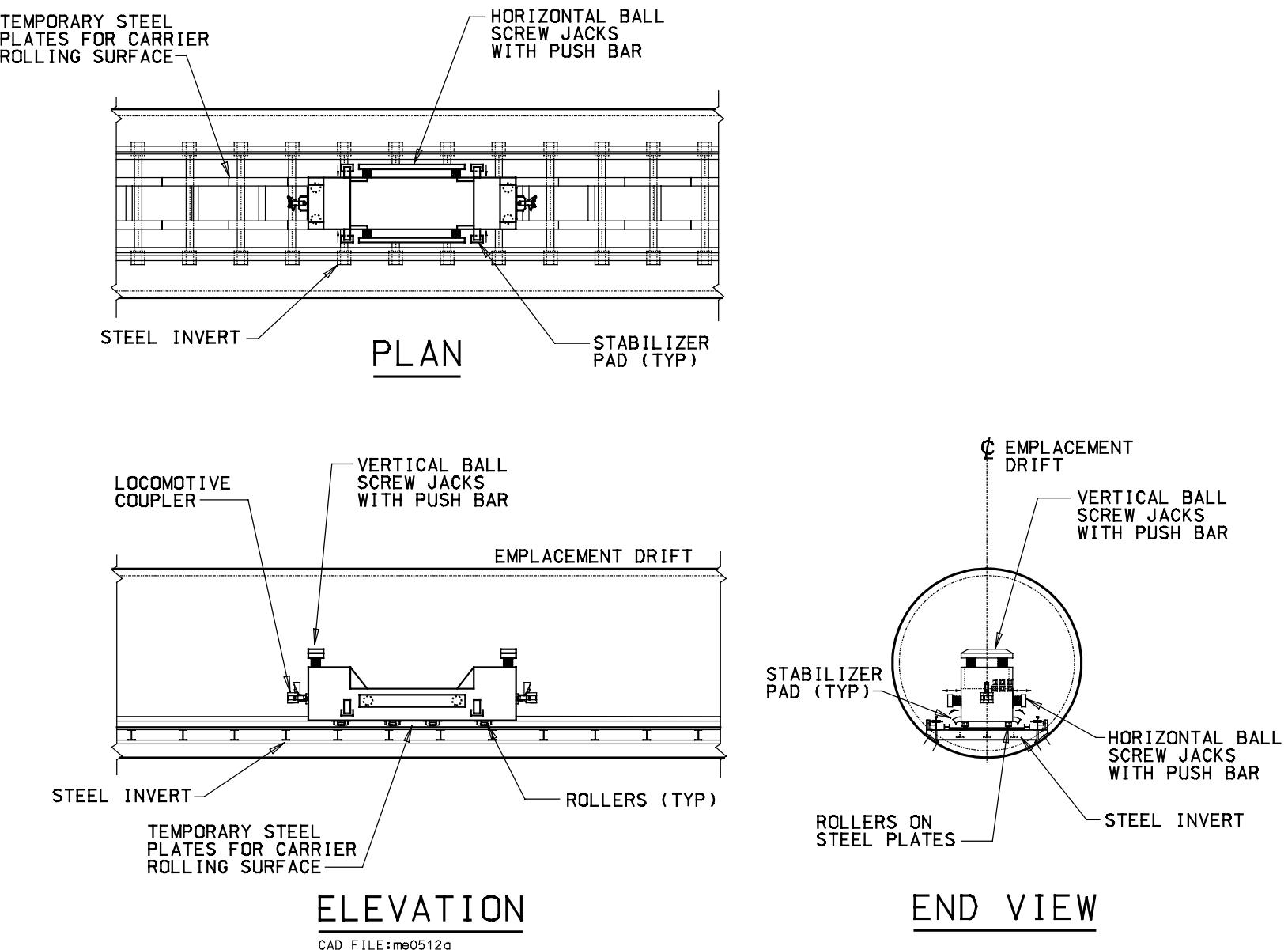


Figure 7. Emplacement Gantry Carrier

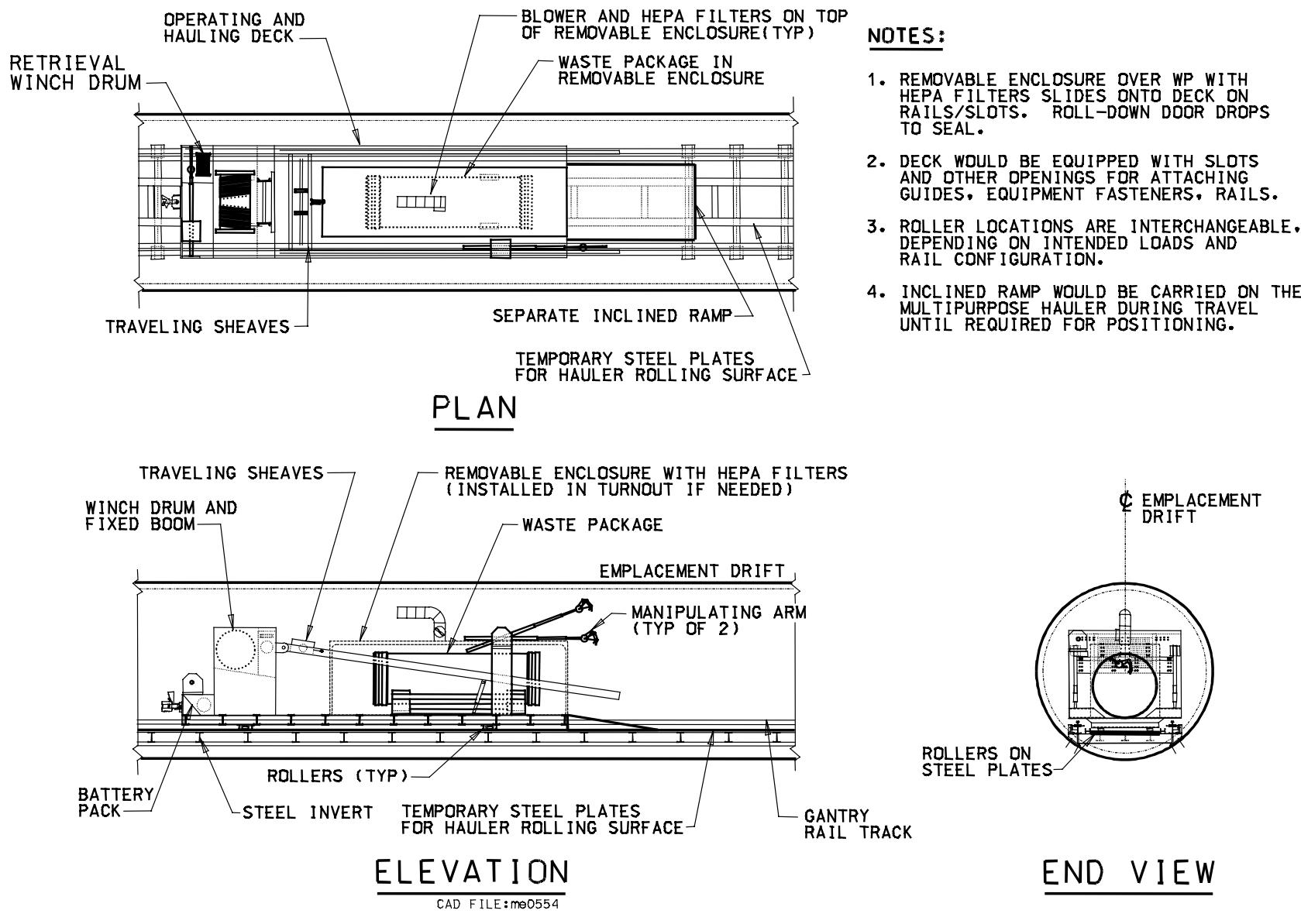


Figure 8. Multipurpose Hauler

multipurpose hauler could perform the installation of the steel plates on top of the steel invert and ballast within the emplacement drift. These plates will allow the emplacement drift gantry carrier and multipurpose vehicle to operate as intended (CRWMS M&O 2000b, Section 6.2.4).

There are two major alternatives for the rerailment of a derailed emplacement gantry:

- The use of rerailers
- The use of an emplacement drift gantry carrier

Use of rerailers—As the name suggests, a typical rerailer is a portable device designed to rerail a railcar that has come off its track. When two rerailers, one on each side of the tracks, are installed, the disabled railcar is then pulled over the rerailers. The shape and design of the rerailers lift and align the wheels of the railcar with the rail-head, as the wheels are being rolled over the rerailer, thereby putting the railcar back on the track. As a single piece of equipment without any moving parts, a rerailer provides a simple and reliable means to rerail a railcar that has come off of the track.

Adverse conditions, such as high temperatures, high radiation and limited space, may make the remote installation and alignment of rerailers difficult. Additional factors that could inhibit the use of rerailers may include:

- Excessive weight of the gantry with a WP/pallet assembly,
- Position of the emplacement gantry off of the track/rail system.

