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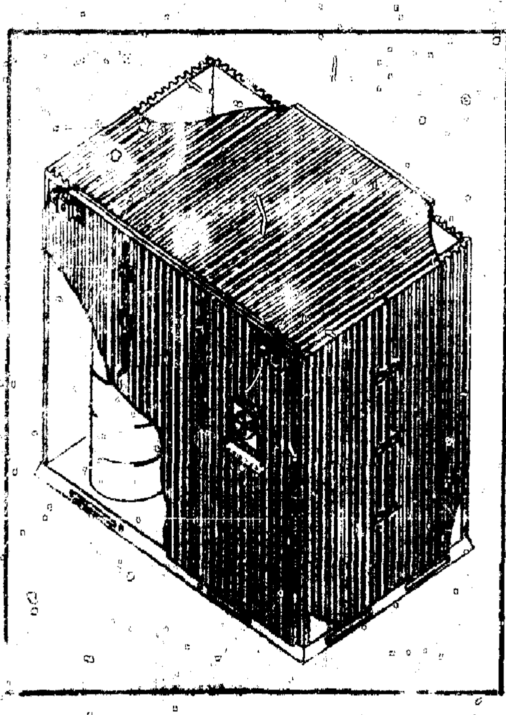
Technical Support for:
Lawrence Livermore Laboratory

MASTER

Conceptual Design of Retrieval Systems for Emplaced Transuranic Waste Containers in a Salt Bed Depository

Final Report - Copy 30 of 35

Criteria, Omni-Container Design, and Outline Specifications



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Contract 7405-Eng. 48

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Technical Support for:

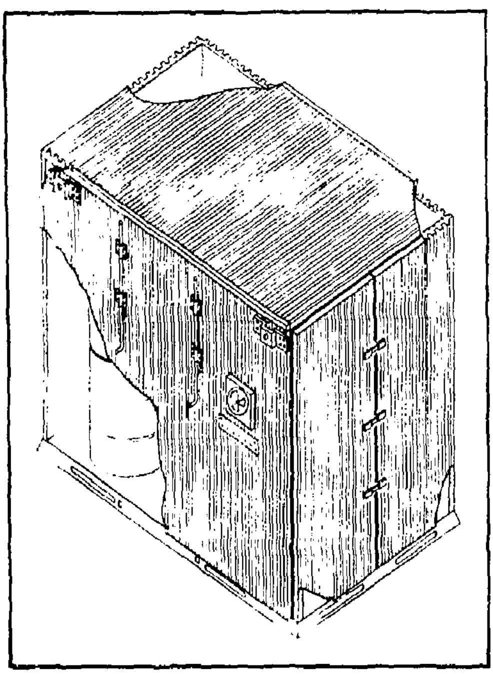
Lawrence Livermore Laboratory

Conceptual Design of Retrieval Systems for Emplaced Transuranic Waste Containers in a Salt Bed Depository

Final Report - Copy of 35

DISCLAIMER

Criteria, Omni-container Design, and Outline Specifications



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UNIVERSITY OF CALIFORNIA

NUCLEAR WASTE MANAGEMENT PROGRAM

CONTRACT NUMBER 7405-ENG. 48

PURCHASE ORDER NUMBER 5811809

LAWRENCE LIVERMORE LABORATORY

CONCEPTUAL DESIGN OF RETRIEVAL SYSTEMS FOR EMPLACED TRANSURANIC WASTE CONTAINERS IN A SALT BED DEPOSITORY

TASK I
PROJECT GUIDELINES
AND DESIGN CRITERIA

TASK II
STANDARDIZED OMNI CONTAINER

TASK III
BASELINE CRITERIA SPECIFICATIONS

Project Number 9046

SUBMITTED TO:

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Revision

Number	By	Description	Date
0	EEH	Draft for approval	19 July 1979
1	SFF	Revised for submittal to LLL	31 July 1979
2	SFF	Revised to delete Failure analysis	15 October 1979
3	SFF/HML	Revised to include inventory control	30 November 1979
4	SFF/HML	Finalized for submittal	10 April 1980

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ABBREVIATIONS

BWR	Boiling-Water Reactor
CH	Contact Handled Waste
DOE	Department of Energy
EIS	Environmental Impact Statement
ERDA	Energy Research and Development Administration
GEIS	Generic Environmental Impact Statement
HEPA	High-Efficiency Particulate Air (Filter)
HLW	High-Level Waste
ILW	Intermediate-Level Waste
LLW	Low-Level Waste
LWR	Light-Water Reactor
MPH	Miles Per Hour
OWI	Office of Waste Isolation
PWR	Pressurized-Water Reactor
RH	Remotely Handled Waste
SAND	Sandia Laboratories
SURF	Spent Unreprocessed Fuel
TRU	Transuranic Waste
WIPP	Waste Isolation Pilot Plant

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- Dr. H. Newkirk, LLL: Project Management
- Dr. H. Levy: critical review of the report, suggestions, and project direction
- .ECO personnel:
  - E. E. Hudson: preliminary design criteria
  - R. N. Skeehan: monitoring system block diagram
  - H. M. Lee: technical support, research, calculations, and writing
  - L. Hannah: editing
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EXECUTIVE SUMMARY

Introduction

Lawrence Livermore Laboratory is assisting government agencies in developing regulations to ensure the safe emplacement, storage, and possible retrieval of transuranium radioisotope contaminated wastes (TRU) in deep geologic salt repositories. The U.S. Department of Energy and the Nuclear Regulatory Commission have jurisdiction over the nuclear waste management program. Design studies were previously made of proposed repository site configurations for the receiving, processing, and storage of nuclear wastes (Ref. 2 and 3). However, these studies did not provide operational designs that were suitable for highly reliable TRU retrieval in the deep geologic salt environment for the required 60-year period.

Purpose

The purpose of this report is to evelop a conceptual design of a baseline retrieval system for emplaced transuranic waste containers in a salt bed depository. The conceptual design is to serve as a working model for the analysis of the performance available from the current state-of-the-art equipment and systems. Suggested regulations would be based upon the results of the performance analyses.

Task I - Criteria

Before beginning the task of conceptual design, data were compiled to identify the performance criteria for which the retrieval system was to be designed. The retrieval systems must ultimately prove to be highly reliable. Therefore, the performance criteria were written to identify anticipated obstacles to safe operations. The criteria developed require that the TRU waste depository shall satisfy the following conditions:

- Protection shall be provided against spillage or leakage to the bio-sphere from the TRU waste containers.

- Protection shall be provided for employees against exposure to nuclear wastes.

- TRU waste containers shall have a 60-year design life with resistance to: corrosion, fire, earthquake, and rupturing from impact in transport at 5 miles per hour.

- Containers shall be of weather-resistant design suitable for temporary outside storage at the surface level.

- TRU waste packages to be received, stored, and retrieved shall include: 55-gallon drums, 83-gallon drums, 4'x 4'x 7 'boxes, and 5'x 5'x 8' boxes (see Table S-1).

- Intermediate-level wastes shall be handled in shielded boxes or within canisters.

- Retrieval operations shall be able to handle more than 88,000 drums (55-gallon capacity each) per year.

- TRU packages shall not be backfilled with salt.

- After allowing for possible salt creep, the minimum net height of the depository room shall be 22'-6". Transport, storage, and retrieval of containers shall be completed within this height limit.

- Ventilation air flows with suitable filters shall be provided to reduce air contaminants and excessive room temperatures during operations.

- Motive transporters and equipment shall have exhaust air pollution control systems.

LINE	MODE	ITEMS TRANSPORTED	CONTAINER DIMENSIONS INSIDE WIDTH X LENGTH X HEIGHT	CONTAINER DIMENSIONS OUTSIDE WIDTH X LENGTH X HEIGHT	WEIGHT ▲ IN TONS	SPACE * USE EFFICIENCY	TIME # AVAILABLE PER RETRIEVAL CYCLE
1	Minimum size, light-weight Omni container	(12)ea. 55-gal. drums or (6)ea. 83-gal. drums or (1)ea. 4' x 4' x 7' box or (1)ea. 5' x 5' x 8' box	5' x 8' x 6.3'	5.4' x 8.4' x 6.8'	6.6 Gross	39.6%	48.0 minutes
2	Overpack container for line 1	Omni 5.4' x 8.4' x 6.8'	5.9' x 8.9' x 7.3'	6.4' x 9.4' x 7.8'	8.0 Gross	-	-
3	Elevator requirements for line 2	Overpack 6.4' x 9.4' x 7.8'	-	Elevator platform 7' x 10' x 8'	8.0 capacity	-	-
4	Mid. size, heavy-weight Omni container	(16)ea. 55-gal. drums or (8)ea. 83-gal. drums or (1)ea. 4' x 4' x 7' box or (1)ea. 5' x 5' x 8' box	5' x 8' x 6.3'	5.4' x 8.4' x 6.8'	8.3 Gross	38.1%	64.0 minutes
5	Overpack container for line 4	Omni 5.4' x 8.4' x 6.8'	5.9' x 8.9' x 7.3'	6.4' x 9.4' x 7.8'	9.7 Gross	-	-
6	Elevator requirements for line 5	Overpack 6.4' x 9.4' x 7.8'	-	Elevator platform 7' x 10' x 8'	10.0 capacity	-	-
7	Large size, heavy-weight Omni container	(32) ea. 55-gal. drums or (24) ea. 83-gal. drums or (2)ea. 4' x 4' x 7' box or (1)ea. 5' x 8' x 8' box	8' x 8' x 6.5'	9' x 9' x 7.5'	17.6 Gross	38.7%	129.6 minutes
8	Overpack container for line 7	Omni 9' x 9' x 7.5'	9.5' x 9.5' x 8.0'	10' x 10' x 8.5'	19.4 Gross	-	-
9	Elevator requirements for line 8	Overpack 10' x 10' x 8.5'	-	Elevator platform 10.5' x 10.5' x 9.0'	20.0 capacity	-	-

\# Cycle time available is based upon 88,942 drums handled per year

▲ Weight listed is based upon a waste form density of 125 pounds per cubic foot.

* Space use efficiency is a ratio: $\frac{\text{net contents, ft}^3 \text{ of 55-gal. drums contained}}{\text{gross volume, ft}^3 \text{ of container}}$

TABLE S-1 TRU WASTE RETRIEVAL CONTAINERS

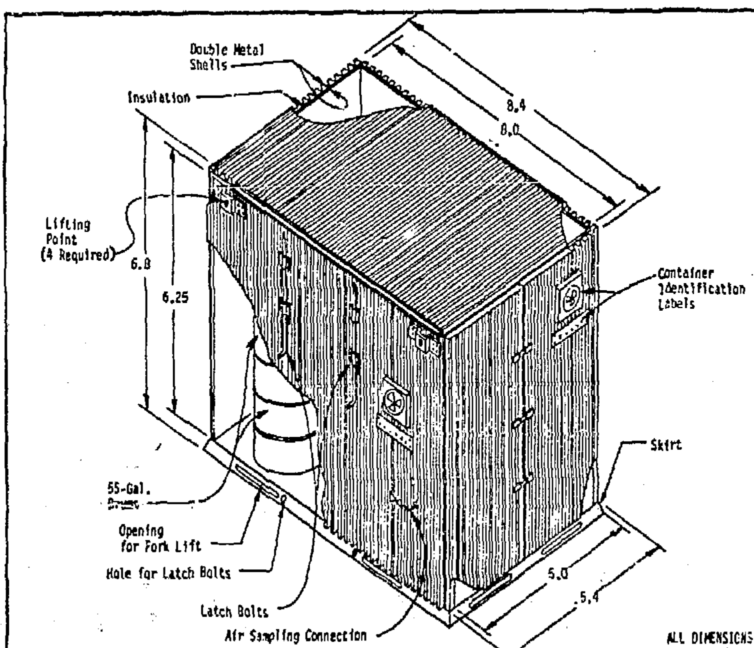

FIG. S-3 OMNI CONTAINER ISOMETRIC VIEW

- The repository shall have stations for receiving, inspecting, classifying, packaging, transporting, and depositing TRU packages in storage; later TRU packages shall be retrieved in reverse order of the above (see Figure S-2).

- Retrieval capability of the TRU packages is required, if solely to ensure the reliable management of emplacement and storage operations. Thus, the systems will allow retrieval of wastes at any time during the 60-year operational period if package performance or site suitability should later appear unsatisfactory.

To meet the above criteria for successful TRU retrieval, the WIPP and GEIS repository designs must be revised (Ref. 2 and 3).

Task II - Conceptual Design

The conceptual design of secondary or Omni containers and system allows the controlled management of TRU waste classification, labeling, transport, emplacement, storage, monitoring, and subsequent retrieval. The Omni container system is based upon existing technology of proven equipment, materials, and methods adapted for this project.

Table S-1 on page ix compares Omni container sizes. It was prepared to aid in selecting the best Omni container size which is (line 4) 5.4' wide x 8.4' long and 6.8' high with a capacity of 8.8 tons. The Omni containers are designed to incorporate the following:

- Double metal wall construction of galvanized steel sheets with joints and openings sealed for corrosion resistance and fire resistance (see Figure S-1, isometric view on page ix).

- Earthquake resistance of containers consisting of a system of interlocking bolts and tapered skirts. The system automatically engages when containers are stacked in storage (containers to be stacked three units high).

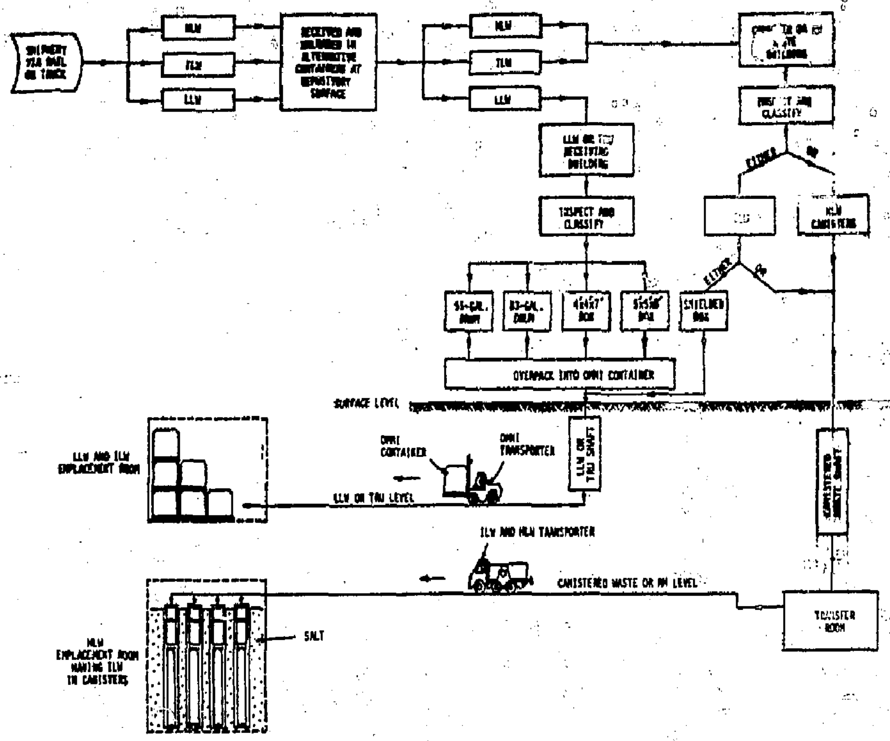

FIG. S-2 SCHEMATIC DIAGRAM OF WASTE PACKAGE EMPLACEMENT

● **OBJECTIVE:** BREACHED OR DAMAGED CONTAINERS MAY SPREAD AIRBORNE PARTICULATES THROUGHOUT THE REPOSITORY AND THEREFORE IT IS DESIRABLE TO ISOLATE SUCH CONTAINERS AS SOON AS AND AS LOCALIZED TO THE SITE AS POSSIBLE. THEREFORE, A MOBILE OVERPACK PROCEDURE IS DEVELOPED AS FOLLOWS:

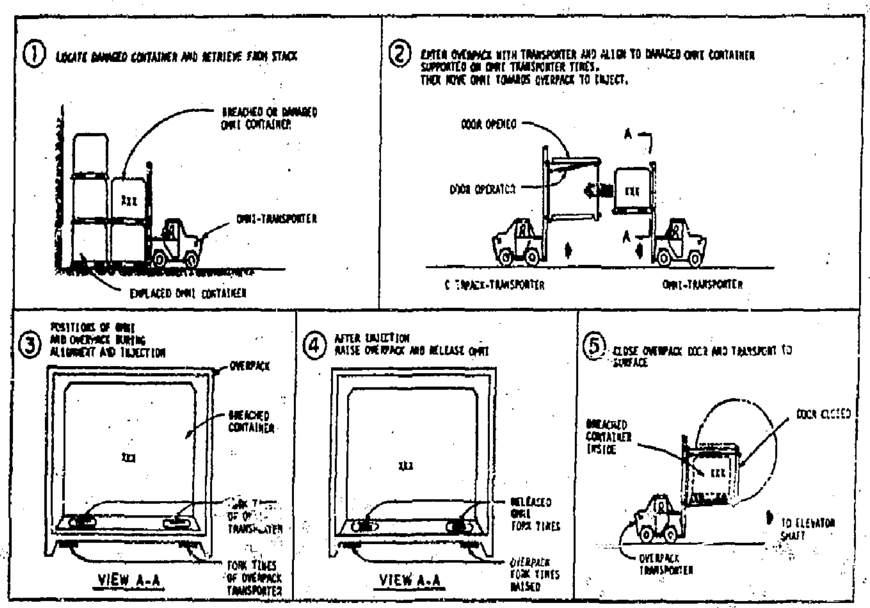

FIG. S-3 WASTE PACKAGE RETRIEVAL-BREACHED CONTAINERS

- Smooth interior surfaces on the container for ease of cleanup from primary container spillage; container doors to be lockable to preclude pilferage; openings in container skirt for forklift handling from all sides; hooks for overhead crane handling; and exterior label to list the contents data and the exact storage location for the container within the depository.

- A retrieval system for defective TRU containers consisting of: overpack containers (similar to the Omni container except for enlarged outside dimensions of 6.4' wide x 9.4' long x 7.8' high) to permit clearances between the two containers when overpacking; a hinged door on each overpack container with remote controlled operators to effect closure; adjacent to the point of retrieval, two forklift transporters to be maneuvered to approach one another so that the TRU container can be sandwiched into the overpack container to minimize spillage; remote controls for all transporter movements to be inside shielded operator cabs as protection from exposure to spilled wastes; and overpack containers to be transportable via the passageways and elevators to the surface (see Figure S-3 on page xi).

The following proposed method of emplacement will provide high standards of operational retrievability and reliability. At the surface facilities, drums or boxes are placed into each Omni container which is then closed, sealed, and transported to the elevator shaft, lowered by elevator, unloaded from the elevator by forklift, transported to the depository room, and finally each Omni container is then stacked into an assigned position. This operation sequence involves only one movement of direct contact between the forklift and the primary waste container. Reducing the number of the movements helps to minimize damage from handling such as dropping, puncturing, or rupturing the primary containers.

Automated management systems for TRU wastes in the depository shall include:

- A container leak detection system consisting of tubes drawing air under vacuum from all container interior annular spaces and delivering the samples to a central air analysis station.

- Each container label having a magnetic or visual identification code which can be read or scanned at the doorway to each depository room.

- Floor emplaced sensors to detect attempts to lift or move any emplaced container in storage.

- A central TRU waste control and inventory monitoring station to receive the redundant signals from all detectors listed above. A programmed control network shall monitor all TRU wastes whose irregularities or "discrepancy alerts" sound alarms; thus, it will facilitate enforcement of strict management procedures (see Figure S-4).

<u>Task III - Baseline Specifications</u>

This task specifies the end results or performance obtainable from the container systems with auxiliaries developed in Task II. These baseline specifications were written as a basis for future regulations. They require all the system performances listed in Task II.

In summary, Task III - Baseline Specifications, requires that the TRU waste system shall be able to manage and control all material handling functions of receiving, transport, storage, and retrieval within the depository, and shall preclude the release of radionuclides to ground water and atmosphere. A synopsis of these system (outline) specifications follows:

- Containers using the multiple barrier concept shall be used with intervening air layers to be monitored to detect leakage;

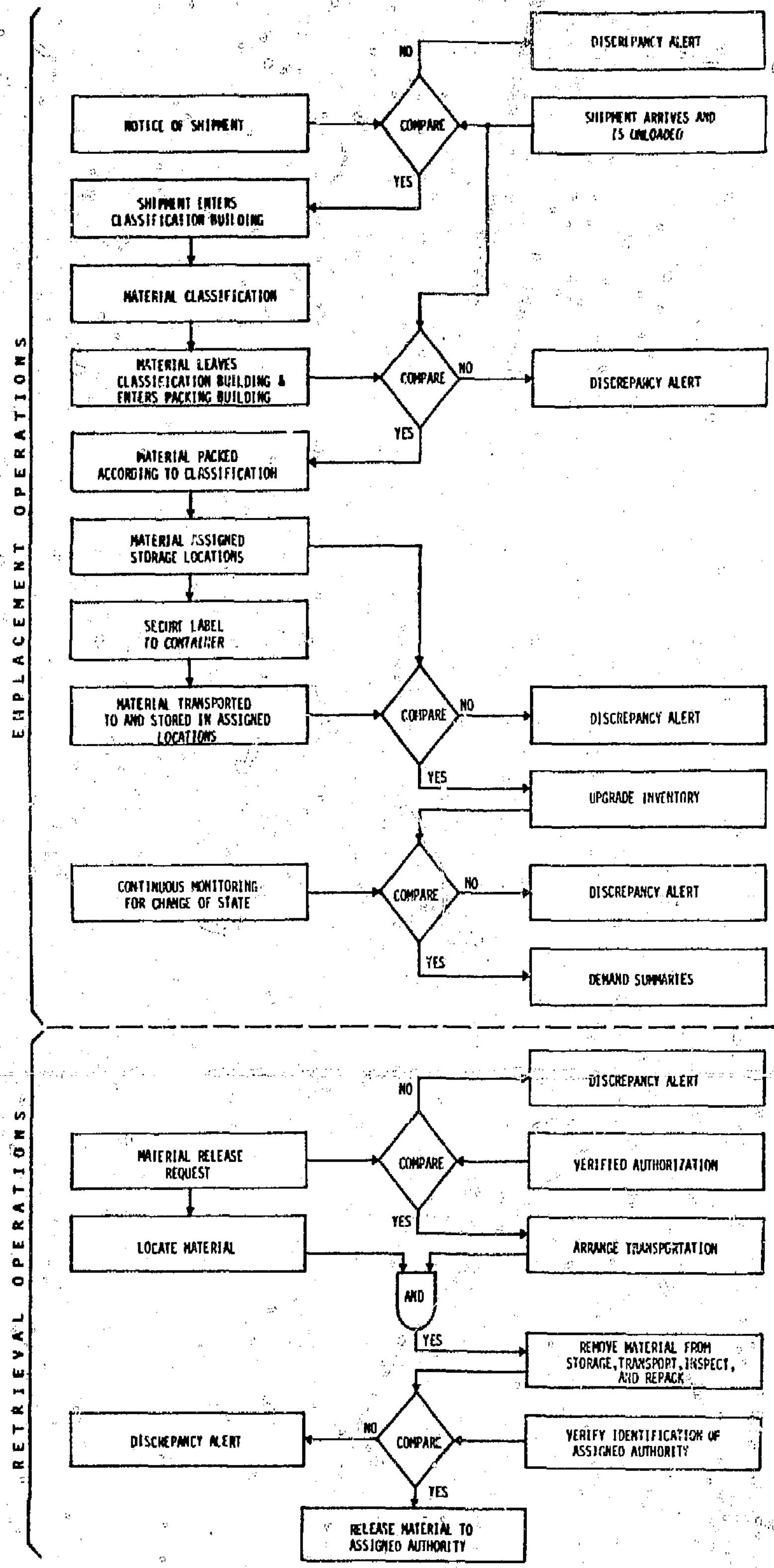

FIG. S-4 TRU INVENTORY CONTROL AND MONITORING SYSTEM - BLOCK DIAGRAM

- The system shall have a 60-year design life;

- Construction shall be fire resistant, corrosion resistant, repairable, and resistant to seismic forces when emplaced in storage;

- The system shall be constructed of ductile materials;

- The system shall be designed to accept a 5-MPH impact in transport without rupture, use containers to be stackable to three units high, be free of internal pockets that could trap particles, be instrumented to detect leakage and internal contamination, have sealed openings, be weatherproof, have lockable doors, have provision for handling by forklift and crane, and have identification labels;

- The system shall have remote alarms to sound if an emplaced container is moved without authorization.

- Overpack containers shall be provided to enclose damaged Omni containers.

- Intermediate-level transuranic wastes shall be transported and stored in shielded containers.

- Mobile equipment for handling containers shall have shielded cabs, remote controls, filtered air systems, and exhaust gas pollution controls.

- All components of the TRU waste systems shall comply with all national engineering, materials, fire, safety, and health codes.

Task III includes the preparation of 14 figures showing the material handling system flows for emplacement and retrieval, the retrieval function, the Omni container and details, the transporters, monitoring system, mobile cleanup unit, and inventory control systems.

Task III preparation work helped to uncover two potential follow-on projects which are significant enough to justify further development:

- A reliable waste management monitoring and inventory control system will be needed to guard against theft, misplacement, or unaccounted losses of nuclear wastes, and to protect against the potential public and media charges of mismanagement of the repository.

- The construction schedule may be expedited by the possible elimination of the need for the TRU levels of the repository when Omni containers are stored in the rooms provided for the high-level radiation wastes. The Omni containers can be adapted for this dual use of storage space in the high-level radiation waste areas of the repository. Consequently, considerable mining and construction efforts (and time) could be eliminated.

CONCEPTUAL DESIGN OF RETRIEVAL SYSTEMS FOR EMPLACED TRANSURANIC WASTE CONTAINERS

1.0 TASK I - PROJECT GUIDELINES AND DESIGN CRITERIA

1.1 Project Objective

The objective of this study is to develop conceptual engineering designs, baseline criteria specifications, and conceptual diagrams for reliable retrieval systems for transuranic waste (TRU), intermediate-level waste (ILW), and low-level (LLW) solid waste containers to be emplaced in a salt bed depository.

This study is developed for DOE low-level waste (LLW), contact-handled transuranic waste (TRU), and DOE intermediate-level waste (ILW). Hereafter, DOE low-level transuranic waste is referred to as LLW, and DOE intermediate-level waste (ILW) which implies DOE intermediate-level transuranic waste (ILW) is referred to as ILW or remotely handled (RH) waste (Ref. 1, 2.1). This study considers retrieval for both the Waste Isolation Pilot Plant (WIPP) site and an operational repository for permanent disposal of wastes referred to in Ref. 2.*

1.2 Project Data and Criteria

The purpose of this section is to develop a commonly acceptable description of the TRU package and emplacement to be suitable for the conceptual design of a reliable waste container retrieval system. Development of a reliable retrieval system requires integration and coordination with the emplacement system design.

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* See page 42 of this report for listing of references, and Appendix A for glossary.

The TRU retrieval system conceptual design will be compatible with the following design criteria:

1. Waste package data for the WIPP site will be as listed in Reference 3, Part II: Tables II.2-2-1-1 and II.2-2-1-2, included in this study as Table I.

2. Waste package data for the repository site will be as listed in Reference 2, Table 5.5, included in this study as Exhibit 1-3.

3. At the WIPP site, intermediate-level waste (ILW) has been planned to be handled by the remotely handled (RH) waste storage facilities (Ref. 3, Part II: 1.1.2) and emplaced in canisters (Ref. 3, Part II: Fig. II.2-4-2-29) during the retrieval period.

4. TRU waste packages of LLW and of ILW in shielded boxes will be stored in open depository rooms. None of the packages to be retrieved will be backfilled in contact with salt with the exception of canistered waste of HLW and ILW.

5. Expected operational capability for the TRU retrieval system must be maintained for the first 60 years after emplacement.

6. The surface temperature of TRU packages is reported to be near ambient. The temperature of the ILW form package is not defined. Therefore, the waste packages will be handled at near ambient temperature; elevated temperatures are not anticipated.

7. At the repository site intermediate-level transuranic waste (ILW) will be handled within shielded boxes or within canisters.

8. The TRU waste packages to be handled, stored, and retrieved will be in accordance with Figures 1A and 1B -- Waste Package Receiving, Emplacement, and Retrieval.

TABLE I LIMITATIONS AT THE WIPP AND REPOSITORY FACILITIES FOR LOW-LEVEL WASTE (LLW) HANDLING

ITEM	FACILITY		
	WIPP	OWI REPOSITORY	
HOISTS		DWG. D27 OF REPORT Y/OWI/TM-36/9	TABLE 5-2 OF REPORT Y/OWI/TM-36/8
Capacity (Tons)	12.5	5	-
Platform Size (Feet)	9 x 13	5 x 7	-
Pallet Size (Feet)	8.5 x 12.5	4 x 6	-
Door Size: Height x Width (Ft.)	10'-0" x 12'-11"	Undefined	-
CORRIDOR			
Width (Feet)	31.5	36	-
Height (Feet)	10	25	-
EMPLACEMENT ROOM			
Width (Feet)	45	18	36
Height (Feet)	16.5	25	20
Length (Feet)	480	1374	2000

NOTE: The table above lists conceptual design values which were proposed by others prior to completion of the design of a reliable retrieval system. Refer to Table III on page 11 for updated design values required for the retrieval system hoist.

9. Table I is a comparison of the maximum weight and dimensional limits for material handling systems for the WIPP and repository facilities as proposed in prior reports. (These limits must be revised.)

1.3 Emplacement Data

1. For the GEIS repository, the following drawings from Reference 2 describe the facilities and are included in Appendix B as:

Exhibit 2-1:	D 25	Mine Master Plan
Exhibit 2-2:	D 26	Mine Partial Plan and Sections
Exhibit 2-3:	D 27	Corridor and Room Layout
Exhibit 2-4:	D 36	Low Level Waste Shaft

2. For the WIPP site the following drawings from Reference 3 describe the facilities and are included in Appendix B as:

Exhibit 3-3:	94541-A1	TRU Waste Facility - First Floor Plan
Exhibit 3-4:	94569-A1	TRU Shaft - General Arrangement

3. WIPP/TRU storage room dimensions are 45'-0" width and height from ceiling to floor of 16'-6" (Ref. 3, Part II: Fig. II.2-2-2-2).

4. WIPP/TRU receiving rate will be 500,000 cubic feet per year in drums and boxes. The container mix is unknown.

5. Depository TRU emplacement room dimensions are width of 18'-0", height from ceiling to floor of 25'-0", and length of 1374'-0" (Exhibit 2-1, Dwg. D 25).

