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TMI-2 FUEL RECOVERY PLANT

FEASIBILITY STUDY

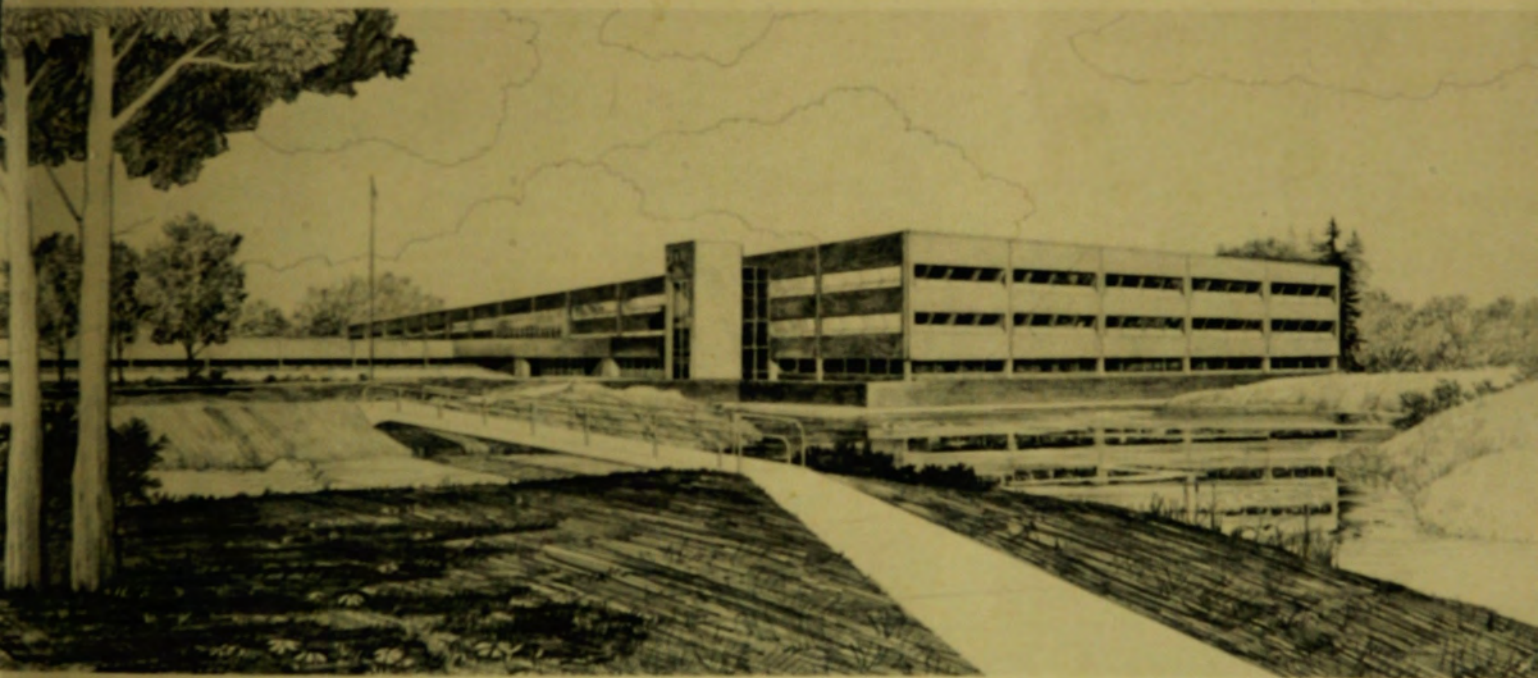
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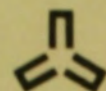
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 **EG&G** Idaho

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PROJECT SUMMARY

This project is a feasibility study for constructing a TMI-2 core Fuel Recovery Plant at the Idaho National Engineering Laboratory (INEL). The primary objectives of the Fuel Recovery Plant (FRP) are to recover and account for the fuel and to process, isolate, and package the waste material from the TMI-2 core.

This feasibility study is predicated on a baseline plant and covers its design, fabrication, installation, testing and operation. Alternative methods for the disposal of the TMI-2 core have also been considered, but not examined in detail for their feasibility.

The baseline FRP will be constructed in a portion of the existing TAN-607 building. Areas in both the TAN Hot Shop and Warm Service Area will be used. Much of the plant support and utility services will be provided by the existing services located in TAN-607.

The FRP will receive TMI-2 fuel in canisters. The fuel will vary from core debris to intact fuel assemblies and include some core structural materials. The canister contents will be shredded and subsequently fed to a dissolver. Uranium, plutonium, fission products, and some core structural material will be dissolved. The uranium will be separated by solvent extraction and solidified by calcination. The plutonium will also be separated by solvent extraction and routed to the Plutonium Extraction Facility. The wastes will be packaged for further treatment, temporary storage or permanent disposal.

The baseline FRP will be designed to process the fuel at a peak rate of 140 kilograms per day with the entire core requiring approximately 1000 days. The total project cost for design, fabrication, installation, testing, and operation is estimated to be \$70 million in 1982 dollars. The plant will be ready for "hot" operation in the mid to late 1980s.

ACKNOWLEDGMENTS

Input from personnel belonging to various organizations at the INEL was used in the preparation of this report. This feasibility study was written under the auspices of M. R. Martin Manager for the TMI Core Activities Program of the TMI Technical Support and Projects Office. Overall task coordination was provided by J. D. McQuary of the Projects and Systems Engineering Office. A. L. Ayers, Jr. of the Waste Technology Branch acted as the technical lead for developing the process concept and designing the flow schematic. A. L. Ayers, Sr. provided information for development of the process based on his past experiences in fuel reprocessing technology. D. R. Evans, H. B. Eldredge, J. R. Dixon and L. W. Fish of the Thermal Analysis Branch provided process analyses and researched melter and extraction equipment designs. R. P. Schuman of Materials Science researched nondestructive test methods for determining the presence of nuclear materials. R. D. Williamson of the Cost Estimating Office prepared the preconceptual cost estimates for the plant. L. W. McClure, R. R. Hammer and C. L. Bendixen of Exxon Nuclear provided valuable guidance and information during the development of the process in addition to providing data on the capability and availability of the Idaho Chemical Processing Plant Facilities.

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1. DESIGN CRITERIA

1.1 General

The following paragraphs contain the major design criteria for the TMI-2 Fuel Recovery Plant (FRP). The design description, indicating how these criteria were developed into a baseline process design, is included in Sections 3., 4., 5. and the drawings.

1.2 Basic Function

The primary objectives of the baseline Fuel Recovery Plant (FRP) are to recover and account for the fuel and to process, isolate, and package the waste material from the TMI-2 core. The core will be received in canisters, the contents of which will vary from core debris to intact fuel assemblies. The contents will be shredded and subsequently fed to a dissolver. Uranium, plutonium, fission products, and some core structural material will then be dissolved. The uranium will be separated by solvent extraction and solidified by calcination. The plutonium will be separated by solvent extraction and routed to the Plutonium Extraction Facility. The wastes will be packaged for further treatment, temporary storage or permanent disposal.

The baseline FRP will process fuel at a peak rate of 140 kilograms per day 24 hours a day, 7 days a week. Processing of the entire TMI-2 core will require approximately 1000 days.

1.3 General Codes and Standards

All design will conform to the latest editions of applicable nationally recognized and accepted codes and standards listed in Section 2.

1.4 Fuel Composition

Feed stock material will consist of an entire range of TMI-2 core materials. The as-loaded core materials are shown in Table 1.1, along with the weights for each type.

The as-received material from the core will vary from relatively intact fuel bundles to loose "gravel" composed of pieces of fuel and metal. This material will be in various sizes ranging from fine, through fractured fuel pellets to partial and complete fuel bundles. Some fuel debris may be partially fused. Estimates indicate that more than 90% of the fuel rods will be ruptured and 40% to 60% of the zirconium in the vessel will be oxidized. The core will be packaged in approximately 300 canisters and stored in the TAN-607 storage pool. TMI-2 ran for approximately 90 effective full power days, indicating approximately 160 kg Pu was produced. For the existing TMI fission product concentration and total element distribution see Appendixes A and B.

1.5 Radiological Plan

The FRP will be designed to provide radiological and chemical protection for the public, operational personnel, other on-site personnel, and the environment. Radiological design of the plant will be based on a proposed damage criterion philosophy outlined in the draft document, "Radiological Design Criteria for the Transuranic Waste Treatment Facility" dated May 1981. This document specifies maximum radiological exposures allowed due to releases during normal operations and for upset and accident conditions. Compliance of the design with this criteria will be determined by the safety analysis developed through the course of the plant design.

All equipment or components whose failure could result in releases greater than the limits specified in the damage criteria will be identified as critical items. Special design considerations will be implemented for those items so that the damage limits will not be exceeded.

TABLE 1.1. ACTIVE CORE REGION MATERIALS INVENTORY^a

Category	Form ^b	Composition	Volume ^d (ft ³)	Weight ^d (lb)
Fuel	Ceramic Pellets	UO ₂ ^c	324.3	205,140
Absorbers	Metal Alloy Rod	Ag-In-Cd	9.55	6,060
	Ceramic Pellets	B ₄ C in Al ₂ O ₃	7.29	1,380
	Ceramic Pellets	Gd ₂ O ₃ -UO ₂	0.46	290
Structures	Fuel Cladding	Zircaloy-4	109.7	44,440
	Guide Tubes	Zircaloy-4	6.65	2,690
	Instrument Tubes	Zircaloy-4	0.62	250
	Control Cladding	304SS	2.70	1,350
	Poison Rod Cladding	Zircaloy-4	4.04	1,640
	Spacer Grids	Inconel-718	5.24	2,670
	Spacer Sleeves	Zircaloy-4	0.64	260
	Plenum Springs	(Stainless)	3.10	1,550
	Ceramic Spacers	ZrO ₂	2.13	730
	Metallic Spacers	(Stainless)	0.90	450
	End Plugs	304SS	0.28	140
	End Plugs	Zircaloy-4	3.69	1,490
	Assembly End Boxes	(Stainless)	13.4	6,730
Trace	SPND	Rhodium-Inconel	--	--
	T/C	Chromel-Alumel	--	--
	Background Detector	(Cobalt)	--	--
	Neutron Source	Am-Be-Cm	--	--
	Instrument Thimble Clad	Inconel	--	--
	Instrument Calibration Tube	(Inconel)	--	--
	Insulation	(Ceramic)	--	--

a. Ref: NSAC/25 "TMI-2 Accident Core Heat-Up Analysis" prepared by Nuclear Associates International and Energy Incorporated.

b. Form shown is as-loaded; as-received form may be substantially different (i.e., oxidation of structural materials, shattering of ceramic pellets, etc.)

c. Average core enrichment 2.57%.

d. Estimated uncertainty less than 10%.

Shielding or access control will be provided, where necessary, to assure that the plant operating personnel exposure will be kept to a minimum. ALARA principles will be utilized.

1.6 Process Requirements

1.6.1 General

This is a feasibility study; hence, no components shall be totally fixed in design and only general principles shall be addressed.

Redundancy shall be provided in process or utility systems which are necessary for safe shutdown, personnel safety, environmental protection, criticality control, and accountability.

Where possible, equipment shall be pre-engineered, standard, off-the-shelf items which can be modified, as required, for remote operation in a contaminated environment.

Equipment in contaminated areas shall be designed to be decontaminated by remote or manual means for subsequent replacement or repair in place. Provisions will be made in the design to transport both contaminated and decontaminated failed units from the plant in instances where in-place repair is not practical.

Systems and subsystems shall be of modular design. Where possible modules shall be designed for radiological and chemical isolation. In general, criticality control shall be by geometrical design and through the use of neutron absorbing poisons.

1.6.2 Shipping and Receiving

The TMI-2 core will be packaged in canisters and stored in the storage pool of TAN-607. The canisters shall be transferred to the Hot Shop on the underwater dolly and then be conveyed to the head end of the processing line.

Recovered fuel and waste materials, which include the undissolved hulls and liquid waste generated during the processing, shall be packaged and prepared for shipping.

1.6.3 Shredding

The shredder shall reduce the material to approximately 0.5-2.0 cm sq. pieces. The shredder shall have an off-gas and containment system which will preclude the spread of contamination.

1.6.4 Dissolver

The dissolver shall receive shredded material in a metal basket. The basket shall be installed such that it may be remotely removed and emptied as a normal operation. The dissolver will be sized to process one canister every 80 hours.

1.6.5 Fuel Extraction

Fuel shall be extracted from the dissolver solution using multi-stage mixer settlers or centrifugal contactors for extraction and stripping. Tributyl phosphate, TBP, (approximately 30% by volume in n-dodecane) will be used as the extraction medium. Equipment for solvent clean-up and re-cycle will be provided.

1.6.6 Uranium Calcination

Uranium shall be solidified and prepared for shipment by calcination. The product shall be appropriately packaged with accountability control.

1.6.7 Waste

Cladding hulls and other undissolved metal shall be processed, packaged, and shipped to an appropriate disposal site. High and low level liquid wastes shall be collected and processed for shipment to the Idaho Chemical Processing Plant (ICPP) or other appropriate treatment facilities.

1.6.8 Off-Gas Treatment System

The function of the off-gas treatment system is to control the off-gas effluents from the process equipment. Effluents including chemical vapors, radioactive and nonradioactive particulates and aerosols shall be collected and controlled to meet the State of Idaho, EPA, and DOE standards. Stack emissions shall be controlled to meet appropriate standards at the Test Area North (TAN/TSF) boundary or the INEL site boundary.

As a minimum the following off-gas systems will be required.

1. The FRP process area off-gas system for general environmental control.
2. Vessel off-gas system for process vessel radiological and nonradiological off-gas.
3. Dissolver off-gas system.
4. Shredder off-gas system.
5. Plutonium handling facility off-gas system.
6. Melter off-gas system.

Off-gas systems will have two stages of HEPA filtration prior to gas discharge to the environment. HEPA filter bagout capacity and in-situ DOP testing shall be provided. HEPA filters shall have a particle removal efficiency of 99.97% for 0.3 micron sized particles. Off-gas systems will include chemical treatment of the gas stream as required.

1.7 Building and Structural Requirements

1.7.1 Structural Design

1. All new structures shall be designed in accordance with the INEL Architectural Engineering Standards.
2. Existing structures were originally designed to UBC Zone 2 earthquake requirements and will not be strengthened.

1.7.2 Containment

The FRP shall provide containment for hazardous materials both radiological and nonradiological.

1. The primary containment barrier shall be the process vessels and piping.
2. The secondary containment shall be provided by compartment walls between modules and cells, catch basins with controlled drains, and associated ventilation and off-gas systems.
3. Personnel occupancy areas shall be separated and shielded from process areas. Airlocks and contamination barriers with sealed penetrations shall be used to prevent the spread of contamination.

1.7.3 Support Areas

The FRP shall be designed for six operational personnel per shift, three shifts per day. The following support areas shall be required:

1. Health Physics Office
2. Shift Operations Offices
3. Administration Offices
4. Lunchroom
5. First Aid Station
6. Conference/Training Room
7. Control Room of sufficient size to house required consoles, instruments, and DAS to monitor and control the plant.
8. An analysis laboratory to provide radiological and chemical analysis of samples taken from process lines, environmental monitoring points, and contamination survey tests. The lab will contain nuclear instrumentation and chemical analysis equipment. A sample cabinet with exhaust hood and contaminated liquid effluent drain is required.
9. Shower and Locker Rooms.

1.7.4 Access Control

Plant layout shall be such that access to the processing areas shall be controlled and require passage through a single point entry office, control room, or keyed doors.

1.7.5 Decontaminable Surfaces

Decontaminable surfaces shall be provided as required to aid in decontamination. Decontaminable surfaces shall include stainless steel lining or a corrosion and radiation resistant paint.

1.7.6 Shipping and Receiving

Areas within the FRP shall be provided for the following:

1. A safe and convenient place to store incoming chemicals used in the processing.
2. Receiving fuel canisters from the TAN-607 storage pool.
3. Packaging and shipping of the Uranium product.
4. Containing and transferring low and high level liquid wastes.
5. Packaging and transferring of solid waste.

1.8 Criticality Control

1.8.1 Function

The function of the criticality control system is to protect the FRP operational staff, other on-site personnel, and the public from radiation hazards by reducing the potential for a criticality. Traditional and tested methods shall be employed to reduce the probability of a criticality and allow recovery from such an event. These methods shall be fully developed in the course of Title I and II design.

1.8.2 Instrumentation and Alarms

Criticality alarms will be provided for each area or piece of process equipment identified as having the potential for a criticality event as the applicable codes require. Each piece of alarm equipment shall have alarms both in the local areas, the H.P. office, the control room, and a post manned 24 hours a day.

1.8.3 Geometrical Considerations

1. All piping and process equipment, where possible, will be designed to be geometrically favorable for both normal and credible upset conditions.
2. The shape of all tanks, vessels, conveying devices, shedders and other components shall be such that they can be easily cleaned to prevent accumulation of fissile bearing waste or residues.

1.8.4 Neutron Poisons

Neutron absorbing poisons may be employed throughout the FRP for criticality control. Where neutron poisons are used, provisions for their continuing presence shall be provided.

1.9 Instrumentation and Control Requirements

1.9.1 Criticality Control

See Section 1.8.

1.9.2 Environmental

The final effluent gas stream that is emitted from the FRP shall be monitored so that any unusual occurrences or upsets in the system can be detected and also to demonstrate compliance with state and federal emissions regulations.

1.9.3 Radiation and Contamination Control

In addition to the instrumentation used to monitor for criticality and environmental emissions, instrumentation shall be provided as follows:

1. Areas occupied by personnel will be continuously monitored for gamma radiation and airborne alpha and beta contamination.
2. Periodic air sampling (and in some cases, continuous monitoring) will be required in all areas that may require intermittent personnel entry.
3. Personnel monitors will also be required at all exits from potentially contaminated areas within the plant.
4. Alarms from selected instruments shall be received in the H.P. Office.

1.9.4 Process and Utility Systems Control

The main function of the process control system is to assure that the process operates within the design limits. The central control computer system, off-gas system instrumentation and controls, criticality and radiation instrumentation, and selected process controls shall be supplied by an Uninterruptable Power System (UPS).

1.9.5 Process Control

A central control computer and data acquisition system shall be utilized to provide the plant operator centralized control over systems that could adversely affect the public and plant personnel. However, upon failure of the central computer, the operator must be able to control the plant in a manual mode to insure a safe and orderly shutdown of the process.

1.9.6 Utility Systems Control

The control and instrumentation system shall provide for central control of the following utility systems from the control room:

1. Ventilation and off-gas systems
2. Liquid radioactive waste system
3. Power systems to include Emergency and Uninterruptible Power Systems
4. Miscellaneous utility systems as required.

1.9.7 CCTV System

A television viewing system shall be provided to assist in various process operations, general plant monitoring and security.

1.9.8 Accountability

The uranium and plutonium inventory shall be kept by both monitoring and assaying various points within the process stream. The FRP data acquisition system shall have the ability to account for all uranium and plutonium present in the system at all times.

The FRP data acquisition system shall produce permanent records of all monitored features for archival storage and special nuclear material accountability.

1.10 Mechanical Services

1.10.1 Remote Manipulators

Remote manipulators shall be used where appropriate throughout the plant to reduce personnel exposure and to provide remote operation and maintenance capabilities.

1.10.2 Cranes

Remotely operated bridge cranes will be used to accomplish the following.

1. Transferring the fuel canisters to the processing system.
2. Transferring liquid waste collection tanks.
3. Removal and replacement of process vessels and modules.

1.10.3 Windows

Shielding windows shall be provided for direct visual observation of remotely operated mechanical procedures involving cranes or manipulators.

1.10.4 Special Doors and Pass-Throughs

Doors between the processing and personnel areas shall be special doors with airtight seals and access control.

Wall penetrations between the process area and operating areas for process chemicals, sampling systems, ventilation systems, and miscellaneous services shall be provided with offsets to prevent radiation streaming.

Removal of wastes from the process system shall be controlled to prevent environmental contamination.

1.11 Building Services

1.11.1 General

All building services required for the FRP shall be provided by modifications to existing services to the maximum extent possible and where economically feasible. New systems shall be provided where services do not exist or cannot be economically modified.

1.11.2 Electrical

1.11.2.1 General. The electrical systems for the FRP facility shall be designed with due consideration for the intended usage, provision for future growth, flexibility in accommodating changes in the intended usage, reliability of electrical service, economical installation and maintenance costs, and for maximum energy conservation. Electrical systems shall include the following.

1. Plant power system
2. Emergency power distribution system
3. Uninterruptable power distribution system
4. Instrument power distribution
5. Lighting distribution system
6. Telephone system
7. Fire detection/suppression alarm system
8. Intercom systems
9. CCTV system
10. Plant ground and instrument ground system
11. Off-gas stack lightning protection system.
12. Radiation monitoring system.

1.11.2.2 Emergency Power. Emergency power shall be supplied to the FRP facility.

1.11.2.3 Uninterruptable Power. An Uninterruptable Power System (UPS) shall be required for selected instrumentation, process control computer, alarms, safety and HVAC instrumentation functions for safe shutdown and confinement.

1.11.2.4 Instrument Power: All instruments and monitoring equipment shall be supplied with commercial power where not supplied by the UPS.

1.11.3 Domestic and Process Water

Water shall be supplied as required for the processes. All process connections to existing water systems shall incorporate backflow preventers that meet AWWA standards to prevent any possible contamination of the potable water system.

1.11.4 Air Systems

1.11.4.1 Breathing Air. Breathing air shall be provided to all areas where life support equipment will be required. The air supply shall meet Grade E quality requirements in accordance with the Compressed Gas Association (CGA) Bulletin G7.1, "Commodity Specification for Air." The system shall have stationary bottled breathing air for backup and a low pressure alarm system.

1.11.4.2 Instrument Air. Oil free, dried, compressed instrument air system, including distribution piping, shall be provided as required for system operations. Pressure shall be 15 to 30 psi.

1.11.4.3 Plant Air. Oil free compressed air at 125 psi shall be provided for general plant use as required.

1.11.5 Liquid Rad Waste

The purpose of the liquid rad waste system is to hold, sample for accountability, and neutralize contaminated liquid waste. The system shall

provide mechanisms for routing liquid waste to either a truck for transport to ICPP for processing, or storage at TAN for future processing at the FRP.

1.11.6 Steam

Steam shall be provided as required for system operations. As a minimum, it shall be provided for the following:

1. Process steam
2. Process heating
3. Liquid transferring

1.11.7 Communication Systems

Existing telephone services shall be extended to provide service in all offices, analytical lab, control room, and at or near all decentralized (local) operating control panels. The existing service shall have at least two channels upgraded for data handling.

A public address system, controlled from the control room, shall be installed, such that messages can be exchanged from the control room to all of the local process control stations, selected process areas, and the HP office.

1.11.8 Fire Protection System

1.11.8.1 General. Automatic fire suppression systems shall be provided where prescribed by NFPA and ID-12044 standards. Automatic sprinklers used in contaminated or criticality risk areas shall require special precautions.

