U.S. Department of Energy
Office of Civilian Radioactive Waste Management

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DOE/NRC Technical Exchange on Yucca Mountain Surface and Subsurface Facilities

Las Vegas, Nevada

September 14-15, 2004

Enclosure 3

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

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Meeting Roadmap

Presented to:
DOE/NRC Technical Exchange on Yucca Mountain Surface and Subsurface Facilities

Presented by:
Joe C. Price
U.S. Department of Energy

September 14-15, 2004
Las Vegas, Nevada

NRC/DOE Technical Exchange "Roadmap"

- Surface Facility Concept of Operations
  - High-level Description of Waste Forms, Handling, and Movement
  - Overview of Structures, Systems, or Components (Sscs) that are Important to Safety (ITS)
  - Overview of Procedural Safety Controls
- Surface Facility Design and Operations
  - Description of selected operations
    - Transportation Cask Handling
    - Waste Transfer
    - Waste Package Closure
    - Waste Package Transporter Loading

NRC/DOE Technical Exchange "Roadmap"

(Continued)

- Surface Facility Design Descriptions
  - Design Criteria
  - Codes and Standards

- **Subsurface Facilities**
  - Concept of Operations
  - Subsurface Systems and Equipment
    - Design Criteria
    - Codes and Standards

- **Project Decision Schedule**

NRC/DOE Technical Exchange "Roadmap"

(Continued)

- Update of Preclosure Safety Analyses (PCSA)
  - PCSA Process and Products
  - Examples
    - Description of Event
    - Quantification of Event Sequences
    - Nuclear Design Basis
    - Q-List
  - Consequence Analysis

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Surface Facility Concept of Operations

Presented to:
DOE/NRC Technical Exchange on Yucca Mountain Surface and Subsurface Facilities

Presented by:
Richard L. Craun
Acting Director, Office of Project Management and Engineering
U.S. Department of Energy

September 14-15, 2004
Las Vegas, Nevada

Preclosure Safety Analysis Process

- Internal and external hazards analyses identify hazards
- Screening and assessment analyses estimate frequency of event sequences
- Consequence analyses estimate doses to public and workers from event sequences
- Classification analyses identify systems, structures, and components that are important to safety (ITS)
- Nuclear safety design basis document captures design requirements

Implementation of Preclosure Safety Analysis in Design

- Repository is designed to prevent event sequences where possible; mitigate those not preventable
- Structures, systems, and components that prevent or mitigate Category 1 or 2 event sequences are ITS
- Evaluations based on maximum facility capacity and throughput rates for Category 1 event sequence frequency analyses, and on nominal rates for normal operations
- Consequence evaluations of Category 2 event sequences based upon maximum facility capacity

Implementation of Preclosure Safety Analysis in Design

(Continued)

- Component reliability assigned based upon industry historical data; becomes design requirement for equipment procurement
- If a potential event sequence is prevented by design, and therefore doesn't result in dose, it is not identified as a final event sequence
- Results show Category 1 event sequences driven by handling large numbers (approximately 221,000) of individual commercial spent nuclear fuel (CSNF) assemblies
- Category 2 event sequences driven by handling of casks, canisters, and waste packages

Implementation of Preclosure Safety Analysis in Design

(Continued)

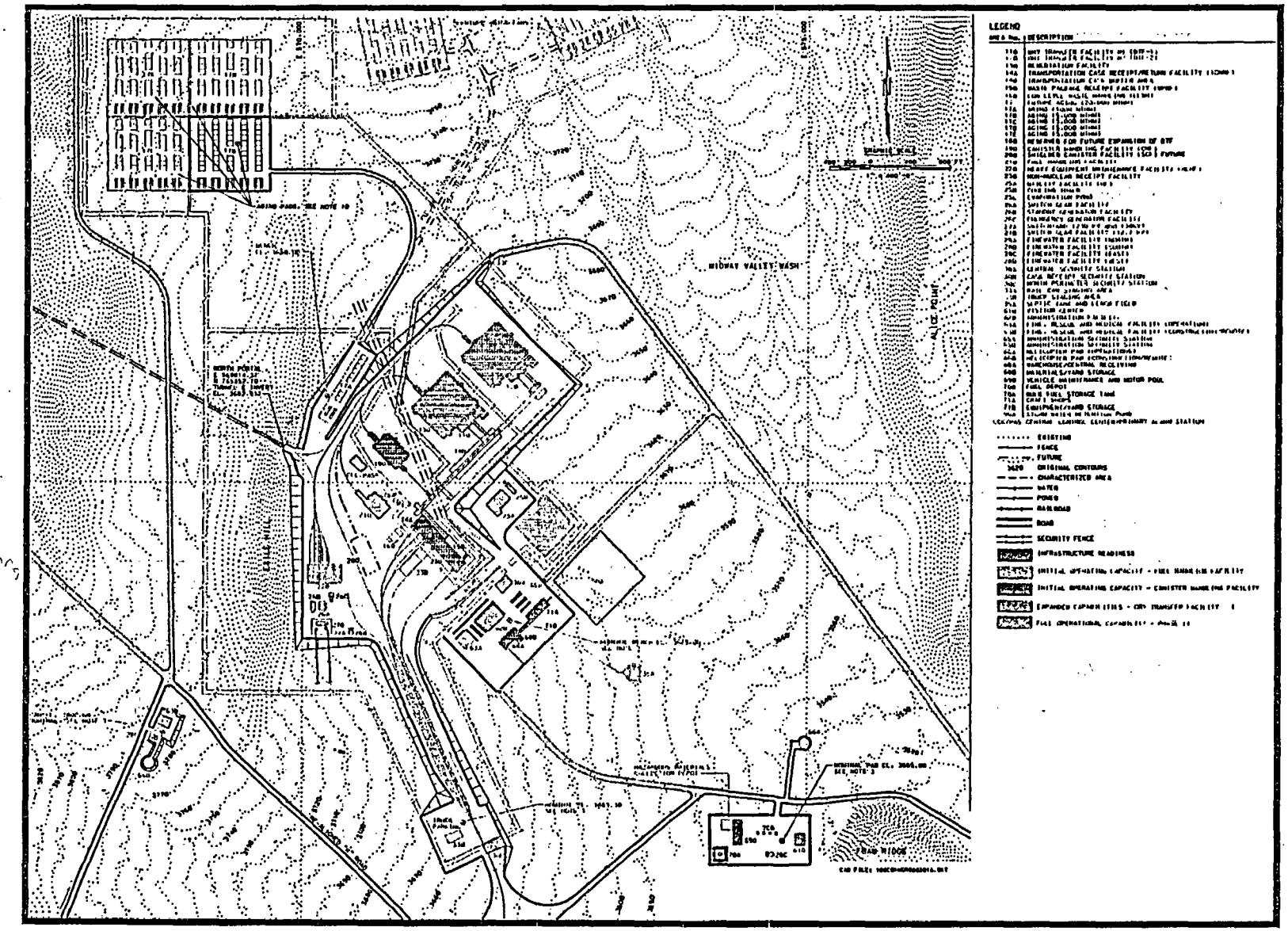
- Category 1 Event Sequences
  - Two event sequences (Fuel Handling Facility [FHF] and Dry Transfer Facility [DTF] only)
    - Drop of individual CSNF assembly
    - Collision of individual CSNF assembly
- Category 2 Event Sequences
  - Three event sequences bound about 30 total
    - Drop and breach of transportation cask with 74 boiling water reactor (BWR) or 36 PWR CSNF assemblies
    - Drop and breach of transportation cask with five high-level waste (HLW) canisters
    - Drop and breach of one naval canister

Implementation of Preclosure Safety Analysis in Design

(Continued)

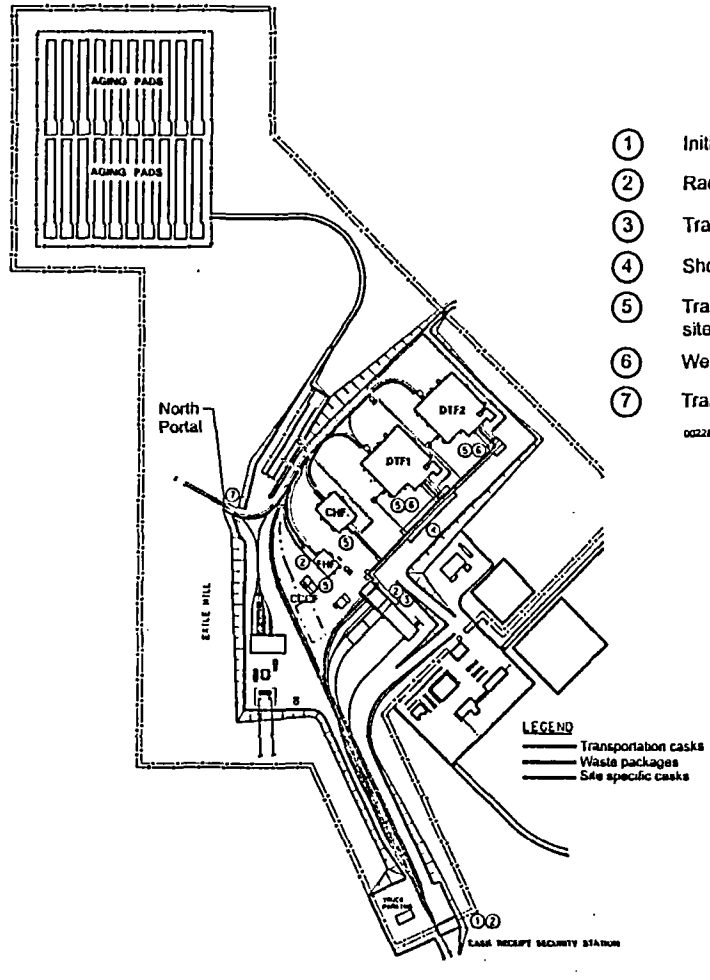
- ITS components for prevention
  - Facility structure provides protection from hazards and support for handling equipment
  - Handling devices, including cranes, fuel transfer machines, and carts, are credited with sufficient reliability to minimize number of drops
  - Moderator controls for preclosure criticality
- ITS components for mitigation
  - Portions of ventilation system, including HEPA filters, exhaust system and fans, and supply air ductwork, as well as related portions of the electrical system
  - Provides air exchanges and filtration to trap particulates resulting from drop or collision of spent nuclear fuel (SNF) assemblies

Surface Facility Description



Surface Facility Operations

Normal Operations Flows



SUMMARY OF ACTIVITIES

1. Initial receipt waste acceptance criteria confirmation and security screening
2. Radiological survey
3. Transfer of transportation cask to site rail transfer cask
4. Short-term staging of transportation casks in buffer area
5. Transfer of waste to waste package or site specific cask; closure of waste package or site specific cask; waste package surface inspection; shielded waste package transporter
6. Wet or dry remediation of damaged fuel or non-standard items
7. Transport of waste package to assigned emplacement drift

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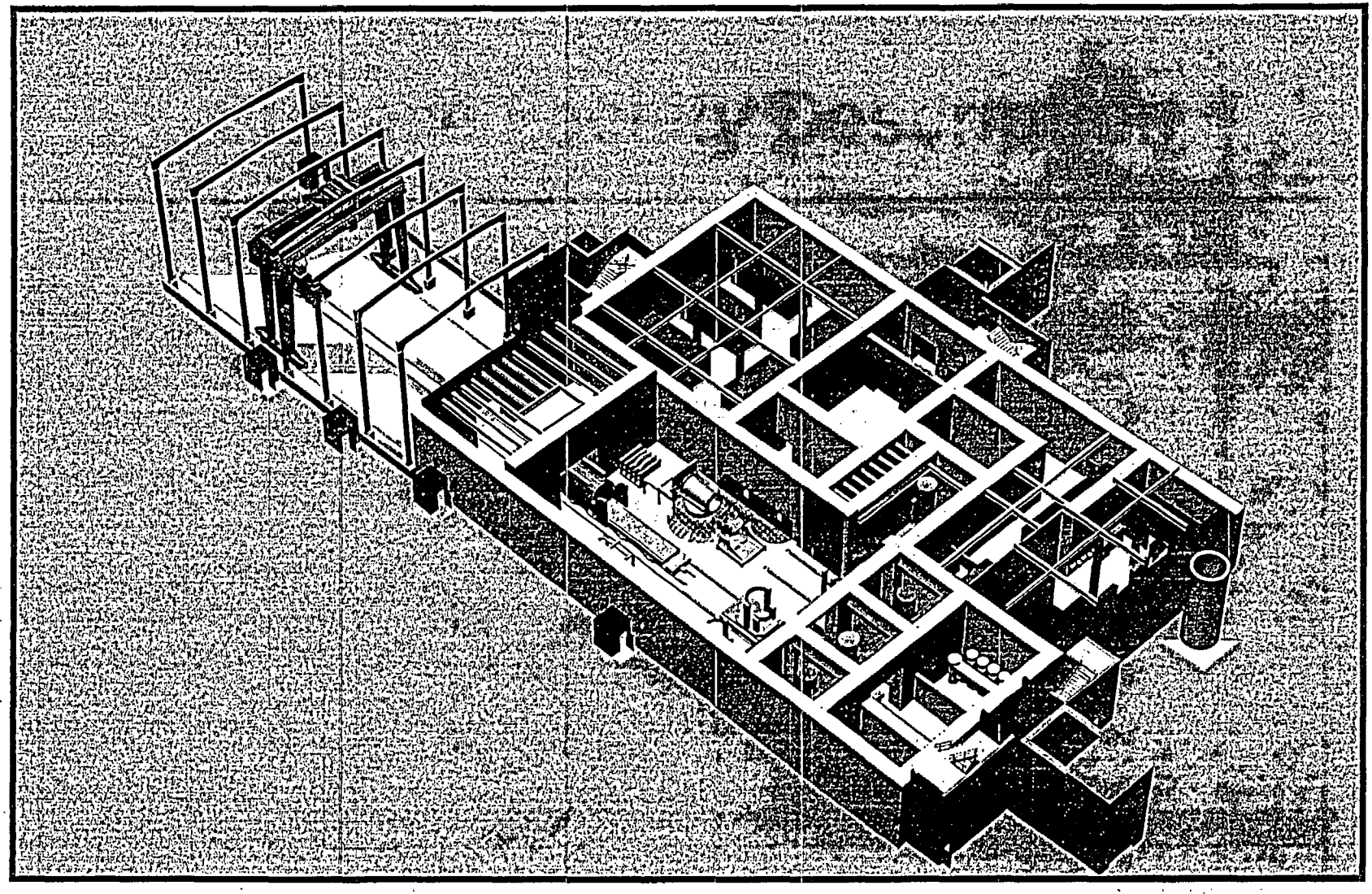
Waste Handling Facilities

FHF: Up to 40 Waste Packages/yr
- CSNF
- HLW and DOE SNF

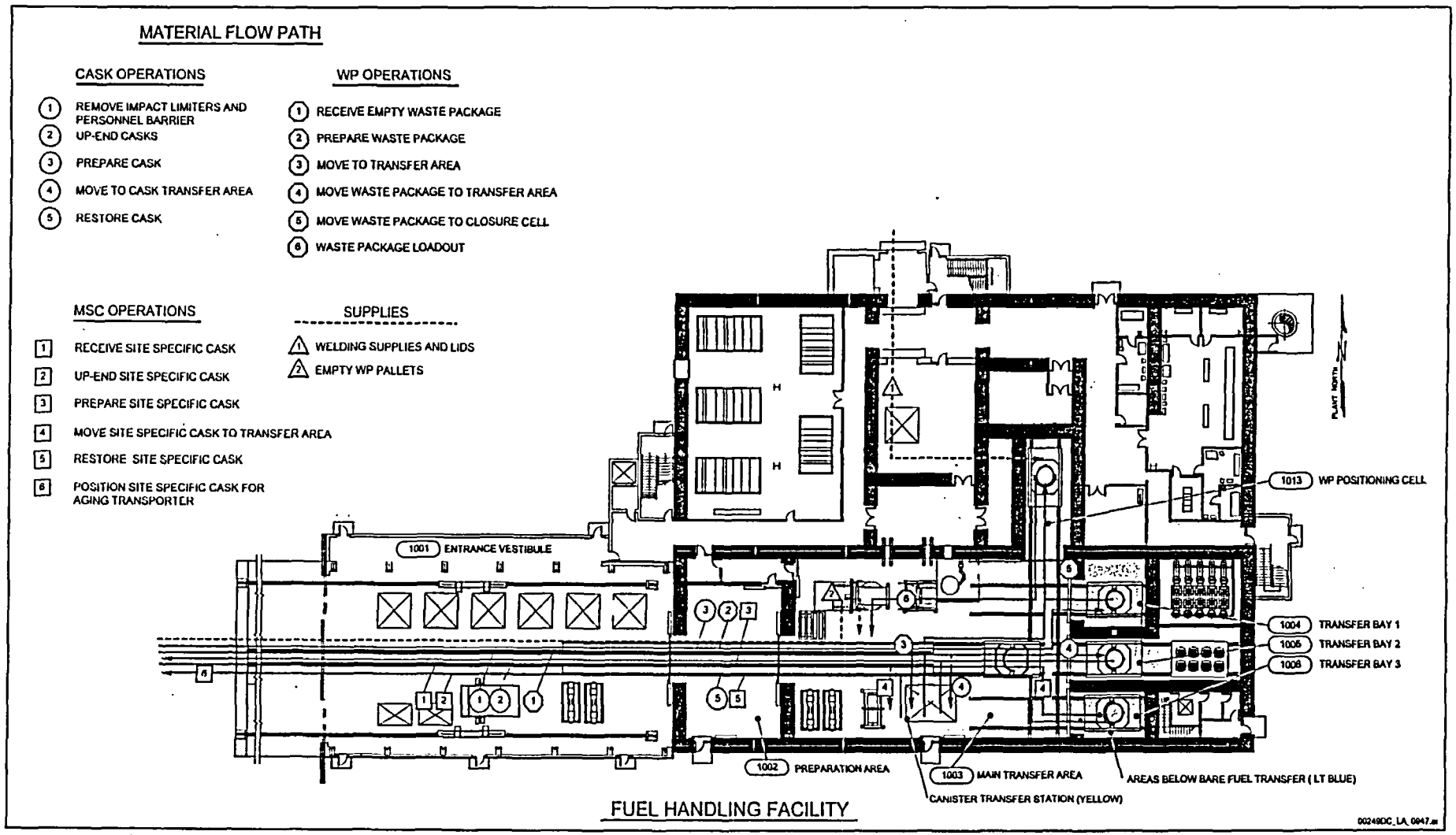
CHF: Up to 180 Waste Packages/yr
- HLW and DOE SNF

DTF: Up to 180 Waste Packages/yr
- CSNF
- HLW and DOE SNF
- Full remediation capability

Fuel Handling Facility Description



Fuel Handling Facility Operations



Fuel Handling Facility: Important to Safety Structures, Systems, or Components

Mitigation ITS SSCs
FHF Structure (confinement, shielding)
HVAC Primary Confinement (confinement, filtration)
Electrical (support HVAC)

Prevention ITS SSCs
FHF Structure (hazards protection)

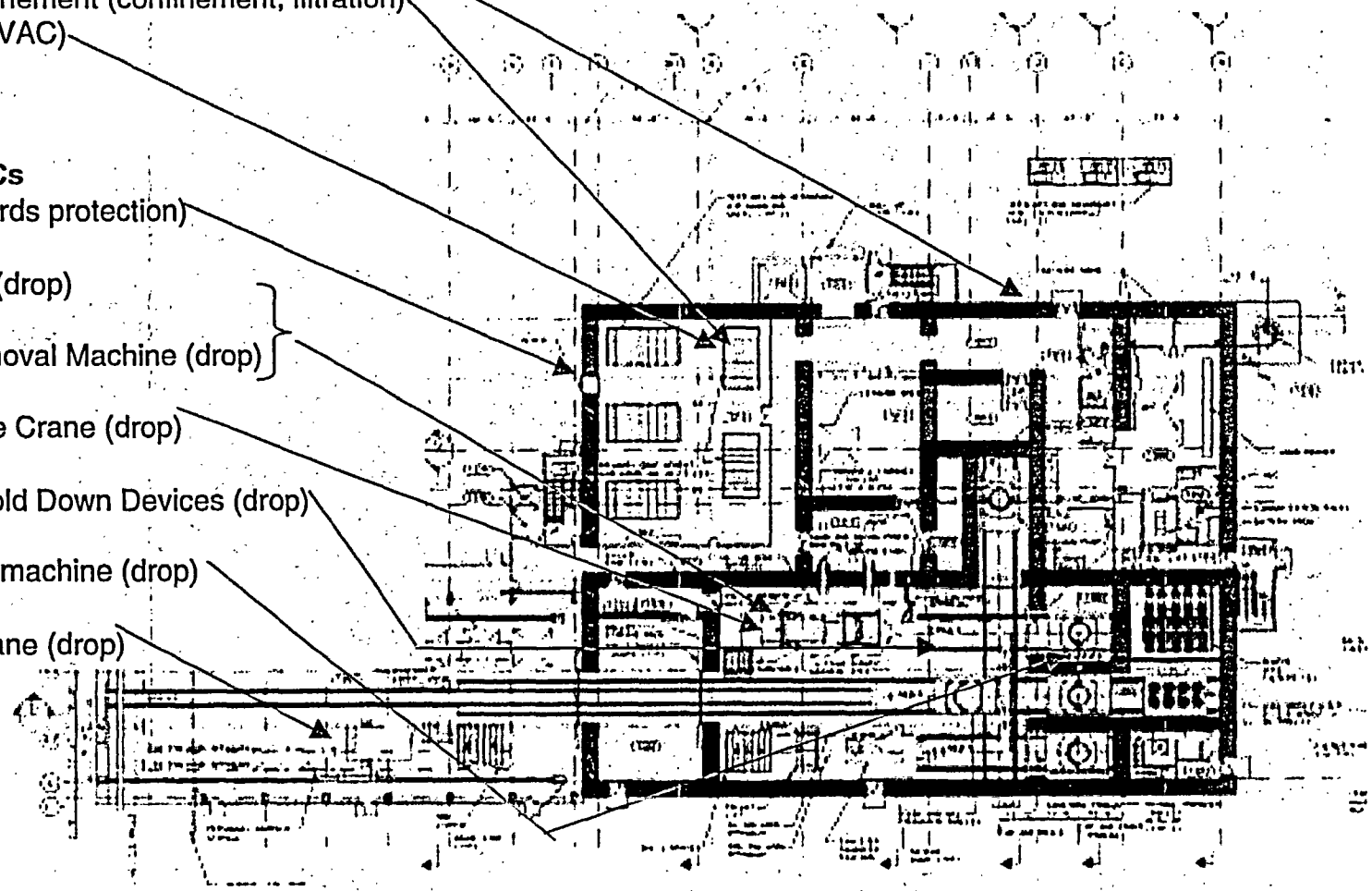
WP Tilting Machine (drop)
WP Turntable (drop)
Trunnion Collar Removal Machine (drop)

Main Transfer Bridge Crane (drop)

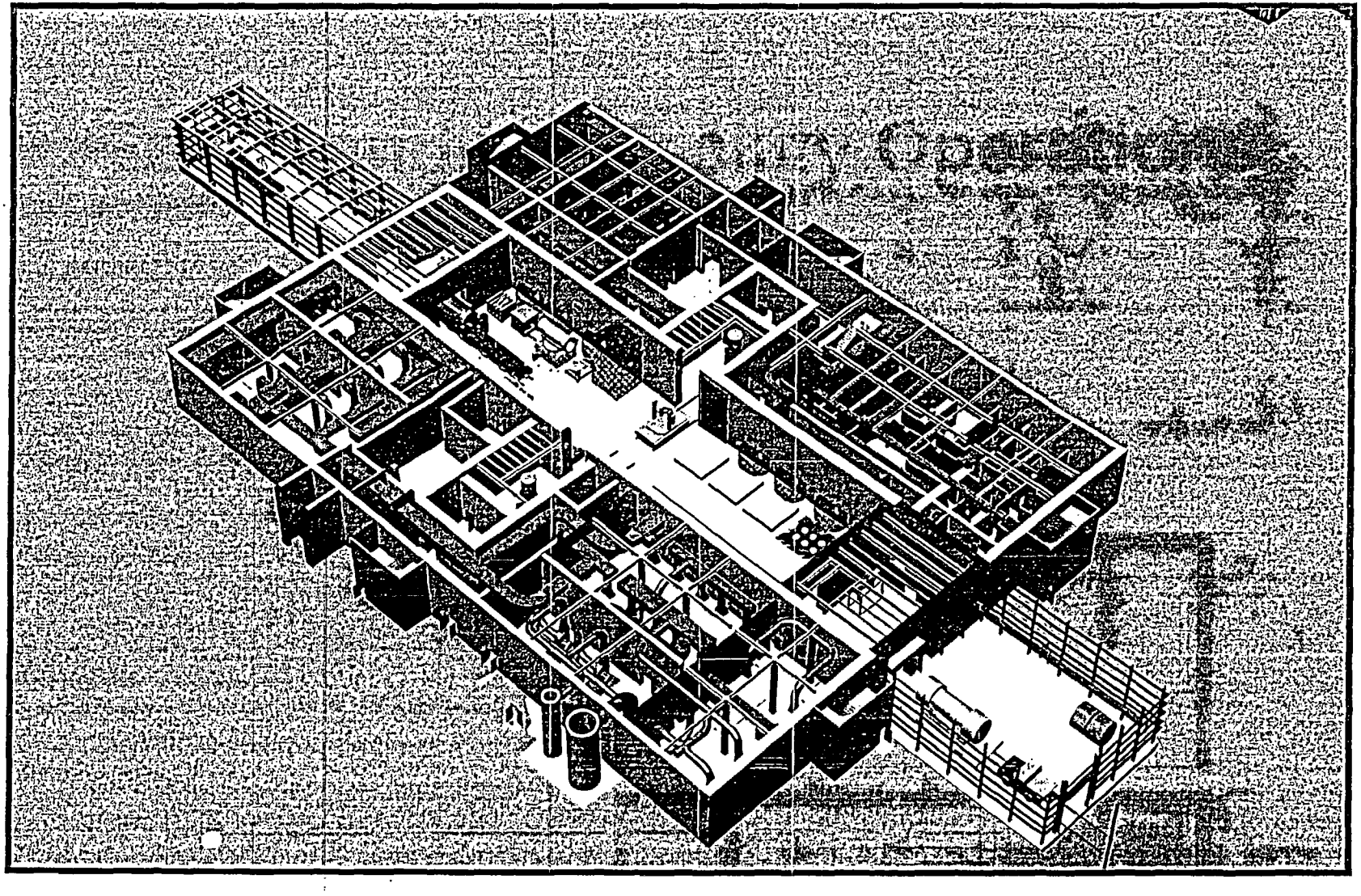
Trolley, Pedestal, Hold Down Devices (drop)

Spent Fuel Transfer machine (drop)

Vestibule Gantry Crane (drop)



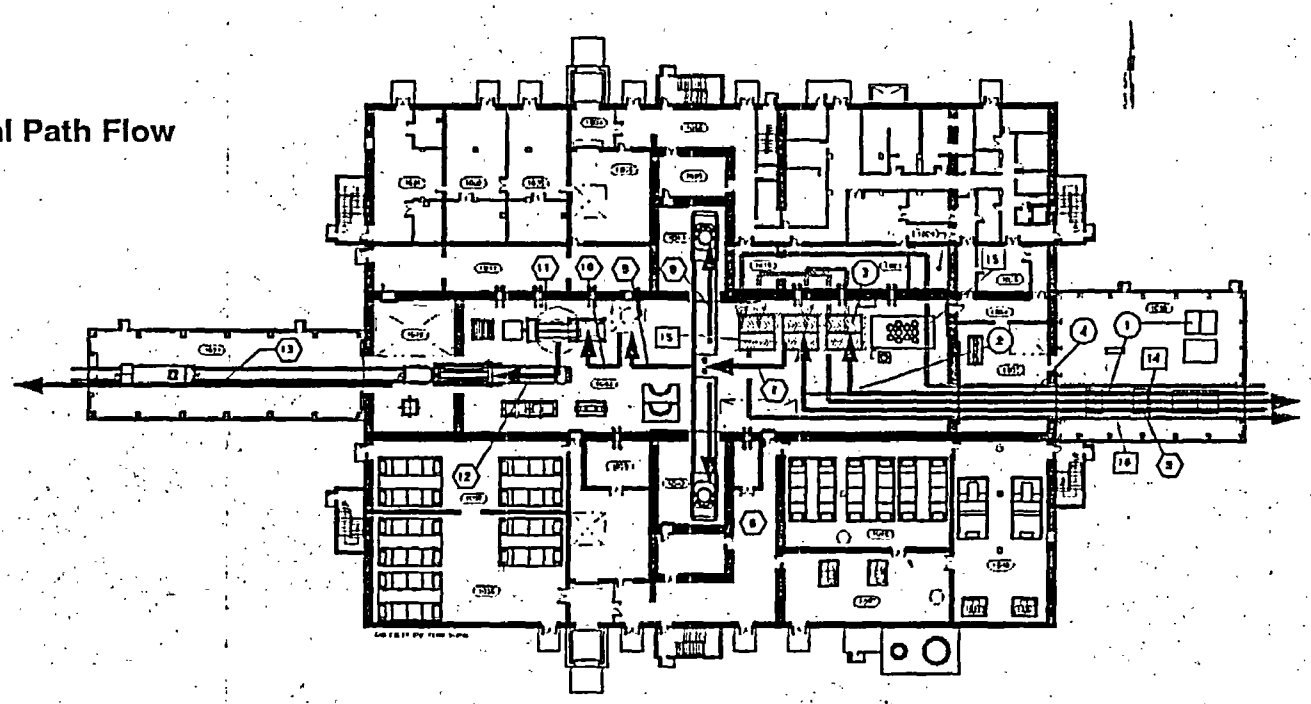
Canister Handling Facility Description



Canister Handling Facility Operations

(Continued)