Use of an emplacement drift gantry carrier—If it is determined that the use of rerailers is not a viable option for the recovery of a derailed emplacement gantry, a second option will have to be utilized. This retrieval option would involve the use of an emplacement drift gantry carrier, which has been conceptually developed to recover a derailed, or otherwise disabled, emplacement gantry within the confines of the emplacement drift envelope. This specialized equipment will be designed to perform the following operations:

- Move and position itself underneath the unloaded emplacement gantry,
- Raise the emplacement gantry above the level of the gantry track,
- Align the emplacement gantry wheels with the track,
- Lower the emplacement gantry back onto the track, or completely haul the emplacement gantry out of the emplacement drift.

The following paragraphs describe a potential gantry derailment scenario and the mitigation strategy for the recovery of the derailed emplacement gantry, which happened to be carrying a WP/pallet assembly.

Gantry Derailment Scenario—Assume that the gantry derailment occurs deep within the emplacement drift, near the ventilation raise. As a result of the derailment, the emplacement drift rails under the derailed gantry are damaged beyond use, and the gantry trucks on the ventilation-raise-side are inoperable (i.e., the gantry will no longer roll). In addition, the electric third rail near the gantry is damaged, thus eliminating the electric power supply to the

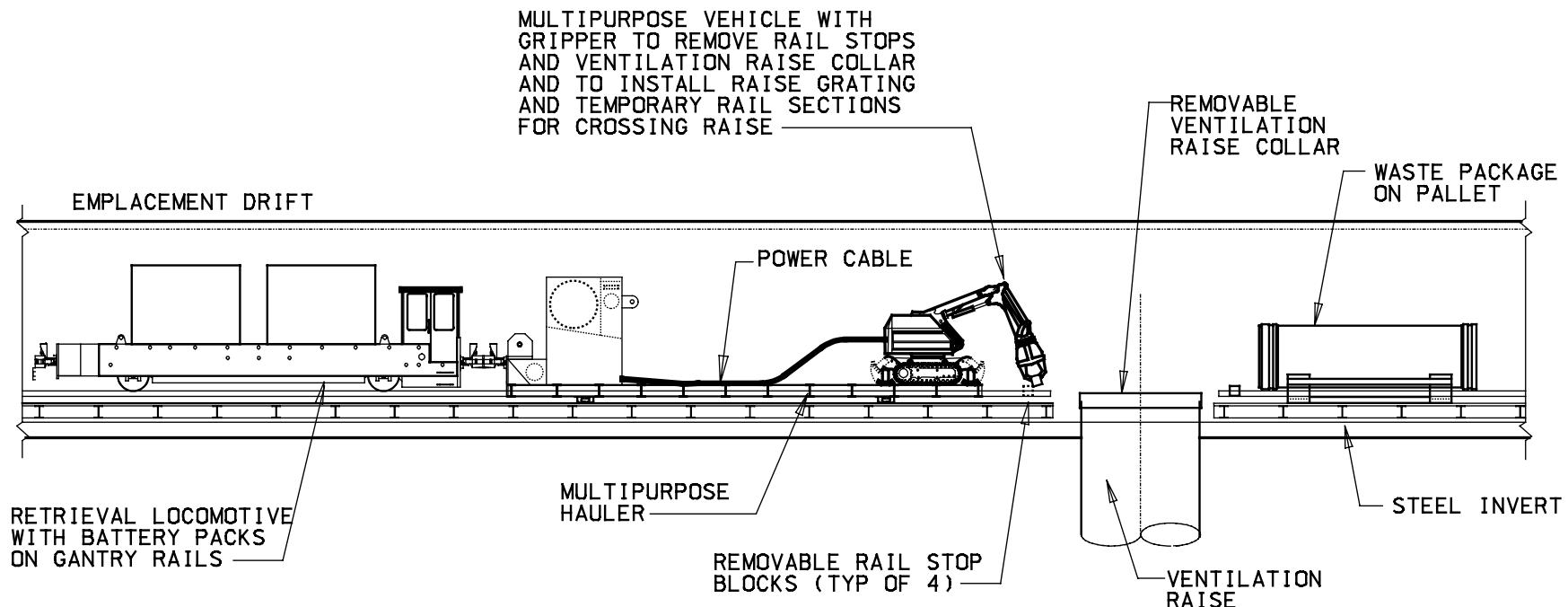
emplacement gantry. The use of rerailers would not be a feasible option for the mitigation of this scenario due to the damaged rail, gantry trucks and electric third rail.

A possible mitigation sequence may be as follows:

Mitigation Plan Development—Because the emplacement gantry trucks closest to the ventilation raise are damaged, these trucks must be raised off the invert and the gantry towed out of the emplacement drift. In the formulation of the mitigation plan, it was determined that access to the derailed emplacement gantry would be from the rear of the emplacement drift, through the drift entrance on the other side of the repository. Gaining access would be accomplished by removing the WPs from the far end of the emplacement drift and any that would be in the drift section between the ventilation raise and the disabled gantry.

WP Removal—WPs that may be limiting access to the disabled gantry would be removed under normal retrieval operations, described in Section 3.3.6.2, using a second emplacement gantry. After all WPs up to the ventilation raise have been removed from the drift, the multipurpose hauler, carrying the multipurpose vehicle, will enter the drift from the other end. To make it possible for the retrieval equipment to travel across the ventilation raise, the remotely controlled multipurpose vehicle would utilize its grippers to remove the elevated collar on the ventilation raise and the stop blocks installed at the ends of the gantry rails. While performing these functions, the multipurpose vehicle would operate from the deck of the multipurpose hauler as shown in Figure 9. An emplacement drift retrieval locomotive would provide the locomotive power to move the multipurpose hauler carrying the multipurpose vehicle. The location of the ventilation raise is currently being reviewed. It may be possible to locate the raise in an alcove off the emplacement drift that would allow rail to run continuously from one emplacement drift entrance to the other. The exhaust main could also be located above the emplacement drifts so the raise would be located off the top of the emplacement drifts. This approach would also allow rail to be run continuously from one drift entrance to the other. This report will discuss the worst case scenario, which is having the ventilation raise in the center of the emplacement drift, with the exhaust main located below the emplacement drift elevation.

The multipurpose vehicle will be a relatively small unit designed to remotely operate in the emplacement drifts, main drifts, and ramp areas, either on the drift invert or from the deck of the multipurpose hauler. The multipurpose vehicle can be fitted with various attachments, each intended to perform a specific function. Such attachments include, but are not limited to, a bucket attachment for removing debris, an impact hammer for reducing debris size, a cutting torch to dismantle damaged equipment or structures, and grippers to remove or install required pieces of retrieval equipment.



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Figure 9. Multipurpose Hauler Removing Obstructions

After removal of the ventilation raise collar, the multipurpose vehicle will install grating, rail, and necessary supports so that equipment can gain access to the derailed emplacement gantry. Once rail integrity has been verified across the ventilation raise, the retrieval locomotive, multipurpose hauler, and multipurpose vehicle will exit the drift from the far end. The second emplacement gantry would again enter the drift and remove the remaining WP/pallet assemblies up to the derailed emplacement gantry as shown in Figure 10. Due to the lack of available third-rail electric power across the ventilation raise, the retrieval locomotive, with on-board batteries, would power or provide the locomotive force to the emplacement gantry and any other equipment not having self-contained power sources.

Removal of the WPs downstream of the ventilation raise is envisioned as follows. The retrieval locomotive would push or power the emplacement gantry as it travels across the raise towards the WPs. The emplacement gantry would then engage the nearest WP/pallet assembly and raise it. Once all necessary interlocks have been satisfied, the retrieval locomotive would pull or power the emplacement gantry as it travels across the raise towards the drift entrance on the other side of the repository. When sufficiently clear of the ventilation raise, and power has been verified to the emplacement gantry, the retrieval locomotive will disengage from the emplacement gantry. The retrieval locomotive would then travel to the drift entrance, ahead of the emplacement gantry, and be taken away by a carrier similar to the emplacement gantry carrier. The WP transporter would then dock at the drift entrance. The gantry would move into position over the WP transporter and lower the WP/pallet assembly onto the bedplate. The bedplate would retract and the WP transporter would then travel to another drift or to facilities on the surface. The retrieval locomotive would be installed in the drift and the process would be repeated until all WPs limiting access to the derailed emplacement gantry have been removed.

Removal of WP/pallet Assembly—When all of the WPs have been removed from the drift, the emplacement gantry and retrieval locomotive will be removed from the drift and the multipurpose hauler, multipurpose vehicle, and retrieval locomotive will enter the drift. The next step toward completing the recovery operations would be to remove the WP/pallet assembly from the derailed gantry. The multipurpose vehicle on the multipurpose hauler could restore power to the derailed gantry by connecting an electrical power and data communications cable to auxiliary receptacles on the disabled emplacement gantry. The multipurpose vehicle would place steel plate onto the invert surface underneath the gantry to form an elevated sliding surface. The lifting mechanism on the disabled gantry would then lower the WP/pallet assembly onto this steel plate.

