CRWMS/M&O

Design Analysis Cover Sheet

Complete only applicable items.

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 QA: ^L~~X~~ NR 9/17/98
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2. DESIGN ANALYSIS TITLE Emplacement Drift Isolation Door Control System			
3. DOCUMENT IDENTIFIER (Including Rev. No.) BCAD00000-01717-0200-00006 Rev 00			4. TOTAL PAGES 26
5. TOTAL ATTACHMENTS 0		6. ATTACHMENT NUMBERS - NO. OF PAGES IN EACH N/A	
	Printed Name	Signature	Date
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11. REMARKS			

Design Analysis Revision Record*Complete only applicable items.*

①.

Page: 2

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2. DESIGN ANALYSIS TITLE**Emplacement Drift Isolation Door Control System****3. DOCUMENT IDENTIFIER (Including Rev. No.)****BCAD00000-01717-0200-00006 Rev 00****4. Revision No.****5. Description of Revision****00****Initial Issue**

1. PURPOSE

The purpose of this analysis is to review and refine key design concepts related to the control system presently under consideration for remotely operating the emplacement drift isolation doors at the potential subsurface nuclear waste repository at Yucca Mountain. This analysis will discuss the key design concepts of the control system that may be utilized for remotely monitoring, opening, and closing the emplacement drift isolation doors.

The scope and primary objectives of this analysis are to:

- ◆ Discuss the purpose and function of the isolation doors (Presented in Section 7.1).
- ◆ Review the construction of the isolation door and other physical characteristics of the doors that the control system will interface with (Presented in Section 7.2).
- ◆ Discuss monitoring and controlling the operation of the isolation doors with a digital control system (either a Programmable Logic Controller (PLC) system or a Distributed Control System (DCS)) (Presented in Section 7.3).
- ◆ Discuss how all isolation doors can be monitored and controlled from a subsurface central control center (Presented in Section 7.4).

This analysis will focus on the development of input/output (I/O) counts including the types of I/O, redundancy and fault tolerance considerations, and processor requirements for the isolation door control system. Attention will be placed on operability, maintainability, and reliability issues for the system operating in the subsurface environment with exposure to high temperatures and radiation.

2. QUALITY ASSURANCE

A quality assurance Classification of the Preliminary MGDS Repository Design (B00000000-01717-0200-00134 Rev 00, TBV-228) (Reference 5.1) has been performed in accordance with QAP-2-3, *Classification of Permanent Items*. The emplacement drift isolation doors are part of the subsurface ventilation system (SS05). The isolation door control system falls under the subsurface ventilation system; operations ventilation system; ventilation commodities; then control devices as presented in the *Q-List* (Reference 5.2). The QA designation for this category is QA-1.

This design analysis activity has been evaluated in accordance with QAP-2-0, *Conduct of Activities*, (Reference 5.3) and has been determined to be quality affecting and subject to the requirements of the *Quality Assurance Requirements and Description* (QARD)(Reference 5.4). This design analysis is subject to quality assurance controls in accordance with NLP-3-18, *Documentation of QA Controls on Drawings, Specifications, Design Analyses, and Technical Documents*.

Although some of the input documents used in the preparation of this analysis contain TBVs, the inputs do not require confirmation because the TBVs do not impact the conclusions of this analysis.

3. METHOD

The method used in the preparation of this design analysis consisted of reviewing previously approved design analyses to obtain operation and materials of construction data regarding the emplacement drift isolation doors. Vendor documentation for systems applicable to the subject matter were then reviewed for applicability in controlling the doors.

4. DESIGN INPUTS

4.1 Design Parameters

Not used

4.2 Criteria

- 4.2.1** The system shall be capable of regulating airflow through emplacement drifts entrances to less than or equal to TBD-318 per drift. (Reference 5.5, Section 1.2.1.2)
- 4.2.2** The system shall be capable of controlling the rate of air temperature change within the emplacement drifts during blast cooling to no greater than TBD-247. (Reference 5.5, Section 1.2.1.5)
- 4.2.3** The system shall secure the emplacement drift entrances to limit unauthorized personnel access to high radiation areas. (Reference 5.5, Section 1.2.2.1.9)
- 4.2.4** The system shall be designed to operate its important to safety SSC's during a loss of primary power (electric and pneumatic). (Reference 5.5, Section 1.2.2.1.12)
- 4.2.5** The system shall provide operational equipment status for the items identified in Table 12 of reference 5.5. (Reference 5.5, Section 1.2.5.5)

4.2.6 Access to high and very high radiation areas shall be controlled in accordance with the requirements specified in 10CFR20.1601 and 10CFR 20.1602. Emplacement drifts shall provide at each entrance or access point to a high radiation area a conspicuous visible or audible alarm signal so that the individual entering the high radiation area and the supervisor of the activity are made aware of the entry. Entryways are locked except during periods when access to the areas are required with positive control over each individual entry. (Reference 5.6, Section 3.2.4.3.2.A, 3.2.4.3.2.B.1.b, and 3.2.4.3.2.B.1.c)