Material Path Flow



TRANSPORTAION CASK OPERATIONS

1. Remove Impact Limiters and Personnel Barrier
2. Open Cask
3. Transfer Cask to Pit
4. Return Cask

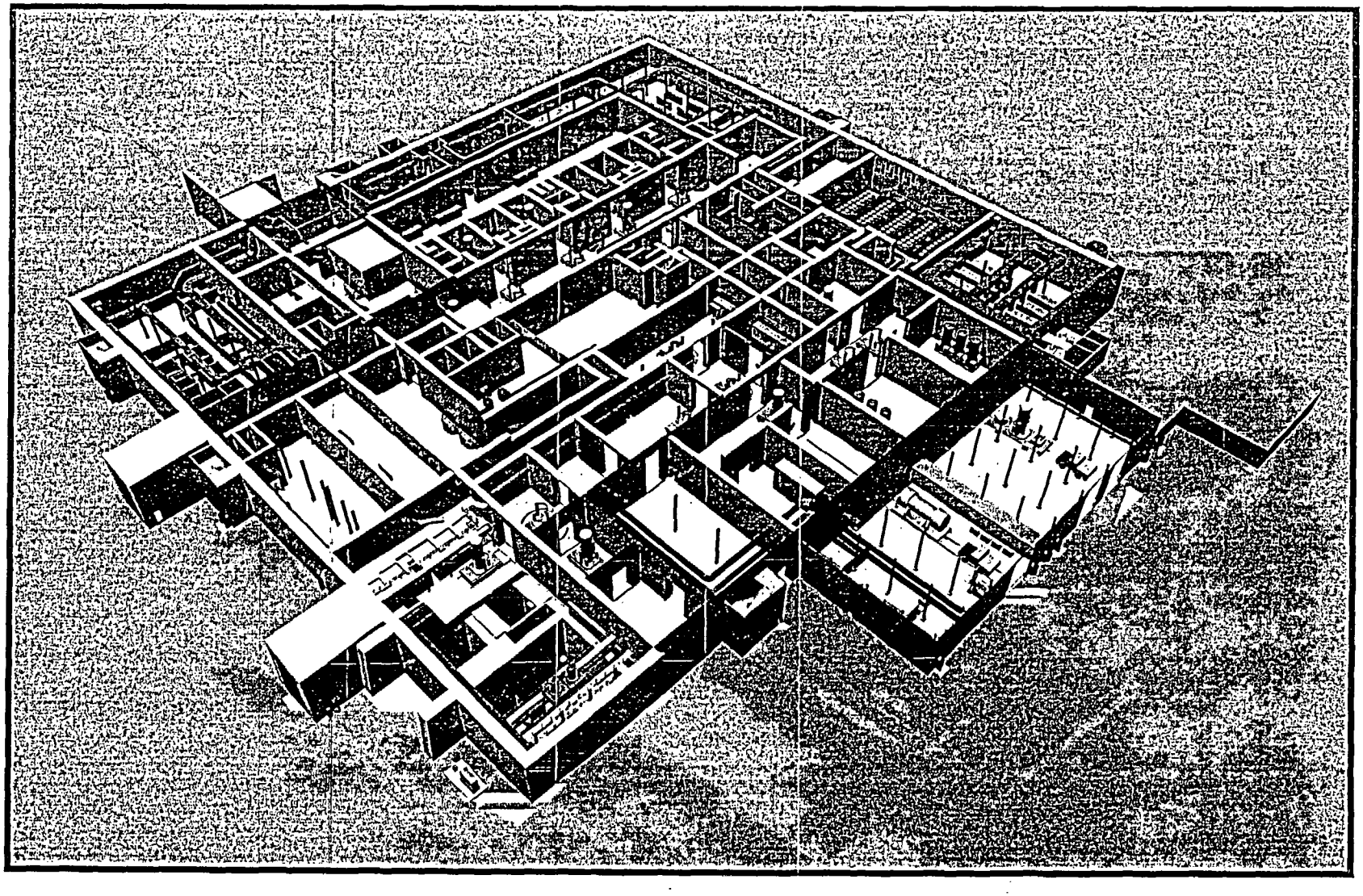
WASTE PACKAGE OPERATIONS

5. Receive Empty WP
6. Transfer WP to Pit
7. Transfer WP to WP Trolley
8. Transfer WP to WP Positioning Cell
9. Transfer Welded WP to Survey Station
10. Transfer to Tilt Station and Down End WP on to WP Pallet
11. Remove WP Trunnions (Both ends)
12. Transfer WP to WP Transporter
13. Transfer WP to Emplacement

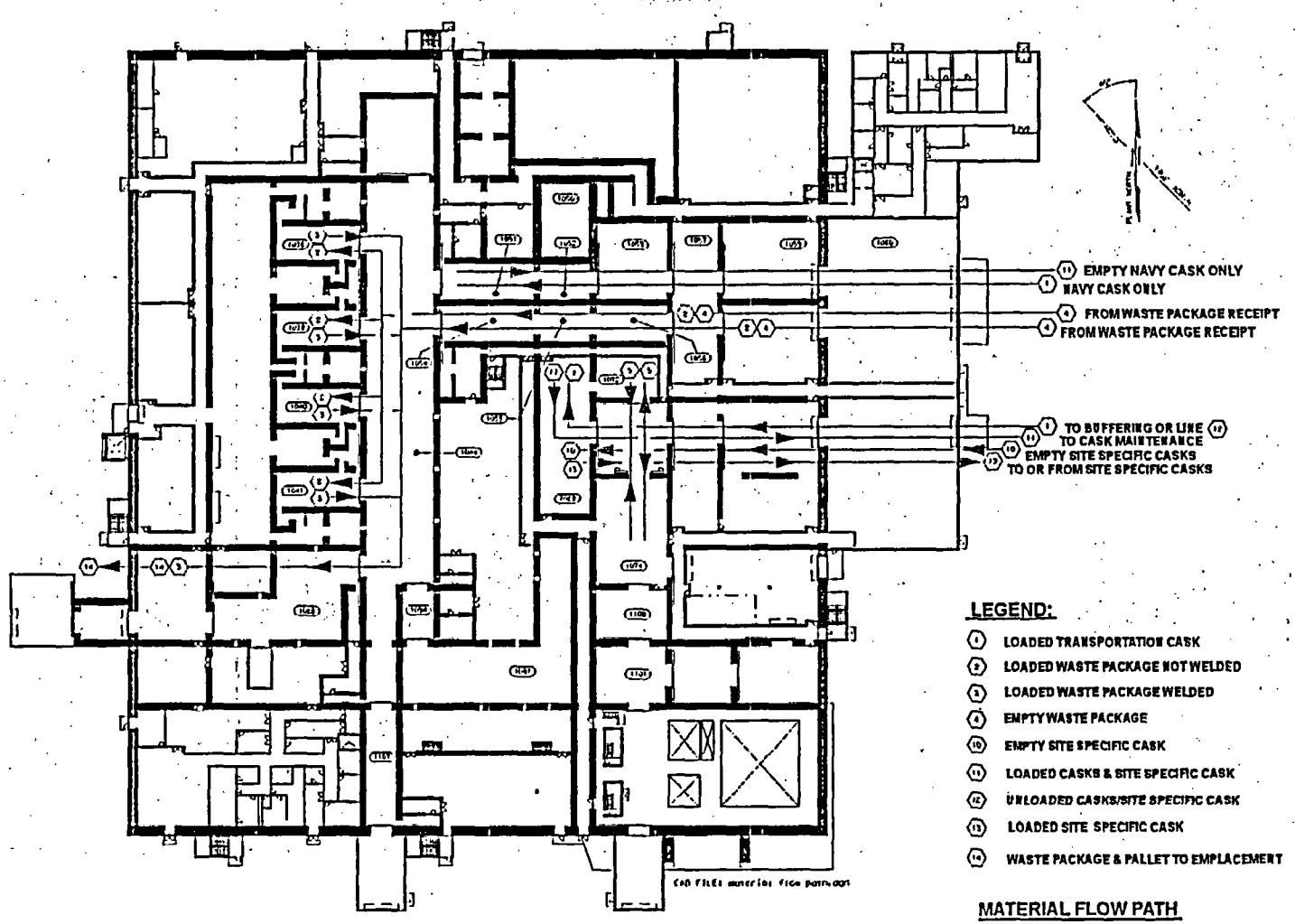
SITE SPECIFIC CASK OPERATIONS

14. Receive Site Specific
15. Transfer Site Specific Cask To Fit
16. Transfer Loaded Site Specific Casks

Dry Transfer Facility Description

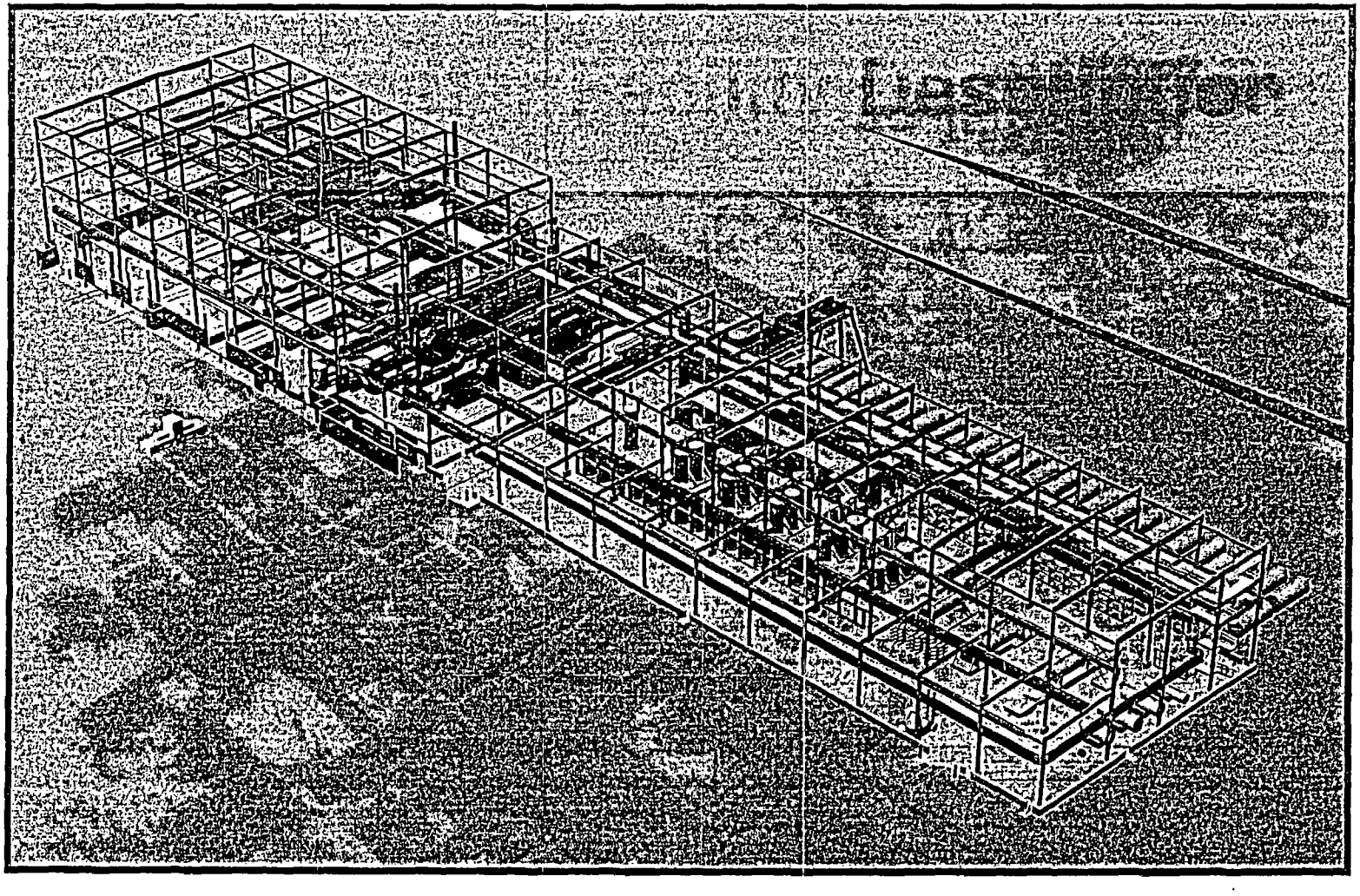


Dry Transfer Facility Operations



GROUND FLOOR PLAN AT EL +0'-0" (UN0)

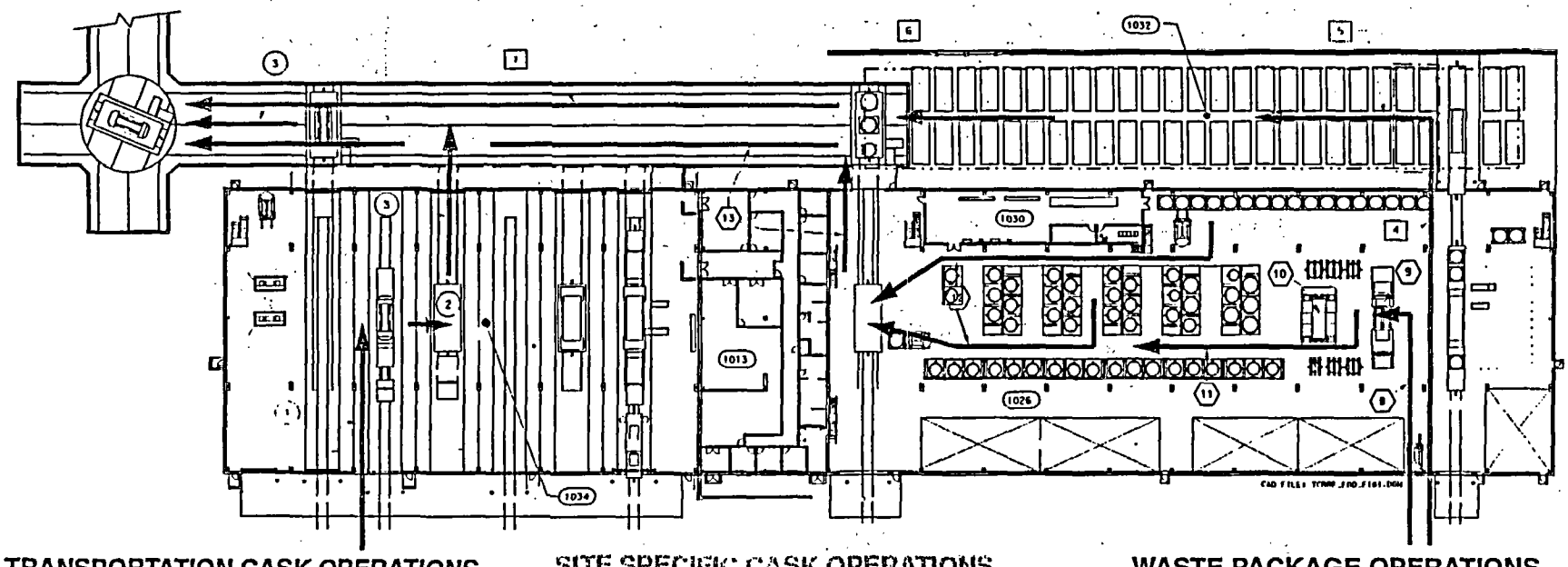
Cask and Waste Package Receipt Building Description



Cask and Waste Package Receipt Building Operations

Transportation Cask Receipt Return Facility

Warehouse Non-Nuclear Receipt Facility



TRANSPORTATION CASK OPERATIONS

- PERFORM TRANSPORTATION CASK RECEIPT INSPECTION AND SURVEY
- CASK/SKID TRANSFER TO SITE RAIL TRANSFER CAST (SRTC)
- TRANSFER OF SRTC FROM RECEIPT BLDG. TO PROCESSING VIA BUFFER

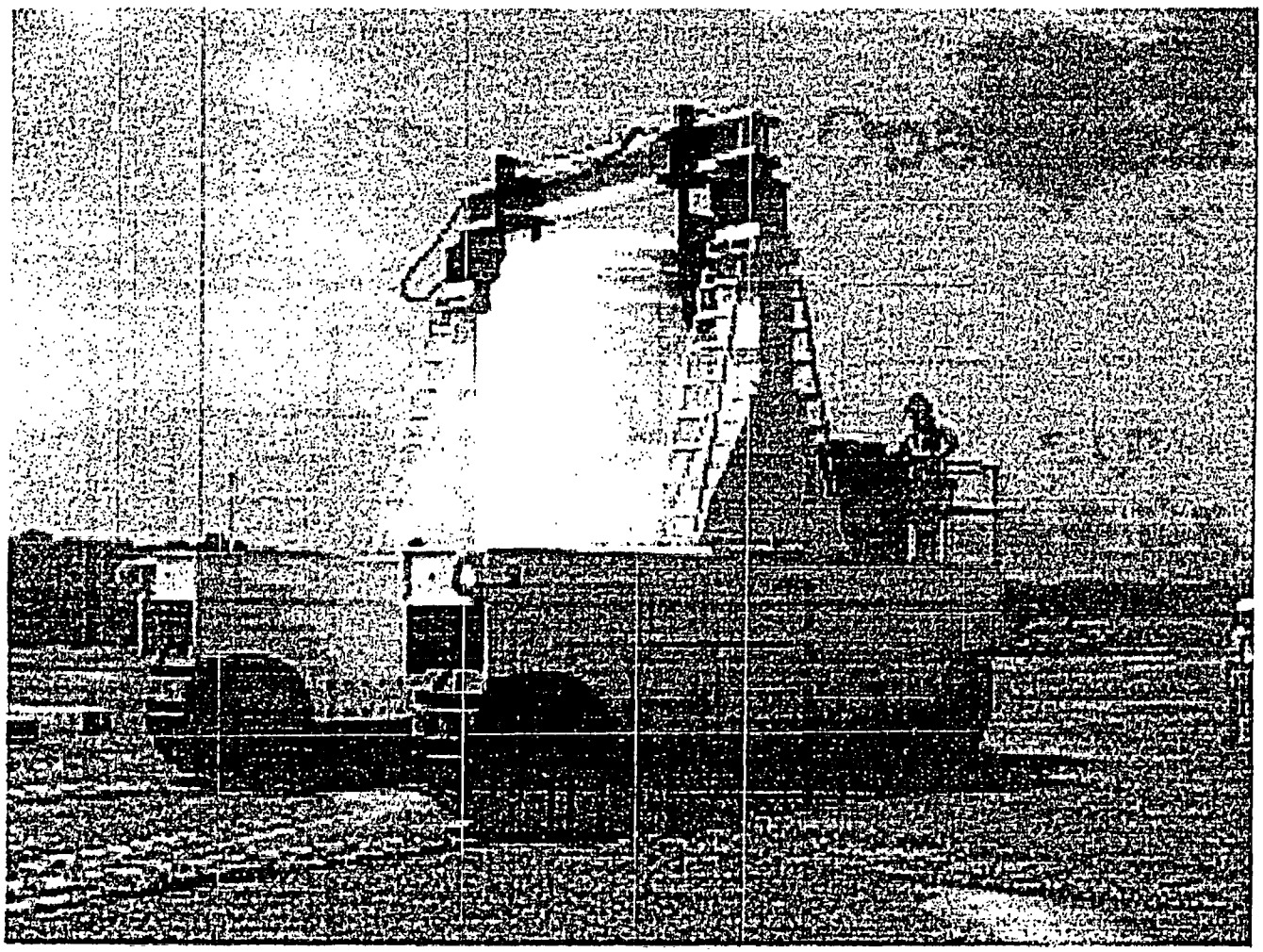
SITE SPECIFIC CASK OPERATIONS

- NEW MSC RECEIPT AND INSPECTION
- TRANSFER MSC/SKID TO STAGEING PAD
- TRANSFER TO MSC/SKID TO SRTC
- TRANSFER OF MSC TO PROCESS BLDG. VIA BUFFER

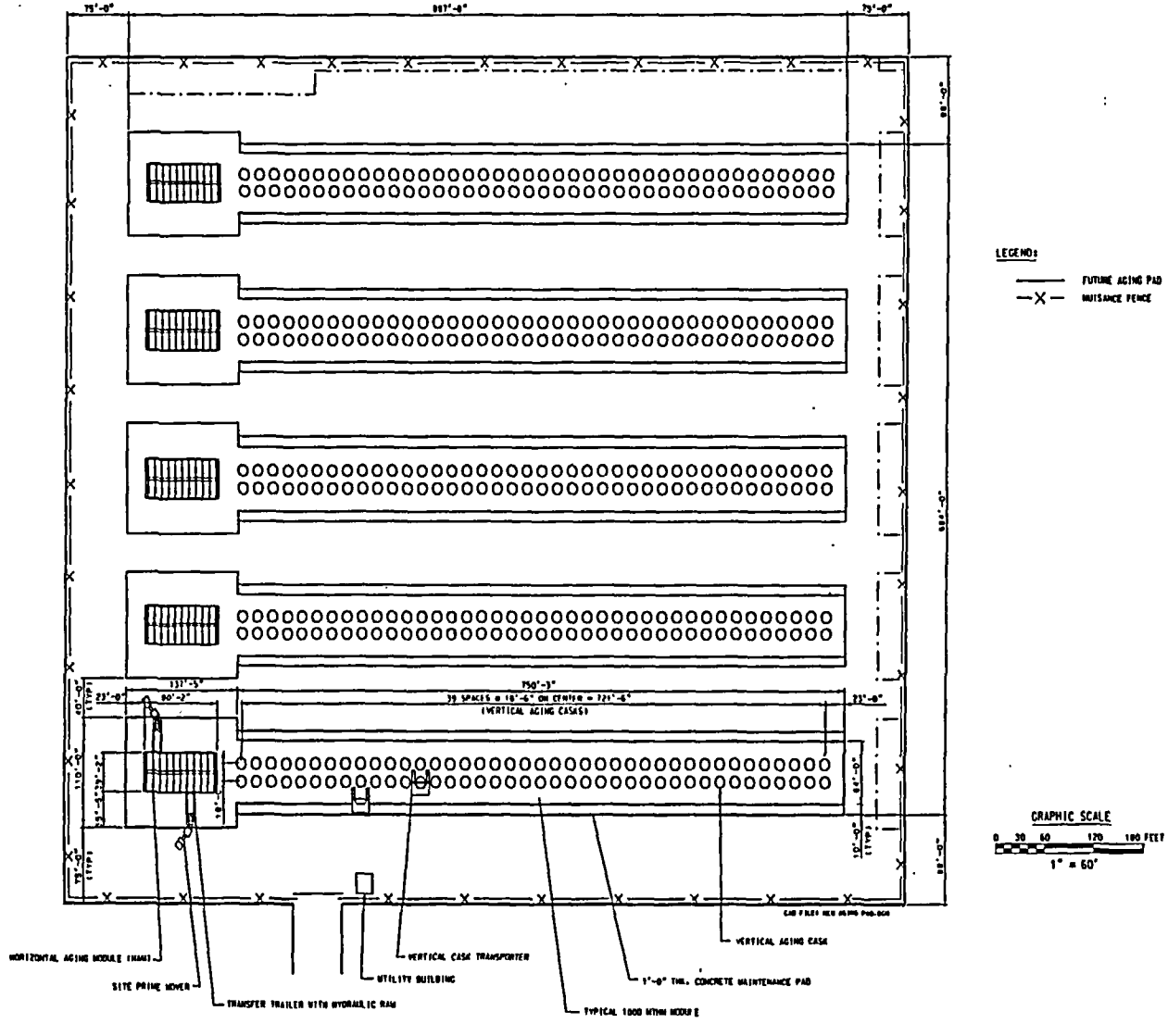
WASTE PACKAGE OPERATIONS

- 1 WASTE PACKAGE LID RECEIPT
- 2 WASTE PACKAGE AND LID TRANSFER TO STAND FOR INSPECTION
- 10 TRUNNION COLLAR INSTALLATION
- 11 VERTICALIZE AND STAGE WASTE PACKAGE AND LID
- 12 WASTE PACKAGE AND LID TRANSFER FOR INVENTORY TO SRTC
- 13 TRANSFER WASTE PACKAGE AND LID FROM RECEIPT BLDG. TO PROCESS BLDG. VIA BUFFER

Aging Transporter



Aging Pad


LEGEND:
FUTURE AGING PAD
NUISANCE FENCE
GRAPHIC SCALE
0 30 60 120 180 FEET
1" = 60'
VERTICAL AGING CASE
VERTICAL CASE TRANSPORTER
UTILITY BUILDING
SITE PRIME MOVER
TRANSFER TRAILER WITH HYDRAULIC RAM
TYPICAL 1000 MTHM MODULE

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Surface Facility Waste Handling Operations

Presented to:
NRC/DOE Technical Exchange on Yucca Mountain Surface and Subsurface Facilities

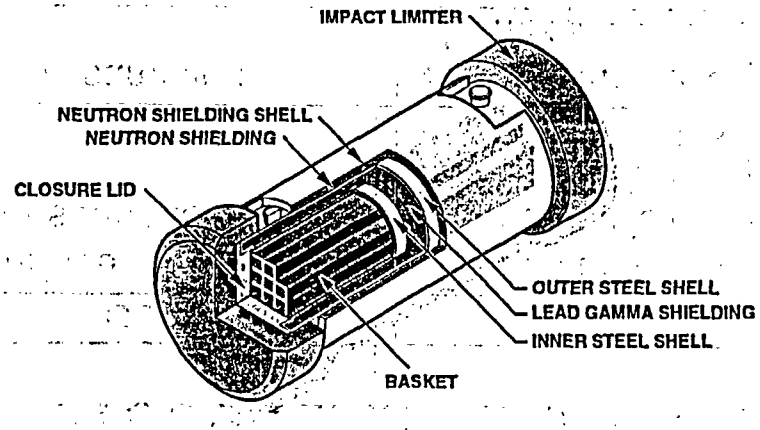
Presented by:
Stephen J. Cereghino
Manager of Licensing
Bechtel SAIC Company, LLC

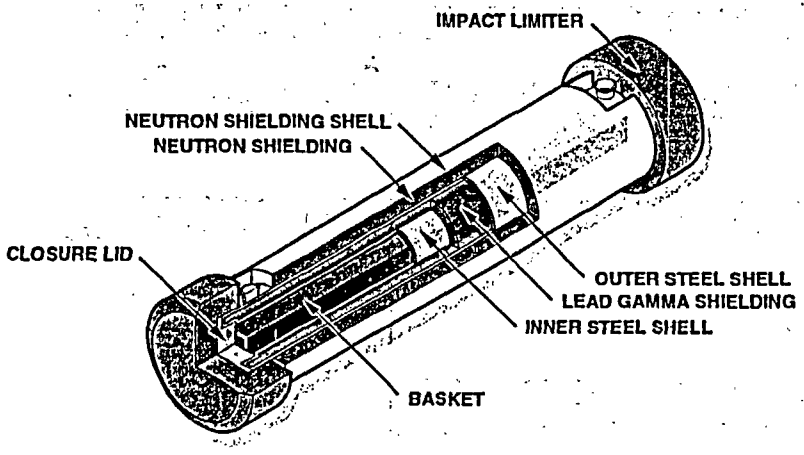
September 14-15, 2004
Las Vegas, Nevada

Surface Facility Waste Handling Operations

- Transportation Casks
- Waste Packages (WPs)
- Waste Transfer Areas
- WP Closure Cells
- Loading of Waste Transporters

Surface Facility Waste Handling Operations
Transportation Casks





- Casks are large, heavy, robust, sealed metal containers
- Multiple layers of radiation shielding
- Cask sizes:
  - Rail casks weigh ~100 to 165 tons and are up to ~27 ft long and ~11 ft in diameter with impact limiters installed
  - Truck casks weigh ~24 tons and are ~16 ft long and ~4 ft in diameter

Surface Facility Waste Handling Operations Transportation Casks

(Continued)

- Transportation casks are important to safety (ITS)
- Capability to withstand design basis natural phenomena while staged on surface
- Procedural safety controls

Control	Basis
Surface transportation control	Ensures that casks are transported on appropriate vehicles. Ensures that other traffic is controlled along route of transport between buildings, buffer area, aging pads, and north portal. Minimizes likelihood of a drop of cask. Minimizes likelihood of collisions between vehicles.
Cask sampling	Ensures that failed fuel is detected and segregated appropriately. Minimizes likelihood of abnormal conditions.

Surface Facility Waste Handling Operations Transportation Casks

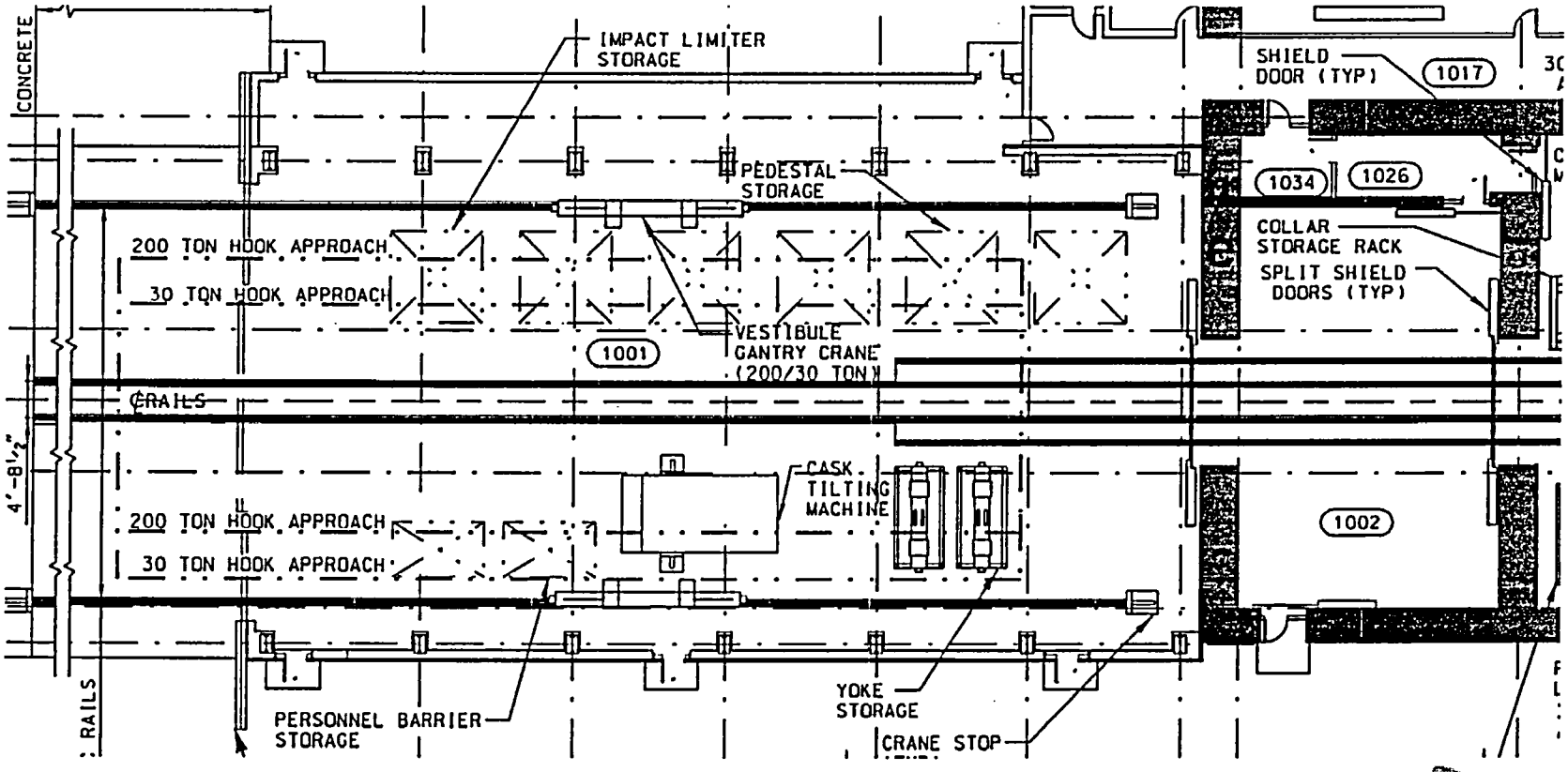
(Continued)

- Transportation cask preparation
  - Casks are either:
    - Moved directly to Fuel Handling Facility (FHF), or
      - Moved to Cask and WP receipt buildings
    - Placed on site rail transfer carts (SRTC)
    - Moved in surface facilities on SRTCs
      - Dry Transfer Facility (DTF)
      - Canister Handling Facility (CHF)
      - Buffer Area
  - Cask preparation activities
    - Remove personnel barriers and tie-downs
    - Remove impact limiters, if necessary
  - Contamination and radiation survey of cask and commercial transporter

Surface Facility Waste Handling Operations Transportation Casks

(Continued)

- **FHF transportation cask receipt areas**
  - Entrance vestibule and preparation room



Surface Facility Waste Handling Operations Transportation Casks

(Continued)

- Major equipment in FHF entrance vestibule and preparation room
  - 200-ton gantry crane for handling casks and WPs
    - Main hook and load path: ITS components
      - » Crane trolley structure, bridge structure, hoisting drive train, load gripping device
      - » Ensure probability of load drop is $< 1 \times 10^{-5}$ drops per lift
      - » During seismic event, will not damage transportation cask containing spent nuclear fuel (SNF) or high-level waste (HLW)
  - Lifting yoke: ITS
  - Import-export trolley: ITS
  - 30-ton auxiliary hook: non-ITS

Surface Facility Waste Handling Operations Waste Packages

- WP preclosure functions
  - Prevent release of radioactivity to preclude Category 1 and 2 event sequences: ITS
    - Drops and slapdowns
      - » Limit vertical drop of multicanister overpack (MCO) to $\leq 3°$ angle
      - » Some events credit trunnions
    - Rockfall
    - Seismic
    - Internal missiles
  - Prevent oxidation of waste form: non-ITS
  - Prevent damage to cladding: non-ITS
- WP ITS components
  - Inner and outer vessels
  - Inner, middle, and outer lids

Surface Facility Waste Handling Operations Waste Packages

(Continued)

