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Yucca Mountain Site CharacterizationsProject Tunnel Boring Machine (TBM) System Safety Analysis

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00	Attachment H	Apendix H	Editorial Change - change Attachment to Appendix
00	H-i	H-i	Editorial Change - change Attachment to Appendix

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1. PURPOSE

The purpose of this analysis is to systematically identify and evaluate hazards related to the tunnel boring machine (TBM) used in the Exploratory Studies Facility (ESF) at the Yucca Mountain Site Characterization Project. This process is an integral part of the systems engineering process; whereby safety is considered during planning, design, testing, and construction. Since the TBM is an "as built" system, the M&O is conducting the System Safety Analysis during the construction or assembly phase of the TBM. A largely qualitative approach was used since a radiological System Safety Analysis is not required. The risk assessment in this analysis characterizes the accident scenarios associated with the TBM in terms of relative risk and includes recommendations for mitigating all identified risks. The priority for recommending and implementing mitigation control features is: 1) Incorporate measures to reduce risks and hazards into the system/subsystem/component design, 2) add safety features and capabilities to existing designs, and 3) develop procedures and conduct training to increase worker awareness of potential hazards, on methods to reduce exposure to hazards, and on the actions required to avoid accidents or correct hazardous conditions.

The scope of this analysis is limited to the TBM during normal operations, excluding hazards occurring during assembly and test of the TBM or maintenance of the TBM equipment.

2. QUALITY ASSURANCE

A QAP-2-0 evaluation was performed to determine if the System Safety Analysis is subject to QARD requirements. The results of the evaluation are presented in a "Quality Activity Evaluation Engineering Specialty", Revision 1, date July 1, 1995.

Based on the results of the QAP-2-0 evaluation, this analysis is not considered to be important to radiological safety or waste isolation.

3. METHODS

The safety/risk assessment methodology used in this analysis is shown in Figure 1. The result of the analysis is a "risk evaluation" of the scenarios identified in this analysis in accordance with MIL-STD-882C. Three steps are required to complete the risk evaluation. The steps are hazard/scenario identification, consequence assessment, and frequency assessment. The word "accident" as used in this analysis refers to events, breakdowns, incidents, or any other occurrence that may have a negative effect on personnel safety.

In addition to the guidance provided in DOE Orders, traditional methods for performing a system safety analysis were reviewed and adopted for this analysis, including methods from sources listed in sections 4 and 7.

Due to the complexity of the TBM, lack of complete up-to-date "as-built" information, and schedule constraints the TBM was decomposed into functional elements and subsystems on which safety analyses could be performed. The elements and subsystems were then prioritized based on the availability of information and a qualitative estimate of potential danger to personnel. The TBM elements and subsystems are (only items 1 through 7 are listed in prioritized order):

1. Invert Segment Hoist
2. Ring Erector
3. Ventilation Pipe Lift
4. Mapping Gantry
5. Cutterhead Control
6. Rail System
7. Operator Control
8. Conveyor System
9. Installation Platform(s)
10. Shotcreting (excluded from this analysis)
11. Fire Suppression and Safety Monitoring
12. Lighting
13. Ventilation System
14. Methane System
15. Laser system (not installed)

This additional step, which preceded the identification of scenarios, allowed the System Safety Analysis to proceed in a logical manner without undo delay.

As an additional cross check, a Process Evaluation Tree (PET) analysis was performed (see Appendix E) which confirmed there is at least one scenario for each functional and support equipment group and one mitigation feature for each scenario.

3.1 Scenario Identification (see "Scenario Analysis" page 3-241 of System Safety Handbook Reference 4.3)

The first step involves the identification of accident scenarios that could have negative consequences for personnel working on and around the TBM and TBM operations. It is important to provide assurance that potentially significant scenarios have been considered and the consequences are appropriately mitigated through design selection, safety design features or devices, detection and warning devices, and/or use of procedures and training.

A systematic procedure has been used to identify the relevant scenarios. The identification of scenarios is a relatively complex task. Analogous scenarios were grouped together to determine if there were any significant differences between them. For example, a group of accident scenarios address personnel injuries because of tripping or falling. The injuries may be minor or they may be severe. The severity of the injury may depend on where the accident occurred (e.g., ladder/stairway, upper deck, lower deck) and what happened to the

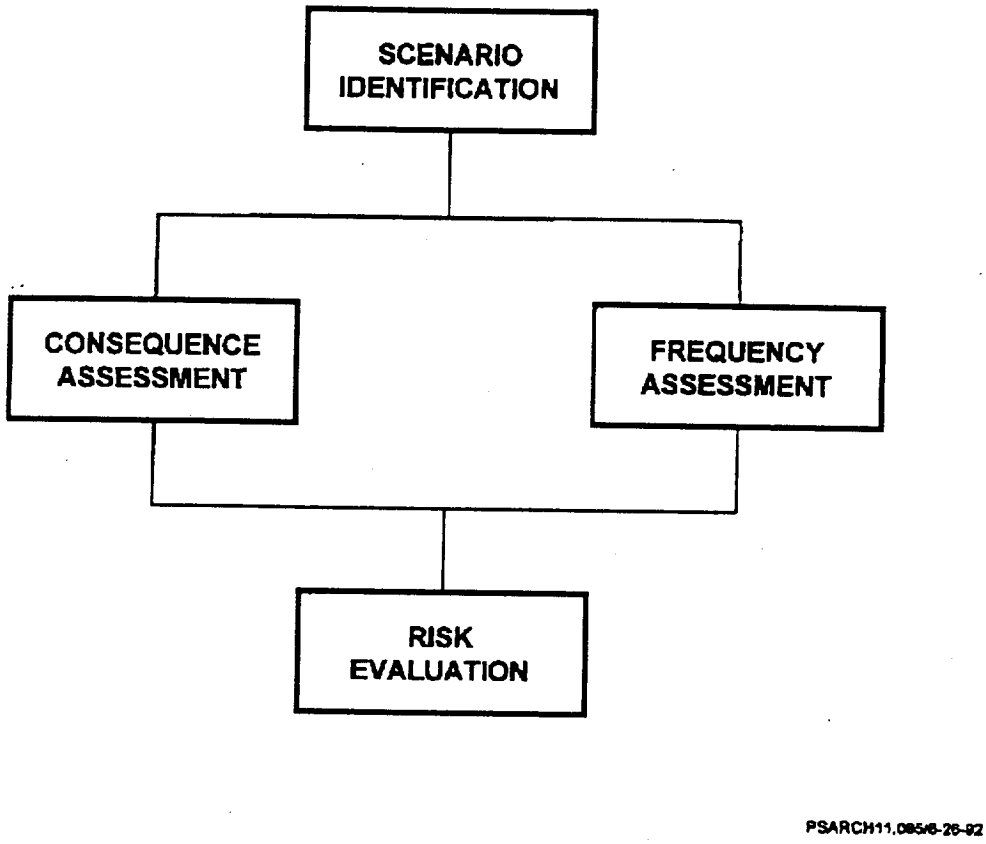

Figure 1. Risk Methodology Conceptual Overview

personnel (e.g., fell/tripped on a surface, fell off a surface, fell between two surfaces). Each of these scenarios could be included in the System Safety Analysis as a separate scenario, a subset of the group of scenarios could be included in the analysis, or a single representative sample scenario could be included in the System Safety Analysis. The decision of whether to include one or more scenarios from a group of potential scenarios in the System Safety Analysis was based on largely qualitative factors such as the probability that the scenarios will result in a significantly different risk designation, the accident can be associated with a particular situation or piece of equipment, and the probability that the accident cause(s) or result(s) will impact the frequency or consequence rating.

Four sources of information and approaches were used to aid in the identification of scenarios:

- Previously identified scenarios;
- "Proximity" Hazards Analysis;
- Failure Modes Effects and Criticality Analysis (FMECA); and
- Human Factors Engineering Analysis.

Although the use of these four sources produced some duplication of effort, the relatively small duplication of effort was outweighed by the benefit of reducing the chances of overlooking an important scenario.

3.1.1 Previously Identified Scenarios (see "Scenario Analysis" page 3-241 of System Safety Handbook, Reference 4.3)

Previously identified scenarios consist of those scenarios that were produced based on an inspection of the TBM during assembly at CTS, preliminary drawings, and an understanding of TBM operations to the extent known at that time. These scenarios have been modified as more information on the TBM has become available. The scenarios are contained in Appendix A.

3.1.2 "Proximity" Hazards Analysis (see "Energy Analysis" page 3-77 of System Safety Handbook, Reference 4.3)

Hazard analyses are performed to identify safety critical subsystems and functions and potentially hazardous designs, operations, and interfaces. These analyses diagnose hazards and mishaps and recommend appropriate control and mitigation actions, where necessary. In some instances it is obvious that the component could adversely impact personnel. In other instances the analysis must be continued to determine if a hazardous condition could be created. The "proximity" hazards analysis is presented in Appendix B.

The proximity analysis identifies primary sources of energy used and produced by the TBM and assumes that personnel are near enough to the energy source to be directly affected by equipment malfunction or failure and/or improper human action(s). Aids, in the form of lists of typical energy sources, general threat categories, and undesired events facilitate identification of energy sources.

3.1.3 Failure Modes, Effect, and Criticality Analysis (see page 3-115 of System Safety Handbook, Reference 4.3)

A Failure Modes, Effect, and Criticality Analysis (FMECA) is a "bottom up" technique which examines equipment and component failures and determines the effect on the system, including the seriousness, i.e., criticality, of the failure. The FMECA was used in the TBM analysis for selected subsystems to determine if a component(s) failure produced a hazardous condition, and thus, could result in increased risks to personnel safety. The subsystems to which the FMECA

was applied were selected on early judgments as to which subsystems had the greatest potential to produce accidents. Appendix C presents the three FMECAs performed in support of the System Safety Analysis.

3.1.4 Human Factors Engineering Analysis (see "Human Factors Analysis" page 3-151 of System Safety Handbook, Reference 4.3)

The objective of Human Factors Engineering (HFE), as stated in DOE Order 6430.1A, "General Design Criteria," is to improve the performance of systems dependent on human interaction. Improved performance includes increasing productivity, reducing human error, decreasing equipment and property damage, and improving the operation and maintenance of the TBM.

Specific HFE objectives include:

- Meeting system performance goals through proper design of equipment and environment, i.e., personnel-equipment combination;
- Eliminating or minimizing those design features which constitute a hazard to personnel; and
- Eliminating potential error-inducing equipment design features.

Refer to Appendix D for the TBM human factors engineering analysis.

3.2 Frequency Assessment

Bounding frequency estimates were developed for the accident scenarios and system failures. The frequency rating scale contains five levels of estimated frequency. The frequency levels are shown in Table 1.

A System Safety Working Group comprised of representatives from the M&O, DOE, REECo, Kiewit, and SAIC met September 6-7, 1994, to define the Frequency and Consequence Scales and to review the hazard scenarios with the agreed-to definitions. The System Safety Working Group's agreed-to definition of the Frequency Rating Scale was:

Frequent - Greater than 4.5 occurrences during the life of the TBM or more than one occurrence per year.

Probable - Greater than 2.25 but not more than 4.5 occurrences during the life of the TBM or one or less occurrence per year.

Occasional - Greater than 1.0 but not more than 2.25 occurrences during the life of the TBM or one or two occurrences during the life of the TBM.

Remote - Greater than .25 but not more than 1.0 occurrences during the life of the TBM or the occurrence may happen once.

Improbable - From 0 to .25 occurrences during the life of the TBM or very unlikely, probably no occurrence ever.

Table 1. Frequency Rating Scale

Frequency		Description
A	Frequent	Likely to occur frequently
B	Probable	Will occur several times in the life of an SSC*
C	Occasional	Likely to occur some time in the life of an SSC*
D	Remote	Unlikely but possible to occur in the life of an SSC*
E	Improbable	So unlikely, it can be assumed occurrence may not be experienced

* SSC = system/structure/component (e.g., TBM, design package)

3.3 Consequence Assessment

The potential range of consequences, from minor health effects to injury and/or fatality, was determined by using a consequence rating scale. The rating scale and definitions are presented in Table 2. The consequence rating scale also addresses potential impacts to site characterization data ranging from no loss of data to an irretrievable loss of license application data. The determination of consequence for each scenario, like the frequency estimate, was based on engineering experience and judgment and historical operating data.

