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SAFETY EVALUATION

OF

MANNED CONTROL CAR (MCC)

AND

ENGINE INSTALLATION VEHICLE (EIV)

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I. INTRODUCTION

This document, prepared jointly by NTO Health and Safety and REON Safety, contains information pertaining to a safety evaluation of the as-built Manned Control Car (MCC) and Engine Installation Vehicle (EIV).

The MCC is to be used in conjunction with the EIV and a Prime Mover locomotive for the transport, installation, and removal of the NERVA nuclear engine in fulfillment of NERVA engine testing requirements. The MCC is a specially designed and constructed railway locomotive equipped with remote controls for the Prime Mover and EIV. These controls are located in the central control cab which is designed to shield the operators from the nuclear radiation environment.

The EIV is a specially designed railway vehicle which is to be used to install or remove the NERVA engine from the test stand and to support this engine during transport between the test stand and the Engine Maintenance Assembly/Disassembly Building (E-MAD). As noted above, all controls for the EIV are located in the MCC shielded cab.

This safety evaluation is primarily a determination of the adequacy of MCC/EIV design in meeting basic safety requirements, as outlined in Part II of this document. However, other features of design, which involve safety implications, have also been investigated. Recommendations, as necessary, are made for the correction of noted deficiencies. Other recommendations involve operational checkout and testing to verify integrity of installed systems or to obtain experimental data to determine the need for further modifications. These recommendations have been previously discussed on an informal basis with cognizant NERVA engineering personnel. Consequently, some of the deficiencies, identified herein, may have been resolved or will be in the process of resolution by the time this report is issued.

Drawings of the MCC/EIV are contained in Part VII for reference purposes.

II. SAFETY REQUIREMENTS

A. Radiation monitoring systems, as follows, are required:

1. A gamma monitoring system, including appropriate readout and alarm appurtenances, shall be provided. This system shall have the capability for continuously monitoring the maximum intensity in the radiation environment to which the MCC cab (both exterior and interior) is to be subjected.

2. A neutron monitoring system, including appropriate readout and alarm appurtenances, shall be provided to indicate an accidental criticality occurring during handling and transport of a hot or cold engine with the MCC/EIV.

3. An air sampling system shall be provided inside the MCC cab to determine whether the operators have been exposed to significant amounts of airborne radioactivity during normal handling of a hot engine or in the event of accidental criticality.

B. An adequate breathing environment shall be maintained for the MCC operators for both normal and emergency conditions during transport and handling of the nuclear engine.

C. The MCC cab shall be shielded to reduce the radiation level to an intensity of approximately 25 mrem/hr during hot engine handling and transport.

D. A means for emergency escape from the cab shall be provided as backup to the normal exit door.

E. A system shall be provided for detection and suppression of fires in the engine compartments of the MCC. Both manual (inside and outside cab) and automatic system activation capability shall be provided. Appropriate portable fire extinguishers shall be provided inside the MCC cab.

F. Fail-safe braking systems operable from within the MCC and capable of braking both MCC and EIV during transport and holding on a 5% grade shall be provided.

G. Provisions shall be made for the MCC operators to communicate with the ETS-1 Control Point and E-MAD Master Control Room and to personnel outside the cab, when applicable.

H. Appropriate audible alarms shall be provided on the exterior of the MCC to warn of emergency conditions.

I. Backup traction and electrical power shall be provided for operation of the MCC/EIV.

J. Assurance that the integrity of structural load-bearing members of the EIV will be maintained during operational handling and transport of the engine shall be provided.

III. RADIATION SAFETY

A. RADIATION SAFETY SYSTEMS

1. Air Monitoring

a. Description

An air monitoring system (Tracerlab) for determining presence of airborne radioactivity is installed inside the MCC cab. This system consists of an unshielded, beta scintillation detector with alarm and

readout appurtenances, pump assembly, and air filter media. The system samples and monitors air inside the cab and records and displays the radioactivity in counts per minute.

The log ratemeter display has a range of 20 cpm to 200 K cpm with the alarm setting adjustable over this range. After 2 to 3 hours of operation, the rate of decay of the short half-life radon and thoron should equal the rate of deposition giving an equilibrium count rate reading of 100 to 1000 cpm on the ratemeter.

b. Discussion

It is not believed that there is adequate justification to support the need for a monitoring system as described in (a) above because:

(1) Present engine test plans require removal of a hot engine from the test stand approximately 24 hours after shutdown from the test run. It is not expected that significant amounts of airborne particulate radioactivity will exist in the vicinity of the test stand at this time. In addition, the heating, ventilation, and air conditioning system (HVAC), provided for the MCC cab, has capability for effectively removing particulates that may be present, (see IV. A. 1.) Gaseous activity will normally have completely dissipated in the vicinity of the test stand after the 24-hour period.

(2) In event an accidental criticality occurs during engine handling in which significant amounts of both gaseous and particulate airborne activity could be introduced into the MCC cab air intake, the operators can secure the HVAC system and immediately utilize the positive air breathing supplies. (A 3-hour air supply is available.) Indication of accidental criticality is provided by the Neutron Detection system with backup of the Gamma Detection System discussed in Parts III. A. 2. and 3. of this document.

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However, it is standard radiological safety practice, in such cases, to provide verification that personnel have not been exposed to significant amounts of airborne radioactivity. Thus, some means is necessary for verifying the MCC operators were not exposed to airborne radioactivity (both particulate and gaseous). This can be determined by utilizing the air sampling system and subsequently analyzing the filter paper media. This is the basis for the requirement for an air sampler established in Part II. A. 3. of this document and in Part 3.3.9.4 of the Reference (1) Equipment Specification. The installed system meets this safety requirement for air sampling within the MCC cab.