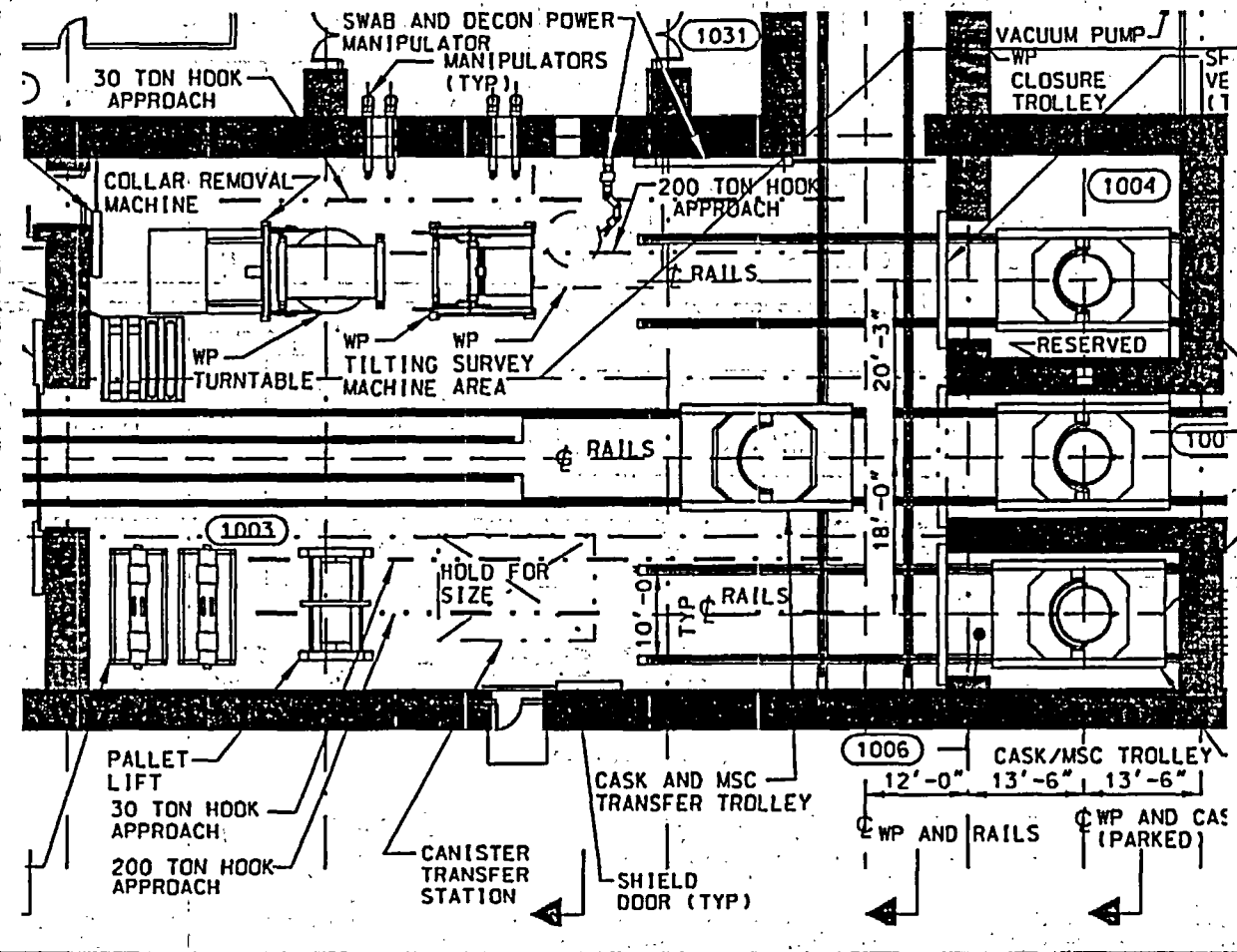
- WP postclosure functions
  - Prevent/reduce water contact with waste form: Important to Waste Isolation (ITWI)
  - Provide dry, inert environment prior to breach to delay onset of waste form degradation: ITWI
  - Provide internal materials that sorb radionuclides to limit release from breached WP: ITWI
  - Conduct heat to protect cladding: ITWI
  - Criticality control: ITWI

Surface Facility Waste Handling Operations
Waste Packages
(Continued)

- WP ITWI components :
  - Inner and outer vessels
  - Inner, middle, and outer lids
  - Interting gas
  - Basket materials
  - Thermal shunts and inerting gas
  - Absorber plates

Surface Facility Waste Handling Operations
Waste Transfer Areas

FHF Transfer Areas Plan – Ground Floor

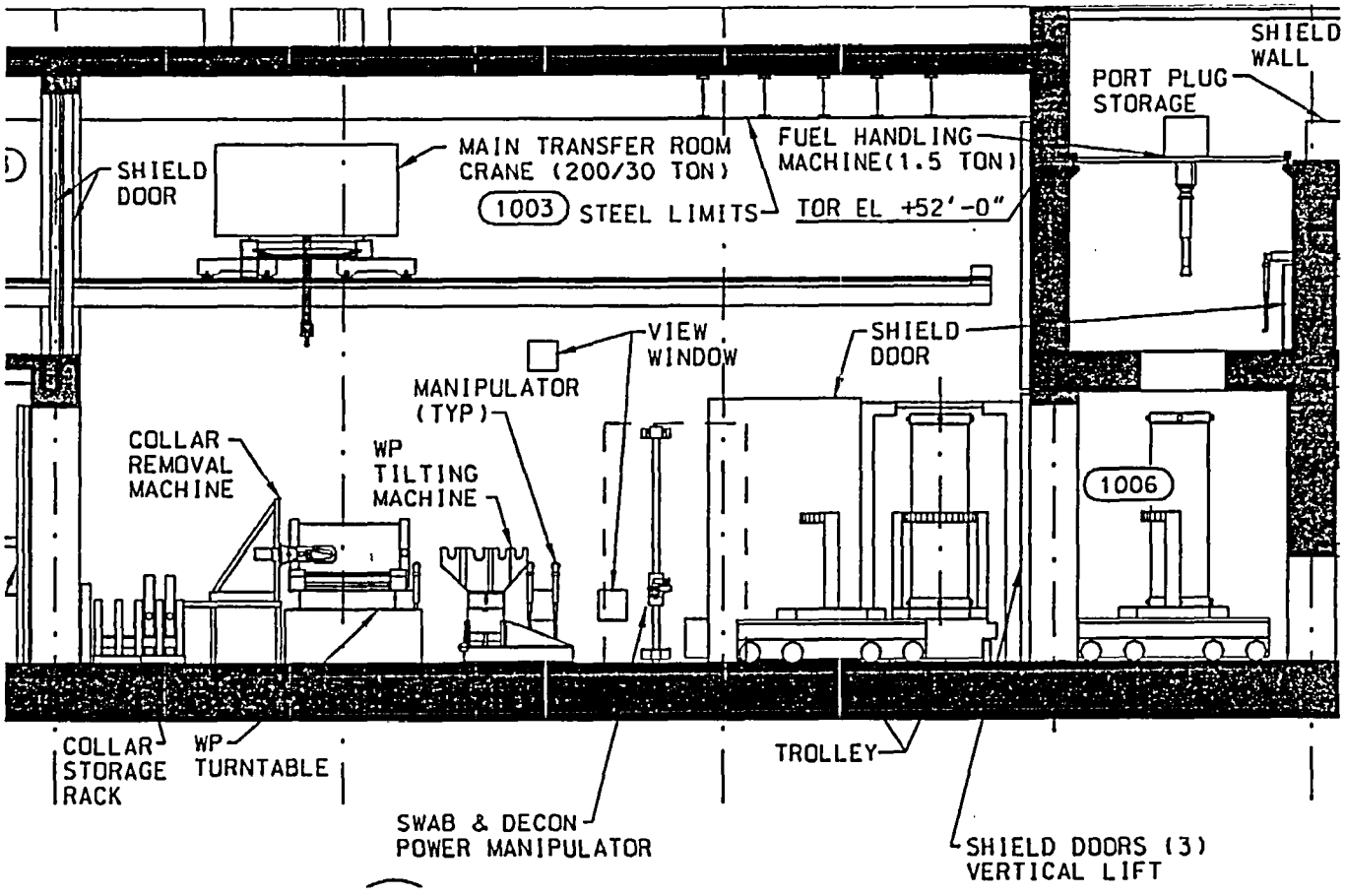


Main transfer room

Transfer bays #1, 2, 3

Surface Facility Waste Handling Operations
Waste Transfer Areas
(Continued)

FHF Transfer Areas – Section



Surface Facility Waste Handling Operations
Waste Transfer Cell

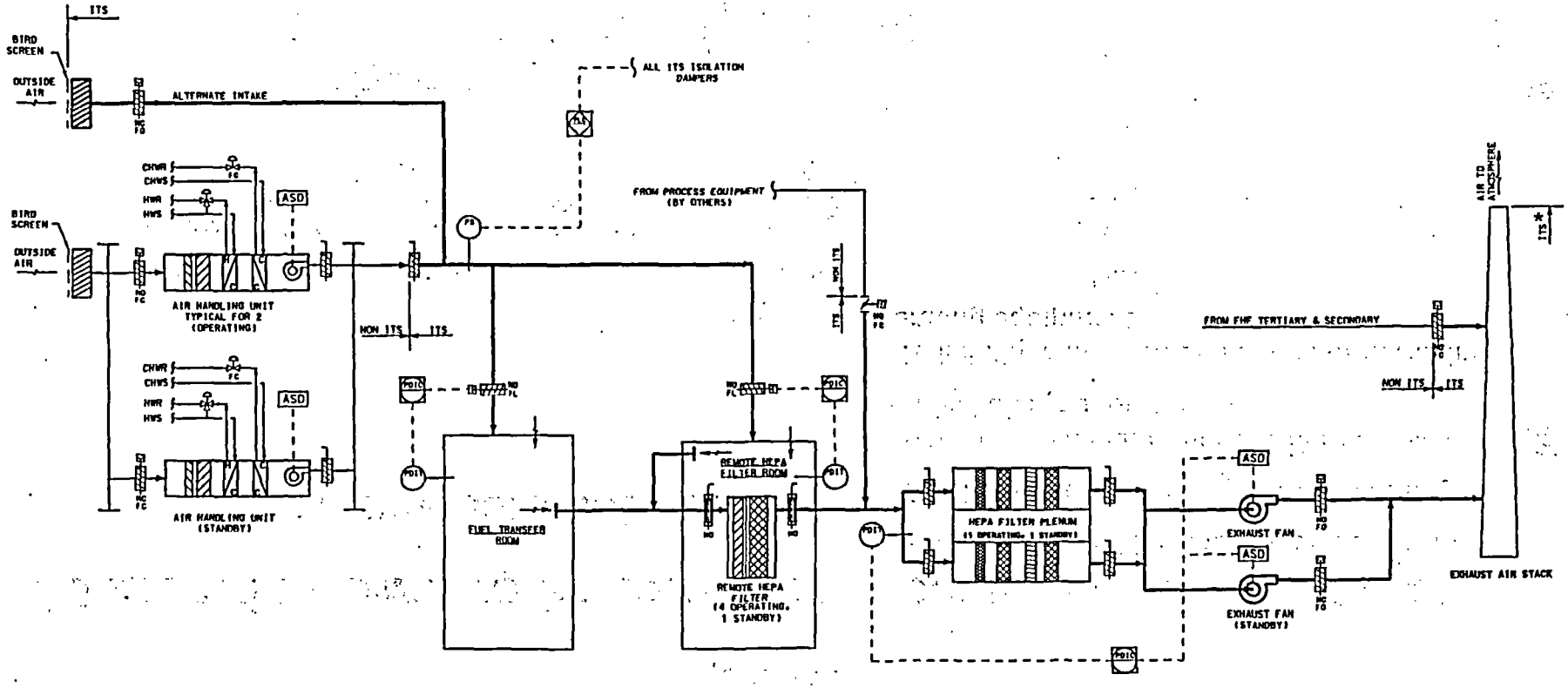
- Major equipment in FHF transfer cell
  - Cranes handling SNF and HLW are ITS
  - 200-ton overhead bridge crane
    - Main hook and load path: ITS
    - Specific trolley structures, bridge structures, hoisting drive trains, and load-gripping devices are ITS components
    - Reduce the probability of a load drop
    - Ensure that seismic event does not cause crane to overturn, derail, lose any main structural components, or drop load
  - Cask lifting yoke: ITS
  - 30-ton auxiliary hook: non-ITS
  - Transfer bay trolley: ITS
  - Hold-down devices: ITS
  - Pedestals: ITS
  - Three docking stations
    - Lid grapple, mechanical seal, and port plug are ITS: part of confinement boundary
  - 1.5-ton capacity spent fuel transfer machine (SFTM): ITS
  - 30-ton fuel transfer maintenance crane: non-ITS

Surface Facility Waste Handling Operations
Waste Transfer Cell
(Continued)

- Major equipment in FHF transfer cell
  - Nuclear heating, ventilation, and air-conditioning (HVAC) system for confinement zones
    - Three confinement subsystems
    - Primary confinement exhaust air cleaning units: ITS
      - » Two stages of high-efficiency particulate (HEPA) filters
      - » Alternate air supply to primary confinement subsystem: ITS
      - » ITS controls and electric power
    - Normal supply air handling units: non-ITS
  - Industrial HVAC system: non-ITS

Surface Facility Waste Handling Operations Waste Transfer Areas

FHF Primary Confinement HVAC Block Diagram



** Elevated release through stack is not credited in preclosure safety consequence analysis.*

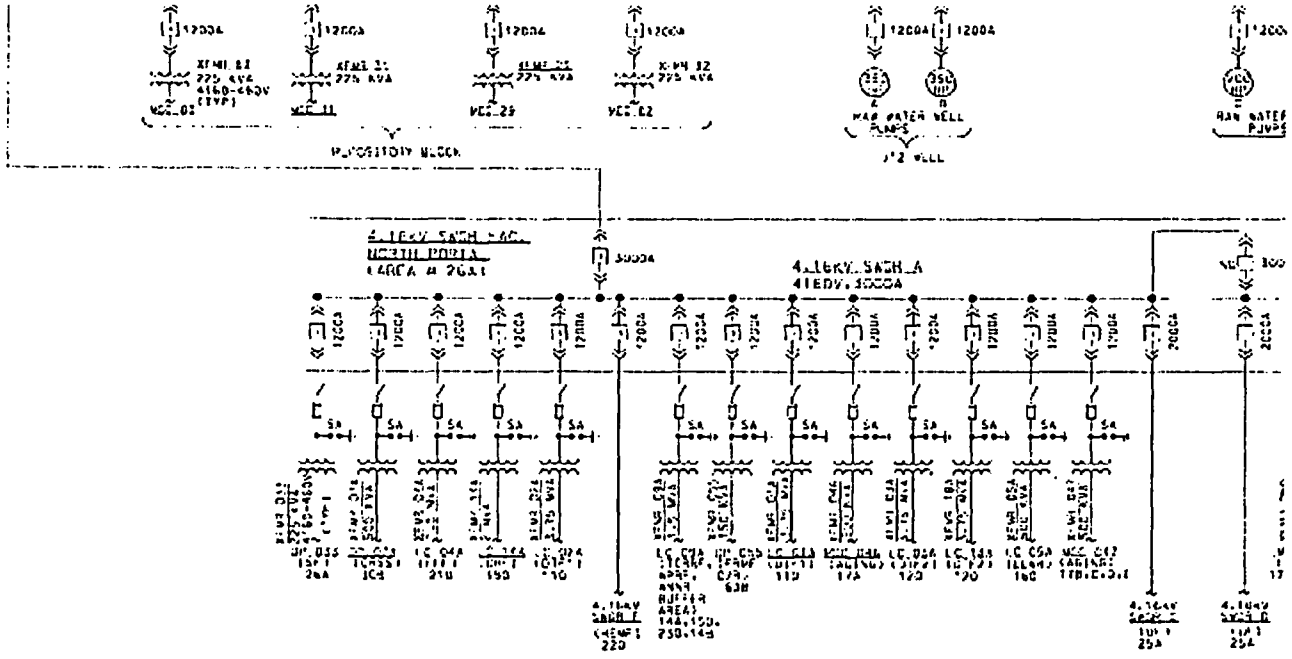
Surface Facility Waste Handling Operations Waste Transfer Areas

(Continued)

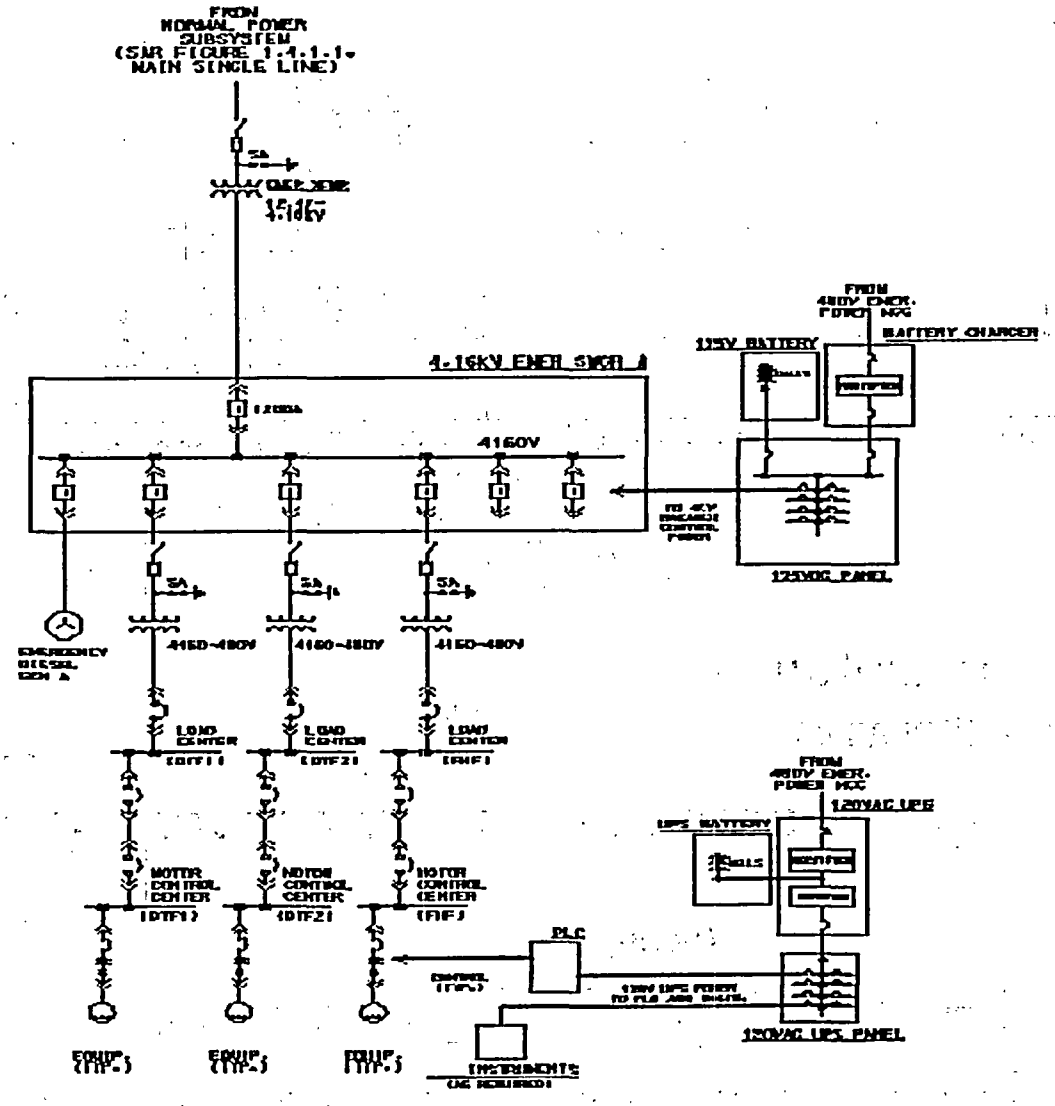
ITS Electric Power to Primary Confinement HVAC – Load Side

- "B" switchgears not shown

- Estimated reliability is for required mission time
- ITS distribution to appropriate generating source
- Reliability estimate will consider complete electrical distribution system
- Reliability enhanced due to use of normally operating equipment



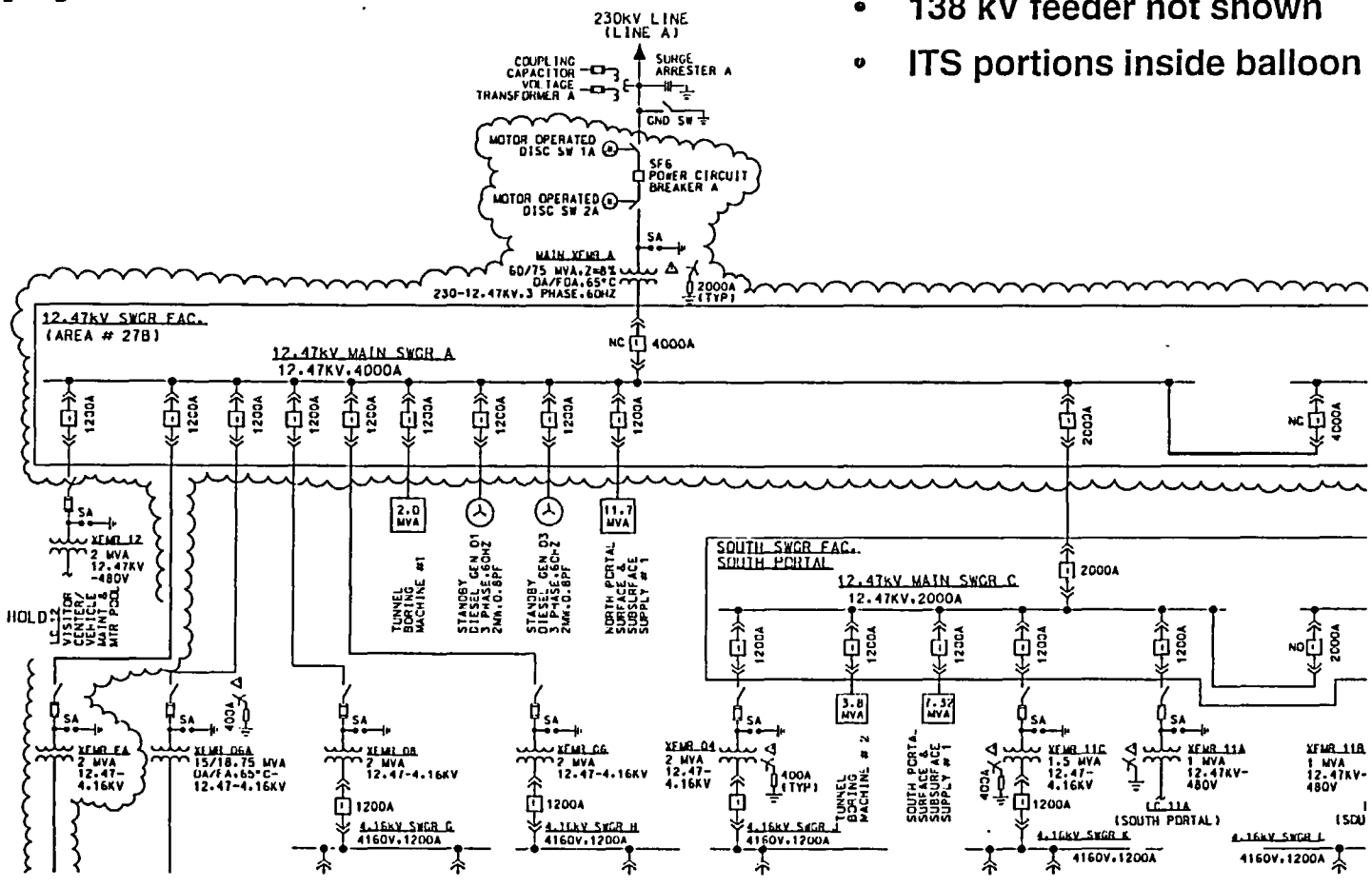
Surface Facility Waste Handling Operations
Waste Transfer Areas (continued)



Surface Facility Waste Handling Operations
Waste Transfer Areas
(Continued)

ITS Electric Power to Primary Confinement HVAC – Power Supply Side

- 138 kV feeder not shown
- ITS portions inside balloon



Surface Facility Waste Handling Operations Waste Transfer Areas

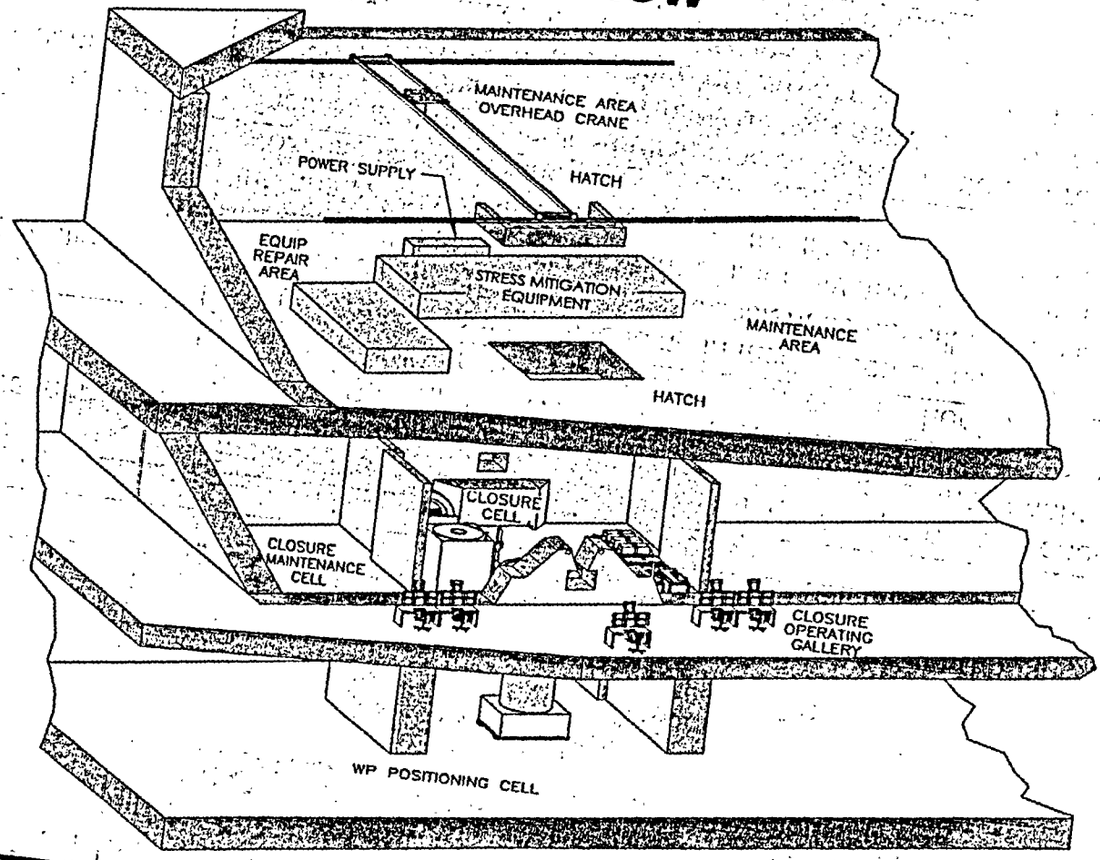
(Continued)

Procedural Safety Controls

Control	Basis
SNF/HLW mechanical handling	Ensures that cranes, transporters, rigging, load paths, and energy absorbing crush pads are selected and in place for the variety of lifts involving SNF and HLW. Ensures that cranes, rigging, load paths, and protective barriers are selected and in place for other heavy load handling
Combustible material control	Ensures that combustible loading in facility rooms and external to the facilities is limited. Ensures that transient combustibles are limited. Minimizes the likelihood of a fire of intensity and duration that is beyond the analyzed conditions. Minimizes the likelihood of a range fire in close proximity to the facility.
Transient moderator material control	Ensures that only small quantities of moderator material are transferred into the processing cells manually by the operator when waste forms are present. Ensures that waste forms are not present when large quantities of moderator material are brought into the processing cells manually by the operator. Minimizes the likelihood of a criticality event.
Waste package loading; thermal and criticality requirements	Ensures that waste forms are inserted in the appropriate waste package configuration. Minimizes likelihood of excessive heating of SNF cladding. Minimizes likelihood of criticality due to lack of neutron absorber, inappropriate geometric configuration, or excessive fissile material.