The System Safety Working Group's agreed-to definition of the Consequence Rating Scale was:

Catastrophic - Death
Critical - Permanent partial or complete disability. Injury does not allow worker to return to same job (e.g., loss of limb or eye).
Marginal - Nonpermanent, recoverable injury that would not preclude performing the same job (e.g., broken bones).
Negligible - First aid injury with no loss of work time.

3.5 Exclusions

The following systems, structures, and components; processes; activities; and functions were not considered in this analysis:

- Pad operations;
- Concrete invert segment manufacturing;
- Transportation of supplies, equipment, and personnel to and from the TBM;
- Movement of the train (e.g., muck cars, empty supply cars) off the TBM;
- Maintenance procedures;
- Industrial hygiene exposure; and
- Emergency response/contingencies and off-normal operations.

In addition, this System Safety Analysis does not include determining hazards associated with maintenance, maintenance facilities, training, testing, and support operations.

4. CODES, STANDARDS AND REFERENCES

4.1 MIL-STD-882C; "System Safety Program Requirements," 19 January 1993

4.2 DOE Order 5481.1B; "Safety Analysis and Review System," 23 September 1986

4.3 SYSTEM SAFETY HANDBOOK-A source book for safety practitioners, July 1993, published by the System Safety Society.

4.4 Preliminary Safety Analysis for the Yucca Mountain Project Exploratory Studies Facility and Site Characterization Program.

4.5 Minutes of the TBM Safety and Analysis Comment/Resolution meeting, September 6 - 7, 1994.

5. CRITERIA

- The initial System Safety Analysis (Appendices A, B, C, D, E, and F) considered the TBM design and assembly as of Revision A of the CTS Operation and Service Manual. In limited cases Revision B was used. Subsequent analyses (Appendices G and H) used the CTS Operation and Service Manual when the information applicable to the item(s) being analyzed was contained in the manual and other information, such as drawings, site visits, and discussions with CTS personnel.
- Verification of design features must be accomplished by a complete review of the as-built documentation, visual inspection, and/or observation of TBM operations after assembly is complete and the final documentation has been delivered.

6. ASSUMPTIONS

- The DOE CMO is responsible for determining whether the identified hazards associated with the as-built TBM have been adequately mitigated to proceed with the testing and operation of the TBM.
- It is the TBM operating and maintenance contractor's responsibility to mitigate the hazards identified in this report and to document that the hazards have been mitigated.
- The information, i.e., Analysis and Conclusions, contained in this System Safety Analysis are limited to only the scenarios identified.
- Future design changes will need to be evaluated for risk to personnel.
- A sneak circuit analysis was not performed to support the TBM System Safety Analysis due to the absence of integrated circuitry controlling TBM operations. However, unexpected starting, stopping, or operation of equipment (normally one of the results of a sneak circuit analysis) was considered.
- All procedures, training, manuals, and other documentation identified as mitigation features are complete, comprehensive, and accurate.

7. SOURCES OF INFORMATION

7.1 Construction and Tunneling Services, "Operation and Service Manual - Yucca Mountain Tunnel Boring Machine - Model 760-8 (Draft)," 18 March 1994

7.2 DOE Order 6430.1A, "General Design Criteria," 6 April 1989

7.3 "Exploratory Studies Facility Design Requirements," 14 July 1993, YMP/CM-0019

7.4 IOC from Bruce T. Stanley, "Initial Configuration of Tunnel Boring Machine (TBM) for Startup of Operations (SCP:N/A)," 24 June 1994

7.5 Letter from Lester P. Skousen, Acting Director, Engineering & Development Division, Yucca Mountain Project Office; "Implementation Guidance to Apply the Concept of Safety/Reliability and Graded Quality Assurance to the ESF Design Process," 1 September 1988, NN1.880901.0049

8. COMPUTER PROGRAMS

N/A

9. RESULTS

Based on the results of the analyses Preliminary Safety Analysis scenarios (see Section 4.4) were modified and the need for new scenarios was identified. Table 3 identifies the scenarios contained in Appendices A, B, G, and H. Each scenario was assigned to a risk category based on the consequence and the frequency of occurrence, and the scenario identification number was plotted on the risk rating matrix shown in Figure 3. Table 4 lists the scenarios in rank order from high to low risk levels.

Detailed TBM scenario descriptions are contained in Appendices A, B, G, and H.

Based on the frequency and consequence ratings, there were no scenarios with a high risk designation, ten scenarios with a medium risk designation, fifty-six with a low risk designation, and seventy-five with an extremely low risk designation.

10. CONCLUSIONS

The TBM System Safety Analysis has identified hazards related to the design of the TBM; analyzed the hazard consequences; assessed the risk(s); and identified measures to eliminate or mitigate hazards by design or operational controls. Information concerning the design was obtained from the Construction and Tunneling Services, "Operation and Service Manual - Yucca Mountain Tunnel Boring Machine - Model 760-8 (Draft)" manual; preliminary drawings of the mapping gantry; inspection of the TBM as it was being assembled; and interviews with the TBM operating and maintenance contractor and CTS personnel, as well as personnel experienced in TBM operations within the M&O. There remain a number of issues and areas which need to be addressed, including, but not necessarily limited to:

- This System Safety Analysis has focused on the design of the TBM. While the analysis addresses procedural and training issues, especially as they pertain to mitigating personnel risks, detailed operational information has not been included or available for this analysis. Other safety related inputs, such as personnel hazards analyses, operating and support hazard analyses, Job Safety Analyses (JSAs), constructor job packages, training, health and safety (e.g., industrial hygiene), and OSHA audits must be considered when making a judgment concerning the overall safety of any system.

- Three scenarios were removed from Appendix A of this document. The scenarios were withdrawn since they were determined to be maintenance activities and are not related to normal TBM operations. The scenarios are UI0221, UI0235, and UI0263.

- Because the scope of this analysis focuses on normal TBM operations only, it is recommended that the construction contractor document TBM maintenance and off-normal operations (e.g., assembly, testing, etc) in manuals or procedures which are based on job or other safety analyses.

- Modifications to the TBM, whether documented or not documented, and previously undocumented TBM features, must be identified and evaluated for the need to perform a system safety analysis.

Even if the TBM operates based on the findings of this report and the other safety related information, additional analyses may be required to identify hazards, safety features, and risks associated with the integration of the TBM and the permanent muck conveyor system, new

components and subsystems, and the integration of these components and subsystems with each other and the TBM.

11. APPENDICES

This report has eight appendices. Appendix A contains the Accident Analysis Summary sheets prepared for the initial TBM System Safety Analysis. Appendix B contains the TBM Proximity Hazards Analysis. Appendix C contains the Failure Mode, Effects, and Criticality Analysis. Appendix D contains the Human Factors Engineering Analysis. Appendix E contains the Process Evaluation Tree results. Appendix F contains the TBM operating and maintenance contractor's letter verifying that certain TBM features do not create hazards. Appendix G presents the Accident Analysis Summary sheets developed specifically for the rock bolt drills which are to be installed on the ring erector and roof bolter traveling deck. The scenarios for the mapping gantry are presented in Appendix H.

The information contained in Appendices G and H apply only to accident scenarios unique to the ring erector and roof bolter rock bolt drills and the mapping gantry, respectively. The information presented in Appendices A, B, C, D, and E apply to the entire TBM, including the ring erector and roof bolter traveling deck and the mapping gantry. Any accident scenarios or system/component failures, identified in Appendices A, B, C, and D which can occur on the ring erector and roof bolter traveling deck or the mapping gantry must also be mitigated with the mitigation control features.

Appendix A

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ACCIDENT ANALYSIS SUMMARY

SCENARIO NUMBER: UI0310 REVISION: 00 REVISION DATE: 3/31/95

LOCATION:

Subsurface Development Face

SCENARIO:

Personnel injury/death due to being struck by train while accessing/exiting the TBM by walking on train access ramp on trailing gear car 14 (also see UI0311 and UI0314).

SYSTEM/COMPONENT FAILURE:

- Lack of dedicated personnel access/egress
- Dual use of ramp (i.e., equipment access and personnel access)
- Failure to adhere to safety rules and procedures (e.g., not obeying loci operator, walking in unauthorized area)

ACCIDENT CLASSIFICATION AFTER MITIGATION:

Frequency Rating: E - Improbable

Consequence Rating: I - Catastrophic

Risk Designation: Low

MITIGATION/CONTROL FEATURES:

- Relocate portable toilet so that there is an unobstructed walkway along the entire length of trailing gear car 14.
- Provide steps for personnel climbing onto and off the back of the TBM.

NOTE: The Construction Management Office (CMO) and Kiewit/PB have taken the position that the installation of permanent stairs will create an additional hazard because there is the possibility of injury if personnel are on the stairway during a train derailment. Kiewit/PB is going to provide a portable ladder for emergency conditions. The CMO's concurrence is documented in a memo dated January 8, 1996, from Richard C. McDonald to James Robertson, entitled "Stairs at Rear of TBM." Kiewit's position and solution is documented in a memo dated September 13, 1995,

SCENARIO NUMBER: UI0310

from W. D. Wightman to R. C. McDonald, entitled "Rear Stair on TBM, Your Letter No. 95-006651, To Daniel Koss." Copies of both memos are included in Appendix F.

- Post safety/warning signs.
- Provide safety training (e.g., watch for trains traveling/parked on the TBM ramp, obey loci operator orders, loci operator checks for personnel).

MITIGATION DOCUMENTATION:

- 29 CFR 1926.800(b)(2)
- 29 CFR 1926.1051(a), (a)(3)
- TBM Operation and Service Manual (includes drawings and information on safety, operation, and maintenance)*
- Operators Manuals*
- Training Manuals*
- Safety Manuals*

* It is the TBM operating and maintenance contractor's responsibility to assure that the hazard(s) associated with this scenario have been mitigated through proper documentation.

ACCIDENT ANALYSIS SUMMARY

SCENARIO NUMBER: UI0311 REVISION: 00 REVISION DATE: 3/31/95

LOCATION:

Subsurface Development Face

SCENARIO:

Personnel injury/death while climbing on/off TBM due to falling off TBM trailing gear car 14 while train is traveling/parked on TBM access ramp (also see UI0310 and UI0314).

SYSTEM/COMPONENT FAILURE:

- Lack of dedicated personnel access/egress
- Dual use of ramp (i.e., equipment access and personnel access)
- Failure to adhere to safety rules and procedures (e.g., not obeying loci operator, walking in unauthorized area)

ACCIDENT CLASSIFICATION AFTER MITIGATION:

Frequency Rating: D - Remote

Consequence Rating: I - Catastrophic

Risk Designation: Medium

MITIGATION/CONTROL FEATURES:

- Relocate portable toilet so that there is an unobstructed walkway along the entire length of trailing gear car 14.
- Provide steps for personnel climbing onto and off the back of the TBM.

NOTE: The Construction Management Office (CMO) and Kiewit/PB have taken the position that the installation of permanent stairs will create an additional hazard because there is the possibility of injury if personnel are on the stairway during a train derailment. Kiewit/PB is going to provide a portable ladder for emergency conditions. The CMO's concurrence is documented in a memo dated January 8, 1996, from Richard C. McDonald to James Robertson, entitled "Stairs at Rear of TBM." Kiewit's position and solution is documented in a memo dated September 13, 1995,

SCENARIO NUMBER: UI0311

from W. D. Wightman to R. C. McDonald, entitled "Rear Stair on TBM, Your Letter No. 95-006651, To Daniel Koss." Copies of both memos are included in Appendix F.

- Post safety/warning signs.
- Provide safety training (e.g., watch for trains traveling/parked on the TBM ramp, obey loci operator orders, loci operator checks for personnel).

MITIGATION DOCUMENTATION:

- 29 CFR 1926.800(b)(2)
- 29 CFR 1926.1051(a), (a)(3)
- TBM Operation and Service Manual (includes drawings and information on safety, operation, and maintenance)*
- Operators Manuals*
- Training Manuals*
- Safety Manuals*

* It is the TBM operating and maintenance contractor's responsibility to assure that the hazard(s) associated with this scenario have been mitigated through proper documentation.

