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BUILDING 3026, SEGMENTING FACILITY - HAZARDS EVALUATION, VOL. 8

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ABSTRACT

The SRE fuel, consisting of natural uranium slugs, 2.8% enriched, clad in stainless steel and NaK bonded, is the first fuel scheduled for processing in the Segmenting Facility. The stainless steel cladding is removed by hydraulic expansion and hydraulical or mechanical expulsion of the slugs. The uranium slugs are washed, canned, and stored, and the NaK is decomposed by steam in a nitrogen-blanketed reactor. The hazards present are primarily from inadvertent reaction of steam or water with NaK and the resultant hydrogen gas in explosive concentrations. Equipment and procedures are described which permit the safe operation of the facilities.

Standards of construction and containment, assumptions made to evaluate the potential hazards of release of radioactive material, and methods of calculation used for development of this hazards analysis are given in ORNL-2956, Summary Report-Hazards Analyses of Radiochemical Processing and Waste Disposal at Oak Ridge National Laboratory, Sects. 4.0, 5.0, and 6.0.

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BUILDING 3026, SEGMENTING FACILITY

1.0 INTRODUCTION

1.1 Purpose and Uses

Chemical processing cells in Bldg. 3026 were modified to satisfy the requirements for remotely operated high-level radioactive containment cells in which large components or equipment, such as fuel elements, reactor equipment, or in-pile engineering test loops, could be disassembled or segmented or remotely operated equipment for processing power reactor fuels could be developed, such as for the dejacketing of the stainless steel-jacketed NaK-bonded uranium fuel from the SRE reactor, the first program scheduled for the Segmenting Facility. The original building was built in two sections; the first section was completed in 1944 for the separation of radioisotopes for biology and weapons development, and the second section was completed in 1945 for the separation and isolation of Ba^{140} for the weapons program. The first section of the building now has only limited usage; major changes to the cells of the second section were completed in 1959 to adapt the facility to meet the new requirements. After the SRE program, other mechanical processing techniques will be developed for stainless steel-jacketed NaK-bonded uranium, thorium-uranium, and uranium-molybdenum fuels, such as PRDC and CPPD, stainless steel-UO_2 fuels such as NSS, Florida West Coast, and EGCR, and stainless steel-ThO_2-UO_2 fuels such as RCPA and Consolidated Edison. A shear has been designed and is being constructed to shear the fuel bundles into short lengths to permit acid leaching and recovery of the fertile and fissionable materials without dissolution of the stainless steel cladding. The shear and leaching equipment is scheduled to be installed in the cells after the SRE program.

1.2 Location and Distance from Other Facilities

The facility is located on Central Avenue approximately 175 ft west of the Radioisotope Production Area and directly north and across the street from the old Chemistry Building, 3550, a distance of approximately 85 ft. It is bounded on the west by the Central Machine Shop, 3024, and on the north by the Solid State Building, 3025, at distances of approximately 75 and 120 ft, respectively. The maximum amount of fuel received in a carrier shipment will be ten elements, equivalent to 3.8×10^4 curies of activity. The maximum amount of fuel in process at any one time will be one element, or the equivalent of 3.8×10^3 curies of activity. The amount of fuel in storage after processing of the first reactor core will not exceed 2.09×10^6 curies of activity.

1.3 Building Description

The facility is housed in the original wooden frame structure which has received only necessary maintenance services to keep the structure habitable. The cell structure itself, with a biological shield of 5 ft of normal concrete, is considered the primary containment for activity. Secondary containment is provided by a concrete block and sealed wooden enclosure on both ends of the cells for charging and discharging operations; a concrete block and metal enclosure over the top of the cell structure and end rooms serves as an area for the maintenance of equipment. All cell wall plugs not in use are covered by the continuous stainless steel cell liner, covering the cell walls and floor. Plugs in use are capped by a welded stainless steel plate, and penetrating lines are welded to the plate whenever possible or are sealed with resin-impregnated glass fiber compound. The only other cell penetrations are the through tubes for the ten Model 8 manipulators. These tubes resist air flow by virtue of their construction but would allow inleakage of air under normal cell operation and would provide a passage for the escape of activity in an incident in which pressure buildup in the cell resulted from failure of the ventilation system coupled with a fire or explosion and release of the CO_2 fire extinguisher system. For this reason the manipulators are booted inside the cell with a primary and secondary boot and outside the cell by enclosure and boot which serve as a double containment barrier. The building is shown in sketch form in Figs. 1-3. The overlays in red show the primary containment area, and the overlays in green show the secondary containment barriers.

1.4 Personnel Control

Sixteen people are normally employed in the building, and a total of 345 people are normally employed in the surrounding buildings. The number of people by building and location is shown on the plot plan, Fig. 4.

1.5 Process Description

The mechanical processing program for the SRE fuel involves removal of the end hardware of the element and the fuel rod cladding, disposal of the NaK bonding, washing of the uranium slugs, and canning the slugs in aluminum cans for storage until required by the chemical processing plant. The fuel is received in a carrier with a maximum capacity of ten elements. One element at a time is charged to the cell from the carrier through a charging port in the cell door. Jigs and fixtures position the element under an abrasive wheel saw, which cuts the end hardware from the element and allows separation of the element into seven individual rods. The rods are placed one at a time in a mechanical decladding machine of unique design which operates under a bath of mineral oil to avoid exposure of the NaK to moisture. Roll cutters remove the end plugs from the cladding. The cladding is hydraulically expanded to free warped or swollen slugs, and the fuel and NaK are expelled from the cladding by either hydraulic pressure or a mechanical pressure screw. The slugs are collected in a basket and transferred to a steam-operated cleaner to remove the residual NaK and mineral oil. The clean slugs are canned in aluminum cans and transferred in a critically safe storage rack through an underground transfer tunnel to the storage cell, where they are stacked in a critically safe array to await chemical processing. The NaK is decomposed by

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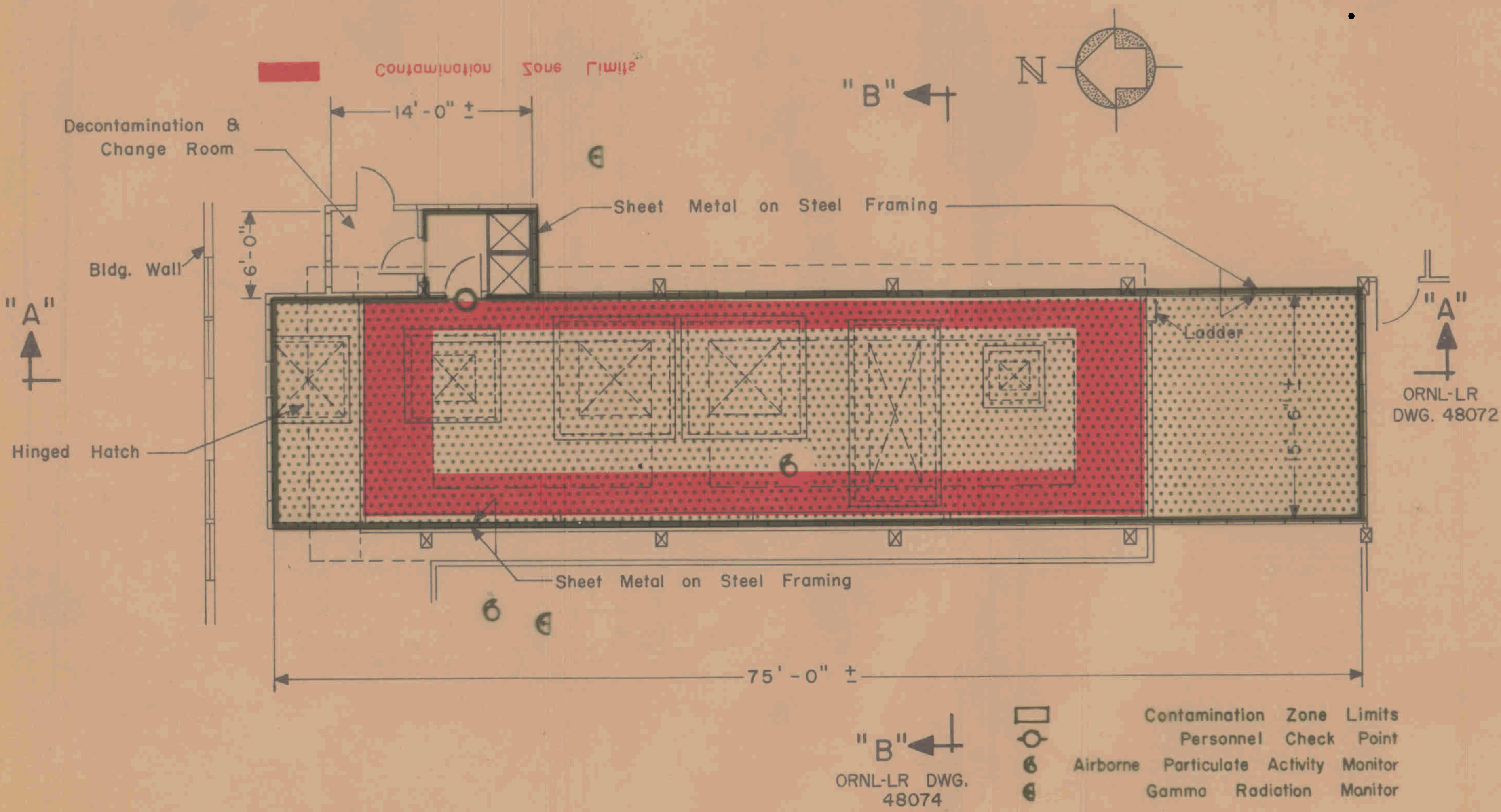

Fig. 1 THIRD FLOOR PART PLAN - BLDG. 3026

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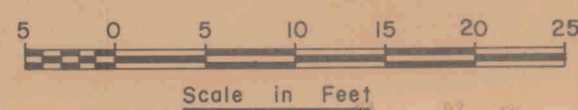
LIMITS OF SECONDARY CONTAINMENT