Other types of automatic systems such as Halon shall also be required in the plant. In addition, hose stations, portable hand extinguishers, manual dry chemical, or metal-x systems may be required.

1.11.8.2 Alarm System. A supervised fire alarm system shall be provided with a centralized alarm annunciator panel located in the control room. The system shall provide Class A fire alarm circuits for fire alarm signals and Class B circuits for designated supervisory circuits and have a self-contained uninterruptable battery power system. The fire alarm control modules shall also forward the alarm signals to the INEL fire alarm system. Local alarms will also be required.

1.11.9 Heating Ventilating and Air Conditioning (HVAC)

The FRP shall be provided with an HVAC system meeting the following criteria:

1. Three ventilation confinement zones shall be provided. Zone III for areas of greatest contamination potential (interior of the Hot Shop), Zone II for intermediate contamination potential (Sample Gallery and airlocks), and Zone I for areas of least contamination potential (support areas). Airflow shall be from Zones of less contamination to Zones of higher contamination.
2. All Zone II areas shall have single-stage HEPA filters on both inlet air and exhaust air. Zone III shall have two stages of HEPA filtration on the exhaust and a single stage of HEPA filtration on the inlet. All HEPA filtration systems shall have provisions for hands-on maintenance and bagout procedures.
3. Continuous air monitors (CAM) shall be provided at Zone III and Zone II exhaust systems prior to the final HEPA filters.
4. The design airflow rate for Zone III and Zone II shall be one air change per hour. Zone I areas, including; control room, offices, and personnel occupancy area shall be air conditioned for personnel comfort.

2. APPLICABLE DESIGN CODES AND STANDARDS

All work on this project shall be governed by the latest edition and applicable sections of the following codes and standards.

2.1 General Reference Codes

Air Conditioning and Refrigeration Institute (ARI) Standards

Air Moving and Conditioning Association (AMCA) Standards

210, "Test Code for Air Moving Devices"

American Concrete Institute (ACI) Standards

318, "Building Code Requirements for Reinforced Concrete"

American Conference of Governmental Industrial Hygienists (ACGIH)

"Industrial Ventilation Manual of Recommended Practice"

American Gear Manufacturers Association (AGMA)

American Institute of Steel Construction (AISC) Standards

"Specifications for the Design, Fabrication, and Erection of Structural Steel for Buildings"

American National Standards Institute (ANSI), "Codes and Standards"

B31.1, "Code for Pressure Piping, Power Piping"

B31.3, "Code for Chemical Plant and Petroleum Refinery Piping"

C2, "National Electrical Safety Code"

MC 96.1, "Temperature Measurement Thermocouple"

N 13.10, "Instrumentation for Continuously Monitoring Radioactivity in Effluents"

NQA-1-1979 "QA Program Requirements for Nuclear Power Plants"

American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) Handbook and Product Directory

American Society of Mechanical Engineers (ASME),
"Boiler and Pressure Vessel Code"

American Society for Testing and Materials (ASTM) Standards

American Water Works Association (AWWA) Standards

American Welding Society (AWS) Standards

Compressed Gas Association (CGA) Standards
Bulletin G7.1, "Commodity Specification for Air"

Crane Manufacturers Association of America (CMAA) Specifications

Factory Mutual (FM) Engineering Association Standards

Illuminating Engineering Society (IES), "Lighting Handbook"

Institute of Electrical and Electronics Engineers (IEEE) Standards

Instrument Society of America (ISA), "Standards and Practices for
Instrumentation"

- S 5.1, "Instrumentation Symbols and Identification"
- S 5.14, "Instrument Loop Diagrams"
- S 12.4, "Instrument Purging"
- S 39.3, "Control Valve Sizing"
- S 50.1, "Analog System"
- S 51.1, "Process Instrumentation Terminology"
- S 61.1, "Industrial Computer Systems"

Insulated Power Cable Engineers Association (IPCEA)

International Conference of Building Officials (ICBO)
"Uniform Building Code" (UBC)

National Council on Radiation Protection and Measurements (NCRP) Reports
57, "Instrumentation and Monitoring Methods for Radiation Protection"

National Electrical Manufacturers' Association (NEMA) Standards
ICS 1-110, "Enclosures"
PB 1, "Panelboards"

National Fire Protection Association (NFPA), "National Fire Codes"
13, "Sprinkler Systems"
30, "Flammable and Combustible Liquids Code"
72D, "Standard for the Installation, Maintenance and Use of
Proprietary Protective Signalling Systems for Watchmen, Fire Alarm,
and Supervisory Service"
78, "Lightning Protection Code"
101, "Safety to Life from Fire in Buildings and Structures"
70, "National Electric Code"
82, "Standards on Incinerators, Waste, and Linen Handling Systems and
Equipment"
58, "Standard for the Storage and Handling of Liquefied Petroleum
Gases"

Occupational Safety and Health Administration (OSHA) Standards
29 CFR 1910, "Occupational Safety and Health Standards"
29 CFR 1926, "Safety and Health Regulations for Construction"

Portland Cement Association (PCA) Standards

Public Law 95-95, "The Clean Air Act" as Amended 1977

Rules and Regulations for the Control of Air Pollution in Idaho, Department
of Health and Welfare

Sheet Metal and Air Conditioning Contractors National Association (SMACNA)
Guide and Data Book

Underwriters' Laboratories, Inc. (UL), Standards and Directories of Listed Products

2.2 Department of Energy Codes

DOE Order 5630.2, "Control and Accountability of Nuclear Materials, Basic Principles"

DOE Order 5632.3, "Physical Protection of DOE Property"

DOE/EV/1830-T5, "A Guide to Reducing Radiation Exposures to As Low As Reasonably Achievable (ALARA)"

DOE Order 6430 "Facilities General Design Criteria," Part 1

DOE Order 5480.1A, Chapter 4, "Nuclear Criticality Safety"

DOE Order 5480.1A "Environmental Protection, Safety and Health Protection Program for DOE Operations"

DOE Order 5484.1, "Environmental Protection, Safety and Health Protection Program for G.O.C.O. Facilities"

WIPP-DOE-069, Rev. 1, dated September 1981, "TRU Waste Acceptance Criteria for the Waste Isolation Pilot Plant"

INEL Architectural Engineering Standards

ID-12044, "Operational Safety Design Criteria Manual"

ID-12045, "Criteria for HEPA Filter-System Installations at the INEL"

ERDA Manual Chapters/Appendixes

6203, "Site Development and Facility Utilization Planning"

6301, "Facilities General Design Criteria"

ERDA Publications

76-21, "Nuclear Air Cleaning Handbook"

77-24, "A Guide for Environmental Radiological Surveillance at ERDA Installations"

WASH-1245-1 "Electronic Computer/Data Processing System"

2.3 Code of Federal Regulations

Title 10 CFR 20, (NRC) "Standards for Protection Against Radiation"

Title 10 CFR 50 (NRC) "Licensing of Production and Utilization Facilities"

Title 10 CFR 73.55, (NRC) "Personnel Access Monitor"

Title 49 CFR 173,398^(b) (DOT) "Transportation Chapter I-Research and Special Programs Administration, Standards for Type A Packaging"

2.4 EG&G Documents

EG&G Hoisting and Rigging Manual

EG&G Nuclear Material Custodian Handbook

EG&G Quality Manual

EG&G Safety Manual

INEL Welding Procedures Specification Manual

3. PROCESS DESCRIPTION

This section contains a description of the baseline process, shown on Sketch 3, for the TMI-2 Fuel Recovery Plant (FRP). This process was selected to provide a safe and economical method to dispose of the wastes and recover and account for the fuel contained within the core. For a discussion of alternative processes see Section 5.

3.1 General Considerations

The objectives of the proposed work are to dispose of the core in a safe manner in a form that would be acceptable for long term storage and to account for the uranium and plutonium that exist in the core. The baseline process that is discussed in the following sections is designed to achieve these objectives and additionally to recover the uranium and plutonium in the core material.

The process is similar to a typical PUREX (Plutonium Uranium Reduction Extraction) process. The core material is dissolved, and the extraction cycles remove fission products from the uranium and plutonium. Fission products are solidified into a solid form; plutonium is separated from the uranium and recovered as a byproduct.

Calculations of the process performance have been made using the SEPHIS (Solvent Extraction Process Having Interacting Solutes) computer program. The SEPHIS program was developed at Oak Ridge National Laboratory specifically for analysis of the PUREX process. Results of preliminary SEPHIS calculations for the baseline process are contained in Appendix C.

The flowsheet is divided into seven sections which are composed of unit operation modules. Modules may be added to or deleted from the baseline process as necessary to achieve desired objectives in an economical manner. The process sections are the (1) head end operations, (2) first cycle extraction, (3) second cycle extraction, (4) solvent cleanup, (5) liquid waste treatment, (6) solid waste treatment, and

(7) off-gas treatment. Each of these sections, with their unit operation modules, will be discussed in the following sections.

3.2 Head End Treatment

The head end consists of a shredder, dissolver, accountability and feed adjustment tanks, and off-gas treatment.

3.2.1 Waste Receiving

The TMI-2 core will be shipped to the INEL site in 12 in. diameter by 14 ft long stainless steel canisters. The canisters will be stored in the TAN-607 storage pool. The canisters will be transferred to a shredder to begin the processing operations.

3.2.2 Shredder

The core material contained in the canisters will be mechanically shredded into 0.5-2.0 cm sq. pieces. The shredding operation breaks up large pieces of the core and increases the surface area to enhance the dissolution rate. The off-gasses generated during shredding may contain up to 10% of the gaseous fission products (I, Kr, Xe) and must be routed to the waste gas treatment system.

3.2.2 Dissolver

The dissolver operates in a batch mode. A dissolution time of 8 hr/batch is anticipated with one canister being processed every 80 hours.

In the dissolver, nitric acid is used to dissolve the uranium and plutonium oxides and the soluble fission products. The shredded fuel is placed in the dissolver with cold (room temperature), concentrated (9-10 M) nitric acid. The fuel is added to cold acid to prevent foaming. Steam is injected to bring the mixture up to operating temperature (80°C). The condensate from the steam reduces the acid concentration to about 8 M. Dissolution proceeds at a fairly high rate; essentially all of the

uranium oxide should be dissolved at the end of two hours. The PuO_2 and soluble fission products should be dissolved at the end of five hours. The acid is continuously circulated by an air lift to assure adequate mixing.

Heat is released as the oxide fuel dissolves. This heat of dissolution will have to be removed either by an external heat exchanger or by cooling coils that form an integral part of the dissolver. Gadolinium nitrate ($\text{Gd}(\text{NO}_3)_3$) will be added to the dissolvent for criticality control. Gases generated during dissolution will contain gaseous fission products and nitrogen oxides. These gases will be routed to the off-gas system for adsorption and cleanup.

After dissolution, the fuel solution is drained from the dissolver and centrifugally filtered to remove small particles of undissolved cladding and fission products. The undissolved debris and cladding hulls that remain in the dissolver are washed, removed, air dried, and stored until they can be treated for final disposal.

If desired, the debris remaining in the dissolver may be completely dissolved. This alternative is discussed in Section 5.

3.2.4 Accountability and Feed Adjustment Tanks

The amount of uranium, plutonium, and fission products that have been dissolved from the core material will be measured and sampled for chemical analysis in an accountability tank.

The debris that is removed from the dissolver will also be analyzed for uranium, plutonium and fission product content. The analysis may be conducted in various ways such as chemical analysis, passive gamma counting, or neutron interrogation. Neutron interrogation and delayed neutron counting will probably be the preferred method used in this analysis. The analytical methods used to assay the concentrations of these materials will be accurate to within $\pm 10\%$.

After analysis, the dissolver solution is transferred to the feed adjustment tank. Water and nitric acid will be added to the solution to obtain the desired uranium and nitric acid concentrations for feed to the first cycle. The process feed tank is capable of holding several days inventory of process feed solution. This allows mixing of several dissolver batches to ensure process solution homogeneity.

3.3 First Cycle Extraction

The first extraction cycle consists of a 16 stage extractor, a 24 stage stripper, and an evaporator.

3.3.1 Extractor

A sixteen stage extraction unit is provided for the first cycle extraction. The extractant is 30% by volume TBP in n-dodecane. A 3 M nitric acid scrub is used to separate the fission products from the uranium and plutonium. The fission products remain in the aqueous phase while the uranium and plutonium are selectively extracted into the organic phase. The aqueous feed from the head end dissolution enters the extractor at Stage 8. The extractant enters at Stage 16 and the acid scrub enters at Stage 1. The organic product containing the uranium, plutonium, and a small fraction of the fission products, leaves from Stage 1 and is fed to the stripper. The aqueous waste, containing the fission products and a small amount of uranium and plutonium, leaves at Stage 16 and is routed to the waste solidification facility.

3.3.2 Stripper

The uranium and plutonium are removed from the organic phase by stripping with dilute nitric acid. The stripper consists of two units having 16 and 8 stages, respectively. Two units are necessary to avoid problems with plutonium polymer formation.

Plutonium IV ion (Pu^{+4}) can, at low hydrogen ion (H^{+}) concentrations, react with water to form plutonium hydroxide (PuOH^{+3}) which polymerizes. This plutonium polymer is insoluble in aqueous solutions and deposits as a sticky coating on tank walls, in pipes and pumps. Accumulation of this polymer can lead to severe criticality problems. The hydrogen ion concentration (acidity) of the solution must be kept high to prevent polymer formation. At 25°C , the acid concentration must be kept above 0.3 M to ensure that no plutonium polymer is formed.

In the first stripper unit, with 16 stages, a 0.4 M nitric acid solution is used. About 75% of the uranium and essentially all of the plutonium is removed from the organic phase in the first unit. In the second 8 stage unit a 0.01 M nitric acid solution is used to remove the remainder of the uranium from the organic phase. With this two unit arrangement the aqueous plutonium-bearing stream will have a hydrogen ion concentration of greater than 0.3 M.

3.3.3 Evaporator

The two aqueous streams from the stripper are combined, concentrated, and adjusted prior to entering the second cycle extraction step.

The aqueous strips are combined, decanted, steam stripped to remove traces of TBP, and fed to the evaporator feed tank. The flow rates from the two strippers are such that the acid concentration will usually remain at or above 0.3 M. During off specification conditions, it may be necessary to add a small amount of nitric acid to the tank to maintain the required acid concentration.

The solution from the feed tank is concentrated in a steam heated evaporator. The distillate is essentially water. The concentrate contains all the uranium, plutonium, and nitric acid that were recovered in the first cycle extractor and stripper.

After evaporation, the nitric acid concentration is adjusted to the proper value by adding a small amount of concentrated nitric acid. The adjusted solution is then fed to the second cycle extractor.

3.4 Second Cycle Extraction

The second extraction cycle consists of a 16 stage extractor followed by an 8 stage partitioner, uranium stripper, and plutonium glovebox.

3.4.1 Extractor

The second cycle extractor is similar to the first extractor and consists of 16 stages, scrubbed by 3 M nitric acid, and uses 30% by volume TBP in n-dodecane as the extractant. As in the first cycle, feed enters Stage 8, scrub enters Stage 1, and extractant enters Stage 16, while organic and aqueous products are removed from stages 1 and 16, respectively. The organic stream contains the majority of the uranium and plutonium, while the aqueous stream contains small amounts of uranium and plutonium plus the fission products that were not removed in the first cycle. The organic product is fed to the partitioner, and the aqueous wastes are routed to the waste treatment area.

3.4.2 Partitioner

The uranium is separated from the plutonium in the partitioner by reducing the Plutonium IV ion (Pu^{+4}) to non-extractable Pu III (Pu^{+3}) by ferrous ion (Fe^{+2}). The reduction of Pu IV with ferrous ion is essentially instantaneous in the aqueous phase. The plutonium enters the aqueous phase as Pu III and the uranium remains in the organic stream. Sulfamate ion ($\text{SO}_3\text{NH}_2^{-1}$) is added to prevent re-oxidation of Pu III to Pu IV by nitrite (NO_2^{-1}) ion. The aqueous scrub is 3 M nitric acid. The high nitrate concentration acts as a salting agent to prevent the uranium from leaving the organic phase. The organic stream from the partitioner is fed to the uranium stripper; the aqueous strip containing the plutonium and some uranium is fed to the plutonium extraction facility.

3.4.3 Uranium Stripper, Evaporator and Calciner

The organic stream from the partitioner is stripped with 0.01 M nitric acid. Low concentration acid can be used in this stripper since the plutonium was removed in the partitioner and poses no polymer formation problems.

After stripping, the aqueous solution, containing the uranium is decanted, steam stripped and concentrated in an evaporator. The concentrated and purified uranyl nitrate-nitric acid solution is then fed to a calciner to produce the final UO_3 product. The UO_3 product will be blended, sampled, and weighed for accountability prior to removal for storage. Water and nitric acid from the evaporator and calciner are collected and treated for re-use in the process.

3.4.4 Plutonium Extraction Facility

The aqueous plutonium-uranium solution from the partitioner is routed to the Pu extraction facility for final cleanup of the plutonium. The uranium is removed from the plutonium in ion exchange columns. The uranium is recovered from the columns during regeneration and recycled to the second cycle feed. The plutonium is further purified in an oxalate precipitation step. The plutonium oxalate is filtered, dried, and calcined to give the final plutonium oxide product. The plutonium product will be blended, sampled, and weighed for accountability prior to removal from the facility. It may be possible to operate the precipitator and calciner in a batch mode because of the low rate of plutonium accumulation.

3.5 Solvent Cleanup

The extractant leaving the first and second cycle strippers contains small amounts of uranium and radiolysis-induced degradation products such as di-butyl phosphate, (DBP) mono-butyl phosphate (MBP) and phosphoric acid. These contaminants must be removed before the solvent can be reused.

The solvent is cleaned by a sodium carbonate wash followed by a weak nitric acid strip. The sodium carbonate solution removes some of the uranium and essentially all of the DBP, MBP, and phosphoric acid. The remainder of the uranium and other contaminants is removed in the nitric acid strip.

The wash and strip solutions are routed to the waste treatment area.

3.6 Liquid Waste Treatment

Liquid wastes are divided into two categories, high and low level waste. High level wastes will be routed to the solid waste treatment facility, concentrated in an evaporator, calcined, and encapsulated in a solid waste form such as borosilicate glass or iron-enriched basalt. Low level wastes will be purified, either by evaporation or ion exchange, and the purified water will be recycled to the process. Concentrated wastes from the evaporator or ion-exchange units will be classified as high level waste and treated as described in Section 3.7.

3.7 Waste Treatment and Solidification

This section presents preliminary process information for the immobilization of the high level liquid waste and handling the undissolved core debris. A calciner is used to convert the liquid waste, after concentration by evaporation, into a fine calcine product suitable for melting into a borosilicate glass. The undissolved core debris from the dissolver is air-dried and then melted into an iron-enriched basalt. Both solid forms are carefully poured and cooled to render them suitable for permanent waste disposal.

3.7.1 High Activity Liquid Waste (HAW)

The high-activity liquid waste from the first and the second-cycle extractors which contains water, nitric acid, fission products, uranyl nitrate, plutonium nitrate, and gadolinium nitrate is to be concentrated by evaporation of water in a steam-jacketed vessel and then fed to a storage

tank for subsequent delivery to a spray calciner. The calcining process operates by spraying the liquid waste into the calciner vessel using air as the atomizing gas. Process heat is supplied by an in-bed combustion or a resistance furnace surrounding the chamber. As the atomized waste droplets are heated, the water is evaporated, and the waste is concentrated, dried and oxidized to form a fine calcine product. The calciner chamber is typically operated at 750°C. Glass-forming material called frit is mixed with the calcine in the proportion of 1/3 calcine to 2/3 frit. The frit should have a composition of 66% SiO_2 , 24% Na_2O , 8% B_2O_3 , and 2% CuO by weight. The mixture is then fed to a melter to produce a borosilicate glass, that when cooled, is suitable for permanent storage.

The off-gas from the calciner and the melter contains air, particulates, nitrogen oxides, sulfur oxides, and volatile ruthenium, cesium and iodine compounds. This gas must be cooled and cleaned before discharge to the atmosphere. Particulate removal will occur in a quench tower and venturi scrubber, where the off-gas is cooled and scrubbed with nitric acid. Entrained liquid is removed by a demister. A condenser will aid in removal of the volatile compounds. The noncondensable gas is then passed through an off-gas treatment system which contains adsorber columns and HEPA filters. The condenser liquid is sent to the scrub solution surge tank for recycle to the HAW evaporator feed storage tank.

3.7.2 Core Debris Solid Waste in Iron-Enriched Basalt

The indissoluble core debris leaving the dissolver is air-dried, mixed with soil, clay or dolomite, and fed to the melter to produce an iron-enriched basalt (IEB). Research at INEL has shown that the IEB, a glass-ceramic whose principal constituents are SiO_2 , Fe_2O_3 , FeO , and Al_2O_3 , can successfully immobilize core debris, zeolites and resins. The IEB composition can be tailored to fit the various diverse applications. For example, the IEB for the core debris should have a

composition of 50% SiO_2 , 10% Al_2O_3 , 9% CuO , 20% Fe_2O_3 , 3.5% MgO , 2.5% K_2O , and up to 20% (U + ZrO_2), by weight. This means the melter mix should be 1/5 core debris and 4/5 filler material.

3.7.3 Joule-Heated Melter

The joule-heated melter is an apparatus that can heat material by conductance of electricity to high enough temperatures to melt metals, etc. into molten basalt. The initial charge to a cold melter is heated with an auxiliary system to a temperature at which it will conduct electricity. A large voltage applied across a series of electrodes causes the surrounding furnace charge to be melted. The various constituents in the charge can be further mixed and the melt-time can be shortened by air or oxygen bubbled through the melt. The electrodes are typically made of molybdenum and must be covered by melt, sand, etc. to minimize their degradation by oxidation. The maximum melt and pour cycle time should be less than 8 hours. The operating temperatures for the melter are 1150-1200°C for the borosilicate glass melt and 1500°C for the IEB melt. The melter will produce off-gas that must be processed in the off-gas treatment system.

A cooldown oven is required to allow controlled cooling of the melt casting in order to generate the desired crystalline structure or the relaxation of thermal stresses. The melt typically will be poured into cylindrical, 12-in. diameter canisters for proper cooldown. Controlled cooled castings of IEB and borosilicate glass have exhibited fine-grained structure with a near absence of microcracks and is a very durable waste form.

Significant uncertainties with this melter system include:

- (1) electrode lifetime, (2) electrical shorting of the electrodes,
- (3) remote handling capability of the system, (4) off-gas flow rate and composition, (5) quantity of air or oxygen flow through the melter, and
- (6) capability to tilt the melter such that all molten contents can be poured quickly.

Waste volumes of borosilicate glass containing the high activity liquid waste is estimated to be about 170 ft³, assuming a 1/3 waste loading factor, while the IEB volume containing indissoluble core debris is estimated to be about 1620 ft³, assuming a 1/5 waste loading factor. If the entire core volume were to be immobilized into IEB, the waste volume would be 6450 ft³.

3.8 Off-gas Treatment

Off-gases from the shredder, plutonium handling facility, dissolver, extractors, strippers, partitioner, and evaporators will be routed to the off-gas treatment system.