ACCIDENT ANALYSIS SUMMARY

SCENARIO NUMBER: UI0314 REVISION: 00 REVISION DATE: 3/31/95

LOCATION:

Subsurface Development Face

SCENARIO:

Personnel injury/death while climbing on/off TBM trailing gear car 14 due to train derailment while train is traveling on TBM access ramp (also see UI0310 and UI0311).

SYSTEM/COMPONENT FAILURE:

- Lack of dedicated personnel access/egress
- Dual use of ramp (i.e., equipment access and personnel access)
- Failure to adhere to safety rules and procedures (e.g., not obeying loci operator, walking in unauthorized area)

ACCIDENT CLASSIFICATION AFTER MITIGATION:

Frequency Rating: E - Improbable

Consequence Rating: I - Catastrophic

Risk Designation: Low

MITIGATION/CONTROL FEATURES:

- Relocate portable toilet so that there is an unobstructed walkway along the entire length of trailing gear car 14.
- Provide steps for personnel climbing onto and off the back of the TBM.

NOTE: The Construction Management Office (CMO) and Kiewit/PB have taken the position that the installation of permanent stairs will create an additional hazard because there is the possibility of injury if personnel are on the stairway during a train derailment. Kiewit/PB is going to provide a portable ladder for emergency conditions. The CMO's concurrence is documented in a memo dated January 8, 1996, from Richard C. McDonald to James Robertson, entitled "Stairs at Rear of TBM." Kiewit's position and solution is documented in a memo dated September 13, 1995, from W. D.

SCENARIO NUMBER: UI0314

Wightman to R. C. McDonald, entitled "Rear Stair on TBM, Your Letter No. 95-006651, To Daniel Koss." Copies of both memos are included in Appendix F.

- Post safety/warning signs.
- Provide safety training (e.g., watch for trains traveling/parked on the TBM ramp, obey loci operator orders, loci operator checks for personnel).

MITIGATION DOCUMENTATION:

- 29 CFR 1926.800(b)(2)
- 29 CFR 1926.1051(a), (a)(3)
- TBM Operation and Service Manual (includes drawings and information on safety, operation, and maintenance)*
- Operators Manuals*
- Training Manuals*
- Safety Manuals*

* It is the TBM operating and maintenance contractor's responsibility to assure that the hazard(s) associated with this scenario have been mitigated through proper documentation.

Appendix B

Analysis: BABFBA000-01717-0200-00001 REV. 00

TUNNEL BORING MACHINE PROXIMITY HAZARDS ANALYSIS

1. INTRODUCTION

Hazard analyses, in general, are performed to identify safety critical subsystems and functions, and potentially hazardous designs, operations, and interfaces. These analyses diagnose hazards and mishaps, and recommend appropriate control and mitigation actions where necessary. In some instances it is obvious that the component could adversely impact personnel (proximity analysis). In other instances the analysis must be continued (to other support systems) to determine if a hazardous condition could be created (FMECA).

The purpose of this proximity hazards analysis is to identify primary sources of energy used by the Tunnel Boring Machine (TBM)/Mapping gantry rail cars and to assume that personnel are near enough to be directly affected by improper actions or equipment failure. Aids, in the form of lists of typical energy sources, general threat categories, and undesired events are used as guides.

The scope of this analysis is limited to conditions pertaining to the TBM during normal operations (excludes hazards occurring during assembly and test of the TBM or TBM downtime during equipment maintenance which are covered by the procedures and programs developed from Job Safety Analysis findings--the operating and maintenance contractor's responsibility). This analysis does not duplicate analyses on subsystems on which FMECAs have been performed nor does it reanalyze previously identified scenarios. This analysis does, however, refer to FMECAs, previously identified scenarios, and the results of Human Factors Engineering analyses performed on the TBM.

NOTE:

THE TBM, AS WITH ANY "AS BUILT" DESIGN MUST INCORPORATE SOME CHANGES AS THE TBM IS UNDER CONSTRUCTION. ALTHOUGH EVERY EFFORT HAS GENERALLY BEEN MADE TO INCORPORATE SAFETY FEATURES INTO THE DESIGN, IT IS OFTEN NECESSARY TO RELY ON PROCEDURES AND TRAINING TO MITIGATE SITUATIONS THAT CAN PRODUCE HAZARDS. SAFETY IN TBM OPERATIONS IS, THEREFORE, HEAVILY DEPENDENT ON ADEQUATE TRAINING AND PROCEDURES. INADEQUATE TRAINING OR PROCEDURES OR FAILURE TO STRICTLY ADHERE TO TRAINING AND PROCEDURES CAN LEAD TO SEVERE INJURIES OR DEATH.

2. DESCRIPTION OF ANALYSIS PROCEDURE

Experience has shown that most hazardous conditions derive from uncontrolled sources of energy. Therefore, the general analysis method has been structured to key on energy sources

Analysis: BABFBA000-01717-0200-00001 REV. 00

ACCIDENT ANALYSIS SUMMARY

SCENARIO NUMBER: HA0062 REVISION: 00 REVISION DATE: 9/7/94

LOCATION: Subsurface Development Face

SCENARIO: Human Factors (these are threats that predominantly affect personnel, not equipment) due to Environment; examples include noise, stress, biological contaminants*, etc.

SYSTEM/COMPONENT FAILURE OR HAZARDOUS EVENT: Dust from TBM operation

ACCIDENT CLASSIFICATION AFTER MITIGATION:
Frequency Rating: A-frequent
Consequence Rating: IV-negligible
Risk Designation: 14 low

MITIGATION/CONTROL FEATURES:
1. Dust control through ventilation (including air scrubber) and water spray.
2. Operator/personnel training.
3. Provide breathing protection where necessary (breathing protection requirements provided by site safety).

MITIGATION DOCUMENTATION:
1. YMP-025-1-SP05 rev.3 (Nov. 92) Sec. 11910 Part 2-2.15 "Ventilation" This specification places emphasis on the control of TBM dusty air.

2. All associated industrial hygiene related hazards must be evaluated. (IT IS THE TBM OPERATING AND MAINTENANCE CONTRACTOR'S RESPONSIBILITY TO DOCUMENT THAT HAZARDS ASSOCIATED WITH THE ABOVE PROCEDURES HAVE BEEN MITIGATED.)

* Biological contaminants were determined not to be credible.

Appendix C

Appendix D

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HFE REPORT

1. INTRODUCTION

This is the report on the results of the HFE safety analysis of the TBM.

2. SCOPE

This analysis evaluated the HFE aspects of the TBM design as it pertains to safety only. It does not include an evaluation with regard to OSHA/MSHA/California tunneling requirements, nor evaluation of operational or maintenance procedures, nor evaluation of off-normal procedures, nor environmental conditions while operating the TBM in the tunnel. This report is limited to the evaluation of user/machine TBM design.

3. APPROACH

The analysis was conducted by a review of available documentation, visual inspection, measurement, written questions to and answers from REECo and Kiewit/PB, and from meetings with TBM engineers and information in the Yucca Mountain TBM Vendors Training Sessions II-C, II-D.5, III-A.1, III-A.2, III-A.3, III-B, III-C, III-D, III-E, IV-A.1, IV-A.2 and IV-A.3 that was given to the M&O on July 6, 1994, by Steve Short. It is not known whether these procedures have changed in the interim. The quality of this evaluation is a function of the quality of the information that was transmitted to the M&O. If a hazard has been identified in an earlier TBM Safety Analysis, those findings may not be repeated here. Findings in this report that relate to existing scenarios in the TBM Safety Analysis (Appendix A) or in the Proximity Analysis (Appendix B) have been cross-referenced to that particular scenario. The findings in this report have not been operationally validated as of February 9, 1996.

Results are presented in a front-to-rear location of TBM equipment. Results within a section are listed in a chronological order. As changes to the TBM are made, the chronological order of findings reflects this. Results of the HFE findings have been included in the Appendices A and B scenarios.

4. RESULTS

The TBM is composed of the TBM forward section (cutterhead; forward shield; grippers; ring erector and roof bolting traveling deck; hydraulic control/maintenance cage; operator control cab; hydraulic, water, and power lines; and supporting structures) and trailing gear (five cars). [3/28/94 M&O Trip Report]

No operational procedures were available to aid in the analysis. Assumptions were made about what would be prudent procedures.

4.1 CUTTERHEAD

4.1.1 Access to Cutters

The area behind the cutterhead and the tail shield/grippers is very congested. To gain access to this area personnel must crawl under, over, and around large components/structures. Since assembly operations (e,g., welding) were still being performed I was not able to inspect this area very closely. The one thing that I did observe is that the opening which gives personnel access to the back of the cutterhead is located at the bottom of the TBM and there is very little illumination. [3/28/94 M&O Trip Report]

There is no designed path to the cutterhead and the area is difficult to traverse. All floor and grate surfaces to the cutterhead were covered with oil. [M&O 7/14/94 Site Visit]

Adequate illumination will be provided for cutter installation by portable quartz lights hung inside the cutter head during cutter removal and installation. Auxiliary lighting will be provided by flashlight and cap lamps. [AVO RESPONSE received 8/5/94.]

4.1.1.1 Access to Cutterhead Hazard (reference scenario HF0001, UI0247, UI0259)

Injury is possible due to low illumination and crawling under, over, and around large components/structures.

4.1.1.2 Access to Cutterhead Hazard Mitigation (reference scenario HF0001, UI0247, UI0259)

Provide adequate illumination, handles, and non-slip steps and platforms so personnel do not have to crawl under, over, and around large components/structures.

4.1.2 Replacing Cutters

The TBM is designed so that the cutters can be replaced from the back of the TBM cutterhead. Thus, there is no reason, under normal conditions, to expect personnel to be required to climb between the front of the TBM cutterhead and the rock face. [3/28/94 M&O Trip Report]

Dual cutters can weight up to 450 pounds. Transporting a cutter from the tail shield to the back of the cutterhead is accomplished by pulling the cutter up a ramp from the concrete invert segment installation area to the back of the cutterhead with a nylon sling. The cutterhead is then hoisted with a chain hoist and placed in a cutter box that is used to slide the cutter into the correct position. [7/6/94 M&O Site Visit - Steve Short]

Cutter boxes are not used to stick the cutter into the correct position. The cutter box is used to transport cutters to the rear end of the bottom gripper. [AVO RESPONSE received 8/5/94.]

Cutters nearer the perimeter of the cutter head will be replaced with the same procedures as all other cutters, i.e., the cutter is rigged off the hoist and trolley, then positioned with ratchet hoists, pinch bars, and tapered bars for alignment and torqued into their saddles. [AVO RESPONSE received 8/5/94.]

It was estimated that there is approximately 10 feet by 12 feet inside the cutterhead to change the cutters. [7/3/94 telephone conference call with Steve Short] There appears to be ample space for cutter replacement at least for the middle cutters. Outer cutters replacement appeared to be more difficult. No muck ladder at the cutterhead was observed and it was not obvious that there should be personnel above and below one another as stated in the *Yucca Mountain TBM Vendor Training Session* III-A.3, page 1. Not all questions about cutter replacement at the site could be answered. [7/14/94 M&O Site Visit]

There is no "muck ladder" for cutter replacement. [AVO RESPONSE received 8/5/94.]

Bolt tightening is done under the muck shoot with a standard air impact wrench or could be hand tightened. Tightening requires 750 to 1000 ft/lbs to torque bolts. [7/3/94 telephone conference call with Steve Short]

Lockout for inching hazards includes removing key after locking out inching motor. [Bob Law - 7/14/94 M&O Site Visit]

Lockout procedure for the inching brake system includes removing the key from the inching brake station after placing the key into the lockout position and prior to entering the cutter head. [AVO RESPONSE received 8/5/94.]

4.1.2.1 Replacing Cutters Hazards

a. Operator inadvertently actuates inching motor. (reference scenario number HF0003)

b. See scenario number UI0208 for certain hazards. The Ingersoll-Rand VL-2-010-15-13 hoist and other possible jacks were not installed and the hazards associated with it in removing and installation cutters and the interaction with other installed equipment could not be evaluated. The cutter handling basket was not at the pad so its interaction with other installed equipment could not be evaluated.