The multipurpose hauler carrying the multipurpose vehicle will then travel to the drift entrance where the multipurpose vehicle will be removed. The multipurpose hauler would be sent back into the emplacement drift and travel to the disabled gantry. The winch cable on the hauler would be attached to the lower section of the pallet frame that supports the WP using the manipulator arm, and the WP/pallet assembly would be pulled onto the deck of the hauler as shown in Figure 11. Some slipping of the multipurpose hauler may occur during the winch operation. However, any slipping that may occur is insignificant to the design or operation of the hauler and would not preclude the hauler from retrieving the WP/pallet assembly. After the recovery of the WP/pallet assembly, the multipurpose hauler would be transported to the drift entrance for removal on an emplacement gantry carrier or equivalent type of transport vehicle.

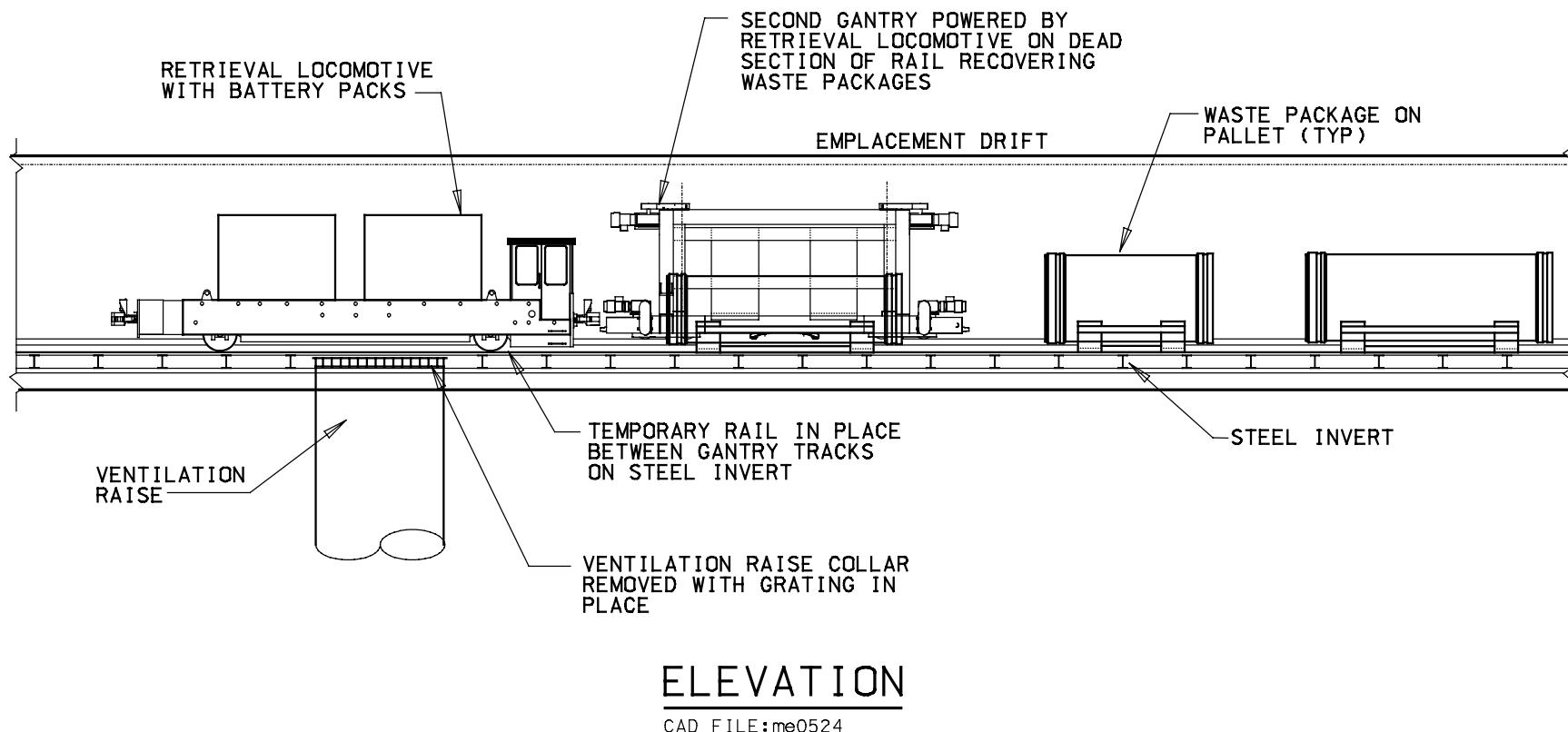
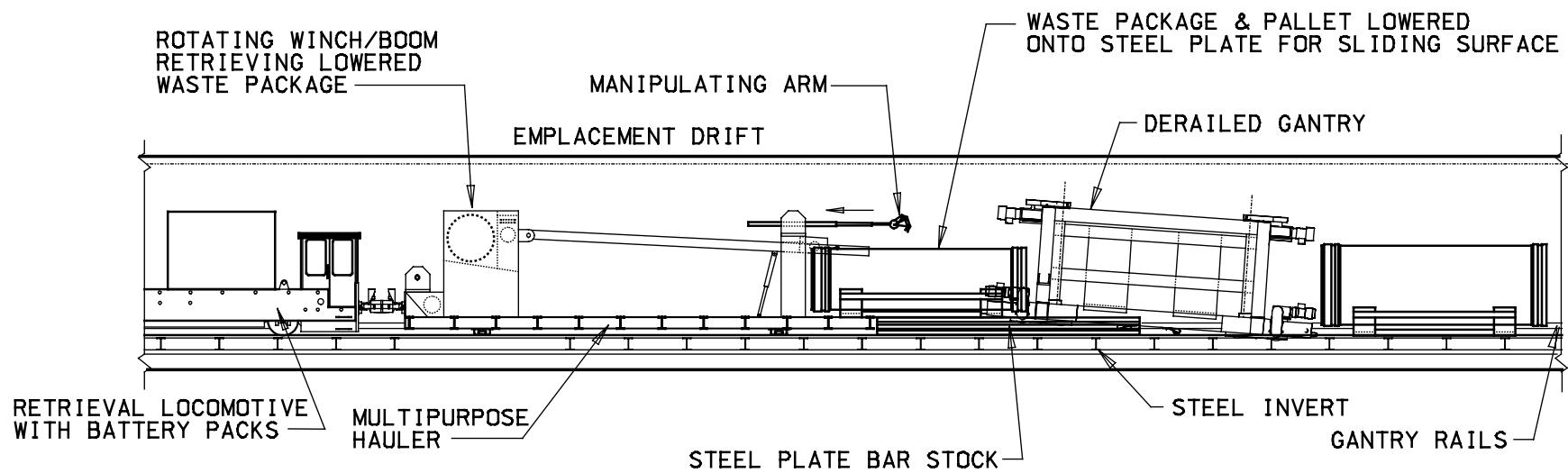


Figure 10. Second Gantry Removing WP



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Figure 11. Hauler Retrieving Trapped WP

In the event of a breached WP, the multipurpose hauler could be equipped to accept a temporary contamination enclosure (see Figure 8). Due to limited workspace within the emplacement drift, the enclosure would have to be installed within the drift turnout once the hauler was clear of the emplacement drift.

The enclosure on the multipurpose hauler would be maintained under a negative pressure (i.e., a vacuum), with a blower exhausting into a High-Efficiency Particulate Air (HEPA) filter (CRWMS M&O 2000b, Section 6.2.4). The enclosure would contain any airborne contamination particles emanating from the WP, but it would not provide any radiation shielding. Due to this condition, personnel access would have to be restricted to areas at a safe distance from the WP during transport from the subsurface areas to the surface facilities.

After the release and removal of the WP/pallet assembly from within the emplacement drift, the gantry lifting mechanism would be raised to an elevated position to allow free access to the underside of the derailed gantry. The following paragraphs provide details for the preparation and removal of the derailed emplacement gantry.

Removal of Derailed Gantry—To provide the emplacement drift gantry carrier with an even rolling surface, steel plates would be set by the multipurpose vehicle onto the invert, between the emplacement drift rails. The emplacement drift gantry carrier would be carried into the drift and placed on the steel plates by a second emplacement gantry. A retrieval locomotive would then push the emplacement drift gantry carrier into place under the derailed gantry as shown in Figure 12. Stabilizer pads on the emplacement drift gantry carrier would be extended to contact the drift invert and provide the necessary stability while the vertical ball screw jacks on the emplacement drift gantry carrier contact the gantry frame from underneath and attempt to raise it above the gantry rail.

If lifting of the gantry were not possible due to ground support interference, the horizontal ball screw jacks on the emplacement drift gantry carrier would be deployed, shifting the gantry towards the gantry rail. The derailed gantry, now clear of the ground support interference, would then be raised just above the damaged tracks, and pulled to an area where good track rail exists.

Once the gantry is aligned with the good rail track, two possible scenarios to recover the gantry from within the emplacement drift exist. These scenarios would depend on the severity of the gantry derailment.

If the gantry can be re-railed by the emplacement drift gantry carrier, as described above, and the gantry remains functional, i.e., the drive system and controls remain in working condition, the gantry would travel under its own power to the emplacement drift entrance. At the entrance, the gantry would board the gantry carrier, not to be confused with the emplacement drift gantry carrier, and be moved to the surface maintenance and storage facility for repair.