Since the as-built MCC is provided with an air monitoring system which includes detector and readout and alarm appurtenances, consideration should be given to the practicality of utilizing this system in its present state.

The presently-installed system includes a beta scintillation detector which is unshielded. Normally, two inches of lead are required around the detector to reduce the natural background sufficiently for accurate counting of the filter paper media. The gamma sensitivity of the detector is approximately 650 counts per minute in a 1 mr/hr environment, which is significantly higher than natural background. The background inside the cab from direct radiation (decay gamma) of the hot engine may be as high as 25 mrem/hr (see III. B.) This poses a problem in accurately counting radioactivity deposited on the filter media even if 2 inches of lead were installed around the detector. The problem is further increased because extensive modification would be required to shield the detector in its confined location.

Therefore, in view of the gamma sensitivity of this detector, the expected gamma background inside the cab, and the lack of shielding around the detector, it is concluded that the presently-installed system cannot be effectively used for air monitoring purposes. Air monitoring involves continuous operation of the scintillation detector unit, with readout, in combination with the air sampling portion.

c. Recommendations

(1) Utilize the air sampling portion of the system for collecting activity on the filter media for subsequent analysis.

(2) Filter paper discs of activated charcoal impregnated fiberglass are recommended as filter media to assure collection of particulate activity and gaseous activity such as I^{131} .

(3) Experimentally test the presently-installed beta scintillation detector to gamma environment conditions expected during normal operation as a check on the conclusion reached in the above discussion. This check could be accomplished during the Shielding Integrity Check (SIC) of the cab recommended in III. B.

2. Neutron Detection

a. Description

Two neutron detectors, with readout and alarm appurtenances, are provided. These detectors are polyethylene-moderated compensated ionization chambers. The readout and alarm appurtenances are installed in the MCC cab. The output from the detectors is fed to a log ratemeter in the cab which reads 1 to 100,000 counts per minute. Conversion from counts per minute is 2.5×10^2 n/cm²/sec/cpm.

These neutron detectors, which have not yet been installed, are shown on the Reference (15) drawing to be located on the EIV lateral-azimuth carriage which supports the engine.

b. Discussion

As noted in Part II. A. 2. of this document, the safety requirement for neutron monitoring involves capability for detecting accidental criticality during handling and transport of a hot or cold engine.

Title 10, Part 70, Paragraph 70.24 of the Code of Federal Regulations, specifies a requirement for criticality monitoring of areas where special nuclear materials are "handled, used, or stored" as follows:

"Maintain in each area in which special nuclear material subject to such license is handled, used, or stored, a monitoring system, including gamma or neutron-sensitive radiation devices, which will energize clearly audible alarm signals in the event a condition of accidental criticality occurs which generates radiation levels of 300 rem per hour one foot from the source of the condition. The monitoring device in the system shall have a preset alarm point of not less than 5 millirem per hour (in order to avoid false alarms) nor more than 20 millirem per hour. In no event may any such device be farther than 120 feet from special nuclear material being handled, used, or stored; lesser distances may be necessary to meet the requirements of this subsection on account of intervening shielding or other pertinent factors."

Although the requirements of 10 CFR 70 are neither directly applicable nor binding for MCC/EIV nuclear engine handling, they do represent basic guidelines which are the product of considerable experience in the field of reactor safety.

It is concluded that the monitoring system, as presently designed, meets the 10 CFR 70 requirement, and thus meets the basic requirement for an accidental criticality monitoring system as specified in Part II. A. 2. of this document.

A further point to consider, however, is that when these detectors are used in conjunction with handling a hot engine following shutdown from the test run, they will be subjected to an environment of photoneutrons, originating from the δ, n reaction in beryllium, and also to high level decay gamma radiation. The proposed location of these detectors is in close proximity to the engine. In view of this, and considering the magnitude of photoneutron and gamma backgrounds at this location approximately 24 hours after shutdown (References (13) and (17)), it appears some difficulty may be encountered in achieving proper compensation voltage to discriminate against gamma radiation and to correct for photoneutrons to assure effective criticality monitoring. Therefore, it may be necessary to relocate the detectors at a greater distance from the engine than presently proposed.

It is indicated in Reference (7) that an additional neutron monitor should be provided to obtain a two-out-of-three logic criticality monitoring system for MCC/EIV to negate extraneous alarms. Although this logic would assure fewer extraneous alarms than that occurring with two detectors, each of which could activate an alarm, it is not considered necessary to make the modification to provide this change in logic based on the following:

(1) In event of alarm of either or both of the neutron detectors of the present system, the gamma monitoring systems (with alarms), discussed in III. A. 3. of this document, can be utilized for verifying an accidental criticality condition.

(2) Extraneous alarms are more tolerable for monitoring of the nuclear engine during handling with the MCC/EIV than in most other cases involving reactor assemblies. Immediate evacuation of personnel from the affected area, in most cases involving accidental criticality, is normally required following the alarm. It is vital, in these cases, to minimize extraneous alarms and assure that a passive attitude of personnel does not develop and result in excessive personnel exposure. However, for the MCC/EIV case, personnel in the vicinity of the reactor will normally be limited to the 2 MCC operators who are located in the heavily-shielded cab. In event of alarm, the operators should normally remain in the shielded cab and initiate action to determine the validity of the alarm. Passive attitude becomes less significant in this case because it does not jeopardize the safety of personnel.

c. Recommendations

(1) Utilize the neutron monitoring system as currently designed. (See IV. F. 3. for recommended change in audible alarm connected with this system.)

(2) Compile experimental data on shutdown photoneutrons and decay gamma radiation from NRX testing (approximately 24 hours after shutdown). Subject the two available neutron detectors to gamma and neutron sources to determine specific detector sensitivities and compensation voltages required. Utilize this information to determine the most optimum location for installation of the detectors to assure effective criticality monitoring.