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ORNL-LR DWG. 48072 A

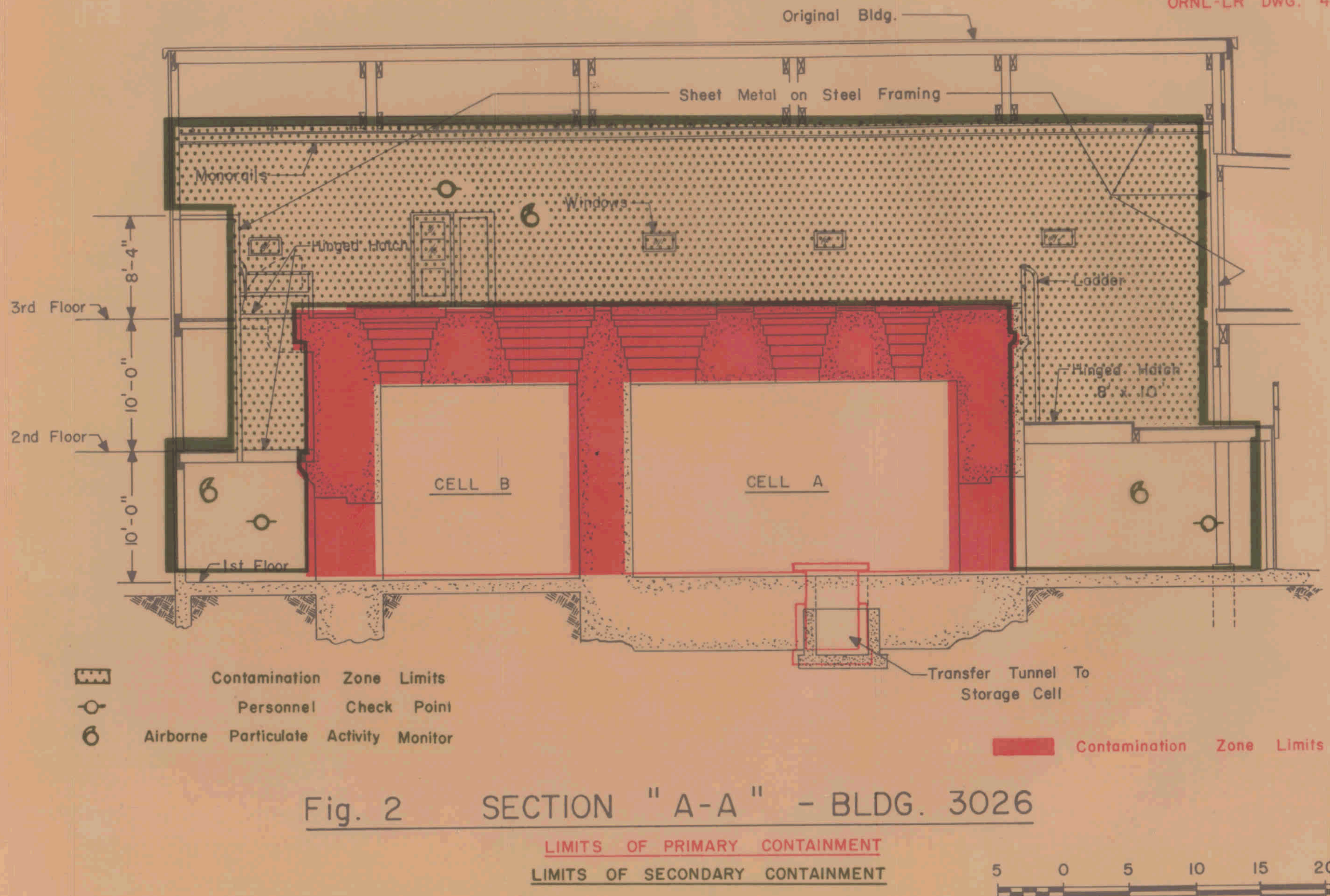

Fig. 2 SECTION "A-A" - BLDG. 3026

LIMITS OF PRIMARY CONTAINMENT

LIMITS OF SECONDARY CONTAINMENT

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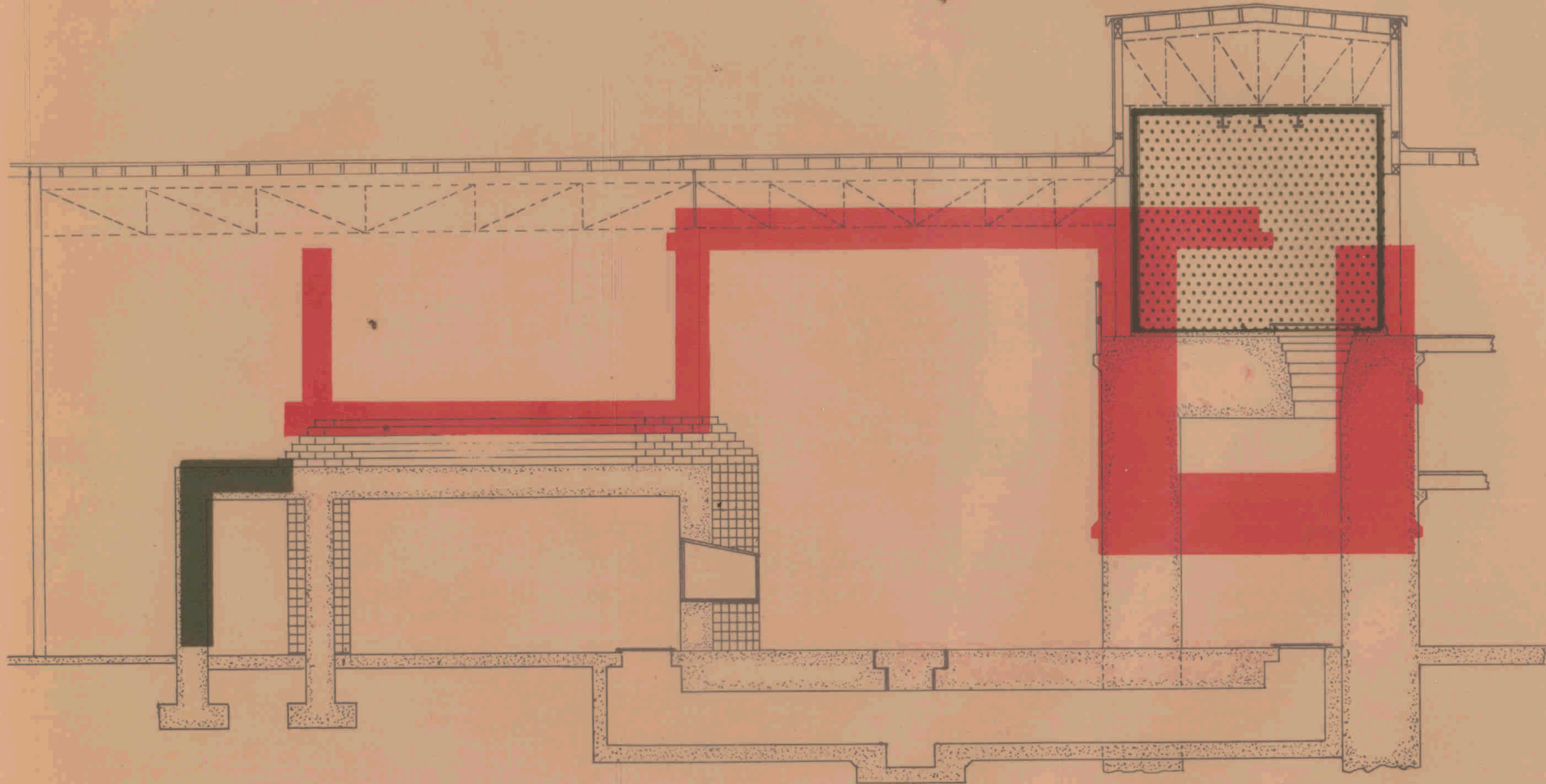

Contamination Zone Limits

Fig. 3 SECTION "B-B" - BLDG. 3026

LIMITS OF SECONDARY CONTAINMENT

5 0 5 10 15 20 25
Scale in Feet

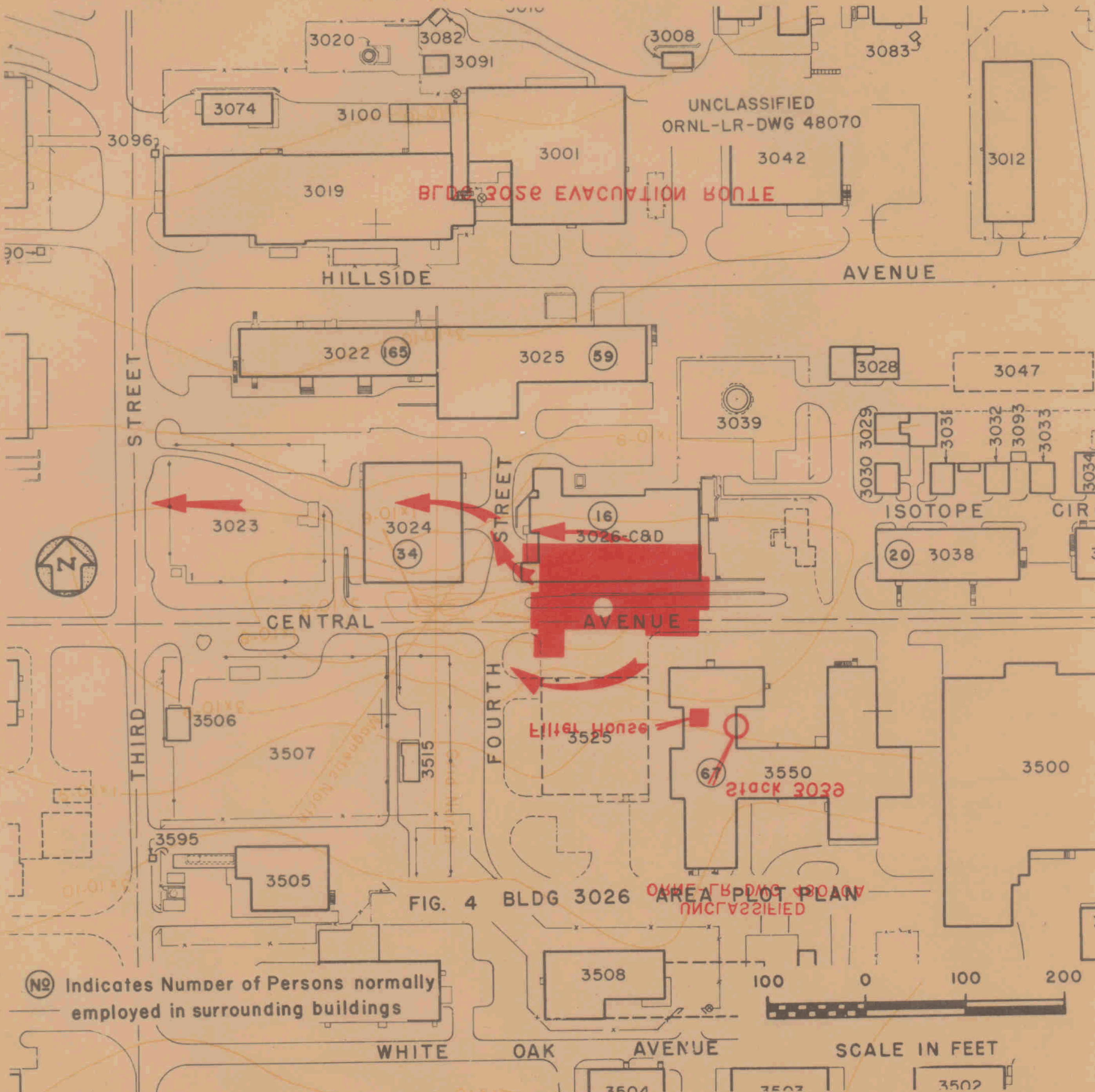

FIG. 4 BLDG 3026 AREA PLOT PLAN

steam by a controlled reaction in a special reactor operating under an inert nitrogen blanket. Stainless steel inert end hardware and cladding which has been wound into a flat spiral by the decladding machine is placed in a scrap container and removed, through the underground transfer tunnel, to a bottom-loading carrier on the operating floor and thence to the burial grounds. An auxiliary decladding device is used for jammed slugs. The process is shown schematically in Fig. 5. Future plans for mechanical processing involve the use of a hydraulically operated shear of 250 tons capacity, which is capable of reducing the majority of power reactor fuel elements into discrete 1-in. lengths for subsequent leaching of the fuel by acid. The stainless steel scrap would be discarded without dissolution. For the shear-and-leach program the vessel off-gas system and possibly the cell off-gas system will receive limited quantities of Kr^{85} and iodine. Before shear-and-leach experimentation is started, a separate hazards report will be written. A schematic flowsheet of the shear-and-leach process is shown in Fig. 6.

1.6 Criticality

The fuel carrier for the SRE program has been designed with fixed structural poisons to permit shipment of as many as ten fuel elements at one time; it is critically safe even though the carrier is submerged in water. Cell limits of one fuel element at any time have been placed on the operations to avoid any criticality incident. The storage racks for the canned fuel have been designed to be critically safe when stacked in rows on opposite sides of the storage cell.

1.7 Liquid Waste Systems

Liquid wastes consist largely of condenser cooling water, steam condensate, sodium and potassium hydroxide from the decomposition of the NaK, and some mineral oil. Filters are provided to prevent any fuel particles, radioactive scale, or active metal fragments from entering the waste system. All liquid waste is discharged to the radiochemical waste system and is collected in tank W-16 (800 gal capacity) in the waste tank farm. Waste is monitored and jetted to an appropriate tank in the intermediate-level chemical waste system when the level reaches 600 gal.

1.8 Gaseous Waste Systems

The cell ventilation system is shown schematically in Fig. 7. Air enters cell A from the maintenance facility, while cell B and the storage cell depend on inleakage only. Inlet air to cell A is filtered by roughing filters in the wall of the maintenance facility and by absolute filters in the cell A air inlet duct. The exit air from cell A is filtered by roughing and absolute filters before it leaves the cell and again outside the building with another set of roughing and absolute filters before it reaches the stack. Air from the storage cell is filtered by an absolute filter before it leaves the cell and again outside the building, using the same filters as the exhaust air from cell A before it reaches the stack. Cell B exhaust air follows the same flow pattern.

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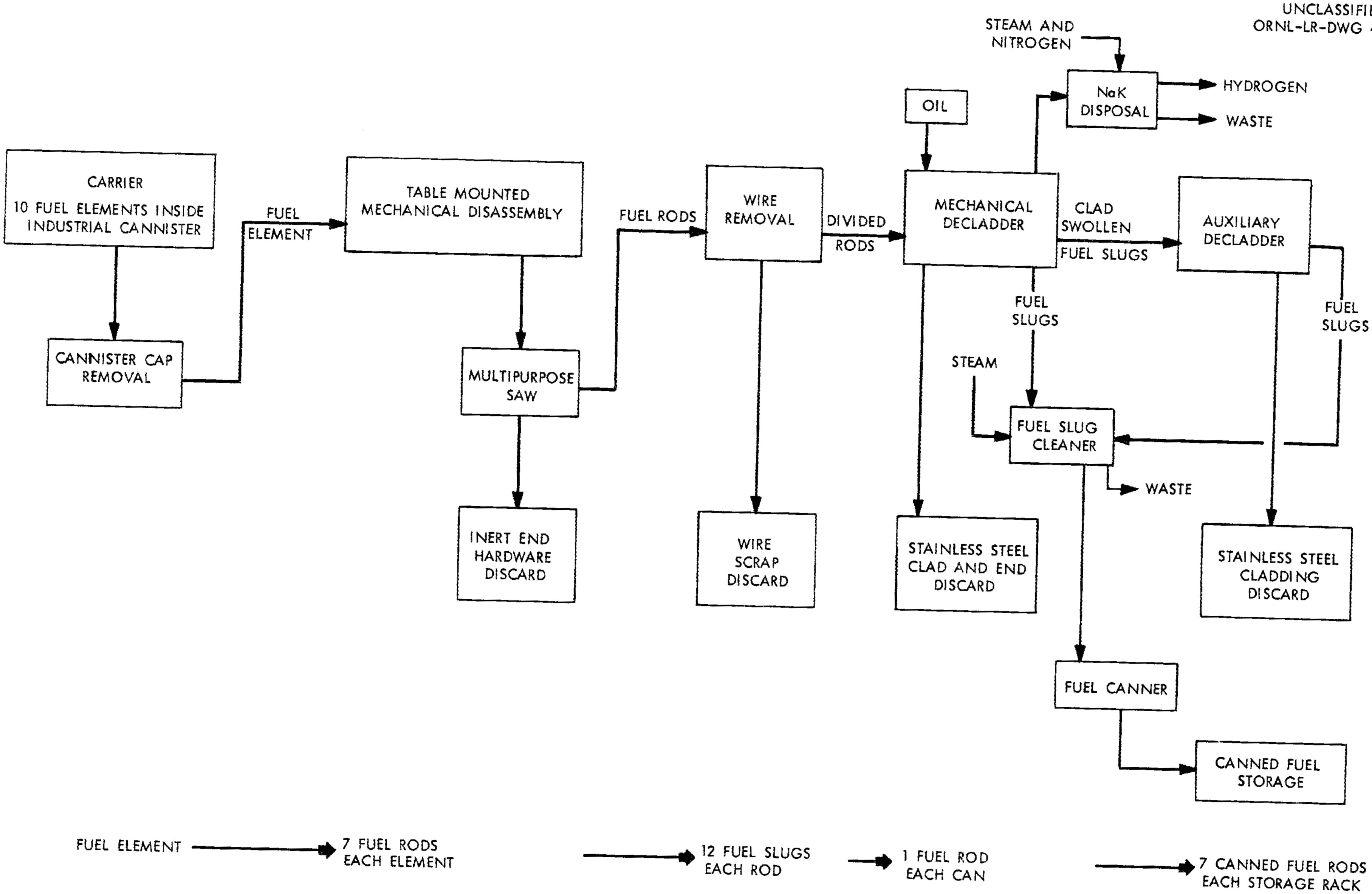

FIG. 5. BUILDING 3026 SCHEMATIC FLOWSHEET OF SRE FUEL ELEMENT REPROCESSING IN SEGMENTING FACILITY.