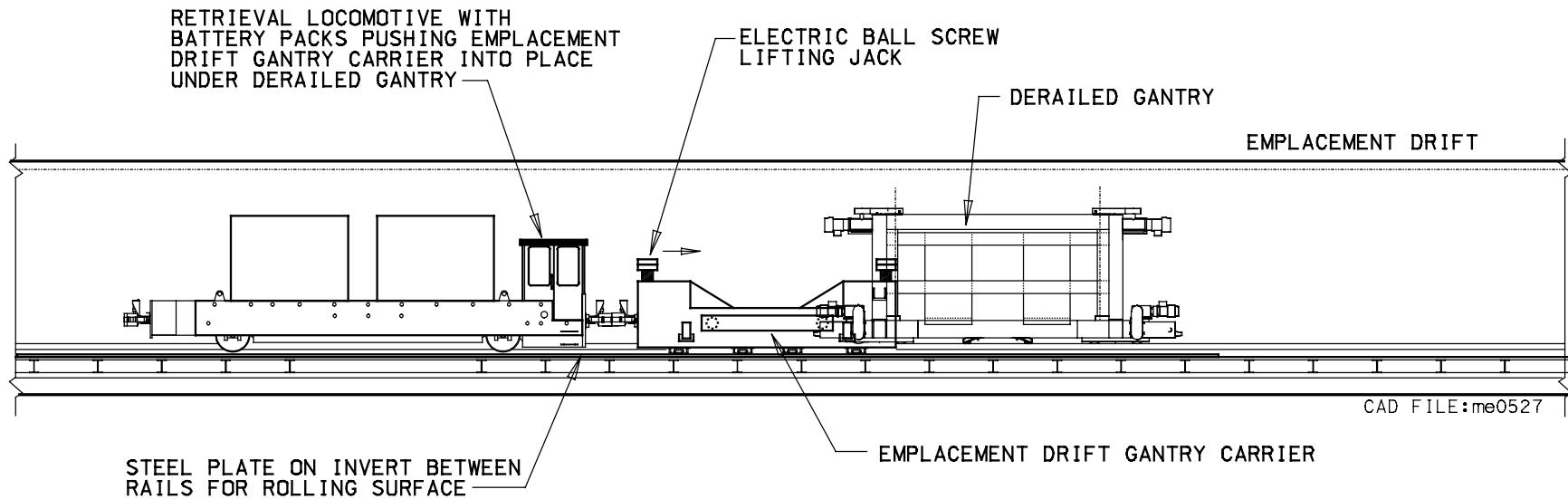


Figure 12. Emplacement Drift Gantry Carrier Pushed into Position

However, if the gantry trucks, drive mechanism, and/or control system have been severely damaged and are no longer functional, the emplacement drift gantry carrier would then be used to transport the emplacement gantry to the emplacement drift entrance. The emplacement drift gantry carrier, moved by a retrieval locomotive, would raise the gantry off the rail and tow the gantry to the emplacement drift entrance as shown in Figure 13.

The above discussion is definitely a worst case scenario. Gaining access to a disabled gantry from the other entrance to an emplacement drift does introduce a number of challenging operations, which while difficult, are not impossible. It is anticipated that any derailments could be dealt with operations conducted from the same drift entrance so travel across the ventilation raise, should there be one, will not be required. Operations conducted from the same drift entrance will not require the removal of any emplaced WPs, which should significantly reduce the total amount of time to correct the situation.

3.3.6.3.2 Rock fall or Ground Support Failure

A rock fall or ground support collapse within an emplacement drift will require an abnormal retrieval activity to be executed if it is determined that the WP/pallet assemblies should be removed from the damaged drift. Another emplacement gantry or mobile piece of surveying equipment could be used to inspect the emplacement drift after the rock fall was observed. Items to be surveyed would include the amount of rock in the emplacement drift, the presence of radionuclide contamination, the position of any equipment (if involved), condition of the ground support, and the condition of the drift invert and gantry tracks.

Ground Support Failure Scenario—One example scenario would be if a portion of the ground support fails within an emplacement drift causing a blockage within the drift. To make the scenario more severe, it can be envisioned that WP emplacement has begun, WPs are present, and a loaded emplacement gantry is in the area of the rock fall and becomes partially buried as shown in Figure 14. In addition, repository infrastructure components, including the ground support, rail tracks, electric third rail, and communication systems are severely damaged and inoperable downstream of the area of the rock fall. Data communication and associated video signals from the emplacement gantry would be lost, putting the remote operators in a total blackout condition.

A remote inspection vehicle, possibly the one intended to obtain performance confirmation data, would be sent into the drift to survey the damage. The remote inspection vehicle would be transported to the drift entrance on the gantry carrier and docking and unloading operations would be the same as those discussed in section 3.3.2.1. Video signals of the rock fall and surrounding damage would then be transmitted to the main control room. Sensory equipment would also transmit data representative of the environmental conditions in the drift. These signals could include ambient temperature, radiation levels, amount of airflow, humidity, and gases of interest, such as carbon monoxide, or tracer gases if such are used in the fabrication of the WP.