The system is designed to remove iodine and particulates from the off gases prior to venting. The iodine will be adsorbed on silver impregnated ion adsorption columns. Additional equipment will be required to remove NO_x and adjust the chemical composition of the vented off-gases. HEPA filters will be used to remove particulate materials from the off-gases. The treated gases will be monitored to ensure adequate cleaning prior to venting to the stack.

4. PLANT DESIGN DESCRIPTION

This section contains a description of the baseline Fuel Recovery Plant (FRP) established in Section 3 and meeting the design criteria given in Section 1. The FRP is a processing system placed in the TAN-607 Hot Shop and the Warm Service Area. The FRP will use existing TAN-607 facilities which will be upgraded, modified, or supplemented as required. For alternative siting locations see Section 5.

4.1 Site Development

4.1.1 General Site Description

The proposed site for the Fuel Recovery Plant (FRP) is in Building TAN-607, located at the TAN/TSF area of the Idaho National Engineering Laboratory shown on Sketch 1. The building location is shown on Sketch 2. The existing Hot Shop and Warm Service Area will be modified to accommodate the FRP.

Portions of the existing TAN-607 office spaces will be used to house FRP personnel. The existing Analytical Laboratory will be used and expanded to provide support for the FRP.

4.1.2 Hot Shop

The existing Hot Shop has two pair of adjacent railroad tracks extending approximately 90 ft into the shop from the west end. A specially constructed railroad car containing the FRP process equipment will be placed on the south set of tracks. Liquid waste tanks for both low and high level wastes shall be placed on the east end of the north set of tracks. A railroad transfer car shall be placed on the west end of the north tracks. The transfer car may be used for temporary storage of fuel canister awaiting processing or transferring packaged waste material out of the Hot Shop, see Sketch 4.

4.1.3 Warm Service Area

The existing Warm Service Area will be modified to accommodate a new process addition, a new two story structure, see Sketch 8. The first floor shall contain new change rooms, an H.P. Office, an Uranium Calcination Cell, and an Electrical Switchgear Room, see Sketch 5. The second floor shall contain a new Control Room, Process Control Room, shift offices for operating personnel and a shift supervisor, and interfaces to existing TAN-607 offices and the South Control Gallery of the Hot Shop, see Sketch 6. The roof or third floor shall contain a new Sample Gallery, Off-gas Cell, and Process Fluids Make-up area see Sketch 7.

4.1.4 Roads, Walkways, Parking and Drainage

Existing roads, walkways and parking areas shall be used. Truck access to the plant will be through the existing TAN Gate House along existing roads to the west side of TAN-607 and the existing sliding truck door into the Warm Service Area. Walkways and parking facilities presently being used at TAN-607 will accommodate FRP personnel. Existing drainage systems will require no modifications or additions for this project.

4.1.5 Site Utilities

The existing TAN-607 utility systems shall be used. Utility systems shall be upgraded, modified, or supplemented as required by the FRP processes.

4.2. Architectural - Structural

4.2.1 General Description

The FRP is a processing system installed in TAN-607 Hot Shop and Warm Service Area.

4.2.1.1 Hot Shop. The FRP processing equipment shall be placed on a specially constructed railroad car sited in the Hot Shop. The railroad car shall support a two story structure constructed of stainless steel. The structure shall support the FRP process equipment and use a modular design for equipment layout, see Sketches 9 and 10. Modules contained within the structure shall be separated by shielding or partitioning walls as required by the process.

Both low and high level liquid waste tanks shall be placed within the Hot Shop for liquid waste collection. Waste tanks shall be remotely moveable from their service position to the transfer car.

A transfer car shall be placed in the Hot Shop to receive package wastes for removal from the FRP and fuel canister from the storage pool dolly.

4.2.1.2 Warm Service Area. A new process addition to house support services will be constructed in the Warm Services Area. This structure shall have some walls constructed for shielding and floors designed for equipment loads as required. The two story addition will structurally interface with the existing Hot Shop South Control and Equipment Galleries.

4.2.2 Foundations and Floor Slabs

The floor slabs in the Hot Shop and Warm Service Area shall be modified as required to accommodate the FRP. New floors and foundations required by the new process addition shall be sized to adequately support their loads.

4.2.3 Walls

Existing shielding walls of the Hot Shop will shield the personnel occupancy areas from the processing area. Shielding walls shall be employed around the processing system to allow access of plant personnel to

the Hot Shop while processing. Shielding walls shall be incorporated into the new process addition around the Calcination Cell, the Sample Gallery, and the Off-gas Cell.

4.2.4 Roof

The roof of the new process addition will be constructed to support the equipment necessary to prepare and store the process make-up fluids. The roof of the existing Hot Shop Control Gallery will be reinforced to support the Sample Gallery and the Off-gas Cell.

4.2.5 Windows

An existing wall shall be removed between the new process addition and the South Control Gallery. This new passageway will unite the new Control Room and the South Control Gallery. The Control Gallery contains existing shielding windows which will give the operating personnel direct observation of the entire processing module.

4.2.6 Doors

Existing doors within TAN-607 will be used and upgraded. New doors shall be installed as required. All doors between personnel occupancy areas and process areas will be provided with airtight seals and double door airlocks. In airlocks, the two doors leading to and from the airlock shall be interlocked electrically to prevent both doors from being opened simultaneously. Size of the doors will be determined during Title I design.

4.2.7 Painting

All the walls, ceilings and floors in the processing rooms and working galleries which are not stainless steel shall be painted with a decontaminable paint. Areas outside the processing rooms and working galleries shall be painted with one primer coat and two finish coats of enamel paint.

4.2.8 Stainless Steel Surface Coverings

The process area, Calcination Cell, Off-gas Cell, Sample Gallery, and Chemical Make-up area shall have stainless steel floor and wall coverings to facilitate decontamination.

4.2.9 Personnel Safety

The FRP shall be designed to provide an integrated approach to controlled access and emergency egress. Working galleries, airlocks, and service areas are laid out to provide rapid, easy egress through emergency exits from the plant and building in case of evacuation and to provide easy access for routine operations.

The following features shall be provided for industrial safety:

1. Use of non-combustible construction materials.
2. Use of fire protection systems.
3. Use of double confinement barriers around the process area. This includes physical barriers and ventilation air pressure control to ensure that flow of air is from uncontaminated to potentially contaminated zones.

4.2.10 Ease of Decontamination

The FRP shall be designed so that decontamination can be accomplished easily on a routine basis. Building surfaces shall be smooth, accessible, and of simple configuration. Use shall be made of special protective coatings or stainless steel liners for floors, walls, and ceilings. The special protective coatings used in moderately hazardous spaces shall be impervious to penetrations by contaminants and resistant to cleaning solvents and corrosive materials. On surfaces of potentially greater

contamination and more frequent decontamination, stainless steel shall be used for better durability. In general the base material for walls, floor, and ceilings shall be either stainless steel or concrete.

4.2.11 Double Containment

The FRP shall be designed to provide double containment of in-process material from the point of fuel receiving through the final packaging of the product or waste materials. Airlocks shall be provided between containment barriers and the periphery of the FRP for incoming or outgoing material and personnel. Where necessary, doors and hatches will be provided with seal breaking hardware so that doors can be opened between areas of differential air pressure. All wall, door, hatch, window, piping, electrical conduit, or duct penetrations between containment zones shall have positive seals. Construction materials shall form an airtight barrier so that contamination cannot migrate through the wall from one zone to another.

4.2.12 Earthquake Design

The FRP shall be designed in accordance with the INEL Architectural Engineering Standards and include the following:

1. New construction of non-nuclear buildings and other structures shall be designed to meet the requirements of the Uniform Building Code (UBC) Zone 2.
2. The containment and confinement portions of new nuclear process facilities shall, as a minimum, be designed to UBC Zone 3 including a static vertical acceleration $2/3$ of the horizontal value.
3. New high fission-product or transuranic inventory facilities 10 CFR 50 "Licensing of Production and Utilization Facilities" seismic requirements shall apply.

4. Existing structures and facilities were originally designed for UBC Zone 2 and will not be up-graded.
5. New building services that may be attached to the existing structure will be designed to Zone 2 requirements except safety related or critical systems which will be Zone 3. However, no modification or strengthening of the building will be made to bring it to Zone 3 requirements at the location of the service.

4.3 Mechanical

4.3.1 Process Equipment

4.3.1.1 Vessels. Process and process support vessels for the FRP shall be individually designed. They shall in general be of the approximate size and located in the positions shown on Sketches 7, 9, and 10. Materials of construction, generally stainless steel, shall be selected based on their service environment. The majority of vessels will be provided with the following; off-gas venting, decontamination, sparging, sampling, and level, density, and temperature monitoring. All vessels shall be coded and have a code stamp per ASME Boiler and Pressure Vessel Code Section VIII, Division 1.

Existing Government surplus equipment available at the West Valley Nuclear Facility shall be used where practicable. This equipment needs to be investigated as to its size, materials of construction, nozzle and support locations, and methods of construction. The West Valley Equipment which is available appears to be of the correct material for the project. Also some of the tanks appear to be of the correct size; however, during the conceptual design further evaluation of the available surplus equipment will be undertaken.

Vessels shall be installed, where practicable, to allow their removal from the system by remote means.

4.3.1.2 Solvent Extraction Equipment. Liquid-liquid extraction equipment was selected by preparing a list of process objectives then rating available equipment as to how they effectively met those objectives. Of the list of possible solvent extraction equipment only two types were given detailed consideration based upon their availability and proven performance under similar conditions. These include the Robatel centrifugal contactor and the pump-mix mixer settler.

The Robatel centrifugal contactor is considered by many to be the state-of-the-art in solvent extraction equipment. It utilizes multi-stage contacting and centrifugal separation in a compact, critically-safe device with high throughput and minimum residence time. Proven performance under PUREX type process conditions is a significant factor that isolates this contactor as the likely choice for the first stage extraction and possibly the second stage.

The pump-mix mixer settler is a horizontal partitioned trough with a vertically installed motor and impeller to provide the mixing effect and hydraulic head for heavy phase flow. Settling is accomplished in one of the two chambers by gravity forces within the individual stages. These units along with numerous modified versions have long been the standard of the industry for bench-scale and process development. They are an excellent alternative to centrifugal equipment for first and second stage extraction and are probably the best choice for ancillary extraction operations such as solvent washing.

4.3.1.3 Specialized Equipment. Two pieces of equipment shall be specially designed for the FRP; these will be the joule melter and the fuel shredder.

4.3.1.4 Piping. The piping systems in the FRP will be designed and installed in accordance with ANSI 31.1 and 31.3. Piping, in general shall be welded, flanged and constructed of stainless steel. Piping shall be arranged to facilitate the remote removal of vessel and other process equipment from the system.

4.3.1.5 Valves. The process valves shall be nuclear grade and be constructed of materials selected for their service. Process control valves shall be remotely operable from the Control Room.

4.3.1.6 Pumping. Fluids shall be transferred by gravity where possible. Jets and airlifts will be used to the maximum extent possible. Mechanical pumps, when used, shall be remote head positive displacement diaphragm pumps.

4.3.2 Off-Gas, Heating, Ventilating and Air Conditioning

4.3.2.1 General. Heating and ventilating systems are provided to maintain the required temperature, ventilation and contamination control environments within the TAN-607 area and the FRP addition within TAN-607. Minimum heating temperatures are controlled as required for the efficient performance of the operating personnel. Ventilation and confinement control provides an essential part of the final and internal confinement system and acts as a barrier to minimize the spread of contamination. The release of radiological and nonradiological particulates, aerosols, fumes and vapors are controlled to as low as reasonably achievable (ALARA) and will meet all applicable Federal, State, EPA and DOE requirements. This control is maintained during normal operation. The contaminants shall further be confined to specific areas within FRP using physical barriers, to prevent dispersion of materials into areas normally occupied by personnel. Ventilation air flow is from zones of no contamination to zones of increasing contamination potential. Air conditioning is provided in the FRP control room only. Systems required to operate for a safe shutdown in the event of a power outage shall be electrically connected to the existing diesel generator bus or to a new uninterruptable power supply (UPS) both of which are described in the electrical sections hereinafter.

4.3.2.2 Off-gas Systems. Separate off-gas treatment and dispersal system will be provided for the following:

1. Vessel off-gas (VOG)
2. Dissolver off-gas (DOG)
3. Shredder off-gas (SOG)
4. Plutonium handling facility off-gas system (POG)
5. Melter off-gas system (FOG).

These systems will pass through appropriate chemical treatment, HEPA filtration, monitoring and dispersal. A new corrosion resistant stack will be required.

4.3.3 Utility Systems

Existing utility systems shall be extended to the FRP, including potable water, steam, plant air, breathing and instrument air. Tie ins to these systems are available in the immediate vicinity of FRP. Expansion of these systems shall be as required to meet the needs of FRP.

4.3.4 Analytical Laboratory

An existing laboratory, Room 119A, will be used and expanded to service the FRP.

4.3.5 Liquid Waste System

A new process liquid waste holding system will be installed for the FRP. The system shall receive and contain all liquid radioactive waste generated by the FRP facility. The system will include instrumentation and controls to monitor levels, densities, temperatures, and route liquids to subsequent holding tanks.

4.3.6 Decontamination System

Personnel decontamination shall be performed in existing facilities within TAN-607. In place decontamination of equipment will be performed using water washers, steam, water and detergent scrubbing on a case by case basis as required. Effluent shall be drained to the new liquid waste system.

4.3.7 Cranes and Manipulators

Existing cranes and manipulators shall be used in the TAN-607 Hot Shop to service the processing system. The existing crane in the TAN-607 Warm Service Area shall be used to service the chemical make-up area. Existing cranes and manipulators shall be upgraded as required. Specialized tools used by cranes and manipulators shall be supplied as required.

4.3.8 Fire Detection/Suppression

The FRP fire detection/suppression system shall be an extension of the existing TAN-607 wet pipe system where appropriate. New Halon or dry chemical systems shall be applied where required.

Installations will be in accordance with applicable NFPA Standards and include wet pipe sprinkler systems per NFPA 13, halon systems per NFPA 12A, dry chemical systems per NFPA 17 Metal-X systems per NFPA 10 and explosion suppression systems per NFPA 69.

4.4 Electrical

4.4.1 Power Distribution System

Electrical power shall be supplied to the FRP process areas and control room from a new MCC. The MCC shall be dedicated to FRP electrical equipment and to provide for future expansion of the FRP. The new MCC shall be supplied from the existing 480 V distribution system at TAN-607.

480 V, 3-phase, 3 wire, 60 Hz power shall be distributed from the new MCC to new off-gas equipment, manipulators, shredder motors, and other motor loads with capacities of 1 hp and larger. Fractional horsepower motor loads shall be supplied from the 120 or 208 V distribution systems.

120/208 V 3 phase, 4 wire power shall be distributed to provide for 120 V receptacles, selected small motor loads, and general purpose equipment loads. The need for special purpose receptacles (208 V, 480 V, etc.) shall be determined during Title I design.

4.4.2 Emergency Power System

Emergency power shall be supplied from an existing emergency diesel generator set. Emergency power shall be distributed from the existing PCC switchgear to a new EMCC for FRP.

480 V emergency power shall be supplied to the off-gas induced draft fans, supply fans, HVAC equipment and other equipment essential to the safe shutdown of the processes and to the prevention of airborne contamination during commercial power outages.

One 120/208 V, 3 phase, 4 wire emergency panel shall be provided for exit lights, emergency lighting, fire protection and suppression systems, telephone system, selected incinerator and off-gas system controls, airlock doors, radiation monitoring equipment, and UPS charging system.

The existing emergency generator starts automatically upon loss of commercial power and the identified loads will be transferred to emergency power by means of an existing Automatic Transfer Switch (ATS). At present, the emergency generator and associated ATS can transfer and re-energize the entire TAN-607 emergency system load within 10 seconds after loss of commercial power.

The charging system for the UPS system shall be connected to the emergency power system by means of a manual transfer switch. This will allow for UPS battery recharging during prolonged commercial power outages.

4.4.3 Uninterruptable Power System (UPS)

Power for selected off-gas and other process controls, key process and off-gas monitoring instrumentation, and criticality control monitoring instruments shall be provided from a 120/208 V, 3 phase, 4 wire UPS.

Power for the process controller and data acquisition mini-computer systems shall be provided by an additional UPS unit furnished integrally with the computer system. All computer and associated peripheral equipment shall use special purpose receptacles which shall be electrically isolated from the commercial 120/208 V distribution system.

4.4.4 Instrumentation Power System

Instruments not supplied by the UPS shall be supplied with Instrumentation Power. Motor or inverter loads shall not be connected to Instrumentation Power.

Instrumentation Power shall be supplied from the new EMCC through an Isolation Type Transformer to a 120/208V, 3 phase, 4 wire power panel. All instrumentation power shall be hard wired or use special plugs for isolation from plant power.

4.4.5 Lighting

New lighting shall be required for all new construction areas within the FRP. New lighting systems shall utilize 120 V where practical. Local control lighting circuits shall be provided at all control station areas.

Emergency lighting shall be provided to ensure safe egress during power outages.

4.4.6 Grounding System

4.4.6.1 General. All structural steel contained within the FRP facility shall be bonded to the existing ground grid system of TAN-607.

The off-gas exhaust stack lightning protection system shall also be bonded to the TAN-607 building ground grid with additional local grounding as required.

All equipment shall be grounded in accordance with Article 250 of the NEC. Equipment ground wires shall be provided throughout.

4.4.6.2 Instrument Ground. An instrument ground bus shall be installed in the control room. The instrument ground shall be isolated from equipment grounds to the maximum extent possible. The instrument ground shall be bonded to the building ground grid at one location. This connection shall be removable to provide for trouble shooting and verifications of the grounding system.

4.4.6.3 Computer Ground. A computer ground bus shall be installed in the control room. The computer ground system shall be isolated from all equipment grounds to the maximum extent obtainable. The computer ground bus shall be connected to the building ground grid at one location as described for the instrument ground bus.

4.4.7 Communications Systems

An intercom and paging system shall be furnished to provide communications between the FRP control room and operator work stations and selected process areas.

The existing TAN-607 telephone system shall be expanded as required to provide service to the FRP areas. Telephone cabinets and conduit shall be provided as required. All telephone wiring to be done by others.

4.4.8 Closed Circuit Television (CCTV) System

As a minimum, the following process areas shall be monitored by a CCTV System. Additional systems shall be included as required:

1. Process System (~5 cameras)
2. Calcination Cell
3. Chemical Make-up Area
4. Sampling Vault

The CCTV camera control, monitor screen, and associated hardware shall be located in the main control room.

4.4.9 Evacuation Alarm System

The existing evacuation alarm system at TAN-607 shall be extended to provide coverage for the FRP process areas and offices. Evacuation system shall be completely independent of any other system.

4.4.10 Instrumentation and Controls

4.4.10.1 Operational Safety. Instrumentation and controls shall be provided for operational safety monitoring and control requirements as described in Paragraph 4.4.13.

4.4.10.2 Criticality Control. Criticality control methods shall be employed as described in Paragraph 4.5.

4.4.10.3 Process Control. Instrumentation shall be provided throughout the facility to control, monitor, and operate the process. All process control and alarm wiring and HVAC control wiring shall be designed such that affected equipment fails in a safe operating mode. The process instrumentation and control system will provide the following:

1. Monitor facility flows, temperatures, fluid levels, pressures, operating status, and other parameters, as required.
2. Provide alarms of existing or impending abnormalities in the system status.
3. Provide a means of controlling valves, motors, fans, heaters, coolers, and other process equipment required to operate the plant.
4. Provide local work station panels together with the main control console from which plant operations can be systematically performed.
5. All instrument signal transmission shall be electric or electronic to facilitate future computer expansion and interface for control and surveillance.

4.4.11 Process Controller (PC) System

The PC system shall be a computer based, integrated control system, including line printer/writer and interactive CRT/keyboards for operators, capable of remote and automated operation of the FRP. The PC shall have the capability to be interfaced with the instrumentation and control system. The PC shall also be interfaced with an override panel for manual operation of the FRP from the control room.

The PC shall be used to monitor and interface with the FRP system by means of analog inputs/outputs, contact transfer inputs, and digital control signal outputs. This input/output capability shall provide for monitoring and alarms of temperature, process flowrates, pressure, levels and operational status as well as interlocking controls of fans, motors, valves, temperature, and control system.

4.4.12 Data Acquisition System (DAS)

The DAS shall be a microprocessor based with real-time operating system capable of information processing and storage, and criticality data analysis. In addition, the DAS shall have the capability to be expanded to monitor and maintain historical data on selected process system parameters. These requirements will be investigated and determined during Title I design. DAS shall be furnished complete with operator interactive line printer/writer, graphics terminal, all necessary interactive CRT/keyboards, permanent copy magnetic tape storage and associated tape drive equipment, and peripheral communication interface capability.

4.4.13 Operational Safety Monitoring

4.4.13.1 Radiation Monitoring. All FRP areas and process flow streams will have an assumed established safe radiation level of operation. The source strength or safe radiation operating level in a process space will be set such that the design guide limit specified in the EG&G Safety Manual, Radiation Safety Section 5020 "Personnel Protection Guide" in surrounding occupied spaces will not be exceeded. Upper limit contamination levels will be established. There will be radiation and contamination detectors located throughout the FRP to ensure that these safe levels are not violated. Monitors will include the following:

1. Fixed filter air monitors.
2. Constant air monitors (CAM).

3. Portal monitors.
4. Off-gas monitors.
5. Large area detector.
6. Radiation area monitors (RAM).
7. Portable (hand-held) survey meters with alpha, beta, and gamma detection capability.
8. Criticality alarms.

4.4.13.2 Stack Monitoring System. An off-gas monitor shall be provided on the final filtered flow of the various off-gas streams and HVAC exhaust. An extraction probe will circulate stack gas through the off-gas monitor. The probe shall be sized to provide isokinetic sampling at stack design flowrate. The off-gas sampler will be a collection of samplers and analyzers that provide continuous monitoring for possible radiological and chemical contaminants in the gas flow stream. The monitor shall alarm if any of the possible constituents of the gas flow (alpha, beta-gamma, NO_x , SO_x , HCl, CO, CO_2 , or opacity/particulate) approach the predetermined limits.

4.4.13.3 Radiation Level Alarms. All radiation or other hazardous condition sensors shall provide alarms above established setpoint levels. The signal actuates alarms locally, in the control room, in the Health Physics Office, and in a post manned 24 hours a day.

4.5 Criticality Control Methods

Criticality control methods shall be provided for the FRP to protect the operational staff, other on-site personnel, and the public from

radiation hazards. Traditional and tested methods shall be employed to reduce the probability of a criticality and allow recovery from such an event.

4.5.1 Instrumentation and Alarms

Criticality alarms will be provided for each area or piece of process equipment identified as having the potential for a criticality event as the applicable codes require. Each piece of alarm equipment shall have alarms both in the local areas, the H.P. office, the control room, and a post manned 24 hours a day.

4.5.2 Geometrical Considerations

1. All piping and process equipment, where possible, will be designed to be geometrically favorably for both normal and credible upset conditions.
2. The shape of all tanks, vessels, conveying devices, shredders and other components shall be such that they can be easily cleaned to prevent accumulation of fissile bearing waste or residues.