6. Storage of TRU waste containers will be in rooms sufficiently derated in size to prevent containers from being locked in by stress-induced creep closure or shrinkage of the salt during the 60-year design retrieval period.

7. The repository waste package receiving rates are used to determine the rate for the retrieval system design capacity. The annual number of units to be emplaced is shown in Table II as listed in the Office of Waste Isolation reports (Ref. 2).

TABLE II WASTE FORM EMPLACEMENT - RETRIEVAL RATES

WASTE FORM	CASE	NUMBER OF UNITS AT MAXIMUM ANNUAL RATE	TABLE NO.	PAGE NO.	REPORT NO.
HLW Canisters	Total Recycle	3,980	9-12	9-73	Y/OWI/TM-44
ILW Canisters	Total Recycle	9,860	9-14	9-75	Y/OWI/TM-44
ILW 55 Drums ac 1 to 10R/hr.	Total Recycle	9,830	9-15	9-76	Y/OWI/TM-44
LLW 55 Drums	Total Recycle	88,942	5.5	-	Y/OWI/TM-36/8
LLW 4x6x6 Boxes	Total Recycle	300	9-16	9-77	Y/OWI/TM-44

1.4 Retrieval System Operating Criteria

1. Waste retrieval operations will normally be carried out using the same or similar equipment as used for emplacement.

2. Retrieval of units will be at the maximum rate of emplacement which, as noted above, is 88,942 drums per year.

3. Special machinery and operating methods will be required for retrieval of breached packages.

4. The level of radiation output for intermediate-level waste (ILW) is of a magnitude that requires significant shielding to protect personnel during all handling operations (Ref. 3, Part II: 2.4.2.12).

5. The retrieval of TRU packages considered herein will be based on storage in a salt bed depository. However, backfilling with salt around the TRU containers will not be done, since the salt would interfere with retrieval operations while failing to provide any specific advantage in storage.

6. Maximum emplacement room height from which retrieval is required will be 22'-6" net to allow for room shrinkage from the original 25'-0" ceiling height planned for the GEIS repository.

7. Prior to start of retrieval operations, ventilation air flow will be re-established in the emplacement room to reduce temperatures and air contaminants to levels safe for human occupancy.

8. Retrieval equipment and subsystems shall be of fire resistant design.

9. Motive power for subsurface retrieval equipment, such as forklifts, transporters, and retrieval machines, shall be based upon existing mobile equipment power systems as presently used in mines that comply with the Code of Federal Regulations 30, Mineral Resources and the Federal Mine Safety and Health Act of 1977, Public Law 91/173 as amended by Public Law 95/164. In general, this means that motive power by diesel engines may be acceptable when adequate, reliable exhaust gas pollution control devices and mine ventilation systems are provided; or, motive power by electric battery-driven vehicles may be acceptable where adequate vehicle horsepower ratings are available to match the waste container rated loads to be transported.

10. Subsurface ventilation systems will be in operation during retrieval operations to minimize the unsafe concentration of combustible and hazardous gases, dusts, and particulates.

1.5 Repository Baseline Design

Design of a reliable TRU retrieval system requires close integration with the repository facility design and all material handling requirements. This is especially true where retrieval operations affect emplacement operations. Therefore, the existing repository designs have been critiqued from the standpoint of design requirements for the TRU retrieval system. Consequently, the following revisions in repository design and material handling methods are recommended:

- The prior repository design anticipated the following sequence of operations: TRU waste drums are to be packaged onto pallets and transported by elevator to the lower level. At the lower level the elevator would be unloaded by forklift, and the drums placed onto a truck transporter to be transported to the depository room. At the depository room the truck would be unloaded by another forklift. The drums would be depalletized, and stacked by forklift in loose, piled stacks in the depository room. This operations sequence would involve 5 separate movements in which direct contact is made between the forklift trucks and the TRU primary waste containers. Punctures or ruptures are possible at such contact points.

- The following proposed method of emplacement will provide high standards of operational retrievability and reliability. At the surface facilities, drums or boxes are placed into each Omni container which is then closed, sealed, and transported to the elevator shaft, lowered by elevator, unloaded from the elevator by forklift, transported to the depository room, and finally each Omni container is then stacked into an assigned position. This operation sequence involves only one movement of direct contact between the forklift and the primary waste container. Reducing the number of the movements helps to minimize damage from handling such as dropping, puncturing, or rupturing the primary containers.

- The planned size of the TRU elevator shaft platform (4 ft x 7 ft) is inadequate in space and weight capacity for transport of either the required 5-ft x 8-ft boxes or the Omni container. Minimum elevator requirements are 7 ft x 10 ft x 8 ft, as shown in Table III on page 11, line 6.

- The third critique item involves the potential cost savings and resulting operating mode changes possible if the TRU levels of the depository are eliminated. The total volume of the depository rooms for canister wastes is more than 8 times the volume required for storing the maximum number of Omni containers (see Appendix B). Thus, consideration should be given to doubled-up depository rooms whereby in each room the canister wastes would be stored below the floor level, while Omni containers are stored above the floor, stacked in line along one wall of each room to allow for normal ingress and egress. The doubled-up depository would involve the inconvenience of temporarily shifting or moving Omni containers in the event of an unscheduled need for oversize equipment access to retrieve a damaged container. Since the Omni containers would be designed for ease of movement by assigned forklift transporters, these temporary shift movements would be more expeditiously accomplished than the original work needed to excavate and construct the entire TRU underground facilities. Considering the savings in construction time, a doubled-up depository would be available for use sooner than the planned dual waste facilities.

2.0 TASK II - STANDARDIZED OMNI CONTAINER AND AUXILIARIES

The TRU waste container retrieval requirements are listed in Table III for alternatives to handle TRU drums and boxes.

Comparisons were made of three alternative sizes of containers and their respective overpack containers. These comparisons considered the relative requirements of elevator lifting capacities, elevator platform sizes, and the efficiency of space use in the depository. The limiting criteria for the material handling system capacities are the number of 55-gallon drums to be received and retrieved - a maximum of 88,942 drums per year. The cycle times listed were calculated on the operating basis of:

- 3 shift operations, 20 hours per day during maximum retrieval rate of the Omni containers.
- 6-day weeks and 12 holidays resulting i [illegible] n days per year for retrieval operations.
- Elevator shaft height of approximately 2,000 vertical feet, average horizontal distance from elevator shaft to emplacement room of 2,500 lineal feet (according to Reference 2, Repository Preconceptual Design Studies: Salt.)

The space use efficiency for each Omni container is listed in Appendix B to evaluate effectiveness of the containers when emplaced in the repository.

LINE	MODE	ITEMS TRANSPORTED	CONTAINER DIMENSIONS INSIDE WIDTH X LENGTH X HEIGHT	CONTAINER DIMENSIONS OUTSIDE WIDTH X LENGTH X HEIGHT	WEIGHT Δ IN TONS	SPACE * USE EFFICIENCY	TIME # AVAILABLE PER RETRIEVAL CYCLE
1	Minimum size, light-weight Omni container	(12)ea. 55-gal. drums or (6)ea.83-gal. drums or (1)ea.4' x 4' x 7' box or (1)ea.5' x 5' x 8' box	5' x 8' x 6.3'	5.4' x 8.4' x 6.8'	6.6 Gross	28.6%	48.6 minutes
2	Overpack container for line 1	Omni 5.4' x 8.4' x 6.8'	5.9' x 8.9' x 7.3'	6.4' x 9.4' x 7.8'	8.0 Gross	-	-
3	Elevator requirements for line 2	Overpack 6.4' x 9.4' x 7.8'	-	Elevator platform 7' x 10' x 8'	8.0 capacity	-	-
4	Min. size, heavy-weight Omni container	(16)ea. 55-gal. drums or (6)ea.83-gal. drums or (1)ea.4' x 4' x 7' box or (1)ea.5' x 5' x 8' box	5' x 8' x 6.3'	5.4' x 8.4' x 6.8'	8.8 Gross	38.1%	64.8 minutes
5	Overpack container for line 4	Omni 5.4' x 8.4' x 6.8'	5.9' x 8.9' x 7.3'	6.4' x 9.4' x 7.8'	9.7 Gross	-	-
6	Elevator requirements for line 5	Overpack 6.4' x 9.4' x 7.8'	-	Elevator platform 7' x 10' x 8'	10.0 capacity	-	-
7	Large size, heavy-weight Omni container	(32) ea. 55-gal. drums or (24) ea. 83-gal. drums or (2)ea.4' x 4' x 7' box or (1)ea.5' x 5' x 8' box	8' x 8' x 6.5'	9' x 9' x 7.5'	17.6 Gross	38.7%	129.6 minutes
8	Overpack container for line 7	Omni 9' x 9' x 7.5'	9.5' x 9.5' x 8.0'	10' x 10' x 8.5'	19.4 Gross	-	-
9	Elevator requirements for line 8	Overpack 10' x 10' x 8.5'	-	Elevator platform 10.5' x 10.5' x 9.0'	20.0 capacity	-	-

Cycle time available is based upon 60,942 drums handled per year

Δ Weight listed is based upon a waste form density of 125 pounds per cubic foot.

* Space use efficiency is a ratio: $\frac{\text{net contents, ft}^3 \text{ of 55-gal. drums contained}}{\text{gross volume, ft}^3 \text{ of container}}$

TABLE III TRU WASTE RETRIEVAL CONTAINERS

2.1 Omni Container Selections

Table III lists alternatives for three container sizes considering space use efficiency and the required elevator sizes and capacities. The minimum size, heavy weight Omni container as shown on line 4 would be efficient spacewise and would require the smaller size elevator platform. The elevator lifting capacity must be 10 tons minimum for transport of the overpack container to the surface.

2.2 Omni Container - Meeting Detail Criteria Requirements

The imposed requirements of storage, monitoring, and retrieval for 60 years of safe and manageable operations are the most difficult to accomplish with known hardware and construction methods. However, as shown by Figures 1 through 5, all operating conditions are achievable. The following brief descriptions are presented in the same sequence as the regulatory requirements proposed as the minimum acceptable operating performance levels:

(1) Schematic Diagram Figure 1A, 1B, and 1C illustrate the sequence of the receiving, inspection, classification, storage, transport, and retrieval functions. Fulfillment of these functions will require a TRU universal or Omni container design. Based upon the current state-of-the-art for commercially available container materials and proven experience, a multiple-barrier containment system will be required to meet the container performance requirements. Future development of nonbrittle, corrosion-resisting, low cost, impact-resisting, nonleaking, fire-resisting, and long-lived containers may permit omission of need for the container multiple barriers. However, current container engineering practice would require that the Omni container shown serve as a secondary container, following the multiple-barrier concept as a proposed regulatory guideline. The outer barrier is to guard the primary waste form container from undetected damage

during material handling operations. Later during 60 years of emplaced storage of the waste form, these undetected damage points in a single-barrier container would undoubtedly fail or leak from one of the hazards of atmospheric corrosion, ground-water flooding, salt corrosion, earthquake, ground movement, or fire. Such container failure could release contaminants to the working environment or ground water unless the containment system is the redundant, multiple-barrier type, having inner primary waste form containers (drums or boxes) together with a secondary outer container (Omni). Leakage is minimized by providing an annulus space between the barriers from which air may be withdrawn to maintain an internal negative air pressure. Failure or leakage of either the outer or inner container enclosures could be detected by continuous monitoring of air samples drawn from the annulus space to the central instrumentation station (see Figure 4). Leak indicator gases such as helium or fluorocarbons could be initially injected into the primary containers as special indicators to alert the instrumentation system of a primary leak. Small leaks in the Omni container would not have a noticeable effect on the workers' environment so long as the air sampling system remains in operation to maintain a negative air pressure in the annulus spaces.

(2) Sixty-year life of the Omni containers in the difficult environment will prohibit the use of plywood and plastics because of unproven long-term life and lack of fire resistance. Organic materials are to be avoided because of possible off-gassing. A container outer shell of steel will be required for toughness and resistance to puncture in transport. Omni containers will be required to be retrievable to make needed repairs, correct for accidental leakage which may develop, and, sometime in the future reprocessing of the wastes may be required. The Omni transporter (forklift truck), the overpack transporter (forklift truck) and the mobile vacuum cleanup unit (custom designed truck) will

all be replaceable for service, repair, or renewal during the 60-year life of the project without disruption of operations.

(3) Provision for container fire resistance will consist of: insulation, if required, between the inner and outer metal shells to resist the spread of heat from accidental fires starting on either side of the shells; an outer shell of corrugated steel to provide structural integrity for the container; and the combination of inner and outer shells to act as containments for the insulation and as barriers against the spread of flammable gases. The need for insulation will be evaluated by thermal heat transfer studies of the container during simulated fire conditions. Insulation, if used, is to be of the inorganic type to preclude off-gassing. Manually-operated, portable fire extinguishers will be used as fire protection during retrieval and emplacement operations.

(4) Container inner and outer shells will be of galvanized steel. They are the most cost effective materials available to provide strength and corrosion resistance. Since the galvanizing protective action proceeds as a slow sacrifice of the zinc coating, the protection can be economically restored during the 60-year life by recoating with zinc-rich paint which is effective in repairing worn or depleted galvanized surfaces. The depository central leakage monitoring system described in paragraph (1) above would indicate if an Omni container has corroded through from any exterior corrosion before the primary containers are attacked. Thus, this design combination provides for a tough outer shell, with cost effective corrosion protection, repairability, and a leak monitoring system for reliability during long-term storage.

(5) Impact resistance of the Omni container in 5-MPH crashes is provided by the lower skirt with guiding ring, and the double metal shells (with interior insulation if required) to cushion the shock loading and reduce the possibility of rupture or puncture.

(6) The Omni container inner shell will be sealed and made smooth on all interior surfaces to permit cleanup of interior waste spills.

(7) Vertically oriented retractable latch bolts (see Figure 2E) which interlock between containers will resist overturning of emplaced Omni containers when stacked in the depository. (Latch bolts used on the lower tiers will be interlocked to the Omni above. Latch bolts on the top tiers will be driven into the emplacement room ceiling.) Horizontal forces acting on the top container are thereby resisted by these latch bolts in the salt ceiling. Thus, a structural column of containers having lateral stability can be created during emplacement. The containers have structural base skirts with sloping sides to match mating surfaces of equal slope that are built into the top edges of the containers which serve as a self-guiding feature during emplacement. The overlap of these sloping surfaces provides an inherent self-locking resistance to horizontal forces and allows rapid emplacement and retrieval of a container when needed without complex rigging, special bolts, or tools. All Omni containers will be identical except for labeling and identification of contents on the exterior. See paragraph (11) for the overpack container description.

(8) In order that storage use efficiency be near a practical optimum, the Omni floor is an integration of: a sloping skirt on the outer periphery, an inner floor reinforcement with an angle iron structure, and slots for forklift tines to be inserted from any of four directions. The outer container

walls are required to be corrugated for maximum rigidity and lateral stability without excessive weight.

(9) Omni emplacement and retrieval shall be compatible with the TRU depository room requirements as listed in Ref. (2): Twenty-eight rooms each 2,000 feet long x 36 feet wide x 20 feet high for a total of 40,320,000 cubic feet. The maximum of 896,155 LLW 55-gallon drums (as shown in Exhibit 1-3) could be stored in 56,010 Omni containers which would occupy 17,276,173 cubic feet of the depository's TRU level of 40,320,000 cubic feet. This is adequate to allow for transporter traffic aisles, inspection passageways, utility spaces, and room shrinkage. Mining construction costs may be reduced by selecting reduced room widths and adjusting other room dimensions proportionately. The Omni container outside dimensions of 5.4 feet x 8.4 feet x 6.8 feet in even multiples are to be coordinated to be compatible with any new room dimensions selected for the depository.

(10) Should TRU wastes be stored temporarily in the canistered waste rooms, the maximum quantity of LLW 55-gallon drums plus other packaged TRU wastes in Omni containers would occupy 11.9 percent of the total volume of the HLW canistered waste rooms, as measured above the floor levels, as designed in Ref. (2).

(11) The overpack container, as shown on Fig. 2D, is designed for retrieval and overpacking of damaged Omni containers. The Omni and overpack transporters are to be brought together and aligned as shown on Fig. 1C using the retractable mirrors shown on Fig. 2D. The Omni is then injected into the overpack container, the Omni transporter withdrawn, and the overpack door closed. All operations will be performed by remote operator control consoles behind shielded cabs on the transporters. The overpack container with the retrieved Omni can then be transported to the TRU elevator shaft for hoisting to the surface facilities for reprocessing. The overpack container will also serve as the shielded box shown on Figures 1A and 1B.

(12) The mobile vacuum cleanup unit shown on Fig. 5 is to be employed to clean up spillage leaking from damaged Omni containers by a manual operator seated within a shielded cab. The mobile unit will have remote controls for one vacuum pickup for floor cleaning and one for ceiling and wall cleaning of the depository room, the adjoining containers, and adjacent equipment. Dirty air is to be drawn into bag-type prefilters and then HEPA final filters, which are all located within a detachable debris box. When filled with contaminated debris, the detachable box can be aligned to the overpack container. The box is then to be ejected from the mobile cleanup unit, encased within the overpack container, and transported to the TRU elevator for hoisting and reprocessing the waste at the surface facilities.

(13) Acceptance of an operational repository by the public, the Congress, local governments, and the assigned responsible government agencies is not expected unless the project can be managed to include rigid inventory control of all waste containers during emplacement, storage, and retrieval.

The facilities manager must have a monitoring system so that he can be answerable for the location, condition, and storage of all waste containers at all times.

The material handling industry has developed sophisticated inventory control systems using computers operating with transporters (forklift trucks) and storage racks to control the movement, storage, and retrieval systems which are similar to those proposed for inventory control of the TRU waste management system. Sample descriptions of these commercial inventory control systems are included in Appendix B as Exhibits 4, 5, and 6.

The private industry sector was motivated to develop these automated inventory control systems primarily for "rigid cost control." However, their success in performance and the increasing number of installations indicate that the systems should perform equally as well for a different reason: "rigid control for security".

3.0 TASK III - BASELINE CRITERIA SPECIFICATIONS FOR THE TRANSURANIC WASTE RETRIEVAL SYSTEMS

(1) Transuranic wastes shall be capable of being received, inspected, classified, labeled, packaged, transported, stored, and then retrieved under physically controlled, monitored, and manageable conditions to preclude mismanagement of wastes and release of radionuclides to ground water, the atmosphere, or the working environment for personnel within the depository. To meet these requirements using current best container practices requires use of the multiple-barrier concept as applicable to the combined system of primary plus secondary waste containers. Consequently, the following requirements are written as keyed to the multiple-barrier concept. However, if a future suitable single-wall container is developed, these proposed regulations will be complied with when the specified performances are obtained.

(2) The transuranic waste container emplacement system shall be operable over a design life of 60 years. The material handling system components and waste containers shall be selected to comply with this targeted life expectancy. Where this design life cannot be guaranteed by experience, components shall be replaceable or repairable and accessible for maintenance. During the 60-year design life the mobile handling equipment (not including the emplaced containers) may be replaced by new equipment as needed to maintain high reliability. Consequently, individual pieces of mobile equipment such as the transporters need not comply with the 60-year design life requirement so long as they can be replaced safely without disrupting operations.

(3) Emplaced transuranic waste system components shall be fire-resistant and shall comply with the Code of Federal Regulations, Title 30, Subpart L - Fire Protection.

(4) Exterior surfaces of the system components shall be corrosion-resistant or coated with multiple redundant-type protective coatings. Access shall be obtainable for recoating or repairing the exterior surfaces during the 60-year period.

(5) Outer secondary containers, where employed, shall be adaptable to accept either groups of 55-gallon or 83-gallon drums, or 4 x 4 x 7-foot boxes or 5 x 5 x 8-foot boxes.

(6) Transuranic waste secondary containers shall be designed so that when stacked and emplaced in the emplacement rooms they shall be able to resist seismic forces or ground movement to prevent overturning with a possible release of radionuclides to the atmosphere.

(7) To guard against potential corrosion, where outer secondary containers are used they shall be sealed on the exterior for exclusion of water entrapment in case of flooding, and for the exclusion of brine particles. All openings or cracks connecting to the enclosure interior shall be sealed off to minimize interior corrosion.

(8) Where secondary or outer enclosing containers are used they shall comply with the following:

(8.1) Have a minimum of internal pockets or crevices that could trap debris or radionuclide particles;

(8.2) Have provision for internal cleanup operations in the event of a primary container spill;

(8.3) Have provision for instrumentation connections to detect internal spillage or contaminations;

(8.4) Have seals on all openings to retain all potential spills;

(8.5) Be weatherproof for occasional or emergency storage at surface when exposed to all elements of weather;

(8.6) Have lockable doors to minimize pilferage;

(8.7) Have external permanent labels to identify the contents or level of activity of the internal waste form;

(8.8) Have signal detectors with remote alarm to sound when a container is removed from the emplacement room;

(8.9) Be designed to accept occasional vehicle impact of five MPH without major structural failure, during which deflection or deforming of the enclosure would be acceptable as with a ductile material but rupture as with a brittle material would not be acceptable;

(8.10) Have openings for pickup and handling by forklift transporter from 4 sides;

(8.11) Be adaptable for pickup by overhead or truck crane when appropriate lifting sling spreaders are employed;

(8.12) Be stackable to three units high at maximum rated loading.

(9) Intermediate-level transuranic wastes to be transported, stored, or retrieved shall have their outer enclosing containers shielded to reduce the radiation transmission to the outside ambient to 10 rems maximum, and shall be specially labeled on the container

exterior. Operating hazards in handling ILW and LLW shall be reduced by providing mobile equipment of a common design for both waste classifications so that there will be no risk in switching or cross utilizing the mobile equipment.

(10) The transuranic waste outer enclosing containers shall be designed to allow for their controlled emplacement or temporary storage above the floor level within the SURF or HLW canister emplacement rooms. The combination of a container with forklift transporter shall have overall dimensions with sufficient wall and ceiling clearances to allow rapid retrieval of the TRU waste containers. Access to the SURF or HLW canisters, when required, is critical and requires that the clearances and mobile equipment maneuverability shall allow for container retrieval.

(11) Emplacement of TRU waste containers shall be able to proceed in a manageable and orderly manner over a 60-year period, as outlined in paragraphs (1) and (2) above. Provision shall be made to correct or overcome normal system and equipment failures during this period so that:

(11.1) The TRU material handling system shall be capable of retrieving emplaced waste containers at a rate which is approximately the same as used during emplacement. Retrieval operations shall be designed to use the same mobile equipment as used during emplacement. Equipment performance specifications shall accommodate both functions.

(11.2) The transporting vehicles shall have cabs with shielding to protect the operators against maximum exposures of 10 rems (Ref. 5) during any accidental rupture or leakage of both primary and secondary containers in transit. Cab shielding shall also include an operator's air system with HEPA filters.

(11.3) Overpack containers carried by mobile equipment shall be provided for enclosing damaged or leaking Omni containers in locations adjacent to the point of spillage. Mobile equipment shall have cab shielding and an operator's air system as required above. The overpacking of damaged Omni containers shall be operable by remote equipment controls located within shielded cabs of mobile transporters. The transporters shall be able to maneuver the overpack container from all emplacement rooms and to deposit it on the elevator platform for transport to the surface for repackaging.

(11.4) In the event of a collision of any TRU transporter vehicle, it shall be possible to rescue the operator from any damaged vehicle by shearing break-away or shear bolts provided for the cab enclosure. Rescue equipment including a portable breathing apparatus shall be provided.

(11.5) Provision shall be made for cleanup after a TRU waste spill by a mobile cleanup unit having the following: shielded operator cab, vacuum pickup hoses, large and small vacuum pickups, pickup scoops having remotely controlled arms for the vacuum pickups to reach and clean the walls, ceilings, and floors, HEPA filters on the exhaust air discharge stream, shielded debris box with remotely controlled capability to dispose of waste into an overpack box, and an operator's air circulation system with HEPA filters.

(12) Safe operation of the TRU emplacement and retrieval systems requires that the repository ventilation system shall be able to provide air flow patterns directed from the supply air shafts towards the emplaced waste containers where air exhaust openings should be provided to minimize the spread of any airborne contaminants that could spread from a waste spill.

Ventilation systems shall be operated to reduce contaminants and repository room temperatures before operators are allowed to enter the rooms to work.

(13) All mobile equipment propulsion engines within the repository shall have suitable exhaust gas pollution control systems to reduce the carbon monoxide, hydrocarbons, oxides of nitrogen, and particulates to levels safe for the operator's occupancy.

(14) The TRU retrieval and emplacement systems shall comply with the highest level of applicable industrial safety standards as required by the Code of Federal Regulations, U.S. Bureau of Mines, the National Fire Protection Association Fire Codes, the Department of Transportation, the National Electrical Code, the American Society of Mechanical Engineers, the Uniform Mechanical Code, the American Society of Heating, Refrigerating and Air Conditioning Engineers, and the Occupational Safety and Health Administration. Where conflict exists between the listed codes, the most stringent code shall apply.

(15) TRU Waste Inventory Control and Monitoring System

The proposed regulations are to require that all waste forms received at the repository shall be inventoried, labeled, monitored, and so controlled at all times to assure full inventory responsibility by the repository management. A repository central monitoring system and data center shall be provided to record all waste form information from each container as shown on Figure 6A. Figure 6B is a simplified conceptual block diagram of one approach that may be used to fulfill the monitoring and inventory control system. This diagram is intended for use with a central computer; but, this does not rule out other types of systems. However, a computer system has the advantage of exact repeatability and can achieve through redundancy of systems any order of reliability required.

The proposed system shown on Figure 6B would function in the following sequence:

(15.1) The facility would receive a notice of impending shipment of waste materials. This notice would identify the type of material, quantities, type of containers, mode of transportation, and other identification traits associated with the shipment. This information would be entered into the Inventory Control System as the first step.

(15.2) The system would ascertain that storage space and facilities would be available on the anticipated date of shipment arrival.

(15.3) When the shipment arrives and is unloaded, all the pertinent information about the shipment is carefully recorded and entered into the system. The system would compare this information with that contained by the shipping notice. In the event that there are discrepancies the system sounds an alert which is to be recorded. This alert would institute an investigation to determine the cause or defect. If there are no discrepancies the shipment would proceed to the classification buildings for processing. Again after classification, as the materials leave the buildings to proceed to the packing buildings, the system compares the quantities to ascertain that no material is mislaid. Any discrepancies would cause the system to institute an "alert" requiring investigations to be made and the discrepancies rectified. After packing the system then assigns storage locations, and identification labels would be attached to each container package. The system then would assign transportation facilities to the various storage facilities and check that the various containers would reach their assigned storage locations.

(15.4) It should be noted that the computer would produce material location summaries denoting the location in the processing cycle of all materials inside the repository.

(15.5) After storage the system would upgrade the inventory records and begin continuous monitoring as to the condition of the stored waste materials. This would necessitate the installation of various "location" transmitters and security systems. Figure 4 shows a monitoring system that is to be provided.

(15.6) Upon the monitoring system noting a discrepancy in the location of stored waste material an "alert" would institute an investigation as to its cause. This alert could be caused by rupture of a containment package or the removal of material by an unauthorized person or persons.

(15.7) In addition the system would be able to produce summaries upon demand as to inventory, location of materials, and even previous alerts.

All waste repository facilities would be equipped for the eventual retrieval of the stored materials. It is envisioned that such a capability would be incorporated into the inventory control system.

(15.8) The first step would be the receipt of a "material release request." The information on the request would be inputed into the computer.

(15.9) The system would immediately verify the request and its authorization. If any discrepancies are found an alert would be instituted and investigated.

(15.10) If no discrepancies exist the computer would locate the required material and arrange retrieval and transportation back to the processing facilities buildings.

(15.11) As during the storage processing, the system would monitor the location of all material being processed.

After inspection and repacking for shipment the system would verify the identification of the assigned personnel from the authorized recipients. If no discrepancies in identification occur, the material would be released.

Alerts: The discrepancy alerts shown on Figure 6B, Block Diagram, must be positive controls as free from human error as is possible. When an "alert" is recorded at central control, positive action must be taken by operators or it may prove necessary to have key doors and gates closed automatically until such "alerts" are corrected.

Containers deposited within a depository room may require position detection systems such as the air pressure monitoring system, as shown on Figure 4, plus under-the-floor load cell indicators plus magnetic signal transponders at the door of each repository room. Any one of these redundant position detectors could be instrumented to record an "alert" during an unauthorized movement.