4.3 Assumptions

4.3.1 Doors are required at entrances to emplacement drifts. (Used throughout)(Reference 5.16, DCSS 036)

4.4 Codes and Standards

Not Used

5. REFERENCES

- 5.1** CRWMS M&O 1997. *Classification of the Preliminary MGDS Repository Design*. B00000000-01717-0200-00134, Rev. 00. Las Vegas, Nevada: Author. MOL.19980211.1192.
- 5.2** U.S. Department of Energy, YMP 1998. *Q-List*. YMP/90-55Q, Rev. 05. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. MOL.19980513.0132.
- 5.3** CRWMS M&O 1998. *Remote Handling & Controls - Analyses (WP# 12472375MA, RP123770, RP123772, RP123790)*. Activity Evaluation. Las Vegas, Nevada: Author. January 15, 1998. MOL.19980220.0152.
- 5.4** U.S. Department of Energy 1998. *Quality Assurance Requirements and Description*. DOE/RW-0333P, Rev. 8. MOL.19980601.0022.
- 5.5** CRWMS M&O 1998. *Subsurface Ventilation System Description Document*. BCA000000-01717-1705-00016 Rev 00 ICN 1. Las Vegas, Nevada: Author. MOL.19980604.0151. MOL.19980515.0170. MOL.19980518.0156
- 5.6** U.S. Department of Energy, YMP 1994. *Repository Design Requirements Document*. YMP/CM-0023, Rev 00, ICN 1. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. MOL.19980429.0779.

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- 5.7 CRWMS M&O 1997. *Emplacement Drift Air Control System*. BCAD00000-01717-0200-00005 Rev 00. Las Vegas, Nevada: Author. MOL.19980102.0034.
- 5.8 CRWMS M&O 1997. *Subsurface Construction and Development Analysis*. BCA000000-01717-0200-00014 Rev 00. Las Vegas, Nevada: Author. MOL.19971210.0560.
- 5.9 CRWMS M&O 1997. *Subsurface Waste Package Handling - Remote Control and Data Communication Analysis*. BCA000000-01717-0200-00004 Rev 00. Las Vegas, Nevada: Author. MOL.19970714.0655.
- 5.10 CRWMS M&O 1995. *Subsurface Repository Remote Handling & Robotics Evaluation Report*. BC0000000-01717-5705-00016, Rev 00. Las Vegas, Nevada: Author. MOL.19960402.0542.
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- 5.12 Effector, Inc. 1998. *Sensor Catalog 1998*. [Product Catalog]. Exton, PA: Effector, Inc. TIC # 238882.
- 5.13 Pepperl & Fuchs. 1997. *Sensors - North American Edition 1997*. [Product Catalog]. Twinsburg, Ohio: Pepperl & Fuchs Inc. Catalog # SEN497. TIC # 238881.
- 5.14 Banner Engineering Corp. 1997. *Photoelectric Sensors 1997*. [Product Catalog]. Minneapolis, MN: Banner Engineering Corp. Publication: P/N 97000. TIC # 238880.
- 5.15 Allen-Bradley Co. Inc. 1997. *Automation Systems*. [Product Catalog]. Publication B112. TIC # 238883
- 5.16 CRWMS M&O 1998. *Controlled Design Assumptions Document*. B00000000-01717-4600-00032, Rev 05. Las Vegas, Nevada: Author. MOL.19980804.0481

6. COMPUTER SOFTWARE

Not Used

7. DESIGN ANALYSIS

7.1 The Purpose of an Emplacement Drift Isolation Door

The emplacement drift air control system will consist of both an inlet structure and an outlet structure for each emplacement drift. These structures are required because airflow through the parallel emplacement drifts would be impossible to control without some form of physical regulators. Inlet and outlet structures are both required so that ventilation can still be controlled when one of the structures is open or undergoing repair. In addition, with inlet and outlet structures the entire emplacement drift could be isolated in the event of a leaking waste package. The requirement for opening and closing the inlet structure of the emplacement drifts is derived from the fact that waste packages will be stored in the drifts. These waste packages will need to enter the drift for placement and thus the inlet structure will need to open and close to allow the placement to occur. This inlet structure can be more commonly called an emplacement drift isolation door. From the above, it can be shown that the main purpose of the emplacement drift isolation door will be as a ventilation control device.

In addition to being a ventilation control device, the emplacement drift isolation doors will also limit entry into the drift to authorized operations only. The emplacement drift can be considered a high radiation environment which will require various administrative controls for personnel to gain entry. Controlling the door position (opened or closed) will ensure that only those activities requiring entrance into the drift are allowed. These activities could consist of unloading the emplacement gantry, unloading a WP, removing the gantry, removing WPs, retrieving WPs and unloading/removing the performance confirmation remote inspection vehicle.

The emplacement drift isolation doors will also provide a limited amount of shielding from the radiation emanating from the waste packages placed therein. The current estimate of the dose rate at the drift entrance door, with a shadow shield installed in the drift, is 24 mrem/hr with the door closed. When the door is open, the total dose rate is estimated to be approximately 85 mrem/hr (Reference 5.11).

7.2 Isolation Door Construction

The emplacement drift isolation doors may be constructed out of metal or reinforced concrete. Typical metals used on doors are either aluminum or steel. A door made entirely of concrete would be heavy and could crack over time. These cracks could be the pathway for significant air leakage through the structure. A composite door with a steel exterior and a concrete filled interior would alleviate these concerns.