4.1.2.2 Replacing Cutters Hazards Mitigation

a. The inching motor pushbutton is recessed. (reference scenario number HF0003)
Personnel must stand back from cutterhead when operator is near inching motor pushbutton.
Key is removed after locking out inching motor.

b. See scenario number UI0208 for certain mitigations. Additional mitigations are not known at this time since all equipment has not been installed.

4.2 FORWARD SHIELD

There is human movement in the Forward Shield areas during operations. It is considered a relatively safe area during operations. However, personnel must be careful in moving around this area. [7/6/94 M&O Site Visit - Steve Short]

There is very little room to move around and access to equipment is difficult. There is no designed path to the cutterhead and the area is difficult to traverse. All floor and grate surfaces were covered with oil. [M&O 7/14/94 Site Visit]

Pinch points exist at all areas between rock and shield, at the ends of hydraulic cylinders when rams are retracted, between the cutter head support and the bottom gripper, between shield segments, and at access doors to the cutter head. [AVO RESPONSE received 8/5/94.]

4.3 GRIPPERS

There is human movement in the Forward Shield areas during operations. It is considered a relatively safe area during operations. However, personnel must be careful in moving around this area. [7/6/94 M&O Site Visit - Steve Short]

There is very little room to move around and access to equipment is difficult. There is no designed path to the cutterhead and the area is difficult to traverse. All floor and grate surfaces were covered with oil. [M&O 7/14/94 Site Visit]

CTS manual warns personnel of possible pinch points. [*CTS Operation & Service Manual Yucca Mountain Tunnel Boring Machine Model 760-B*, Volume 1, page 1.3, D.2]

As the grippers expand and retract, the pinch points exist between the grippers and the rock and between the bottom gripper and the lower cutter head support. As one set of grippers advances, there may be a pinch point ahead of the advancing gripper. [AVO RESPONSE received 8/5/94.]

4.4 TAIL SHIELD

One stairway was installed. It leads from the front of the segment installation area to the space behind the tail shield/grippers. It is not obvious whether or not a rail will be installed (e.g., there are no holders for a railing to be inserted or holes drilled for mounting a railing). [3/28/94 M&O Trip Report]

Update: The railing is not installed. [7/14/94 M&O Site Visit] (reference scenario number UI0213)

A platform by the hydraulic pumps blocks the DOWN button on the forward hoist control panel. To correct this condition relocate the forward hoist control panel so that it is not blocked by the platform or trim the portion of the platform blocking access to the push button. [6/22/94 M&O Trip Findings] (reference scenario number HF0020)

4.4.1 Ring Erector and Roof Bolter Traveling Deck

The deck has a normal fore and aft movement of 8 feet but can be changed to 11 feet. [7/6/94 M&O Site Visit - Steve Short and *Yucca Mountain TBM Vendor Training Session III-B*] The deck is moved by moving the DECK TRAVEL joy stick on the erector pendant box to the left for FWD and right for BACK. See Section 4.5.2 for a discussion on the erector pendant box design. The deck is moved only with the control on the pendant box. [7/13/94 telephone conference call with Steve Short] The forward segment hoist passes under this deck and through the lower portion of the ring erector. [7/14/94 M&O Site Visit]

There is a limiting switch in back of the traveling deck. [6/22/94 M&O Trip Observation] If the switch fails, the bore stroke of the cylinder controlling the traveling deck is only a few inches longer [7/13/94 telephone conference call with Steve Short] so that it cannot get near the upper deck of car 1.

There is no railing on the back side of the deck and the conveyor belt just behind the deck is not covered. [7/14/94 M&O Site Visit]

4.4.1.1 Ring Erector and Roof Bolter Traveling Deck Hazards

a. No rail is installed on the stairway to the tail shield. (reference scenario number UI0213)

b. The ring erector and rock bolt traveling deck does not have any guard rails on either the front and back or the sides. (reference scenario number UI0213)

c. If personnel are climbing the ladder while the deck is moving, there is increased probability of personnel injury, especially if there is oil on the ladder. (reference scenario number UI0213)

d. The conveyor belt is not covered. (reference scenario number UI0224)

4.4.1.2 Ring Erector and Roof Bolter Traveling Deck Hazards Mitigation

a. Install a railing on the stairway to the tail shield. (reference scenario number UI0213)

b. Install guard rails. (reference scenario number UI0213)

c. Procedures should specify that ladder climbing should be avoided while the deck is traveling. (reference scenario number UI0213)

d. Cover the conveyor belt. (reference scenario number UI0224)

4.4.2 Rock Bolting

Rock bolting will be performed by first drilling and then emplacing a bolt through the gaps in the tail shield. The tail shield protects against roof collapse before rock bolting is completed. The rock bolting traveling deck should remain stationary as the cutterhead moves forward. The deck has a normal traveling distance of 8 feet fore and aft and has no vertical movement. The movement envelop of rock bolting equipment is unknown at this time as the rock bolting equipment has not been selected.

Since the rock bolt drill(s) are being supplied by another vendor and they will not be installed until the TBM is assembled at Yucca Mountain the drill(s) characteristics and features will have to be determined at a later time. [3/28/94 M&O Trip Report]

The rock bolting equipment still has not been selected. [7/6/94 M&O Site Visit]

4.4.2.1 Rock Bolting Hazards (reference scenario number HA0032)

a. If the TBM is allowed to continue mining when the deck reaches the end of its stroke while drill steel is engaged in the ground, equipment damage or injury could result. (reference scenario number HF0002)

b. If drill steel or rock bolting equipment with rock bolt is engaged in the ground and the deck is moved, the drill or bolt could break causing injury. (reference scenario number HF0002)

c. Additional hazards with the drilling and bolting equipment and the interaction of it with other pieces of equipment or personnel in the drill travel envelop are not known at this time as the equipment has not been selected or installed.

4.4.2.2 Rock Bolting Hazards Mitigation

a. Mitigation for this hazard is the limiting switch located on the traveling deck. When the deck hits the limiting switch, the switch shuts down the TBM. [*Yucca Mountain TBM Vendor Training Session III*-B, page 4, step 6] (reference scenario number HF0002)

b. Mitigation is to have equipment logic that does not allow deck travel with drills or bolts engaged. (reference scenario number HF0002)

c. Additional mitigations are not known at this time as the rock bolting equipment has not been selected or installed.

The ring erector and rock bolt traveling deck control box is tethered to the traveling deck with a 20 foot cable (I did not actually see where the cable is attached to the deck). It is assumed that the operator will stand on one of the drill platforms or the bottom deck to control the ring erector and rock bolt traveling deck. Since the operator is controlling the rock bolt drill(s) and the erector ring using the control box there should be a clear line-of-sight to these devices. I was unable to verify if, in fact, the operator can observe the device(s) he/she is controlling. In addition, the control box contains only one rock bolt drill control. If there are two rock bolt drills the question which must be raised is, how does the operator control two drills with one control? [3/28/94 M&O Trip Report]

Update: Operator uses one control to move both drills in the fore and aft direction. There will be one drill operator for each drill. Drills move relative to the traveling deck. [7/13/94 telephone conference call with Steve Short]

The ring erector operator does not need to observe the ring segments from the travelling deck as they are being put together. [AVO RESPONSE received 8/5/94.]

Based on the available information that the M&O could obtain, the M&O believes that uninterrupted line-of-sight for ring placement is important.

See Section 4.5.2 for hazards associated with using the pendant box.

4.4.3 Jib Hoist

Refer to hazards and mitigations in Yucca Mountain TBM Vendor Training Session III-D. Jib hoist was not operational on any site visit and additional evaluations cannot be made.

There are no operational hazards foreseen. There is a mechanism for rotation on the jib hoist, therefore, the risk of back injury or falling is not foreseen. [AVO RESPONSE received 8/5/94.]

If the load is not within easy reach of personnel on the traveling deck, a hook will be used to pull the load over the deck. This avoids personnel from bending over the railing. [8/17/94 M&O/Kiewit/REECo meeting]

4.5 RING ERECTOR

4.5.1 Steps for Ring Erection

Ring segments weight up to 600 pounds each. [June 21, 1994 Kiewit/PB letter]

The segments are stored on the transport flat car or on the invert segment under the bridge conveyor. One or two can be stored at one time. [June 21, 1994 Kiewit/PB letter]

The segments are hoisted by the forward segment hoist to the installation area, manually pivoted 90 degrees, and manually clamped to the ring erector. The three large ring segments are loosely bolted together and then raised to the tunnel crown by two hydraulic cylinders. It was estimated that the segments are then expanded one to two feet [7/13/94 telephone conference call with Steve Short] and permanently installed. After final installation, the clamps are manually removed from the ring erector and the ring erector is reset. [7/6/94 M&O Site Visit - Steve Short]

The ring segment is transported to position just behind the ring erector, lowered to the invert and unrigged from the forward hoist. The ring segment is then barred into position and secured to the ring erector. [AVO RESPONSE received 8/5/94.]

Ring erection and invert segment installation cannot occur at the same time as the segment would have to pass through the ring segment. [Bob Law - 7/14/94 M&O Site Visit]

4.5.1.1 Ring Erection Hazards (reference scenario number HA0017, UI0214)

a. Operator error in accidently actuating controls causing ring segments to fall off the ring erection equipment and causing an injury or fatality.

b. Clothing or extremities get caught in the rotating ring erector. (reference scenario number HF0004)

4.5.1.2 Ring Erection Hazards Mitigation

a. Mitigation for injury from falling ring segments is the clamping of the ring segments to the ring erector.

b. Provide screening for equipment or procedurally lockout ring erector when any personnel are near ring erector and institute dress restrictions. (reference scenario number HF0004)

4.5.1.3 Ring Expansion

Site personnel were unable to describe exactly which method and equipment for ring expansion were to be used so hazards associated with ring expansion are not currently known and cannot be evaluated.

Rings will be pushed to the crown with the hydraulic rams at the top of the ring erector, rings will be expanded with hydraulic jacks near the invert, and dutchman bolted into place after expansion. [AVO RESPONSE received 8/5/94.]

Avoidance of pinch point between expanding ring and rock and between dutchman and ring segment are possible hazards. [AVO RESPONSE received 8/5/94.]

4.5.2 Ring Erector Pendant

The ring erector and rock bolt traveling deck control box contains a key lockout, two "joystick" type controls, and a 2 position travel speed control. The joysticks are actually 4 position potentiometers; they can be moved left, right, up, down to activate an operation. To execute an action the user presses and holds the joystick control in the designated direction; when the user releases the control the joystick returns to the neutral position and the action ceases. The speed control knob is spring loaded; the default position is "slow." To change the speed to "fast" the user turns and holds the knob in the "fast" position. [3/28/94 M&O Trip Report]

Update: The speed control knob is spring loaded; the default position is a neutral position between "slow" and "fast." To change the speed to "slow" or "fast" the user turns and holds the knob in the "slow" or "fast" position. [7/14/94 M&O Site Visit]

The left potentiometer and the travel speed control are used in conjunction with one another. The potentiometer is located above the speed control on the left side of the control box. This means that the user must either use the left hand to control one function and reach across the control box with the right hand to manipulate the other control, or the user must try to press and hold both controls with one hand. [3/28/94 M&O Trip Report]

Update: It is a two-handed operation. [7/14/94 M&O Site Visit]

The ring erector pendant is 8 x 6 x 3 5/8 inches. It has two joy stick controls on top. One joy stick controls the forward and backward movement of the deck and the forward and back movement of the rock drill.

There are two drills. [7/6/94 M&O Site Visit - Steve Short] The one control on the pendant controls the two drills in parallel. [7/13/94 telephone conference call with Steve Short] The other joy stick extends and retracts the erector ring and controls the clockwise and counter-clockwise movement of the ring erector.

There are two other controls. One to lock and unlock the ring erector and another that controls the travel speed of the ring erector, fast and slow. Fast speed is used only to reset the ring erector and for drill travel. [7/13/94 telephone conference call with Steve Short] The drill travel and deck travel control has no lock provisions and could be accidently actuated while putting on, putting down, or temporarily storing the pendant box.

There is no logic that prohibits actuation of the 2 joy sticks simultaneously. The joy sticks can be operated in parallel and in some cases simultaneous operation is desirable. [7/6/94 M&O Site Visit - Steve Short] However, *Yucca Mountain TBM Vendor Training Session III-B page 5*

recommends that only one motion on the erector mechanism be active at any one time. The current design of the pendent has the two joy sticks approximately 3 inches apart and while operating one control the other could be easily and unintentionally actuated.