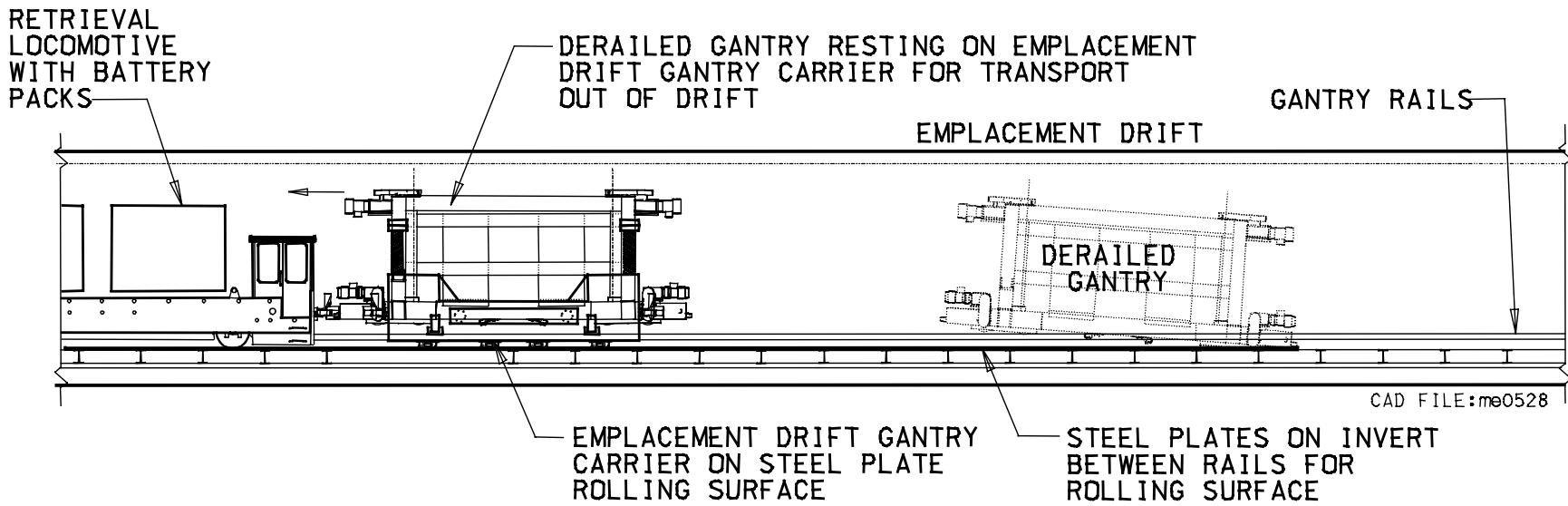


Figure 13. Emplacement Drift Gantry Carrier Moving Derailed Gantry

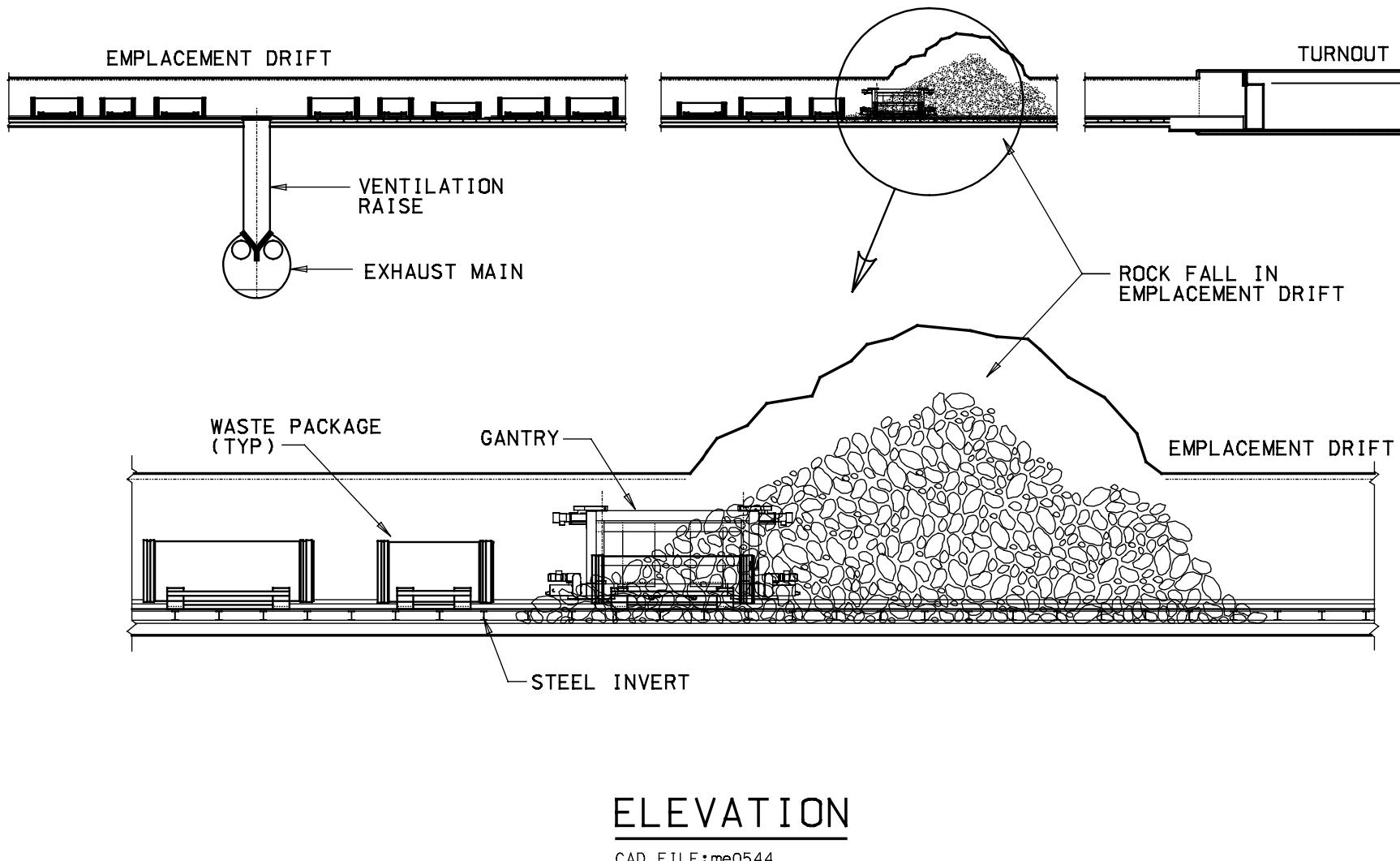


Figure 14. Rock Fall in Emplacement Drift Partially Covering Equipment

A specialized investigative team would interpret the data and video signals transmitted by the remote inspection vehicle and develop a mitigation plan. For the above scenario the mitigation plan could include the following steps.

Mitigation Plan Development—Ventilation was severely interrupted by the drift/ground support collapse that occurred in the loaded drift midway between the emplacement drift entrance and the ventilation raise, and some form of temporary ventilation is required to cool the disabled portion of the drift. Without the temporary ventilation, the drift temperature would rise above predetermined operational limits for the retrieval equipment. A possible mitigation plan could determine that to provide the pathway for the temporary ventilation, an emergency ventilation airway could be bored from an adjacent drift to the damaged drift.

WP Removal—To implement the recovery operations of the conceptual mitigation plan, all WP/pallet assemblies of the adjacent drift would need to be removed. This would be accomplished using the normal retrieval operational concepts as discussed in Section 3.3.6.2. The removal of all WP/pallet assemblies would then provide access for personnel and mining equipment so a tunnel could be constructed to the disabled drift. A roadheader, drill-and-blast, and/or other mining equipment and techniques would be used in the construction of the emergency ventilation airway.

Prior to the start of any tunneling activity, the WP/pallet assemblies located in the damaged drift but outside the rock fall area would be removed using normal retrieval procedures, as described in Section 3.3.6.2. These WP/pallet assemblies would likely be located downstream of the ventilation raise and access to them would be from the other side of the emplacement drift. The WP/pallet assemblies retrieved under these conditions would be those that are undisturbed, not buried by rock fall, and where the electric power supply and control system is still in working order. The mobile equipment for this operation would consist of the typical emplacement gantry without the need for additional equipment.

Emergency Airway Construction—With the WPs removed from the adjacent drift, it would be safe for workers to enter the drift in order to establish a temporary roadway for excavating equipment. The emergency ventilation airway would be bored through the pillar separating the drifts using normal underground excavation procedures. The airway would be bored until just before the wall of the damaged drift is breached. Final access to the drift, containing the buried WPs, would be completed using remotely controlled boring equipment. The ventilation raise and the isolation doors of the drift used for boring would then be closed to permit the cooling airflow through the blocked drift section.

WP/pallet Assembly Removal—The next operation would be to retrieve WP/pallet assemblies within the damaged emplacement drift that are located between the rock fall and the ventilation raise, without the availability of electric power and/or a working control system. This group of WP/pallet assemblies would be removed using the same retrieval procedures and equipment under abnormal retrieval conditions, as described in Section 3.3.6.3.1. The mobile equipment for this operation would consist of the typical emplacement gantry, the multipurpose hauler, the multipurpose vehicle, all working in conjunction with the battery powered retrieval locomotive. Therefore, electric power to operate the retrieval equipment within the damaged section of the

emplacement drift would be provided through the battery operated emplacement drift locomotive.

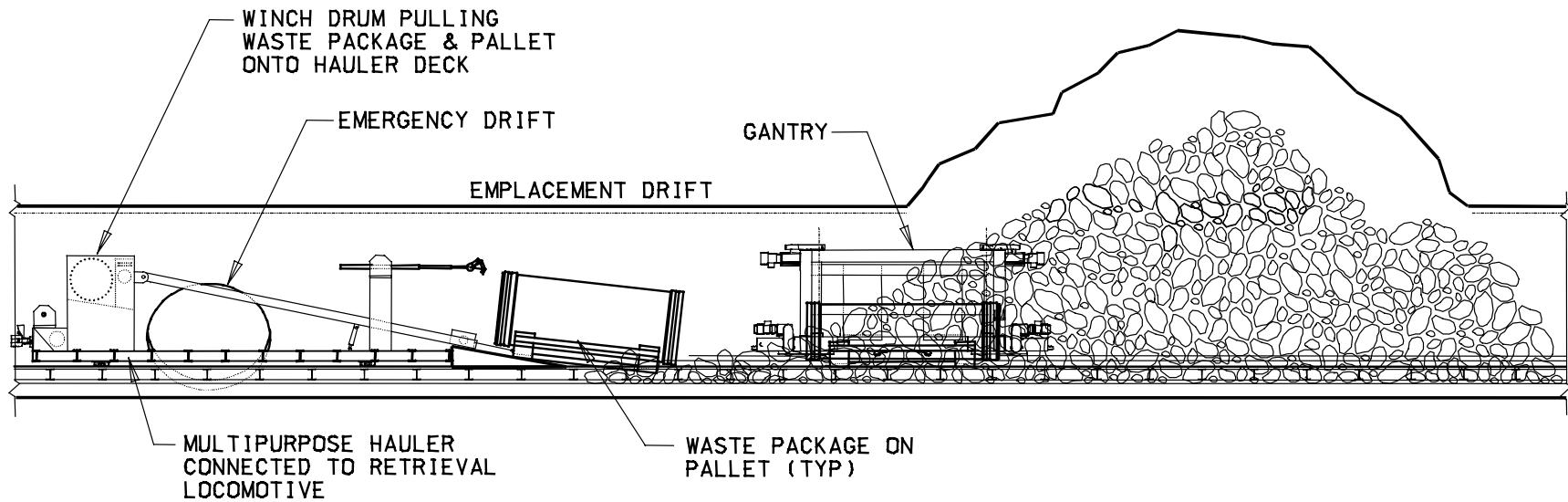
Once the rock fall area becomes accessible to the mitigation equipment, the next step would be to clear remaining debris accumulation from the invert in front of the main rock fall. Enough debris would be cleared to permit the installation of temporary ground control by the remotely controlled multipurpose vehicle on either side of the rock fall. Part of the retrieval system is the installation of temporary ground support to permit safe conduct of retrieval operations.

Buried WP/pallet Assembly Removal—Remaining WP/pallet assemblies that are partially buried and have to be recovered from underneath the rock fall would have to be removed by use of the multipurpose hauler, in conjunction with the battery powered retrieval locomotive. Removal of buried WPs would take priority over buried equipment. When a buried WP/pallet assembly becomes exposed, the winch cable on the multipurpose hauler would be attached to the lower part of the pallet and the entire WP/pallet assembly would be pulled onto the hauler. Additional equipment may include the use of the multipurpose vehicle to clear any rock and other debris to access a WP/pallet assembly. Typical details of a buried WP/pallet assembly in an emplacement drift and some of the recovery equipment are shown in Figure 15.

Drift Restoration—When all WP/pallet assemblies have been removed from the debris, work would continue to remove the remaining debris around the buried equipment, with the bucket attachment on the multipurpose vehicle as shown in Figure 16. Other attachments required for reducing the size of the debris would be attached as necessary, such as jack-hammers or crushers. The multipurpose vehicle could be interchanged with a scaling machine to remove loose material around the edges of the opening created by the rock fall. A muck container for the rock fall material would be placed on the deck of the hauler, next to the operating multipurpose vehicle, to reduce vehicle travel in and out of the emplacement drift. Normal mining equipment and vehicles would be used to transport the muck to the surface, or other suitable site.