An all steel door can be composed of two steel plates which are joined together by steel spacers. The thickness of the door could be approximately 18 cm to be structurally sound and provide an adequate surface area to install a seal. A single leaf door would weigh approximately 5,000 kg (Reference 5.7).

The door and its associated frame can be installed at the interface between the short turnout and the beginning of the emplacement drift. The door and frame can be set in a bulkhead which may be made of steel. The steel bulkhead and associated door and frame can be mounted against the rock at the entrance of the emplacement drift. Expandable foam or caulking could be installed to fill any cracks which might exist between the bulkhead and rock surface. This form of construction should help to reduce air leakage around the bulkhead.

The emplacement drift isolation door will be furnished with some form of mechanical actuation to open and close it. The door actuator may be electric, pneumatic, or hydraulic and will provide the energy necessary to move the door open and closed. Regardless of the type of actuator used, it will require a contact closure to initiate its activation (i.e., solenoid valve or relay). One actuator can be designed, with the addition of linkages, to operate both leafs of the isolation door. It is however, recommended that each leaf have a separate actuator. If two actuators are used to operate one door assembly, one contact can be used to energize both actuators at the same time, or two separate contacts can be utilized.

As stated in section 7.1, the emplacement drift isolation door is primarily a ventilation control device. Therefore there must be a means to allow airflow through the door. This can be easily accomplished with the addition of a set of adjustable louvers. The louvers will allow a varying amount of air to flow through them depending on the amount they are open. It is possible to procure louvers which have very low leakage rates when in the closed position. The emplacement drift isolation doors will be furnished with an appropriately sized louver. If a single leaf door is used, then one adjustable louver would be sufficient. If a double leaf door is used, each leaf would be furnished with an adjustable louver.

From a ventilation control standpoint, a single leaf door is appealing. There will be less opportunity for air leakage because there will not be a seam down the middle of the door, as is the case with a double leaf door. Without this extra seam, sealing and alignment requirements for the door would be greatly reduced.

A single leaf door is presently under design evaluation for use as an emplacement drift isolation door. Since the control requirements are more involved with a double leaf door, this analysis will focus its discussion on the double leaf design. Because there is only one leaf in the single leaf door design, the control requirements for this type of door would be roughly one half those of the double leaf design.

7.3 Isolation Door Operation and Automation

The construction and development of the repository will be completed in a series of blocks (also called panels) of emplacement drifts, with each panel consisting of between 5 and 22 emplacement drifts (Reference 5.8). The increments will allow completion of the repository in phases and the subsequent turnover to emplacement operations of drifts that are ready to receive waste packages. The current development concept involves relocating the isolation airlocks as panels of emplacement drifts are determined to be ready to receive waste packages. The varying number of drifts to be turned over to emplacement operations should be taken into account in the control system design for the emplacement drift isolation door control system. This analysis will base the initial design of the isolation door control system on the number of drifts to be turned over as stated in Reference 5.8. The exact size of the blocks could vary with minimal effect on the final control system design.

The isolation door at the entrance of each emplacement drift will need to open and close each time entrance into the drift is required. Activities that require entrance into an emplacement drift consist of unloading the emplacement gantry, unloading a WP, removing the gantry, removing WPs, retrieving WPs and unloading/removing the performance confirmation remote inspection vehicle. It is unknown at this time exactly how many times over its life a particular door will be opened and closed, but this number is estimated at over 100. Radiation levels at the emplacement drift entrance will vary depending on how full the drift is with WPs. In any case, these radiation levels may be sufficiently high to warrant remote operation of all isolation doors, taking into account the number of times each of the isolation doors are to be opened and closed.

Sensors and instrumentation should be added to the door assembly to detect whether the door is in the opened or closed position, and this information should be transmitted to a remote monitoring station. A variety of limit switch sensors are available including mechanical-contact, and non-contact electro-optical and electro-magnetic technologies (Reference 5.9 and 5.10). The specific type of sensor to be used in the design has not yet been determined, however, refer to section 7.3.1 for a discussion of available types.

A hand operated emergency release switch can be installed inside the emplacement drift to prevent an individual from being trapped inside. This approach would allow an individual to get out of the emplacement drift should there ever be an instance where he/she is inadvertently in the drift when the door closes. Key operated switches can be installed outside the emplacement drift so only authorized individuals can manually open the door should the need arise. Details regarding the manual switch installations can be completed once the type of door actuator is finalized.

A rotating beacon and alarm horn can be installed at the entrance of each emplacement drift to provide audible and visual alarms associated with the high radiation areas inside the emplacement drifts. Prior to the doors actually opening, the alarm horn can sound for a predetermined amount of time. This time can be determined after studying how long it would take a person to safely exit the emplacement drift entrance area, should they happen to be there when the door is directed to open. The door sequence could be that the door is directed to open, the alarm horn could sound for 15 or 20 seconds, the door would actually open, the horn would stop sounding, and the rotating beacon would remain on. When the door is directed to close, the rotating beacon would go off when the door reaches the closed position. Whenever the door is open, the rotating beacon should be on to alert personnel who may be approaching that the area should be avoided. Details regarding this portion of the design can be worked out once the radiation levels at the emplacement drifts are more fully understood. The isolation door control system will also be designed with local lock-out capabilities that prevent remote operation of the doors to ensure personnel safety during maintenance or other activities taking place near the doors.