The *Yucca Mountain TBM Vendor Training Session III-A.1* page 3 recommends locking out the erector pendant when the erector is not in use or when climbing ladders while carrying the pendant. It is further recommended that the key be removed from the lockout position to avoid accidental actuation.

4.5.2.1 Ring Erector Pendant Hazards

a. There are no controls on the traveling deck that duplicate those on the pendant box except for the ring erector lockout function. Duplicate controls on the traveling deck should be required. The pendant is too heavy and awkward to carry up ladder. No personnel should be required to travel up and down a ladder with a pendant box. This is a potential safety problem. (reference scenario number HF0005)

b. Operator inadvertently actuates control. (reference scenario number HF0006, UI0231, UI0260)

4.5.2.2 Ring Erector Pendant Hazard Mitigation

a. Duplicate erector pendant box controls on traveling deck. Allow only one set of controls to be active at any one time. (reference scenario number HF0005)

b.1 Provide logic to equipment such that if ERECTOR RING is in the EXTEND position, DECK TRAVEL cannot be active. Likewise, if DECK TRAVEL is active, deactivate ERECTOR - EXTEND. (reference scenario number HF0006, UI0231, UI0260)

b.2 Remove lockout key from pendant after placed in lockout position. (reference scenario number HF0006, UI0231, UI0260)

4.6 INSTALLATION AREA

There will be a small conveyor belt installed in the invert segment installation area. This conveyor will take excess muck and debris from the invert segment installation area forward into the back of the cutterhead. Personnel will be required to clear the muck and debris from the segment installation area. Procedures are required which define the conditions (e.g., TBM stopped) under which personnel can perform this task and the roles and responsibilities of other TBM personnel (e.g., TBM operator) for ensuring the safety of personnel entering and working in the invert segment installation area. In addition, sign(s) should be posted warning personnel of the danger(s) of entering and working in this area. [3/28/94 M&O Trip Report]

Invert concrete segment, rail, and ring emplacement occurs in this installation area. Depending upon what stage of operations, this area was estimated to vary from 40 to 50 feet in length. [7/13/94 telephone conference call with Steve Short] The concrete segment is 25 inches high, 12.75 feet wide, 4 feet in depth and weighs 5.5 tons.

The invert concrete segment is attached to the forward hoist assembly on car 1 by placing clamps on the hoist onto a mushroom shaped protrusion on each end of the segment. This method of attachment produces a relatively rigid load. The segment is then lifted tight to the hoist, transported to the installation area, lowered to just above the installed segments, manually pivoted 90 degrees, lowered onto the floor of the tunnel, and the segment detached from the hoist. [7/6/94 M&O Site Visit - Steve Short]

Clamps have not been seen and cannot be evaluated for safety problems.

Each rail segment is 33 feet in length and weighs 85 to 90 pounds per yard or (11 x 85 = 935 pounds) no less than 935 pounds per rail. The rails will be hoisted by a cable sling from car 1 to the installation area. The sling can oscillate and create a pendulum effect. The rails will have to be manhandled into place. [7/6/94 M&O Site Visit - Steve Short]

Ring segments weigh 600 pounds [K/PB 6/21/94 letter] and are moved by slings. [7/6/94 M&O Site Visit - Steve Short]

The hoist has no left/right movement (when facing the cutterhead) capability. If the inverts, rail segments and ring segments are not stored directly under the hoist, these objects could oscillate when lifting them from off-center.

4.6.1 Installation Area Hazards (See descriptions of hoist operations in Section 4.8)

a. The loads carried by the hoist are very heavy and can be extremely hazardous if load falls or operator moves load with personnel nearby. (reference scenario number HA0005, HA0006, UI0215, UI0248, UI0249)

b. Rail and ring segment loads can oscillate in transit and can be extremely hazardous if personnel are nearby. (reference scenario number HA0005, HA0006, UI0215, UI0248, UI0249)

c. Hoisted loads picked up from off-center relative to the hoist location can oscillate. (reference scenario number HF0007)

4.6.2 Installation Area Hazards Mitigation

a.,b.,c. • Personnel should never work under a suspended load. No one should be under the load while it is in the air. [*Yucca Mountain TBM Vendor Training Session III*-C, page 1] (reference scenario number UI0215, UI0248, UI0249)

- Personnel should never stand in front of a moving load. [*Yucca Mountain TBM Vendor Training Session III*-C, page 2] (reference scenario number UI0215, UI0248, UI0249)

- Personnel should never leave a suspended load unattended. The load should be lowered to the floor before leaving it unattended. [*Yucca Mountain TBM Vendor Training Session III*-C, page 2] (reference scenario number UI0215, UI0248, UI0249)

c. • Develop procedures to minimize oscillation of loads and to keep personnel out of possible load travel envelop. (reference scenario number HF0007)

4.7 OPERATOR CAB

In response to the following statements and question "The *Yucca Mountain TBM Vendor Training Sessions III-A.1* calls for locking out the conveyors at the operators console and shutting off the power source at the conveyor circuit breaker and using proper tagout procedures. The M&O recommends that the power source for the TBM cutterhead circuit breaker also be shut off and tagged out when personnel are in the cutterhead location. Will this be done?", the AVO RESPONSE was "No, the lockout is at the operator cab for the cutter head. This is standard operating procedure for TBM operation." [AVO RESPONSE received 8/5/94.]

See additional warnings in the *Vendor Training Outline Yucca Mountain TBM Session II - TBM Operator Training*.

4.7.1 Operator Controls/Displays

4.7.1.1 Lockout Key

There is a lockout key on the operator's console.

4.7.1.1.1 Lockout Key Hazards (reference scenario number HA 0001, UI0069, UI0255)

The operator accidently starts the TBM while personnel are near the cutterhead and causes an injury or a fatality. (reference scenario number HA0001, UI0069)

4.7.1.1.2 Lockout Key Hazards Mitigation

The following are electrical and procedural mitigations to prevent the operator from accidently starting the TBM.

a. In the lockout position, the Master Control Relay is de-energized so that all down stream equipment controlled by the operator is de-activated. If the Master Control Relay fails, it fails in the open position. [7/6/94 M&O Site Visit - Steve Short] (reference scenario number UI0069)

b. The *Yucca Mountain TBM Vendor Training Session III-A.1* calls for locking out the conveyors at the operators console and shutting off the power source at the conveyor circuit breaker and using proper tagout procedures. The M&O recommends that the power source for the TBM cutterhead circuit breaker also be shut off and tagged out when personnel are in the cutterhead location. (reference scenario number UI0069)

c. The first person to get to the area shall have the lock out key. There is only one key in the tunnel. The last person out of the area shall have the lock-out key. [*Yucca Mountain TBM Vendor Training Session III-A.1*, page 1] (reference scenario number HA0001, UI0069)

d. Two-step procedure to start TBM, turn lockout key and press RESET button. (reference scenario number UI0069)

4.7.1.2 TBM Operation

Reference the CTS Operation and Maintenance Manuals for safety precautions, proper operating procedures, and maintenance program which must be followed to prepare for safe and efficient tunnelling. [CTS 7/27/94 letter]

There is an emergency stop control in the TBM operator's cab. It is located below the front (i.e., facing the TBM cutterhead) window. The location and design of the emergency stop (i.e., the control appears to be a push to activate, the control is not recessed) increase the potential for accidently activating the control. [3/28/94 M&O Trip Report]

The emergency stop button has not changed in the operator's cab. [AVO RESPONSE received 8/5/94]

The TBM direction controls (i.e., ROLL CCW, ROLL CW, UP, RIGHT, DOWN, LEFT) located on the operator's console are not labelled (e.g., "CUTTERHEAD DIRECTION," "CUTTERHEAD ROTATION," "CUTTERHEAD MOVEMENT") or outlined to identify that all the controls and displays within the border are functionally related to one another. [3/28/94 M&O Trip Report]

The Alarm Message Display was not installed when I inspected the TBM. It appears to be a 6-8 character LED display. Messages are supposed to be presented on this display. It is not known if the messages will scroll on the display or if a complete message will be displayed at one time. If messages will be scrolled there is no control to stop-start the scrolling so the operator can read the message. If a complete message is to be displayed at one time it will have to be very brief.

A potential concern is whether the displayed messages will be meaningful or will the operator be required to refer to a manual for a description of the error. [3/28/94 M&O Trip Report]

The Alarm Message Display is located on the upper left (i.e., next to the back window) portion of the main operator's control panel. While there are no other controls or displays adjacent to the Alarm Message Display to distract the operator, the location of the Alarm Message Display is on the periphery of the operator's normal line of sight. [3/28/94 M&O Trip Report]

In addition to the Alarm Message Display there are a number of other alarm controls and displays (i.e., RESET, SIREN, ALARM ACKNOWLEDGE, ALARM PANEL). It is not clear from the layout of the operator's control panel if these alarm controls and displays are associated with/used in conjunction with the Alarm Message Display. If they are used in conjunction with the Alarm Message Display the layout of the control panel should clearly show the relationship. [3/28/94 M&O Trip Report]

4.7.2 Color Coding of Displays

4.7.2.1 Operator's Console

Operator's Console

Display	Color of indicator
Start	Green
Stop	Red
Power On	White
Reset	Green
Siren	Red
Alarm Ack Pushbutton	Black
Alarm Panel	Red
Cutterhead Speed - High	Green
Cutterhead Speed - Low	Red
Seal Grease Flow	Green
Tunnel Conveyor	Green
Tail Trim Overload	Amber
Cutterhead direction	Amber
Cutterhead system activated	Red

Inconsistent color coding. Hazard comes from misinterpretation of color. Also see Section 4.7.2.3.

4.7.2.1.1 Operator's Console Hazards

Inconsistent color coding. Hazard comes from taking incorrect action based on misinterpretation of color. Red is used to indicate STOP, SIREN ON, ALARM PANEL ON, LOW CUTTERHEAD SPEED, and TBD for CUTTERHEAD. (reference scenario number HF0008)

4.7.2.1.2 Operator's Console Hazards Mitigation

Develop consistent color code scheme. (reference scenario number HF0008)

4.7.2.2 Instrumentation Panel Layout

The response to another question, "What is the meaning of the red mark on the psi displays?", was "Maximum." [June 27, 1994 REECo letter] The response does not indicate whether the maximum referred to maximum possible or maximum safe.

The red line indicates maximum suggested working pressure. Exceeding this pressure is an indication of a problem such as an incorrect pressure setting or overpressure. [AVO RESPONSE received 8/5/94.]

The response to the question, "Why is the red mark missing on the erector (?) display?", was "There is no erector display. We are unable to respond to this question." [June 27, 1994 REECo letter]. The Erector and TOW PSI displays have no red marks. [7/14/94 Site Visit]

The displays lack color coding for the normal operating range. [Trip Observation and CTS manuals]. Hazard results from faulty memory and allowing equipment to operate in a non-normal range. Mitigation features is to lessen memory requirements by adding color coding to normal operating ranges or to the non-normal ranges.

The reply to the question, "What is the normal amp and psi operating range for the amp and psi displays in the operator's cab, and why isn't the normal operating range color coded on the displays?", was "The normal amp and psi operating ranges for the operator's console vary, depending on the operating system. These will also vary depending upon rock quality and mode of operation. It is not necessary or industry practice to use color range code display on gauges." [June 27, 1994 REECo letter]

Red marks are for the convenience of the operator. Operator training will inform operators as to normal operating pressures for all circuits. [AVO RESPONSE received 8/5/94.]

4.7.2.2.1 Instrumentation Panel Layout Hazards (reference scenario number HF0009, UI0220)

The operator takes wrong action because operator cannot remember what the normal amp and psi operating ranges for the given operating system.

4.7.2.2.2 Instrumentation Panel Layout Hazard Mitigation (reference scenario number HF0009, UI0220)

Color code displays for normal or off-normal ranges for each operating system to remove operator memory requirements.