4.5.3 Neutron Poisons

Neutron absorbing poisons may be employed throughout the FRP for criticality control. Where neutron poisons are used, provisions for their continuing presence shall be provided.

4.5.4 Operational Procedures

Operational procedures shall be established and approved which administratively control process conditions such as, concentrations, mass flows, etc. to prevent and anticipate unsafe conditions.

5. ALTERNATIVE DESIGNS

5.1 General

Sections 3 and 4 described a baseline Fuel Recovery Plant for installation in TAN-607. This section will give some alternatives to the baseline facility.

5.2 Process Alternatives

The process flowsheet described in Section 3 is a baseline flowsheet. This section examines alternatives to the baseline process.

5.2.1 Total Core Dissolution

Depending on the final state of the core material, it may be necessary to use hydrofluoric acid to completely dissolve the debris remaining after nitric acid dissolution of the uranium and plutonium. Dissolution would proceed as described in Section 3.2. The liquid containing most of the uranium and plutonium would be filtered and fed to the accountability tank. The debris and particulate material remaining in the dissolver, composed primarily of zirconium, along with the fines removed in the filter, would be treated with hydrofluoric acid until completely dissolved. The zirconium from the core structures complexes with fluoride ion (F^-) to form inextractable aqueous zirconium fluoride complex (ZrF_4^-). Nitric acid is added after the zirconium is complexed to dissolve any remaining uranium or plutonium. Aluminum nitrate is added to complex any remaining fluoride ion to prevent corrosion problems in subsequent stainless steel equipment. An insoluble heel composed of stainless steel components remains after the nitric acid leach. This heel is allowed to collect for several dissolution cycles and then is dissolved with sulfuric acid.

The solutions from total core dissolution are analyzed for uranium, plutonium and fission product accountability and then enter the first extraction cycle in the same manner as the fuel from the nitric acid dissolution step.

5.2.2 Alternate Process Flowsheet

Preliminary calculations show that an alternative process flowsheet based on centrifugal contactors will produce acceptable purification of the uranium and plutonium streams. The main advantage of this simplified system is that it will have lower capital and operating costs. Another important advantage is that the volume of liquid wastes generated using this alternate flowsheet would be reduced by approximately 80%. This process should be further investigated during conceptual design.

5.2.3 Alternate Methods of Processing Core Material

The previous two sections have described additions or alterations to the existing baseline flowsheet when fuel recovery is desired. Other alternatives exist for processing the core material. These alternatives are summarized in this section.

Three major alternatives or options exist for processing the core material. These are (1) the baseline process flowsheet as discussed in Section 3 with the variations presented above, (2) recovery of the uranium in the core at the Idaho Chemical Processing Plant (ICPP), and (3) no fuel recovery from the core. These major options are further divided into suboptions. The major options with their suboptions are discussed in the following sections.

5.2.3.1 Baseline Process Flowsheet. A large number of variations exist in the baseline process. These have been divided into the following two options.

5.2.3.1.1 Partial Dissolution of the Core. Processing in this option would begin by shredding the core. The shredded core would be dissolved and processed to recover the majority of the uranium and plutonium. The undissolved debris could be directly canned, melted into IEB or BSG, or mixed with cement for disposal as TRU waste. For this study, it was assumed that cement mixing would meet TRU waste repository requirements. High level liquid waste (HLW) would be melted into BSG. Final waste form design would be based upon HLW repository requirements which have not been issued at this time. This flowsheet could be modified to not recover plutonium at a reduced cost.

5.2.3.1.2 Total Dissolution of the Core. Processing in this option would begin by shredding the core. The shredded core would be totally dissolved to provide for total core fission product inventory and to recover the majority of the uranium and plutonium. The resulting liquid would be processed to remove the plutonium and uranium. The resultant HLW would be melted into BSG. Final waste form design would be based on HLW repository requirements which have not been issued at this time. This flowsheet could be modified to not recover plutonium at a reduced cost.

5.2.3.2 Uranium Recovery at ICPP. The Idaho Chemical Processing Plant (ICPP) will replace the present process line in the early 1990's. It is possible that the existing line could be used to process the core if some modification is made to the system. At this time, no formal agreements have been made with ICPP personnel but some modifications to the existing plant would be required in order to process the core. In all options, a new denitrator would be required to meet the baseline process time. New HLW tanks would be required to segregate commercial wastes from existing defense wastes. A melter for conversion of HLW to BSG would also be required. The ICPP process would not be able to recover plutonium without a substantial upgrade, which has not been addressed in this study. This project would not include decontamination and decommissioning the existing ICPP process line.

5.2.3.2.1 ICPP Processing. This option assumes that the core would be shredded at TAN-607 with all processing taking place at ICPP. The shredded materials would be transported to ICPP for dissolution and recovery of the uranium. Although not addressed in this study, some modifications to the fuel receiving facilities and the dissolvers at ICPP might be required for TMI materials.

5.2.3.2.2 ICPP Processing with Partial Dissolution at TAN. Processing in this option would begin by shredding core materials at TAN. The shredded material would be fed into a dissolver to remove most of the fission products from the uranium and plutonium. These liquids would be dried and shipped to ICPP for processing. The undissolved debris could be directly canned, melted into IEB or BSG, or mixed with cement for disposal as TRU waste. For this study, it was assumed that melting the debris would be used for a baseline. Alternative methods and cost factors may be reviewed during conceptual design. The final waste form would be required to meet TRU waste repository requirements which have not been issued at this time.

5.2.3.2.3 ICPP Processing with Total Dissolution at TAN. Processing in this option would begin with shredding core materials at TAN. The shredded material would be fed into a dissolver to totally dissolve the core materials. These materials would be dried and shipped to ICPP for processing.

5.2.3.3 No Fuel Recovery. Three options were investigated for the disposal of the TMI core without fuel recovery. The resulting wastes would not strictly meet the definition for High Level Waste, however this definition most closely approximates TMI core materials and was used as a baseline for this study. Final requirements have not been issued for a HLW repository; however, draft requirements were issued in September 1981. These draft requirements were used in this study.

5.2.3.3.1 Direct Disposal. Processing in this option begins with shredding the core materials. The resulting materials would be melted into BSG or IEB and placed into canisters. Mixing the shredded debris with cement might be an option that could be investigated during conceptual design.

5.2.3.3.2 Partial Dissolution of Core. Processing in this option would begin with shredding the core materials. These materials would be dissolved to remove most of the uranium, plutonium and fission products. The resulting liquid would be concentrated and placed in canisters as BSG or IEB. The waste form would be designed to HLW repository requirements. The undissolved debris would be mixed with cement for TRU repository disposal. Additional methods for disposal of debris such as direct canning of the material or melting into BSG or IEB may be included or studied during conceptual design.

5.2.3.3.3 Total Dissolution of Core. Processing in this option begins with shredding the core material. All this material would be dissolved. The resulting liquid would be concentrated and placed in canisters as BSG or IEB. The waste form would be designed to HLW repository requirements. The mixing of these materials with cement is a variation that might be reviewed during conceptual design.

5.3 Siting Alternatives

5.3.1 Relocation of the New Process Addition

The siting of the new process addition within the TAN-607 Warm Service Area has as an alternative the siting of the addition on the north side of the Hot Shop. The North Control Gallery could be used much the same as the South Control Gallery for process operations. The major difference would be that the new addition would be an exterior structure. The new addition would require a roof over the process make-up area and an area for

receiving and storage of process chemicals. A method of conveniently joining the new addition to TAN-607 from a personnel standpoint would be required to take advantage of the support facilities available in TAN-607.

5.3.2 New Facility

The construction of a new facility to house the FRP is an alternative to siting it within TAN-607. A new facility could be dedicated to FRP and would require the duplication of many of the features available in the Hot Shop.

6. OUTLINE SPECIFICATIONS

6.1 Architectural - Structural

6.1.1 Painting

6.1.1.1 Decontaminable Paint. Surfaces identified to receive decontaminable paint shall be painted with an epoxy based corrosion resistant paint. Surfaces shall be prepared and paint applied according to manufacturer's recommendations for the surface being painted.

6.1.1.2 Other Surfaces. Surfaces which are to be painted but not with decontaminable paint, shall receive one prime coat and two finish coats of enamel paint.

6.1.2 Structural Carbon Steel

Structural carbon steel will conform to ASTM A36. Fabrication and erection will conform to AISC "Specification for the Design Fabrication and Erection of Structural Steel Buildings."

6.1.3 Stainless Steel Liner Plate

Stainless steel liner plate will be 11 gauge chromium-nickel austenitic stainless steel conforming to the latest revision of ASTM A240 Type 304L. Plate on walls and floor coverings shall be seal welded.

6.1.4 Welding

Welding will conform to the applicable sections of the INEL Welding Manual.

6.2 Mechanical

6.2.1 Process Vessels

All vessels shall be designed and constructed in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1. Vessels shall be sized and constructed from materials appropriate to their service.

6.2.2 Mechanical Support Equipment and Systems

6.2.2.1 Eductors. Where possible, steam and air powered eductors shall be used in place of mechanical pumps for moving fluids from one process point to another.

6.2.2.2 Cranes and Manipulators. The existing cranes and manipulators in the Hot Shop shall be used.

6.2.2.3 Pipe and Fittings. Pipe and fittings for all process streams shall be welded or flanged and constructed of 304L stainless steel.

6.2.2.4 Valves. Valves where used on process lines shall be nuclear grade and match the pipe materials of construction.

6.2.2.5 Welding. Welding on piping systems shall be in accordance with applicable sections of the ASME Boiler and Pressure Vessel Code, ANSI B31.1, ANSI B31.3, and qualification in accordance with the INEL Welding Manual.

6.2.2.6 Fire Suppression. Fire suppression systems shall be installed. Sprinkler systems will be the wet pipe type and installed in accordance with NFPA No. 13. Halon systems shall be in accordance with NFPA No. 12A. Dry chemical systems shall be in accordance with NFPA No. 17. Metal-X systems shall include portable extinguisher bottles and fixed nozzles connected by quick connectors. The systems shall be in accordance with applicable sections of NFPA No. 10.

6.2.2.7 Pipe Insulation. Insulation on steam and condensate piping will be in accordance with ASHRAE 90-75 standards.

6.2.3 Ventilation and Off-gas Treatment System

6.2.3.1 HEPA Filters and Housings. HEPA filters shall be fluid sealed 24 in. x 24 in. x 11-1/2 in. deep with prefilters. HEPA shall remove 0.3 micron sized particles with 99.97% efficiency. Housings shall be designed and placed to facilitate filter bagout and DOP testing.

6.2.3.2 Supply and Exhaust Fans. Fans shall be standard industrial fans constructed of materials selected for their service.

6.2.3.3 Duct and Dampers. Ducts and dampers shall be sized to system requirements. Material of construction shall be selected to match their service.

6.2.3.4 Ventilation Control System. The existing TAN-607 HVAC shall be used where possible. New HVAC system shall be installed as required.

6.2.3.5 Off-gas Clean-up System. New off-gas treatment systems shall be installed for the following: vessel off-gas, dissolver off-gas, shredder off-gas, melter off-gas, and plutonium handling facility off-gas. These systems shall be sized and constructed from materials as determined by their service.

6.2.3.6 Off-gas Control Instrumentation. Off-gas systems shall be monitored for flow rate, temperature, and radiological and chemical content.

6.3 Electrical and Instrumentation

6.3.1 Electrical Basic Materials and Methods

6.3.1.1 Switchgear Circuit Breakers. Feeder circuit breakers shall be drawout air circuit breaker type, 3 pole, 480 V and be compatible with existing switchgear units.

6.3.1.2 Motor Control Center. The motor control centers shall be 277/480 V, 3 phase, 4 wire, 60 hertz, free-standing, dead-front, dead-rear, NEMA Class II, Type B wiring consisting of vertical sections containing copper phase busing, terminals, copper ground bus, wireways, and housing modular plug-in type equipment drawers behind interlocked hinged doors. The enclosures shall be NEMA 1. An individual, 480-120 V control transformer with secondary fuse shall be provided for each motor starter.

6.3.1.3 Panelboards. Panelboards shall be dead-front, totally enclosed, with NEMA 1 enclosure. Panelboards shall be equipped with main circuit breakers and shall conform to NEMA PB1 and UL 67.

Panelboards shall be rated 208-Y/120-V, 3 phase, 4 wire. Bolt-on circuit breakers shall be used. The assembled panelboard shall have a withstand rating not less than 10,000 amp RMS symmetrical at 120/208 V.

6.3.1.4 Uninterruptable Power Supply. The uninterruptable power system (UPS) shall be 120/208 volt, 3 phase, 60 hertz and sized as required. The frequency stability shall be 60 ± 0.6 Hz and the voltage regulation will be $\pm 1\%$. The UPS system shall consist of charger, 1/2 hour rated lead-calcium batteries with seismic design rack, inverter, static switch with manual bypass, and automatic synchronizing.

6.3.1.5 Conduit. All conduit systems shall be UL approved, rigid steel, zinc coated or 304L seamless stainless, Schedule 40 pipe. Flexible metallic conduit shall be liquid tight. Conduits shall be 3/4 in. minimum and identified as to voltage, phase circuit number, and whether supply is normal, emergency, UPS, or Instrument Power.

6.3.1.6 Wireways and Auxiliary Gutters. Wireways and auxiliary gutters used in dry locations shall be provided as required.

6.3.1.7 Manual Transfer Switch. Manual transfer switch shall be double throw safety switch, non-fused, NEMA 1 enclosure, service equipment rating with voltage, current rating and number of poles as required to accommodate the UPS.

6.3.1.8 Motors. Motors shall be of sufficient size for the duty to be performed. All motors shall have full nameplate horsepower available with a service factor of at least 1.0 at 5000 ft elevation and 1.15 at sea level. Unless otherwise specified, all motors shall be totally enclosed, and shall have a continuous duty classification based on a 40°C, ambient temperature of reference. Motors shall be the premium efficiency type. The motor insulation shall be Class F minimum. Two-speed motors shall be the two-winding type. Motors connected to the diesel generator emergency power shall be capable of starting on a voltage reduction of 20 to 30 percent.

6.3.1.9 Starters. Combination magnetic starters with 120 volt transformer and control shall be provided for 460 volt, 3 phase motors that are 1 hp through 150 hp, and manual starters shall be provided for all 115 volt, single phase motors smaller than 1 hp.

6.3.1.10 Wiring. Minimum wire size of power conductor shall be No. 12 AWG copper. Control conductors shall be No. 14 unless otherwise indicated. Wire size No. 10 AWG and smaller shall be solid, Type THHN or THHW, and wire size No. 8 AWG and larger shall be stranded with Type THHN or THHW insulation. Insulation types shall be as defined in NEC Article 310 and conductors shall bear the UL-listed label. All wiring shall be copper.

System ground conductors shall be sized per NEC Article 250 and as shown on the drawings. The conductors shall be bare, stranded, medium-soft drawn copper. Equipment grounding conductors shall be identified by a continuous green color. Instrument ground conductor will be a continuous green with yellow stripe directly connected to the instrument ground bus.

Lightning protection ground conductors shall be minimum No. 2 woven bare copper and bonded to building steel where practical.

6.3.1.11 Receptacles. Convenience outlets shall conform to NEMA Standard configuration 5-20R and shall be 3 wire, duplex, grounding type, 120 Vac, 20 amp.

Receptacles for 480 volt, 3 phase service shall be 30 or 60 amp, 4 pole, 4 wire type, combined with spring door and a non-fused, heavy-duty, inductive rated disconnect switch.

6.3.1.12 Safety Switches. Safety switches shall be the heavy-duty type, horsepower rated, with voltage, current rating, number of poles, and fusing as required. The enclosure shall be NEMA 1 for indoor devices.

6.3.1.13 Light Switches. Light switches installed for the control of lighting luminaires shall be heavy-duty, general purpose, UL approved devices.

6.3.1.14 Boxes and Fittings. Outlet boxes shall be rust-resistant, cast-iron alloy boxes with threaded hubs or bosses for conduit connection. Pullboxes and their covers shall be constructed of galvanized steel except boxes located in areas with stainless steel lining; these shall be water-tight, stainless steel, with threaded construction throughout, tapered, threaded hubs or bosses, threaded covers with suitable radiation-resistant gasket, and stainless steel fittings. Conduit fittings in areas with stainless steel lining shall be stainless steel.

6.3.1.15 Relays. Control relays shall be magnetically operated relays with 120 Vac coils, and contacts rated for applicable loads.

6.3.1.16 General Lighting. Commercial type recessed fluorescent luminaires with acrylic lenses and high power factor and energy saving Class P ballasts and F40 CW lamps shall be used in control room, change rooms, and offices. Ballasts shall not contain PCB capacitors. Industrial type, high temperature, fluorescent luminaires with upward component reflectors shall be utilized in the process equipment areas.

The emergency lighting shall be battery backed for 15 minute continuous operation.

6.3.1.17 Lightning Protection. Lightning protection shall be provided for the off-gas exhaust stack.

6.3.1.18 Intercommunication System. The intercom system shall consist of an expandable multi-channel locate/reply system. The system shall provide up to six channels for two-way voice communication, and up to six individual channels of voice locating, while serving a minimum of 20 stations. The intercom system shall be interconnected with the fire alarm with an override microphone position. The system shall be composed of a combination of multi-channel headset stations and sound reproducers, power supplies, power boosters, and all necessary wiring, conduit, junctions boxes and accessories required to provide a complete operating system.

6.3.1.19 Fire Alarm Detection System. The fire detection/alarm system shall include control panels, detectors appropriate to the type of fire/explosion condition postulated (rate compensated thermal, ionization, pressure sensing), initiating devices, annunciators, emergency "battery back-up" power supply, and conduit and wire for both fire alarm and equipment status supervision, all of which must be compatible with and can be connected to the existing INEL fire alarm system to form a complete operational system. The system(s) provided shall be UL listed or FM approved for that application.

6.3.2 Instrumentation

6.3.2.1 Portal Monitor The walk-through portals entering the FRP facility area are used to detect alpha emitting material and nuclear materials on personnel entering and leaving the area.

6.3.2.2 Continuous Air Monitor (CAM). These air monitors continuously monitor particulate matter collected on a filter and initiate an alarm signal when airborne contamination exceeds the predetermined level. These units monitor normally clean areas where there is a potential for contamination such as airlocks leading to process cells and work galleries.

6.3.2.3 Large Area Detector. Large area detectors will be located in airlock/change room entries to process cells and to every exit from the process area. These detectors will be used by personnel passing these check points to verify that they are not carrying and spreading contamination from controlled areas.

6.3.2.4 Radiation Area Monitor (RAM). These monitors measure the beta/gamma radiation from nuclear sources in the process area and initiate an alarm signal when radiation levels exceed the predetermined level.

6.3.2.5 Criticality Monitor. These units shall be used to monitor criticality in various places in the process stream, the calcination cell, sample gallery, the plutonium handling facility, and the liquid waste storage tanks. These areas will be continuously monitored by a detection system that employs a passive neutron sensor and beta-gamma sensor. Alarms will be provided when both the neutron detector and beta-gamma detector have reached pre-determined activity levels. This system provides for maximum reliability and personnel protection. Criticality monitoring equipment shall be selected during Title I design.

6.3.2.6 Stack Gas Monitor. The final exhaust flow in the stack shall be monitored for possible radiological and chemical contaminants.

Exhaust gas shall be extracted from the stack and circulated through the monitor. The extraction probe and piping shall be designed per ANSI N13.1 and sized to yield isokinetic flow into the probe when the flow in the stack is at the design flowrate. The probe shall be heat traced to maintain stack design temperature in the probe line.

The stack gas monitor is a collection of samplers and analyzers that provide continuous monitoring for radiological and chemical contaminants. If any of the possible constituents of the gas flow, radiological or chemical, approach the predetermined limits an alarm condition is provided.

6.3.2.7 Process Controller (PC) System. The PC shall be a computer based, controlling and monitoring system with a real-time operating system. The PC shall have adequate memory addressing and programming to accomplish the control and monitoring functions intended. The PC shall be furnished with all necessary software for real-time operating system and high-level language usage and shall have minimum input/output (I/O) capability for monitoring, alarms, setpoints, and process control information. Provisions to expand PC signal I/O capability shall be furnished. The PC system shall be furnished with line printer/writer and CRT/keyboard, both capable of providing interactive operator interface with the PC. The PC shall be furnished with integral power supply. All voltage conditioning equipment required shall be provided with the PC. Final PC configuration shall be determined during Title I design.

6.3.2.8 Data Acquisition System (DAS). The DAS shall be a microprocessor based information processing and storage system with real-time operating system. DAS architecture shall contain sufficient memory for CPU operations and programming capability intended. Memory to be non-volatile type or battery backed for 30 minutes. DAS memory requirements to be determined during Title I design.

DAS shall be provided with software for operating system and high-level language capability. In addition, software shall be provided for the following; peripheral communication support, mass storage support, I/O interface support, and real-time support. The DAS shall be furnished with interactive line printer/writer, interactive CRT/keyboards, graphics terminal, mass storage unit, DAS power supply, analog and digital I/O signal ports and associated signal conditioning equipment, and all necessary peripheral communication and I/O interface hardware.

6.3.2.9 Closed Circuit Television System (CCTV). The CCTV system for the process areas is made of the following--cameras, remote camera controls, viewing monitors, video switching unit, VTR, and all required mounting hardware. Cameras shall be continuous duty, radiation hardened, pan and tilt movement, zoom lens, with black and white image tube. Camera units shall be located in the various process areas. Viewing monitors, video switches, VTR, and remote camera controls shall be located in control room.

6.3.2.10 Control Room Control Panels. Control panels in the main control room shall be used for mounting and housing of control and monitoring devices for the FRP processing liquid radwaste system, off-gas system, ventilation, facility utility systems and the PC.

A panel shall typically contain the following equipment: CCTV monitor, CCTV camera controls, annunciator panel, control switches, indication lights, digital readouts, and recording equipment for indication of selected process parameters.

6.3.2.11 Local Control Panels. The local control panels shall be used for mounting and housing of control and monitoring devices required at local control work stations.

7. SAFEGUARDS AND SECURITY REQUIREMENTS

7.1 Operations

The Fuel Recovery Plant (FRP) is located in a section of building TAN-607 within the existing administratively controlled area of TAN/TSF. The TAN/TSF area is equipped with a perimeter fence, and a guardpost operated 24 hours/day by security guards controlling access/exit of personnel and vehicles. The guardpost is a portion of Building 601. Provisions are made there for all personnel authorized to enter the TAN/TSF area to obtain the required identification devices and/or health physics dosimetry badges. All personnel will be required to wear health physics dosimetry badges during working hours. Need to know access authorization passes and visitor credential check for access to the FRP are also provided at the existing guardpost.

The FRP will also be checked periodically by the TAN area security guard patrol presently provided which is on duty 24 hours per day. Control of materials entering or leaving the FRP area will be by direct inspection by the security guards at the Guardpost at TAN-601. Property removal and health physics permits will be required. Direct inspection and control of material at the FRP processing area will also be done by operating personnel.