3. Gamma Detection

a. Description

The gamma detection system consists of two (2) ionization chamber detectors with readout and alarm appurtenances. One detector unit is mounted on the outside of the cab at the left rear location; the other unit being located under the MCC control panel inside the cab. Readout and alarm appurtenances for both units are located inside the cab.

The detector unit inside the cab has a range from 0.1 mr/hr to 10,000 mr/hr. The unit outside the cab has a range of 1 to 1 M (10^6) counts per minute with a conversion factor of 0.1 R/hr per count per minute (100 mr/hr to 100,000 R/hr).

b. Discussion

The presently-installed gamma detection system fulfills the safety requirement of Part II. A. 1. of this document with the exception that it will not indicate the maximum gamma intensity to which the cab exterior is subjected during hot engine handling. The detector outside the cab, being mounted at the rear location, will be shielded from direct radiation from the engine; therefore it will not indicate the highest intensity. This detector must be mounted at the front of the cab to completely fulfill the safety requirements.

The basis for the safety requirement for a front-mounted unit is supported by the following factors:

(1) It is standard radiological safety practice to monitor the highest intensity on entry to a radiation environment. With the detector mounted on the front of the MCC, the detector reading would be

utilized to establish the approximate gamma intensity of the hot engine. The MCC operators can relay this information to personnel at E-MAD and ETS-1 facilities who, in turn, can utilize this information for establishing specific personnel and operational control requirements during removal and transport of the engine.

(2) The MCC operators would be aware of the highest level they would be subjected to in the unlikely event it were necessary to evacuate from the cab. It may not, in all cases, be advisable for the operators to utilize an evacuation route directly behind the shielded cab.

(3) A front-mounted detector is more effective as backup and/or verification for the neutron detection system in detecting accidental criticality because it is not shielded by the heavy cab walls.

(4) In event the MCC is needed for entry to high radiation areas other than the test stand, a front-mounted detector can be utilized to ascertain the highest gamma field intensity during entry.

(5) A front-mounted unit is subjected to less scattering than a rear unit. A rear-mounted detector will be strongly affected by scattering surfaces to the rear of the cab. Thus, appreciable changes in radiation readings can be indicated with no change in source level.

c. Recommendations

(1) Relocate the ionization chamber from the rear of the MCC cab to the front.

(2) Replace the meter readout of this same ionization chamber with a unit that reads directly in R/hr so that a conversion from counts per minute by the operators is not required.

B. SHIELDING

1. Description

The MCC cab is constructed as follows:

Front Wall - 285 lb/ft³ ferro-phosphorous concrete 26" thick plus 6" masonite.

Side Walls- - 285 lb/ft³ ferro-phosphorous concrete 10" thick plus 6" masonite.

Roof & Rear Wall - 285 lb/ft³ ferro-phosphorous concrete 10" thick plus 6" masonite.

Floor - Lead blocks, 3" thick over 9" of masonite.

Front Window - 6 high-density lead glass slabs with alternate slabs of plexiglas set into metal framework with combined thickness of 33.5".

Rear Window - 3 high-density lead glass slabs with alternate slabs of plexiglas set into metal framework with combined thickness of 16".

All joints are caulked with high-density lead putty to eliminate radiation streaming.

2. Discussion

The safety requirement of Part II. C. of this document indicates that cab shielding shall be provided to reduce the radiation intensity inside to approximately 25 mrem/hr during hot engine handling and transport. Based on the current plans for testing at ETS-1 and assuming a conservative period of 8 hours handling time per engine test, radiation exposure of the cab operators shall be well within AEC exposure limits and even less than the administrative limits imposed at NRDS if a dose rate of 25 mrem/hr is used.

Shielding calculations with associated engine operating data are presented in Reference (17) as follows:

Time after shutdown	24 hours
Length of test run	1200 seconds
Power	1120 mw
Radiation intensity at 60 ft	250 R/hr gamma, 0.2 rem/hr neutron
Calculated dose rate inside cab	Approximately 26 mrem/hr (total gamma plus neutron)

Based on the above data, it is concluded that the cab shielding design adequately fulfills the above safety requirement. It is understood that a shield integrity check was performed on the cab following construction. However, a significant amount of effort remains regarding assembly and analysis of data.

3. Recommendations

In event the Shielding Integrity Check (SIC) data mentioned above is not conclusive, a further test should be performed on the MCC cab as early as possible to verify integrity and assure all voids are corrected prior to operational use.

IV. MCC GENERAL SAFETY

A. HEATING, VENTILATING, AND AIR CONDITIONING SYSTEM

1. Description

The HVAC System supplies 72-85° air to the MCC cab with a maximum humidity of 50%. The make-up air is passed through a high efficiency filter capable of removing 99.97% of all particles 0.3 micron size or greater. The intake opening to the system is located at the side of the engine com-

partment midway between the trucks approximately five feet off the ground. This system circulates 300 cubic feet per minute of air with 60 cubic feet per minute of make-up air. Sixty cubic feet per minute of air is exhausted through electronic cabinets for equipment cooling purposes.

In addition to manual controls, the HVAC System is provided with a shutdown switch that will be automatically activated when the CO₂ fire extinguishing system is in operation. (See Part IV. B.) A light is provided in the cab to indicate excessive loading of the HVAC filter.

2. Discussion

The high efficiency filter of the cab HVAC System has the capability for removing 99.97% of all particles 0.3 micron size or greater. Experience from past NRX testing has shown that fallout has been composed of fragmented beads between 1 and 100 microns in size and fission products (from erosion) of 1 to 5 microns. Based on these data, the MCC cab HVAC system should be capable of effectively removing particulates that may be encountered.