When all impeding debris have been removed from the damaged emplacement drift, any remaining emplacement/retrieval equipment would then be removed. If there were no breached WPs during the rock-fall and clean-up, and all WPs have been removed, the equipment removal may be performed manually. The method used for equipment removal would depend on the operational status of the equipment and the condition of the gantry rails. If the rails are usable and the equipment is relatively intact, the gantry may be re-railed or pulled by other means back to the emplacement drift transfer dock (see Section 3.3.6.3.1) for removal. However, if the rails are damaged beyond use and/or the equipment is not worth salvaging, fill material would be imported, as required, to fully cover the emplacement drift invert providing a road bed. This would permit access to the damaged equipment by non-rail vehicles and equipment. The damaged emplacement equipment would be dismantled or, in worst case, cut into manageable pieces and removed.

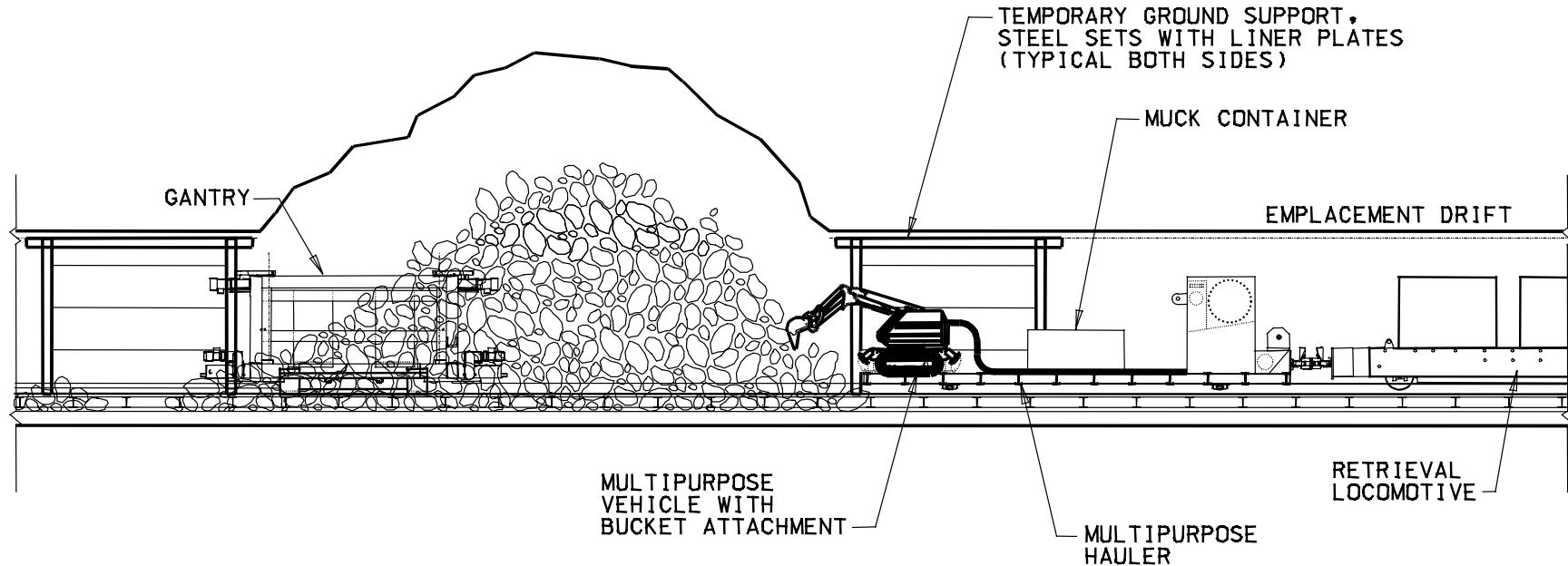
Once the equipment has been removed from the drift, work may commence to rebuild the infrastructure. Additional loose material from the rock fall may have to be removed to stabilize the drift walls and crown. Further stabilization of the drift may require the use of rock bolting or



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Figure 15. Multipurpose Hauler Retrieving Buried WP



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Figure 16. Multipurpose Hauler Removing Debris

other stabilization methods. The ground support and related systems would then be rebuilt using normal underground construction procedures.

3.3.6.3.3 Retrieval of Contaminated Waste Packages

As soon as contamination above specified limits is detected, or if monitoring indicates unusual levels of contamination, operational concepts dealing with the mitigation of this abnormal event will be instituted. Should the contamination be detected in the WP transporter, it may be directed to return to decontamination facilities on the surface. If the contamination is detected in an emplacement drift, a remote inspection vehicle could be sent into the drift to verify the level and source of the contamination. The emplaced WP(s) may need to be retrieved for inspection and possible decontamination if the contamination level is determined to be above the established threshold limits. The following paragraphs will present possible strategies for the retrieval of a potentially contaminated WP.

Two principal strategies may be used to control the movement of contamination during WP transport and retrieval. These strategies may be used independently or simultaneously as warranted by the particular situation.

The first strategy is to contain, to the extent possible, the further spread of contamination to uncontaminated areas. This is most readily accomplished by the use of physical barriers between the contaminated and uncontaminated areas. HEPA filter bulkheads would be used to contain contamination generated by an abnormal event. Bulkheads could be installed upwind and downwind from the abnormal event to isolate the contamination site from continued operations and to maintain worker safety. The second strategy is to prevent the flow of ventilation from areas of higher contamination to areas of lower contamination. This is most readily accomplished by placing an auxiliary ventilation intake near the source of contamination and directing the exhaust air through HEPA filters. This can be accomplished by the use of the mobile filtration units consisting of HEPA filters, pre-filters, a plenum, and one or more fans.

In the case of a transporter in which high airborne contamination levels have been detected, the appropriate containment strategy would be to seal any openings through which air may leak (e.g., transporter shield doors). This should be accomplished prior to moving the transporter back to the surface. A reduction in the contamination levels may be accomplished by drawing air inside the transporter through a HEPA-filtered exhaust fan. This approach would also have the additional benefit of creating a negative-pressure air space inside the transporter relative to the outside air.

During retrieval of one or more suspect WPs from an emplacement drift, all personnel not directly involved in the transporter operation will be evacuated from the emplacement side of the repository. The locomotive operators will wear appropriate protective clothing including air filtration respirators. All of the WPs that are not contaminated will be removed from the drift using the normal retrieval procedures discussed in Section 3.3.6.2.

The emplacement drift locomotive and multipurpose hauler, carrying the multipurpose vehicle, will then enter the emplacement drift containing the contaminated WP. The multipurpose

vehicle, under remote control, will cover the accessible surfaces of the WP with a heat-resistant, nonpermeable material, such as lead vinyl or Herculite, to reduce the spread of contamination during transport of the WP. After successfully installing the material over the WP/pallet assembly the emplacement drift locomotive, multipurpose hauler, and multipurpose vehicle will exit the drift.

After the emplacement drift locomotive, multipurpose hauler, and multipurpose vehicle have exited the drift, locomotives will transport the gantry carrier and emplacement gantry to the contaminated emplacement drift entrance. The emplacement gantry will be unloaded in the drift.

A temporary heat-resistant liner or sleeve will be placed inside the WP transporter at the surface facilities. Locomotives will then transport the specially fitted WP transporter to the contaminated emplacement drift entrance. Once the WP transporter is docked at the drift entrance, the emplacement gantry will engage the WP/pallet assembly and carry it to the emplacement drift entrance where it will be lowered onto the bedplate of the WP transporter. The bedplate would retract inside the shielded enclosure of the transporter, the locomotive would pull the transporter away from the drift dock, and the WP transporter doors would close. The second locomotive would engage the WP transporter in the main drift and the two locomotives would move the WP transporter to a specially prepared decontamination room at the surface. This procedure would have to be repeated for all WPs that are contaminated.

Following the retrieval of contaminated WPs, it will be necessary to perform a radiological survey on all interior and exterior surfaces of the equipment involved in the operation, (e.g., WP transporter, emplacement gantry, multipurpose vehicle, multipurpose hauler, and/or gantry carrier). To reduce the spread of contamination from the WP transporter or gantry surfaces, these surfaces should be decontaminated to the extent possible by using a HEPA-filtered vacuum cleaner or other appropriate method. The equipment shall have an appropriate surface finish and geometry to facilitate decontamination and limit the accumulation of particulate or surface contamination (CRWMS M&O 2000d, Section 1.2.1.21).

In addition, surveys of the main drift, turnout, and all pathways followed by the returning equipment, such as WP transporter, gantry, and gantry carrier, will be performed. Contaminated areas will be decontaminated in compliance with regulatory requirements and ALARA policies. A contamination survey of the emplacement drift may be needed as well. For an emplacement drift, a remotely controlled inspection vehicle could perform the survey. If unacceptable levels of contamination were found, the inspection vehicle would have to be removed from the subsurface repository using the same procedure as for the emplacement/retrieval gantry. A decision would then have to be made whether to remove all WPs in that drift and decontaminate the drift. The waste packages would be removed using the steps discussed above.

