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SECTION 1 OF 3

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Abstract

This Final Safety Analysis Report (FSAR) addresses health, safety, and environment protection matters pertaining to the operation of the plutonium uranium reduction extraction (PUREX) Plant located in the U. S. Department of Energy Hanford Site.

This document fulfills the requirements of DOE Order 5480.1A, Chapter 5.

A Preliminary Hazards Analysis is presented. These hazards were reviewed by personnel experienced in the operations of the PUREX Plant. Comparison of the predicted accident consequences with established criteria result in the judgement that PUREX Plant operations may be conducted with an acceptable level of risk.

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SUMMARY OF REVISION

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Page 2.1

Rev. Ltr./ Chg. No.	Description Of Changes	Approvals / Date
REV 3	Chapters 1, 2, 4, 5, 6, 7, 8, 9, 10, 11 and Appendix C were revised to reflect the status of the PUREX Plant as of April 1985 (17 months after the startup in November 1983). The environmental dose calculations in Chapter 9 were updated and two changes were made to the Operational Safety Requirements in Chapter 11 which have been approved by DOE-RL. Specific areas of revision are denoted by a vertical line in the right margin. These changes did not significantly affect the overall conclusions of this document.	

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PUREX FSAR

CHAPTER 1.0 INTRODUCTION AND GENERAL PLANT DESCRIPTION

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1.0 INTRODUCTION AND GENERAL PLANT DESCRIPTION

1.1 INTRODUCTION

This Final Safety Analysis Report (FSAR*) addresses health, safety, and environmental protection matters pertaining to the operation of the Plutonium Uranium Reduction Extraction (PUREX) Plant for plutonium-uranium solvent extraction processing and plutonium oxide production. The PUREX Plant is located on the 570 mi^2 U.S. Department of Energy (DOE) Hanford Site in southeastern Washington State (Fig. 1-1). The PUREX Plant (Fig. 1-2) is located in the southeastern portion of the 200 East Area near the center of the Hanford Site.

This document fulfills DOE requirements which establish procedures ensuring the safety of nonreactor nuclear facilities.[1,2] Analyses have been performed on a system-by-system basis to ensure that all potentially significant risks and impacts are identified and that appropriate mitigating measures are taken.

The structure of this document follows the FSAR framework of the U.S. Nuclear Regulatory Commission (NRC) guide for safety analysis reports for fuel reprocessing plants.[3] Chapter 1.0 summarizes the plant structure. Plant operation is defined in detail in Chapters 3.0 through 8.0. Chapter 2.0 summarizes the results of the hazards analyses and risk assessments in Chapter 9.0. Chapter 10.0 describes the organizational structure associated with the PUREX Plant. Chapter 11.0 discusses the Operational Safety Requirements (OSR). In addition, a glossary is presented in Appendix A, a PUREX Plant history is provided in Appendix B, the PUREX Plant Operational Flow Diagram is shown in Appendix C, and the PUREX Plant Fault Tree Analysis is displayed in Appendix D.

1.1.1 Plant Mission and History

The mission of the PUREX Plant is to reprocess irradiated fuels from the Hanford Site N Reactor for the recovery of uranium and plutonium.

The program to design and construct the PUREX Plant and the associated support facilities was initiated in 1952 by the U.S. Atomic Energy Commission (AEC, now DOE). The plant was one of the mainstays in the United States' nuclear fuel separations program, processing irradiated production reactor fuels for the recovery of uranium and weapons-grade plutonium. From the first operation in 1956 to shutdown in September 1972, refinements were made in the plant to upgrade equipment, achieve process versatility, and adapt to changing feed material.

*A complete list of all acronyms used in this document is provided in Appendix A.

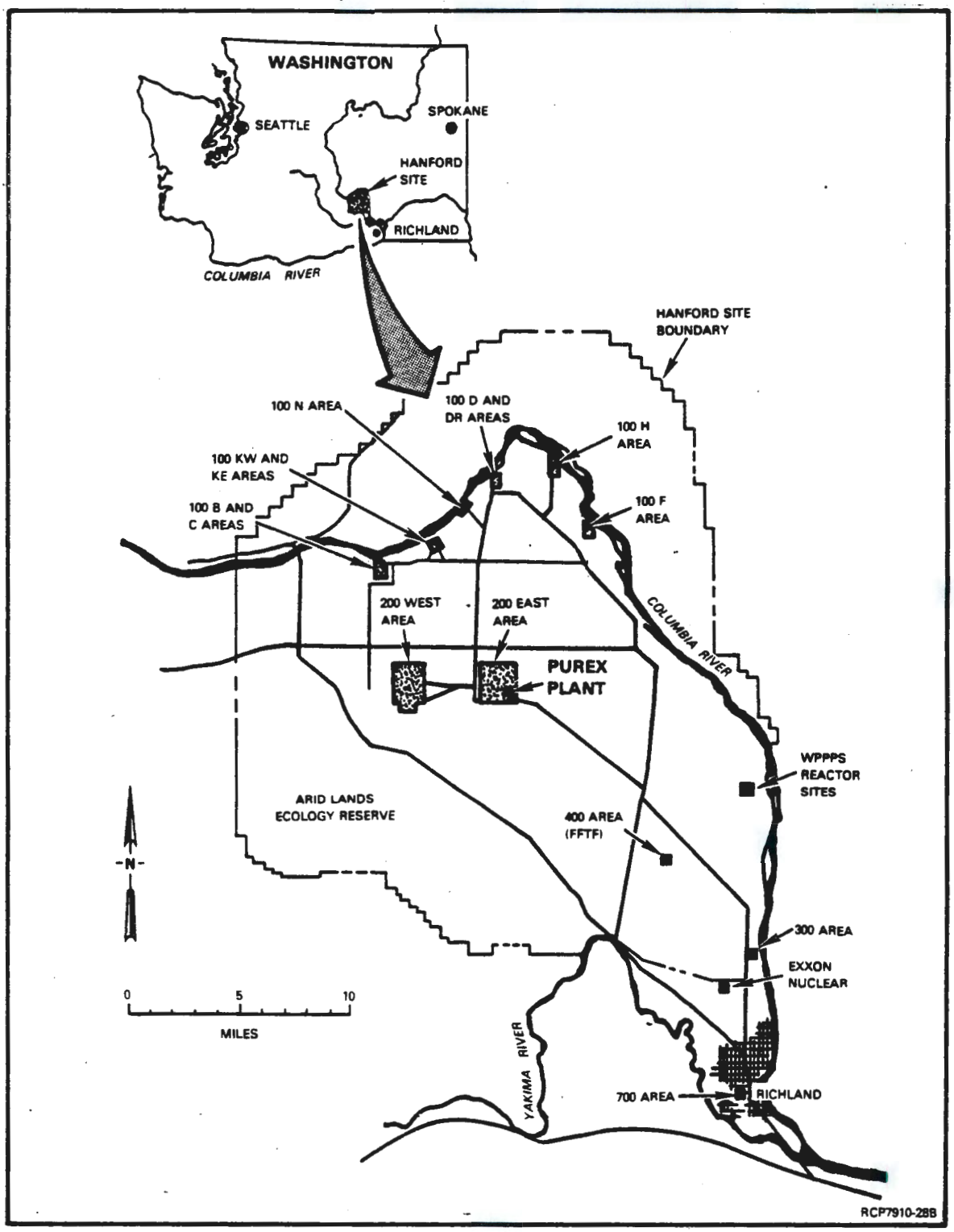

FIGURE 1-1. Hanford Site.

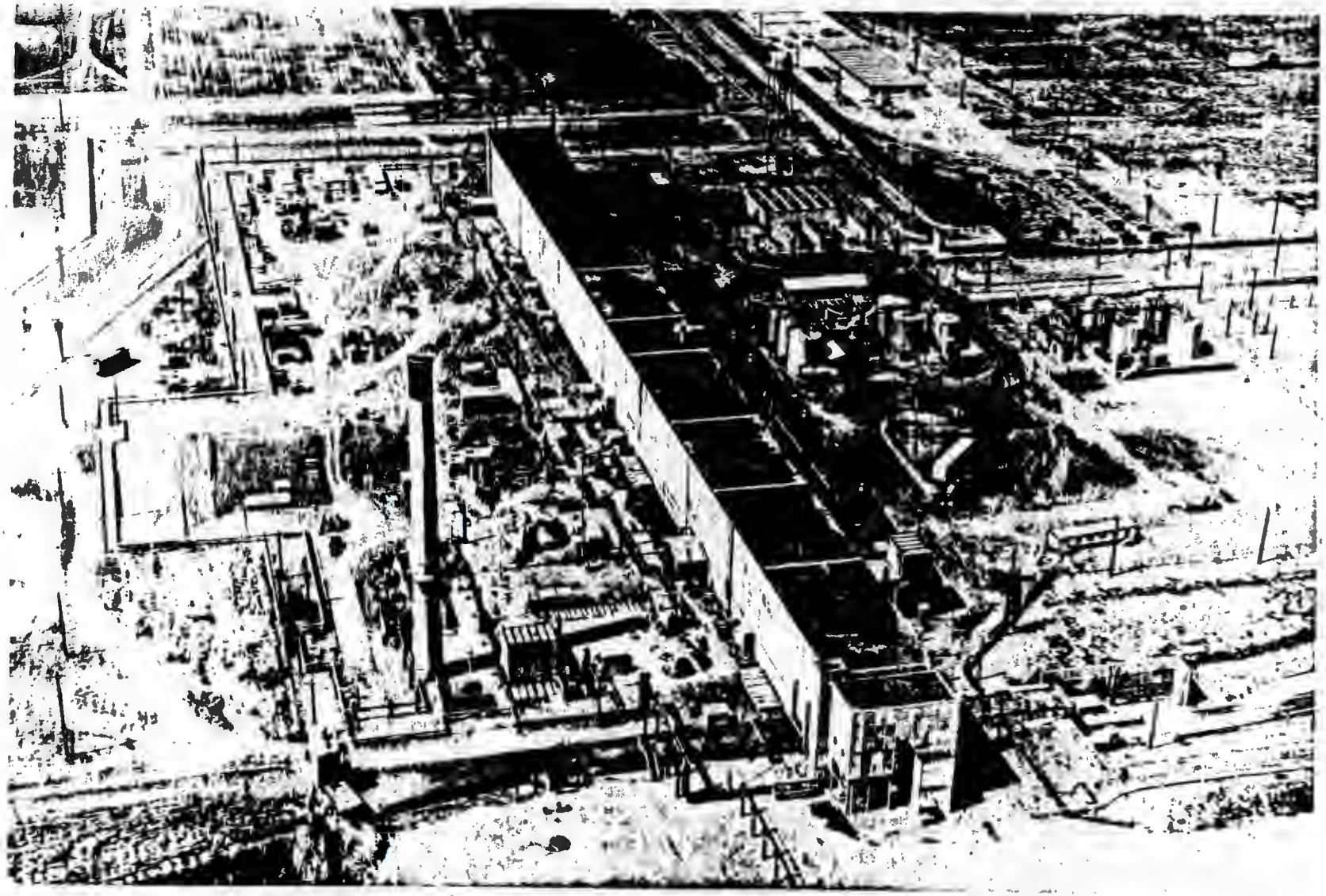

FIGURE 1-2. PUREX Plant--200 East Area.

Shutdown in 1972 was the result of the closure of eight of the nine production reactors at Hanford. Between shutdown and 1978, the plant was maintained in a "wet standby" condition. Major plant equipment, such as extraction columns and associated tankage, was periodically flushed with a dilute nitric acid solution. Pumps, column pulsers, jets, and other mechanical equipment were operated on a regular basis. Failed equipment was either upgraded or replaced, or the failures were formally documented for replacement. From 1978 to 1983, a program consisting of operability, readiness, and cold startup tests was in progress at PUREX to establish the plant's readiness to reprocess fuels in anticipation of restart. The PUREX Plant was started in November 1983 and has been operating to date on the recovery of plutonium from irradiated uranium fuel.

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1.1.2 Fuels to be Processed, Plant Capacity, Process, and Products

The plant has a nominal processing capacity of 10 tons/d of Zircaloy-clad 0.947% enriched (preirradiation ^{235}U content) or 6 tons/d of "spike" fuel elements. (Spike fuel consists of 0.947% enriched inner element and 1.25% enriched outer element.) The process steps consist of chemical decladding of the fuel elements, metal dissolution, product decontamination, and product separation and purification by solvent extraction. The uranium product, uranyl nitrate hexahydrate in an acidic solution (UNH), is stored in large tanks and ultimately transferred by tank trailer to the Uranium Oxide Plant (referred to as the UO_3 Plant) for conversion to uranium trioxide. The plutonium, concentrated as an acidic solution of plutonium nitrate, is converted to plutonium oxide and placed into temporary storage facilities located at the Hanford Site.

With adequate preparation, the plant has the capability to produce a neptunium product.

1.1.3 Wastes

Liquids essentially free of radioactive contamination are discharged to artificial ponds. An estimated discharge rate of about 2.9×10^9 gal/yr of nonradioactive liquid wastes is expected. Slightly contaminated liquid wastes are discharged to underground trenches (cribs). Liquid wastes, containing mixed fission products (FP), are neutralized at PUREX and routed to underground tanks for storage. Noncontaminated solid waste is compacted and buried in a sanitary landfill. Contaminated solid wastes are segregated as to level and type of contamination. Industrial solid wastes contaminated with FP are buried in regulated zone burial trenches, while wastes containing transuranics are packaged and buried in 20-yr retrievable storage.

All radioactive elements in gaseous effluents from the PUREX Plant will be below the concentration limits specified by guidelines[4] for unrestricted areas. Krypton and tritium will be present in concentrations somewhat above the guidelines in the gases at the top of the 200-ft-high stack; however, these elements will be rapidly dispersed by a factor of 10^6 to 10^8 as these gases move away from the stack. The concentrations will be well below the limits as the stack plume travels toward the Hanford Site boundary (see Table 7-3).

1.2 GENERAL PLANT DESCRIPTION

1.2.1 Principal Plant Characteristics

The PUREX Plant and adjacent structures are indicated in Figure 1-3. This FSAR covers those buildings and structures located within the double-fenced exclusion area. The PUREX Plant is comprised of the main canyon building (202-A) and a number of auxiliary structures and facilities, including waste disposal sites and contaminated equipment burial tunnels. In addition, other facilities (tank farms, cribs, retention basin, etc.) are identified and located in Figure 1-3. Most of these facilities are required for direct support of PUREX Plant operations. Their functional relationship to the PUREX Plant is described in appropriate sections of subsequent chapters within this document.

The plant structures were built to safely handle materials of varying degrees of radioactivity. The canyon structure with below-grade, isolated chemical processing cells was selected as being most appropriate for a bulk radiochemical separations operation.

Structures built prior to 1968, which include the 202-A canyon building and most of the other structures handling highly radioactive materials, were designed for typical static vertical live and dead loads in accordance with uniform building codes, Hanford standards, and other applicable design documents in effect at the time of construction. Structures built after 1968, with the exception of the third PUREX filter, were designed for the most severe possible combination of dead, live, and operating loads appropriate for the given criteria. Seismic provision is made in the load calculations for a maximum credible earthquake producing a 0.25-g horizontal ground acceleration and a 0.17-g vertical acceleration. The third filter, which would not impact safe shutdown of the plant after a seismic event, conforms to the less restrictive seismic provisions of the uniform building code.

1.2.2 Building 202-A Structural Description

As shown in Figures 1-4 and 1-5, 202-A building consists of three main structural components: (1) a thick-walled, heavily shielded concrete portion called the canyon which contains processing equipment; (2) a section comprised of three gallery levels parallel to and isolated from the canyon; and (3) a steel and transite annex to the north of the gallery section which houses offices, the laboratory, and a number of building service areas. A crane maintenance platform provides access to the east end of the canyon. A detailed discussion of the facility is presented in Chapter 5.0.

The canyon area proper is a narrow structure, 1,005 ft long, 30.5 ft wide, and 104 ft high, with about 40 ft of this height below grade. The canyon is subdivided into a single row of 12 process cells paralleled on the south side by a "hot" (radioactive) pipe trench with an air tunnel connected to the cells running underneath the pipe trench. East of the canyon, a

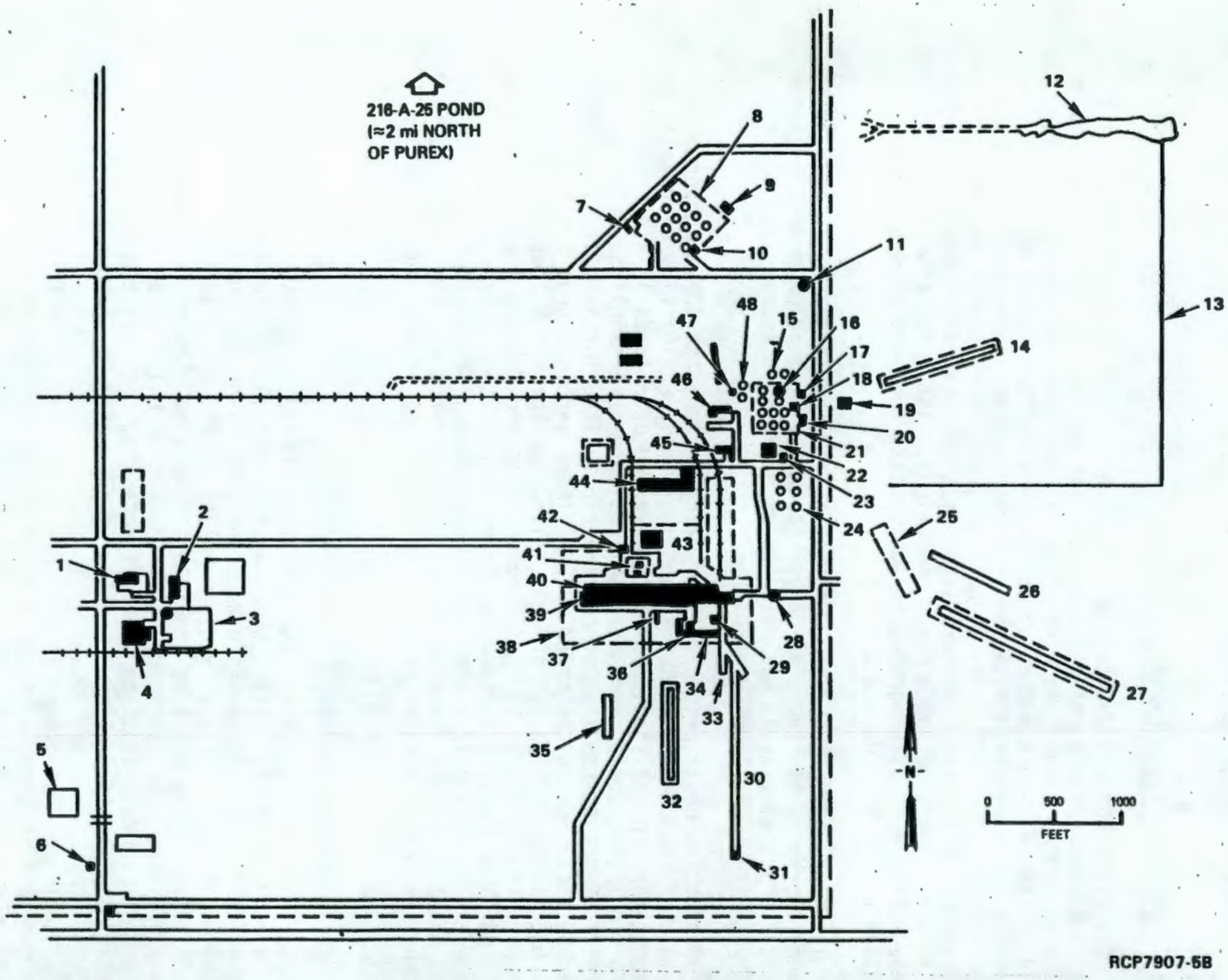

FIGURE 1-3. PUREX Plant and Adjacent Facilities. (Sheet 1 of 2)

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Legend

1. Filter plant (283-3)
2. Powerhouse (284-E)
3. Coal pile
4. Reservoir (282-E)
5. Waste Management Surveillance Building (2750-E)
6. Office equipment repair (2709-E)
7. Diversion boxes (241-C-151 to -153 241-CR-151 to -153, 241-C-252)
8. Waste storage tank farm (241-C)
9. Cesium loadout (241-C-801)
10. Control house (271-CR)
11. Emergency water well
12. B Plant pond (216-B-3)
13. PUREX chemical sewer ditch
14. Contact condenser crib
15. Waste storage tank farm (241-AZ)
16. Transfer box (241-A-153)
17. Coolant building (241-A-401)
18. Change and control building (2707-AX)
19. Cribs (216-A-1 and -7)
20. Diversion box (241-A-302-B)
21. Waste storage tank farms
22. Evaporator building (242-A)
23. Retention basins (207-A)
24. Waste storage tank farm (241-AW)
25. Retention basin (216-A-42)
26. Steam condensate crib (216-A-37-1)
27. Steam condensate crib (216-A-30)
28. Cooling water tank (241-A-201)
29. Offgas treatment and acid recycle building (293-A)
30. Railroad tunnel (218-E-15)
31. Monitoring station
32. Cribs (216-A-2, -4, -21, -36)
33. Railroad tunnel 218-E-14)
34. Fanhouse and stack (291-A)
35. Process condensate crib (216-A-10)
36. Exhaust filters
37. Storage
38. Exclusion-area fence (double)
39. Separations building (202-A)
40. PUREX building annex
41. Chemical storage (211-A and 2714-A)
42. Gatehouse (2701-A)
43. UNH storage area
44. Warehouse (275-E)
45. Waste diverter station (241-AX-151)
46. 244-AR vault
47. Stack (291-AR)
48. Waste storage tank farm (241-AY)

FIGURE 1-3. PUREX Plant and Adjacent Facilities (Sheet 2 of 2)

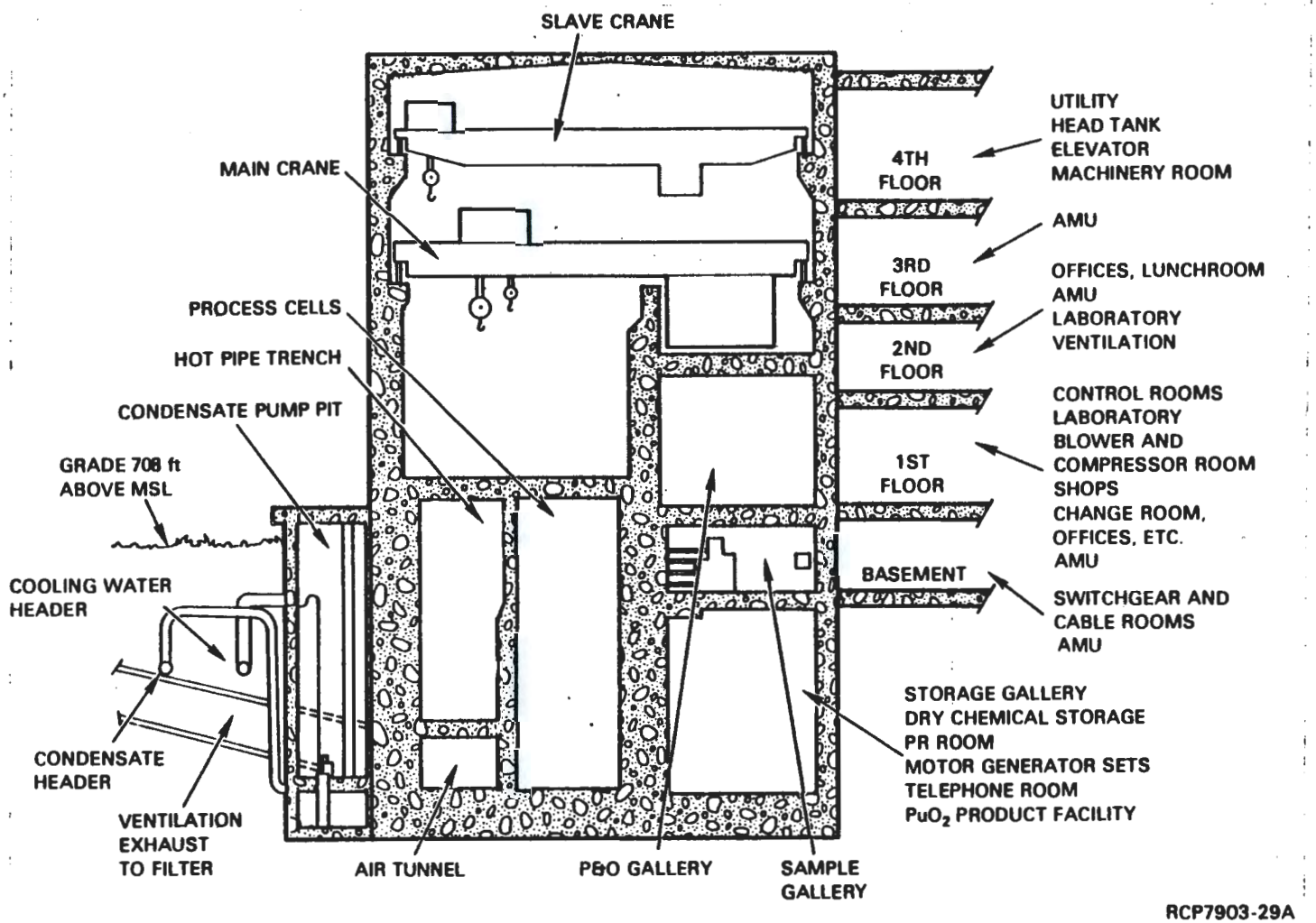

FIGURE 1-4. Cross Section of PUREX Facility.

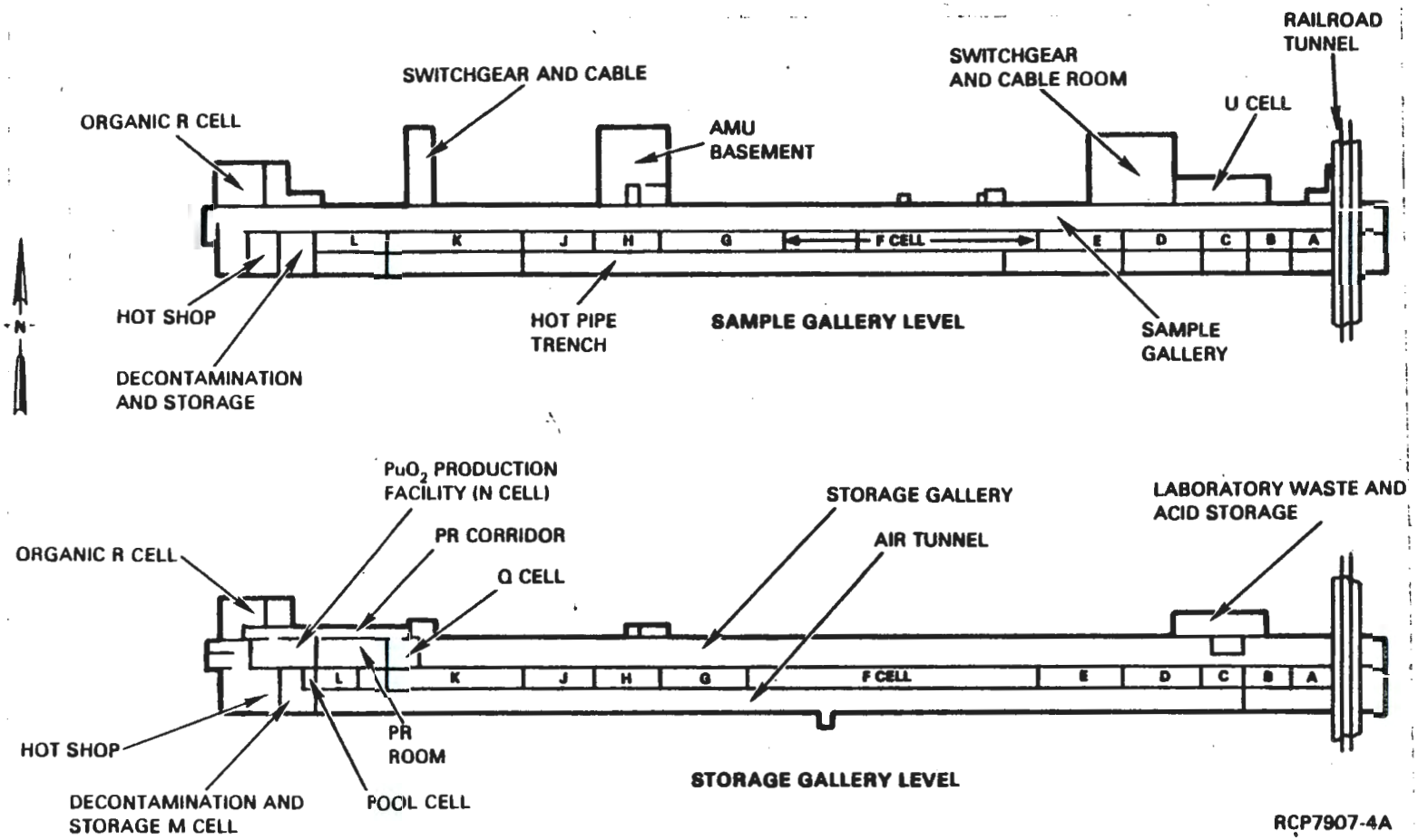

FIGURE 1-5. Plan Views--PUREX 202-A Building. (Sheet 1 of 2)

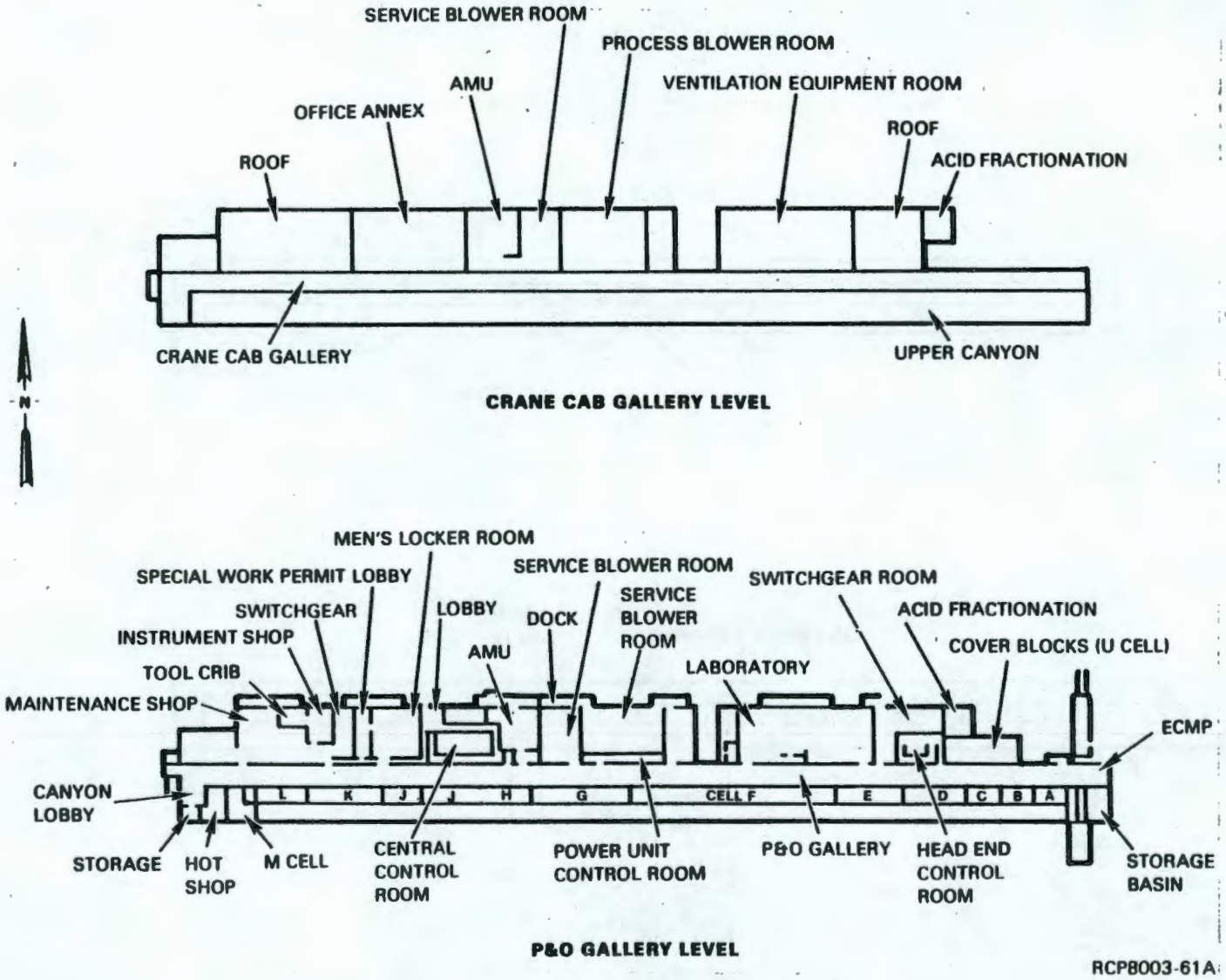

FIGURE 1-5. Plan Views--PUREX 202-A Building. (Sheet 2 of 2)

railroad spur enters the plant below grade through a tunnel. Both a vertical door and a horizontal, remotely operated door are provided to the railroad tunnel. These doors, used in proper sequence, maintain canyon ventilation balance and access control. The vertical door controls access from the outside and is always closed while the cask is open. The horizontal door allows access to the tunnel from the canyon. These two doors are not open at the same time. At the east end of the canyon is an inactive fuel storage basin. The basin is administratively controlled and is used for storage of aluminum-clad fuel. No new fuel will be added to this basin.

The east crane maintenance platform (ECMP) is in an extension that was added to the existing 202-A building in 1957. The extension is 71 ft 3 in. tall, 36 ft wide, and 61 ft 6 in. deep, and is a reinforced concrete and steel-beamed structure. The three exterior sides are made of 2-in.-thick asbestos-cement board, which is in turn covered with 9-in. precast concrete panels above the 731-ft elevation and 4-in. precast concrete panels below the 731-ft elevation. Three interior, 3-in.-thick, steel-plate shielding doors separate the canyon from the ECMP. Below the 731-ft elevation, 10 in. of concrete of the original building separate these structures. The roof is made up of coal-tar pitch, roofing felt, mineral-surfaced roofing, plastic roofing cement, and roofing gravel. This addition serves as the containment vessel when the shielding doors are open.

The hot-pipe trench contains an array of pipe headers interconnecting the cells and permitting intercell transfers of radioactive solutions. Also, the pipe trench contains the piping for transfers to facilities outside 202-A building.

The air tunnel, which lies directly below the pipe trench, exhausts the ventilation air from the individual cells (which in turn draw air from the canyon void above each cell and pipe trench cover blocks) to the main ventilation exhaust filters and from there to the main stack.

A craneway runs nearly the length of the canyon for two master and one slave, bridge-type, 40-ton-capacity cranes. The two master cranes are equipped with periscopes for viewing during remote maintenance of cell equipment and allow operators to work in crane cabs located behind a shielding parapet. The slave crane is remotely controlled from the other two cranes and used primarily to assist in removing large equipment items from cells.

Three gallery levels, parallel to, but isolated from, the canyon on the north side of the structure, contain service piping and process instrumentation, equipment for obtaining process samples, and storage space for equipment and dry chemicals. The relative locations of the galleries are shown in Figure 1-4.

The pipe and operating (P&O) gallery contains instrument transmitter racks, electrical motor controls, steam and cooling water supply lines, and the piping and associated valves for transferring nonradioactive solutions which serve the in-cell equipment.

The sample gallery contains the remote samplers for obtaining process solution samples from the cell equipment. A shielded pipe chase behind the remote sampler boxes contains header piping for recovered nitric acid, organic solvent, sampler drains, and sampler lines to and from the cell equipment.

The west end of the storage gallery is a separate area containing the deactivated neptunium purification and loadout facility (in Q cell), the plutonium product handling and removal (PR) room, and the plutonium oxide production facility (in N cell). An equipment maintenance and decontamination area (in M cell) and a low-level contaminated equipment maintenance shop, which are used for maintenance of equipment removed from the canyon, are located at this level, but are not part of the storage gallery proper.

The service annex is adjacent to the galleries and consists of two separate areas. The larger main area contains the maintenance shops, offices, lunchroom, locker room, radiation zone entry lobby, ventilation air and supply room, a switchgear room, compressor room, central control room, and the aqueous makeup (AMU) facility. The smaller laboratory area contains the analytical laboratory, the headend control room, and a switchgear room.

External to building 202-A are U and R cells, located on the north side of the structure. The U cell is just east of the laboratory area and contains recovered nitric acid storage tanks and laboratory waste tanks. The R cell is located west of the main area and contains process equipment for cleanup of process solvent.

1.2.3 Auxiliary Facilities

Descriptions of the PUREX Plant auxiliary facilities follow.

- 203-A Tank Farm

  A pump house and concrete pad enclosed and sectionalized with concrete dikes containing four 100,000-gal tanks used for receipt, storage, and tank trailer loading of UNH. A small UNH concentration tank and a waste receiver tank are also included.

- 205-A Facility

  A transite building housing the (deactivated) silica gel beds (formerly used for uranium product treatment) and a concrete tank pad enclosed by a concrete dike wherein storage tanks receive and store recovered nitric acid shipped from the UO_3 Plant in the 200 West Area.

- 206-A Facility

  A concrete structure adjacent to U cell containing a vacuum fractionator and associated equipment for concentrating PUREX and UO_3 Plant recovered nitric acid.

- 211-A Facility

  A steel and transite pump house and associated tank farm for receipt, storage, and transfer of bulk process chemicals. The process water demineralizer units are also located in the pump house.

- 2714-A Building

  A steel warehouse for receipt, storage, and transfer of process chemicals received in less than bulk quantities.

- 212-A Building

  A steel building for load-in and load-out of liquid wastes (inactive).

- 213-A Building

  A steel building now used for temporary storage of contaminated dry waste.

- 218-E-14 and -15 Tunnels

  Two earth-covered tunnels extending southward from the east end of building 202-A for storage of large, contaminated equipment on rail cars.

- 291-A Facilities

  The canyon exhaust air filtration and discharge facilities. These facilities include two below-grade concrete filter cells, an unused, third filter cell, four parallel exhaust fans, and a 200-ft-high concrete stack.

- 292-A Building

  A wood structure adjacent to the east side of the 200-ft stack, housing stack monitoring, sampling, and flush equipment.

- 293-A Building

  A concrete structure of two levels containing absorption towers used to remove oxides of nitrogen and residual radioiodine from dissolver offgas (DOG).

- 294-A Facility

  A small steel building above grade and three filter cells below grade. It is located north of building 293-A and provides secondary filtration of DOG.

Facilities that could be considered auxiliary to the plant (such as the evaporator facility, the tank farms, etc.) that are outside the building 202-A controlled access area (fenced) are not within the scope of this FSAR, but are described in Reference 1-5.

1.2.4 Plant Features and Engineered Safety Aspects

1.2.4.1 Ventilation Systems. 202-A building is serviced by four separate ventilation systems designed and operated so the normal work areas are kept free of airborne radioactive contamination. This is done by maintaining differential pressures (DP) to ensure airflows from zones containing no contamination into zones of progressively greater radioactive contamination potential. Ventilation systems are described in detail in Chapter 5.0.

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Ventilation system 1 serves the canyon and process cells, the areas of greatest radioactive contamination potential. Ventilation air supplied to the main canyon area is drawn into the cells from the top. From the cells, air is drawn through small ports into the air tunnel, then through the 291-A filter, and is exhausted through the stack by either three electric fans or a steam turbine backup. The exhaust air is monitored and sampled for radionuclide content.

Electrical power failure or instrument air failure will cause a shutdown of the normal supply and exhaust blowers, at which time a steam-driven exhauster will automatically start and the supply fan dampers will open. High canyon pressure, about 0.05 in. water gauge (WG) below atmospheric, will cause a shutdown of the supply fans with the exhaust dampers open. Low canyon pressure is relieved by spring-loaded gravity dampers (vacuum breakers), which start to open at a canyon pressure of about 0.7 in. WG less than atmospheric pressure and admit outside air to the canyon.

Ventilation system 2 services the areas of the building that have a potential for contamination, but are routinely occupied or entered by the work force. Air is supplied to the sample gallery, the regulated shop, N cell, Q cell, R cell, U cell, the PR room, and the canyon lobby. There are six exhaust fans for these areas. Exhaust air is continuously sampled and monitored for radionuclide content. Primary safety features of the system include connections of three exhaust fans to standby electrical power with automatic changeover switchgear and dampers for operations during a failure of the primary power supply.

Ventilation system 3 services the P&O gallery, storage gallery, AMU areas, and the shops and office areas, all of which have the lowest potential for becoming contaminated. In the general case of power failure, supply fans shut down and suction and discharge dampers open.

About 60% of the P&O gallery exhaust, which has the potential for contamination from a suckback and line rupture, will not routinely be filtered. Detection of airborne contamination by continuous air monitors

(CAM) will automatically shut down the nonfiltered exhausters, causing the air to be drawn through the white room filtered exhaust which is connected to the standby power bus, or through the ECMP to the canyon.

Ventilation system 4 services the PUREX Plant laboratory area and is largely independent of systems in the building proper. This regulated area includes the decontamination room, laboratory rooms, and the sample storage room. Exhaust air is discharged from hoods and rooms through high efficiency particulate air (HEPA) filters and is then exhausted through two local stacks. Two exhaust fans are provided. Exhaust air is monitored and sampled prior to discharge. The exhaust fans are connected to the standby power supply system and will continue to operate with loss of normal power. Supply fans are interlocked so that operation is prevented unless one exhaust fan is running.

1.2.4.2 Utilities Systems. Water for the PUREX Plant is drawn from the Columbia River and pumped to the 200 East Area through a header supplied by the B Reactor pump house, with the D Reactor pump house acting as a backup. Dual supply mains, which supply the 200 East Area, are available on this "export" system. Emergency water supply is assured through the use of diesel pumps at B Reactor and steam-powered pumps at the 200 East Area powerhouse.

Two types of water are supplied to PUREX Plant: raw water and sanitary water. The raw water system, located in the 200 East Area powerhouse area, consists of a 3,000,000-gal reservoir (building 282-E) and five pumps. The sanitary water system treatment and pumping facilities are located in 283-E building and are also supplied from the reservoir. In addition to the reservoir storage capacity, an elevated, 50,000-gal tank is provided at PUREX. Both water systems provide cooling and fire protection.

Steam used in the PUREX Plant is produced in the 200 East Area powerhouse (284-E building) by five coal-fired boilers. Under maximum steam demand conditions, one boiler is available on a standby basis. The building is constantly attended by power plant operators. The coal feeder drive is equipped with both electric and steam drives. The boiler feed water is continuously monitored and sounds an alarm in the event of low water conditions. A manually activated emergency water supply is available to prevent boiler tube damage.

The PUREX Plant steam use during full operation averages 100,000 to 125,000 lb/h, delivered at 225 lb/in.^{2}. Most of the steam is used in process vessel heating coils, and in particular, the process solution concentrators (evaporators); other uses are for operating heating and ventilating equipment, process steam jets, and outside facilities. High-pressure steam is available for the operation of the standby exhaust, turbine-driven fan before the steam line enters the canyon building. This turbine has first priority on the high-pressure steam. If other demands reduce the pressure on the turbine system below an established minimum, the other uses are throttled back to maintain at least this minimum.

Normal electrical power to the PUREX Plant is obtained from the Northwest Power Pool at the 251-W substation, located about 3 mi northwest of the Plant. The 251-W substation is supplied by the Bonneville Power Administration's Midway substation at Vernita, Washington and by the White Bluffs Substation. Power is delivered through 23-kV overhead lines, equipped with static wire protection, incoming from two directions, with either line capable of providing the necessary services.

Electrical power from the 251-W substation to PUREX is routed through two independent, 13.8-kV, overhead lines to two independent, 2.4-kV buses in the PUREX Plant switchgear room. If one line is impaired, the load is switched in the plant by the 2.4-kV switchgear. Other 13.8-kV lines can be switched to carry the the PUREX Plant load should the need arise.

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Backup power is supplied by three 300-kW, diesel-driven AC generators located adjacent to the PUREX Plant; with two of the three generators on line, the standby power needs of the plant can be met. The generators are connected to an automatic control that starts within 15 s when one of the following conditions exists for at least 3 s:

- Secondary voltage drops below 106 V or exceeds 129 V
- Frequency drops below 56 Hz or exceeds 64 Hz.

A programmable load selection controller determines which standby bus gets power based on an established priority system and power availability.

About 20% of the building lighting, all the perimeter lighting, the instrument power panels, the air compressors, and the safeguard and security systems are connected to the standby supply. In addition to this load, motors in critical ventilation and agitation service are supplied from the emergency electrical system.

Process air is supplied by two compressors interlocked to operate on plant demand, with a third on standby. The 100-lb/in.^{2} process air is used for operating sampler jets, blowing out transfer lines, operating steam jets in case of steam supply failure and blowing water from coils. Process air is reduced to 80 lb/in.^{2} and dried for use as instrument air. The compressors are connected to the standby electrical supply system so that there will be instrument air available at all times.

Breathing air for respirators is supplied by another compressor, also connected to the standby electrical system. The air is passed through a water separator and filter to piping that serves the sample gallery, laboratory, regulated shop, railroad tunnel, decontamination cell, hot shop, PR room, 276-A building, ECMP, acid storage vault, and laboratory ventilation equipment room.

Those gloveboxes in the new plutonium oxide conversion facility that require a dry air supply are served by a dry-air system located in a separate building, consisting of a nonlubricated rotary compressor, filters,

absorption dryer, and related equipment. Dry-air supplies to these gloveboxes are equipped with moisture analyzers and alarm systems.

A central vacuum system is provided to collect air samples and to service the CAM. Connections to this system are provided for continuous beta, gamma, and alpha air monitoring in all operating areas, storage areas, exhaust air filter banks, exhaust stacks, and service galleries where personnel access is permitted.

1.2.4.3 Process Instrumentation. Remote control of most of the PUREX Plant process is required because of the intense radiation from the process material. Massive radiation shielding is in place between people and process areas. Most of the remote instrumentation is monitored in the headend and central control rooms, which are continuously manned during process operations. The dispatcher's office serves as a focal point for information transmittal in the plant. Safety and environmental alarms that require immediate action are duplicated and annunciate in the dispatcher's office.

There are three levels of data measurement and display. The first level consists of measurements essential to safe operation of the facility and are displayed, recorded, controlled, and alarmed in the control rooms; additionally, key safety and environmental data are alarmed in the dispatcher's office. The second level involves measurements necessary for the normal operation of the plant and are displayed and/or alarmed in the control rooms. Second-level measurements include radiation levels in some potentially contaminated effluent systems, as well as principal operational parameters. The third level includes measurements of noncritical parameters for operation of the facility and are displayed on local instruments or alarmed in the control rooms.

1.2.4.4 Fire Protection. The facility arrangement and the structural design elements include the following features to provide for fire prevention, fire extinguishment, fire control, and control of hazards created by fire.

- Buildings and support facilities are separated to limit fire spread and to aid in control and extinguishment.
- Fire-resistant or noncombustible materials are used.
- Potential fire areas are isolated by using fire walls and fire doors to contain and isolate hazardous materials and operations.
- Vertical openings (e.g., stairways, elevator shafts, pipeways, etc.) are enclosed to prevent fire spread to upper floors.
- Exhaust ventilation systems are designed with high fire integrity and the canyon exhaust is equipped with a water spray system.

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- Electric service and distribution systems utilize approved components and are designed and installed to minimize any contribution to ignition of flammables where special fire hazards are present.

- Ample means of exit are provided for personnel so that safe egress is assured for all anticipated fire events.

- Fire extinguishers are located throughout the occupied areas of the plant.

- Fire alarm pull boxes are located throughout high-occupancy areas. Telephones may be used to summon the Hanford Fire Department, which can reach the area within 6 min. Automatic or manual actuation of any sprinkler system automatically summons the Hanford Fire Department.

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Automatic sprinkler protection on standard wet- and dry-pipe systems is installed in essentially all of the normally occupied or hazardous areas of the PUREX Plant in accordance with Factory Mutual Research Corporation recommendations. All sprinkler installations are low-activation temperature, closed-head systems, utilizing standard spacing and pipe sizes. Control is mostly by readily accessible valves, post-indicator valves, or outside screw and yoke valves in safe areas.

Areas covered by sprinkler protection include the hot shop, east and central storage gallery, N and Q cells, the PR room, extreme east end of sample gallery and the 202-A annex, including the laboratories, laboratory storage area, AMU area (two floors), offices, shops, and change rooms. Additional sprinklers are being installed throughout the sample gallery.* A standard dry-pipe automatic sprinkler system is provided for the loading dock, laundry storage room, gas cylinder storage area, and power transformers which are located on the exterior of the facility along the north wall. A carbon dioxide system is provided for the in-line monitor equipment room which contains a great deal of sensitive electronic gear.

Fire screens (stainless steel mesh with 1/8-in. openings) are installed in the exhaust duct manifolds in each analytical laboratory room and glovebox and the main manifolds of the PR room and Q cell gloveboxes to prevent burning material from reaching the HEPA filters. The prefilters in the N cell glovebox exhausts also act as combination fire screens and mist eliminators.

In the plutonium oxide production facility housed in N cell, all process, powder, and maintenance gloveboxes are provided with Halon 1301, full-flooding fire-suppression systems. Wet-pipe sprinkler protection is provided throughout the rest of the N cell facility.

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*Work may not be complete at startup.

Those cells containing large inventories of organic solvent (G, R, H, J, and K cells) are equipped with an automatic "light water" foam system. Fire detection in these cells is by rate-compensated thermal detectors, which sound alarms locally and at the 200 Area fire stations. The crane cabs have Halon systems that do not alarm at the fire station.

Fire protection in the other canyon process cells is provided by a system of peripherally mounted, water-spray nozzles controlled by manual gate valves. Manual actuation of the systems depends on the detection of fire by "Fire-eye" flame detectors. These detection units activate alarms in the central control room and in the dispatcher's office. Failed "Fire-eye" detectors are replaced with Fenwal "Detect-A-Fire" elements.

1.2.4.5 Radiological Safety. Gamma and/or neutron shielding is provided to reduce radiation intensities during all phases of PUREX operations. The principal shielding elements in the canyon structure are the concrete walls, cell cover blocks, and roof. Process cell walls are 6 ft thick, wall thickness above the cell blocks is 4 ft and the cover blocks are 3 ft thick. The original shielding designs limited dose rates to 0.1 mrem/h in all areas except the sample gallery, hot shop, regulated shop, and PR room, which were designed for 1.0 mrem/h. The canyon shielding has met design criteria throughout the operating history of the plant.

Other operating zones are shielded as required. The R cell (solvent system) is in concrete cells below grade, as are the building exhaust filters and the U cell or recovered-acid storage tanks. The acid recovery systems and the DOG treatment systems are housed in thick-walled, above-ground concrete structures.

The plutonium oxide production facility, housed in N cell, has an upgraded design based on the experience on the plutonium oxide line at Hanford's Z Plant. Most product loadout operations are shielded. Both fixed and movable shielding panels are utilized. Gamma and neutron shielding is provided around the gloveboxes. An equipment maintenance glovebox is provided.

Contaminated and potentially contaminated areas within the facilities are well defined and appropriately marked. Administrative controls for entrance into potentially contaminated areas are enforced by operations supervision. Entry to zones where high radiation levels or severe contamination exist is controlled by electrically activated door locks opened from the dispatcher's office. The dispatcher maintains a log of entries and exits. Canyon entries, in addition, require use of a supervisor-controlled key to unlock the door. Radiation detection instruments are mounted in all regulated areas. Instrument readings print out on recorders in the dispatcher's office, and audible and visible alarms are provided for abnormal intensity of radiation fields.

Hand and shoe counters, as well as portable radiation survey instruments, are provided at exit points from regulated areas for individual surveys.

Material shipments out of the 202-A building area require either a survey and release confirming absence of radioactive surface contamination or shipment documentation detailing radioactive materials present, level of activity, and nature of contamination. All materials to be removed from regulated areas are subjected to a thorough radiation survey prior to area release. Product solutions are sampled and analyzed prior to loadout to ascertain radioactive material content. Upon completion of loadout, receiving containers are surveyed for external surface contamination and cleaned if contamination is present. The containers are then resurveyed prior to shipment.

Contaminated solid waste generated within the PUREX complex is disposed of by one of several methods. Large items (primarily failed canyon equipment) are put in burial boxes and buried in trenches or placed in the burial tunnel. The FP wastes are packaged and buried. Wastes contaminated with transuranic materials are packaged for 20-yr retrievable storage. Boxes containing plutonium wastes are nondestructively assayed to determine plutonium content.

Cooling water and chemical sewer waste, usually uncontaminated, are disposed of in surface ponds. Potentially contaminated steam condensate is sent to an underground trench or crib. Cooling water discharge lines are equipped with radiation monitoring instruments, alarms, and diversion valves that will automatically divert radioactive contaminated water to a retention basin from which it can be returned to the 202-A building for recycle.

The PUREX Plant offgas and ventilation systems have been upgraded to reduce the discharge of chemical and radioactive gases to the environment to conform to the as low as reasonably achievable (ALARA) concept. As noted earlier, gaseous releases are within applicable federal standards.

1.2.4.6 Nuclear Criticality Safety. The design of the PUREX Plant facilities and equipment for handling fissile materials includes, where practical, geometric limitations to minimize the probability of a criticality. In addition, there is a criticality prevention system based on written specifications and implemented by written procedures. The specifications establish limits based on the double-contingency principle: two failures or human errors must occur before a criticality is possible in a shielded facility. In an unshielded facility, the limits are based on a triple-contingency principle: three failures or human errors must occur before a criticality is possible.

1.2.4.7 Industrial Safety. The basic responsibility for safety rests with line management having immediate authority over workers. An Industrial Hygiene and Safety Department (IHSD) provides assistance, surveys, and monitoring to assume compliance with the Occupational Safety and Health Act,

and DOE and Rockwell Hanford Operations (Rockwell) Standards. An Accident Prevention Standards Manual provides Standards, Accident Prevention Bulletins, Health Bulletins, and Chemical Safety Guides.(6) In addition to line management responsibilities, a safety survey of the facility is conducted every other month and an industrial hygiene survey is conducted annually by IHSD. Resolution of any survey findings requires prompt attention.

1.3 GENERAL PROCESS DESCRIPTION

The PUREX Plant provides chemical decladding and dissolution of irradiated fuel elements and separation, recovery, and purification of uranium and plutonium by solvent extraction. Process support systems provide recovery and reuse of nitric acid and organic solvents; recycle of waste streams; and handling, treatment, and disposition of gaseous, liquid, and solid wastes. The process feed materials and effluents are shown in an input-output diagram (Fig. 1-6).

Chapter 6.0 is exclusively devoted to a detailed description of the process and of the particular operations involved. The process chemical solutions, steam, water, etc. provided by the utilities systems are discussed in Section 5.4. Confinement and management of PUREX process wastes are discussed in Chapter 7.0.

1.3.1 PUREX Process Flow

The PUREX process flow is diagrammed in Figure 1-7; a description follows.

1.3.1.1 Irradiated Fuel Receipt. Irradiated fuel elements, enclosed in canisters and loaded into a shipping cask, are received in the PUREX railroad tunnel in specially designed rail cars.

The charging operation begins when the double barrel canisters are individually removed from the cask by the canyon crane. A radiation-measuring device is installed in the PUREX railroad tunnel in a location that allows detection and measurement of the radiation emanating from the fuel as the canisters are removed from the cask and transported to the dissolver. The approximate age of the material is then determined from instrument calibration data. This helps to ensure that the fuel has been aged at least 180 d to allow the natural decay of the short-lived radionuclides. Should a canister show a high radiation level and further checking of records and instruments fails to explain the problem, the canister is returned to N Reactor. Otherwise, the canisters are transferred to the dissolver. Empty canisters are replaced in the cask and the rail car is cleaned and returned to the N Reactor area.

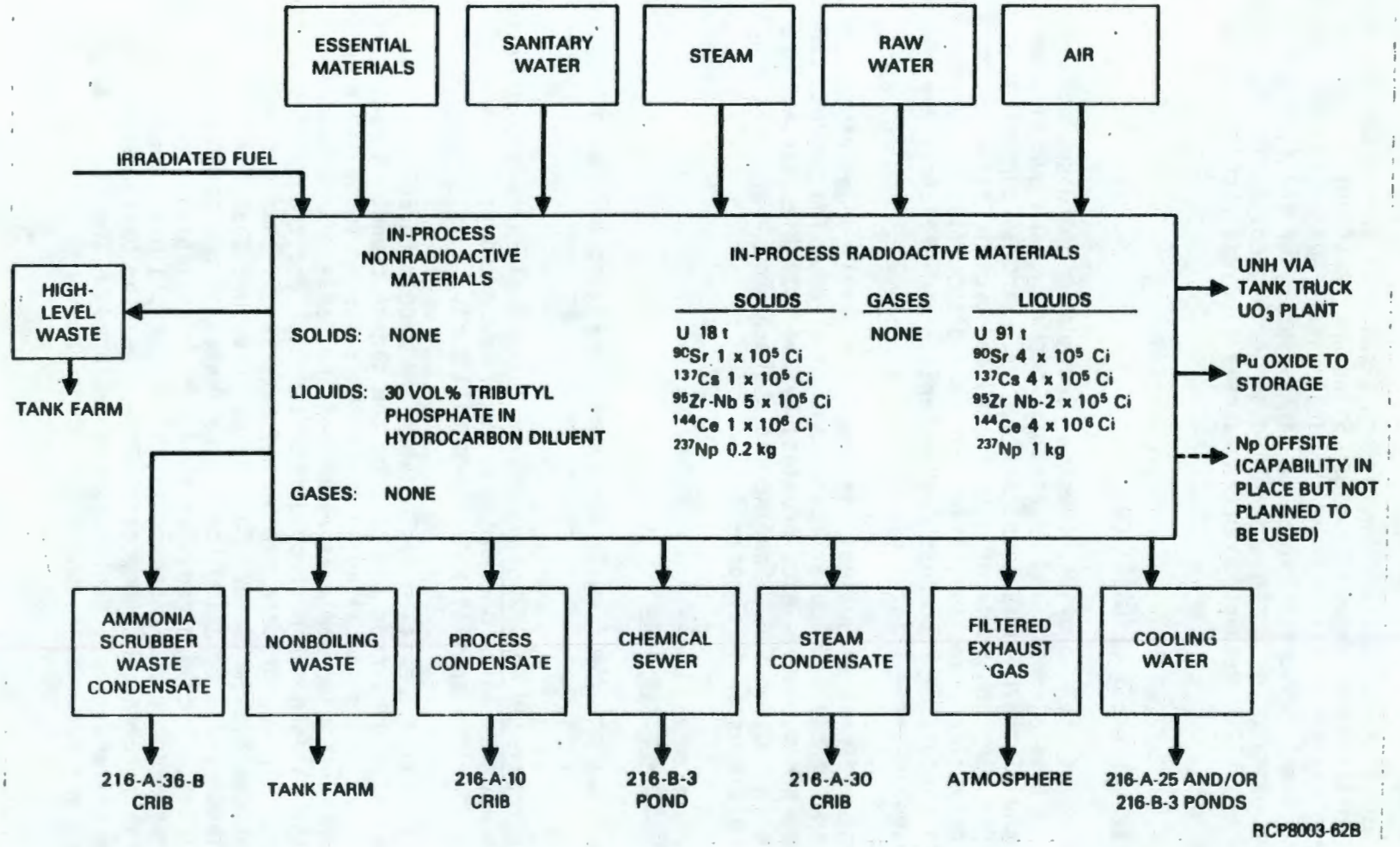

FIGURE 1-6. PUREX Plant Input-Output Diagram--Operating N Fuels.

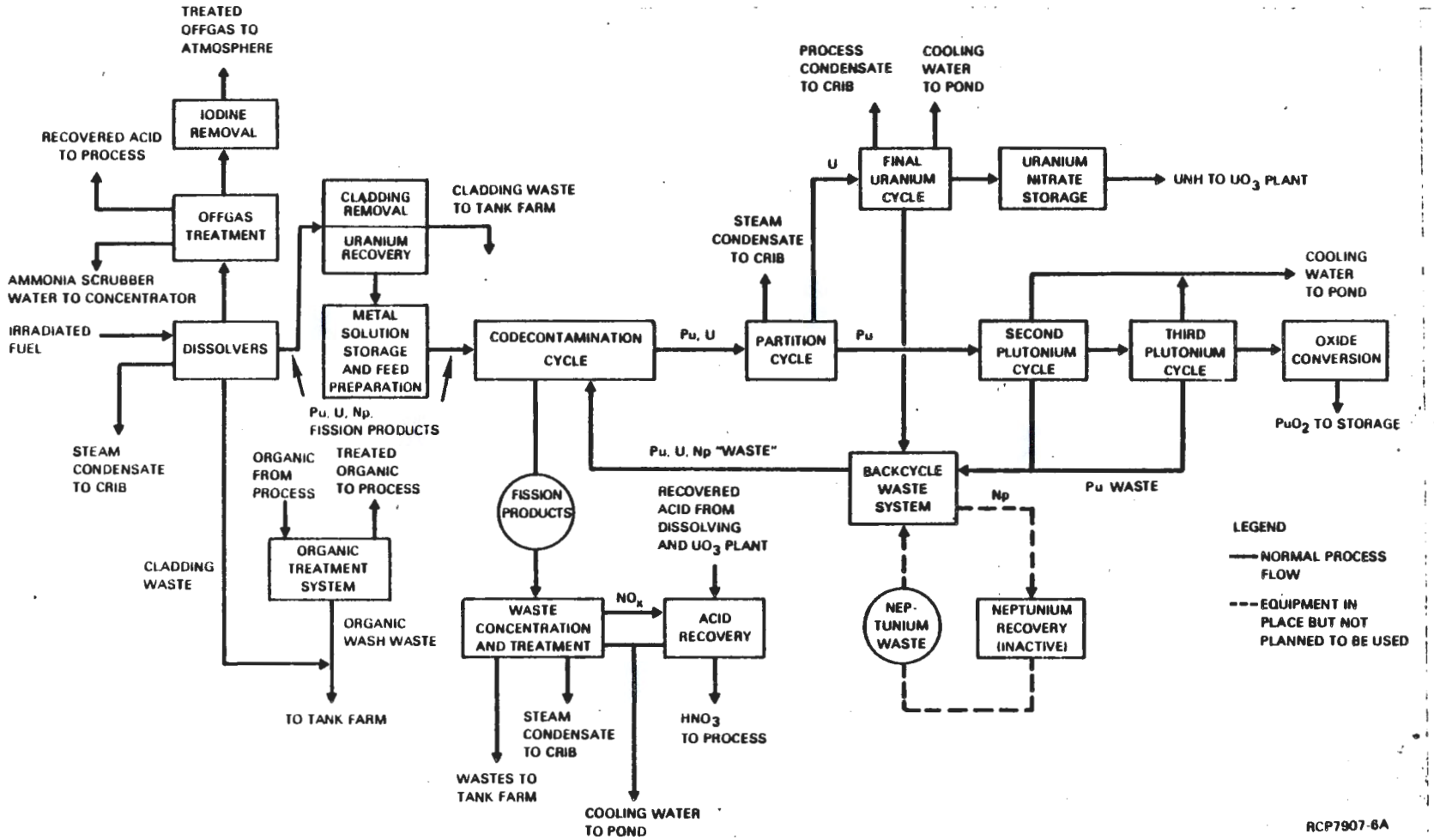

FIGURE 1-7. PUREX Plant Simplified Flow Diagr ...

1.3.1.2 Feed Preparation. The properly aged fuel elements in the canisters are charged (dumped) to dissolvers. To remove the Zircaloy cladding from the fuel elements, the Zirflex process is used. This process employs a boiling solution of ammonium fluoride and ammonium nitrate to dissolve the cladding. Potassium hydroxide is then used to convert uranium and plutonium fluoride compounds to hydrated oxides (metathesis). The cladding waste, metathesis waste, and rinse solutions are centrifuged to remove solid uranium and plutonium compounds. These compounds are metathesized (if required) and/or dissolved in nitric acid. The resulting acid solution is blended with the feed.

After completion of decladding and metathesis, the uranium is dissolved in nitric acid and the metal solution is transferred to accountability and storage tanks. The uranium metal solution from the dissolving step is given any needed adjustments in composition or concentration, and rework solutions (returned from subsequent process steps) are added for recycle. At this point, the feed solution is a slightly acidic aqueous solution of uranyl nitrate, containing plutonium and essentially all of the nonvolatile fission products.

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1.3.1.3 Codecontamination Cycle (No Neptunium Recovery). In this cycle, the uranium and plutonium are extracted into an organic solvent to separate them from the bulk of the FP, the americium, the neptunium and the curium that remain in the aqueous stream. The organic solvent is a 30 vol% tributilized phosphate (TBP) extractant in hydrocarbon diluent. The aqueous waste stream is concentrated, partially denitrated, made alkaline, and stored in underground storage tanks.

1.3.1.4 Partition Cycle (No Neptunium Recovery). The uranium-plutonium organic solvent stream is then contacted in a partitioning column (1BX) with an aqueous countercurrent stream containing a chemical reducing agent that causes the plutonium to transfer into the aqueous phase, and thus be contained in the stream leaving the bottom of the column. This aqueous product solution enters the 1BS column where it is scrubbed with fresh organic solvent to remove residual uranium and is then routed to the second plutonium cycle. The bulk of the uranium remains in the organic solvent stream that flows out the top of the 1BX column.