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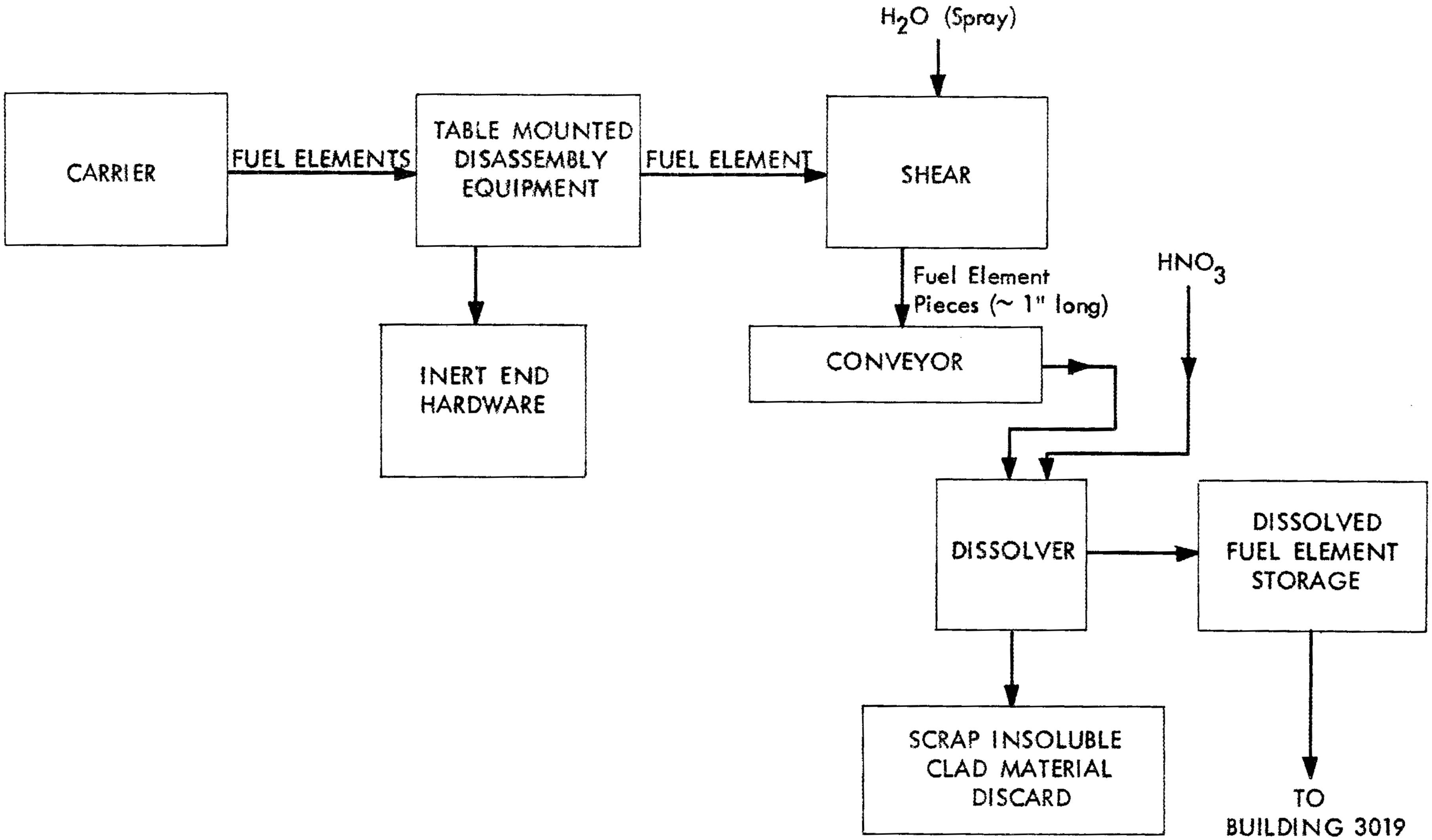

Fig. 6. Schematic Flowsheet of Proposed Future Shear and Leach Installation for Fuel Element Processing, Building 3026.

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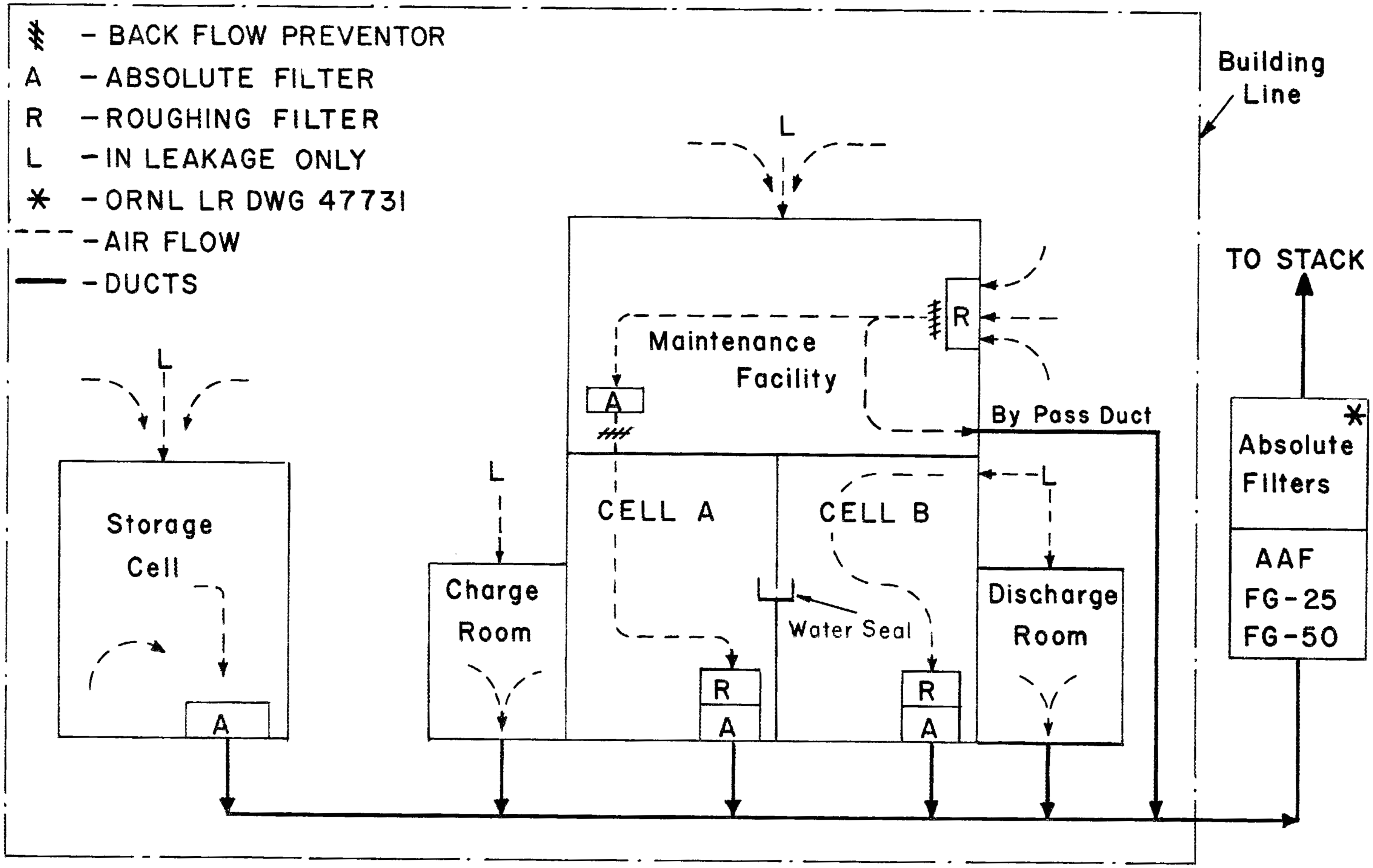

Fig. 7 BLDG. 3026 - SCHEMATIC CELL VENTILATION FLOW DIAGRAM

1.9 Monitoring Systems

Monitoring devices planned for use in the building include the following:

Type	Location	Purpose
Monitron	First floor operating area Charging room Discharging room Maintenance facility	To monitor background radiation up to 125 mr/hr; for gamma and hard beta radiation
Constant air monitor	First floor operating area Third floor outside of containment shell	To monitor air-borne activity up to 20,000 cpm for beta-gamma radiation
Alpha air monitor	First floor operating area Third floor outside containment shell	To monitor air-borne activity up to 5000 cpm for alpha radiation
Hand-foot counter	First floor operating area	To monitor personnel for beta-gamma contamination

2.0 SUMMARY*

2.1 Nuclear Safety Hazards

2.1.1 Maximum Radioactive Material Content

The following data are for the first SRE processing program.

Material	Design Capacity Cell A	Design Capacity Storage Cell	Inventory Cell A	Inventory Storage Cell	Inventory Largest Vessel
Iodine-131, curies	0	0	0	0	0
Krypton-85, curies	35	0	35	0	0
Mixed nonvolatile fission products, curies	3800	2.09×10^5	3800	2.09×10^5	543
Heavy elements					
Pu^{239}, kg	~0.04	~2.2	~0.04	~2.2	~0.0057
U^{235}, kg	~1.84	~101.2	~1.84	~101.2	~0.25
U^{236}, kg	0.01	0.55	0.01	0.55	0.0014
U^{238}, kg	67	3685	67	3685	9.57
U^{233}, kg	0	0	0	0	0
Th^{232}, kg	0	0	0	0	0
Am^{241}, curies	0	0	0	0	0
Other, curies	0	0	0	0	0

2.1.2 Criticality Incident Potential

Location of Hazard	Fissionable Isotope	Design Capacity, kg limit	Shield	Type of Controls Used
Cell A	U^{235}	~1.84	5 ft normal concrete	Mass
	Pu^{239}	~0.04	5 ft normal concrete	Mass
Storage Cell	U^{235}	~101.2	5 ft normal concrete	Geometric
	Pu^{239}	~2.2	5 ft normal concrete	Geometric

*Calculations and assumptions are given in Volume I of this report.

2.2 Explosion and Fire Hazards

2.2.1 Description of Combustible or Explosive Material and Probable Reactions That Can Occur

a. Uranium. The metal in its massive form is difficult to ignite and is not normally considered combustible; however, under unusual conditions it has been known to burn and is therefore included. The reaction with air results in the formation of U_3O_8:

$$3U + 4O_2 \rightarrow U_3O_8$$

b. NaK. This alloy of 78% K and 22% Na is used as a heat transfer medium between the uranium and the stainless steel jacket of the fuel element. The danger lies in the inadvertent reaction of NaK with steam or water to evolve the highly combustible hydrogen gas:

$$NaK + 2H_2O \rightarrow NaOH + KOH + H_2$$

c. Mineral oil. Mineral oil is a clear colorless liquid obtained from the distillation of petroleum and is actually a mixture of liquid hydrocarbons. The oil is combustible when heated to its ignition temperature and reacts with oxygen, evolving carbon dioxide and water:

$$C_nH_{2n+2} + \left(\frac{3n + 1}{2}\right) O_2 \rightarrow nCO_2 + (n + 1)H_2O$$

d. Hydrogen. Hydrogen is released to the cell ventilation air, by a controlled reaction, from the NaK reactor as the result of decomposition of NaK with steam. Mixtures of hydrogen and air from 4.2 to 75% hydrogen are considered in the explosive range and potentially dangerous:

$$2H_2 + O_2 \rightarrow 2H_2O$$

2.2.2 Specification of Closed-cup Flash Point for Organics

Mineral oil is the only organic combustible material used in the current process and was selected on the basis of high flash point, specific gravity, high degree of transparency, and low cost. The closed cup flash point is >205°F; the open cup flash point is 315°F.

2.2.3 Specification of Lower Explosive Limits in Air

a. Uranium and NaK as handled in the process are not considered as potentially dangerous from the standpoint of air dispersal in explosive proportions. Neither uranium nor NaK is exposed to the air in the cell during the process, but is always covered by mineral oil until the final stages where the clean uranium slugs are canned and the NaK is decomposed by steam.

b. Mineral oil undoubtedly can be ignited or exploded under proper conditions if it is finely dispersed in air; however, no data are available on the limits of explosion or flammability under these conditions. No operations are carried out that would create conditions considered favorable for such an occurrence.

c. Hydrogen and air form explosive mixtures if they contain from 4.2% to 75% hydrogen.