All uranium and plutonium will be accounted for through analysis of the input, product, and waste streams. Periodic physical inventory verification will be conducted to determine system holdup and to obtain a material balance.

7.2 Construction

The construction site is within an "administratively controlled area" (TAN/TSF). Construction personnel will be required to have security identification badges only (normally button-type badges) which will be obtained through the established security documentation system.

Construction personnel will be restricted to the construction area and will be required to pass through the TAN Guardhouse monitors when entering or leaving TAN. Vehicles will be inspected by the guards at the Guardhouse.

The Subcontractor will be responsible to provide his own temporary construction trailer and fencing of equipment and materials.

7.3 Special Nuclear Materials Requirements

7.3.1 DOE Policy

It is the Department of Energy's (DOE) policy to account for all Special Nuclear Material (SNM) and to physically protect all SNM against theft or diversion. DOE Orders 5632.2, dated February 16, 1979, "Physical Protection of Special Nuclear Materials" and 5630.2, dated August 1980, "Control and Accountability of Nuclear Materials Basic Principles" are designed to facilitate effective safeguards and security systems through graded and performance evaluated accountability and physical protection requirements for SNM. The minimum standards have been designed to satisfy the policy requirement that the effectiveness of nuclear safeguards and security systems in DOE activities provide comparable effectiveness with that required of licensees by the Nuclear Regulatory Commission.

7.3.2 Provisions

The provisions of the above order apply to all elements of the Department of Energy, contractors, and subcontractors to the extent they possess SNM not subject to a Nuclear Regulatory Commission (NRC) license. The provisions of this directive, or the level of protection applied to SNM, may be reduced when one or more of the following conditions exist:

1. The SNM is not readily separable from other radioactive material and the combination of the SNM and other radioactive material delivers an external radiation dose of approximately 100 rems per hour or more at one meter from any accessible surface without intervening shielding material.

2. The SNM is contained in material that has been declared as waste.
3. The SNM is in a chemical, isotopic, or physical form or is within isolated in-process, or remote inaccessible, containment which provides comparably effective protection, to that specified herein, against malevolent use or theft.
4. Where the foregoing conditions exist, they should be specifically and clearly described in the facility safeguards and security plan to demonstrate a logical basis for the physical protection system provided. When material is to be shipped, it shall be the responsibility of the shipper to determine if any of these conditions exist. At certain facilities, a level of physical protection exceeding that specified herein may be necessary in order to assure a satisfactory level of integrated safeguards and security effectiveness.

7.3.3 Categories

DOE Order 5632.2 categorizes all SNM by type, quantity, and enrichment. Category III B quantities of SNM are as follows:

1. Uranium 235 (contained in uranium enriched to 20% or more in the isotope U-235) when the total of the U-235 content is one gram to 349 grams.
2. Plutonium and/or Uranium 233 when the plutonium and/or uranium 233 content is from one gram to 219 grams.
3. Uranium 235 contained in uranium enriched to less than 20% in the isotope U-235 in all quantities above 0.99 grams.

Category III B quantities of SNM shall be received, used, processed, and stored in accordance with operations office approved Safeguards and Security plans.

7.3.4 TMI-2 Core Description

Appendix A of the INEL Facilities Readiness Study, EG&G-TMI-5966-TBM-8-82, provides the parameters and description of the original as well as the present TMI-2 core.

Original core fuel was UO_2 , 2.57% average enriched, arranged in 177 fuel assemblies.

Present core fuel is 81,600 kg UO_2 and 160 kg Pu (induced or inbred Pu).

Radiation: 10^6 to 10^7 R/hr on contact (entire core)
 10^3 to 10^4 R/hr on contact (canisters)

Rubble Bed: Generally concluded that a large portion of the core is fragmented and the size of the fragmented particles would be a few millimeters and larger than dust-like.

Fuel Assemblies Intact: There is a theory that some intact fuel assemblies may exist at the periphery of the core.

Sections 1, 2, and 4, as described in Section 7.3.2 apply to the TMI-2 core examination program, i.e., 1 - greater than 100 R/hr at contact, 2 - physical form, and 4 - security plan.

7.3.5 TMI-2 Core Categorization

If the radiation field of the TMI-2 core material decays to less than 100 R/hr at one meter, the material will be defined as Category III B, due to less than 20% enrichment.

7.3.6 Plutonium

Recovery of the plutonium will require a Category I, II, or III facility depending upon the quantity present. The process and storage requirements for plutonium are set forth in DOE Orders 5632.2 "Physical Protection of Special Nuclear Materials" and 5631.1 "Physical Protection of Classified Matter." Plutonium is categorized by quantities and the quantity determines the degree of protection demanded. Protection will include requirements during transit. Conceptual design will determine the degree of plutonium recovery and the support facility requirements.

7.3.7 Nuclear Material Accountability

All nuclear material introduced into, held in, or discharged from the fuel recovery process as waste or product will be accounted for. This will be accomplished through the use of input, process, and waste stream accountability tanks, chemical analysis, neutron interrogation, sampling, and weighing. A closed material balance will be maintained for the process system and periodic physical inventory verification will be conducted. Exact methods for accomplishing this will be developed in Title I and Title II design.

8. PRELIMINARY SAFETY ANALYSIS

8.1 General

This section represents a preliminary safety analysis for the TMI-2 Fuel Recovery Plant (FRP) Feasibility study. A thorough safety analysis can be completed upon identification of the facility where the fuel recovery will take place, a description of the processes within the facility including the physical layout, process flow rates, construction and size of equipment and details of all operations within and related to the fuel recovery.

Preparation of a Safety Assessment Document (SAD) by the Technical Safety Support Division for the facility can be initiated during Title 1 Design. The SAD will include a detailed evaluation of the consequences of normal and abnormal operations. It will have an analysis of all processing equipment and safety-related systems for preventing or mitigating the consequences of abnormal events or accidents. The SAD will describe how the facility is in conformance with all applicable guides, codes, and standards. It will be demonstrated with reasonable assurance that the facility can be operated without undue risk to the health and safety of the public, facility and other INEL employees, and provide adequate provisions for the protection of property and the environment.

The FRP Feasibility Study is presently investigating options for processing fuel from TMI-2 at TAN-607. The options vary from the relatively simple task of storing the fuel canisters at TAN-607 and then shipping them to the ICPP for processing; to total dissolution of core materials, separating and recovering the uranium and plutonium, and converting the high level waste to borosilicate glass. The remainder of this preliminary safety analysis will address those criteria provided in the Department of Energy (DOE) Order 5481.1, "Safety Analysis and Review System". Much of the discussion will be of a general nature, such as listing of safety goals, until the facility becomes more defined.

8.2 Summary of the Safety Analysis

Possible abnormal operations, potential accidents, risk evaluation, hazard elimination, and accident amelioration related to fuel recovery have been discussed in this analysis. Further analysis by the Technical Safety Support Division will be required as the facility and its operations become defined. Experience at the INEL and elsewhere indicate that the consequences of the FRP during normal operations, credible accidents, and abnormal events will be found acceptable to management.

8.3 Description of the Site and Facility

The baseline site for the FRP Facility is Building-607 at the TAN/TSF area of the INEL. The facility design has not been specified.

8.4 Consequences of Normal Operations

Normal operations for the FRP have yet to be defined. The principal processes used in fuel recovery are described in the following subsections. The processes used to isolate uranium and plutonium are based on technologies that have been well established in many plant years of use. Some modifications of established practice may be made where consequent improved safety or end product quality can reasonably be expected.

8.4.1 Fuel Receipt and Storage

The technologies for handling and storing irradiated fuels in water basins are well established at the INEL. The water transfers the heat of radioactive decay from the fuel and protects operating personnel from gamma and neutron radiation emitted by the core material. The water can be kept clean by use of ion exchange and filtration systems.

The facility can be designed for transferring core material canisters from transport casks to the storage pool without immersion of the cask in the pool and with a minimum of radiation exposure to personnel. Surface contamination should not occur to the environs during transfers because of the very low limits of contamination allowed upon the core material containers before shipment from TMI.

8.4.2 Mechanical Processing of Core Material

Shredding of the core material will be necessary prior to chemical processing. This will be conducted in an enclosure to confine dust and blanketed in an inert atmosphere to avoid the possibility of zirconium combustion. A fraction of the krypton and iodine may be released during this process.

8.4.3 Dissolution

Most of the uranium, plutonium, and the fission products can be dissolved in hot nitric acid. Off-gases can be scrubbed with water in an oxygen blanket to convert the nitrogen oxides formed back into nitric acids. This minimizes the volume of the off-gases to be processed. Krypton, tritium, and iodine will evolve during any dissolution process. Most tritium is oxidized and will become part of the process water. All of the krypton will pass unretarded through iodine adsorbers and filters. The only iodine isotope present in any extent will be ^{129}I . The iodine content of any excess process water will be determined before it is evaporated or otherwise released to the environment.

8.4.4 Accountability

During processing, numerous accountability tanks and sampling systems will be employed to account for the special nuclear material.

8.4.5 Solvent Extraction

The well-established PUREX process can be used or adopted in modified form to isolate uranium and plutonium from each other and from other radionuclides. This process is based upon the selective extraction of uranium and/or plutonium from a 2-3 molar acid solution into an organic solvent which consist of 30 volume percent tributyl phosphate (TBP) in n-dodecane. Other radionuclides remain in the aqueous phase. The uranium-plutonium solvent is then scrubbed with a nitric acid solution to remove contaminants and then contacted by a dilute (<0.4 molar) solution of nitric acid to strip the products back into the aqueous phase. The uranyl nitrate can be thermally decomposed in a fluidized bed to form uranium trioxide.

8.4.6 Production of Borosilicate Glass and Iron Enriched Basalt

Process options listed for the FRP include the production of Borosilicate Glass (BSG) or Iron Enriched Basalt (IEB). High level waste has been converted to BSG and its physical and chemical properties have been studied by the Battelle Northwest Laboratory, Savannah River Plant, and at the INEL. Laboratory scale conversion of radioactive waste to BSG have been performed by EG&G Idaho. Studies have demonstrated the practicality of applying this process to an industrial process.

8.4.7 Auxiliary Operations

Auxiliary operations for safety and environmental protection include liquid and solid waste treatment, system decontamination off-gas treatment, maintenance of equipment and facilities, and monitoring of personnel and the plant for radioactive contamination.

8.4.8 Industrial Safety

The operations at the FRP will be similar to other facilities at the INEL where manufacturing, construction, fuel and nuclear waste storage, and reprocessing take place. The incident rate of accidents during normal

conditions and operations is a function of the safety awareness and training of the operating personnel and management, proper maintenance of equipment, and design of the plant. In order to minimize accidents all work shall be performed in accordance with established regulations in effect at the INEL, including but not necessarily limited to the safety and health regulations issued in ID-12044, "Operational Safety Design Criteria Manual," ID Appendix 0550 "ID Standard Operational Safety Requirements," and CFR 1910 OSHA Standards.

8.4.9 Radiation Safety

8.4.9.1 Radiation Exposure Control. To the extent practicable, sufficient shielding will be provided around radiation sources so that facility personnel can work in radiation intensities approaching ambient levels. Design features will be included to permit personnel to reduce their exposure by the use of such techniques as special tools, portable shields, or limited times of exposure in those operating areas where it is not practical to have sufficient shielding to reduce radiation fields to near ambient levels.

The exposure of facility personnel to ionizing radiation will be minimized by strictly limiting the time that they can spend in radiation fields.

Radiation dosimeters will be worn by all personnel in the facility. Radiation detectors with both visual and audible alarms will be located throughout the facility to monitor the levels of the radiation fields and contamination of the air.

In areas of high radiation operations will be conducted remotely using pneumatic, hydraulic, and electric systems to sense and control the operation. Process equipment in such areas will be designed to be maintained and replaced remotely. Equipment components that will probably require frequent maintenance will be located in readily accessible shielded enclosures.

Equipment will be designed such that radioactive contaminants can be chemically flushed sufficiently to permit personnel to approach such equipment without undue exposure to ionizing radiation.

Semi-remote maintenance techniques will be used to adjust, repair, or replace small equipment pieces such as valves and pumps in high radiation fields. Work will be accomplished by the use of long-handled tools or manipulators working through shields. Personnel entry will normally not be permitted in high radiation fields but may be possible after extensive decontamination and/or equipment removal.

Equipment with little or no surface contamination and very low levels of penetrating radiation may be contact operated and maintained. Protective clothing, respirator equipment, long-handled tools, and portable shields will be used as necessary to protect personnel.

8.4.9.2 Contamination Control. Removal of all equipment, containers, tools, etc. from potentially contaminated areas will not be permitted until contamination on the exterior surface has been measured and been shown to be less than specified limits. Contaminated items removed from process areas will be packaged before being transported to a decontamination or waste-handling area.

Personnel leaving a potentially contaminated area will pass through a change area where protective clothing can be changed and the absence of clothing and skin contamination can be confirmed. Personnel decontamination facilities will be provided for use as needed.

The movement of airborne radioactive particles and vapors from contaminated areas to clean areas will be minimized by passing the air through specially designed sorbent beds and/or HEPA filters. Maintaining sufficient air pressure differential to move air from clean areas into the contaminated areas, and moving personnel and equipment between clean and contaminated areas through airlocks designed to minimize the flow of air from contaminated to clean areas will significantly reduce the probability of contamination spreading through the facility.

Continuous air samplers and monitoring systems will be located throughout the facility. Local and central audio and visual alarms and recorders will be provided by these systems.

8.4.9.3 Criticality Prevention, Detection, and Response. Design features to be incorporated into the facility will be the prevention of a criticality, a monitoring and alarm system that will notify all personnel in the facility promptly in the event that a criticality occurs, provide clearly marked evacuation routes for rapid movement of personnel to reach a safe staging area, and provide a central location for the assessment of personnel safety.

The design of the facility will be such that at least two unlikely, independent, and concurrent equipment failures or changes must occur before a criticality accident is possible.

Criticality detectors will be located in areas where more than 700 g of ^{235}U or 450 g of Pu are routinely handled. The detectors will activate alarms locally, in the control room and in a post manned 24 hours a day. Instrumentation shall be such that the criticality can be located and monitored.

Process materials shall be able to be moved, diluted, or otherwise treated without personnel entry into areas where a criticality may occur.

8.4.9.4 Radioactive and Non-Radioactive Effluent Monitoring. The TMI-2 Fuel Recovery Facility will be designed to meet DOE Order 5480.1A, Chapter XI, "Requirements for Radiation Protection". Solid and liquid waste will either be temporarily stored or re-routed for processing. All gaseous effluents will be scrubbed and processed through HEPA filters prior to being discharged to the atmosphere. Radiological and nonradiological emissions, including SO_x , HCl, radioactive particulates, vapors, gases, and aerosols will be monitored and controlled to meet the State of Idaho, EPA, and DOE effluent standards. NO_x emissions will be monitored. The atmosphere emissions are controlled to meet appropriate standards at the TAN/TSF area and for the INEL boundary.

The facility will be designed, as a minimum, in accordance with the following standards for controlling the release of solid, liquid, and gaseous emissions to the environment:

1. National Ambient Air Quality Standards NAAQS, CFR Title 40, Protection of the Environment, Part 50.
2. DOE Order 5480.1.
3. American Conference for Government and Industrial Hygiene, ACGI.
4. Industrial Ventilation Manual for Recommended Practices.
5. Rules and Regulations for the Control of Air Pollution in Idaho, Department of Health and Welfare.
6. Secondary Treatment Information, CFR Title 40, Protection of Environment, Part 133.
7. Department of Transportation Regulations, CFR Title 49, Hazardous Materials Regulation.
8. ERDAM Chapter 0511, Radioactive Waste Management.

8.4.10 Fire Prevention, Detection, and Suppression

Features will be provided to prevent fires, detect fires should they occur, and extinguish fires that do occur. Detection devices will activate audible alarms and indicate the source of the alarm on annunciators at the appropriate control center. All fire suppression systems will activate automatically.

8.5 Accident Analysis

Abnormal events have been categorized as major and minor events. Minor events are those events which could release very small amounts of radionuclides outside primary confinement systems. Incidents in this category involve such occurrences as operational errors or single failures of a facility component or system. Major events are defined as those unplanned occurrences which could result in release of significant amounts of radioactive materials. The facility will be designed and operated such that minor events will be limited to the category of the anticipated events as described in Table 8.1. Major events will be limited to the definition of unlikely events as defined in Table 8.1. As described in Table 8.1 for each probability of occurrence there is an associated release limit which would result in specific exposures to anyone who would be located at the location of release or at the site boundary. The following definitions describe the three event categories:

Anticipated Fault--An abnormal condition which is expected to occur once or more during a plant lifetime due to an expected single fault.

Unlikely Fault--The abnormal conditions caused by a single fault which is not expected to occur during plant operation but which may occur due to the probabilistic nature of component failures.

Extremely Unlikely Fault--An abnormal condition of such low probability that no events of this type are expected to occur during a plant lifetime.

Preparation of the SAD during Title I design will demonstrate compliance of the Fuel Recovery Facility design with the proposed categories listed in Table 8.1.

TABLE 8.1 TMI-2 FUEL RECOVERY FACILITY DESIGN CRITERIA GUIDELINES

Type	Frequency of Occurrence (events/yr)	Annual Maximum Radiation Dose		Contamination Spread (20 dpm/dm ² Alpha) (200 dpm/dm ² Beta-Gamma)
		Dose (Rem Whole Body) On-Site	Off -Site	
Anticipated	1.0 to 0.1	3	0.05	Restricted to within the facility
Unlikely	0.1 to 0.001	5	0.50	Restricted to within the facility fenced boundary
Extremely	0.001 to 0.0001	25	5.0	Contamination beyond the facility fenced area and potentially off the INEL

8.5.1 Earthquake

The structural failure of the TAN-607 building during an earthquake could cause radioactivity to be released into TAN-607 and the atmosphere. TAN-607 was originally designed to UBC, Zone 2 guidelines. The structure is constructed to resist stresses produced by lateral forces, such as those caused by earthquakes or high winds. The INEL is classified as Seismic Zone 2 as defined by UBC. However, no earthquake considered destructive (Modified Mercalli Intensity--MMI IX or greater) has been recorded at INEL. The facility will not be designed to withstand collapse of the TAN-607 building.

In the event of a severe earthquake with an epicenter close to INEL, significant damage to the facility could be expected. Equipment and confinement failure could cause contamination spread throughout the facility. Release of radioactivity to the environment could occur. Future SAD activities will document the specific consequences.

8.5.2 Tornadoes

The INEL and State of Idaho in general are in an area where weather patterns are unfavorable for producing large, severe tornadoes. However, the most probable consequence of a tornado in the TAN area would be loss of electrical commercial power. Commercial power loss would cause no significant problem due to standby power at the facility.

If a tornado were to strike TAN-607 directly, it is likely that damage to the building would occur. In addition, some contamination spread may result from containers, process equipment, or confinement rooms punctured by missiles or breached by wind pressures. In addition to the structural considerations, the passing of a tornado across the facility can cause air flow to be reversed inside the core material area. Atmospheric pressure outside the building below that maintained in the controlled zones inside the facility could cause the spread of contamination beyond the fuel and core material processing areas. To prevent this, the processing rooms will be designed with airlocks and the HVAC systems will be designed with HEPA filters on the inlet air supply. Future SAD activities will document the specific consequences of a tornado accident.

8.5.3 Floods

The unique hydrological features of the area limit the production of flood waters to periods when frozen-ground conditions exist at nearby local slopes. In addition, flood control measures, consisting of low-level dikes, drainage or diversion ditches, emergency injection wells, and settling basins, have been instituted. Flood control provisions at TAN are expected to handle more than twice the estimated 100-year flood flow.

8.5.4 High Winds

Design of the Fuel Recovery Facility will be in accordance with the UBC wind requirements. Maximum wind gusts recorded at the INEL are below the design wind velocities prescribed in the UBC. In the event of an

unexpected high wind, the stack could fail or building TAN-607 could sustain damage. Neither case would release radiation or contamination to the atmosphere.

8.5.5 Explosion, Fire

An explosion of sufficient intensity to rupture a vessel would create an aerosol of the tank contents which, in the worst case, would fill the entire room. ORNL investigators have examined the nature of aerosols and estimated upper limit concentrations for both solid and liquid aerosols as a function of particle size. If the maximum size is assumed to be 30 microns (about the maximum size which could be suspended in the ventilation air), the corresponding upper limit concentration would be 10^2 and 10^7 mg/m³ for aerosols of liquids and solids, respectively. The upper limit concentration of 100 mg/m³ for liquids appears reasonable, as it approximates the concentration of a rain or drizzle. Caution must be used in applying the upper limit concentration of 10^7 mg/m³ for solids, since solids spread uniformly throughout a cell at this concentration would generally represent more material than is available for dispersal. For explosions in vessels containing solids, a more logical basis for the aerosol concentration would be a determination of the amount of solids smaller than 30 micron which are available for suspension in the ventilation air.

The behavior of non-volatile radionuclides in a fire can be expected to parallel that of other non-volatile materials, e.g. metals, ceramics, etc., mixed with the combustible material. In trash or rubbish fires, these nuclides would be entrained roughly in proportion to the amount of fly ash produced. An upper limit to the production of fly ash is estimated to be less than 30 pounds per ton of refuse (1-1/2 percent of the burned material) from incinerator experience. Of the fly ash, most (~80 percent) is reported to be larger than 5 μ . Thus, an assumption that 5 percent of the burned material, with the associated radionuclides, is carried to the filter system would be conservative.

Zirconium fires within the facility could involve fines and bulk pieces mixed together. Because of its pyrophoricity zirconium powder in bulk quantities can burn rapidly; a highly concentrated aerosol could be expected in such a case. Solid pieces of zirconium, however, burn more slowly. As in the case of plutonium, only a small part (~1 percent) becomes airborne, mostly in a particle size range below 5 μ .

As burning zirconium becomes very hot, volatilization of radionuclides can be expected. No measurements of radionuclide releases from burning zirconium cladding have been reported.

Solvent fires tend to concentrate non-volatile components in the unburned residue. The entrainment of non-volatile radionuclides is assumed to be one percent of that in the burned solvent.

The consequence of a serious fire could range from damaging or destroying essential equipment resulting in operations delays to the destruction of an entire confinement area. Future SAD activity will more fully assess the consequences of a release to the environment and damage to the facility from a postulated fire.

8.5.6 Criticality

The general philosophy for criticality control in the facility is to maintain fissile material concentrations below safe limits for the different areas and processes. An inspection and measurement program will be used to verify that unexpected build-up of TRU to a level that might make a criticality accident credible is essentially precluded.

However, a criticality accident, while not credible, can be postulated. A release of fission gases to the environment would result and exposure to operators could be severe. Physical damage in equipment would be minimal. Future SAD activity will address the consequences and preventative measures for a criticality accident.

9. ENVIRONMENTAL EVALUATION

9.1 General

Preliminary evaluations of the environmental impact of the TMI-2 Fuel Recovery Plant (FRP) indicate an Environmental Assessment (EA) will be required for construction and operation. The EA would be required to comply with the National Environmental Policy Act (NEPA) process.