4.7.2.3 Remote Control Panel Layout

Remote Control Panel Layout

Equipment	Color for Start	Color for Stop	Color for On	Color for Run
Invert Conveyor	Green	Red	NA	NA
Lube Fill	Green	Red	NA	NA
Hydraulic Fill	Green	Red	NA	NA
Fan Motors	Green	Red	NA	NA
Inching Station		[OFF] None. 2-position switch.	[ON] None. 2-position switch.	Blue (2 lights - inching station run and conveyor run)
Air Compressor	Blue	Red	Green	

4.7.2.3.1 Remote Control Panel Layout Hazard (reference scenario HF0008)

Inconsistent color coding. Hazard comes from misinterpretation of color. Blue is used for start (instead of green) and green is used for ON for Air Compressor while Blue is for RUN on Inching Station.

4.7.2.3.2 Remote Control Panel Layout Hazard Mitigation (reference scenario HF0008)

Develop a consistent color scheme.

4.7.2.4 Display Failure

The response to the question, "When the displays fail, the indicator (pointer) fails to zero, off-scale, midrange, or where?", was "Must contact CTS for a response. [June 27, 1994 REECo letter] Failure location is important to avoid misinterpretation.

Panel meters drop to zero or below scale. Digital display flashes or goes blank. [7/13/94 telephone conference call with Steve Short] No written response as yet so further verification cannot be done.

4.7.2.4.1 Display Failure Hazard (reference scenario HF0015)

Display fails to midrange and operator does not realize display has failed.

4.7.2.4.2 Display Failure Mitigation (reference scenario HF0015)

Display must fail off-scale if analog. Digital display must flash if no other failure indicator is present. Digital display can go blank if there is another failure indicator.

4.8 INVERT SEGMENT HOIST

The segment hoist is actually composed of two different hoists. The first segment hoist, located on cars 2 and 3, is used to lift the segment from the train cars (probably one at a time) and move the segment forward to the front of car 2. The second segment hoist is used to move the segment from car 2 to the segment installation area (located between the forward section and car 1) or to store the segment(s) on car 1.

Update: Rear segment hoist takes object to car 1. Forward segment hoist takes object from car 1 to invert segment area. [7/6/94 M&O Site Visit]

The controls for the segment hoists are located on vertical posts on cars 3 and 1 and in the forward section of the TBM. There are five segment hoist control boxes: Update: six control boxes. [7/14/94 M&O Site Visit]

- 1 box which controls power to the segment hoist motor(s). This box has two buttons - "on" and "off." It is located on a vertical post on the walkway side of car 3. I was unable to determine if this box controls power to both segment hoist motors or if there are two control boxes. If there is a second control box I was not able to locate it.

  Update: one "on/off" box for the rear segment hoist on car 3 and one "on/off" box for forward segment hoist on car 1. [7/14/94 M&O Site Visit]

- 2 boxes to control the rear segment hoist. The boxes control "forward," "reverse," "up," and "down" movement of the hoist. One control box is located on the walkway side of car 3 and the other control box is located on car 1, on the opposite side of the cars.

- 2 boxes to control the forward segment hoist. The boxes control "forward," "reverse," "up," and "down" movement of the hoist. One control box is located on the walkway side of car 1 (i.e., the opposite side of the car from the rear segment hoist control), and the other control box is located on the forward section of the TBM, inside the tail shield/grippers.

The segment hoist power box and the control box located on car 3 are placed on opposite sides of the same post. This creates the potential for the user to accidently apply or remove power from the hoist. The situation can occur if the user reaches his/her hand around the post while bending over the railing to view the train or position of the rear segment hoist and depresses one of the buttons on the control box. It is also possible for the user to accidently move (i.e., up, down, forward, reverse) the segment hoist when observing the position of the train or the hoist from the other side of the post. It is less likely to occur from this position because there is an opening in the railing where the user can walk through/stand.

Update: The power and control boxes for the rear segment hoist are on same side of column on car 3. [7/14/94 M&O Site Visit]

The placement of a number of control boxes (e.g., invert segment hoist, rail system) requires the operator to bend over the railing and extend his/her neck around a post get a clear view of the position and movement of the object/device being controlled.

Moving and placing the invert segment on car 1 or in the segment installation area requires two persons - one person operates the controls and the other person guides/handles the invert segment. There is also the possibility for the users to change roles while placing an invert segment in the installation area. A scenario of how this may occur is:

- User 1 is operating the control box located on car 1
- User 2 is guiding the invert segment in the installation area
- User 1 is unable to safely control the movement of the hoist (e.g., lack of clear line-of-sight)
- User 1 stops the hoist
- User 2 climbs out of the installation area to the control box located inside the tail shield/grippers
- User 1 climbs into the installation area (an alternative is to have User 1 move forward to the control box located inside the tail shield/grippers and User 2 continue to guide the invert segment).

Procedures are required which identify the conditions under which personnel can perform this task, the sequences of action, and the roles and responsibilities of the individuals performing this task.

The roles and responsibilities of other TBM personnel (e.g., TBM operator) for ensuring the safety of personnel performing tasks, such as installing invert segments, also needs to be defined. In addition, sign(s) should be posted warning personnel of the danger(s) of entering and working in this area.

The segment hoist control box inside the tail shield/gripper area has an emergency shut off switch located in close proximity to the segment hoist control box. The emergency switch is for the hydraulic system. In addition, it appears that another control will be placed between the segment hoist control box and the emergency shut off control. Without identifying labels there is an increased potential for operator error, e.g., the operator may incorrectly assume that the emergency hydraulic system shut off switch shuts off the segment hoist. [3/28/94 M&O Trip Report for the above in this section]

4.9 RAIL SYSTEM

A single battery powered locomotive with or without small rail cars traverses rail car 5 to rail car 2 and maybe back of rail car 1. The locomotive has not been selected. [7/6/94 M&O Site Visit - Steve Short]

The muck rail car is 5 feet 4 inches wide and 7 feet 6 inches to 7 feet 7 inches high. [7/6/94 Site Visit and 7/14/94 M&O Site Visit]

Unobstructed distance between columns is 9 feet on car 1 and 9 feet 7 inches on rail car 2. The ceiling to floor distance is 7 feet 11 inches. [7/14/94 M&O Site Visit] Muck car height clearance is 4 to 5 inches and width clearance would be [(9 feet 7 inches - 5 feet 4 inches)/2] 2 feet 1 and 1/2 inches to each side on deck 2 and 3.

Movement of the trains is controlled from a box located on a vertical post on the trailing cars. The control box contains a red indicator, which is normally illuminated, and two push to activate buttons. The red indicator indicates stop. The two buttons are used to control forward and reverse travel direction. When the buttons are depressed signals located on cars 1, 3, and 5 illuminate. When the buttons are not depressed a red signal located on cars 1, 3, and 5 is illuminated. [3/28/94 M&O Trip Report]

The colors for forward and reverse are white and blue. White is normally used to indicate a functional position or an action in progress, and blue is used only if an additional color is required and then as an advisory light. Unless this color coding scheme is standard in the mining/tunneling industry, or there is another reason for using these colors, it is recommended that the color coding scheme be changed to green for forward and yellow for reverse. The use of red, green, and yellow to identify stop, forward and reverse is similar to the color coding scheme used in automobiles with automatic transmissions, where red is used is used to identify the park position, green is used to identify forward drive positions, and yellow is used to identify the reverse position. [3/28/94 M&O Trip Report]

Update: Colors are mining convention.

A preliminary inspection of the train lamps mounted on cars 1, 3, and 5 indicates that standard, clear, incandescent "household" type bulbs are being used. If these are the types of bulbs being used it is recommended that they be replaced with long life dual filament bulbs. When one of the bulb filaments fails the decrease in light intensity should be sufficient to identify the need for replacement. The use of long life dual filament bulbs will increase the time between bulb replacement, and will reduce the probability of an operator error or accident because of a burned-out bulb. [3/28/94 M&O Trip Report]

Update: Florescent and flood lights are being used.

4.9.1 Rail System Hazards (reference scenario numbers HA0002, HA0003, HA0004)

Hazards associated with the rail system are:

a. Personnel are injured by moving train when trying to go through small clearances between locomotive, cars, and the deck columns in the train travel area. (reference scenario numbers HA0002, HA0003, HA0004)

b. Personnel struck because of not seeing train. (reference scenario numbers HA0002, HA0003, HA0004)

c. Rail contents (concrete invert segments, rail tracks, ring segments, rock bolt, and other equipment) fall off the flatbed car. (reference scenario numbers UI0261)

d. Detached rail car moves. (reference scenario HF0010)

4.9.2 Rail System Hazards Mitigation

a., b. Exclude personnel from train travel area when trains are moving. Also, provide flashing lights on the locomotive when moving.
b. Use spotters for trains. Use sirens and flashing beacons to indicate train motion.
c. Provide training to properly tie down equipment and supplies. (reference scenario numbers UI0261)
d. Block rail car wheels when required to be stationary. (reference scenario HF0010)

4.10 CONVEYOR SYSTEM

There is a gap between the conveyor belt and the conveyor belt frame where debris can fall through. This area should be protected to prevent debris from falling and striking personnel walking/working below the conveyor belt. [3/28/94 M&O Trip Report]

There is a gap between conveyor belt and side of the conveyor. This gap could allow muck to fall to the lower car deck. [6/22/94 M&O Trip Findings]

The conveyor belt is not covered in all areas. An individual can walk along the conveyor belt while it is moving, or the conveyor can be started/stopped while someone is walking on the conveyor belt. The conveyor belt should be covered in all areas where there is danger of personnel injury because of a fall; being struck by muck or other debris falling off the conveyor belt; or getting an arm, hand, finger, leg, or foot stuck in the conveyor belt system. As a minimum, warning signs should be posted along all exposed areas of the conveyor belt and adjacent to the conveyor belt controls. [3/28/94 M&O Trip Report]

The emergency pull is 5 feet 10 inches from the floor. It is the same color as TBM. [7/14/94 M&O Site Visit]

Car 3 has a walkway over the conveyor. Only area where workers should walk over belt. [7/13/94 telephone conference call with Steve Short]

Sprayers are located under the hoods and are not automatically turned on when conveyor is turned on. Sprayers are turned on by the operator in the operator's cab. [7/13/94 telephone conference call with Steve Short]

There are only two conveyors on the TBM. Stop #1 controls the water spray at the #1 to #2 transfer location. Stop #2 controls the transfer points at the discharge and of conveyor #2. Spray control #3 is "Muck pan water" located at the cutter head hopper. [AVO RESPONSE received 8/5/94.]

A siren is on for 8 seconds and 3 flashing yellow lights are on before conveyors start. Beacons are active while conveyor is running. [7/13/94 telephone conference call with Steve Short]

Site visit questions were not fully answered about the conveyor operation. These operations are not fully understood at this time. Location, interlocks, and operational relationship for all conveyor controls not understood at this time.

4.10.1 Conveyor System Hazards (reference scenario number HA0010, UI0246)

a. There is a gap between the conveyor belt and the conveyor belt frame where debris can fall through. (reference scenario number UI0224)

b. The conveyor belt is not covered in all areas. An individual can walk along the conveyor belt while it is moving, or the conveyor can be started/stopped while someone is walking on the conveyor belt. (reference scenario number UI0224)

c. Conveyor belt is fire hazard due to friction. (reference scenario number UI0224) (reference scenario number HA0052)

4.10.2 Conveyor System Hazard Mitigation

a. Add flashing to conveyor belt frame. (reference scenario number UI0224)

b. Cover conveyor belt. Warning signs should be posted along all exposed areas of the conveyor belt and adjacent to the conveyor belt controls. (reference scenario number UI0224)

c. Use fire retardant conveyor belt. (see TBM specifications) (reference scenario number UI0224)

4.11 ELECTRICAL SYSTEM

The main electrical power distribution cabinets have internal lighting (fluorescent fixtures), "plexiglass" shields along the top of the cabinets to isolate cabling, and "plexiglass" shields in front of junction boxes. There is enough space between the shields and the top of the cabinets for a user to insert his/her hand or a tool. To reduce the possibility of personnel injury or damage to the cables the space between the shields and the cabinet should be reduced and/or additional shielding should be mounted vertically in the front of the cabinet. [3/28/94 M&O Trip Report]

"Plexiglass" shields will also be installed in the bottom of the cabinets when cabling in these spaces has been completed. [3/28/94 M&O Trip Report]

Plexiglass shields have not been installed 8/4/94. [AVO RESPONSE received 8/5/94.]