2.2.4 Inventory

a. Total inventory in plant

	Cell A	Storage Cell
Uranium	69.864 kg (normal) (153.70 lb)	3842.5 kg (maximum) (8453.5 lb)
NaK	608.3 g (688.1 ml, 42 cu in.)	None
Mineral oil	18.0 gal (126.2 lb)	None
Hydrogen, maximum potential limit	18.1 g (201 liters, 7.1 cu ft)	None
Normal operating limit	2.58 g (28.7 liters, 1.01 cu ft)	None

b. Total inventory in largest single vessel

Uranium	9.981 kg (21.957 lb)
NaK	86.9 g (98.3 ml, 6.0 cu in.)
Mineral oil	18.0 gal (126.2 lb)
Hydrogen	2.58 g (28.7 liters, 1.01 cu ft)

2.2.5 Energy Release

a. Energy release per pound

Uranium to U_3O_8	484 kcal/lb (1,920 Btu/lb)
NaK	597 kcal/lb (2,369 Btu/lb)
Mineral oil	4,989 kcal/lb (19,800 Btu/lb)
Hydrogen	13,000 kcal/lb (51,590 Btu/lb)

b. Total potential energy release in plant

Cell A	705,329 kcal (2,799,099 Btu)
Storage cell	4,089,888 kcal (16,230,720 Btu)

c. Total potential energy release from largest tank. The energy release would be represented by one fuel rod and the mineral oil in the main decladding machine, which would represent ~640,460 kcal or 2,541,665 Btu.

2.2.6 Means of Preventing Explosions

a. Equipment installed to prevent explosions. No equipment is known that will prevent explosions in our process. Hydrogen and air mixtures are the only probable source of an explosion; hydrogen detection instrumentation is installed to monitor the atmosphere and is set to alarm when the lower explosive limit is approached. The dump tank is designed to split lengthwise in the event of a rapid pressure rise and will not fragment in the case of an explosion.

b. Dilution or blanketing gas to prevent explosive mixtures. In vessels where hydrogen is normally released, primarily the NaK reactor and to a slight degree in the slug washer, nitrogen blanket gas or steam flow at a sufficient rate is passed through the vessel to keep the concentration of hydrogen below the explosive limit. Cell ventilation air flow also is more than sufficient to keep the hydrogen released to the cell below the explosive limit. Actually, the total volume of hydrogen evolved represents less than 0.19% of the cell air volume and is well below the explosive limit of 4.2%.

c. Maximum explosive release of energy estimate. The maximum explosive release of energy would result from the hydrogen evolved in the NaK-water reaction from the quantity of NaK contained in one fuel rod. If the hydrogen is assumed to explode under the worst conditions, as opposed to detonating, a cell peak overpressure of the order of 140 lb/sq ft would result. The actual energy represented by the hydrogen is 74 kcal or 294 Btu.

d. Probability of an explosion and containment in primary containment system. The probability of an explosion is considered highly remote due to the difficulty of reacting NaK and water when the NaK is coated with mineral oil, as is the case in the current process. At best, under this condition the reaction is slow unless it is purposely agitated. The hydrogen evolved would be more than adequately diluted in either case to keep the concentration far below the explosive limit.

The energy should be contained within the primary containment system, although the cell filters may be ruptured and the secondary bank would be required to take the load during the period required for replacement. Manipulator boots also may be ruptured; however, restricted flow should minimize the escape of activity. As soon as the momentary peak overpressure subsides, the cell ventilation would cause air flow into the cell through the ruptured boots and prevent escape of activity. The pressure would be insufficient to lift the roof plugs or damage the glass windows.

2.2.7 Fire Prevention

a. Equipment installed to prevent fires. No equipment is installed to prevent fires; however, the equipment is designed to minimize the probability of fires by the use of blanketing gas or oil over the hazardous materials to reduce the chances of contact with air or moisture and the resulting undesirable or uncontrollable reactions.

b. Equipment installed to fight fires and proposed fire fighting methods.

CO_2 system. The system was installed to handle mineral oil fires only. The system will dilute the air in the cell so that its oxygen content is 13% or below and will maintain this percentage for a 30-min period. A provision is also made to allow the use of the fire department Cardox truck (Y-12) to supply CO_2 past the 30-min period if required. The system is either manual or automatically actuated by the rate of rise of temperature in sensing devices located in plugs in the roof of the cell.

Powdered graphite extinguishers. Plastic bags of powdered graphite are stored in convenient locations in the cell so that they can be readily placed on liquid metal fires. These bags would be handled by either the Model 8 or General Mills manipulator.

d. Probability of fire and containment without serious spread of radioactive material. The chance of a fire is rather remote even if water should contact liquid metal under mineral oil, since the mineral oil tends to isolate the NaK and the water and reduces the reaction rate. The oil itself would have to be raised to its ignition temperature before a fire could be sustained. Ample time would be available to allow dumping the oil to a blanketed dump tank or flooding the cell with CO_2 to extinguish the fire.

A fire should be contained in the cell, even if permitted to burn until extinguished by lack of oxygen in a sealed cell. Using a pessimistic estimate of radiation heat transfer and convection film coefficient, the cell air temperature is found to be about 450°F or ~350°F higher than the wall temperature. No damage to the shield windows would be expected. In a sealed cell, a pressure rise would result from the temperature rise in the air. However the exhaust duct cannot be closed completely and will prevent any significant rise in the cell pressure. Although the inner manipulator boots would be destroyed by fire, the external boots should not be affected and activity should be confined to the cells.

2.3 Evaluation of Noncriticality Event Leading to Release of Radioactive Material

2.3.1 Description of Cell Involved in Credible Accident

Name	Cell A
Volume, cu ft	3750
Ventilation purge flow rate, cfm	500

	Analysis of Content	Total Amount Vaporized or Suspended after Accident
Material	Massive uranium	
Pu^{239}, curies	2.45	2.45
U^{235}, curies	3.1×10^{-3}	
U^{238}, curies	2.2×10^{-2}	
Heavy elements (U^{233}, Am, Cm, etc.)	--	
Mixed fp's, curies	3800	3800
I^{131}, curies	0	0
Kr^{85}, curies	35	35

2.3.2 Effects of Accidental Release of Radioactive Material from Maximum Credible Noncriticality Accident, Building 3026

	Mixed fp's	Pu^{239}	Kr^{85}
Cell off-gas release*			
Total amount, curies	340	0.22	-
Max. downwind integrated dose, rem	0.82	1.77	<0.001
Distance downwind of max. dose, m	1760	1760	1760
Release into secondary containment zone			
Total amount, curies	3.8×10^{-3}	2.45×10^{-6}	3.5×10^{-5}
Concentration, curies/m^3	6.2×10^{-6}	4.0×10^{-9}	5.7×10^{-8}
2-min dose to building personnel, rem	0.110	0.24	0.01
Release from secondary containment zone* (assuming ventilation system works)			
Total amount, curies	6.0×10^{-5}	3.27×10^{-7}	-
Max downwind integrated dose, rem	<0.001	<0.001	<0.001
Distance downwind of max dose, m	150	150	150
Ground fallout at 20 m, curies/m^2	1.8×10^{-9}	1.2×10^{-12}	-
Release from secondary containment zone* (assuming ventilation system fails)			
Total amount, curies	1.87×10^{-3}	7.64×10^{-6}	-
Max downwind integrated dose, rem	<0.001	0.006	<0.001
Distance downwind of max dose, m	150	150	150
Ground fallout at 20 m, curies/m^2	6.8×10^{-9}	2.8×10^{-11}	-

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3.0 DESCRIPTION OF PROCESS AND FACILITY

3.1 Description of First Program for Segmenting Facility

Mechanical head-end treatment is an alternative approach to the chemical head-end treatment being developed to demonstrate the production feasibility for the processing of power reactor fuels. Core 1 of the Sodium Reactor Experiment (SRE) of Atomics International, Canoga Park, California, is the first fuel that has been assigned to ORNL for mechanical processing. Large remotely controlled radioactive cells, capable of handling engineering-scale components, house the equipment for this program.

The SRE fuel consists of natural uranium slugs, 2.8% enriched, clad in stainless steel tubing with NaK bonding for heat transfer. The equipment is designed to separate a fuel element into its component rods and remove the cladding from the uranium slugs, safely dispose of the NaK, wash the uranium free of contaminants, and can the uranium rods in aluminum containers. The aluminum-canned slugs are stored until they are processed in the ORNL Pilot Plant by standard solvent extraction techniques. The hazards involved in the processing of the fuel have been carefully studied, and equipment and techniques have been developed to permit safe handling of the fuel. All equipment is remotely operated, and some is remotely maintained. Since major maintenance requires removal of equipment from the cell to a maintenance area located directly over the cells where direct maintenance techniques are used, the equipment is designed for remote removal. The facility is designed to provide secondary containment to protect against inadvertent leakage of radioactive materials from the cell proper.

Following the SRE program, mechanical processing techniques for other power reactor fuels will be developed to handle stainless steel-clad NaK-bonded uranium, thorium-uranium, and uranium-molybdenum fuels, such as PRDC and CPPD, for stainless steel-UO_2 fuels such as NSS, Florida West Coast, and EGCR, and/or stainless steel-ThO_2-UO_2 fuels such as RCPA and Condolidated Edison. A shear has been designed and is being constructed to cut the fuel bundles into short lengths to permit acid leaching and recovery of the fertile and fissionable materials without dissolution of the stainless steel cladding. The shear and leaching equipment is scheduled to be installed in the cells after the SRE program. The hazards of the processes and the adequacy of the facility will be evaluated for each new operation and the evaluation reviewed by ORNL safety and criticality review committees before actual processing will be permitted.

3.2 Description of Facility

The Segmenting Facility was constructed by converting chemical processing cells to remotely operated dismantling and processing cells equipped to handle large radioactive reactor components, in-pile engineering loop and bomb experiments, and pilot quantities of power reactor fuels for the development of mechanical head-end processing techniques. The cells are housed in the original wooden structure, which has remained basically unchanged and received only necessary maintenance, repairs, and painting. A 50-ton hoist with supporting steel frame was installed adjacent to the building for the loading and unloading of heavy casks and is provided with a ramp for motor transport access to the hoist. Figure 8 is a pictorial illustration of the facility showing the cells, end enclosure rooms, and maintenance facility, which are described in the following paragraphs.

The Segmenting Facility has a biological shield of 5 ft of normal concrete and is divided by a 4-ft normal concrete wall into two basic cells, A and B. Cell A is 25 ft long; cell B is 15 ft long and is divided into two sections by a stainless steel partition extending from the floor to the ceiling. The cells are 10 ft wide and 15 ft high. Cell B has a false stainless steel floor installed 3 ft above the floor level. Cell A has three zinc bromide viewing windows approximately 4 ft by 4 ft; cell B has two windows of the same size. Each window position is equipped with two Model 8 manipulators. Cell A, the largest cell, is also equipped with a 750-pound-capacity General Mills manipulator and a 3-ton overhead crane. Sub-cells B-1 and B-2 are equipped with 1-ton overhead cranes. All cells have roof plugs, and the front and rear faces of each cell contain removable plugs for installation of service piping or electrical circuits. The cell walls and floors are lined with stainless steel, and the roof is protected by Amercoat paint and glass fiber surfacing. The cell liner is intact over all wall plugs not in use. Wall plugs in use are welded to the liner, and entering lines are welded or sealed with glass fiber-reinforced resin to close any leakage paths. An underground transfer tunnel connects cell A to an adjacent storage cell, approximately 9 ft wide by 21 ft long by 10 ft high. The storage cell also has a biological shield equivalent to 5 ft of normal concrete and is equipped with a 4 by 4 ft zinc bromide viewing window. The cell has been treated with Amercoat protective paint on walls, ceiling, and floor, and the floor treatment incorporates glass cloth for additional abrasive protection. A 3-ton overhead bridge crane and a 75-lb Lee manipulator are mounted on the bridge. Cells A and B are connected by an underwater transfer device with a water seal of approximately 2 in.

Air from cells A and B and the storage cell is filtered by roughing and/or absolute filters located in the respective cells. Cell A has a bank of absolute filters on the air inlet located on the cell roof in the maintenance area. A positive air flow up to 1000 cfm is provided in cell A for cooling the cell and removing air-borne activity; air is drawn in to cell B and the storage cell by inleakage only. Back flow preventers on the cell A inlet are instrumented to close under disaster conditions to minimize the amount of contaminated air forced from the cell under positive pressure buildup. A flow diagram of the cell ventilation system is shown in Fig. 7.