7.3.1 Sensors

The environment inside the emplacement drifts will be relatively hot (~200 °C) and the waste packages will generate a relatively high radiation field. The initial estimate of the dose rate at the drift entrance door, with a shadow shield installed in the drift, is 24 mrem/hr with the door closed. When the door is open, the total dose rate is estimated to be approximately 85 mrem/hr (Reference 5.11). Based on these quantities, it would be advantageous to physically mount all door position sensors outside of the emplacement drift. The sensors to transmit the door's position could be installed on the turnout side of the emplacement drift isolation doors. This would ensure that the switches and associated wiring could be maintained and/or replaced without reducing the inherent availability below requirements.

7.3.1.1 Mechanical Contact Limit Switches

A mechanical, lever type, spring return limit switch can be used to reliably transmit the door closed position. This type of limit switch is operated by means of a lever which is clamped to a knurled shaft extending from the operating head. The rotation of the lever causes the contacts of the switch assembly to operate. Total travel of the lever can be 90° in either direction. The limit switch can be mounted so that a bracket installed on the door contacts the lever and rotates it, which thereby activates the contact in the switch as the door closes. This type of switch is routinely furnished with a spring return mechanism so once released, the lever rotates back to the home condition and the contacts subsequently change state. Refer to Figure 7.3-1.

A mechanical, push type, spring return limit switch can be used to reliably transmit the door open position. Limit switches of this type are actuated by means of a rod or plunger located on the top or side of the operating head. Pushing the plunger into the switch assembly causes the contacts to operate. These types of switches can be furnished with adjustable rods minimizing installation and operation concerns. The limit switches can be mounted on support brackets so that as the door swings open, the door itself contacts the switch plunger which thereby activates the contact in the switch. Refer to Figure 7.3-2.

7.3.1.2 Non-Contact, Solid-State, Proximity Sensors

Of the numerous types of non-contact proximity switches available, three general types have become widely used in industry: inductive, capacitive, and photo-electric. Banner, Turck, Pepperl & Fuchs, Efector, Allen-Bradley, and Contrinex are a few of the companies currently manufacturing proximity sensors for various applications.

Inductive proximity sensors consist of a resonance coil and ferrite core arrangement, an oscillator and detector circuit, and a solid-state output circuit. The oscillator generates a high frequency current that is passed through the resonance coil. A high frequency electromagnetic field is induced by the coil in the region around the coil axis. When a ferromagnetic target enters the high-frequency field, eddy currents are induced on the surface of the target. This results in a loss of energy in the oscillator circuit and, consequently, a smaller amplitude of oscillation. The detector circuit recognizes a specific change in amplitude and generates a signal which will turn the solid-state output "on" or "off." When the metal object leaves the sensing area, the oscillator regenerates, allowing the sensor to return to its normal state. (Reference 5.13, pg. 22). Depending on the sensor and manufacturer, this process can be repeated hundreds of times per second.

Inductive proximity sensors, due to their design, have relatively short sensing ranges. This range is a function of the core diameter, target size, target material, and sensor manufacturer. Generally, sensing ranges of a large steel target are from 1-3 millimeters for a 8 millimeter core to 25-60 millimeters for a 20 millimeter core (Reference 5.12, pg. 99).

Capacitive proximity sensors are self-contained solid-state devices that exhibit the same general operating characteristics as inductive sensors. Unlike inductive sensors, capacitive sensors can detect metal and non-metal targets. Therefore, it is possible for capacitive sensors to detect water and other liquids, wood, plastic, rubber, or any target which increases the sensors' capacitance field. (Reference 5.12, Pg. 141)

PROXIMITY SENSOR
MECHANICAL CONTACT
LIMIT SWITCH
PLUNGER

ISOLATION DOOR
HARDSTOP WELDMENT

ALT. DETAIL
ISOLATION DOOR HARDSTOP
SCALE: 1:4

ISOLATION DOOR HARDSTOP
PROXIMITY SENSOR
MECHANICAL CONTACT
LIMIT SWITCH

DETAIL
SCALE: 1:4
B
7.3-1

FIGURE: 7.3-2
ISOLATION DOOR OPEN POSITION
MECHANICAL/PROXIMITY SWITCH

A capacitive sensor, like the inductive, contains an oscillator, detection circuit, and a solid-state output circuit. Rather than an inductive coil, a capacitive sensor contains two plates, or electrodes. When charged, an electric field is projected away from these plates, and this projected area is the sensing area. This area is synonymous to a capacitor's dielectric. The oscillator is tuned such that when there is nothing (or air) in the sensing area there is no oscillation produced. However, as soon as an object changes this field, or dielectric, an oscillation is produced. The internal circuitry detects the oscillation and produces a solid-state output. (Reference 5.12, pg 218 & Reference 5.13, pg. 22). Therefore, any substance which changes the sensor's capacitance can be a suitable target.