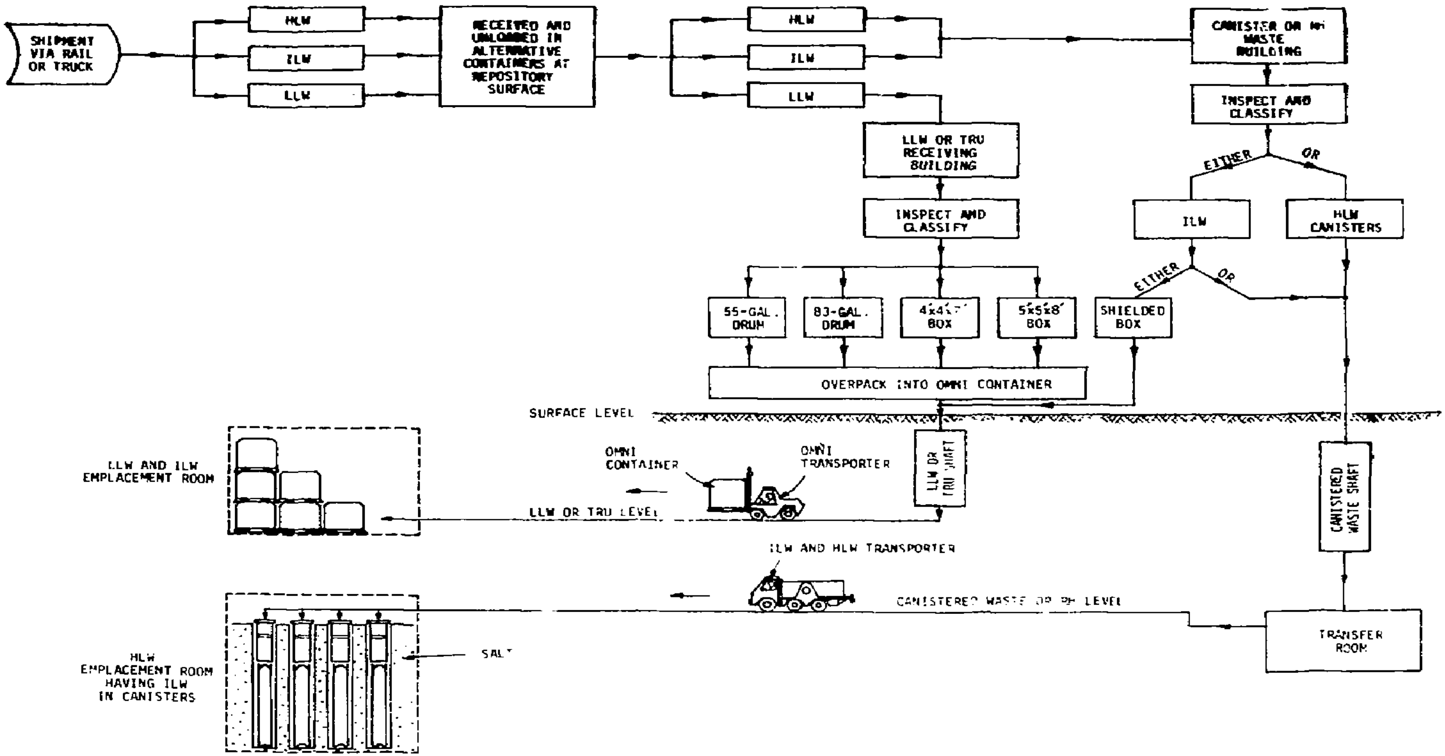


FIG. 1A SCHEMATIC DIAGRAM OF WASTE PACKAGE EMPLACEMENT

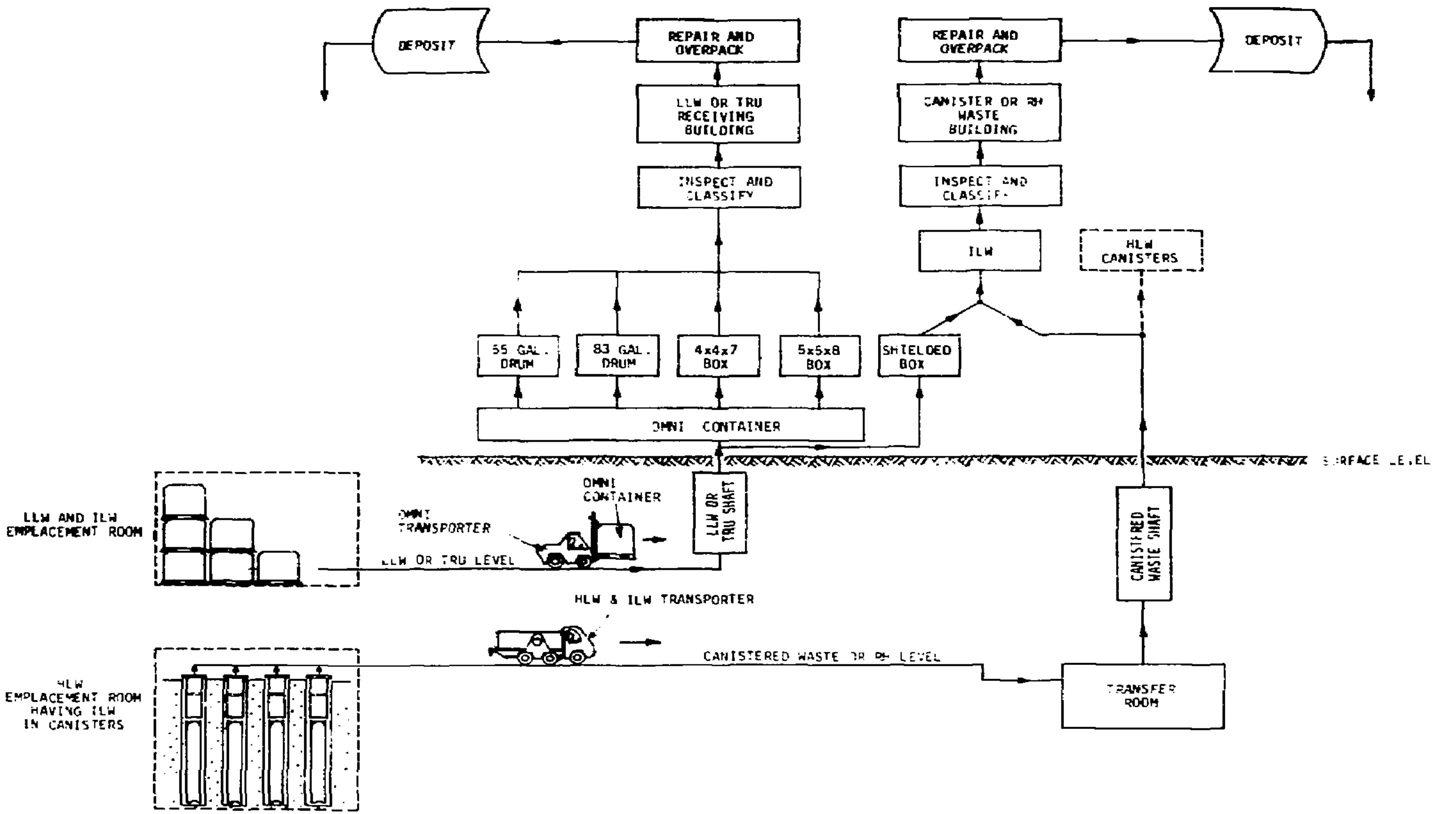


FIG. 1B SCHEMATIC DIAGRAM OF WASTE PACKAGE RETRIEVAL-INTACT CONTAINERS

● OBJECTIVE: BREACHED OR DAMAGED CONTAINERS MAY SPREAD AIRBORNE PARTICULATES THROUGHOUT THE REPOSITORY AND THEREFORE IT IS DESIRABLE TO ISOLATE SUCH CONTAINERS AS SOON AS AND AS LOCALIZED TO THE SITE AS POSSIBLE. THEREFORE, A MOBILE OVERPACK PROCEDURE IS DEVELOPED AS FOLLOWS:

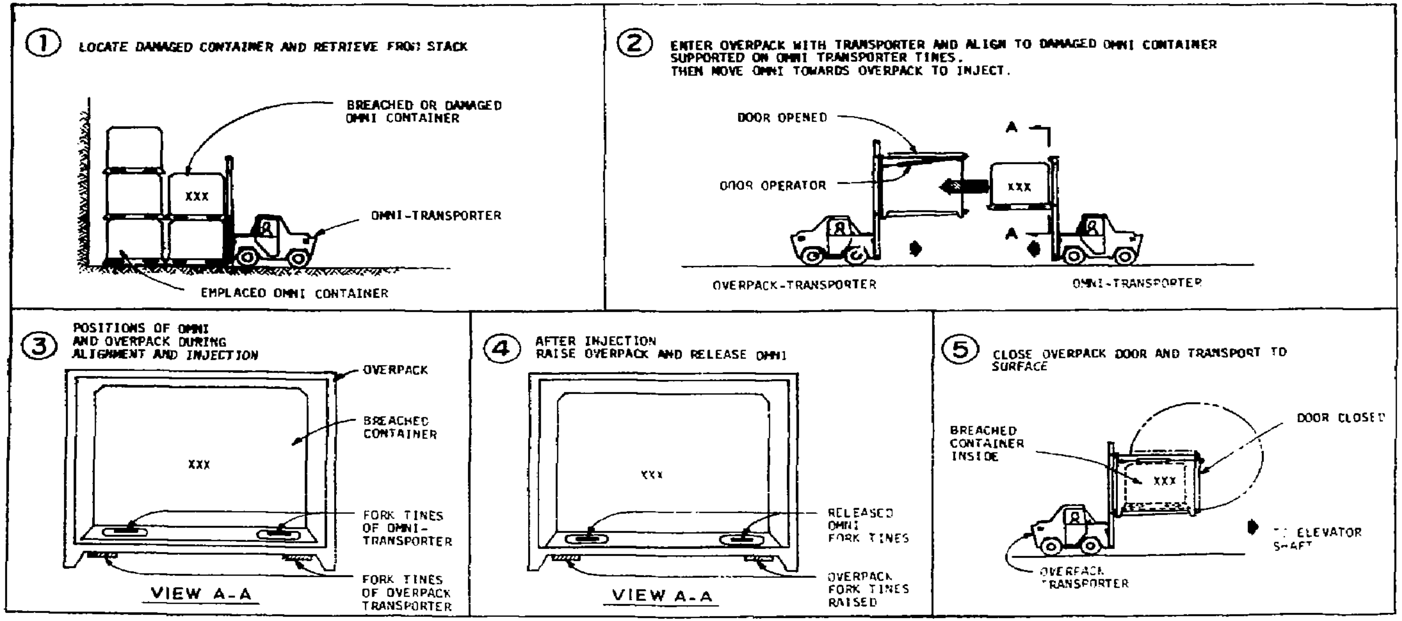


FIG. 1C WASTE PACKAGE RETRIEVAL-BREACHED CONTAINERS

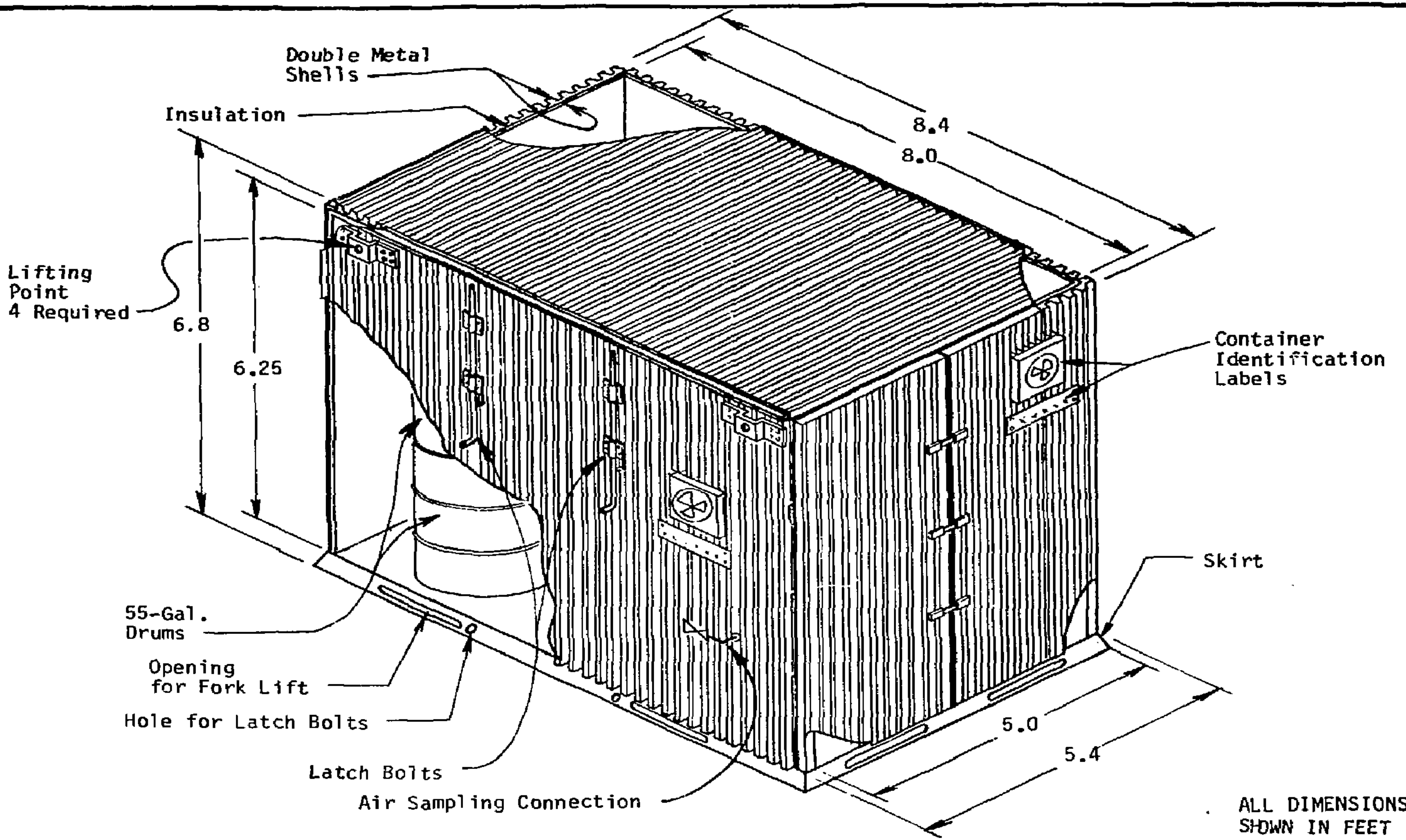


FIG. 2A OMNI CONTAINER ISOMETRIC VIEW

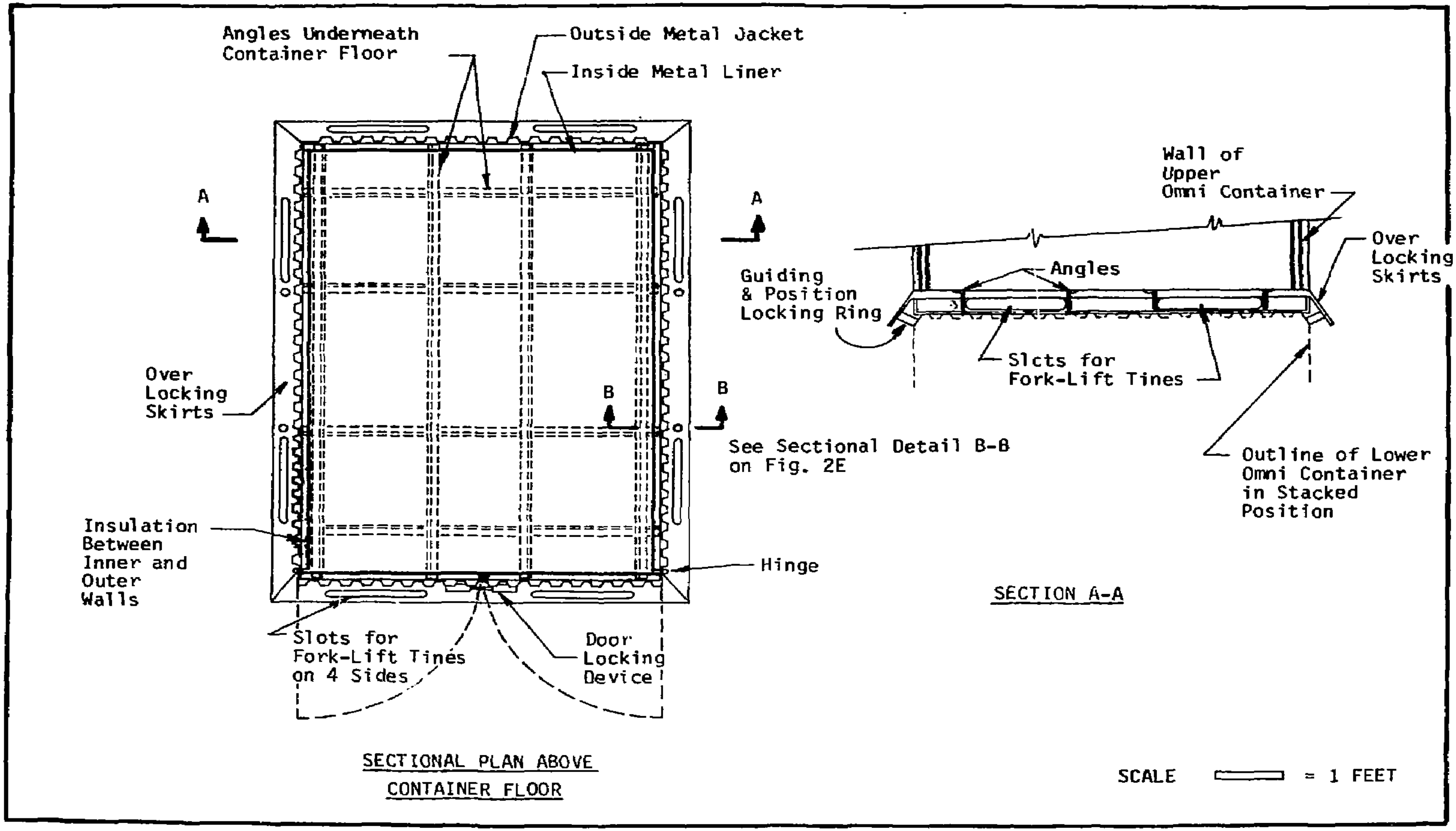


FIG. 2B OMNI CONTAINER SECTIONAL PLAN (I)

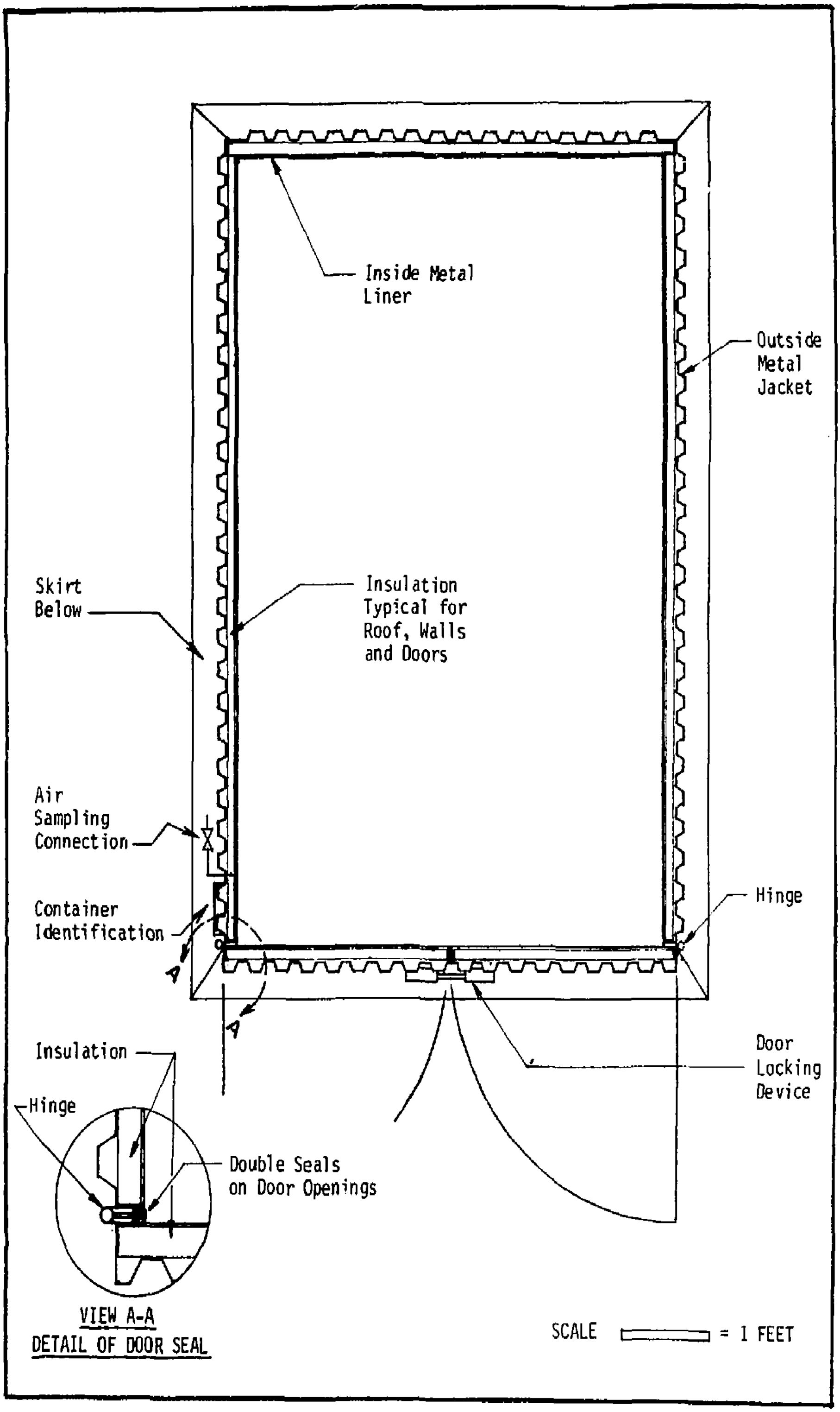


FIG. 2C OMNI CONTAINER SECTIONAL PLAN (II)

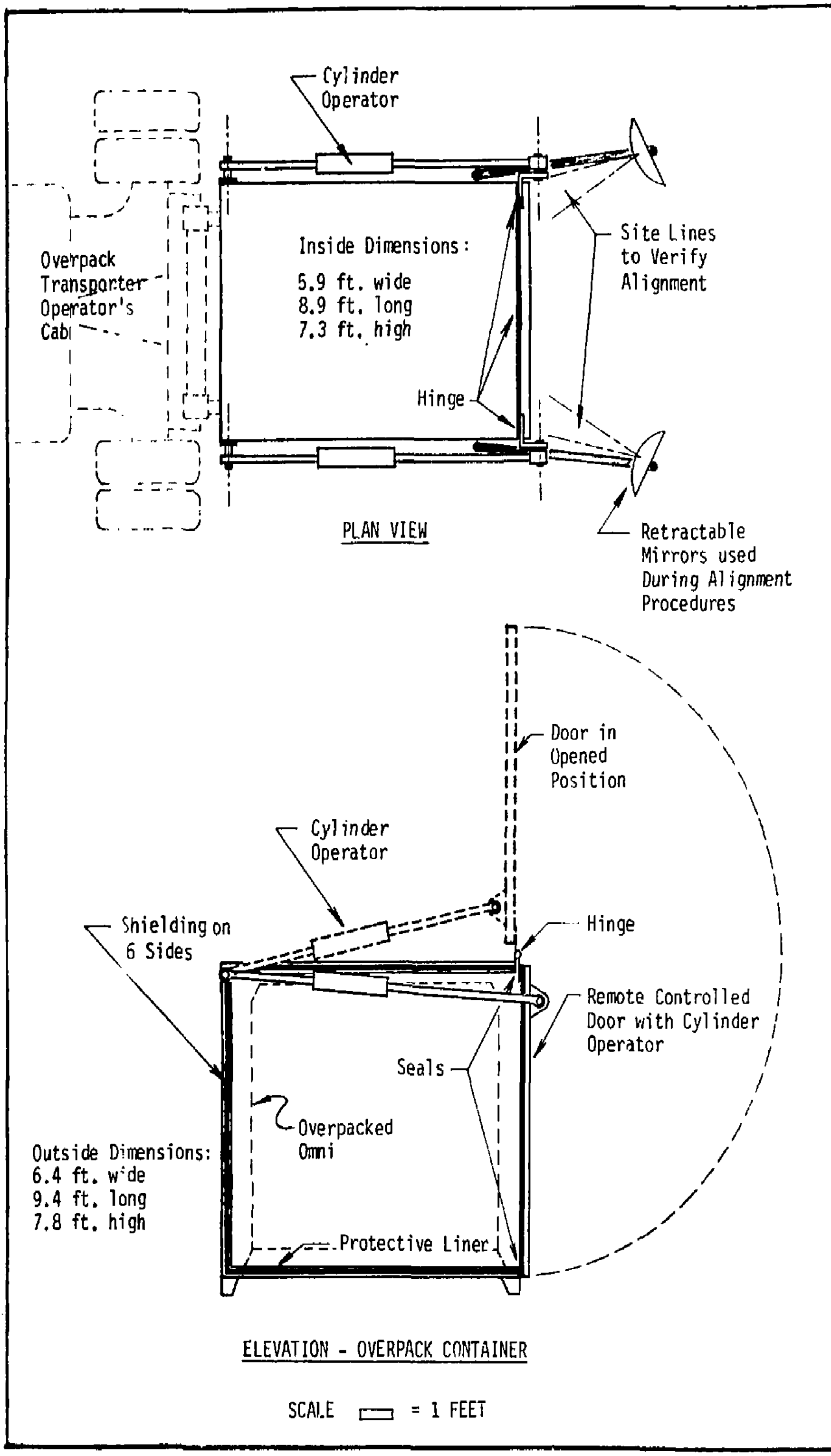


FIG. 2D OVERPACK CONTAINER

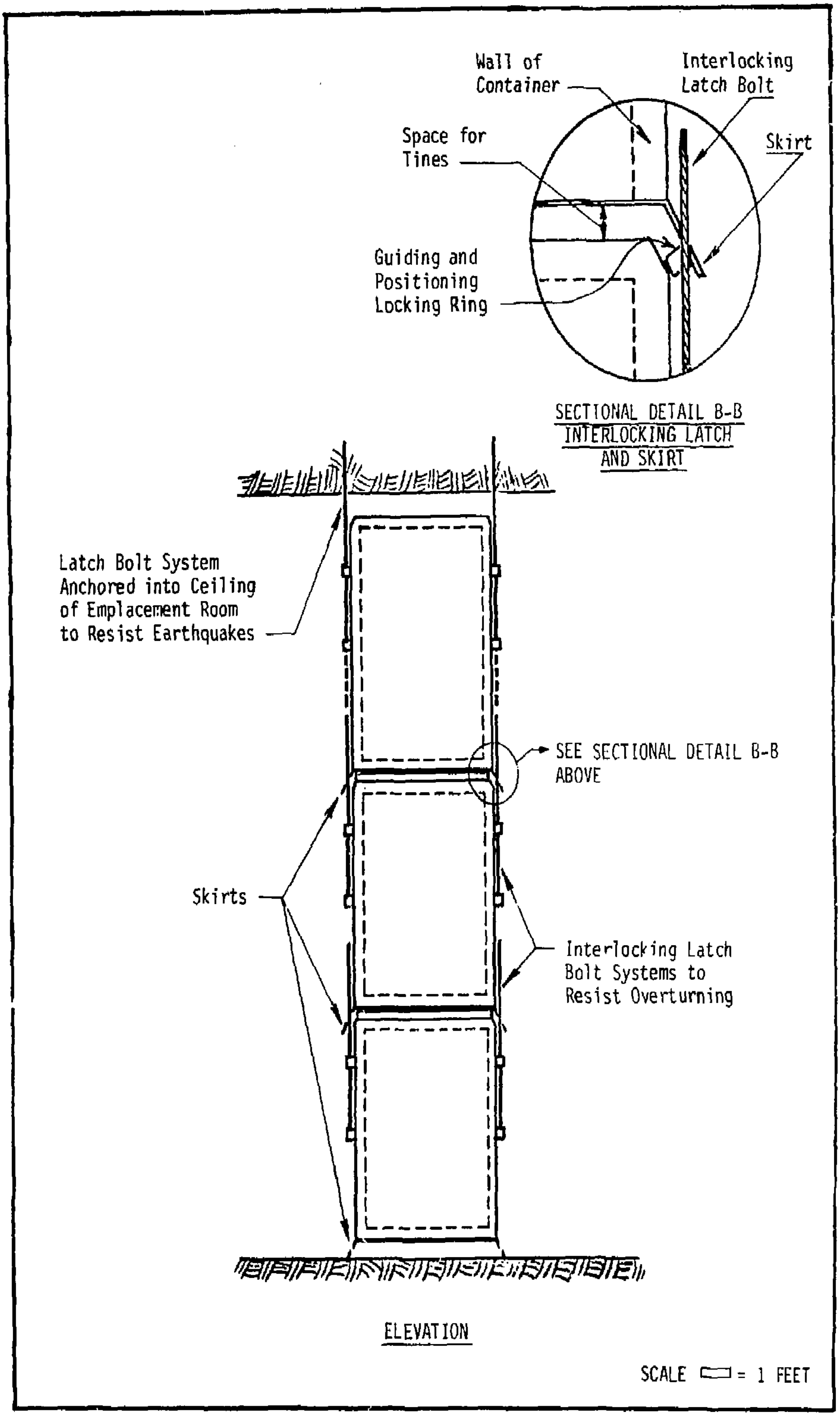
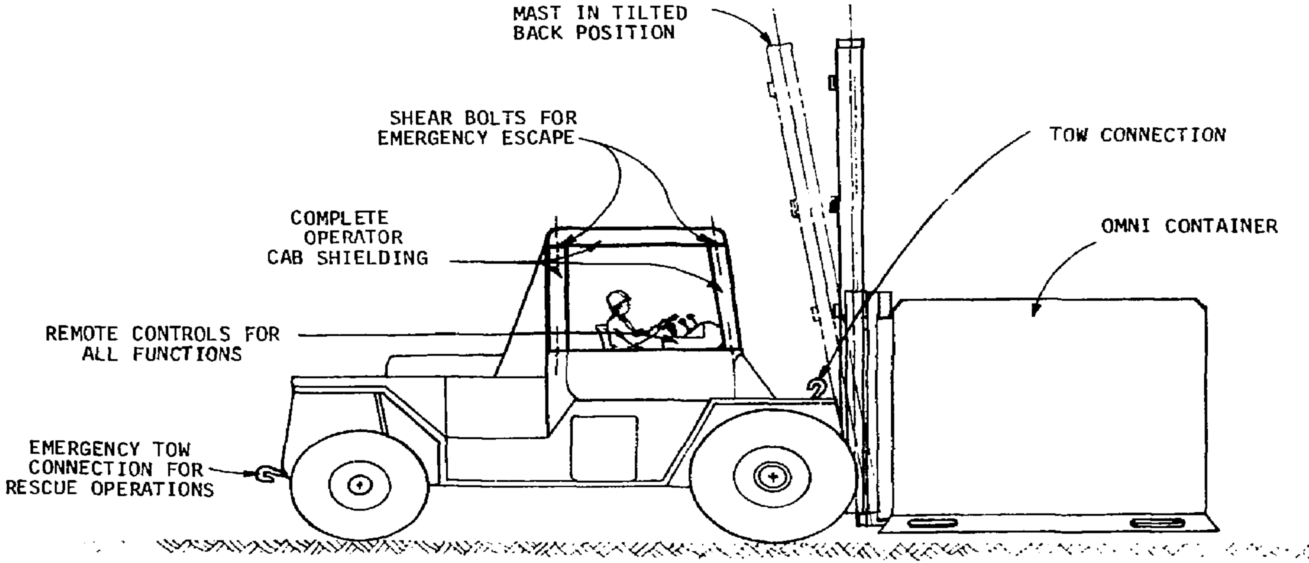


FIG. 2E EMPLACED OMNI CONTAINERS SECURED IN POSITION



● NOTE:
1. Carrying capacity 10 tons minimum
2. Lifting height 16 feet
3. Overpack transporter to be similar
4. Safety control system interlocks prevent transporter travel above 1 MPH unless mast is tilted back.