9.2 Requirements

Requirement of an EA is anticipated due to, but not limited to, the following reasons:

- o Based on the information provided, there could be significant radiochemical impacts on the environment from the operation of the facility (e.g., permissible gamma concentrations in air for some substances are exceedingly low).
- o Although the proposed project will not involve new construction of a facility, it will require major modification to an existing facility.
- o The proposed project will involve components of a commercial reactor and the TMI incident as a whole is already of public concern.

9.3 Document Definition

Per DOE Order 5440.1B (May 14, 1982), an Environmental Assessment is defined as a NEPA document which assesses whether a proposed action is a "major Federal action significantly affecting the quality of the human environment," and which serves as the basis for a determination as to whether an Environmental Impact Statement (EIS) is needed.

If the funding for the proposed action is approved by Nuclear Energy Projects at DOE Headquarters, the sequence of actions necessary for environmental compliance should be as follows:

1. A meeting should occur as early in the planning process as possible to establish a plan of action for environmental compliance. In attendance should be appropriate representatives from the Project and Systems Engineering Office, the Operational Safety Division at DOE-ID, and the Environmental Sciences Branch of the Earth and Life Sciences Office. A mutually-agreeable plan should be documented from this meeting.
2. A preliminary environmental assessment should be prepared by Environmental Sciences personnel. Adequate information should be available to include in the document a concise description of the proposed action, location of the proposed action, and potential environmental problems. That document will be submitted to DOE-ID for review.
3. DOE-ID will make recommendations on the required level of environmental documentation to DOE Headquarters.
4. DOE Headquarters will consider the recommendation and render the decision on the level of environmental documentation required, either an EA or EIS.

10. QUALITY ASSURANCE PROVISIONS

10.1 General

The TMI-2 Fuel Recovery Plant (FRP) will implement a quality assurance program which conforms to the requirements of ANSI/ASME NQA-1-1979 "Quality Assurance Program Requirements for Nuclear Power Plants." This standard provides general requirements and guidance pertaining to such activities as design, procurement, fabrication, handling, shipping, storing, testing and documentation which affects the quality and credibility of programs, processes, structures, systems, and components.

10.2 Quality Assurance Program

EG&G's Quality Assurance Program, which is documented by the EG&G Quality Manual, satisfies the requirements of ANSI/ASME NQA-1-1-1979.

EG&G has implemented this Quality Assurance (QA) Program to ensure that all facilities and equipment designed, procured, and produced by EG&G or its subcontractors will be safe, reliable, and cost effective. The Program also ensures that the Company will produce data consistent with QA standards.

This Program is a management system that establishes and implements controls for planning and performing tasks so that adequate products, technical services, and data are consistently achieved. The QA Program, consisting of 19 elements, identifies the responsibilities of organizations performing quality-related activities and requires each program or project to further identify reviews that must be conducted by service or support organizations before tasks are approved and completed.

Some of the major elements of this QA Program are:

Organization--identification of the structure and responsibilities of organizations involved in quality-related activities.

Design Control--control of design analysis, review, design qualifications testing, approval, release and changes.

Control of Instructions, Procedures, and Drawings--control of instructions, procedures, and drawings, including planning the work package to integrate quality requirements during fabrication, construction, maintenance and inspection.

Document Control--control of all types of quality-related documentation including special control measures for computer code configuration and computer code analysis.

Control of Purchased Material, Equipment, and Services--control of purchased material, equipment, and services; evaluation of suppliers and planning for procurement inspection.

Control of Special Processes--control of special processes such as heat-treating processes, cleaning, and welding and brazing materials; and certification of welding personnel and nondestructive examination personnel.

Test Control--control of testing, test data review and certification of operational readiness.

Measurement Control--measurement control including calibration procedures and intervals, definition of systems, devices for indicating calibration status, handling and use of measuring devices, the system for recalling measurement devices for maintenance and calibration, and requirements for traceability to standards set by the National Bureau of Standards.

Handling, Packaging, Preservation, Storage and Shipping--control of handling, packaging, preservation, storage, and shipping of procured or manufactured items.

Inspection, Test, and Operating Status--indications of quality status of items through inspection and testing, and indications of the operating status of facilities.

. Quality Records--identification and control of quality-related records to be generated, updated, collected, and retained so they can be readily retrieved.

Quality Audits--requirements for performing audits of quality-related activities in order to determine compliance with and effectiveness of the QA Program.

Each major program or project Quality Program Plan tailors the elements of the QA Program to its specific needs and ensures that adequate and appropriate quality assurance requirements are implemented.

The QPP:

- o Serves as the top Quality document for the program or project.
- o Identifies the applicable Company quality-related policies and procedures.
- o Described implementation procedures.
- o Identifies the responsibilities of the performing organizations.

The authority for a program or project to deviate from the requirements of the Quality Manual or to impose additional requirements is documented in the QPP. The Quality Division reviews and concurs with all QPPs or changes to them before they are implemented.

The specific details for the FRP program will be further defined and documented in a Quality Program Plan (QPP) specific for this project.

Project Management is responsible for the preparation and release of the Quality Program Plan.

11. COST ESTIMATE SUMMARY

11.1 Baseline Cost Estimate

The following cost estimate was obtained for the baseline TMI-2 Fuel Recovery Plant (FRP).

Facility Total Cost		40,000,000
Engineering Design and Inspection	3,100,000	
Construction and Equipment	24,333,000	
Project Administration	500,000	
Contingency	12,067,000	
Operations Total Cost		24,000,000
Cold Testing Labor	800,000	
Processing Labor	12,600,000	
Move In-Move Out and Decontaminate	1,500,000	
Processing Material and Disposal	4,000,000	
Contingency	5,100,000	
Program Management		4 ⁶ ,000,000
Management Team	600,000	
Conceptual Design	2,500,000	
R&D Activities	1,400,000	
Contingency	1, 0 ⁵ ,000,000	
Total Program Cost		<hr/> 70,000,000

11.2 Cost Estimates for Processing Alternatives

With the estimate for the baseline FRP as a reference, costs for alternative process system were developed. Cost for those alternatives as developed in Section 5 are as follows.

Section 5.2.3.1.1	"Partial Dissolution of the Core" (baseline) with plutonium recovery	\$70,000,000
	without plutonium recovery	\$63,000,000
Section 5.2.3.1.2	"Total Dissolution of the Core" with plutonium recovery	\$72,000,000
	without plutonium recovery	\$65,000,000
Section 5.2.3.2.1	"ICPP Processing"	\$60,000,000
Section 5.2.3.2.2	"ICPP Processing with Partial Dissolution at TAN"	\$73,000,000
Section 5.2.3.2.3	"ICPP Processing with Total Dissolution at TAN"	\$75,000,000
Section 5.2.3.3.1	"Direct Disposal"	\$32,000,000
Section 5.2.3.3.2	"Partial Dissolution of Core"	\$38,000,000
Section 5.2.3.3.3	"Total Dissolution of Core"	\$40 000,000

12. FEASIBILITY CONCLUSIONS AND RECOMMENDATION

12.1 Conclusions

This feasibility study has addressed a baseline plant for the processing and recovery of TMI-2 nuclear core material to be sited in the INEL TAN-607 Hot Shop. A baseline process for recovering the uranium and plutonium from the core has been discussed, along with several alternatives to the baseline process. Safety, siting, and security issues have been addressed, and preliminary cost estimates have been obtained.

The feasibility study has shown that the proposed plant is technically and economically feasible. Calculations show that the plant would achieve satisfactory recovery and purification of the nuclear core materials. The estimated total capital and operating costs of the plant as established by this study are within 10% of the estimated value of the recovered uranium and plutonium.

12.2 Recommendations

It is recommended that a conceptual design be initiated immediately covering the shredder and waste disposal processes. Together with mass balance data acquisition and core debris disposal, the above two subsystems are appropriate to overall program objectives. If recovery of the fuel is determined to be desirable the conceptual design can be expanded to include the additional processing subsystems.

APPENDIX A

The composition, activity and decay heat of the TMI-2 fuel inventory were estimated using the point isotopic generation and depletion Code ORIGEN2.⁽¹⁾ The radioisotopic concentrations in the core were determined for March 1985 and 1987. Table A1 lists radioisotopes for 1985 as a concentration of startup uranium weight. In general, isotopes with a concentration less than 10^{-10} curies per gram were not considered. However, an exception was made for zirconium and niobium. The removal of these isotopes in fuel processing is less efficient than most other isotopes and they were retained to insure sufficient removal. Krypton 85 was deleted from the list and it was assumed that they were either released during the accident or during the dissolution of the core.

A significant quantity of Tritium, strontium and cesium isotopes are known to have been released to the reactor coolant. However, this list assumes that all these isotopes are retained in core materials.

A significant quantity of activation isotopes were produced in the operation of TMI-2. However, an assessment of those isotopes has not been completed and are not included in Table A1.

Ref: 1. A. G. Croff, ORIGEN2--A Revised and Updated Version of the Oak Ridge Isotope Generation and Depletion Code, ORNL-5621, July 1980

TABLE A1

TMI FUEL PROCESSING FISSION PRODUCT RADIOISOTOPIC CONCENTRATION

<u>Isotope</u>	Concentration
	$\frac{(Ci/g)^{(a)}}{(b)}$
H 3	3.6(-5)
Sr 90	8.0(-3)
Y 90	8.0(-3)
Zr 95	4.8(-11)
Nb 95	1.1(-10)
Nb 95m	3.5(-13)
Tc 99	1.4(-6)
Ru 106	6.6(-4)
Rh 106	6.6(-4)
Ag 110m	7.1(-8)
Cd 113m	2.7(-6)
Sn 119m	8.4(-8)
Sn 123	8.9(-9)
Sb 125	3.4(-4)
Te 125m	8.3(-5)
Te 127	3.4(-9)
Te 127m	3.6(-9)
Cs 134	2.8(-4)
Cs 137	9.0(-3)
Ba 137m	8.5(-3)
Ce 144	1.4(-3)
Pr 144	1.4(-3)
Pr 144m	1.7(-5)
Pm 147	7.9(-3)
Sm 151	1.3(-4)
Eu 152	5.4(-7)
Eu 154	6.2(-5)
Eu 155	1.7(-4)
Th 231	4.8(-8)
Th 234	3.3(-7)
Pa 234m	3.3(-7)
Am 241	1.8(-5)
Cm 242	5.7(-9)
Total	4.7(-2)

----- of uranium at TMI startup.

thesis are powers of 10.

APPENDIX B

Table B1 lists the major element of the TMI reactor core expected to be processed by this unit if the core is to be totally dissolved. The structural components are based upon TMI FSAR and NSAC-25 for configuration and weights. The element distribution was developed from commercial specifications for individual metals. The gadolinium and uranium from experimental fuel rods and Boron Carbide and Aluminum of the Burnable Poison Rods (BPR) were not included since relative concentration was not known. The total weight of pellets in Gd_2O_3 and UO_2 was 132 kilograms.

The total weight of BPR pellets was 626 kilograms of B_4C and Al_2O_3 .

The oxides were not included in this assessment. The core has had severe damage and has probably oxidized a significant portion of the metallic components. Further information on oxides should be developed as the core is removed from the reactor.

The fission product weights listed in Table B1 were based upon ORIGEN2 calculations. To be consistent with the structural components, oxides were not included and UO_2 of the fuel, for example, has been converted to and listed as elemental uranium.

TABLE B1
TMI TOTAL ELEMENT DISTRIBUTION (a)

Element	Atomic Number	Structural Components (g)	Fission Products (g)	Total (g)
C	6	3.63(3) ^(b)	--	3.63(3)
Mg	12	9.09(4)	--	9.09(4)
Al	13	1.86(3)	--	1.86(3)
Si	14	5.77(4)	--	5.77(4)
Ti	22	1.23(3)	--	1.23(3)
Cr	24	8.64(5)	--	8.64(5)
Mn	25	1.23(3)	--	1.23(3)
Fe	26	3.12(6)	--	3.12(6)
Ni	28	4.70(5)	--	4.70(5)
Cu	29	2.45(4)	--	2.45(4)
Ge	32	--	5.81(0)	5.81(0)
As	33	--	1.75(0)	1.75(0)
Se	34	--	5.07(2)	5.07(2)
Br	35	--	2.00(2)	2.00(2)
Rb	37	--	3.44(3)	3.44(3)
Sr	38	--	8.28(3)	8.28(3)
Y	39	--	4.60(3)	4.60(3)
Zr	40	2.43(7)	3.28(4)	2.43(7)
Mo	42	--	2.77(4)	2.77(4)
Tc	43	--	7.00(3)	7.00(3)
Ru	44	--	1.48(4)	1.48(4)
Rh	45	--	4.27(3)	4.27(3)
Pd	46	--	4.46(3)	4.46(3)
Ag	47	2.50(6)	2.65(2)	2.50(6)
Cd	48	1.45(5)	4.16(2)	1.45(5)
In	49	4.70(5)	5.77(1)	4.70(5)
Sn	50	3.68(5)	6.15(2)	2.69(5)
Sb	51	--	1.73(2)	1.73(2)
Te	52	--	3.41(3)	3.41(3)
I	53	--	1.65(3)	1.65(3)
Cs	55	--	2.20(4)	2.20(4)
Ba	56	--	1.22(4)	1.22(4)

Element	Atomic Number	Structural Components (g)	Fission Products (g)	Total (g)
La	57	--	1.03(4)	1.03(4)
Ce	58	--	1.98(4)	1.98(4)
Pr	59	--	9.54(3)	9.54(3)
Nd	60	--	3.42(4)	3.42(4)
Pm	61	--	7.01(2)	7.01(2)
Sm	62	--	6.76(3)	6.76(3)
Eu	63	--	4.81(2)	4.81(2)
Gd	64	--	1.96(2)	1.96(2)
Tb	65	--	8.09(0)	8.09(0)
Dy	66	--	3.68(0)	3.68(0)
Hf	72	2.50(3)	--	2.50(3)
W	74	2.45(4)	--	2.45(4)
U	92	--	8.16(7)	8.16(7)
Np	93	--	1.61(3)	1.61(3)
Pu	94	--	1.61(5)	1.61(5)
Am	95	--	4.40(2)	4.40(2)
		<u>3.24(7)</u>	<u>8.21(7)(C)</u>	<u>1.15(8)</u>

(a) Table does not include noble gases. Oxide components of elements are also not included due to unknown distribution inside the core.

(b) Numbers in parenthesis are powers of 10.

(c) Total fission products without uranium and plutonium is 2.78(5) grams.

161.000 kg

APPENDIX C

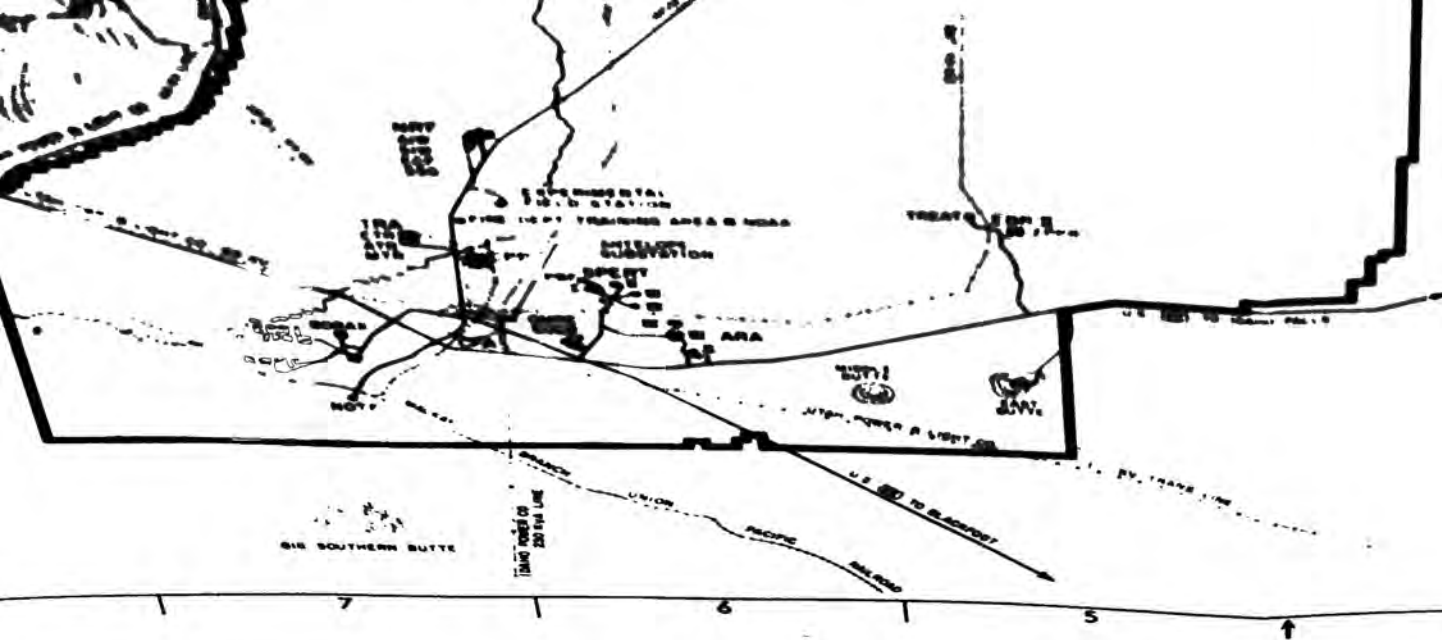
Table C1 lists the value of the mass flowrates for the various chemical species as calculated by SEPHIS. The values given are calculated for a 1000 day, 90% load factor to give a basis of 23652 hours of processing time.

These values are calculated assuming perfect separations in the extractor equipment, no back extraction, or non-idealities due to equipment geometry. Fission product distributions were calculated using data from the PUREX Technical Manual.

TABLE C1
MASS BALANCE - RESULTS

STREAM DESIGNATION	Component Flowrate (g/hr)										
	$\text{UO}_2(\text{NO}_3)_2$	$\text{Pu}(\text{NO}_3)_4$	$\text{Zr}(\text{NO}_3)_4$	$\text{Ru}(\text{NO}_3)_3$	Other FP	HNO_3	H_2O	$\text{Gd}(\text{NO}_3)_3$	TBP	n-C12	Other
①	5720.66	13.93	5.16	1.77	12.02	1400.53	5743.75	145.49	0.00	0.00	0.00
1AF	5720.66	13.93	5.16	1.77	12.02	1829.85	9843.95	145.49	0.00	0.00	0.00
1AS	0.00	0.00	0.00	0.00	0.00	1135.16	5351.01	0.00	0.00	0.00	0.00
1AX	0.00	0.00	0.00	0.00	0.00	15.50	0.00	0.00	11076.05	19937.35	0.00
1AP	5712.97	13.91	6.11E-6	1.26E-15	4.10E-18	504.31	0.00	4.96E-17	11076.05	19937.35	0.00
1AW	7.69	0.02	5.16	1.77	12.02	2456.08	15194.96	145.49	0.00	0.00	0.00
1BX1	0.00	0.00	0.00	0.00	0.00	756.24	29600.75	0.00	0.00	0.00	0.00
1BX2	0.00	0.00	0.00	0.00	0.00	24.01	38023.80	0.00	0.00	0.00	0.00
1BP1	3705.33	13.91	6.11E-6	1.26E-15	4.10E-18	1153.89	29657.59	4.96E-17	0.00	0.00	0.00
1BP2	2007.63	6.18E-4	2.71E-10	5.60E-20	0.00	129.65	37966.96	0.00	0.00	0.00	0.00
1BW	5.66E-3	0.00	0.00	0.00	0.00	1.02	0.00	0.00	11076.05	19937.35	0.00
⑨	0.00	0.00	0.00	0.00	0.00	0.00	58133.50	0.00	0.00	0.00	0.00
⑩	5712.96	13.91	6.11E-6	1.26E-15	4.10E-18	1203.54	9491.05	4.96E-17	0.00	0.00	0.00
2AF	5712.96	13.91	6.11E-6	1.26E-15	4.10E-18	1874.85	9973.29	4.96E-17	0.00	0.00	0.00
⑪	0.00	0.00	0.00	0.00	0.00	591.31	482.24	0.00	0.00	0.00	0.00
2AS	0.00	0.00	0.00	0.00	0.00	1135.16	5351.01	0.00	0.00	0.00	0.00
2AX	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11076.05	19937.35	0.00

STREAM DESIGNATION	Component Flowrate (g/hr)										
	$\text{UO}_2(\text{NO}_3)_3$	$\text{Pu}(\text{NO}_3)_4$	$\text{Zr}(\text{NO}_3)_4$	$\text{Ru}(\text{NO}_3)_3$	Other FP	HNO_3	H_2O	$\text{Gd}(\text{NO}_3)_3$	TBP	n-C12	Other
2AP	5706.42	13.90	7.23E-12	0.00	0.00	504.80	0.00	0.00	11076.05	19937.35	0.00
2AW	6.54	1.30E-2	6.11E-12	1.26E-15	4.10E-18	2520.71	9973.29	4.96E-17	0.00	0.00	0.00
2BX	0.00	0.00	0.00	0.00	0.00	1173.61	5532.40	0.00	0.00	0.00	$\text{Fe}(\text{NH}_4\text{SO}_3)_2$ 14.15
2BP	201.41	$\text{Pu}(\text{NO}_3)_3$ 12.13	7.23E-12	0.00	0.00	1107.60	5532.40	0.00	0.00	0.00	Fe salts 14.15
2Bu	5505.01	9.53E-14 (9.7E-9 ppb)	2.70E-20	0.00	0.00	570.81	0.00	0.00	11076.05	19937.35	0.00