Certain arrangements of photoelectric sensors are well suited for proximity detection. Depending on the target, air/particle conditions, and sensor alignment, photoelectrics can sense a target from many feet. Photoelectric sensors, used in proximity sensing, emit an infrared or visible light which is bounced off a target. The reflected light is detected by photoelectric sensors within the sensor unit, at which time the unit produces an output. Because photoelectric sensors are often much larger than capacitive or inductive sensors, the generated and reflected light energy is often channeled through a single fiber-optic cable, known as bifurcated fibers, to the target or sensing area. These glass fibers are able to withstand very high temperatures and can be used to isolate the sensing electronics from damaging heat. (Reference 5.14, pp. 579-583)

Although sensor reliability varies between manufacturers, applications, and environmental conditions, the overall reliability of a non-contact proximity sensor is much higher than that of a mechanical contact switch. This is because of their solid-state design, i.e. no moving parts, which reduces the probability of component failure, increasing the mean-time between failure (MTBF).

However, inductive and capacitive sensors are subject to errors in high electromagnetic fields (EMF), such as near arc welding applications. The high associated current often induces a voltage in the switch electronics or saturates the finite core. (Reference 5.12, pg. 83)

7.3.1.3 Sensor Installation

Two switches can be installed on a door leaf, one switch representative of the open position and the other switch representative of the closed position. It is possible for both leaves of the isolation door assembly to be connected by a series of linkages and operated by one actuator. By monitoring one leaf's position, the position of the other leaf can be implied. This approach is not recommended. What should be monitored is each door leaf's true position. Linkages can jam, disconnect, or break. To say one side of the door is in the same position as the other, which is monitored, leaves a lot to interpretation. Each door's leaf position should be monitored for both the opened and closed position. This approach would require a minimum of four switches per emplacement drift isolation door.

The issue of redundancy and fault tolerance was not addressed in the previous discussion. The limit switches on the isolation doors can easily be installed in a redundant and fault tolerant configuration. If it is deemed necessary, two different types of switches can be installed to monitor each position of each leaf of the isolation door. To monitor the open position one mechanical push-type switch can be installed along with a non-contact proximity sensor. Two different types of switches can also be mounted to monitor the closed position of the door. One mechanical lever operated switch can be installed along with a non-contact proximity sensor to transmit the door closed position. Refer to Figure 7.3-2. This redundant, diverse approach would require eight switches per emplacement drift isolation door (4 - non-contact proximity sensors and 4 - mechanical limit switches). Because of the increased reliability, this type of installation is recommended. If the door consists of only one leaf, then a total of four limit switches would be required per emplacement drift isolation door.

7.3.1.4 Louver Position Sensors

As stated in section 7.2, the emplacement drift isolation doors will be furnished with adjustable louvers. If a double leaf door is used, each leaf would be furnished with an adjustable louver. The quantity of ventilation air flowing into a drift is inversely proportional to the drift resistance; the higher the resistance, the lower the quantity of air. The repository is not symmetrical with respect to airflow and therefore the pressure head will vary with the emplacement drift's distance from the North ramp and the emplacement exhaust shaft (Reference 5.7). To provide relatively equal amounts of air to each drift, it will be necessary to adjust the louvers and thereby vary the drift resistance accordingly. To assist in this exercise, remotely controlling and monitoring the position of the inlet louvers will be required.

There are numerous manufacturers who make actuators and transmitters to accomplish this task. At this stage of design development it is impossible to finalize this control requirement. Details such as the size of the louvers, type of actuation, torque requirements, linkage arrangement, etc are required and will be the subject of future analysis as the door design develops. What is known is that the signals representative of louver position and louver actuation will be analog in nature.

Analog signals vary according to the range of the input parameter. Louver position of 0 to 100 percent could be transmitted to the control system. 0 percent could be representative of the closed position and 100 percent could be representative of the wide open position. Typical electrical analog signal ranges are 0-5 Volts DC (VDC), 1-5 VDC, 0-10 VDC, ± 10 VDC, ± 5 VDC, and 4-20 milliamp DC (mADC). It is recommended that analog signals with an elevated zero be used in the repository design. Transmitters with output signal ranges of 0-5 VDC, 0-10 VDC, ± 10 VDC, and ± 5 VDC should not be used. If a wire should break or become disconnected from the terminals, then the control system will think the transmitter is transmitting a zero voltage signal. If analog signals with an elevated zero, such as 1-5 VDC or 4-20 mADC, are used, the control system can determine that it has lost communication with the transmitter and will alarm this condition should it occur.

Each emplacement drift isolation door will therefore need to transmit 2 analog signals representative of louver position. In addition, each door will also need to receive 2 analog signals to remotely operate the louver actuator.

7.3.1.5 Isolation Door I/O Summary

Based on the information stated in sections 7.3.1.3 and 7.3.1.4, each emplacement drift isolation door will require the following amount of signals to be transmitted or received by the control system in support of remote operation (Refer to Figure 7.3-1):

- 4 -- Discrete input signals representative of door closed
- 4 -- Discrete input signals representative of door open
- 2 -- Discrete output signals to activate the door actuators
- 2 -- Analog input signals representative of louver position
- 2 -- Analog output signals to modulate the louvers

The quantities listed above are for a double leaf door. If a single leaf door is selected, the control requirements would be exactly one half of those shown.

There will be a varying amount of between 5 and 22 emplacement drifts (called panels) turned over from the development side of the repository to the emplacement side (Reference 5.8). Each turnover panel will contain the following number of emplacement drifts:

Panel 1	5 Emplacement Drifts
Panel 2	16 Emplacement Drifts
Panel 3	22 Emplacement Drifts
Panel 4	20 Emplacement Drifts
Panel 5	21 Emplacement Drifts
Panel 6	21 Emplacement Drifts
Total	105 Emplacement Drifts

The number of emplacement drifts within a panel and the total number of emplacement drifts could vary with minimal effect on the final control system design.