A large charging door, approximately 6 ft wide by 7 ft high, is located in the south end of cell A to permit installing and removing equipment or moving of large casks. The door is normally closed and sealed with a pneumatically sealed gasket, and material is charged from the carrier external to the cell through a 27-in. charging hole. This port is sealed on the inside by a gasketed air-operated shutter and on the outside by a lead door. Cell B has a smaller door, approximately 4 ft wide by 6 ft high, intended for removal of casks containing radioactive specimens sectioned in cell A. An enclosure

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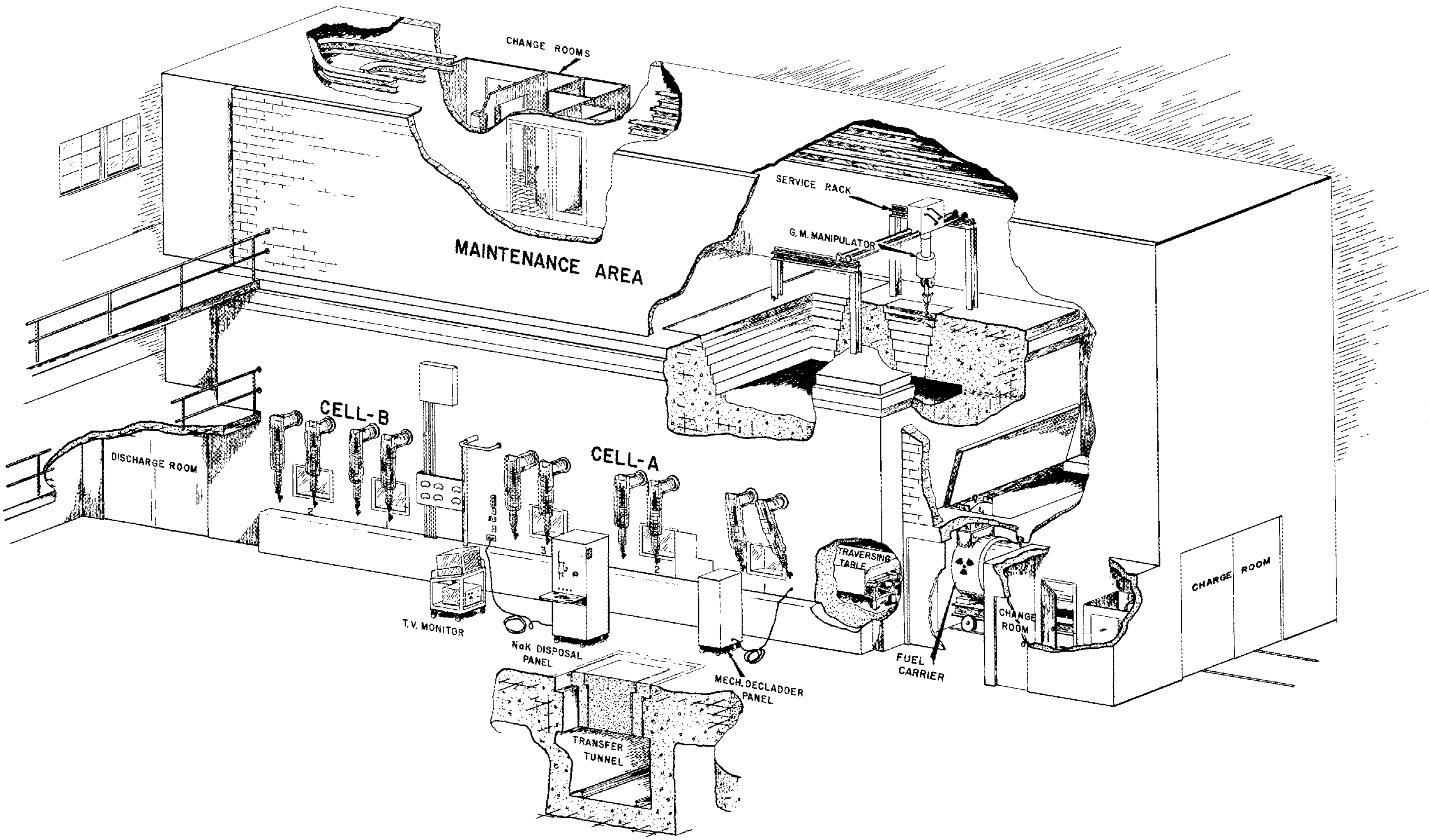

SECONDARY CONTAINMENT FOR CELLS
BLDG. 3026
FIG. 8

room is provided at both the south and north ends of the cell, which acts as a containment area to confine activity when the large cell doors are open.

An enclosed space on top of the cell bank and extending over the end enclosure rooms, known as the "maintenance facility," together with the end enclosure rooms themselves, acts as a secondary containment shell for the cell. Contaminated equipment can be removed from the cell, through the roof plugs, into this shell for maintenance and/or repair. The facility is provided with a 3-ton overhead crane system. Suitably clothed maintenance personnel are able to enter this room through an air-lock system and work under acceptable limited working tolerances without the necessity for major decontamination of the cell or total decontamination of the equipment. The back face of the cell has no penetrations that are not completely sealed by welded or gasketed covers. Air will enter the maintenance facility through filters in the walls of the structure and be exhausted to the cell A ventilation system, after entering cell A through the filter bank located on top of the cell. Air from the end enclosures is exhausted to the cell ventilation duct external to the cell and passes through a bank of filters before reaching the stack.

The openings on the front of the cell are sealed similarly to those at the back except for the penetration of the Model 8 manipulators. Rupture of the manipulator boots would allow activity to be released from the cell under disaster conditions if pressure is built up. To minimize such incidents, the manipulators are provided with an additional boot on the shoulder joint inside the cell, the area of greatest possible leakage in the event of damage to the main boot. No positive guarantee can be made for the integrity of the boot inside the cell, since the boots will deteriorate from both usage and the effects of radiation; booting of the control arm external to the cell is considered a second containment barrier. The boots are fabricated with a nylon cloth material impregnated with vinyl plastic and have a very high resistance to tearing.

The facility has been evaluated[1,2] to determine damage which could result from a pressure buildup in the cell due to a fire or explosion and the release of the CO_2 fire extinguisher system. For the present SRE program a mineral oil fire initiated by the reaction of NaK with water is considered the maximum credible accident and can be safely confined to the primary cell structure. Ultimately, the zinc bromide viewing windows are considered the weakest point in the primary containment shell and have been reviewed from the standpoint of adequacy under various conditions to which they may be subjected. The problems were reviewed with a representative of the Pittsburgh Plate Glass Company, the source of supply for plate glass of this type. A conservative engineering opinion on the integrity of the installation is:

Hazard	Comment	Safety Factor
Impact	Highly resistant to impact by tools or equipment accidentally contacted with glass	1-in. annealed glass outside the 1-in. tempered glass acts as safety shield; even though the annealed glass is completely shattered, the strength of the window with respect to pressure is unchanged

Hazard	Comment	Safety Factor
Fire	Heat from a fire is not expected to affect the windows adversely, even if subjected to thermal shock by release of the CO_2 system	Separate piece of 1-in. tempered plate is installed on the hot side of each window for additional protection
Pressure	Capable of withstanding sustained pressure of at least 500 lb/sq ft	10
Explosion	Capable of withstanding shock wave pressure of at least 2250 lb/sq ft	6
Radiation damage	The plastic laminating material in the windows, polyvinylbutyral, is subject to damage at 1 to 2.5 x 10^7 r/hr	The extra glass will allow greater radiation protection
Missile damage	Capable of withstanding missile damage equivalent to small arms ammunition	The extra glass will provide additional protection

3.3 Description of Process for SRE Fuel

The SRE element (Figs. 9 and 10, Table 1) is a bundle of seven stainless steel-clad NaK-bonded uranium or uranium alloy fuel rods with inert stainless steel end hardware. Each fuel element is contained in a cannister made of stainless steel tubing with one end sealed and the other end fitted with a gasketed screw closure. Ten elements can be shipped in a carrier modified specifically for this purpose. The carrier (Fig. 11) has a revolving inner cylinder, which can be indexed to any of the ten positions for charging an element to the cell.

The carrier is unloaded outside the building and placed on a special track-mounted dolly which permits the carrier to be rolled up and aligned with the loading door of the cell. The lead shielding doors on the carrier and cell are raised and the air seal door to the cell is unlocked and swung to one side, providing access to the fuel cannisters. The arrangement of the equipment in the cell is shown in Figs. 12 and 13. A traversing table located in front of the operating windows of the cell is capable of traveling the entire length of the cell. Table-mounted devices (Fig. 14) permit removal of the cannister cap and withdrawal of the fuel element into a covered trough for disassembly. The trough is provided with covers and special end boxes which engage with the saw guard of an abrasive wheel saw to form a closed envelope for particle retention. The element is

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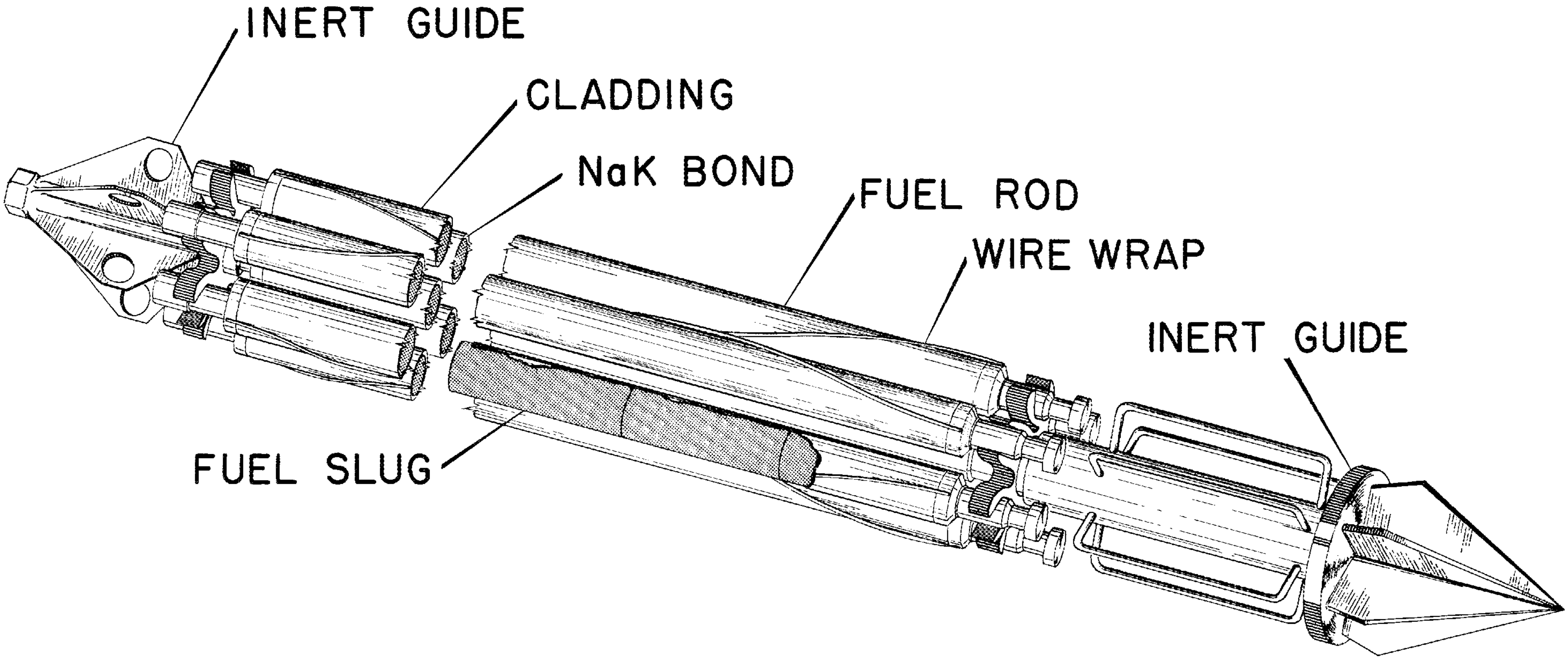

FIG. 9 SRE FUEL ELEMENT

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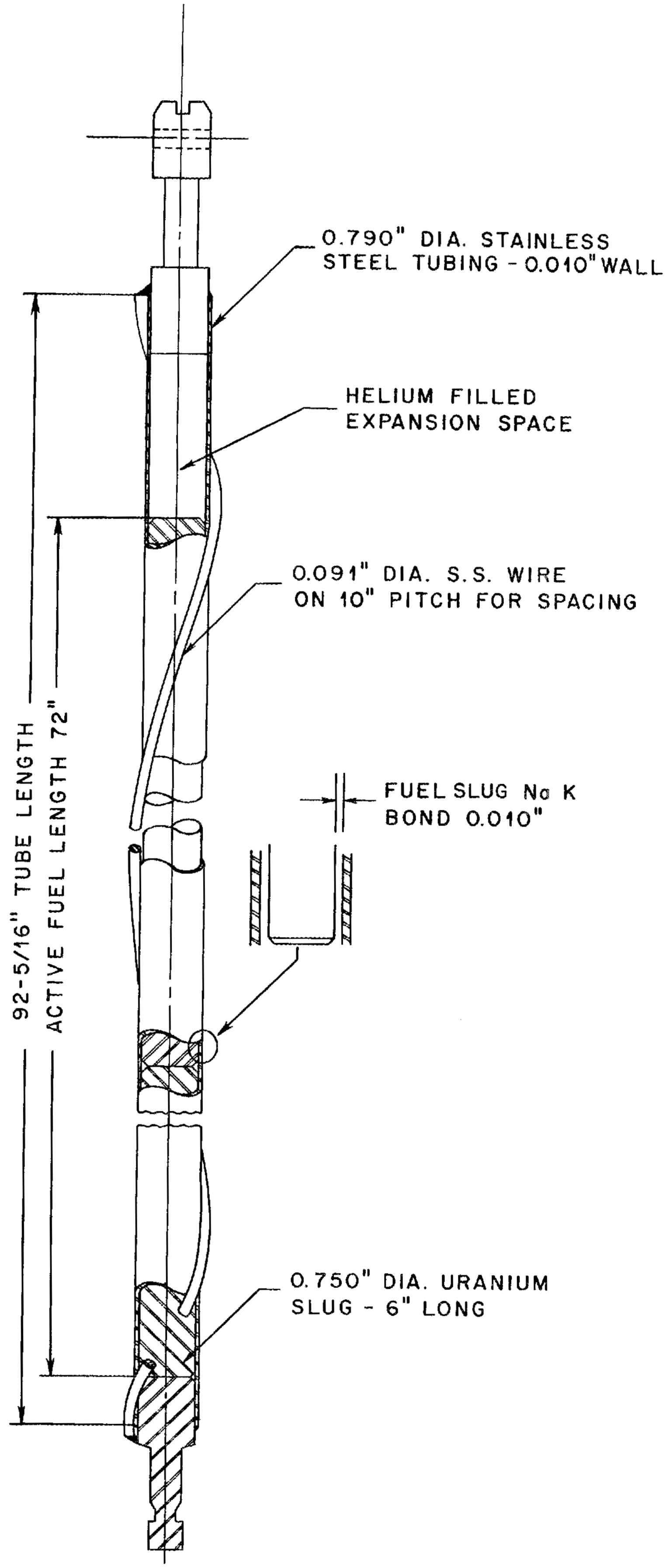