Latches, rather than knobs, are used on cabinet doors (e.g., electrical power distribution cabinets). The latches securely closed the cabinet doors, and, it appears, padlocks can be inserted in the latch handles to prevent unauthorized access and the doors from opening accidentally. [3/28/94 M&O Trip Report]

4.11.1 Electrical Hazard (reference scenario number HF0011)

a. The space between the shields and the cabinet is too wide so that personnel could insert their hand or a tool.

b. No plexiglass shield installed on bottom of the electrical cabinets.

4.11.2 Electrical Hazard Mitigation (reference scenario number HF0011)

a. Reduce space.

b. Install plexiglass shields.

4.12 ZED-26 TUNNEL GUIDANCE SYSTEM

The laser is installed on a support bracket hung from the tunnel rib. There is a window shown on the attached sketch. (no sketch attached). The target is mounted on the back of the cutterhead in the same window. [June 27, 1994 REECo letter]

Safety procedures must be in place so that personnel cannot be harmed by the laser.

4.13 ILLUMINATION

The expected illumination level around the rail cars, ladders, invert installation area, and tail shield is 10 foot-candles. [June 27, 1994 REECo letter] This lighting primarily comes from a series of florescent lights on the rail cars. [7/6/94 M&O Site Visit] There are approximately fifty 4-foot fluorescent fixtures and fourteen 400-watt flood lights. Spacing varies. [June 21, 1994 Kiewit/PB letter] There are no Halogen lights. [June 21, 1994 Kiewit/PB letter, 5A]

400 watt flood lighting aimed at the tunnel is expected for the upper deck. [7/6/94 M&O Site Visit - Steve Short] Whether this lighting creates glare problems once in the tunnel for reading displays on the upper deck or where ever cannot be evaluated as the TBM is outside the tunnel.

We do not expect glare problems from flood lighting. [AVO RESPONSE received 8/5/94.]

4.14 RAIL CAR 1

4.14.1 Handrails

No handrails on ladder to upper deck on car 1. [6/22/94 M&O Trip Findings] (reference scenario number UI0213)

4.14.2 Labeling

Permanent and not temporary labeling is needed on the Vickers Directional Valve (up, fwd). Currently, labeling is done with tape. [6/22/94 M&O Trip Findings] (reference scenario number HF0012)

4.14.3 Meters

The meter for the equipment under the Vickers Directional Valve on upper deck of car 1 cannot be read as it is next to the railing and faces the cutterhead. [6/22/94 M&O Trip Findings] (reference scenario number HF0020)

4.15 RAIL CAR 2

4.15.1 Segment Hoists

The rear segment hoist is located on rail cars 3. This hoist lifts the segment from the train cars and moves it forward to the front of car 1. The forward segment hoist is used to move the segment from car 1 to the invert segment area.

4.15.2 Meters

Water pressure meter is difficult to read as the meter faces away from the center of the car and toward the radiator fan. [6/22/94 M&O Trip Findings]

4.15.3 Controls

Due to the installed position of the Posi-drain close to the deck flooring, the settings for the bottom control knob are hard to see and read. [6/22/94 M&O Trip Findings]

4.16 RAIL CAR 3

4.16.1 Railings

There are no railings to prevent someone from falling off the back of car 3. Guard rails will be installed when the TBM is assembled at Yucca Mountain. [3/28/94 M&O Trip Report]

4.16.1 Controls

The control box for the ventilation tube door is located on the top deck, on a post approximately 1.5 - 2 feet above the deck. While personnel will not be able to stand erect on the top deck when the TBM is in the ramp/drift, the control box is inconveniently located. In addition, the control box is placed between the back of the ventilation door opening and the end of car 5. [3/28/94 M&O Trip Report]

Deck door operating controls have not been moved. [AVO RESPONSE received 8/5/94.]

Access to upper deck was denied on 7/14/94 site trip and control box could not be evaluated.

4.16.2 Labeling (reference scenario number HF0012)

a. Permanent and not temporary labeling is needed on the Vickers Directional Valve (up, fwd). Currently, labeling is done with tape. [6/22/94 M&O Trip Findings]
b. Circuit breakers in the industrial control system are not labeled. [6/22/94 M&O Trip Findings]

c. Circuit breakers in the lunch room are not numbered. [6/22/94 M&O Trip Findings]
d. The black knob on the Delphian meter is not labeled. [6/22/94 M&O Trip Findings]

4.16.3 Illumination

a. No lighting fixtures were observed on the second floor of the cars. It appears that the Delphian meter will be hard to read under low levels of illumination. [6/22/94 M&O Trip Findings]

   This finding was superseded by: 400 watt flood lighting aimed at the tunnel is expected for the upper deck. [7/6/94 M&O Site Visit - Steve Short] Whether this lighting creates glare problems once inside the tunnel for reading displays on the upper deck or where ever cannot be evaluated as the TBM is outside the tunnel.

b. Meter by the strainer access on the second floor will be hard to read under low levels of illumination. [6/22/94 M&O Trip Findings]

4.16.4 Obstruction

Vent tube by lunch room stairs interferes with using stairs. It is too close to the stairs. [6/22/94 M&O Trip Findings]

4.16.5 Access

Inspection plate for the right (while facing the cutterhead) vent line next to lunch room door has been installed incorrectly. It cannot be inspected from the deck. [6/22/94 M&O Trip Findings]

Update: Most recent REECo letter indicated that these sliding covers are used for balancing.

4.17 RAIL CAR 4

4.17.1 Railings

On the side opposite the walkway on car 4 there is no upper deck. There is no upper deck on this car because the space will be used to bring the muck system conveyor from the top deck to the side at a later date.

4.17.2 Ventilation Fan

Not installed and could not be evaluated.

4.17.3 Backup Conveyor Dump

Not installed and could not be evaluated.

4.17.3 Conveyor Traveling Tailpiece

Not installed and could not be evaluated.

4.18 RAIL CAR 5

4.18.1 Railings

There are no railings to prevent someone from falling off the back of car 5. Guard rails will be installed when the TBM is assembled at Yucca Mountain. [3/28/94 M&O Trip Report]

The response to the question, "Is there railing at the back side of the second floor of deck 5?", was "No." [June 21, 1994 Kiewit/PB letter, #7]. No railing is a safety problem.

4.18.1.1 Railing Hazard (reference scenario UI0258)

Falling off upper deck.

4.18.1.2 Railing Hazard Mitigation

Install railing.

4.18.2 Ventilation Pipe Lifting and Installation

A single ventilation pipe is 20 feet long, 66 inches in diameter, and weighs at least 840 pounds (message from Romeo Jurani on 7/8/94) but no more than 2750 pounds. See *Yucca Mountain TBM Vendor Training Session III-E* for additional hazards and mitigation procedures associated with ventilation pipe lifting and installation.

Vent line hoist free wheel lever is not recessed. [AVO RESPONSE received 8/5/94.]

On/off power to the folding door is the same as to the aft segment hoist. The on/off power switch is located on car 3 where the control panel to the aft segment hoist is also located. [*Yucca Mountain TBM Vendor Training Session III-E*, page 4] After the gantry cars are installed, there will be nine cars and a considerable distance between the on/off control on car 3 and the folding door on car 5. This distance will increase the probability that an accident will occur.

Site visit questions were not fully answered about the operation of vent pipe lifting and installation. These operations are not understood at this time and could not be evaluated.

4.18.2.1 Ventilation Pipe Lifting and Installation Hazard (HA0007, UI0257)

a. Inadvertent opening of folding doors (reference scenario number HF0013)

b. Injury from installation during TBM operations (reference scenario number HF0014)

4.18.2.2 Ventilation Pipe Lifting and Installation Hazard Mitigation

a. Mitigation for accidental opening of the folding doors is the requirement to simultaneously depress the SAFETY and OPEN pushbuttons. These pushbuttons should be recessed. (reference scenario number HF0013)

b. Procedural mitigations include: (reference scenario number HF0014)

- Mining must be stopped every 20 feet to install a new piece of vent line. *[Yucca Mountain TBM Vendor Training Session III-E*, page 1]
- The TBM ventilation fans are not to be operated when the vent line is being erected. The air velocity could blow dirt into workers eyes. *Yucca Mountain TBM Vendor Training Session III-E*, page 2, step 10]
- The TBM ventilation fans are to be tagged out. *[Yucca Mountain TBM Vendor Training Session III-E*, page 4]

4.18.3 Feeder Cable Monorail

The response to the question, "What is the function of the feeder cable monorail?", was "To feed the power cable into the cable storage box." [June 27, 1994 REECo letter]

To replenish the cable, the new cable is brought in 1000 feet segments and stretched out in a straight line. It is then wound into the flight cable box by using the feeder cable monorail, or other equipment, or it could be wound manually. [8/17/94 M&O/Kiewit/REECo meeting]

4.18.4 Feeder Cable Flight Box (reference scenario number UI0250)

Initially, it was thought that cable would be fed to the cable tray from the feeder cable flight box. However, the response to the question, "What piece of equipment raises the cable boxes up through the bi-fold platform to the cable box storage platform?", was "This system has been eliminated from the TBM training gear." [June 27, 1994 REECo letter] This answer with the answer to the question in section 4.19 (*Initially, it was thought that installation of the cable tray was to take place on the TBM trailing cars. However, the cable tray will not be installed off a rail car. A "jumbo" or "traveler" will be used. To date, it has not been designed or procured. It may move on rails as does the traveling mapping. [June 27, 1994 REECo letter]*) is being interpreted as elimination of the need for the feeder cable flight box.

Site visit questions were not fully answered about the cable operation. These operations are not understood at this time and could not be evaluated.

4.19 CARS 1 to 5

Openings are provided along the length of the car walkways to allow users to access the train travel area and the other side of the cars. Swinging gates will be installed when the TBM is assembled at Yucca Mountain. [3/28/94 M&O Trip Report]

Each car has an emergency pull to stop the conveyor. The pulls are located on the lower deck approximately 6.5 feet to 7 feet above the surface. This may make it difficult to stop the conveyor, depending on the size of the user and the force required to pull the emergency stop. [3/28/94 M&O Trip Report] Update: Pull is 5 feet 10 inches from floor.

Other characteristics which may affect operation of the emergency pulls include:

- The pulls are painted white, the same color as the TBM, making them difficult to see.
- The pulls are located on the inside of the train travel area on the side opposite the walkways. The user must cross the train travel area and walk around a train, if one is present, to stop the conveyor.
- The emergency pulls on cars 2 and 3 are located very close to the segment hoist travel rail. A user wearing gloves or with large hands may have difficulty pulling the emergency stop. [3/28/94 M&O Trip Report]

There are numerous control boxes (e.g., invert segment hoist, rail system, emergency shut off, oil siphon pump(s), ventilation tube door) located throughout the TBM. While individual controls and displays in a given control box are labelled, the function or the device which is being controlled by the box is not labelled. Thus, there is the increased potential for activating an incorrect device. [3/28/94 M&O Trip Report]

There are two water pressure gauges installed on the trailing cars - one for clean water and the other for dirty water. One of the gauges is located on the same side of the TBM as the walkway. The second gauge is located on the other side of the car. The gauge located on the walkway side is intended to be read from the walkway, but the template which displays the values is mounted so that the user must enter the train travel area to read the template, In addition, the template is mounted upside down. To read the water pressure gauge on the other side of the cat the user must cross the train travel area. [3/28/94 M&O Trip Report]

Water pressure gauges are in the same position. [AVO RESPONSE received 8/5/94.]

Flow meters for radiator are located across from the walkway and user must enter train travel area to read the meters. [7/6/94 M&O Site Visit.]

While not within the scope of the current analysis, it is recommended that the design of the eight additional TBM cars include train lamps/controls. [3/28/94 M&O Trip Report]

The fire suppression and external lighting system were not installed. They will be installed when the TBM is assembled at Yucca Mountain. [3/28/94 M&O Trip Report] External lighting on cars 4 and 5 have not been installed. [7/14/94 M&O Site Visit]

Fire suppression system is not complete 8/4/94. [AVO RESPONSE received 8/5/94.]

External lighting is not complete 8/4/94. [AVO RESPONSE received 8/5/94.]