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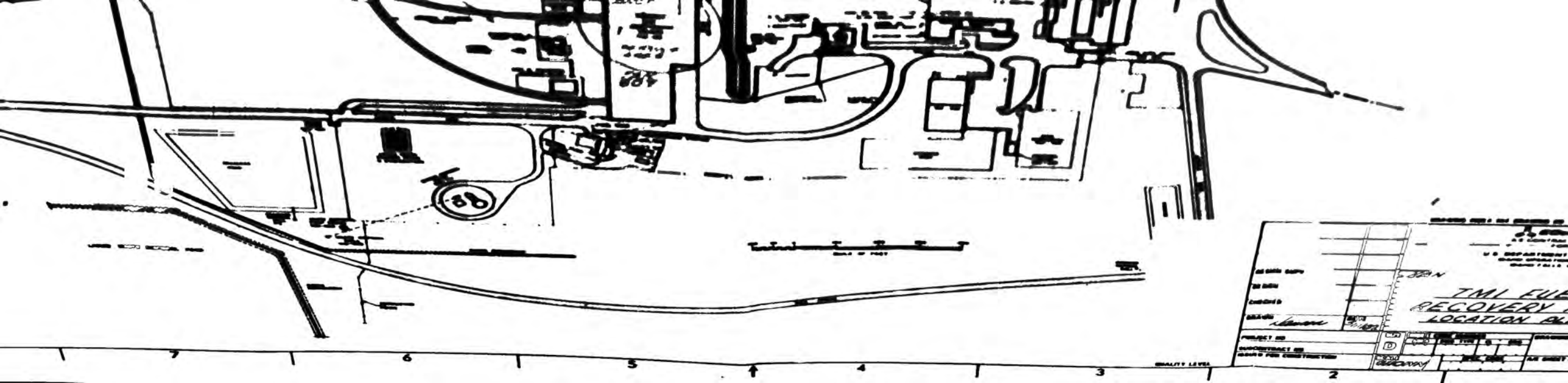
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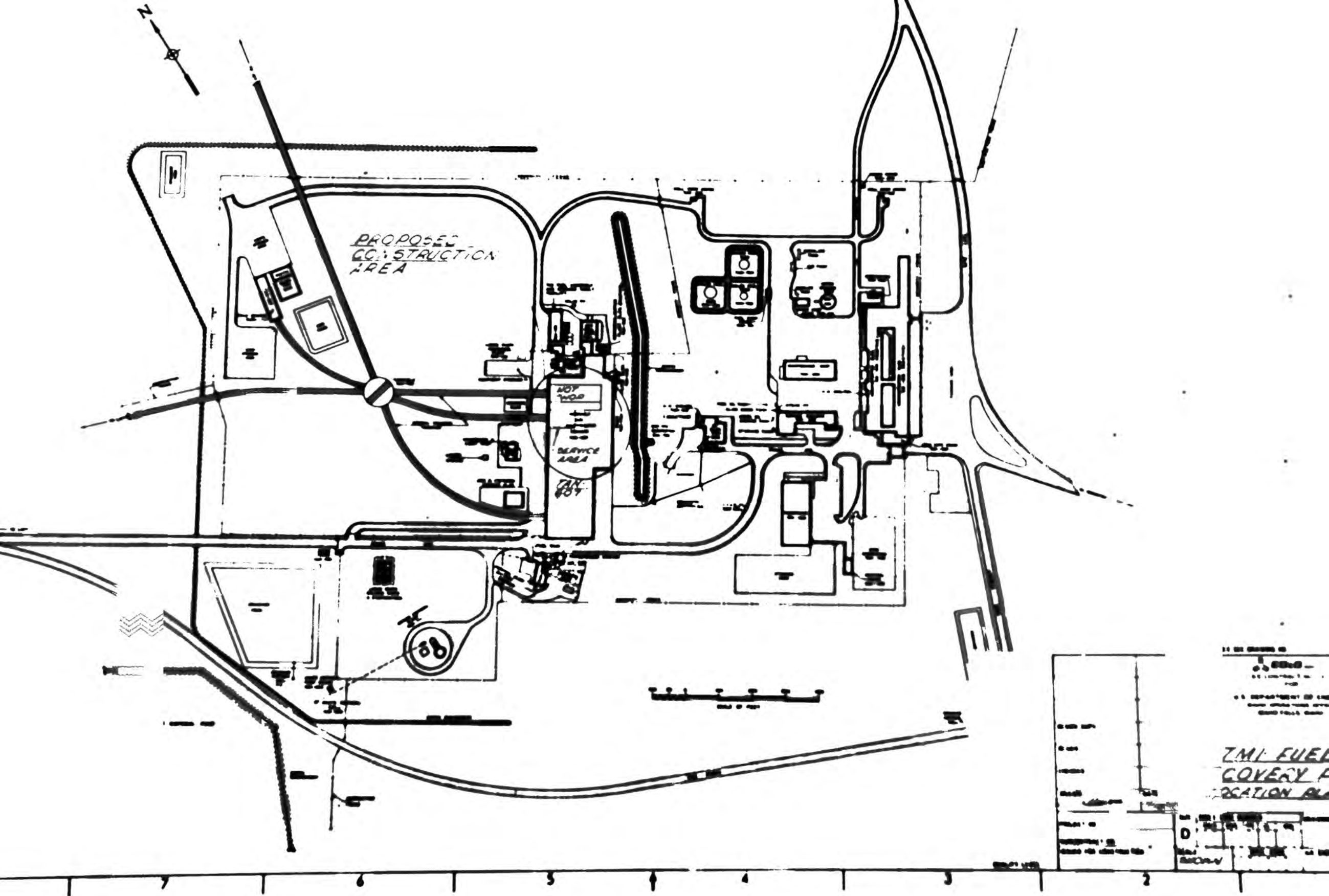


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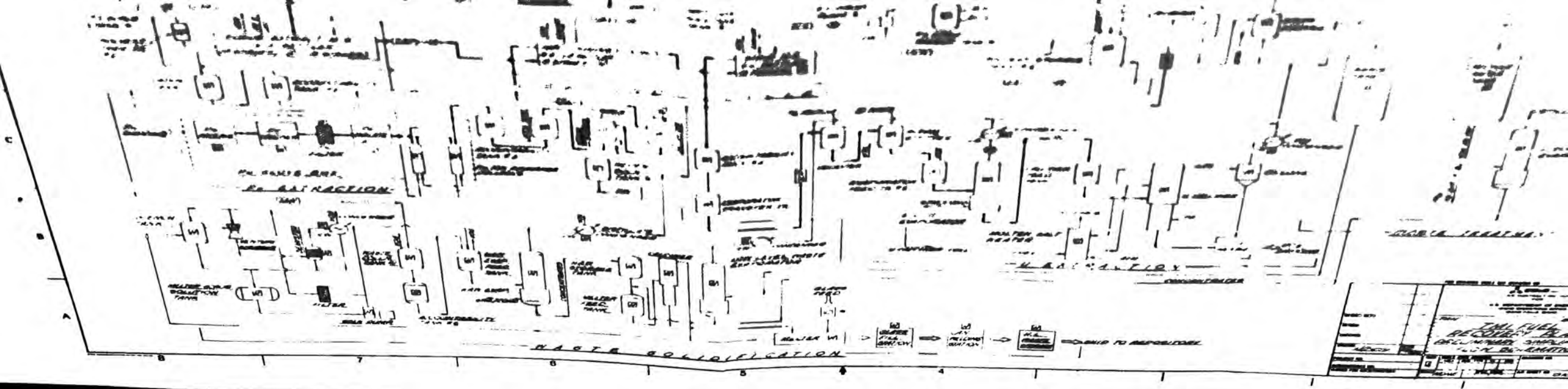
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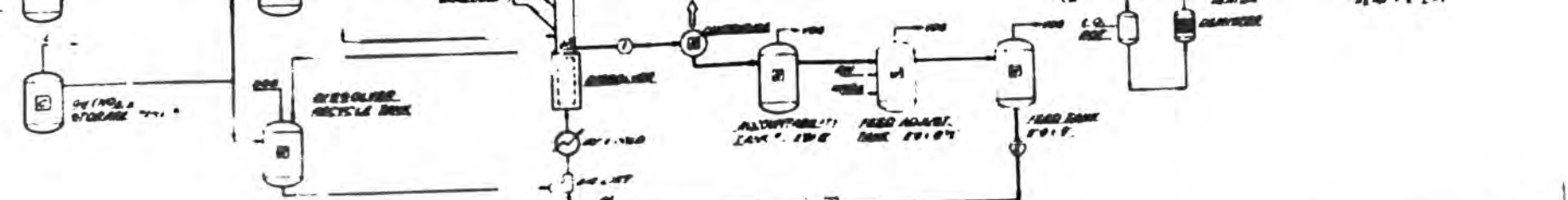
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ENGINEERING CENTER
FORT BELLEVILLE, ILLINOIS

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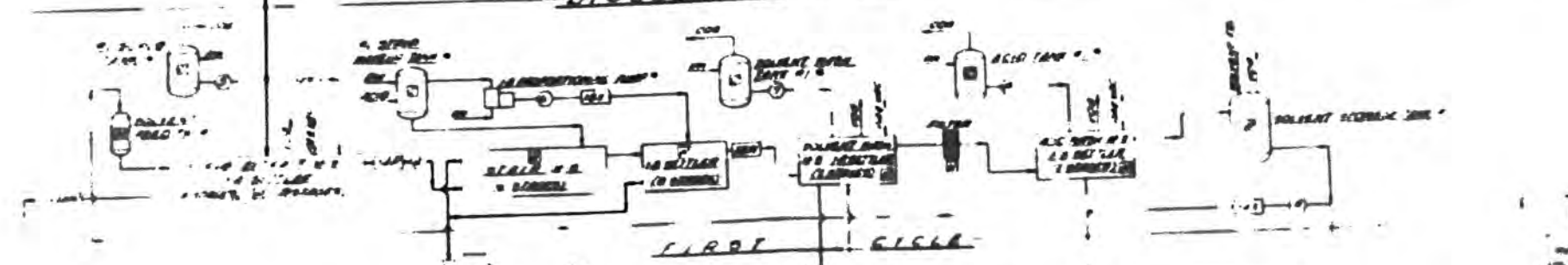


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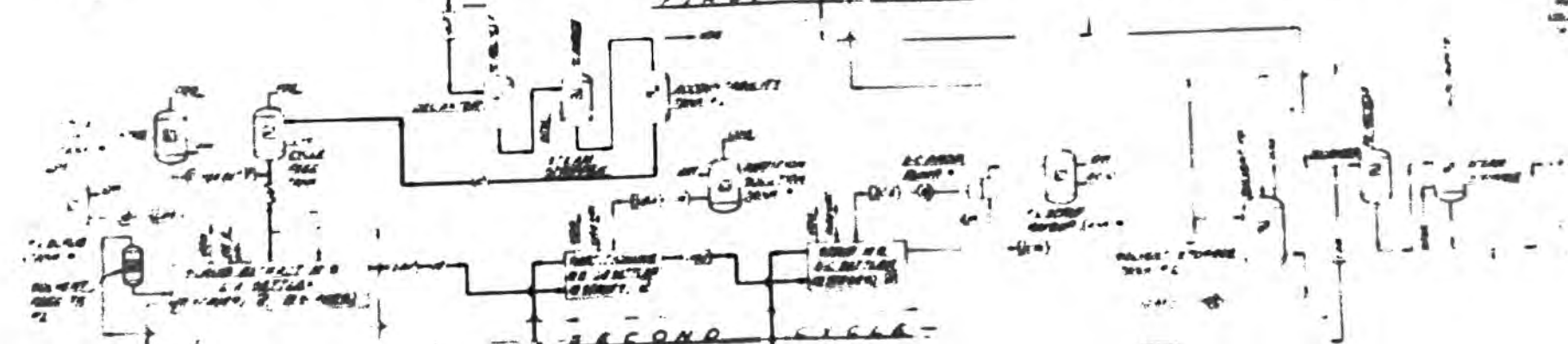


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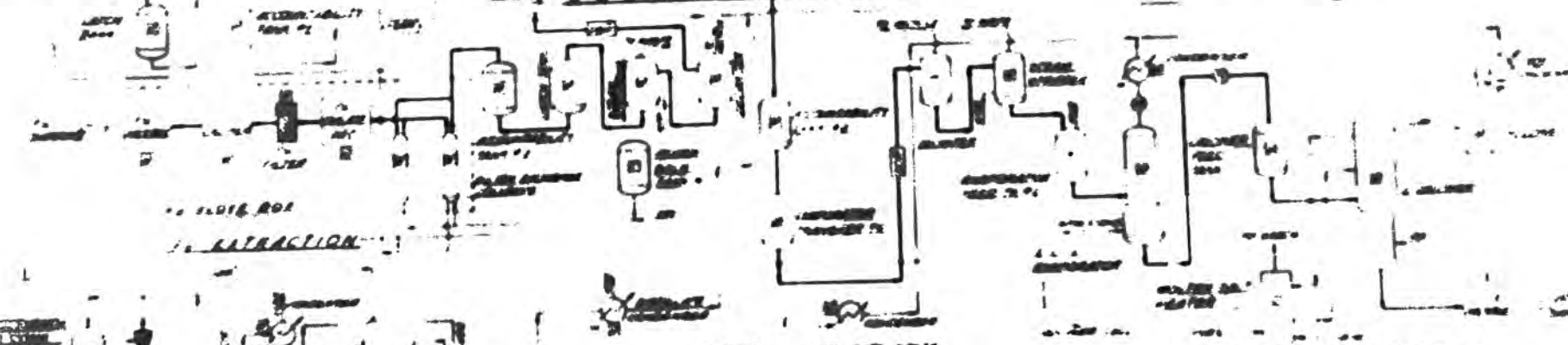
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FIRST CYCLE



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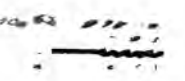
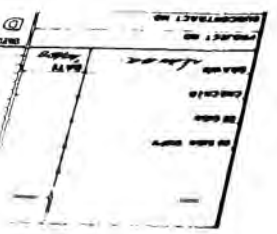


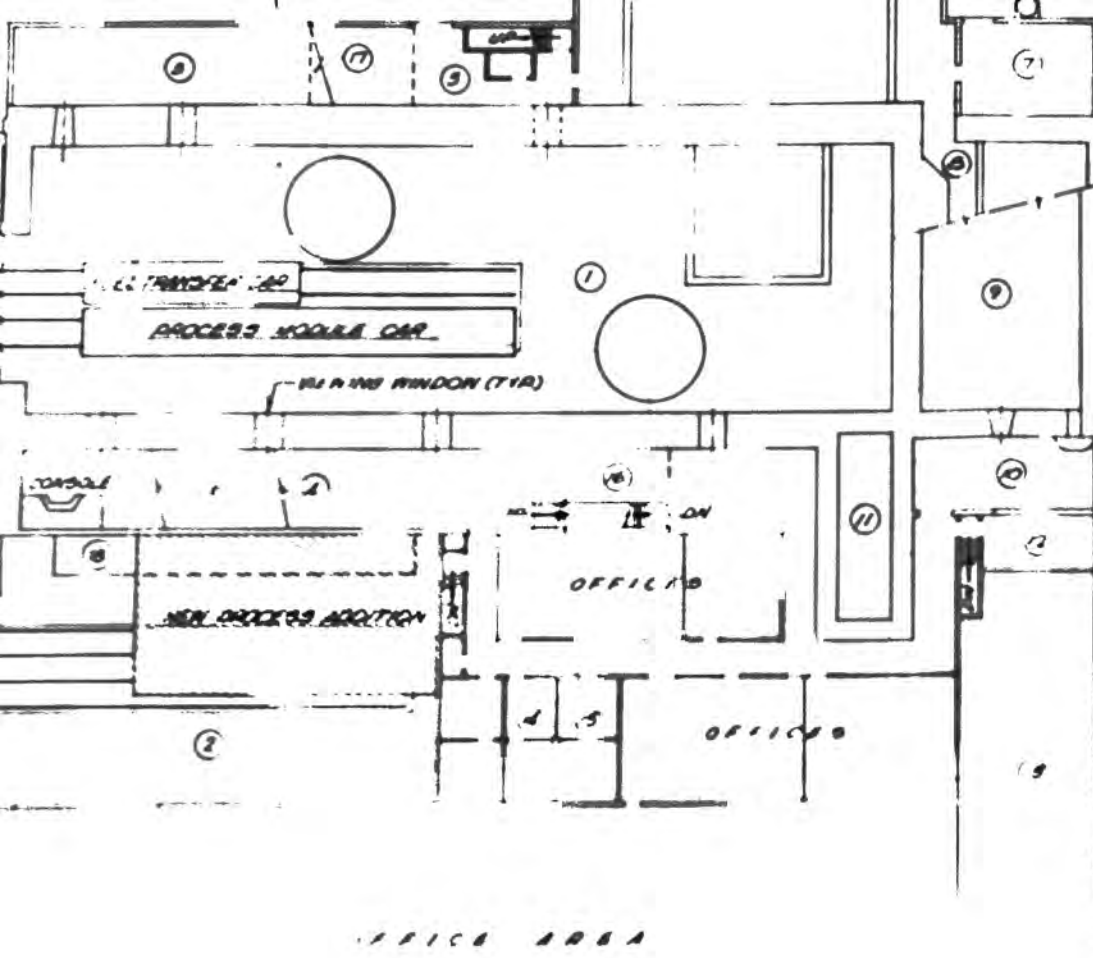
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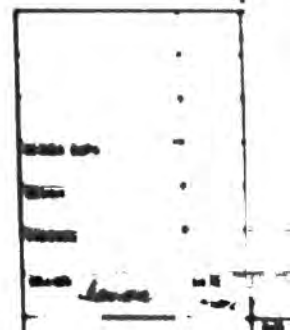


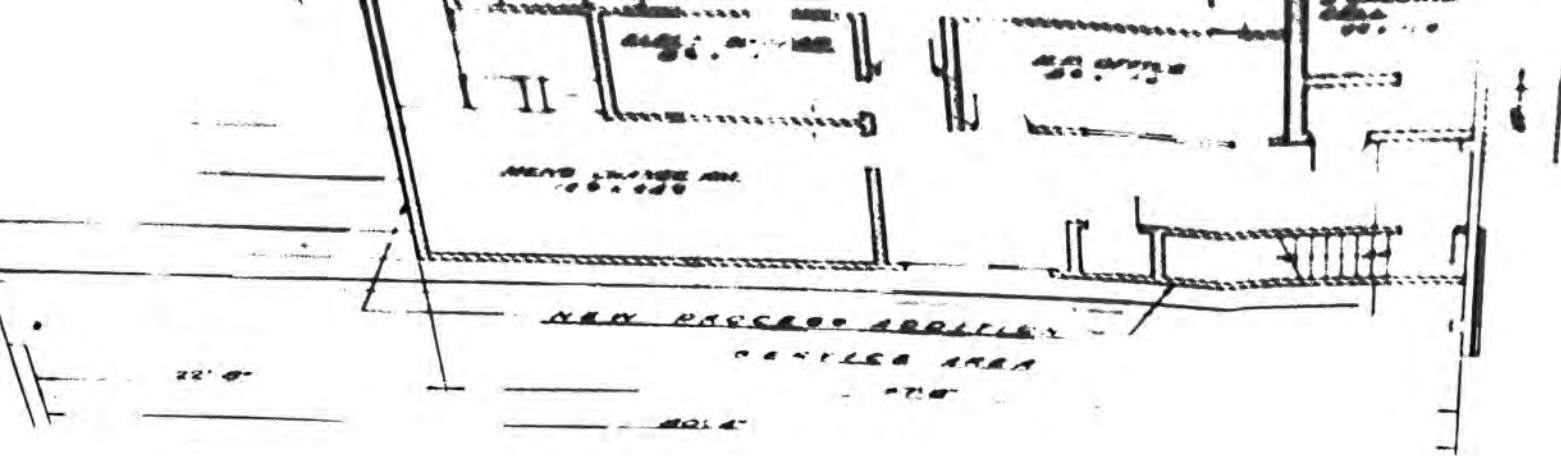


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- ③ SOUTH CONTROL RM
- ④ NORTH EQUIPMENT
- ⑤ SOUTH EQUIPMENT
- ⑥ FAN ROOM
- ⑦ CONTROL ROOM
- ⑧ SPECIAL EQUIPMENT
- ⑨ CONTROL RM
- ⑩ RM NOT CELL
- ⑪ ACID RM
- ⑫ BURNING RM
- ⑬ MEN
- ⑭ MEN
- ⑮ CONTROL RM
- ⑯ CONTROL RM
- ⑰ CHANGE RM
- ⑱ STORAGE ROOM

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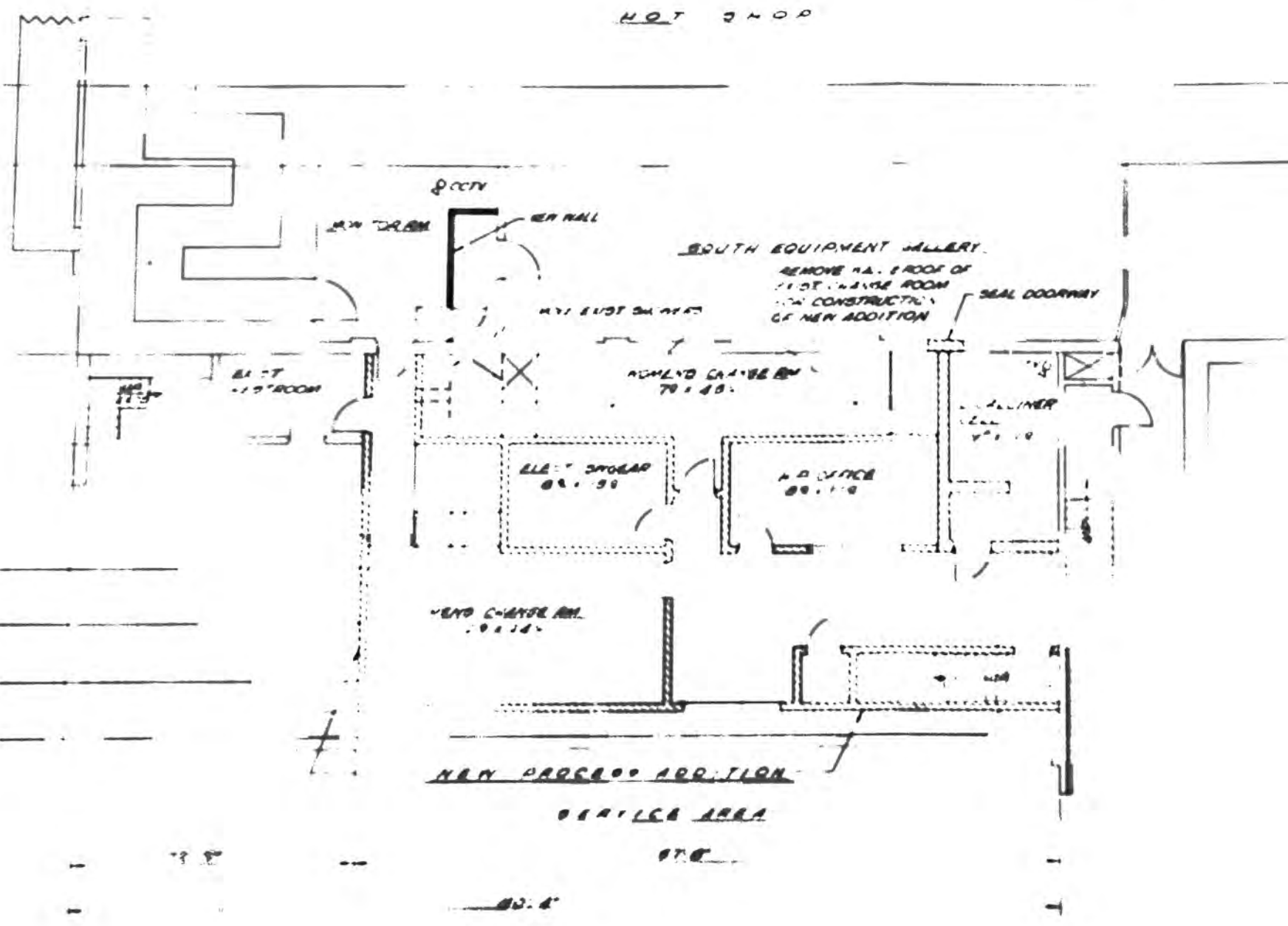