The exiting organic stream is fed to another column in which the uranium is countercurrently stripped from the organic phase into a dilute aqueous nitric acid stream. The stripped organic solvent is treated in the organic recovery system and reused in the process.

The exiting aqueous uranium product stream is fed to the tower of a steam-heated concentrator, where it is concentrated by a factor of 7 to 8. The concentrator is designed and operated to remove, by steam-stripping, entrained organic solvent which might have entered with the product stream. This prevents accumulation of an organic phase in the concentrator and

reduces the possibility of formation of potentially explosive "red oil," a complex of nitrated degraded solvent with uranium or other heavy metals. The process condensate stream is recycled as makeup water for various solvent-extraction streams.

1.3.1.5 Second Plutonium Cycle. The plutonium stream is processed through a second extraction and stripping cycle for continued purification from uranium, FP, and other metallic impurities.

1.3.1.6 Third Plutonium Cycle. The third plutonium cycle further reduces the FP and other metallic impurities to complete the purification of the plutonium product.

The product stream is also steam-stripped to remove residual organic solvent and to reduce the probability of the red oil formation. The product stream is then concentrated to product level concentration and transferred to storage tanks, where it is sampled, analyzed, and held for conversion into plutonium oxide.

The overhead process condensates from the stripper and concentrator, normally containing only trace amounts of plutonium, are routed to the third plutonium cycle feed tank for rework and recovery.

1.3.1.7 Plutonium Oxide Production. The plutonium nitrate solution is converted to plutonium oxide by precipitating the plutonium as the oxalate, which is calcined to produce the oxide. The detailed process is described in Chapter 6.0. The plutonium oxide then goes to a blender, is thoroughly mixed, and sampled. If the sample analyses indicate that the plutonium oxide meets product specifications, it is transferred to the canning operation; if not, it is returned for recycling through the second stage calciner or the plutonium oxide rework (dissolution) facility. The final product is chemically and radiolytically stable.

Can filling operations are remotely controlled. The cans are weighed, filled, the slip-lid is placed on the can, and the filled can is weighed. The can lid is then tape sealed. After tape sealing, the can is bagged out and placed into a second can, which is sealed by a commercial can-sealing machine. The can assembly is sent by conveyor to a final canning location where the assembly is loaded into a third can. The third can is then labeled, sealed, and the can assembly placed into a shipping container for transfer to storage.

As a backup system, the existing capability to load out plutonium nitrate into containers (PR cans) will be maintained. A permanent facility to be located in the PR room is being designed for the loadout of plutonium nitrate solution into either the metal PR cans or polyethylene bottle-type containers. This facility will also accommodate the loadin of product solution from these containers to the process equipment.(7) The temporary storage of plutonium nitrate at the PUREX Plant and its transport to a nearby existing plutonium production facility at the site is an alternative

procedure to the production of plutonium oxide in the new facility within the PUREX building. Safety analyses indicated an acceptable risk for the loadout and temporary storage of plutonium nitrate at PUREX.[8,9]

1.3.1.8 Final Uranium Cycle. The concentrated uranium product solution from the partition cycle is adjusted as feed for the final uranium cycle. This cycle provides final decontamination from plutonium and FP, and consists of extraction into the organic phase followed by stripping back into the aqueous phase. The uranium product solution is steam stripped to remove residual organic solution, concentrated, transferred to 203-A for interim storage, and then shipped to the UO_3 Plant.

The final uranium concentration step includes basically the same elements as described previously for the partition cycle uranium stream except that the relatively uncontaminated process condensate is sent to an underground crib for final disposal instead of being recycled within the process.

The aqueous waste contains a small percentage of the uranium plus the residual plutonium and FP. It is routed to the backcycle waste concentrator and subsequently fed, along with virgin feed metal solution, to the codecontamination cycle.

1.3.1.9 Neptunium Recovery (Deactivated). With adequate preparations, the PUREX Plant can produce a neptunium product. When neptunium recovery is not employed, most of the neptunium is in the codecontamination cycle aqueous waste stream where it is rejected with the FP and americium.

The aqueous waste stream from both the uranium and plutonium cycles contains neptunium. These streams are collected in the backcycle waste system and concentrated for recycle back to the codecontamination cycle to minimize true losses of associated uranium, plutonium, and nitric acid. Should neptunium recovery be required, a portion of the concentrated backcycle waste stream is used as feed for the neptunium recovery cycle where, in a continuous extraction-stripping cycle, neptunium continues to accumulate as other nuclides (e.g., plutonium, uranium, and FP) are removed and returned to the backcycle waste system. This operation continues until the neptunium concentration reaches the desired level, after which the neptunium cycle is isolated and operated on total Np recycle until the concentrations of plutonium, uranium, and FP are low enough for neptunium product transfer to the final purification system. In the final purification system, neptunium is loaded on an ion exchange resin which is then washed to remove residual FP and plutonium and is then eluted from the resin. It may be retained in a storage tank or packaged for eventual shipment offsite. The remaining effluent stream and the wash are either retained in tankage or routed to the backcycle waste system. The reactivation of the J cell package (extraction-stripping cycle) for recovery of neptunium is planned for FY 1986 and will be described in a future addition to this FSAR.

1.3.1.10 Solvent Recovery. The organic solvent is washed after its use to remove impurities and chemicals and radiolytic degradation products which would interfere with proper process operation. Two separate solvent treatment systems are used. The first processes all the solvent except that from the final uranium cycle. Solvent from the final uranium cycle is processed separately in the second system.

1.3.1.11 Backcycle Waste. The backcycle waste system accumulates product-bearing aqueous waste streams from the uranium and plutonium cycles following the partition cycle, and concentrates and recycles this material to the solvent extraction process. This provides recovery of products routed from the individual product purification cycles by reextraction in the codecontamination cycle. The backcycle waste system also provides the nitric acid needed for efficient extraction operation of this cycle.

The overhead condensate from the waste concentrator is routed to the first-cycle uranium concentrator where the condensate is reevaporated along with the principal uranium product stream.

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1.3.2 Process Support System

1.3.2.1 Offgas Treatment. The offgas from the decladding step contains hydrogen and ammonia, both kept well below their lower explosive limit concentrations by water scrubbing or dilution with the large flow of process air through the system. (The presence of the nitrate ion inhibits hydrogen formation in the dissolvers.) The decladding offgas is water scrubbed to remove ammonia and then passed through steam and electric heaters, a silver reactor (for the removal of radioiodine), two fiberglass filters in series, and out the main ventilation stack to the atmosphere. The ammonia-bearing offgas stream from the ammonia removal system is scrubbed with water, filtered, and discharged to the atmosphere via a separate stack. The ammonia scrubber water containing some radionuclides is concentrated and sent to underground storage. The concentrator condensate is cribbed.

The offgas from the dissolving step is passed through steam and electric heaters, a silver reactor (for the removal of radioiodine); the in-cell, fiberglass filter, the secondary fiberglass filter, and into the backup facility. In the backup facility, much of the remaining iodine and oxides of nitrogen are removed from the offgas by two acid absorbers in series. The offgas is then discharged through the main ventilation stack to the atmosphere. The oxides of nitrogen reduction system, as discussed in Chapter 7.0, will assure that oxides of nitrogen releases meet applicable federal and state limits. The dilute nitric acid produced in the absorbers is recycled to the PUREX acid recovery system where it is concentrated and recycled to the process.

1.3.2.2 Acid Recovery. Nitric acid is one of the principal chemicals used in the PUREX process. In addition to being used to dissolve irradiated fuels, it is also used as the "salting" agent in the solvent extraction cycles to help force the transfer of plutonium and uranium from the aqueous phase into the organic extractant. Because of the large volume used, nitric acid is recovered and reused.

A major recovery source is the aqueous high-acid waste from the solvent extraction cycles. Most of the acid is recovered by evaporation in the high-level waste concentrator. Further treatment of the concentrated waste by sugar denitration reduces acid levels and produces oxides of nitrogen. These oxides of nitrogen are partially converted to acid in the acid absorber, which treats the vapor from the high-level waste concentrator. The resulting dilute nitric acid stream is fed to the acid fractionator along with the acid streams returned from the DOG backup facility and from the UO_3 Plant.

1.3.2.3 Waste Treatment. Aqueous waste from the codecontamination cycle contains essentially all the FP that enter the PUREX process, except the radioactive gases, a fraction of the halogens, and part of the tritium. This acid waste is routed to the high-level waste feed tank where it is diluted to enhance acid recovery and is then sent to the waste concentrator.

The concentrated waste, partially deacidified by boiling acid overhead, overflows continuously from the concentrator to a waste receiver tank. After the concentrated waste has been sampled, analyzed, and confirmed for transfer, it is partially denitrated by the addition of a sugar solution. The gases produced, principally carbon dioxide and oxides of nitrogen, are routed back to the vapor tower of the concentrator and then to the acid absorber where the oxides of nitrogen are partially recovered as nitric acid.

The concentrated, denitrated waste is made alkaline and transferred from the PUREX Plant to underground storage in the tank farms.

1.4 IDENTIFICATION OF AGENTS AND CONTRACTORS

1.4.1 Prime Contractor

Rockwell, the prime contractor for operation of the PUREX Plant, is part of the Energy Systems Group of Rockwell International. Operation of the PUREX Plant is part of Rockwell's contract with DOE (DE-AC06-77RL01030), which defines Rockwell's responsibilities for operations at the Hanford Site. Under the contract, DOE has the right to conduct surveillance, inspection, evaluation, and audits of the Rockwell program. Rockwell's organization, as it pertains to the PUREX Plant, is presented in Chapter 10.0.

1.4.2 Other U.S. Department of Energy Contractors

The following contractors to DOE support operation of the PUREX Plant.

- Battelle-Northwest, a division of Battelle Memorial Institute, operates the Pacific Northwest Laboratory (PNL), a research and development facility. The laboratory provides contract research and development work. The Hanford-wide radiological and environmental surveillance programs are also provided by PNL.

- Boeing Computer Services Richland, Inc., a subsidiary of Boeing Computer Services, provides computer services for Rockwell and other Hanford contractors.

- Hanford Environmental Health Foundation (HEHF), a nonprofit organization, provides industrial hygiene, medical, and occupational health services for Rockwell and other Hanford contractors. In addition, HEHF provides nonradiological air and water analyses.

- J. A. Jones Construction Services Company performs miscellaneous construction services.

- United States Testing Company, Inc. provides laboratory testing services related to personnel radiation protection.

- Kaiser Engineers Hanford Company provides architectural and engineering services.

- The UNC Nuclear Industries supplies the fuel elements (fuel fabrication and reactor operation) to be reprocessed by the PUREX Plant.

1.5 REFERENCES

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PUREX FSAR

CHAPTER 2.0 SUMMARY SAFETY ANALYSIS

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2.0 SUMMARY SAFETY ANALYSIS

2.1 CONCLUSIONS

This Final Safety Analysis Report (FSAR) was prepared in accordance with the requirements of the U.S. Department of Energy (DOE).[1,2] Operations have been and are being independently reviewed to assure that these activities are in accordance with safety standards established by Rockwell Hanford Operations (Rockwell), DOE, and regulatory agencies.

Although the Plutonium-Uranium Reduction Extraction (PUREX) Plant construction was completed in 1956, it meets most of the requirements of new reprocessing plants. Exceptions have been fully evaluated as to their effect on occupational and public safety. In many cases, upgrade programs have been implemented. In all cases, these evaluations have shown that the PUREX Plant can be operated with adequate protection of operating personnel and the general public.

Stable operation of the PUREX Plant involves close control of process parameters and implementation of administrative procedures. The Operational Safety Requirements (OSR) define acceptable conditions, safe boundaries and bases, and management controls required to ensure safe operation of the PUREX Plant during the processing of irradiated fuels. Operation outside of the specified boundaries and conditions could result in an unacceptable level of risk to the public, site workers, or environs or a compromise of facility integrity. In accordance with DOE Order 5480.1A, Chapter V, the OSR are discussed in Chapter 11.0.[1] The objective of the normal control philosophy is to ensure stable plant operation with a significant and manageable margin between the operating range and the safety boundaries and safety conditions. The operating range is bounded by identified control features which support each safety boundary and safety conditions. Specific limiting control settings and limiting conditions for operation are defined in internal Rockwell documentation. An audit link exists between the OSR, the accident safety analysis (Chapter 9.0) and the internal Rockwell documentation.

Detailed descriptions of the site, facility, process, waste management, and radiation protection are presented along with analyses of the effects of normal plant operations and radiological consequences of potential abnormal and accident situations on operating personnel and the general public. A review of the information presented in this FSAR allows the following conclusions to be drawn.

- The PUREX Plant area is characterized by relatively mild weather conditions and low seismic activity. The plant is not subject to severe or highly unfavorable natural forces such as adverse meteorological conditions, flooding, tornadoes, or earthquakes. The plant site was chosen, in part, for its distance from populated areas (about 20 mi). This isolation would mitigate the consequences of potential accidents to the public.

- The operating history of the PUREX Plant has demonstrated that the facility, equipment, and processes are capable of safely processing N Reactor fuel. The N Reactor fuel is stored for at least 180 d in the reactor areas and is normally shipped to the PUREX Plant on a first-in, first-out basis. Since the fuel is held in the reactor basins, the short half-life radionuclides decay and the PUREX Plant receives a less hazardous material than discharged from the reactor. A review of the normal, abnormal, and accident situations reveals that no conditions were noted which would result in unacceptable risks.

- The PUREX Plant consists of a shielded processing (canyon) building and auxiliary structures located within a double-fenced exclusion area. All PUREX structures are built to safely handle material of varying degrees of radioactivity. It has been concluded that the plant can be operated without exceeding the radiation exposure limits to personnel and the public set forth in RHO-MA-139,(3) which conservatively implements various DOE orders, national standards, and company policies, as noted in Chapter 7.0. Adequate provision has been made for protection of property and the environment.

- The PUREX Plant liquid and solid fission product (FP) wastes are disposed in the Hanford waste management facilities. Transuranic (TRU) wastes are stored in waste sites for eventual disposal in approved Federal repositories. About 3% of the 365,000-acre Hanford Site is used for structures and waste disposal sites that require long-term commitment to such use. Releases of heat and chemicals to the air and Columbia River produce no observable effects(4) from operation of all facilities within the Hanford Site.

- The environmental consequences addressed in the PUREX and Uranium Oxide Plant Environmental Impact Statement indicates that the PUREX Plant will comply with applicable standards.(5) The conclusions drawn by this safety analysis do not conflict with the conclusions of the Environmental Impact Statement.

2.2 SITE ANALYSIS

2.2.1 Natural Phenomena

2.2.1.1 Earthquakes. The Hanford Site is located in the Columbia Basin, an area of low seismicity in which moderate-level earthquakes have occurred. A history of seismic activity for this area and the results of seismic studies and analyses are presented in Chapter 3.0. The July 15, 1936, Milton-Freewater Modified Mercalli (MM) VII event occurred within the Columbia Basin and cannot be definitely associated with a causative fault; therefore, a similar event is conservatively assumed to have the

potential to recur anywhere in the Columbia Basin. This assumption is made even though historical data indicate that no events larger than MM V or VI have occurred in the center of the basin in the vicinity of the PUREX Plant. In the absence of definitive evidence, the Rattlesnake-Wallula Lineament is assumed to be an active fault. To allow for additional conservatism, the current practice of the U.S. Nuclear Regulatory Commission (NRC) is used. That is, this lineament is assumed to have the potential to generate an earthquake of MM VIII, which is one intensity unit higher than may have occurred or could conceivably occur. An MM VIII intensity corresponds to a zero-period, free-field horizontal ground acceleration of 0.25 g, which has been designated the safe shutdown earthquake (SSE) and is used as a design criterion for new, nonreactor, nuclear facility construction at Hanford.(6) The Hanford Regional Historical Earthquake (HRHE) is postulated as the largest historical earthquake known to have occurred within the Columbia Basin Plateau on the Rattlesnake-Wallula Fault at its nearest point to the site. The level of peak horizontal ground acceleration produced by the HRHE at the PUREX site has been calculated to be 0.1 g.(7)

Seismic analyses are summarized in Table 2-1.(8,9)

TABLE 2-1. Seismic Analyses Summary.

Facility	HRHE	SSE
202-A building	Survives[a]	Fails[b]
ECMP	Fails	Fails
R cell	Survives	Survives
202-A annex	Survives	Fails
291-A filter cells, tunnels, and plenum	Survives	Survives
291-A fans and motors	Survives	Survives
291-A belt drives and metal ductings	Survives	Fails
291-A stack	Survives	Fails
Utilities[c]	Fails	Fails

[a]Structure survives event in "as-is" condition.
[b]Structure may require upgrades to withstand event.
[c]Includes steam, water and electrical services. May imply loss of power to ventilation exhaust fans.

The PUREX Plant was not originally designed to withstand the possible stresses associated with an earthquake of this magnitude; therefore, some loss of structural integrity could occur and utility systems could be lost. Risk analysis of seismically induced accidents produced the following conclusions:

- Offsite(10)
  - Two seismic upgrades have been implemented to ensure drown tank capability for the dissolvers and provide a seismic resistant fire suppression system for the H-J cell.
  - With implementation of these upgrades, none of the accident scenarios evaluated results in an unacceptable offsite dose commitment.
- Onsite(11)
  - Based on the extremely low probability of the occurrence of seismically induced dispersions, the risk to onsite personnel is at an acceptable level.
  - No additional upgrades of the PUREX Plant are warranted to mitigate onsite risk, based on onsite risk resulting from seismic activity.

2.2.1.2 Lightning. Thunderstorms have been observed in the area in every month except November, but severe lightning activity is rare. The only adverse effects caused by lightning have been numerous grass fires and occasional electrical transformer damage, which results in short power outages. The PUREX buildings are concrete and metal and have an extensive grounding network for lightning protection.

2.2.1.3 Tornadoes. There have been only three tornado funnel clouds observed on the Hanford Site since 1945. Of these, only one touched ground and it caused no damage. The likelihood of a tornado strike at the PUREX facilities is considered extremely remote. Although the auxiliary buildings are subject to damage by a tornado, the radioactive materials are contained and processed in the canyon building (202-A). The massive structure of the canyon building can withstand all credible tornadic winds; however, some utilities could be lost and some process systems rendered inoperable through loss of control rooms. While personnel injuries could occur, the exposure to the public would be minor due to the limited source of radioactive material outside the structure of the canyon building.

2.2.1.4 Missiles. The generation of missiles by tornadic winds could result in disruption of some utility and service systems, but due to the thick, concrete walls, the effect on canyon building containment is negligible. The generation of internal missiles, described in Chapter 9.0, could result in minor plant damage or personnel injury, but no breach of containment would occur.

Missile damage to the laboratory has not been analyzed in depth because the aggregate release is estimated to be less than 2.0 g of plutonium and less than 5.0 g of mixed FP. A preliminary study using fault tree analysis was conducted and concluded no significant consequence would result (see Section 9.1.6).

2.2.1.5 Flooding. The probability of flooding of the plant due to precipitation at the site or due to high water levels in the Columbia River is so remote for this facility that it is not considered a credible event.

2.2.1.6 Loss of Water Supply. The PUREX Plant water demands are met by pumping water from the Columbia River. Therefore, loss of water supply as a natural phenomena results in a loss of river water. This is not considered a problem in the forseeable future. A new ice age or other climatological condition would have to occur before loss of water supply would be considered a natural phenomena of consequence. Suction pipes on the pumps are sufficiently deep to allow for river level fluctuations.

A serious earthquake could damage the water supply system; however, the plant can be brought to a safe shutdown with a minimal amount of water. Water tanks needed to stop the dissolver operations are hardened for earthquake protection. Temperature in the high-level waste tanks (see Section 7.5) is normally controlled by cooling water. If cooling water is interrupted, direct addition of dilution water to the tanks may be possible and can be continued indefinitely, thus removing heat by boiling off or refluxing the added water. If plant water is not immediately available, at least 3 d are required before the tanks would boil to dryness, allowing time for water to be transported from the Columbia River by tank truck or to be pumped from any existing water wells that survive the earthquake.

2.2.1.7 Snow Loading. The heaviest 24-h snowfall ever recorded at Hanford was 7.1 in. in 1954. The maximum depth of snow accumulated was 12.1 in. in 1964. The roof of the PUREX Plant and auxiliary structures has been designed to withstand up to 20 lb/ft^2, (which is comparable to 16 in. of snow of typical density) as required by the 1952 Uniform Building Code. There has been no snow load or other roof live load damage to the PUREX structures to date.

2.2.1.8 Ash Fallout. The Hanford Site has experienced mild ash fallout as a result of the eruption of Mt. St. Helens. No problems have been experienced in the past from such fallout, although a heavy deposition could present health hazards due to respiration of ash and water supply contamination. Such an event may require the evacuation of nonessential personnel and the shutdown of operations.

2.2.2 Site Characteristics Affecting the Safety Analysis

The PUREX Plant is located in the central part of the Hanford Site, which was originally established as a site for the large-scale production of plutonium and handling of radioactive material. This site selection

was based on site characteristics which are conducive to the safe operation of such facilities--that is, the potential for extrinsic accidents and their consequences are minimized. A summary of site characteristics (see Chapter 3.0) that are considered potential contributors to extrinsic accidents follows.

- The site is located in a region in which local weather conditions can best be described as moderate. Likelihood of damage to the plant caused by severe weather phenomena such as tornadoes, high winds, lightning, snow, and ice is minimal.

- The PUREX Plant is located on a high, flat plain. General flooding of the plant caused by local precipitation or as a result of the maximum projected water levels of the Columbia River is not considered credible.

- Seismic activity at the site has been described as infrequent, with moderate intensity levels. An earthquake giving a horizontal ground acceleration of 0.25 g has been selected as the Hanford SSE.

In addition to minimizing the probability of extrinsic accidents, the site characteristics also would mitigate the consequences of any potential accident; examples follow.

- The PUREX Plant is located on an isolated site in a region of sparse vegetation with a low animal population. The closest metropolitan area is located 20 mi away, and the nearest agricultural activity within a 20-mi radius of the site is limited to localized zones of irrigated and dryland farming, which could be described as low to moderate activity.

- The water table is 300 ft below the PUREX Plant. Groundwater monitoring is conducted to measure levels of radionuclides and chemicals. Studies have been conducted to ascertain the impact of accidental releases of radioactive liquid to the underground water supply. (For information on similar studies conducted in the West Lake basin, see ARH-CD-775.)[12] Monitoring and studies are an inherent part of the ongoing waste management surveillance programs.

- The PUREX Plant site is generally subject to dispersive atmospheric conditions; very stable (inversion) conditions that are nondispersive prevail only about 6% of the time. Downwind diffusion and dispersion of airborne radioactive effluents released during a potential accident would be under favorable meteorological conditions 94% of the time--this will minimize the subsequent exposure to individuals in the surrounding populations.

2.2.3 Effect of Nearby Industrial, Transportation, and Military Facilities

The PUREX Plant is located near the center of the Hanford Site. The nearest public transportation facilities are Washington State Highways 24 and 240, which are 5 mi from the PUREX Plant site at the nearest point. All other facilities on the Hanford Site are controlled or licensed by DOE or NRC. The effects of nearby facilities on PUREX operations can then be summarized in the following manner.

- There are no explosion hazards from storage of chemicals, ammunitions, explosives, or from natural gas pipelines.
- The fire hazard from nearby facilities or vegetation is negligible.
- There are no sources of airborne pollutants which would adversely affect important plant components or operations.
- The nearest large sources of toxic gases are the 12,200-gal ammonia storage tank located at B Plant, about 1.5 mi from PUREX and the about 0.9 t chlorine gas cylinders located at the water treatment plant, about 0.5 mi away. Under certain meteorological conditions, a gross leakage from either of these tanks could result in a possible evacuation of PUREX Plant personnel. No damage to PUREX equipment is foreseen.
- Due to the very low volume of air traffic and distance from airports to the site, an aircraft impact on the PUREX Plant is considered unlikely.
- The potential effects of the Washington Public Power Supply System (WPPSS), Fast Flux Test Facility, and N Reactor operations on PUREX Plant and personnel were reviewed. Review of the postulated accidents for each of these facilities indicates no unacceptable radioactive or toxic exposure of PUREX Plant personnel and no damage to PUREX equipment.
- Highway 240, which runs through the Hanford Site, can be administratively controlled in the event of a significant radiological release.

In summary, an examination of possible effects from the operations of nearby facilities revealed no unacceptable hazards for either plant components or operating personnel.

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2.3 RADIOLOGICAL IMPACT OF NORMAL OPERATIONS

The PUREX Plant has been operated for about 17 yr, and the occupational exposures from operations as well as the offsite effluent concentrations are known. These factors, combined with the thorough knowledge of the Hanford Site's geology, hydrology, and meteorology, allow the projection of radiological impact with a greater degree of confidence than would be possible with a new plant. This section summarizes the description of radioactive wastes, radioactivity released to the environment, occupational exposure, and incremental exposure to the general public that are presented in more detail in Chapters 7.0 and 8.0.

2.3.1 Summary of Gaseous, Liquid, and Solid Radioactive Effluents

Gaseous effluents are filtered to reduce the release of radioactive particulates to as low as reasonably achievable. Additional filtration has been provided beyond that in use when the PUREX Plant was operating. A schematic of the principal ventilation exhaust points at the PUREX Plant is shown in Figure 2-1. The filtration provided for each exhaust duct and the height of the discharge point are shown on Figure 2-1. The projected radionuclide releases from PUREX gaseous effluents after plant startup are shown in Table 2-2. The concentration of the radionuclides is given at three locations: at the discharge stack; at ground level in a nearby, onsite occupational site; and at a representative offsite location. These concentrations are average values for normal operations over a 1-yr period. The 1972 actual release valves are also shown.

For comparison purposes, the airborne radioactivity guidelines from DOE Order 5480.1A[13] are given for the onsite occupational location and for the offsite general population location. The comparison shows that both guidelines are met with a substantial margin. In the case of the offsite location, the projected concentration of radionuclides is at least one hundred thousand times less than the guidelines, with the exception of krypton which is a thousand times less.

The liquid effluent streams leaving the PUREX Plant are shown schematically in Figure 2-2. Any radioactivity in the cooling water and chemical sewer waste is normally below the detection limits. These two waste streams are sent to man-made ponds. Stations that monitor these two liquid effluent streams for radioactivity also provide for automatic diversion to a retention basin if radionuclide contamination is detected.

The three remaining liquid effluent streams that may contain low levels of radioactivity are sent to cribs. After startup, the process condensate and ammonia scrubber waste streams are concentrated and scheduled to be recycled as soon as practical in accordance with the process test plan[14] to further reduce radioactivity discharges. The process condensate (except process condensate from the second uranium extraction cycle which meets Table II[13] guidelines on an annual basis) is recycled during normal operations.

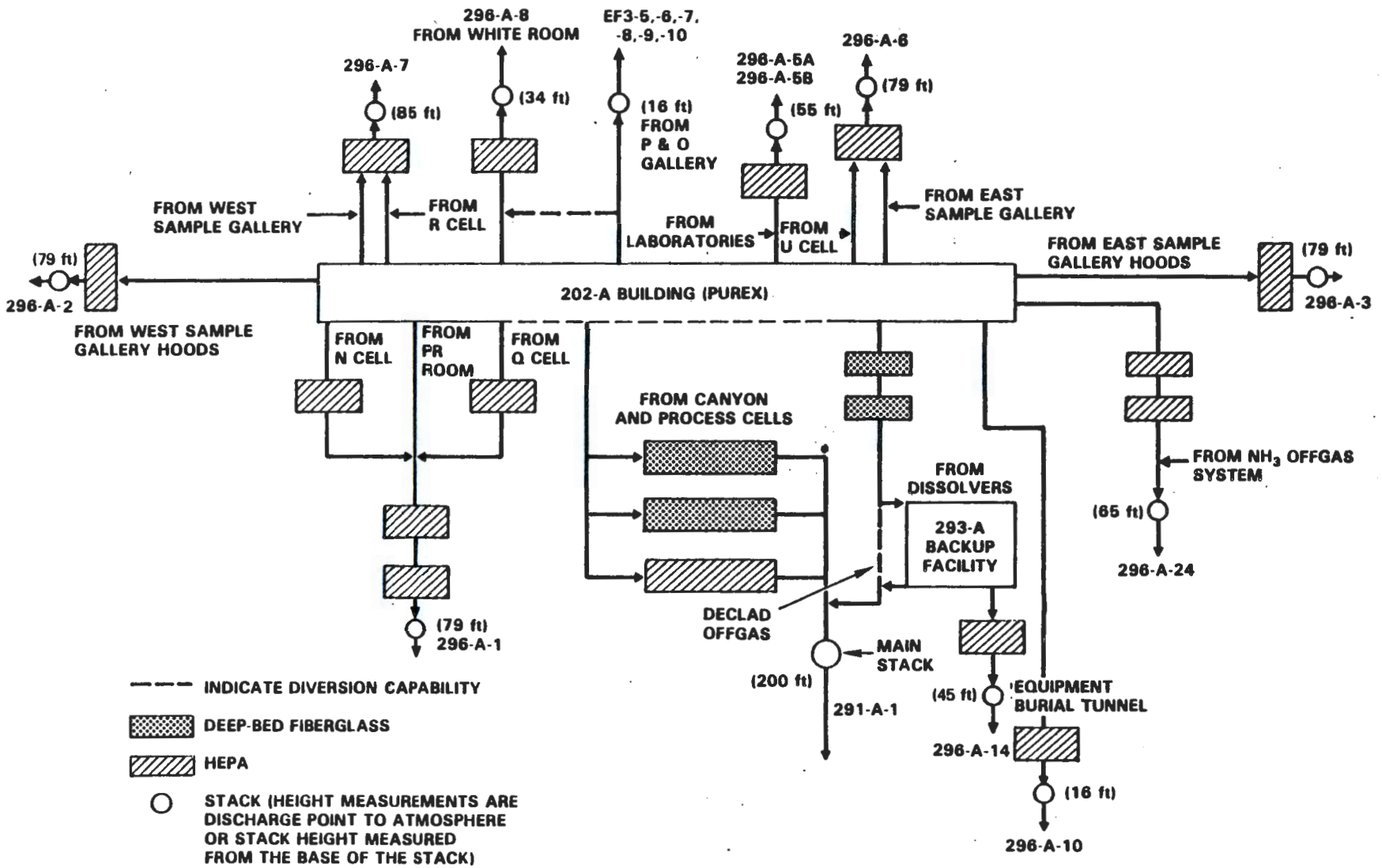

FIGURE 2-1. Principal Gaseous Waste Discharge Points from the PUREX Plant.

TABLE 2-2. Projected Radionuclide Release in the Gaseous Exhaust from the PUREX Plant.

Radionuclide	1972 Actual[a]	Projected average annual values[b]				DOE Order 5480.1A, Chapter XI[13]	
	Annual (Ci)	Annual (Ci)	Average concentration at the source (μCi/mL)[c,d]	Average concentration onsite (μCi/mL)[e]	Average concentration at the site boundary (μCi/mL)[f]	Onsite concentration guide (μCi/mL)[g]	Offsite concentration guide (μCi/mL)
Total (as ^{239}Pu)	4.3×10^{-3}	6.3×10^{-3}	1.7×10^{-12}	4.7×10^{-17}	8.9×10^{-19}	2×10^{-12}	6×10^{-14}
Total (as ^{90}Sr)[g]	5.9×10^{-1}	4.6×10^{-1}	1.3×10^{-10}	5.3×10^{-15}	6.5×10^{-17}	1×10^{-9}	3×10^{-11}
^{129}I	1.4×10^{-1}	4.0×10^{-2}	2.0×10^{-11}	1.5×10^{-15}	5.6×10^{-18}	8×10^{-10}	2×10^{-11}
^{131}I	2.1×10^{-1}	2.9×10^{-1}	1.4×10^{-10}	1.1×10^{-15}	4.1×10^{-17}	4×10^{-9}	1×10^{-10}
^{85}Kr	4.1×10^{5}[h]	1.3×10^{6}	6.5×10^{-4}	2.9×10^{-9}	1.8×10^{-10}	1×10^{-5}	3×10^{-7}
^{3}H	1.0×10^{3}[h]	2.2×10^{3}	1.3×10^{-6}	1.1×10^{-11}	3.6×10^{-13}	5×10^{-6}	2×10^{-7}
^{14}C	7.0×10^{-1}[h]	6.9×10^{0}	3.5×10^{-9}	7.3×10^{-16}	9.9×10^{-16}	4×10^{-6}	1×10^{-7}

[a]The 1972 emissions are based on processing a total of 1,013 t of fuel, including about 525 t of 3.5% ^{240}Pu weapons-grade irradiated fuel.

[b]Projected emissions are based on processing 2,100 t of 12% ^{240}Pu irradiated fuel, 20% of which is spike fuel. The 2,100 t of fuel is the sum of six equal portions weighing 350 t each with cooling times of 1/2, 2, 3, 4 1/2, 6, and 7 1/2 yr. Processing of 6% ^{240}Pu irradiated fuel would result in lower emissions.

[c]These values were determined by dividing the annual curies by the total effluent volume. These numbers are statistically derived and are given for comparison purposes only.

[d]Source concentration is the quotient of the annual curie release and the combined stack ventilation flow rates from the PUREX Plant. For total alpha and total beta, a combined stack flow rate of 3.6×10^{15} mL/yr is used. For the other isotopes, the combined stack flow of the main canyon ventilation and process offgas is used (2.0×10^{15} mL/yr).

[e]The maximum annual average concentration at an onsite ground location is expected to be at a point 0.5 mi southeast of the plant. The average annual dispersion factor for this location is 1.67×10^{-7} s/m^3, as calculated from meteorological data collected at Hanford.

[f]The site boundary, for the purpose of calculating the maximum annual average release, is represented by the southeast sector at 15 mi from the PUREX Plant. The annual average atmospheric dilution factor has been measured as 4.5×10^{-9} s/m^3 for this purpose.

[g]As particulate material.

[h]Calculated values; gas streams were not sampled and analyzed for these elements.

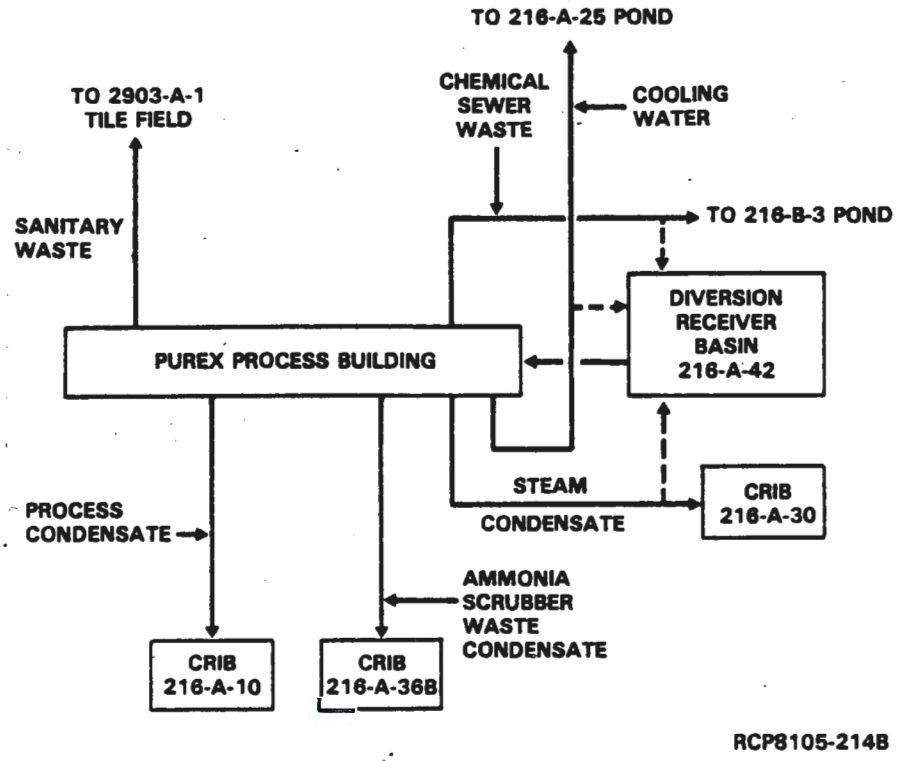

FIGURE 2-2. Liquid Effluent Streams Leaving the PUREX Plant.

The ammonia scrubber waste formerly routed to a crib is concentrated with the bottoms being discharged to a waste storage tank and the condensate routed to a crib. These effluent streams are monitored before discharge, therefore, no diversion capability is required. Under normal operating conditions, the steam condensate contains only trace amounts of radionuclides from previous contamination events where steam coils in high-activity tanks were breached. However, automatic monitoring and diversion to the retention basin are provided to protect against a significant release of radionuclides to the soil, should a breach in a process steam coil occur.

As a result of the type of soil and the hydrology of the site, all radionuclides, with the exception of tritium, are retained in the soil and do not contribute to the exposure of the general population. The predicted release of tritium to onsite groundwater is below the DOE concentration limits for drinking water.

The level of radioactivity projected to be contained in the liquid effluent streams upon startup of PUREX is compared in Table 2-3 with DOE concentration limits. None of these radionuclides will migrate offsite, with the exception of tritium. Tritium could reach the Columbia River 23 yr after discharge to the ground; however, the concentration of tritium in the groundwater prior to dilution in the river has been measured as less than 300 pCi/mL.(12) The release of tritium offsite will meet DOE standards.

The FP-contaminated solid wastes that leave the PUREX Plant are buried on the Hanford Site. The TRU-contaminated solid wastes are placed in 20-yr retrievable storage. Large process vessels are stored in the burial tunnel associated with the plant and will be decommissioned along with the rest of the plant. The projected quantity and activity of radioactive waste from the PUREX Plant after startup is given in Table 2-4. The radionuclides in the solid waste are contained on the Hanford Site and do not contribute any incremental exposure to the general population. Treatment and transportation of the stored TRU waste to a federal repository is possible in the future and will be addressed as a separate program at the appropriate time.

2.3.2 Projected Offsite Dose

The concentrations of the radionuclides routinely released as a result of the renewed operation of the PUREX Plant will be many times below the guidelines established for offsite locations.(13) Any radiation dose received by the general population will be a very small fraction of the normal background dose from natural sources.

TABLE 2-3. Annual Radioactive Waste Discharges from the PUREX Plant to Cribs and Ponds.

Radionuclides	DOE Order 5480.1A, Chapter XI[13]		1972 Actual[a]		1985 Projected[b]	
	Offsite concentration guide (μCi/mL)	Onsite concentration guide (μCi/mL)	Average concentration at the source[c] (μCi/mL)	Annual curies	Average concentration at the source[c] (μCi/mL)	Annual curies
Discharges to Cribs						
^{239}Pu	5×10^{-6}	1×10^{-4}	1.9×10^{-5}	4.3[d]	1.3×10^{-6}	2.7×10^{-1}
^{238}U	4×10^{-6}	1×10^{-3}	6.1×10^{-9}	1.4×10^{-3}[d]	6.6×10^{-9}	1.4×10^{-3}
^{3}H	3×10^{-3}	1×10^{-1}	1.4×10^{-1}	7.0×10^{3}[e]	2.0×10^{-1}	3.4×10^{4}[f]
^{90}Sr	3×10^{-7}	1×10^{-5}	6.5×10^{-4}	1.5×10^{2}	1.0×10^{-5}	6.0
^{137}Cs	2×10^{-5}	4×10^{-4}	7.4×10^{-4}	1.7×10^{2}	8.6×10^{-6}	1.8
^{106}Ru	1×10^{-5}	3×10^{-4}	3.5×10^{-3}	8.1×10^{2}	1.1×10^{-5}	2.4
^{60}Co[f]	3×10^{-5}	1×10^{-3}	8.3×10^{-5}	1.9×10^{1}[d]	4.1×10^{-7}	8.4×10^{-2}
Discharges to Ponds						
^{239}Pu	5×10^{-6}	1×10^{-4}	2.6×10^{-8}	4.4×10^{-1}[d]	2.9×10^{-8}	2.7×10^{-1}
^{238}U	4×10^{-6}	1×10^{-3}	1.1×10^{-9}	1.9×10^{-2}[d]	2.0×10^{-9}	2.0×10^{-2}
^{3}H	3×10^{-3}	1×10^{-1}	g	g	7.2×10^{-6}	6.1×10^{1}
^{90}Sr	3×10^{-7}	1×10^{-5}	1.8×10^{-8}	0.3[d]	4.5×10^{-8}	4.3×10^{-1}
^{137}Cs	2×10^{-5}	4×10^{-4}	1.1×10^{-7}	1.8[d]	1.1×10^{-7}	1.0
^{106}Ru	1×10^{-5}	3×10^{-4}	2.9×10^{-7}	4.9[d]	1.2×10^{-8}	1.1
^{60}Co	3×10^{-5}	1×10^{-3}	5.9×10^{-8}	1.0[d]	5.9×10^{-8}	5.7×10^{-1}

[a]The 1972 discharges are based on processing a total of 1,013 t of fuel including about 525 t of 3.5% ^{240}Pu weapons-grade irradiated fuel.

[b]Projected discharges are based on processing 2,100 t of 12% ^{240}Pu irradiated fuel, 20% of which is spike fuel. The 2,100 t of fuel is the sum of six equal portions weighing 350 t each with cooling times of 1/2, 2, 3, 4 1/2, 6, and 7 1/2 yr. Processing of 6% ^{240}Pu irradiated fuel would result in lower discharges. The projected discharges to cribs are based upon process condensate recycle to be implemented shortly after startup.

[c]These values were determined by dividing the annual curies by the total effluent volume. These numbers are statistically derived and are given for comparison purposes only.

[d]Values are the sum of 12 composite samples. The detection limit varied, depending on the sample size and counting time.

[e]Calculated from previous sample results.

[f]Estimates higher than 1972 data are based on higher exposure rates (i.e., 12% ^{240}Pu).

[g]Not analyzed.

TABLE 2-4. Annual Radioactive Solid Waste Discharged from the PUREX Plant.[14]

Waste type/source	Volume (m^3)	Total (Ci)	^{90}Sr, ^{137}Cs, ^{106}Ru (Ci)	Pu (g)
1972 (Actual)				
TRU	1.9×10^2	180	a	43
Non-TRU	4.5×10^2	31,000	2,500	<0.1[b]
1984 and Beyond[c]				
TRU				
PUREX	3.8×10^2[c]	360	-	86
PuO_2 line	3.8×10^1[c]	-	-	1,840
Burial boxes	1.6×10^2[c]	-	-	1,000[d]
Non-TRU	8.0×10^2[c]	54,000	4,400	0.2

[a]Data not available.

[b]Less than values are derived from the lower limits of detection.

[c]Annual estimate based on processing 2,100 t of irradiated fuel per year.

[d]This is the maximum amount allowed; actual values will probably be less.

A sophisticated model of exposure pathways has been developed at the Pacific Northwest Laboratory. Exposure from radionuclides that are in the air, that have been deposited on the soil, or that have entered the food chain is calculated by a series of codes that model these various pathways to man. The dose predictions are made for both the general population and for a hypothetical member of the general population who could receive the largest dose. The dose predictions for the general population are given in units of man-rem. This unit is obtained by multiplying the number of people living within 50 mi of the site with the average dose for that location. The dose prediction for the greatest individual exposure is based on a hypothetical individual who farms at Ringold (the closest location) and who derives a substantial part of his diet from vegetables, meat, and milk produced on this farm. The dose predictions do not contribute significantly to the exposure to the general population or the hypothetical individual.

The predicted dose that will be received by the general population due to the operation of the PUREX Plant is given in Table 2-5. The dose is evaluated in terms of the yearly dose and a lifetime dose. The yearly dose is based upon a dose received during 1 yr of PUREX operation. However, the radionuclides that are deposited on the hand and in the body continue to contribute a small amount of exposure over a lifetime. Therefore, the total dose predicted over a 70-yr period as a result of operating PUREX for 16 yr is also given. The total body dose for the maximally exposed individual over a 70-yr period is predicted to be 0.9 mrem. The total background dose from natural sources is about 7,000 mrem over this 70-yr period. Based on this comparison, the operation of the PUREX Plant contributes an almost negligible amount of exposure to the offsite general population.

2.3.3 Occupational Doses to Employees

The total complement of workers located at and directly involved in the PUREX Plant when it is in full operation is about 400, including operations, maintenance, laboratory, engineering support services, and supervision. In 1972, the annual average whole body occupational radiation dose to the PUREX workers was about 0.9 rem, the maximum was 2.9 rem and the minimum was 0.0 rem (see Table 8-8). The DOE dose commitment standard is 5 rem/yr. The working guide for PUREX employees and other workers in the 200 Areas is 3 rem/yr.

2.3.4 Radiological Protection Features

Rockwell will continue the long-standing commitment of maintaining personnel and public radiation exposures to as low as reasonably achievable and within DOE guidelines.(13) Implementation of this policy, described in detail in Chapter 8.0, includes process and effluent radiation monitoring, criticality safety, plant design features, administrative procedures, health physics surveillance, and environmental monitoring programs. A summary of the radiological protection features is presented in the following sections.

TABLE 2-5. Total Body Radiation Doses from Routine Releases from the PUREX Plant, Starting from 1983 to 1999, over a 50-mi Radius Area.

Total body pathway	Maximum individual dose (rem)		Population dose (man-rem)[a]	
	1-yr release/ 1-yr accumulation[b]	16-yr release/ 70-yr accumulation[c]	1-yr release/ 1-yr accumulation	16-yr release/ 70-yr accumulation
Air submersion (^{85}Kr)[d]	1.3×10^{-5}	2.1×10^{-4}	1.5×10^{0}	2.4×10^{1}
Inhalation (^{90}Sr, ^{239}Pu)[d]	2.0×10^{-7}	1.9×10^{-5}	3.2×10^{-2}	3.0×10^{0}
Ground Deposition (^{129}I)[d]	3.6×10^{-9}	3.6×10^{-6}	3.8×10^{-4}	3.8×10^{-1}
Ingestion (^{129}I, ^{90}Sr)[d] (fruit and vegetables)	2.4×10^{-6}	6.8×10^{-4}	1.7×10^{-2}	4.1×10^{1}
Totals from all exposure pathways	1.6×10^{-5}	9.1×10^{-4}	1.7×10^{0}	6.8×10^{1}

[a]The population dose is an estimated population of 417,000. All local population doses are based on this population distribution within a 50-mi radius of the Hanford Meteorological Station, located at about the center of the Hanford Site.

[b]A 1-yr release/1-yr accumulation is the dose received in the first year from exposure in that year.

[c]A 16-yr release/70-yr accumulation is the total dose accrued over a lifetime of continuous exposure to residual radiation both during and after the 16 yr of PUREX Plant operation.

[d]Primary radionuclides contributing to dose.

2.3.4.1 Administrative Procedures. The PUREX Plant operations will be conducted in accordance with Rockwell policies, which are implemented by Rockwell radiation protection standards and controls for radiological purposes. These standards are then implemented by line management and Radiation Monitoring personnel. All operations to be performed in posted radiological areas are conducted in accordance with detailed written radiation work permits. Plant operating procedures have been prepared to provide operational control. This system of policies and procedures, representing the results of past operational experience with PUREX Plant operations, will be continually reviewed and updated.

2.3.4.2 Facility Design Features. Effective control of personnel radiation exposure is accomplished by incorporation of the following summarized design features.

- Confinement Barriers

  Confinement of radioactive materials is maintained through a system of multiple barriers.

- Shielding

  Shielding design throughout the plant was based on maximum anticipated process conditions (in 1956 during original construction) for fuel irradiation to 600 MWd/t and cooling for 90 d. Recent calculations indicated that, even with fuel irradiated to 4,000 MWd/t and cooled for 180 d, the installed, 6.0-ft-thick concrete walls will reduce the dose rate in uncontrolled areas to less than 0.01 mR/hr. Therefore, it is concluded that dose rates from processing N Reactor fuel (irradiated to 2,500 MWd/t, 180 d cooling) will also be well below the design values (see Chapter 8.0).

  The plutonium oxide production facility at PUREX will utilize a combination of fixed and movable shielding on the gloveboxes and shielding walls and windows around the control room. The shielding has been designed to ensure that workers will not receive doses in excess of 1 rem/yr average (based upon a workforce of 25).

- Ventilation

  The plant ventilation system has been designed to ensure that airflow is from zones of lesser contamination potential to zones of greater contamination potential. The pressure differential, with respect to the outside environment, becomes increasingly negative as one approaches the area of greatest contamination potential. A system of interlocks, alarms, and air locks, as well as ventilation system backup, has been provided to minimize the probability of airflow reversals or the release of radioactive contamination to the environs.

- Gaseous Effluents Monitoring

Gaseous effluents are continuously sampled for particulates and radioiodine to provide a record and inventory of actual releases. Alarm levels are set to permit prompt corrective action before unacceptable concentrations are reached. Continuous beta/gamma and alpha air sample collectors are located in each potentially contaminated exhaust stack, and filter tests are conducted annually to check performance and efficiency. (More information on gaseous effluent monitoring can be found in Chapter 7.0.)

- Liquid Effluent Monitoring

Radioactive liquid wastes (solutions, suspension, and sludges) are categorized as releasable to the environment or high-level liquid wastes. With the exception of tritium and strontium released to cribs, liquid wastes discharged to open ponds, ditches, or cribs will be essentially free from radioactive material and are projected to be well below DOE guidelines.)(13) The concentration of tritium is predicted to be slightly higher than DOE guidelines, but the environmental effect is inconsequential and the release is to an onsite crib. Operational criteria for the release of radioactive liquids are detailed in Chapter 7.0.

- Solid Waste Monitoring

Solid waste materials are surveyed to estimate the radioactive material and special nuclear material content prior to interim storage. Contamination levels on, and radiation levels at, exterior surfaces of the package are measured and documented prior to shipment. The TRU wastes are assayed for plutonium content using special devices and the wastes are handled accordingly.(15)

- Personnel Monitoring

Gamma radiation levels are continuously measured by installed gamma detectors in all areas where personnel access is permitted. Continuous air monitors (CAMs) are installed in appropriate areas throughout the plant. Portable air samplers are used when required. Personnel are also provided with the usual personnel radiation dosimeters to record the total dose received during employment at the site.

- Dose Rate Control

Dose rate criteria and allowable radiation and contamination levels have been established for the various areas and facilities in the plant. To limit personnel radiation exposures, access controls have been instituted to limit access to the site, to the process building, and within the process building.

- Criticality Safety

  The double contingency principle (triple contingency for areas where shielding does not provide protection in the event of a criticality accident) has been employed throughout the plant to minimize the probability of criticality. Mechanisms employed in the design and operation of the plant include geometrically favorable equipment, nuclear blanks, and administrative control of mass or concentration of plutonium. Additional restrictions are placed on the introduction of firefighting water to further minimize the potential for criticality.

- Health Physics

  The radiation monitoring organization implements the radiation protection program at the PUREX Plant. This includes plant surveillance, air sampling and contamination surveys, and documentation.

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2.3.4.3 Environmental Protection Program. It is Rockwell policy that activities be conducted in a manner that protects the safety and health of all employees, and prevents loss or damage to facilities. All operations will be conducted in compliance with applicable DOE health and safety requirements, and will adhere to generally recognized and accepted high standards of performance in the areas of occupational health; nuclear, radiological, industrial, and fire safety; and environmental protection.

An environmental protection organization has been established in Rockwell to monitor the effects of plant effluents on the environment. This is accomplished by means of a site surveillance program for air, surface, and vegetation sampling. This organization maintains permanent records of survey results and advises plant operations personnel and management on compliance with DOE operational requirements and Rockwell policy. The environmental protection organization has the responsibility and authority to close down any operation that constitutes an immediate and significant hazard to safety, health, property, or the environment.

2.4 ACCIDENTS

The approach taken for the accident analysis of the PUREX Plant is derived from WASH-1400(16) and from the DOE-developed Management Oversight and Risk Tree program. The accidents are defined as those potential events caused by operations (system malfunctions, operator error, or improper operating conditions) or by natural phenomena which result in the release of radioactive material beyond the PUREX exclusion area or by the release of radioactive materials in such a manner as to seriously endanger personnel.

A Preliminary Hazards Analysis (PHA) was developed for PUREX Plant operations. The effects of natural phenomena were analyzed separately[10,11] from plant operations related accidents. The hazards identified in the PHA were reviewed by experienced Rockwell personnel and an offsite subcontractor. Preliminary risk assessment was used to screen for primary risk contributors. Fault tree analysis was used to confirm this list of primary risk contributors as well as to provide approximate frequency of occurrence of the accidents. The accidents were developed as scenarios with calculated onsite and offsite doses to maximum exposed individuals and populations.

The analysis was performed understanding the limitations of the numerical estimates of the probabilities and consequences of accidents associated with any industry. The set of accidents chosen to represent the risk of PUREX operations is acknowledged to be incomplete. The intention of this analysis is that by careful selection of the accident set and conservative treatment of those selected, the results will approximate the true risk. To initiate the selection, the analysis was centered on the key safety related areas of the PUREX Plant operation. Safety related areas were identified by three criteria, which govern potential radiological consequences:

- Inventory of radioactive material
- Chemical and physical form of the radioactive material
- Presence of processing conditions that contain driving forces for potential accidents.

Based upon these criteria, the following areas were selected for analysis:

- Fuel receiving (includes handling and transferring)
- Fuel decladding and dissolving
- Feed preparations
- Solvent extraction
- Plutonium concentration
- Plutonium oxide conversion
- Waste treatment (primarily high-level) within the PUREX Plant.

Obviously, accidents with no radiological consequences may occur during the operating life of the facility: fires, chemical reactions, falls, etc. In this respect, the PUREX Plant shares the same risks as

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those presented by nonnuclear chemical processing facilities. While these accidents are discussed, they are not included in the total estimated risk of the facility.

To limit the number of detailed analyses to those accidents that effectively determine the risk envelope for the PUREX Plant, a screening process was developed to identify those important contributors.

The screening is based on a simplification of a more complete risk expression. The risk of a radionuclide release is a mathematical product of five terms such that:

$$\text{Risk} = A \times B \times C \times D \times E$$

where

A = probability of release sequence

B = release magnitude

C = measure of the radiological characteristic of the released material

D = measure of the environmental transport factor

E = measure of population at risk.

The total risk involved in operation of the facility is, therefore, the summation of this expression for all release sequences.

For the purpose of comparing and screening sequences for one facility at one site, the expressions C, D, and E may be held as constants, leaving only the requirement for the determination of A and B to determine risk. The PUREX PHA was reviewed by a team of highly experienced PUREX personnel with representation from Operations; Health, Safety and Environment; and Research and Engineering. Probability estimates were made on each accident sequence identified in the PHA based on the criteria in Table 2-6. Consequence estimates were made based on the criteria in Table 2-7. Using these terms, a risk factor was developed for each accident identified in the PHA: Risk = A x B.

TABLE 2-6. Probability Classes.*

Probability level	Estimated probability (yr^{-1})	Description
3	1	Incident considered as part of normal operations. May occur several times during lifetime of facility
2	10^{-2}	May occur sometime during lifetime of facility
1	10^{-6}	Probably will not occur during lifetime of facility (design basis accidents)
0	10^{-8}	No reasonable scenario is conceivable

*Based upon accident classifications in ANSI N287-1976.(17)

TABLE 2-7. Consequence Classes.*

Severity level	Descriptive word	Description
0	No	No onsite or offsite impact to people or environment
1	Low	Minor onsite and negligible offsite impact to people or environment
2	Moderate	Considerable potential onsite impact to people or environment
		Minor potential offsite impact
3	High	Potential for major onsite or offsite impact to people or environment

*Based upon classes defined in DOE Order 5481.1A.(2)

Several accidents were selected for detailed discussion; those accidents identified as potential risk contributors were analyzed in detailed scenarios. Scenario development includes determination of source terms, releases, and potential doses to onsite and offsite personnel. In addition, the fault trees are quantified to provide an estimate of probability of occurrence of accidents that may result in "above normal release of radioactivity." The following information was derived for each:

- Cause of accident
- Barriers against events leading to accident
- Fault tree of accident
- Probability of occurrence
- Source term or amount of radioactive material available for release
- Radiological consequences.

A condensed listing of the preliminary hazards analysis is shown in Table 2-8. Those accidents that have no reasonable scenario of occurrence (probability level 0), as defined in Table 2-6, or onsite or offsite impact to people or environment are excluded from Table 2-8. A complete listing is given in Table 9-3. The lowest probability class listed in Table 2-8 is the design basis accident (level 1). The lowest consequence class listed in Table 2-8 represents minor onsite and negligible offsite impact to people or environment (low). Based on airborne releases, no plant operations-related accidents of probability level 3 or consequence level 3 were found. However, it was determined in Reference 11 that potential existed for major onsite impact to personnel as a result of a seismic event.

2.5 EVALUATION OF RESULTS

The dose and dose risk consequences of airborne releases from PUREX accidents are summarized in Table 2-9. Direct radiation consequences resulting from a postulated N cell criticality event and overexposure during fuel charging were also evaluated in the PHA.