The HVAC System does not have the capability for removing fission product gases. However, as noted in Part III. A. 1., it is expected that these gases will have completely dissipated by the time the MCC enters the test stand area. Also, the system has no capability for removing gases such as CO₂ from the fire suppression system or diesel exhaust. However, the activation of the CO₂ system causes automatic shutdown of the ventilation system. Positive air breathing supplies are available for the operators in event of shutdown of the ventilation system. Since the diesel exhaust stacks

are located on the opposite/side of the MCC from the cab air intake and elevated, it is highly unlikely that significant amounts of this exhaust will be introduced into the air intake. Therefore, the HVAC system satisfies the requirement for providing a suitable breathing environment for the operators.

3. Recommendations

a. Perform DOP tests on the filtering system, prior to operations, to verify integrity.

b. Check the cab atmosphere with the MCC diesel engines in operation under varied weather conditions to verify exhaust pickup is not a problem. Appropriate modification, if necessary, can be made at that time.

B. FIRE PROTECTION SYSTEM

1. Engine Compartment

a. Description

A CO₂ fire extinguishing system, consisting of an automatic (main) and manual (reserve) control subsystem is provided. Thermostats rated at 225°F provide automatic activation of the main subsystem. Three manual pull-switches, two of which are located at each end of the engine compartments and one inside the cab, provide controls to the reserve subsystem.

The 32 VDC battery system is the electrical power source for the entire fire protection system. Activation of either subsystem will cause automatic shutdown of the MCC cab ventilation system and the traction and power diesels.

The main and reserve CO₂ subsystems are each supplied with two 50-lb CO₂ bottles connected in pairs to a manifold. The pairs are isolated from each other by check valves in the manifold.

b. Discussion

Since activation of both main and reserve CO₂ subsystems is dependent on the 32 VDC electrical system, there will be no means for activating (from the cab or outside of the MCC) the reserve CO₂ subsystem if a malfunction or failure of this electrical system should occur.

c. Recommendations

Each electrical control head used for the main and reserve CO₂ subsystem has a local manual control lever that overrides the electric control mechanism. It is recommended that the cab be provided with a connecting wire rope to the CO₂ control head manual levers. Thus, this actuator system will provide positive manual means for activating the CO₂ systems in the event of any malfunction or failure of the automatic sensing subsystem or the battery power subsystem. Also, by utilizing a two-position actuator system, capability can be provided for manual activation of both main and reserve CO₂ subsystem, i.e., 100% usage of the available 200 lb of CO₂.

2. MCC Cab

a. Description

Two portable fire extinguishers, 5-lb CO₂ are provided.

b. Recommendations

CO₂ extinguishers should be replaced with dry chemical type to eliminate the potential for an oxygen deficient atmosphere if these extinguishers are used for fire suppression or otherwise discharged in the cab.

C. CAB DOOR AND ESCAPE HATCH

1. Description

The door, used for normal entrance of personnel and equipment, is at the rear of the cab and is 16 inches thick (10 inches concrete; 6 inches masonite) and weighs 6500 lb. It is electric motor-driven from battery power, controlled by a "dead man" switch both inside and outside the cab and capable of operation against a 5 per cent grade. A manual override, operable from inside and outside the cab, is also provided.

The emergency escape hatch (same thickness and construction as the door) weighs 600 lb, is 28-3/8 inches in diameter, and is used only in the event that the door drive assembly fails to open the MCC door. The hatch can be removed from inside or outside the cab by operating a release jack mechanism. The hatch is conical shaped tapering toward the cab interior to allow it to slide from its normal position once it has been dislodged.

Latches for locking the MCC door are provided both inside and outside the cab.

2. Discussion

Emphasis is placed here on the safety aspects of normal and emergency entrance into and exit from the cab.

With exception of the inside and outside cab door latches, there appears to be no pertinent safety problems regarding the cab door and escape hatch. The need for these door latches is not clear. Further, it is apparent that these latches can pose a safety problem in that inadvertent locking of the door from the inside could create an operator recovery problem if both operators are disabled; or inadvertent locking of the outside would significantly delay evacuation of operators from the cab in an emergency, if required, especially during transport of a hot engine.

3. Recommendations

a. The cab door latches should be removed (both inside and outside).

b. Removal of the escape hatch should be included in pre-operational checks to assure it can be easily removed by one person. A safe method for re-installing the hatch should be established. Use of a handling fixture usable on the MCC is suggested.

D. LIGHTING

1. Description

Quartz-iodine vapor headlights (24 units, each 500 w) and standard fluorescent lights inside the cab, mechanical equipment compartments, and undercarriage sides are provided. There is one 32 v emergency light in the cab interior and a single quartz-iodine vapor light at the rear of the MCC near the coupler. Electrical power for illumination is described in Section IV. H.

2. Discussion

Lighting provided for the MCC appears to be adequate for illumination of vital components during night operations.

3. Recommendations

No specific recommendations for modifications to present provisions for lighting are considered necessary.

E. COUPLER AND UMBILICAL

1. Description

AAR Type H, tight block couplers are used at both ends of the MCC. Remote uncoupling by electro-pneumatic-mechanical means is provided from within the cab. Side-operated uncoupling rigging is used for manual operation.

The umbilical boom assembly provides support for the electrical and pneumatic cables which supply power to the EIV. This assembly permits these cables to continue to supply power when the MCC is decoupled from the EIV and the EIV is being inched into the test stand. The boom permits a maximum separation of 15 feet between MCC and EIV. An override cable, connected between the boom support base and the umbilical connector limits the amount of overtravel in event the EIV inching drive fails to cut off. Too much overtravel would result in the boom being fully extended and possible disengagement and/or damage to the service lines.