FIG. 3 TRANSPORTER FOR TRU WASTE OMNI CONTAINERS

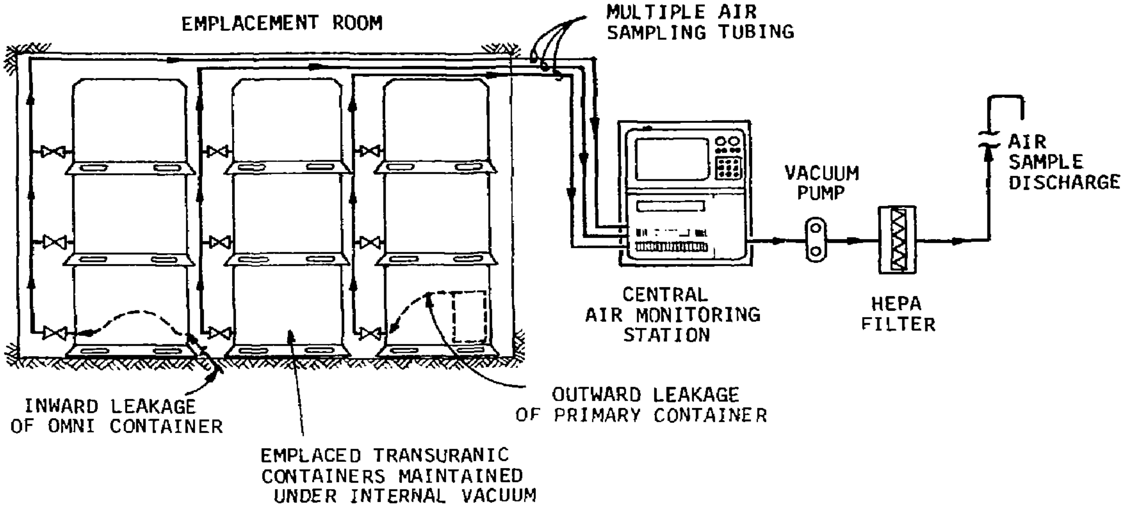


FIG. 4 ELEVATION VIEW - MONITORING SYSTEM

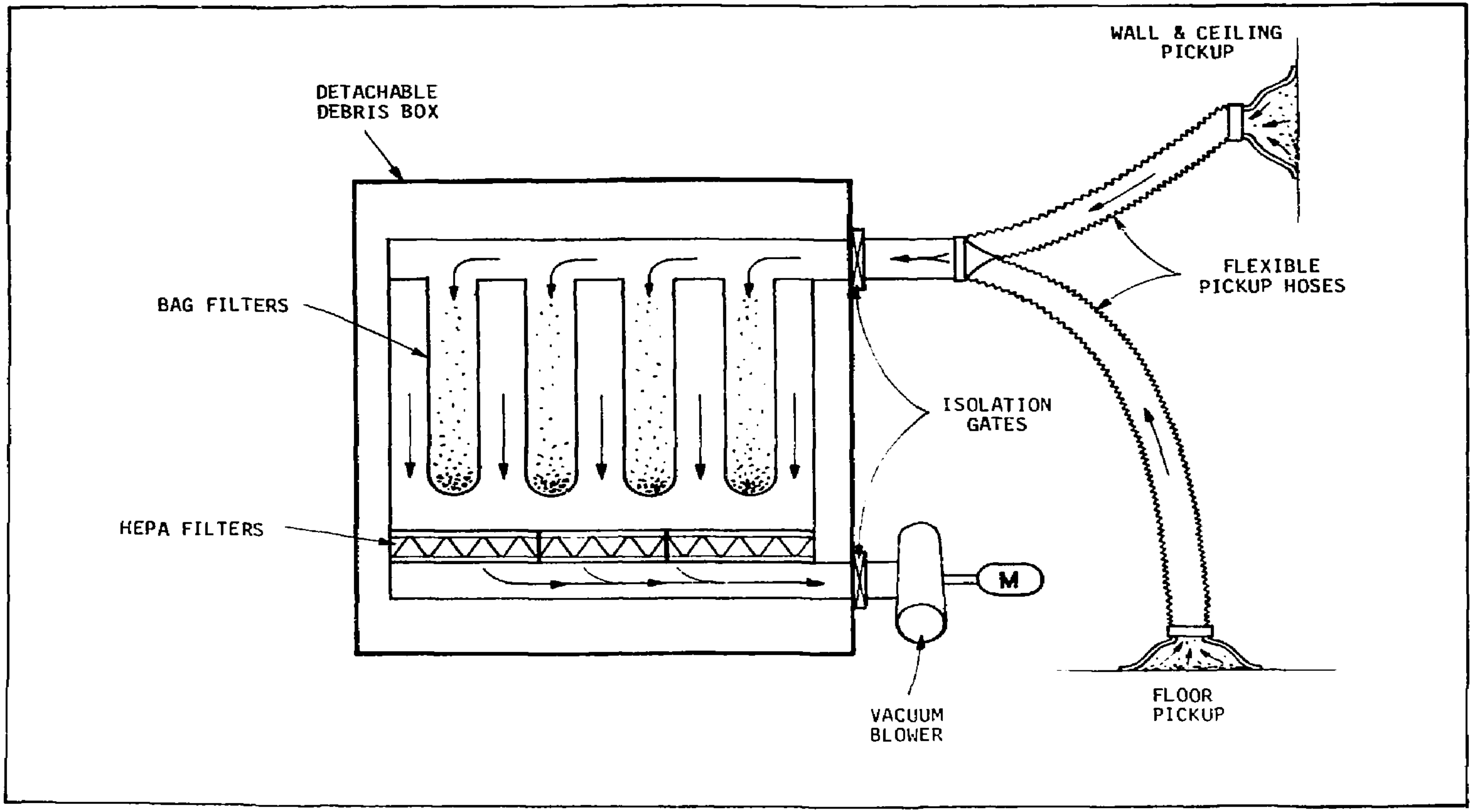


FIG. 5A SCHEMATIC OF MOBILE VACUUM CLEANUP UNIT

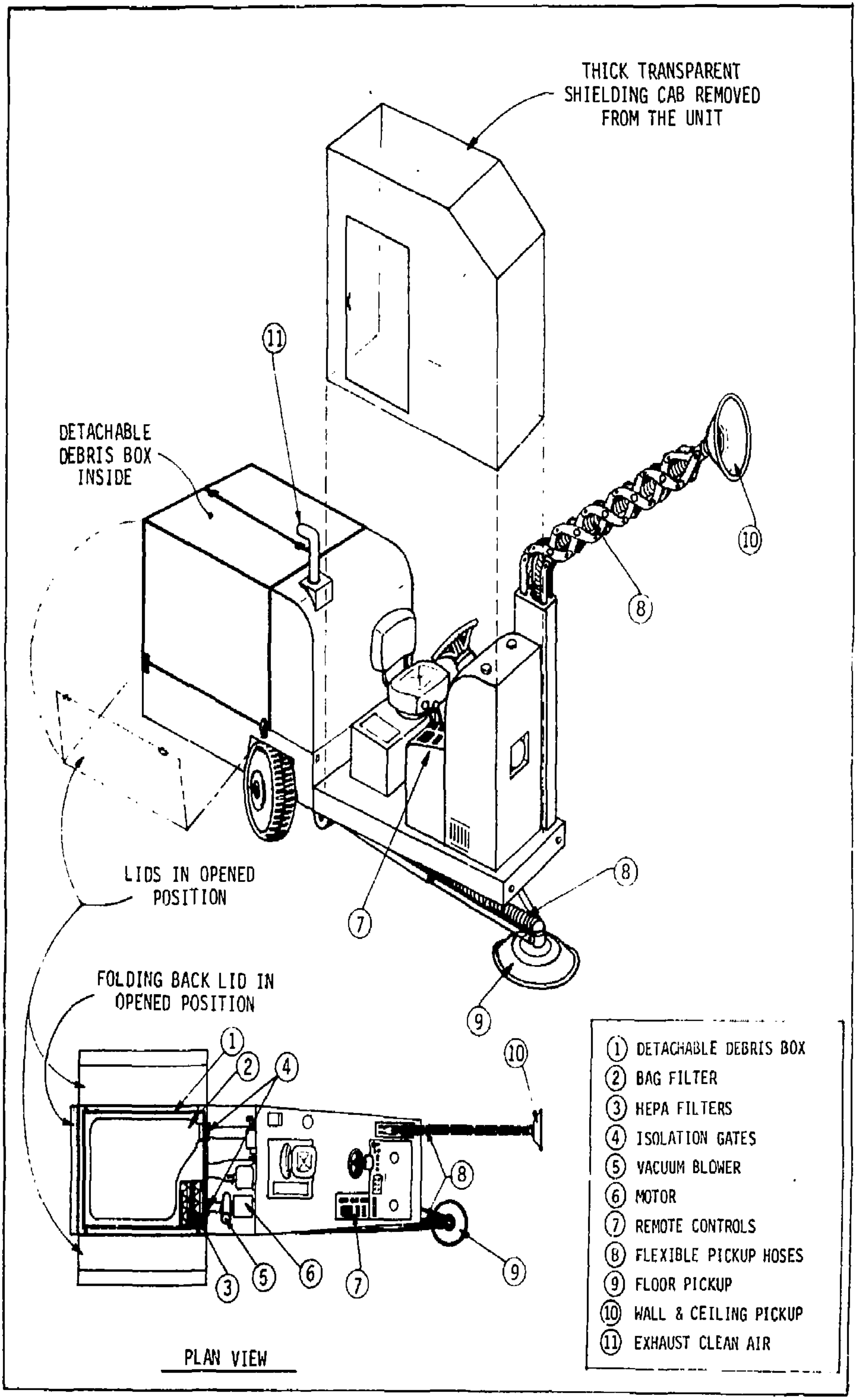
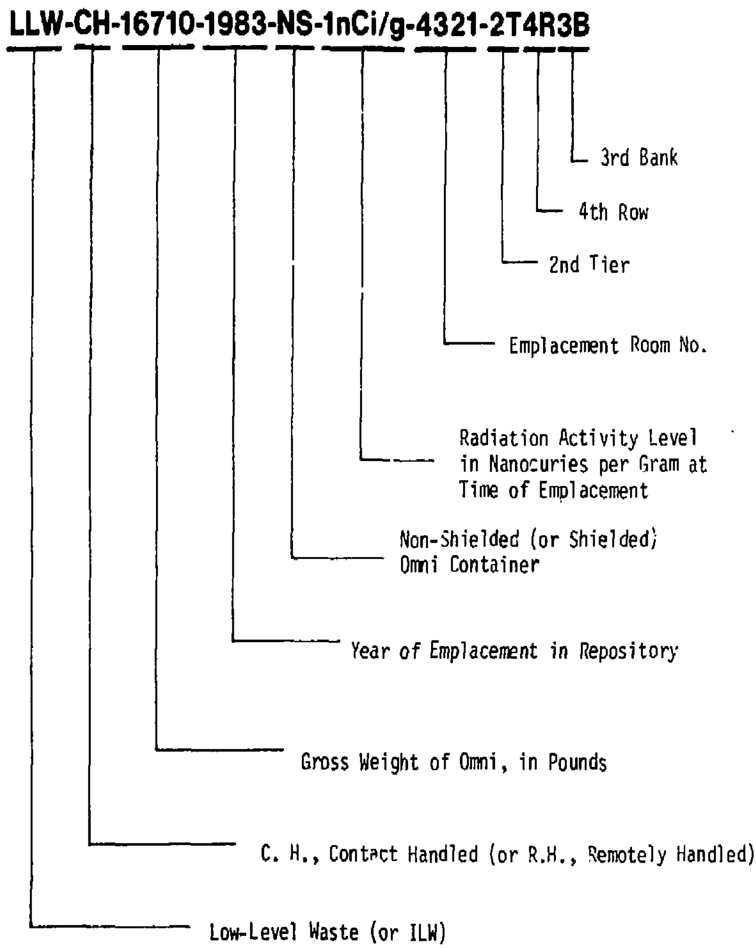


FIG. 5B MOBILE VACUUM CLEANUP UNIT

FIG. 6A

OMNI CONTAINER LABELING DATA FOR
REPOSITORY INVENTORY MANAGEMENT CONTROL

The following data is considered to be minimum required to be displayed on the exterior of each Omni Container for proper waste form inventory control.



All data noted above is to be entered into permanent memory banks at the repository control center, updated and revised whenever a package is retrieved, reprocessed, or relocated within the repository.

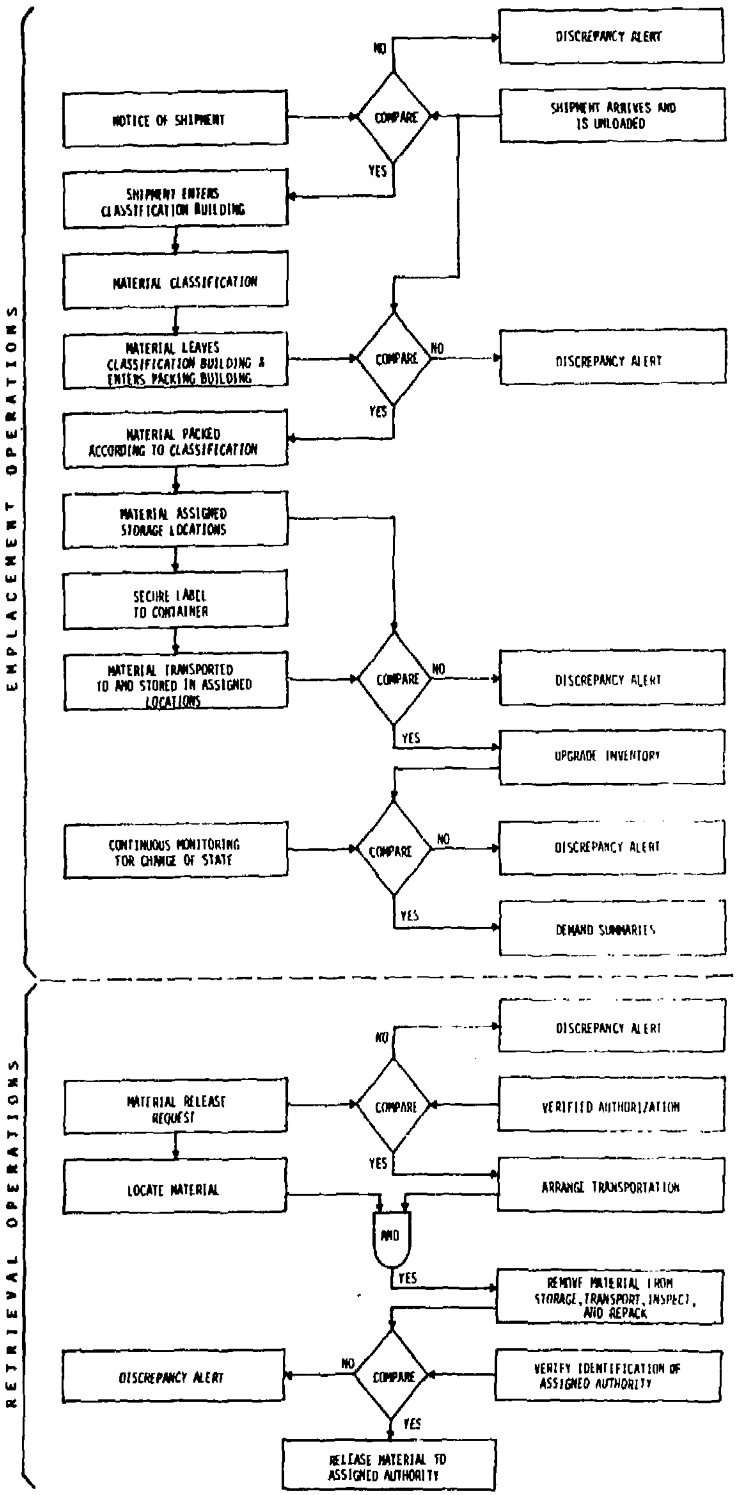


FIG. 6B TRU INVENTORY CONTROL AND MONITORING SYSTEM - BLOCK DIAGRAM

REFERENCES

Waste form, package, and emplacement design data were obtained from the following publications:

- Ref. (1) ERDA-76-43, Vol. 4, Alternatives of Managing Wastes from Reactors and Post-Fission Operations in the LWR Cycle.

- Ref. (2) Y/OWI/TM-36, Vol. 1-23, and Y/OWI/TM-44, Technical Support for GEIS: Radioactive Waste Isolation in Geologic Formations, OWI/Union Carbide, April 1978.

- Ref. (3) SAND 77-0274-P1-P2, Waste Isolation Pilot Plant (WIPP) Conceptual Design Report, Sandia Laboratories, June 1977.

- Ref. (4) UCRL-15025, Retrieval System for Emplaced Spent Unreprocessed Fuel (SURF) in Salt Bed Depository: Baseline Concept Criteria Specifications and Mechanical Failure Probabilities, International Engineering Company, Inc., May 1979.

- Ref. (5) DOE/EIS-0046-D, Draft Environmental Impact Statement: Management of Commercially Generated Radioactive Wastes, Page E.4, Table E.1, Note b., U.S. Dept. of Energy, April 1979.

APPENDIX

A

GLOSSARY

1. Canister is a special use container (i.e., spent fuel canister, HLW canister).

2. Cladding waste includes solid fragments of zircalloy, stainless steel cladding, and structural elements that remain after dissolution of the spent fuel cores. This waste is radioactive due to neutron activation of the cladding and residual fission product and TRU contamination.

3. Contact handled (CH) waste has sufficiently low-level radiation to permit contact by personnel with the package exterior.

4. Container is a metallic or non-metallic barrier in contact with, and enclosing the radioactive waste.

5. Degraded package is any package which is so deteriorated that it cannot be retrieved by using the standard retrieval equipment similar to that used for emplacement.

6. Depository means a facility for storage or disposal of packages constructed in an extensive underground rock formation having inherent properties that provide effective isolation of the radionuclides from the biosphere.

7. Emplacement room is a room in a depository wherein the TRU packages are emplaced.

8. Failure probability refers to the probability of failure during a single cycle of operation of a component or subsystem.

9. High-level waste (HLW) means the solidified waste shipped to a federal repository for storage or disposal which meets the requirements of the Code of Federal Regulations Title 10 Part 50, Appendix F. For the TRU project, the material handling, storage, and retrieval systems are not designed for HLW.

10. Intermediate-level TRU waste (ILW) is defined as those materials (other than high-level) that contain long-lived alpha emitters in known or suspected concentrations greater than 10 nanocuries per gram, and also have sufficiently high radiation levels after packaging to require shielding before handling is allowable. For the TRU project, all ILW will be remotely handled and will be transported and contained within either (1) shielded boxes or (2) canisters as specified by the report: Retrieval System for Emplaced Spent Unreprocessed Fuel (SURF) in Salt Bed Depository: Baseline Concept Criteria Specification and Mechanical Failure Probabilities, by International Engineering Company, Inc., (Ref. 4).

11. Low-level TRU waste (LLW) is defined as those materials which contain plutonium or other long-lived alpha emitters in known or suspected concentrations greater than 10 nanocuries per gram, and yet have sufficiently low radiation levels after packaging to permit contact handling.

12. Overpack is a permanently attached secondary or tertiary barrier enclosing a radioactive waste package.

13. Package means the canister and radioactive waste form contents. (May be used with a prefix, e.g., spent fuel package.)

14. Packaging is the operation of placing radioactive waste in a container.

15. Remotely handled (RH) waste is noncontact waste of significant radiation levels to prohibit direct contact by personnel with the package exterior.

16. Repository means the entire surface and subsurface complex for receiving, isolation storage, and retrieval of nuclear waste packages such as described by the Office of Waste Isolation Report No. Y/OWI/TM-36 for the GEIS repository (Ref. 2).

17. Retrievability is the term used to describe the ability to recover the radioactive waste package from surface or geologic storage with minimum loss of both radioactive material and container integrity.

18. Retrieval system refers to a total system which is employed to locate the waste package, retrieve same and move it to a hoist facility, and then bring it to a surface receiving area.

19. Storage is the retrievable emplacement of radioactive waste packages in either a surface or geologic repository.

20. Subsystem is any single major component of the total system; for example, subsystems are the hoist or the subsurface transport.

21. Transuranic waste (TRU) is any waste material measured or assumed to contain more than a specified concentration of TRU radionuclide elements (e.g., 10 nanocuries of activity per gram).

22. TRU elements are those chemical elements having atomic numbers higher than that of uranium (i.e., greater than 92). Some wastes to be stored include isotopes of uranium with the TRU elements.

APPENDIX

B

Table 1-1

CANISTER RECEIPT CRITERIA RECOMMENDATIONS

	Canister		Overpack			Maximum Radiation Level (Rem/Hr)			
						At Surface		10' from Ctr. Line	
Contents	Outside Diameter (inches)	Overall Length (feet)	Outside Diameter (inches)	Overall Length (feet)	Age (Years)	gamma dose rate	neutron dose rate	gamma dose rate	neutron dose rate
HLW in Glass	12-3/4	10	14	11	10	2.0×10^{5}	1.0×10^{2}	1.0×10^{4}	1.0×10^{1}
HLW in Calcine	8-5/8	10	10-3/4	11	10	5.0×10^{5}	1.0×10^{2}	5.0×10^{4}	1.0×10^{1}
IL-TRU	12-3/4	10	14	11	5	1.0×10^{2}	1.0×10^{-1}	1.0×10^{1}	5.0×10^{-3}
Cladding	12-3/4	10	14	11	5	1.0×10^{3}	1.0×10^{-1}	1.0×10^{1}	5.0×10^{-3}
PWR	14	16	16	16-1/2	10	7.0×10^{4}	1.0×10^{1}	3.5×10^{3}	5.8×10^{-1}
BWR	10-3/4	16	12-3/4	16-1/2	10	5.0×10^{4}	1.0×10^{1}	2.5×10^{3}	5.8×10^{-1}

ADDITIONAL RECEIPT CRITERIA
(For All Canisters)

Max. Weight (incl. overpack) = 3000 lbs.

Max. outer surface contamination
with transferable radioisotopes:

beta-gamma radiation emitting nuclides: 10,000 dis/min/dm^2 (disintegration/minute/100 cm^2)
alpha emitting nuclides: 300 dis/min/dm^2

Source: TM-36/2, Commercial Waste Forms, Packaging and Projections for Preconceptual Repository Design Studies.

(Source of Exhibit 1: Reference 1, TM-36/8, Repository Preconceptual Design Studies: Salt)

Exhibit 1-1

Table 5-2

SALT REPOSITORY SUMMARY

Cycle (Date Filled)	Waste Type	Capacity (No. Containers)	Room Length (feet)	Room Opening W x H (ft.)	Approx.[1] Area (Acres)	No. Rooms	Waste Units/ Room	Total No. Panels	Rooms per Panel	No.[2] Rows	Longitud. Spacing ea. Row	Storage Configuration
I-Total Recycle (2006)	HLW (Glass)	41,340	560	18 x 20	1018	780	53	1 19	20 40	1	10 ft.	Canisters in holes
	IL-TRU CW	274,485 57,055	1575 3150 1850	36 x 20	649 135	4 108 32	1265 2580 1495	36	4	5	6 ft.	Canisters in holes
	LL-TRU	571,200	2000	36 x 20	108	28	20,400	7	4	-	-	Palletized drums
II-Spent Unreprocessed Fuel (2008)	PWR	134,648	3500 1300	18 x 22	700	104 36	1150 418	26 9	4	2	6 ft.	Canisters in holes
	BWR	200,016	3500 2910	18 x 22	1035	144 36	1150 956	36 9	4	2	6 ft.	Canisters in holes
	LL-TRU	60,192	1374	18 x 22	97	12	5016	3	4	-	-	Palletized drums
III-U only Cycle (2007)	HLW (Glass)	44,460	560	18 x 20	1018	780	57	1 19	20 40	1	9 ft.	Canisters in holes
	IL-TRU CW	246,780 60,260	1575 3150 1850	36 x 20	649 135	4 108 32	1190 2390 1380	36	4	5	6.5 ft.	Canisters in holes
	LL-TRU	81,600	1000	36 x 20	14	8	10,200	2	4	-	-	Palletized drums

1) Approximate area is gross acreage associated with each storage section including main corridors, exhaust corridors and buttress pillars; it is not the net area used to calculate areal heat loads.

2) Refers to rows of canisters in each room.

Exhibit 1-2

ILW AND LLW RECEIVING RATES - U+Pu RECYCLE[a] (CYCLE I)

	ILW Canisters[b]		LLW Drums[c]	
Year	Annual	Accumulated	Annual	Accumulated
1985[d]	1404	1404	481	481
1986	5618	7022	1923	2404
1987	6180	13202	2404	4808
1988	5618	18820	3846	8654
1989	6742	25562	9135	17789
1990	5056	30618	6731	24520
1991	12191	42809	9808	34329
1992	11629	54438	11250	45578
1993	12191	66629	16058	61636
1994	13315	79944	16538	78174
1995	13876	93820	18462	96636
1996	8989	102809	21154	117790
1997	10674	113483	25000	142790
1998	11236	124719	28846	171636
1999	12360	137079	31731	203367
2000	13483	150562	37500	240867
2001	14607	165169	40865	281732
2002	16292	181461	46635	328367
2003	16854	198315	50000	378367
2004	18539	216854	57212	435579
2005	19663	236517	62500	498079
2006	20787	257304	68750	566829
2007	21348	278652	73558	640387
2008	22472	301124	80288	720675
2009	23034	324158	86538	807213
2010	23596	347754	88942	896155

[a] Based on projections prepared by OWI (June-1977). Assumes 460 GWe installed nuclear capacity in year 2000 (5 year delay prior to burial).

[b] ILW Reference canister is 10 ft. long, 1 ft. diameter with an active volume of 6.28 ft^3 (0.178m^3).

[c] LLW reference drum is a type 170,55 gallon (7.35 ft^3 or 0.208 m^3).

[d] Prior to 1985 backlog of 30,056 ILW and 10,577 LLW canisters is accumulated. This backlog is worked off between 1991 and 1995.

SPENT FUEL - LLW RECEIVING RATES[a] (CYCLE II)

	Number of LLW Drums[b]	
Year	Annual	Accumulated
1985[c]	208	208
1986	962	1170
1987	1093	2263
1988	1225	3488
1989	1363	4851
1990	1508	6359
1991	2438	8797
1992	2589	11386
1993	2741	14127
1994	2899	17026
1995	3056	20082
1996	2423	22505
1997	2575	25080
1998	2719	27799
1999	2866	30665
2000	3011	33676
2001	3147	36823
2002	3147	39970
2003	3147	43117
2004	3147	46264
2005	3147	49411
2006	3147	52558
2007	3147	55705
2008	3147	58852
2009	3147	61999
2010	3147	65146
2011	3114	
2012	3094	
2013	3081	
2014	3048	
2015	2995	
2016	2935	
2017	2057	
2018	2823	
2019	2782	
2020	2753	
2021	2700	
2022	2631	
2023	2553	
2024	2452	
2025	2315	

[a]Based on projections prepared by OWI (June-1977). Assumes 480 GWe installed nuclear capacity by year 2000 and 13.7 m^3 waste generated per GWe-yr. (With a compaction factor of 10).

[b]Reference drum is DOT type 17C 55 gal. drum containing 7.35 ft^3 ($0.208 m^3$) of waste.

[c]Backlog acquired before 1985 worked off between 1991-1995. Waste is shipped 1 year after generation - after the backlog is worked off.

Table 5-8 Exhibit 1-5

ILW AND LLW RECEIVING RATES[a] - U RECYCLE (CYCLE III)

Year	ILW Canisters[b] Annual	ILW Canisters[b] Accumulated	LLW Drums[c] Annual	LLW Drums[c] Accumulated
1985	1404	1404	481	481
1986	5618	7022	1923	2404
1987	6180	13202	2404	4808
1988	5618	18820	1923	6731
1989	6742	25562	2404	9135
1990	5056	30618	1923	11058
1991	12191	42809	4038	15091
1992	11067	53876	4038	19129
1993	12191	66067	4038	23167
1994	12753	78821	4519	27686
1995	13314	92135	4519	32205
1996	7865	100000	2885	35089
1997	8989	108989	2885	37974
1998	9551	118540	3365	41339
1999	10112	128652	3365	44704
2000	11236	139888	3846	48551
2001	11798	151686	3846	52397
2002	12360	164046	4327	56723
2003	13483	177529	4327	61050
2004	14045	191574	4808	65858
2005	14607	206181	4808	70666
2006	15169	221350	5288	75954
2007	15169	236519	5288	81242
2008	15169	251688	5288	86530
2009	15169	266857	5288	91818
2010	15169	282026	5288	97106

[a]Based on projections prepared by OWI (June-1977). Assumes 480 GWe installed nuclear capacity in year 2000 (5 year delay prior to burial).

[b]Reference ILW canister is 10 ft. long, with 1 ft. diameter (6.28 ft^3 or .178m^3).

[c]Reference LLW container is a type 17C, 55 gallon drum (7.35 ft^3 or .208m^3).

[d]Backlog of 30056 canisters ILW and 10575 drums LLW in 1985 to be worked off during 1991-1995.