TABLE 2-8. Summary PUREX Preliminary Hazards Analysis. (Sheet 1 of 9)

System/subsystem	Potential accidents	Causal factors	Barriers	Characteristic source term	Category		Controlling OSR
					Probability	Consequence	
1.4 Charge fuel to dissolver	Dissolution of short-cooled fuel, with release of short-lived FP	DOG[a] system not designed to accommodate short-lived FP and Lack of control of material charged to dissolvers resulting in charge of green fuel	Adminstrative control by procedure on material brought to PUREX Radiation monitor verification of fuel age Heat sensor in rail car carrier	Short-lived FP gases, including Kr, Xe, and I_2	1	2	11.2.1, 11.3.2
	High personnel exposure	Charging of fuel in presence of personnel	Administrative control dispatcher check-in/check-out		1	1	11.3.5
2.0 Fuel decladding and dissolution	Discharge from tank into leaking coils and then to pond: o Discharge to pond from TK-E3, -E5, -D3, -D4, and -D5	Coil failure, and Suckback occurrence, and Failure to divert to catch basin	Bypasses on certain cooling water shut-off valves to maintain pressure Radiation monitor causes automatic diversion of contaminated water to retention basin 216-A-42	Dissolver/metathesis decladding solution released in cooling pond	1	1	11.3.4 11.3.5
	NH_3 or H_2 explosion in dissolver or DOG	Radiolytic or chemical generation of H_2 or chemical generation of NH_3	Ensure presence of ammonium nitrate in decladding solution H_2 and NH_3 monitor, administrative controls		1	1	11.2.2, 11.2.3 11.3.5
2.2 Metathesis process	U metal fire in dissolver melts through dissolver releasing liquid in A, B, or C cell	Metal heating due to FP decay and exothermic U reactions, and Makeup water omitted, and U melting point higher than dissolver stainless steel	Long time span required to sufficiently heat fuel to cause fire Administrative control on length of time fuel can remain uncovered	FP aerosol in DOG system and in A, B, or C cells	1	2	11.2.4 11.3.5
2.3 Fuel dissolution	Criticality in a dissolver containing dissolved fuel	Addition of metathesis solutions from TK-D1 causing precipitation of dissolver solution	Administrative control which includes a supervised lock and tag for KOH addition to dissolver	Dissolver aerosol and volatile short half-life isotopes to DOG system	1	1	11.2.4 11.3.1 11.3.5

TABLE 2-8. Summary PUREX Preliminary Hazards Analysis. (Sheet 2 of 9)

System/subsystem	Potential accidents	Causal factors	Barriers	Characteristic source term	Category		Controlling OSR
					Probability	Consequence	
2.3 Fuel dissulution (Continued)		and Double charge of fuel or miscommunication as to enrichment of fuel in dissolver	Administrative controls as to dissolver charge as a function of fuel enrichment				
	U metal fire in dissolver		See Analogous Accident in Section 2.2[b]				
2.4 Jet solution to holding tanks TK-D3, -D4, and -D5	Criticality due to KOH-triggered precipitation of feed solution	Addition to methathesis solution to tank from the dissolver or TK-D2 while tank is full or nearly full and Excess plutonium inventory in affected tanks	Administrative procedure control Supervised lock and tag system	Dissolver aerosol and short half-life isotopes and gases including Kr, Xe, and I_2	1	1	11.3.5 11.3.1
2.4 Feed solution holding tanks TK-D3, -D4, and -D5	H_2 explosion in tank atmosphere	Radiolytic H_2 formation, and Lack of air dilution, and Source of ignition	Administrative control to provide air dilution to tank Lack of readily identifiable ignition source Explosion needs to blow off vessel covers	Dissolved metal solution aerosol in D cell	1	1	11.3.3 11.2.3 11.3.5
2.5 Feed makeup tank TK-E6	H_2 explosion in tank atmosphere	Radiolytic H_2 formation, and Lack of air dilution, and Source of ignition	Administrative control to provide air dilution to tank Lack of readily identifiable ignition source Explosion needs to blow off vessel covers	Dissolved metal solution aerosol in D cell	1	1	11.3.3 11.2.3 11.3.5
	Criticality in TK-E6	TK-E6 not geometrically safe, and An excessive amount of Pu jetted from TK-L11 or N cell to TK-E6 because of either operator error or erroneous laboratory results,	Procedures limiting transfers of TK-L11 or N cell to TK-E6 plus a required laboratory analysis Criticality limits require at least double batching to create a criticality	Dissolver aerosol and short half-life isotopes	1	1	11.3.1 11.3.5

TABLE 2-8. Summary PUREX Preliminary Hazards Analysis. (Sheet 3 of 9)

System/subsystem	Potential accidents	Causal factors	Barriers	Characteristic source term	Category		Controlling OSR
					Probability	Consequence	
2.5 Feed makeup tank TK-E6 (Continued)		and Both agitators fail in TK-E6	$Cd(NO_3)_2$ required for transfer of concentrated Pu solution from TK-L11 or N cell to TK-E6 Redundant agitators in TK-E6				
3.1 NH_3 scrubbing with H_2O during declad (T-A3-3, B3-3, C3-3)	NH_3 explosion in electric heater Azide explosion in silver reactor	Failure to turn on condenser cooling water and scrubber water, and Low silver reactor temperature allows formation of explosive compound, and NH_3 reactions with silver forming potentially explosive compounds, and Restoration of heat to silver reactor	Alarm sounds if dissolver is in declad stage with low H_2O flow to NH_3 scrubber NH_3 detector installed in-line to alarm on high NH_3 flow past NH_3 scrubber Silver reactor maintained at operating temperature during all phases of dissolver operations to preclude formation of azides Low temperature alarm on silver reactor	^{131}I from silver reactor out through stack	1	1	11.2.2 11.3.5
6.4 Pu-U partitioning column	1BX column criticality	Excessive ferrous ions present in column and Excessive nitrite in column organic feed causing reflux	Procedures on means of recovery from loss of partitioning Laboratory analyses of both ferrous concentration and 1BX makeup Neutron monitors positioned along column	Short-lived FP offgasing to vessel vent system	1	1	11.3.1 11.3.5
7.0 Final Pu cycle	A solvent fire involving loaded Pu solvent	A solvent leak to the cell floor and Source of ignition	Administrative control over the materials collected in sumps Lack of readily identifiable source of ignition Fire fog system Low solvent inventory	Pu aerosol filling L cell	1	1	11.2.5

TABLE 2-8. Summary PUREX Preliminary Hazards Analysis. (Sheet 4 of 9)

System/subsystem	Potential accidents	Causal factors	Barriers	Characteristic source term	Category		Controlling OSR
					Probability	Consequence	
7.0 Final Pu cycle (Continued)	Criticality in L cell	Leak of Pu solution to floor from vessel or connecting piping, and The flooding of L cell, and No periodic cell flush or visual inspection	Procedure control of sump contents Product loadout monitors to detect gross leakage Level alarms Pu leak to cell floor forms slab configuration	Pu aerosol with volatile FP in L cell	1	1	11.3.1 11.3.5 11.2.5
7.1 Pu cycle feed tank (TK-J5)	Criticality in J cell sump	Filling of J cell sump with solution from TK-J5 (2AF) and Presence of a precipitating agent in the sump	Sump monitor Administrative control over contents of sumps along with control of material added to J cell sump Operational depth of Pu on cell floor may not exceed stated limits	Pu aerosol plus FP gases from criticality in J cell	1	1	11.3.1 11.2.5 11.3.5
7.5 Air pulser to 3A column	Blowback into P&O gallery to environment	Leak in pulser system in P&O gallery	Routine pressure checks of pulsers Filtered exhaust Glovebox around air pulser	3A column solution aerosol to P&O gallery thence to environment through white room stack	2	1	11.3.5 11.3.3
7.6 Air pulser to 3B column	Blowback into P&O gallery to environment	Leak in pulser system in P&O gallery	Routine pressure checks of pulsers Filtered exhaust Glovebox around air pulser	3A column solution aerosol to P&O gallery thence to environment through white room stack	2	1	11.3.5 11.3.3
7.7 Pu stripper (T-L6)	Suckback into P&O gallery from tube bundles	Failure of a tube bundle and Leak in P&O gallery	Routine pressure checks of tube bundles Pressurized air is an automatic backup for low steam pressure in tube bundle Filtered exhaust	Pu solution aerosol from TK-L6 in P&O gallery white room to white room stack	2	1	11.3.5 11.3.3

TABLE 2-8. Summary PUREX Preliminary Hazards Analysis. (Sheet 5 of 9)

System/subsystem	Potential accidents	Causal factors	Barriers	Characteristic source term	Category		Controlling OSR
					Probability	Consequence	
7.7 Pu stripper (T-L6) (Continued)	Criticality in L cell	Slow leak from vessel to hot surface then agglomerating to slowly form critical mass (cell flooding will reduce mass required)	Pu accountability system Periodic cell flush Molarity and composition of solution inhibits evaporation to dryness Cell sump design Routine visual inspection of cell Preventative maintenance	Volatile FP in L cell atmosphere	1	1	11.3.1 11.2.5 11.3.5
7.8 Pu product concentrator (E-L7-1)	Blowback into P&O gallery from tube bundles	Failure of a tube bundle and Leak in P&O gallery	Routine pressure checks of tube bundles Aerosol formation required for spread of contamination Pressurized air is automatic backup to low steam pressure in tube bundle	Pu solution aerosol from E-L7-1 in P&O gallery white room to white room stack	2	1	11.3.5 11.3.3
	Criticality in L cell	Slow leak from vessel to hot surface then agglomerating to slowly form critical mass (cell flooding will reduce mass required), and No routine visual inspection of cell, and No preventative vessel maintenance, and No periodic cell flush-out	Pu accountability system for large leaks Vessel integrity	FP aerosol and gases in L cell	1	1	11.3.1 11.2.5 11.3.5
7.13 PR room series HEPA filters to PR stack	Loss of filtration capability resulting in spread of Pu aerosol from stack	Aerosol formation in rooms or vessels and Loss of filters efficiency caused by damaged filters/filter frames or incorrect installation	Two-stage HEPA filters in series PR room stack monitor DOP testing will be performed on HEPA filters upon installation and then annually	Pu aerosol	1	2	11.3.3 11.3.5

TABLE 2-8. Summary PUREX Preliminary Hazards Analysis. (Sheet 6 of 9)

System/subsystem	Potential accidents	Causal factors	Barriers	Characteristic source term	Category		Controlling OSR
					Probability	Consequence	
7.14 Product load-out to PR bottles from TK-L13-10	Spill of a PR can on either the dock or elevator thereby releasing Pu aerosol	Loose PR bottle lid, and Tipping of PR can, and No filtering of aerosol formed	Procedural control on how cans are handled Procedure instructing the bottle lids to be closed tightly Not performed routinely	Ground-level release of Pu aerosol in building ventilation system or on loadout dock	2	1	11.3.5
8.0 Organic recovery system 1	Major organic fire	Organic leakage to G cell and Ignition prior to removal	Administrative control of material in sumps Lack of ignition sources Firefighting system, including tunnel spray Large conflagration required to affect filters Redundant sump level alarms	Aerosol formation resulting from burning of solvent to main exhaust filters Zr-Nb and Ru	1	1	11.2.5 11.3.5
12.6A Final facility filtering (HEPA) (deep beds assumed to be removed from service)	Fire in HEPA filter	NH_4NO_3 and organic in filter and Source of ignition	Lack of ignition source All NH_3 streams processed separately and resulting NH_3 vent releases are discharged through a separate stack Concentration of NH_4NO_3 too low to support combustion Water seal on HEPA HEPA filters in series resulting in reduced activity and less NH_4NO_3 in final stage	Aerosol of HEPA filter activity (negligible)	1	2	11.3.3 11.2.2 11.3.5
	Sudden blockage of filter by water seal resulting in air reversal from canyon	Water seal provided to permit HEPA filter isolation	Administrative procedures	Canyon air dispersed into normally clean areas	2	1	11.3.5
12.6B	Smoke plugging of deep-bed filters	Solvent fire in canyon cell	Firefighting system, including tunnel spray		1	2	11.3.3 11.2.5 11.3.5

TABLE 2-8. Summary PUREX Preliminary Hazards Analysis. (Sheet 7 of 9)

System/subsystem	Potential accidents	Causal factors	Barriers	Characteristic source term	Category		Controlling OSR
					Probability	Consequence	
14.1 Waste concentration (TK-F6, -F26, -F15, or -F16)	Release in P&O gallery from suckback from jets Suckback from leaky tube bundles Blowback in instrumentation lines	Failure of jet gang valves to blow steam out of line and Instrument line leakage	Maintenance on jet gang valves Testing of tube bundles at every plant outage Pressurized air is automatic backup for low steam pressure in tube bundle	IWW solution aerosol released to P&O gallery	2	1	11.3.3 11.3.5
14.5 Waste denitration (TK-F15)	H_2 explosion in tank atmosphere	Excessive radiolytic H_2, and Lack of air dilution, and Source of ignition	Vessel vent system provides air dilution to tank atmosphere Source of ignition not readily identifiable	IWW aerosol formation in F cell	1	1	11.2.3 11.3.3 11.3.5
14.6 Sump waste receiver (TK-F18) (TK-F18)	Criticality in TK-F18	Collecting of excess Pu containing solution leaked to sumps and Failure to acidify TK-F18	Control of leaks by maintenance Procedures for not adding caustic to TK-F18 until after laboratory sample results are known Sample taken of sump prior to shipping to TK-F18 Sample taken in TK-F18	FP aerosol and gases in TK-F18	1	1	11.3.1 11.2.5 11.3.5
15.0 PuO_2 conversion	Nuclear criticality in N or L cell sumps	Transfer of solutions to full tanks (TK-M3, -M4, -M5, or -M6) and overflow to sump via -M12 and Leaking tank	Administrative controls including lock and tag, accountability for transfers, and fissile mass and depth limits Proper operating procedures Criticality drain in N cell Liquid-level instruments and alarms on tanks and sumps	Aerosols of Pu solutions plus short-lived FP gases into N cell glovebox and L cell	1	1	11.3.1 11.2.5 11.3.5
	Criticality in M or N N cell vessel sumps and piping	Low acid concentration permits Pu polymer formation resulting in precipitation and hold up of Pu at concentration exceeding 450 g/L	Closed loop cooling of all vessels with 1.2M acid coolant No water addition normally possible	Aerosols of Pu solutions/sludges plus short-lived FP gases into VOG[c] and N cell glovebox	1	2	11.3.1 11.3.5

TABLE 2-8. Summary PUREX Preliminary Hazards Analysis. (Sheet 8 of 9)

System/subsystem	Potential accidents	Causal factors	Barriers	Characteristic source term	Category		Controlling OSR
					Probability	Consequence	
15.0 PuO_2 conversion (Continued)			Dilution normally available only with 1.2M acid condensates 1M acid PUREX operating procedures nuclear materials accountability Fissile mass within single vessel insufficient for criticality				
	Fire in oxide conversion facility	Accumulation of combustible solvent or solid waste and source of ignition	Wet pipe sprinkler system in N cell Administrative controls on accumulation of combustible material Design of R cell doors to minimize possibility of solvent entering N cell	Aerosol of PuO_2	1	2	11.2.5 11.3.5
15.5 Vacuum drum filter	Nuclear criticality at or near drum filter	Leak/spill of solids or liquid followed by evaporation, permitting Pu buildup in glovebox or on outide of equipment	Administrative controls of inventory solution depth Housekeeping and periodic inspections of TV and periscope Proper operating procedures Filtration of glovebox atmosphere	Aerosols of Pu solutions/sludges, plus short-lived FP gases into VOG and N cell gloveboxes	1	2	11.3.1 11.3.3 11.3.5
	Nuclear criticality at or near calciner	Bridging of filter cake, or Filter cake fails to fall into calciner, or Calciner backs up to vacuum drum filter	Adequate design Proper operating procedures, including visual observation by television monitors Manual assist available if needed Administrative controls Filtration of air in vessel systems, in cell, and in canyon air	Aerosols of Pu sludge and powder plus short-lived FP gases into N cell glovebox	1	2	11.3.1 11.3.3 11.3.5
15.7.8 Transfer to TK-L11	Spill in canyon cell	Component mechanical failure	Administrative procedure coordination between control rooms and operators welding piping Sump alarm	Weight factor error 15 L of recycle Pu nitrate 90 L of Pu nitrate	2	0	11.3.5 11.2.5

TABLE 2-8. Summary PUREX Preliminary Hazards Analysis. (Sheet 9 of 9)

System/subsystem	Potential accidents	Causal factors	Barriers	Characteristic source term	Category		Controlling OSR
					Probability	Consequence	
15.8 Rotary scalper screen	Nuclear criticality in rotary scalper screen	Design limit of 3 g/cm^3 for Pu in solid form exceeded	Tests show 3 g/cm^3 is higher than can be obtained The equipment is not normally capable of producing solids of this high density Administrative control of inventory (would need too long to fill calciner blender)	Short-lived FP and noble gases released into VOG and H cell glovebox	1	2	11.3.1 11.3.5
15.13 Filtrate holding	Nuclear criticality in TK-E6	Excessive Pu to filtrate, or Oxalic acid pump fails, or Insufficient oxalic acid in strike solution, or Inadequate filtration of Pu, or Failure of TK-N7 agitator, or Inadequate heating in TK-N13 leaves oxalate in -N15 or -N16 for recycle to -E6	Proper operating procedures Volume and weight of additions to TK-N35 or -N36 are measured, and composition is analyzed Administrative controls Inspection of solutions in TK-N7 and -N11 Filtration of VOG and canyon air N-13 is designed for adequate residence time	Aerosols of Pu solutions plus short-lived FP gases into VOG and ventilation air	1	1	11.3.1 11.3.5

[a]Dissolver offgas.

[b]Probabilities and consequences are the same for analogous accidents.

[c]Vessel offgas.

TABLE 2-9. Accident Analysis Summary. (Sheet 1 of 2)

Accident	Accident frequency (yr^{-1})	Organ of concern	Dose in rem to maximum onsite individual		Dose in rem to maximum offsite individual		Dose risk (rem/yr) to maximum onsite individual	Dose risk (rem/yr) to maximum offsite individual
			1 yr	50 yr*	1 yr	50 yr*	1 yr	1 yr
Criticality in the PuO_2 production facility	7.5×10^{-5}	Total Body	6.0×10^{-1}	6.0×10^{-1}	3.0×10^{-3}	3.0×10^{-3}	4.5×10^{-5}	2.3×10^{-7}
		Bone	6.0×10^{-1}	6.0×10^{-1}	3.3×10^{-3}	3.3×10^{-3}	4.5×10^{-5}	2.5×10^{-7}
		Lung	8.3×10^{-1}	8.3×10^{-1}	4.3×10^{-3}	4.3×10^{-3}	6.3×10^{-5}	3.2×10^{-7}
		Thyroid	2.7×10^{0}	2.7×10^{0}	9.0×10^{-2}	9.3×10^{-2}	2.0×10^{-4}	6.8×10^{-6}
Dissolving short-cooled fuel	2.5×10^{-7}	Total Body	4.2×10^{-2}	4.5×10^{-2}	5.5×10^{-3}	6.9×10^{-3}	1.1×10^{-8}	1.4×10^{-9}
		Bone	7.1×10^{-2}	1.3×10^{-1}	7.4×10^{-3}	1.3×10^{-2}	1.8×10^{-8}	1.9×10^{-9}
		Lung	6.1×10^{-2}	6.1×10^{-2}	4.3×10^{-3}	4.3×10^{-3}	1.5×10^{-8}	1.1×10^{-9}
		Thyroid	6.8×10^{-1}	6.8×10^{-1}	1.0×10^{0}	1.1×10^{0}	1.7×10^{-7}	2.5×10^{-7}
U Metal fire in a dissolver	2.0×10^{-3}	Total Body	5.9×10^{-3}	2.4×10^{-2}	2.5×10^{-3}	2.9×10^{-2}	1.2×10^{-5}	5.0×10^{-6}
		Bone	6.2×10^{-2}	3.6×10^{-1}	9.2×10^{-3}	1.0×10^{-1}	1.2×10^{-4}	1.8×10^{-5}
		Lung	8.3×10^{-1}	1.1×10^{0}	4.1×10^{-3}	6.2×10^{-2}	1.7×10^{-3}	8.2×10^{-6}
		Thyroid	9.2×10^{-4}	9.3×10^{-4}	3.2×10^{-3}	9.8×10^{-3}	1.8×10^{-6}	6.4×10^{-6}
Silver reactor explosion	1.0×10^{-3}	Whole Body	4.3×10^{-4}	4.6×10^{-4}	1.3×10^{-3}	1.2×10^{-2}	4.3×10^{-7}	1.3×10^{-6}
		Bone	4.3×10^{-3}	8.9×10^{-2}	1.0×10^{-3}	2.1×10^{-2}	4.3×10^{-6}	1.0×10^{-6}
		Lung	1.8×10^{-3}	1.8×10^{-3}	2.0×10^{-4}	5.2×10^{-3}	1.8×10^{-6}	2.0×10^{-7}
		Thyroid	1.3×10^{-1}	1.4×10^{-1}	9.2×10^{-1}	2.9×10^{0}	1.3×10^{-4}	9.2×10^{-4}
H_2 explosion in a dissolver	1.2×10^{-3}	Whole Body	4.4×10^{-5}	1.2×10^{-4}	3.1×10^{-5}	1.2×10^{-4}	5.3×10^{-8}	3.7×10^{-8}
		Bone	4.9×10^{-4}	1.9×10^{-3}	7.7×10^{-5}	4.2×10^{-4}	5.9×10^{-7}	4.1×10^{-8}
		Lung	4.4×10^{-4}	4.4×10^{-4}	2.5×10^{-5}	3.4×10^{-5}	5.3×10^{-7}	3.7×10^{-7}
		Thyroid	4.8×10^{-3}	4.8×10^{-3}	1.6×10^{-2}	1.9×10^{-2}	5.8×10^{-6}	1.9×10^{-5}
In-canyon criticality	1.5×10^{-2}	Whole Body	2.2×10^{-1}	2.2×10^{-1}	6.3×10^{-4}	6.7×10^{-4}	3.3×10^{-3}	9.5×10^{-6}
		Bone	2.2×10^{-1}	2.2×10^{-1}	1.7×10^{-3}	1.9×10^{-3}	3.3×10^{-3}	2.6×10^{-5}
		Lung	2.6×10^{-1}	2.6×10^{-1}	5.7×10^{-4}	5.7×10^{-4}	3.9×10^{-3}	8.6×10^{-6}
		Thyroid	6.3×10^{-1}	6.3×10^{-1}	9.7×10^{-2}	1.0×10^{-1}	9.5×10^{-3}	1.5×10^{-3}

TABLE 2-9. Accident Analysis Summary. (Sheet 2 of 2)

Accident	Accident frequency (yr^{-1})	Organ of concern	Dose in rem to maximum onsite individual		Dose in rem to maximum offsite individual		Dose risk (rem/yr) to maximum onsite individual	Dose risk (rem/yr) to maximum offsite individual
			1 yr	50 yr*	1 yr	50 yr*	1 yr	1 yr
Solvent fire in H cell	8.6×10^{-6}	Whole Body	2.6×10^{-3}	8.4×10^{-3}	9.2×10^{-4}	1.2×10^{-2}	2.2×10^{-8}	7.9×10^{-9}
		Bone	2.9×10^{-2}	1.2×10^{-1}	4.1×10^{-3}	4.1×10^{-2}	2.5×10^{-7}	3.5×10^{-8}
		Lung	3.0×10^{-1}	4.0×10^{-1}	1.5×10^{-2}	2.2×10^{-2}	2.6×10^{-6}	1.3×10^{-7}
		Thyroid	4.6×10^{-4}	4.6×10^{-4}	1.5×10^{-3}	3.8×10^{-3}	4.0×10^{-9}	1.3×10^{-8}
Solvent fire in L cell	5.9×10^{-5}	Whole Body	8.5×10^{-6}	1.6×10^{-3}	1.9×10^{-6}	3.6×10^{-2}	5.0×10^{-10}	1.1×10^{-10}
		Bone	2.2×10^{-4}	3.6×10^{-2}	5.0×10^{-5}	8.2×10^{-3}	1.3×10^{-8}	3.0×10^{-9}
		Lung	8.3×10^{-3}	2.1×10^{-2}	1.9×10^{-3}	4.7×10^{-3}	4.9×10^{-7}	1.1×10^{-7}
		Thyroid	0	0	0	0	0	0
Pu release via P&O gallery	1.8×10^{-6}	Whole Body	1.8×10^{-2}	5.9×10^{-1}	4.1×10^{-4}	1.4×10^{-2}	3.2×10^{-8}	7.4×10^{-10}
		Bone	4.5×10^{-1}	1.4×10^{1}	1.0×10^{-2}	3.2×10^{-1}	8.1×10^{-7}	1.8×10^{-8}
		Lung	2.8×10^{-1}	2.8×10^{-1}	6.4×10^{-3}	6.5×10^{-3}	5.0×10^{-7}	1.2×10^{-8}
		Thyroid	1.8×10^{-9}	1.8×10^{-9}	4.2×10^{-11}	4.2×10^{-11}	3.2×10^{-15}	7.6×10^{-17}
FP release via P&O gallery	1.8×10^{-6}	Whole Body	3.4×10^{-1}	7.6×10^{-1}	8.0×10^{-3}	1.8×10^{-2}	6.1×10^{-7}	1.4×10^{-8}
		Bone	4.4×10^{0}	1.1×10^{1}	1.1×10^{-1}	2.7×10^{-1}	7.9×10^{-6}	2.0×10^{-7}
		Lung	4.0×10^{0}	4.0×10^{0}	9.6×10^{-2}	9.6×10^{-2}	7.2×10^{-6}	1.7×10^{-7}
		Thyroid	3.4×10^{-4}	3.4×10^{-4}	8.1×10^{-6}	8.1×10^{-6}	6.1×10^{-10}	1.5×10^{-11}
Oxide line fire	3.7×10^{-5}	Whole Body	1.2×10^{-2}	2.2×10^{0}	3.0×10^{-4}	5.4×10^{-2}	4.4×10^{-7}	1.1×10^{-8}
		Bone	3.0×10^{-1}	5.0×10^{1}	7.5×10^{-3}	1.2×10^{0}	1.1×10^{-5}	2.8×10^{-7}
		Lung	1.1×10^{1}	2.9×10^{1}	2.9×10^{-1}	7.1×10^{-1}	4.1×10^{-4}	1.1×10^{-5}
		Thyroid	0	0	0	0	0	0
Cooling coil leak to 216-A-25 pond	1.3×10^{-7}	Whole Body	1.7×10^{-3}	2.0×10^{-3}	4.3×10^{-3}	2.0×10^{-2}	2.2×10^{-10}	5.6×10^{-10}
		Bone	3.3×10^{-3}	6.1×10^{-3}	4.4×10^{-3}	2.2×10^{-2}	4.3×10^{-10}	5.7×10^{-10}
		Lung	9.7×10^{-4}	1.0×10^{-3}	8.1×10^{-4}	1.3×10^{-2}	1.3×10^{-10}	1.1×10^{-10}
		Thyroid	3.5×10^{-6}	3.8×10^{-6}	7.1×10^{-4}	1.4×10^{-2}	4.6×10^{-13}	9.2×10^{-11}

*Lifetime.

2.5.1 Hazard Level

The criteria for the determination of hazard level[16] in terms of potential for annual radiation exposure are listed in Table 2-10.

TABLE 2-10. Hazard Level Criteria.

Hazard level	Total body exposure to maximum individual (rem/yr)	
	Onsite	Offsite
Low	≤5	≤0.5
Moderate	>5 to <25	>0.5 to <5
High	≥25	≥5

With the exception of three accidents, the seismic event, the N cell criticality event, and overexposure during fuel charging, all accidents analyzed were found to be in the low hazard level category when compared to the criteria listed in Table 2-10.

Both the N cell criticality and the seismic event were evaluated as having the potential for significant exposure to nearby (onsite) personnel, including a potential for lethal exposure to individuals in close proximity to the event. The overexposure during fuel charging was evaluated as having the potential for exposure to a nearby individual of 74 rem. However, due to the extremely low probability of these events occurring, these three accidents as well as all others analyzed, meet the criteria for acceptable risk as described in Section 2.5.2.

2.5.2 Risk Acceptability

Risk acceptance guidelines have been implemented by Rockwell to provide assurance that risks have been limited to a level which is acceptable. Criteria for acceptable risk are presented in terms of potential radiological dose commitment and corresponding maximum acceptable accident probability which are shown in Table 2-11.[18]

For normal operations, radiological dose criteria for the onsite worker will not exceed the values of dose stated in the Rockwell Radiological Standards and Operational Controls Manual.[19] The occupational total body dose to radiation workers is 1.25 rem per calendar quarter and/or 3.0 rem per year. For the general public, the "maximum individual" total body dose is 0.5 rem per year. These dose values for normal operations are converted to risk by application of a probability of 1 per year. Actual doses will be limited to as small a fraction of the above values as is practicable under the ALARA Program.[20]

TABLE 2-11. Radiological Dose Criteria for Risk Acceptance.

Event		Maximum potential dose commitment (rem)					
		Offsite			Onsite		
Description	Estimated probability of occurrence, P (yr^{-1})	Whole body	Bone surface and thyroid	Lung and other organs	Whole body	Bone surface and thyroid	Lung and other organs
Incidents or events of moderate frequency which may occur several times during the lifetime of a facility.	$1 \geq P \geq 10^{-1}$	0.01/year	0.06/year	0.03/year	0.1/year	0.6/year	0.3/year
Infrequent incidents or events which may occur during the lifetime of a facility.	$10^{-1} > P \geq 10^{-3}$	0.5/year	3/year	1.5/year	3/year	15/year	7.5/year
Events which are limiting faults and are not expected to occur during the lifetime of a facility.	$10^{-3} > P > 10^{-7}$	25/lifetime	300/lifetime	75/lifetime	25/lifetime	300/lifetime	75/lifetime

For abnormal operations and accident situations, the following considerations apply to the onsite and offsite maximum exposed individual(18) as defined in the referenced guide.

- Incidents or events of moderate frequency which may occur several times during the life of a facility ($1 \geq P \geq 10^{-1}$) are acceptable if the incremental consequences produce a maximum individual onsite first year dose no greater than one-tenth the ALARA design objective (0.1 R whole body) for occupational radiation dose recommended by DOE.(20) Risks are acceptable if the maximum offsite individual dose is no greater than one-tenth the onsite value.

- The risk is acceptable, if the consequences of infrequent incidents or events which may occur during the life of a facility ($10^{-1} > P > 10^{-3}$) produce incremental doses, which are comparable to those for normal operations.

- Design basis accidents and events which are limiting scenarios and are not expected to occur during the life of a facility ($10^{-3} > P > 10^{-7}$) are evaluated using the siting guidelines provided in 10-CFR-100 Reactor Site Criteria(21) and DOE Order 6430.1(22) These events are postulated because their consequences would include potential for the release of significant amounts of radioactive material and because they represent upper bounds on failures or accidents with a probability sufficiently high to require consideration in design. A postulated accident is not considered in design if the probability of its occurrence resulting in unacceptable consequences is less than 10^{-7} per year.

2.5.3 Consequence Guidelines

The guidelines for evaluation of accident consequences are shown in Table 2-11.

2.6 SUMMARY

In summary, a safety analysis was developed for the PUREX Plant, based upon plant operations PHA and natural forces (seismic and tornado) analyses. The hazards identified were reviewed by personnel experienced in the operations of the PUREX Plant. Preliminary risk assessment was used to screen the PHA for primary risk contributors as well as to provide approximate frequency of occurrence of the accidents. The accidents were developed as scenarios with onsite and offsite doses to the maximum exposed individuals and onsite and offsite population doses calculated.

Comparison of the predicted accident consequences with established criteria result in the judgement that PUREX Plant operations may be conducted with an acceptable level of risk.

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CHAPTER 3.0 SITE CHARACTERISTICS

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3.0 SITE CHARACTERISTICS

3.1 GEOGRAPHY AND DEMOGRAPHY OF SITE

3.1.1 Site Location

The Plutonium-Uranium Reduction Extraction (PUREX) Plant is located within the U.S. Department of Energy (DOE) Hanford Site, a 570-mi^2 area to which access is controlled for reasons of national security and health and safety considerations. The site is located in the State of Washington, as shown in Figure 3-1. The PUREX Plant is within a fenced area of the 2,000-acre 200 East Area, near the center of the Hanford Site. Figures 3-2 and 3-3 are maps of the Hanford Site and 200 East Area, respectively. The legal location description of the PUREX Plant is SE1/4 Sec. 2, T.12N., R.26E., Willamette Meridian.(1) The plant coordinates are: 46° 32' 58.231" latitude and 119° 31' 90.586" longitude. The Universal Transverse Mercator coordinates are: 5157968.558 mN and 306902.612 mE.

3.1.2 Site Description

The PUREX Plant is located on a terrace, locally referred to as the "200 Areas Plateau," near the center of the Hanford Site. The PUREX Plant is within the 200 East Area, which is bounded by a security fence to limit general access. The plant is further bounded by another security fence to exclude all but those personnel having duties and responsibilities associated with the operation of the plant and auxiliary facilities.

Traffic routes are shown in Figure 3-2. State Highway 240, for general public use, passes within 5 mi of the PUREX Plant. A fourstrand, barbed wire fence separates the highway right-of-way and the site.

All activities conducted within the Hanford Site are controlled by DOE through various contractors, or by lease arrangements. The PUREX Plant is operated by Rockwell Hanford Operations (Rockwell). The Hanford Site (controlled area) boundaries and the distances from the PUREX Plant to the Hanford Site boundary are shown in Figure 3-2. Activities near the 200 Areas are further controlled within a "200 Areas controlled zone."

From the 200 Areas Plateau, the ground surface slopes gently toward the Columbia River. The topography of the Hanford Site is shown on the contour map in Figure 3-4.

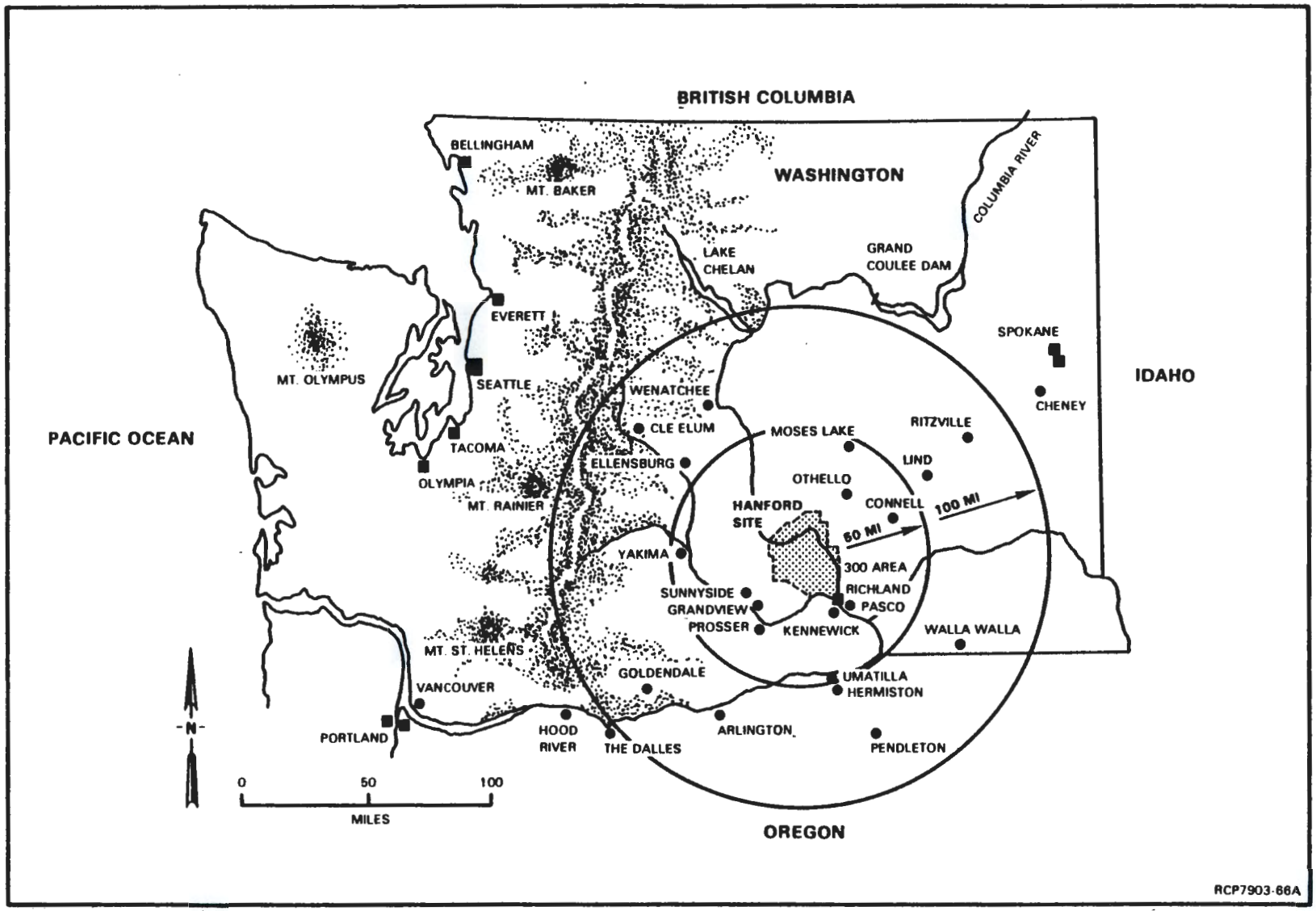

FIGURE 3-1. Location of Hanford Site in Washington State.

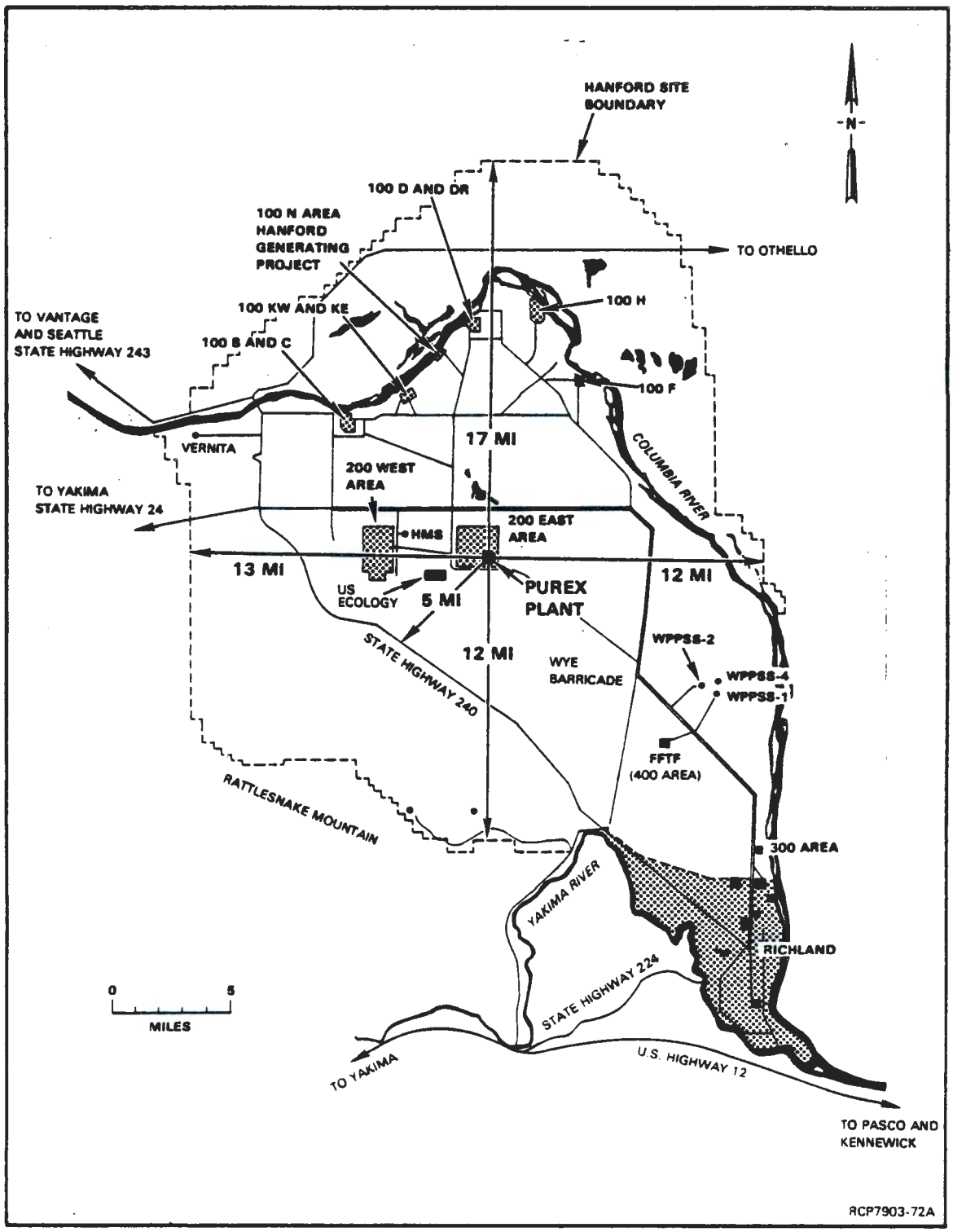

FIGURE 3-2. Hanford Site Map.

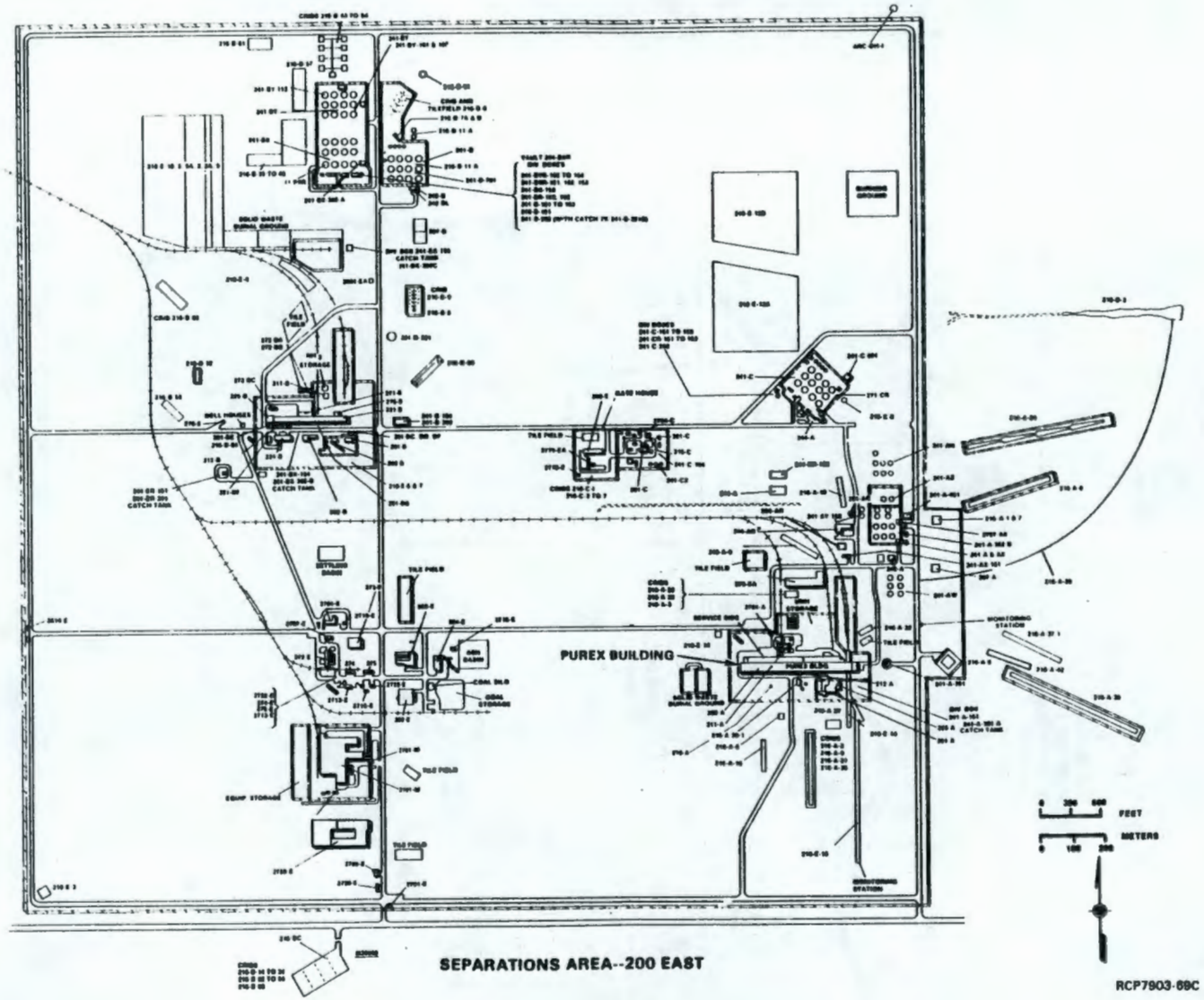

FIGURE 3-3. Detailed Map of the 200 East Area.

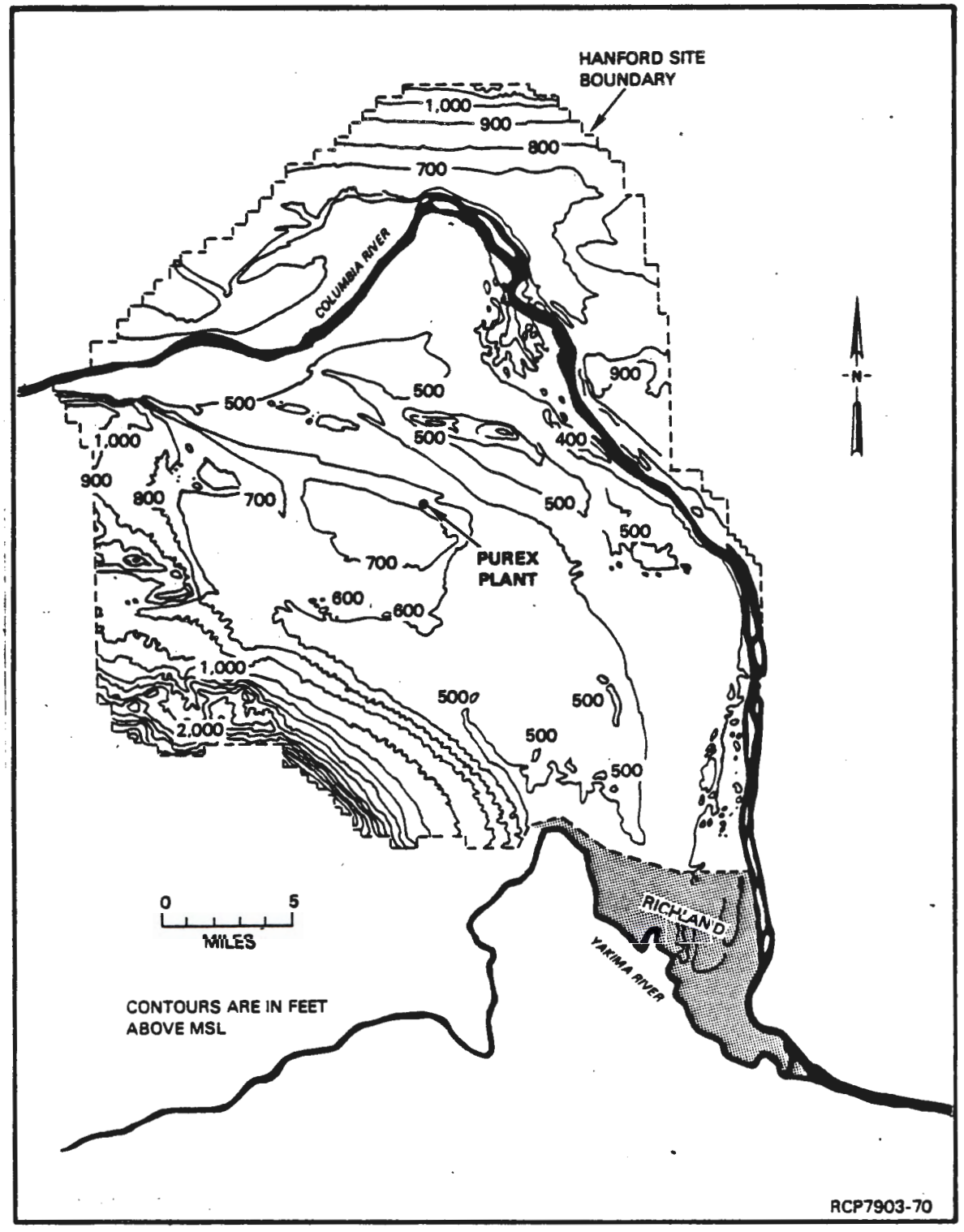

FIGURE 3-4. Hanford Site Topographic Map.

The vegetation mosaic of the Hanford Site consists of eight major kinds of shrub-steppe communities identified by the following conspicuous or most abundant plant species:[2]

- Sagebrush/bluebunch wheatgrass
- Sagebrush/cheatgrass or sagebrush/Sandberg's bluegrass
- Sagebrush-bitterbrush/cheatgrass
- Greasewood/cheatgrass-saltgrass
- Winterfat/Sandberg's bluegrass
- Thyme buckwheat/Sandberg's bluegrass
- Cheatgrass-tumble mustard
- Willow.

The most broadly distributed vegetation on the site is the sagebrush/cheatgrass or sagebrush/Sandberg's bluegrass association. This vegetation occurs as a broad zone surrounding the PUREX Plant and is between the sagebrush/bluebunch wheatgrass type and the sagebrush-bitterbrush/cheatgrass type. It differs from the sagebrush/bluebunch wheatgrass principally in that wheatgrass is absent. Another important difference is that sagebrush plants tend to be larger and provide more ground cover. Spiny hopsage and rabbitbrush may be intermingled with sagebrush shrubs. Fire can burn through this kind of vegetation, killing sagebrush, but hopsage and rabbitbrush survive burning, sending out new growth during the growing season following the fire. Recovery of this vegetation following fire is not as readily apparent as in the sagebrush/bluebunch wheatgrass bluegrass vegetation because large perennial grasses are scarce. The general paucity of herbaceous cover also tends to favor invasion by Russian thistle (tumbleweed), with or without fire. The sagebrush/cheatgrass and sagebrush/Sandberg's bluegrass communities provide very limited forage for livestock or wildlife.

The climate of Eastern Washington is arid to semiarid as a result of being in the rain shadow of the Cascade Range. Because of the arid environment and prevailing winds, the Hanford Site is blanketed by a thin veneer of wind-blown (eolian) sediments.[2] These sediments range in size from silts to fine to coarse sands. Most of the Hanford Site is underlain by generally coarse grained sediments deposited by catastrophic glacial floodwaters during the Pleistocene epoch.

Water erosion on the plateau around the PUREX Plant is minor because of the minimal precipitation, high soil porosity, and relatively flat topography.

Winds are a significant factor in the area because they can erode the land surface. Erodible soils,[2] mainly Rupert Sand and Burbank Loamy Sand, exist on the plateau. The shear stress of the wind at the earth's surface determines whether sufficient force exists to move sand grains. Where vegetation exists, the shear stress is reduced sharply and erosion is thereby limited. However, where vegetation is destroyed by fire, construction, plowing or other means, the sandy soils are easily transported by strong winds.[2]

3.1.3 Population Distribution and Trends

The 1970 population living within a 50-mi radius of the Hanford Meteorological Station (HMS) was 246,000.[2] The 1980 population was about 341,000.[3] (The HMS is used as the population reference point for the PUREX Plant because of the availability of data and its proximity: 4 mi west of the plant.) The 1979 populations of communities within a 50-mi radius centered on the HMS are shown in Figure 3-5. Population estimates were made through the year 1990[3] based upon 1980 census information, current birth rate trends, and estimates of net migration into or out of the state as economic and employment opportunities change over the forecast period. Figures were updated by allocating increased population on a proportional basis to sectors in the Tri-Cities area (Richland, Kennewick, and Pasco), where the most rapid growth has occurred. It is assumed that the Hanford Site will remain under the control of DOE and that no persons will reside within the site boundaries. The population residing in the unincorporated areas was calculated on the basis of uniform population density in the portion of a specific census district which lies within the area. This assumes an even distribution of population throughout the unincorporated areas of each census district. It is further assumed that the rate of population growth will be the same for both incorporated and unincorporated areas on a county-by-county projection.[3] The distribution of population within a 50-mi radius of the HMS for the year 1980 is shown in Figure 3-6 while the projection for year 1990 is shown in Figure 3-7.

3.1.4 Uses of Nearby Land and Waters

The nature and extent of present land use[2] are presented here on the basis of arcs from the HMS. The Hanford Site vicinity map with sectors overlaid is shown in Figure 3-8. Starting from a line directly north of the HMS, the 0- to 10-mi zone between the 0° and 150° radials is a limited access area under DOE control. Land north of the river is controlled by the U.S. Bureau of Sports Fisheries and Wildlife as the Saddle Mountain National Wildlife Refuge, and the Washington State Department of Game as the Wahluke Wildlife Recreation Area. Most of the zone between the 150° and 270° radials consists of the Arid Lands Ecology Reserve, which is also limited-access DOE land under the control of Pacific Northwest Laboratory. Between the 270° radial and the starting radial, land south of the Columbia River is DOE controlled limited access, while north of the river the Saddle Mountain National Wildlife Refuge is again encountered.

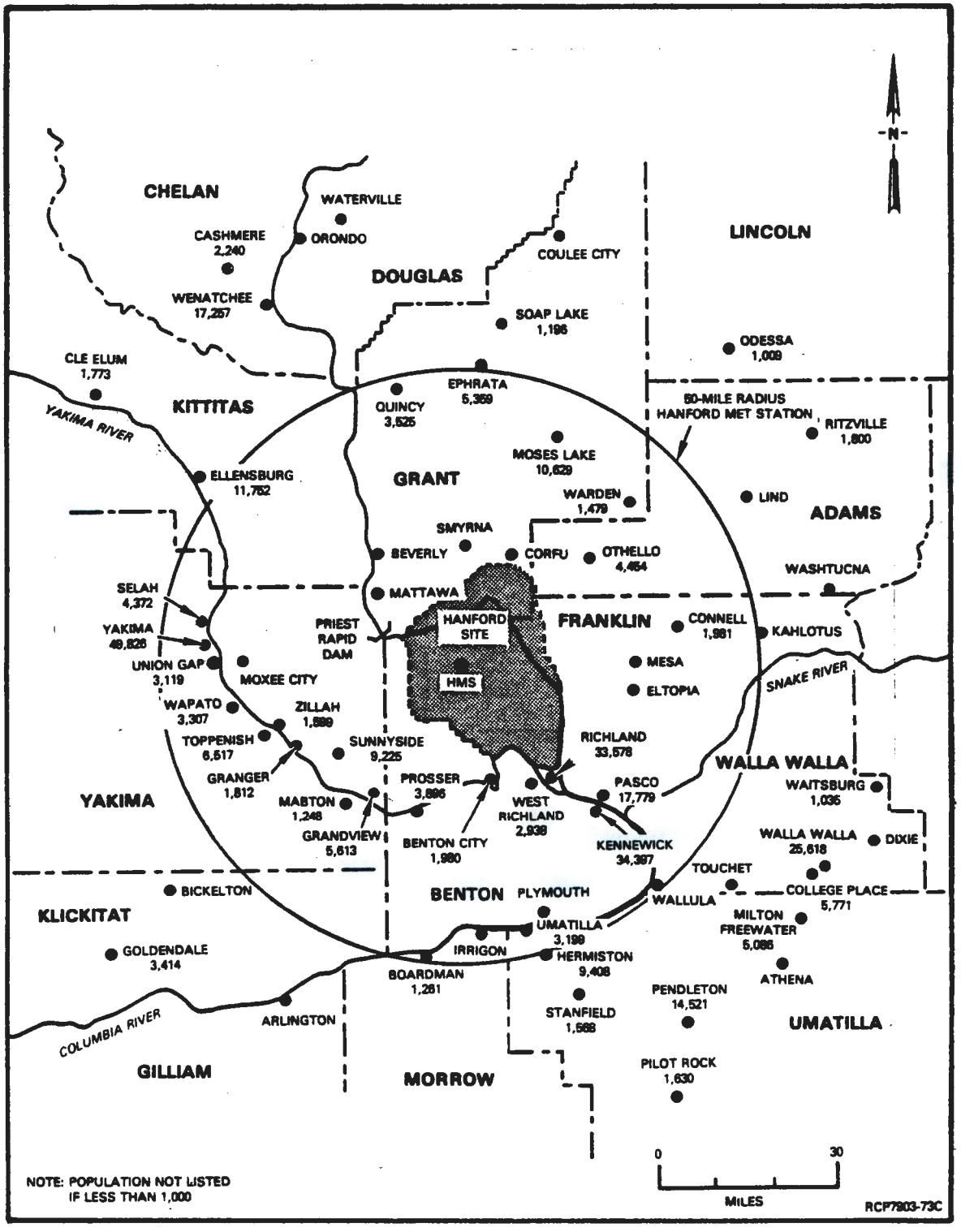

FIGURE 3-5. Population of Communities in the Hanford Site Area, August 1979.

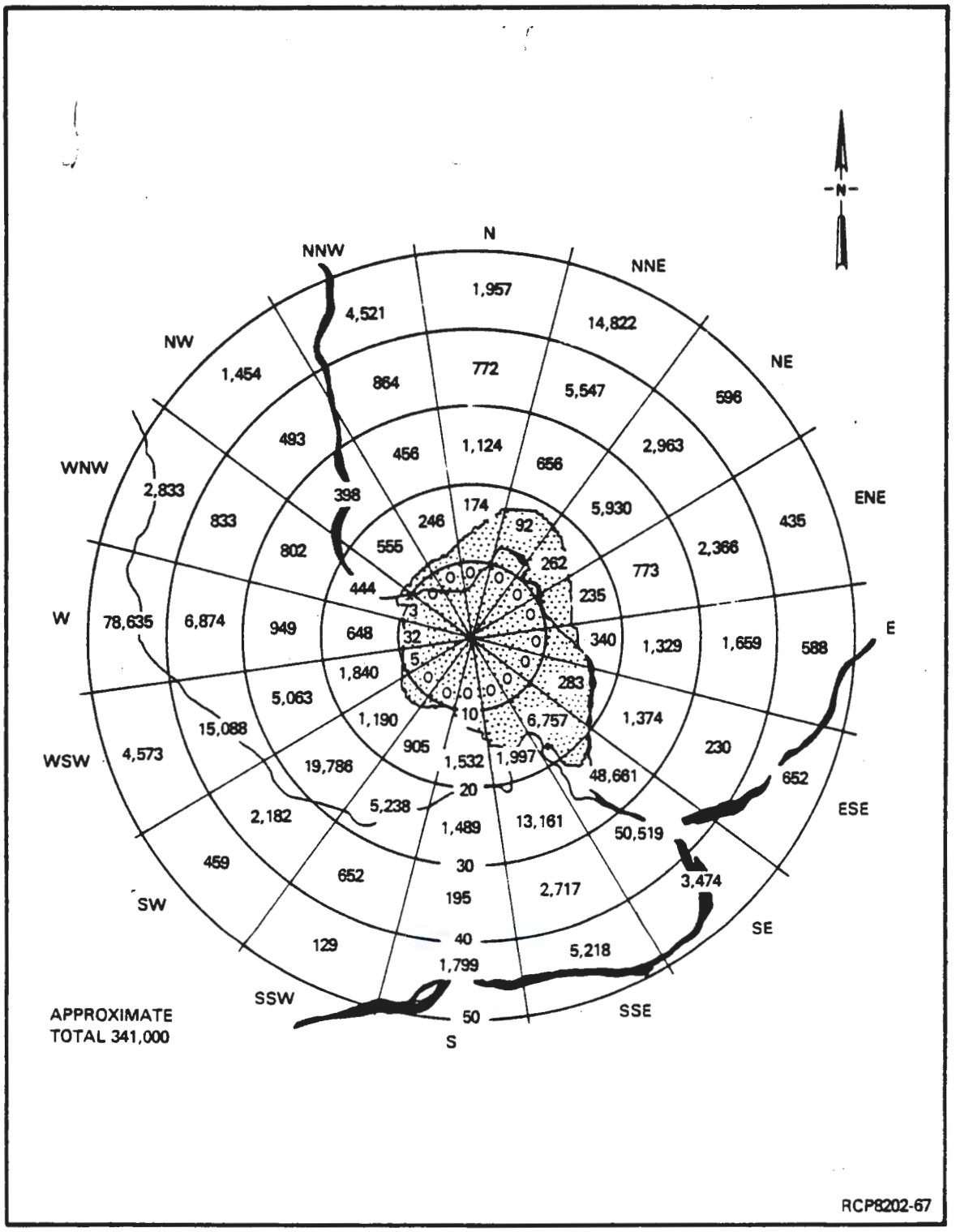

FIGURE 3-6. Estimated Geographic Distribution of the 1980 Population within a 50-mi Radius of the Hanford Meteorological Station.

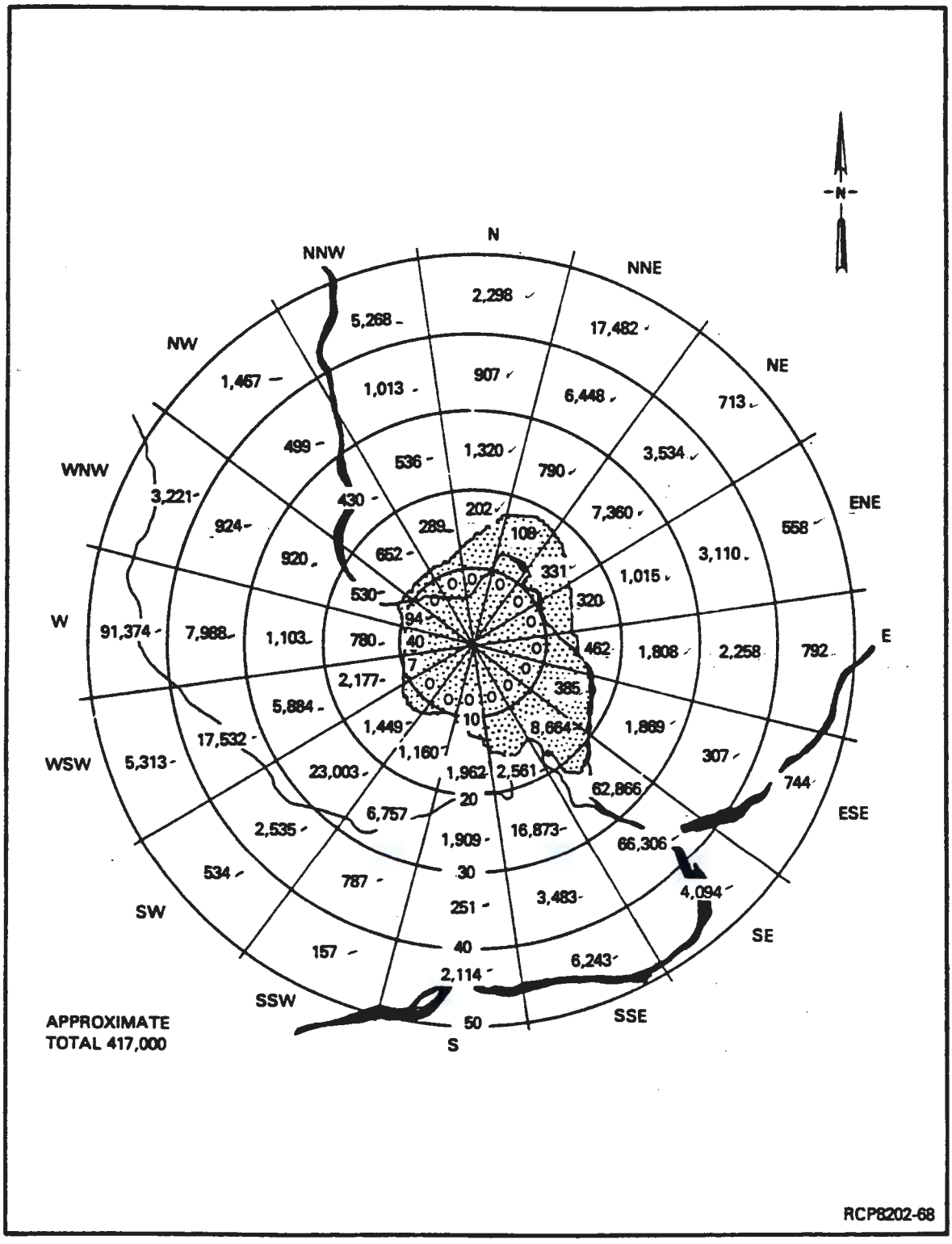

FIGURE 3-7. Estimated Geographic Distribution of the Year 1990 Population within a 50-mi Radius of the Hanford Meteorological Station.

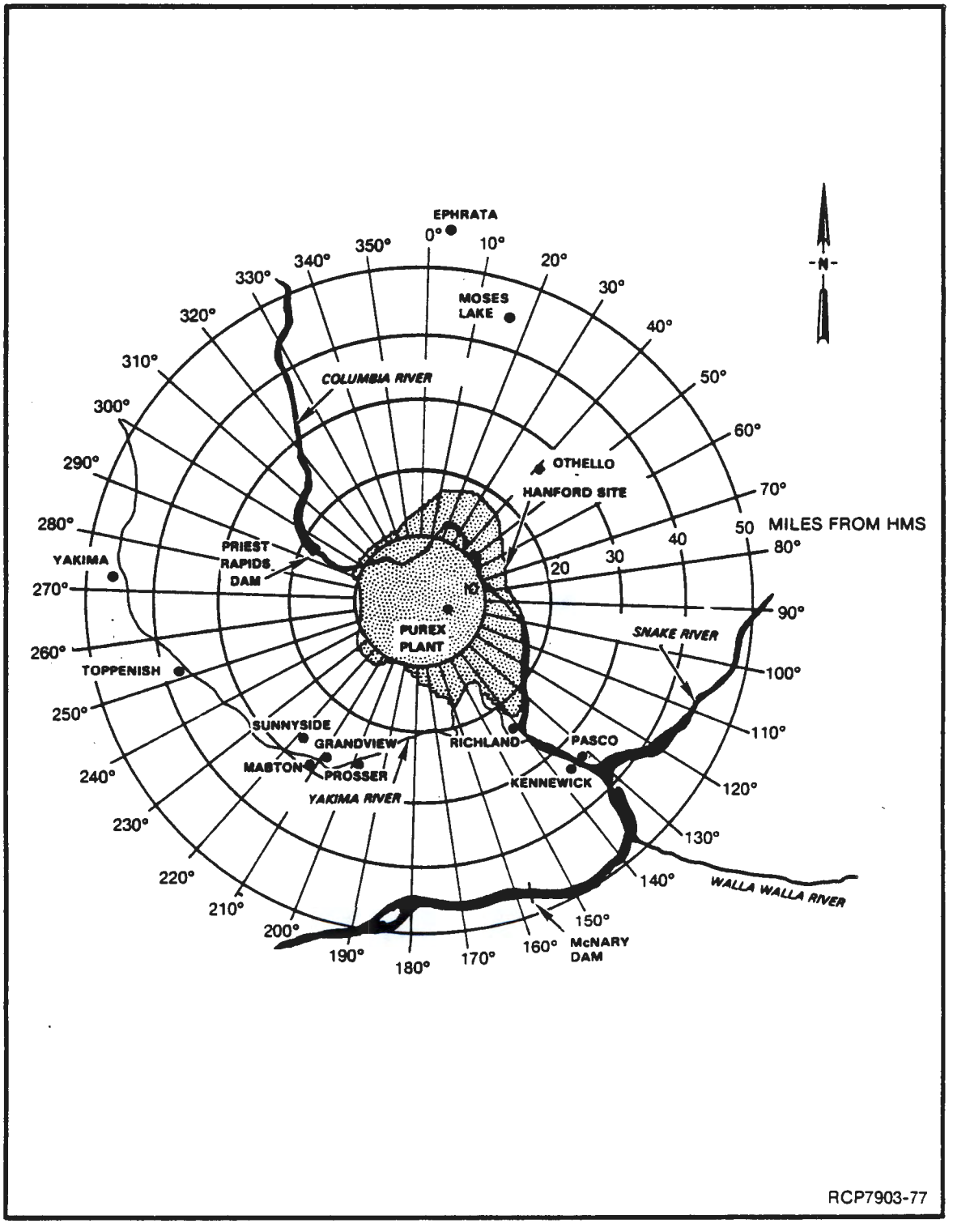

FIGURE 3-8. Hanford Site Vicinity Map.

Again starting from the 0° radial, the 10- to 20-mi zone is a continuation of the Saddle Mountain National Wildlife Refuge. Farther north, this zone includes the easternmost portion of the Wahluke Slope and the Saddle Mountains. Between the Wahluke Branch Canal and the Columbia River, the zone consists of lands in the Columbia Basin Project that are irrigated or being developed for irrigation. The area west of the river is a limited access area (Hanford Site). There are no private industrial facilities located within the 10- to 20-mi radius of the PUREX Plant site. From the 140° to the 360° radial and within the 10- to 20-mi radius, the area outside the Hanford Site is available for residential living or farming, which is not now substantial. This area is mainly unirrigated and used for grazing cattle and sheep. South and west of the Columbia River, in the vicinity of Priest Rapids Dam, are 411 mi^2 of undeveloped and unpopulated land used for the U.S. Army Yakima Firing Range. Northeast of Priest Rapids Dam and Reservoir is the Wahluke Slope portion of the Columbia Basin Project. This area is partially irrigated, with the rest (outside the Hanford Site) expected to be irrigated in the next 10 yr.

The 20- to 30-mi zone on the 0° radial is north of the Saddle Mountains and is irrigated farmland, part of the Columbia Basin Project. The area from lower Crab Creek to northwest of Othello is generally undeveloped. From Othello south to the Columbia River, the land is irrigated farmland. On the west side of the river is the City of Richland. West from Richland, the 20- to 30-mi zone includes the Yakima River and the towns of Prosser, Sunnyside, Grandview, and Mabton. Land along the Yakima River is primarily in orchard use. Higher land away from the valley floor is used primarily for grazing livestock, with some land used for grain crops. At about the 270° radial, the U.S. Army Yakima Firing Range is again encountered. At 320° is the Ginkgo Petrified Forest, a state park and national landmark.

At the 0° radial, the 30- to 40-mi zone consists of an undeveloped area of sagebrush and sand dunes. At 20°, the Potholes Reservoir, a recreation area surrounded by sand dunes, is located south of Moses Lake. Between 30° and 50°, this zone encompasses a major portion of the U.S. Water and Power Resources Service Columbia Basin Irrigation Project. At about the 130° radial, the Columbia River is encountered, with the City of Pasco on the north side and the City of Kennewick on the south side. South and west of Kennewick, the 30- to 40-mi zones run south of the Horse Heaven Hills. Although this land is primarily used for dryland wheat farming, there are about 88 sections (56,320 acres) where permits have been granted for private irrigation development. Crossing the Horse Heaven Hills, the 220° zone includes part of the Yakima Valley, containing the towns of Granger, Toppenish, Zillah, and Wapato. This land is largely in orchards and truck crops, with livestock grazing at the higher elevations. Northeast of Yakima is the U.S. Army Yakima Firing Range, east of which lies irrigated farmland of the Columbia Basin Project.

At the 0° radial in the 40- to 50-mi radius, the land is primarily rangeland with some irrigated farmland. The town of Moses Lake is in this zone at about the 20° radial. Between the 20° and 90° radials is a large portion of land planned for irrigation development as part of the Columbia Basin Project. At about 70° between the 40- and 50-mi radius, the land is used for dryland wheat production. Between the 90° and 120° radials and extending to the 50-mi radius, the land is used for dryland wheat production. An exception is the area at the confluence of the Snake and Columbia Rivers, where private irrigation projects are under way. Land on both sides of the Columbia River below McNary Dam supports private irrigation projects totalling about 345 sections (220,800 acres). Between the 200° and 260° radials, the terrain is very rugged and, for the most part, undeveloped. At the 260° radial, the Yakima Valley commences with the city of Yakima at 270°. North of the Umtanum Ridge and Manastash Ridge is the Kittitas Valley. This is an area of both irrigated and dryland farming and cattle production. At 330°, a portion of the Wenatchee National Forest is encountered.

An estimated 200,000 acre-ft of water may be taken annually for irrigation from the Columbia River in the Hanford vicinity.(2) This estimate is based on the best data available from the State of Washington Department of Ecology. These are "paper water rights" (legal permits to limit usage) and are estimated to be twice the actual pumpage, even though not all withdrawals of water are listed. Water rights received after 1969 are not reflected, and not everyone who withdraws water has applied to the state for water rights. However, the data given are an adequate upper limit for current water usage to 40 mi downstream from the PUREX Plant.(2)

For the next 65 mi of downstream flow, the Columbia River forms the border between Washington and Oregon. Private irrigation development is extensive on both sides of the river. Land that is now irrigated or is to be irrigated in the next 5 to 10 yr totals about 227,000 acres.

Within the Hanford Site are numerous facilities concerned with nuclear energy. Descriptions of the various facilities and activities are contained in Reference 2. Figure 3-9 is a diagrammatic representation of those activities directly related to the PUREX Plant.

3.2 NEARBY INDUSTRIAL, TRANSPORTATION, AND MILITARY FACILITIES

The PUREX Plant is located near the center of the Hanford Site and there are no nearby industrial or military facilities. A commercial facility, U.S. Ecology, is located on land leased from the State of Washington. The site is within 5 mi of the PUREX Facility and handles low-level radioactive wastes. The nearest military facility is the U.S. Army Yakima Firing Range, located just northwest of the Hanford Site western boundary. All facilities on the site are controlled or licensed by DOE or the U.S. Nuclear Regulatory Commission (NRC) (see Fig. 3-2, a map of the site showing the location of all major facilities).