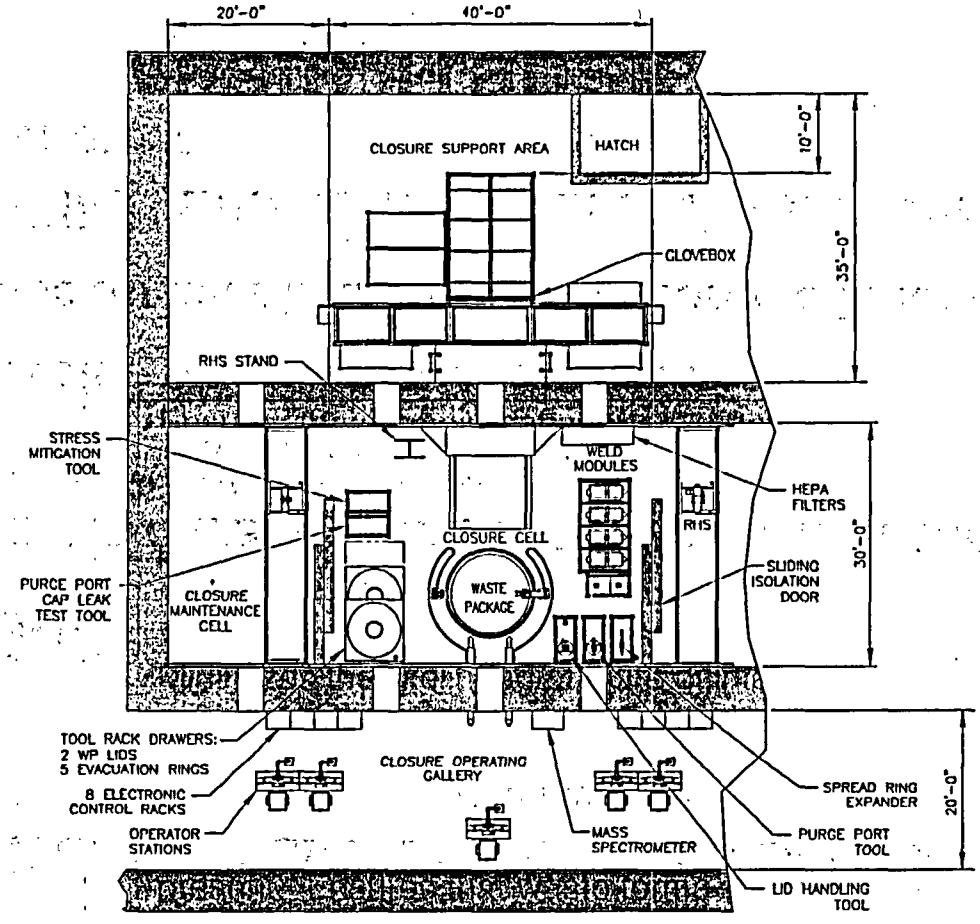
Surface Facility Waste Handling Operations
Waste Package Closure Cells

WP Closure Areas – Side View



Surface Facility Waste Handling Operations
Waste Package Closure Cells
(Continued)

WP Closure Areas – Operating Floor

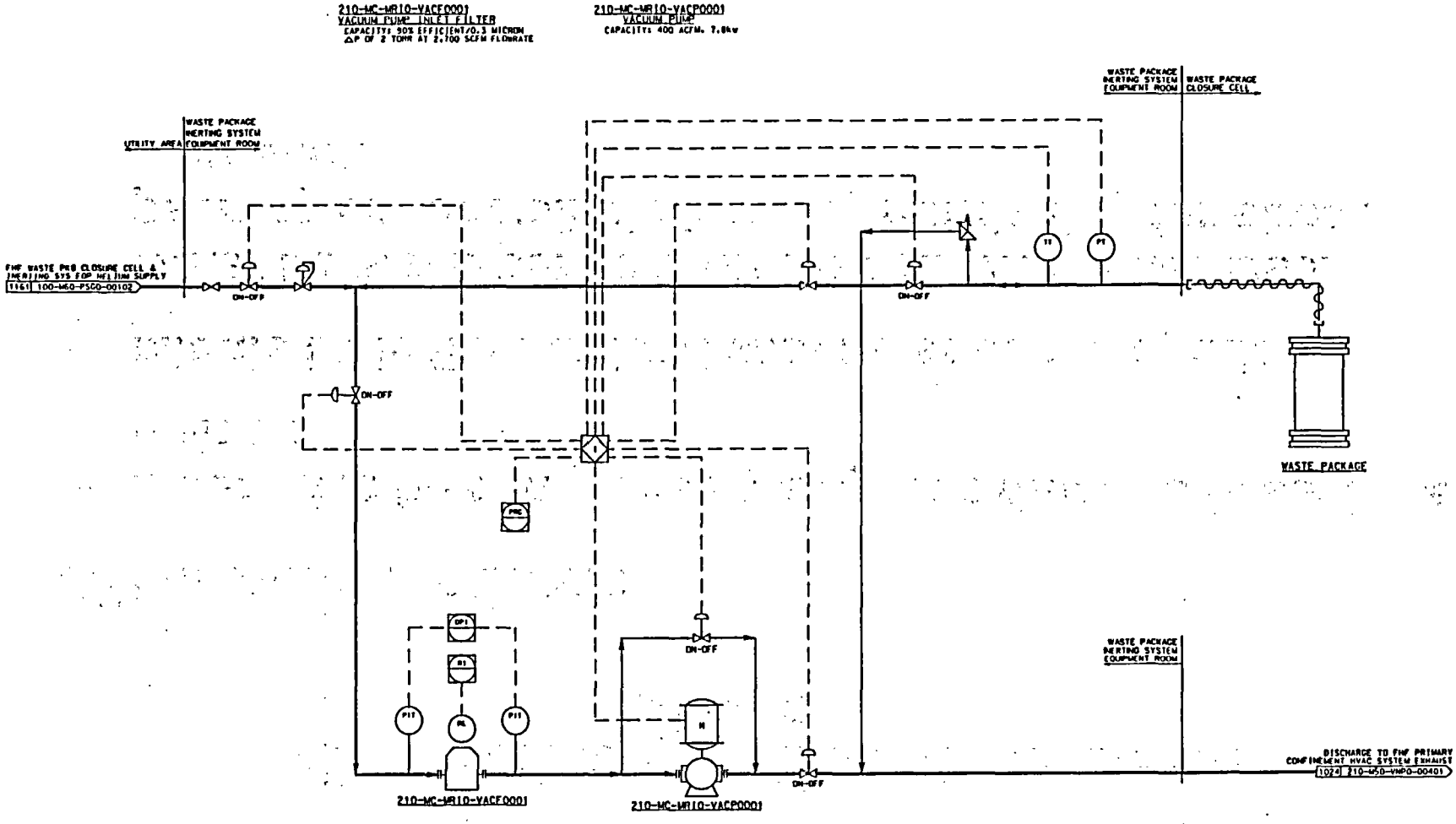


Surface Facility Waste Handling Operations
Waste Package Closure Cells
(Continued)

- **WP fill gas**
  - Before closure, inner vessel is evacuated and helium is added through purge port
    - Prevents oxidation of waste form
    - Helps transfer heat from waste form to inner vessel wall
  - After filling and successful leak test, port is plugged and welded shut

Surface Facility Waste Handling Operations
Waste Package Closure Cells
(Continued)

WP Inerting System



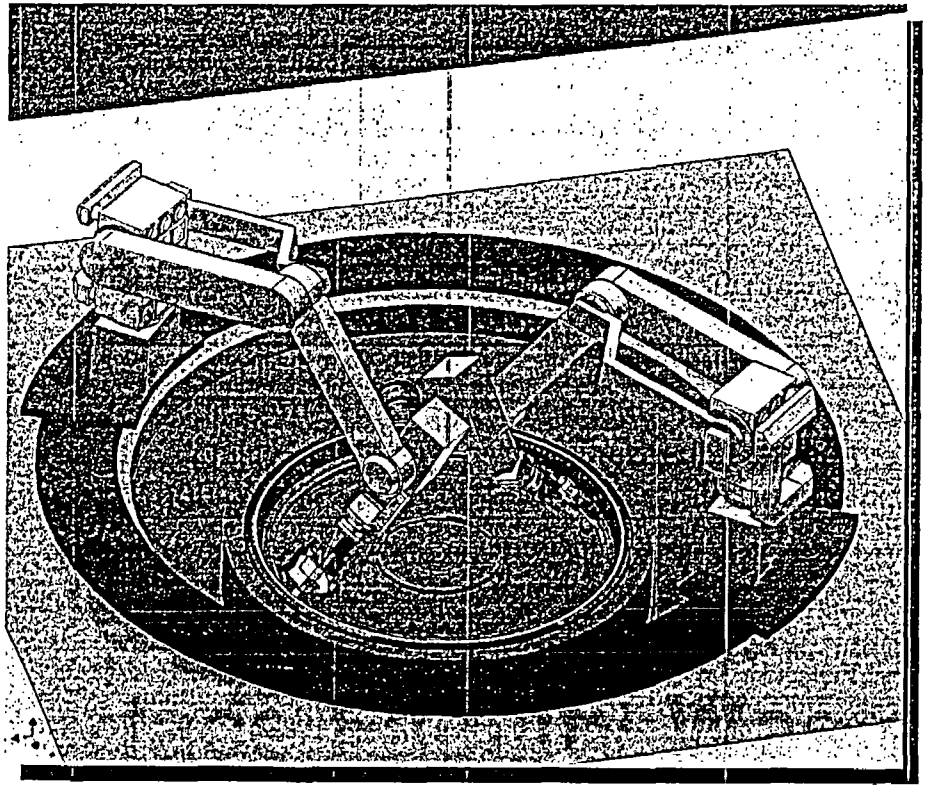
Surface Facility Waste Handling Operations
Waste Package Closure Cells
(Continued)

- **WP closure methods**
  - Inner lid is held in place by a spread ring and is seal welded
  - Middle lid is fillet welded with no stress mitigation
  - Outer lid is full-penetration welded with either laser peening or controlled plasticity burnishing for stress mitigation

Surface Facility Waste Handling Operations Out of Package Criticality Control

- Passive design features preclude or minimize presence of moderator:
  - No utility or cooling water piping
  - No water- or foam-based fire suppression
  - Low-hydrogen-content hydraulic oil for cranes
  - Double retention barriers to minimize hydraulic oil leaks
  - Curbs at entries and drains
  - Watertight doors, walls, and barriers
  - Watertight penetration seals
  - Limited reservoirs
    - Ultrasonic coupling fluid
    - Low plasticity burnishing

Surface Facility Waste Handling Operations
Waste Package Closure Cells

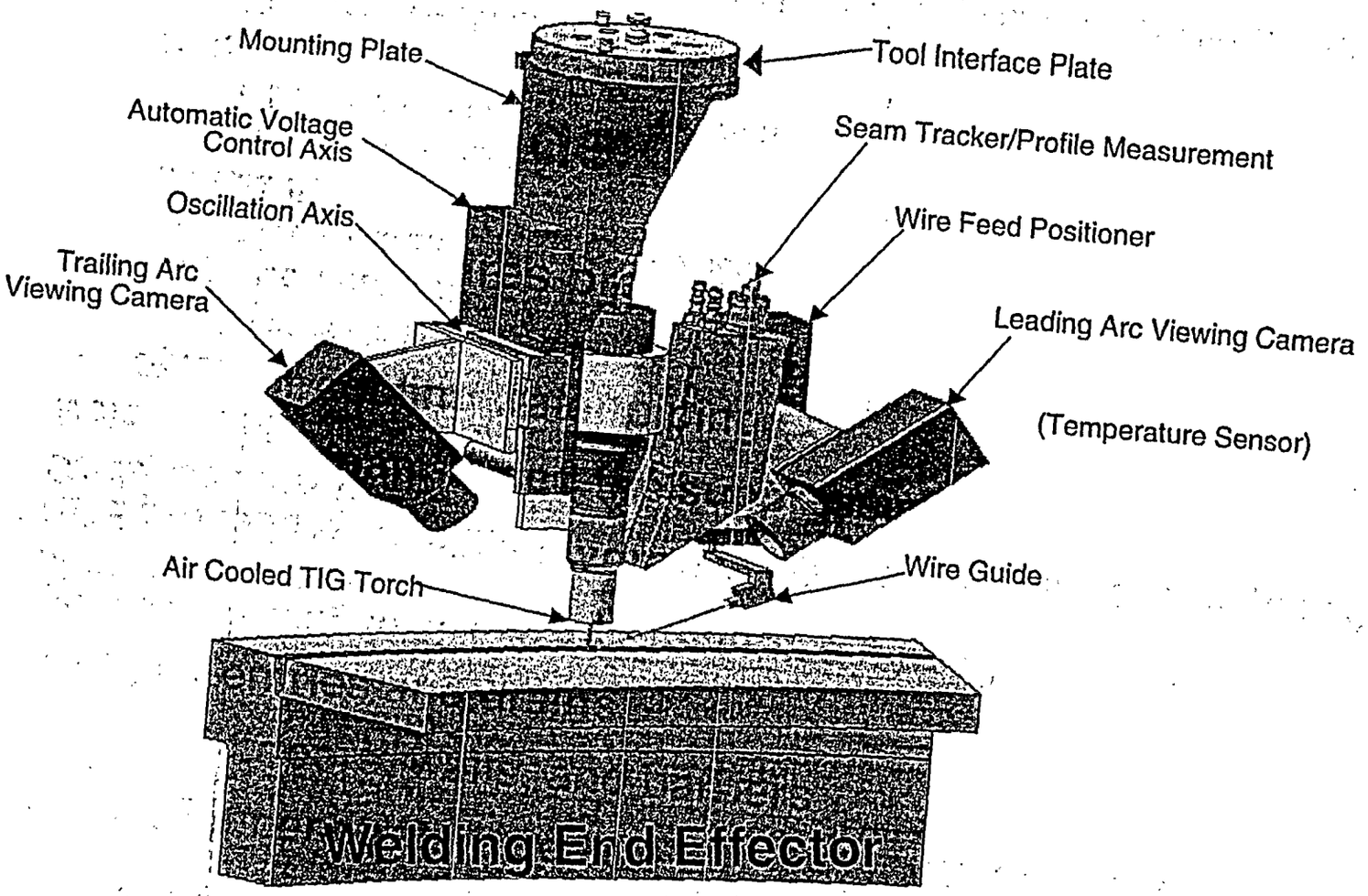


Welding robots

Two robots, 180° apart, on circular track, perform welding and non-destructive examination (NDE).

- WP closure system is not ITS
- WP closure system equipment
  - Welding equipment
  - NDE equipment
  - Stress mitigation equipment for treatment of the outer lid weld
  - Inerting equipment
  - Robotic manipulators
  - Spread ring expander tool
  - Glovebox
  - Cameras
  - Cranes

Surface Facility Waste Handling Operations
Waste Package Closure Cells
(Continued)



Surface Facility Waste Handling Operations
Waste Package Closure Cells

(Continued)

- WP Weld NDE
  - Closure welding is inspected using visual, eddy current, and ultrasonic methods
  - NDE procedures qualified to *ASME Boiler & Pressure Vessel (B&PV) Code*, Section V
  - Weld examinations include:
    - Spread ring and inner lid
      - » Tack welds and seal welds – visual
    - Purge port cap and inner lid
      - » Tack welds and seal welds – visual
    - Middle lid
      - » Tack welds – visual
      - » Fillet weld – visual and eddy current
    - Outer lid
      - » Tack welds – visual
      - » Narrow groove weld is inspected visually, eddy current, and ultrasonically after welding and again after stress mitigation

Surface Facility Waste Handling Operations
Waste Package Closure Cells
(Continued)

Procedural Safety Controls

Control	Basis
Waste package inerting	Ensures that waste packages are inerted with helium prior to emplacement. Minimizes likelihood of excessive heating of SNF cladding and minimizes likelihood of oxidation of damaged fuel.
Waste package closure welding and post-welding mitigation	Ensures that structurally sound closure welds are fabricated and that residual stresses are appropriately relieved. Minimizes likelihood of waste package breach due to drop or rockfall. Minimizes sites for stress cracking corrosion. Minimizes likelihood of early failures.
Waste package non-destructive examination	Ensures that structurally sound closure welds are fabricated. Minimizes likelihood of waste package breach due to drop or rockfall. Minimizes likelihood of early failures.
Waste package inspection (pre-emplacement and in-drift)	Ensures that surface finish of Alloy-22 outer corrosion barrier is free of unacceptable blemishes. Minimizes sites for onset of corrosion and minimizes likelihood of early failures.

Surface Facility Waste Handling Operations
Loading of Waste Transporters

- WP is visually inspected and surveyed for external contamination and decontaminated, if necessary
- Trolley moves WP into the loadout cell
  - WP loadout handling crane lifts WP by collar trunnions to vertical
  - WP tilting machine tilts WP to horizontal
  - Crane lowers WP onto emplacement pallet on turntable
  - Trunnions removed
  - Extendable bedplate on transporter moves emplacement pallet off turntable and into transporter
  - WP and bedplate are retracted into shielded enclosure

Surface Facility Waste Handling Operations
Loading of Waste Transporters
(Continued)

WP Transporter Procedural Safety Controls

Control	Basis
SNF/HLW mechanical handling	Ensures that cranes, transporters, rigging, load paths, and energy absorbing crush pads are selected and in-place for the variety of lifts involving SNF and HLW. Ensures that cranes, rigging, load paths, and protective barriers are selected and in-place for other heavy load handling over or in the vicinity of SNF/HLW. Minimizes the likelihood of an unacceptable or unanalyzed drop or collision involving a waste form. Minimizes the likelihood of a drop or collision of a heavy load onto a waste form.
Surface transportation control	Ensures that casks and waste packages are transported on appropriate vehicles. Ensures that other traffic is controlled along route of transport between buildings, buffer area, aging pads, and emplacement portal. Minimizes likelihood of a drop of cask or waste package. Minimizes likelihood of collisions between vehicles.

U.S. Department of Energy
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Surface Facilities Design and Operations

Presented to:
DOE/NRC Technical Exchange on Yucca Mountain Surface and Subsurface Facilities

Presented by
Preston McDaniel
Mechanical Lead
Bechtel SAIC Company, LLC

September 14-15, 2004
Las Vegas, Nevada

Surface Facilities Design and Operations

- Design Criteria
  - Development of Design Criteria
  - Important to Safety (ITS) Criteria Development
    - Fuel Handling Facility
    - Aging System
    - Cranes Handling Waste Forms
- Surface Facility Descriptions
  - Fuel Handling Facility (FHF)
  - Canister Handling Facility (CHF)
  - Dry Transfer Facility (DTF)
  - Aging System
  - Central Control Center Facility (CCCF)

Design Methodology - Fuel Handling Facility

- FHF Design Bases
  - Withstand natural phenomena (seismic, wind, flood)
  - Prevent potential flooding for moderator control
  - Door travel speeds are limited to preclude tipover of load with waste form
  - Shielding after Category 1 event sequence same as normal operation
  - No sharp objects under waste form load paths
  - Rail systems preclude tipover during normal operations and Design Basis Ground Motion-2 (DBGM-2) events
  - Structure does not collapse during DBGM-2 and 10,000 year return period seismic events

Design Methodology - Fuel Handling Facility

(Continued)

- FHF Design Parameters
  - Natural Phenomena
    - Seismic
    - Wind, including tornado - 189 mph, 0.81 psi pressure drop, 0.30 psi/sec rate of pressure drop, tornado missiles
    - Flood - protected against probable maximum flood
  - Criticality
  - Shielding
  - As low as is reasonably achievable (ALARA)

Design Methodology - Fuel Handling Facility

(Continued)

- FHF Seismic Design
  - Two levels of ground motions to meet code requirements
    - Design Basis Ground Motion-1 (DBGM-1), Mean Annual Probability of Exceedance (MAPE) $1x10^{-3}$ (1000 year return period), horizontal peak ground acceleration 0.37 g @ 100 Hz
    - DBGM-2, MAPE $5x10^{-4}$ (2000 year return period), horizontal peak ground acceleration 0.58 g @ 100 Hz
  - Evaluate structural capacity at Beyond Design Basis Ground Motion, MAPE $1x10^{-4}$ (10,000 year return period), horizontal peak ground acceleration 1.19 g @ 100 Hz
  - 3D finite element computer models - SASSI for soil structure interaction and GTSTRUDL for forces and moments - used during detailed design
  - Structural design codes
    - ACI-349 Nuclear Safety Related Concrete Structures
    - ANSI/AISC N690 Steel Safety-Related Structures

Design Methodology - Fuel Handling Facility
(Continued)

- Criticality
  - Demonstrate prevention and control of criticality
  - Passive engineered features for criticality safety
    - Moderator control in Spent Nuclear Fuel (SNF) processing areas
    - Defense in depth
      - » Limit amount of fissile material
      - » Geometrically favorable configurations
      - » Fixed neutron absorbing materials
  - Analyses to show no criticality under normal operations, Category 1 and 2 event sequences
  - Codes and Standards
    - ANSI/ANS-8 Nuclear Criticality Safety Standard Documents

Design Methodology - Fuel Handling Facility
(Continued)

- Shielding
  - Meet radiation protection objectives in 10 CFR 63.111(a)
  - Standard computer codes for shielding analyses
  - Worker protection during normal operations and Category 1 event sequences
    - Thick concrete walls/floors/ceilings
    - Shielded viewing windows, shield doors and shield plugs
  - Design basis source terms
    - Pressurized Water Reactor (PWR) fuel assembly, 5 percent initial enrichment, 80 GWd/MTU burnup, 5 years out of reactor
    - Waste package, 21 PWR, 4 percent initial enrichment, 60 GWd/MTU burnup, 10 years out of reactor
  - Codes and Standards
    - ANSI/ANSI-6.1.1, Dose Rate Factors
    - ANSI/ANSI-6.4, Concrete Radiation Shielding

Design Methodology - Fuel Handling Facility
(Continued)

- ALARA
  - Doses maintained at ALARA levels
    - ALARA goal 500 mrem/year individual worker dose
  - Radiation protection features
    - Control access to restricted areas
    - Control and limit radiation area access
    - Area radiation monitoring system, local detection
    - Airborne radioactivity monitoring
    - Cell design to isolate high dose areas and contamination
  - Incorporate Regulatory Guide 8.8 ALARA design features
  - Industry Practices - benchmarking, best practices

Design Methodology - Fuel Handling Facility
(Continued)

- Example Codes and Standards
  - ACI 349-01 Reinforced Concrete
  - ANSI/AISC N690 Structural Steel
  - AREA Manual for Railway Engineering
  - ASCE 4-98 Seismic Analysis
  - ASCE 7-98 Wind Analysis
  - ASTM C 1217-00 Design of Equipment for Processing Nuclear and Radioactive Materials
  - AWS D1.1/D1.1M:2002 Structural Welding
  - AREMA Manual for Railway Engineering
  - NFPA 101 Life Safety Code
  - NFPA 801 Fire Protection for Facilities Handling Radioactive Materials

Design Methodology - Fuel Handling Facility
(Continued)

- Example Regulatory Guides
  - 1.59 Design Basis Floods
  - 1.61 Damping Values
  - 1.69 Concrete Radiation Shields
  - 1.92 Combining Modal Responses and Spatial Components
  - 1.102 Flood Protection
  - 1.117 Tornado Design Classification
  - 1.122 Floor Response Spectra
  - 1.143 Design Guidance for Systems, Structures and Components
  - 1.199 Anchoring Components and Structural Supports
  - 3.71 Criticality Safety Standards
  - 8.8 ALARA

Design Methodology - Aging System

- Aging Design Bases
  - Site Specific Casks, Transporter and Pad
    - Withstand design basis natural phenomena - seismic, tornado winds, flood, etc.
    - DBGM-1 and DBGM-2 event sequence seismic event
  - Aging Pad
    - Cask layout on pad not to exceed 15 percent of pad area
  - Cask Transporter
    - Stable and limited in speed
    - Not allow a drop or slapdown to exceed design basis
    - Probability of runaway beyond Category 2
    - Hydraulic ram pressure does not breach Dual Purpose Canister

Design Methodology - Aging System
(Continued)

- Aging Design Parameters
  - Natural Phenomena
    - Seismic
    - Wind, including tornado - 189 mph, 0.81 psi pressure drop, 0.30 psi/sec rate of pressure drop, tornado missiles
    - Flood - protected against probable maximum flood
  - Criticality
  - Shielding
  - ALARA

Design Methodology - Aging System

(Continued)

- Aging Seismic Design
  - Two levels of ground motions to meet code requirements
    - Design Basis Ground Motion – 1 (DBGM-1), Mean Annual Probability of Exceedence (MAPE)
    - 1×10^{-3} (1,000 year return period), horizontal peak ground excelleration 0.37 g at 100 Hz
    - DBGM-2, MAPE 5×10^{-4} (2,000 year return period), horizontal peak ground excelleration 0.58 g at 100 Hz
  - Evaluate structural capacity at beyond design basis ground motion (BDBGM), MAPE 1×10^{-4} (10,000 return period), horizontal peak ground excelleration 1.19 g at 100 Hz
  - 3D finite element computer model – SASSI for soil structure interaction GTSTRUDL for forces and moments – used during detailed design
  - Structural design codes
    - ACI-349, Nuclear safety related concrete structures
    - ANSI/AISC N690, Steel safety – related structures

Design Methodology - Aging System
(Continued)

- Criticality
  - Demonstrate prevention and control of criticality
  - Passive engineered features for criticality safety
    - Moderator control by Site Specific Casks
    - Defense in depth
      - » Limit amount of fissile material
      - » Geometrically favorable configurations
      - » Fixed neutron absorbing materials
  - Analyses to show no criticality under normal operations, Category 1 and 2 event sequences
  - Codes and Standards
    - ANSI/ANS-8 Nuclear Criticality Safety Standard Documents

Design Methodology - Aging System

(Continued)

- Shielding
  - Meet radiation protection objectives in 10 CFR 63.111(a)
  - Standard computer codes for shielding analyses
  - On-site and off-site radiation protection during normal operations and Category 1 event sequences
    - Use of NRC certified casks for aging
    - Develop equivalent site-specific aging casks, as needed
    - Locate aging pads with sufficient standoff distances
    - Use supplemental shielding (e.g. shield wall) if required
    - Reduce site boundary dose from direct and skyshine radiation
  - Bounding source terms - maximum allowable cask content
  - Codes and Standards
    - ANSI/ANSI-6.1.1, Dose Rate Factors
    - ANSI/ANSI-6.4, Concrete Radiation Shielding

Design Methodology Aging System

(Continued)

- ALARA
  - Doses maintained at ALARA levels
    - ALARA goal 500 mrem/year individual dose
  - Radiation protection features
    - Control access to restricted areas
    - Area radiation monitoring system
    - Airborne radioactivity monitoring
    - Remote locations
  - Incorporate Regulatory Guide 8.8 ALARA design features
  - Industry Practices - benchmarking, best practices

Design Methodology - Cranes

- ITS Crane Design Bases
  - Seismic
  - Collision
  - Load paths and end stops
  - Lift heights
  - Loss of power
  - Load drops

Design Methodology - Cranes

(Continued)

- ITS Crane Design Requirements
  - Seismic
    - Requirements
      - » Does not fall or fail and damage waste forms
      - » Designed to meet DBGM-1 and DBGM-2
      - » Designed not to collapse for 10,000 year return period seismic event
      - » Interactions with ITS systems, structures and components
    - Codes and Standards
      - » ASME NOG-1 Overhead and Gantry Cranes
      - » NUREG-0554 Single Failure Proof Cranes

Design Methodology - Cranes

(Continued)

- ITS Cranes Design Requirements
  - Collision
    - Requirements
      - » Avoid collisions
      - » Travel speeds limited for safe handling of waste forms
    - Codes and Standards
      - » ASME NOG-1 Overhead and Gantry Cranes
      - » NUREG-0554 Single Failure Proof Cranes
    - Procedural Safety Controls
      - » SNF/High-Level Waste (HLW) Mechanical Handling

Design Methodology - Cranes

(Continued)

- ITS Crane Design Requirements
  - Load Paths and End Stops
    - Requirements
      - » Avoid collisions
      - » Avoid travel into prohibited areas
    - Codes and Standards
      - » ANSI/ANS-57.1 Fuel Handling Systems
      - » ASME NOG-1 Overhead and Gantry Cranes
      - » NUREG-0554 Single Failure Proof Cranes
    - Procedural Safety Controls
      - » SNF/HLW Mechanical Handling

Design Methodology - Cranes

(Continued)

- ITS Crane Design Requirements
  - Lift Heights
    - Requirements
      - » Limit lift height
    - Codes and Standards
      - » ANSI/ANS-57.1 Fuel Handling Systems
      - » ASME NOG-1 Overhead and Gantry Cranes
      - » ANSI N14.6 Special Lifting Devices for Shipping Containers
      - » NUREG-0554 Single Failure Proof Cranes
    - Procedural Safety Controls
      - » SNF/HLW Mechanical Handling

Design Methodology - Cranes

(Continued)

- ITS Crane Design Requirements
  - Loss of Power
    - Requirements
      - » Stop and retain load on loss of power
      - » Instruments and controls fail in safe mode
    - Codes and Standards
      - » ASME NOG-1 Overhead and Gantry Cranes
    - Procedural Safety Controls
      - » SNF/HLW Mechanical Handling

Design Methodology - Cranes

(Continued)

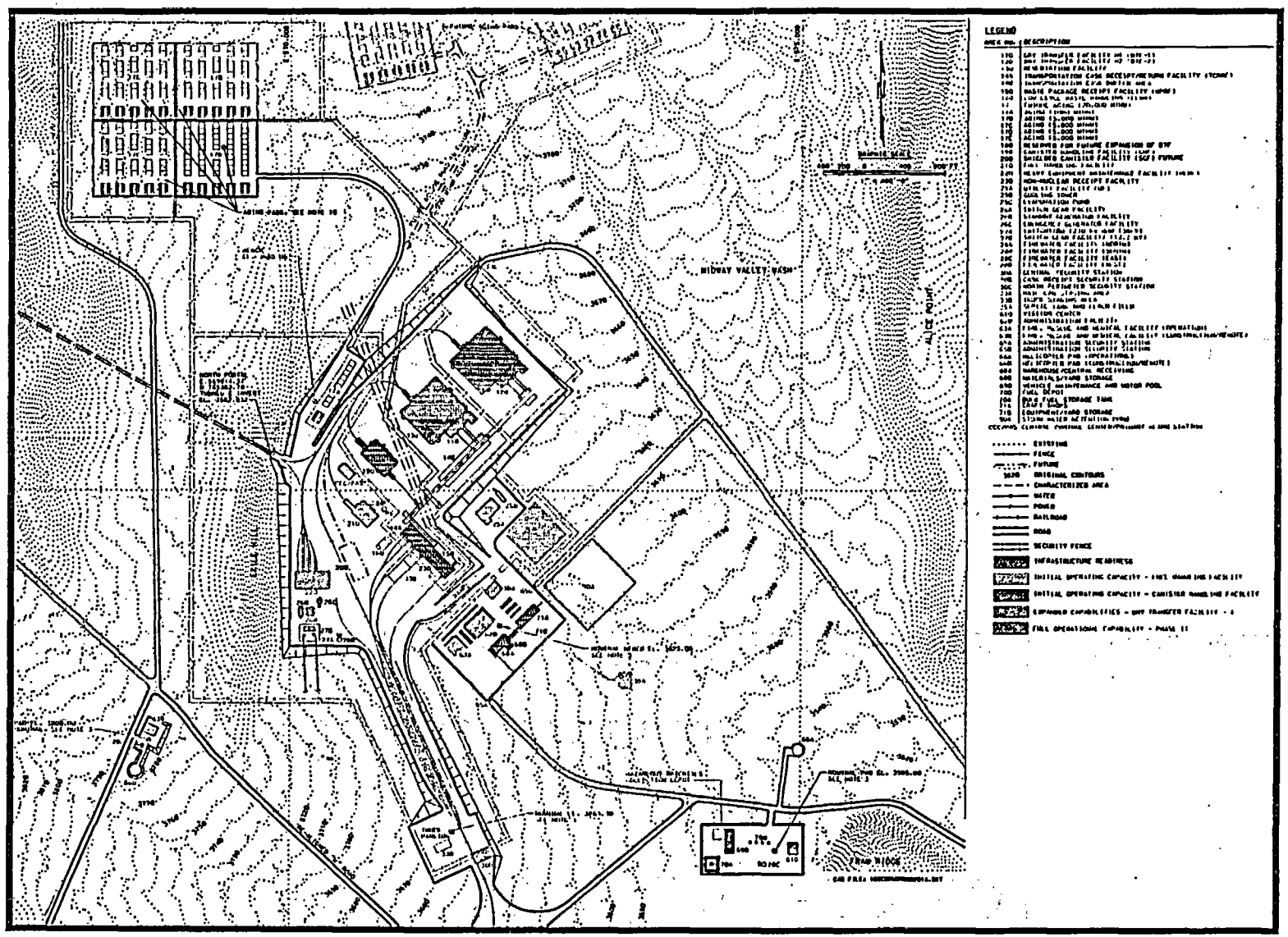
- ITS Crane Design Requirements
  - Load Drops
    - Requirements
      - » Reliability to meet less than 1×10^{-5} drops/transfer for SNF handling
      - » Interactions with ITS systems, structures and components
    - Codes and Standards
      - » ASME NOG-1 Overhead and Gantry Cranes
      - » ANSI N14.6 Special Lifting Devices for Shipping Containers
    - Procedural Safety Controls
      - » SNF/HLW Mechanical Handling

Design Methodology - Cranes

(Continued)

- Other Codes and Standards
  - CMAA-70 Bridge and Gantry Overhead Traveling Cranes
  - CMAA-74 Traveling Cranes With Trolley Hoist
  - NUREG-0612 Control of Heavy Loads
  - NUREG-0700 Human-System Interface

Surface Facility Descriptions



Surface Facility Descriptions
Fuel Handling Facility

- FHF Concept of Operations
  - Process commercial SNF (CSNF) and canistered waste forms
  - Interface with Aging System
  - Limited remediation capability
  - Designed to mitigate Category 1 and 2 event sequences
    - Category 1 - CSNF fuel assembly drop; collision
    - Category 2 - CSNF Transportation cask drop and breach; HLW transportation cask drop and breach; naval canister drop and breach

Surface Facility Descriptions
Fuel Handling Facility
(Continued)

MATERIAL FLOW PATH

CASK OPERATIONS

1. REMOVE IMPACT LIMITERS AND PERSONNEL BARRIER
2. UP-END CASKS
3. PREPARE CASK
4. MOVE TO CASK TRANSFER AREA
5. RESTORE CASK