FIG. 10 SRE FUEL ROD

Table 1. Characteristics of SRE Fuel Element

Fuel Element	
Fuel slugs per rod	12
Fuel rods per element	7
Total length	92.312 in.
Active length	72 in.
Outside diameter	2.79 in.
Over-all length of assembly	105.6 in.
Weight of fuel	68.964 kg
Total weight of element, plus end hardware	163 lb
Fuel Slug	
Material	Uranium or uranium alloy
Diameter	0.750 in.
Length	6 in.
Enrichment	2.78% U^{235}
Weight	0.821 kg
Fuel Slug Tube (Cladding)	
Material	304 stainless steel
Outside diameter	0.790 in.
Wall thickness	0.010 in.
Fuel Slug Tube Wrap	
Wrap spacing	10 in. pitch
Material	Stainless steel wire
Diameter of wire	0.091 in.
Bonding	
Material	NaK (78% K - 22% Na)
Quantity	6 cu in. per fuel rod
Burnup	
Maximum	1000 Mwd/ton
Decay	
Minimum	120 days

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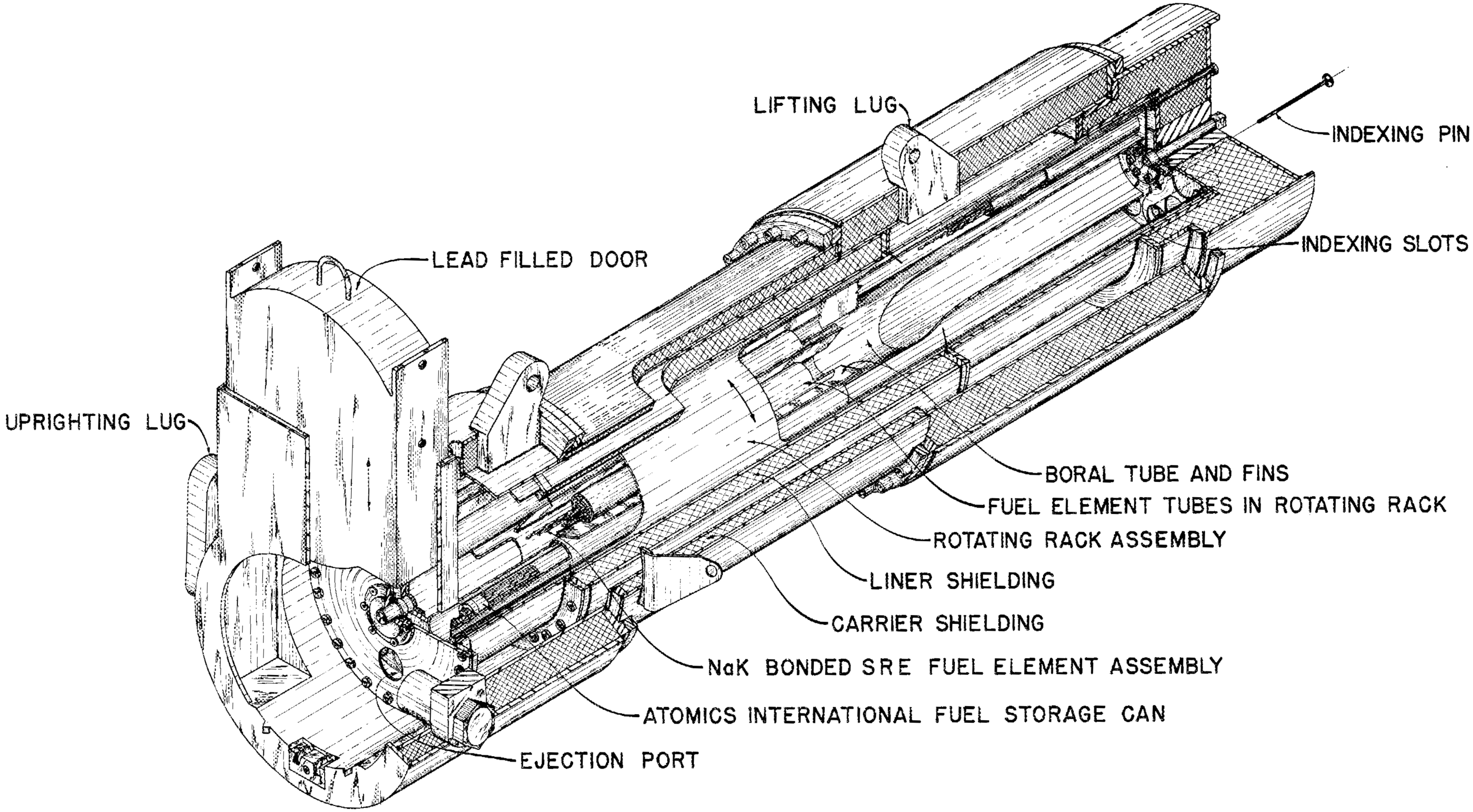

FIG. 11 SRE FUEL ELEMENT CARRIER

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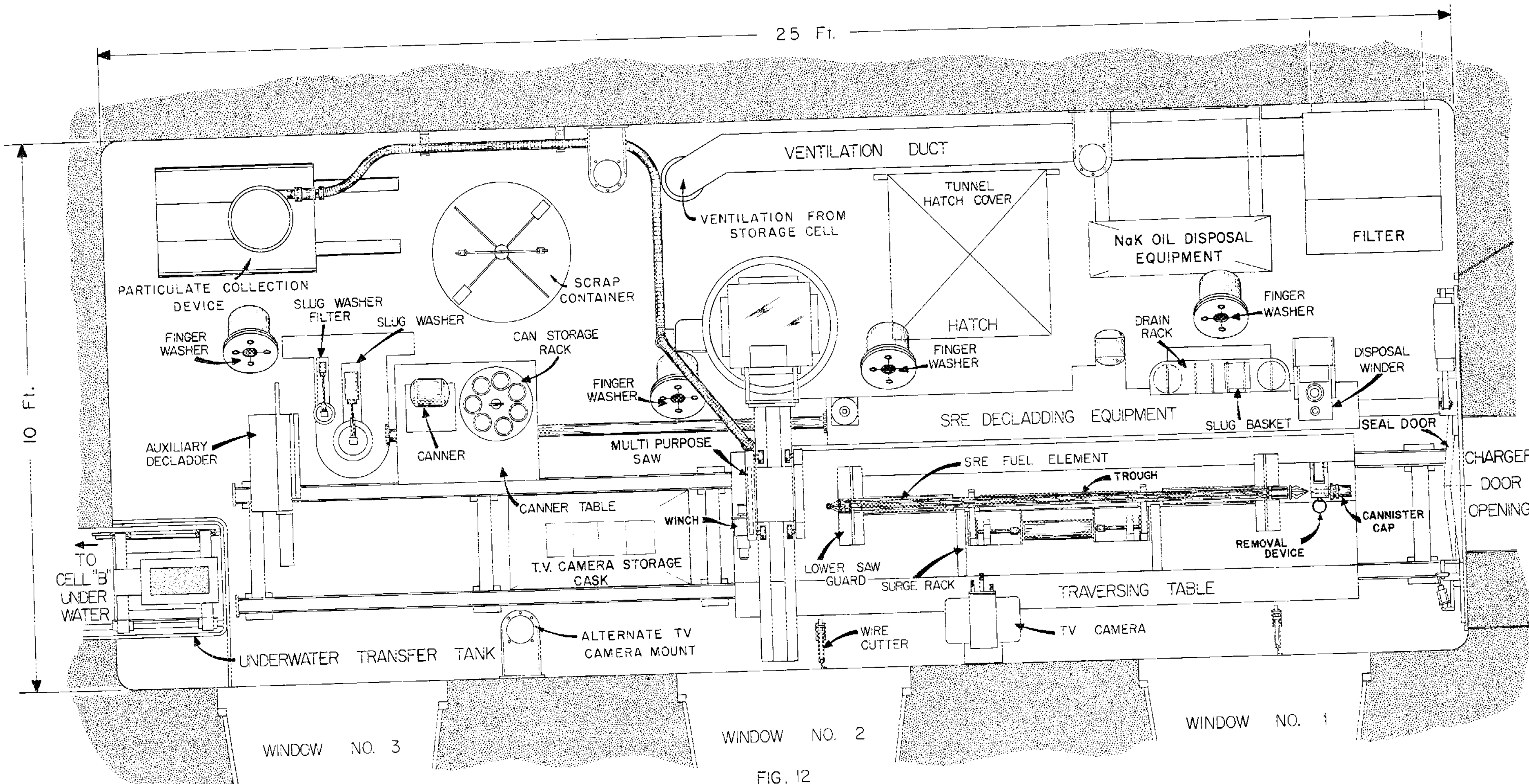

FIG. 12

Proposed Installation Of SRE Fuel Element Reprocessing Equipment - Bldg. No. 3026

Plan View - Cell "A"

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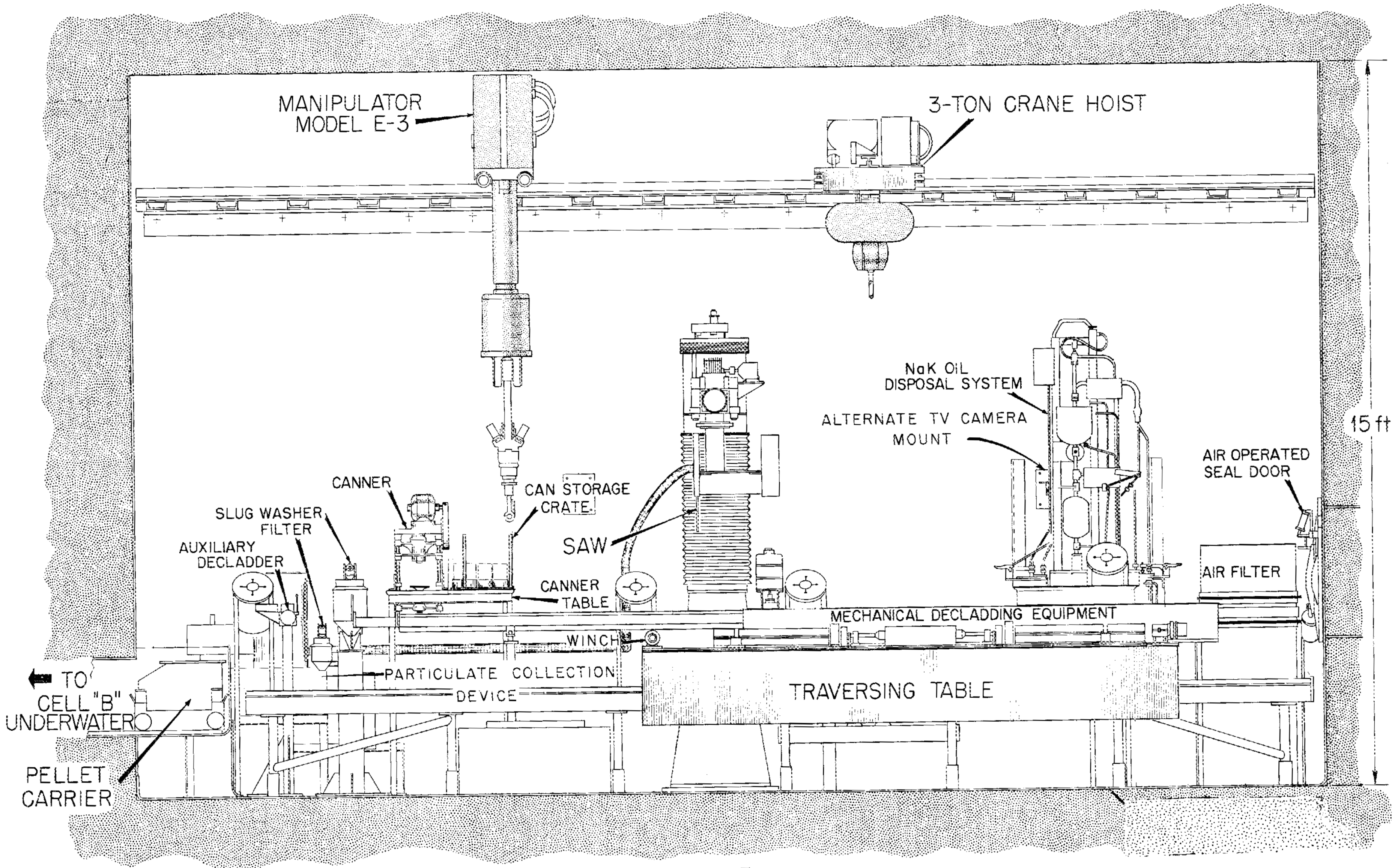

FIG. 13
Proposed Installation Of SRE Fuel Element Reprocessing Equipment - Bldg. 3026
Front Elevation — Cell "A"