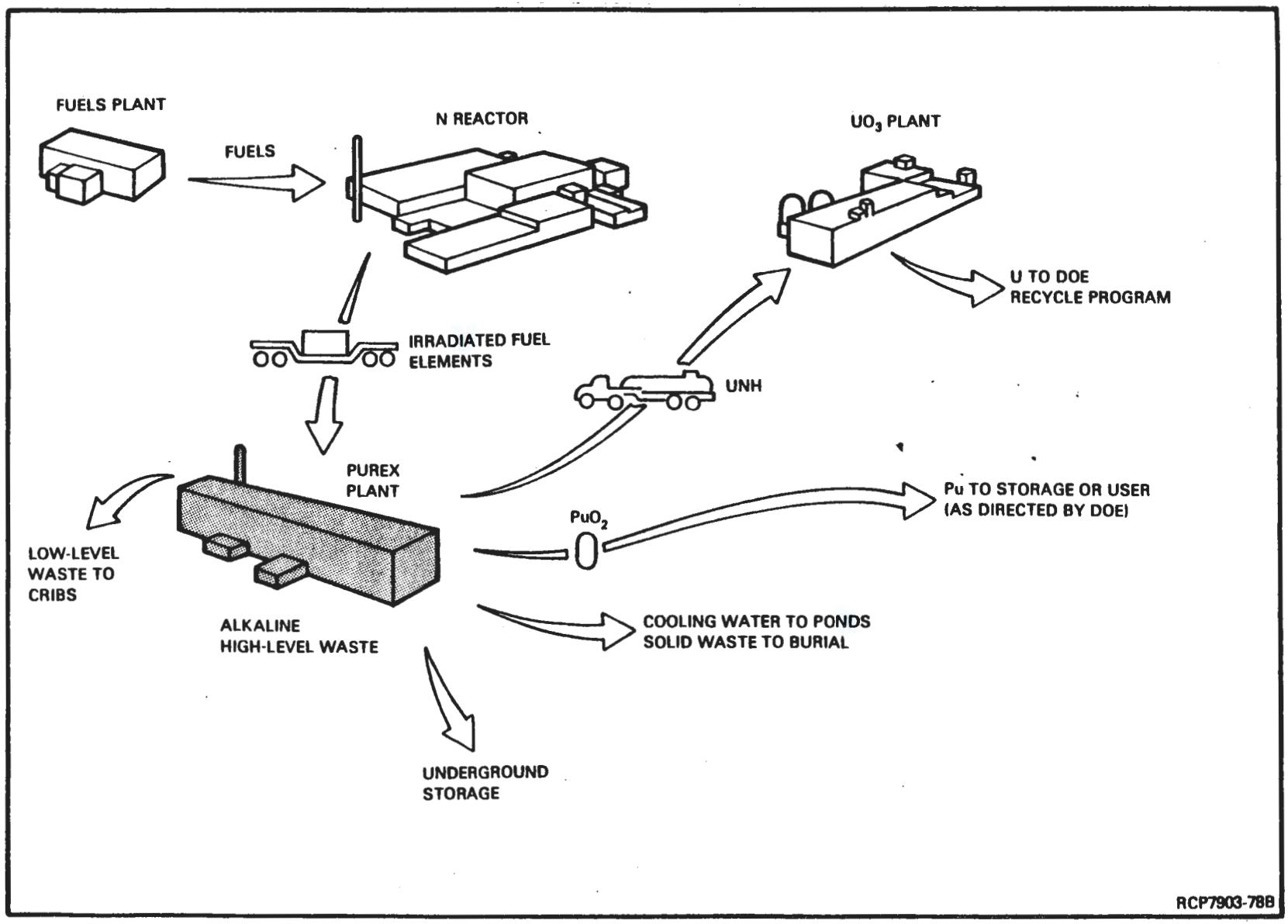

FIGURE 3-9. Hanford Activities Related to the PUREX Plant.

Roads near PUREX include State Highways 24 and 240 (Fig. 3-2). These highways and the site roads are used by many types of vehicles including commercial trucks for deliveries of gas, diesel fuel, chemicals, and reagents. However, the separation of the roads from the PUREX Plant is such that no adverse effects from highway accidents are projected for PUREX operations.

There are no private or commercial airports within a distance of 20 mi from PUREX. The Richland Airport, nearest to the site, is a small, general utility airport. The Tri-Cities Airport at Pasco, used by local carriers, is 28 mi from the site. Due to the low volume of air traffic and distance of airports from the site, the probability of aircraft affecting the plant is remote.

There are no refineries, major oil storage facilities, munition or explosive storage facilities within 20 mi of the site. The nearest natural gas transmission pipeline is approximately 30 mi away. The considerable distance of these facilities eliminates these potential hazards to PUREX from fires and explosions.

A tabulation of the active nuclear areas on the Hanford Site is presented in Table 3-1. The possible accidents at these facilities and the effects of such accidents on the safe operation of the PUREX Plant were reviewed. The safety analyses for the Washington Public Power Supply System (WPPSS) Plants, the Fast Flux Test Facility (FFTF), and N Reactor indicate that the radioactive releases as a result of the postulated maximum credible accident for each facility will not present an unacceptable risk to PUREX operations. The distance of these facilities from PUREX and the engineered safeguards built into each plant provide adequate assurance that no significant hazard to the PUREX Plant or personnel could result from nuclear areas outside the 200 Areas.

The Z Plant, located in the 200 West Area, is about 5 mi from the PUREX Plant. This is sufficiently close to PUREX to have an impact on PUREX operations should a major release of plutonium occur. An analysis of Z Plant plutonium handling operations has been made with the conclusion that undue risk does not exist.(4)

A review of potential hazards in the immediate vicinity of the PUREX Plant was conducted. The only potential hazard noted was a 12,200-gal ammonia storage tank located at B Plant (about 1.5 mi from PUREX). Under certain meteorological conditions, a gross leakage from this tank could result in a possible evacuation of PUREX personnel. No damage to PUREX equipment is foreseen.

Toxic gas (chlorine) is stored in 1-ton cylinders at the water treatment plant located about 0.5 mi away. A gross leakage could result in a possible evacuation of PUREX personnel.

TABLE 3-1. Active Hanford Nuclear Areas.

Area	Facilities	Distance from PUREX (mi)
100	100 N Reactor, irradiated and nonirradiated fuel storage, laboratory, test loop, Hanford Generating Project	9
200 East	PUREX, B Plant, critical mass laboratory, laboratories, waste retention and treatment	0.5 to 1.5
200 West	Plutonium processing, storage, and reclamation, waste storage and disposal, laboratories	5
300	Fuel and fissile material storage, metal fabrication development, plutonium laboratory, fuels manufacture, radiochemistry, radiometallurgy, waste vitrification, subcritical facility	17
400	FFTF	11
600	U.S. Ecology	3
WPPSS	WPPSS-1, -2, -4 Reactors (under construction)	11
-	Exxon Nuclear Company, Inc., (fuels plant)	17

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3.3 METEOROLOGY

3.3.1 Regional Climatology

The Cascade Range to the west greatly affects the climate of the Hanford area. Storm tracks generally move from the Pacific Ocean across the Cascade Range and then across the Hanford Site. The orographic effect of this range helps create the moderate winters, hot summers, and the relative dryness of the Hanford area.[2]

Average annual precipitation is 6.25 in.; 41% of the annual precipitation occurs during November, December, and January, whereas only 11% occurs in July, August, and September. The driest month is July with 0.18 in. and the wettest month is January with 0.98 in.

A maximum annual rainfall of 15 in. has only 0.2% chance of occurring (see Fig. 3-10). Precipitation in excess of 0.5 in. during a 24-h period occurs on an average of twice a year. Rainfall of 1 in. has occurred only 3 d in the last 30 yr of recorded data (1946 through 1975). One of these was the record storm of October 1 through 2, 1957. During this storm, a total rainfall of 1.91 in. was recorded in 24 h. Of this total, 1.08 in. were recorded in 3 h, 1.68 in. in 6 h, and 1.88 in. in 12 h. At the other extreme, there have been 81 consecutive days without measurable precipitation (June 22 to September 10, 1967) and 172 d with only 0.32 in. (February 24 to August 13, 1968).

About 39% of all precipitation from December through February is in the form of snow. However, an accumulation of as much as 6 in. on the ground can be expected only one winter in eight. The average seasonal number of such days of reported precipitation in the form of snow is 4, although the 1964-65 winter had 35, 32 of which were consecutive.

The Cascade Range serves as a source of cool air, especially during the summer months, and has a considerable effect on the Hanford Site wind regime. The drainage (gravity) wind, plus topographic channeling, causes a considerable diurnal range of speeds during the summer. In July, average speeds range from a low of 5.2 mi/h, from 0900 to 1000 h, to a high of 13.0 mi/h from 2100 to 2200 h. In contrast, the corresponding speeds for January are 5.5 and 6.3 mi/h (see Fig. 3-11 and Table 3-2).

While gravity winds occur with regularity in the summer, these are seldom strong unless reinforced by frontal activity. In June, the month of highest average speed, there are fewer instances of hourly averages exceeding 31 mi/h than in December, the month of lowest average speed. It is also notable that, although channeling results in a prevailing west-northwest or northwest wind the year around, the greatest wind speeds are from the southwesterly direction (see Fig. 3-12 and Table 3-3).

Light winds at Hanford in winter cause considerable atmospheric stagnation. December, for example, has an average of 10 d with a peak gust under 13 mi/h. By contrast, only once in 7 yr does June have even one such day.

The average maximum temperatures in January and July are 37°F and 92°F, respectively. The average minimum temperatures for the same months are 22°F and 61°F, respectively. The average monthly relative humidity varies from a low of 31.8% in July to a high of 80.4% in December. The minimum diurnal temperature in winter seasons ranges from -27°F to 22°F; the maximum diurnal temperatures in summer seasons vary from 100°F to 115°F.(2)

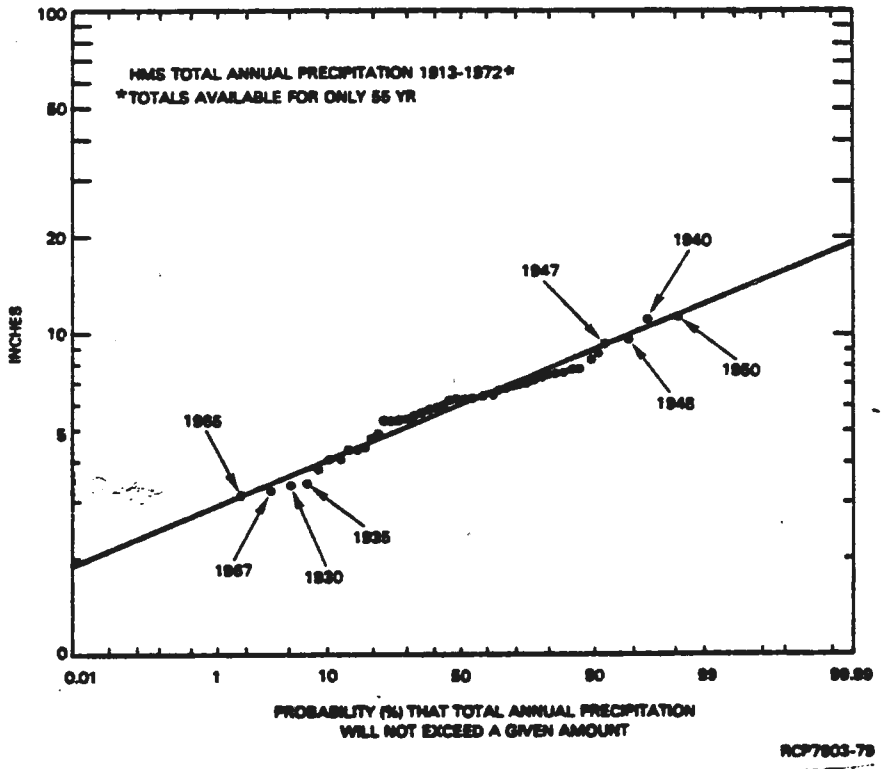

FIGURE 3-10. Hanford Meteorological Station Total Annual Precipitation, 1913 to 1972.

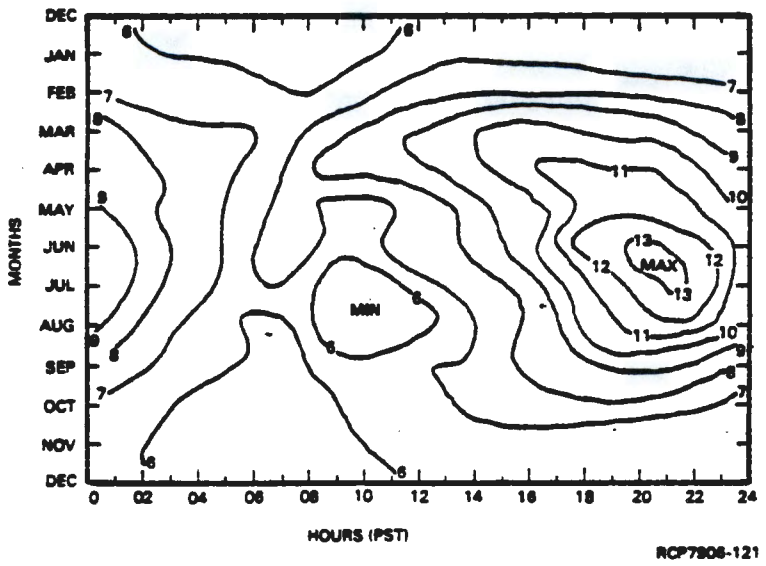

FIGURE 3-11. Seasonal and Diurnal Variation at 50-ft Level Wind Speed, 1955 to 1970.

TABLE 3-2. Percentage Frequency Distribution of 50-ft Wind Distribution Versus Speed. (Sheet 1 of 7)

Direction	Speed class (mi/hr) 0 to 3	4 to 7	8 to 12	13 to 18	19 to 24	25 to 31	32 to 38	39 to 46	>46	Total	Average speed
January											
N	2.8	1.2	0.2	0.3	0.2					4.7	4.3
NNE	2.0	0.8	0.4	0.1	0.1	*				3.4	4.6
NE	1.8	0.7	0.2	0.1	0.1	*				2.9	4.4
ENE	1.3	0.5	0.1	*	*					1.9	3.0
E	1.8	0.6	0.1	*						2.4	3.0
ESE	1.8	0.7	0.2	0.1	*					2.8	3.4
SE	2.7	1.5	0.4	0.2	*	*				4.8	4.0
SSE	1.6	0.8	0.3	0.1	0.1					2.9	5.4
S	1.4	0.9	0.4	0.5	0.2	0.1	0.1	*		3.6	7.7
SSW	1.2	1.0	0.6	1.0	0.6	0.3	0.1	*		4.8	11.5
SW	1.4	1.4	1.4	1.6	0.7	0.3	*			6.8	10.7
WSW	1.4	1.5	1.7	0.8	0.4	0.2	*			6.0	8.9
W	1.8	2.3	1.3	10.6	0.1					6.1	6.3
WNW	2.4	5.6	5.1	0.9	*	*				14.0	7.1
NW	3.6	7.8	6.6	1.2	0.1	*				19.3	6.9
NNW	3.0	2.8	0.6	0.1	*					6.5	4.2
VAR	1.3	0.1								1.4	1.8
CALM	5.4									5.4	
TOTAL	38.7	30.1	19.6	7.6	2.6	0.9	0.2	*		100.0	6.2
February											
N	2.6	1.6	0.4	0.2	*	*				4.8	4.5
NNE	1.8	1.3	0.8	0.4	0.1	0.1				4.5	6.3
NE	2.2	0.9	0.2	0.2	*					3.5	3.8
ENE	1.3	0.6	0.1							1.9	3.3
E	1.3	0.7	*							2.0	3.0
ESE	1.3	0.7	0.1							2.1	3.3
SE	1.9	1.1	0.3	0.1						3.4	4.0
SSE	1.2	0.8	0.4	0.2	*					2.6	5.2
S	1.3	0.7	0.4	0.3	0.1	0.1				2.9	6.6
SSW	1.0	1.0	0.8	0.6	0.5	0.2	0.1	*		4.2	10.5
SW	1.0	1.6	1.3	1.8	1.1	0.5	0.1	*		7.4	12.6
WSW	0.9	2.1	2.1	1.4	0.5	0.3	0.1	*		7.4	10.5
W	1.6	3.4	2.9	1.1	0.2	0.1				9.3	7.8
WNW	1.9	4.9	6.8	1.5	0.3	0.1				15.5	8.3
NW	3.3	6.9	6.4	1.5	0.2	0.1				18.4	7.3
NNW	2.3	2.5	0.8	0.1	*					5.7	4.8
VAR	1.3	0.2	*							1.5	1.8
CALM	2.4									2.4	
TOTAL	30.6	31.0	23.8	9.4	3.0	1.5	0.3			100.0	7.1

TABLE 3-2. Percentage Frequency Distribution of 50-ft Wind Distribution Versus Speed. (Sheet 2 of 7)

Direction	Speed class (mi/hr) 0 to 3	4 to 7	8 to 12	13 to 18	19 to 24	25 to 31	32 to 38	39 to 46	>46	Total	Average speed
March											
N	1.9	1.8	1.0	0.2	*					4.9	5.4
NNE	1.4	1.6	0.9	0.6	*	*				4.5	6.8
NE	1.7	1.2	0.3	0.2	0.1	*				3.5	4.8
ENE	0.7	0.8	0.1	*	*	*				1.6	5.0
E	0.9	0.8	0.2	*	*					1.9	4.2
ESE	1.0	1.1	0.2	0.1						2.4	4.4
SE	1.4	1.7	0.5	0.1	*					3.7	5.0
SSE	0.6	1.1	0.8	0.3	*					2.8	7.1
S	1.0	1.4	0.7	0.4	0.2	*				3.7	7.4
SSW	0.6	1.3	1.1	1.2	0.7	0.3	0.1			5.3	12.1
SW	0.8	2.0	2.0	2.5	1.5	0.8	0.2	*	*	9.8	13.5
WSW	0.8	2.5	3.0	2.5	1.0	0.4	0.2			10.4	11.7
W	1.1	3.9	3.1	1.2	0.2	0.1				9.6	8.2
WNW	1.1	4.4	5.8	2.2	0.8	0.1				14.4	9.5
NW	1.5	4.4	5.3	1.8	0.6	0.1				13.7	8.9
NNW	1.4	2.4	1.1	0.2	*					5.1	5.6
VAR	1.3	0.2	*							1.5	2.1
CALM	0.7									0.7	
TOTAL	19.9	32.6	26.1	13.5	5.1	1.8	0.5			100.0	8.6
April											
N	1.6	1.6	0.7	0.3	*					4.2	5.5
NNE	1.0	1.3	0.6	0.3	0.1	*				3.3	6.8
NE	1.4	1.2	0.4	0.2	*	*				3.2	5.3
ENE	0.6	1.0	0.2	0.1						1.9	5.2
E	0.8	1.0	0.5	*						2.3	5.0
ESE	0.8	1.0	0.2	*						2.0	4.5
SE	1.0	1.5	0.5	0.1						3.1	5.2
SSE	0.5	1.0	0.8	0.2						2.5	6.8
S	0.7	1.4	0.7	0.3	0.1	*				3.2	6.7
SSW	0.7	1.5	1.1	0.9	0.4	0.1				4.7	9.6
SW	0.7	2.3	2.1	2.1	1.6	0.6	0.1			9.5	12.7
WSW	0.8	2.6	3.8	2.5	1.1	0.4	0.1			11.3	11.4
W	1.1	4.2	4.3	1.7	0.5	0.1	*			11.9	8.8
WNW	0.8	3.9	6.0	4.2	1.3	0.3				16.5	11.0
NW	1.2	3.7	4.2	3.2	1.5	0.4	*			14.2	11.0
NNW	0.9	1.9	0.6	0.2	*					3.6	5.8
VAR	1.6	0.5								2.1	2.7
CALM	0.5									0.5	
TOTAL	16.7	31.6	26.7	16.3	6.6	1.9	0.2			100.0	9.1

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TABLE 3-2. Percentage Frequency Distribution of 50-ft Wind Distribution Versus Speed. (Sheet 3 of 7).

Direction	Speed class (mi/hr) 0 to 3	4 to 7	8 to 12	13 to 18	19 to 24	25 to 31	32 to 38	39 to 46	>46	Total	Average speed
May											
N	1.2	1.7	0.9	0.1						3.9	5.7
NNE	0.6	1.4	0.7	0.3	*					3.0	6.7
NE	1.0	1.5	1.0	0.1	0.1					3.7	6.4
ENE	0.8	1.1	0.3	0.1						2.3	5.0
E	0.9	1.2	0.3	*						2.4	4.7
ESE	0.9	1.0	0.3	*						2.2	4.6
SE	1.0	1.5	0.6	0.1						3.2	5.4
SSE	0.6	1.3	0.6	0.2	*					2.7	6.4
S	0.6	1.7	0.5	0.1	*					2.9	5.6
SSW	0.7	1.3	0.8	0.4	0.1	*				3.3	7.4
SW	0.6	2.4	1.7	1.1	0.5	0.1	*			6.4	9.6
WSW	0.9	2.7	3.5	1.8	0.7	0.2	*			9.8	10.1
W	1.2	4.0	4.4	1.6	0.2	*				11.4	8.3
WNW	0.8	3.9	6.7	4.7	1.7	0.2	*			18.0	11.2
NW	1.2	3.6	4.9	4.4	2.6	0.5	*			17.2	12.0
NNW	1.0	1.8	0.7	0.1						3.6	5.5
VAR	1.9	1.3	*							3.2	3.2
CALM	0.6									0.6	
TOTAL	16.5	33.4	27.9	15.1	5.9	1.0	*			100.0	8.7
June											
N	0.9	2.0	0.9	0.2						4.0	6.0
NNE	0.6	1.8	0.8	0.4	*					3.6	7.1
NE	0.8	1.4	0.8	0.5	0.1	*				3.6	7.5
ENE	0.4	1.0	0.4	0.1	*	*				1.9	6.5
E	0.5	1.3	0.3	*	*					2.1	5.6
ESE	0.6	1.3	0.3	*						2.2	5.0
SE	0.7	1.6	0.4	*						2.7	5.2
SSE	0.5	1.1	0.4	0.1	*					2.1	5.8
S	0.6	1.7	0.3	0.1						2.7	5.5
SSW	0.4	1.5	0.7	0.2	0.1	*				2.9	7.3
SW	0.7	2.5	2.0	1.0	0.3	*				6.5	8.8
WSW	0.6	2.5	3.5	1.5	0.4	0.1	*			8.6	9.7
W	0.7	4.1	4.4	1.6	0.3	*				11.1	8.8
WNW	0.6	3.5	6.9	6.2	2.1	0.4	*			19.7	12.1
NW	0.7	3.7	5.1	5.4	3.4	0.7	*			19.0	13.0
NNW	0.6	2.0	0.8	0.1	*	*				3.5	6.3
VAR	1.6	1.7	*							3.3	3.4
CALM	0.3									0.3	
TOTAL	11.8	34.7	28.0	17.4	6.7	1.2				100.0	9.3

TABLE 3-2. Percentage Frequency Distribution of 50-ft Wind Distribution Versus Speed. (Sheet 4 of 7)

Direction	Speed class (mi/hr) 0 to 3	4 to 7	8 to 12	13 to 18	19 to 24	25 to 31	32 to 38	39 to 46	>46	Total	Average speed
July											
N	1.1	2.6	0.6	0.1						4.4	5.3
NNE	0.7	2.1	0.8	0.2	*					3.8	6.0
NE	0.9	2.1	0.5	0.2	*					3.7	5.7
ENE	0.5	1.2	0.2	*						1.9	5.0
E	0.7	1.5	0.3							2.5	4.9
ESE	0.7	1.3	0.3	*						2.3	4.9
SE	0.9	1.7	0.3	*						2.9	4.9
SSE	0.4	1.0	0.4	*		*				1.8	5.6
S	0.7	1.5	0.2	0.1	*	*				2.5	5.3
SSW	0.5	1.3	0.5	0.2	*	*				2.5	6.5
SW	0.8	2.3	1.7	1.0	0.4	0.1	*			6.3	9.1
WSW	0.7	3.0	2.8	1.4	0.4	0.2	*			8.5	9.5
W	1.0	4.4	3.5	0.9	0.1	*				9.9	7.7
WNW	0.7	4.2	7.7	4.8	1.8	0.2				19.4	11.2
NW	0.9	3.8	5.6	5.1	3.0	0.5				18.9	12.4
NNW	0.8	2.0	0.7	0.1	*					3.6	5.8
VAR	2.6	1.8	*							4.4	3.3
CALM	0.4									0.4	
TOTAL	15.0	37.8	26.1	14.1	5.7	1.0				100.0	8.6
August											
N	1.3	2.5	0.4	0.1						4.3	5.0
NNE	1.0	1.8	0.5	0.1						3.4	5.1
NE	1.3	1.6	0.3	0.1	*					3.3	4.4
ENE	0.7	1.1	0.1	*						1.9	4.3
E	0.9	1.3	0.2	*						2.4	4.5
ESE	0.8	1.6	0.3							2.7	4.7
SE	1.1	1.8	0.5	*						3.4	4.8
SSE	0.7	1.1	0.6	*	*					2.4	5.5
S	0.8	1.4	0.3	*						2.5	4.8
SSW	0.6	1.6	0.7	0.2	0.1					3.2	6.6
SW	1.0	2.7	1.6	0.8	0.2	0.1	*			6.4	8.1
WSW	0.9	3.2	2.9	1.4	0.1	0.1				8.6	8.5
W	1.3	5.1	4.1	0.7	*					11.2	7.5
WNW	0.9	4.1	7.6	4.1	1.3	0.2				18.2	10.6
NW	1.2	3.8	5.1	4.5	2.3	0.5				17.4	11.8
NNW	1.0	2.3	0.5	0.1	*					3.9	5.4
VAR	2.8	1.3								4.1	3.0
CALM	0.6									0.6	
TOTAL	18.9	38.3	25.7	12.1	4.0	0.9	*			100.0	7.9

TABLE 3-2. Percentage Frequency Distribution of 50-ft Wind Distribution Versus Speed. (Sheet 5 of 7)

Direction	Speed class (mi/hr) 0 to 3	4 to 7	8 to 12	13 to 18	19 to 24	25 to 31	32 to 38	39 to 46	>46	Total	Average speed
September											
N	1.9	2.4	0.9	0.3	*	*				5.5	5.3
NNE	1.5	1.8	1.0	0.4	0.1	*				4.8	6.4
NE	1.8	1.8	0.6	0.3	0.1	*				4.6	5.6
ENE	1.3	0.9	0.1	0.1						2.4	3.9
E	1.6	1.1	0.2	*						2.9	3.7
ESE	1.2	1.5	0.2							2.9	4.1
SE	1.4	2.1	0.4	*						3.9	4.6
SSE	0.9	1.3	0.5	0.1						2.8	5.3
S	0.9	1.3	0.3	0.1	*					2.6	5.2
SSW	0.8	1.6	0.5	0.2	0.1	0.1				3.3	7.0
SW	0.8	2.1	1.3	1.0	0.5	0.3	*			6.0	9.9
WSW	1.0	3.0	2.7	1.3	0.6	0.1	*			8.7	9.4
W	1.3	4.9	3.7	0.8	0.3	0.1				11.1	7.6
WNW	1.2	4.0	5.6	2.9	0.9	0.1				14.7	9.8
NW	1.4	3.6	4.9	3.3	1.4	0.2				14.8	10.5
NNW	1.3	2.6	0.9	0.2	*					5.0	5.7
VAR	2.0	0.6								2.6	2.6
CALM	1.2									1.2	
TOTAL	23.5	36.6	23.8	11.0	4.0	0.9				100.0	7.5
October											
N	2.6	1.7	0.4	0.1						4.8	3.9
NNE	2.1	1.1	0.3	0.1						3.6	3.9
NE	2.4	0.8	0.2	0.1	*					3.5	3.5
ENE	1.4	0.7	0.1	*	*					2.2	3.6
E	1.8	0.9	0.1							2.8	3.1
ESE	1.8	1.4	0.1							3.3	3.6
SE	2.5	1.9	0.6	0.1						5.1	4.2
SSE	1.0	1.5	0.7	0.1	*					3.3	5.7
S	1.1	1.4	0.5	0.3	0.2	*				3.5	6.7
SSW	1.0	1.4	0.7	0.7	0.5	0.2	*	*		4.5	9.7
SW	1.0	2.0	1.5	1.4	1.0	0.4	*			7.3	11.3
WSW	1.0	2.8	3.0	1.6	0.6	0.1	*			9.1	9.5
W	1.7	4.6	3.6	0.7	0.1	*				10.7	7.1
WNW	1.7	4.7	5.0	1.4	0.4	*				13.2	8.1
NW	2.4	4.4	4.0	1.6	0.4	0.1	*			12.9	8.0
NNW	2.1	2.5	0.6	0.1	*	*				5.3	4.7
VAR	1.6	0.1	*							1.7	1.8
CALM	2.7									2.7	
TOTAL	31.9	33.9	21.4	8.3	3.2	0.8	*	*		100.0	6.7

TABLE 3-2. Percentage Frequency Distribution of 50-ft Wind Distribution Versus Speed. (Sheet 6 of 7)

Direction	Speed Class (mi/hr) 0 to 3	4 to 7	8 to 12	13 to 18	19 to 24	25 to 31	32 to 38	39 to 46	>46	Total	Average speed
November											
N	2.7	1.3	0.4	0.2						4.6	4.0
NNE	2.2	0.7	0.4	0.2	*					3.5	4.0
NE	1.9	0.5	0.1	*						2.5	2.8
ENE	1.8	0.4	*							2.2	2.5
E	1.9	0.6	*							2.5	2.6
ESE	2.0	1.0	0.1							3.1	3.1
SE	2.5	1.4	0.3	0.1						4.3	3.9
SSE	1.4	1.2	0.4	0.2	0.1	*				3.3	5.3
S	1.7	1.2	0.5	0.5	0.3	*				4.2	6.8
SSW	1.4	1.2	0.8	0.9	0.7	0.2	0.1			5.3	9.9
SW	1.6	1.6	1.4	1.5	0.8	0.3	0.1	*		7.3	10.5
WSW	1.3	2.1	1.9	1.3	0.4	0.1	*	*		7.1	9.1
W	2.1	3.4	1.9	0.6	0.1	0.1	*			8.2	6.8
WNW	2.5	4.6	4.9	1.0	0.3	0.1				13.4	7.5
NW	3.6	5.9	4.7	0.7	0.1	0.1	*			15.1	6.6
NNW	3.0	2.8	1.0	0.2						7.0	4.6
VAR	1.4	0.1								1.5	1.6
CALM	4.7									4.7	
TOTAL	39.7	30.0	18.8	7.4	2.8	0.9	0.2	*		100.0	6.1
December											
N	2.7	1.0	0.3	0.2						4.2	3.5
NNE	1.6	0.6	0.2	*						2.4	3.6
NE	1.7	0.5	*	*						2.2	2.6
ENE	1.5	0.5	*							2.0	2.4
E	1.6	0.6	0.1	*	*					2.3	2.9
ESE	1.9	0.7	0.2	0.1	*					2.9	3.6
SE	2.6	1.2	0.4	0.1	*					4.3	3.6
SSE	1.7	1.2	0.2	0.2	0.1					3.4	4.7
S	1.7	0.8	0.4	0.4	0.2	0.1	*			3.6	6.7
SSW	1.3	0.7	0.6	0.8	0.5	0.4	0.1	*		4.4	11.1
SW	1.5	1.3	1.2	1.4	1.0	0.5	0.1	*	*	7.0	11.8
WSW	1.6	1.8	1.7	1.1	0.4	0.1	*			6.7	8.6
W	2.1	2.7	1.5	0.5	0.1	*				6.9	6.0
WNW	2.9	5.7	5.3	0.8	0.1	*				14.8	6.9
NW	3.8	7.3	6.0	1.0	0.1					18.2	6.7
NNW	2.9	2.4	0.9	0.1						6.3	4.3
VAR	1.5	0.1								1.6	1.7
CALM	6.8									6.8	
TOTAL	41.4	29.1	19.0	6.7	2.5	1.1	0.2	*	*	100.0	5.9

TABLE 3-2. Percentage Frequency Distribution of 50-ft Wind Distribution Versus Speed. (Sheet 7 of 7)

Direction	Speed class (mi/hr)									Total	Average Speed
	0 to 3	4 to 7	8 to 12	13 to 18	19 to 24	25 to 31	32 to 38	39 to 46	>46		
COMPOSITE OF ALL MONTHS											
N	2.0	1.8	0.6	0.2	*	*				4.6	4.9
NNE	1.4	1.4	0.6	0.3	*	*				3.7	5.7
NE	1.6	1.2	0.4	0.2	*	*				3.4	4.9
ENE	1.0	0.8	0.2	*	*	*				2.0	4.1
E	1.2	1.0	0.2	*	*					2.4	3.9
ESE	1.2	1.1	0.2	*	*					2.5	4.0
SE	1.6	1.6	0.4	0.1	*	*				3.7	4.5
SSE	0.9	1.1	0.5	0.1	*	*				2.0	5.7
S	1.0	1.3	0.4	0.2	0.1	*	*	*		3.0	6.4
SSW	0.9	1.3	0.7	0.6	0.3	0.2	*	*		4.0	9.5
SW	1.0	2.0	1.6	1.4	0.8	0.3	0.1	*	*	7.2	10.9
WSW	1.0	2.5	2.7	1.6	0.5	0.2	*	*		8.5	9.9
W	1.4	3.9	3.2	1.0	0.2	*	*			9.7	7.7
WNW	1.5	4.5	6.1	2.9	0.9	0.1	*			16.0	9.7
NW	2.1	4.9	5.2	2.8	1.3	0.3	*			16.6	9.6
NNW	1.7	2.3	0.8	0.1	*	*				4.9	5.1
VAR	1.7	0.7	*							2.4	2.7
CALM	2.2									2.2	
TOTAL	25.4	33.4	23.8	11.5	4.1	1.1	0.1	*	*	100.0	7.6

*Denotes less than 0.05%.

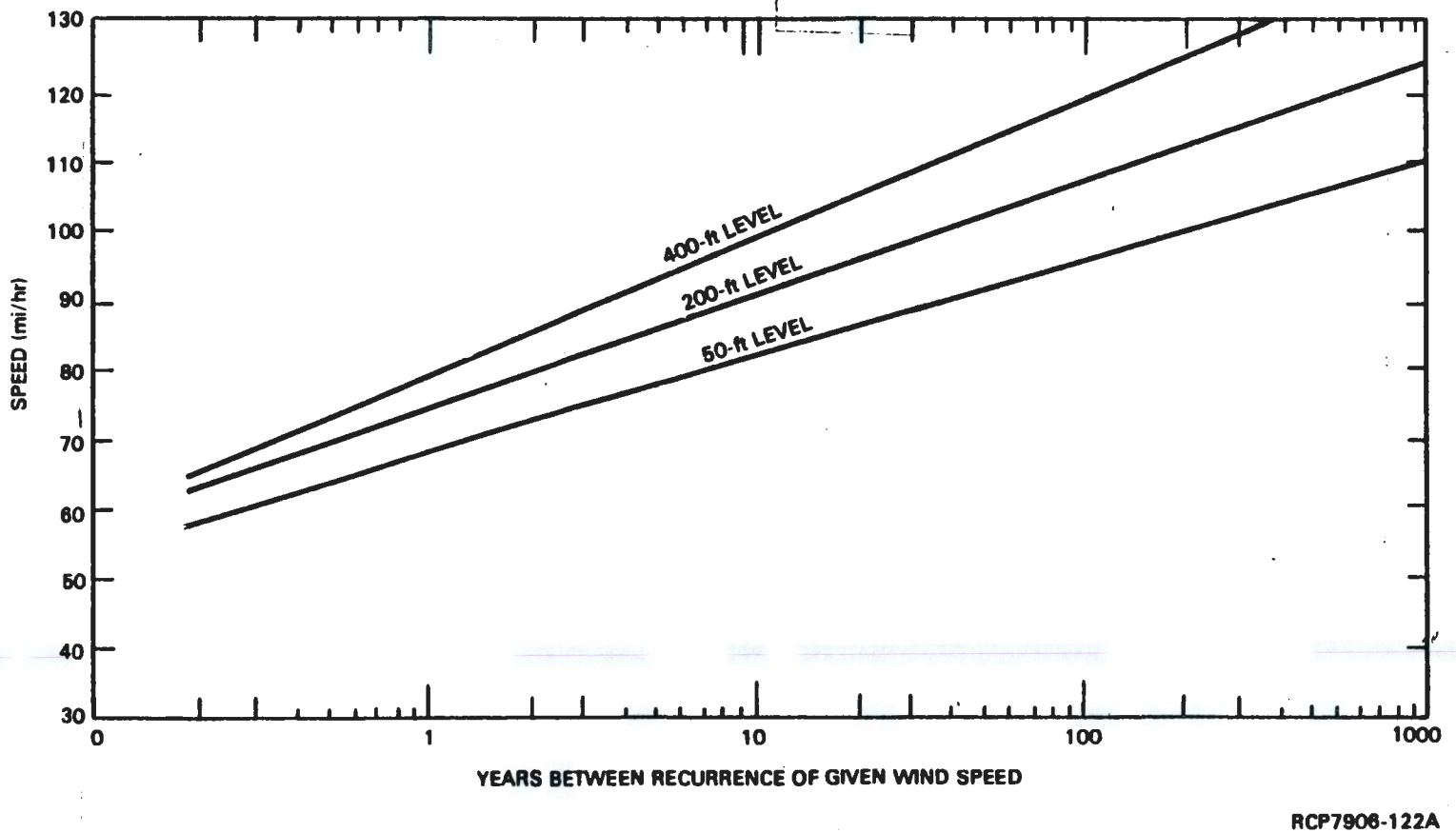

FIGURE 3-12. Peak Wind Gust Return Probability Diagram.

TABLE 3-3. Averages and Extremes of Climatic Elements at Hanford. (Sheet 1 of 2)

	TEMPERATURE (°F)															DEGREE DAYS (BASE 65°F)											PRECIPITATION (INCHES)													
	1912-1975 AVERAGES							1912-1975 EXTREMES								HEATING 1974-1975 TOTALS					COOLING 1960-1975 TOTALS					1912-1975 TOTALS							SNOW, ICE PELLETS (SLEET)						
								DAILY MAXIMUM				DAILY MINIMUM																											
	DAILY MAXIMUM	DAILY MINIMUM	MONTHLY	HIGHEST MONTHLY	YEAR	LOWEST MONTHLY	YEAR	RECORD HIGHEST	YEAR	RECORD LOWEST	YEAR	RECORD HIGHEST	YEAR	RECORD LOWEST	YEAR	MEAN MONTHLY	MAXIMUM MONTHLY	YEAR	MINIMUM MONTHLY	YEAR	MEAN MONTHLY	MAXIMUM MONTHLY	YEAR	MINIMUM MONTHLY	YEAR	MEAN MONTHLY	MAXIMUM MONTHLY	YEAR	MINIMUM MONTHLY	YEAR	MAXIMUM IN 24 hr	YEAR	MEAN MONTHLY	MAXIMUM MONTHLY	YEAR	MAXIMUM IN 24 hr	YEAR	MAXIMUM DEPTH	YEAR
JAN	37.0	22.2	29.6	42.5	1953	12.1	1950	72	1971	-2	1950	53	1971	-23	1934	1085	1640	1950	694	1953	0	0	---	0	---	0.92	2.47	1970	0.13	1962 -	1.08	1948	5.1	23.4	1950	7.1	1954	12.0	1969
FEB	45.4	27.6	36.4	44.5	1958	21.4	1929	71	1924	-3	1950	55	1932	-23	1950	778	1147	1956	576	1958	0	0	---	0	---	0.60	3.08	1940	T	1967 -	1.24	1916	2.4	26.0	1916	5.6	1975	10.0	1969
MAR	56.5	33.7	45.1	49.9	1926	39.4	1955	83	1960	24	1960	54	1942	6	1955	641	794	1955	476	1947	0	0	---	0	---	0.37	1.86	1957	0	1942 -	0.59	1949	0.3	4.2	1951	2.2	1957 -	2.3	1957
APR	66.1	39.9	53.1	59.6	1934	47.5	1955	95	1934	41	1945	60	1956	12	1935	396	522	1955	266	1947	1	5	1968 +	0	1975 +	0.38	1.22	1969	0	1933 -	0.53	1951	T	T	1975 -	T	1975 -	0	---
MAY	75.6	48.0	61.9	68.8	1947	56.6	1933	103	1936 -	49	1918	70	1956	28	1954	154	255	1962	36	1947	49	99	1971	3	1962	0.47	2.03	1972	0	1931	1.39	1972	T	T	1960	T	1960	0	---
JUNE	83.2	55.4	69.4	75.4	1922	63.0	1953	110	1912	55	1966	81	1924	33	1933	34	90	1953	3	1958	192	310	1969	59	1971	0.56	2.92	1950	0	1919	1.50	1934	0	0	---	0	---	0	---
JULY	91.9	61.1	76.5	81.8	1960	72.4	1963	115	1939	59	1966	82	1925	41	1935	3	22	1955	0	1975 +	404	518	1960	232	1963	0.15	0.31	1966	0	1939 -	0.73	1914	0	0	---	0	---	0	---
AUG	89.4	59.3	74.3	81.5	1967	69.8	1964	113	1961	63	1920	81	1961	40	1918	5	32	1960	0	1974 +	338	508	1967	171	1964	0.20	1.18	1920	0	1955 -	0.69	1975	0	0	---	0	---	0	---
SEPT	79.6	50.7	65.2	71.7	1967	58.8	1926	102	1950	52	1934 -	72	1955	25	1926	71	179	1972	13	1967	107	216	1967	27	1970	0.30	1.34	1947	T	1961 -	0.32	1947	0	0	---	0	---	0	---
OCT	65.3	40.7	53.0	59.0	1952	48.8	1930	90	1933	31	1935	60	1945 -	6	1935	377	479	1946	200	1952	2	10	1971	0	1975 -	0.58	2.72	1957	0	1917 -	1.91	1957	*	1.5	1973	1.5	1973	1.5	1973
NOV	48.6	31.5	40.0	46.0	1954 -	31.3	1955	75	1975	14	1955	52	1959 -	-1	1955	747	1008	1955	567	1954	0	0	---	0	---	0.86	3.05	1926	T	1939 -	0.78	1966	1.3	12.7	1955	4.8	1955	5.1	1946
DEC	39.3	26.0	32.7	42.0	1933	18.5	1919	68	1933	-3	1919	56	1975	-27	1919	990	1224	1964	822	1957	0	0	---	0	---	0.89	2.53	1931	0.11	1946	1.00	1958	3.9	19.1	964	5.4	1965	12.1	1964
					JULY		JAN		JULY		FEB		JULY		DEC			JAN		JULY			JULY		OCT			FEB		AUG		OCT			FEB		JAN		DEC
YEAR	64.8	41.3	53.1	81.9	1960	12.1	1950	115	1939	-3	1950 -	82	1925	-27	1919	5271	1640	1950	0	1975 +	1093	518	1960	0	1975 +	6.28	3.08	1940	0	1955 -	1.91	1957	13.0	26.0	1916	7.1	1954	12.1	1964

	WIND (mi/hr)									RELATIVE HUMIDITY (%)								SKY COVER SCALE (0-10)					SOLAR RADIATION (LANGLEYS)*								
	1946-1975 AVERAGES						PEAK GUSTS			1946-1975 AVERAGES					1946-1975 EXTREMES				1946-1975 AVERAGES (SUNRISE TO SUNSET)					1953-1975 AVERAGE DAILY TOTALS					1953-1975 EXTREME DAILY TOTALS			
	PREVAILING DIRECTION	MEAN MONTHLY SPEED	HIGHEST MONTHLY	YEAR	LOWEST MONTHLY	YEAR	SPEED	DIRECTION	YEAR	MEAN	HIGHEST MONTHLY	YEAR	LOWEST MONTHLY	YEAR	HIGHEST	YEAR	LOWEST	YEAR	MONTHLY	HIGHEST MONTHLY	YEAR	LOWEST MONTHLY	YEAR	MONTHLY	HIGHEST MONTHLY	YEAR	LOWEST MONTHLY	YEAR	HIGHEST MONTHLY	YEAR	LOWEST MONTHLY	YEAR
JAN	NW	6.6	10.3	1972	3.1	1955	80	SW	1972	75.2	88.8	1960	60.0	1963	100	1975 -	13	1963	7.8	9.0	1969	4.3	1949	120	136	1973	88	1955	277	1969	16	1971 -
FEB	NW	7.1	9.4	1961	4.6	1963	66	SW	1971	70.0	86.9	1963	54.0	1967	100	1975 -	14	1962	7.4	8.9	1961	5.9	1964	202	238	1960	164	1954	422	1958	37	1970 -
MAR	WNW	8.4	10.7	1964	5.9	1958	70	SW	1956	55.8	65.9	1950	44.0	1966	100	1974 +	12	1965 -	6.8	7.9	1950	4.9	1965	340	388	1965	305	1961	542	1968	47	1972
APR	WNW	9.1	11.1	1972 +	7.4	1958	73	SSW	1972	46.5	64.5	1963	36.9	1966	100	1973 -	9	1954	6.4	8.1	1963	3.7	1951	475	535	1973	374	1963	704	1972	75	1974
MAY	WNW	8.9	10.5	1965 +	5.8	1957	71	SSW	1948	42.3	61.9	1948	31.2	1966	100	1975 -	7	1953	5.8	7.7	1960	4.5	1949	576	634	1970	511	1962	782	1959	67	1962
JUNE	WNW	9.2	10.7	1949	7.7	1950 -	72	SW	1957	39.5	53.5	1950	30.0	1949	100	1972 -	10	1964 -	5.3	7.0	1950	2.8	1961	628	698	1960	563	1953	821	1971	112	1965
JULY	WNW	8.6	9.6	1963	6.8	1955	55	WSW	1968	31.8	40.5	1955	21.9	1959	99	1972	6	1951	2.8	4.5	1974 -	0.9	1953	659	714	1973	588	1955	808	1974	118	1972
AUG	WNW	8.0	9.1	1946	6.0	1956	66	SW	1961	34.5	43.8	1968	24.5	1967	100	1972 -	7	1951	3.2	5.9	1968	0.6	1955	558	613	1955	475	1968	721	1957	107	1959
SEPT	WNW	7.5	9.2	1961	5.4	1957	65	SSW	1953	40.6	55.1	1959	33.2	1974	100	1962 -	10	1962 -	4.0	6.1	1959	1.4	1975	423	463	1975	354	1959	591	1970	61	1957
OCT	WNW	6.7	9.1	1946	4.4	1952	63	SSW	1950	57.0	74.2	1962	42.5	1952	100	1975 -	10	1962 -	5.9	8.0	1975	3.9	1952	262	299	1958	216	1975	434	1973	33	1974
NOV	NW	6.1	7.9	1945	2.9	1956	64	SSW	1949	73.5	88.1	1972	64.2	1963 -	100	1975 -	16	1959	7.6	9.1	1972	6.2	1957	132	180	1957	97	1964	295	1971	14	1969
DEC	NW	6.1	8.3	1968	3.9	1963 -	71	SW	1955	80.1	90.5	1950	69.0	1968	100	1975 -	26	1972	8.1	9.2	1962	6.8	1954	92	116	1970	57	1969	196	1972	9	1973
				APR		NOV			JAN			DEC		JULY		DEC		JULY			DEC		AUG			JULY		DEC		JUNE		DEC
YEAR	WNW	7.7	11.1	1972 -	2.9	1956	80	SW	1972	53.9	90.5	1950	21.9	1959	100	1975 -	6	1951	5.9	9.2	1962	0.6	1955	372	714	1973	57	1969	821	1971	9	1973

EXTREME AVERAGES OR TOTALS AND YEAR OR SEASON OF OCCURRENCE

1912-1975 TEMPERATURE AVERAGES (°F)		
HIGHEST ANNUAL	56.2	1958 -
LOWEST ANNUAL	50.2	1929
HIGHEST WINTER (D-J-F)	41.1	1933-34
LOWEST WINTER	24.2	1948-49
HIGHEST SPRING (M-A-M)	58.2	1947
LOWEST SPRING	48.0	1955
HIGHEST SUMMER (J-J-A)	78.2	1958
LOWEST SUMMER	70.3	1954
HIGHEST FALL (S-O-N)	56.6	1963
LOWEST FALL	49.6	1946
1912-1975 PRECIPITATION TOTALS (IN.)		
GREATEST ANNUAL	11.45	1950
LEAST ANNUAL	3.26	1967
SNOW, ICE PELLETS (SLEET)		
GREATEST SEASONAL	43.6	1915-16
LEAST SEASONAL	0.3	1957-58
1945-1975 WIND SPEED AVERAGE (mi/hr)		
HIGHEST ANNUAL	8.3	1968 -
LOWEST ANNUAL	6.3	1957
1946-1975 RELATIVE HUMIDITY AVERAGE (%)		
HIGHEST ANNUAL	57.9	1950 -
LOWEST ANNUAL	49.4	1967
1946-1975 SKY COVER AVERAGES (SUNRISE TO SUNSET SCALE 0 - 10)		
HIGHEST ANNUAL	6.4	1966
LOWEST ANNUAL	5.1	1949
1953-1975 SOLAR RADIATION AVERAGE DAILY TOTAL (LANGLEYS)		
HIGHEST ANNUAL	390	1973
LOWEST ANNUAL	357	1967

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TABLE 3-3. Averages and Extremes of Climatic Elements at Hanford. (Sheet 2 of 2)

NUMBER OF DAYS (1945-1975)**

	CLEAR					PARTLY CLOUDY	CLOUDY					THUNDERSTORMS					HEAVY FOG (VISIBILITY 1/4 mi OR LESS)					PRECIPITATION 0.10 in. OR MORE					SNOW 1.0 in. or MORE				
	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR
JAN	3	7	1963	0	1955 -	6	22	27	1969	17	1963	0	0	---	0	---	5	14	1965	0	1949	3	8	1970	0	1972 -	2	10	1950	0	1967 -
FEB	5	9	1968 -	1	1972 -	5	18	26	1958	12	1964	#	1	1972 -	0	1975 -	3	11	1963	0	1971 -	2	5	1961 +	0	1972 -	2	4	1975 -	0	1974 -
MAR	6	12	1965 -	2	1961	8	17	22	1968	9	1965	#	1	1969 +	0	1975 -	1	5	1951	0	1975 -	2	8	1957	0	1973 -	#	2	1957 -	0	1975 -
APR	6	12	1962	1	1963	10	14	21	1963	6	1956	1	3	1948	0	1975 +	#	1	1975 -	0	1974 +	1	5	1948	0	1973 -	0	0	---	0	---
MAY	9	14	1973	2	1960	10	12	19	1960	6	1958	2	7	1956	0	1974 +	#	1	1958	0	1975 +	2	4	1967 +	0	1968 -	0	0	---	0	---
JUNE	10	21	1961	5	1972 -	10	10	15	1973 -	5	1960 -	3	8	1972 -	0	1963 -	#	1	1971	0	1975 +	2	8	1950	0	1973 -	0	0	---	0	---
JUL	20	26	1960	13	1974	7	4	9	1974	1	1961	2	7	1975	0	1973 -	0	0	---	0	---	1	3	1974 +	0	1973 -	0	0	--	0	---
AUG	19	30	1955	11	1968	7	5	13	1968	0	1969 -	2	8	1953	0	1974 -	#	1	1959	0	1975 -	1	4	1975	0	1974 -	0	0	---	0	---
SEPT	15	27	1975	8	1969	7	8	13	1969	1	1975	1	4	1959	0	1975 -	#	1	1957	0	1975 -	1	5	1959	0	1975 -	0	0	---	0	---
OCT	9	14	1970	1	1975	7	15	22	1973	9	1970	#	1	1975 -	0	1974 -	1	6	1962	0	1974 -	2	8	1950	0	1972 -	#	1	1973	0	1975 -
NOV	4	10	1957	1	1973 -	5	21	25	1973 -	15	1961	0	0	---	0	---	6	13	1965	0	1960	3	10	1973	0	1967	#	6	1955	0	1974 -
DEC	3	7	1972 -	1	1962 -	5	23	28	1962	18	1967 +	#	1	1971	0	1975 -	8	17	1950	2	1968 +	3	10	1964	0	1949 -	2	6	1964	0	1974 -
			AUG		JAN				DEC		AUG			JUNE					DEC					NOV		SEPT			JAN		
YEAR	109	30	1955	0	1955 -	87	169	28	1962	0	1969 -	11	8	1972 -	0	---	24	17	1950	0	---	23	10	1973	0	1975 -	6	10	1950	0	---

REFERENCE NOTES

* CALORIES/cm²

** SKY COVER AND PRECIPITATION OBSERVATIONS NOT BEGUN UNTIL 1946

\# LESS THAN 1/2

\- ALSO ON EARLIER YEARS

	NUMBER OF DAYS (1945-1975)										NUMBER OF DAYS (1912-1975)																																	
	3 in. OR MORE SNOW ON GROUND					PEAK GUST 40 mi/hr OR GREATER					MAXIMUM TEMPERATURE 90°F OR ABOVE					MAXIMUM TEMPERATURE 100°F OR ABOVE					MAXIMUM TEMPERATURE 32°F OR BELOW					MINIMUM TEMPERATURE 32°F OR BELOW					MINIMUM TEMPERATURE 0°F OR BELOW				
	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR
JAN	5	23	1969	0	1975 -	3	11	1972	0	1973 -	0	0	---	0	---	0	0	---	0	---	11	29	1937	0	1967 -	28	31	1960 -	9	1953	2	14	1950	0	1975 -
FEB	3	16	1950	0	1974 -	3	6	1961 -	0	1973 -	0	0	---	0	---	0	0	---	0	---	3	15	1956	0	1974 -	22	28	1944 +	5	1958	1	9	1929	0	1975 -
MAR	0	0	---	0	---	3	9	1956	1	1973 -	0	0	---	0	---	0	0	---	0	---	#	2	1960	0	1975 -	16	25	1944 +	6	1968 -	0	0	---	0	---
APR	0	0	---	0	---	3	7	1972	0	1967	#	4	1926	0	1975 -	0	0	---	0	---	0	0	---	0	---	5	15	1935	0	1974 -	0	0	---	0	---
MAY	0	0	---	0	---	2	6	1971 +	0	1963 -	3	11	1924	0	1974 -	#	1	1966 +	0	1975 -	0	0	---	0	---	#	3	1938	0	1975 -	0	0	---	0	---
JUNE	0	0	---	0	---	2	6	1973	0	1971 -	9	20	1940 -	0	1953	1	9	1970	0	1975 -	0	0	---	0	---	0	0	---	0	---	0	0	---	0	---
JULY	0	0	---	0	---	1	4	1962 -	0	1975 -	21	29	1941	8	1963	7	16	1971 +	0	1963 -	0	0	---	0	---	0	0	---	0	---	0	0	---	0	---
AUG	0	0	---	0	---	1	5	1951	0	1974 -	18	29	1915	7	1948	4	16	1942	0	1975 -	0	0	---	0	---	0	0	---	0	---	0	0	---	0	---
SEPT	0	0	---	0	---	2	4	1946	0	1975 -	5	16	1938	0	1970 -	#	2	1955 +	0	1975 -	0	0	---	0	---	#	4	1933 -	0	1975 -	0	0	---	0	---
OCT	0	0	---	0	---	2	8	1967	0	1974 -	#	1	1933	0	1975 -	0	0	---	0	---	#	2	1935	0	1975 -	5	12	1916	0	1962 -	0	0	---	0	---
NOV	#	10	1955	0	1975 -	2	5	1973 -	0	1974 -	0	0	---	0	---	0	0	---	0	---	2	15	1955	0	1974 -	17	30	1936	4	1949	#	1	1955 -	0	1975 -
DEC	2	14	1955	0	1975 -	3	8	1957 +	0	1969 -	0	0	---	0	---	0	0	---	0	---	8	19	1914	0	1974	26	31	1963 -	14	1933	1	14	1919	0	1975 +
			JAN					JAN					JULY					JULY					JAN					DEC					JAN		
YEAR	10	23	1969	0	---	27	11	1972	0	---	56	29	1941 +	0	---	12	16	1971 -	0	---	24	29	1937	0	---	119	31	1963 -	0	---	4	14	1950 -	0	---

NUMBER OF DAYS		
CLEAR (0-3 TENTHS SKY COVER, SR TO SS)		
GREATEST ANNUAL (1946-75)	141	1951
LEAST ANNUAL (1946-75)	85	1966
CLOUDY (8-10 TENTHS SKY COVER, SR TO SS)		
GREATEST ANNUAL (1946-75)	181	1969 -
LEAST ANNUAL (1946-75)	84	1949
THUNDERSTORMS		
GREATEST ANNUAL (1974-75)	23	1948
LEAST ANNUAL (1974-75)	3	1949
HEAVY FOG VISABILITY 1/4 mi OR LESS)		
GREATEST SEASONAL (1945-1975)	42	1950-51
LEAST SEASONAL (1946-75)	9	1948-49
PRECIPITATION 0.10 in. OR MORE		
GREATEST ANNUAL (1946-75)	39	1950
LEAST ANNUAL (1946-75)	10	1965
SNOW 1.0 in. OR MORE		
GREATEST SEASONAL (1946-75)	15	1955-56
LEAST SEASONAL (1946-75)	0	1957-58
3 in. OR MORE SNOW ON GROUND		
GREATEST SEASONAL (1946-75)	40	1964-65
LEAST SEASONAL (1946-75)	0	1966-67 -
PEAK GUST 40 mi/hr OR GREATER		
GREATEST ANNUAL (1945-75)	41	1961
LEAST ANNUAL (1945-75)	13	1958
MAXIMUM TEMPERATURE 90°F OR ABOVE		
GREATEST ANNUAL (1912-75)	85	1940 -
LEAST ANNUAL (1912-75)	31	1964
MAXIMUM TEMPERATURE 100°F OR ABOVE		
GREATEST ANNUAL (1912-75)	32	1942
LEAST ANNUAL (1912-75)	1	1954
MAXIMUM TEMPERATURE 32°F OR BELOW		
GREATEST SEASONAL (1912-75)	53	1955-56
LEAST SEASONAL (1912-75)	1	1937-38
MINIMUM TEMPERATURE 32°F OR BELOW		
GREATEST SEASONAL (1912-75)	141	1916-17
LEAST SEASONAL (1912-75)	75	1957-58
MINIMUM TEMPERATURE 0°F OR BELOW		
GREATEST SEASONAL (1912-75)	18	1949-50
LEAST SEASONAL (1912-75)	0	1974-75 -

LOCATION AND HISTORY

PRESENT LOCATION 25 mi NW OF RICHLAND, WASHINGTON LATTITUDE 46°34'N; LONGITUDE 119°36'W, ELEVATION 733 ft OBSERVATIONS FROM 1913 TO 1944 WERE BY UNITED STATES WEATHER BUREAU COOPERATIVE OBSERVERS AT A SITE ABOUT 10 mi ENE OF PRESENT LOCATION. BETWEEN 1944 AND 1975, OBSERVATIONS HAVE BEEN MAINTAINED ON A 24 hr-A-DAY BASIS BY THREE DIFFERENT GOVERNMENT CONTRACTORS.

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Temperatures at Hanford are colder in winter and warmer in summer than would be the case without the Cascade Range. However, other mountain ranges shield the area from arctic surges, and half of all winters are free of temperatures as low as 0°F. However, six winters in 63 yr of record have contributed a total of 16 d with temperatures of -20°F or below; in January through February, 1950, there were four consecutive such days. There are recorded 10 d when even the maximum temperature failed to get above 0°F. At the other extreme, in the winter of 1955-56, the lowest temperature all season was 22°F. Although daytime temperatures reach 90°F or above for an average of 56 d/yr, nighttime temperatures of 70°F or above occur only an average of 8 d/yr. The cool nights are a result of the gravity winds mentioned earlier.

Thunderstorms have been observed at the HMS in nearly every month of the year, but are very rare during the winter months. Although severe thunderstorms are rare, the site is vulnerable to lightning strikes causing grass fires; the most notable occurrences were in August 1961, July 1963, July 1970, and August 1973.(2)

The formation of a severe tornado of the Midwest type is highly unlikely under the climatologic and orographic conditions of the Pacific Northwest. There have been only two tornado funnel clouds and one small tornado (June 16, 1948) observed on the Hanford Site in the 34-yr period 1945 through 1978. Although one of these touched ground, it caused no damage. The nearest reported tornado damage was in Yakima (April 30, 1957), about 45 mi to the west, and at Wallula Junction (June 26, 1958), about 50 mi to the southeast.(2) Only minor damage was noted.

3.3.2 Local Climatology

3.3.2.1 Data Sources. The principal source of climatologic data for the Hanford Site is the HMS, with its 410-ft tower, located between the 200 East and 200 West Areas (see Fig. 3-2). Elevation of the station is 733 ft above mean sea level. This meteorological station has been collecting data since 1944. From 1912 through 1942, weather records were kept at a U.S. Weather Bureau cooperative station near the old Hanford townsite.

Wind measurements were taken at eight tower levels from 1944 through 1970, but were reduced to six tower levels in 1971. Temperature measurements were recorded at nine tower levels from 1944 to 1970, but changed to eight levels in 1971. The following chart shows present tower observation levels:

	Tower levels (ft)							
	20	50	100	150	200	250	300	400
Temperature	x	x	x	x	x	x	x	x
Wind		x	x		x	x	x	x

Surface observations of dewpoint temperatures and ambient air temperature are taken about 75 ft northwest of the tower. About 1,500 ft west of the tower is a pyranometer, a precipitation gauge, and an instrument shelter with maximum and minimum thermometers.

At the HMS Site, upper wind measurements are made by the pilot-balloon-theodolite (pibal) method. These measurements are available for the period January 1, 1969, through the present. Some of these observations are summarized for climatologic use. Observations are presently taken at 0100 and 1300 h Pacific standard time (PST).

3.3.2.2 Normal and Extreme Values of Meteorological Parameters. These data are given in Table 3-3.

3.3.2.3 Topography. The topography around the PUREX Plant basically slopes downward to the Columbia River to the north and east and slopes up to the hills to the south and west. Contours within a 50-mi radius are shown in Figure 3-13. Cross sections showing profiles of the ground surface are presented in Figure 3-14.

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3.3.3 Onsite Weather Forecasting and Climatology Capability

Meteorological and climatological services available from the HMS include the following list.

- Emergency Response Capability

  In the event of an accidental release of radioactive material, the forecaster on duty would immediately compute a downwind centerline concentration and identify the endangered area. To do this, one uses wind data available from a network of 20 wind stations which are on a telemetry network and automatically reported each hour. On a routine basis, these wind data are used to construct airflow charts over the Hanford Site at 0400, 1000, 1600, and 2200 h, PST. The next duty of the forecaster is to incorporate the wind data and stability category with an interactive mesoscale diffusion and transport computer model to produce computer printouts of trajectories and concentrations over the Hanford Site. This service is available 24 h a day, 365 d a year.

- Severe Weather Advisories

  This service is provided to facilitate safe and efficient operation of the Hanford plants. These advisories consist primarily of winds in excess of 35 mi/h and thunderstorms; however, occasional warnings are required for drifting snow and freezing rain. Although tornadoes are seldom seen in the Hanford Site, if conditions were such that a tornado could be produced, a warning to that effect would be issued over the emergency warning system. People designated by each contractor are notified to take appropriate action.