B-6

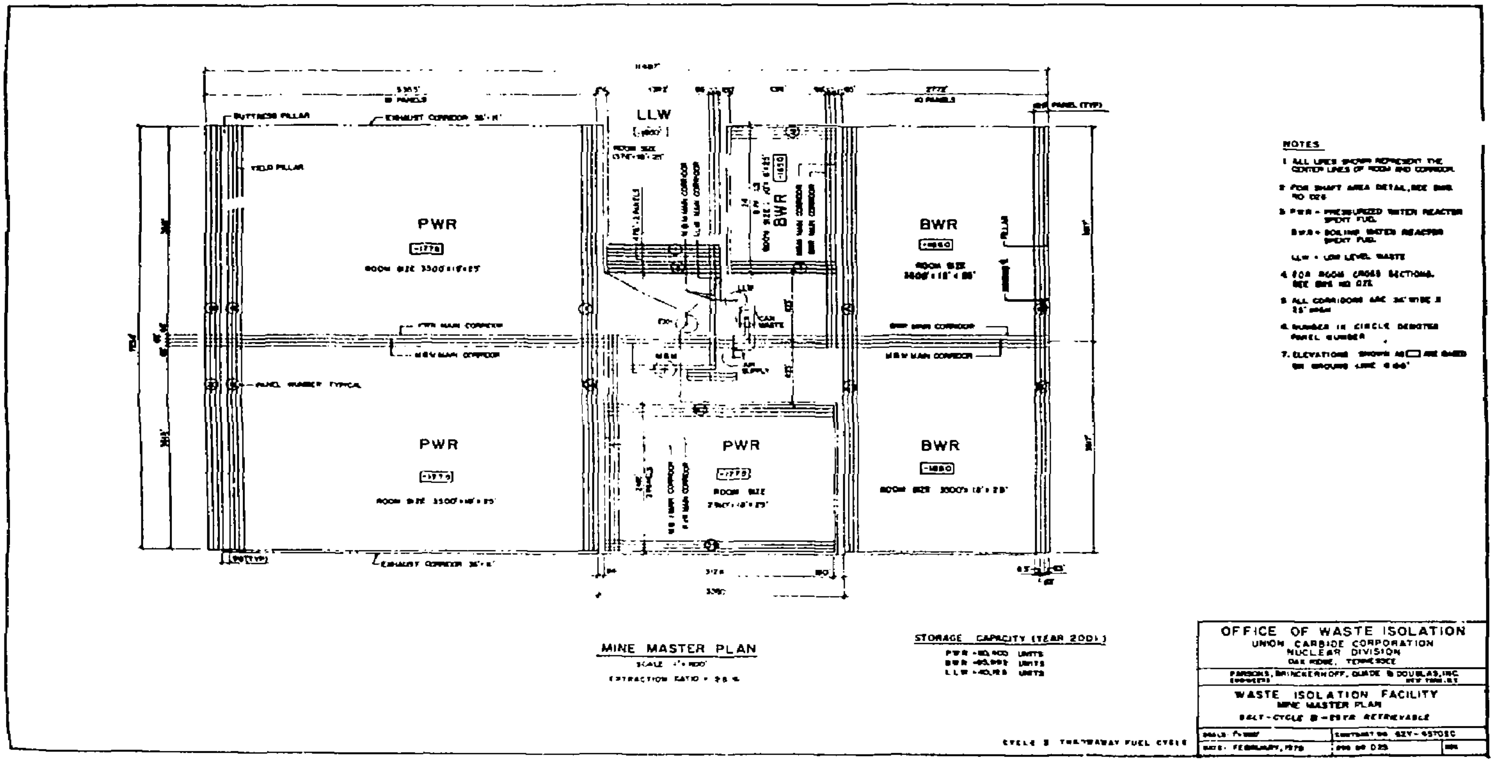
Table 5-11

REPOSITORY SUMMARY - SALT
25-YEAR RETRIEVABLE CASES

Cycle (Date Filled)	Waste Type	Capacity (No. Containers)	Room Length (ft.)	Room Opening W x H (feet)	Approx.[1] Area (acres)	No. Rooms	Waste Units/ Room	Total No. Panels	No. Rooms per Panel/Panel Number	No.[2] Rows	Longitud Spacing ea. Row	Storage Configuration
Cycle II (Heat Removal) (2004)	PWR	87,472	2910 3500	18 x 25	964	36 128	460 554	41	4/P #1 to 41	1	6' 3"	Can. in Trench
	BWR	137,117	1300 3500	18 x 25	810	36 120	382 1028	39	4/P #1 to 39	2	6' 9"	Can. in Trench
	LL-TRU	60,192	1374	18 x 25	31	12	5016	3	4/P #1 to 3			Palletized Drum
Cycle II (Non-heat Removal) (2001)	PWR	60,400	2910 3500	18 x 25	1106	36 152	276 332	47	4/P #1 to 47	1	10'6"	Can. in Holes
	BWR	95,992	1300 3500	18 x 25	568	36 80	382 1028	29	4/P #1 to 29	2	6' 9"	Can. in Holes
	LL-TRU	40,128	1374	18 x 25	19	8	5016	2	4/P #1 to 2			Palletized drum

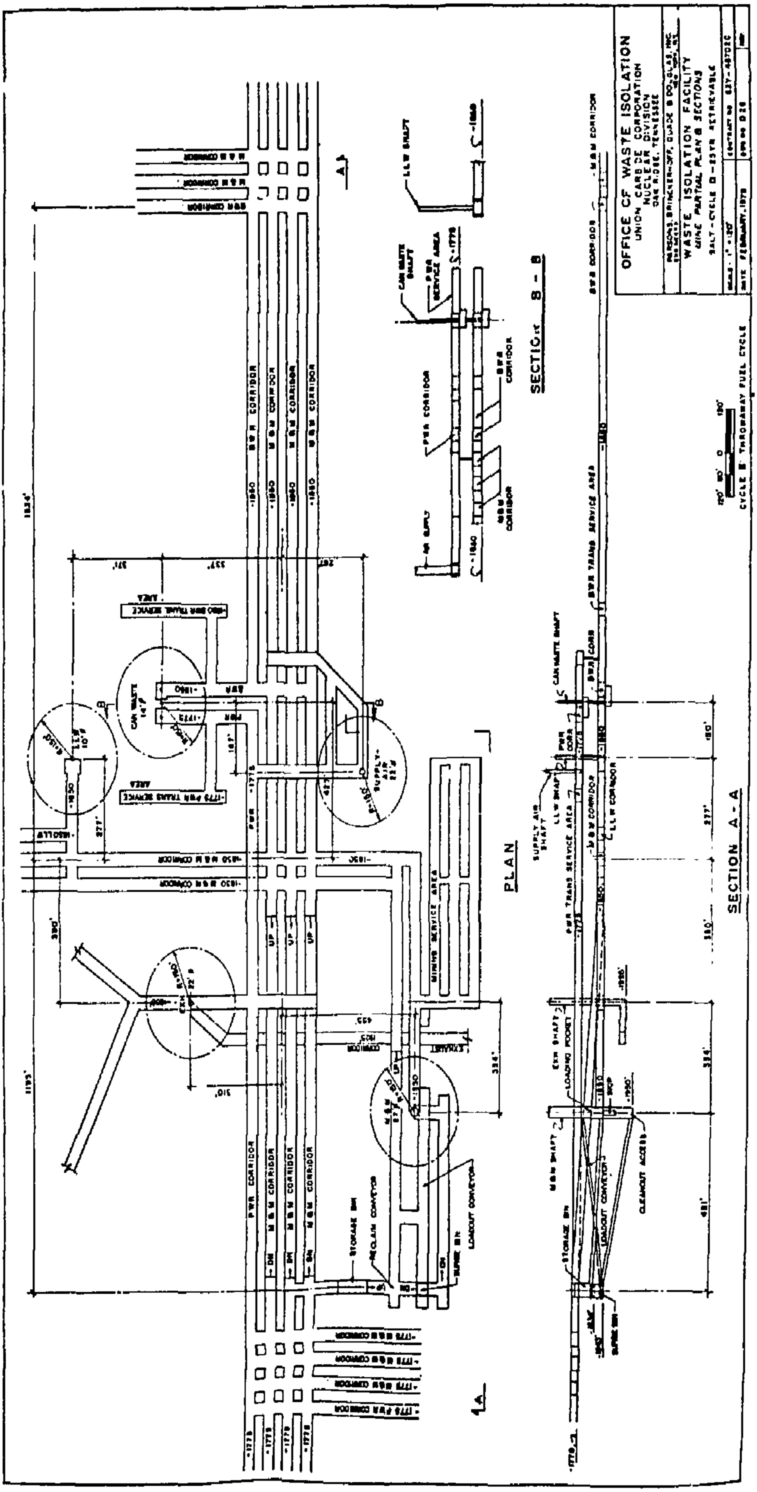
1) Approximate area is gross acreage associated with each storage section including main corridors, exhaust corridors and buttress pillars; it is not the net area used to calculate areal heat loads.

2) Refers to rows of canisters in each room.



(Source of Exhibit 2: Reference 1, TM-36/9, Drawings for Repository Preconceptual Design Studies: Salt)

Exhibit 2-1



OFFICE OF WASTE ISOLATION
UNION CARBIDE CORPORATION
NUCLEAR DIVISION
OAK RIDGE, TENNESSEE
WASTE ISOLATION FACILITY
MINE PARTIAL PLAN & SECTIONS
SALT-CYCLE B-25YR RETRIEVABLE
PLAN
SECTION A - A
SECTION B - B
CYCLE B' THROWAWAY FUEL CYCLE

Exhibit 2-2

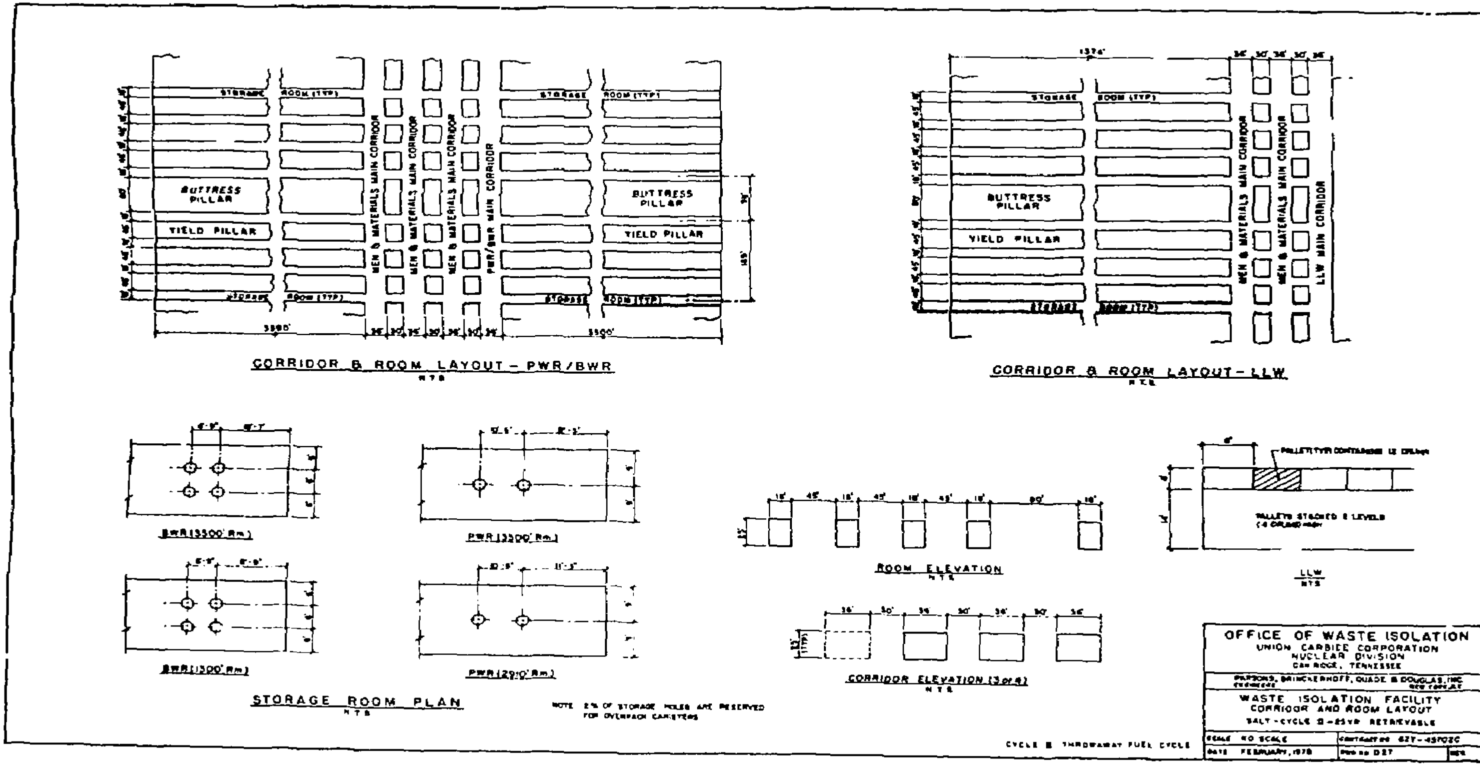

STORAGE ROOM (TYP)
BUTTRESS PILLAR
YIELD PILLAR
MEN & MATERIALS MAIN CORRIDOR
PWR/BWR MAIN CORRIDOR
LLW MAIN CORRIDOR
3500'
1374'
CORRIDOR & ROOM LAYOUT - PWR/BWR
NTS
CORRIDOR & ROOM LAYOUT - LLW
NTS
BWR(3500' Rm.)
PWR(3500' Rm.)
BWR(1300' Rm.)
PWR(290' Rm.)
STORAGE ROOM PLAN
NTS
NOTE 2% OF STORAGE HOLES ARE RESERVED FOR OVERPACK CANISTERS
ROOM ELEVATION
NTS
CORRIDOR ELEVATION (3 of 4)
NTS
PALLETS STACKED 2 LEVELS
LLW
NTS
CYCLE B THROWAWAY FUEL CYCLE
OFFICE OF WASTE ISOLATION
UNION CARBIDE CORPORATION
NUCLEAR DIVISION
OAK RIDGE, TENNESSEE
PARSONS, BRINCKERHOFF, QUADE & DOUGLAS, INC.
WASTE ISOLATION FACILITY
CORRIDOR AND ROOM LAYOUT
SALT - CYCLE B - 25YR RETRIEVABLE
SCALE NO SCALE
DATE FEBRUARY, 1978

Exhibit 2-3

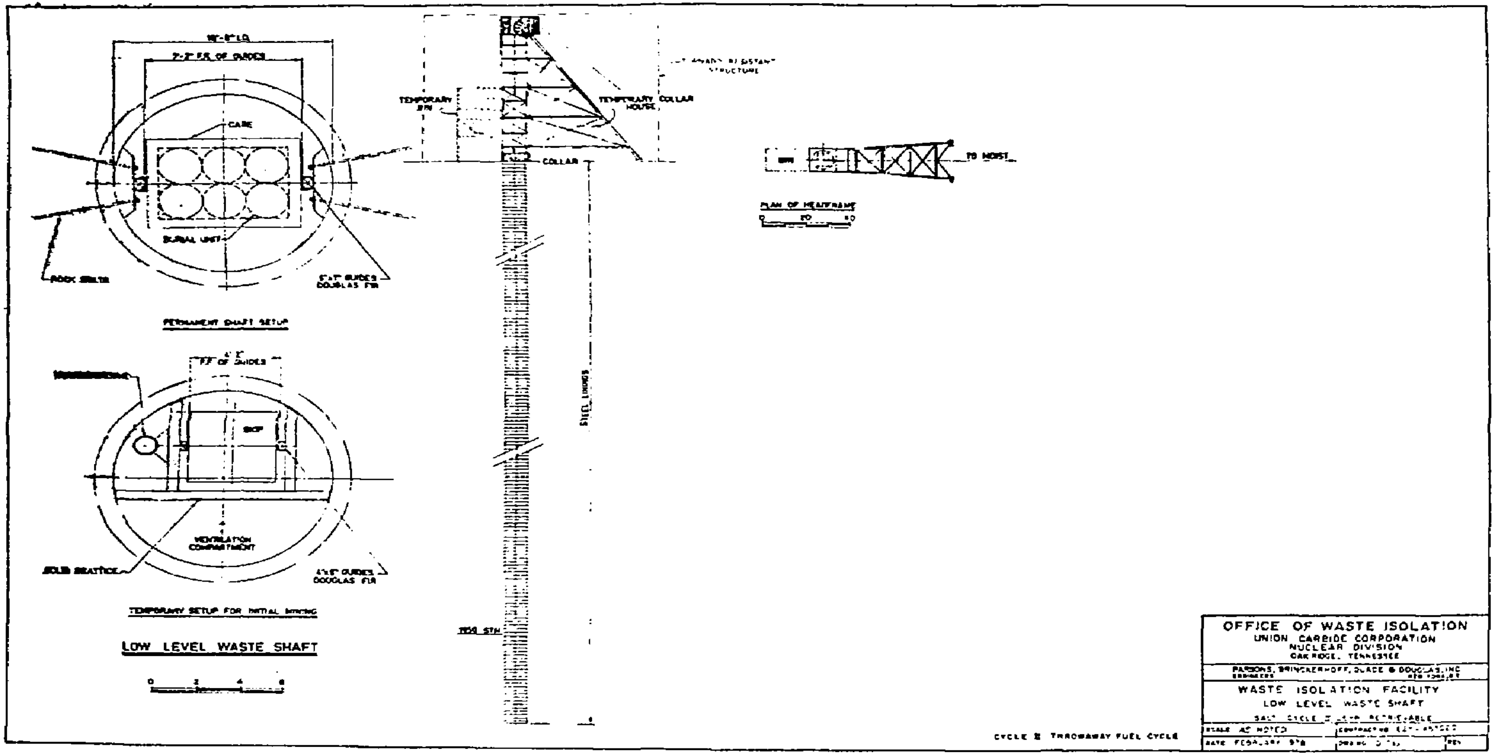

CARE
BURIAL UNIT
ROCK BOLTS
PERMANENT SHAFT SETUP
SKIP
VENTILATION COMPARTMENT
SOLID BRATTICE
TEMPORARY SETUP FOR INITIAL MINING
LOW LEVEL WASTE SHAFT
TEMPORARY BIN
TEMPORARY COLLAR HOUSE
COLLAR
STEEL LININGS
TO HOIST
PLAN OF HEADFRAME
CYCLE II THROWAWAY FUEL CYCLE
OFFICE OF WASTE ISOLATION
UNION CARBIDE CORPORATION
NUCLEAR DIVISION
OAK RIDGE, TENNESSEE
WASTE ISOLATION FACILITY
LOW LEVEL WASTE SHAFT

Exhibit 2-4

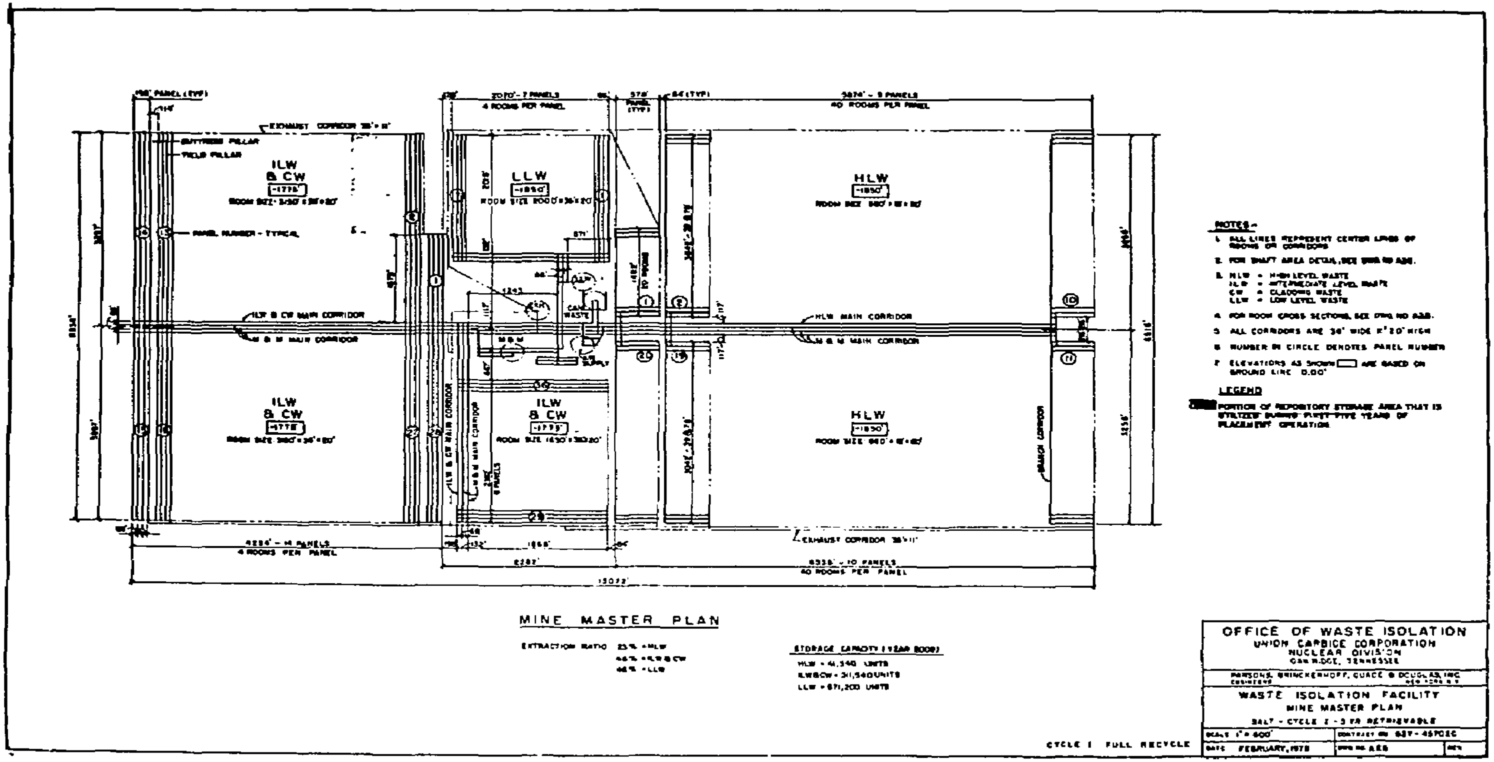
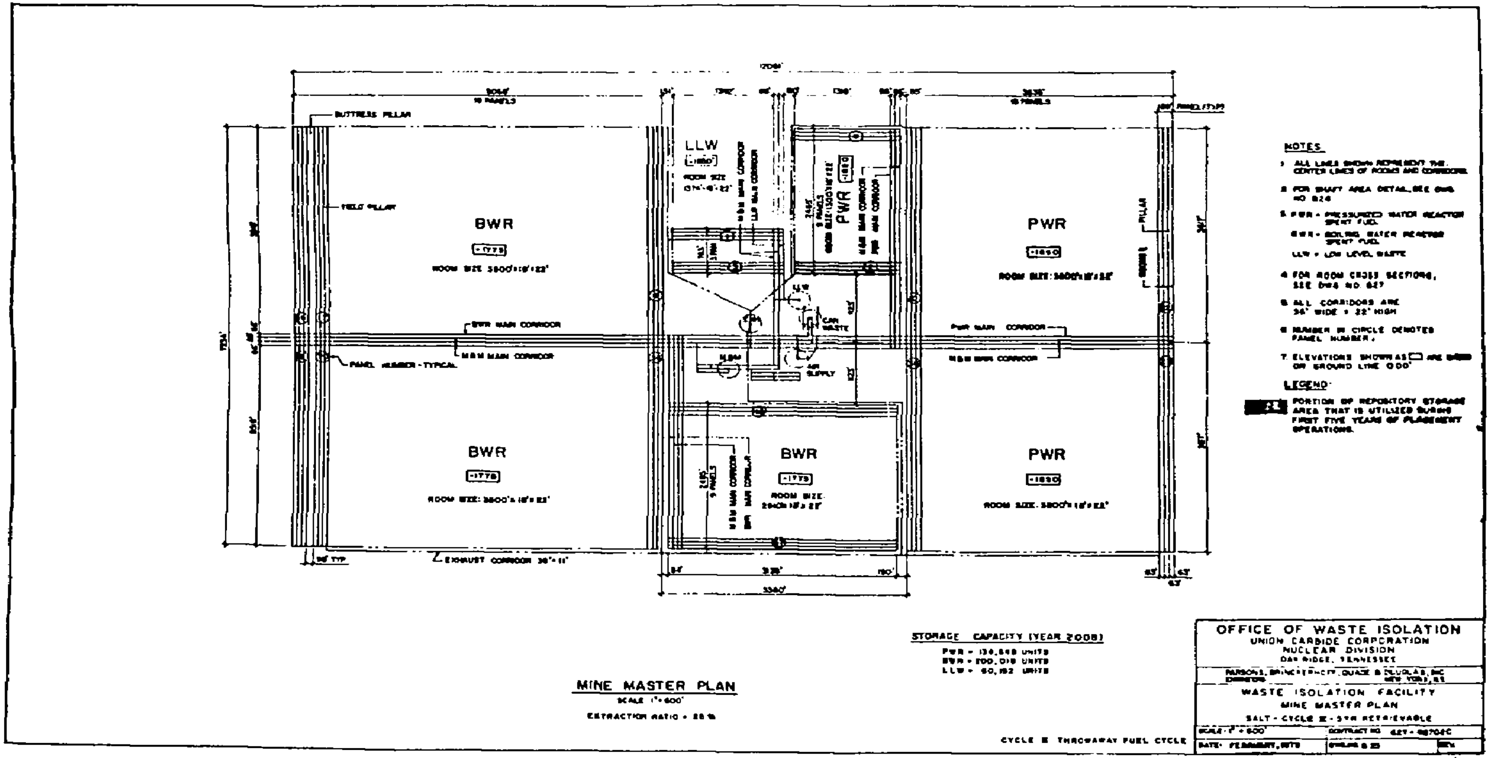

MINE MASTER PLAN
HLW
ILW & CW
LLW
HLW MAIN CORRIDOR
EXHAUST CORRIDOR
BRANCH CORRIDOR
PANEL NUMBER - TYPICAL
BUTTRESS PILLAR
FIELD PILLAR
CAN'D WASTE
40 ROOMS PER PANEL
4 ROOMS PER PANEL
15022'
STORAGE CAPACITY (YEAR 2000)
HLW = 41,340 UNITS
ILW & CW = 311,540 UNITS
LLW = 671,200 UNITS
NOTES -
5. ALL CORRIDORS ARE 38' WIDE X 20' HIGH
LEGEND
OFFICE OF WASTE ISOLATION
UNION CARBIDE CORPORATION
NUCLEAR DIVISION
OAK RIDGE, TENNESSEE
WASTE ISOLATION FACILITY
MINE MASTER PLAN
SCALE 1" = 600'
DATE FEBRUARY, 1978
CYCLE I FULL RECYCLE

Exhibit 2-5



BWR
BWR
BWR
PWR
PWR
PWR
LLW
MINE MASTER PLAN
OFFICE OF WASTE ISOLATION
UNION CARBIDE CORPORATION
NUCLEAR DIVISION
WASTE ISOLATION FACILITY
MINE MASTER PLAN
STORAGE CAPACITY (YEAR 2008)
NOTES
LEGEND

Exhibit 2-6

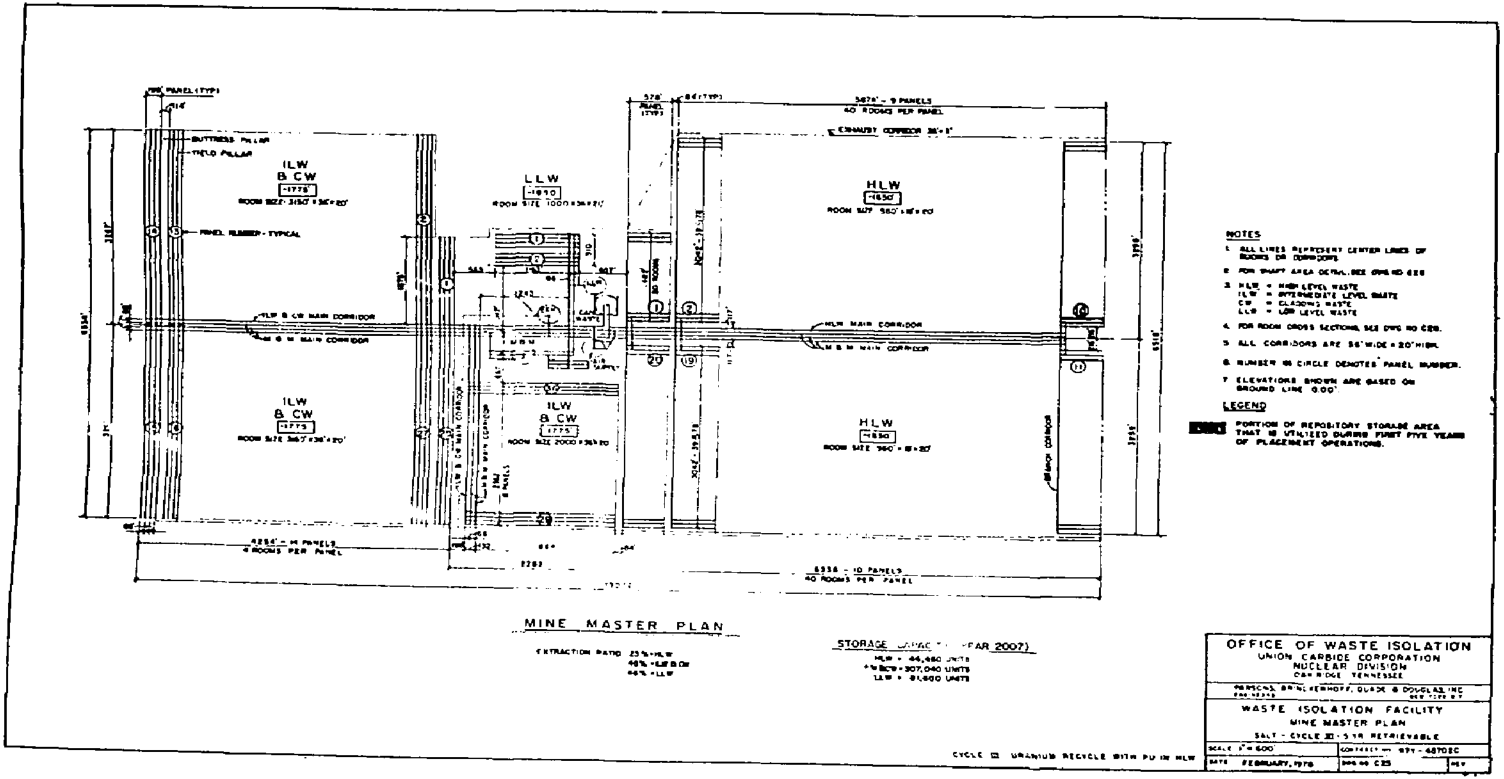

ILW
B CW
LLW
HLW
HLW MAIN CORRIDOR
NOTES
LEGEND
MINE MASTER PLAN
OFFICE OF WASTE ISOLATION
UNION CARBIDE CORPORATION
NUCLEAR DIVISION
WASTE ISOLATION FACILITY
MINE MASTER PLAN

Exhibit 2-7

TABLE II. 2-2-1-1

TRU Waste Facility Package Specifications

Item	Symbol	Dimensions (ft)			Maximum Weight (lb)		Shipping Method
		Length	Width	Height	Gross	Tare	
Supertiger Container	ST	20	8	8	UP 44,300 P 46,700	17,000 17,000	T/FC
Cargo Container	CC	20	8	8	UP 44,000 P 43,700	5,000 5,000	ATMX
Rocky Flats Fiberglassed Box	RF	7	4	4	10,000	---	ATMX
Overpack Fiberglassed Box	OB	8	5	5	11,000	1,000	ATMX
M3 Container	M3	5	4	6	UP 6,000 P 8,000 C 10,000	750 750 750	ATMX
55-gal Drum, DOT-17C	55D	2 Dia.	---	3	UP 650 P 900	--- ---	CC/ST
83-gal Overpack Drum	83D	2.3 Dia.	---	3.2	UP 750 P 1,000	--- ---	CC/ST