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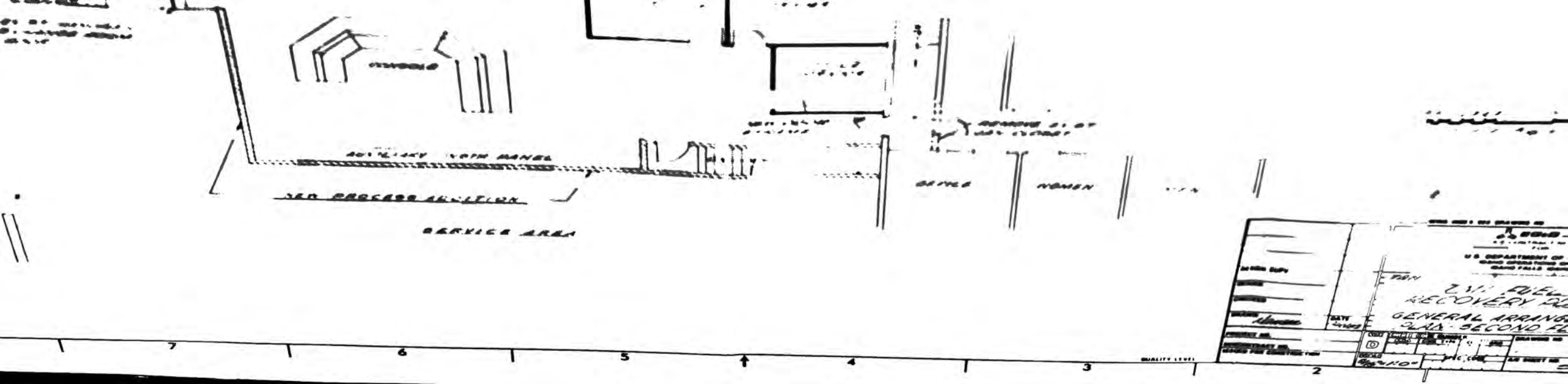
PROJECT MODULE 24

HOT SHOP

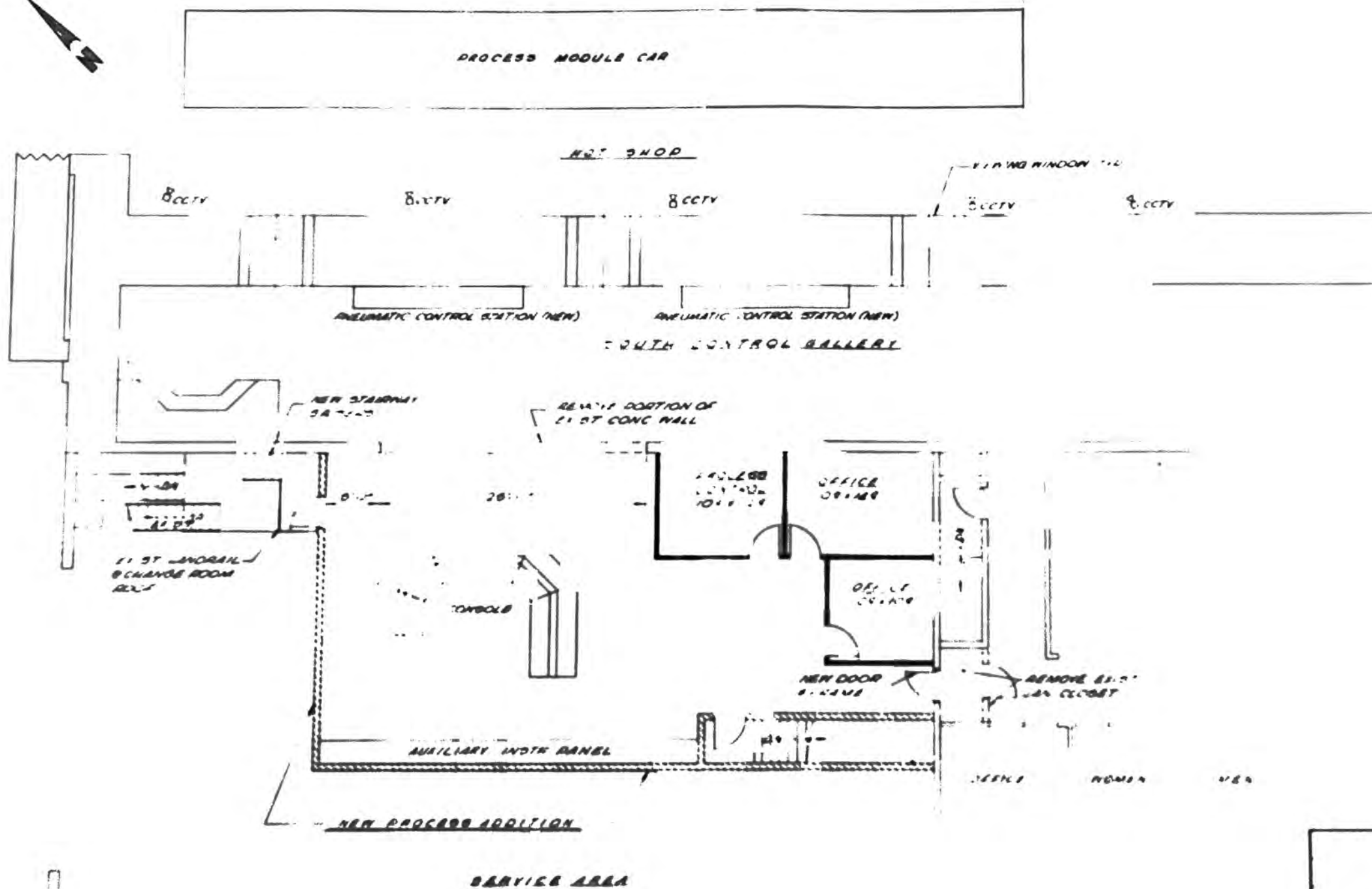


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<p>PROJECT NO. _____</p> <p>DATE _____</p> <p>BY _____</p> <p>CHECKED BY _____</p> <p>APPROVED BY _____</p>		<p>U.S. DEPARTMENT OF ENERGY</p> <p>OFFICE OF ENERGY RESEARCH AND DEVELOPMENT</p> <p>WASHINGTON, D.C. 20545</p> <p>FORM E-100 (Rev. 1-78)</p>
<p>PROJECT TITLE</p> <p>PROJECT LOCATION</p> <p>PROJECT DESCRIPTION</p>		<p>PROJECT NO.</p> <p>DATE</p> <p>BY</p> <p>CHECKED BY</p> <p>APPROVED BY</p>



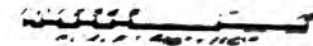
DRAWING NO. 1000	
U.S. DEPARTMENT OF ARMY ENGINEERING CENTER WASHINGTON, D.C.	
2.1. FUEL RECOVERY PL.	
GENERAL ARRANG.	
PLAN - SECOND FL.	
DATE 2-1-53	SCALE 1" = 10'
DESIGNED BY J. H. H. H.	CHECKED BY J. H. H. H.
APPROVED BY J. H. H. H.	DATE 2-1-53
PROJECT NO. 1000	DRAWING NO. 1000
REVISIONS 1. 2-1-53	REVISIONS 1. 2-1-53



SCALE 1/8" = 1'-0"

REVISIONS	
NO.	DESCRIPTION
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ML FILE
OPERY 24
KALARRANG
SECOND FL

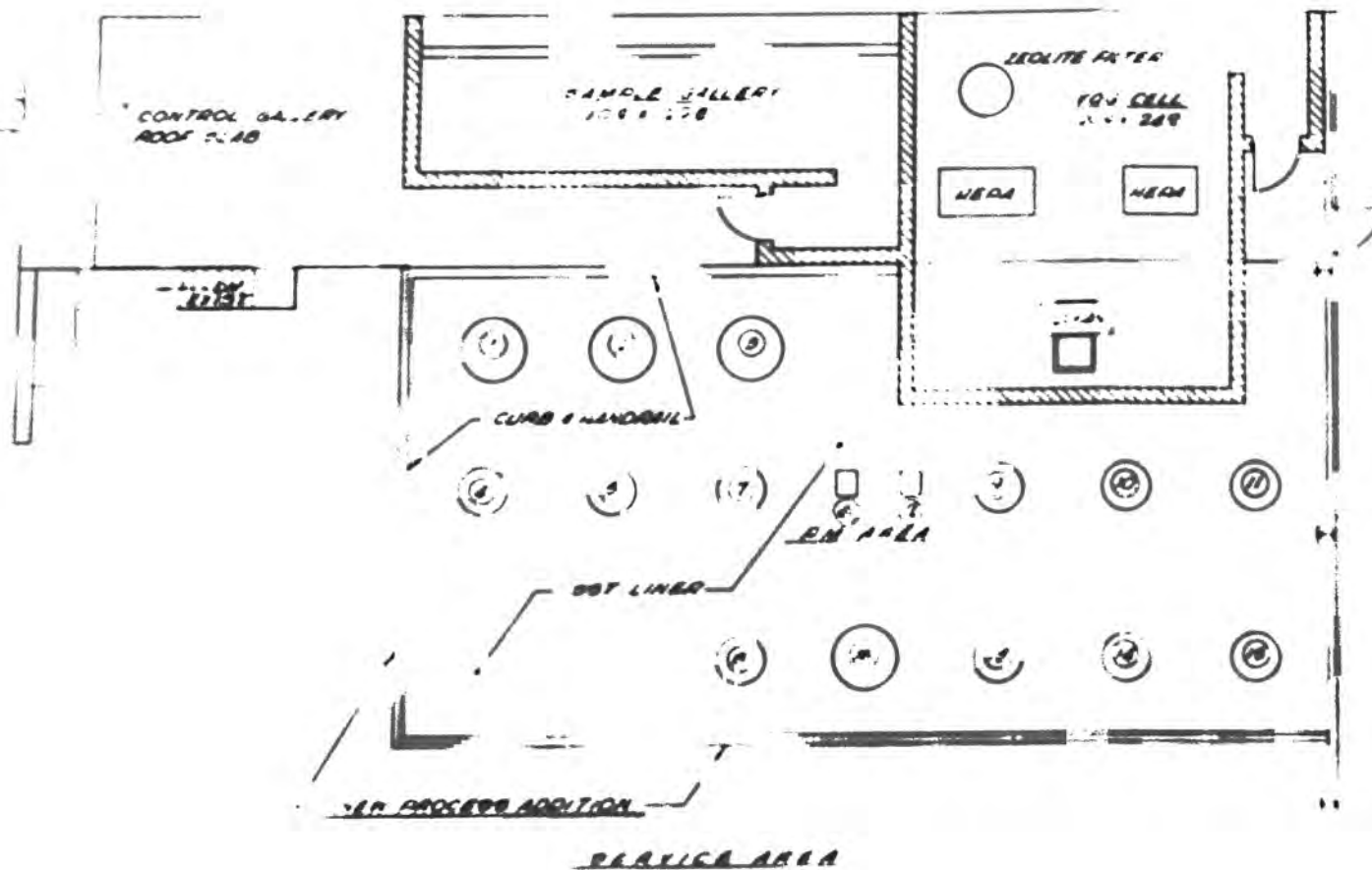


1. TO BE A 100% FUEL RECOVERY PLANT
 2. TO BE A 100% FUEL RECOVERY PLANT
 3. TO BE A 100% FUEL RECOVERY PLANT
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 18. TO BE A 100% FUEL RECOVERY PLANT
 19. TO BE A 100% FUEL RECOVERY PLANT
 20. TO BE A 100% FUEL RECOVERY PLANT

PROJECT NO.		DRAWING NO.	
CONTRACT NO.		SHEET NO.	
DESIGNED FOR CONSTRUCTION		DATE	
PROJECT NO.		DRAWING NO.	
CONTRACT NO.		SHEET NO.	
DESIGNED FOR CONSTRUCTION		DATE	

100% FUEL RECOVERY PLANT
 GENERAL ARRANGEMENT
 2-1/2" - THIRD FLOOR

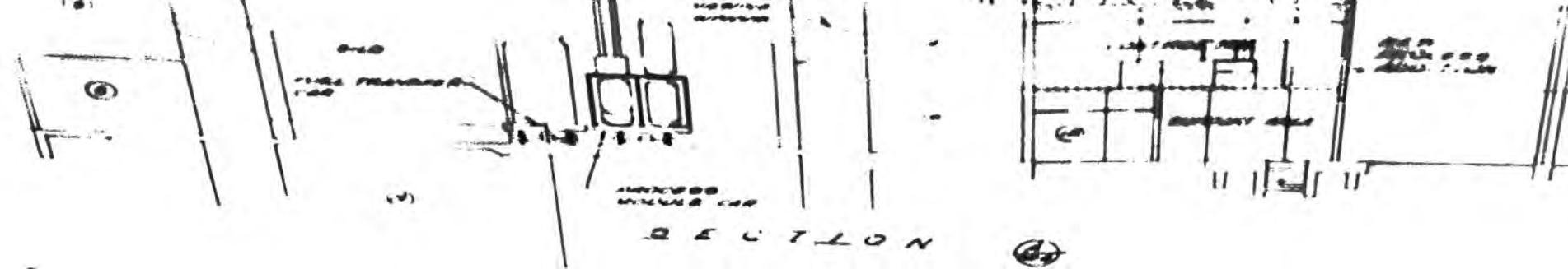
HOT SHOP



- ① ACID STORAGE TANK
- ② ACID STORAGE TANK
- ③ 50% HCl STORAGE TANK
- ④ 50% HCl STORAGE TANK
- ⑤ 50% HCl STORAGE TANK
- ⑥ 50% HCl STORAGE TANK
- ⑦ 50% HCl STORAGE TANK
- ⑧ 50% HCl STORAGE TANK
- ⑨ 50% HCl STORAGE TANK
- ⑩ 50% HCl STORAGE TANK
- ⑪ 50% HCl STORAGE TANK
- ⑫ 50% HCl STORAGE TANK
- ⑬ 50% HCl STORAGE TANK
- ⑭ 50% HCl STORAGE TANK
- ⑮ 50% HCl STORAGE TANK

100 FEET
SCALE 1" = 10'

FUEL	
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99	100



DESIGN	DATE
DESIGN	DATE
CHECKED	DATE
MADE	DATE
PROJECT NO.	
SUBCONTRACT NO.	
ISSUED FOR CONSTRUCTION	

U.S. DEPARTMENT OF ENERGY
Nuclear Energy Research and Development Administration
GENERAL ARRANGEMENT
SECTION

SCALE	1" = 10'
DRAWING NO.	
SHEET NO.	5A



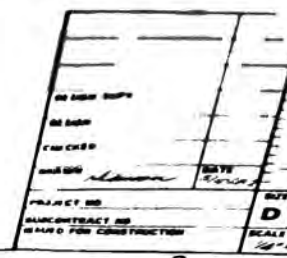
- 1 SOLVENT
- 2 SOLVENT RECYCLE
- 3 ENTRANCE
- 4 ACCOUNTABILITY TANK #1
- 5 FEED ADJUSTMENT TANK
- 6 FEED TANK
- 7 CONDENSER
- 8 KNOCK OUT POT
- 9 DEMISTER
- 10 SCRUB-EXTRACT M.B./A. SETTLER
- 11 STRIP M.B.
- 12 I.B. SETTLER
- 13 SOLVENT WASH M.B./I.B. SETTLER
- 14 FILTER
- 15 ACID WASH M.B./I.B. SETTLER

- 16 SOLVENT STORAGE TANK #1
- 17 STRIP DECANTER
- 18 STRIP STRIP STRIPPER
- 19 ACCOUNTABILITY TANK #2
- 20 SOLVENT FEED TANK #1
- 21 2-C CATCH TANK
- 22 2-C EXTRACT M.B./A. SETTLER
- 23 PARTIALING M.B./B. SETTLER
- 24 STRIP M.B./I.C. SETTLER
- 25 SOLVENT STORAGE TANK #2
- 26 SOLVENT FEED TANK #2
- 27 2-A CATCH TANK
- 28 ACCOUNTABILITY TANK #3
- 29 2-B DECANTER
- 30 2-B STEAM STRIPPER

- 31 2-B CATCH TANK
- 32 2-B WASH TANK #1
- 33 EXTRACT M.B./A. SETTLER TANK
- 34 ACCOUNTABILITY TANK #4
- 35 2-C DECANTER
- 36 2-C STEAM STRIPPER
- 37 2-C COLLECTOR TANK #1
- 38 ACCOUNTABILITY TANK #5
- 39 MAIN EVAPORATOR FEED TANK
- 40 MAIN EVAPORATOR
- 41 MAIN STORAGE TANK
- 42 MELTER FEED TANK
- 43 LOW LEVEL WASTE TANK
- 44 CALCINER
- 45 MELTER

- 46 QUENCH TANK
- 47 VENTURI DEWASHER
- 48 DEMISTER
- 49 1/2" TER BORUS BELT TANK
- 50 WASTE COLLECTOR TANK #1
- 51 WASTE DEMISTER
- 52 WASTE TANK
- 53 RECYCLE WATER TANK
- 54 DISCHARGE EVAPORATOR
- 55 ION EXCHANGE COLUMN
- 56 DI ALATE POT
- 57 DI FILTER
- 58 DI CALCINER

- 59 WASTE DEWASHER
- 60 WASTE CLEAN STORAGE

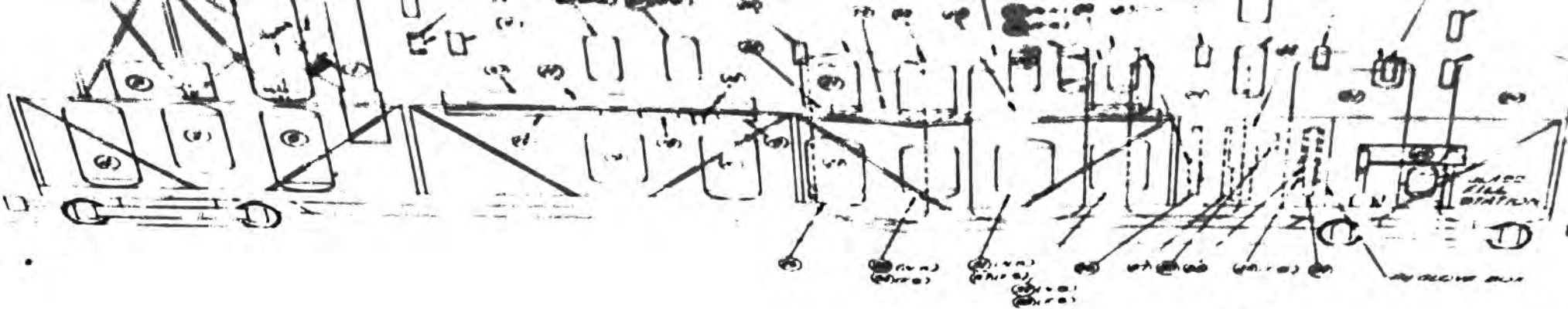


U.S. DEPARTMENT OF ENERGY
 SANDIA NATIONAL LABORATORIES
 SANDIA REPORT
 SAND-78-0000

TMI FUEL RECOVERY PLANT

FUNCTIONAL ARRANGEMENT PLAN

PROJECT NO. _____
 DRAWING NO. _____
 SCALE 1/8" = 10'



NOTE: BUILDINGS NOT SHOWN FOR CLARITY



DESIGN BY DATE CHECKED DRAWN PROJECT NO. DISCREPANCY NO. ISSUED FOR CONSTRUCTION		U.S. DEPARTMENT OF ENERGY TMI FUEL RECOVERY PLANT FUNCTIONAL ARRANGEMENT ELEVATION DATE SCALE SHEET NO.	
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10T HOOK

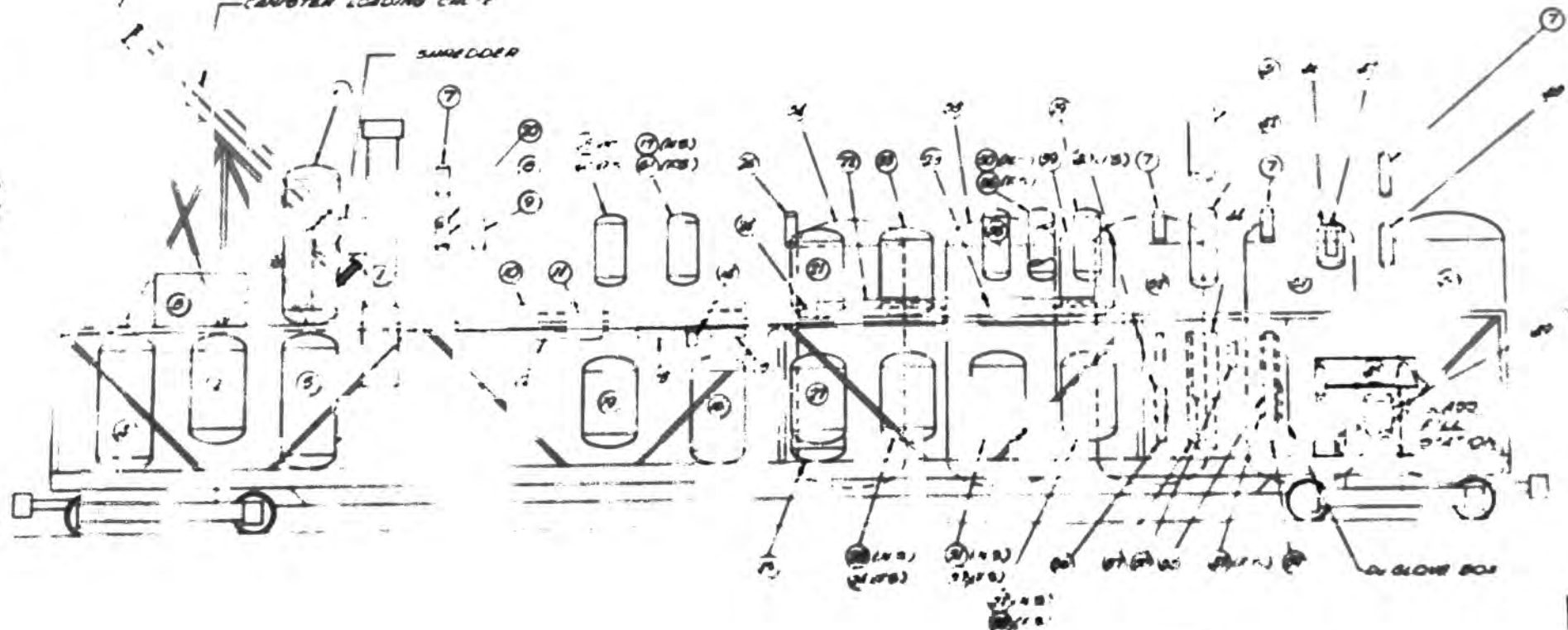
MIN CLEARANCE @ DOOR

8TH MAIN BRIDGE

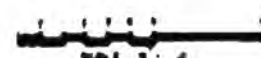
RAM

CANISTER LOADING CRANE

SHREDDER



NOTE:
SHREDDER NOT SHOWN FOR CLARITY



TMI FUEL OVERY PL OVAL ROOM ELEVATION	
D	

Additional text and markings are present in the bottom right corner, including 'TMI FUEL OVERY PL', 'OVAL ROOM', 'ELEVATION', and 'D'.