It is planned to have a separate control system network running down both the East and West mains of the repository. The controls for the isolation doors allowing drift access off of the East main will interface to the network running down the East main. Similarly, the controls for the isolation doors allowing drift access off of the West main will interface to the network running down the West main. This analysis will discuss the emplacement drift isolation door control system as it relates to panels of emplacement drifts. The discussion will of course apply to both the East and West mains of the repository.

The first panel of emplacement drifts to be turned over to emplacement operations will have the following I/O, per main, associated with isolation door control:

- 20 -- Discrete input signals representative of door closed
- 20 -- Discrete input signals representative of door open
- 10 -- Discrete output signals to activate the door actuators
- 10 -- Analog input signals representative of louver position
- 10 -- Analog output signals to modulate the louvers

Panel two will have the following I/O, per main, associated with isolation door control:

- 64 -- Discrete input signals representative of door closed
- 64 -- Discrete input signals representative of door open
- 32 -- Discrete output signals to activate the door actuators
- 32 -- Analog input signals representative of louver position
- 32 -- Analog output signals to modulate the louvers

Panel three will have the following I/O, per main, associated with isolation door control:

- 88 -- Discrete input signals representative of door closed
- 88 -- Discrete input signals representative of door open
- 44 -- Discrete output signals to activate the door actuators
- 44 -- Analog input signals representative of louver position
- 44 -- Analog output signals to modulate the louvers

Panel four will have the following I/O, per main, associated with isolation door control:

- 80 -- Discrete input signals representative of door closed
- 80 -- Discrete input signals representative of door open
- 40 -- Discrete output signals to activate the door actuators
- 40 -- Analog input signals representative of louver position
- 40 -- Analog output signals to modulate the louvers

Panels five and six will each have the following I/O, per main, associated with isolation door control:

- 84 -- Discrete input signals representative of door closed
- 84 -- Discrete input signals representative of door open
- 42 -- Discrete output signals to activate the door actuators
- 42 -- Analog input signals representative of louver position
- 42 -- Analog output signals to modulate the louvers

The total I/O associated with isolation door monitoring and control for the entire repository is therefore estimated as follows:

- 840 -- Discrete input signals representative of door closed
- 840 -- Discrete input signals representative of door open
- 420 -- Discrete output signals to activate the door actuators
- 420 -- Analog input signals representative of louver position
- 420 -- Analog output signals to modulate the louvers

2,940 -- Total points

7.3.2 PLC Control

Because most (> 72%) of the I/O devices required to effectively monitor and control the emplacement drift isolation door operation will be of the discrete type (on-off), a control system built upon a Programmable Logic Controller (PLC) platform is highly recommended. PLC systems are robust microprocessors specifically designed to process large amounts of discrete I/O such as limit switches, push buttons, indicating lights, horns, and relay outputs (Reference 5.15). These solid state devices employ a programmable electronic memory for storing control instructions to implement specific logic, sequencing, timing, counting, and mathematical calculations. PLCs are programmed using what is known throughout the industry as relay ladder logic (RLL). This programming language is readily understood by most maintenance electricians employed in industrial plants where PLCs are in use. Because of its simplistic structure, RLL is particularly useful in equipment start-up, troubleshooting, and testing situations.

A PLC system can be designed with a remote I/O communication link. The remote I/O link connects remote I/O chassis containing input and output cards to the PLC processor. The I/O chassis and other devices on the link can be mounted over 3,000 meters from the PLC processor. More than one I/O chassis can be connected to the remote I/O link. A twinaxial cable is simply "series-ed" or looped between the various devices on the link. A remote I/O communication network significantly reduces the amount of field wiring because the I/O racks can be distributed, locating the system I/O terminals closer to the sensors and output actuators.

The repository application lends itself for implementing a PLC system with a remote I/O network because the emplacement side will grow as panels of emplacement drifts get turned over. A PLC processor and an I/O chassis can be installed in each main of the first turnover panel consisting of five drifts. The next panel would require only an I/O chassis per main. The third panel would also require only an I/O chassis per main. At the fourth panel, another PLC processor and I/O chassis could be installed and the installation sequence of only installing an I/O chassis can be repeated as the networks extend down the East and West mains to panels five and six.

The above approach allows for the I/O chassis and associated cards of a panel, which is ready to be turned over, to be exhaustively checked out prior to connecting to the "real" system. Prior to turning over a panel of emplacement drifts, a portable programming terminal or laptop personal computer can be connected to the I/O chassis to simulate connection to the "on-line" PLC. The door operation can then be started up and the correct operation can be verified. Once deemed satisfactory, the I/O chassis can be connected to the remote I/O link of the "on-line" PLC processor as part of the drift turnover sequence.

Discrete I/O modules have digital I/O circuits that interface to on/off devices such as limit switches, push buttons, indicating lights, horns, and relay outputs. The discrete inputs then directly control the state of corresponding bits in the PLC processor's data table while the discrete outputs are directly controlled by the state of corresponding bits in the PLC processor's data table. Discrete modules are available in different densities (maximum of 32 channels per module) for greater flexibility and cost savings. For purposes of this analysis discrete input modules with 16 channels and discrete output modules with 8 channels will be used.