UP = Unprocessed Waste
P = Processed Waste
C = M3 bin--with contaminated waste

T = Truck
FC = Rail Flatcar
ATMX = Special Railcar

(Source of Exhibit 3: Reference 3, SAND 77-0274-P1-P2, WIPP Conceptual Design Report)

Exhibit 3-1

TABLE II. 2-2-1-2

Pallet Loading Configurations-TRU Waste Packages

Waste Container Type	Number of Containers Per Pallet	Weight of Each Container (lb)	Weight of Loaded Pallet (lb)
55-gal Drum--unprocessed waste	24	650	17,600
55-gal Drum--processed waste	24	900	23,600
83-gal Overpack Drum--unprocessed waste	15	750	13,250
83-gal Overpack Drum--processed waste	15	1,000	17,000
RF Box	2	10,000	22,000
Overpacked RF Box	2	11,000	24,000
M3 Bin--contaminated waste	2	10,000	22,000

Exhibit 3-2

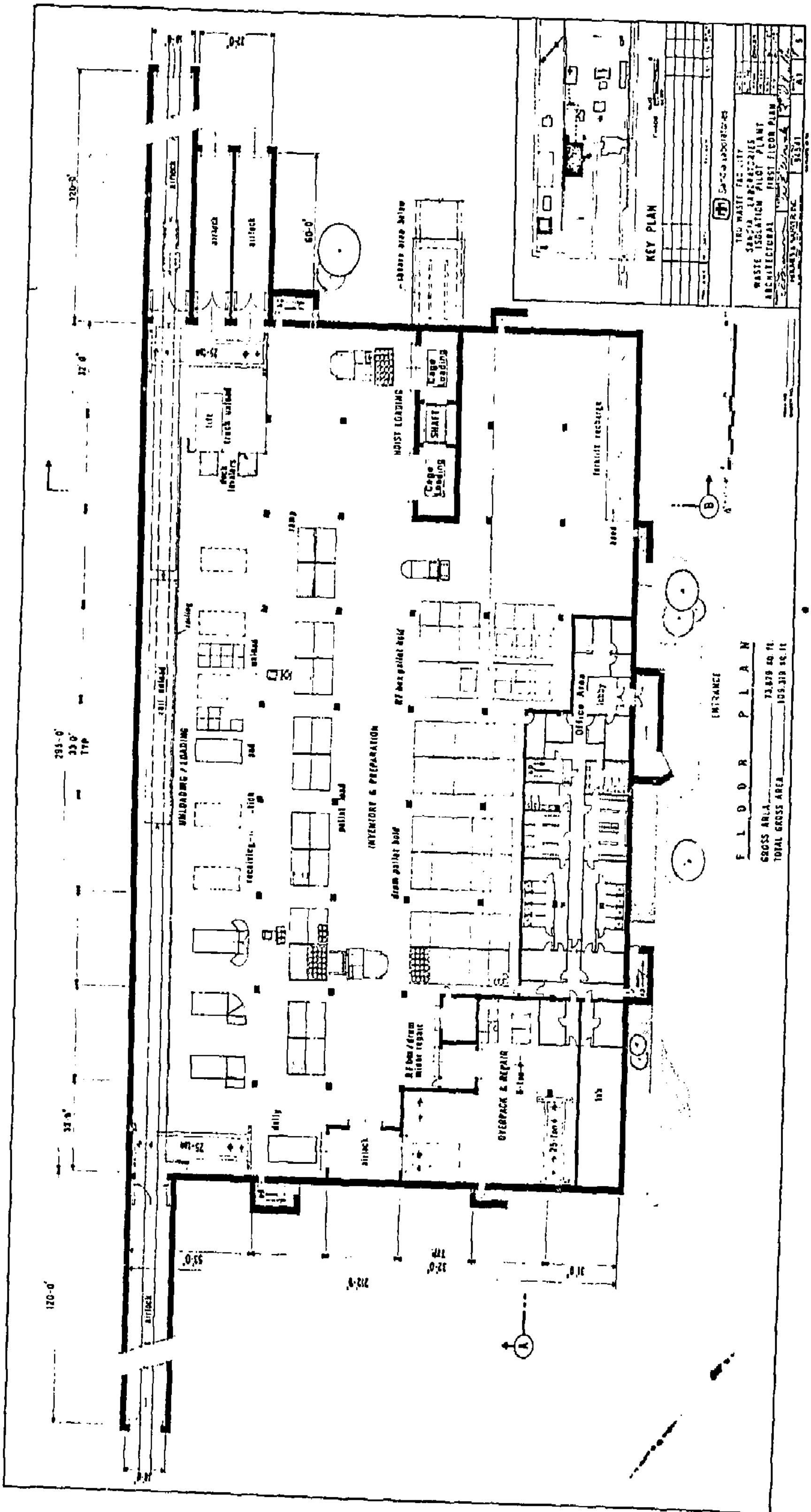

FLOOR PLAN
KEY PLAN
UNLOADING / LOADING
INVENTORY & PREPARATION
OVERPACK & REPAIR
HOIST LOADING
SHAFT
Cage Loading
Office Area
ENTRANCE
airlock

Exhibit 3-3

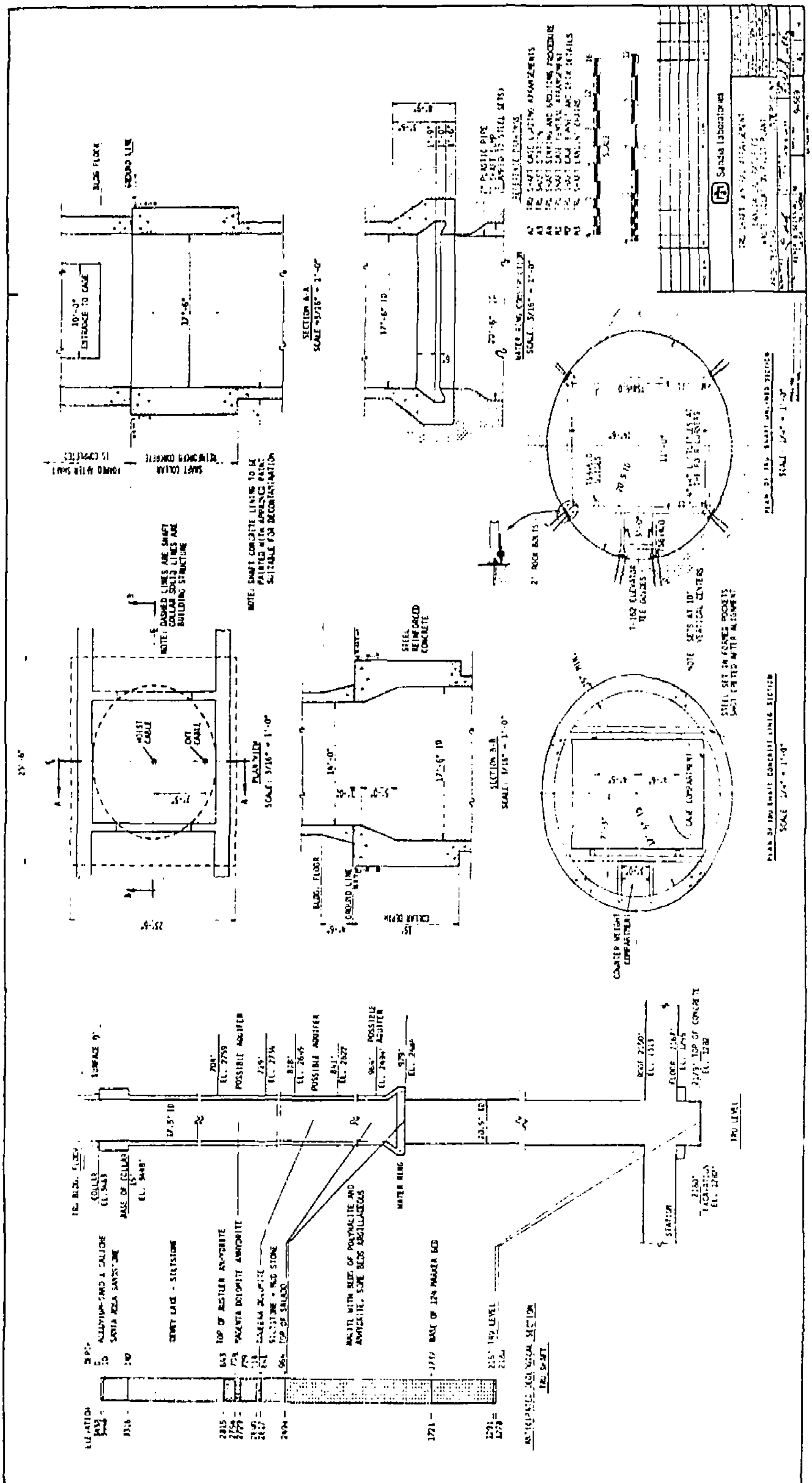


Exhibit 3-4

Stores Control

Exhibit 4-?

While INVENTORY MANAGEMENT regards inventory as sets of items measured in terms of quantity, STORES CONTROL regards it in physical terms with characteristics such as weight, volume, perishability, and physical location. INVENTORY MANAGEMENT and STORES CONTROL together create a complete inventory control capability.

In many cases, inventory control systems have not lived up to their potential because the physical stores aspects have not been adequately considered. The existing system must usually be overhauled to achieve the operating standards necessary for accurate inventory accounting. Physical control over stored materials is a prerequisite to valid inventory management systems.

objectives

The major objectives of the STORES CONTROL system are to maintain close and accurate physical control over the company's inventories, to reduce the amount of materials handling within the stores, and to reduce the cost of storage.

The need for recordkeeping by storekeepers is greatly reduced. The system keeps track of where items are stored, and information regarding item quantities and locations is immediately available at the stores via terminal inquiry.

Inventory rotation is ensured, which reduces losses due to item deterioration — an important consideration in some industries.

Picking lists are generated by the system as late as possible in order to minimize the effect of changes. They can be produced in bin number sequence by storekeeper in order to minimize the number of trips made to each bin location (Figure 40).

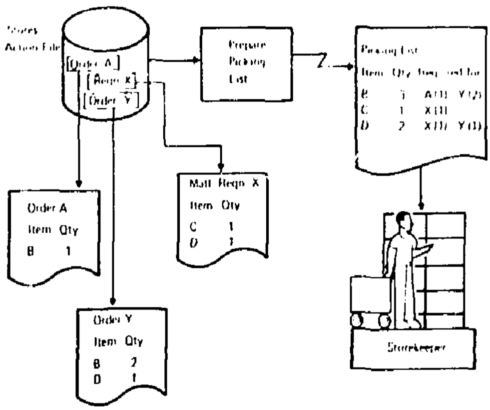


Figure 40. Picking lists are generated by the system from a number of orders and material requisitions

(Source of Exhibit 4: IBM Brochure, Communications Oriented Production Information and Control System - Management Overview)

Better definition of the storage requirements of each specific item and of the individual stores facilities leads to improved physical handling and storage of items and allows the system to select the best location for each receipt from its inventory of available locations.

system functions

As Figure 41 indicates, STORES CONTROL involves the major physical and recordkeeping aspects of receiving, storing, and issuing stocked items.

- *Establishing basic disciplines* deals with the basic disciplines necessary for effective control over physical inventories. Improved transaction and documentation control, and identification of responsibility for transactions provide the level of accuracy necessary to support the remainder of the system.
- *Location control* matches item characteristics with appropriate storage facilities, with the aim of improving space utilization and labor productivity.
- *Order or requisition filling* improves the efficiency of picking activities and reduces the number of unplanned and unauthorized movements.
- *Automated warehouse control* is the application of the system to automated warehouses, with particular reference to high bay (stacker crane) storage techniques. A computer based system enables the full potential benefit of this storage method to be developed, including the elimination of manual errors, improved item location, and increased storage facility utilization.

Cost Planning and Control

Few business decisions can be made unless the factors involved are expressed in comparative financial terms. Management's requirements from a cost planning and control system can therefore be summarized by the questions:

- What *should* it cost to make and sell each of the company's products?
- What *does* it cost to make and sell each of the company's products?
- Where do the variances occur, and how can they be reduced?

Providing the answers to these questions requires accurate information and creative financial analysis. This is mainly the responsibility of the company financial executive.

Among the financial executive's responsibilities is the performance of two major functions:

- Under the chief executive officer he carries financial responsibility for the company's assets and profits. This is, in effect, a policing role, the aim of which is to answer such questions as: What did it cost to make the product? Did we make a profit? Was this quantity produced and shipped?

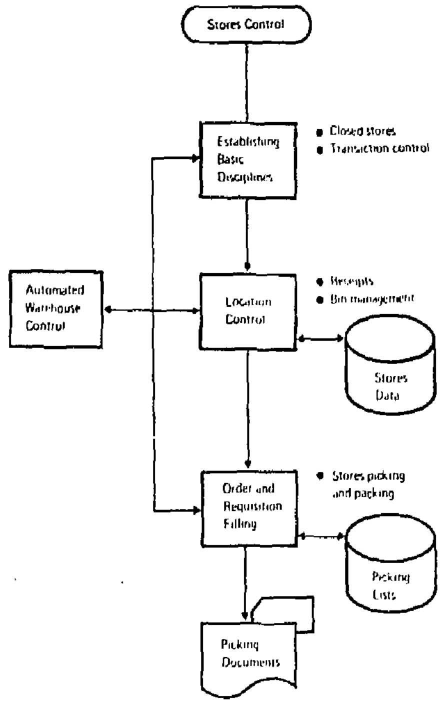


Figure 41. Basic functions of STORES CONTROL

- As the top-management team member who must evaluate management actions in terms of effect on profits, he answers an entirely different set of questions: What will it cost? How will this affect profits? Are we using this resource the best way?

In the first of these roles, the financial executive is concerned with the past; in the second, with a prediction of the future.

A major problem often encountered by the financial executive is the poor quality of the data provided by the rest of the organization. The information supplied by Manufacturing is often inaccurate and too late to detect problems in order to take corrective action. This does not mean that Manufacturing is at fault. Often, the immediate interests of Finance differ from those of the manufacturing departments. For example, the financial executive is concerned with inventory value, the cost of financing inventory, and the likelihood of obsolescence in other words, with those items where there may be too much stock. Manufacturing people, however, are more concerned with shortages – in other words, with those items where there is too little stock.

Accounting personnel often attempt to solve the data accuracy problem by maintaining their own basic records. As a result, two separate inventory record systems are maintained. Neither, however, can be better than the transaction data received, and it is unlikely that the two systems will ever be in line.

One of the most significant advantages of COPICS is that it is an integrated system utilizing a common set of records, called a *data base*. The logic ties all the recordkeeping functions together. From recognition of the need to make a product, through planning, manufacture, and eventual shipment to the customer, each part of the system passes the information it develops directly to the next. This means logical checks on accuracy can be made. The objectives of the manufacturing departments begin to change when they use an integrated system. Instead of trying to solve each problem as it arises, they begin to operate within the constraints of a plan in which the important rules and policies have been chosen by top management.

The objective of COST PLANNING AND CONTROL is to provide the financial executive with the capabilities he needs in his management role and with techniques which, although developed for organizing and managing production data, can also be used for managing cost and accounting data. objectives

The facilities that become available to Finance when the system is installed are presented under the following topics: system functions

- *Direct Labor and Material*, which includes planning direct labor and material costs, and controlling variances
- *Other Direct Costs*, which addresses the incorporation of some variable overhead costs in direct costs
- *Overhead Costs*, which involves apportioning overhead costs to departments and products, and planning and controlling departmental expense budgets
- *Allocating Company Resources*, which considers possibilities in the areas of long-range planning, capital expenditure, and work-in-process investment

All activities in a company provide information for specific functions of COST PLANNING AND CONTROL (Figure 42).

SAMPLE OF AN EXISTING INVENTORY CONTROL SYSTEM BY IBM

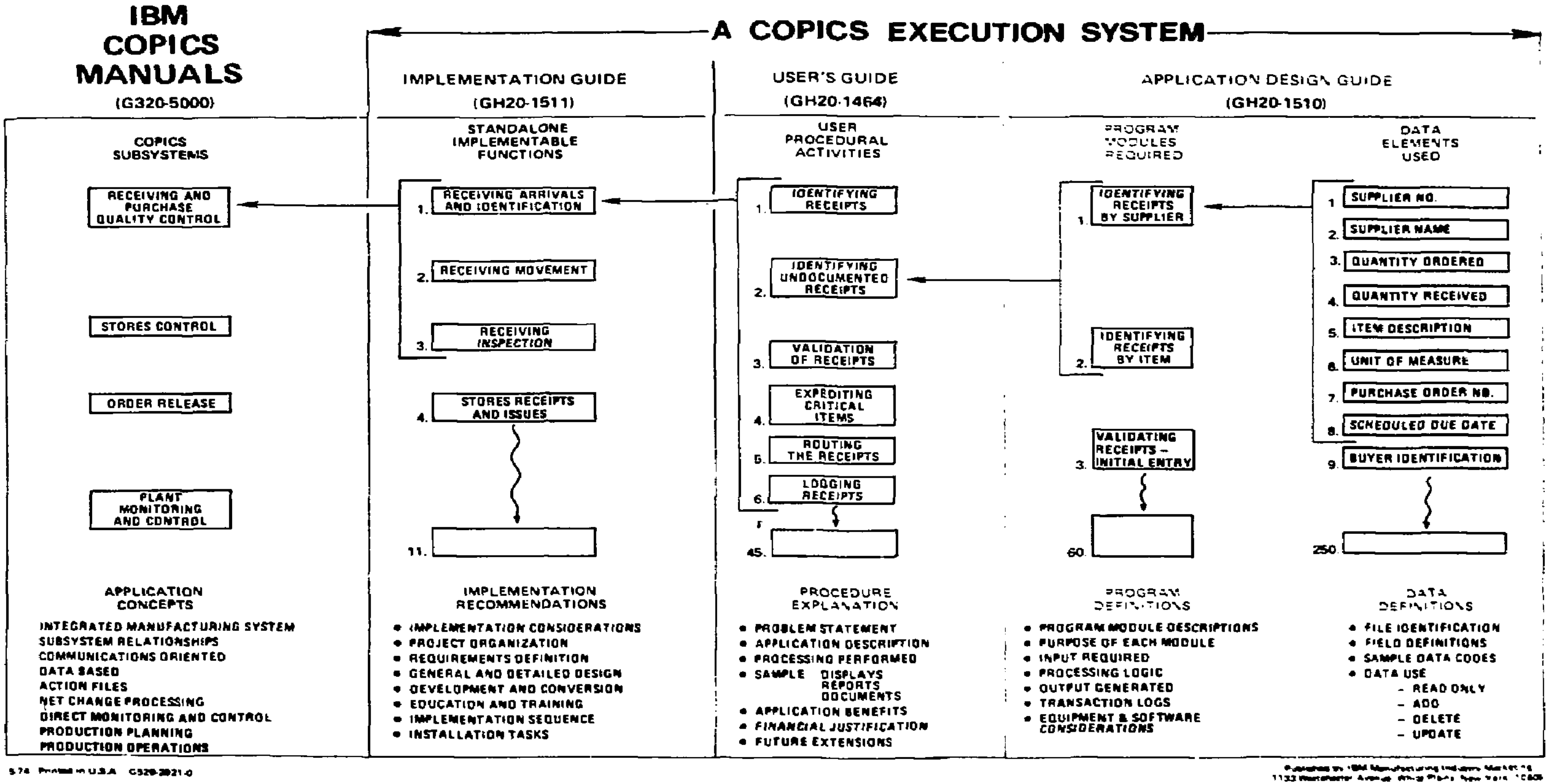


Exhibit 4-2

(Source of Exhibit 5: Material Handling Engineering, March 1979)

How to forecast storage space requirements quickly and reliably

JAMES A. KOENIG
International Business Machines Corp., San Jose, CA.

This simple and reliable method of forecasting the space requirements for bulk production inventories was developed for a computer assembly plant but translates directly to much broader application across industry. It fits business planning cycles for forecasting business-as-usual bulk inventory space and for projecting requirements for space in automated storage and retrieval systems (AS/RS).

All assembly lines require storage space for parts and components. The bulk or palletized load space requirements vary greatly, thus introducing the need for some system of forecasting and allocation of storage space.

To meet the challenge of changing space requirements effectively, we proceeded to design and develop a forecasting method. Experimental results have led to using the method in planning a multimillion-dollar material distribution center.

The new method not only forecasts bulk inventory space but is also useful in forecasting unit load requirements which are essential to planning automatic storage and retrieval systems (AS/RS).

First, collect and assume

Acknowledging that our production inventory (PI) forecasts would be subject to continually changing planning assumptions (especially production schedules), and that our manpower would be limited for using and maintaining a forecasting model and its associated data base, our space forecasting method was designed to:

•Provide a first-cut approximation of the PI requirement forecast which will endure the test of reasonableness.

•Be simple and quick to evaluate and track planning changes.

•Incorporate, as possible, the dynamic complexities of our inventory to reflect product mix, special feature and field replacement requirements, varying inventory turn rates, multiple E/C levels of various parts, inventory policies of production control and purchasing.

•Utilize current, actual, physical PI requirements as the baseline for all forecasting.

The key asumptions are that:

•Existing inventory policies (good and bad) will continue.

•No financial data is required.

A method you can live with

After investigating several approaches we arrived at what I call the "tops-down" storage function approach. Briefly, this method requires an equation for each machine type to determine the bulk PI requirement as a function of a readily available, independently forecasted, and relevant variable. In our case we used the machine production schedules. For a first-cut solution, we developed an equation for each product family in the simplest linear form ($Y = A \times X$). Philosophically, this function incorporates the inventory "complexities" using the baseline data to establish the equation coefficients, while avoiding the cited time-consuming individual part number data base development and maintenance.

Our 6-step procedure for implementing the forecasting method is as follows.

1. Assess Baseline Inventory

TABLE I Sample printout of unit load data

Prod Code	P/N	Shelf Space	Flr Sqft	Load on Flr	Total Load	Safe Stack Hght	Type*	Unit Load W	D	H	Qty	WGT
7	[illegible]414223	15	15	1	1	[illegible]	1	82	40	15	72	200
7	2663060	87	40	2	2	2	6	38	36	67	16	600
7	[illegible]53866	70	80	5	6	3	1	52	41	70	1008	500
7	5271384	67	20	1	1	2	6	38	38	67	14	600
23	2518476	40	50	3	7	[illegible]	1	40	33	40	24	400
23	2517898	39	106	4	7	3	1	48	31	30	56	300
23	2517702	40	100	12	24	4	6	36	26	40	16	400
23	2518472	38	50	2	4	2	1	46	48	38	36	400
23	2517313	38	20	1	2	2	1	48	40	38	36	500
31	2281281	35	120	3	6	2	1	48	40	35	19	500
31	2292234	67	10	1	1	3	6	36	38	67	15	800
31	2232284	39	144	3	7	3	3	80	19	38	8	1000
31	2291141	34	120	4	26	6	1	48	40	34	10	300
31	2[illegible]2260	66	200	17	34	2	6	35	35	66	18	500
31	2281336	27	240	9	43	7	1	48	40	27	8	350

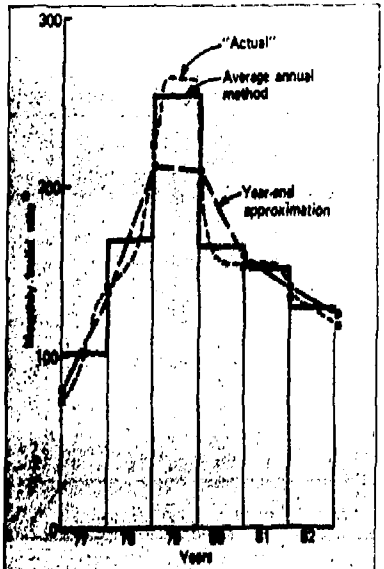
* 1 pallet, 2 1/2 pallet, 3 skid, 4 tub, 5 frame, 6 carton box, 7 reel

TABLE II Baseline inventory

How Recorded		Building	Storage Type	P/N	Unit Loads	Floor Space	Cube Space
				Percentage			
Measure	83	074	Stacked	3%	25%	27%	27%
Measure	87	074	Stacked	1%	15%	20%	19%
Measure	34	008	Racked-ASRS	33%	39%	25%	28%
SUBTOTAL MEASURED:				37%	79%	72%	74%
Estimate	19-25, 28-33	007	Racked-FLT	14%	6%	10%	8%
Estimate	35-38	008	Racked-FLT	35%	10%	9%	10%
Estimate	84,86	074	Racked-FLT	14%	5%	9%	8%
SUBTOTAL ESTIMATED:				63%	21%	28%	26%
TOTAL				100%	100%	100%	100%
BASE				6134	21843	2366ф	42486ф

TABLE III Product codes

Consolidated Product Code	Product Group	Products
12	Misc. files	Miscellaneous file inventory
40	3345	3340, 3344, 3350
33	333X	3330, 3333
32	2305	2305
31	Control Units	3830,2835
39	Printers	3800
36	Libraries	3851
7	Misc. tapes	Miscellaneous tape inventory
23	341X	3410/11
57	3420	3420
58	3803	3803



*Cubic-weighted, equivalent new units per month
Figure 1
Monthly build rates comparison (example)

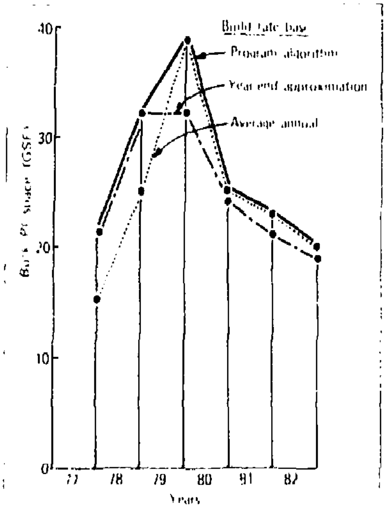


Figure 2
Bulk PI space forecast comparison

In the storage areas having a high unit-loads-per-part-number ratio, data was collected on unit load quantities, size, weight, etc., by part number shown in Table I. Specifically, this was done in the areas where parts were stacked. It took about five man-days to collect and two man-days to enter/verify data.

In areas where there was a very low unit-loads-per-part-number ratio (e.g., the racked areas serviced by forklifts), the total unit load data and floor space cube usage were measured and then prorated to the products per their respective percentage of part numbers in that area. The part number data was obtained off our plant's manufacturing data base. Table II shows a summary of the data for these aras.

2. Consolidate Product Codes

The product menu of current and follow-on products was consolidated into groups based on manufacturing similarities (Table III).

3. Choose Variable/Assess Baseline Value

Chosen as the independent variable: The product build schedule. This schedule determined the baseline monthly production. However, since our plant not only builds new machines but also reconditions (recons) used units, we decided to adjust the recon build to its equivalent amount of new build. Assuming that it requires more bulk PI to produce one new unit per month than it does to recondition (recon) one, the recon build data was accordingly diminished and then added to the new build quantities per consolidated product codes to arrive at an equivalent new, baseline monthly build rate.

4. Determine PI Storage Function

The baseline inventory was divided by the equivalent new, baseline monthly build rate to derive the coefficient A of the PI storage function per consolidated product code, i.e., inventory required to build one equivalent new unit per month. The form of the function is Y = A x X, where X is a monthly rate build and Y is the resulting PI requirement.

5. Project Independent Variable

The projected build schedules were grouped by consolidated product codes, and transformed into equivalent new builds. To account for the impact of follow-on products, the follow-on product schedule in each consolidated product group was weighted by its finished volume of that group's representative product. This established the cubic-weighted, equivalent new, *projected* monthly build rates.

6. Forecast PI Requirement

First, each cubic-weighted, equivalent new, projected monthly build rate was tested to find the greater of its year's average annual or year-end monthly build rate. The appropriate rate was then multiplied by its PI storage function to project the year-end PI requirements per consolidated product code.

Note that the monthly build rate, when using an average annual rate, will understate the year-end rate during an increasing schedule and overstate it during a decreasing one. A close approximation to the actual year-end rate is found by averaging any year's average annual rate with its average annual rate for the next year. Figure 1 shows a comparison of an "actual" monthly build rate to both the average annual rate and the year-end rate approximation.

In real-life, as schedules increase, Production Control closely plans inventories to minimize the risk of surpluses due to last minute engineering changes, unfulfilled build forecasts, etc. Also, without hard tooling completed, initial parts de-

TABLE IV APL program: GSF

```
TYPE  UL GSF GCF  OR  STOP
⎕
      GSF  ◄── (1)

SPECIFY BASE PLAN
97X31  ◄── (1)

**GROSS OUTSIDE SQUARE FT**  ◄── TIME STAMP
1978 8 18 11 42 0 397

**BASELINE INVENTORY ASSESSMENT**  ◄── (1)

                 ----------------------CONSOLIDATED PRODUCT CODES----------------------  ◄── (2)
   WRU     12     40     33     32    [31]    39     36      7     23     17     58    TOTAL

  83.0    1.7   42.1    2.5     .4    2.6    4.0    5.6     .4    3.1    1.5    1.6    65.5
  87.0    3.0    6.0    1.3     .7    4.2   22.3    5.2     .8     .7     .3    2.5    46.2
  84.0    3.5    1.6     .5     .5     .5    1.7    1.0     .3     .0     .8     .8     9.1
  86.0    5.4     .7    2.2     .2     .1     .2     .0    1.1     .6     .8     .1    11.4
  34.0    9.5   14.0    3.5    1.2    5.8    8.7    2.4    2.3    1.7    7.0    2.3    50.2
  35.0    3.5    4.6    1.2     .6    1.7    5.3    1.7     .8    1.2    1.7     .4    20.8
  19.0    2.5    4.0    1.2     .5    2.2    7.2    2.2    1.0    1.2    1.7    1.0    24.9

         28.7   72.9   12.5    3.9  [17.1]  47.4   18.0    6.0    8.6   13.8    8.8   236.2

**BASELINE EQUIV NEW, MONTHLY BUILD RATES**  ◄── (3)

  QUANTITY OF RECON TO EQUAL ONE NEW BUILD....
  SPECIFY FOR EACH PRODUCT CODE ABOVE (11 NUMBERS)
⎕
      3 4 2 4 4 5 1 4 3 4 6

  NEW        1100    978      0     15    107     31     15     97     42      8     55

  RECON       392    135    232      3     24      0      0    251     98    141     28
  REC/NEW       3      4      2      4      4      5      1      4      3      4      6

  EQV NEW    1231   1011    116     16  [113]     31     15    160     72     35     58

**STORAGE FUNCTION  PI REQUIREMENT FOR ONE EQUIV NEW BUILD PER MONTH**  ◄── (4)

            .0233  .0721  .1074  .2458 [.1511] 1.5355 1.2020  .0378  .1198  .3688  .1372

**CUBIC-WEIGHTED,EQUIV NEW, PROJECTED MONTHLY BUILD RATES**  ◄── (5)

CODE  MACH  N/EW    78     79     80     81     82     83

  40  9331    1      2     31    220    293    289    317
  40  9331    0      0      0      0      1      3     11
  40  9342    1      1     29     31     20     21     24
  40  9342    0      0      0      3      5      5      4

                     3     61    262    320    318    356

  33  9333    1      1      3    307    829   1283   1015
  33  9333    0      0      0      2     15     37     79

                     1      3    309    844   1321   1094

  32  9433    1     18     70    140    329    450    182

                    18     70    140    329    450    182

  31  9382    1      1     46    167    222    240    159

                     1     46    167   [222    240]   159

  12  9999    2     23    179    878   1714   2328   1792

  39  9882    1      0      1      2     11     30     43
  39  9882    0      0      0      0      0      0      1

                     0      1      2     12     30     43

**PI REQUIREMENTS FORECAST**  ◄── (6)
**GROSS OUTSIDE SQUARE FT**

CODE   STRG FNCTN   78     79     80     81     82     83

  12     .0233       2     12     38     48     55     42
  40     .0721       2     12     21     23     25     26
  33     .1074       0     17     62    117    143    118
  32     .2458      11     26     50     74    112     45
  31     .1511       4     16     30   [33]     37     24

      BASD TOTAL    19     83    202    320    370    256

  39    1.5355       0      2     11     33     73     98

      PRNTR TOTAL    0      2     11     33     73     98
```

liveries typically experience delays. However, as schedules flatten and ultimately decrease, Production Control will induce a lag in the corresponding inventory reduction to hedge against a parts-short situation due to any unexpected schedule reversal.