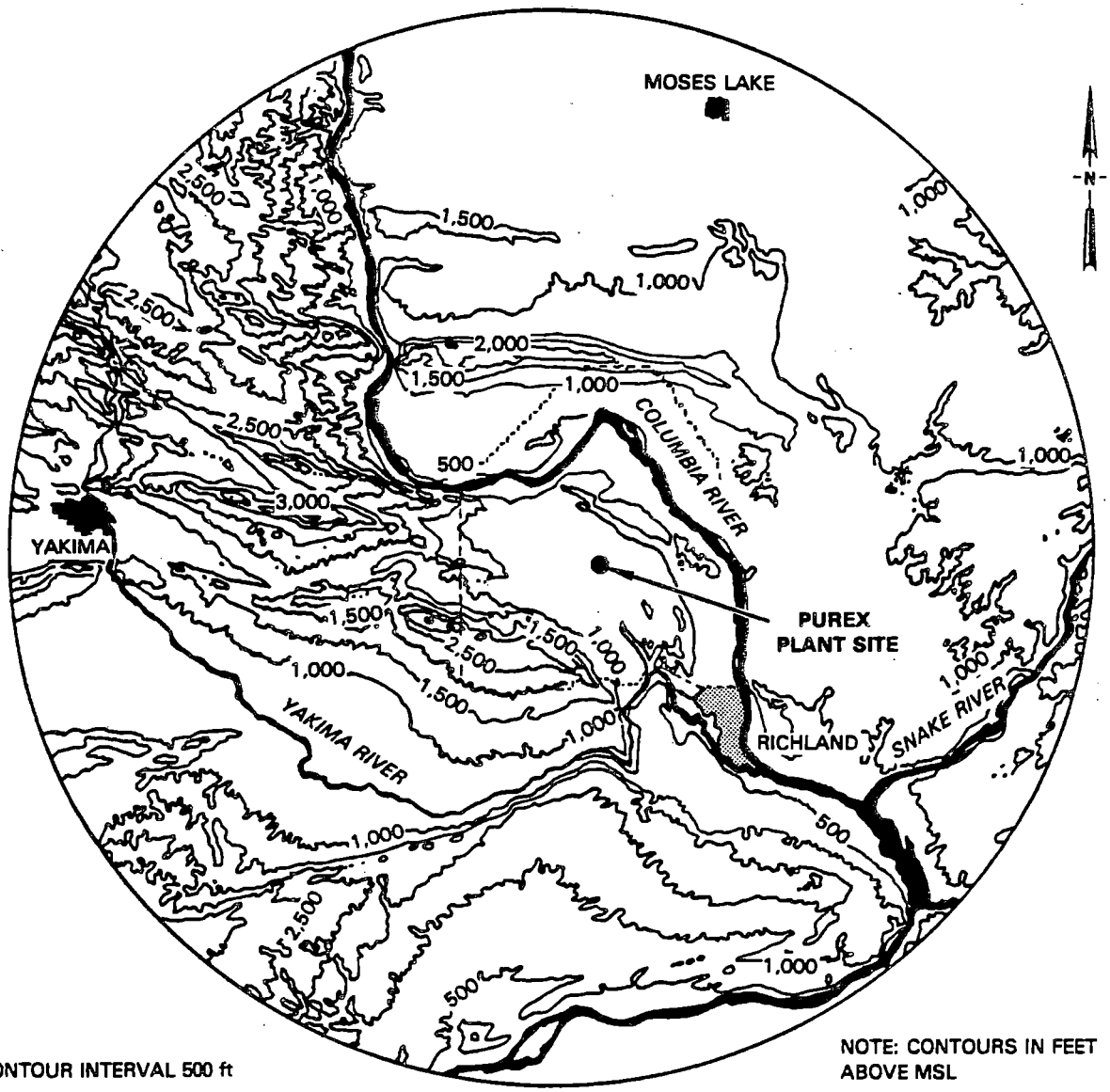
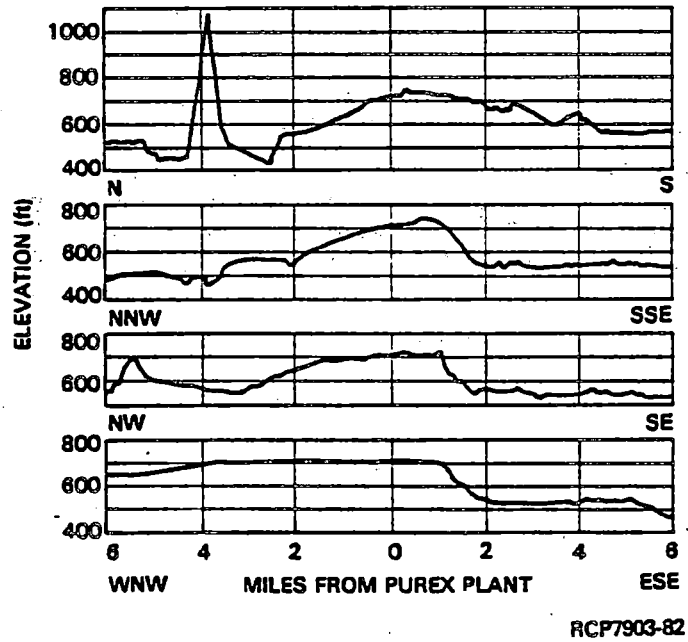


FIGURE 3-13. Topographic Map of the Region Surrounding the PUREX Plant.



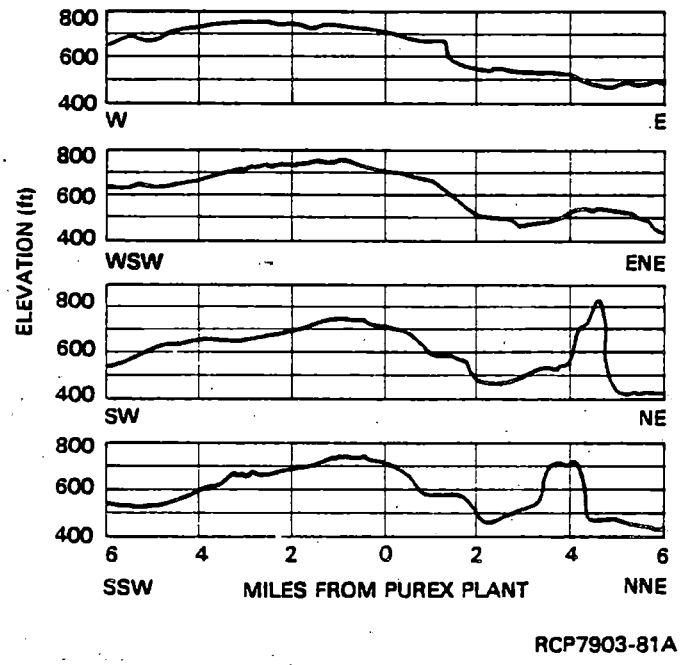


FIGURE 3-14. Ground Surface Cross Sections.

- General Weather Forecasts

  General weather forecasts are prepared and recorded at 0700 and 1500 h each day. The forecasts are tailored to the requirements of DOE and Hanford contractors for general work scheduling.

- Climatology

  Climatologic data and analyses for the Hanford Site are provided to assess energy demands for preliminary site assessments and for the design and construction of facilities in which environmental control is essential.

One of the functions of the HMS is to monitor and record the wind speed and direction and stability data from the HMS tower. Joint frequency distribution of wind speed, wind direction (at 200 ft), and stability data (ΔT between the surface and 200 ft), are given in Table 3-4 for the period 1973 through 1975.

Atmospheric stability refers to the degree of turbulence in the air; when the atmosphere is thermally stable, turbulent motions are suppressed and less mixing and dilution of contaminants can occur.

Stability is a function of the vertical thermal gradation of the atmosphere (Table 3-5). Divided into classes: class A represents the most unstable atmospheric conditions and class F represents the most stable conditions (Table 3-6).

Figure 3-15 presents a wind rose for all stability classes combined.

3.3.4 Short-Term Diffusion Estimates

Diffusion estimates for short-term, accidental releases have been described and calculated using Pasquill's parameters(5) with Gifford's(6) conversion giving standard deviations of plume concentration distribution.(7)

Calculated diffusion estimates for a 200-ft stack release show that for the unstable class the maximum concentration of radionuclides would occur at a distance of 1,300 to 1,900 ft from the source. The maximum concentration of radionuclides for the neutral class would be expected to occur at 3,300 to 6,600 ft, and for the moderately stable class at 3 to 18 mi. The very stable class gives a maximum concentration of radionuclides at about 60 mi.

The seasonal and daily variation in stability classes indicates that, on the average, the unstable class dominates on summer days and the stable class is most prevalent at night. During winter, stable or neutral conditions are more prevalent.

TABLE 3-4. Joint Frequency Distribution of Wind Speed Direction at 200-ft Level Versus Atmospheric Stability.

Wind speed (mi/hr)	Stability type*	Wind direction															
		NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N
0-3	VS	0.06	0.05	0.03	0.06	0.08	0.12	0.08	0.04	0.08	0.05	0.07	0.12	0.08	0.10	0.07	0.11
	MS	0.38	0.28	0.18	0.30	0.38	0.60	0.37	0.30	0.19	0.26	0.36	0.39	0.51	0.46	0.52	0.43
	N	0.42	0.50	0.34	0.37	0.38	0.48	0.28	0.21	0.13	0.16	0.22	0.20	0.24	0.33	0.39	0.47
	U	0.62	0.71	0.33	0.29	0.37	0.41	0.19	0.13	0.10	0.23	0.12	0.17	0.15	0.19	0.32	0.44
4-7	VS	0.04	0.02	0.02	0.01	0.04	0.07	0.10	0.07	0.07	0.11	0.10	0.24	0.23	0.20	0.14	0.11
	MS	0.28	0.18	0.16	0.19	0.37	0.56	0.41	0.36	0.31	0.42	0.58	0.86	1.13	1.20	0.93	0.52
	N	0.28	0.21	0.17	0.20	0.31	0.28	0.14	0.17	0.12	0.16	0.19	0.23	0.48	0.62	0.56	0.44
	U	1.04	0.79	0.56	0.57	0.59	0.65	0.37	0.34	0.41	0.50	0.43	0.34	0.52	0.93	1.31	0.91
8-12	VS	0.01	0.01	0.00	0.00	0.01	0.02	0.02	0.03	0.03	0.04	0.13	0.24	0.33	0.45	0.22	0.01
	MS	0.21	0.15	0.11	0.14	0.13	0.31	0.37	0.25	0.28	0.39	0.77	1.69	2.73	2.37	0.97	0.34
	N	0.16	0.10	0.04	0.07	0.15	0.12	0.10	0.10	0.21	0.21	0.29	0.36	0.76	1.01	0.29	0.21
	U	0.54	0.25	0.12	0.13	0.08	0.17	0.10	0.09	0.29	0.48	0.50	0.27	0.52	1.31	0.57	0.40
13-18	VS	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.01	0.02	0.08	0.13	0.26	0.79	0.08	0.01
	MS	0.08	0.04	0.02	0.03	0.03	0.12	0.22	0.15	0.21	0.40	0.97	1.53	3.65	2.67	0.42	0.06
	N	0.14	0.07	0.01	0.01	0.02	0.03	0.08	0.11	0.22	0.38	0.53	0.50	1.15	0.86	0.17	0.09
	U	0.23	0.08	0.02	0.01	0.00	0.02	0.03	0.04	0.12	0.48	0.75	0.25	0.61	0.84	0.13	0.10
19-24	VS	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.05	0.12	0.00	0.00
	MS	0.00	0.01	0.00	0.00	0.00	0.01	0.05	0.07	0.16	0.31	0.56	0.26	1.31	1.20	0.04	0.01
	N	0.00	0.02	0.01	0.00	0.00	0.00	0.03	0.06	0.20	0.43	0.35	0.19	0.99	0.80	0.05	0.02
	U	0.05	0.04	0.00	0.00	0.00	0.00	0.00	0.01	0.10	0.28	0.30	0.12	0.31	0.63	0.03	0.01
25-7	VS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	MS	0.00	0.02	0.00	0.00	0.00	0.02	0.04	0.04	0.19	0.31	0.15	0.05	0.37	0.39	0.00	0.00
	N	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.04	0.23	0.51	0.24	0.04	0.63	0.93	0.01	0.01
	U	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.34	0.30	0.03	0.26	0.67	0.01	0.02

*VS = Very stable
MS = Moderately stable
N = Neutral
U = Unstable

TABLE 3-5. Hanford Stability Types.(see Table 3-12).

Type	$\Delta T/\Delta z$ (°F/200 ft)
VS	≥ 3.5
MS	-0.4 to 3.5
N	-1.4 to -0.4
U	≤ -1.4

TABLE 3-6. Key to Stability Classes.

Surface wind speed at 10 m (m/s)	Day			Night	
	Incoming solar radiation[a]			Thinly overcast or broken low clouds	Scattered clouds
	Strong	Moderate	Slight		
< 2	A	A, B	B		
2 to 3	A, B	B	C	E	F
3 to 5	B	B, C	C	D[b]	E
5 to 6	C	C, D	D	D	D
> 6	C	D	D	D	D

[a]Strong incoming solar radiation corresponds to a solar altitude 60° with clear skies; slight insolation corresponds to a solar altitude of 15° to 35° with clear skies.

[b]The neutral class D should be assumed for overcast conditions day or night.

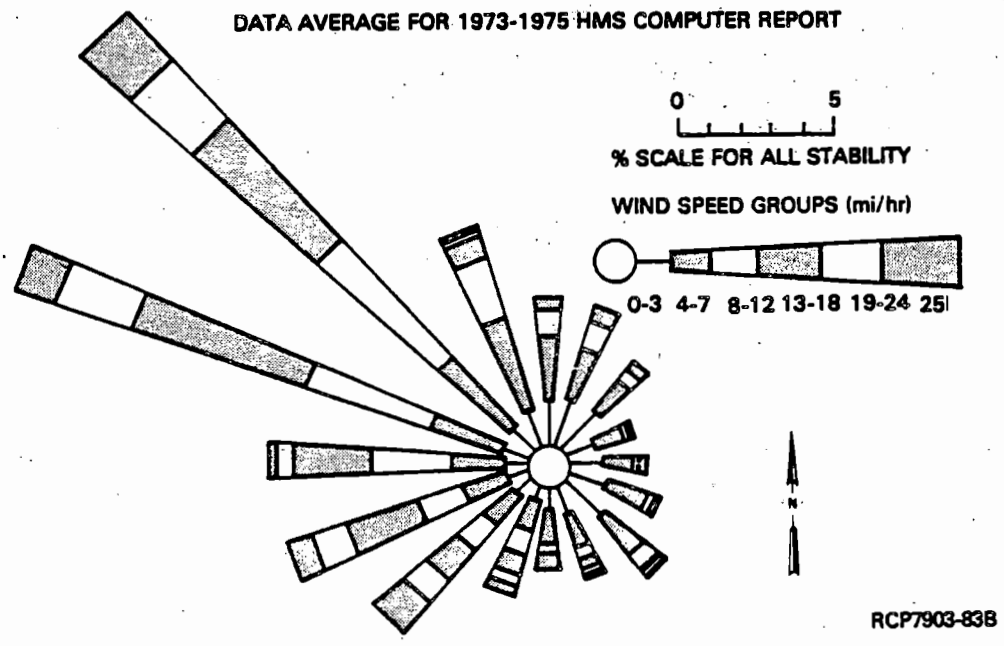


FIGURE 3-15. Joint Frequency Distribution of Wind Speed Direction.

3.3.5 Long-Term (Routine) Diffusion Estimates

Using the joint frequency distribution of wind speed and direction versus atmospheric stability (Hanford diffusion model) for the period 1973 through 1975 (see Table 3-4 and Fig. 3-15) atmospheric dilution factors were calculated for all 16 compass sectors and distances to 35 mi. Results of these calculations are shown in Figure 3-16. These estimates are for a 200-ft stack release.

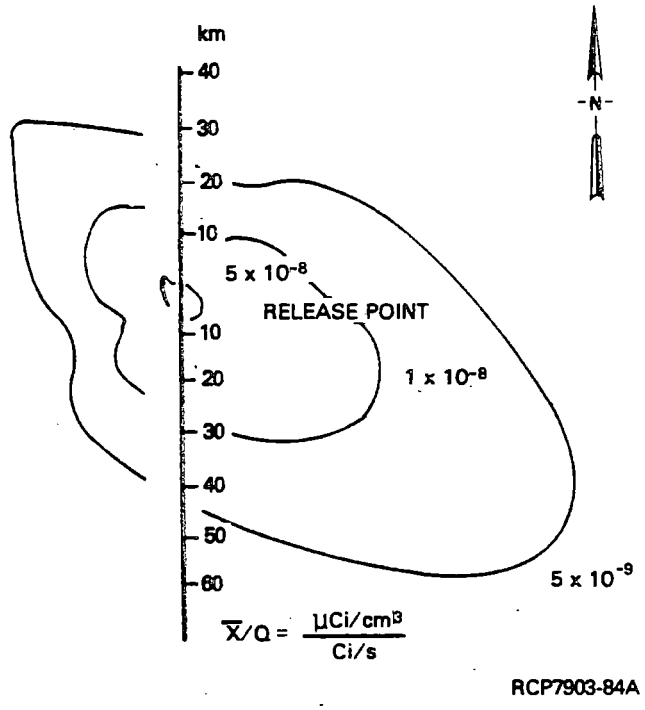


FIGURE 3-16. Isopleths of Average, Normalized Cloud Concentrations.

3.4 SURFACE HYDROLOGY

3.4.1 Surface Water

The surface water located within the boundaries of the Hanford Site consists of the Columbia River, various ditches and ponds in and near the 200 Areas, and three ponds located in the 300 Area. These are shown in Figure 3-17. Two ephemeral streams just west of the Hanford Site, Cold and Dry Creeks, may flow for a short period after a heavy rainfall or snowmelt. The Yakima River borders part of the Hanford Site southern boundary.

The surface hydrology of the Hanford Site has been extensively studied.(2,8) These studies include an analysis of the Columbia and Yakima Rivers, as well as extensive investigations as to the nature of a number of man-made ditches and ponds used for the disposal of low-level radiactive liquid waste, certain industrial waste, and cooling waters from various processes. A complete list of the ditches and ponds, with their physical dimensions and radioactive inventories, has been compiled.(2)

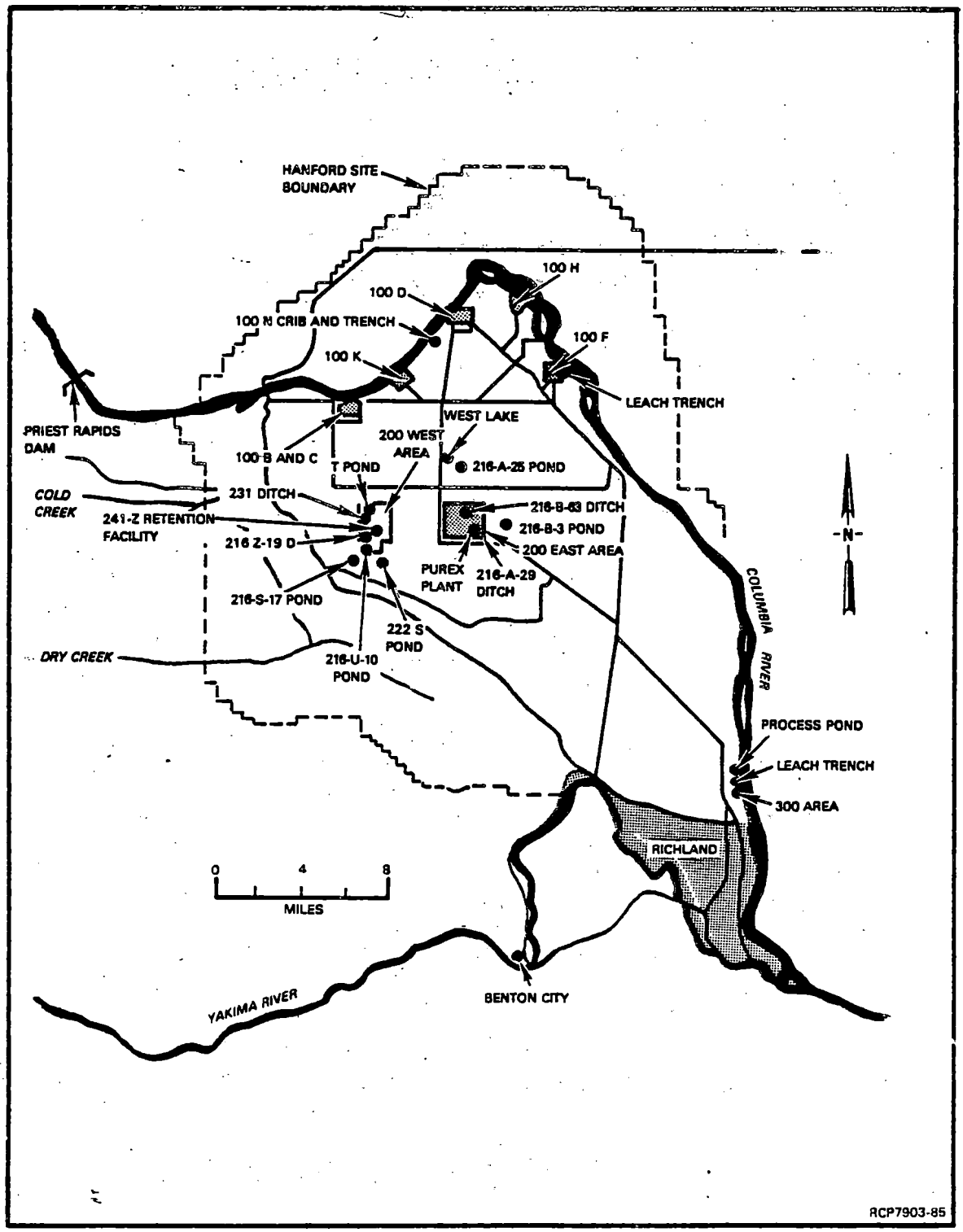


FIGURE 3-17. Surface Water Areas on the Hanford Site.

3.4.2 Floods

As discussed in previous sections, the climate at the Hanford Site is arid to semiarid with an average annual rainfall of 6.25 in. The projected maximum annual rainfall that might occur in the next 1,000 yr is about 18 in. (a threefold increase in the recorded average annual precipitation).(2)

A calculation of the effect of a Columbia River flood that might occur in the next 1,000 yr on waste management operations has been performed and reported.(2) The flooding condition used in the analysis is the dam-regulated "probable maximum flood" (PMF) previously predicted(2) by the U.S. Army Corps of Engineers. This projection was derived using extensive data and computer modeling techniques and incorporating assumptions for a combination of conditions which are the most severe and are considered "reasonably possible" for the Columbia River Basin. Contributing factors of winter snow accumulation, spring melting, and runoff-season rainstorms were maximized.

The basic cause of the PMF would be spring snowmelt runoff in the mountains of the Columbia River watershed following exceptionally cold and wet weather during the October to April snow accumulation season. It was assumed that, over the Columbia River Basin as a whole, the October to April precipitation equaled 1.3 times the normal annual precipitation. Unusually rapid melting due to meteorologic conditions was predicted as a result of the assumption of extreme seasonal values for air temperatures, dewpoint, solar radiation albedo, and wind speed. In addition, two hydrologically significant (the most severe considered "reasonably possible") basin-wide rainstorms were assumed. It was also assumed that rain contributions to the PMF fell entirely during two 5-d periods during the snowmelt season. Mid-May was arbitrarily chosen for the first storm; the second was timed to maximize the natural peak discharge of the lower Columbia River. The calculation shows that, even under these circumstances, there would be no effect on the PUREX Plant and other operations in the 200 Areas.

The probable maximum 24-h precipitation that can be expected in the Hanford region at least once in 1,000,000 yr is 11 in.(9) The maximum recorded 24-h precipitation has been 1.91 in. Even an 11-in., 24-h downpour would not cause flooding of the 200 Areas.(2)

Estimates of the consequences of hypothetical (artificial) floods have been reported.(10) A worst-case event would result from a postulated 50% breach of Grand Coulee Dam. The ensuing flood of 8,000,000 ft^3/s would crest at about 460 ft above MSL in the channel between 200 East Area and Gable Mountain (see Fig. 3-4). The PUREX Plant would be well above the crest of the flood, but normal operations could not be continued. (The export water line and certain electrical transmission lines would be affected by the flood, necessitating the use of backup services at the PUREX Plant.)

Aside from the hypothetical breach of Grand Coulee Dam, surge- or seiche-type flooding cannot occur there.

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3.4.3 PUREX Water Discharge and Disposition

The PUREX Plant is located within the 200 East Area on a plateau about 700 ft above MSL (see Fig. 3-4). This plateau is 300 ft above the Columbia River water level and about 7 mi from the closest point to the river.

Full-scale PUREX operation is projected to discharge an average of 5,500 gal/min. Maximum water discharge could reach 6,000 to 8,000 gal/min. Of this amount, 4,000 gal/min are planned to be routed to pond 216-A-25 with the remainder going to pond 216-B-3. During periods of PUREX shutdown, discharge to pond 216-A-25 will be about 2,000 gal/min.

Water samples are collected weekly from ponds 216-A-25 and 216-B-3 and the effluent ditches and analyzed for total alpha and beta concentrations. Special analyses are conducted following any known radioactive release.

3.4.4 Environmental Acceptance of Radionuclides

The sediments beneath the site consist of a thin mantle of windblown silts and sands which cover layers of sand and gravels up to 200 ft thick deposited by catastrophic Pleistocene floods. Older sands, silts, and gravels lie beneath the flood deposits. These sedimentary deposits have the capacity to sorb and retain radioactive contaminants from the waste streams and from accidental spills or leaks from waste tanks.

Because of the mild, dry climate (average annual precipitation of 6.25 in.), the influence of precipitation and evapotranspiration on the sediment moisture content is most pronounced in the surface 6 to 7 ft, with measurable changes occurring as deep as 40 ft.(11) Even though the sorption capacity of the sediments is low, the total sorption capacity of the sediment column between waste release point and the water table is high because of the long length of the column (up to about 320 ft in the 200 East Area). The high column sorption capacity and low precipitation provide excellent conditions for maximum sorption of radionuclides released to the sediments. This prevents most of the radionuclides (except neutral and negatively charged species) released to the sediments from reaching the water table.(2)

3.5 GROUNDWATER HYDROLOGY

3.5.1 Regional Hydrogeology

The Hanford Site lies within the Pasco Basin, a structural and topographic low within the Columbia Plateau physiographic province. The Pasco Basin (Fig. 3-18) is bounded by the Saddle Mountains to the north, the Umtanum and Yakima Ridges to the west, the Rattlesnake and Horse Heaven Hills to the south, and a broad regional monocline (known locally as the Jackass Mountain monocline) to the east.

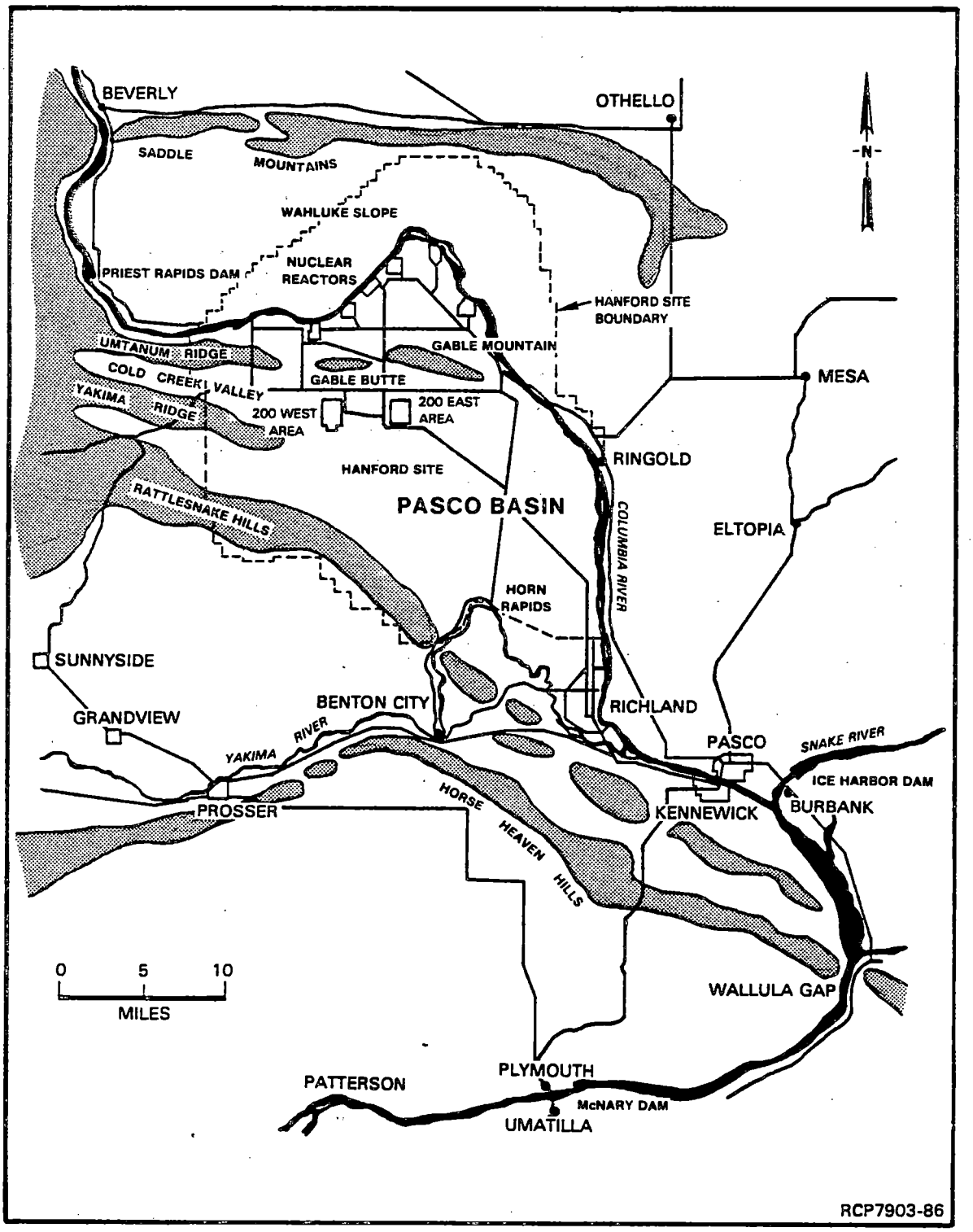

FIGURE 3-18. The Setting of the Pasco Basin.

The regional geology of the Hanford Site has been extensively studied and documented.(12) From a hydrologic standpoint, the area is composed of a series of confined aquifers (primarily sedimentary interbeds of the Ellensburg Formation and interflow zones within the Columbia River Basalt Group) overlain by an unconfined aquifer in the upper and middle Ringold Formation and overlying sediments of the Hanford formation (informal name). The hydrologic characteristics of the various stratigraphic horizons are summarized in Table 3-7.

Based upon interpretations from available geologic data, numerous lava extrusions flowed out from extensive fissure systems and flowed across the Columbia Plateau during the late Tertiary. The highly fluid lavas covered the surrounding terrain and flowed into the regional low areas such as the Pasco Basin. As basining continued, thick sections of basalt accumulated within these low regions. Because of the geometry of the flows and the erosion or deposition of various sediments between the flows, there exists within these rock units several artesian aquifers (e.g., the Mabton-Priest Rapids aquifer in the Cold Creek area and the Frenchman Springs aquifer in the Quincy-Odessa area). Water recharged these aquifers about 14,000 yr ago, based on radiogenic age-dating using the radioactive ^{14}C technique.

During the late Tertiary, the number and size of fissure eruptions decreased markedly and finally ceased. Even though volcanic activity ceased, basining continued and was accompanied by a regional north-south compression. As a result of these compressional forces acting on the basalt rocks, several east-west-trending anticlinal ridges (e.g., Saddle Mountains--see Fig. 3-18) were formed in the western part of the Columbia Plateau. The formation of these ridges had a significant impact on the course of the Columbia River. Where the Columbia River was able to erode the basalt at least as quickly as the anticlinal ridges, little change in the course of the Columbia River occurred. Where the ridges rose faster than the water was able to erode, the river was temporarily halted and lakes were formed. As basining continued, lacustrine and fluvial deposits continued to fill the Pasco Basin and covered previously deposited basalts. These sedimentary deposits comprise the Ringold Formation. The White Bluffs just east of the Columbia River and north of Richland represent the upper portion of the Ringold Formation.

The total thickness of the Ringold Formation in the Pasco Basin is about 1,200 ft. It is characterized by clay, silt, and fine sand with some gravel lenses in the lower section, cemented gravels in the middle, and silts and sands in the upper part of the section. The Ringold sediments are well to poorly sorted and show a wide range of cementation. Locally, the coarse silts, sands, and gravels possess high hydraulic conductivities and are capable of storing vast quantities of groundwater. The silty clay and silty very fine sand beds have very high porosity, but yield little or no water. These deposits are considered to be impermeable under hydraulic gradients of normal magnitude. The water table over the Western portion of the Hanford Site occurs near the top of the Ringold Formation. In the eastern half of the site, the water table rises well above the Ringold Formation and saturates the lower portion of the overlying Hanford formation.

TABLE 3-7. Hydrogeologic Characteristics of the Pasco Basin.

GEOLOGIC TIME SCALE			GEOLOGIC CHARACTERISTICS					HYDROGEOLOGY	
ERA	PERIOD	EPOCH	RADIOGENIC DATE, YEARS BEFORE PRESENT	STRATIGRAPHIC UNIT	BED OR FLOW UNIT	GENERAL LITHOLOGIC CHARACTER	AVERAGE THICKNESS (FT)	HYDROLOGIC CHARACTER	AQUIFER
CENOZOIC	QUATERNARY	HOLOCENE	6,600	ALLUVIUM COLLUVIUM AND EOLIAN SEDIMENTS		SANDS, SILTS, GRAVELS, AND CLAYS MODIFIED BY WIND EROSION	DUNES TO 60	OCCUR EVERYWHERE ABOVE THE WATER TABLE	DRY
			10,000						
		PLEISTOCENE	12,500	GLACIOFLUVIAL SANDS AND GRAVELS (HANFORD FORMATION)	TOUCHET SILTS	FIND-GRAINED FACIES OF THE GLACIO-FLUVIAL DEPOSITS. BEDDED IN QUIET WATER	0-400	OCCUR ABOVE THE WATER TABLE EXCEPT BETWEEN THE HIGH TERRACE PLATEAUS AND THE COLUMBIA RIVER. HAS VERY HIGH TRANSMISSIVITY AND STORAGE	OCCASIONALLY AN UNCONFINED AQUIFER OR DRY
			<12,000		PASCO GRAVELS	PREDOMINANTLY COARSE-GRAINED GRAVELS, COBBLES AND SANDS WITH CUT-AND-FILL STRUCTURE			
			<18,000		PALOUSE SOIL	CALCAREOUS SAND AND SILT EOLIAN DEPOSIT MAINLY DERIVED FROM RINGOLD FORMATION	0-80	ABOVE WATER TABLE WHEN PRESENT	DRY
			40,000						
			1,000,000						
	TERITIARY	PLIOCENE		RINGOLD FORMATION	UPPER RINGOLD	LOCALLY CAPPED BY CALICHE. MOSTLY WELL-BEDDED FLUVIAL SILTS AND SANDS WITH SOME GRAVELS	0-400	SANDS AND GRAVEL BEDS HAVE VERY HIGH HYDRAULIC CONDUCTIVITY AND STORAGE SOME BEDS OF SILTY CLAY OR CLAY ARE ESSENTIALLY IMPERMEABLE	UNCONFINED AQUIFER
					MIDDLE RINGOLD	SANDS AND GRAVELS, WELL SORTED. COMPACT, BUT VARIABLY CEMENTED			
					LOWER RINGOLD	SILTS AND CLAYS WITH INTERBEDDED GRAVELS AND SANDS. CLAY IS CHARACTERISTICALLY BLUE, BUT MAY BE GREEN, BROWN, OR TAN	0-400		AQUICLUDE
			4,000,000						
			5,500,000						
		MIOCENE	11,000,000	COLUMBIA RIVER BASALT GROUP	SADDLE MOUNTAINS	BASALT FLOWS WITH INTERFLOW ZONES SEVERAL SEDIMENTARY INTERBEDS OR ELLENSBURG FORMATION ARE PRESENT	900	FLOWS ARE DENSE WITH LOW-HYDRAULIC CONDUCTIVITY INTER-FLOWS AND INTERBEDS HAVE HIGHER HYDRAULIC CONDUCTIVITY AND TRANSMISSIVITY	CONFINED AQUIFERS
			16,000,000		WANAPUM	BASALT FLOWS WITH INTERFLOW ZONES FEW INTERBEDS OF ELLENSBURG FORMATION ARE PRESENT	1,000		
					GRANDE RONDE	BASALT FLOWS WITH INTERFLOW ZONES INTERBEDS OF ELLENSBURG FORMATION ARE INFREQUENT AND VERY THIN WHEN PRESENT	3,000		

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The gravel zones in the basal and lower units of the Ringold Formation tend to form a local confined aquifer system. The upper part of the Ringold Formation and the overlying Hanford formation constitute the major unconfined aquifer beneath the Hanford Site.

The extent of the Columbia River downcutting that took place primarily during the Pleistocene is an influential factor in the unconfined aquifer. Significant paleochannels of very high hydraulic conductivity were formed as a result of this downcutting. The nature and location of the paleochannels have been studied using data from about 3,000 wells drilled on the Hanford Site and from a gravity survey.[13]

3.5.2 The Uppermost Confined Aquifers

The uppermost confined aquifers consist of the lower and basal units of the Ringold Formation and the uppermost sedimentary interbeds and interflow zones.[8,14,15] From a water supply standpoint, the only significant confined aquifer is in the Priest Rapids Member of the Columbia River Basalt Group.[8] This aquifer is about 975 ft below the surface at the PUREX location.

Within the Hanford Site and vicinity, the hydrostatic head in all the uppermost confined aquifers is about the same at any location. The shape of the potentiometric surface of these aquifers is used to obtain an approximate picture of the regional flow system (Fig. 3-19). Flow lines are perpendicular to contours of equal hydrostatic head contours. Recharge into these aquifers appears to occur within the ridges and plateaus fringing the Pasco Basin, with discharge being toward the Columbia River. The eastern portion of the Hanford Site appears to be a regional discharge area for the uppermost confined aquifers.[8]

The hydraulic properties of the uppermost confined aquifers have been studied and reported by various investigators.[15] These properties are summarized in Table 3-8.

The uppermost confined aquifers are interconnected in places to the overlying unconfined aquifer. This occurs in areas where the confining layer has been eroded or subjected to extensive warping and deformation, such as along the anticlinal axis that runs from Umtanum Ridge to Gable Mountain.

3.5.3 The Unconfined Aquifer

The unconfined aquifer consists of sand and gravel deposits of both the Hanford and Ringold Formations. Since these materials are very heterogeneous, greater lithologic differences appear more often within a given bed than between beds. The water table represents the top of the unconfined aquifer at any given time (Fig. 3-20). The aquifer bottom is either basalt bedrock or silt and clay zones of the Ringold Formation (Fig. 3-21). The aquifer bottom has been determined using information from hundreds of wells drilled at Hanford.

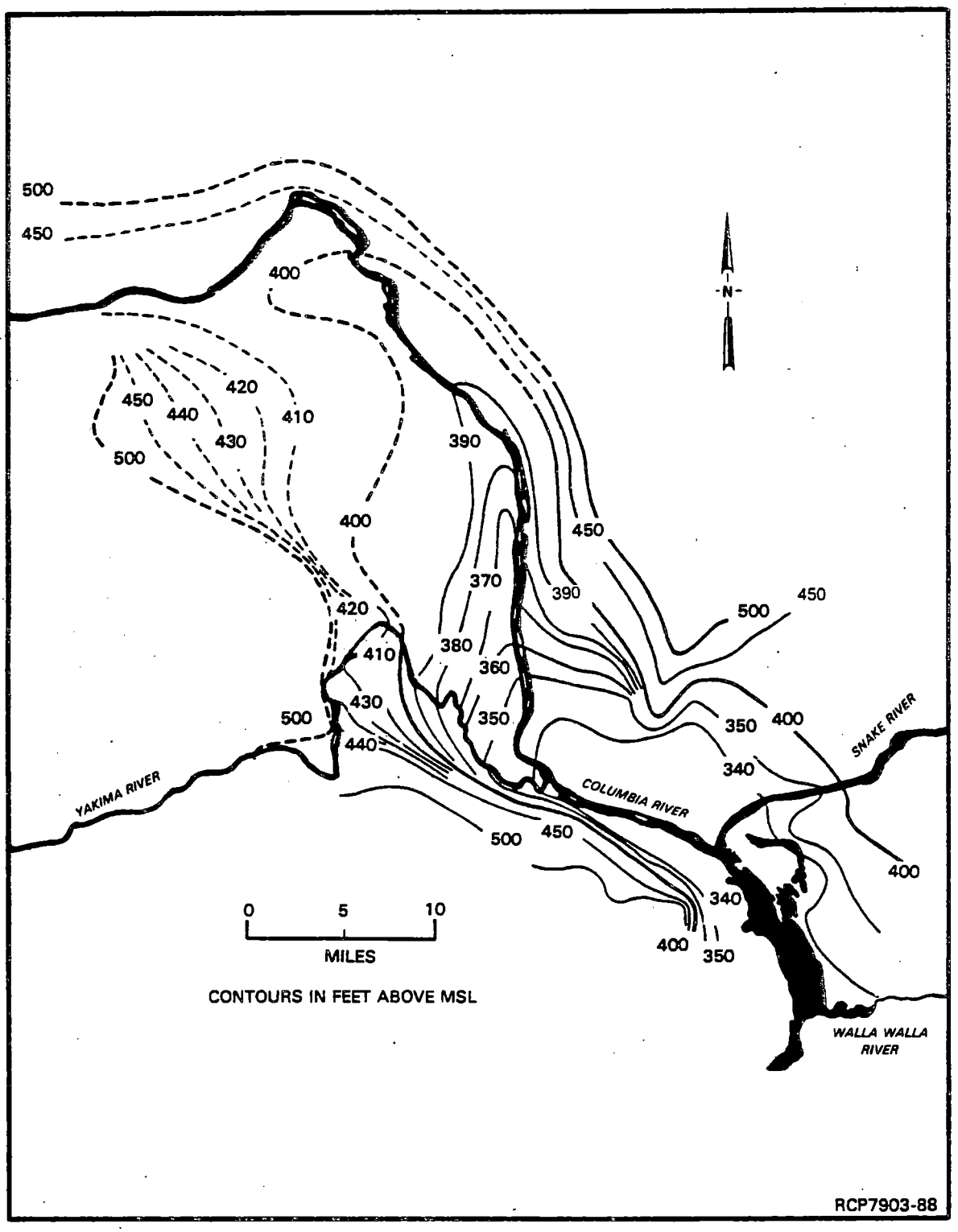

FIGURE 3-19. Average Potentiometric Surface of the Upper Confined Aquifer System.

TABLE 3-8. Hydraulic Characteristics of the Uppermost Confined Aquifers.

Well number	Transmissivity (ft^2/d)	Hydraulic conductivity (ft/d)
Lower Ringold		
699-84-35P	4	0.11
699-24-1P	90	5
699-S11-E12	40	0.5
699-20-E12P	350	7
Mean	120	3
Range	4 to 350	0.11 to -7
Rattlesnake Ridge		
199-B3-2P	3.5	0.25
199-H4-2	3	0.3
699-14-E6Q	600	30
Mean	200	10
Range	3 to 600	0.25 to 30
Mabton, Wanapum, Grande Ronde		
ARH-DC-1 Range	0.1 to 200	0.006 to 10
DH-8 Range	600 to 2000	20 to 66

NOTE: Other Properties: The porosity for the uppermost confined aquifers ranges between 0.3 and 0.4 (30% to 40%). Hydraulic conductivity in the interbeds ranges between 1.6×10^{-3} ft/d and 6×10^{-3} ft/d. The storage coefficient approaches the compressibility of water.

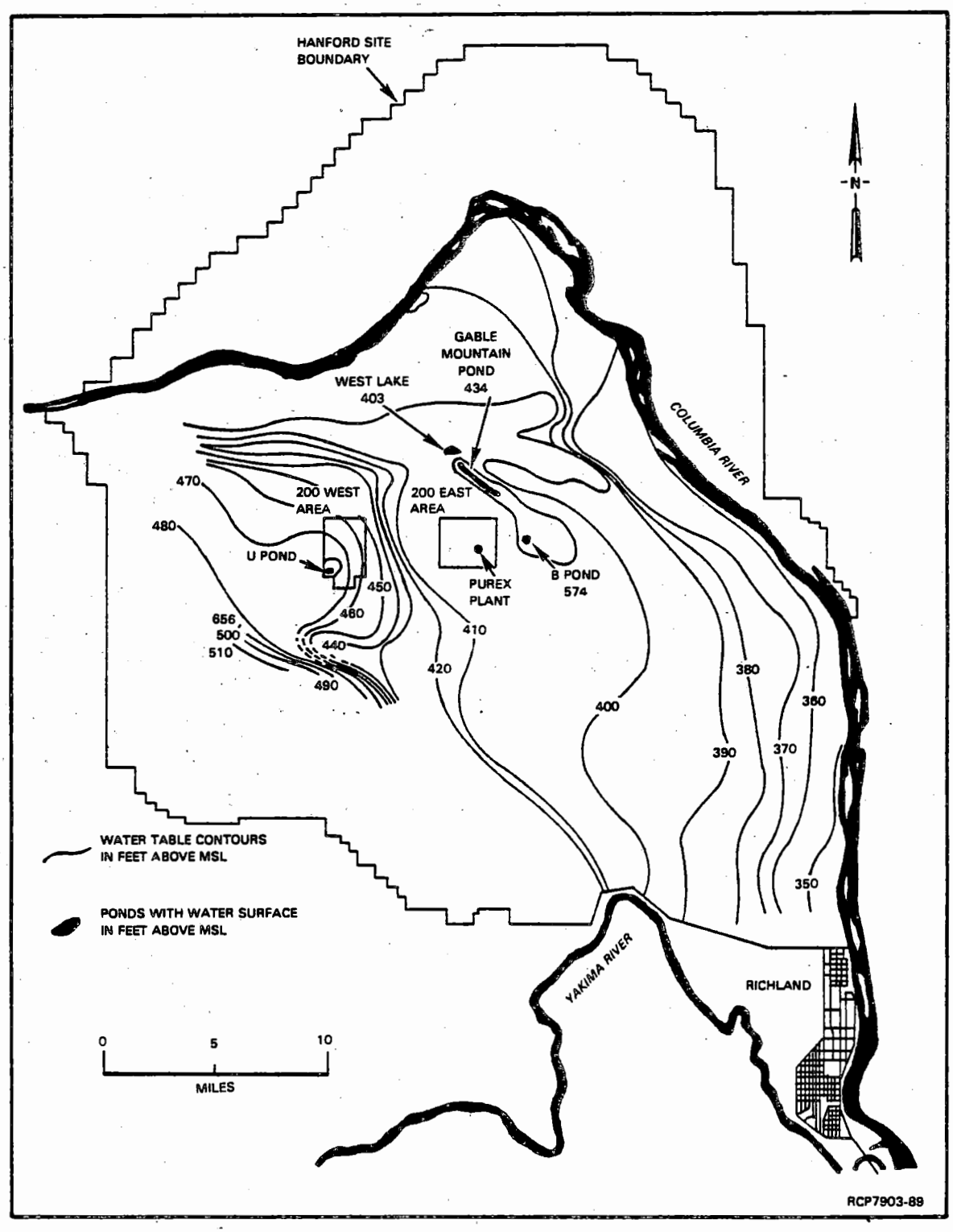

FIGURE 3-20. Hanford Site Water Table Map.

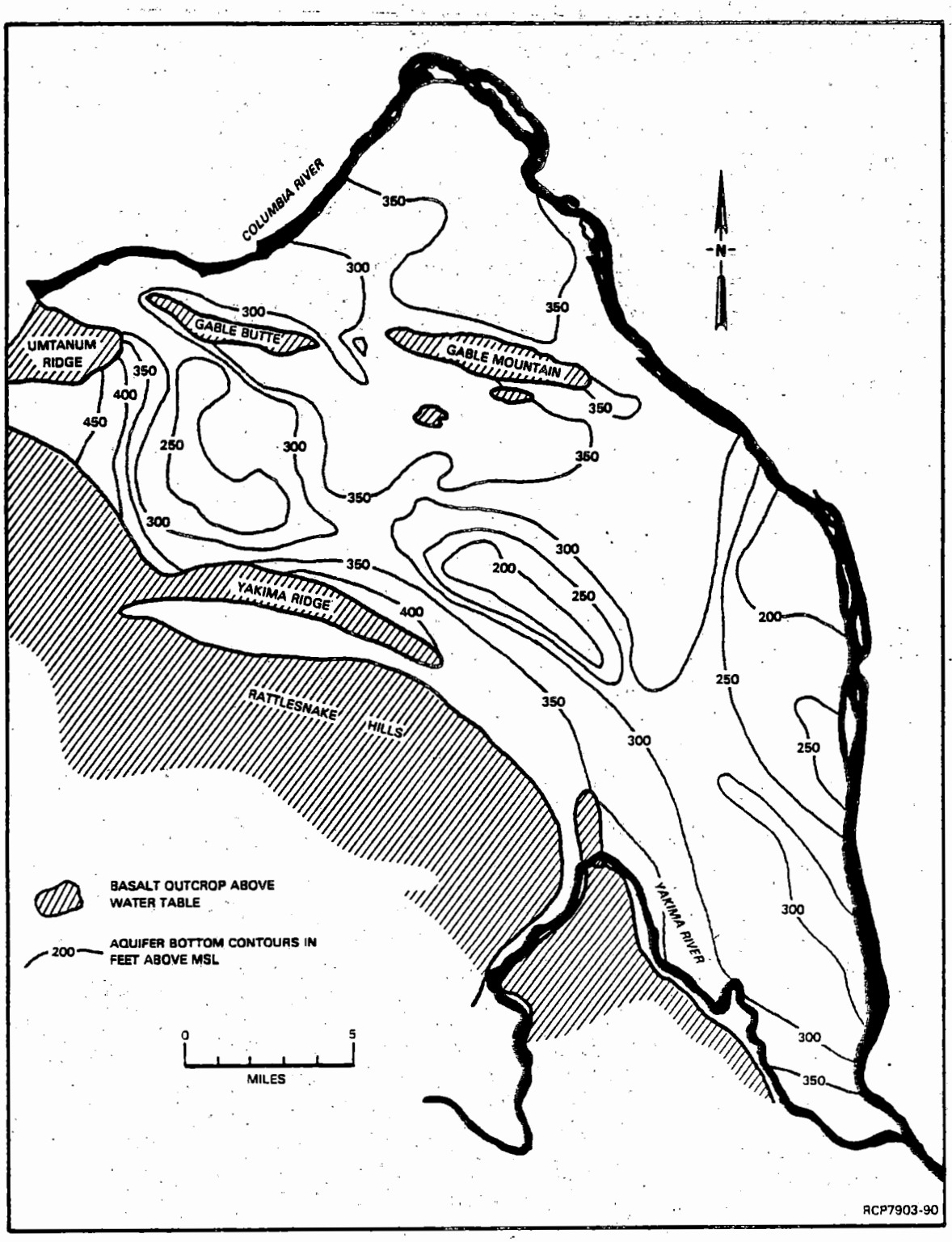

FIGURE 3-21. Unconfined Aquifer Bottom.

The hydraulic characteristics of the unconfined aquifer are quite variable and are summarized in Tables 3-9 and 3-10. The storage coefficient is not sufficiently known to plot its areal distribution; however, as a result of extensive pump testing and geologic studies, a map was developed[13] from the vertically averaged hydraulic conductivity distribution for the unconfined aquifer system (Fig. 3-22). A zone of high hydraulic conductivity is situated between Gable Butte and Gable Mountain and continues through the middle of the site.

TABLE 3-9. Hydraulic Conductivity of the Unconfined Aquifer.

Interval tested (formation)	Hydraulic conductivity (ft/d)
Hanford	500 to 20,000
Hanford and Ringold	100 to 1,000
Ringold (including clay)	1 to 200

TABLE 3-10. Transmissivity of the Unconfined Aquifer.

Region	Transmissivity (ft^2/d)
North of Gable Butte and Gable Mountain	4,000 to 25,000
On the flank of Gable Butte and Gable Mountain and along paleochannels	40,000 to 600,000
Other areas of the site	2,000 to 40,000

NOTE: Storage coefficient ranges from 0.05 to 0.15 throughout the site.

The Rattlesnake Hills, Yakima Ridge, and Umtanum Ridge to the west and southwest (Fig. 3-23) are impermeable boundaries. Gable Mountain and Gable Butte, as well as other small areas of basalt rise above the water table, distorting the groundwater flow. The Yakima River recharges the unconfined aquifer along its reach from Horn Rapids to Richland. The Columbia River represents a hydraulic discharge boundary for the aquifer. Groundwater flow and bank storage are affected by seasonal river stage fluctuations of the Columbia River.

The flow pattern that originally prevailed in the unconfined aquifer prior to waste discharges was primarily to the east and northeast with discharge into the Columbia River.[2] Natural recharge occurs in the Cold Creek and Dry Creek valleys along the margin of the Rattlesnake Hills and Yakima Ridge. Groundwater flow appears to be distorted by a buried extension of Yakima Ridge, which parallels the Rattlesnake Hills for a distance of about 2 mi.

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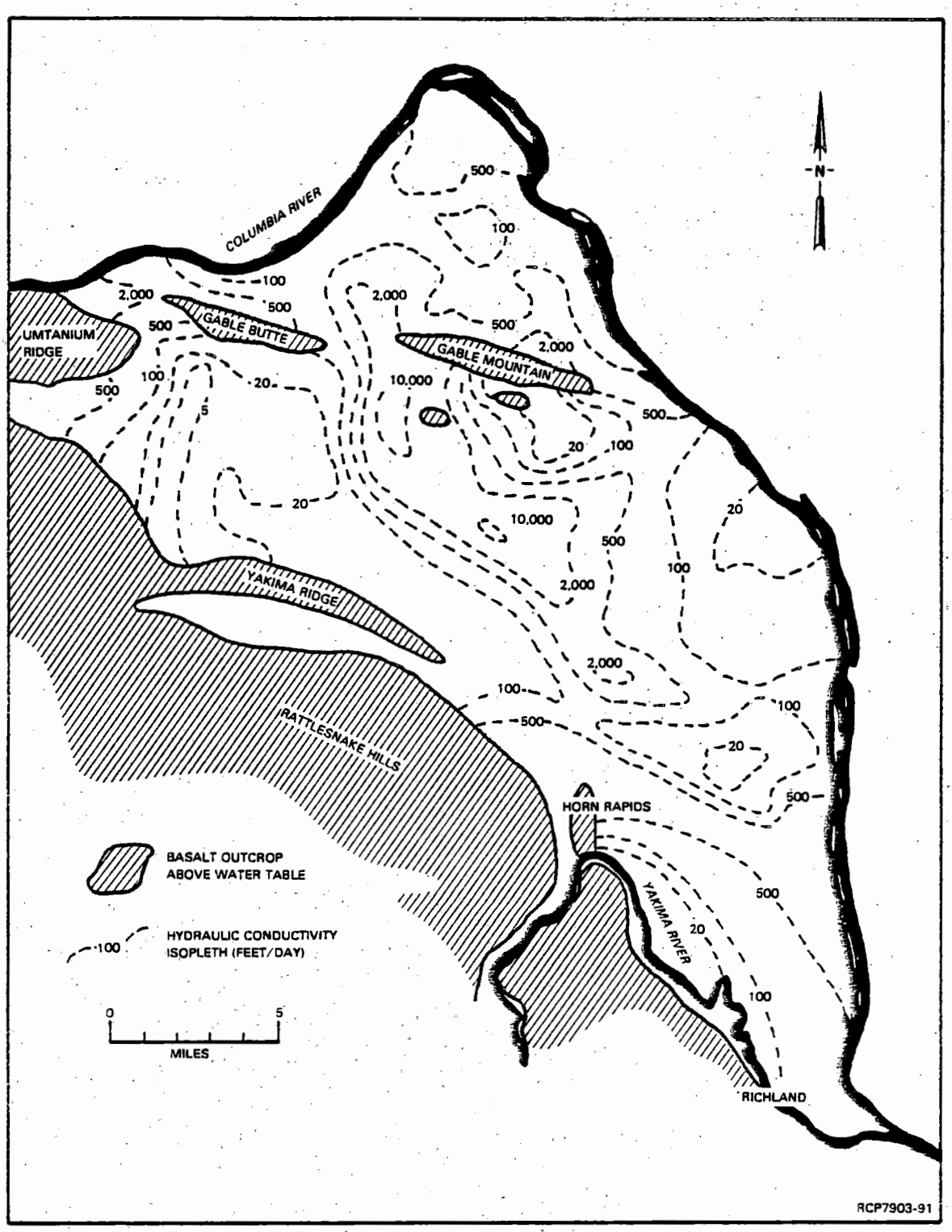

FIGURE 3-22. Vertically Averaged Hydraulic Conductivity Distribution in the Unconfined Aquifer.

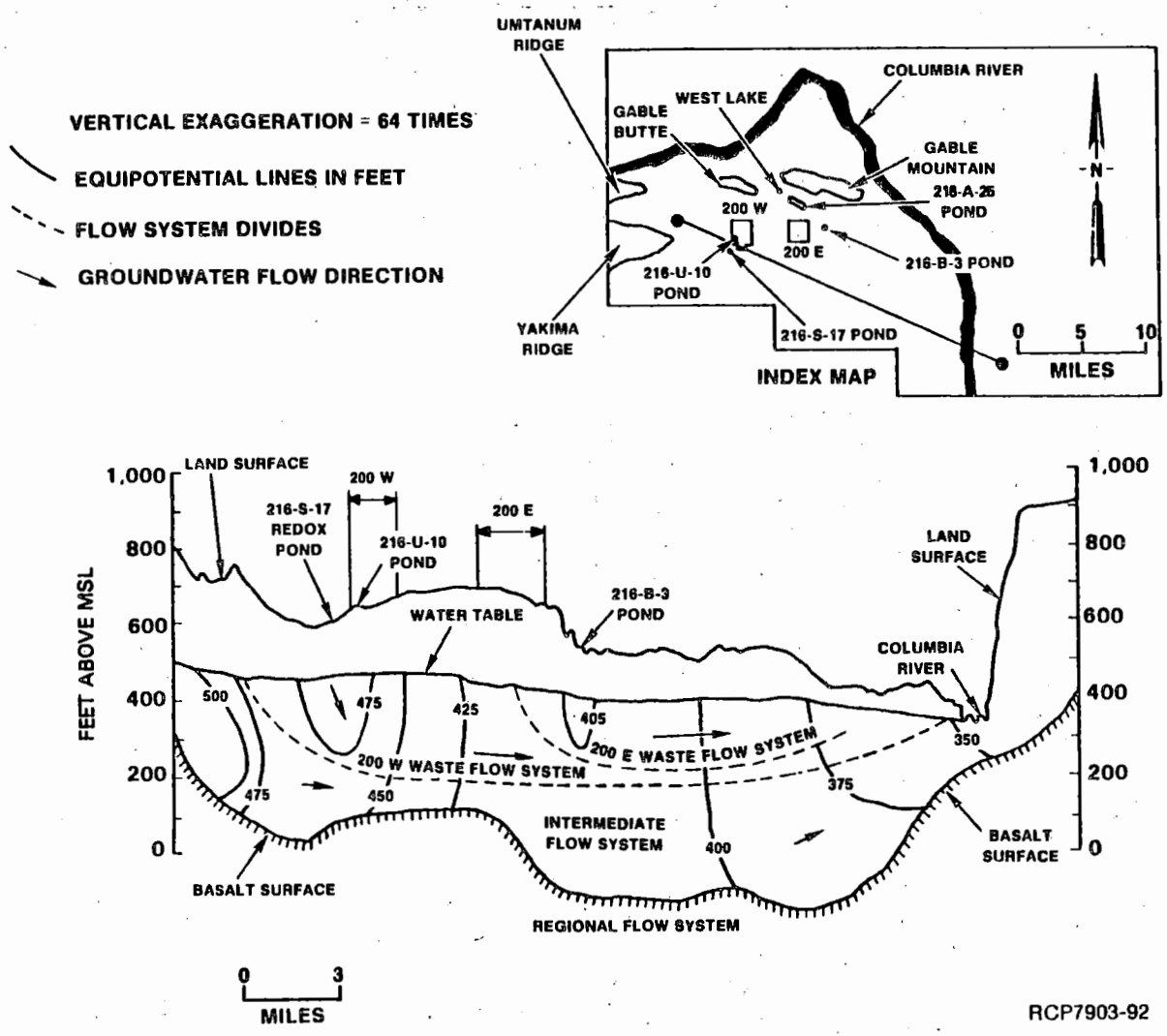

FIGURE 3-23. Generalized Hanford Groundwater Flow System.

As a result of waste disposal activities at Hanford, the unconfined groundwater system has been modified by the imposition of two synthetic flow systems: the 200 West Area and the 200 East Area (see Fig. 3-23).

The 200 West Area receives about one-third of the liquid disposed of at the Hanford Site. Based upon piezometer measurements, groundwater from this area appears to underflow that of the 200 East Area.(16)

The flow system of the 200 East Area and pond 216-A-25 receives about two-thirds of the liquid waste disposal at the Hanford Site. The input of 200 Areas effluents forms two "local" flow systems imposed over the "intermediate" flow system. (See Fig. 3-23.)

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3.5.4 The Unsaturated Zone

The unsaturated (vadose) zone has been defined by the U.S. Geological Survey's Committee on Redefinition of Groundwater Terms as:

> "...the zone between the land surface and the water table. Characteristically, this zone contains liquid water under less than atmospheric pressure, and water vapor and air or other gases usually at atmospheric pressure. In parts of this zone, interstices may be temporarily or permanently filled with water. Perched water bodies may exist within the unsaturated zone."(17)

On the Hanford Site, the thickness of the unsaturated zone varies from 0 to 350 ft.

The movement of water in the unsaturated zone is influenced by the physical properties of the sediments in two ways: the size and structural arrangement of the sediment particles determine the space configuration through which the water moves, and the interaction between the sediments and the water gives rise to water-moving forces. In sediments where pores are completely filled with water, the fluid is a single phase. Where water does not completely fill the pores, the hydraulic potential depends on the gravitational field and on the absorptive forces associated with interfacial boundaries in the sediments. Where air partially fills the soil pores, with water occupying the remaining void space, a two-phase flow can take place. As the percentage of liquid water decreases, it occupies the smallest capillaries that exist between soil particles.

During the year August 1, 1973, through July 31, 1974, Hanford experienced 170% of normal rainfall. At a field test site located south of the 200 East Area, where rainfall moisture penetration is measured routinely, this excessive rainfall penetrated about 8 ft into the sediments. Moisture from rainfall during this period appears to have evaporated to the atmosphere. The data indicate that the loss of moisture by evaporation is greater than that gained through precipitation, forming a desiccated zone at the near-surface during the summer months.(18) The Hanford sediments below a depth of about 30 ft are essentially dry.

3.5.5 Characteristics of the PUREX Plant Site

The PUREX Plant is underlain by three major stratigraphic units: basalt of the Columbia River Basalt Group which forms the local bedrock, semiconsolidated sediments of the Ringold Formation which overlie the bedrock, and unconsolidated sand, silt, and gravel of the Hanford formation (Ref. 12 and 19 through 21).

The surface of the Columbia River Basalt Group beneath the PUREX Plant lies about 300 ft above mean sea level, whereas the PUREX Plant is about 700 ft above MSL. The water-table elevation beneath the PUREX Plant is about 400 ft above MSL. Prior to Hanford operations, the water table beneath the PUREX site and the present 200 East Area waste disposal ponds was about 380 ft above MSL. The water table has been raised by the disposal of effluent to surface ponds and cribs. The water-table rise beneath the two major surface ponds (ponds 216-A-25 and 216-B-3), has been about 25 ft. Beneath the PUREX Plant itself, the water level has risen about 20 ft.(2)

The groundwater monitoring network surrounding the PUREX Plant and ponds 216-A-25 and 216-B-3 are shown in Figures 3-24 and 3-25, respectively. Wells used for water-level monitoring and geochemical sampling are noted. Three hydrographs, representative of the typical water-level rises in the vicinity of the PUREX Plant and the waste disposal ponds, are shown in Figure 3-26. The ground-water monitoring results for three sites near the PUREX Building are listed in Table 3-11. The monitoring results for three wells located near ponds 216-A-25 and 216-B-3 are given in Table 3-12.

Groundwater wells are currently sampled near the PUREX Plant and ponds 216-A-25 and 216-B-3 in accordance with the Rockwell and Pacific Northwest Laboratory groundwater monitoring schedule.(22,23)

In the vicinity of the PUREX Plant and the associated liquid waste disposal ponds, the unconfined aquifer has a very high transmissivity and hydraulic conductivity. Consequently, the migration of liquids from disposal ponds down into the unconfined aquifer could occur rapidly. This is particularly true for pond 216-A-25, where the local water table is 30 ft below the pond level. Migration from pond 216-B-3 to the unconfined aquifer would take longer, since the unconfined aquifer lies about 150 ft below the pond. Radionuclides which are not readily absorbed on sediments would tend to move with the liquids.

3.6 REGIONAL GEOLOGY AND SEISMIC INFORMATION

3.6.1 Regional Physiography

The Hanford Site is situated within the Columbia Plateau physiographic province, characterized by the occurrence of a thick sequence of tholeiitic basalts varying significantly in topographic expression as well as structure. The Columbia Plateau physiographic province is bordered by the

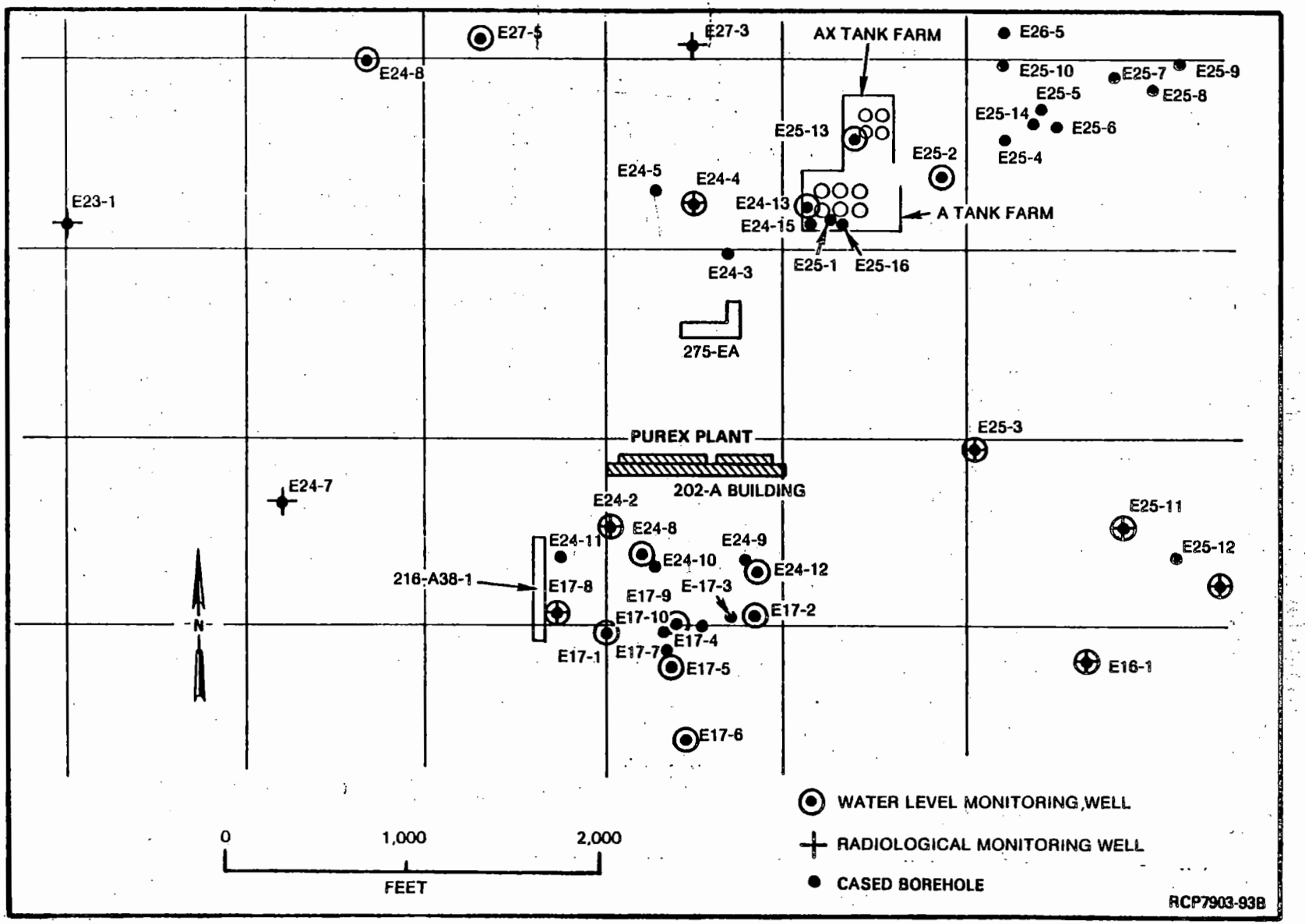

FIGURE 3-24. Groundwater Monitoring Network Surrounding PUREX Plant Facilities.