3.3.6.4 Evaluation of Lower-Temperature Operating Modes on Retrieval Operations

This section of the report evaluates the five scenarios presented in Sections 3.2.1 through 3.2.5 against the operations described in section 3.3.6.

3.3.6.4.1 Evaluation of Lower-Temperature Operating Modes on Normal Retrieval Operations

The normal retrieval operations will be exactly opposite of the emplacement operations described in Sections 3.3.3 and 3.3.4. The effects of a lower-temperature repository will therefore be the same as those identified in Sections 3.3.3.5 and 3.3.4.4. The major impact is that with a potentially larger emplacement area, the equipment may require additional maintenance because of the longer distances and extended travel times that the equipment must endure as compared to the base case design.

3.3.6.4.1 Evaluation of Lower-Temperature Operating Modes on Abnormal Retrieval Operations

As stated in Section 3.3.6.3, abnormal retrieval conditions result when one or more abnormal events occur before or during waste emplacement, caretaking, or normal retrieval operations. Abnormal events may be the result of an unexpected or unplanned process occurring within the repository that would hinder normal operation. In the event that an abnormal condition should occur, cooling of the emplacement drift or location where abnormal retrieval operations are required, will be part of the mitigation plan. The *Subsurface Ventilation System Description Document* states that the particular location shall be maintained at a maximum temperature of 50 °C for remote access to accommodate the retrieval operations (CRWMS M&O 2000c, Section 1.2.1.4).

It is anticipated that abnormal retrieval operations will be limited to a localized area of the subsurface repository. In other words, abnormal retrieval operations would take place in a specific emplacement drift, emplacement drift turnout, or portion of the main drifts. It is highly doubtful that the entire repository will require waste package retrieval under abnormal conditions. Because of this reasoning, the effects of a lower-temperature repository will be the same as the base-case design and the temperature of the operating mode of the repository, should it be lower, will have no impact on the intended concepts of abnormal retrieval.

3.4 SYSTEM INTERFACES WITH THE WASTE EMPLACEMENT/RETRIEVAL SYSTEM

The Waste Emplacement/Retrieval System must interface with a number of systems to safely accomplish the task of emplacing waste. The Waste Emplacement/Retrieval System interfaces with the Monitored Geologic Repository Operations Monitoring and Control System (MGR OMCS) for the transmission of data to and from the emplacement equipment, and for the remote control of the equipment when necessary. The Waste Emplacement/Retrieval System also interfaces with the Subsurface Ventilation System for the emplacement drift operating environment and for travel through the emplacement drift isolation doors. The emplacement equipment will travel exclusively on rails and receive electrical power to operate, both functions will be provided by the Subsurface Emplacement Transportation System. These interfaces are presented below to discuss the significance of each interface and are shown in Figure 17. For a complete listing of all other interfaces, refer to the *Waste Emplacement/Retrieval System Description Document* (CRWMS M&O 2000d, Section 1.2.4).

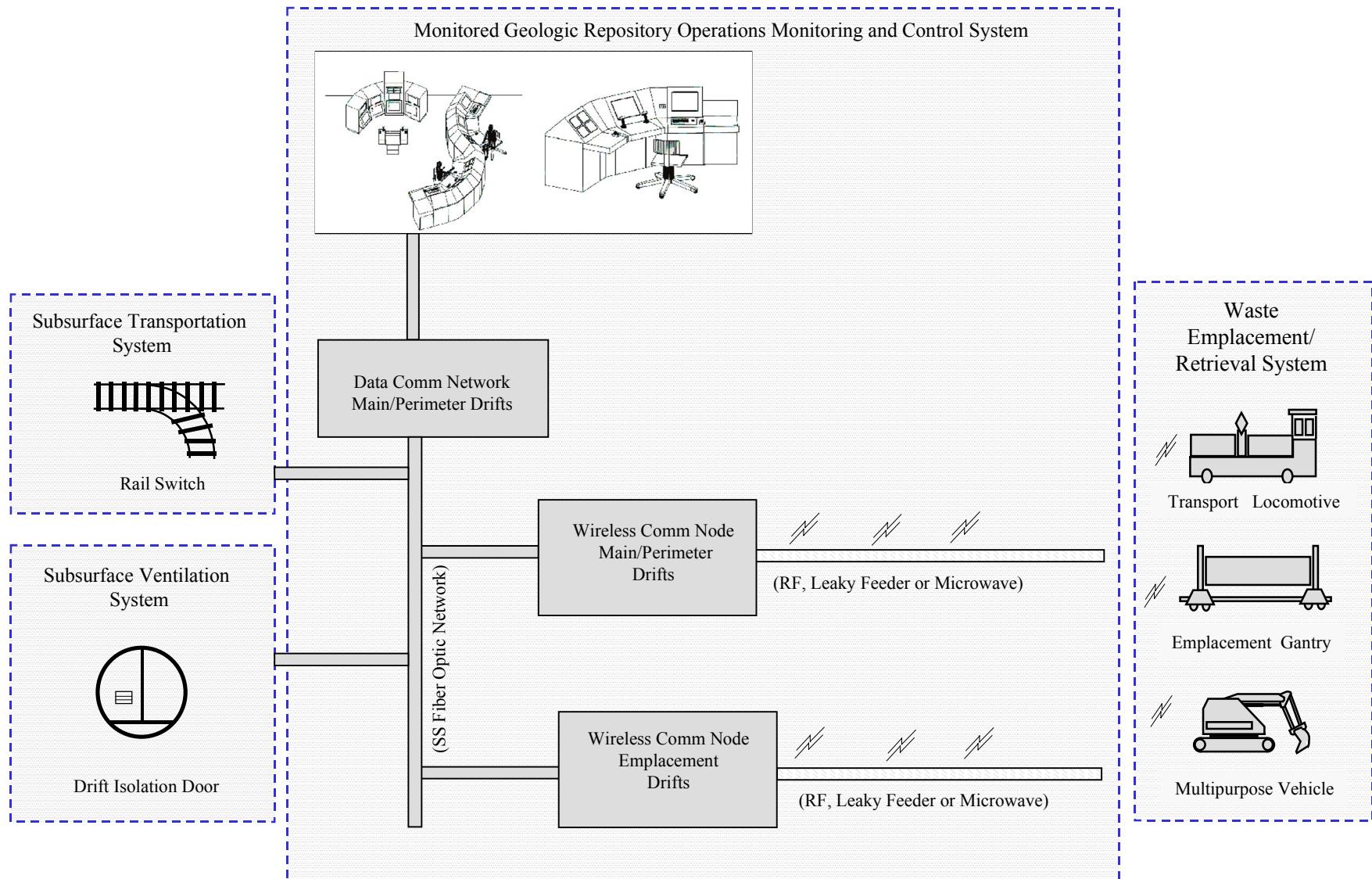


Figure 17. Waste Emplacement/Retrieval Interface with the MGR Operations Monitoring and Control System

3.4.1 Operations Monitoring and Control System (OMCS) Interface

This section will discuss the interface to the MGR OMCS and the relevance of this system in the waste emplacement process.

The OMCS provides supervisory control, monitoring, and selected remote control of primary and secondary repository operations. Primary repository operations consist of both surface and subsurface activities relating to waste receipt, preparation, and emplacement. Secondary repository operations consist of support operations for waste handling and waste treatment, utilities, subsurface construction, and Balance-of-Plant activities. Remote control of subsurface operations is the direct responsibility of this system (CRWMS M&O 2000f, Section 6.2.2.1). The system provides repository operational information, alarm capability, and human operator response messages during normal and emergency response situations. The system also has the ability to place equipment systems and utilities in a safe operational mode during emergency response situations. The OMCS provides data communications, data processing, managerial reports, data storage, and data analysis.

3.4.1.1 Operator Interfaces and Control Stations

All of the devices for transmission of the emplacement process data will be networked together and will allow personnel on the surface to remotely operate the waste emplacement equipment. It is anticipated that the OMCS command center will consist of a control room from which all subsurface operations will be monitored and controlled. This control room will be equipped with engineering workstations, mainframes, and graphics terminals that will provide the operators with direct real-time data. Sufficient storage capacity should exist for time-stamping the data as it is received. This control room will also have a large, wall-sized mimic board so operators can immediately gain insight as to what is occurring underground. The network can be installed with sufficient access points underground to allow an authorized individual to temporarily hook up a lap top or notebook computer and have access to the transmitted data and assume control of the emplacement equipment. Versatility, accuracy, timeliness, and robustness are all attributes that can be implemented in the OMCS to enhance the emplacement process.