To model this situation, the year-end month build rate approximation is used for increasing schedules and the average annual rate is used for stable or decreasing schedules. The algorithm for this is to use the greater monthly build rate. Figure 2 shows the impact of this algorithm on the PI forecast.

APL Program: Example

An APL program was designed to evaluate data for unit loads (UL), thousands of gross outside square feed (GSF), or thousands of gross outside cubic feet (GCF). Table IV illustrates the output using the hypothetical example below:

•The program first prompts the user for the desired evaluation mode and for the business plan identification. In this case, GSF was selected for business plan 97X31. It then prints the baseline inventory data.

•The data is grouped throughout the program by the consolidated product codes. This example uses product code 31.

•Using the product build schedule as the independent variable, and interactively inputting our assumption of requiring four times as many bulk parts to build new machine as it does a recon, the program calculates the equivalent new baseline *monthly* build rates. For product code 31, the equivalent new rate is 113, i.e., 107 new plus (24 divided by 4) recon.

•The storage *function* is calculated from the baseline data. For product code 31, the coefficient is .1511 GSF to build one equivalent new unit per month, i.e., 17.2 GSF divided by 113 equivalent new per month. This *function* assumes total variability of the PI requirement relative to a subsequent change in the equivalent new monthly build rate (see line A in Figure 3). Remember that the .1511 GSF is not just the PI required to build one unit but also to accommodate the additional stock which supports the cited inventory complexities.

Using a project build schedule matrix which the user initially establishes, the program weights all projections by ratio of the product's finished volume to the volume of the group's representative product. It also converts the recon schedules to equivalent new. The cubic-weighted, equivalent new, projected monthly build rate is then printed *for all product codes in columns indicating* the product code, the machine type, a 1 or 0 to designate new or equivalent new monthly build schedule, and the years for the projected schedule. The program then prints the PI requirement forecast for each year by product type and total. For product code 31, for year-end 1981, the projection is 35 GSF, i.e., 222 + 240 divided by 2 year-end rate multiplied by 1.01 calibration factor. (see Results versus Criteria section). The program again prompts for the evaluation mode. The same data was run for unit loads, in Table V and then "STOP" was invoked.

Some cautions

Obviously, one must invoke a test of reasonableness each time a computer run is made. Our experience shows that the results can be greatly distorted primarily in two ways.

First, beware of those monthly build rates which are far above or below the baseline rate shown in Figure 3. The more realistic storage function approximation has a fixed and variable portion (line B), rather than being completely variable (line A) as the current storage function depicts, causing an over or underestimate, respectively. However, additional data points are required before line B's equation can be estimated. This reasoning also applied to products where baseline build rate is very low (about 20 or less). At this point, one appears

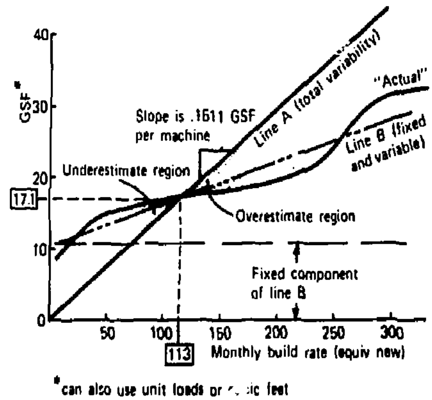


Figure 3
Storage function (product 31 example)

to be seeing much of the "fixed" portion of the storage function so that assuming total variability will similarly induce over-estimates for any larger projected rates.

Second, beware of the recon-to-new assumption involving those products whose only production was for recon during baseline data collection. Their inventory likely contains large quantities of surplus parts awaiting disposition or in market reserve. This will inflate the storage function and tend to magnify the forecasts of new build of follow-on products in that product code. Product codes 33 and 57 are examples of this.

Forecast vs. Design criteria

For initial calibration, we measured the total, actual year-end 1977 gross outside floor square footage used for bulk PI to 246 GSF. Balancing the year-end 1977 projection from the October baseline to this required about 1 percent added as experimental error. This calibration factor is applied to all year-end bulk PI projections. Referring to the baseline data, the projections can easily be tested and modified as reason dictates. Note that the floor (and cube) space projected from this point yields business-as-usual requirements. The projected unit loads are key factors when altering current storage methods, e.g., planning as ASRS.

Since the computer programming language is APL, it can be easily assessed and updated for new baseline or projected schedule data. Tracking is done by maintaining previous schedule projections (or whatever independent variable is used). A minimum amount of manpower (only seven man-days) was required to assess the baseline inventory and we expect that this only needs to be repeated once or twice a year for adequate data base maintenance.

The baseline inventory incorporates, although per a snapshot, the entire spectrum of normal (good/bad) parts analyzing, purchasing buy-aheads, long/short turn rate items, field replace-

TABLE V APL program: UL

```
SPECIFY BASE PLAN
97X31

**UNIT LOADS**
1970 0 10 11 44 30 417

**BASELINE INVENTORY ASSESSMENT**

                 ----------------------------------CONSOLIDATED PRODUCT CODES----------------------------------
     WHU      12      40      33      32      31      39      34       7      23      57      58    TOTAL

    83.0    77.0  4848.0   155.0    11.0   150.0   704.0   133.0    13.0   137.0   131.0    53.0   5344.0
    87.0   193.0   721.0   119.0    70.0   359.0  1151.0   211.0     3.0    66.0    30.0   262.0   3184.0
    84.0   144.9    82.4    27.9    11.7    22.9    87.0    58.4    13.7      .0      .0      .0    450.0
    86.0   310.2    39.6   125.4    13.2     6.6    11.2      .0    66.0    33.0    46.2     6.6    660.0
    34.0  1350.2  2037.4   509.3   549.8   848.9  1273.3   339.6   339.6   254.7  1018.7   339.6   8489.0
    35.0   407.3   527.1   141.8    71.9   191.7   181.4   191.7    95.8   143.8   191.7    47.9   2396.0
    19.0   131.7   209.9    65.6    26.2   118.1   300.5   118.1    52.5    65.6    91.8    52.5   1312.0

          2640.8  7663.4  1141.0   575.8  1705.2  1496.4  1241.7   563.6   720.0  1569.4   761.6  21043.0

**BASELINE EQUIV NEW, MONTHLY BUILD RATES**

  QUANTITY OF RECON TO EQUAL ONE NEW BUILD....
  SPECIFY FOR EACH PRODUCT CODE ABOVE (11 NUMBERS)
0
     5 4 2 4 4 5 1 4 5 4 6

  NEW          1100     778       0      15     107      51      15      92      42       0      55

  RECON         392     133     352       1      24       0       0     251      90     141      20
  REC/NEW         3       4       2       4       4       5       1       4       3       4       6

  EQV NEW      1231    1013     176      16     113      51      15     160      72      35      58

**STORAGE FUNCTION: PI REQUIREMENT FOR ONE EQUIV NEW BUILD PER MONTH**

          2.1459  7.5802  9.8365  33.8629  15.0899  11[illegible]  [illegible]  5.6533  50.0000  4.1899  15.0553

**CUBIC-WEIGHTED,EQUIV NEW, PROJECTED MONTHLY BUILD RATES**

CODE  MACH  N/EN     78     79     80     81     82     83

  40  9311    1       2     11    226    295    289    517
  40  9331    0       0      0      0      1      3     11
  40  9342    1       1     29     31     20     21     24
  40  9342    0       0      0      1      3      5      4

                      3     41    262    320    318    556

  33  9333    1       1      3    307    829   1283   1015
  33  9333    0       0      0      2     15     37     79

                      1      3    309    844   1321   1094

  32  9415    1      18     70    140    329    450    182

                     18     70    140    329    450    182

  31  9362    1       1     46    167    222    240    159

                      1     46    167    222    240    159

  12  9999    2      23    179    870   1714   2520   1792

  39  9882    1       0      1      2     11     30     63
  39  9882    0       0      0      0      0      0      1

                      0      1      2     12     30     63

**PI REQUIREMENTS FORECAST**
**UNIT LOADS**

CODE   STRG FNCTN      78      79      80      81      82      83

  12     2.1459       219    1144    2864    4372    5036    3826
  40     7.5802       244    1234    2274    2442    2575    2724
  33     9.8365        20    1547    5717   10734   13097   10848
  32    33.8629      1051    2526    5641    9368   10825    4374
  31    15.0899       358    1617    3954    4508    4645    2424

       DASD TOTAL    1893    8048   19341  [illegible]  35579   24247

  39   112.2074        33     137     771    2392    5330    7211

       FRNTK TOTAL     33     137     771    2392    5330    7211
```

ments, and feature stock, etc., that characterize the inventory composition for each product code.

This method calibrates PI requirements using the inventory which is actually packaged and stored in our warehouse rather than estimating what it theoretically should be using, inventory rules, usage per machine, etc. No assumptions are made for quantum inventory policy changes and there is no dependence on financial data.

Getting more from the program

Most space forecasting methods have potential for further enhancements. Here are some suggestions for our method.

Take several measurements of the inventory/schedule to: (1) Using linear regression, establish a more realistic baseline PI storage function, i.e., one with a fixed and variable component (see Figure 3), and (2) provide periodic recalibration.

Meanwhile permitting, calibrate the projection to unit loads rather than total floor square footage, so one is independent of space utilization variances.

Select a group of part numbers which have the highest contribution to PI requirements and apply them individually to their respective product schedules based on their actual levels.

Scrutinize the new/recon ratio assumption for each product code; adjust accordingly.

Provide "what if?" capability in the APL program for sensitivity analysis.

Floating slot storage: more space in the same space

An on-line, computer-based inventory management system helped this grocery wholesaler gain 30% in storage capacity without physical expansion. Incidentally, it also eliminated double handling, lowered labor costs, raised productivity, speeded throughput, cut product loss and improved customer service.

Dealing with constant growth is nothing new for the management team of American Seaway Foods, Inc. Rather, unrelenting growth of recent years has become a simple fact of life for this full-line grocery wholesaler.

Headquarters for the firm is a sizable distribution center in the Cleveland suburb of Bedford Heights, Ohio. The 600,000-sq-ft facility serves nearly 1,000 independent supermarkets and retail grocers in Ohio and parts of Pennsylvania.

Along with these traditional customers, a growing list of institutional food service accounts puts an additional burden on the throughput capabilities of the facility. Combined customer needs call for a regular inventory of almost 12,000 different merchandise items, including fr--zer and cooler goods.

Customer orders pour into the distribution center at a rate of some 1,100 a day, and, on peak days, order volumes often reach 1,500 or more. A highly tuned operation is obviously at work to be able to maintain such volumes and still provide good customer service.

Some time ago, American Seaway installed a pair of computer-based, on-line systems to cope with the heavy and growing w-rkloads. One system handles on-line order entry from customers, while the other system handles the merchandise received from suppliers.

Both systems run on the facility's IBM System 370/138 computer. The receiving procedure involves on-line interaction between IBM 3270 CRT terminals on the delivery dock and in various warehouse departments. When a delivery arrives, the operator of the dock terminal keys in the vendor number and the associated purchase order number. This immediately calls out a screen display of that order, listing item code and order quantity, pack size and description, and pallet specifications.

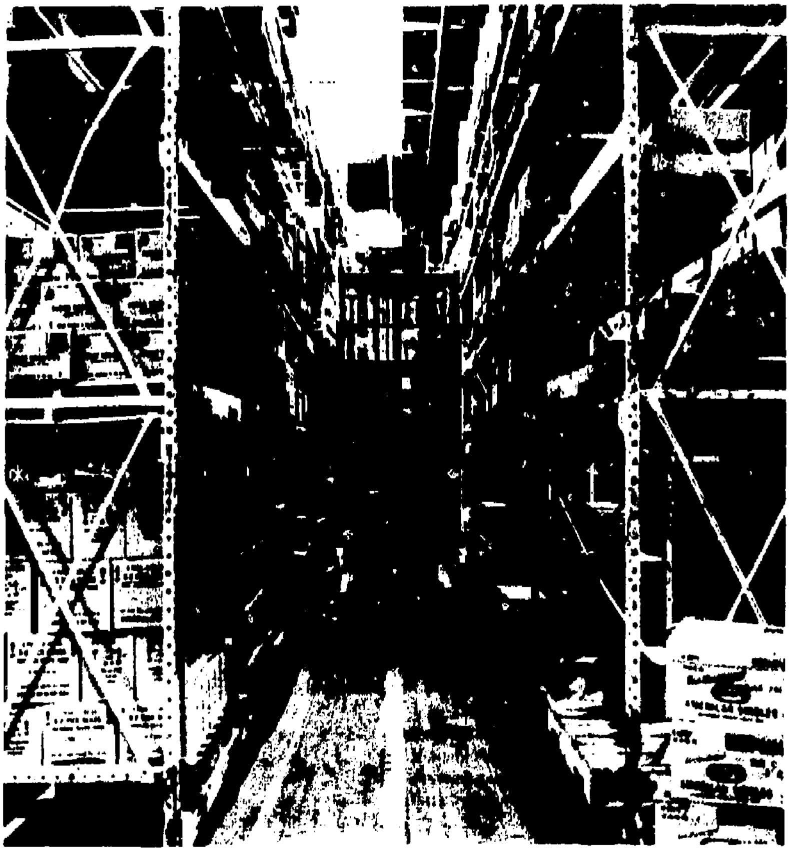
The terminal operator runs down the displayed order list line by line, and matches the quantity of each item received with the quantity ordered. Any discrepancy between ordered and received quantities is noted and recorded by the computer.

Orders from individual stores are similarly handled on-line. This system is set up to report order quantities that are unusual, approved item substitutions in case of stock-outs and other matters particular to a given retail account.

Despite the success of the two on-line systems being used for dry goods, freezer and cooler goods remained a major concern of American Seaway's management -m. Because of their very nature, freezer/cooler -ems constituted a kind of triple jeopardy: specific item value was high, they were perishable, and they were use-dated.

While the risk of financial loss is ever-present when perishable goods are handled, that risk can be minimized through efficient inventory management and proper stock rotation. In Seaway's case, a gradual change of circumstances was making the operation in the freezer/cooler building less and less efficient.

As an example, the inventory had steadily grown with the introduction of many new food items, but storage capacity had remained constant. High



Permanently assigned storage had resulted in a percentage of all locations empty at any time, and too much double handling. Under floating slot control, the computer assigns locations based on the product, its relative velocity, pallet size, and slot availability within the proper velocity zone.

throughput complicated matters to the point that existing capacity was not being fully utilized.

A brief analysis led Seaway to the primary stumbling block, which was the assignment of freezer/cooler items to a permanent storage slot by product code. This resulted in a certain percentage of all storage locations being empty at a given time, with an even higher percentage only half full most of the time.

A worker might go to a location to pick an order, find it empty, then have to make an extra trip to resolve the problem. Similarly, a worker might attempt to store a load only to find the assigned location partially full. Again, an extra trip and wasted motion.

A lot of double handling was taking place simply because of the way the freezer/cooler operation was organized. Beyond the high labor costs associated with rehandling, customer service was at stake. It was bad enough to occasionally ship the wrong product to a customer. An even more worrisome problem, though, was the possibility of shipping use-dated items too close to the expiration date on the package. If this happened, the shelf-life of the product was gone, and Seaway had to absorb the loss.

A perfect chance to resolve these problems came about a year ago, when the firm began a program of expansion and modernization in the freezer/cooler building. The operation was carefully studied, and the study confirmed what the management team already knew: fixed slot storage had to go. As long as this method was being used, optimal storage space utilization would never be a reality.

A method of solving the problem came, in a

A computer listing of incoming warehouse transactions is examined by John Prall, director of systems at American Seaway Foods with the aid of a co-worker. The IBM 370/138 computer handles all online receiving functions including floating slot storage assignments for freezer and cooler items.

manner of speaking, through the back door. In the course of purchasing additional orderpicking equipment from Barrett Electronics, the idea of a "floating slot" storage system was brought to Seaway's attention.

The idea was not new. Both the concept and the software had already been fully developed by IBM. Furthermore, the approach was completely compatible with existing computer hardware at the distribution center.

Under the guidance of John Prall, director of systems, Seaway's data processing staff examined the floating slot concept. They knew it would work, but they wanted to be able to accurately predict the impact of this approach on overall warehouse operations.

"Converting from fixed to floating slot warehouse operations demands a certain amount of reorganization of space and aisle arrangements," Mr. Prall explained. "But after we refined the concept for our application and decided to go with it, we needed only an additional eight weeks to complete the necessary programming."

Three aisles were set up for floating slot merchandise within the freezer/cooler building, two for freezer and one for cooler items. Each aisle has multiple tiers of storage slots and is served by man-aboard stockpicking vehicles. Aisles were also divided into three zones along their length, with fastest moving items stored nearest the order assembly area.

Under the floating slot system, no item has any permanently assigned storage slot or reserve storage area. The computer makes these assignments, basing its decisions on the product and its relative velocity, the size of incoming pallets and slot availability within the proper velocity zone.

Mr. Prall explained that the system was set up with a limit of six storage slots per product code. "Any additional pallets of the same item are routed to a reserve storage area which the computer also selects. The computer records this information," he said, "and also keeps tabs on the quantities of items in each floating slot as well as the available empty slots. In short, our computer monitors all items, quantities and locations."

When information regarding inbound merchandise is keyed into a terminal, the computer will recognize any items under floating slot system control by a unique item code. At present, floating slot assignments are made by the computer for about 1,000 freezer stock items and another 700 cooler stock items.

Fast-moving, high-turnover items are not included under the new system's control because such items are stocked very heavily and would tie up too many slots. "This is one of the benefits of the new system," Mr. Prall told MHE. "It gives us tighter control over those normal velocity items that make up some 80% of our freezer/cooler inventory."

After slot assignments are made under the new system, the CRT terminal operator must re-key the slot number and quantity for each item as it is displayed on the screen. This is a means of verification for the computer. Once the computer accepts this item/quantity/slot number verification, the system immediately updates the available inventory records. The goods are then moved from the dock to the assigned slots.

As customer orders are entered and processed through the on-line entry system, the computer specifically indicates which slots are to be picked for that order. A first-in, first-out inventory basis is followed, and inventory records are again updated to reflect withdrawals.

At the end of each day, the computer produces a list of all slots that have been emptied as a result of the day's picking activity. A visual verification is made so that accurate slot assignments can be made the next day. The computer is seldom, if ever, wrong.

The system has inquiry capability for floating slot inventories at all times. Workers can inquire either by item number or slot number through any of the CRT's. If necessary, change-data to correct discrepancies can be entered on-line too.

Productivity figures are not available, but the new system is undeniably responsible for a healthy increase in the freezer/cooler building. The floating slot assignment eliminates the double handling that almost always occurs under a fixed slot storage system. Between the effects of a more efficient operation overall and the elimination of double handling, productivity could well have doubled.

Mr. Prall reports that receiving time has been cut, which in turn has sharply reduced labor costs. This alone saves the company thousands of dollars a year, and the savings will recur.

The new system also insures better utilization of high-demand freezer space. Rack and aisle rearrangement alone could have accounted for only a modest improvement; the floating slot system was responsible for an increase of 30% or more usable storage space, and this figure is conservative.

Inbound shipments are validated by comparing bill-of-lading with original order on an IBM terminal. The computer recognizes any floating slot items by a unique product code, makes storage assignments, and records all items, quantities and locations.

"In addition," Prall stresses, "customer service is much improved by the floating slot system because of the swifter availability of newly received merchandise at the picking stations. Furthermore, orderpicking delays resulting from suddenly empty picking slots have been virtually eliminated."

The floating slot storage system has performed so well that it will be expanded to serve a major portion of the conventional warehouse by midsummer. This project will also entail a layout modification, some other physical changes and the addition of AC-powered, rail-guided orderpicking vehicles. If a current study yields favorable justification figures, some degree of automatic laser scanning will be included too. It will undoubtedly be interfaced with the expanded, on-line computer system.

There's no question at American Seaway Foods about the effectiveness of the floating slot system, according to John Prall who ought to know. "The floating slot is, in our opinion, the primary warehousing tool of the future, and we intend to take as full advantage of it as we can, as rapidly as we can," he said. "Its many advantages, including labor, time and cost savings, improved customer service, tighter operations control and better utilization of storage space, are too valuable to ignore."

—**ROGER BETZ**, senior editor

New Navy guide to warehousing based on ratio of transactions to inventory

Newly-released publication offers assistance in developing feasibility studies in functional warehousing layout and material handling systems. Although your systems constraints may not match those of the Naval Supply Systems Command, you can benefit from the data collected and analyzed in this study.

Warehouse Modernization and Layout Planning Guide. Department of the Navy, Naval Supply Systems Command. NAVSUP Publication 529. Written by E. Ralph Sims Jr. & Associates, Lancaster, Ohio, in concert with NAVSUP personnel.

Scope:

- *Applicable to functional concept planning for new facilities or modernization of existing facilities.*
- *Describes basic storage and material handling state-of-the-art system concepts.*
- *Provides modular layouts, system design-selection criteria and comparative costs for self-help analysis of storage activities.*
- *Provides techniques for facility, inventory, product and transaction data analysis to be used in developing preliminary alternative functional designs.*
- *Furnishes guidance for developing budgetary costs and final studies for which external assistance may be required.*

Copies of the document soon to be available through the Naval Document Service.

"Warehouse Modernization and Layout Planning Guide" is intended to provide guidance in initiating feasibility and concept studies pertaining to warehouse modernization and functional layout/elevation planning. It comprises methodology whereby Navy general supply activities can, without significant resident expertise, determine what modification to existing facilities or what new facilities will be required, given the current state of the art.

All designs of powered mobile equipment were included in the study so that the systems design configurations would be universal.

The following copy, edited from the Guide, explains how the program works:

There are three basic handling classes of storage to be considered in the Navy system. They can be described as:

1. High cube and large lots:
   A limited amount of bulk storage activity is needed to store bulky or high cube units and large volumes of inventory on pallets.
2. Palletized packaged material:
   Various sizes, shapes and configurations of packaged products are stored throughout the system.
3. Shelf or bin merchandise:
   This category includes handpicked items such as electronic and mechanical components, etc.

Basic parameters

Among the several basic components in the Navy supply system which have been accepted as a basis for the development of decision criteria and procedures are:

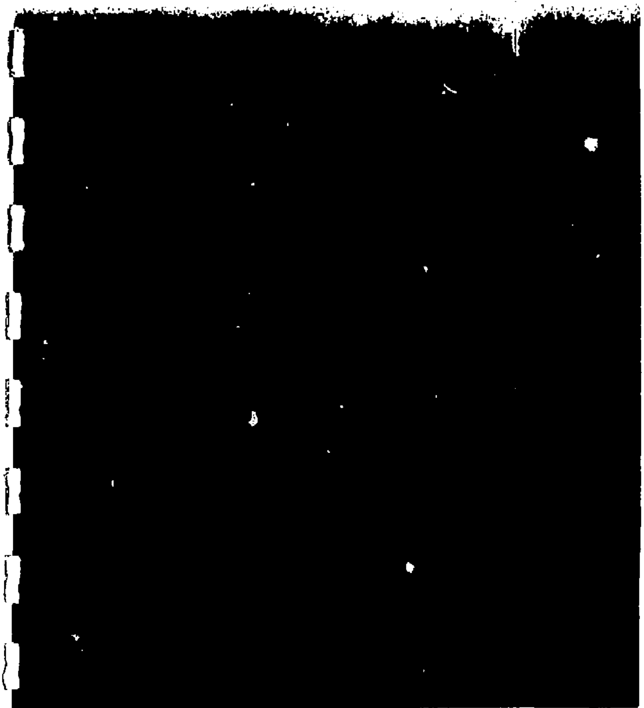
1. The use of standard 40" x 48" pallet dimension for the majority of operations.

2. An inventory issue, withdrawal transaction, or order handling system based upon a single line order entry document.

These two basic factors are accepted as "given" in all elements of the program. Racks, aisles, and machinery characteristics are all based upon the pallet size, and all transaction rate analyses are based upon the single line document pattern.

Transaction/Inventory Ratio

The available systems are ranked in order of in-



A graphic representation of the T/I ratio. The lines T_1I_1 and T_2I_2 represent the cost equations of Systems A and B, respectively. The crossover point X represents the transaction and inventory values T_e and I_e which produce equality in the annual cost equations. The slope of the line OX passing through this point and the origin is represented by the T/I ratio of T/O. Clockwise rotation of this line moves into a region of inventory control, where T decreases and I increases.

creasing cost based upon a Transaction/Inventory Ratio (T/I) for each height range. For a given T/I ratio, the least cost system for each height can be determined. These alternatives can then be compared to determine the optimum height for the facility.

All labor costs are graphed in units of manhours. Conversion to dollar cost can be accomplished at the prevailing local wage rate.

Vehicle costs are accounted for by two methods. In the case of wheeled vehicles (free path equipment), the vehicle count is independent of inventory. In these systems, vehicle cost is allocated on the basis of labor hours. The cost figure includes equipment cost and regular maintenance and operating costs averaging over 10 years at 2,000 hours a year.

In the case of captive equipment, such as the carousel and the S/R machines, the number of units is determined by inventory quantity and the number of aisles or storage units, in addition to the transaction rate. In these systems, the equipment purchase and operating cost is made an integral part of the storage equipment cost figure. The storage structure and handling equipment function is one unit and cannot be separated. The vehicle count based upon transaction rate must be compared to the count based upon inventory. When the count based upon inventory is greater than the count based upon transactions, the total cost figure should be adjusted to lower costs by the amount of the excess equipment.

Cost equations are developed in examples in the Guide. After the cost equations are developed, it is possible to compute the Transaction/Inventory (T/I) Ratios, which are helpful in making comparisons between systems. With differing costs for the transaction and inventory portions of the equations, it is possible to compare two systems and determine a level of inventory and transactions at which the annual costs are equal. Higher values of T/I favor the system with lower transaction cost. Lower values of T/I favor the system with the lower inventory cost. In making the comparison, a set of two equations with two unknowns is developed. If a value for either inventory or transactions is inserted, the other variable can be determined. Without inserting specific values, an infinite number of transaction/inventory combinations is possible which will produce equality of the two annual costs.

By solving the equations for a ratio of the variables, a fixed ratio of T/I or I/T can be found which will maintain the equality. Either ratio can be used for the comparison of systems; but since the inventory is generally the known quantity and is relatively stable and much greater than the transactions, it is used as the denominator. When transactions are applied, the T/I ratio will increase with an increasing number of transactions. If the ratio of inventory to transactions had been used instead, the ratio would vary inversely with transactions, possibly complicating understanding of the concept and relationship of the ratio. In practice, a T/I ratio greater than one would not normally be encountered, since this would indicate that in one day all of the inventory had been rotated. Transactions will normally be a small percentage of the available storage location.

Since "Warehouse Modernization and Layout Planning Guide" is not yet in publication form, circle Reader Service Number 150 for the latest ordering information.

Exhibit G-1

(Source of Exhibit 6: Material Handling Engineering, September 1977)

Productivity is an IBM 370/158 teamed up with a lift truck fleet

You don't have to have an automated material handling system to enjoy the benefits of computerization. Exxon ties together a variety of material handling hardware with computerized order filling.

Manual picking from conventional storage facilities sounds like a pretty straightforward operation. At Exxon's Central Distribution Center in Baton Rouge, however, the operation is anything but simple. As many as five different crews pick from as many locations for one order. But mass confusion is prevented thanks to some highly sophisticated computer programming.

In part, the computer system was justified because it made random storage possible. And random storage was chosen because it reduced the size of the warehouse by about one third.

"With a conventional storage warehouse, we would have needed about 150,000 sq ft to store and ship the same amount of product that we are currently handling in a 113,000-sq-ft warehouse," explained Scott Farrin, warehouse superintendent.

The new Exxon distribution center was built to serve two basic functions. First, to handle storage and shipping for the adjacent Exxon oil refinery, and secondly, to serve as a marketing warehouse.

The existing facilities in Baton Rouge—a 50,000-sq-ft refinery warehouse and a 28,000-sq-ft marketing warehouse—didn't provide adequate storage space or work area for meeting the company's standards for customer service. Neither facility could be expanded. Processing units surrounded the refinery warehouse so additional property couldn't be made available. Because of the layout and variations in ceiling heights, the existing marketing warehouse could not be effectively expanded either.

Exxon therefore decided to consolidate the two operations under one management and build a new facility to accommodate both. Industrial Handling Engineers, Inc. in Houston were consultants on the project.

Locations outside of Baton Rouge were considered, but the proximity of the Baton Rouge site to Exxon's oil refinery made it an advantageous location. Exxon thought that transportation costs would be prohibitive if they moved away from the supply source.