2. Discussion

Although a specific safety requirement has not been established in this document relative to the coupler and umbilical components, it was deemed desirable to review the design of these assemblies for possible safety implications.

Based on available reference literature, discussions with cognizant engineers and personal observation, it appears that there does not exist any serious safety deficiencies relative to these components. Specific attention has been given to the adequacy of the override, or safety cable which limits the amount of overtravel in event the EIV inching drive fails to cut off. This cable is considered acceptable for the purpose intended.

It is considered, however, that it would be desirable to provide the MCC operators with a means for observing the coupler between the MCC and EIV to assure ease of coupling and decoupling.

3. Recommendations

It is recommended that a mirror be installed near the coupler between the MCC and EIV such that the operator can easily observe coupling and decoupling operations.

F. COMMUNICATIONS AND WARNING SYSTEMS

1. Description

Two portable radiophones (one-channel transmitter-receiver units) are provided. An existing NRDS radio network will be used for communications between the MCC and NRDS facilities (E-MAD and ETS-1). A sound-powered phone handset is used for communication between MCC operators and personnel outside the cab (one handset inside cab; two outside).

A one-way PA system and alarm amplifier serves as a dual purpose system with built-in internal electronic siren as well as conventional speech amplifier. A weatherproof speaker is mounted on top of the shielded cab assembly. The front panel has controls for mode selection, gain and siren. The siren is manually controlled, the selector switch having "steady siren", "yelp" and "wail" audibles. An aircraft type flashing red warning light is provided on the top of the cab.

2. Discussion

No modifications and/or additions to the communications systems are considered necessary.

Regarding the warning systems, it is felt that the only need for an audible alarm on the exterior of the MCC is for accidental criticality. In accordance with Reference (6), Klaxons are to be exclusively utilized at NRDS for accidental criticality. Therefore, in order to maintain consistency with this NRDS standard, a Klaxon providing a sound similar to others used at NRDS must be provided. The speaker presently mounted on the cab may suffice.

3. Recommendations

a. Since the presently mounted horn unit on top of the cab has several audible mode selections as described above, it is recommended that the unit be tested in the various modes to determine similarity to the klaxon sound used at NRDS. If similarity does not exist, the unit should be replaced with another unit to provide the appropriate alarm sound.

b. The circuitry to the audible alarm on top of the cab should be modified so that the alarm is automatically activated when the Neutron Detection System (Part III. A. 2.) detects an accidental criticality condition.

G. BRAKING SYSTEMS

1. Description

Normal braking power is provided by air brakes with control in the MCC cab. Two controls are provided; one for the MCC, EIV, and Prime Mover for simultaneous operation and a separate control for only the MCC. The brakes are disc type in which pads are held away from the disc by air pressure. This system is supplied normally by the two (2) air compressor systems of the Prime Mover with backup by auxiliary air compressor in the MCC. Transfer of primary air to auxiliary is automatic in event of failure of the primary. These brakes are designed to stop and hold the MCC on a 5% down-grade from an initial velocity of 6 mph within a distance of 250 feet. The brakes automatically lock in event of loss of air pressure in the brake systems. An additional control, a standard wheel type hand brake, located on the MCC platform, applies the wheel disc brakes through chains and mechanical linkage.

A parking brake system, controlled from the cab and functioning on the drive shaft, is also provided. This system is independent of the air brake system.

(The EIV has a similar air braking system, operated from the MCC, along with a holding brake capable of being applied either manually or remotely from the MCC.)

2. Discussion

Design of the braking system fulfills the safety requirement for fail-safe operation. It is highly improbable that the two air compressor systems of the prime mover and the auxiliary compressor system of the MCC would simultaneously fail resulting in automatic locking of the brakes. However, in the unlikely event all compressor air systems fail, it is understood that the brakes cannot be unlocked. Therefore, it appears that serious difficulty would be encountered in moving or uncoupling the transport vehicles. If a hot engine is being transported, it may be advisable for the MCC operators to evacuate the MCC cab until some means is provided to release the brakes or other corrective action is taken. Based on the engine radiation intensity data of Part III. B., it is concluded that the operators could leave the cab and evacuate the area by a route away from the EIV without receiving an over-exposure.

3. Recommendations

Prior to transport of the nuclear engine, it is recommended that the braking systems for both MCC and EIV be fully checked out on the steepest grade between E-MAD and ETS-1 at a velocity of 6 mph. The checkout should also include testing the parking brakes to assure they hold on this steepest grade. Further, an investigation should be conducted relative to a means for unlocking the brakes in lieu of the problem posed in the above discussion.

H. POWER PLANTS

1. Description

Traction Power - The tractive power system for the MCC consists of a diesel engine and hydraulic torque converter and serves as the backup power to that of the Prime Mover. The EIV is transported by this traction power.

Electrical Power - This power is supplied by an A-C generator driven by diesel engine on the MCC. (Auxiliary power is provided by a similar diesel generator set on Prime Mover with automatic engine start upon loss of MCC power.) The MCC furnishes the primary source of electrical power for operation of the EIV. The A-C generator is 440 V-75 KVA. Batteries (32 VDC) provide a power source for diesel startup (both power and traction), cab door operation, fire control system, and PA amplifier operation. The battery compartments (2) are provided with slits in the compartment door for venting hydrogen gas. Two battery charging receptacles are mounted near the battery compartment below the side sills with one receptacle on each side of the MCC and directly connected to the engine circuit for charging and/or starting engine from outside electrical circuits.

2. Discussion

The power plants, as described above, afford adequate tractive and electrical power from a safety standpoint and fulfill the safety requirement for backup power both for traction and electrical power supply.

It appears, however, that a more positive exhaust of hydrogen gas from the battery compartments may be necessary since this gas could rise to the top of the compartment and create an explosive hazard.