Analog I/O modules perform the required Analog/Digital (A/D) and Digital/Analog (D/A) conversions to directly interface the analog signals to the PLC processor data tables using up to 16 bit resolution. For purposes of this analysis analog input modules with 8 channels and analog output modules with 4 channels will be used.

Based on the above information, the following card counts are provided for each panel of emplacement drifts:

- ◆ Panel 1 (per East and West main)
 - 3 -- Discrete Input Cards
 - 2 -- Discrete Output Cards
 - 2 -- Analog Input Cards
 - 3 -- Analog Output Cards

- ◆ Panel 2 (per East and West main)
 - 8 -- Discrete Input Cards
 - 4 -- Discrete Output Cards
 - 4 -- Analog Input Cards
 - 8 -- Analog Output Cards

- ◆ Panel 3 (per East and West main)
 - 11 -- Discrete Input Cards
 - 6 -- Discrete Output Cards
 - 6 -- Analog Input Cards
 - 11 -- Analog Output Cards

- ◆ Panel 4 (per East and West main)
 - 10 -- Discrete Input Cards
 - 5 -- Discrete Output Cards
 - 5 -- Analog Input Cards
 - 10 -- Analog Output Cards

- ◆ Panel 5 (per East and West main)
 - 11 -- Discrete Input Cards
 - 6 -- Discrete Output Cards
 - 6 -- Analog Input Cards
 - 11 -- Analog Output Cards

- ◆ Panel 6 (per East and West main)
 - 11 -- Discrete Input Cards
 - 6 -- Discrete Output Cards
 - 6 -- Analog Input Cards
 - 11 -- Analog Output Cards

The I/O cards listed above would require mounting in an I/O chassis. The I/O chassis are manufactured in a variety of slot widths. Each slot accepts an I/O card. Chassis can be furnished with 4, 8, 12, or 16 slots (Reference 5.15). Panel 1 would require one I/O chassis. All of the other panels would require a minimum of three I/O chassis to support the isolation door I/O.

The PLC processor for isolation door control should be furnished with the appropriate quantity of communication ports to support the remote I/O networks and to also communicate to the surface facilities. Communication with the surface facilities can be accomplished with an Ethernet port on the PLC. This port can be connected to the fiber optic backbone which runs in the main and access drifts of the repository. Access to all the points within the PLC database would then be possible from the surface. Commands to open-close a door as well as monitoring the state of all doors could be conducted from the safe confines of the command control center.

It is recommended that the PLC processors be provided in a redundant manner so that a secondary PLC can assume immediate control of the system, without interruption to the functionality of the process, in the event of the failure of the primary PLC. A backup control module can constantly monitor the self diagnostic features of each PLC. Upon detecting an error, the module can switch control from the primary PLC to the backup PLC. If the backup PLC should develop an error, the backup control module can alarm this condition so appropriate maintenance activities can be initiated.

An alternative to a PLC with a remote I/O network would be to install a PLC processor and associated I/O cards in each panel of emplacement drifts. Every panel would contain a PLC processor instead of just an I/O chassis as with the remote I/O network approach. Each PLC would require an Ethernet communication port to connect to the fiber optic backbone and communicate with the command control center. To avoid single points of failure, all of these PLCs would have to be furnished in a redundant manner. This approach would be more costly than the remote I/O approach without adding significantly more capability or availability. The I/O card structure would be exactly the same. The only difference would be instead of having two larger, redundant PLCs controlling 86 isolation doors (the first three turnover panels), there would be six smaller, redundant PLCs, each pair controlling the isolation doors in the turnover panel. Also, instead of having two connections to the fiber optic backbone, as in the remote I/O case, there would be six connections required in the turnover block PLC approach. More hardware also leads to more maintenance and the increased possibility of device failure. For these reasons, redundant PLCs with multiple remote I/O networks is highly recommended.

I/O cards can be replaced with minimal disruption to the process if channel errors are detected on a particular I/O card. Redundancy can also reduce these risks. It is recommended that the PLC processor have two communication ports dedicated to receive/transmit data from/to I/O cards. Each I/O communication port would be connected to a series of I/O chassis or racks. Each chassis would have dedicated I/O cards to process the input or output. The limit switches representative of door position can have one switch wired to a card in one I/O rack and the other redundant switch wired to another card located in the other I/O rack. Refer to Figure 7.3-3 and 7.3-4.

FIGURE 7.3-4
PLC NETWORK FOR
ISOLATION DOOR CONTROL

The PLC program could be written so that "two out of two" logic will be required to correctly process the information. In other words, both isolation door open inputs must be received by the PLC before the door is recognized as truly open. Inappropriate inputs ("one out of two") can be annunciated so the appropriate maintenance activities can be initiated. The closed circuit television system can be used for an initial assessment of the discrepancies received by the control system.

A PLC system with two remote I/O networks for control and monitoring of the emplacement drift isolation doors is viable. By automating the process, the risk of overexposing personnel is reduced. The system can be designed with total redundancy in mind. Single points of failure can be eliminated from the system design. Redundant limit switches can detect the door's position and reliably transmit the status signals to the PLC system. The PLC system can communicate with the facilities on the surface providing status and control capabilities at the command control center.