Hydraulic, water, and power lines are run along the length of the TBM. In most cases, they are suspended well out of the way on the superstructure approximately 8 feet above the deck. At selected locations along the trailing cars the lines are mounted on brackets which hold the lines securely in place. [3/28/94 M&O Trip Report]

Holes are cut through the top of the lower deck and the floor of the top deck for hydraulic lines to run through. These openings are not protected (e.g., rubber grommets) to prevent damage to the lines. [3/28/94 M&O Trip Report]

No protection yet for hydraulic lines running through decks. [AVO RESPONSE received 8/5/94.]

Water lines which have rigid piping along the length of the cars have flexible hoses between cars. [3/28/94 M&O Trip Report]

The decks, ladders, and stairways have non-slip surfaces. The lower decks and stairways (only two stairways were inspected) are solid with indentations. The upper decks and ladders are open with serrated crisscrossing metal strips. [3/28/94 M&O Trip Report]

The upper decks do not have any toe kicks or other devices to prevent a user from catching his/her foot between the tunnel/ramp wall and the end of the deck or kicking a tool off the deck. [3/28/94 M&O Trip Report]

Between each car there is a gap of approximately 8 inches. This space will be covered with a grate/cover when the TBM is assembled at Yucca Mountain. [3/28/94 M&O Trip Report] (reference scenario UI0237)

The emergency cord is on the opposite side of the walkway. It is painted white, same as TBM structure. The same makes it more difficult to quickly identify. It should be painted in a contrasting color. Cars 1,2,3. [6/22/94 M&O Trip Findings]

The cables for rear and forward segment hoist are not covered. If it snaps, injury or damage could occur. [6/22/94 M&O Trip Findings] Factor of safety designed in. See Proximity Analysis.

The chain for the rear segment hoist is not covered. If it snaps, injury or damage could occur. [6/22/94 M&O Trip Findings] Factor of safety designed in. See Proximity Analysis.

4.19.1 Hazards (reference scenario number HA0033, UI0245, UI0253, UI0256)

a. Emergency pull to stop the conveyor:

- The pulls are painted white, the same color as the TBM, making them difficult to see.
- The pulls are located on the inside of the train travel area on the side opposite the walkways. The user must cross the train travel area and risk being struck by a train or walk around a train, if one is present, to stop the conveyor. (reference scenario number UI0245, UI0253)

b. Individual controls and displays in a given control box are labelled, the function or the device which is being controlled by the box is not labelled. Thus, there is the increased potential for activating an incorrect device. (reference scenario number UI0256)

c. The user must enter the train travel area to read meters. (reference scenario number HF0017)

d. Holes are cut through the top of the lower deck and the floor of the top deck for hydraulic lines to run through. These openings are not protected (e.g., rubber grommets) to prevent damage to the lines. (reference scenario number HF0018)

e. The upper decks do not have any toe kicks or other devices to prevent a user from catching his/her foot between the tunnel/ramp wall and the end of the deck or kicking a tool off the deck. (reference scenario number HF0019)

4.19.2 Hazard Mitigation

a. Paint with a contrasting color to the TBM and relocate emergency pull near the walkway. (reference scenario UI0245, UI0253)

b. Provide labeling that describes device associated with given controls. (reference scenario number UI0256)

c. Relocate meters. (reference scenario number HF0017)

d. Provide grommets. (reference scenario number HF0018)

e. Provide toe kicks. (reference scenario number HF0019)

4.20 CABLE TRAY

Initially, it was thought that installation of the cable tray was to take place on the TBM trailing cars. However, the cable tray will not be installed off a rail car. A "jumbo" or "traveler" will be used. To date, it has not been designed or procured. It may move on rails as does the traveling mapping. [June 27, 1994 REECo letter]

Cable will be placed in the cable tray. Normal procedure will be to "coil" the cable in the tray, hoisting the cable with rope and hoists to the tray. [AVO RESPONSE received 8/5/94.]

Appendix E

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Appendix F

ATTACHMENT F

Reynolds Electrical & Engineering Co., Inc.
Post Office Box 98521 • Las Vegas, NV 89193-8521

IN REPLY REFER TO
580-01-864

WBS 1.2.6
QA: N/A

September 9, 1994

L. Dale Foust
Technical Project Officer
TRW Environmental Safety
Systems, Inc.
101 Convention Center Drive
Suite P-113
Las Vegas, NV 89109

RESPONSE TO OPEN ITEMS ON THE TUNNEL BORING MACHINE (TBM) SAFETY ANALYSIS REPORT (SCPB: N/A)

The enclosed letter from our subcontractor, Kiewit/Parsons Brinckerhoff, are submitted in response to a request from Mr. M. L. Renegar of the Construction Management Office. These are the responses to the open items of the System Safety Analysis.

If you require any additional information, contact E. W. Pokorny at 794-7304.

Daniel L. Koss, Manager
Yucca Mountain Project Division
YMP Technical Project Officer

DLK:EWP:jmc

Enclosure
Letter, Wightman to REECo, w/encl.,
08-25-94 (6 pages)

cy: See page 2

SPECIAL UPDATING INSTRUCTIONS:

Replace the last page of Appendix F with the following 2 pages.

KIEWIT/PB
YUCCA MOUNTAIN PROJECT
4460 SO. ARVILLE ST., SUITE 6, LAS VEGAS, NV 89103
(702) 295-2101
FAX (702) 295-2319

September 13, 1995

QA: N/A
SCPB: N/A
K/PB Letter No. 2081

M&O/MK Contractor Office
101 Convention Center Drive
Las Vegas, NV 89109

Attn.: R. C. McDonald, M/S 423

SUBJECT: REAR STAIR ON TBM , YOUR LETTER NO. 95-006651, TO DANIEL KOSS

We have determined that a stairway at the rear of the TBM would create a high potential for serious or fatal injury to any person(s) occupying the stairway in the event of train derailment on the access ramp. We will satisfy the emergency egress concern by locating a portable ladder at that location which will be clearly identified for use in emergency situations only.

Very truly yours,

W. D. Wighuman
Project Manager

WDW:jmw

cy: D. L. Koss, REECo, M/S 408
J. P. Morris, Kiewit/PB, M/S 741
D. L. York, Kiewit/PB, M/S 741
T. Touchstone, M&O/Duke, M/S 423
Job File

WORK SHEET

Project YMP
Type of Work

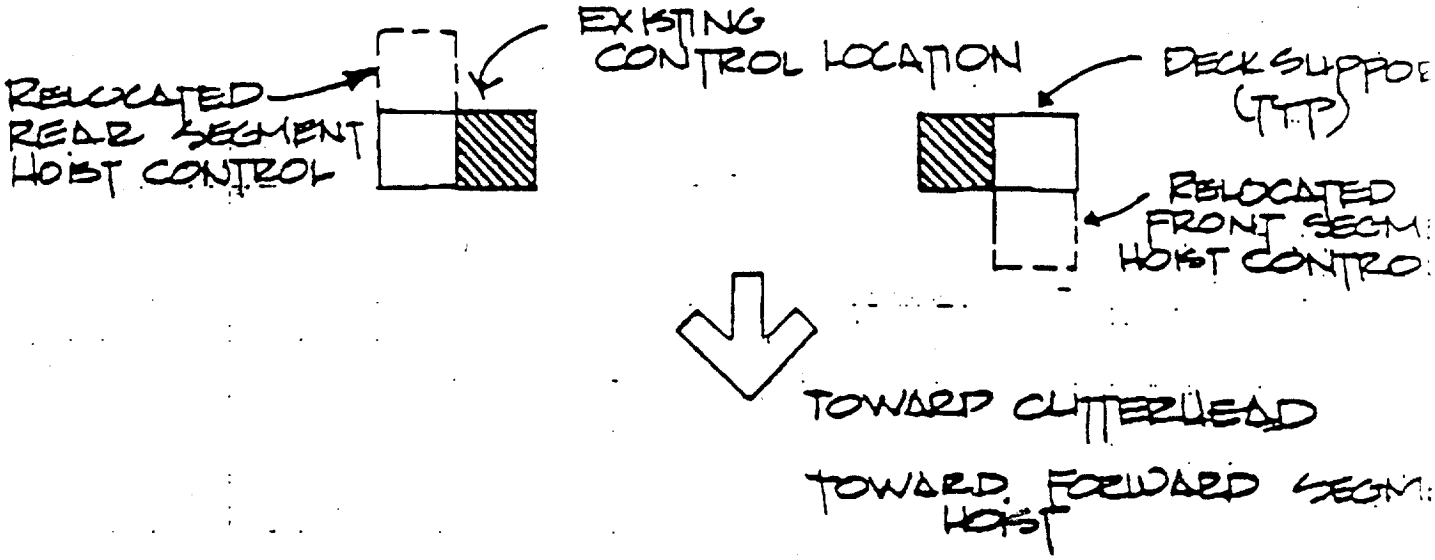
Estimator MCM
Date 8/23/94

Item No.
Sheet No. 1/1

SKETCH

RELOCATE SEGMENT HOIST CONTROLS

PLAN VIEW ~ SCHEMATIC



Interoffice Correspondence

Civilian Radioactive Waste Management System
Management & Operating Contractor

TRW

TRW Environmental
Safety Systems Inc.

Subject:
Stairs at Rear of TBM
(SCPB: N/A)

Date
January 8, 1996
LV.YM.RIL.01/96-006

WBS: 1.2.6
QA: N/A
From
Richard C. McDonald RCM

To
James Robertson, TES3/423

cc
R. R. Dresel, TES3/423
CMO File Copy
RPC

Location/Phone
TES3/763
(702) 295-3703

The Construction Management Organization concurs with the determination made by Kiewit/PB in the attached letter, K/PB No. 2081, dated September 13, 1995.

RCM:jl

Attachment:
as stated

Appendix G

Analysis: BABFBA000-01717-0200-00001 REV. 00

ACCIDENT ANALYSIS SUMMARY

SCENARIO NUMBER: UI0212 REVISION: 00 REVISION DATE: 09/7/94

LOCATION:

Subsurface Development Face

SCENARIO:

Personnel injury (e.g., hit by falling rock or roof bolt) while installing rock bolts outside of tail shield (also see HA0032, HA0016, UI0226, UI0227, UI0209, UI0222).

SYSTEM/COMPONENT FAILURE:

- Debris falling from ramp crown
- Human error (e.g., dropping rock bolt or drill bit, improper/incomplete installation of rock bolts)
- Failure to adhere to safety procedures and rules (e.g., not wearing hard hat or eye protection)

ACCIDENT CLASSIFICATION AFTER MITIGATION:

Frequency Rating: C - Occasional

Consequence Rating: III - Marginal

Risk Designation: Medium

MITIGATION/CONTROL FEATURES:

- Use approved rock bolts.
- Require safety belts during work in unprotected areas per MSHA 57.15005.
- Provide safety training for rock bolt drill operators and all other personnel working on the TBM/around the rock bolt drill.
- Establish inspection, maintenance, and housekeeping procedures and schedule. Maintain inspection, maintenance, and housekeeping records.
- Provide procedure to prohibit work directly under rock bolting operations. Controls for drills are not directly under where rock fall, therefore, the bolting operator is not directly under bolting operation.
- Abide by ground support procedures.

Appendix H

NOTICE

APPENDIX H CONTAINS SCENARIOS COVERING THE MAPPING GANTRY. THERE ARE A NUMBER OF SCENARIOS IN THIS APPENDIX FOR THE ROCK BOLT DRILLS. THE ROCK BOLT DRILL SCENARIOS ADDRESS ONLY SAFETY RELATED ISSUES PERTAINING TO THE INSTALLATION OF THE ROCK BOLT DRILLS ON THE MAPPING GANTRY; THEY DO NOT ADDRESS THE DESIGN OF THE ROCK BOLT DRILL CONTROL PANEL, THE DESIGN OF THE ROCK BOLT DRILLS, OR THE OPERATION OF THE DRILLS AS SPECIFIED BY THE MANUFACTURER. FOR ADDITIONAL INFORMATION ABOUT THE ROCK BOLT DRILLS REFER TO APPENDIX G.

DIVISION: Brocum

CC: Baumeister

CC: Craun

CC: Dixon

CC: Elder

CC: Fortner

CC: Keplogle

CC: Barnds w/o

CC: Kuyer w/o

REC'D IN YMP

2/27/96