WP OPERATIONS

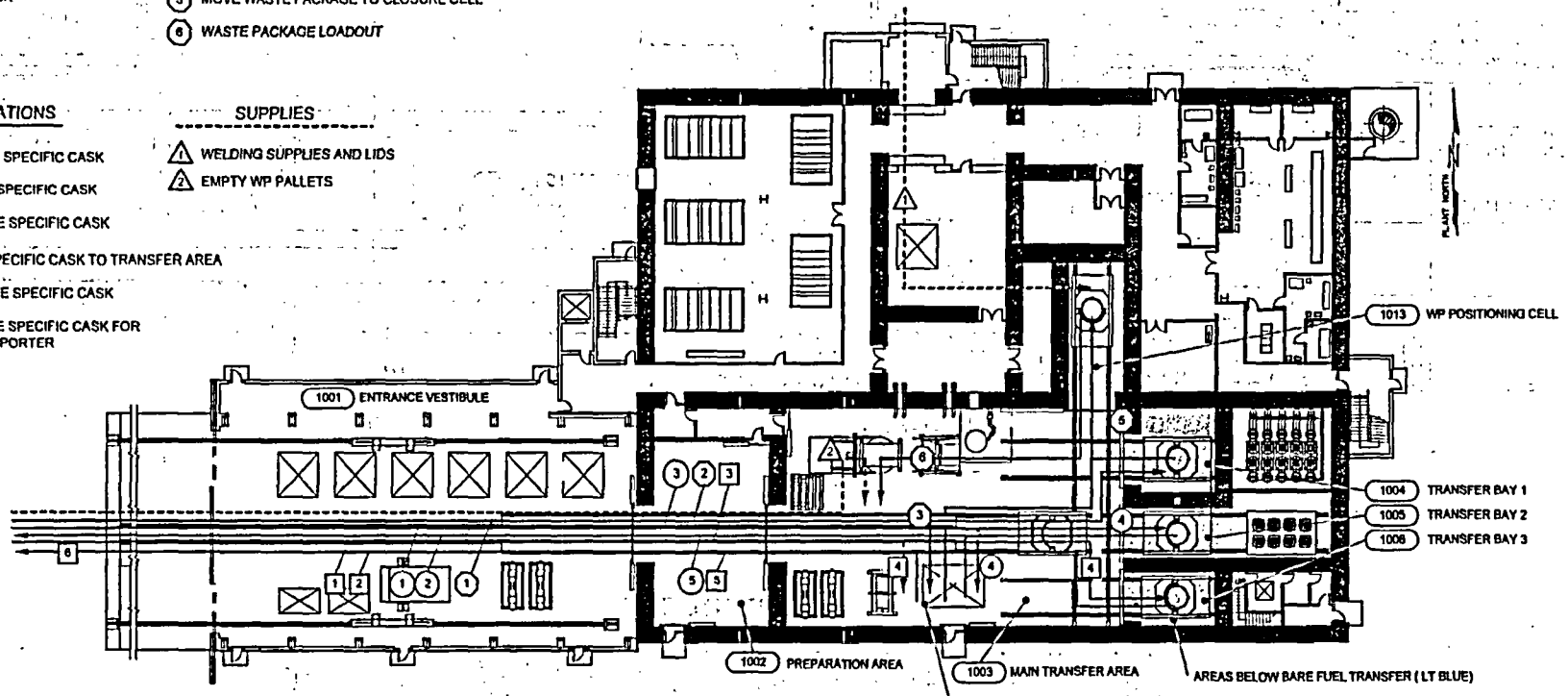
1. RECEIVE EMPTY WASTE PACKAGE
2. PREPARE WASTE PACKAGE
3. MOVE TO TRANSFER AREA
4. MOVE WASTE PACKAGE TO TRANSFER AREA
5. MOVE WASTE PACKAGE TO CLOSURE CELL
6. WASTE PACKAGE LOADOUT

MSC OPERATIONS

1. RECEIVE SITE SPECIFIC CASK
2. UP-END SITE SPECIFIC CASK
3. PREPARE SITE SPECIFIC CASK
4. MOVE SITE SPECIFIC CASK TO TRANSFER AREA
5. RESTORE SITE SPECIFIC CASK
6. POSITION SITE SPECIFIC CASK FOR AGING TRANSPORTER

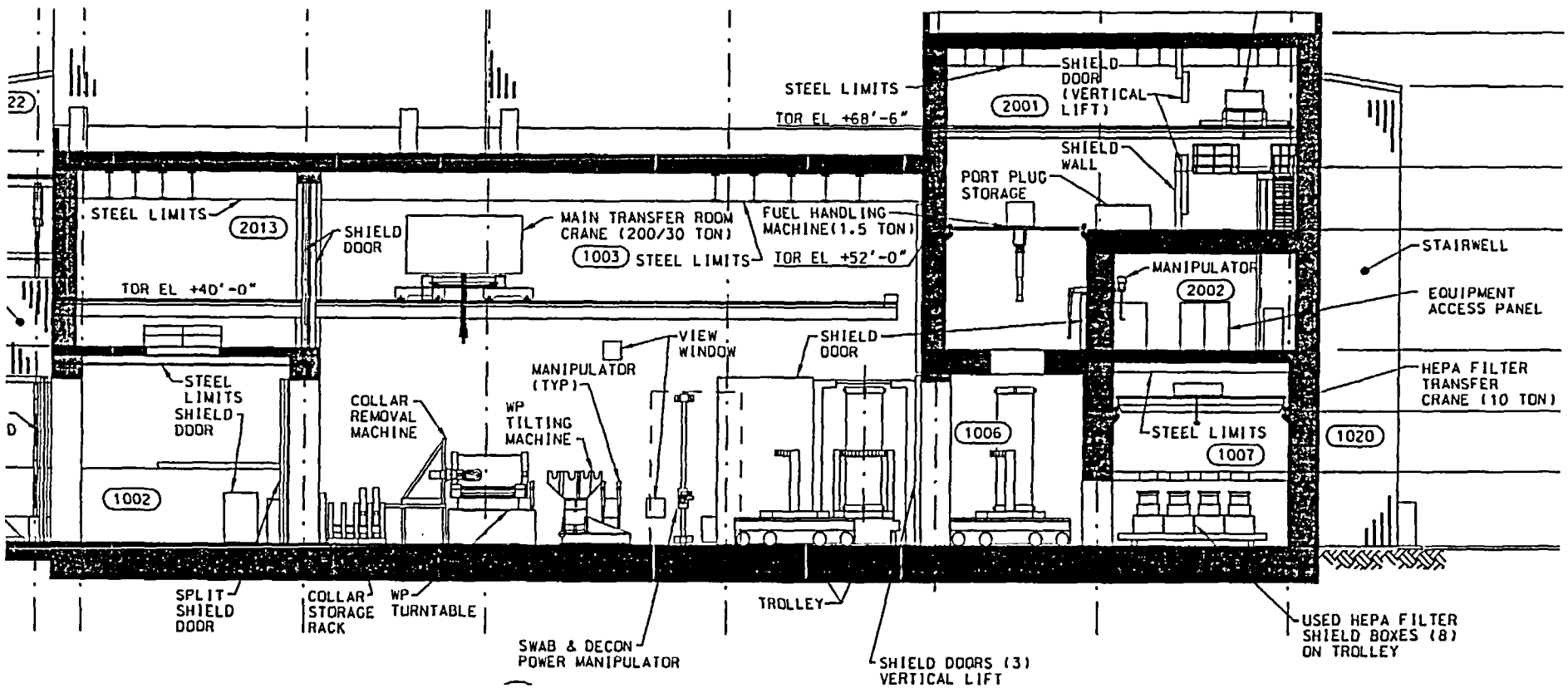
SUPPLIES

1. WELDING SUPPLIES AND LIDS
2. EMPTY WP PALLETS

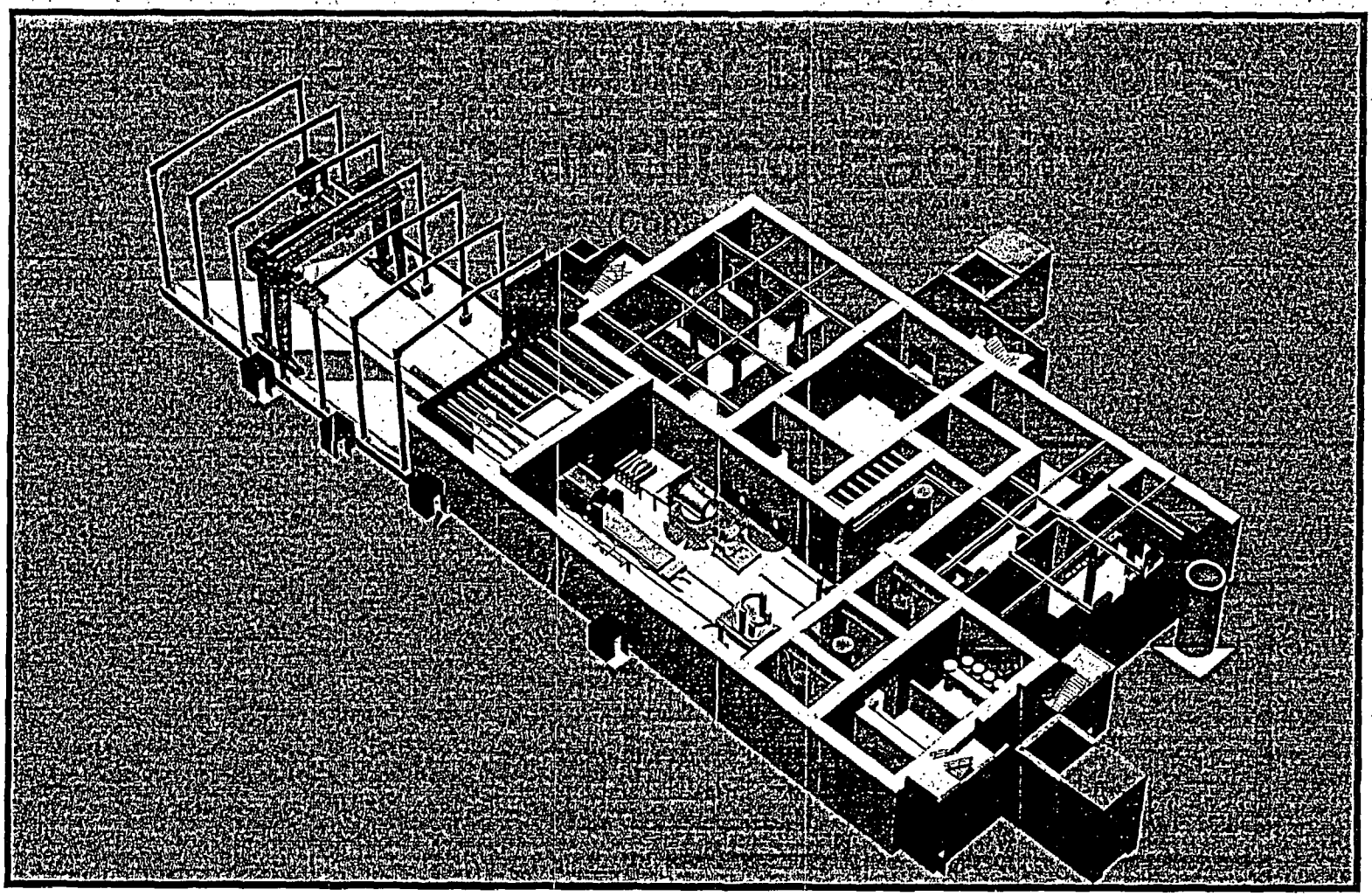


FUEL HANDLING FACILITY

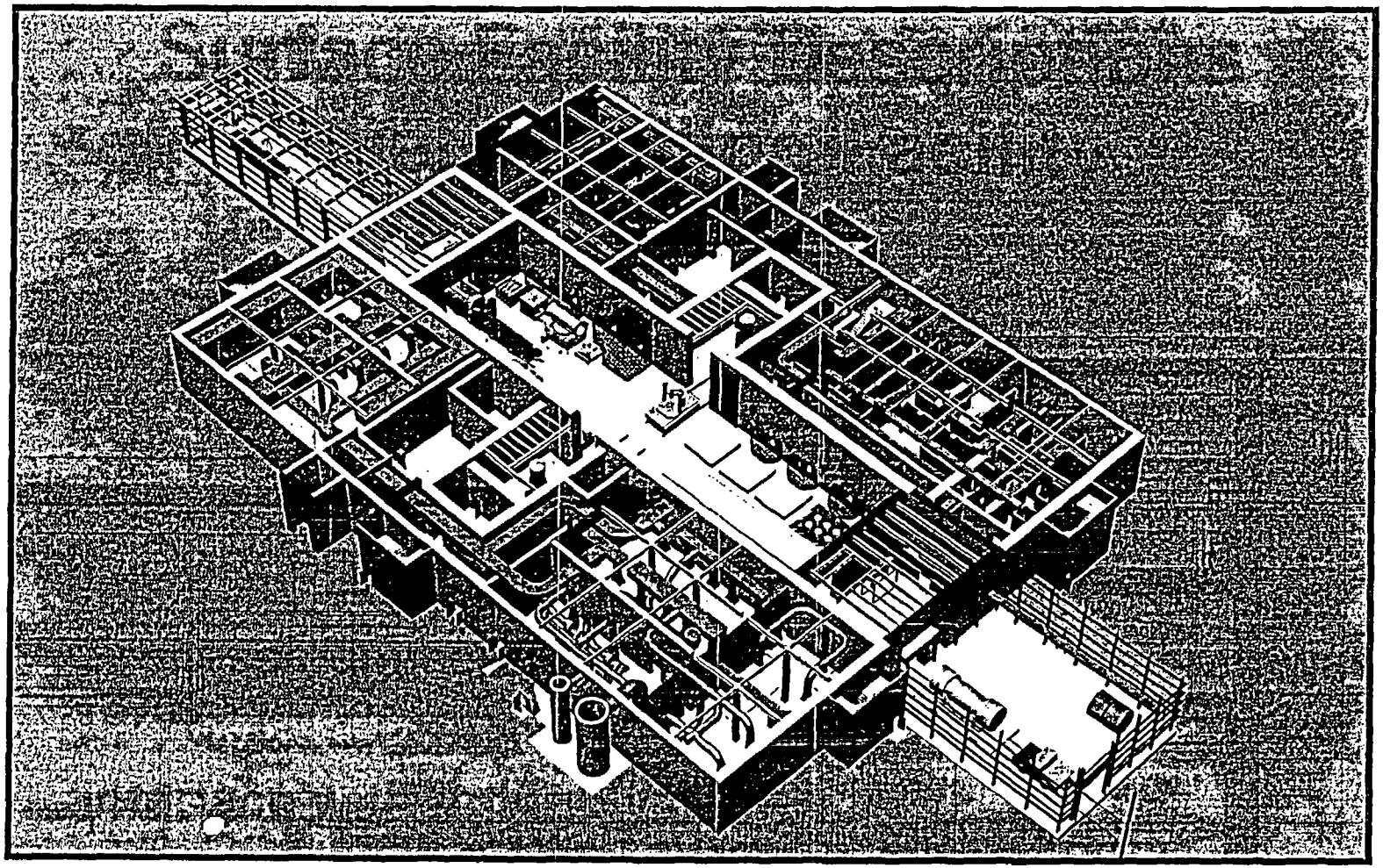
Surface Facility Descriptions
Fuel Handling Facility
(Continued)



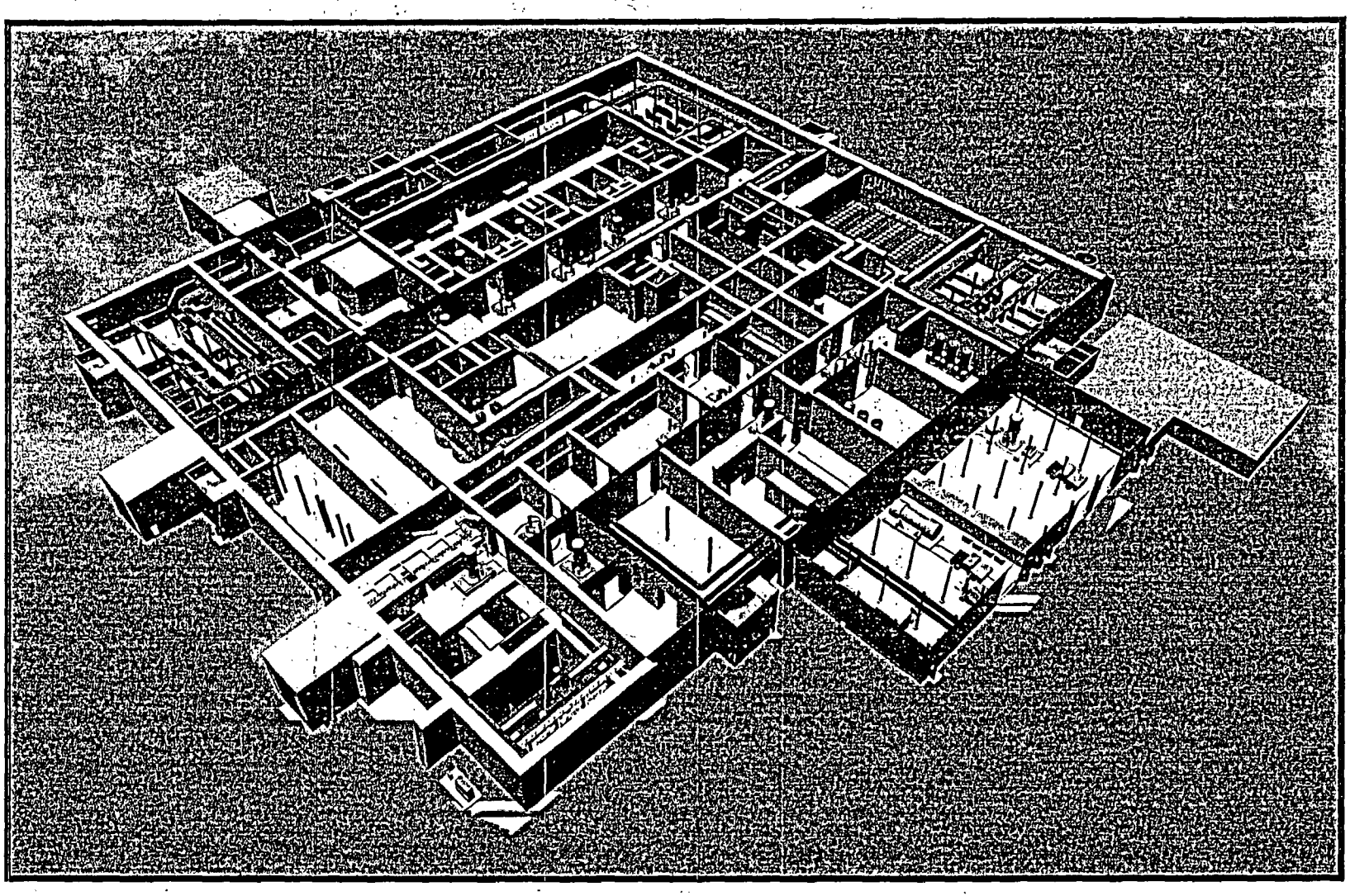
Surface Facility Descriptions
Fuel Handling Facility
(Continued)



Surface Facilities Description
Canister Handling Facility

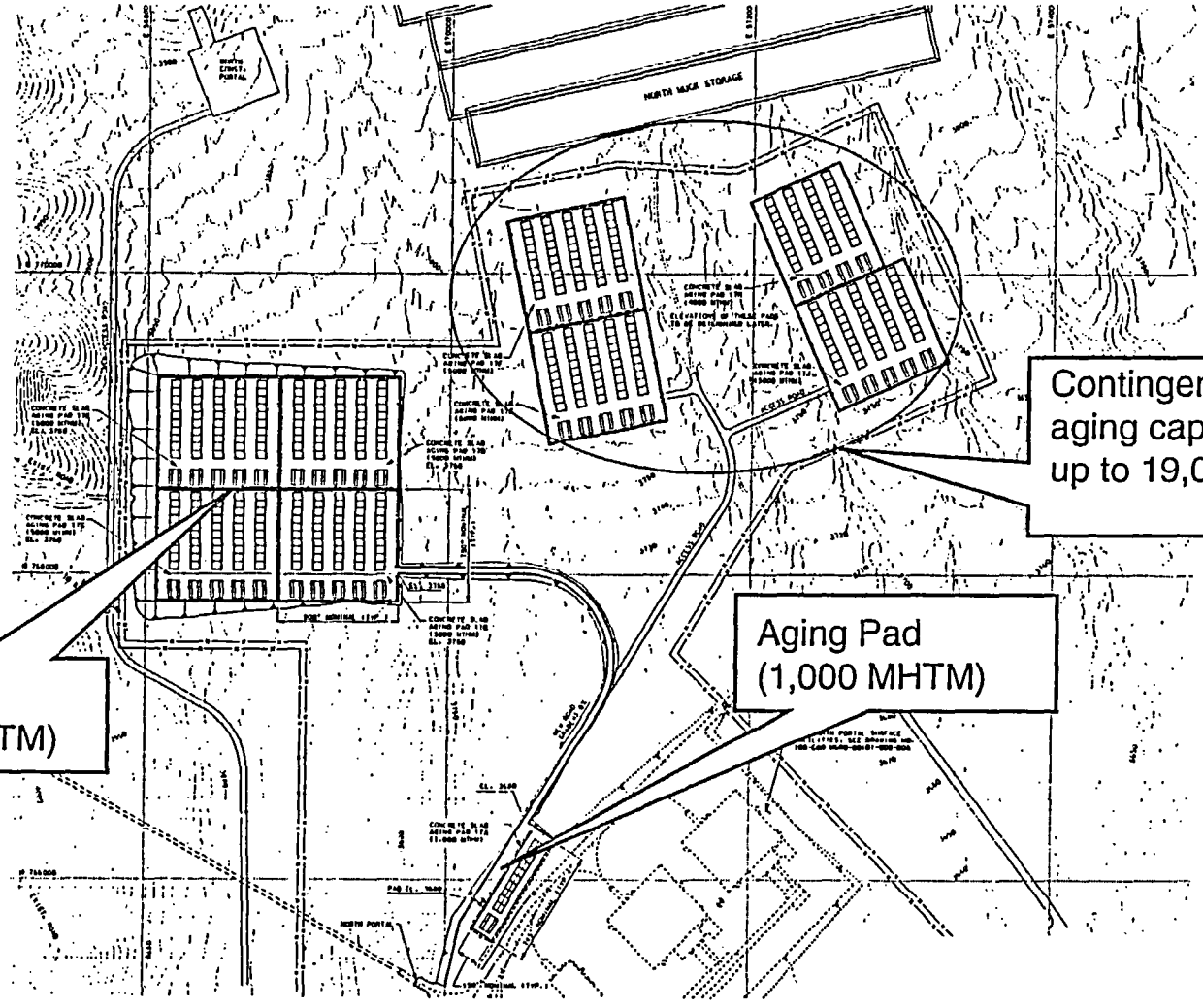


Surface Facilities Description
Dry Transfer Facility



Surface Facilities Description - Aging

(Continued)



Surface Facilities Description
Central Control Center

- One Central Control Center located in Central Control Center Facility
  - Permanently staffed 24 hrs/day
  - Provisions for habitability
    - Regulatory Guides
      - » 1.78 Habitability of Nuclear Power Plant Control Room During Hazardous Chemical Release
      - » 1.196 Control Room Habitability
  - 9 Digital Control and Management Information System (DCMIS) Human/Machine Interface (HMI) consoles

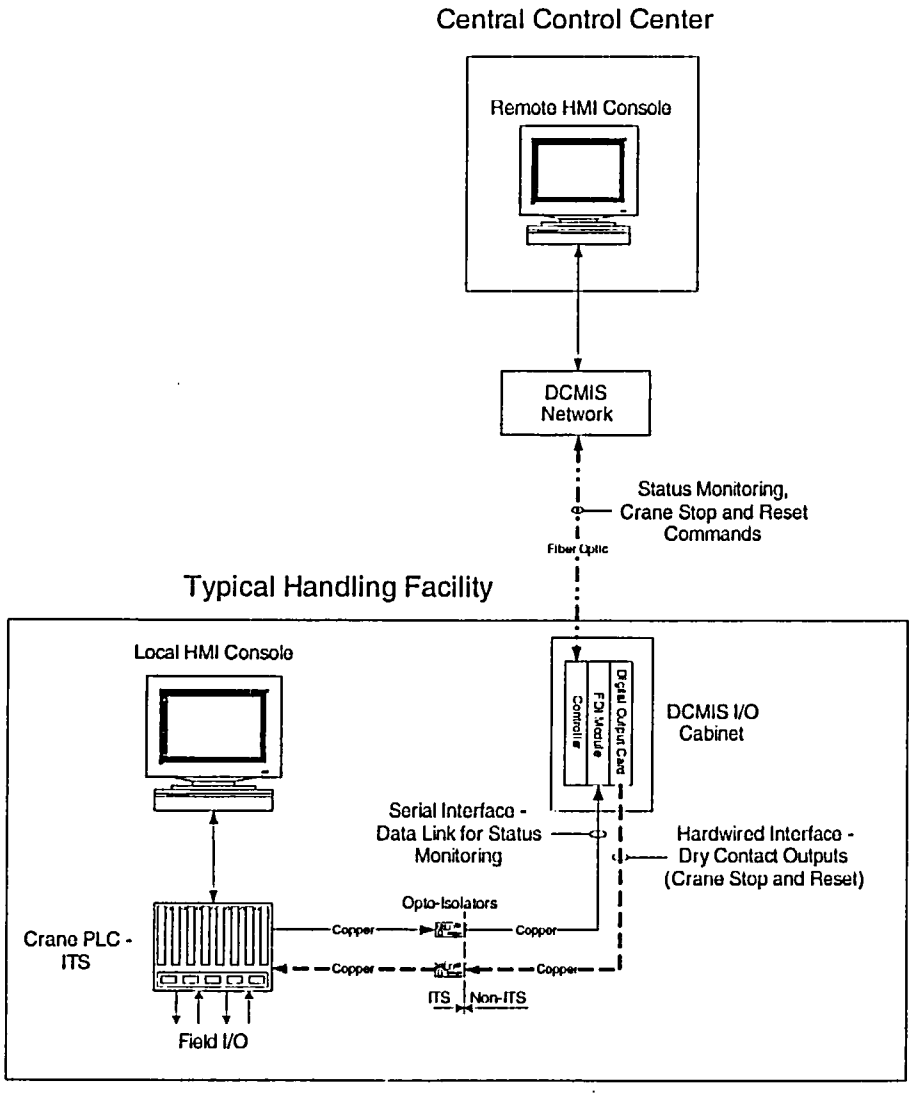
Surface Facilities Description Distributed Control Management Information System Functions/Capabilities

- Distributed Control Management Information System (DCMIS)
  - Not ITS
  - Status monitoring, alarm off-normal conditions, report displays for entire repository
  - Oversight and capability to stop select waste handling and robotic operations
  - Video surveillance for entire repository (except security which will be in other locations)
  - Control utility systems (e.g. electrical, water, etc.)
  - Control subsurface emplacement operations
  - Event sequence monitoring
  - Data collection and storage, can transmit data offsite

Surface Facilities Description
Waste Handling and Robotic Control

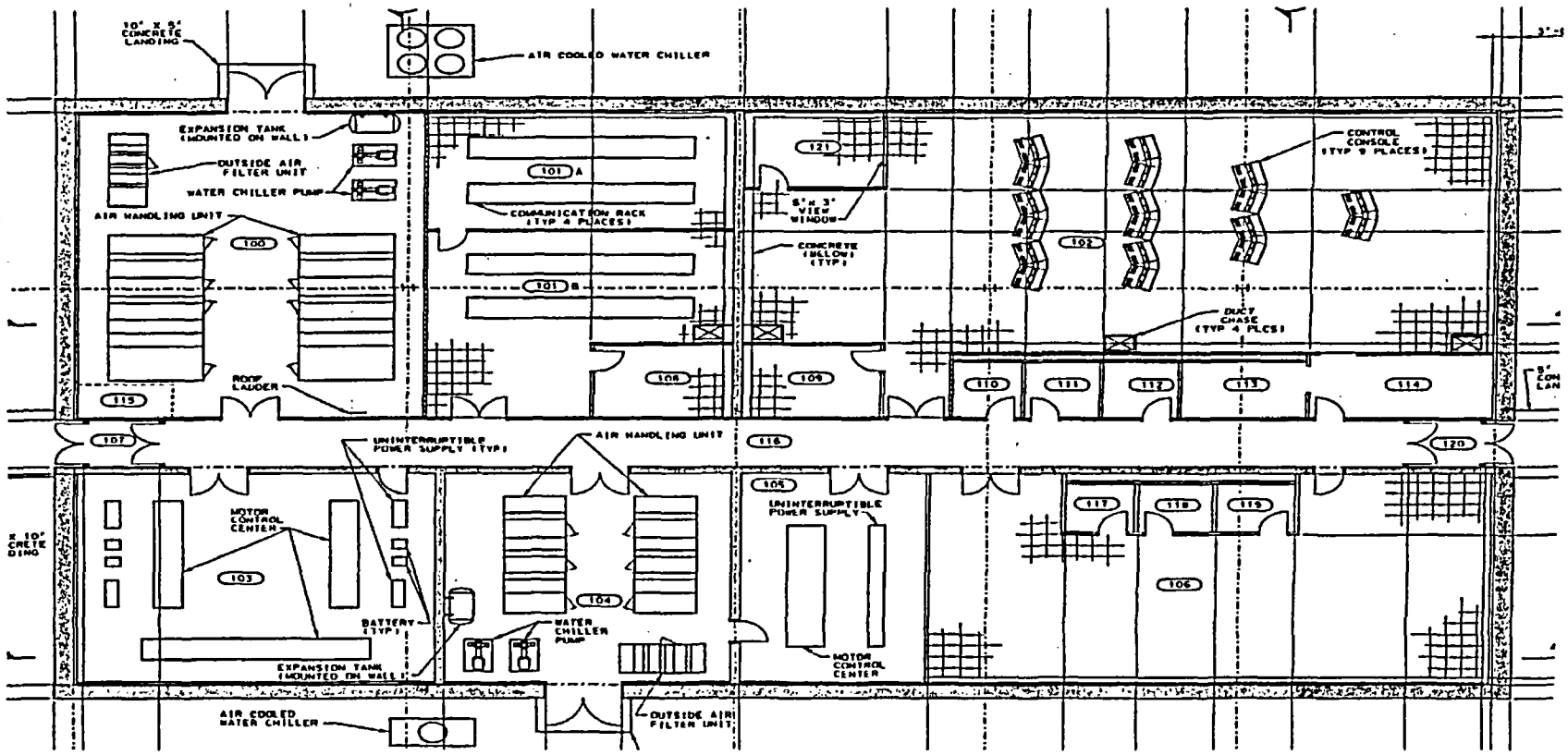
- **Waste Handling Operations**
  - Controlled from local stations in general area of the operation with stop/override capability in CCC
  - Control systems for waste handling and robotic operations designed and supplied by equipment suppliers
  - Degree of automation determined with equipment suppliers as the design develops

Surface Facilities Description
Distributed Control Management Information System/Important to Safety Control Systems Interface



HMI	Human Machine Interface
DCMIS	Distributed Control and Management Information System
PLC	Programmable Logic Controller
I/O	Input/Output
FDI	Foreign Device Interface

Surface Facilities Description
Central Control Center



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Subsurface Facilities Design and Operations

Presented to:
DOE/NRC Technical Exchange on Yucca Mountain Surface and Subsurface Facilities