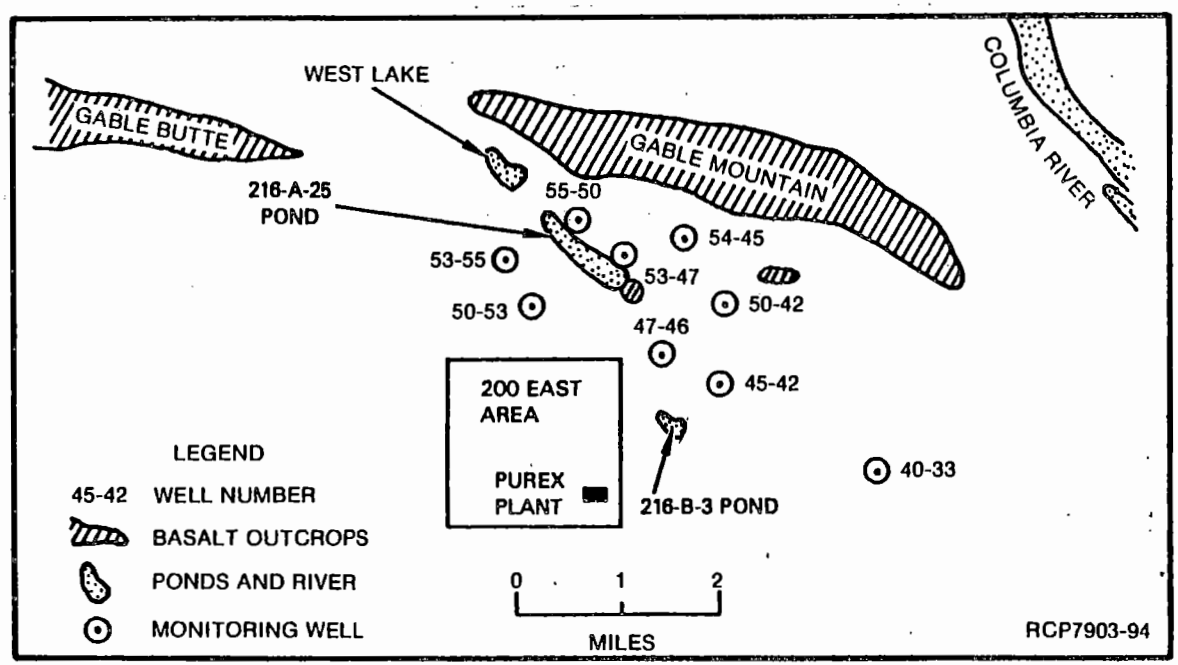

FIGURE 3-25. Groundwater Monitoring Network Near Ponds 216-A-25 and 216-B-3.

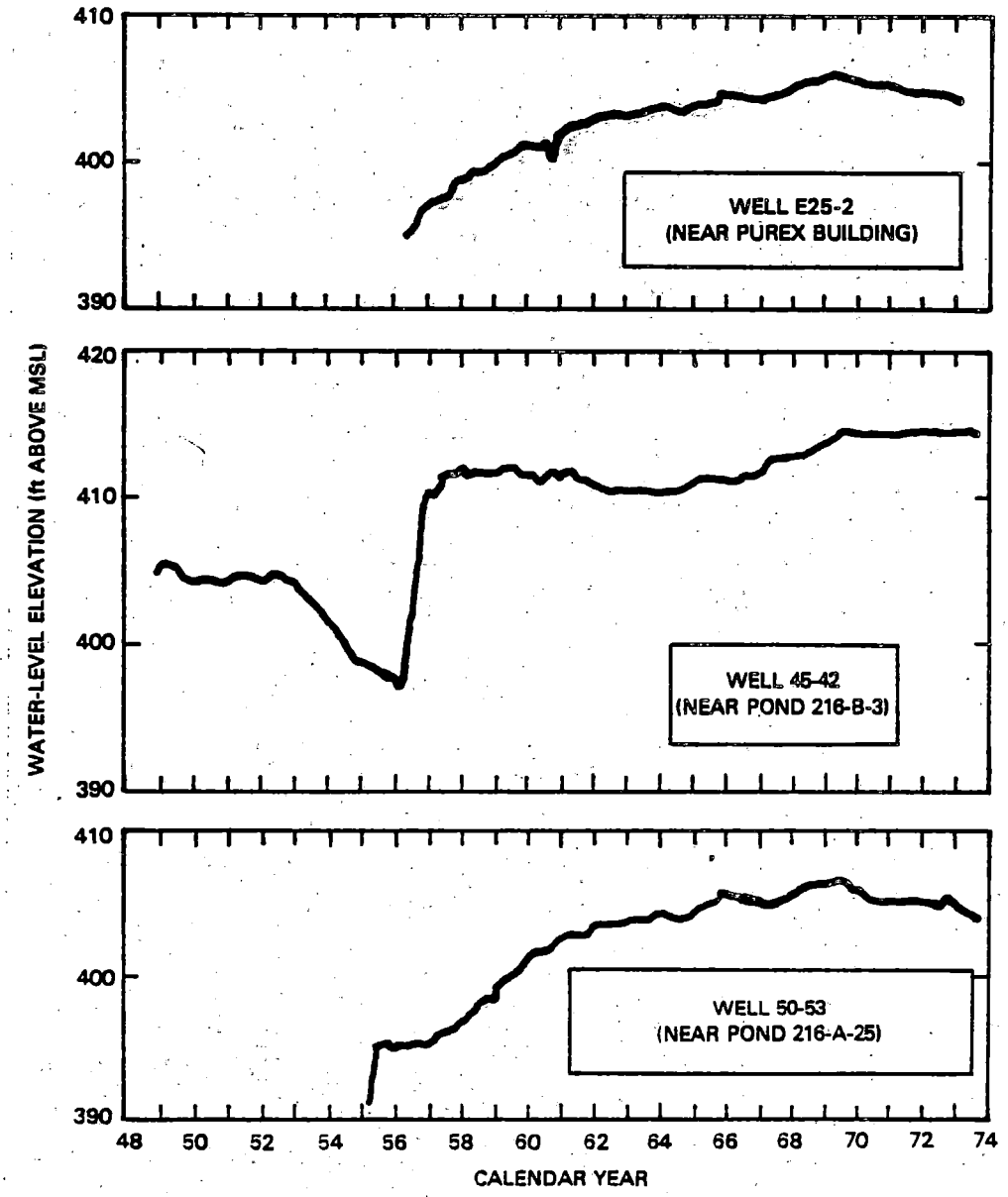

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FIGURE 3-26. Hydrographs for Selected Wells.

TABLE 3-11. Groundwater Quality Near PUREX Building.*
(See Fig. 3-24 for well locations.)

Well	Site monitored	Date	pCi/L							mg/L
			Total alpha	Total beta	^{60}Co	$^{89,90}Sr$	^{137}Cs	^{3}H	^{106}Ru	Nitrate*
E24-2	216-A-10	1/13/71	17	1,800	140	35	33	-	-	230
		1/13/72	17	790	49 ± 16	33	15	-	310 ± 71	-
		1/16/73	17	330	20	30	10	-	710 ± 610	-
		1/22/74	17	180	20	32	20	-	-	-
		1/16/75	17	80	30	10	25	6.7×10^6	-	-
		1/14/76	17	80	23 ± 24	16 ± 2.7	24	4.4×10^6	-	-
E24-12	216-A-31	1/13/72	17	870	28 ± 13	26	13	-	420 ± 67	160
		1/16/73	17	470	20	30	10	-	170 ± 70	176
		1/22/74	30	200	20	29	20	-	-	200
		1/16/75	22	120	-	-	-	4.8×10^6	-	-
		1/14/76	54	100	-	-	-	4.2×10^6	-	-
E17-9	216-A-36-A	1/13/72	17	7,000	12 ± 13	76	11	-	3,600	-
		1/16/73	17	3,100	20	99	30	-	-	-
		1/22/74	17	230	30 ± 30	47	20	-	-	-
		1/16/75	17	120	31	38	20	-	-	-
		1/14/76	17	80	55 ± 26	33 ± 10	28	-	-	-

*As N.

TABLE 3-12. Groundwater Quality Near Ponds 216-B-3 and 216-A-25.

Well	Year	Average Concentrations			
		pCi/L			mg/L
		Total beta	^{3}H	$^{89,90}Sr$	Nitrate*
699-42-42 (near pond 216-B-3)	1970	150	1.0×10^{6}	27	34.6
	1971	-	0.6×10^{6}	-	73.3
	1972	-	1.0×10^{6}	-	13.1
	1973	-	0.5×10^{6}	-	10.3
	1974	80	0.6×10^{6}	7.8	13.0
	1975	75	7,200	3.0	1.5
	1976	75	8,200	3.4	2.6
699-53-47 (near pond 216-A-25)	1970	160	5,400	-	0.5
	1971	-	3,100	-	0.5
	1972	-	3,400	-	0.5
	1973	-	3,600	-	0.5
	1974	-	810	-	0.5
	1975	-	1,200	-	0.5
	1976	-	840	-	0.5
699-55-50 (near pond 216-A-25)	1970	-	2,500	-	0.5
	1971	-	2,000	-	0.5
	1972	-	2,500	-	1.1
	1973	-	1,300	-	0.6
	1974	75	1,800	-	0.5
	1975	75	-	-	0.5
	1976	80	-	-	-

*As N.

Northern Rocky Mountains physiographic province to the north and east, the Basin and Range physiographic province to the south, and the Cascade and Pacific Border physiographic provinces to the west (Fig. 3-27).

3.6.1.1 Columbia Plateau Physiographic Province. The Columbia Plateau physiographic province can be subdivided into several smaller physiographic sections. The divisions are made as follows: Columbia Basin section, sometimes referred to as the Columbia Plateau; the Blue Mountains section; and the Harney-Snake River Plateau section.(24)

3.6.1.1.1 Columbia Basin Physiographic Section. The interior lowland portion of the Columbia Plateau, represented by a broad, geologic, and structural basin, is referred to as the Columbia Basin physiographic section.

The major topographic relief forms are several east- to southeast-trending ridges on the western side. The Frenchman Hills, Saddle Mountains, Horse Heaven Hills, Rattlesnake Hills, Yakima Ridge, and Umtanum Ridge are surface expressions of anticlinal folds of Tertiary Columbia River basalts and sedimentary interbeds. Within the Hanford Site, Rattlesnake Mountain, Yakima Ridge, and Umtanum-Gable Mountain Ridge represent an eastward to southeastward continuation of the ridge system.

The Pasco Basin is lowest of the several structural sub-basins within the Columbia Basin (Fig. 3-28). The PUREX Reprocessing Facility is in the Pasco Basin.

The Columbia Basin contains the Channeled Scablands formed at the close of Pleistocene glaciation. The Cordilleran Ice Sheet extended into northern Washington, but its maximum extent was 61 mi north of the Hanford Site. Ice-dammed lakes formed in northern Idaho and western Montana when ice lobes filled major drainage valleys. The failure of these dams resulted in multiple, catastrophic flooding as the water spilled across the Columbia Basin section. Maximum discharge through scabland channels has been estimated to be as much as 752 x 10^6 ft^3/s.(25) These floods eroded the basalt, Ringold Formation and Palouse Formation, forming large coulees and thick sequences of glaciofluvial sediments.(26)

The eastern portion of the Columbia Basin is comprised of rolling hills mantled by the Palouse loess derived from degradation of Quaternary sediments from the west-southwest and northwest.

The Columbia Basin section is drained by three major rivers: the Yakima River and its tributaries drain the southwestern portion, the Columbia River and its tributaries drain the central and northern portion, and the Snake River and its tributaries drain the southeastern portion.

3.6.1.1.2 Blue Mountains Section. The Blue, Ochoco, and Wallowa Mountains all occur in this section and contain elevated plateau basalts similar to those of the Columbia Basin, as well as older rocks that have become exposed by erosion. Alpine glaciers were present in the Wallowa Mountains during the Pleistocene.

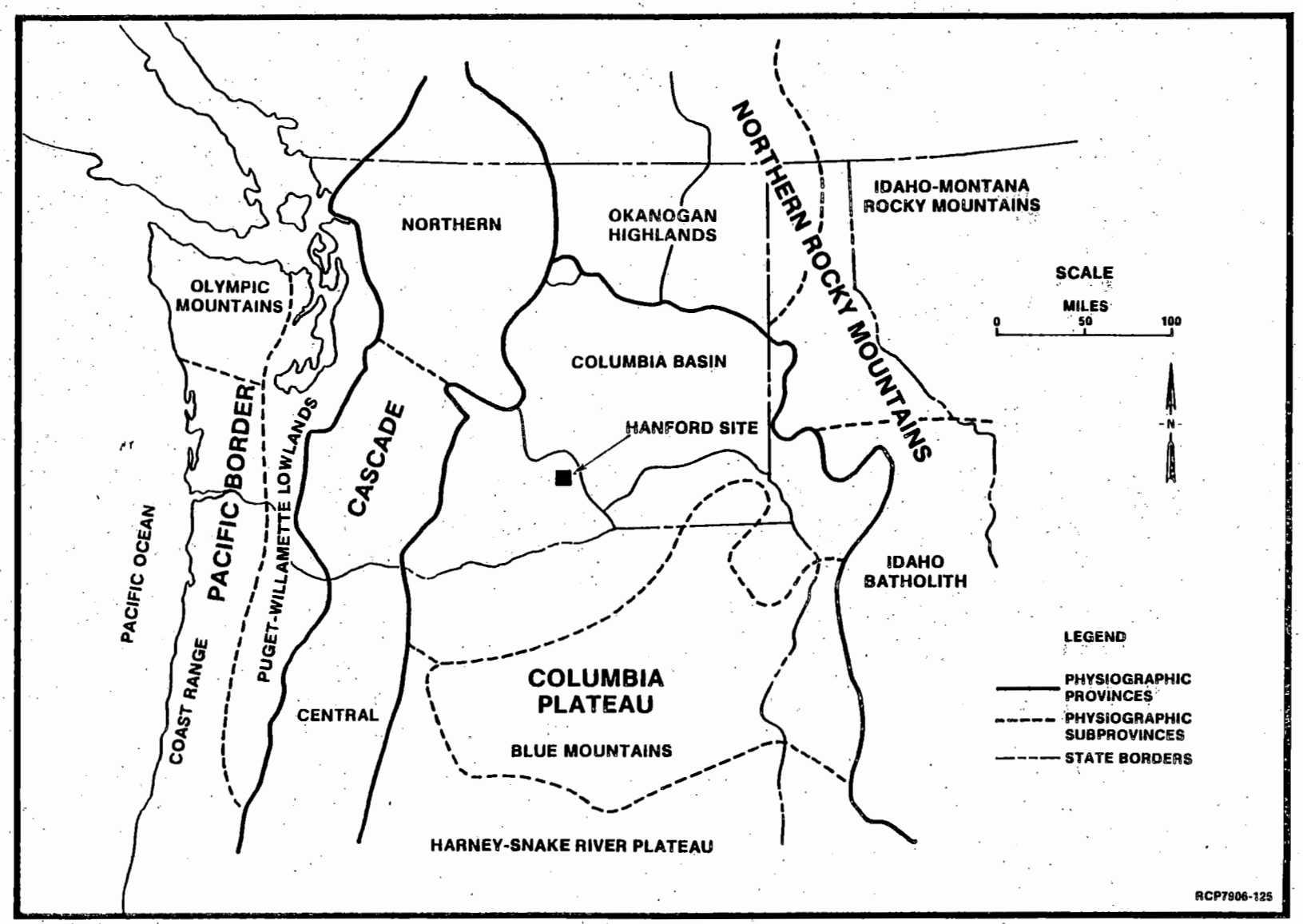

FIGURE 3-27. Physiographic Provinces.

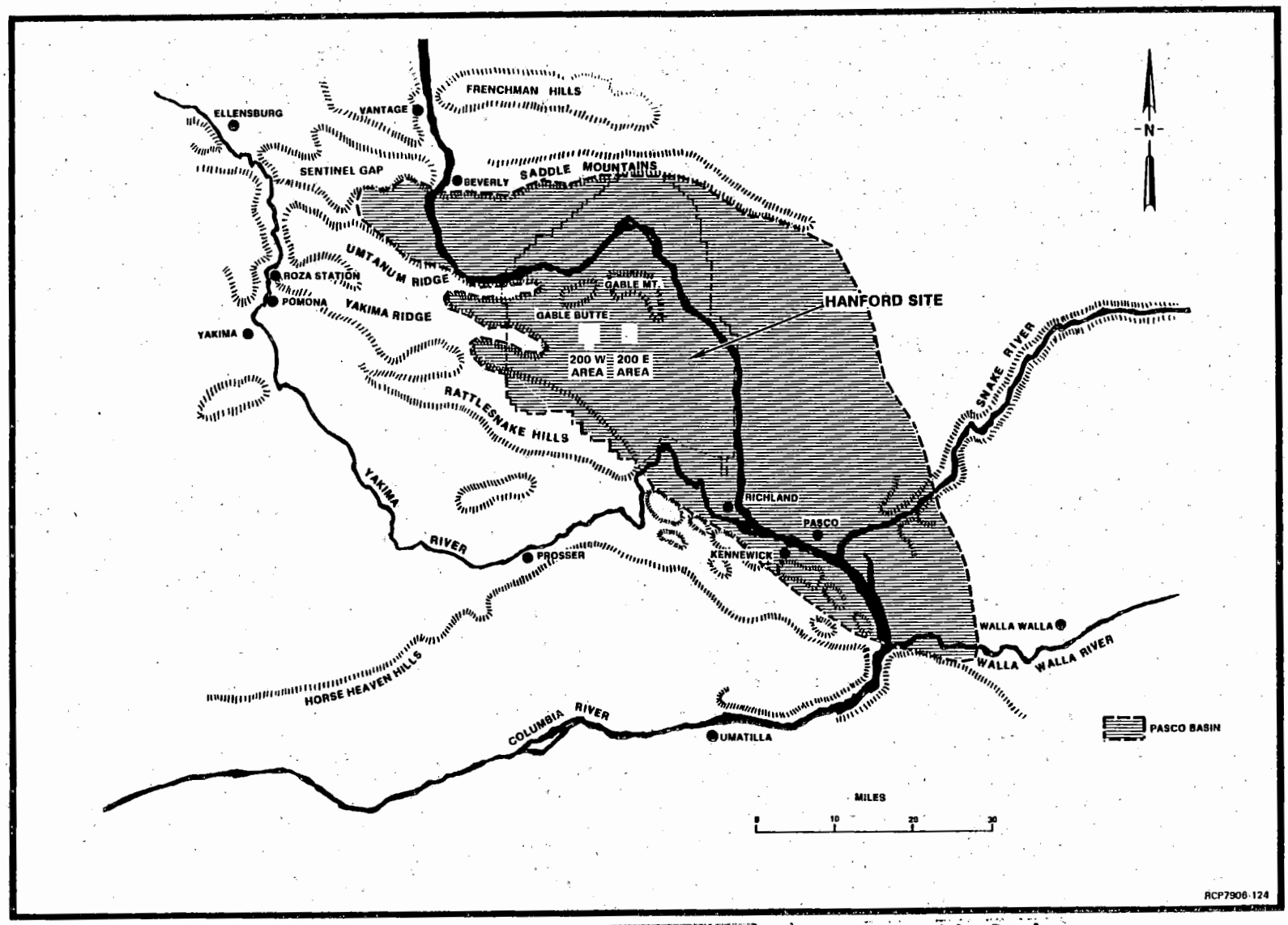

FIGURE 3-28. General Topography of Part of the Columbia Basin Physiographic Section (Pasco Basin).

The structure and topography of this section, which lies mostly in northeastern Oregon, has more in common with the Northern Rocky Mountains physiographic province than with the Columbia Basin section. The mountains rise above the Columbia Basin section to the north and the Harney-Snake River Plateau to the south. The Snake River crosses the eastern portion of this section through deeply entrenched gorges. The eastern portion is bordered by the Idaho Batholith section, a section of the larger Northern Rocky Mountains physiographic province.

The Wallowa Mountains are the southeastern end of the Olympic-Wallowa Lineament, a linear topographic feature.[27] This alignment is further described in Section 3.6.6.

3.6.1.1.3 Harney-Snake River Plateau Section. The Harney region lies south of the Blue Mountains and is a high plain with little local relief, except for volcanic craters mostly Quaternary in age. Internal drainage is characteristic of this region.

The Snake River Plateau region lies beyond the 200-mi radius.

3.6.1.2 Northern Rocky Mountains Physiographic Province. The Northern Rocky Mountains are subdivided into the Okanogan Highlands section, the Idaho-Montana Rocky Mountains section, and the Idaho Batholith section.

3.6.1.2.1 Okanogan Highlands Section. This section lies north of the Columbia Basin section of the Columbia Plateau. The southern boundary is where the Columbia River basalt laps onto the highland. It is made up of north-south-trending mountains between the Cascade Range physiographic province to the west and the Idaho-Montana section of the Northern Rocky Mountains physiographic province to the east. The region slopes toward the south with stream drainage into the Columbia Basin. The Okanogan Highlands molded by Pleistocene glaciation have been highly dissected by fluvial erosion.

3.6.1.2.2 Idaho and Montana Northern Rocky Mountains Section. The mountains of this section of the Northern Rocky Mountains physiographic province have a north-northwest fabric and are drained by the Clark Fork River, Kootenai River, Pend Oreille River, and other tributaries of the Columbia River. The section was glaciated by both continental and alpine glaciers. The flood waters which formed the Channeled Scablands of the Columbia Basin had their origin in this section when ice blocked the Clark Fork River and formed Glacial Lake Missoula.

3.6.1.2.3 Idaho Batholith Section. This section of the Northern Rocky Mountains is defined geologically. It lies east of the Blue Mountains section and is drained by the Salmon and Clearwater Rivers, which flow into the Snake River.

3.6.1.3 Cascade Range Physiographic Province. The Cascade Range is bordered by the Columbia Plateau and Northern Rocky Mountain physiographic provinces on the east and the Pacific Border physiographic province on the west. In Washington, the northern section of the range is referred to as the Northern Cascade Range. In Oregon, the Cascades are divided into the

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Western Cascade Range and the High Cascade Range which extends into Washington. Mount Hood, Mount Rainier, Mount Adams, and Mount St. Helens are prominent Quaternary stratovolcanoes of the High Cascades. Many glaciers are present on the high peaks of the Cascades. The Columbia River cuts across the Cascade Range at the Washington-Oregon border.

3.6.1.4 Pacific Border Physiographic Province. The Pacific Border physiographic province [28] includes the Puget-Willamette Lowlands section, the Coast Range section, and the Olympic Mountains section.

3.6.1.4.1 Puget-Willamette Lowlands Section. This lowlands section extends from Eugene, Oregon to Vancouver, British Columbia. The northern part of this section, which lies in general between the Cascade Range and the Olympic Mountains, was modified during the Pleistocene by the Puget Sound ice lobe. The southern portion of the Puget-Willamette Lowlands is drained by the Willamette River and contains fluvial and glaciofluvial valley fill.

3.6.1.4.2 Olympic Mountains Section. Included in this section are the Olympic Mountains of Washington. The Olympics are higher, wider, and more rugged than the Oregon Coast Range, and many alpine glaciers are found there.

3.6.1.4.3 Coast Range Section. The Coast Range extends about 600 mi along the Pacific Coast of Washington and Oregon. The anticlinorium in the Coast Range south of the Olympic Mountains is Miocene and Pliocene in age.

3.6.2 Regional Geology

The regional geology is dominated by Cenozoic volcanic rocks and structures. A generalized geologic map of the region is shown in Figure 3-29. A regional tectonic map is shown in Figure 3-30. The major regional geologic provinces are described in the following subsections.

3.6.2.1 Columbia Basin. The Columbia Basin is a broad structural basin that was downwarped while lavas were periodically being extruded. The region continued to deform, forming anticlinal ridges coincident with the axis of the anticlines. The Columbia Basin contains a thick sequence of Miocene basalt flows with intercalated sedimentary interbeds overlain by Pliocene-Pleistocene lacustrine and fluvial sediments, Pleistocene glaciofluvial sediments and Holocene alluvium, colluvium, and eolian deposits.

3.6.2.2 Blue Mountains. The Blue Mountains section is a northeasterly trending complex of deformed Paleozoic and Mesozoic sediments and intrusive Cenozoic rocks that lie south of the Columbia Basin section. The structure is generally described as an asymmetric anticline with a steep northern flank and gently dipping southern flank. Some of the region is covered with basalt which has been elevated and deformed by continued orogenic activity. Resulting erosion has stripped much of the younger basalts and exposed Paleozoic and Mesozoic rocks not found in the Columbia Basin. The present topography is a result of major Pliocene deformation and Quaternary erosion.

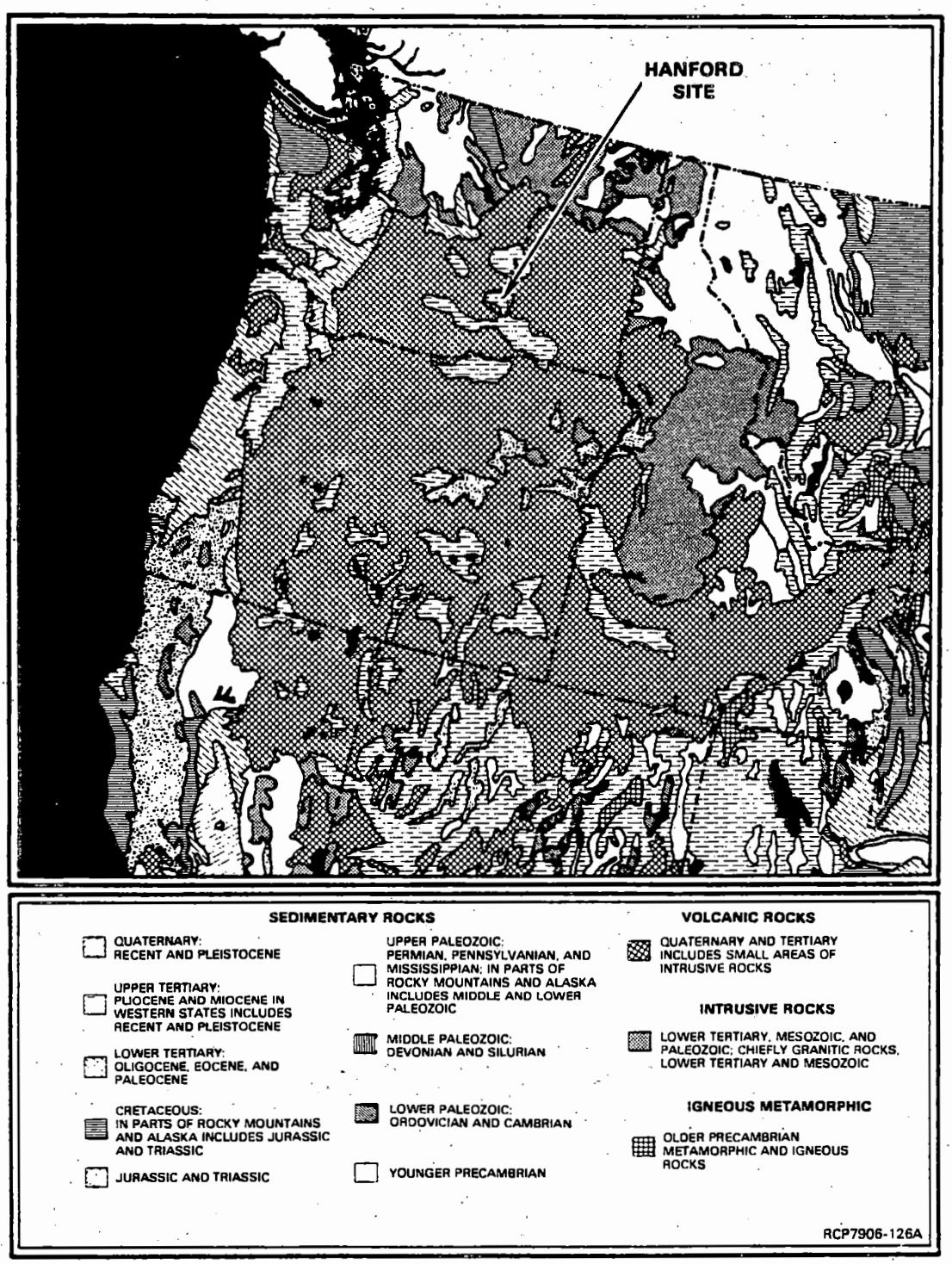

FIGURE 3-29. Regional Geologic Map.

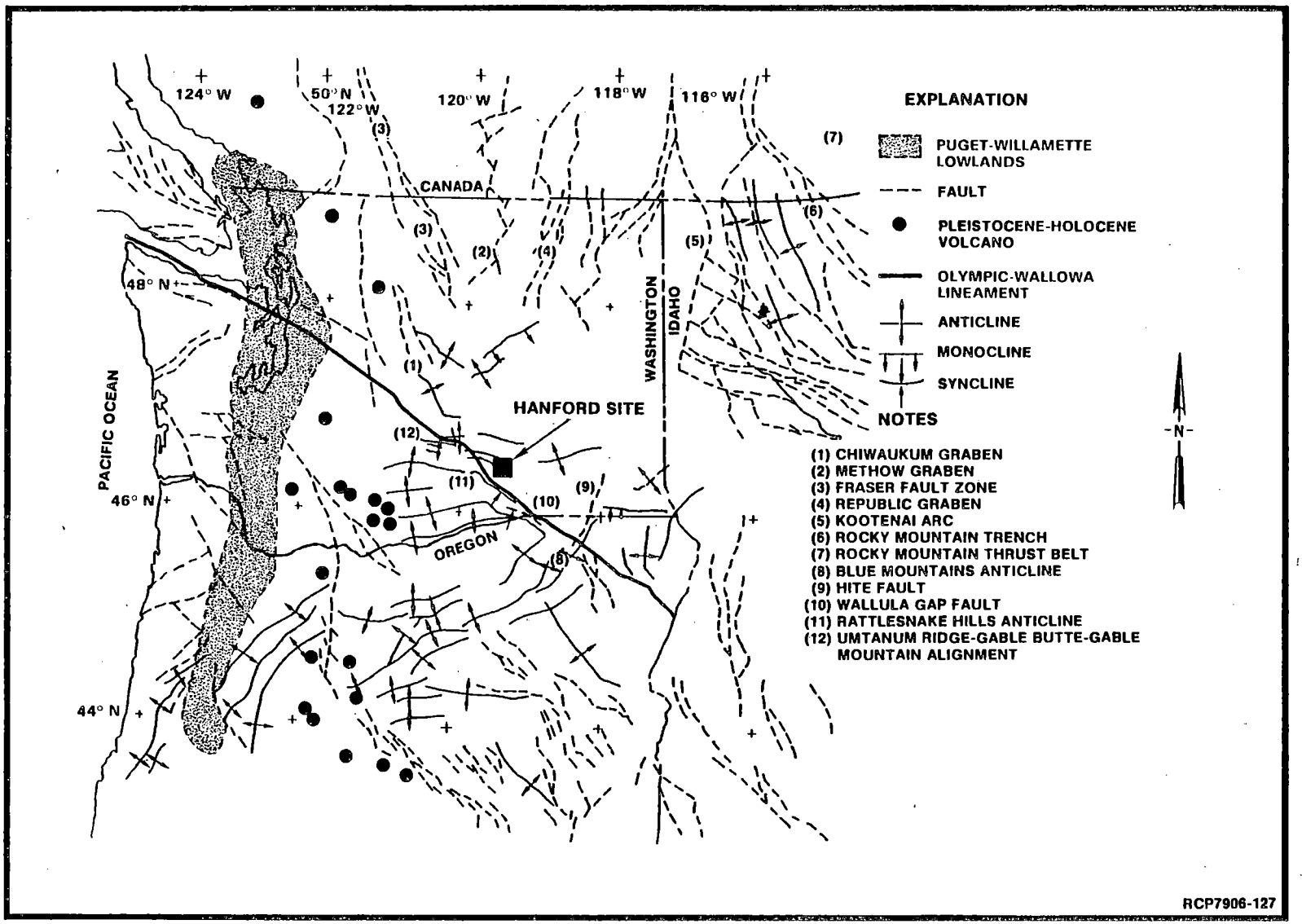

FIGURE 3-30. Regional Tectonic Map.

3.6.2.3 Harney Region. This region lies south of the Blue Mountains and extends from the Cascades to the Steens Mountains in southern Oregon. This region is similar to the Columbia Basin in that it is dominated by basalt flows and sedimentary interbeds. The region lacks the fluvial and eolian overburden found in the Columbia Basin.

3.6.2.4 Idaho Batholith. The area lies southeast of the Columbia Basin and south of the Idaho-Montana Northern Rocky Mountains. The most prominent rock types are quartz monzonites and granodiorites with some granites. The main batholithic intrusion took place during the Cretaceous.

3.6.2.5 Idaho and Montana Northern Rockies. This section is northeast of the Columbia Basin and primarily consists of an extensive segment of Precambrian crystalline and sedimentary rocks. The dominant rock types are quartzites, slates, and argillites of the Belt Supergroup. Major deformation and mountain building took place during the Mesozoic.

3.6.2.6 Okanogan Highlands. This section, which lies north of the Columbia Basin, can be divided into two geologic regions.(26) East of the Columbia River, the region is composed of Precambrian Beltean rocks and lower Paleozoic rocks primarily composed of quartzite, phyllites, and carbonates. This portion of the highlands has been folded and faulted during several periods of deformation and was intruded by granitic intrusions of British Columbia. The folds of this belt are cut by pre-Tertiary faults.

The area west of the Columbia River is composed of graywacke, greenstone, slate, chert, conglomerates, and limestone. The sediments have been intruded by late Mesozoic quartz monzonites and granodiorites. Tertiary volcanics unconformably cap the older rocks. The western portion contains north-south-trending, high-angle, normal faults which have preserved the Tertiary rocks by down faulting into older crystalline rocks.

3.6.2.7 Cascade Range. This north-south-trending morphologic geotectonic unit extends from southern British Columbia to northern California along the western boundary of the Columbia Basin. The broad uparching occurred normal to a north-south axis during late Pliocene and early Pleistocene time. The uplift increased to the north, reached a maximum in the North Cascades near the Canadian border, and decreased to the south. Quaternary volcanic activity has built large stratovolcanic cones which dominate the southern portion of the range and decrease in number to the north. The Cascade Range can be divided into three geologic subprovinces: the Western Cascades of Oregon, the High Cascades of Oregon and Washington, and the Northern Cascades of Washington.(29) The High Cascades are composed of coalescing Pliocene shield volcanoes capped with Quaternary stratovolcanoes. The Western Cascades of Oregon extend the length of Oregon and into southern Washington and are composed of slightly to moderately deformed rocks of Eocene through Miocene age. The Northern Cascades include the part of the range north of Snoqualmie Pass and are dominated by pre-Cenozoic igneous and metamorphic rocks.

The geology of the North Cascades is strongly influenced by large steeply dipping faults of late Mesozoic, early Cenozoic age. The crystalline core is composed of deformed schists and gneisses and is flanked by younger sedimentary and volcanic rocks. In general, the oldest rocks are the most strongly deformed.

3.6.2.8 Puget-Willamette Lowlands. This section lies between the Cascade Range and the Coast Range. The structure is a broad downwarp with transverse-trending faults and folds. Rock outcrops are closely related to the Tertiary rocks of the nearby Cascade and Coast Range provinces. The lowland contains thick deposits of Quaternary fill.

3.6.2.9 Coast Range. The Coast Range of Washington and Oregon extends about 600 mi from the Klamath Mountains of southwestern Oregon to the Strait of Juan de Fuca in northwestern Washington. Tertiary eugeosynclinal sediments are exposed in the core of the Olympic Mountains and the Coast Range, the oldest of which are low-grade metasediments, argillites, and graywackes. The flanks of the Olympics are made up of marine basalts and marine sedimentary rocks of Eocene and Miocene age. The anticlinorium in the Coast Range south of the Olympic Mountains is Miocene and Pliocene in age.

3.6.3 Geological Setting of the Pasco Basin

The Pasco Basin (Fig. 3-31) is one of several structural and topographic basins within the western Columbia Plateau. The Pasco Basin is partly surrounded by large anticlinal ridges, the Yakima Folds, that developed during Miocene and Pliocene time. The Saddle Mountains form the northern boundary of the Pasco Basin, Umtanum Ridge and Yakima Ridge form the western boundary, Rattlesnake Hills and Horse Heaven Hills form the southern boundary, and a broad zone of gradually increasing westward dip forms the eastern boundary. Umtanum Ridge and Yakima Ridge plunge eastward, decrease in relief, and die out within the basin interior.(12)

The Pasco Basin occupies about 2,000 mi^2 between 46°00' and 46°50' north latitude, and 119°00' and 120°20' west longitude. It is a semiarid steppe with a sparse covering of vegetation. Descriptions of the climate, soil, vegetation, terrain, and other aspects of the geography of the basin are in reports that describe the Hanford Site environment.(2,30)

The Pasco Basin is underlain by a bedrock section of the Columbia River Basalt Group at least 4,800 ft thick. This bedrock section is overlain by 0 to greater than 700 ft of fluvial, lacustrine, and glaciofluvial sediments of Pliocene and Pleistocene age, with the greater sediment thicknesses in the synclinal positions in the basin interior. Volcaniclastic sedimentary layers are interbedded between the basalt flows in the upper part of the bedrock section. Many of the basalt flows throughout the bedrock section are apparently blanket-like and extend laterally as single rock-stratigraphic units (and time-stratigraphic units) across the Pasco Basin and beyond; whereas other flows are less extensive, although still blanket-like, and pinch out within the basin. A few flows in the upper part of the section were emplaced as valley fills and are restricted in their lateral extent.(12)

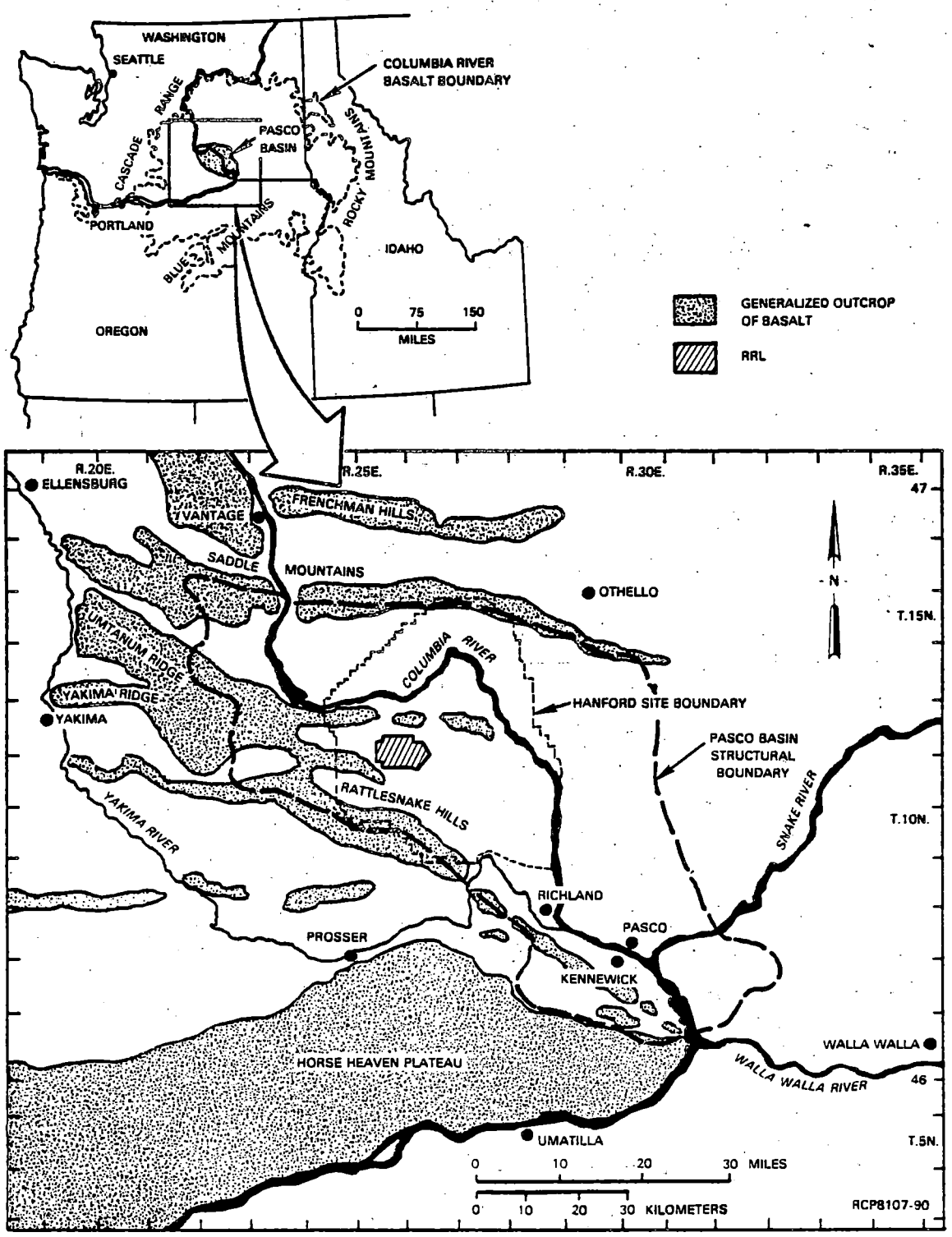

FIGURE 3-31. Geologic Setting of the Pasco Basin.

Yakima Folds bound the Pasco Basin on the north and south and plunge eastward into the basin from the west (see Fig. 3-31). Structural deformation that formed the Yakima Folds was occurring during deposition of the younger basalt flows and sedimentary interbeds. Consequently, these younger units are thick in synclines and thin or pinch out toward anticlines. Most anticlines are asymmetric and have second-order folds in their hinge zones. Their style of deformation changes along strike and their steep flanks are commonly faulted where structural relief is high. Synclines between the anticlines are generally broad, open folds. Drill holes and geophysical surveys reveal that most subsurface structures in the central Pasco Basin appear to be extensions of the Yakima Folds and their associated second-order structures, but a few subsurface structures might be related to northwest-trending, structures that appear to cross-cut the east-west-trending Yakima Folds.[12]

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3.6.4 Geology of the Pasco Basin

3.6.4.1 Stratigraphy and Lithology. The Pasco Basin is underlain by five major rock units: Pre-Columbia River Basalt Group rocks, Columbia River Basalt Group, Ellensburg Formation, Ringold Formation including the Palouse Soil, and Hanford formation (informal name). These major rock units are locally mantled by surficial sediments. All major rock units crop out within the Pasco Basin except for Pre-Columbia River Basalt Group rocks, although they are partially penetrated in borehole RSH-1 at depths below about 4,000 ft. Formal rock stratigraphic nomenclature used in the Pasco Basin is shown in Table 3-13.[12] The surface of the basalt is given in Figure 3-32.[31] Generalized geologic cross sections of the Pasco Basin are given in Figures 3-33 and 3-34.[31]

3.6.4.1.1 Pre-Columbia River Basalt Groups Rocks. The deep-seated, crustal rocks of the Pre-Columbia River Basalt Group are interpreted from geophysical data and from one deep borehole. The geophysical techniques included an unreversed, north-south refraction profile across eastern Washington;[32] seismic modeling;[33,34] and magnetotelluric surveys.[35] The borehole data are from RSH-1 drilled by Standard Oil Company of California on the south slope of Rattlesnake Mountain.

Results from these surveys and borehole data indicate a deep-seated crystalline basement, possibly of granite origin, overlain by a 3,000- to 6,000-ft-thick section of sedimentary rocks. A volcanic rock sequence is interpreted to overlie the sedimentary rocks. Details of the geophysical surveys and borehole data are given in Reference 12.

3.6.4.1.2 Columbia River Basalt Group. Lavas of the Columbia River Basalt Group on the Columbia Plateau (see Fig. 3-31) comprise a tholeiitic flood-basalt province of moderate size covering an area of about 78,000 mi^2 and having an estimated volume of about 41,000 mi^3.[36] The plateau is both a structural and topographic depression with its lowest elevation in the center of the province, the approximate location of the Pasco Basin (see Fig. 3-31 and 3-32). Here, the accumulation of flows of the Columbia River Basalt Group and interbedded sediments attain their maximum known thickness, greater than 4,550 ft.[28]

TABLE 3-13. Pasco Basin Stratigraphic Nomenclature.

PERIOD	EPOCH	GROUP	SUBGROUP	FORMATION	K-Ar AGE YEARS x 10⁶	MEMBER OR SEQUENCE	SEDIMENT STRATIGRAPHY OR BASALT FLOWS	
QUATERNARY	Pleistocene/ Holocene					SURFICIAL UNITS	LOESS	
							SAND DUNES	
							ALLUVIUM AND ALLUVIAL FANS	
							LANDSLIDES	
							TALUS	
							COLLUVIUM	
	Pleistocene			Hanford		TOUCHET BEDS/ PASCO GRAVELS		
TERTIARY	Pliocene			Ringold			UPPER RINGOLD (FANGLOMERATE)	
							MIDDLE RINGOLD (FANGLOMERATE)	
							LOWER RINGOLD (FANGLOMERATE)	
							BASAL RINGOLD (FANGLOMERATE)	
	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Saddle Mountains Basalt	8.5	ICE HARBOR MEMBER	GOOSE ISLAND FLOW	ELLENSBURG FORMATION Tel
							MARTINDALE FLOW	
							BASIN CITY FLOW	
							LEVEY INTERBED	
					10.5	ELEPHANT MOUNTAIN MEMBER	UPPER ELEPHANT MOUNTAIN FLOW	
							LOWER ELEPHANT MOUNTAIN FLOW	
							RATTLESNAKE RIDGE INTERBED	
					12.0	POMONA MEMBER	UPPER POMONA FLOW	
							LOWER POMONA FLOW	
							SELAH INTERBED	
						ESQUATZEL MEMBER	UPPER GABLE MOUNTAIN FLOW	
							GABLE MOUNTAIN INTERBED	
							LOWER GABLE MOUNTAIN FLOW	
							COLD CREEK INTERBED	
						ASOTIN MEMBER	HUNTZINGER FLOW	
						WILBUR CREEK MEMBER	WAHLUKE FLOW	
						UMATILLA MEMBER	SILLUSI FLOW	
							UMATILLA FLOW	
					13.6		MABTON INTERBED	
				Wanapum Basalt		PRIEST RAPIDS MEMBER	LOLO FLOW	
							ROSALIA FLOWS	
							QUINCY INTERBED	
						ROZA MEMBER	UPPER ROZA FLOW	
							LOWER ROZA FLOW	
							SQUAW CREEK INTERBED	
						FRENCHMAN SPRINGS MEMBER	APHYRIC FLOWS	
							PHYRIC FLOWS	
					14.5		VANTAGE INTERBED	
				Grande Ronde Basalt		SENTINEL BLUFFS SEQUENCE	UPPER Cr FLOWS	
							INTERMEDIATE Cr FLOWS	
							LOWER Cr FLOWS	
							McCOY CANYON FLOW	
						SCHWANA SEQUENCE	INTERMEDIATE-Mg FLOW	
							LOW-Mg FLOW ABOVE UMTANUM	
							UMTANUM FLOW	
							HIGH-Mg FLOW BELOW UMTANUM	
							VERY HIGH-Mg FLOWS	
					16.5		AT LEAST 30 LOW-Mg FLOWS	

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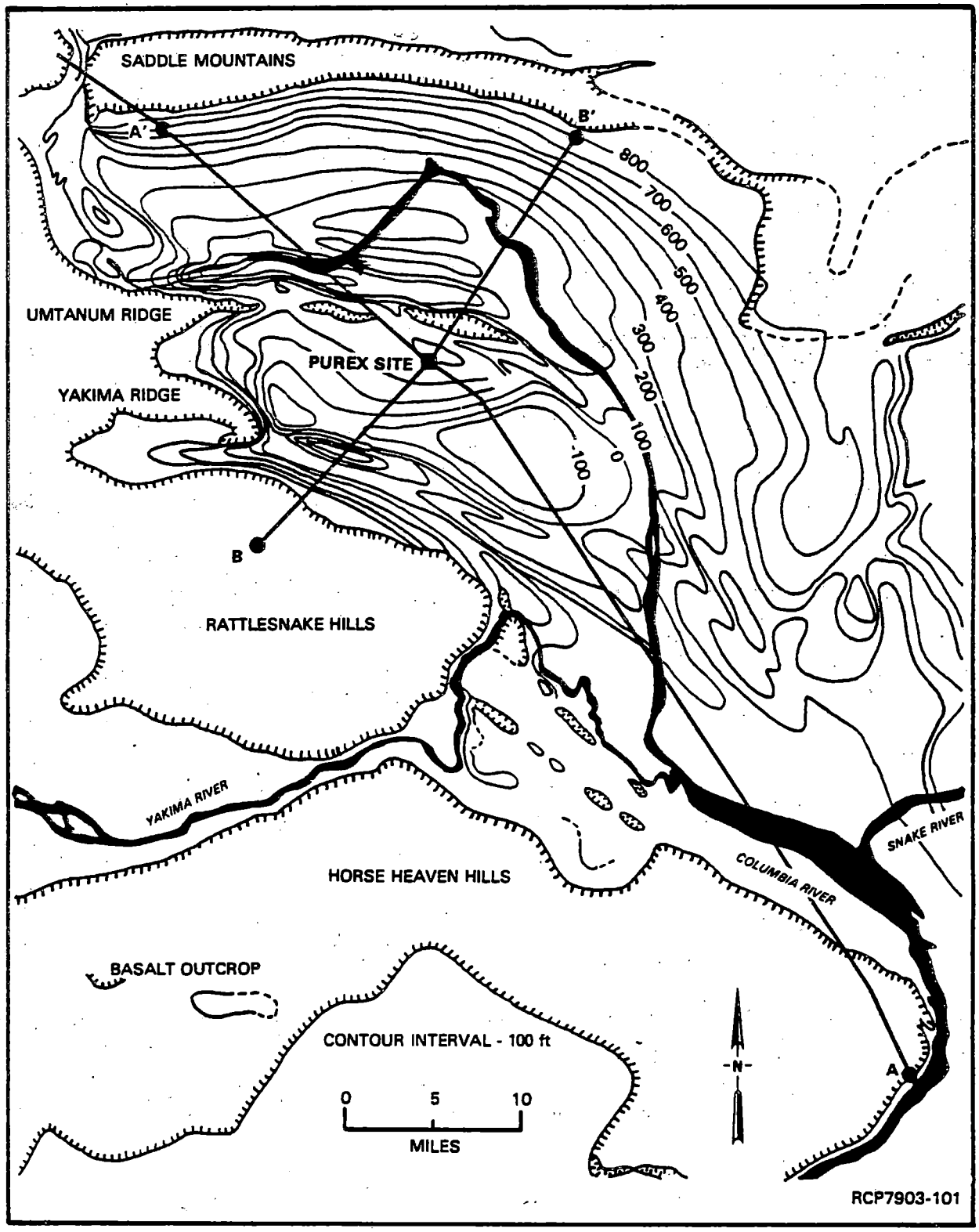

FIGURE 3-32. Surface of the Basalt in the Pasco Basin.

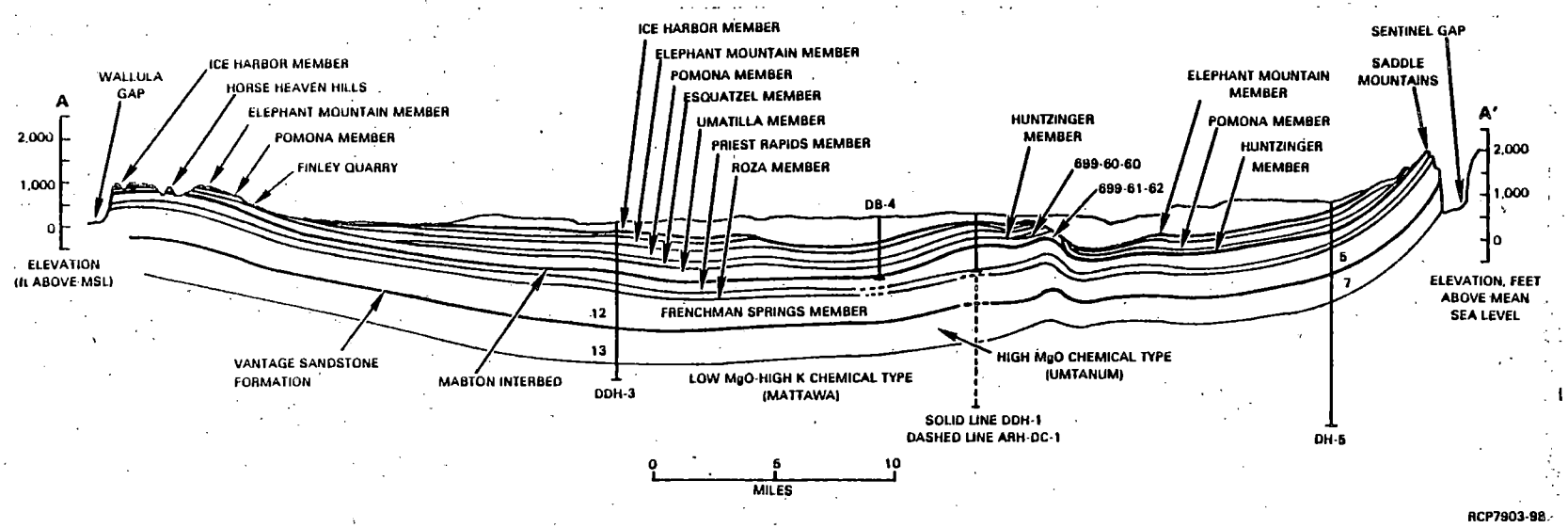

FIGURE 3-33. Generalized Geologic Cross Section Underlying the Pasco Basin, Cross Section A-A'.

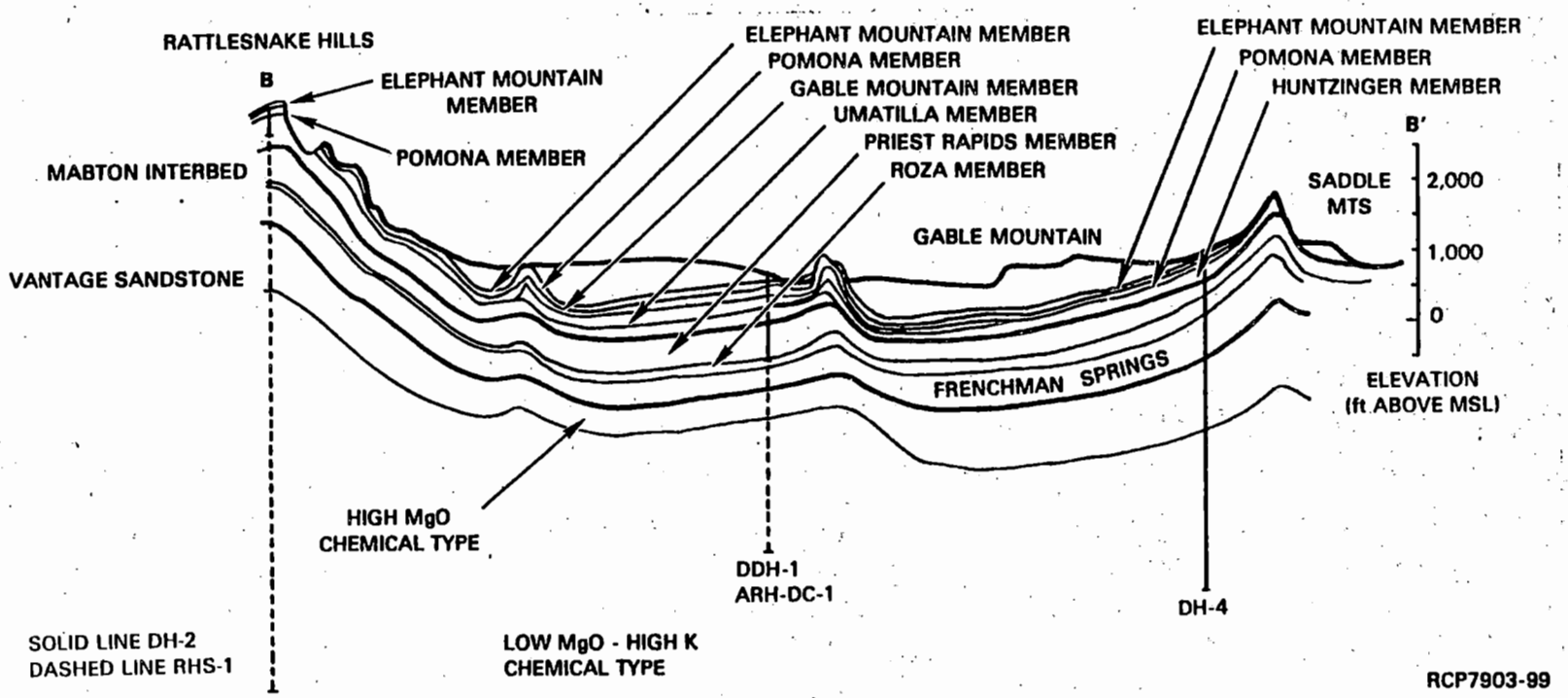

FIGURE 3-34. Generalized Geologic Cross Section Underlying the Pasco Basin, Cross Section B-B'.

The Columbia Plateau is the earth's youngest recognized flood-basalt province. It was formed between 16.5 and 6 million years ago,[37,38] when large volumes of lava were erupted from north-northwest-trending linear vent systems now preserved as dikes.[39,40] Individual Columbia River basalt flows are voluminous, generally 2 to 6 mi^3, with a maximum known volume of 145 mi^3. Flows range in thickness from a few inches to about 300 ft, with an average thickness of 90 to 120 ft. The thickest flows are generally caused by ponding in pre-basalt valleys, in structurally controlled basins that developed during volcanism, or in narrow canyons previously eroded into older flows.[36]

The Columbia River Basalt Group in the Pasco Basin consists of three formations: Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt (see Table 3-13). Detailed stratigraphic and lithologic descriptions of the Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt are given in Reference 12.

3.6.4.1.3 Ellensburg Formation. Within the upper part of the basalt sequence, sedimentary materials are increasingly prevalent upward, beginning with the Vantage sandstone.[12] These volcaniclastic materials include tuffs and tuffaceous sediments of many kinds, now partly altered to clay. Virtually every basalt flow above the Vantage sandstone horizon is capped at one site or another by stream-deposited sediments. The extent and thickness of these interbedded sediments generally increase upward in the section and are more extensive in the western portion of the Columbia Plateau. The lower beds tend toward rock types common to the Okanogan Highlands, southern British Columbia, and the North Cascades. The upper beds show an increasing abundance of volcanic debris, referred to as the Ellensburg Formation.

Approximately 15,000,000 yr ago, the ancestral Columbia River was crossing central Washington, laying down trains of gravels, sands, silts, and clays comparable to today's Columbia River sediments. As the basalt flows advanced upon the river, the river was forced westward toward Yakima. As the basin subsided, the river returned by gravity to the basin center, leaving its sediment trains as a mark of earlier courses. East of the current course, river sediments are virtually nonexistent between basalt flows, attesting to the shift exclusively westward from the current basin center.

3.6.4.1.4 Ringold Formation. The Ringold Formation was deposited in response to a flattening of the gradient of the Columbia River, perhaps related to the uplift of the Horse Heaven Hills, and consequent deposition of the sediments carried. Previously, deformation of the basin was accompanied by basalt flow extrusion into the topographically low areas. Cessation of flows about 6,000,000 yr ago permitted the deposition of a continuous sequence of sediments. Initially, these were blends of up-river rock types derived from the North Cascades and the Okanogan Highlands, with volcanic debris, largely of andesitic composition, from the central and southern Cascades. These latter sediments were transported to the Pasco Basin by the ancestral Yakima and related rivers. With time, the composition of the sediments being deposited in the Pasco Basin became more and more that of the Okanogan rock type.

The beginning of anticlinal uplift, especially to the west and slightly prior to the eruptions of the latest basalt flows, locked the Columbia River into the Pasco Basin and halted the east to west migration. Somewhat later, uplift of the Horse Heaven Hills resulted in a continuously rising base level for the river and deposition of sediment. Today, the Ringold Formation is recognized only upstream from the Horse Heaven Hills, reflecting the control of deposition by those hills.

The Ringold Formation has arbitrarily been divided into a basal lower gravel, a lower blue clays unit, a middle gravel or conglomerate unit, and an upper sand-silt unit. This division can be generally applied to the Pasco Basin as a whole. Sands, silts, clays, and gravels are interbedded and inter-layered throughout the basin in a manner indicating a nearly continuous stream flow and continuous fluvial deposition. Locally, the finer grained sediments are true lacustrine deposits.

3.6.4.1.5 Palouse Soils. Eolian silt (loess) and fine sand overlie part of the eroded surface of the Ringold Formation and caliche bed beneath the western part of the Hanford Site.(41) These fine-grained sediments are considered to be the equivalent of the Palouse soils (loesses) of eastern Washington and western Idaho. The climate during the period was probably comparable to that of today, with effective wind transport and deposition of sediment.

3.6.4.1.6 Hanford Formation. The Ringold Formation and the basalts and sedimentary interbeds were eroded and truncated by normal flow of the Columbia River and by multiple floods that occurred when ice dams breached during the Pleistocene. These ice-dammed glacial lakes released catastrophic torrents. The floods scoured the land surface of the Hanford Site, leaving a network of buried channels filled with the outwash sands and gravels.

The glaciofluvial sediments in the Pasco Basin were deposited on the basalt and Ringold Formation. These sediments can be divided into the coarser sands, gravels, and boulders and are referred to as the Pasco Gravels;(42) the fine-grained sand and silt units are called the Touchet Beds.(43)

The Touchet Beds represent low-energy deposits in Glacial Lake Lewis, which formed when floodwaters were backed up behind the Wallula Gap constriction. The Pasco Gravels represent higher energy deposition in areas of more rapid water flow. In general, the Touchet Beds are found in the margins of the basin and the Pasco Gravels in and near the center of the basin. The characteristic variability of sediment size and degree of sorting within the "gravel" unit can be attributed to changes in water velocity and water level which occurred during the flooding process. The thickness of the Hanford formation varies significantly within the basin, with the thickest occurrence in the region of buried channels.

3.6.4.1.7 Volcanic Ash Deposits. Several volcanic ashfalls were deposited in the late Pleistocene and Holocene over the Pasco Basin sediments. The thin, widespread ash associated with the last major flood was identified as the Mount St. Helens Set S,(44) and dated at

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13,000 radiocarbon years before present (BP). Younger ash, such as that from Mount Mazama (6,600 yr BP) and Glacier Peak (12,000 yr BP) have been found in the basin where the environment was favorable for preservation. The latest ashfall to be preserved in the Pasco Basin is from the May 18, 1980 eruption of Mount St. Helens.

3.6.4.1.8 Eolian Deposits. Loess and sand dunes mantle the surface of the Pasco Basin. These deposits are primarily reworked sediments of the Hanford formation. The thickness of the wind-blown sediments varies considerably, ranging to greater than 50 ft in some dunes.

3.6.4.2 Structure. The major structural elements of the region surrounding the PUREX Plant are shown in Figures 3-33, 3-34, and 3-35. Tectonic deformation has resulted in folding and related secondary faulting.(12,45,46)

3.6.4.2.1 Folds. The prominent structural features in the Columbia Basin are the folds in the Columbia River basalts. Folding has divided the Columbia Basin into several subbasins and produced numerous anticlinal ridges. Although the orientation of the folds is generally east-west, the folds can be classified into three general orientations: east-west trending, west-northwest trending, and northeast trending. Examples follow.(12,29)

- East-West-Trending Folds

  The Toppenish anticline, Wapato syncline, the western portion of the Rattlesnake anticline, Moxee syncline, and Yakima anticline make up an asymmetrically folded ridge system with steep north slopes and gentle south slopes. The Saddle Mountains, Frenchman Hills, and Soap Lake anticlines are north and east of this fold system and are also asymmetrical, with the steep dips on the north slopes.