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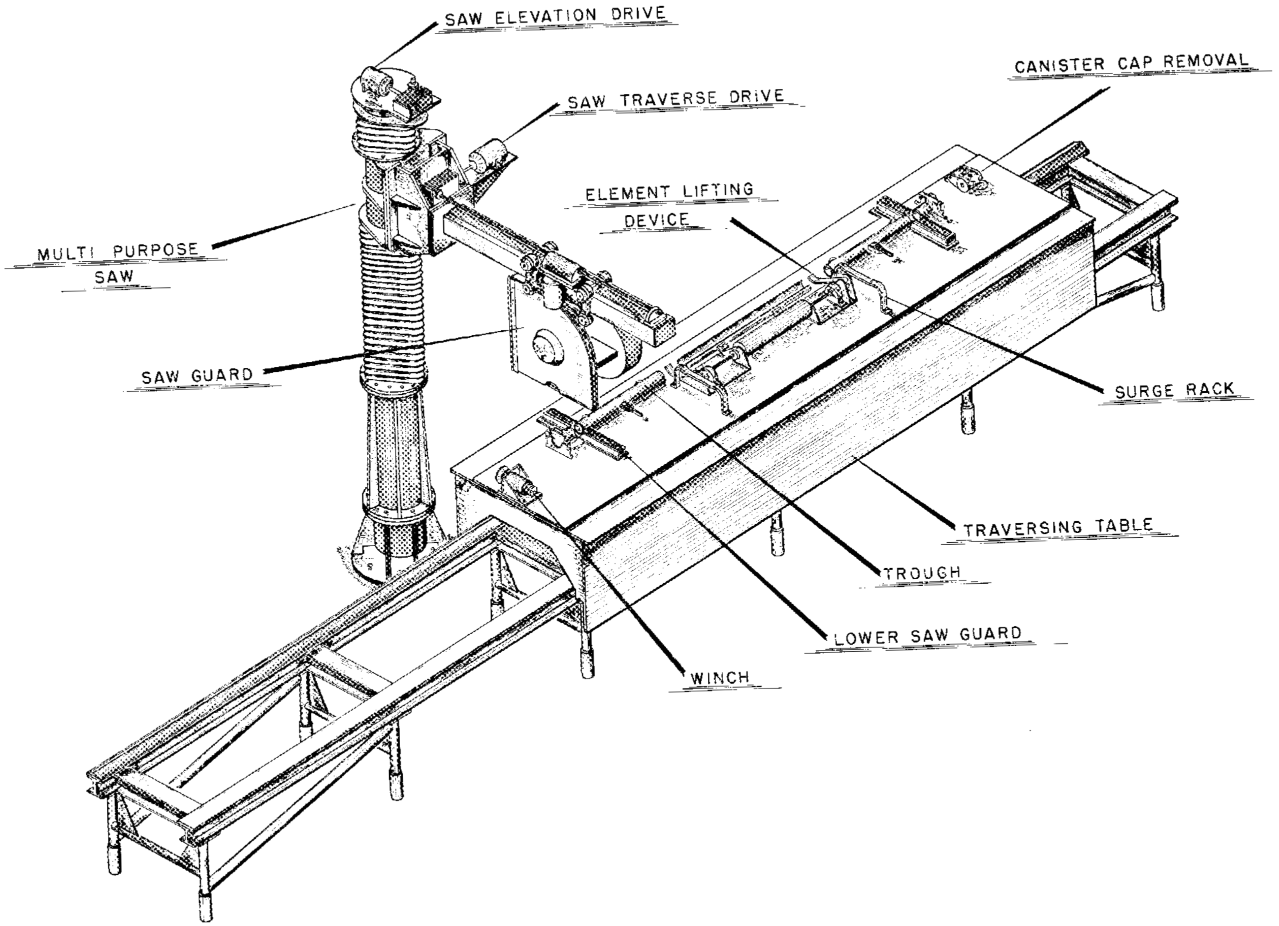

FIG.14 - TABLE MOUNTED DEVICES

positioned and checked by means of gages to index the inert end hardware under the cutting wheel. A cut is made adjacent to the weld point of the cladding in the end plug so that the NaK is retained in the rod; the other end of the element is removed similarly. This operation separates the element into seven separate rods. Lifting arms operated by an air-actuated rotary cylinder remove the rods from the trough and allow them to roll on a surge rack. Manipulator-operated hydraulically actuated wire cutters are used to remove the wire wrap from the six outer rods. The fuel rods are then placed one at a time in the main decladding machine (Fig. 15). The decladding operations are carried out under a bath of mineral oil to avoid exposure of the NaK to air. The fuel element rests on a pair of revolving rolls; these rotate the element under wheel cutters at each end of the machine which cut the stainless steel cladding free from the end plugs. The cladding is engaged in a collet at one end of the machine, which holds the cladding on both the inner and outer surfaces and forms a hydraulic seal with the cladding. Mineral oil is forced under pressure to the cladding to expel the NaK and slugs. If the slugs are tightly held by the cladding, an alternative procedure is used in which only one of the end plugs is removed and the hydraulic pressure is used to expand the cladding to release the slugs. The other end plug is then removed and the hydraulic pressure is applied to force the NaK and slugs from the cladding. In the event the hydraulic pressure is insufficient to expel the slugs, a mechanical screw is available to drive them out. The cladding is discarded after being wound into a flat spiral coil with a winding device built into the machine. If slugs are tightly bound to the cladding or jammed, a gage is used to locate the jammed slugs and a section of the rod can be cut out. An auxiliary decladder used to remove the cladding from such slugs (Fig. 16) consists of a die with cutting wheels through which the slug is forced by means of a hydraulic cylinder.

The NaK released from the elements is collected in sumps on both decladding machines and flows to a dump tank and then to a metering tank operated by a remotely controlled valve system. The metering tank is designed to hold the volume of NaK released from each fuel rod. The NaK, along with some mineral oil, is transferred by nitrogen pressure to a reactor where live steam is reacted with the NaK under a mineral oil and nitrogen blanket. The hydrogen evolved is diluted with sufficient nitrogen to keep the mixture well below the explosive limit for hydrogen. The sodium and potassium hydroxides formed are sent to the waste system along with some mineral oil.

The declad slugs, coated with mineral oil and some residual NaK, are placed in a steam cleaning device. Steam jets impinge on the rods held in a wire basket, which revolves by the jet action. The cleaned slugs are transferred to the canning table and canned in aluminum cans by a modified standard canning device. A storage rack holds seven cans of slugs, from one complete fuel element, which are transferred by an underground cart to the storage cell (Fig. 17). The storage racks are designed to stack three high and are placed in rows on opposite sides of the storage cell to constitute a critically safe arrangement.

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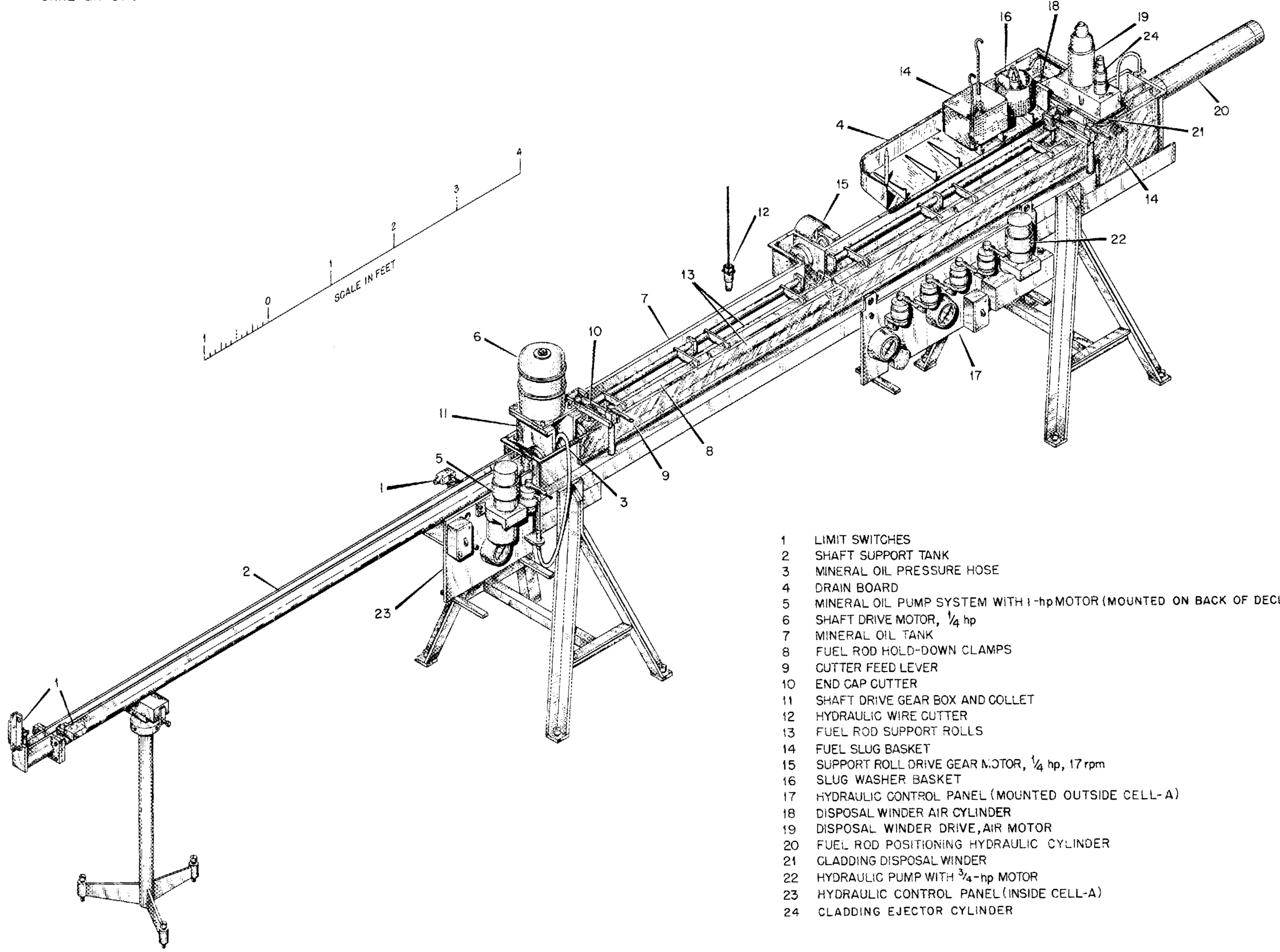

1 LIMIT SWITCHES
2 SHAFT SUPPORT TANK
3 MINERAL OIL PRESSURE HOSE
4 DRAIN BOARD
5 MINERAL OIL PUMP SYSTEM WITH 1-hp MOTOR (MOUNTED ON BACK OF DECLADDER)
6 SHAFT DRIVE MOTOR, 1/4 hp
7 MINERAL OIL TANK
8 FUEL ROD HOLD-DOWN CLAMPS
9 CUTTER FEED LEVER
10 END CAP CUTTER
11 SHAFT DRIVE GEAR BOX AND COLLET
12 HYDRAULIC WIRE CUTTER
13 FUEL ROD SUPPORT ROLLS
14 FUEL SLUG BASKET
15 SUPPORT ROLL DRIVE GEAR MOTOR, 1/4 hp, 17 rpm
16 SLUG WASHER BASKET
17 HYDRAULIC CONTROL PANEL (MOUNTED OUTSIDE CELL-A)
18 DISPOSAL WINDER AIR CYLINDER
19 DISPOSAL WINDER DRIVE, AIR MOTOR
20 FUEL ROD POSITIONING HYDRAULIC CYLINDER
21 CLADDING DISPOSAL WINDER
22 HYDRAULIC PUMP WITH 3/4-hp MOTOR
23 HYDRAULIC CONTROL PANEL (INSIDE CELL-A)
24 CLADDING EJECTOR CYLINDER

FIG. 15 MECHANICAL DECLADDING EQUIPMENT FOR SRE FUEL ELEMENT RODS

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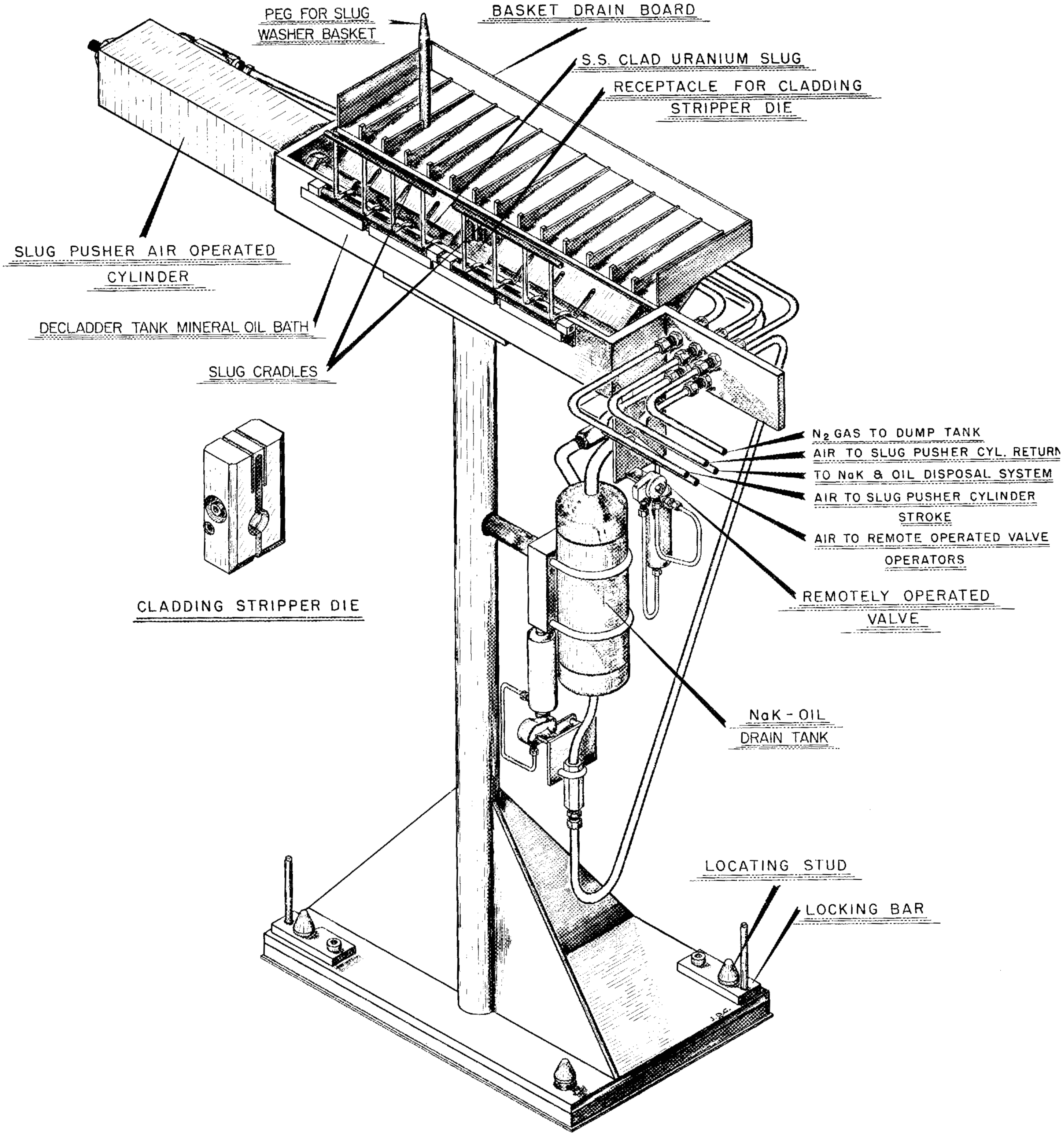