7.3.3 DCS Control

A Distributed Control System could also be used to operate the emplacement drift isolation doors. DCSs are typically designed to accommodate large amounts of analog I/O, although recent DCS modifications have developed the technology to give them entry into the discrete manufacturing world that PLCs have traditionally handled so well. DCSs are more expensive to implement than PLCs, unless the I/O count is large and is mostly analog in nature.

The structure of a DCS network is fairly similar to a PLC network. Operator interface is usually made from workstations which are nodes on the data highway. Other nodes on the data highway could contain the controllers and I/O cards where the system would interface with the sensors, transmitters and actuators of the real world. Appropriately sized racks with the necessary quantity of I/O cards could be installed in the turnover panels in a manner very similar to that of the PLC installation.

DCS hardware is also not quite as robust as that of PLCs. An evaluation would have to be performed to investigate if DCS hardware could survive in the subsurface environment of the East and West mains.

The project needs to determine if signals from different subsystems can be intermixed within one control system platform. In other words, can signals for the isolation door control system reside within the same control system for radiation or utility monitoring? If the answer to this question is yes, then it would be attractive to incorporate the control functions for isolation door control within a DCS. As previously stated, large amounts of analog I/O are the market for DCSs.

7.4 Centralized Isolation Door Control

The emplacement drift isolation doors will interface with a variety of activities associated with the operation of the subsurface repository. Their primary function will be to serve as a ventilation control device. They will also need to be opened and closed in support of the waste emplacement process. In order to admit the performance confirmation gantry for in-drift inspections, the doors will also need to open and close.

All subsurface repository operations will be monitored and controlled from a centralized facility. This facility will be the area in which all subsurface activities are coordinated. It is recommended that the operation of the doors be controlled from this location.

This subsurface control center will be the hub for all activities. When the doors need to open, this center will determine that it is alright to do so. Ventilation, waste emplacement, and performance confirmation are not necessarily related activities among themselves, but all do involve the operation of the isolation doors. For instance, when the doors open, a large amount of air will flow into that particular drift because of the lack of resistance. By coordinating the operation of the door with ventilation, the drift outlet airflow regulator can pinch closed in anticipation of this inrush of air. By limiting the amount of air flowing into a drift with an open isolation door, air flowing to other emplacement drifts should be minimally disturbed. This is just one instance where operating the doors from a centralized location would be advantageous.

8. CONCLUSIONS

Due to the unqualified/unconfirmed input data used in the preparation of this analysis, the following conclusions from this analysis can not be used as input into documents supporting procurement, fabrication, or construction unless the unqualified/unconfirmed input data are controlled and tracked as TBV or TBD in accordance with NLP-3-15 or other appropriate procedures.

As a result of the discussions in section 7.3, the design of the emplacement drift isolation door control system must take into account the sequence in which the repository will be constructed. The emplacement operation side of the repository will be completed in increments of completed emplacement drifts. The increments will allow completion of the repository in phases and the subsequent turnover to emplacement operations of drifts that are ready to receive waste packages. This varying number of drifts to be turned over to emplacement operations must be taken into account in the control system design for the isolation door control system.

Section 7.3.1 has determined that the switches necessary to transmit door position should be mounted outside of the emplacement drift to increase maintainability due to the radiation environment inside of the emplacement drift. With the addition of brackets and other types of mounting hardware available, this should be easily accomplished. Details regarding the installation of the position sensors can be determined once more information is available about the door design itself. The basic requirement for mounting all door sensing devices outside of the emplacement drift should be carried forward.

Section 7.3.1.3 has determined that redundant, diverse isolation door position sensors should be utilized in the design of the door control system. One of the sensors could be a mechanical type and the other sensor to transmit the same door position signal could be of the non-contact type. Once again, details regarding the selection of the position sensors can be determined once more information is available about the door design itself.

It has also been recommended in section 7.3.1.4 that analog signal ranges with an elevated zero be used in the repository design. If analog signals with an elevated zero, such as 1-5 VDC or 4-20 mADC, are used, the control system can determine that it has lost communication with the transmitter should there be a broken or disconnected signal wire. This condition could be alarmed by the control system.

The summary of emplacement drift isolation door control signals was presented in section 7.3.1.5. A total of approximately 2,940 points will be required for all 105 emplacement drifts and their 210 isolation doors.

Various options regarding PLC control were discussed in section 7.3.2. It is recommended that redundant PLCs with two remote I/O networks be implemented. By automating the process, the risk of overexposing personnel can be greatly reduced. The isolation door control system can be designed with total redundancy in mind. Single points of failure can almost be eliminated from the system design. Redundant limit switches can detect the doors position and reliably transmit the status signals to the redundant PLCs. The PLC network can communicate with the facilities on the surface providing status and control capabilities at a subsurface control center as discussed in section 7.4.

More work needs to be done to investigate whether the implementation of a Distributed Control System (DCS) can be accomplished. DCSs are more expensive than PLC-based systems, but provide many advantages for relatively large, primarily analog control systems. If control signals for the isolation door control system can reside within the same control system as radiation and utility monitoring, then it is definitely viable to utilize a DCS. This subject should be addressed in the coming year as the system design description documents are completed.

9. ATTACHMENTS

None