Presented by:
Kirk D. Lachman
U.S. Department of Energy

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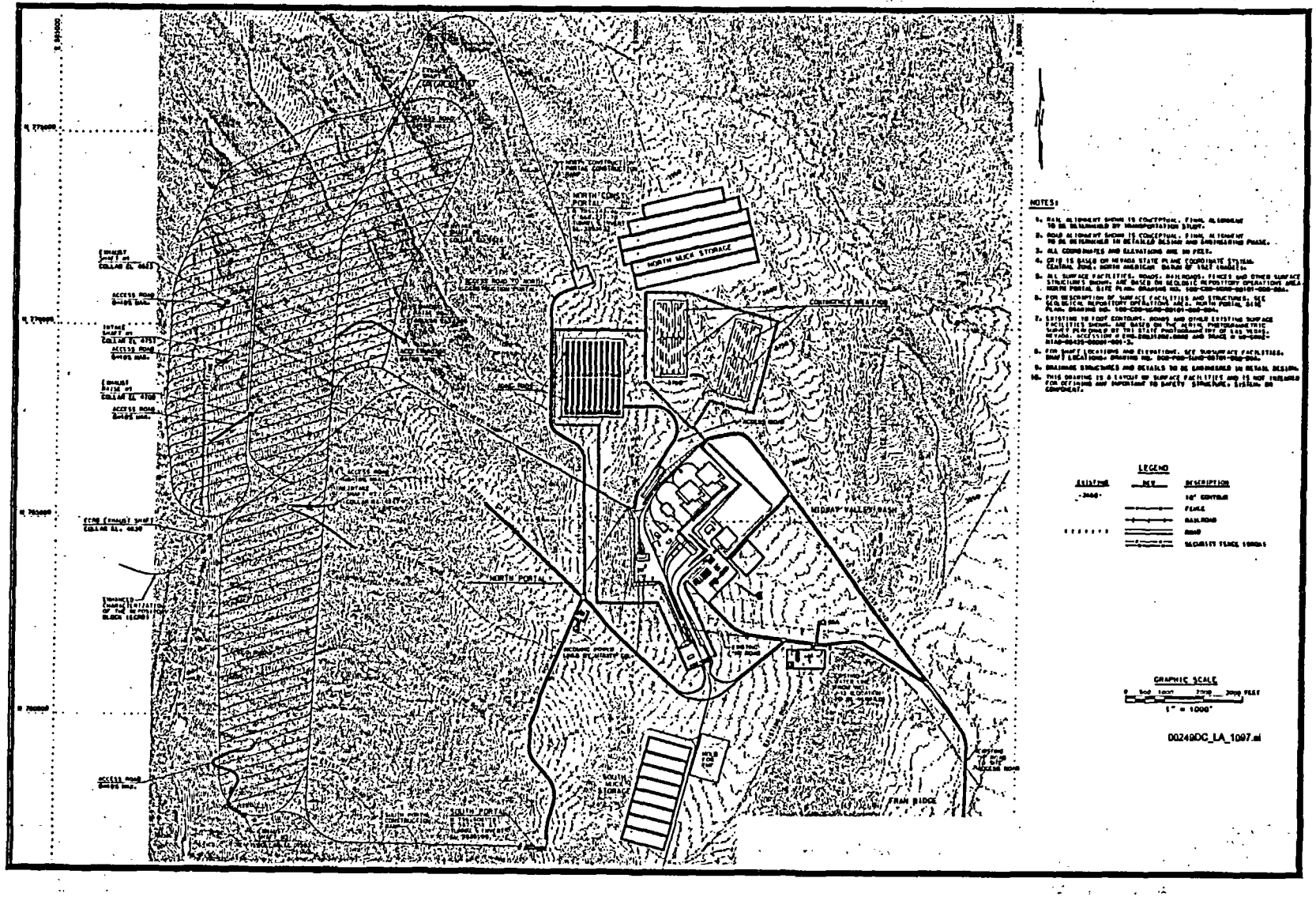
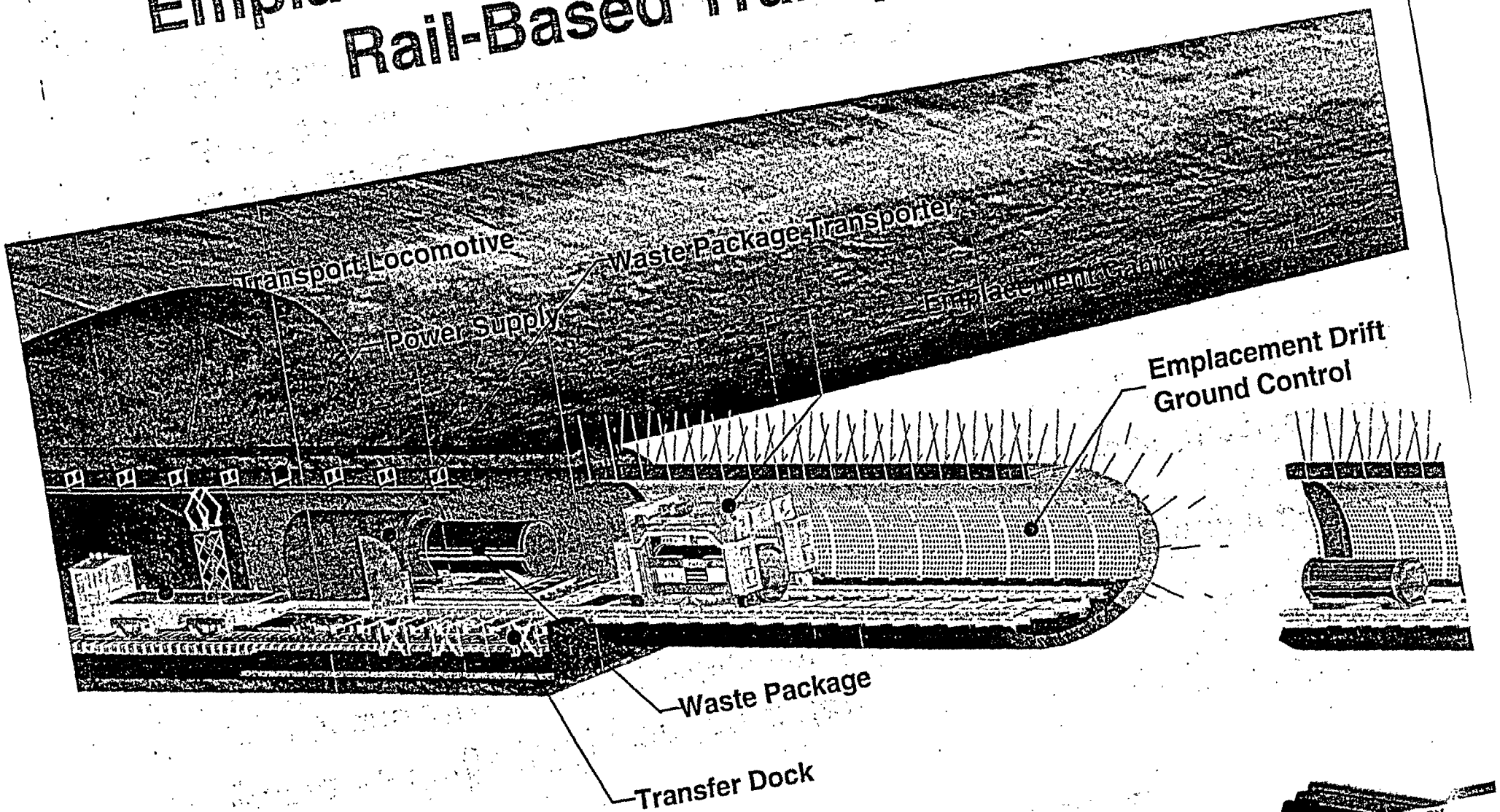
Site Plan


NORTH MUCK STORAGE
CONTINGENCY AREA POND
MURRAY VALLEY WASH
NORTH PORTAL
SOUTH MUCK STORAGE
SOUTH PORTAL
FRAN RIDGE
NOTES:
LEGEND
GRAPHIC SCALE
1" = 1000'
D0249DC_LA_1097.ai

Emplacement Drift Transfer Dock
Rail-Based Transport



Concept of Operations

- Waste Package (WP) transportation
  - WP and emplacement pallet loaded in surface facilities
  - WP transporter moves underground to the turnout under manual control
  - The WP transporter moves to the transfer dock at the entrance of the emplacement drift under remote control
- Waste Emplacement
  - WP and emplacement pallet moved to transfer deck
  - Emplacement gantry lifts waste package and emplacement pallet
  - Emplacement gantry moves waste package and emplacement pallet into drift
  - Emplacement gantry lowers waste package and emplacement pallet and disengages
  - Emplacement gantry returns to transfer dock
  - Emplacement gantry controlled remotely from Surface Central Control Center

Thermal Management Goals

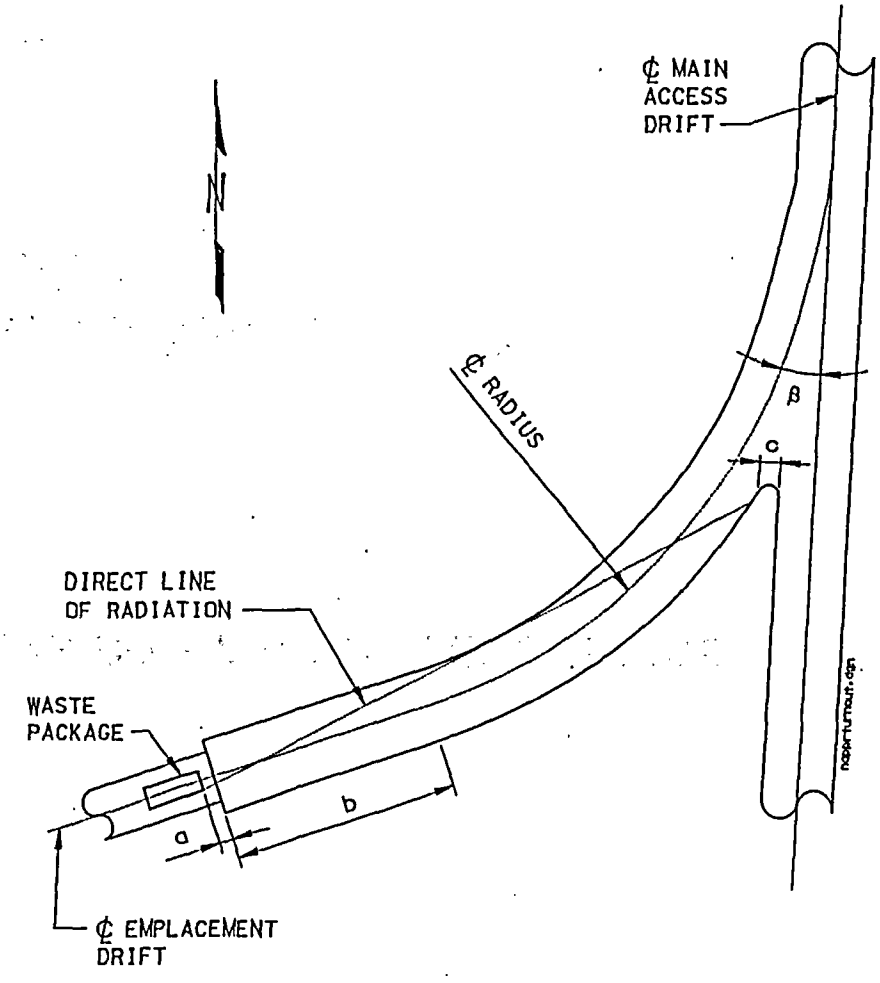
- Preclosure
  - Maximum drift wall temperature is 96°C
- Postclosure
  - Maximum cladding temperature is 350°C
    - Provide margin to failure by creep rupture
  - Maximum postclosure drift wall temperature is 200°C
    - Avoid adverse mineralogical transitions
  - Provides free drainage of liquid phase water between drifts

Thermal Management Operational Solutions

- Thermal line load
  - 1.45 kW/m
- Waste package spacing
  - Minimum 0.1 m
- Emplacement drift spacing
  - 81 m
- Maximum WP power
  - 11.8 kW

Subsurface Radiation Protection

- Turnout design
  - Curvature of turnout blocks direct line of radiation
- Maintenance
  - Items in high radiation areas designed for no planned maintenance

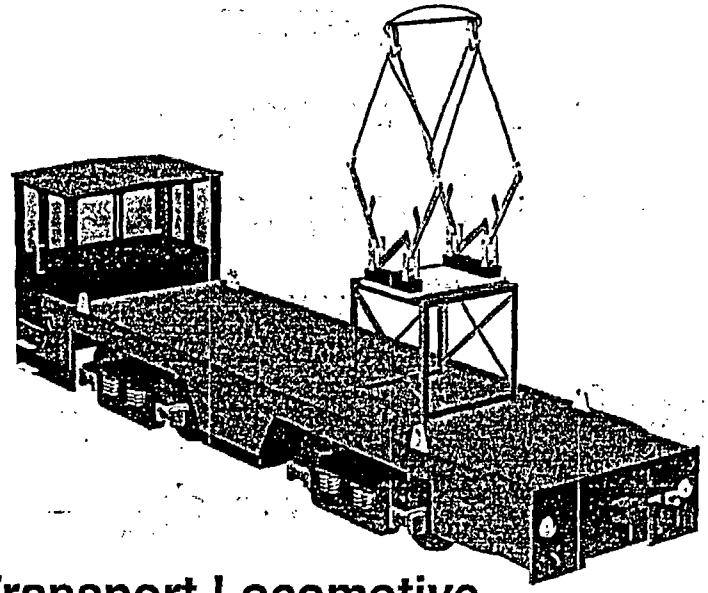


Subsurface Radiation Protection

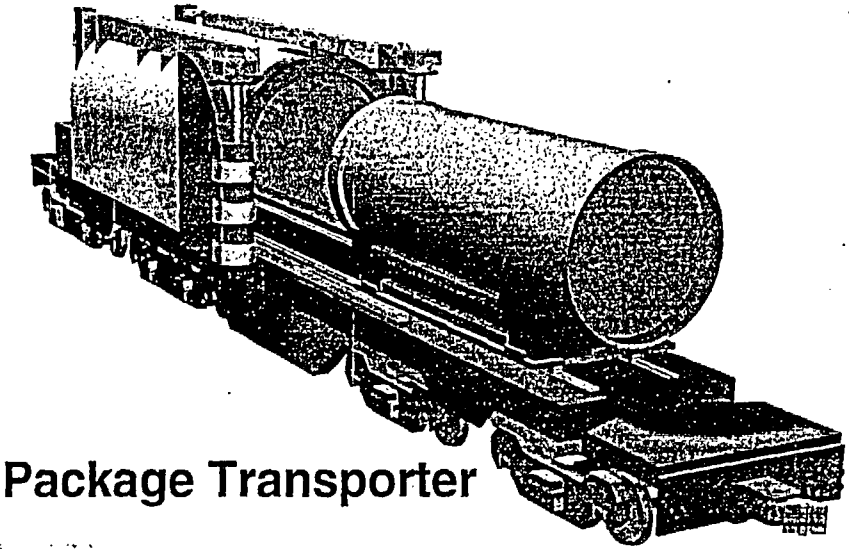
(Continued)

- Personnel access
  - Remote control handling
  - Physical and administrative controls to subsurface
- Ventilation
  - Monitoring of airflows
  - Airflow is designed to prevent back flow into construction areas and mains
- Shielding
  - Waste package transporter
  - Locomotive operator cab

Waste Package Transporter and Locomotive



Transport Locomotive



Waste Package Transporter

Waste Package Transporter and Locomotive

(Continued)

- Design bases
  - Runaway
  - Collision
  - Tip Over
  - Waste package ejection
  - Rock fall
  - Natural phenomena
    - Tornado and high winds
    - Seismic
    - Lighting strikes

Waste Package Transporter and Locomotive

(Continued)

- Important to Safety features
  - Braking system
  - Coupler
  - Limit speed
  - Limit waste package transporter height
  - Interlocked shield doors and bed plate
  - Structural integrity
  - Lightning arresters

Note: Not every element or appurtenance of an SSC is ITS

Waste Package Transporter and Locomotive

(Continued)

- Design requirements
  - Runaway
    - Design bases
      - » Probability of runaway shall be beyond Category 2 event sequences
    - Design requirement
      - » Important to safety (ITS) braking system with high reliability (ITS diverse, redundant brakes, and ITS coupler)
    - Codes and standards
      - » *Association of American Railroads (AAR) Manual of Standards and Recommended Practices*
  - Braking system to maintain safety function during derailment

Waste Package Transporter and Locomotive

(Continued)

- **Design requirements**
  - **Collision**
    - **Design bases**
      - » **Waste package transporter shall not travel at speeds that may result in a collision impact velocity that exceed the design basis impact velocity for a waste package**
    - **Design requirement**
      - » **Waste package transporter speeds shall not exceed 5 mph**
    - **Codes and standards**
      - » ***AAR Manual of Standards and Recommended Practices***

Waste Package Transporter and Locomotive

(Continued)

- **Design requirements** (Continued)
  - Tip over
    - Design bases
      - » Waste package transporter shall not transport a waste package at a height that exceeds the design basis drop height
    - Design requirement
      - » The design of the waste package transporter wheels, trucks, and bed plate assembly shall limit the height of the waste package to 2.0 m to bottom of pallet
    - Codes and standards
      - » *AAR Manual of Standards and Recommended Practices*

Waste Package Transporter and Locomotive

(Continued)

- **Design requirements** (Continued)
  - Waste package ejection
    - Design bases
      - » Spurious or operator-induced opening of the subsurface waste package transporter shielding compartment doors, followed by actuation of the bed plate rollout mechanism, shall be precluded when the waste package transporter is in motion
    - Design requirement
      - » Waste package transporter shield doors and bed plate shall be interlocked to prevent movement during transportation
    - Codes and standards
      - » ANSI/ISA-S84.01-1996, *Application of Safety Instrumented Systems for the Process Industries*

Waste Package Transporter and Locomotive

(Continued)

- **Design requirements** (Continued)
  - Rock fall
    - Design bases
      - » The waste package transporter shielded compartment shall withstand subsurface rock fall events without jeopardizing the structural integrity of the waste package
    - Design requirement
      - » The waste package transporter shielded compartment shall withstand a set of rock falls having a total mass of 5.4 MT
    - Codes and standards
      - » AISC M016, *Manual of Steel Construction, Allowable Stress Design*

Waste Package Transporter and Locomotive

(Continued)

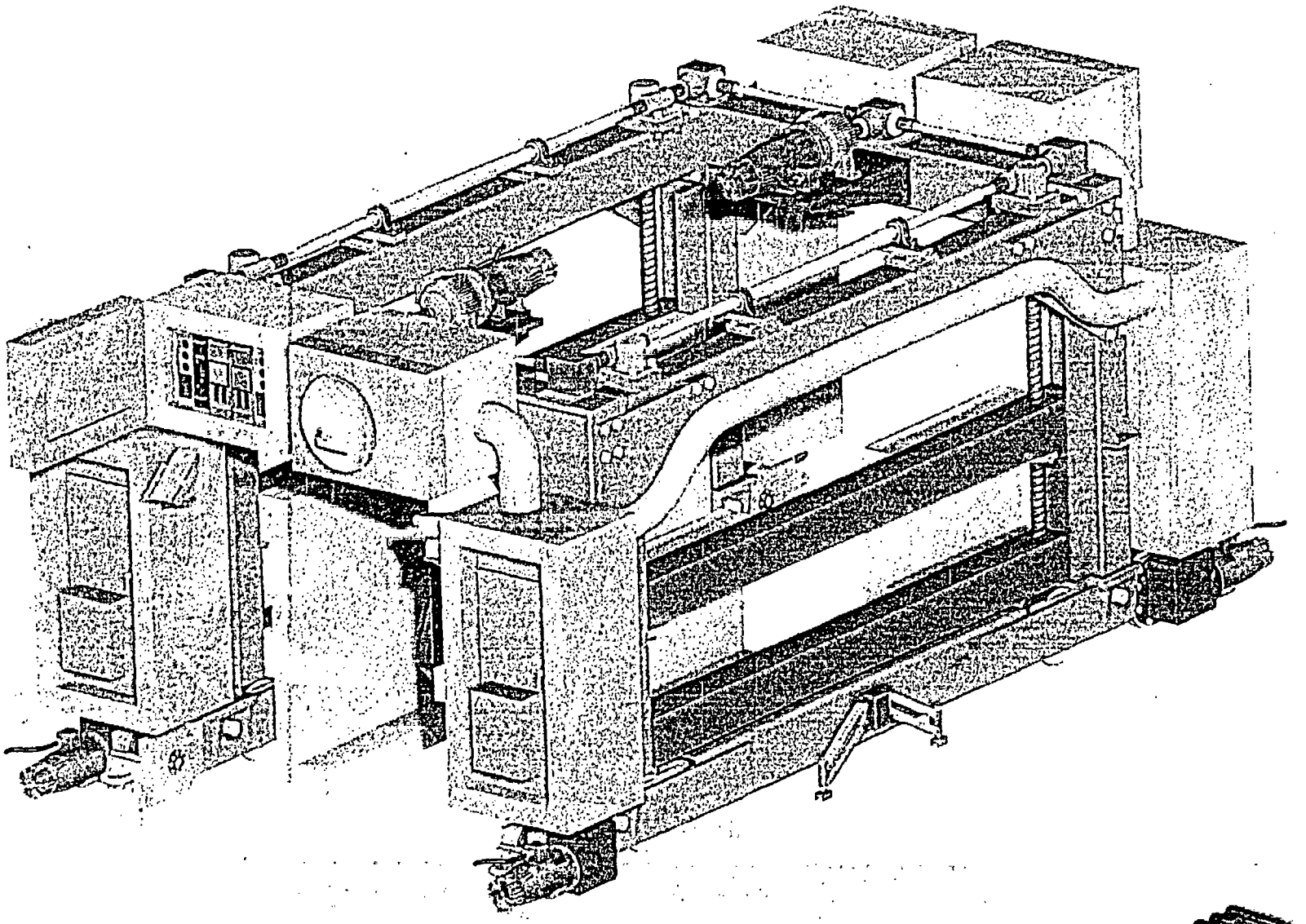
- **Design requirements** (Continued)
  - Seismic
    - Design bases
      - » The system shall not fail in a manner that may result in a breach of a waste package
    - Design requirement
      - » Designed to remain with code allowable values for design basis ground motion (DBGM-2) with a return period of 2,000 years
      - » Designed to assure structural integrity and functionality for beyond design bases ground motions (BDBGM) with a return period of 10,000 years
    - Codes and standards
      - » AISC M016, *Manual of Steel Construction, Allowable Stress Design*

Waste Package Transporter and Locomotive

(Continued)

- **Design requirements** (Continued)
  - Natural phenomena
    - Design bases
      - » Waste package transporter shall be designed to withstand, without loss of credited safety functions, the design basis conditions for natural phenomena
    - Design requirement
      - » Waste package transporter shall be protected with lightning arresters and surge capacitors
      - » Waste package transporter shall withstand tornado winds of 189 mph
    - Codes and standards
      - » AISC M016, *Manual of Steel Construction, Allowable Stress Design*
      - » NFPA 780-2001, *Standard for the Installation of Lightning Protection Systems*

Emplacement Gantry



Emplacement Gantry
(Continued)

- Design bases
  - Drop loads
  - Collision
  - Overtravel
  - Seismic

Emplacement Gantry
(Continued)

- Important to Safety Features
  - Braking system
  - Limit speed
  - Limit lifting height
  - Overtravel controls and end stops
  - Structural integrity

Note: Not every element or appurtenance of an SSC is ITS

Emplacement Gantry

(Continued)

- **Design requirements**
  - Drop loads
    - Design bases
      - » Emplacement gantry shall not vertically lift the waste package at a height that exceeds the design basis drop height
    - Design requirement
      - » Emplacement gantry shall not vertically lift the waste package on a pallet higher than 2 m to the bottom of the pallet
    - Codes and standards
      - » NUREG 0554, *Single-Failure Proof Cranes for Nuclear Power Plants*
      - » ASME NOG-1, *Rules for Construction of Overhead and Gantry Cranes*

Emplacement Gantry

(Continued)

- **Design requirements**
  - **Collision**
    - **Design bases**
      - » **Emplacement gantry shall not travel at speeds that may result in a collision impact velocity that exceed the design basis impact velocity for a waste package**
    - **Design requirement**
      - » **Emplacement gantry speeds shall not exceed 1.7 mph**
    - **Codes and standards**
      - » **CMAA 70, *Specifications for Top-Running and Under Running Single Girder Electric Overhead Traveling Cranes Utilizing Under Running Trolley Hoist***

Emplacement Gantry

(Continued)

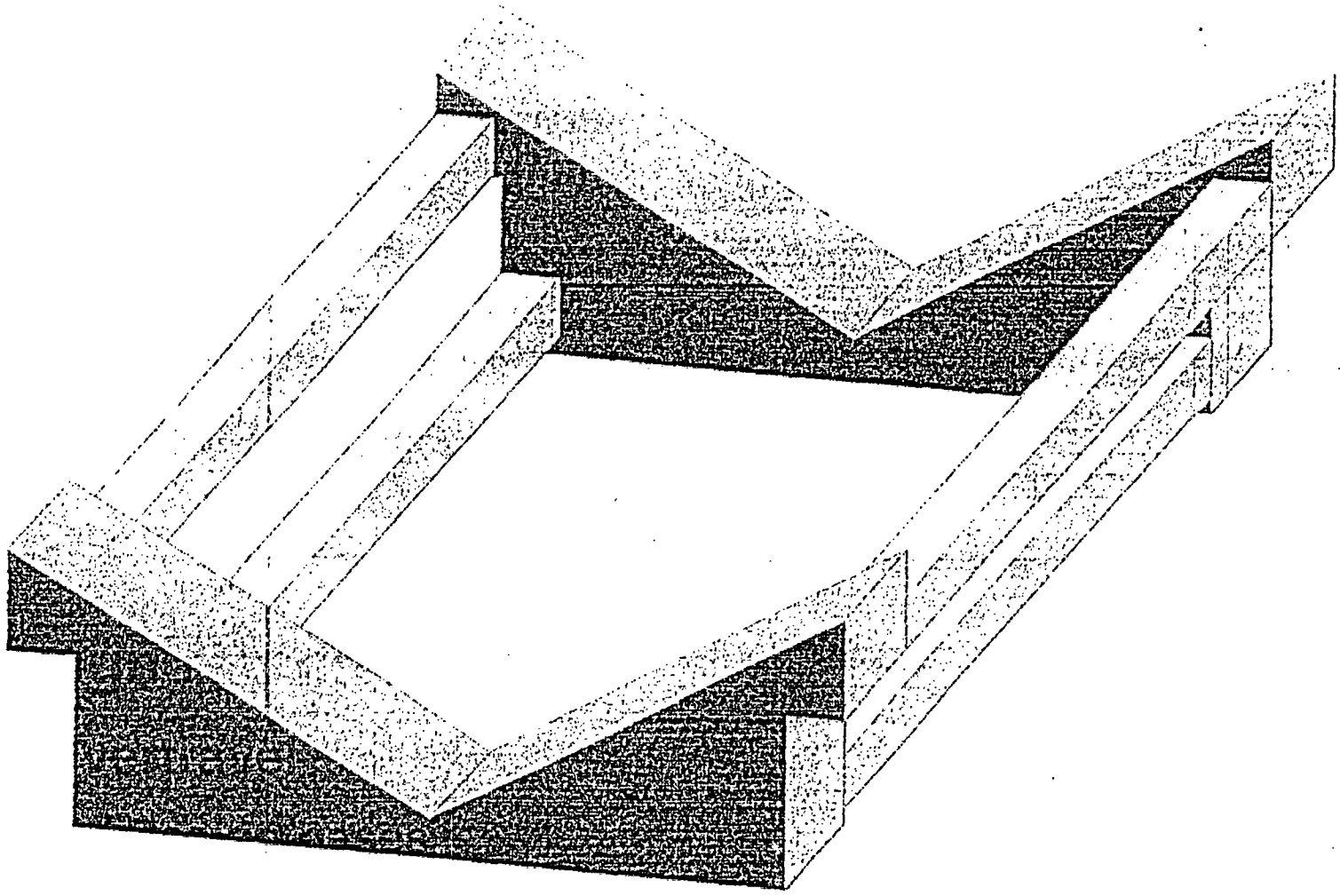
- **Design requirements**
  - Overtravel
    - Design bases
      - » The emplacement gantry, carrying a waste package, shall not be capable of running off the end of the emplacement drift or transfer dock rails
    - Design requirement
      - » The emplacement rails shall have end stops to prevent overtravel of the emplacement gantry
    - Codes and standards
      - » AISC,
      - » CMAA 70, *Specifications for Top-Running and Under Running Single Girder Electric Overhead Traveling Cranes Utilizing Under Running Trolley Hoist*

Emplacement Gantry

(Continued)

- Design requirements
  - Seismic
    - Design bases
      - » The system shall not fail in a manner that may result in a breach of a waste package
    - Design requirement
      - » Designed to remain with code allowable values for DBGM-2 with a return period of 2,000 years
      - » Designed to assure structural integrity for BDBGM with a return period of 10,000 years
    - Codes and Standards
      - » AISC M016, *Manual of Steel Construction, Allowable Stress Design*

Emplacement Pallet



00277DC_Figure 1.ai

Emplacement Pallet
(Continued)

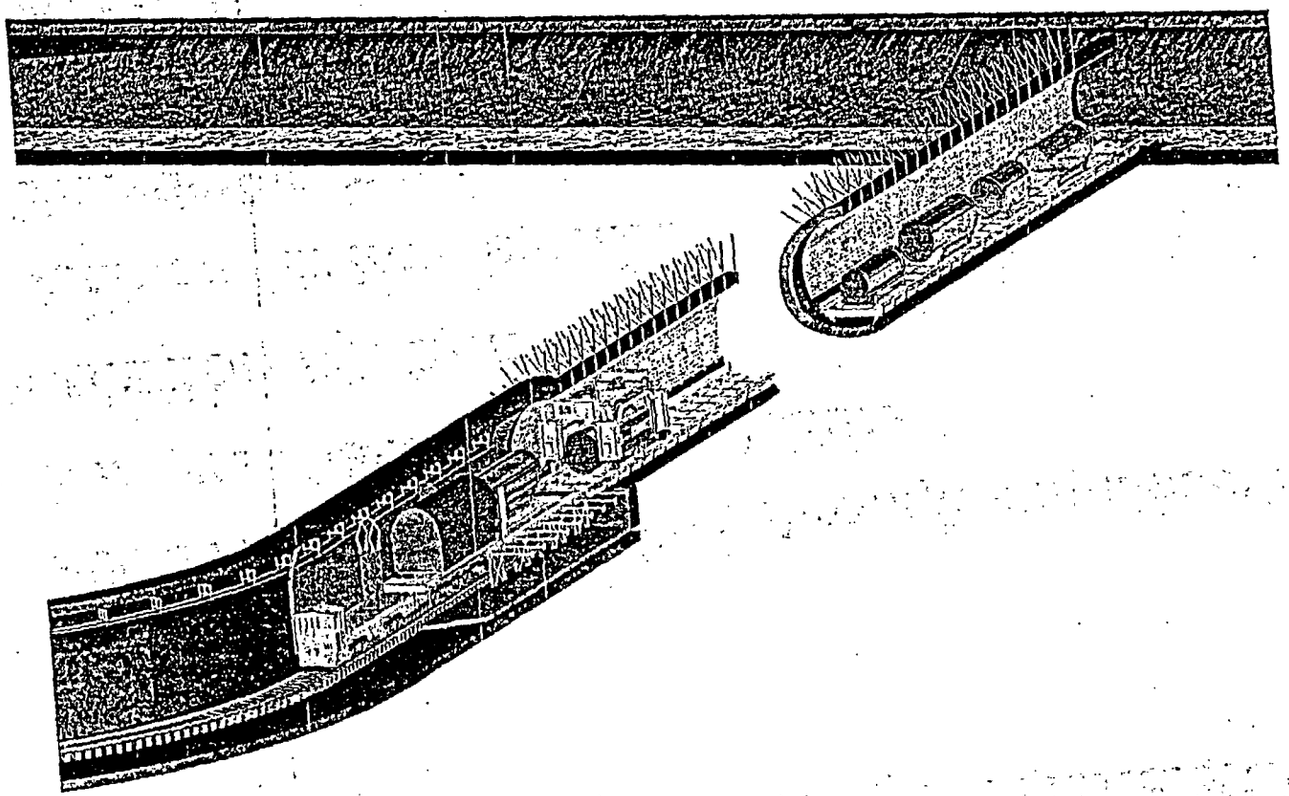
- Design bases
  - Drop loads

Emplacement Pallet

(Continued)

- Design requirements
  - Drop loads
    - Design bases
      - » The emplacement pallet mitigates the effects of a Category 1 or 2 event sequence in the waste package horizontal drop with emplacement pallet analyses
    - Design requirement
      - » The emplacement pallet shall absorb some of the impact energy in the waste package horizontal drop scenarios to protect integrity of a waste package
    - Codes and standards
      - » ASME Boiler & Pressure Vessel Code (B&PV). The appropriate sections of the ASME B&PV code are used as guidance for fabrication of the emplacement pallet