FIG. 16 AUXILIARY DECLADDER - SLUG

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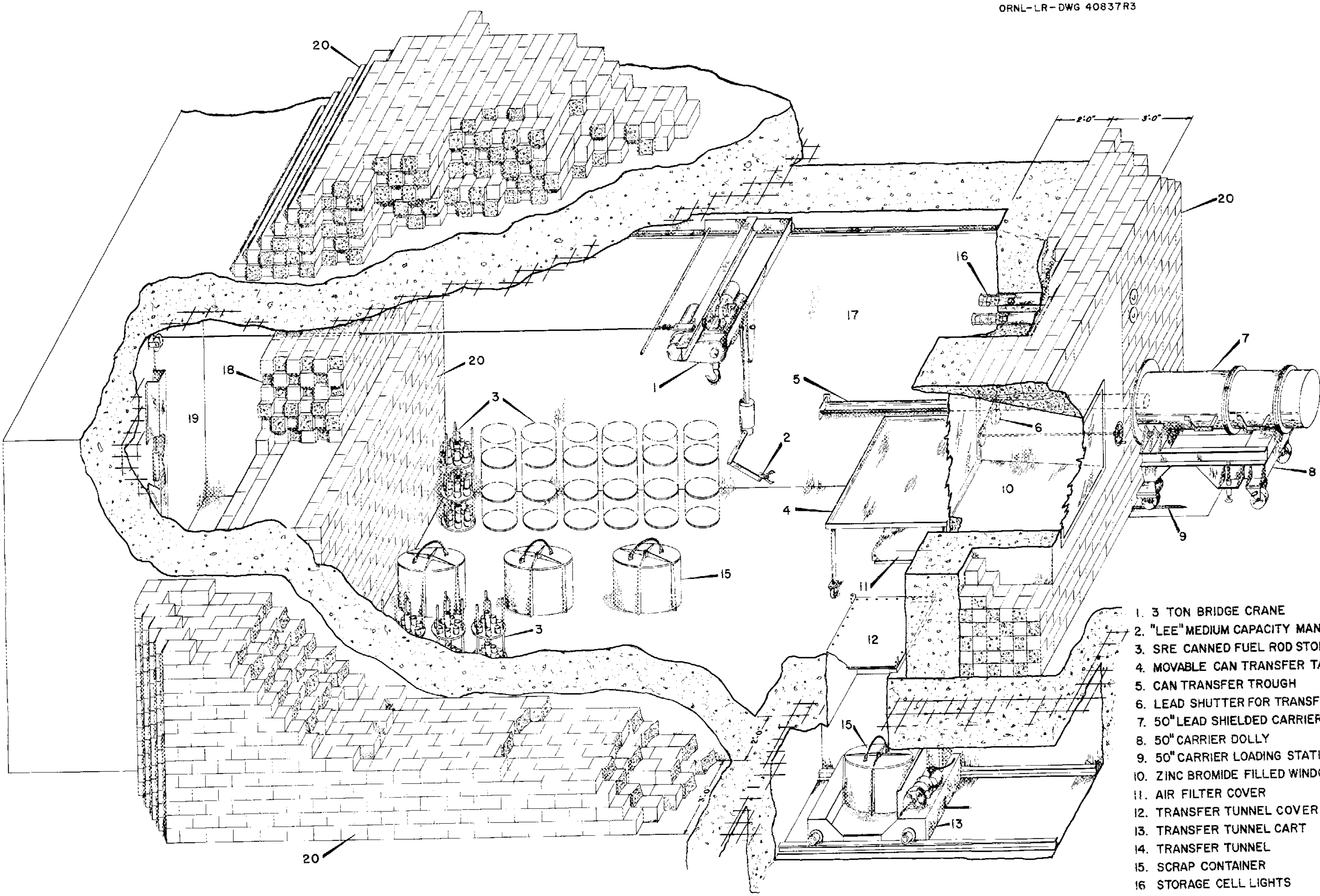

1. 3 TON BRIDGE CRANE
2. "LEE" MEDIUM CAPACITY MANIPULATOR
3. SRE CANNED FUEL ROD STORAGE CRATES
4. MOVABLE CAN TRANSFER TABLE
5. CAN TRANSFER TROUGH
6. LEAD SHUTTER FOR TRANSFER TROUGH
7. 50" LEAD SHIELDED CARRIER
8. 50" CARRIER DOLLY
9. 50" CARRIER LOADING STATION
10. ZINC BROMIDE FILLED WINDOW
11. AIR FILTER COVER
12. TRANSFER TUNNEL COVER
13. TRANSFER TUNNEL CART
14. TRANSFER TUNNEL
15. SCRAP CONTAINER
16. STORAGE CELL LIGHTS
17. STORAGE CELL
18. STACKED BLOCK FOR CRANE REMOVAL
19. CRANE MAINTENANCE AREA
20. STACKED BLOCK ADDITIONAL SHIELDING

FIG. NO. 17
STORAGE CELL BLDG. NO. 3026

3.4 Description of Liquid and Gaseous Waste System

3.4.1 Liquid Waste System

The original radioactive waste system for the cells consisted of five lines: two 0.5-in. and three 2-in. lines. One of the 2-in. lines also services the storage cell and is normally valved off from the waste system. Only one of the 2-in. lines is being used in cell A for the current operation. Liquid waste flowing through this line goes to a holdup tank of 800 gal capacity in the waste tank farm where it is monitored. The waste is jetted when the level reaches 600 gal. In the case of major decontamination of the cell, where large quantities of water are used, a 2-in. process waste line can be used. Process waste drains are in the charging room and in the maintenance area. The maintenance area also has a radioactive drain discharging through cell B.

All liquids discharged from the cell are dumped to the radioactive chemical waste system. Since the fuel processed is in the metal form, no fuel should go to the waste drain system. In certain operations where small chips or pieces of the slugs may collect in processing equipment, filters are provided.

3.4.2 Gaseous Waste System

An off-gas system is installed in the cells, but is not being used in the present program, since the only radioactive gas released is krypton which is handled in the cell ventilation system.

3.4.3 Cell and Secondary Containment Ventilation System

The cell secondary containment ventilation system is shown schematically in Fig. 7. Air enters cell A from the maintenance facility, while cell B and the storage cell depend on inleakage only. Inlet air to cell A is filtered by roughing filters in the wall of the maintenance facility and by absolute filters ahead of the cell A air inlet duct. The exit air from cell A is filtered by roughing and absolute filters before it leaves the cell and again outside the building with another set of roughing and absolute filters. It then goes to stack 3039. Air from the storage cell is filtered by an absolute filter before it leaves the cell and is filtered again by roughing and absolute filters outside the building ahead of stack 3039. Cell B exhaust air follows the same flow pattern. A minimum air flow of 500 cfm will be maintained in the maintenance facility-cell A system. Inleakage air is assumed to be 100 cfm. A minimum pressure differential of 1.0 in. of water will be maintained in cells A and B and the storage cell; the pressure differential in the maintenance facility will be somewhat less.

4.0 HAZARD DESCRIPTION

4.1 Radiation

The radioactive material handled in the current SRE program is limited by supervisory control to one complete fuel assembly in the processing cell. The storage cell will contain the fissionable and fertile material from up to 55 SRE elements stored in a critically safe array.

4.1.1 Quantity

The maximum radiation levels based on average burnup for the current SRE program, assuming 120 days' decay, are:

	Total Curies	Gamma Curies	Beta and Alpha Curies
Cell A	3.8×10^3	2.1×10^3	1.3×10^3
Storage cell	2.09×10^5	1.16×10^5	7.2×10^4

4.2 Criticality

4.2.1 Quantity of Fertile and Fissionable Materials

The following maximum quantities of radioactive materials would be present in the handling of SRE fuel irradiated to 1000 Mwd/ton of uranium and decayed 120 days:

Element	Cell A	Storage Cell
U^{235}	~1.84 kg	~101.2 kg
U^{236}	0.01 kg	0.55 kg
U^{238}	67 kg	3685 kg
Pu^{239}	~0.04 kg	~2.20 kg

4.2.2 Control

All equipment has been reviewed and approved as critically safe. The amount of material in cell A is limited to one complete assembly at any one time. Only two items of equipment require special provisions to prevent criticality incidents: (a) the fuel carrier that acts as a charger for cell A was designed to hold ten elements in a circular array using fixed poison separator plates; and (b) the storage rack for holding the fuel from one fuel assembly was designed to hold the seven aluminum cans at a critically safe distance. The racks are also designed to be critically safe when stacked one above the other in the storage cell. Specific locations in rows on opposite sides of the storage cell have been approved as a critically safe arrangement.

4.3 Chemicals

Chemicals other than mineral oil and water will not be used in mechanical processing of the SRE fuel elements.

4.4 Fire and Explosion

4.4.1 Quantity of Flammable and Explosive Materials

Hazardous materials in the cell are NaK, hydrogen, mineral oil, and uranium. The quantities involved are shown in Table 2.

4.4.2 Control

Fires and explosions in the SRE fuel element mechanical processing would be limited to the following possible combinations of conditions:

a. NaK reaction with water and/or steam. Every effort and safeguard is made to keep NaK and water and/or steam from accidental contact. In two operations steam is deliberately reacted with NaK under controlled conditions.

(1) The NaK disposal system is an especially designed series of equipment items in which the NaK is stored under a blanket of mineral oil and nitrogen until it is transported in small metered 6 cu in. batches (approximately 90 g) to the NaK reactor, where it is reacted with steam.

(2) The fuel slugs removed from the mineral oil bath of the decladder will have a coating of NaK and oil, which will be removed with steam in a steam-saturated cleaner. The quantity of NaK carried into the slug cleaner will be of the order of a few grams total.

b. Hydrogen. Hydrogen will be evolved when NaK reacts with steam or water. Two hydrogen detectors are installed in the cell, the first a part of the NaK reactor and the second in the immediate vicinity of the reactor to monitor the air in the cell in the region of highest possible concentration. Alarms will indicate if the hydrogen content of the cell air approaches the possibly explosive value of 4%.

c. Mineral oil. Oil fires are possible as a result of NaK-H_2O reactions or of an electrical short. The mineral oil is a hydrocarbon with a high flash point and is difficult to ignite.

Table 2. Hazardous Materials in Cell During SRE Fuel Element Mechanical Processing

Material	Maximum Amount: In Cell at Any Time	In Cell in Process at Any Time	Of Product Generated at Any Time
Uranium	69,864 kg	9,852 kg	--
NaK	42 cu in. (688.1 ml, 608.3 g)	6 cu in. (98.3 ml, 86.9 g)	--
Hydrogen	(18.1 g potential)	--	2.58 g
Mineral oil	18 gal	4 cu in.	--

d. Uranium. Uranium is not considered a hazard since it is all in massive form and at room temperature.

A fire is controlled in three ways:

a. Supervisory control. Control will be exercised by supervision by physically and purposefully limiting the quantity of free NaK in the cell to 6 cu in. maximum at any one time.

b. A carbon dioxide fire extinguisher system is available and can be operated manually or automatically with a rate-of-rise initiation for release. This system will flood the cell with CO_2 for at least 30 min. A Cardox truck can be connected to a cell nozzle to extend this period if required.

c. Powder graphite extinguishers. Powdered graphite in plastic bags (5-lb) will be placed at convenient points in the cell to extinguish NaK fires. They can be placed directly over the fire with cell manipulators.

4.5 Maximum Credible Accident

The maximum credible accident would involve an NaK and/or mineral oil fire started from causes or for reasons given in earlier hazards reports*

4.5.1 Control

The automatic CO_2 release should supply a blanket of CO_2 to smother the fire. In addition, the CO_2 release will trigger an alarm which will alert people in the building and summon the aid of the fire fighting personnel of the Laboratory.

5.0 OPERATING PROCEDURES

A complete set of operating procedures**has been written, and as new requirements are brought to light additional procedures will be prepared. These procedures will be tested and proved during the nonradioactive testing period. At this time a series of check sheets, material balance sheets, record sheets, and notebooks will be developed. Operations will not be carried out in the cell except in strict conformity with the procedures developed; no deviations from these procedures will be permitted except with written approval of the supervising engineer, and all such deviations will be recorded in suitable log sheets and record books.

The operators will be trained in these procedures with a series of runs with simulated fuel elements and with actual fuels which have not been irradiated.

6.0 EMERGENCY PROCEDURES

Emergency procedures for the processing equipment are being developed, but the formalization will be deferred until actual operating experience is gained during the preoperational test period.

The emergency procedure for the building is being developed, the main requirement being an orderly disposal of materials in process and exit. The facility ventilation is operated by fans in the stack area, which are provided with auxiliary power service in case of an emergency.

Other than ventilation air, no other service is necessary for the system since equipment is either designed to fail safe in case of power failure or is self-sufficient, e.g. the CO_2 system.

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*W. F. Schaffer, Jr., "Survey of Segmenting Facility, Building 3026," ORNL-CF-60-2-85 (Feb. 5, 1960), and B. B. Klima, "SRE Fuel Elements Reprocessing - Safety Report," ORNL-CF-59-11-122, Rev. 1 (Feb. 5, 1960).

**B. B. Klima, "Mechanical Processing: SRE Fuel Element - Operating Procedures," ORNL-CF-60-2-9 (Feb. 4, 1960).

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