More than 2,000 different packaged petroleum and TBA (tires, batteries and accessories) products are handled at the Central Distribution Center. Packaged petroleum products are referred to at Exxon as speciality products. They include motor oils, greases and industrial oils produced at the Baton Rouge refinery. The distribution center ships these speciality products to the entire domestic market. In addition, the distribution center markets all products in a five-state area including Louisiana, Alabama, and parts of Mississippi, Florida and Georgia. Speciality and TBA products are shipped by common carrier or in Exxon vans.

Dispatcher keys in all merchandise

Speciality products from the oil refinery are packaged and shipped from a building in the Exxon complex about one mile from the distribution center. The oils and greases are brought to the warehouse by two special shuttle trailers, each equipped with an air chain conveyor that runs along the bed of the trailer. These conveyors are linked with a conveyor system at the refinery, allowing the oils and greases to be loaded with the push of a button.

At the distribution center, the trailers pull in to one of two special docks equipped with a roller conveyor system, to which the trailer conveyor is linked. Off-loading is done with the push of another button. This receiving conveyor system (Alvey, Inc.) has the capacity to hold the maximum 60,000-lb load from a 40-ft van. The trailers exceed normal width and are overweight for public highways. However, their use is restricted to refinery property.

Oils and greases will then travel along the conveyor to a forklift truck dispatcher (FLD) who keys information from incoming goods into the computer via a CRT terminal. The computer then generates a ticket with an adhesive back that can be affixed to the container, giving instructions for handling that product. The instructions can include three separate jobs for the forklift truck operators.

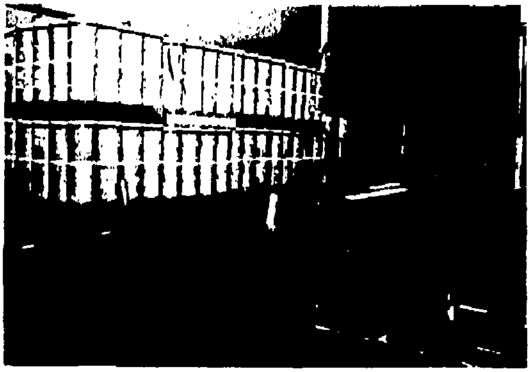
"If a restock move has been entered into the computer at that time, it is given first priority. Restock means taking petroleum and TBA products from their random storage location to a fixed picking location," explained Farrin. "The restock move will be attached to a receipt move—putting the petroleum and TBA products into a storage location. At the same time, if we have activated a loading area for that day's shipment, the computer will order a staging move. This means goods will be taken from a storage location to the loading dock."

Tires, batteries and accessories, and petroleum products from other Exxon refineries arrive by common carrier at 12 docks in the front of the building. These docks serve as both receiving and shipping docks to help facilitate short lift truck runs in which drivers pick up and put away a load in one trip. The distribution center also has three boxcar docks.

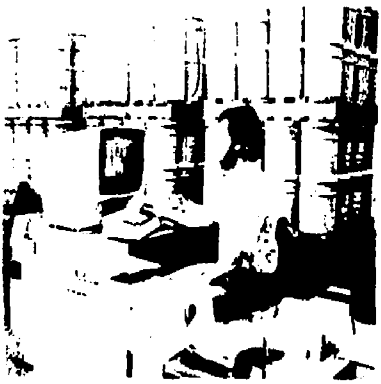
Goods received at these docks are checked in, itemized and palletized by a receiving crew. Forklift operators pick up the incoming goods and take them to the FLD with the receiving document showing the item and quantity involved.

The FLD enters this information into the computer. Instructions printed for TBA products and petroleum products from other Exxon refineries will be the same as those printed for incoming Baton Rouge refinery products. By entering all incoming goods into the computer, Exxon can keep its stock locations constantly updated.

After the computer-generated ticket is affixed to incoming petroleum and TBA products, the goods are conveyed to the end of the receiving conveyor where they are picked up by a forklift operator.



Packaged petroleum products from the nearby Baton Rouge refinery are off-loaded with the push of a button. A conveyor on the bed of the trailer is linked with the roller conveyor at one of two special docks.



The forklift truck dispatcher keys information concerning the incoming oils and greases into the computer. The computer then generates a move ticket with instructions for storing the product.

Storage is both random and fixed

Method of storage depends on the volume that a particular product occupies on the average for its maximum inventory.

Very fast-moving products that use a large amount of storage space are kept in floor storage. Usually, these are fast-moving packaged petroleum products which are stored in greater than-eight-palletload quantities. There are also some fast-moving automotive accessories—primarily oil and air filters—that fall into this category.

Fifty-five-gallon drums, which hold refinery products, are stacked on pallets, five-high. Exxon

Random floor storage is used to store fastmoving packaged petroleum products stocked in greater-than-eight-palletload quantities. Petroleum products in fifty-five-gallon drums are stacked on pallets, five-high.

Bin carts are used for multi-order picking and sorting of small automotive accessories. When the orders are filled, the employee takes the cart to a sequencing area where he packs the accessories into cartons.

has seven 4,000-lb forklift trucks (Eaton Corp.) equipped with masts with a reach of 227 in. that allow them to stack five-high.

Floor storage consists of pallet-size modules, two to five pallets deep. All modules are kept full except for the current in- and out-modules.

There are some fast-moving products that are stored in floor storage—such as cases of motor oil and accessories like double wipes and antifreeze—but are picked from a fixed pick location. These pick locations are in gravity conveyor racks (Alvey, Inc). Orders for less-than-palletload quantities are picked from gravity conveyor racks.

Pallet rack (American Steel Products Co.) is used to store tires, batteries, accessories and packaged petroleum products not kept in inventories great enough to justify floor storage, but in quantities too great to justify storage in deck rack or shelving. These products are stored randomly and picked from fixed locations.

When the entire inventory of a particular product is small enough to be stored entirely in one location, it is kept in deck rack (American Steel Products Co.) or shelving (Lyon Metal Products, Inc.) These products are all stored in and picked from fixed locations.

Tires, batteries and accessories are not sent to their storage locations directly from receiving. The computer will first route them to the mixed TBA area, where picking crews will put them into deck rack or shelving at a later time.

There is a similar area for packaged petroleum products that are received in less-than-half-palletload quantities. These products are routed first to the mixed packaged petroleum area.

"We don't want these less-than-half-palletload quantities to tie up an entire pallet rack location because we'd lose too much storage space. So we put them in the mixed packaged petroleum area and have picking crews take them to the fixed pick locations," said Farrin.

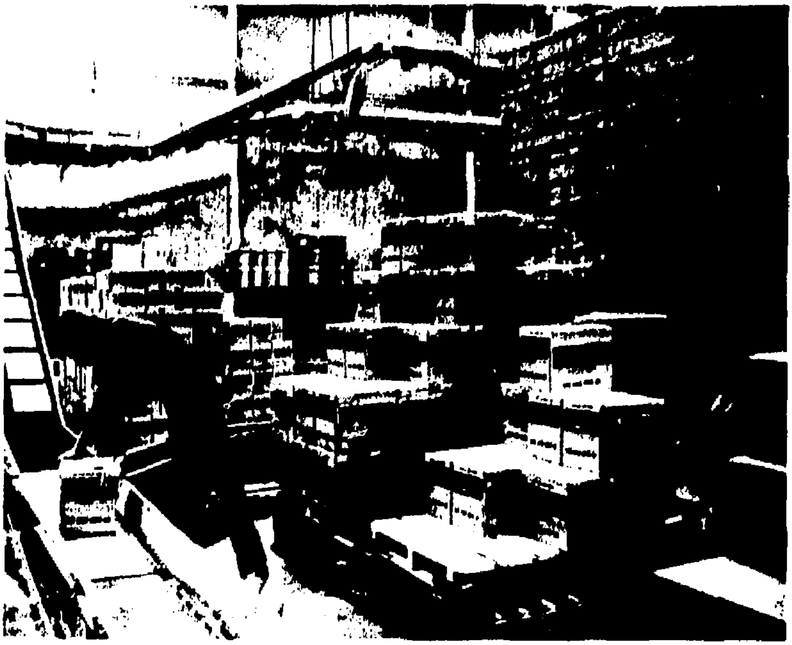
"The same procedure is used for mixed palletloads. Products are sorted before being moved to a picking location. In all cases, the computer updates the fixed pick location, assuming that the goods have been put there."

Area code determines picking

The warehouse is divided into areas, each of which is given a code. For example, location codes beginning with the letter "A" designate floor storage. This would be followed by a letter designating the aisle in which the product is stored, followed by two numerals designating the horizontal location, and one designating the vertical location. The computer determines how a product will be picked by its area code.

There are five modes of picking. Full pallet quantities of case oil, and any quantity of certain products stored in drums are moved by forklift from storage to the staging area. Instructions for picking are printed by the computer on move tickets generated at the FLD terminal.

Certain flammable products are stored in a special combustible room that has a fire wall separating it from the rest of the warehouse. If flammable products are part of an order, the



Overhead case shipping conveyors descend to the loading dock where a shipment is being staged. The cases of motor oil travel along these conveyors to telescoping conveyors which lead into the trailers at the dock.

computer will print a note on the loading document directing the loading crew to pick those items.

Certain large products, including all tires, are batch picked in blocks for an entire van. Batch pick products have been pre-determined by the ease with which they can be sorted in the sequencing area.

The picking crew working in the gravity conveyor rack area picks cases of motor oil and automotive accessories onto two takeaway conveyors (ACCO). These travel overhead to one of four loading docks. The longer of these conveyors leads to the Exxon vans, the other to the common carriers. At the dock, telescoping conveyors lead into the trailers.

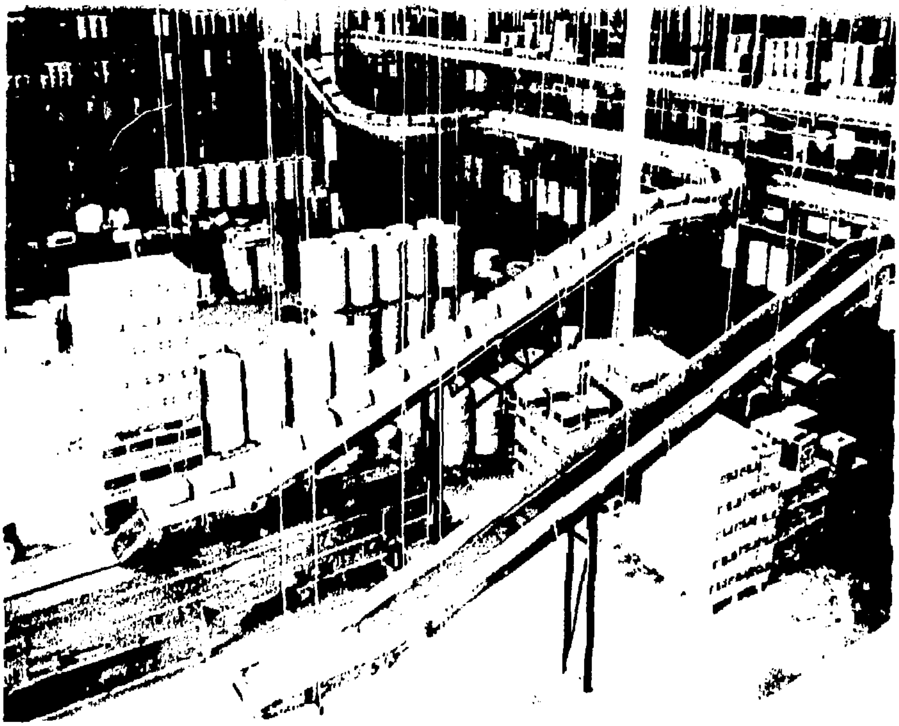
The gravity conveyor crew, which will be working on the same orders that crews in other parts of the warehouse are working on, picks by customer order for a particular van. At the end of each customer order, the pallet flow rack crew will affix a strip of white tape around the top of the last case in the order. When they've completed all the orders in a particular truck load, they will affix a strip of red tape around the last case. This notifies the loading crew that a trailer load is complete and they should move on to the next trailer.

In the shelving area, crews use multi-pick documents to pick into bin carts (Thomas Truck & Caster Co.) that were built specially to Exxon specifications. The document gives the location, product and quantity to be put in each bin so that orders are sorted as they are picked. When the employee has filled all the orders on the document, he takes the bin cart to a sequencing area. In the sequencing area, the crews will take the orders out of the bin carts, pack them in cartons and put them in sequence for delivery.

At the same time, crews from the batch pick area will have brought larger items such as tires, batteries and full cases of oil treatment additives to the sequencing area. They will then use a sequencing document to manually sort the batch picked items by customer order and put them in the proper sequence. All goods in the sequencing area are then put on pallets. When a van load is ready, the dispatcher is notified. He sends a forklift operator to move the goods to the staging area.

When everything has been picked, the status of the trailer load will be as follows:

• Fast-moving packaged petroleum products and automotive accessories from floor storage and



High volume cased oil is picked from gravity conveyor rack onto case shipping conveyors which take them to the docks. Orders filled from these racks are for less-than-palletload quantities.

flammable products from the combustible room will be staged at the loading dock.

- Cases of motor oil and accessories from the gravity conveyor rack area will be held on the overhead conveyors.
- Multi-pick and batch-pick products—mostly tires, batteries and accessories—will be staged in the sequencing area.

At this time, the loading crew—which has a document summarizing everything that is on the various picking documents—can begin loading the trailer. The crew knows from the document the number of orders that go in each quarter of the van, and the total number of cases, drums, bales, kegs and accessories that are in each order. With this information, they can plan how that particular trailer will be loaded.

Why use a computer?

"Our purpose in installing the computer system was primarily to make random storage possible. In addition, we wanted to optimize our forklift movement, thereby cutting down on investment in forklift trucks," said Farrin.

"There were two other goals we had in mind when we installed the computer system: to automate our clerical function as much as possible and to use the system as a management information tool. We were primarily interested in operating information rather than statistical or historical information," he said.

Exxon has five man-years of investment in programming which includes 35 real programs and 44 batch programs.

The host computer is an IBM 370/158 which is located in the Baton Rouge refinery. The distribution center is tied in with the host computer by telephone line. Peripheral equipment includes five CRT terminals, three slow printers, one high speed printer and one tape punch.

Problems in debugging the system were relatively minor, according to Farrin. And the computer system was very reliable.

"The most difficult aspect of bringing the system on line was in changing people's ways of doing things. Employees from the old warehouse were used to handling one order to completion. Now the order is divided into five different sections and only the driver and loading crews see the total order," he said.

When asked what he would change were he to do it over, Farrin said, "I think we went a little overboard in the efficiency of the computer system. It was difficult for our employees to intervene and handle the many exceptions necessary because of the complexity of customer demands. A more flexible system would be less efficient but would allow us to handle special situations with less exposure to error.

"The triple-cycle capability has caused some problems that we've had to circumvent. However, I think the basic concept of the system is sound and is working within the tolerances we established. But training a new person to make decisions based on what is happening throughout the system is difficult because the system is so complex," he said.

As to the success of the new system, Farrin says: "We have 25 warehouse employees handling about 10 times the volume by weight that we handled with 11 employees in the old warehouse. This puts us right on target for our part of the project. We're shipping about 600,000 lb per day or about 12,000 units.

"In our old operation we had an error frequency of between two and two and a half percent. At the present time, through the entire operation, we have an error frequency of less than one percent," said Farrin.

Apparently, this complex system at Exxon's Central Distribution Center isn't too complex for the computer to handle.

—SUSAN SUSEL, associate editor

Exhibit 6-2

Consultants' analysis of Exxon's new central distribution center

Joseph F. Reilly, Jr., president, Industrial Handling Engineers, Inc.
Ralph M. Cox, manager of engineering

In the Spring of 1973, Industrial Handling Engineers, Inc. (IHE) was retained by Exxon Company, U.S.A., Marketing Division, Distribution and Engineering Department, Memphis, TN, to develop plans for the new Central Distribution Center in Baton Rouge, LA. The Central Distribution Center receives, stores and distributes approximately 2,000 items of packaged petroleum and TBA to service stations and commercial accounts primarily in the southern part of the United States. Some specialized packaged petroleum products are shipped to the entire U.S. domestic market.

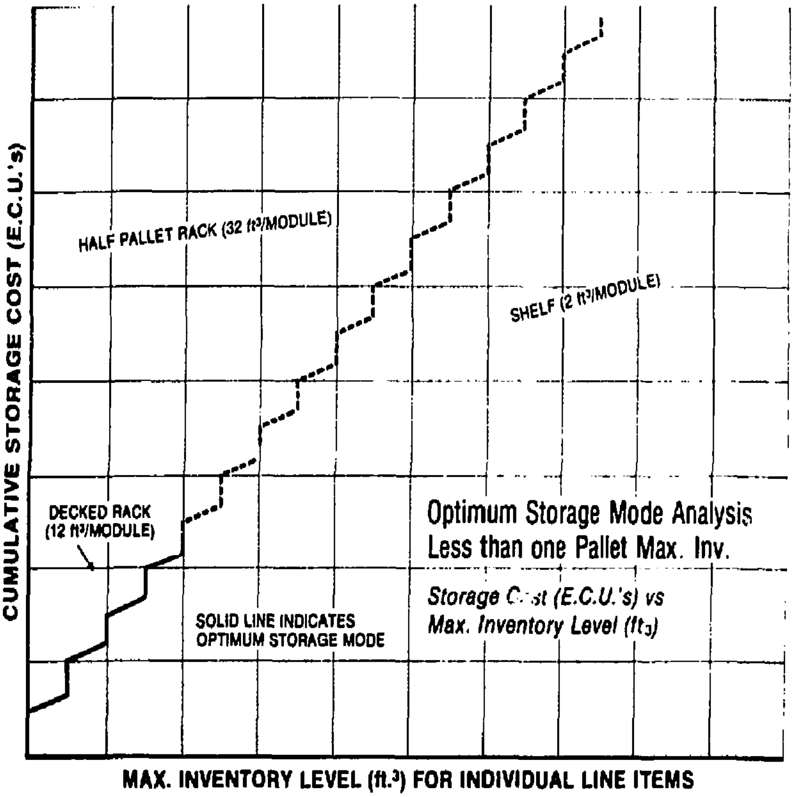
Throughout the planning phases, Exxon posed many questions in an attempt to obtain the best possible design for the facility. Some are as follows:

- Can the amount of handling for tires be reduced?
- How should TBA mixed item pallets be controlled?
- How are returned goods to be handled?
- Should fixed location or random access storage be used for all petroleum products?
- Can double deep pallet rack be utilized to save space?
- Is it economical to completely eliminate manual handling of empty pallets?
- How will the refinery shuttle trailer be designed?
- What procedures are to be used when the computer is down?

Alternative answers to these questions, as well as many others, were investigated. The ultimate goal in the design of the facility was a system that was cost effective from the standpoint of building space, fixed and mobile capital equipment and labor and other operating costs, while providing improved customer service.

At the start of the analysis, product movement (throughput) charts were developed indicating the anticipated receipts (by refinery shuttle, common carrier, box car, Exxon Van back haul and returned goods) and shipments (by Exxon Van, common carrier, piggyback, box car and customer pick-up) for the years 1981 and 1996. These projections, as well as most of the analysis, grouped the items to be handled into seven groups—drums, kegs, pails, cases, tires, batteries and automotive accessories. Together with the product distribution curve (indicating annual movement by product), the shipping curve (indicating monthly movement by item group), the anticipated inventory and receipt quantities by product, the physical sizes of the products and the typical orders, the basis for design was formed.

In order to assist in the analysis of various alternatives, each having different cash flow requirements, lives, types and periods of depreciation, Equivalent Cost Units (ECU's) were developed. ECU's are essentially after tax, present worth units of measure which reflect the overall, long term impact to Exxon for a given type of investment or expense. ECU's were developed for investments in buildings, fixed equipment (such as pallet racks), mobile equipment (such as forklift



The graphs above illustrate typical storage mode cost curves for (1) items having a total inventory of less than one pallet and (2) items having a total inventory greater than one pallet. These curves are in the form of cumulative storage costs (expressed in Equivalent Cost Units) versus the maximum inventory level for an individual line item. The analysis involves the development of all costs for various types of storage and the plotting of these costs *in order to determine the optimum storage mode for items* having various inventory levels.

The graph for items having a maximum inventory of less than one pallet includes the "fixed" costs of building space and storage equipment as well as the "variable" stocking and order picking costs calculated on the basis of the average turn level for each item group. The graph for items having a maximum level greater than one pallet includes only the "fixed costs" of the building space and storage equipment, inasmuch as the full pallet stocking and picking costs are essentially the same for all of the storage modes being considered.

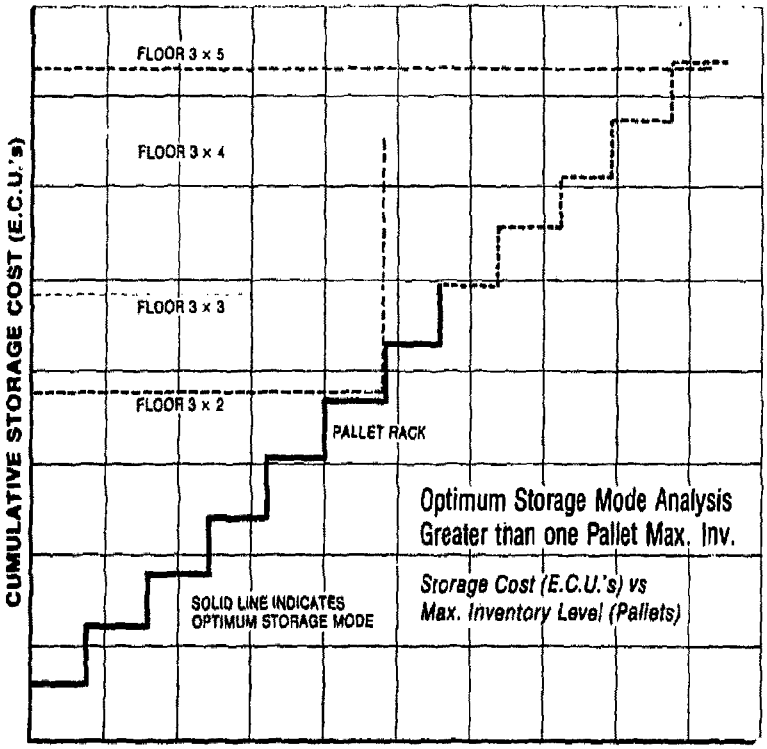
trucks) and for operating expenses. Exxon's discount rates, anticipated inflation rate and tax rates were of course, included. The use of ECU's enabled ready comparison of complex alternatives on an "apples and apples" basis.

Detailed analysis was performed with respect to the selection of the most economical storage mode *for each item, based on its inventory level and* movement. (See charts above.)

After the development of the most economical storage mode for each item, and prior to any area relationship analysis, two layouts were studied in order to compare the size of the building based on (1) fixed storage locations and (2) random access storage locations. Primarily due to the packaged petroleum products, a building size reduction of approximately 37,000 sq ft could be obtained through the use of random access storage. When *the difference in building costs* was compared with the cost of *an on-line terminal* to the Baton Rouge refinery computer, it became apparent that random access storage locations were indicated.

Utilizing the storage modes developed for random access locations, a detailed flow diagram was prepared in order to accurately determine the total movement into and out of each of the various storage zones, as well as the approximate size of each. Following the area relationship diagrams were prepared indicating the frequency of movement between each area in the warehouse (expressed in pallets per hour) and the minimum mean distance between each of the areas (expressed in feet). The product of these two factors (pallet - feet per hour) was used as the criterion for determining optimum locations for each area within the building. This was done by utilizing a trial and error process to develop a proximity diagram which would minimize the criteria in question. Based on the results of the proximity analysis, a number of preliminary, internal layouts were prepared for the building and the best layout was tentatively selected.

During the course of the analysis leading up to the determination of the preliminary layout, many



alternatives were investigated and recommendations made. Stacker cranes for handling unit loads of packaged petroleum products were investigated, but could not be justified economically. Several different types of forklift trucks were investigated, having various power sources, configurations and aisle width requirements. The forklift trucks selected are counterbalanced, electric sit-down models. Based on the analysis done, this type of truck was most economical considering the building space costs, the mobile equipment capital costs and the operating costs for fuel and maintenance.

The manpower requirements for the building were calculated based on detailed identification of each task to be performed, the number of times which it would have to be performed per day and the rate at which it can reasonably be expected to be performed.

The refinery shuttles selected were overwidth, overweight combinations of conventional tractors and special trailers having full width and full length powered conveyors within them. The use of two shuttle trailers and one tractor was recommended, based on the route selected from the refinery Packaging and Shipping Building to the distribution center. The route selected allows the shuttles to remain completely within the confines of the refinery, while minimizing delays which might result from red lights, stop signs or train crossings.

Special emphasis was placed on safety in the design of the facility. By observing OSHA standards related to color codes, aisle markings, powered industrial trucks, conveyor systems and similar equipment, as well as N.F.P.A. standards for indoor, general storage of materials and N.E.C. standards, the risks of injury to operators and other personnel have been minimized to a great extent.

After the preliminary layout was selected, detailed plans, specifications, descriptions of operations and cost estimates were prepared by IHE for all of the material handling and storage systems within the distribution center. Additionally, an architectural engineering firm was retained for the development of detailed plans and specifications covering the building structure and site work.

The project was appropriated in 1974, and IHE was retained to provide recommendations as to vendors and to assist in the procurement of bids, bid evaluation, approval drawing checking, expediting, and on the job assistance with installation and start-up of the systems. Operations began in the Spring of 1976. Certain concepts employed within Exxon's Central Distribution Center, particularly the use of computer controlled, dual cycle forklift truck stocking and order picking, together with the use of both fixed and random access storage locations as well as single order, multiple single order and batch order picking, are new to warehousing and distribution, in general, as well as to the petroleum industry in particular.

Exhibit 7

San Francisco Examiner, October 23, 1979

Nevada shuts next-to-last nuclear dump

RENO (AP) — The radioactive waste dump at Beatty was ordered closed by Nevada Gov. Robert List, an action that leaves only one commercial, low-level waste site operating in the nation.

Five drums containing radioactive waste were discovered buried 40 feet beyond a dump trench at the waste site on Sunday by a U.S. Geologic Survey Team.

"It was irrefutable evidence to our satisfaction of gross mismanagement," said state Human Resources Director Ralph DiSibio, who inspected the site yesterday.

Bill Phillips, a spokesman for List, said the shutdown would be effective as soon as paperwork is completed, probably today, and would remain in effect until the state Board of Health holds a hearing Nov. 27-28 on a state petition to revoke the operator's license.

Earlier this month, Washington Gov. Dixy Lee Ray temporarily shut down the commercial disposal site at the Hanford Nuclear Reservation after defective packaging of radioactive waste was discovered.

Both the Hanford and Beatty sites are operated by Nuclear Engineering Co. Inc. of Louisville, Ky.

South Carolina's Barnwell site, the largest of the three, is the only site left open. But South Carolina Gov. Richard Riley has said that he will not allow waste to be diverted there from states with closed dumps.

List has shut down the Beatty site twice before this year. He closed it for about two weeks in May after improperly packaged waste was found smoldering on a truck parked outside the dump. And he shut it for about three weeks in July after leaking waste containers were discovered.

Nuclear Engineering spokesman George Kolbenschlag said the company would not comment on the action until it has seen the governor's proclamation closing the site.

Exhibit 8

Sheet 1 of 2

Project TRU RETRIEVAL SYSTEMS — Contract No. 9046 — File No.
Feature ALTERNATIVE STUDY — Designed JWB — Date 10-31-79
Item OMNI CONTAINER EMPLACEMENT STUDIES — Checked — Date

CYCLE	WASTE TYPE	ROOM[1] SIZE (W×H×L, FT.)	ROOM[1] NO.	ROOM[1] TOTAL VOL. ($10^6 FT^3$)	NO. OF DRUM[2] TO BE STORED	NO. OF[6] CONTAINERS REQUIRED	TOTAL[6] VOLUME OF CONTAINERS ($10^6 FT^3$)	CONTAINER % OF ROOM VOL.
CYCLE I	HLW	18 × 20 × 560	780	157.248	896,155[3]	56,010	17.27	11
	ILW & CW	36 × 20 × 1,575	4	4.536				5.9
		36 × 20 × 3,150	108	244.944				
		36 × 20 × 1,850	32	42.624				
CYCLE II	PWR	18 × 22 × 3,500	104	144.144	65,146[4]	4,072	1.26	0.3
		18 × 22 × 1,300	36	18.533				
	BWR	18 × 22 × 3,500	144	199.584				
		18 × 22 × 2,910	36	41.485				
CYCLE III	HLW	18 × 20 × 560	780	157.248	97,106[5]	6,070	1.87	1.2
	ILW & CW	36 × 20 × 1,575	4	4.536				0.6
		36 × 20 × 3,150	108	244.944				
		36 × 20 × 1,850	32	42.624				

1) Ref.: ⌜Y/OWI/TM-36/8, Table 5-2⌟, 5-year retrievable
2) Accumulated number of LLW drums by the year 2010
3) Ref.: ⌜Y/OWI/TM-36/8, Table 5-5⌟
4) Ref.: ⌜Y/OWI/TM-36/8, Table 5-7⌟
5) Ref.: ⌜Y/OWI/TM-36/8, Table 5-8⌟
6) Size 5.4′ × 8.4′ × 6.8′ and volume 308.4 ft^3, containing 16 55-gallon drums

Sheet 2 of 2

Project TRU RETRIEVAL SYSTEMS Contract No. 9046 File No. ______
Feature ALTERNATIVE STUDY Designed FMG Date ______
Item OMNI CONTAINER EMPLACEMENT STUDIES Checked ______ Date ______

CYCLE	WASTE TYPE	ROOM 1)			NO. OF DRUM 2) TO BE STORED	NO. OF 3) CONTAINERS REQUIRED	TOTAL 3) VOLUME OF CONTAINERS ($10^6 FT^3$)	CONTAINER % OF ROOM VOL.
		SIZE (W×H×L, FT)	NO.	TOTAL VOL. ($10^6 FT^3$)				
CYCLE II	PWR	18×25×2910	36	47.142	65,146	4,072	1.26	0.3
		18×25×3500	152	239.4				
	BWR	18×25×1300	36	21.06				
		18×25×3500	80	126				

1) 25-year retrievable, Ref.: 「Y/OWI/TM-36/8, Table 5-11」
2) Accumulated number of LLW drums by the year 2010,
Ref.: 「Y/OWI/TM-36/8, Table 5-7」
3) Size 5.4'×8.4'×6.8' and volume 308.4 ft³, containing 16 55-gallon drums