Emplacement Drift



Emplacement Drift Ventilation

- Functions
  - Positive control of air flow through emplacement drifts
  - Removes heat during preclosure
- Ventilation system
  - Ambient air from surface
  - Exhausting system
- Ventilation period
  - Planned for 50 years after final emplacement
- Ventilation flow rate
  - Approximately 15 m^3/s per emplacement drift

Emplacement Drift Invert

- Functions
  - Important to Waste Isolation (ITWI) crushed tuff creates an engineered barrier to diffuse flow of radionuclides during postclosure period
  - Structural steel provides a stable travel way and supports the emplacement pallet and waste package during preclosure
  - Crushed tuff supports pallet, waste package, and drip shield during postclosure
- Two components:
  - Steel frame
    - Preclosure corrosion allowance - 1/16 inches
  - Crushed tuff ballast material
    - 100 percent passing 2 inches
    - <5 percent passing U.S. #200 sieve size

Note: Not every element or appurtenance of an SSC is ITS

Emplacement Drift Invert

(Continued)

- Codes and standards
  - Structural steel conforms to ASTM A588
  - Structural steel bolts conform to ASTM A325
  - Structural steel AISC M016, *Manual for Steel Construction – Allowable Stress Design*
  - Welding AWS D1.1, *Structural Welding Code - Steel*

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

www.ocrwm.doe.gov

Project Schedule Discussion

Presented to:
DOE/NRC Technical Exchange on Yucca Mountain Surface and Subsurface Facilities

Presented by:
Richard L. Craun
Acting Director, Office of Project Management and Engineering
U.S. Department of Energy

September 14-15, 2004
Las Vegas, Nevada

Introduction/Purpose

- Yucca Mountain Project (YMP) Project Scope Overview
- Accomplishments to Date
- Benchmarking Efforts
- Work Breakdown Structure
- Nuclear Facilities Overall Schedule
- Ongoing Challenges to Schedule
- Key Upcoming Events/Milestones

Yucca Mountain Project Scope Overview

- Yucca Mountain Repository's major surface facilities occupy approximately 1.5 square miles
- Approximately 70 miles of tunnel 18-25 feet in diameter
  - Approximately 40 miles of 18-foot in diameter emplacement drifts
- Peak construction craft staffing over 2000
- 12 construction cranes on site (4 towers and 8-150-ton capacity)

Yucca Mountain Project Scope Overview
(Continued)

- Summary of commodities:
  - 4.3 million cubic yards of excavation
  - 650,000 cubic yards of concrete
  - 21,000 tons of steel
  - 1.1 tons of heating, ventilation, and air-conditioning (HVAC) duct and supports
  - 400,000 linear feet of electrical raceway
  - 2.7 million linear feet of wire and conduit
- Over 20,000 activities loaded in current schedule

Accomplishments to Date

- *Quality Assurance Requirements and Description* (QARD)
- License Application (LA) submittal preparation – 85 percent complete
  - Draft LA currently in DOE review
    - Technical review completed
    - Integrated chapter review completed
    - Management review in progress
- 100 percent complete on Key Technical Issues (KTIs) Agreement Responses
  - Total of 293

Accomplishments to Date

(Continued)

- Preclosure Safety Analysis (PCSA) 90 percent complete
- LA design 95 percent complete
- Integrated Engineering, Procurement, and Construction (EPC) "proof of concept" schedule being developed

Benchmarking Efforts

- Sites/projects benchmarked:
  - Hanford Waste Treatment Plant, Richland, WA
  - Private Spent Fuel Storage Initiative
  - MOX Facility – Savannah River Site
- Benchmarking attributes/characteristics:
  - Overall complexity
  - Licensing/permitting
  - Commodities
  - Schedule durations
  - Budget performance
  - Organizational alignments
- Benchmarked against commercial nuclear licensees

Work Breakdown Structure

- Refer to Work Breakdown Structure (WBS) (Attachment A)

Nuclear Facilities Overall Schedule

- Overall durations and sequencing
  - Walkthrough schedule (Attachment B)

Ongoing Challenges to Schedule

- Availability of sufficient numbers of qualified craft personnel
- Ability to meet concrete pour schedules
- Availability of aggregate to support the concrete activities
- Congestion, human factor concerns in scheduling work activity locations
- Coordination/sequencing of construction activities and operations

Key Upcoming Events/Milestones

- LA submittal to NRC – December 2004
- Final Environmental Impact Statement (FEIS)/ Environmental Report accompanies LA
- Full-scale waste package prototype – June 2005
- Start Final Design (Fuel Handling Facility (FHF), Canister Handling Facility (CHF)) – September 2005
- Preliminary design to support DOE Critical Decision 2
  - Feeds material take-offs
- Independent government estimate

Attachment A

Insert to be Provide During the Meeting

Attachment B

Insert to be Provide During the Meeting

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

www.ocrwm.doe.gov

Update of Preclosure Safety Analyses

Presented to:
DOE/NRC Technical Exchange on Yucca Mountain Surface and Subsurface Facilities

Presented by
Richard L. Craun
Acting Director of Office Project Management and Engineering
U.S. Department of Energy

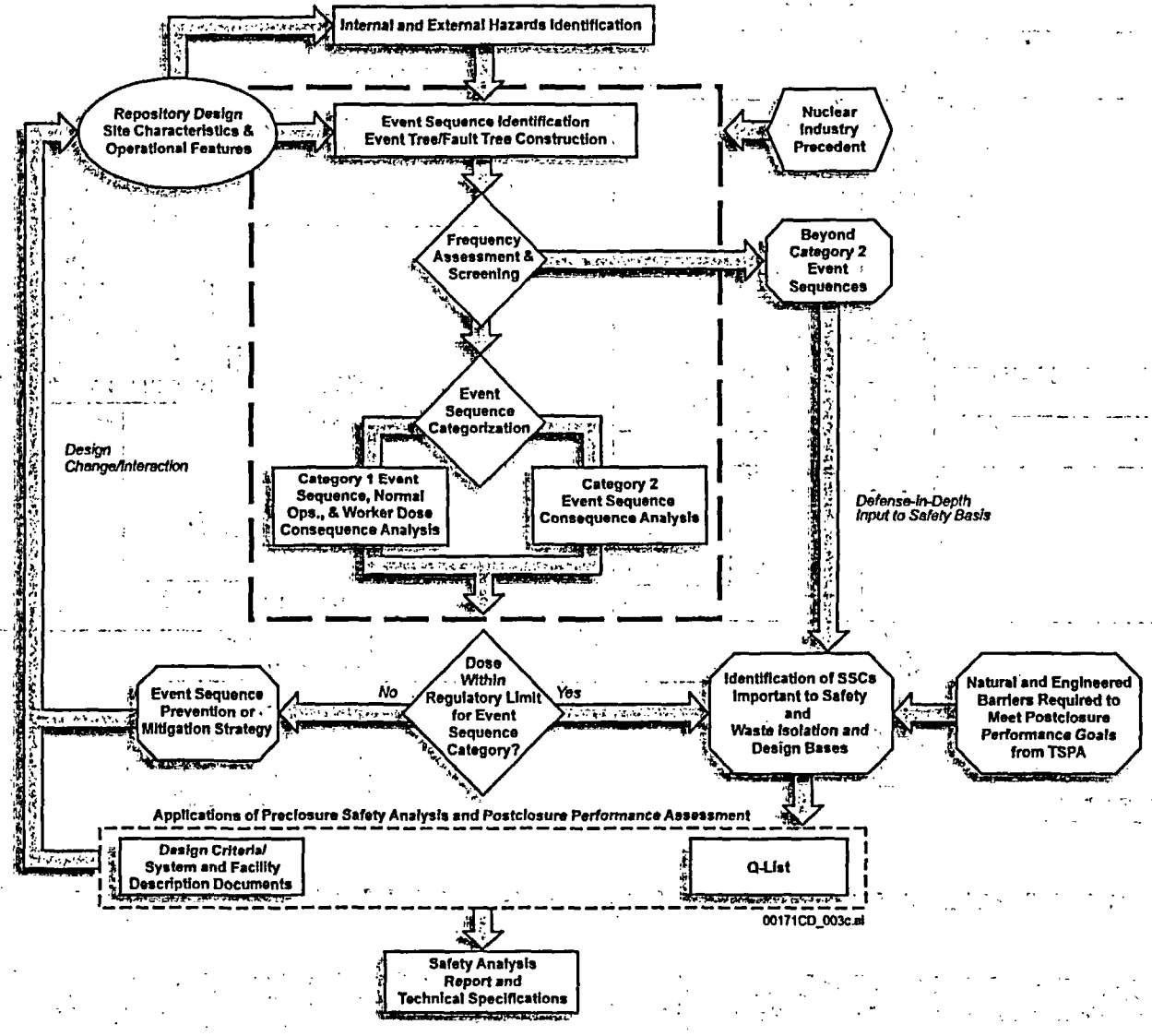
Stephen J. Cereghino
Manager of Licensing
Bechtel SAIC Company, LLC

September 14-15, 2004
Las Vegas, Nevada

Preclosure Safety Analyses

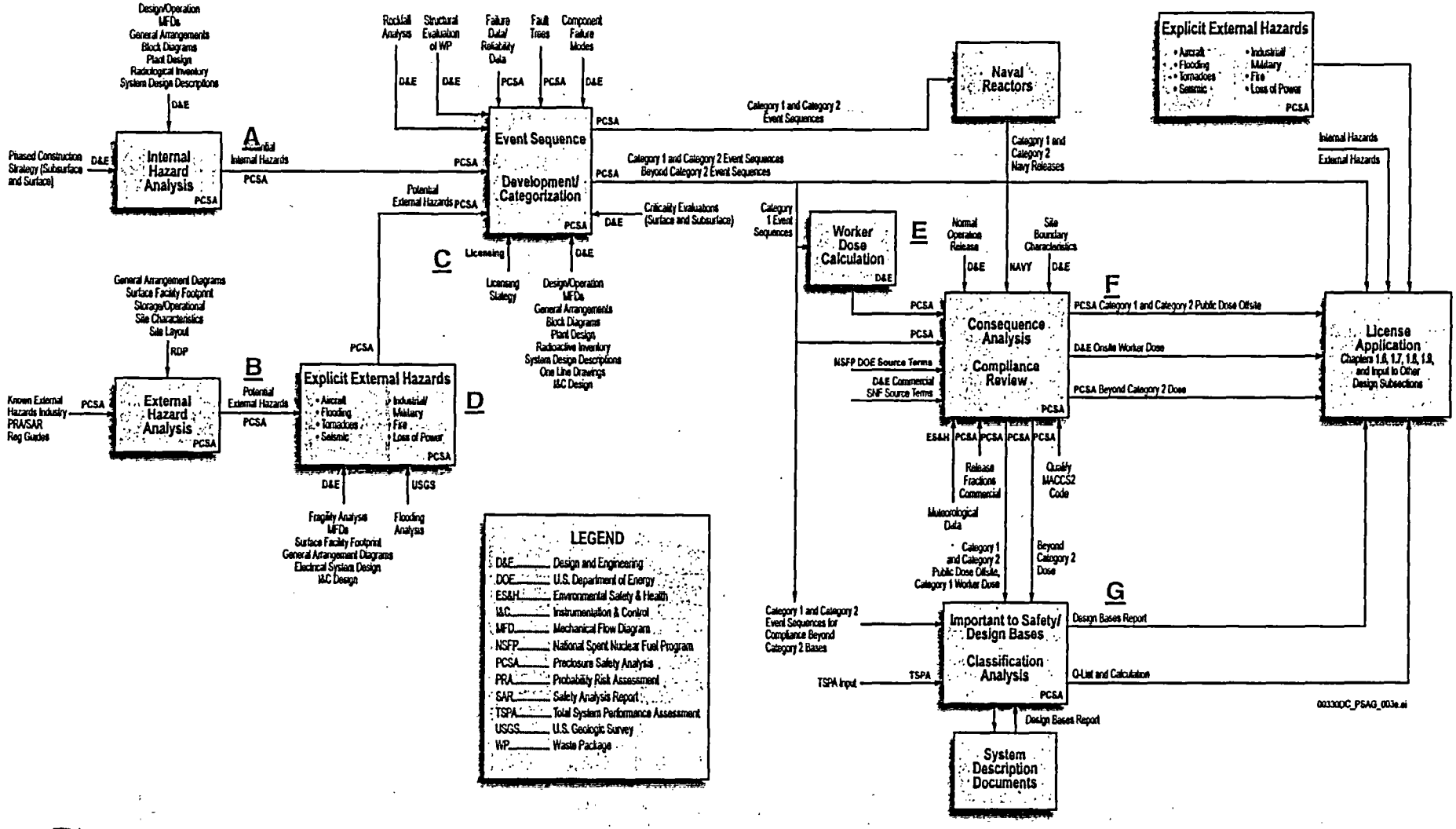
- **Purpose**
  - Discuss projects Preclosure Safety Analyses status regarding implementation of NRC's regulations regarding identification of event sequences and identification of "important to safety" (ITS) structures, systems, or components (SSCs)
- **Objectives**
  - Describe the Project's Preclosure Safety Analysis approach for identifying hazards
  - Describe Selected Repository Initiating Events
  - Discuss Classification of Selected Event Sequences
  - Present Consequence Analysis and Safety Classification

Preclosure Safety Analysis Process



Preclosure Safety Analyses Interfaces

Preclosure Safety Analysis Work Interface Flowchart



Preclosure Safety Analyses Interface Description

A Internal Hazards Analysis for License Application (000-00C-MGR0-00600-000-00A)

B Monitored Geologic Repository External Events Hazards Screening Analysis (000-00C-MGR0-00500-000-00A)

C Categorization of Event Sequences for License Application (000-00C-MGR0-00800-000-00A)

D Seismic Analysis for Preclosure Safety (000-00C-MGR0-00700-000-00A)

Frequency Analysis of Aircraft Hazards for License Application (000-00C-WHS0-00200-000-00A)

Identification of Aircraft Hazards (000-30R-WHS0-00100-000-001)

Industrial/Military Activity-Induced Accident Screening Analysis (ANL-WHS-SE-000004, Rev. 001)

Extreme Wind/Tornado/Tornado Missile Hazard Analysis (000-00C-WHS0-00100-000-00A)

Fire-Induced Event Sequence Analysis (000-00C-MGR0-01300-000-00A)

Bounding Characteristics of Credible Rockfalls of Preclosure Period (800-00C-MGR0-00200-000-00A)

Preclosure Safety Analyses Interface Description

(Continued)

E Normal Operation Airborne Release Calculation (000-HSC-WHS0-00200-000-00A)

Category 1 Event Sequences Worker Dose Calculation (000-HSC-WHS0-00100-000-00C)

Geologic Repository Operations Area Worker Dose Assessment (000-00C-WHS0-00300-000-00B)

F Preclosure Consequence Analyses for License Application (000-00C-MGR0-01000-000-00A)

G Safety Classification of SSC's and Barriers (000-00C-MGR0-00500-000-000, Rev. 00)

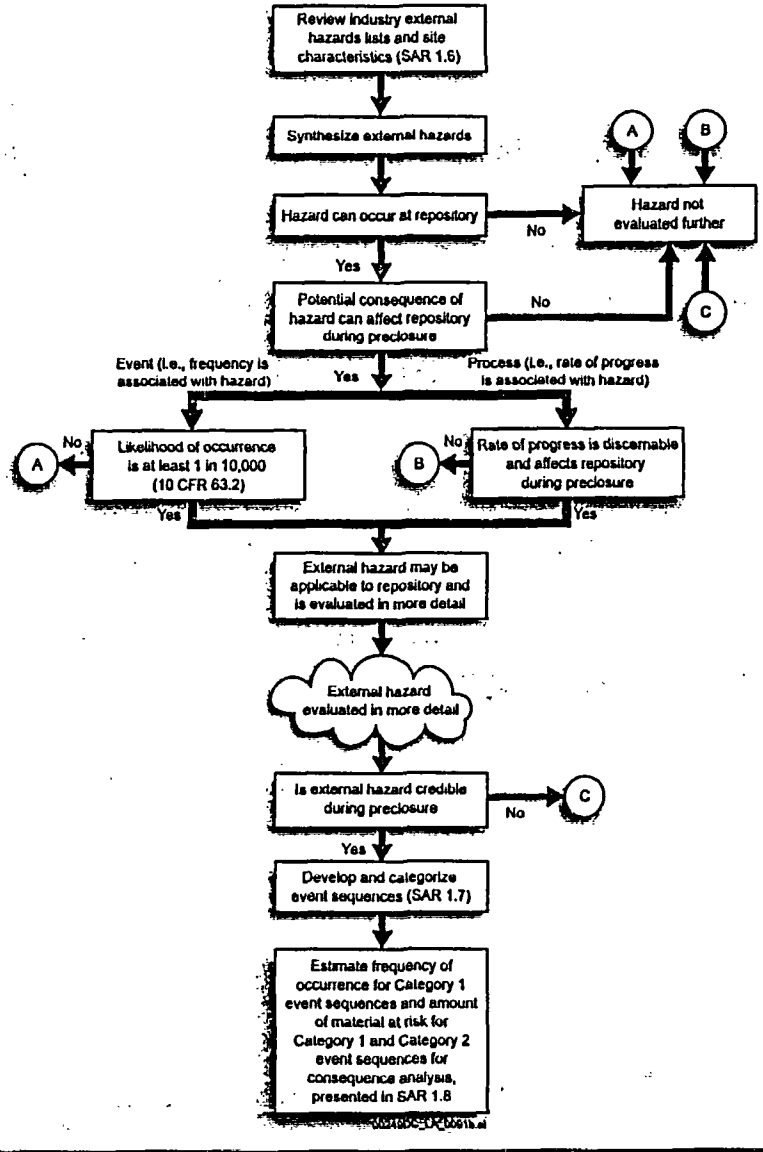
Q-List (000-30R-MGR0-00500-000-000, Rev. 00)

Nuclear Safety Design Bases for License Application (000-30R-MGR0-00400-000-000, Rev.00)

Process Overview

- Process Overview
  - External Hazards Assessment
    - Started with 54 potential external events broadly considered in the nuclear industry
    - Screened and grouped to 11 external events categories that are applicable to the Yucca Mountain Project (YMP)
      - » Each external event evaluated and design requirements established that mitigate their impact
  - Internal hazards assessment are perform on functions in surface and subsurface facilities
    - Identified over 700 potential hazards based on screening methodology
      - » Each event considered when establishing Category 1 and 2 event sequences, identifying ITS SSCs, and establishing operational controls and design requirements

External Hazards Method



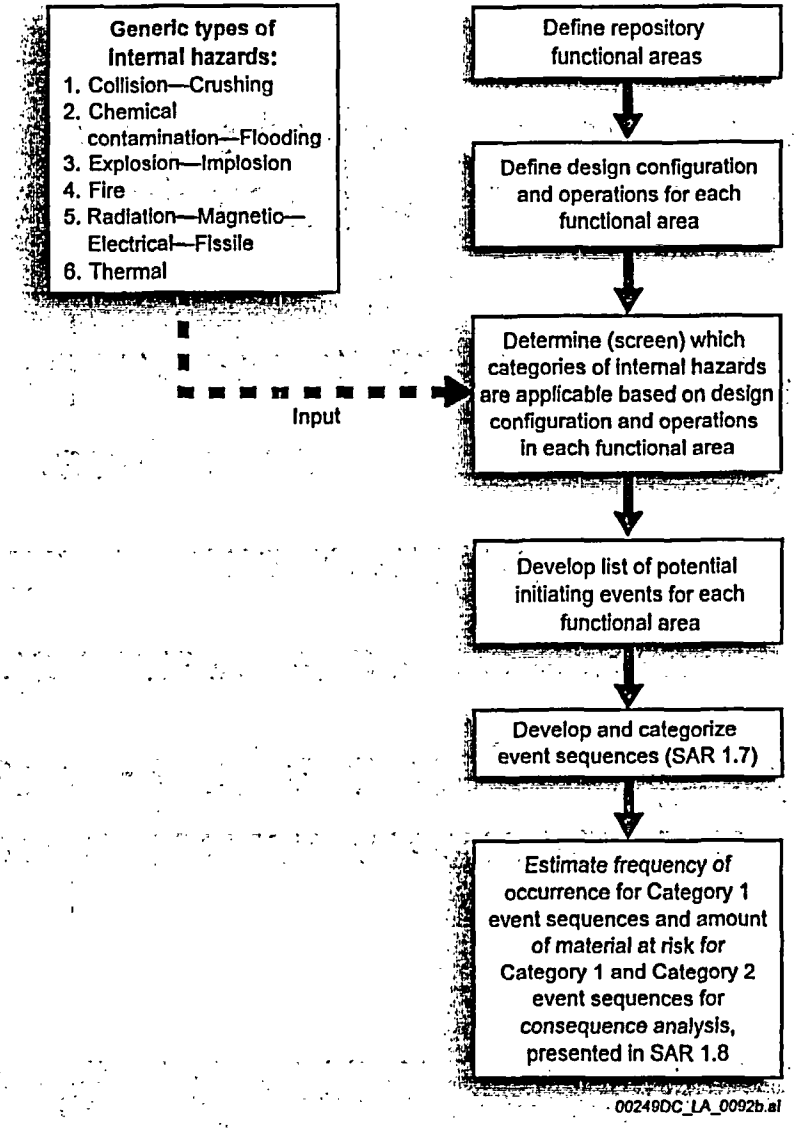
General External Hazard List

- Aircraft crash
- Avalanche
- Coastal erosion
- Dam failure
- Debris avalanching
- Denudation
- Dissolution
- Drift degradation
- Epeirogenic displacement
- Erosion
- Extreme weather fluctuation
- Extreme wind
- Flooding (external)
- Fracturing
- Fungus, bacteria, and algae
- Glacial erosion
- Glaciation
- High lake level
- High river stage
- High tide
- Hurricane
- Inadvertent future human intrusion
- Industrial-activity-induced accident
- Intentional future human intrusion
- Landslide
- Lightning
- Loss of power
- Low lake level
- Low river level
- Meteorite impact
- Military-activity-induced accident
- Orogenic diastrophism
- Pipeline accident
- Rainstorm
- Range fire
- Sandstorm
- Sedimentation
- Seiche
- Seismic activity: earthquake
- Seismic activity: subsurface fault displacement
- Seismic activity: surface fault displacement
- Stream erosion

Applicable External Hazard List

- Aircraft crash
- Drift degradation and fracturing
- Extreme weather and climate fluctuations: temperature transients
- Extreme wind and tornado
- Fire
- Flooding and rainstorm
- Industrial and military activity induced accidents
- Lightning
- Loss of power
- Seismic activity
- Volcanism: ash fall

Internal Hazards Method



Example of Internal Hazards Linking

- Identified internal hazards to be summarized in the Safety Analysis Report (SAR) by linking:
  - Generic hazard event category
  - Potential events identified
  - Event designator
  - Event sequence classification (Category 1, Category 2 or Beyond Category 2)
  - Design or operational requirement, and whether requirement is preventive or mitigative

Summary of Selected Repository Initiating Events

- Commercial spent nuclear fuel assembly drops
  - Drops of single fuel assemblies while being lifted by spent fuel transfer machine
    - Pressurized water reactor (PWR) and boiling water reactor (BWR) fuel assemblies are evaluated
- DOE Canister Drops
  - Drop of a single canister while being lifted by overhead crane
    - DOE standard canister, multicanister overpack (MCOs), and high-level waste (HLW) Canister are evaluated
- Transportation Cask Drops
  - Drops of a single transportation cask while being lifted by overhead crane

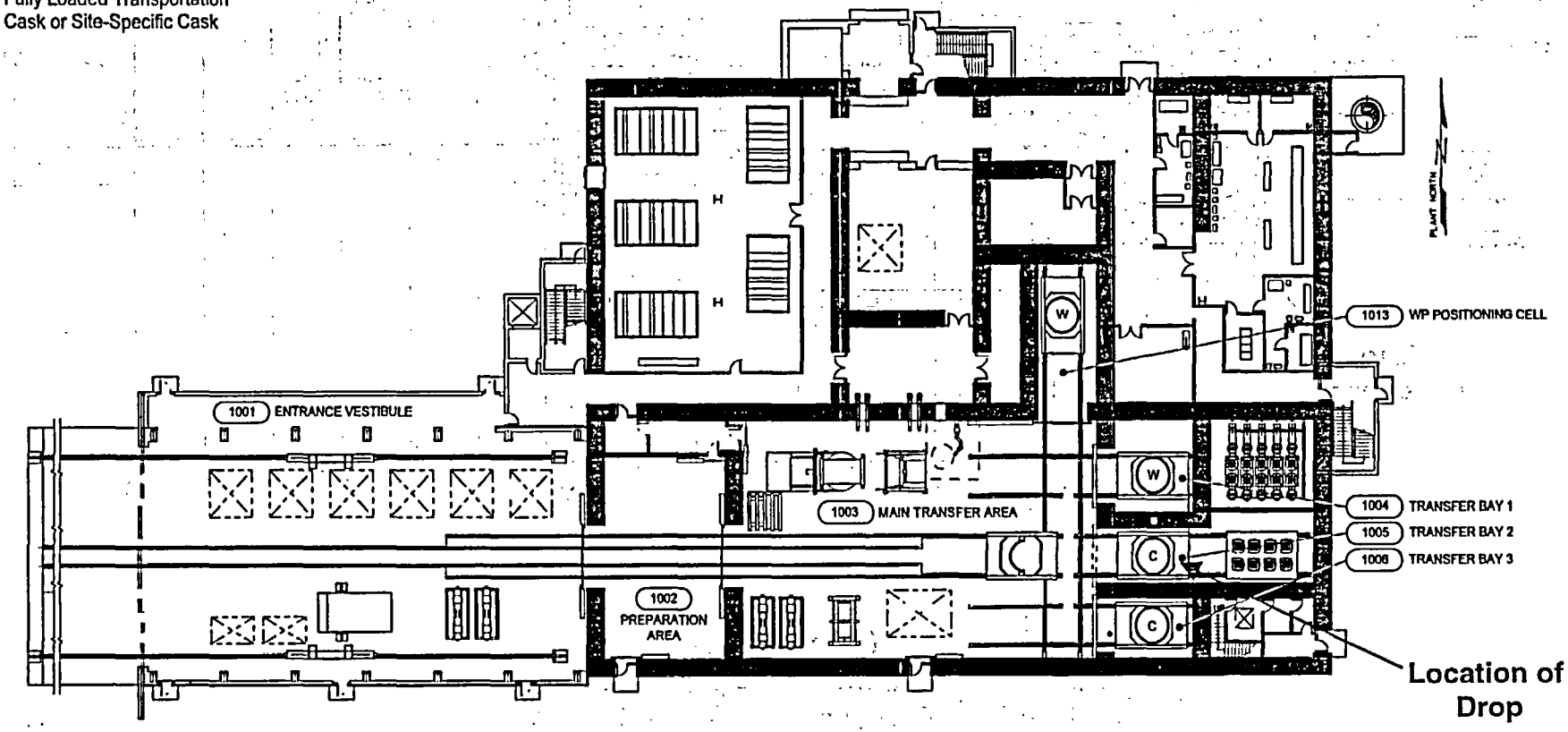
Example 1: Fuel Assembly Drop or Collision Event

What can happen?	Moving a fuel assembly from transportation cask to waste package can result in a drop or collision
Where can this occur and how likely is it?	Fuel Handling Facility (FHF) and Dry Transfer Facility (DTF) waste transfer cell; Depends on number of lifts and equipment reliability
What are the consequences?	Fuel cladding can fail and release a fraction of the fuel inventory of radionuclides to the waste transfer cell confinement

Fuel Handling Facility: Assembly Drop or Collision Example

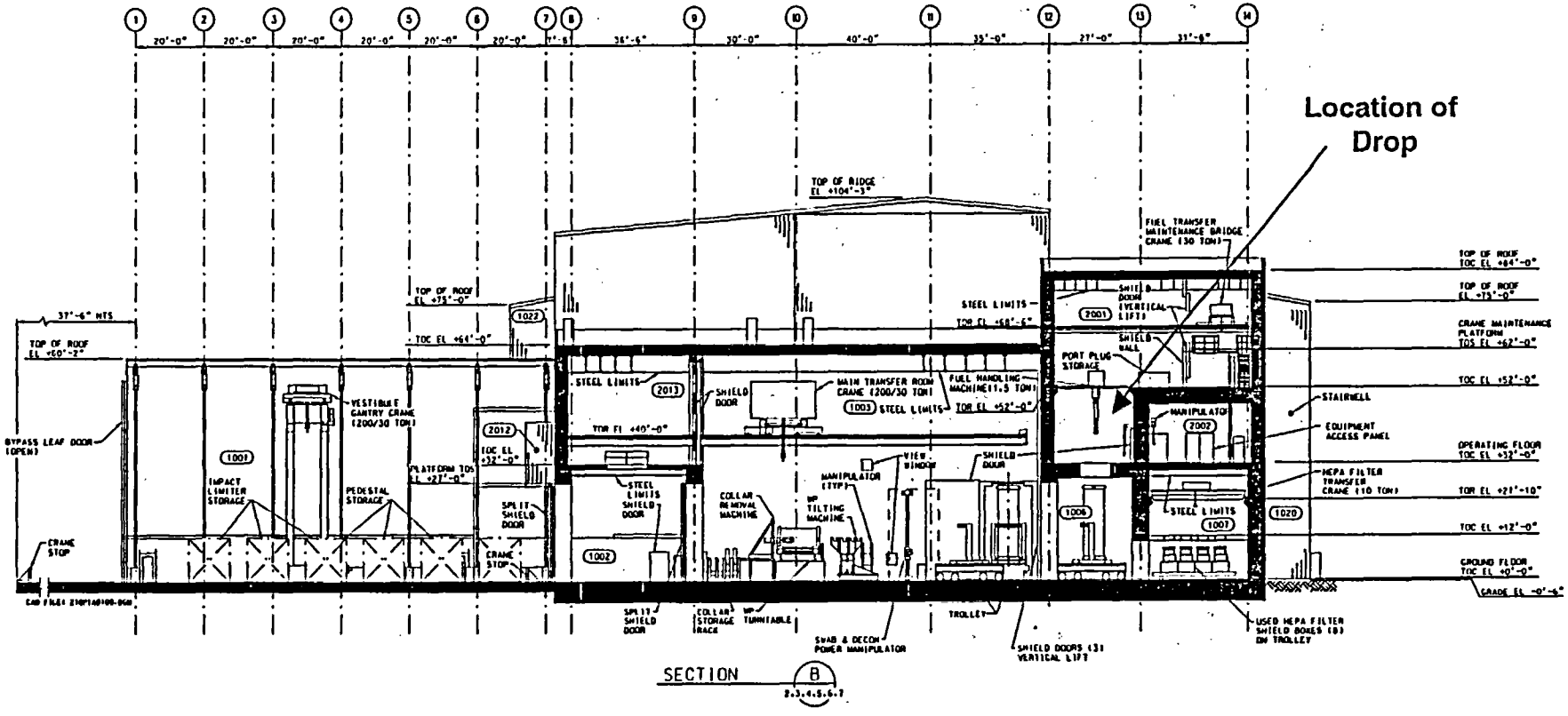
Waste Container Indicators

- (W) Fully Loaded Waste Package
- (C) Fully Loaded Transportation Cask or Site-Specific Cask