- West-Northwest-Trending Folds

  The eastern portion of the Horse Heaven Hills and the Rattlesnake Hills, Umtanum Ridge and Manastash Ridge anticlines all trend west-northwest with steep north slopes. Gable Butte and Gable Mountain appear to be an east-west extension of Umtanum Ridge. Kittitas, Wenas, Wahluke, and Cold Creek are west-northwest-trending synclines. The Cold Creek and Wahluke synclines underlie the Hanford Site.

- Northeast-Trending Folds

  The Columbia Hills, the western portion of the Horse Heaven Hills, and the Beezley Hills are northeast-trending anticlines. The Horse Heaven Hills anticline is asymmetrical, with a steeply dipping north slope and a gently dipping south slope. The Beezley Hills anticline reflects generally the same asymmetry, but the crest is very convoluted and is offset by minor faults and cross folds.(47)

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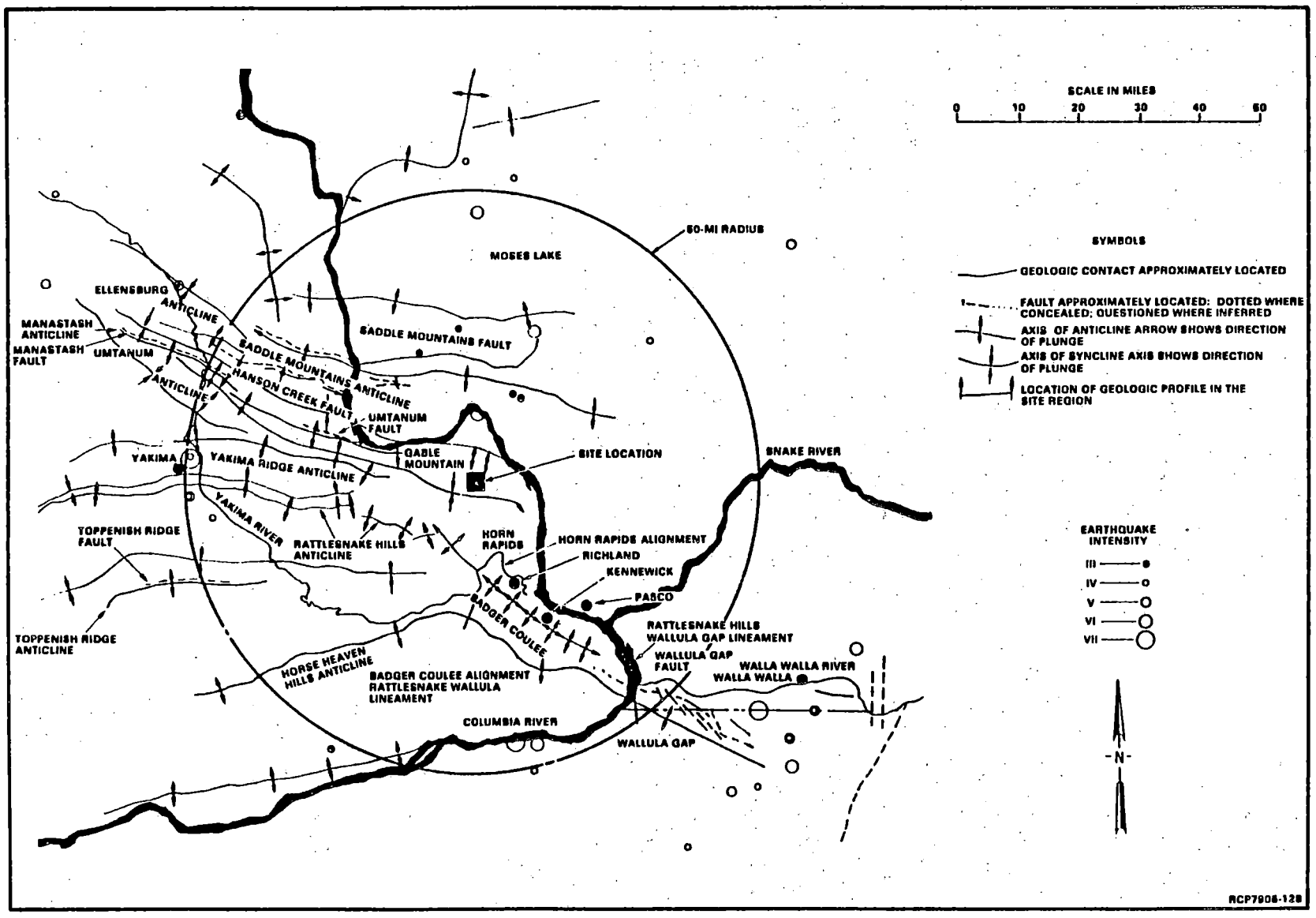

FIGURE 3-35. Columbia Basin Structural Elements.

3.6.4.2.2 Faults. The faults mapped in the Columbia Basin are associated with folds in the basalt and appear to reflect local adjustments to folding. The faults are relatively short in length, with generally small displacements. In most cases, the major faults are about 30 mi in length. The offset is generally less than 500 ft,[12,45,48] but an offset of 1,000 ft of vertical movement in the Wallula Gap fault was found.[49] There are very few geometric features which can be attributed to recent fault activities--a possible exception being the triangular facets to the east of the Columbia River along the Wallula Gap fault. The faults and associated anticlinal folds in the Pasco Basin and vicinity are listed below and shown in Figure 3-35:

- Wallula Gap fault and Rattlesnake Hills anticline
- Umtanum fault and anticline
- Gable Butte and Gable Mountain and minor faults
- Manastash Ridge fault and anticline
- Saddle Mountains fault and anticline[29]
- Toppenish Ridge fault and anticline.

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3.6.5 Tectonic Structures

Tectonic discussions can be found in Reference 29. Significant structures in the Hanford Site are presented in the following subsections.

3.6.5.1 Gable Mountain. Gable Mountain is 4 mi from the PUREX site and is made up of two major, en echelon, doubly plunging anticlines separated by a synclinal trough.[47] The eastern anticline is asymmetrical with a steep north slope and the western anticline is asymmetrical with a steep south slope. A fault on Gable Mountain appears to be of the same period as the folding and has a stratigraphic displacement of 70 ft or less. Glaciofluvial deposits overlying this fault have been ^{14}C dated as being more than 40,000 yr old. No displacement by faulting could be found in these sediments.[48] However, shearing in the glaciofluvial deposits overlying the fault zone has been found on the north side of Gable Mountain. The offset on the shearing is up to 0.3 ft. It is not currently known if these shears are of tectonic origin.

3.6.5.2 Gable Butte. Gable Butte is 6 mi from the PUREX site and is made up of three en echelon anticlines which are gently and symmetrically folded. A fault was postulated[46] to be near the west end of Gable Butte. Subsequent investigations[45,50] have determined that no fault exists at that location.

3.6.5.3 Umtanum Ridge. The Umtanum Ridge anticline extends for about 50 mi in a northwesterly-by-southwesterly direction (see Fig. 3-35). Umtanum Ridge plunges into the Pasco Basin toward Gable Butte and Gable Mountain. The easternmost 9 mi were mapped and this segment:

> "... is asymmetrical to the north with a steeply dipping and locally overturned north slope."[12,29]

To the northwest, Umtanum Ridge is sharply folded into a steep monocline with shear zones of fractured basalt running subparallel to the axis of the monocline.[51] These structures trend eastward beneath the Hanford Site. Several faults were identified[52] on the north limb of the anticline in the vicinity of Priest Rapids Dam. A prominent, high-angle, reverse fault has been traced for about 2 mi southeast of Priest Rapids Dam, and inferred for another 4 mi. No evidence of faulting has been detected in the Hanford formation along the inferred trace of fault activity.[12,29]

3.6.5.4 Saddle Mountains. The Saddle Mountains anticline is an asymmetrical fold with steeply dipping and overturned north limbs (see Fig. 3-35). Faults have been mapped on both the north and south sides of the Saddle Mountains.[47,48,53] A high-angle fault has been traced along the north limb of the Saddle Mountains through a series of widely spread outcrops over a distance of 42 mi.

Several small, pre-Holocene faults on the south side of the Saddle Mountains were found to have no more than 50 ft of vertical offset.[29]

3.6.5.5 Yakima Ridge. The Yakima Ridge anticlinal system is about 35 mi long and extends from the Pasco Basin to the city of Yakima. About 20 mi^2 at the eastern end of the ridge were mapped and consist of three asymmetrical anticlines.[12,29] Two small faults were mapped on the south limb of the southernmost anticline. A reverse fault was traced for 800 ft; it then turned eastward for an additional 1,200 ft. There is no surface expression of the fault in the Touchet sediments where the fold axis plunges into Dry Creek Valley.

The second fault trends obliquely to the reverse fault and is inferred for 1,000 ft from an isolated breccia outcrop. Both faults are interpreted to be adjustment faults associated with the folding of the tightly folded anticline.

3.6.5.6 Rattlesnake-Wallula Lineament. The Rattlesnake-Wallula Lineament is a portion of the Olympic-Wallowa Lineament.[27] This lineament can be traced from the Olympic Peninsula to the Wallowa Mountains. Faults are definitely present at several locations along its strike, and the feature must represent, at least in some segments, an underlying or basement rock feature. However, the Olympic-Wallowa Lineament is not a sharply defined or continuous structure. A segment of this lineament along the Rattlesnake Hills to Wallula Gap is referred to as the Rattlesnake-Wallula Lineament (see Fig. 3-35). The Horn Rapids alignment, the Badger Coulee alignment, and the Horse Heaven Hills anticline (see Fig. 3-35) are structures subparallel to the Rattlesnake-Wallula Lineament.

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Faults have been mapped in the Rattlesnake-Wallula Lineament.(12) In general, these faults can be related as anticlinal deformations. The Wallula Gap fault (see Fig. 3-35) is a zone of normal faulting in the Columbia River basalt, with an offset of 1,000 ft.(49) Horizontal slickensides on the high-angle, locally reversed fault suggest the last movements were strike slip. There was no conclusive evidence of deformation found in the overlying Quaternary sediments. This fault zone continues across the Columbia River where deformation of the Touchet sediments has been noted.(48) If the Touchet sediments were deformed by fault movement, the last activity in this region was less than 12,000 yr ago.

Northwest of the Wallula Gap fault, there are brecciation zones on many of the en echelon, doubly plunging anticlines.(29,40,45,54) Recently, at Finley Quarry, 6 mi northwest of Wallula Gap, sediments overlying deformed basalt were found to be sheared. The age of these sediments is estimated at late Pleistocene (pre-7,000 yr). Elsewhere, the structures are blanketed with loess, and outcropping is limited.

3.6.6 Site Geology

3.6.6.1 PUREX Plant Geologic History. The thick sequence of Columbia River basalt masks the pre-basalt history of the Pasco Basin. The basalts are Miocene in age. An age of 16.5 to 6.5 million years has been inferred from radiogenic ages of basalts that crop out in the region.(37,38)

The Ringold Formation was deposited during Pliocene time. It was suggested(55) that deposition continued into the Pleistocene, but later work(56,57) shows evidence for termination of sedimentation in the latest Pliocene.

During the Pleistocene, Glacial Lake Missoula floods scoured the area north and east of the site and glaciofluvial action put down thick deposits in the Pasco Basin. The PUREX Plant site, shown in Figure 3-36, is situated on an expansion bar of glaciofluvial deposits. Figures 3-37 and 3-38 show general geologic cross sections at the PUREX site.

3.6.6.2 Surface Geology at PUREX. The surface and near subsurface geology at the plant site are shown in Figures 3-37 and 3-38. The lithology, stratigraphy, and structure are discussed in Section 3.6.6.4.

3.6.6.3 PUREX Plant Physiography. The PUREX Plant is in the north-central Pasco Basin. The topography of the Hanford Site is mostly a broad plain. Gable Butte and Gable Mountain are two east-west anticlinal ridges just north of the center of the PUREX Plant Site, and Rattlesnake Ridge forms the western boundary. The topography near the PUREX Plant site is shown in Figure 3-4. The 200 East and 200 West Areas are located on a Pleistocene flood expansion bar referred to as the 200 Areas Plateau.

Large landslides are found on the north slope of Rattlesnake Ridge and are interpreted to be late Pleistocene and early Holocene in age. This hummocky topography is greater than 9 mi from the PUREX Facility. Active landslides occur along the bluffs of the Ringold Formation, east of the Columbia River. This area is greater than 7.2 mi from the PUREX Site.

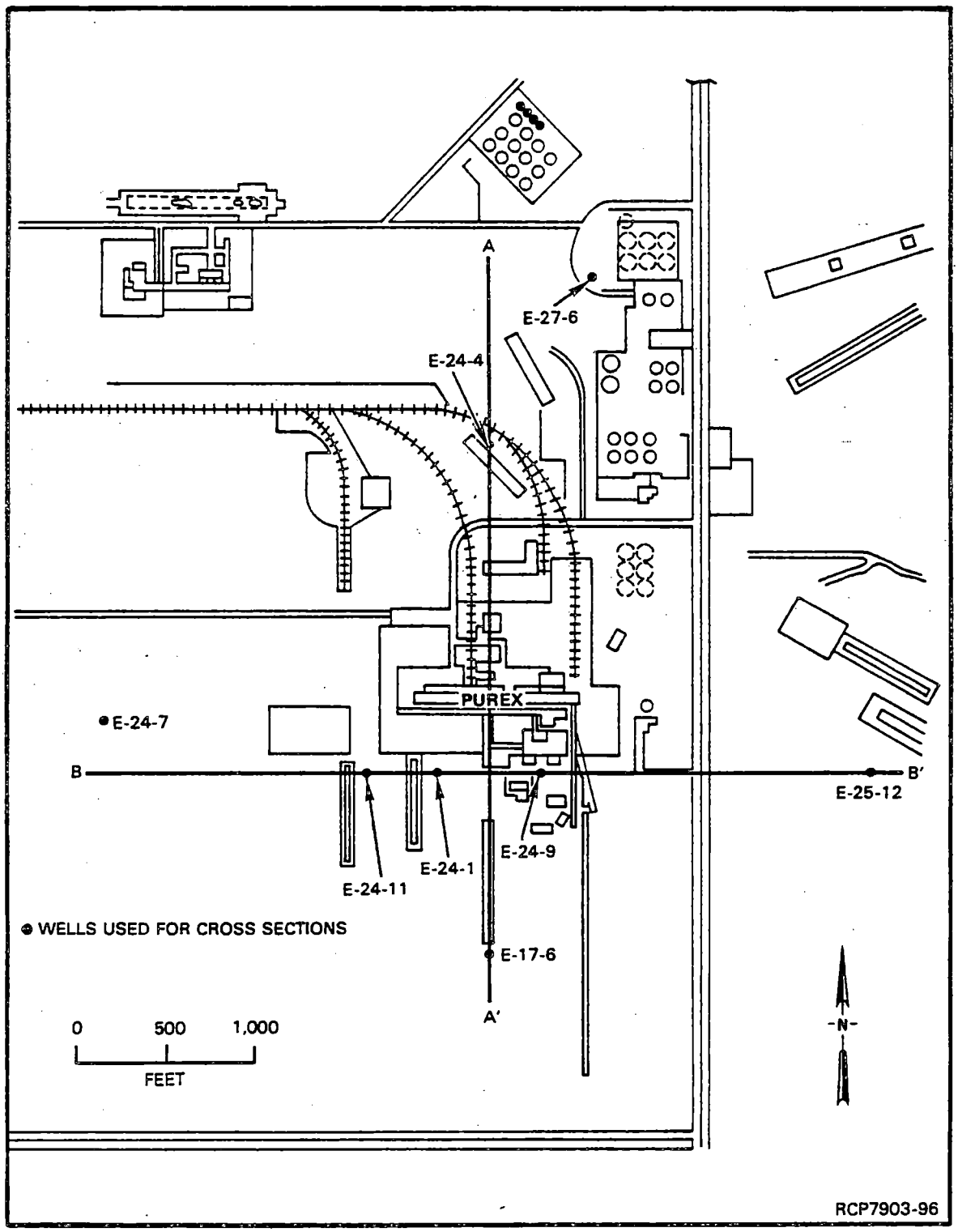

FIGURE 3-36. Reference of Cross Sections at the PUREX Plant Location.

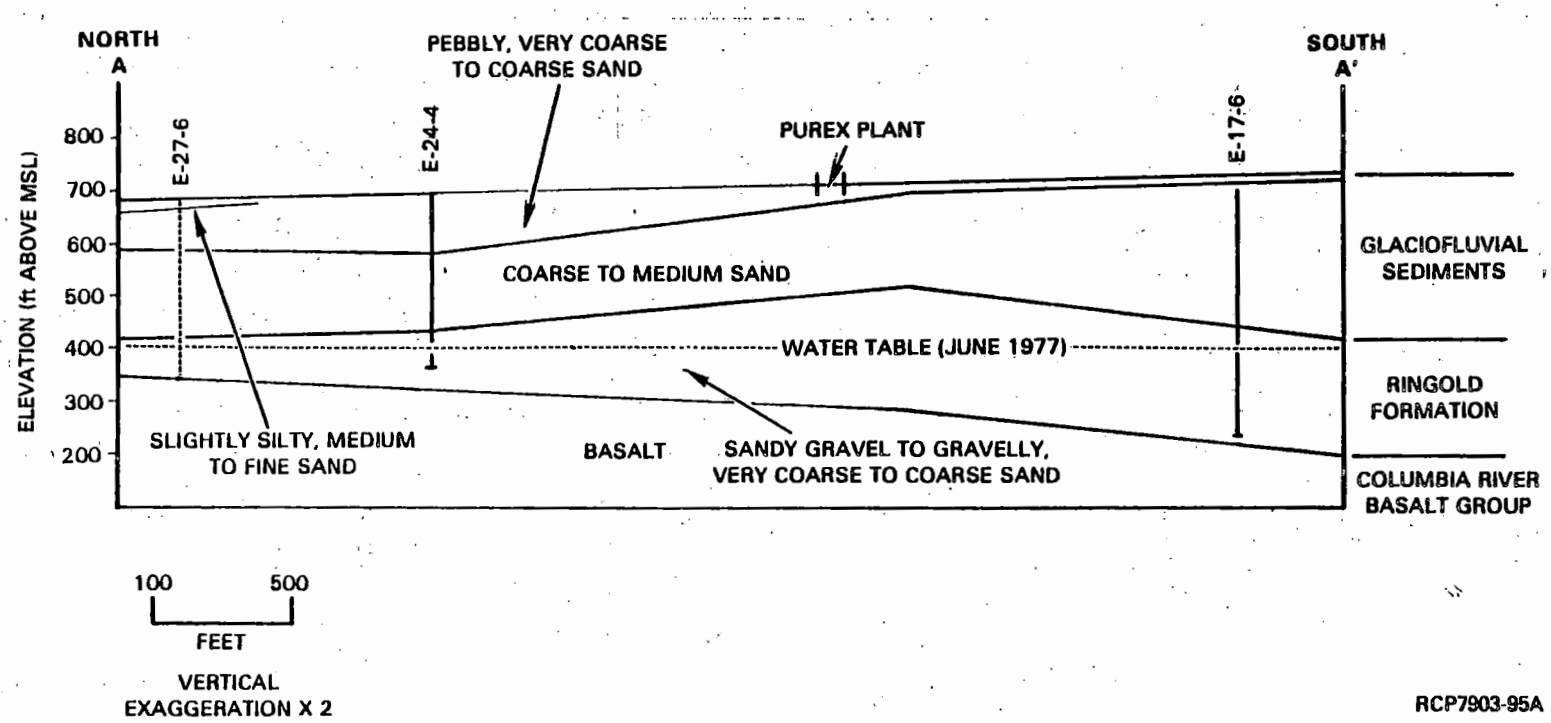

FIGURE 3-37. Generalized Geologic Cross Section A-A' Parallel to the Main Axis of the Pasco Basin.

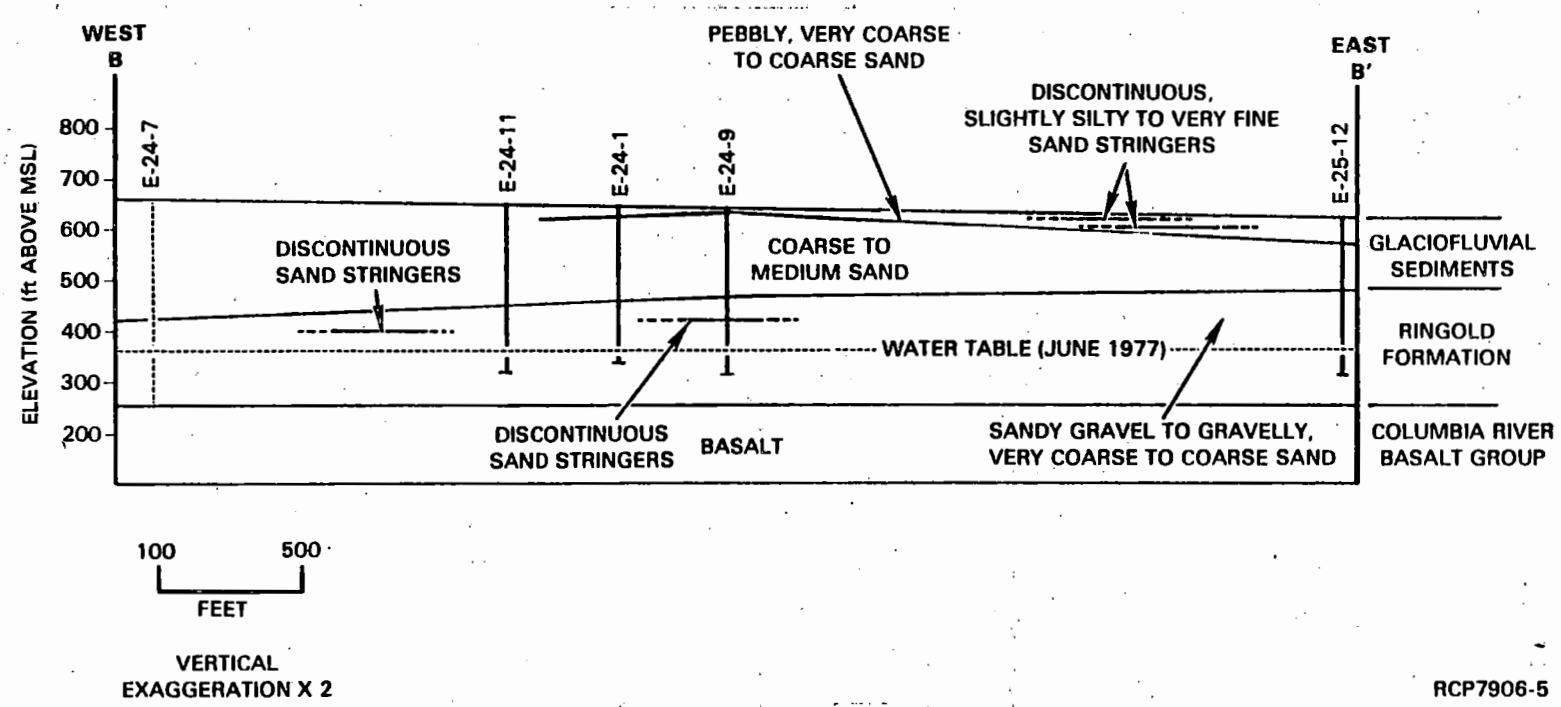

FIGURE 3-38. Generalized Cross Section B-B' Normal to the Main Axis of the Pasco Basin.

3.6.6.4 PUREX Plant Site Geology. Stratigraphic cross sections at the PUREX Plant Site are shown in Figures 3-37 and 3-38. The cross-section locations are shown in Figure 3-36.

The Columbia River basalt lies about 400 ft beneath the PUREX Plant. The basalt stratigraphy is shown in Figure 3-31. The highly fluid lava was extruded intermittently from fissures in and around the periphery of the subsiding Pasco Basin. During quiescent periods between lava extrusions, streams transported sediments from the surrounding highlands into the Pasco Basin. These interbed sediments consist largely of sand and tuff, extending to a thickness of 120 ft. At the cessation of volcanism, the basin had been filled with at least a 4,800-ft thickness of basalt. The surface of the Columbia River basalt lies beneath the PUREX Plant at an elevation about 300 ft above mean sea level (measured from the center of the PUREX Plant).

Following the cessation of the Columbia River basalt extrusions, ancestral rivers transported sediments from the surrounding highlands into the Pasco Basin, where the sediments accumulated to form the Ringold Formation. Beneath PUREX, this formation is the middle Ringold gravel unit and is about 200 ft thick.

Approximately 200 ft of middle Ringold sediments overlie the basalt under the PUREX Plant (see Fig. 3-37 and 3-38). The unit consists predominantly of well-rounded pebbles and cobbles with the interstitial spaces filled with coarse to very coarse sand. The sediments are slightly indurated. Table 3-14 summarizes the grain size distribution and calcium carbonate ($CaCO_3$) content of the Ringold sediments beneath the PUREX Plant.

TABLE 3-14. Typical Grain Size Distribution and Calcium Carbonate Content of Ringold Sediments Beneath PUREX Plant (wt%).

Classification	Pebbles and cobbles	Sand					Silt and clay	$CaCO_3$
		Very coarse	Coarse	Medium	Fine	Very fine		
Very coarse to coarse sandy gravel	34	25	19	12	5	3	2	1.1

Approximately 200 ft of glaciofluvial sediments overlie the Ringold Formation at the PUREX Plant site between the elevations of 489 and 702 ft. This unit is composed predominantly of coarse to medium sand. These sediments vary in sediment sizes and degree of sorting. This is normal in flood deposits where there are abrupt changes in water velocity and water level during glaciofluvial action. Table 3-15 summarizes grain size distribution and $CaCO_3$ content of glaciofluvial sediments beneath the 241-A Tank Farm.(19)

TABLE 3-15. Typical Grain Size Distribution and Calcium Carbonate Content for Major Glaciofluvial Lithologies Beneath 241-A Tank Farm (wt%).

Classification	Pebbles and cobbles	Sand					Silt and clay	$CaCO_3$
		Very coarse	Coarse	Medium	Fine	Very fine		
Pebbly, very coarse to coarse sand	29	32	25	8	4	1	1	1.5
Coarse to medium sand	2	12	36	29	10	5	6	1.5
Slightly pebbly, coarse to medium sand	9	18	34	25	8	4	2	1.0
Slightly pebbly, silty fine sand	9	5	7	9	22	13	35	1.2

Clastic dikes have been found cross-cutting the Ringold and glaciofluvial deposits throughout the Pasco Basin. These dikes range from less than 1 in. to greater than 4 ft in width, to depths of greater than 100 ft below the ground surface. Some clastic dikes were detected in the sediment samples collected from water-monitoring wells around the PUREX Plant, but it was not possible to map them.

The site area is mantled with a thin layer of wind-blown sand and silt.

3.6.7 Vibratory Ground Motion

3.6.7.1 Behavior during Previous Earthquakes. Adverse behavior of the surficial geologic materials (i.e., soils) or the local bedrock during previous earthquakes has not been reported. A review of isoseismal maps indicates that ground motion corresponding to an earthquake of intensity Modified Mercalli (MM) VI is the largest projected (i.e., extrapolated) to have been felt at the site.(29) Such motion is perceptible, but generally causes no adverse behavior of natural geologic materials.

3.6.7.2 Engineering Properties of Materials Underlying the Site. The PUREX Facility is founded on glaciofluvial, medium-to-coarse sand, and gravelly coarse sand known locally as the Hanford formation (informal name). This material is essentially dry, containing 2% moisture by weight--well above the water table--and about 200 ft thick. Underlying the Hanford formation is a sequence of sandy gravel and gravelly coarse sand that is part of the Ringold Formation. Ringold sediments overlie basalts and sedimentary interbeds of the Columbia River Basalt Group and Ellensburg formation. The water table occurs at an elevation of 403 ft above mean sea level, or at a depth of about 300 ft below ground surface.

Seismic refraction surveys have been performed along several lines at the site of the 242-A Building(58) and along a waste line leading from the 202-A Building.(59) As these tests were run close to the PUREX Facility (202-A Building), the velocities for compressional waves in these sediments beneath the 242-A Building, and along the waste line are considered to be representative of those beneath the 202-A Building (Fig. 3-39). The general profile shown by these refraction lines is a surficial unit of 1.6- to 9.8-ft depth in which the velocity of the compression waves (V_p) ranged between 847 to 1,100 ft/s, and a second unit at least 5 ft thick in which V_p ranges between 1,100 to 2,600 ft/s. All of these profiles are restricted to sediments (soils) of the Hanford formation. None of the profiles penetrated deep enough to encounter the Ringold Formation. Shear and elastic moduli for these soils have been calculated.(29)

3.6.7.3 Earthquake History The Columbia Basin, including the smaller structural unit, the Pasco Basin, is an area of low seismicity in which moderate level earthquakes (MM intensity less than or equal to VIII) have occurred. While the historical record of earthquakes is relatively brief, it is sufficiently long to indicate that this area of eastern Washington has experienced fewer earthquakes of generally lower level than areas in the Puget Sound-Willamette Lowlands of western Washington or the Rocky Mountains. The Pasco Basin contrasts markedly with zones of higher seismicity to the west and east.(29) A summary of western Washington earthquakes is presented in Table 3-16. These earthquakes attenuated rapidly eastward, so that the maximum known intensity in the vicinity of the site was MM less than or equal to IV.(60)

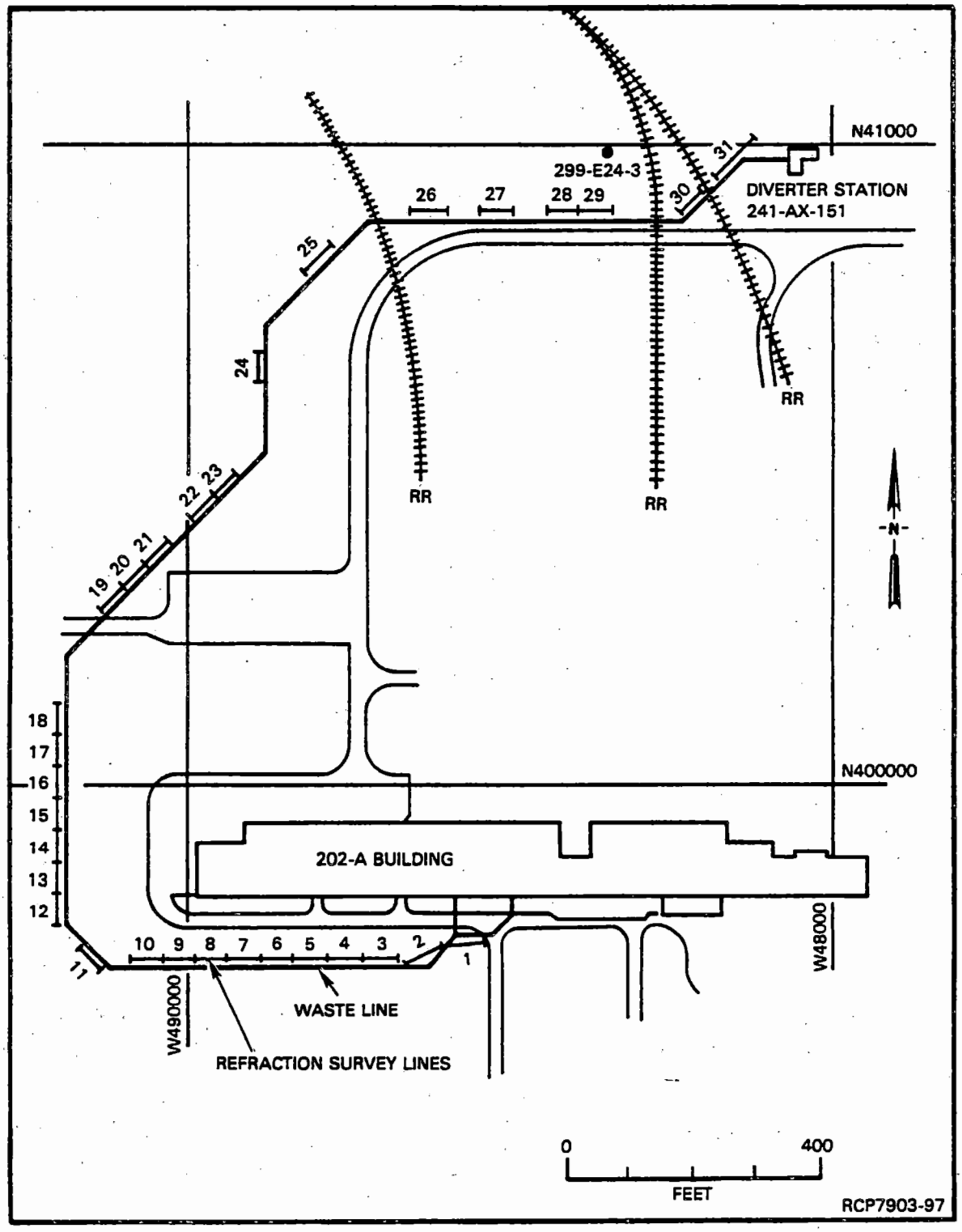

FIGURE 3-39. Location of Seismic Refraction Survey Lines.

TABLE 3-16. Western Washington Earthquake Summary.

Date	Location		Epicentral intensity (MM)	Distance to site (mi)
	°North	°West		
November 12, 1939	47.5	122.5	VIII	155
April 29, 1945	47.75	121.75	VII	134
February 14, 1946	47.5	122.5	VII	155
April 13, 1949	47.25	122.5	VIII	121
April 28, 1965	47.4	122.4	VII to VIII	148

NOTE: PUREX location is 46.5°N and 119.5°W.

A network of seismographs was established in eastern Washington and has been operational since March 1969. Without this dense network of recorders, most events that have been recorded in this period would have gone undetected because of: (1) relatively low population density, (2) small area in which the shock occurred, (3) low levels of stress release that are not generally felt by humans, and (4) too great a distance from the network of established stations prior to 1969. Some spatially and temporally restricted swarms have occurred, but the distribution of earthquakes generally indicates that stress is low, infrequent, and not concentrated in planar zones suggestive of fault activity.

A large earthquake occurred at about 10:40 p.m. on December 14, 1872, in a sparsely populated area of northern Washington and southern British Columbia. Because of scarce data, details of this earthquake are not well established. Research was conducted(61) to determine the epicenter and epicentral intensity of this earthquake, along with any possible relationship to the geologic structure. This research was undertaken in the preparation of preliminary safety analysis reports and amendments thereto for several commercial light-water reactor units located on the Hanford Site. The research included detailed geologic mapping in the epicentral area, as well as in the region, analysis of imagery, compilation and review of contemporary accounts of this earthquake, geophysical investigations, development of a plate tectonic model for the Pacific Northwest, and analysis of both macro-earthquakes and microearthquakes (Ref. 62 through 72). Some of the conclusions reached by a review panel* on the 1872 earthquake follow.(73)

- The epicenter was located in the Northern Cascades-Okanogan area within a zone extending from Lake Chelan in the south to southern British Columbia in the vicinity of Chilliwack.

*Panel members included: Dr. H. A. Coombs, Professor Emeritus of Geology, University of Washington, Seattle, Washington; Dr. W. G. Milne, Victoria Geophysical Observatory, Victoria, British Columbia; Dr. O. W. Nuttli, St. Louis University, St. Louis, Missouri; and Dr. D. B. Slemmons, University of Nevada, Reno, Nevada.

- Contemporary accounts suggest that a few aftershocks of smaller magnitude occurred during the night after the main shocks, which happened about 10:40 p.m. These aftershocks occurred over a broad area initially and may in part account for the large area in which the event was sensed and assumed to be the result of just the main event.

- A widely sensed shock area may be the result of the main shock only or the cumulative effect of the main shock plus seemingly widely scattered aftershocks. Since the records are not adequate to distinguish between these two possibilities, all that can be said is that there is a broad area in which effects corresponded to MM VIII. The epicenter was probably within this broad region. Surface faulting compatible with an 1872-type event has apparently not occurred in the Columbia Plateau (Basin) in the last 11,000 yr.

- Since this was probably a deep crustal event of about 24 mi focal depth, the probability is very remote that it could have occurred, or could occur, in the Columbia Plateau, where the crust is limited to a thickness of 15 mi. An earthquake that occurred at a focal depth of 24 mi in the Columbia Basin would have been generated in the mantle.

- Structures in basement rocks along the margin of the Columbia Plateau do not appear to have affected thin Columbia River basalts that are younger than mid-Pleistocene in age (i.e., there appears to have been no deformation of Columbia River basalts in the last 1,000,000 yr). Geologic and aeromagnetic investigations along the margins of the Columbia Basin disclosed no evidence of late Quaternary deformation.[74]

Since the December 14, 1872 earthquake is of potential significance to the proposed Hanford, Pebble Springs, and Skagit nuclear generating stations, a number of hearings and reviews were conducted after submission of Reference 61 to the NRC in October 1977. Joint hearings involving members of WPPSS, Portland General Electric, Puget Sound Power and Light, the NRC, Advisory Committee on Reactor Safeguards, and the U.S. Geological Survey (USGS) were conducted. As a result of these meetings and reviews of new information on the 1872 earthquake, the USGS and the NRC reevaluated the geology and seismology pursuant to the design of these proposed nuclear facilities. The USGS concluded that: (1) the 1872 earthquake was probably an MM IX because of the numerous landslides reported; (2) an earthquake similar to the 1872 event will not occur in the Columbia Plateau, but could occur along the northern margins of the plateau; and (3) a 0.25-g zero-period horizontal ground acceleration was appropriate for design of WPPSS-1 and -4.[75]

The NRC concluded that: (1) the Columbia Plateau is a unique tectonic province within the context of Reference 76, and is distinct from the area in which the 1872 earthquake occurred;[77] (2) an event similar to the 1872 earthquake need not be considered near WPPSS-1 and -4; (3) a zero-period horizontal ground acceleration of 0.25 g is appropriate

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for design of WPPSS-1 and -4, as earlier stated in the safety evaluation report[78] and (4) the 1872 earthquake should be considered a "strong intensity MM VIII," based on the absence of evidence other than landslides (which have occurred at much lower intensities).

While many details relating to the 1872 event remain uncertain, the recent investigations summarized above indicate that this event was generated at least 118 mi northwest of the site in a sparsely populated area that is geologically different from the Columbia Basin. The epicentral intensity was probably MM VIII, but the site apparently experienced effects corresponding to a maximum MM VI.[73] Geologic investigations indicate that surface faulting apparently did not occur during this earthquake. Therefore, the potential for recurrence of a similar sized event and the potential for surface faulting during an earthquake in the Columbia Basin seem low.

3.6.7.4 Correlation of Epicenters with Geologic Structures. There is no well-defined relationship between macroseismicity and geologic structure in the Columbia Basin or anywhere in the region of the site. Most stress release in the region of the site is concentrated in the Puget Sound-Willamette Lowlands of western Washington where some moderate-to-large earthquakes of focal depths less than or equal to 36 mi have occurred in the past 40 yr (see Section 3.6.7.3).

The broad topographic low of the Columbia Basin is filled with many hundreds of feet of unconsolidated sediments that bury any structures present in the bedrock along which earthquakes may have occurred. Stress in this area may be relieved along the dipping boundary of the already subducted Juan de Fuca plate near the area where the angle of descent changes from about 14° to about 40°.[70] Lengthy strike-slip faults, such as the Straight Creek, Ross Lake, and Pasayten faults along which lengthy displacement apparently occurred in late Mesozoic to early Tertiary times, are found to the east of the Puget Sound-Willamette Lowlands and do not appear to be the focus of present stress release.

The July 15, 1936 MM VII Milton-Freewater earthquake occurred 30 mi east of the area where the extensions of the northwest-trending Horse Heaven Hills and Rattlesnake-Wallula structures merge, along with the projected extension of the Wallula Gap fault. The northeast-trending Hite fault also occurs in this area. Ground rupture was reported in the epicentral area and near Walla Walla.[79] Both areas are underlain by thick sequences of unconsolidated sediments. The nature of these reports suggests nontectonic deformation, especially along the edges of slopes artificially excavated for a highway and a railroad. Several aftershocks of this earthquake suggest that the plane of rupture was oriented northeast, an alignment that agrees with that of the Hite fault and the Blue Mountains anticline. The sensed area and isoseismals also display an elongation in a northeasterly direction.[29,79] It is not certain whether this earthquake occurred along any of the mapped structures in the area. Since it is the only recorded MM VII or greater earthquake within a 72-mi radius of the site, it is unique. In the absence of surface faulting or a fault plane solution, the northeast-trending zone of aftershocks and the northeast-trending felt area suggest a relationship to the Hite fault, an association that is not proven.

Various interpretations have been given to the steep slopes on the north and northeast sides of anticlinal ridges such as the Horse Heaven Hills, Rattlesnake Mountain, Saddle Mountains, and Gable Mountain. A relatively thick layer of loess and other unconsolidated deposits cover the bedrock in many critical areas, complicating the observation and interpretation of these zones of steep slope. Whether the apparent stratigraphic offset of basalt units is due to folding, faulting, or some combination of the two is not clear.(29,46,48,80) At two localities, Warm Springs and Finley Quarry, outcrops clearly expose a fault that offsets suprabasalt sediments, but because of a cover of unconsolidated sediment, it is not possible to trace these faults any distance laterally. In other exposures, the rocks are clearly folded and not faulted, but the lateral extent of the structure has not been determined. The two processes seem to be related, as suggested by the strike of folds and faults. Large blocks of basalt have slid downslope as a result of nontectonic slope processes, further compounding the problem of interpretation. Recent interpretations suggest that these steeply dipping northern flanks may not be continuous structures in length, but rather a composite of several segments, each of which may have behaved independently.(29) Sediments less than 50 ft thick interbedded between basalt flows are commonly sheared along their margins in the areas where dip changes abruptly. Such shearing would be expected where materials of different mechanical properties slide past one another in the process of flexure-slip folding.(81) In some instances, delicate, primary, sedimentary structures such as ripples are well preserved in the central part of interbeds, suggesting that the shearing is confined to the margins of the bed as would be expected in the flexure-slip folding process. In other cases, the shearing appears to be more pervasive, suggestive of fault gouge. For the most part, the interbeds are concordant with the stratification in the basalts, suggesting that faulting has not occurred. However, in at least one locality, an interbed terminates abruptly against basalt with a marginal zone of shearing separating the two lithologies. Large landslides that have displaced large blocks of some of the units on the north sides of these ridges complicate the interpretation of the structure.

With one exception, neither macroearthquakes nor microearthquakes appear to align along any of the northwest-trending zones of steep slope on the north sides of these anticlines. An MM IV-V earthquake that occurred on November 1, 1918 near the town of Corfu (about 10 mi north of the site) has been tentatively located along the Saddle Mountains structure. The accuracy of location of this event is poor. Corfu, the reported epicenter of this event, lies along an extension of a shear zone in basalts along the front of the Saddle Mountains some 15 mi to the west. This shear zone has been interpreted as the Saddle Mountains fault.(48,49) A large block slide has occurred in the vicinity of Corfu. The evidence for association of the Corfu earthquake with the Saddle Mountains fault is equivocal. Subsidence, originally interpreted as a graben produced during the 1918 earthquake,(46) has more recently been interpreted as a landslide.(48)

Microearthquake activity that has been monitored continuously in the Columbia Basin since March 1968 (first by the U.S. Geological Survey and later by the University of Washington with an expanded network) indicates:

- Low levels of stress release
- Shallow focal depths (less than or equal to 5 mi)
- No obvious relationship to any mapped geologic structure
- Except for swarm activity, stress release does not appear to be concentrated in any zone; even within the area of a swarm, there is no concentration of events along planar zones.

Swarm activity has been recorded at Wooded Island and there have been clusters of events in time within controlled zones. Unlike the situation in California, where segments of the Hayward, San Andreas, and Calaveras faults are clearly delineated by microearthquakes, there is no clustering, concentration, or alignment of microearthquake epicenters along any of the mapped northwest-trending structures in the Columbia Basin.

On the basis of probable geomorphic expression in the Touchet Beds (12,000 yr old), a fault extending 5 mi from VanSycle Canyon across the Columbia River to Yellepit Station is considered to be a capable fault.[29] The north side of this fault, known as the Wallula Gap fault, has moved down, displacing stratigraphic horizons greater than 1,000 ft.[49] There is no displacement or geomorphic expression of the fault in Holocene loess deposits. No earthquakes are known to have occurred along the fault.

3.6.7.5 Identification of Capable Faults. In the absence of definitive evidence of the age of last movement, the Rattlesnake-Wallula structure is considered capable, even though there appears to be no earthquakes associated with it.[29,82]

3.6.7.6 Description of Capable Faults. The Rattlesnake-Wallula structure is considered capable and is described in Section 3.6.7.4. Faulting in the central Gable Mountain area (see Section 3.6.5.1) is being studied to determine if this structure is a capable fault.

3.6.7.7 Hanford Regional Historical Earthquake. The largest historical earthquake known to have occurred within the Columbia Plateau and the characteristics of free-field motion expected at the PUREX Site should an earthquake of the same size occur on a postulated extension of the Rattlesnake-Wallula structure, whose surface trace passses within 10 mi of the site, have been identified.[83] This event has been designated as the Hanford Regional Historical Earthquake (HRHE).

A statistical analysis of the completeness for the reporting of felt earthquakes in Washington and northern Oregon was made in 1972.[84] The results show that felt earthquake reporting has approached completeness for MM V and VI since 1933, and for MM VII and VIII since 1870. Hence, the historical record for establishing the HRHE is about a century

in length, which is short in comparison to estimated recurrence intervals for potentially damaging earthquakes in the Columbia Plateau. Therefore, it is an uncertain sample of long-term seismicity. The largest earthquake known to have occurred within the Columbia Plateau was the Milton-Freewater earthquake of July 18, 1936, with an epicentral intensity rated at MM VII.[77]

The minimum HRHE epicentral distance between PUREX and the Rattlesnake-Wallula structure is 10 mi. Recent intensity attenuation investigations for crustal-focus earthquakes indicate that the ground motion intensity falls by half a unit at epicenter distances of 12 mi or less. Therefore, MM VII is the PUREX site intensity for the HRHE estimated.[83]

The expected HRHE peak horizontal ground acceleration at PUREX (for MM VII) is 0.10 g.[83] This estimation was made using the Modified Mercalli intensity/acceleration correlation of Reference 85. The 0.10 g HRHE smoothed mean horizontal response spectra for the PUREX site recommended[83] are given in Figure 3-40.

3.6.7.8 Safe Shutdown Earthquake. The safe shutdown earthquake (SSE) now in use for designing nuclear facilities on the Hanford Site, within the Columbia Plateau and including the PUREX site, would produce a peak horizontal free-field acceleration of 0.25 g. The SSE was originally established for the FFTF in 1970[86,87] and is in compliance with NRC criteria.[76]

3.6.8 Surface Faulting

Surface manifestations of faulting include sudden rupture and displacement, tilting, and gross changes in land level. Hence, surface faults have the potential to severely damage structures. No evidence of surface faulting or potential for surface fault manifestations have been found on the PUREX site.[20]

3.6.9 Stability of Subsurface Material

At one time, the Ringold Formation sediments filled the Pasco Basin to an elevation about 1,000 ft above mean sea level (the crest of the White Bluffs). The 200 to 600 ft of Ringold sediments eroded from the Hanford Site have been a static load and hence a factor in the compaction of the existing Ringold Formation under the PUREX site. The Ringold beds are compacted and partially cemented; these characteristics are confirmed by the measurement of 6,000 to 12,000 ft/s (relatively high) seismic compressional (P) wave velocities in the Ringold Formation.[88]

The Ringold Formation on the PUREX site is covered by about 200 ft of glaciofluvial gravels and associated sediments, informally called the Hanford formation. The Hanford formation gravels and sediments are compact, though uncemented, deposits of late Pleistocene and early Recent times. The Hanford formation was laid down by glacial meltwaters and the Glacial Lake Missoula floods between about 100,000 and 10,000 yr ago. Evidence suggests that in some places the sediments were buried by an

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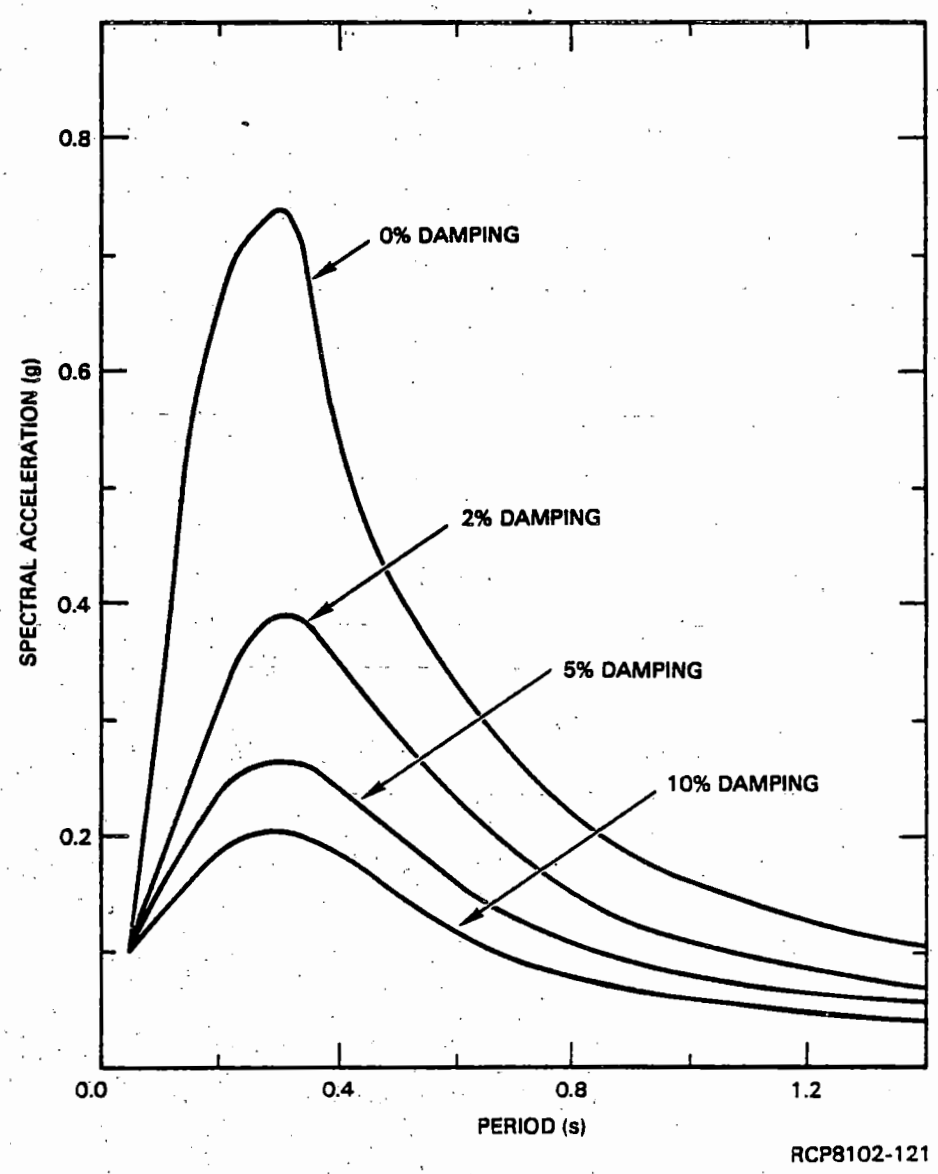

FIGURE 3-40. PUREX Hanford Regional Historical Earthquake Response Spectra.

additional 200 ft of gravel that were later swept away. The Touchet Beds have not been identified below the PUREX site. For at least the upper 100 ft of the Hanford formation, the seismic (P) waves measure consistently low at about 2,000 ft/s. However, the load-bearing capacity of the sediments, without undue settlement and consolidation, generally exceeds 6,000 lbs/ft^2, even at the ground surface. This high capacity confirms the compact nature of the Hanford formation.[20]

The water table is controlled by the elevation of the Columbia River. Over much of the Hanford Site, the Ringold Formation occurs near the river level and is generally saturated. Therefore, the Hanford formation is typically unsaturated. The water table is at a depth of about 300 ft beneath the PUREX Plant; there is no liquefaction hazard.[20,84,88]

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3.6.10 Slope Stability

Within the region along flanks of anticlines and banks of rivers, there are landslides which have been attributed to earthquakes; however, these landslides are more commonly due to groundwater. Recent findings indicate that most of the slides along the north face of the Saddle Mountains were caused by the Glacial Lake Missoula floods about 12,000 yr ago. Groundwater decreases the shear strength of the clay-rich beds common to slopes; pore pressure gradients will occur at the draining face of the slopes. These phenomena plus the added weight of groundwater will create slope instabilities. Also, erosive action on the toes of slopes during floods contributes to landslides.[20,88]

A recent PUREX site reconnaissance revealed that there are no near or adjacent slopes whose failure (instability) might constitute a hazard. Moreover, the soils at the site are typically granular and, hence, relatively resistant to failure due to sliding.[83]

3.7 SUMMARY OF CONDITIONS AFFECTING PUREX SITE CONDITIONS

The PUREX Plant is located near the geographic center of the Hanford Site. All activites within the Hanford Site are controlled by DOE. State Highway 240 passes within about 5 mi of PUREX; the nearest approach of the Columbia River is about 7 mi from PUREX.

The SSE now in use for designing nuclear facilities at the Hanford Site would produce a peak horizontal free-field acceleration of 0.25 g.[72,75] The HRHE determined for the PUREX site would produce a peak horizontal free-field acceleration of 0.10 g.[83]

The volcanic sequence, which lies about 400 ft beneath the PUREX site, is greater than 10,500 ft thick. The Ringold Formation overlies the basalt and is about 200 ft thick at PUREX and about 200 ft of glaciofluvial sediment overlie the Ringold Formation. The sediments are compact and have a high loadbearing capacity. The water table is about 300 ft beneath PUREX. There is no liquefaction hazard. The glaciofluvial sediments, which are normally moisture-deficient (dry) because of the mild and dry climate, can accommodate large discharges of cooling water.

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CHAPTER 4.0 PRINCIPAL DESIGN CRITERIA

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4.0 PRINCIPAL DESIGN CRITERIA

4.1 PURPOSE AND STATUS OF PLANT

The Hanford Site Plutonium-Uranium Reduction Extraction (PUREX) Plant was originally designed, constructed, and operated to receive and process irradiated aluminum-clad fuel from the Hanford production reactors for the recovery and purification of uranium and plutonium. Modifications and additions have been made to the primary processing systems. These changes make it possible for the systems to provide the following services:

- Receive and process Zircaloy-clad fuel from N Reactor
- Recover, purify, and ship neptunium nitrate
- Convert plutonium nitrate to plutonium oxide, then package and transfer to storage.

General and detailed descriptions of PUREX Plant processes and operations are presented in Chapters 1.0 and 6.0, respectively.

The currently defined functions of PUREX follow:

- Receive and process irradiated fuel from N Reactor
- Recover, purify, and transfer uranyl nitrate hexahydrate in acid solution (UNH)
- Produce, package, and transfer plutonium oxide powder.

The processing capacity of PUREX is 10 tons/d for 94-Metal* fuel and 6 tons/d for 94/125-Metal "Spike"** fuel.

More detailed descriptions of the plant feed, products, and functions are provided in the following subsections.

The PUREX Plant was designed in the 1950s (30 yr ago) to design criteria then current with respect to site and national standards such as the 1952 Uniform Building Code (UBC).(1) These "designed-in" features were maintained during its operating life and, during the shutdown-standby period, have been examined and renovated as part of the restart program. More than 5 yr of "operational testing" and "readiness testing" and 2 yr of "readiness review" have been employed to determine the suitability for restart. Any significant deterioration that has occurred since completion of construction has been or will be corrected prior to restart.

---

*Fuel enriched to a ^{235}U content of 0.947% (also called 95-Metal).

**The inner element of the "spike" fuel is enriched to 0.947% ^{235}U and the outer element is enriched to 1.25% ^{235}U.

Startup Criteria[2] for the PUREX Plant have been prepared and approved. These criteria require a number of improvements in the original design of the PUREX Plant, particularly in the measurement and control of gaseous and liquid effluents. The PUREX Plant will restart in conformance with the above criteria.

Beyond the original PUREX Plant Design Criteria of the 1950s and the specific improvements of the Startup Criteria, this Safety Analysis Report (SAR) was prepared in accordance with the backfitting requirements of DOE Order 5481.1A[3] based upon current technical criteria (site and national). The PUREX Plant is not required to meet current design criteria for modern plant construction, such as those contained in DOE Order 6430.[4] However, it shall meet the safety requirements of DOE Manual Chapters covering facility operation. Hazards have been identified which have been or will be eliminated, controlled, or mitigated through reasonable measures. Upgrading actions based on cost-benefit trade-offs have been identified in the text of this SAR. Upgrading actions based on cost-benefit trade-offs not included in the startup configuration are described in supporting (referenced) documentation.

The preceding approach has been used to demonstrate that there is reasonable assurance that PUREX Plant operation can be resumed in a manner that will limit risks to the health and safety of the public and employees and adequately protect property and the environment.

4.1.1 Plant Feed

The feed material to be processed in PUREX consists of irradiated fuel discharged from N Reactor and aged a minimum of 180 d after discharge from the reactor. The fuel elements consist of two concentric cylinders or tubes fabricated of metallic uranium and clad in Zircaloy. The fabrication process is depicted in Figure 4-1. The fuel elements are of two basic types. One (Mark IV) is a two-part, tube-in-tube element; both parts are composed of uranium enriched to 0.947% ^{235}U. The other (Mark IA) is also a two-part element, but with the inner tube enriched to 0.947% ^{235}U and the outer tube enriched to 1.25% ^{235}U. The Mark IA element, called the "spike," is used to obtain the desired reactivity pattern in the N Reactor. As shown in Table 4-1, there are differences in lengths and in cladding thicknesses between the two types and, thus, minor differences in the ratio of uranium and zirconium per unit of length. About 80 wt% of the feed inventory will consist of Mark IV elements; the remaining 20 wt% will be Mark IA elements. Physical characteristics of the Mark IV and Mark IA elements are included in Figure 4-2. For charging, the fissile material limits for the Mark IA elements are set at 12,000 lb of uranium, containing approximately 12 kg of plutonium. For the Mark IV elements, the charging limits are governed only by the physical dimensions of the dissolver. However, the amount of plutonium in solution in the dissolver is limited to the range of 11.7 to 14.5 kg depending on the ^{240}Pu isotopic content. Table 4-2 shows the chemical compositions of the more commonly used spent fuels to be processed.

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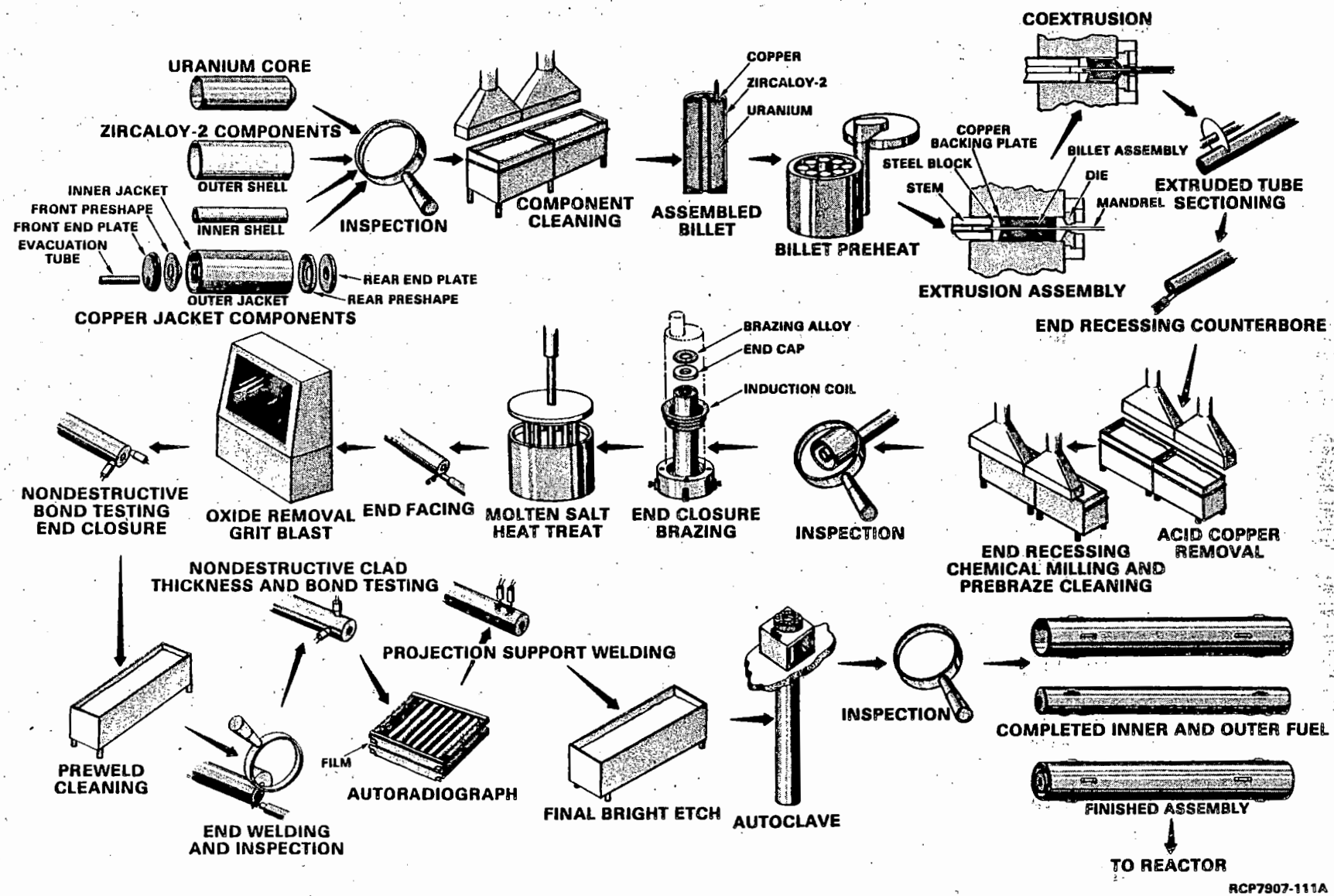
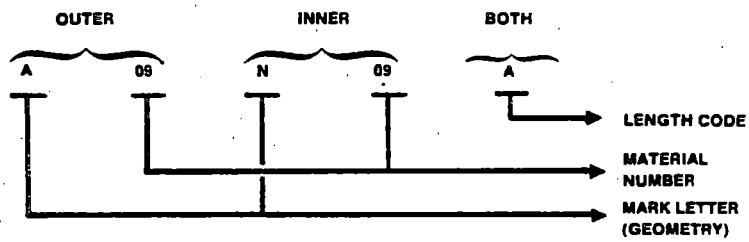


FIGURE 4-1. N Reactor Fuel Element Fabrication Process.

TABLE 4-1. Fuel Identification Codes.

EXPLANATION OF FUEL CODES



MARK LETTERS					
LETTER	GEOMETRY	REFERENCE DIMENSIONS (IN.)			
		O.D.	I.D.	CLAD	
				OUTER	INNER
A	OUTER TUBE	2.404	1.767	0.025	0.025
B		2.425	1.701		0.020
C		2.299	1.437	0.030	0.025
D		2.345	1.360	0.035	
E		2.399	1.718		
F				0.028	
G		2.435	1.770	0.030	
H		2.434	1.776	0.025	0.020
J		2.433	1.762	0.020	0.015
N	INNER TUBE	1.246	0.440	0.040	0.025
P		1.349	0.475		
R		1.344	0.476	0.030	0.020
S		1.337	0.460	0.020	0.015
X		1.279	0.480	0.030	0.020
T	INNER ROD	1.337	—	0.030	—
V		0.379	—		—
W		0.565	—	0.032	—
Q		0.739	—	0.030	—

MATERIAL NUMBERS		
NO.	MATERIAL	
07	0.71	NATURAL URANIUM
09	0.95	ENRICHED URANIUM
12	1.25	
19	1.96	
21	2.10	
90	Al	
70•74	Li and Al	

LENGTH CODES		REFERENCE LENGTH (IN.)		
		OUTER	INNER	
CODE	CALLED (in.)		TUBE	ROD
D	12	11.60	11.54	—
F	15	14.91	14.85	14.714
C	17	17.40	17.34	—
P	19	18.98	18.92	18.830
T	19.5	19.58	19.52	—
B	20	19.90	19.84	—
M	21	20.88	20.82	20.730
A	23	23.20	23.14	23.050
S	24.5	24.56	24.50	—
E	26	26.10	26.04	25.850

FUELS SECTION
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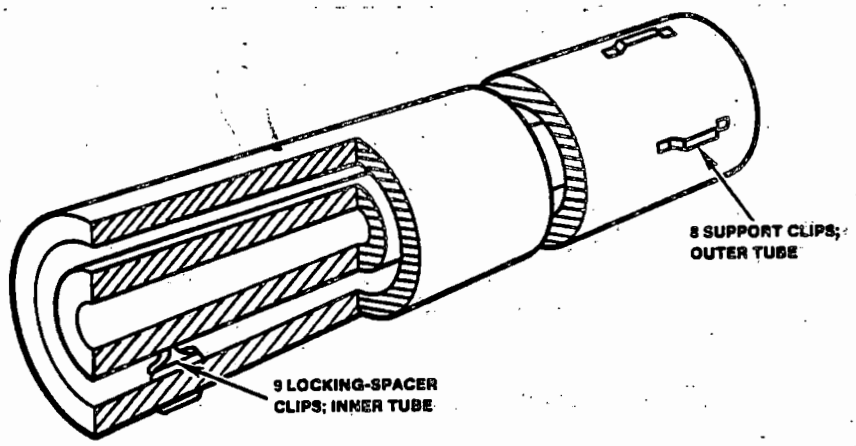

	MARK IV				MARK 1-A		
PREIRRADIATION ENRICHMENT OF ^{235}U	0.947% ENRICHED				1.25-0.947% ENRICHED "SPIKE"		
TYPE - LENGTH CODE	E	S	A	C	M	T	F
OUTER LENGTH (IN.)	26.1	24.6	23.2	17.4	20.9	19.6	14.9
DIAMETER OF ELEMENT (IN.)							
1. OUTER OF OUTER ELEMENT	2.42	2.42	2.42	2.42	2.40	2.40	2.40
2. INNER OF OUTER ELEMENT	1.70	1.70	1.70	1.70	1.77	1.77	1.77
3. OUTER OF INNER ELEMENT	1.28	1.28	1.28	1.28	1.25	1.25	1.25
4. INNER OF INNER ELEMENT	0.48	0.48	0.48	0.48	0.44	0.44	0.44
CLADDING WEIGHT (LBS)							
1. OUTER ELEMENT	2.41	2.20	2.18	1.74	1.94	1.83	1.45
2. INNER ELEMENT	1.21	1.15	1.10	0.88	1.18	1.12	0.89
WEIGHT OF URANIUM IN OUTER (LBS)							
1. (0.947% ^{235}U)	35.2	33.1	31.2	23.1			
2. (1.25% ^{235}U)					24.4	22.9	17.3
WEIGHT OF URANIUM IN INNER (LBS) 0.947% U-235	16.5	15.5	14.6	10.9	12.1	11.3	8.6
WEIGHTED AVERAGE OF URANIUM IN ELEMENT (LBS)	50.3				36.1		
RATIO OF ZIRCALOY-2 TO URANIUM (LBS/TON)	140	141.6	143.2	154.1	171.0	172.5	180.7
WEIGHTED AVERAGE (LBS/TON)	140.7				171.3		
% OF PROCESSING LOAD OF EACH TYPE	88	7	1	4	88	10	2
% OF TOTAL ELEMENTS	80				20		
DISPLACEMENT VOLUME GAL/TON URANIUM	16	16	16	16	16	16	16

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FIGURE 4-2. N Reactor Fuel Element Descriptions.