It is recognized that the electrical circuits of the MCC do not meet the National Electrical Code (NEC) requirements for hazardous environments resulting from hydrogen and propane systems such as exist at ETS-1. However, since this vehicle enters the test stand area only on an infrequent basis, it appears that specific action can be taken to eliminate combustible gas hazards prior to entry. This action may include protective measures such as double blocking and bleeding of systems and checking for and correcting system leaks. (The foregoing also applies to electrical circuits of the EIV).

The diesel exhaust stacks are too short. Exhaust from these stacks, which are located fore and aft of the shielded cab at an elevation approximately the same as the shielded window, may impair the operator's vision through the shielded window.

3. Recommendations

- a. Pre-operational checks should include sampling of gases in the battery compartments to determine if an explosive hazard exists. If there is positive indication of a hazard, modifications should be made to provide adequate ventilation of gases.
- b. The diesel exhaust stacks should be extended at least two (2) feet.

I. NITROGEN PURGE SYSTEM

1. Description

The shielding windows in the front and rear walls of the MCC cab are comprised of layers of lead glass. Inerting of the spaces between these layers with pressurized nitrogen is required to prevent fogging. Nitrogen is supplied by a standard 400 cubic foot compressed gas cylinder through tubing to the window assemblies at a pressure of 2 oz/in² and vents to the atmosphere outside the cab.

Two pressure regulators are located near the compressed gas cylinder (in the engine compartment) for controlling system pressure. A pressure gauge is mounted inside the cab on the door.

2. Discussion

A plastic helical coil tube inside the cab for supplying nitrogen to the rear shielding window was originally utilized to allow opening and closing of the shielded door. This flexible plastic tubing subsequently split and has been replaced by a flexible metal hose. All tubing within the cab is now metal tubing connected with standard fittings. Leak checks, to date, have indicated negative results.

Since the system is equipped with two pressure regulators for controlling system pressure to 2 oz/in.², and in view of the tubing modification mentioned above, it appears there is little potential for leakage of nitrogen into the cab. Further, in the unlikely event leakage into the cab were to occur, it has been calculated that the oxygen concentration would not be reduced significantly during the course of operations based on this low nitrogen flow and cab ventilation rates presented in Part IV. A.

It is highly improbable both pressure regulators would fail and subject the system tubing to high pressure. However, in the unlikely event this should occur and cause high nitrogen leakage into the cab, the operators could utilize the positive air supplies within the cab. The pressure gauge on the cab door can be utilized by the operators to determine system flow irregularities.

Therefore, it is concluded that no modifications to the presently-installed system are necessary.

J. CONTROLS AND INSTRUMENTATION

1. Description

The shielded cab contains the controls and instrumentation for remotely operating and controlling all functions of the EIV and Prime Mover. The control responsibility for the operation of the MCC is divided between the two operators. The controls for the Prime Mover, MCC, are located at the left side of the cab and the control panel for operating the EIV is located on the right side.

The principal control panels and instrumentation are the MCC engine transmission panel, generator control and locomotive, instrument panel, umbilical and uncoupler panel, prime mover control panel, MCC control valve, independent air brake, automatic air brake, air conditioning, fire control and door panel, EIV control panel, TV monitor and TV control panel, radiation monitoring and recording system, PA and alarm amplifiers, a phone handset, and portable radiophones.

Safety features incorporated in operation of the control switches include a key lock which disables the entire EIV control panel during engine transport and a dead man switch for controlling traction power to the Prime Mover. Interlocks also exist for certain control systems.

2. Discussion

In view of the safety features incorporated in the control systems as discussed above and in other sections of this report, there appear to be no pertinent safety problems.

However, the operation of all control systems has neither been observed nor reviewed in detail, particularly from a human error standpoint. Therefore, some deficiencies may exist relative to system lockouts or interlocks in the as-built control systems. It is of primary concern, from a safety standpoint, that critical controls are not inadvertently activated during operation, resulting in an emergency condition.

3. Recommendations

It is recommended that, during checkout of all control systems, specific attention be given to locking and interlocking features. Modifications, as appropriate, should be made to minimize the possibility of inadvertent activation of any switch or control that could cause an emergency condition.

V. EIV GENERAL SAFETY

A. CARRIAGES

1. Description

Vertical Carriage - The vertical carriage is actuated by a pair of drive screws driven by a two-speed, 5:2-1/2 hp electric motor and mounted on a pair of ball-bearing drive screws which are suspended from the tower. The drive system is provided with limit switches and mechanical ball screw stops adjustable to the desired range of upward and downward travel. The drive screw system is capable of holding the carriage in a fixed position in the event of a drive motor failure.

Longitudinal Carriage - This carriage affords fore and aft movement to the carriage system and is driven by a 1/2 hp electric motor. Limit switches and physical stops control extreme movement. The longitudinal

carriage supports the lateral carriage on four trunnion blocks which are mounted on the forward face of the carriage. The longitudinal carriage rests on the vertical carriage and moves fore and aft on rollers which contact hardened steel wear plates.

Lateral Azimuth Carriage - This carriage attaches to the longitudinal and vertical carriage and supports the engine at the external shield by four support blocks. The design of the support block is such that the engine will not drop or topple off the EIV even if two non-adjacent support blocks should fail. A factor of safety of 3 based on yield strength (approximately 5 for ultimate strength) has been established for this carriage.

2. Discussion

It is essential that the carriages, described above, have adequate factors of safety for supporting the engine assembly. Failure of critical structural members could result in a serious emergency.