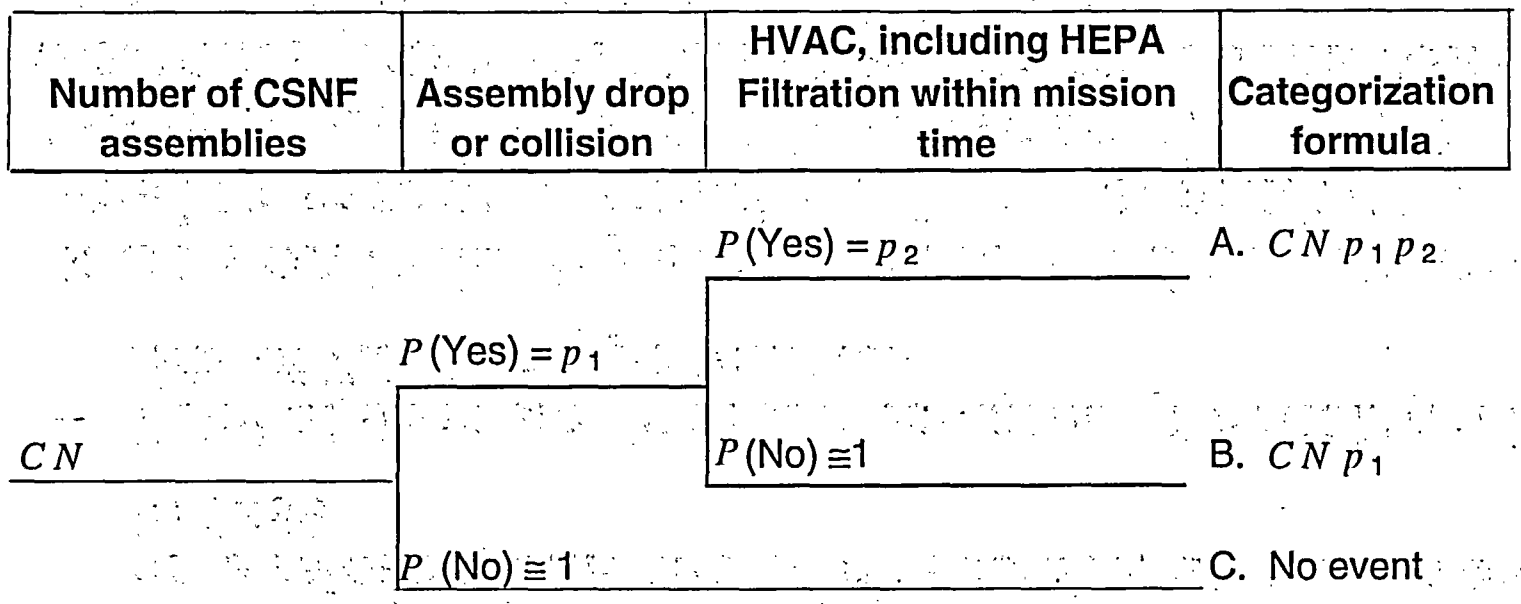


Fuel Handling Facility: Assembly Drop or Collision Example

(Continued)



Event Sequence for Assembly Drop or Collision



Item	Description and Calculation	Value
C	Factor of conservatism.	1.1
N	Number of CSNF assemblies.	221,000
p_1	Probability of a drop (and probability of a collision) of a CSNF assembly is given by the maximum number of transfers (4) times the assembly-drop rate or assembly-collision rate of the spent fuel transfer machine (10^{-5}).	4E-05
p_2	Probability that HEPA filtration becomes unavailable within 4 h of a handling event due to loss of offsite power or failure of the HVAC system.	1E-03

Example: Basis For Commercial Spent Nuclear Fuel Assembly Drop Rate

- Survey of nuclear power plant fuel assembly transfers
  - Total of 1,199,000 assembly transfers associated with core reloads, offloads, and assembly shuffles from 1985 to 1999
  - Total of 9 assembly drops occurred, producing a drop rate of 7.5E-6 drops/transfer
- Based on industry experience 1E-5 drops/transfer used in safety evaluation. This reliability will be required as part of the fuel assembly transfer machine procurement specification This reliability will be required as part of the Fuel Assembly Transfer Machine procurement specification

Categorization of Assembly Drops and Collisions

Event ID	Material at Risk	Categorization Formula	Expected Number of Events	Category	Features Credited in the Categorization Calculation or to Prevent Exposure
A	2 assemblies for drops, 1 assembly for collisions	$C N p_1 p_2$	9.7E-03	Category 2	Numbers of assemblies. Load-drop rate.
B	2 assemblies for drops, 1 assembly for collisions	$C N p_1$	9.7	Category 1	Numbers of assemblies. Load-drop rate. Availability of HEPA filtration for mission time.
C	No event	No event	No event	No event	No event

Summary of Assembly Drop or Collision

- Drops or collision identified as a possible internal hazards in FHF or DTF
- Large number of assembly handlings result in assembly drops in the FHF and DTF with heating, ventilation, and air-conditioning (HVAC)/high-efficiency particulate air (HEPA) operating to be classified as Category 1 event sequences
  - HVAC/HEPA operation for mission time and shielding in waste transfer cell required to meet worker dose requirements
  - Electrical supply distribution required to operate HVAC for mission time
  - Reliable spent fuel transfer machine required to minimize the number of Category 1 events

Summary of Assembly Drop or Collision
(Continued)

- Large number of assembly handlings result in drops of assemblies in the FHF and DTF with loss of HVAC/HEPA operating to be classified as Category 2 event sequences
  - Offsite public doses met without credit for HVAC/HEPA

Design Basis Requirements Credited in Safety Evaluation

System or Subsystem	Component or Function	Nuclear Safety Design Bases
		SNF/HLW Transfer System
Dry Transfer	Spent Fuel Transfer Machine; FHF and DTF	• The reliability of the spent fuel transfer machine shall be such that it has a failure rate of less than 1×10^{-5} drops/transfer.
		Electrical Supply System
Electrical Supply	Normal Power Supply to Surface Nuclear HVAC	• The failure rate of the combined onsite electrical power system components to the fans in the DTF and the FHF shall be less than 1×10^{-5} failures per operating hour.
		Surface Nuclear HVAC System
Primary	N/A	• To mitigate the worker and public doses following a Category 1 event sequence, the Surface Nuclear HVAC system shall be equipped with HEPA filters. This requires a two-stage HEPA filtration system with a particulate removal efficiency of at least 99% per stage. This requirement applies to the DTFs and the FHF. • The failure rate of the HVAC system mechanical components in the DTFs and FHF shall be less than 2.3×10^{-4} failures/operating hr.

Operational Requirements Credited in Safety Evaluation

- HVAC/HEPA in FHF and DTF must be operational within acceptable limits before fuel assembly lifts can be performed
- HVAC/HEPA in FHF and DTF to be monitored during operation to show system performance is within acceptable limits

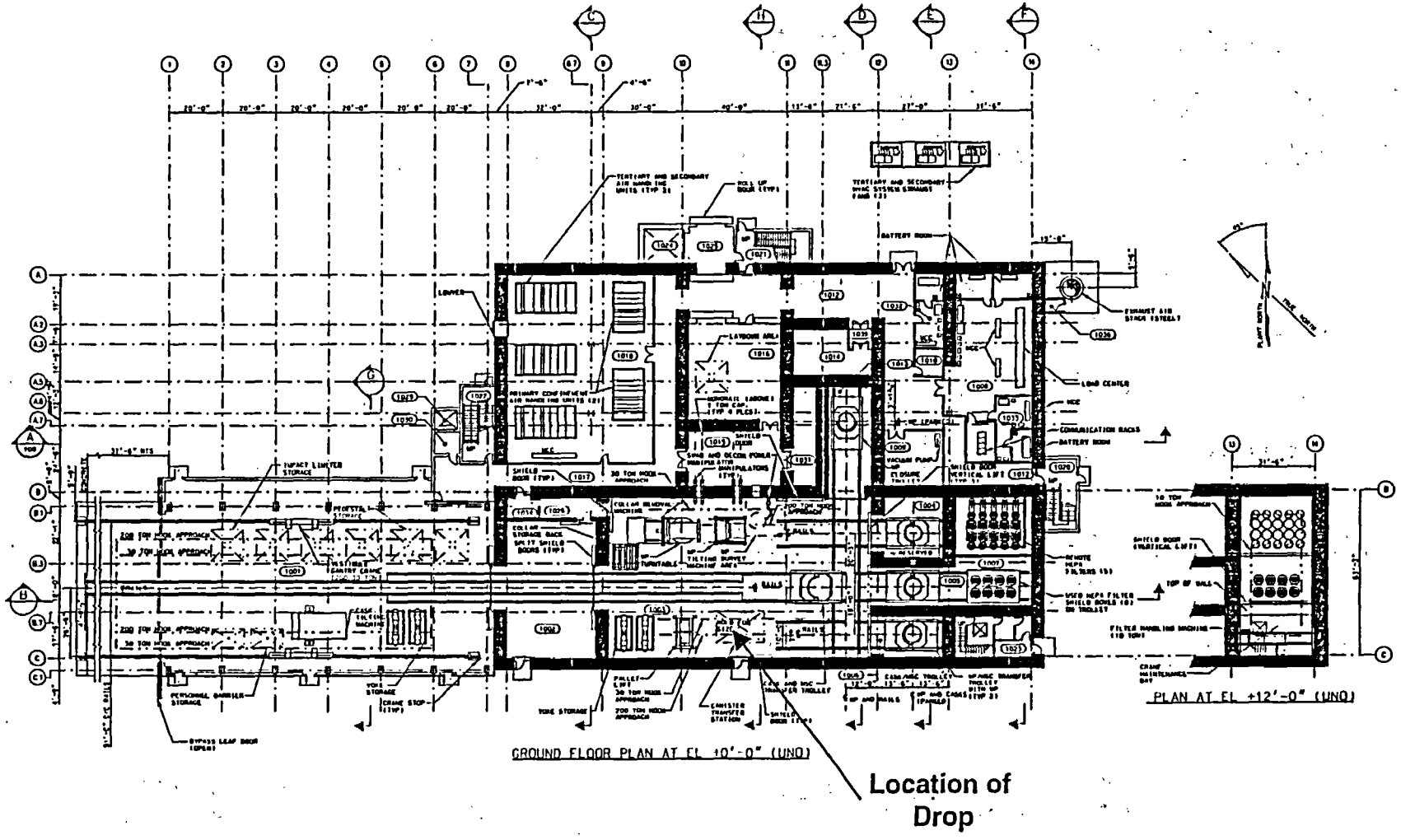
Q-List Documentation

System or Subsystem	Component or Function	Important to Safety (ITS)	Important to Waste Isolation (ITWI)
	SNF/HLW Transfer System		
Dry Transfer	Spent Fuel Transfer Machine (FHF, DTF)	Yes	No
	Surface Nuclear HVAC System		
Primary	Exhaust fans, HEPA filters, exhaust dampers, exhaust ducting for waste transfer cells	Yes	No
	Electrical Power System		
Electrical Power	Switchyard, Normal Power, and Emergency Power	Yes	No
	Normal Power Supply to Surface Nuclear HVAC	Yes	No

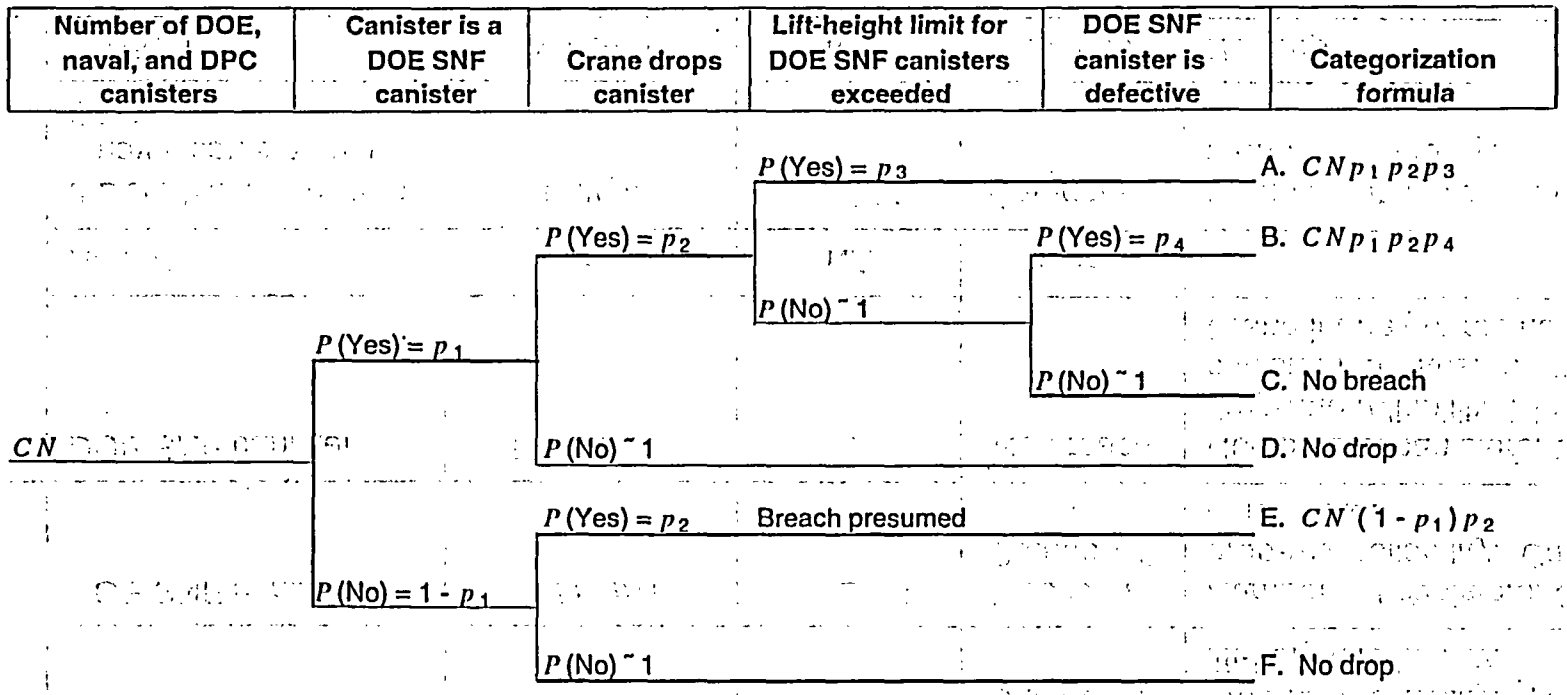
Example 2: Canister Drop Event

What can happen?	Moving a DOE canister from transportation cask to waste package can result in a drop
Where can this occur and how likely is it?	FHF and DTF or Canister Handling Fuel (CHF); depends on the number of lifts and equipment reliability
What are the consequences?	DOE Standard Canister drop is restricted to within canister design basis drop height, canister drop above this height with failure to confine radionuclides is beyond Category 2

Fuel Handling Facility: Canister Drop Example



Event Sequence for Canister Drop Event



Item	Description and Calculation (if applicable)	Value
C	Factor of conservatism.	1.1
N	Number of DOE, naval, and DPC canisters handled	29,485
p_1	Fraction of canisters that are DOE SNF canisters	1.22E-01
p_2	Probability of a handling-equipment drop onto a canister is estimated as the number of transfers (2) times the handling-equipment drop rate per transfer (10^{-5})	2.00E-05
p_3	The conditional probability of exceeding the lift height given a drop	1.00E-04
p_4	The probability that a DOE standardized canister is defective and would breach if dropped from within the lift-height limit.	2.30E-04

Categorization of Canister Drops

Event ID	Material at Risk	Categorization Formula	Expected Number of Events	Category	Features Credited in the Categorization Calculation or to Prevent Exposure
A	DOE SNF canister	$C\,N\,p_1\,p_2\,p_3$	7.9E-06	Beyond Category 2	Numbers of canisters. Crane drop-rate reliability. Crane lift-height reliability.
B	DOE SNF canister	$C\,N\,p_1\,p_2\,p_4$	1.8E-05	Beyond Category 2	Numbers of canisters. Crane drop-rate reliability. Canister defect rate.
C	DOE SNF canister	No breach	NA	No breach	Numbers of canisters. Crane drop-rate reliability. Ability of canisters to withstand drop. Crane lift-height restrictions.
D	No drop	No drop	NA	No drop	No drop
E	2 DOE HLW canisters, 1 naval canister or 1 DPC	$C\,N\,p_2$	5.7E-01	Category 2	Numbers of canisters. Crane drop-rate reliability.
F	No drop	No drop	NA	No drop	No drop

Summary of Canister Drop

- Drops identified as a possible internal hazards in FHF, DTF, and CHF
- Large number of canister handlings result in drops in the FHF, DTF, and CHF to be classified as Category 2 event sequences
  - Reliable overhead crane required to minimize the number of events such that the drops are Category 2
  - Standard DOE canister design drop height capability combined with reliable crane makes canister drop above canister design bases and breach beyond Category 2
  - Offsite public doses met without credit for HVAC/HEPA

Design Basis Requirements Credited in Safety Evaluation

System or Subsytem	Component or Function	Nuclear Safety Design Bases
		Cask/MSC/WP Preparation System
Cask Preparation	Main Transfer Bridge Crane; FHF, 200 ton	• This crane shall have a probability, given a drop, of less than or equal to 1×10^{-4} for lifting a DOE multicanister overpack more than 2 ft (0.6 m) above the floor of the transfer cell or lift a standardized DOE SNF canister or DOE multicanister overpack more than 23 ft (7 m) above the floor of the cask from which it is removed or above the waste package or site-specific cask into which it is to be placed. • This crane shall have a probability, given a drop, of less than or equal to 1×10^{-4} for lifting a naval canister more than 28 ft (8.5 m) above the floor of the cask from which it is removed or above the waste package into which it is to be placed. • The reliability of this crane shall have a probability of less than or equal to 1×10^{-5} drops/transfer.

Q-List Documentation

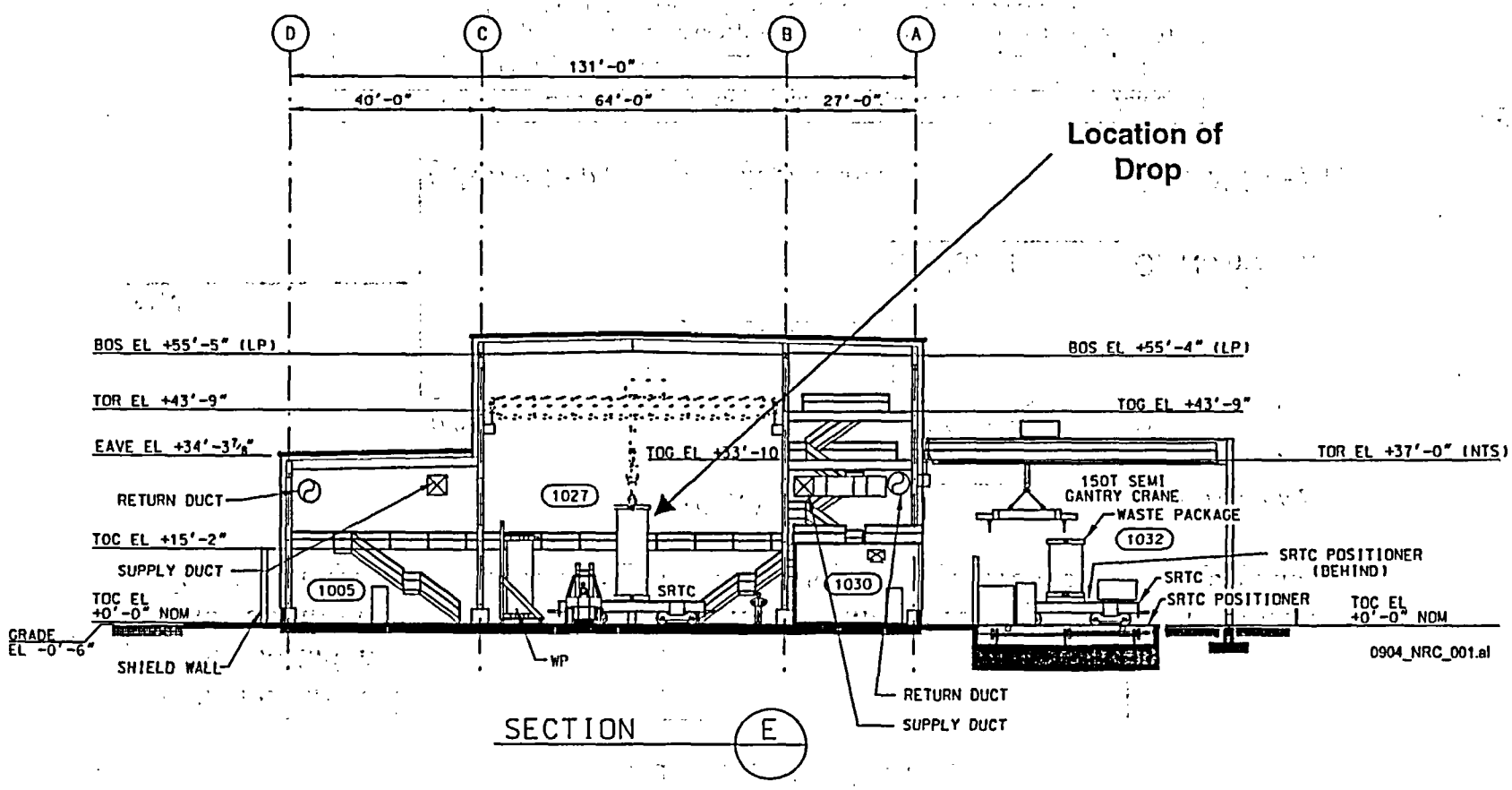
System or Subsystem	Component or Function	Important to Safety (ITS)	Important to Waste Isolation (ITWI)
	DOE SNF Disposable Canister		
DOE SNF Disposable Canister	Standardized DOE SNF Canister	Yes	Yes
	Multicanister Overpack	Yes	Yes
	Cask/MSC/WP Preparation System		
Cask Preparation	Main Transfer Bridge Crane (FHF) 200 ton	Yes	No

Note: Not every element or appurtenance of an SSC is ITS

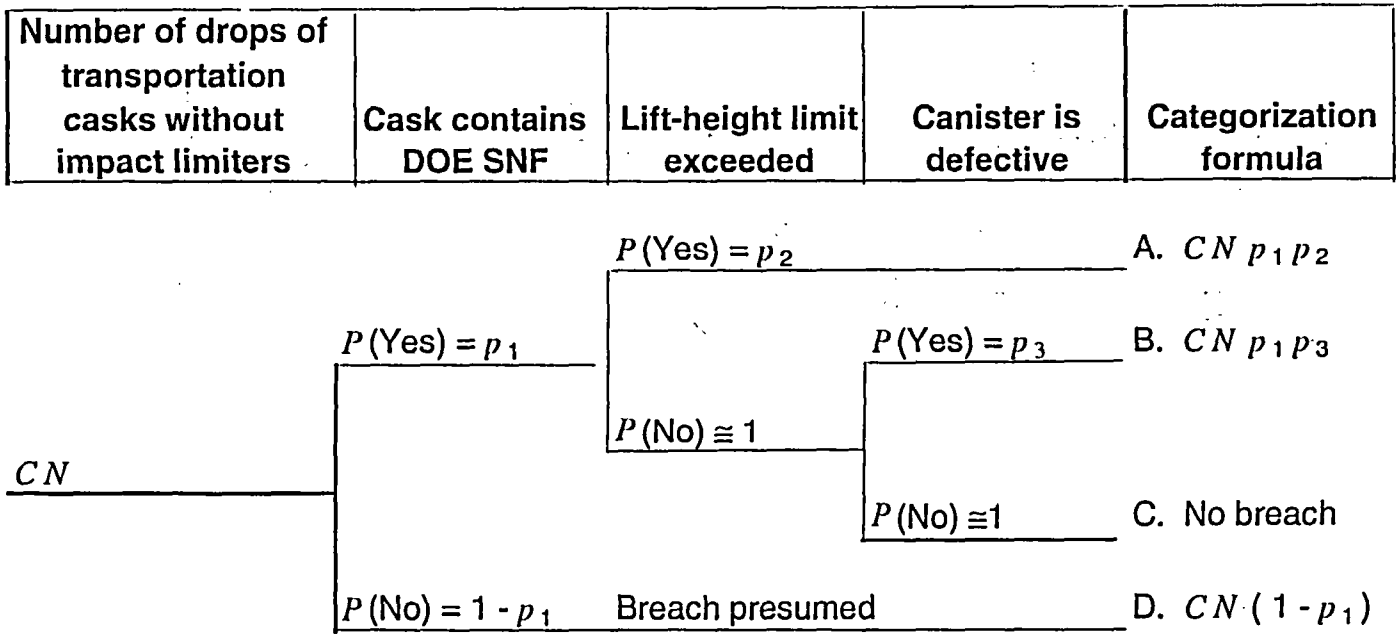
Example 3: Transportation Cask Drop Event

What can happen?	Cask with or without impact limiters can be dropped when moved from a cask conveyance to a Site-Rail Transfer Cart (SRTC)
Where can this occur and how likely is it?	Transportation Cask Receipt/Return Facility (TCRRF) (Cask and Waste Package Receipt Building), FHF, DTF or CHF; depends on the number of lifts and equipment reliability
What are the consequences?	Cask with impact limiter attached will not be lifted above 30 ft (10 CFR71), so cask confinement is maintained if cask dropped, cask without impact limiter attached if dropped can result in loss of confinement function, assembly cladding failure and partial release of radionuclides

Transportation Cask Receipt/Return Facility: Cask Drop Example



Event Sequence for Transportation Cask Drop



Item	Description and Calculation (if applicable)	Value
C	Factor of conservatism	1.1
N	The expected number of dropped transportation casks is given by the number of casks (13,479) the number of times each cask is transferred (2) times the crane drop rate (1E-05 drops / transfer)	2.7E-01
p_1	Fraction of casks that are DOE SNF canister and MCO casks (457 / 13,479)	3.4E-02
p_2	The conditional probability of exceeding the lift-height limit given that a drop occurred	1.0E-04
p_3	The probability that one or more of the DOE canisters in the cask is defective such that it may breach if dropped from within the lift-height limit. The probability that a given canister is defective is 2.3E-04	2.1E-03

Categorization of Transportation Cask Drop

Event ID	Contents of Cask (Material at Risk)	Categorization Formula	Expected Number of Events	Category	Features Credited in the Categorization Calculation or to Prevent Exposure
A	DOE SNF canisters (standardized or MCO)	$C\,N\,p_1\,p_2$	1.01E-06	Beyond Category 2	Numbers of DOE SNF casks. Crane drop-rate reliability. Crane lift-height reliability.
B	DOE SNF canisters (standardized or MCO)	$C\,N\,p_1\,p_3$	2.31E-06	Beyond Category 2	Numbers of DOE SNF casks. Crane drop-rate reliability. Canister defect rate.
C	DOE SNF canisters (standardized or MCO)	No breach	NA	NA	Structural capabilities of DOE SNF canisters.
D	74 BWR or 36 PWR assemblies, 5 DOE HLW canisters, or 1 naval canister	$C\,N\,(1 - p_1)$	2.9E-01	Category 2	Number of transportation cask receipts.

Summary of Transportation Cask Drop

- Drops identified as a possible internal hazards in Cask Receipt and Return Building within FHF, DTF, or CHF when lifting casks
- Number of cask handlings result in cask drops being classified as Category 2 event sequences
  - Reliable crane required to minimize the number of cask drop events so that the event in not Category 1
  - Crane features relied on to limit the cask lift height
  - Credit is taken for DOE canister survivability
  - Credit is taken for casks with impact limiters
- Offsite public dose requirements are met
  - No credit is taken for HVAC/HEPA or shielding

Design Basis Requirements Credited in Safety Evaluation

System or Subsystem	Component or Function	Nuclear Safety Design Bases
		DOE SNF Disposable Canister
DOE SNF Disposable Canister	Standardized DOE SNF Canister	• The standardized DOE SNF canister shall maintain confinement of contents if dropped from less than a height of 23 ft (7m) in any orientation. • The standardized DOE SNF canister in a transportation cask or waste package shall not breach from a drop of 23 ft (7m) in any orientation. • The standardized DOE SNF canister must have a manufacturing defect rate of less than 2.3×10^{-4} so that a drop within the design basis drop height does not result in a Category 2 event sequences
		Transportation Cask
Transportation Cask	Cask	• Transportation casks received at the GROA are designed and licensed in accordance with 10 CFR 71 (30-ft drop capability with impact limiters installed) • Mitigative features to be incorporated into the transportation cask design such that a drop of a cask without impact limiters containing a multicanister overpack does not exceed the energy equivalent of a 2-ft (0.6m) drop in any orientation

Q-List Documentation

System or Subsystem	Component or Function	Important to Safety (ITS)	Important to Waste Isolation (ITWI)
	Cask Receipt and Return System		
Cask Receipt and Return	Cask Handling Crane (TCRRF) 250 ton	Yes	No
	Transportation Cask		
Transportation Cask	Entire	Yes	No
	DOE SNF Disposable Canister		
DOE SNF Disposable Canister	Standardized DOE SNF Canister	Yes	Yes
	Multicanister Overpack	Yes	Yes

Consequence Assessments

- Compliance with 10 CFR 63.111 is achieved by:
  - Category 1:
    - Dose from <u>each</u> Category 1 event sequence
    - Dose from the normal operations and the annual aggregate frequency-weighted dose from each Category 1 event sequence
    - The dose from any combination of Category 1 event sequences whose combined frequency places the combination in Category 1
  - For Category 2:
    - Dose from each Category 2 event sequence

Consequences of Category 1 Event Sequences

- Model for Public and Worker
  - Average Assembly Source Terms
    - Average PWR (4 percent enrichment, 25 years cooling time, and 48 GWd/MTU), average BWR (3.5 percent enrichment, 25 years cooling time, and 40 GWd/MTU)
  - Credit for HEPA filters in Waste Transfer Cell (FHF and DTF)
    - Efficiency per stage of 99 parcent (two stages in series)
  - Ground level release with building wake effect
  - No credit for plume meandering or plume rise
  - Larger of the mean or median X/Q used in MACCS2 for the public and in ARCON96 for the worker
  - Shine, inhalation, air submersion and ingestion dose included for the public (ingestion not considered for the worker)

Preliminary Results of Category 1 Event Sequences

Event Sequence Identifier	Category 1 Events	Material at Risk (No. SFAs)	Public TEDE at 100 m (mrem)	Public TEDE at 11 km (mrem)	Worker TEDE (rem)
1-01	Drop of a CSNF assembly onto 1 assembly in a transportation cask	2	1.9	<0.1	<<0.1
1-02	Collision involving a CSNF assembly	1	0.9	<0.1	<<0.1
Sum of Cat. 1 and normal dose (mrem/yr) (Direct radiation to worker dose does not reflect implementation of ALARS.)			1.3	<0.1	1.6
Two Drops (affecting 4 assemblies) in same year normal dose (mrem/yr) (Direct radiation to worker dose does not reflect implementation of ALARS.)			6.6	<0.1	1.6

1) ...each Category 1 event sequence

2) ...normal operations and the annual aggregate frequency-weighted dose from each Category 1

3) ...any combination of Category 1 event

Consequences of Category 2 Event Sequences

- Model
  - Maximum Source Terms
    - PWR (5 percent enrichment, 5 yr cooling time, 80 GWd/MTU) and BWR (5 percent enrichment, 5 yr cooling time, 75 GWd/MTU)
  - No Credit for HEPA filtration
  - Ground level release with building wake effect
  - No credit for plume meandering or plume rise
  - 95th percentile X/Q used in MACCS2
  - Shine, inhalation, air submersion and ingestion dose included for the public

Preliminary Results of Bounding Category 2 Event Sequences

Bounding Category 2 Events	TEDE (rem/event)	Highest TODE (rem/event)	SDE (rem/event)	LDE (rem/event)
Event 2-01(a): Drop and breach of a transportation cask containing 36 PWR assemblies without HEPA filters	.047	.147	<.1	<.1
Event 2-01(b): Drop and breach of a BWR transportation cask containing 74 BWR assemblies without HEPA filters	<.1	<.1	<.1	<.1
Event 2-02: Drop and breach of one naval SNF canister without HEPA filters	<<.1	<<.1	<<.1	<<.1
Event 2-03: Drop and breach of five Savannah River site DHLW canisters without HEPA filters	<<.1	<<.1	<<.1	<<.1
10 CFR 63 Dose Limit	5 rem	50 rem	50 rem	15 rem

TEDE = Total Effective Dose Equivalent
TODE = Total Organ Dose Equivalent
SDE = Skin Dose Equivalent
LDE = Lens Dose Equivalent