3.4.1.2 Subsurface Ventilation System Interface

The emplacement equipment will obviously require entry and exit from the emplacement drifts. The only way for this equipment to get into and out of the drifts will be through the emplacement drift isolation doors that are part of the Subsurface Ventilation System. The OMCS will be monitoring/controlling the emplacement equipment and will therefore be aware that entry into the drift is necessary. The sequence of operations and how the interfaces will work is envisioned as follows:

- ◆ The emplacement equipment enters the drift turnout under the remote control of operators through the OMCS
- ◆ The equipment stops just short of the drift isolation doors

- ◆ Commands, from the OMCS, will be issued to the Subsurface Ventilation System to stabilize
- ◆ The Subsurface Ventilation System will notify the OMCS once the ventilation system is ready for the drift isolation doors to open
- ◆ If the conditions are acceptable, the OMCS will direct the Subsurface Ventilation System that it is permissible for the isolation doors to open
- ◆ The Subsurface Ventilation System will issue commands for the isolation doors to open
- ◆ The emplacement equipment, still under remote control of operators through the OMCS, will complete the docking process
- ◆ The emplacement equipment will leave the dock once all operations have been completed
- ◆ When emplacement equipment is sufficiently clear of the isolation doors, the OMCS will direct the Subsurface Ventilation System that it is permissible for the isolation doors to close
- ◆ The Subsurface Ventilation System will issue commands for the isolation doors to close
- ◆ The Subsurface Ventilation System will return to normal operation once the doors are detected to be in the closed position

As shown above, isolation door operation will be an integral component of the waste emplacement process that will be coordinated by the OMCS. The only direct interface between the Subsurface Ventilation System and the Waste Emplacement/Retrieval System is that the doors are appropriately sized to permit the equipment to pass through them.

During emplacement operations, the ventilation system will be responsible for controlling the temperature in the emplacement drifts to a maximum of 50 °C (CRWMS M&O 2000c, Section 1.2.1.4). This limit is to ensure operability of all the equipment involved in the operation.

3.4.2 Subsurface Emplacement Transportation (SET) System Interface

All of the emplacement equipment will be rail based. Therefore, wherever the equipment must travel, rail must be suitably installed. The installation of the rail must include provisions so the emplacement equipment can orient itself in the proper direction prior to traveling underground. The layout of the track on the surface and in the subsurface portion of the repository will be designed to have the provision of reversing the direction of the waste emplacement mobile equipment.

Similar to the rail requirements, electrical service must also be provided to the emplacement equipment wherever the equipment must operate. To provide power to equipment in the main drifts, an overhead trolley wire electrical distribution system will be used (CRWMS M&O 1997,

Section 8.2). To provide power to equipment in the emplacement drifts, a conductor bar or third rail electrical distribution system will be used (CRWMS M&O 1997, Section 8.2). The distribution systems will be designed so the required voltage at sufficient ampacity will be provided to the equipment wherever they are located within the repository.

3.5 AUTOMATION OF THE EMPLACEMENT PROCESS

The current concepts of operation are dependent upon a fair amount of human interaction. Operators are currently slated to drive the locomotives down the main drifts to an area near the turnout of an emplacement drift. The uncoupling operation would then take place, and an operator would drive the uncoupled locomotive away. The other operator would leave the locomotive coupled to the transporter and switch control of the locomotive to remote operation. From a remote location, the centralized control room, another operator will control the docking process using joysticks and keyboard commands. This operator depends on video signals and process inputs to perform the required steps in the procedure. However, software and hard-wired interlocks will still be present within the control system to prevent unsafe operations or commands from taking place.

An operator from the centralized control room, through the use of joysticks, will control the forward-backward and raise-lower tasks that the gantry is required to perform. Sufficient information will be available to the operator so that informed decisions can be made during the emplacement of the WP and movement of the emplacement gantry.

The steps involved in the emplacement process could be totally automated with little to no human involvement. It would be possible for an operator to input into a control system the WP identifier, the emplacement drift number, and the location within the emplacement drift (i.e., package number 123456789, drift 7, position 4). The control system could be designed to recognize this data and start the batch operation of transferring a WP underground. Once this input data has been verified, the rail switches would be automatically set to direct the locomotives to the appropriate drift entrance. Having received feedback that the rail switches have been correctly set, the main control system could give a command to start the locomotives. The locomotives would then travel at the designated speed, while on-board systems monitor all safety signals. Should an unsafe condition occur, the locomotives would stop and an alarm would sound at the central command console where a trained operator would evaluate the situation and commence corrective action.

In the East or West Main Drift, near the appropriate emplacement drift, the locomotives could be programmed to begin the docking procedure. This would entail uncoupling the rear locomotive so the Transporter could appropriately dock at the entrance of the emplacement drift. The gantry would be suitably positioned within the drift, all doors would open, the transporter would dock, the WP would be released from the Transporter, the gantry would engage the WP and ultimately place it in the designated position within the emplacement drift. This is a simplified version of the steps necessary to place the WP in a drift. Nothing in this process rules out the possibility of automation.

If the process were totally automated, additional sensors would be required to adequately inform the control system of the status of all on-going operations. Position, for example, would be a parameter that would require additional proximity sensors or limit switches so the locomotives and gantry could determine where they are in the repository. Video signals would be provided so that operators would be able to view the operation from the central command station. In addition to the additional sensory equipment, the amount of software development for a totally automated process would be substantial. The control system would have to incorporate all of the decision-making algorithms and sequential logic involved in the process of emplacing waste.

From the above information it can be shown that the entire waste emplacement operation can be fully automated. However, testing and start-up operations with a completely automated control system may be difficult to accomplish because of the software complexity, purchasing components that can operate reliably in the high temperature and radioactive environment of the repository, maintenance of these components, and the amount of system interfaces required. The recommended approach is to proceed with the design based upon using primarily human interaction. As the physical efforts of moving an 85-metric ton WP become routine, the control system can be further enhanced, in phases, to completely automate the waste emplacement operation in the future.

4. CONCLUSIONS

This report has presented a step-by-step concept of operations of how the waste packages could be emplaced in the emplacement drifts, and retrieved from drifts using the equipment presently included in the base case design. These concepts were then evaluated against the effects of operating the repository in a lower-temperature operating mode. The lower-temperature repository could be achieved by operating the repository in five different modes or operating scenarios. Brief descriptions of the five scenarios were presented in Section 3.2. It is worth noting that the *Subsurface Ventilation System Description Document* (CRWMS M&O 2000c, Section 1.2.1.4) states that underground air temperatures shall be maintained to 50 °C for all areas requiring equipment access for emplacement, retrieval, recovery, and abnormal modes of operation. The effects of the five operating scenarios on the intended concept of operations are summarized below:

Scenario 1—This scenario has the same quantity of waste packages as the base case design. Since the waste packages will be spaced 2 meters apart, additional emplacement area will be required to accommodate the emplacement of all packages. The effect this will have on the emplacement equipment is that the equipment will be required to travel longer distances to reach the turnouts of the additional emplacement drifts. The impacts of the longer haulage and travel distances will not be significant during initial emplacement operations.

Because the equipment will travel longer distances, the cycle time for each trip will increase slightly. Each round trip will take slightly longer, so the equipment will be operating longer. It is anticipated that the maintenance schedules of the equipment will most likely be based on run-hours. Therefore, the equipment may require additional maintenance activities for the number of trips it has made. For example, routine maintenance may be conducted every 40 trips for the base case design. For this scenario, routine maintenance may need to be conducted every 35 or 36 trips. The equipment for waste emplacement will be specified later in the program and exact maintenance impacts can be determined at that time. It is a logical conclusion, though, that additional maintenance will be necessary.

Scenario 2—This scenario has more waste packages than the base case design. Even though the waste packages will be spaced 0.1 meters apart, additional emplacement area will be required to accommodate the additional quantity of waste packages. The effect this will have on the emplacement equipment is that the equipment will be required to make additional trips and travel longer distances to reach the turnouts to the emplacement drifts. The impacts of the longer haulage and travel distances will not be significant during initial emplacement operations.

Similar to scenario 1, the equipment will most likely require additional maintenance activities for the number of trips it has made. For example, routine maintenance may be conducted every 40 trips for the base case design. For this scenario, routine maintenance may need to be conducted every 35 or 36 trips. This scenario will also have more trips than scenario 1, so the maintenance requirements will most likely be more than scenario 1.

Scenario 3—This scenario is very similar to scenario 1 except the waste package spacing is three times larger (6 m) and the emplacement area is 55 percent more. Travel distances per trip

will increase significantly, as will the equipment maintenance requirements. The maintenance activities for this scenario will most likely be more than scenario 1, and equal to or greater than those anticipated for scenario 2.

Scenario 4—This scenario is almost identical to scenario 1. It is therefore anticipated that this scenario will have the same amount of additional maintenance requirements as scenario 1.

Scenario 5—This scenario is almost identical to the base case, and therefore it is anticipated that there will be no effect on the intended operational concepts.

Summary—The largest impact will be because of the changes to the physical layout of the subsurface repository. The first four scenarios have an increased emplacement area because of increased waste package spacing or additional waste packages. Because of the increased area, the equipment will need to travel longer distances from the North Portal, which should undoubtedly increase the maintenance and/or replacement requirements for the waste emplacement and retrieval equipment.

Section 3.4 of this report also discussed major system interfaces with the Waste Emplacement/Retrieval System. The base case design currently has leaky feeder and slotted microwave communication hardware along with third rail power distribution hardware permanently installed in the emplacement drifts (CRWMS M&O 2000a, Section 6.5.3; CRWMS M&O 1997, Section 8.2). While this report focused on the waste emplacement/retrieval equipment it should be noted that reducing the emplacement drift temperature to below 100 °C should enhance the operability of this equipment and reduce the uncertainty of this equipment operating at higher emplacement drift temperatures. Additional effort in this area is recommended.

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