As noted above, a factor of safety of 5 (ultimate strength), which is considered adequate, has been established for the lateral azimuth carriage. Based on discussions with REON design engineers, it is indicated that analyses are in progress regarding factors of safety associated with the vertical and longitudinal carriages. It appears that structural members of these carriages have factors of safety which may be marginal as to adequacy. For example, Table 1 of Reference (18) lists a number of structural members with factors of safety of 2 or less based on yield strength. Estimations of these factors of safety, based on ultimate strength, indicates values of 2 to 3 for these structural members.

3. Recommendations

The analyses, referred to above, should be continued to determine the adequacy of the structural integrity of the longitudinal and vertical carriage structures. These analyses should provide the basis by which, if necessary, structural modification and/or operational limitations may be developed to assure safety of operations. Proof testing should be performed at 125% of the maximum working load. Great care should be exercised to assure no overloading occurs during proof tests.

B. TOWER ASSEMBLY

1. Description

The tower, which supports the carriages, is approximately 20 feet high, 10 feet wide and 4-1/4 feet deep. The four tower columns are fabricated of 4-1/4 x 6-1/4 steel bars having bases fabricated of 10 x 10 x 1 inch steel plates. With the exception of the top rearmost horizontal members, all horizontal members are composed of 6 x 1/4 inch rectangular tubing.

2. Discussion

Discussion above, relative to carriages, applies to the tower assembly also.

3. Recommendations

Same as above for carriage structures.

C. TV/MANIPULATOR BOOM SYSTEM

1. Description

Two TV cameras are to be mounted on the forearm of the TV/ Manipulator boom assembly on each side of the vertical carriage with capability for viewing the complete engine envelope. (TV monitors are located in the MCC cab.) Manipulators are provided at the end of each boom assembly for making remote adjustments, connections, etc.

2. Discussion

There appears to be no unique safety problems regarding this system.

In Section 9 of Reference (13), it was noted that remote maintenance capability, such as could be obtained with a manipulator attached to the MCC/EIV, should be provided for performing on-stand emergency maintenance functions which may be required in the presence of a "hot" engine. Pulling apart of frozen side shields was cited as an example of emergency maintenance.

In view of the complexity of presently-incorporated handling structures at the front of the EIV, it does not appear feasible to add further attachments. Therefore, the manipulators of the TV/Boom system should be considered for emergency maintenance usage even if minor modifications are required. Based on present design, it appears that these manipulators can be utilized for recovery from emergency conditions such as a dropped or toppled engine or frozen side shields. In these emergency cases, it is believed the manipulators can be used to attach cables to either the engine or side shield and structural members of the EIV. Pulling force can then be applied by the MCC/EIV.

3. Recommendations

None

D. LEVELING JACKS

1. Description

Eight leveling jacks (four outboard, four inboard) are provided to permit leveling or aligning of the engine with the respective interfaces at the test stand or receiving stand. The jacks are equipped with limit switches to prevent overtravel. The drive mechanisms are provided with interlocks to render the jacks inoperable whenever the EIV is inching. Each forward outboard jack has a 50-ton capacity and each aft outboard and all inboard jacks a 20-ton capacity. Indicating lights to show jack extended and in retracted positions are provided in the MCC cab.

2. Discussion

There appear to be no unique safety problems associated with design or operation of the leveling jacks.

3. Recommendations

Pre-operational checks should be specifically performed to verify that the jacks are inoperable during inching operation of the EIV.

E. INCHING MECHANISM

1. Description

Inching capability for moving the EIV into position for connecting or disconnecting the engine is provided by a 1/2 hp electric motor. Travel speed is 12 inches per minute. A limit switch de-energizes the drive motor when the EIV reaches the pre-designated position at the test stand.

2. Discussion

No unique safety problems are apparent.

3. Recommendations

Pre-operational checks should include testing of the limit switch to assure that the drive motor de-energizes.

F. LIGHTING

1. Description

The EIV is equipped with non-browning quartz-iodine vapor floodlights located such that they illuminate the following areas:

- a. Upper engine interface.
- b. Upper engine carriage gripper.
- c. Lower engine carriage gripper.
- d. Carriage movement mechanisms.

2. Discussion

The floodlights appear to be adequate for illumination of carriage structures.

3. Recommendations

None

VI. SUMMARY

Design of the as-built Manned Control Car (MCC) and Engine Installation Vehicle (EIV) has been evaluated from a safety standpoint.

Of primary concern is the structural integrity of the vertical and longitudinal carriages and tower assembly of the EIV discussed in Parts V.A. and B. of this document. Analyses of the structural integrity of these components are in progress. Based on information obtained to date, it appears that these components have factors of safety which may be marginal as to adequacy. Further

evaluation based on these analyses with due consideration to operational modes and other possible mitigating factors is necessary for assurance of safety of operations.

There are a few recommended minor design modifications requiring nominal effort and expense. These recommendations are discussed in Parts III. through V. of this document, and are summarized as follows:

1. Relocate the gamma detector from the rear of the MCC cab to a location at the front of the cab. Replace the meter readout unit for this detector with a unit that reads directly in R/hr instead of CPM (counts per minute).

2. Install a connecting wire rope from the cab of the MCC to the CO₂ control head manual levers to provide a positive manual means for activating the CO₂ fire protection systems. Also, replace the CO₂ extinguishers in the MCC cab with dry chemical type.

3. Remove the MCC cab door latches (both inside and outside).

4. Install a mirror near the coupler between the MCC and EIV such that the MCC operators can observe coupling and decoupling operations.

5. Modify the MCC audible alarm system such that the alarm unit on top of the MCC cab automatically sounds in event of activation of the Neutron Detection System.

6. The diesel exhaust stacks on the MCC should be extended a minimum of two (2) feet.

Other recommendations, discussed in this document, involve operational checkouts or testing to verify integrity of installed systems or to obtain experimental data to ascertain whether further modifications or changes are necessary.

VII. MCC/EIV DRAWINGS

1. MCC Engine Compartment
2. Cable Junction Bracket
3. Bumper Stop
4. Wire Rope
5. Umbilical Drum
6. Strain Cable
7. Negator Harness Cable
8. Electrical Cables
9. Pneumatic Cable
10. Umbilical Connector Assembly
11. Guide
12. Override Cables
13. Boom Support Base
14. Boom Stabilizer Cable

Umbilical Boom Assembly

1. Umbilical Connector Assembly
2. Counterweight Mechanism Assembly
3. Umbilical Boom Assembly
4. Cab Support Grillage
5. Front Window Assembly
6. Shielded Cab Assembly
7. Control Cab Arrangement
8. Cab Door and Drive Assembly
9. Engine Compartment

Manned Control Car (HCC)

1. Rear Window Assembly
2. Pressure Relief Valve
3. 0-30 psi Gauge
4. 0-3000 psi Gauge
5. Nitrogen Purge System
6. Nitrogen Cylinder
7. Pressure Regulator
8. Needle Valve
9. Purge Valve
10. Front Window Assembly
11. Shielded Cab Assembly
12. Pressure Regulator

Nitrogen System

1. Lighting Panel
2. Radiation Monitoring Panel
3. Battery Chargers
4. Emergency Light
5. Shock Monitor Recorder
6. Drinking Water Jug
7. Fire Extinguishers
8. Sun Mask
9. Relief Bottle
10. Sun Cylinders
11. Emergency Escape Hatch Release Levers
12. High Pressure Hose
13. Convenience Outlet Panel
14. Binocular Mounting
15. MCC Engine Transmission Panel
16. Air Gauges
17. Brake Valve
18. Gamma Detector
19. PA and Alarm Amplifier
20. Emergency Brake Valve
21. Phone Handset
22. Nitrogen Purge System Pressure Regulator
23. Portable Radiophone
24. Radiation Monitor Recorders
25. Storage Cabinet
26. Air Conditioning, Fire Control and Door Panel
27. Umbilical and Uncoupler Panel
28. Prime Mover Control Panel
29. MCC Control Valve
30. TV Monitor and TV Control Panel
31. EIV Control Panel
32. Generator Control and Locomotive Instrument Panel
33. Handbrake
34. Fuel Cutoff Grip Rings
35. Emergency Air Valve

Control Cab Arrangement

1. Compressed Air Bottle	19. Air Conditioner
2. Exhaust Muffler	20. Junction Box (JBI)
3. Circuit Breaker Cabinets	21. Traction Diesel Starter Battery Enclosure
4. Transformer Cabinet	22. Electrical Cabinet
5. TV and Shock Amplifier Cabinet	23. Junction Box for Prime Mover Controls
6. Fuel Fill Line	24. Traction Diesel
7. Air Brake Reservoir	25. Handbrake
8. Air Intake Shutter	26. Evaporator (Air Conditioner)
9. Air Compressor	27. Compressor (Air Conditioner)
10. Nitrogen Bottle	28. Filter (Air Conditioner)
11. CO ₂ Fire Control Switch	29. Transmission
12. CO ₂ System Alarm Bell	30. Air Intake Shutter
13. Umbilical Connector	31. Nitrogen Bottle
14. Umbilical Boom Counterweight	32. Umbilical Boom
15. Power Diesel	33. Fuel Tank
16. CO ₂ Bottles	34. Coupling
17. Power Diesel Starter Battery Enclosure	35. Hinged Panels
18. Radiation Air Sampler Electrical Cabinet	36. Access Doors

Engine Compartment

38A

1. Handbrake Linkage Attachment
2. Fuel Tank
3. Axle Torque Arm
4. Truck Assembly
5. Underframe Structure
6. Disc Brake Assembly
7. Parking Brake Drum
8. Transmission
9. Torque Converter

MCC Transmission System Assembly

EIV/MCC INTERFACE

EIV PORTABLE CONTROL CONSOLE

EIV OUTBOARD JACK

EIV CARRIAGE

EIV - RIGHT SIDE

EIV AND MCC

REFERENCES

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2. Equipment Specification - AGC 10125D, Engine Installation Vehicle.
3. MCC Design Characteristics, dated 10 November 1965.
4. EIV Design Characteristics, dated 10 November 1965.
5. Memo, L. A. Welge to M. Neder, L. White; Recommendations Regarding the Prime Mover, dated 10 February 1965.
6. Memo, B. P. Helgeson to All NRDS Personnel; Subject: JW1:117, NRDS Emergency Alarm Criteria, dated 19 March 1965.
7. Memo, NTO-M-5645, N. E. Erickson to W. D. Stinnett, dated 27 December 1965; Subject: Operational Requirements on EIV/MCC.
8. Tracerlab Operating and Maintenance Instruction Manual for Radiation Monitoring System AMF P.O. A10794.
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10. Equipment Specification - AGC-10125C, Vehicle, Installation, Engine, Nuclear, dated 17 July 1963.
11. Preliminary Operation and Maintenance Instructions, OMI-ES-1526, Manned Control Car, Part Number 89-73-1000.
12. Functional/Acceptance Test Procedure for Manned Control Car, FTP-ES-1514, dated 6 September 1964.
13. Report No. RN-TM-0237, dated September 1965; Subject: Preliminary ETS-1 Design Safety Evaluation.

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15. AGC Drawing 1115110.
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17. Memo, E. A. Warman to L. E. White, dated 22 August 1963; Subject: Evaluation of Manned Control Car Shield Design.
18. Memo, F. P. Blissmer to R. J. Beck, 7421:0340M, EIV Structural Analysis, dated 14 February 1966.