TABLE 4-2. Chemical Composition of N Reactor Fuel Components.

Element	Uranium alloy 601*	Zircaloy-2*	Braze filler*
Al	700 to 700	75	145
Be	10	-	4.75% to 5.25%
Sn	-	1.20% to 1.70%	0.14% to 1.70%
Fe	300 to 400	0.07% to 0.20%	0.60% to 0.21%
Cr	65	0.05% to 0.15%	0.05% to 0.15%
Ni	100	0.03% to 0.08%	0.028% to 0.08%
C	365 to 735	275	500
U	Balance	2.5	4
Zr	65	Balance	Balance
B	0.25	0.5	0.5
Cd	0.25	0.5	0.5
Co	-	10	20
Cu	75	50	60
Hf	-	200	200
H	2	25	50
Pb	-	100	130
Mg	25	20	60
Mn	25	50	60
Mo	-	50	50
N	75	80	200
Si	124	100	250
Na	-	20	-
Ti	-	50	20
W	-	50	100
V	-	50	50
O	-	-	2,300

*Concentrations given in parts per million maximum or parts per million range unless shown as weight percentage range.

The average operating power level of the N Reactor is between 3,600 and 3,700 MW.[5] Typical isotopic composition of uranium and plutonium in N Reactor spent fuel is listed in Table 4-3. The buildup of ^{240}Pu with respect to exposure is shown in Figure 4-3.

The fission product content of spent fuels is shown in Table 4-4. Two nominal spent fuel decay periods which could be encountered during the upcoming PUREX operation are listed for comparative purposes: 5 yr, the average age of the stored fuel, and 180 d, the current minimum cooling time.

In addition to spent N Reactor fuel, small quantities of other fuel material, including the Shippingport (pressurized water) Reactor core number 2 blanket fuel, may be processed by PUREX at the request of the DOE. These fuels will be within the range of characteristics on which the safety analysis is based, or will be the subject of supplementary analyses prior to processing.

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4.1.2 Plant Products and Byproducts

The normal products to be shipped from the PUREX Plant are plutonium oxide powder and UNH solution.

The plutonium oxide powder will meet the Fast Flux Test Facility,[6] Los Alamos National Laboratory, or Savannah River Plant specifications.[7]

The uranium product stream is a 60 wt% solution of UNH. A quality specification for this product is shown in Table 4-5.[8] The gamma radioactivity level of the UNH product solution is, typically, less than 30% of the specification limit (about equivalent to that of aged natural uranium). The UNH solution is batch-transferred to TK-K6 and sampled, after which it is pumped to one of four 100,000-gal tanks in the 203-A Storage Facility where the temperature is maintained between 45°C and 60°C. Shipments are by 2,800-gal tank truck 6 mi to one of two 100,000-gal feed storage tanks at the Uranium Oxide (UO_3) Plant. During operation, up to five loads per day (one shift) can be shipped. As the name implies, the UNH solution is calcined to UO_3 powder at the UO_3 Plant for offsite shipment.

Product specifications may be modified in some respects because of customer requirements or process capabilities. Such modifications shall not result in adverse safety impact relative to the analyses in this report.

TABLE 4-3. Typical Isotopic Composition of N Reactor Spent Fuel (at 180 d after discharge from the reactor).[5]

Isotope	g/t	Ci/t of U
Mark IV 2,500 MWd/t		
^{234}U	1.02×10^{-1}	6.30×10^{-4}
^{235}U	7.11×10^{3}	1.52×10^{-2}
^{236}U	9.52×10^{2}	6.00×10^{-2}
^{237}U	2.26×10^{0}	1.84×10^{-3}
^{238}U	1.05×10^{6}	3.52×10^{-1}
^{238}Pu	2.05×10^{0}	3.56×10^{1}
^{239}Pu	1.92×10^{3}	1.17×10^{2}
^{240}Pu	2.91×10^{2}	6.61×10^{1}
^{241}Pu	5.97×10^{1}	6.71×10^{3}
^{242}Pu	6.01×10^{0}	2.34×10^{-2}
Mark IA 3,000 MWd/t		
^{234}U	1.35×10^{-1}	8.32×10^{-4}
^{235}U	8.87×10^{3}	1.90×10^{-2}
^{236}U	1.13×10^{3}	7.11×10^{-2}
^{237}U	2.32×10^{0}	1.89×10^{-3}
^{238}U	1.10×10^{6}	3.64×10^{-1}
^{238}Pu	2.13×10^{0}	3.68×10^{1}
^{239}Pu	1.92×10^{3}	1.18×10^{2}
^{240}Pu	2.99×10^{2}	6.79×10^{1}
^{241}Pu	6.03×10^{1}	6.79×10^{3}
^{242}Pu	6.20×10^{0}	2.42×10^{-2}

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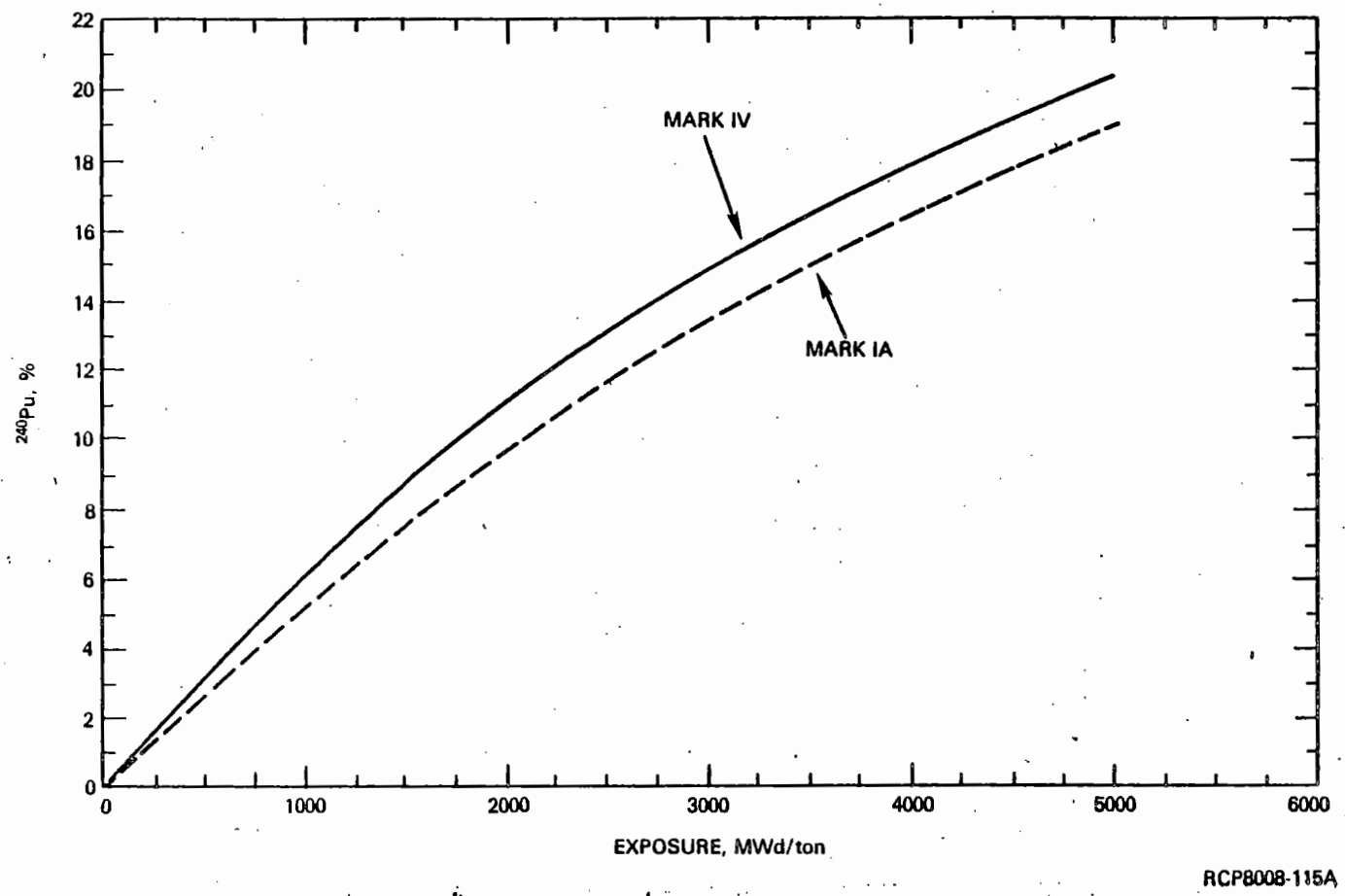

FIGURE 4-3. Percentage of Plutonium Converted to ^{240}Pu with Exposure.(4-6)

TABLE 4-4. Fission Product Activity of Fuels to be Processed (curies per metric ton of uranium).

^{240}Pu content	12%				9%		6%			
Fuel	Mark IV		Mark IA		Mark IV	Mark IA	Mark IV		Mark IA	
^{235}U enrichment	0.947%		1.25%-0.947%		0.947%	1.25%-0.947%	0.947%		1.25%-0.947%	
Exposure: MWd/t	2,500		3,000		1,670	2,030	1,000		1,000	1,000
Cooling time	5 yr	180 d	5 yr	180 d	5 yr	5 yr	5 yr	180 d	5 yr	180 d
^{147}Pm	9.2×10^3	3.0×10^4	1.1×10^4	3.7×10^4	4.6×10^3	7.0×10^3	4.1×10^3	1.3×10^4	4.1×10^3	1.4×10^4
^{137}Cs[a]	8.7×10^3	9.6×10^3	1.0×10^4	1.2×10^4	5.0×10^3	6.2×10^3	3.5×10^3	3.8×10^3	3.4×10^3	3.8×10^3
^{90}Sr[a]	7.7×10^3	8.6×10^3	9.2×10^3	1.0×10^4	4.2×10^3	5.7×10^3	3.3×10^3	3.7×10^3	3.3×10^3	3.7×10^3
^{144}Ce[a]	2.9×10^3	1.6×10^5	3.6×10^3	1.9×10^5	1.6×10^3	2.3×10^3	1.4×10^3	7.5×10^4	1.4×10^3	7.6×10^4
^{106}Ru[a]	1.3×10^3	2.9×10^4	1.6×10^3	3.5×10^4	8.5×10^2	8.0×10^2	3.7×10^2	8.2×10^3	3.5×10^2	7.7×10^3
^{85}Kr	7.8×10^2	1.1×10^3	9.3×10^2	1.3×10^3	4.7×10^2	5.8×10^2	3.4×10^2	4.5×10^2	3.4×10^2	4.5×10^2
^{134}Cs	3.1×10^2	1.4×10^3	3.7×10^2	1.7×10^3	3.7×10^2	1.4×10^2	4.6×10^1	2.1×10^2	5.6×10^1	1.6×10^2
^{125}Sb	2.0×10^2	6.4×10^2	2.5×10^2	7.7×10^2	1.8×10^2	1.3×10^2	6.8×10^1	2.1×10^2	6.7×10^1	2.0×10^2
^{3}H	1.9×10^1	2.5×10^1	2.3×10^1	3.0×10^1	1.7×10^1	2.1×10^1	b	b	b	b
^{129}I	2.3×10^{-3}	2.3×10^{-3}	2.8×10^{-3}	2.8×10^{-3}	1.4×10^{-3}	1.6×10^{-3}	c	c	c	c
^{95}Zr	2.8×10^{-3}	1.0×10^5	3.4×10^{-3}	1.2×10^5	1.2×10^{-3}	2.6×10^{-3}	1.9×10^{-3}	6.7×10^4	2.0×10^{-3}	7.1×10^4
^{95}Nb	6.1×10^{-3}	2.0×10^5	7.3×10^{-3}	2.3×10^5	1.2×10^{-3}	2.6×10^{-3}	4.0×10^{-3}	1.2×10^5	4.3×10^{-3}	1.3×10^5
^{91}Y	c	7.2×10^4	c	8.6×10^4	c	c	c	5.2×10^4	c	5.6×10^4
^{89}Sr	c	4.6×10^4	c	5.3×10^4	c	c	c	3.4×10^4	c	3.7×10^4
^{103}Ru[a]	c	2.1×10^4	c	2.6×10^4	c	c	c	1.4×10^3	c	1.5×10^4
^{141}Ce	c	1.6×10^4	c	1.8×10^4	c	c	c	1.3×10^3	c	1.4×10^4
^{127m}Te	2.7×10^{-2}	9.5×10^2	3.3×10^{-2}	1.1×10^3	1.0×10^{-2}	2.0×10^{-2}	1.2×10^{-2}	4.1×10^2	1.2×10^{-2}	4.1×10^2
^{129m}Te[a]	c	6.5×10^2	c	7.8×10^2	c	c	c	4.5×10^2	c	4.8×10^2

[a]Daughters of these isotopes are also present at the same activity level. Example: ^{90}Sr has a daughter (^{90}Y) which is present in the fuel at the same curie content as ^{90}Sr.

[b]Not available; will be less than 9% or 12% cases.

[c]Less than 1×10^{-3}.

TABLE 4-5. Typical Uranyl Nitrate Quality Specifications.[8]

Chemical or property	Specification
U	3.9 to 4.4 lb/gal
HNO_3	0.10 lb/gal maximum
^{235}U	1.0 wt% maximum
Actinides	
Pu	10[a]
Th	750[b]
Fission products	
$^{95}ZrNb$	10 µCi/lb uranium maximum
^{103}Ru and ^{106}Ru-Rh	20 µCi/lb uranium maximum
All others, excluding ^{99}Tc	20 µCi/lb uranium maximum
Organic	No visual organic phase
Other impurities	
Fe	40[b]
Cr	16[b]
Ni	12[b]
Na	20[b]

[a]Parts per billion parts uranium maximum.
[b]Parts per million parts uranium maximum.

4.1.3 Facility Functions

The PUREX Plant receives scheduled shipments of irradiated, aged, N Reactor fuel elements from the 100 K or 100 N Area storage basins. A Mark IV fuel shipment consists of three or four railroad cask cars, each of which will contain up to nine fuel element canisters; the cars are remotely unloaded one at a time. A typical charge of Mark IV fuel contains less than 23,200 lb of uranium (33 canisters of 14 elements each, for a total of 462 elements). A typical charge of Mark IA fuel contains less than 10,600 lb of uranium (21 short canisters of 14 elements each or 10 long canisters of 28 elements each, for a total of 294 or 280 elements, respectively). Mark IA and Mark IV fuel will not be included in the same dissolver charge.

As further described in Chapter 6.0, the fuel cladding is then removed, the fuel is dissolved, and then separated into the various constituent products, resultant effluents, and waste streams. Effluents and waste streams are further discussed in Chapter 7.0. Utilities and support functions are described in Chapter 5.0.

4.2 STRUCTURAL AND MECHANICAL SAFETY CRITERIA

This section presents the architectural and civil engineering criteria which govern the startup and operation of the PUREX Plant. These criteria include the original plant design criteria[9] and additions intended to limit risks to the health and safety of the public and employees and adequately protect property and the environment. The original design criteria specified that the architectural and structural design requirements of the 1952 UBC be followed.[1] Current safety analyses of DOE operations are required by DOE Order 5481.1A[3] to identify and categorize hazards into three levels: low, moderate, and high. Rockwell guidelines have been formulated for this level determination.[10] Structural upgrades, other backfitting efforts, and administrative controls to mitigate the hazards have been selected using comprehensive natural forces evaluations, hazards risk analyses, and cost benefit studies for the PUREX Plant (Ref. 11 through 14).

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4.2.1 Wind Loadings

Section 2307 of the 1952 UBC[1] specified that the buildings and structures be designed to resist wind pressures of not less than 15 lb/ft^2 for portions less than 60 ft above the ground, and not less than 20 lb/ft^2 for portions greater than 60 ft above the ground. These criteria remain in effect for the startup and operation of the PUREX Plant. There has been no wind damage to the PUREX structures to date. The maximum wind loading of about 17 lb/ft^2 occurred during a 80 mi/h wind in January 1972.[15]

4.2.2 Tornado Loadings

The original PUREX design criteria did not give specific requirements for tornado resistance;[9] the 1952 UBC did not include tornado-resistant design provisions.[1] As a result, special features for tornado resistance were not provided when the original PUREX Plant was built. Currently, a 175 mi/h design basis tornado (DBT) is designated for the Hanford Site, including PUREX, in the Hanford Standard Design Criteria, SDC 4.1:[14]

- Wind Loads

  - Tangential Speed: 150 mi/h
  - Translational Speed: 25 mi/h

- Ambient Pressure

  0.75 lb/in^2 pressure decrease in 3 s, held for 1 s, and returned to ambient at same rate

- Tornado-Borne Missiles

  - 2-in. by 12-in. by 12-ft wood plank traveling 100 mi/h

  - 4-ft by 8-ft by 3/4-in. plywood sheet traveling 150 mi/h

  - 26-in. by 20-ft sheet of 20-gauge corrugated steel siding traveling at 150 mi/h.

Recently completed analyses of PUREX Plant structures and systems concluded that radionuclide releases could result in the event of a DBT, including the following potential effects:[11]

- Breaching of the 202-A east crane maintenance platform (ECMP)

- Loss of the 291-A exhaust ventilation system

- Damage to the PUREX laboratory

- Destruction of the sample gallery exhaust filter plenums and the product removal stack filter plenum.

However, according to data from the following hazards analysis,[14] the maximum offsite individual whole body radiation exposure as a result of DBT damage would be well within Rockwell Hanford Operations (Rockwell) guidelines for "Low Hazard Level".[10]

Maximum DBT-induced individual offsite radiation exposure[12]	Low-level hazard guideline individual offsite radiation exposure[8]
0.06 rem/yr (whole body)	0.5 rem/yr (whole body)

In addition, the probability of the DBT striking PUREX is extremely low ($\leq 1 \times 10^{-7}$/yr).[14]

Costs of upgrading structures to withstand the DBT range from $150,000 for the 291-A ventilation equipment to $12,000,000 for the ECMP.[17]

Thus, the potential radionuclide releases from PUREX in the event of a DBT are concluded to be as low as reasonably achievable (ALARA), and structural upgrades to specifically enhance the tornado resistance of the PUREX Plant are not required or planned.

4.2.3 Water-Level (Flood) Designs

Flooding of the PUREX Plant site was judged to be incredible at the time the original design criteria were prepared, approved, and issued.[9] A more recent evaluation confirms this judgment, and it remains in effect for the PUREX Plant startup and operation.[18]

4.2.4 Missile Protection

Section 11.7.1 of the original PUREX design criteria specified the following for the noncanyon portion of the 202-A building: "Interior partitions shall be designed to minimize the effect of secondary missiles." Design requirements for external missile protection, including definitions of secondary missiles in terms of origin, weight, dimensions, material composition, impact velocity, and orientation were not given. A recently completed PUREX tornado hazards analysis[14] concludes that the offsite individual radiation exposures resulting from DBT-generated missiles would be within Rockwell guidelines[10] for "Low Hazard Level" (see Section 4.2.2).

However, PUREX seismic evaluations indicate that protection of the dissolver drown tanks and the H/J cell fire suppression system from falling items or missiles caused by earthquake ground motions is required (Ref. 11 through 13). This protection was provided by Project B-336, "Structural Upgrade - PUREX Plant" (see Section 4.2.5). Evaluation of other accidents (explosions, centrifuge failure) which could generate PUREX internal missiles did not identify any resulting in significant radioactivity releases.

4.2.5 Seismic Design

The original PUREX design criteria[1] specified that earthquake resistance be provided in accordance with 1952 UBC Zone 2 earthquake regu-lations.[1] The 1952 UBC (Section 2312, seismic design provisions) is interpreted to have required static horizontal forces on the 202-A building at each floor or roof level above the foundation equal to 0.01 W (W = total dead load).[1] A 0.25 g safe shutdown earthquake (SSE) is currently designated for the Hanford Site, including PUREX, in the Hanford Standard Design Criteria, SDC 4.1.[16] Also, a 0.10 g Hanford regional historical earthquake (HRHE) was established for the PUREX site in the seismic analyses.[11] These recently completed seismic analyses of the PUREX structures and systems conclude that radionuclide releases could result in the event of the HRHE or the SSE from the following potential failures:[11]

- Breaching of structural barriers which confine radionuclides
- Loss of the 291-A exhaust ventilation system

- Damage to safety systems and utilities such as radiation monitors, alarms, fire suppression systems, emergency cooling water, steam power, emergency electrical power, etc.

- Process equipment failures with the potential to release radionuclides.

A seismic cost-risk analysis determined that the most severe possible post-earthquake consequences at PUREX, without upgrading to enhance seismic resistance, would be a uranium metal fire in a fuel element dissolver and a solvent fire in H/J cell (codecontamination solvent extraction processing);[12] the potential resultant offsite radiation exposures resulting from a seismic event are given in Table 4-6. Three alternatives for PUREX seismic upgrading for reducing the potential offsite radiation exposures to within Rockwell guidelines for "Low Hazard Level" were developed;[10] relative costs and exposure reductions were reported in the cost-risk analysis and are summarized in Table 4-7.[12] This cost-benefit analysis recommended implementation of Alternative III to preclude a uranium metal fire or an H/J cell organic fire.[12] Hence Project B-336, "Structural Upgrade PUREX Plant", backfitted PUREX with a dedicated fire suppression system for H/J cell and structural modifications to the dissolver drown tanks.

The PUREX Plant seismic hazards onsite risk analysis defined seismic radiological risk to the onsite population as the product of the probability of occurrence of an earthquake and the resulting maximum potential onsite radiation exposure.[13] This analysis concluded that the onsite seismic risks for operating PUREX "as is" presented by the 0.10 g HRHE and the 0.25 g SSE are within an acceptable level, based on the low probability of occurrence established for these events. Hence, modifications to the PUREX Plant to mitigate only the onsite seismic risk are not required or planned.[11,13]

4.2.6 Snow Loadings

The 1952 UBC, Section 2305,[1] specified resistance to a minimum live load of 20 lb/ft^2 for roofs with a rise of less than 4 in./ft, which includes the 202-A building.[1] In addition, the 1952 UBC[1] held the designer responsible to determine whether snow loads could exceed the 20-lb/ft^2 minimum.[1] These criteria remain in effect for the startup and operation of the PUREX Plant. There has been no snow load or other roof live load damage to the PUREX structures to date. The maximum snow accumulation on the ground since plant construction was 12.1 in. in December 1964.[19] This corresponds to a snow loading of about 8 lb/ft^2.

TABLE 4-6. Maximum Offsite Radiation Exposure Resulting from Seismic Event.

Individual	Whole body (rem)
Annual	6.5
Lifetime	36.0

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TABLE 4-7. PUREX Seismic Upgrade Alternatives.

Upgrade	Cost in thousands of 1983 dollars	Individual offsite radiation exposure reduction (rem)	
		Annual	Lifetime
Alternative I - Maintain Safe Structural Barrier			
HRHE - Strengthen 202-A ECMP	2,000	5.4	32.6
SSE - Strenghen 202-A canyon and ECMP	54,300 10,000	5.4	32.6
Alternative II - Maintain Exhaust Ventilation Flow			
SSE - Ensure 291-A exhaust ventilation system remains functional and upgrade the 291-A stack	2,500	5.4	32.6
Alternative III - Preclude Serious Dispersion of Radionuclides			
HRHE - Ensure fire suppression system and drown tanks are functional	830	5.2	29.3
SSE - Ensure fire suppression system and drown tanks are functional	830	5.2	29.3

4.2.7 Process and Equipment Derived Loads

The 1952 UBC, Section 2302, contained the following specifications:[1]

> "In designing floors to be used for industrial or commericial purposes, the actual live load caused by the use to which the building or part of the building is to be put shall be used in the design of such building or part thereof. Special provision shall be made for machine or apparatus loads when such machine or apparatus would cause a greater load than specified for such use in Section 2304, which requires a 125 psf (lb/ft^2) minimum floor live load for heavy manufacturing occupancies."

Section 11.3 of the original design criteria identifies the process equipment; remote maintenance and auxiliary cranes; piping in the hot pipe trench, pipe and operating gallery equipment; and sample gallery equipment as functional components of the 202-A building.[9] These criteria, accounting for current actual live loads, remain in effect for the PUREX Plant startup and operation. There has been no live floor load damage to the PUREX structures to date.

4.2.8 Combined Load Criteria

The general requirement of the 1952 UBC was that live and dead loads be combined without exceeding the material unit stress allowable.[1] The wind loads were to be combined with all vertical loads on the structure, except the roof live load and crane load. The seismic horizontal static forces per the 1952 UBC, Section 2312 were to be used only if these would produce stresses greater than the wind loads.[9] The combined stresses in the structure due to wind or seismic and other loads were permitted to exceed the allowable unit stresses by one-third. An addition to these criteria has been made for the PUREX Plant startup and operation as follows:

> "The combined stresses in PUREX structures, services systems, and components due to seismic or tornado and other loads shall be limited such that the consequences of the SSE or DBT, as defined in terms of maximum individual offsite radiation doses are within Rockwell 'Low Hazard Level' guidelines."[10]

The backfitting efforts required for increased seismic protection described in Section 4.2.5 ensure compliance with these additional criteria.

4.2.9 Subsurface Hydrostatic Loadings

Groundwater-induced hydrostatic loadings on subsurface portions of the 202-A building structure were judged to be incredible at the time the original design criteria were prepared, approved, and issued.[9] This judgment remains in effect for the PUREX Plant startup and operation.

4.3 SAFETY PROTECTION SYSTEMS

4.3.1 General

No items relating to the site location are so unusual or unique as to require special protection systems or other considerations in design beyond those normally required for a facility of this type.

Hydrogen and ammonia are evolved during chemical decladding of the irradiated fuel elements; special equipment is provided for detection, dilution, and/or removal of these from the process ventilation system.

Special design considerations, such as favorable geometry, concentration control, neutron poisons, sump and vent system design, etc., are provided to minimize the probability of a nuclear criticality accident.

The potential exists with the PUREX process for the formation of unstable, nitrated materials (red oil) from the organic. Special design considerations ensure control of such process variables as temperature, acid concentration, and residence time, and provide adequate venting of the system to preclude formation of unstable compounds.

Process solution temperatures are controlled to preclude the potential for flammability/explosion of the organic. Organic aerosol formation is minimized and decant/strip phase separations are performed.

The high-level waste in the waste treatment vessels continuously generates hydrogen by radiolysis; controls are provided to ensure adequate dilution air in the vessels at all times.

Safe shutdown of the processing operations in abnormal events (such as loss of primary services or an incident necessitating evacuation of the facility) is enhanced by design and selection of instrument control systems that ensure response occurs in the safest manner possible.

4.3.2 Protection by Multiple Confinement Barriers and Systems

The confinement system for the PUREX Plant consists of one or more individual confinement barriers and systems which restrict releases of radioactive or otherwise hazardous material to the environment or into areas normally occupied by operating and support personnel. The confinement barriers and systems are designed in accordance with DOE Order 6430[4] and Rockwell[20] criteria.

The confinement systems and barriers limit releases of radioactive materials to the two following areas:

- Restricted areas, so that individuals are not exposed to concentrations of radioactive materials in excess of the guidelines specified in Table I of DOE Order 5480.1A-XI[21]

- Unrestricted areas, so that releases of radioactive materials are ALARA and do not exceed the concentration guidelines specified in Table II of DOE Order 5480.1A-XI. [In this case, the confinement systems limit releases resulting from design basis accidents, including natural phenomena, allowing the maximum offsite individual whole body radiation exposure to fall within the "Low Hazard Level" guidelines (see Sections 4.2.2, 4.2.4, and 4.2.5)].

The methods of confinement depend on the mobility, quantity, type, and intensity of the radioactive material and its radioactive effect on the environment. The primary confinement barriers in PUREX are the walls of the process vessels and piping. Instrumentation is provided to detect leakage from the primary barriers to process cell or glovebox sumps. The secondary barriers are gloveboxes, process cell vault walls, and building walls. These secondary barriers act in conjunction with the "selective" barriers (which are the mass-transfer devices, offgas systems, and ventilation systems) to limit the spread of airborne contamination. This airborne contamination could arise from leakage of either gases or liquids from process and storage vessels into cell or vault air spaces and ultimately into other areas. Barriers also are used to prevent the spread of contamination via leakage of contaminated liquids and solids.

4.3.2.1 Confinement Barriers and Systems. Confinement barriers and systems are selected in accordance with proven practices. In those cases where the systems selected extend beyond proven practice, the system is explained, evaluated, and documented on the basis of either work under development or analytical extrapolations. Confinement barriers and systems are classified according to importance in protecting the health and safety of the public (as discussed in Section 4.4). Barrier design compliance with the standards and guides specified assures that the effects of design basis accidents, including natural phenomena, are considered. The following general criteria were considered in the design of all containment barriers.

- The facility is separated by confinement barriers into areas or zones classified according to the potential level of airborne contamination to limit the spread of radioactive materials.

- Confinement systems are constructed of nonflammable materials, except where this is not possible because of special functional requirements.

- Materials of construction are resistant to the corrosive effects of process and decontamination fluids at the temperatures and pressures encountered. Corrosion allowances are based on a minimum service life of 20 yr.

- Barriers are designed to withstand loadings due to pressure differentials imposed by the process offgas and building ventilation systems, as well as pressure differentials caused by natural phenomena.

- Differential pressure monitors are provided to control and indicate atmospheric pressure differentials between confinement zones to monitor the integrity of total confinement barriers between zones. Continuous air monitors are used to indicate deterioration or loss of function in integrity of a selective barrier which could release radioactivity from a designated confinement area into a monitored area. To monitor a total confinement barrier that is used for liquid confinement, leakage is detected by high-level detection alarm systems, with the detectors in specially designated leakage collection sumps, or by analytical devices which measure and alarm contamination intrusion into normally uncontaminated tanks or process streams.

- Penetrations through confinement barriers which could provide potential pathways for release of radioactivity to the environment or to normally occupied areas have means for isolating the penetration. Air locks may be used at personnel entrances to potentially contaminated zones. Isolation valves may be used in piping penetrations of the barrier, provided the lines between barrier and valves are sealed. In addition, the valves are located as near the barrier as practicable.

- Confinement barriers are designed to maintain functional integrity under the major and design basis accidents hypothesized at the time of construction. Upgrades reduce the consequences of the currently defined SSE or DBT to within low hazard level guidelines.

- Confinement systems and components are designed to facilitate maintenance of the system.

- Alternate power service is provided to those confinement barriers and systems in which loss of confinement capability could result from loss of primary electrical service.

In addition to the above considerations, the following items were considered in the design of specific confinement barriers.

- <u>Process Vessels and Piping</u>

  - Piping systems which penetrate confinement barriers have at least one isolation valve located outside and as close to the confinement barrier as practicable, unless it can be demonstrated that isolation is assured by some other means. Design guides are contained in Hanford Site plant standards for process and service piping.[22]

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- Process vessels and piping systems are designed as primary confinement barriers in accordance with appropriate corrosion and structural criteria.

- Secondary Confinement Barriers

  - Process and waste storage vessels and piping, serving as primary confinement barriers, have a secondary barrier provision so that a breach of the primary does not result in a significant radioactivity release to unrestricted access areas.

  - Structures housing vessels and piping normally containing radioactive liquids are designed to serve as secondary liquid confinement barriers to confine potential leaks from a primary system. The structures are provided, as appropriate, with an impervious liner of a material having adequate corrosion resistance to the liquids which the liner may contain. The structure is capable of containing a liquid volume greater than the credible leakage from a single vessel. Capability for liquid transfer from the structure is provided.

  - The liner and structural anchors are designed and constructed to accommodate stresses due to temperature variation and combinations of applicable live and dead loads. When used as forms for concrete placement, the liners are provided with sufficient structural support to withstand loadings incurred during construction, supplemented by temporary shoring systems if required. The stainless steel liners, when used on floors and walls, are welded to steel embedments in the concrete support structure. The liner welds are tested by proven nondestructive testing methods.

- Selective Confinement Barriers

  - Building ventilation and process offgas systems control the spread of airborne contamination through openings in barriers by regulating the direction of airflow between these zones. Therefore, flow is from zones of low contamination potential to zones of high contamination potential.

  - Capacity of the ventilation system is adequate in relation to confinement system requirements. This assures that the velocity of air flowing through any barrier opening is sufficient to prevent backflow of airborne contaminants through such openings and that airflow patterns are not disrupted by winds, movement of equipment or personnel, or temporary opening of passageways through confinement barriers.

- Standby fans are provided to automatically take over the function of any essential fan that may become inoperative.

- Process offgas systems are designed and installed to confine hazardous chemical or radioactive materials evolved during process operations and radioactive waste storage and to reduce concentrations in gaseous process effluents to ALARA levels.

- Ventilation systems are designed and installed to confine, channel, and control airborne radioactive contaminants and provide normal ventilation requirements.

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4.3.2.2 Ventilation Offgas. The ventilation systems for the PUREX Plant are designed to provide containment of airborne radioactive particulates under both normal and abnormal conditions, to provide comfort conditions for personnel commensurate with the required work, and to provide suitable operating conditions for equipment.

The total ventilation system consists of subsystems which provide supply air, area recirculation, area exhaust, and process exhaust. The total ventilation system is controlled and coordinated with the facility arrangement to achieve the necessary confinement of airborne radioactive materials under all modes of operation, including single failure of equipment and exposure to natural forces as given in Section 4.2.

The building exhaust systems collect, filter, and exhaust the ventilation air from the facility, and provide the necessary airflow patterns, pressure differentials, and ventilation rates for confinement. These systems are coordinated and balanced with the supply air systems and the process exhaust systems to assure that the required differential pressures between ventilation zones are maintained under all conditions. The effect of air expansion due to high temperatures in a fire has been included in the design considerations.

Continuous operation of exhaust systems necessary for maintaining negative pressure in Zones I, II, and III, as defined on the following pages, is achieved by features such as multiple or standby units, alternate power service for controls and machinery, isolation dampers, and automatic interlocks.

The PUREX Plant is divided into the following four main ventilation zones similar to those recommended by the U.S. Energy Research and Development Administration.[23]

- Zone I

  Includes the interior of hot cells, gloveboxes, canyon, open face hoods or other containment for handling radioactive material exposed to the air. Containment features prevent the spread of radioactive material to other zones or release from the building under both normal and abnormal conditions.

Barriers, as defined in Section 4.3.2.1, are provided between the radioactive material and the environs. Air exhausted from Zone I passes through high-efficiency particulate air (HEPA) filters or equivalent adequate to reduce the contamination level to that required by the PUREX startup criteria.[2]

Release of unfiltered contaminated air is prevented by redundant exhaust fans and backup power supplies. Sufficient negative pressure is maintained at all times to assure containment velocity into Zone I through any opening from adjacent zones; this may vary from negligible pressure for open face hoods to -1 in. water gauge (WG) for gloveboxes.

Entry into Zone I requires adherence to provisions of applicable Radiation Work Permits (RWP). Access is only from Zone II or equivalent. Egress requires contamination survey and release before continuing into Zone II. Contaminated apparel is properly packaged and surveyed by Radiation Monitoring before leaving Zone I.

Ventilation airflow provided for Zone I is that required for heating, heat removal, corrosive fume removal, or airborne contaminant control.

The quantity of radioactive material contained in Zone I is unlimited except as defined for available shielding, criticality, radiological safety, heating, and structural vulnerability to radioactivity or other physical limitation.

- <u>Zone II</u>

Includes all areas providing access to Zone I. It may be a glovebox operating area, a hot fume hood operating area, a hot cell service or maintenance area, or another building space where radioactive contamination could be present because of an unplanned release from operations in Zone I.

Containment barriers between Zone II and the environment, or Zone IV, shall be provided per the general criteria in Section 4.3.2.1. Filtration for exhaust air from Zone II consists of at least one HEPA filter or equivalent with parallel filter and fan redundancy so that one can be out of service while the other maintains containment.

Air locks and/or a personnel clothing change facility are provided at entry of Zone II. Personnel are required to wear, at a minimum, laboratory coats and shoe covers in glovebox room operating areas and full protective clothing in service areas as specified by applicable RWP. Respiratory protection is available in the event of an operational upset, but is not required for normal operation.

Uncontrolled radioactive material is not allowed to be present except as contained in Zone I hoods, gloveboxes, etc., or in sealed packages. Limits in such containment are as specified in RHO-MA-220.[24]

- Zone III

Includes general chemical laboratory office areas, a maintenance area, or other general working areas usually free of radioactive materials, but potentially subject to unplanned low levels of airborne radioactive materials. A chemical fume hood is a minimum requirement for operations which could produce greater than maximum permissible concentrations of radioactive,* toxic, or noxious materials. Operating personnel are required to wear lab coats or equivalent protective clothing as specified by applicable RWP. Respiratory gear is available for emergencies and routine airborne radiation monitoring is required.

No planned radioactive material is allowed in Zone III except in sealed containers approved for this purpose.

One barrier from Zone III to the environment or Zone IV is provided as described in Section 4.3.2.1. This may include one HEPA filter on the exhaust. Parallel filters and fans are provided to maintain containment with one unit out of service. Zone pressure settings are 0.1-in. WG below atmospheric pressure or Zone IV and at least 0.1-in. WG above Zone II.

Access to Zone III may be from Zone IV or outside. Egress may require contamination survey or self-survey as determined by Radiation Monitoring.

- Zone IV

Includes offices, clean shop areas, lunchrooms or any areas where radioactive contamination is prohibited, except in an approved container.

No RWP protective clothing, either "clean" or "soiled," is allowed, except under strict control.

Normally, no contamination barriers are required from Zone IV to the environs. Under special conditions, a positive pressure with air locks or containment velocity may be required at exit points.

*Reference 23 allows handling of very small quantities of radionuclides in fume hoods loated in Zone III areas. However, this practice is not permitted at the PUREX Plant.

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Personnel entry is not limited, except from zones of higher contamination or in unusual circumstances.

Ventilation provided in Zone IV is only as required for industrial or personnel purposes.

Zone IV is the cleanest personnel working area; however, the surrounding environment can be more contaminated. Therefore, Zone IV is kept at atmospheric or slightly positive pressure to minimize dust entry and provide proper airflows to surrounding areas.

All zones are maintained with a pressure differential setting of at least 0.05-in. WG between zones. Zone I requires two exhaust fans with a backup source of power to assure continued exhaust on failure of fan, power, or control. All zones are equipped with differential pressure monitoring instruments which will indicate and alarm in a continuously manned location from which corrective action can be taken.

Air locks are provided where frequent personnel passage into Zones I and II is required. This allows differential pressures between zones to be maintained.

Air quantities supplied from outside equal the exhaust requirements less an allowance for building in-leakage. Air intakes are arranged to minimize the effects of high winds, rain, snow, ice and windblown trash on the operation of the system. The outdoor air supply is cleaned to the extent practicable before use in the building. Air intakes are vulnerable to damage from missiles resulting from natural phenomena. However, risk analyses show that the maximum individual offsite dose releases are within guidelines and no upgrades are required.(11)

Systems are provided to distribute ventilation supply air throughout the facility. The design of the supply-air distribution system is coordinated and balanced with the exhaust system. Operation of radiation zone air-supply fans is coordinated and interlocked with the operation of exhaust fans to ensure that the supply-air quantity can never equal or exceed the exhaust air quantity, which would cause a pressure reversal between zones.

Supply inlets and exhaust outlets within operating areas are generally located to provide a downward airflow pattern and minimize the spread of contamination (i.e., airflow is toward areas, enclosures, etc. of higher or potentially higher contamination).

Provisions are made for cleaning of ventilation air or process offgas that may contain radioactive particulates or toxic or noxious materials through the use of filters, scrubbers, mist eliminators, sorbents, and other air-cleaning devices to reduce contamination levels to that required by the PUREX startup criteria.(2)

Sufficient exhaust air capacity and controls are provided for Zone I enclosures so that an inflow of air at an average velocity of at least 125 to 150 ft/min through a maximum credible breach (nondesign basis accident) of the enclosure will be maintained.[24] The 125 ft/min velocity is well above the 50- to 100-ft/min containment velocity recommended in Reference 25. The size of the maximum credible breach depends on the barrier; for example, the maximum credible breach for the canyon is equivalent to the area of the vertical door to the railroad tunnel, whereas the maximum credible breach for the glovebox is the area of the gloveports in use.

Appropriate surveillance instrumentation is provided at a common and conspicuous location for all essential functions of the ventilation systems.

The system is designed to provide for orderly and safe startup, operation, and shutdown to maintain confinement under all normal operating and upset conditions.

Manual or automatic (with manual override) controls are provided based on an analysis of the required system operating modes.

Points in the process zone (Zone I) ventilation system where fissile radioactive materials could potentially accumulate have been analyzed for criticality safety.[26,27]

Filtration is provided as near as practicable to the exhaust of each hood, glovebox, or other enclosure that may contain radioactive particulates.

High-efficiency air cleaning systems are designed to provide for convenient, repetitive, and reliable in-place testing in accordance with Hanford Site specifications.[28] The design includes the necessary provisions such as aerosol injection ports and sampling ports.

The ventilation system is maintained under control at all times, either manually or automatically. The control system is designed so that the failure of any single component shall not significantly degrade the confinement function of the ventilation system. All controls are designed to assume a safe position or mode in case of failure. A power control room is provided which contains controlling, indicating, and alarming devices for essential operating conditions. This system includes airflows, pressure differentials between zones and across filters, temperature indicators which may indicate space or equipment overheating problems, and derivative indications of safety-related control damper positions.

Integral fire detection and suppression equipment is provided for each ventilation exhaust system. This equipment is located to prevent a fire in the space being ventilated from destroying the final filter. When a water

spray cooling chamber is used, a prefilter, mist eliminator, and spark arrestor screen precedes the final filters. Cooling sprays are automatically actuated, and annunciated by fire detection devices. Provisions are made for the collection, retention, and disposal of the cooling water.

Provisions are made so that components of the ventilation system can be tested periodically for operability, efficiency, and required functional performance under conditions as close to design as practicable. These tests include the transfer to alternate power service and ability to deliver design conditions inflow and differential pressure. Penetrations of the building exterior are kept to a minimum.

4.3.3 Protection by Equipment and Instrumentation Selection

Key items of equipment and instrumentation are provided to ensure protection against uncontrolled release of radioactivity or noxious gases. These items are provided in accordance with the following criteria.

- Protective instrumentation is designed to sense potential accident or other hazardous conditions, and automatically activate control equipment, give audible and visual alarms, or otherwise initiate corrective action in a timely manner to assure the safety of the public and operating personnel.
- Protective systems are designed to be fail-safe (i.e., in the event of loss of energy or motive power, or adverse environments, the systems shall revert to the most stable state).
- Sufficient redundancy and independence are provided in the design of the systems to assure that no single failure will result in loss of the protection function.
- Components of protective systems are designed to facilitate maintenance, inspection, periodic checking, and testing of functions or calibrations while the plant is in operation to determine whether failures or losses in redundancy have occurred.

4.3.3.1 Equipment.

4.3.3.1.1 Gaseous Radioactive Environmental Discharges. The design criteria for the exhaust ventilation and offgas systems are detailed in Section 4.3.2.

4.3.3.1.2 Geometrically Favorable Equipment. The design criteria for the subject equipment are detailed in Section 4.3.4.

4.3.3.1.3 Iodine Adsorbers/Absorbers. Iodine removal equipment is installed in an offgas treatment system if the possibility exists for the discharge to the environment of ^{129}I or ^{131}I in excess of Table I limits on a weekly average basis.[24]

4.3.3.1.4 Radiation Shielding. The design criteria for radiation shielding for personnel protection are detailed in Section 4.3.5.

4.3.3.1.5 Fire and Explosion Protection. The design criteria for the subject systems are detailed in Section 4.3.6.

4.3.3.1.6 Liquid Radioactive Environmental Discharges. All aqueous effluent streams, which normally discharge to surface ponds and which have the potential of exceeding Table II concentration guides of DOE Order 5480.1A-XI,(21) are continuously monitored for beta-gamma* activity. Upon detection of radionuclide concentrations in excess of Table I concentration guides of DOE Order 5480.1A-XI,(21) capability is provided to divert the stream to a retention basin for future rework and/or routing to a crib or an underground storage tank, depending upon retention basin sample analyses. Audio/visual alarming to a continuously occupied central surveillance location is also provided.

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4.3.3.2 Instrumentation. Instrumentation is provided for the detection of "green fuel;" alpha, beta-gamma, and ^{131}I in gaseous effluent streams; beta-gamma in liquid effluent streams; a criticality; airborne contamination; and area radiation levels. In addition, provision has been made for primary and secondary safety controls for the process and services associated with the facility.

4.3.3.2.1 Fuel Feed Monitoring. Green fuel (fuel aged less than 180 d) is detected before entry into the process and an alarm will sound in a central surveillance location.

4.3.3.2.2 Effluent Monitoring. Detection capability for alpha, beta-gamma, and ^{131}I is provided on any gaseous effluent discharge system in which significant quantities can be expected. Audio/visual alarming is provided to a central surveillance location. Detection capability for oxides of nitrogen is provided on the primary building exhaust stack (291-A-1). Detection capability for ammonia is provided on the ammonia offgas system stack (296-A-24).

Detection capability for beta-gamma activity is provided for any aqueous effluent discharge system where significant quantities can be expected. Audio/visual alarming is provided at a central surveillance location.

4.3.3.2.3 Nuclear Criticality Monitoring. Nuclear criticality detection capability is provided at noncanyon locations where there is potential for a nuclear criticality. Audio/visual alarming is provided locally and at a central surveillance location.

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*Cooling water streams with a potential for transuranic contamination are routed to the steam condensate crib or recycled within closed-loop cooling systems.

4.3.3.2.4 Airborne Contamination Monitoring. Airborne contamination detection capability is provided at all locations which are considered occupied areas or where there is potential for manned entry. Audio/visual alarming is provided locally and at a central surveillance location.

4.3.3.2.5 Area Radiation Monitoring. Area radiation detection capability is provided in all normally or potentially occupied locations. Audio/visual alarming is provided locally and at a central surveillance location. Portable detection capability is employed to supplement stationary systems.

4.3.3.2.6 Ammonia and Hydrogen Monitors. Monitors are located on sample streams from each of the three dissolver offgas systems and on the vent from the dissolver decladding waste storage vessel to assist in maintaining the concentration of ammonia and hydrogen below explosive limits while operating this equipment.

4.3.3.2.7 Process and General Instrumentation. Process control instrumentation fully monitors and controls all safety-related process variables. It is designed so that its failed mode is a safe mode for the process system and alarms its failed condition. An independent protective system such as manual control also is employed. Fail-safe design requires assured heat removal or cooling for exothermic processes in the event of instrument failure. Instrumentation is provided to prevent or control conditions which lead to explosions or uncontrolled chemical reactions. Instrumentation has backup power sufficient to safely shut down the process and services and to adequately monitor the shutdown condition.

4.3.4 Nuclear Criticality Safety

The PUREX Plant is designed and operated to minimize the potential for a nuclear criticality accident by including criticality prevention criteria in the design of equipment and process where practicable and providing operating criteria to meet the criticality prevention specification (CPS) limits. These criteria and CPS limits are derived from criticality safety analysis reports (CSAR) which meet the contingency philosophy (i.e., at least three separate, unrelated contingencies must occur concurrently before a criticality accident is possible in an unshielded area; if adequate shielding is provided for personnel, only two contingencies may be required). These contingencies may involve equipment failure, accident or operating error, or a combination of failures and errors. The CSAR which defines these contingencies is based on verified data from experiments or validated computational methods (whether empirical or theoretical using computer codes). The nuclear criticality safety program is in compliance with the requirements of DOE Order 5480.1A-V[29] and is implemented by the Rockwell Nuclear Criticality Safety Standards (NCSS) Manual.[30]

4.3.4.1 Nuclear Criticality Safety Criteria. The following basic nuclear criticality safety criteria apply to all phases of fissile material handling throughout Rockwell. Procedures are prepared for the handling, storing,

processing, and shipping of fissile material. The CPS[31,32] impose limits and controls on the handling, processing, storing, and shipping of fissile material. The CPS are based upon the technical CSAR[26,27] which provides the basis for the limits and controls imposed.

Parameters to be controlled include mass (density, enrichment, concentration), geometry (shape, spacing), moderation (material, amount), reflection (material, amount, geometry), and neutron poisons (internal, external). When practical, equipment is designed to be subcritical for the most reactive concentration of fissile material foreseeable. If control by design is impractical, the Criticality Engineering and Analysis Group specifies parameters to be controlled administratively to meet the required contingency philosophy. The facility manager involved (with Process Control Group and/or Engineering Design Group support) is responsible for providing justification to the Criticality Engineering and Analysis Group for the use of such parameters under administrative control. When geometry controls are not used, the Criticality Engineering and Analysis Group preparing the CSAR includes the administrative controls with justification for review by the Nuclear Criticality Safety Committee (NCSC).

Criticality prevention limits shall take into account neutron interaction between systems or individual units (e.g., individual fissile material batches, containers, or vessels), unless the systems are isolated to the extent ensured by one of the following criteria.

- Each system or unit is separated from other systems or units by at least 8 in. of water, or by some other material or combination of materials that gives the equivalent or better isolation than 8 in. of water, and it is not credible that this separating material can be inadvertently removed.

- Solid angle subtended by surrounding fissile material is less than or equal to a fractional solid angle of 0.005.

- Interaction has been shown by previous calculations to be insignificant under the conditions being investigated. Previous calculations shall be referenced when used.

Periodic inspections and reviews are performed to ensure that nuclear criticality prevention requirements are being implemented and to provide information for maintaining and improving nuclear safety.

All facilities not exempt from nuclear criticality safety controls are inspected regularly both by facility personnel and by the Criticality Engineering and Analysis Group according to the schedules and procedures given in the NCSS Manual.[30] It also includes methods and guidelines for performing such inspection, notification channels, and documentation and distribution of the results to assure that appropriate organizational management is informed and that necessary corrective action is taken.

Independent safety reviews are provided by the NCSC for compliance with DOE Order 5480.1A, Chapter V,[29] as implemented by the NCSS Manual.[30] The NCSC reviews all CSAR and CPS for all Rockwell facilities in which fissile material is handled, processed, stored, or analyzed; this review includes packaging and transport systems. The NCSC makes recommendations to the approval authority for approval and conducts an annual appraisal of the overall operation of each fissile facility for compliance with DOE regulations and Rockwell nuclear criticality safety standards. This appraisal reports formal findings of deficiencies and recommends corrective actions.

The CPS and PUREX CSAR are found in References 31, 32, 26, and 27 respectively.

4.3.4.2 Contingency Philosophy. At least three unlikely, independent changes in process conditions must occur concurrently before a criticality accident is possible in areas where personnel are unshielded. In shielded areas, one of the three contingencies may be omitted.

In evaluating the contingency criterion, the margin of subcriticality shall meet one of the following:

- $k_{eff} + 2\sigma^*$ is less than 0.95, including allowances for biases in the calculations. (If the method of calculation can be shown to be accurate by comparison to experimental data for a similar system, a higher value may be justified and approved. The maximum allowable k_{eff} is 0.98.)
- The fraction of a critical dimension, volume, mass, etc., including allowance for accuracy, is equal to or less than 0.90.

4.3.4.3 Verification Analyses/Experimental Bases. The criticality prevention limits are based on experimental data whenever possible. In the absence of directly applicable experimental measurements, the limits are based on theoretical calculations, provided the validity of the calculational method has been proven by correlation with experimental data. Attempts are made to assign limits of error to both experimental and calculational results.

Various computer codes (e.g., KENO, MONK, HFN, DTF) are used for PUREX criticality calculations. These codes will be correlated with experiments and/or other codes which have been verified. The Criticality Handbook[33] has been used to obtain information on sample systems; the values within this handbook were also obtained from correlated codes.

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*In this instance, sigma (σ) means the standard deviation (uncertainty) in k_{eff}, calculated by the Monte Carlo code and included in the printed code output.

4.3.4.4 Criticality Alarm and Dosimetry System. As required by DOE Order 5480.1A, Chapter V, and Standard VII of the NCSS Manual,[29,30] a criticality alarm system to detect and alarm a criticality accident has been installed throughout the plant in noncanyon areas where the potential for criticality exists; in addition, the standard requires a criticality dosimetry system to provide gamma and neutron dose information for individuals after the accident: personal dosimeters, fixed-station dosimeters, biological sample analyses, and "quick-sort" techniques. Criteria for design, installation, calibration, testing, and redundancy are provided in ANSI/ANS 8.3.[34]

Based on evaluation of the most probable criticalities, immediate evacuation will occur in areas of the facility where possible doses exceed 1 rem. In areas where persons could not receive 1 rem, evacuation will be initiated by the dispatcher. The maximum forseeable accident as defined in ANSI/ANS 8.3 is 2×10^{19} fission.[34]

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4.3.5 Radiological Protection

This section contains those design criteria for PUREX Plant access control, shielding, and radiation alarm systems which provide radiological protection. Those radiological protection design criteria pertaining to multiple confinement barriers and to ventilation offgas systems are presented in Section 4.3.2.

These design criteria are supplemented with administrative procedures designed to prevent the spread of radioactive contamination to normally noncontaminated areas within the plant, prevent unauthorized personnel from entering radiation zones, and minimize radiation exposure in excess of established limits.

The design criteria are intended to minimize the exposure of operating personnel to radiation. The design permits PUREX operations to be "conducted in a manner to assure that radiation exposures to individuals and population groups are ALARA within the standards of DOE Order 5480.1A, Chapter XI.[21]

4.3.5.1 Access Controls. The design criteria presented herein are those access controls contributing to radiation protection and to control of radioactive contamination.

The PUREX Plant is located in an isolated area and surrounded by physical barriers so that the general public and other unauthorized personnel who may be unaware of the hazardous consequences of exposure to radioactivity may be restricted from access to the plant and the plant environs. The physical barriers are provided with facilities which make it possible to monitor personnel entering and leaving PUREX.

Certain areas within the PUREX Plant where a potential exists for radioactive contamination and/or exposure are to be identified as personnel-regulated areas.

The other areas within PUREX where the potential for radioactive contamination and/or exposure is extremely low are identified as unregulated areas. Under normal conditions, personnel are allowed to move about in unregulated areas without restrictions for radiological or contamination protection.

Electric doors, which are operated from a central surveillance location, are used to control ingress, and where necessary, traffic within the controlled areas. Controlled areas are areas within regulated areas that have a potential for personnel exposure to high radiation levels or have limited access to help safeguard special nuclear material.

Emergency escape doors are provided so that personnel can, under emergency conditions, leave the controlled areas rapidly. The emergency escape doors are provided with locks for preventing unauthorized entry into the controlled areas. Quick-release hardware is provided so that each door can always be opened easily from within the controlled areas. Each emergency escape door has an electric device which indicates the status of the door (i.e., open or closed). The status indicators are located in a central surveillance location, so that unauthorized use of the emergency escape doors can be detected quickly.

A safety analysis indicated that none of the safeguards and security features would obstruct emergency access and egress from the PUREX Building or from personnel regulated areas within the building.[35]

Facilities are provided for donning and removing protective clothing at all normal entrances to regulated areas.

Monitoring stations are provided at all normal exits from regulated areas so that personnel leaving the areas can be surveyed for radioactive contamination before leaving. These stations are used unless a criticality alarm sounds that is not part of an announced test. Under this condition, the area is evacuated as rapidly as possible and personnel from regulated areas are monitored as they reach the assembly area.

4.3.5.2 Shielding. The design criteria presented herein are those radiation shielding requirements which limit PUREX background radiation to safe dose rate levels. The design objective for radiation shielding shall be to limit onsite PUREX personnel exposures to less than one-fifth of the DOE Order 5480.1A, Chapter XI standards.[21] Design considerations are occupancy time, source term, spacing, processes, equipment, and shielding.

4.3.5.2.1 Regulated Areas. Continuous personnel occupancy is allowed in regulated areas where the radiation dose rate does not exceed 0.5 mrem/h. "Continuous occupancy" is defined for this criterion as time equivalent to 40 h/wk for 50 wk/yr.

In some regulated areas, it is impractical, because of necessary activities, to limit radiation dose rates to 0.5 mrem/h. Thus, regulated areas where radiation dose rates exceed 0.5 mrem/h are posted and administrative controls are used to prevent radiation exposure to personnel who enter these areas from exceeding predetermined safe limits.

4.3.5.2.2 Unregulated Areas. With existing shielding, radiation dose rate levels in the unregulated PUREX areas do not exceed 0.1 mR/h. Because of this low maximum dose rate, there are no occupancy time limitations for unregulated PUREX areas.

4.3.5.3 Radiation Alarm Systems. This section describes the criteria used for action levels from radiation alarm systems. The following monitoring systems for detecting unusual levels of radioactivity are equipped with alarms, which sound at central surveillance locations:

- Nuclear criticality accident detection
- Area radiation detection
- Airborne radiation detection
- Effluent monitoring
- Green fuel detection.

Radiation monitoring systems (area monitors, continuous air monitors, effluent monitors) are appropriately selected, installed, tested, and calibrated following the recommendations of ANSI N13.10-1974.[36] The action level criteria for each of these systems are described in the following sections.

4.3.5.3.1 Nuclear Criticality Accident Detection. In accordance with the requirements of DOE Order 5480.1A, Chapter V,[29] the criticality detectors are capable of detecting a criticality accident which produces an absorbed dose in soft tissue of 20 rads of combined neutron and gamma radiation at an unshielded distance of 6.5 ft from the reacting material within 1 min. The detectors are capable of triggering evacuation alarms for radiation bursts as short as 1 ms. Noncanyon areas where there is a potential for a criticality accident are covered by at least two criticality detectors; concurrent response by at least two detectors is necessary to activate a criticality alarm. Administrative controls limit the amount of fissile material not in approved containers in other noncanyon areas to less than a critical mass. Fissile material is handled, stored, processed, or transported only in designated areas which have been analyzed and are controlled to prevent a criticality accident. There will be administrative procedures to prevent significant quantities of fissile material from being transported to nondesignated areas.

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Since adequate shielding is provided to preclude significant radiation exposure to personnel, criticality detectors are not installed in canyon areas. Any criticality accident occurring in these areas would be detected by effluent monitors (see Section 4.3.5.3.4).

4.3.5.3.2 Area Radiation Monitoring. The area radiation detection/monitoring system is an early warning system which provides alarms at local and central surveillance locations. About 60 fixed radiation detectors are located throughout the plant process-related areas that are frequently occupied or contact maintained.

Each detector in the system activates a warning alarm at a level high enough above the normal area radiation dose rate to avoid an inconvenient number of false alarms, but low enough to prevent high radiation levels from existing for periods long enough to be hazardous. The detectors activate the warning alarms at radiation dose rates ranging from 10 to 100 mrem/h.

4.3.5.3.3 Airborne Contamination Monitoring. All areas within PUREX where a potential for personnel exposure to airborne radioactivity exists are continuously monitored and sampled for particulate airborne radioactivity. The monitors are set to activate warning alarms at radioactivity levels which are as low as possible above background levels, but high enough to preclude frequent false alarms.

4.3.5.3.4 Effluent Monitoring. The gaseous effluent monitors alarm at a central surveillance location. Alarms are triggered at the lowest possible radioactivity concentrations below the Table I guides of DOE Order 5480.1A, Chapter XI,[21] but high enough to avoid frequent false alarms. The canyon stack effluent is monitored for short-lived isotopes (iodine and noble gasses) to detect a criticality within the canyon cells. The liquid effluent monitors perform in the same manner but alarms are triggered below Table II guidelines for transuranic contaminants.

4.3.5.3.5 Green Fuel Detection. A green fuel monitor activates an alarm at a detection level which identifies irradiated fuel containing more than 75 Ci ^{131}I/t of uranium. The monitor must alarm for fuel aged less than 97 d (99% confidence) and shall not alarm for fuel aged more than 180 d. The measurement is indirect and based upon gamma radiation. A check source is provided to periodically verify operability of the monitor.

4.3.6 Fire and Explosion Protection

Fire and explosion protection is provided for the PUREX Plant to meet the "improved risk" level required by DOE Order 5480.1A, Chapter VII.[37] "Improved risk" signifies that qualified engineering judgment has been used to obtain the highest economically justifiable level of industrial loss prevention. The major criteria for the protection system are described in the following paragraph.

Structures, systems, and components are protected so that performance of safety-related functions is not impaired under credible fire and explosion conditions. Noncombustible and fire-resistive materials are used wherever practicable throughout the facility, particularly where associated with or part of confinement barriers and systems. Fire detection, alarm, and suppression systems are provided to be compatible with the radiation, chemical, and temperature environments in which they are to function. Fire suppression systems are provided to quench the maximum credible fire. Fire alarms, supplemented by manually initiated sirens, are audible throughout the facility and ancillary buildings. The location of the fire is indicated on alarm panels at a continuously manned location (i.e., the Dispatcher's office) and transmitted to the fire station. Fire protection systems and equipment are maintained and operated in accordance with national fire codes.(38)

A Factory Mutual fire protection review was conducted in 1971, with recommendations made for improvements necessary to comply with the "improved risk" level;(39) these improvements have been made. A Factory Mutual revisit was made in 1975 to confirm the "improved risk" compliance.(40) However, a survey(41) conducted by Rockwell Industrial Hygiene and Safety in December 1981 revealed several deficiencies for compliance with the life safety code, as required by national fire codes,(38) DOE 5480.1A, Chapter VII,(37) and DOE Order 6430.(4) All critical survey deficiencies have been corrected; less serious deficiencies will be corrected following startup. Future consultant reviews and DOE appraisals, as required by DOE Order 5480.1A, Chapter VII,(37) will be made to maintain the "improved risk" status.

4.3.7 Fuel and Radioactive Waste Handling and Storage

4.3.7.1 Spent Fuel Receiving and Handling. A 20- by 30-ft concrete basin, open to the canyon and containing 12 ft of water is designed to limit the radiation level at the surface to 100 mR/h during interim storage of aluminum-clad production reactor fuel. The storage rack is designed for a nominal capacity of 35 t of fuel in yoke-suspended buckets on one level and a maximum capacity of 68 t on two levels. The yokes are specially designed and will not accept canisters containing N Reactor fuel. Equipment is provided to add water and empty the water by jet to the steam condensate header and the 216-A-30 crib. Weight factor instrumentation, with visual observation as a backup, is used to determine the water level; analyses of periodic dip samples is the method specified to determine fuel element integrity.

The basin will not be used for N Reactor fuel. Additional safety analysis and physical modification would be required to ensure the safe storage of any fuel other than the aluminum-clad production reactor fuel.

The PUREX facility provides for the receipt of N Reactor fuel contained in shielded transport casks. Either "NPR" or "K" casks and cars can be received and handled. The casks are not removed from the waterfilled "well cars" at the PUREX Plant. Principal safety-related design criteria for the fuel receiving and handling facilities include the following:

- Facilities for handling the cask cars, including remote moving and positioning of the cars
- Remotely controlled (lock-unlock) entrance doors to the railroad tunnel to prevent uncontrolled personnel access to the tunnel and, in conjunction with the canyon ventilation system, prevent the spread of contamination to the environment
- Facilities for decontaminating cask cars
- Provisions to measure the temperature of the water in the cask wells and detect abnormally high radiation from the casks or cask wells
- Provision for detecting short-cooled fuel
- Provision for adding water to the cask wells
- Provision for the remote removal of the cask lids and transfer of the irradiated fuel from the casks to the dissolvers.

4.3.7.2 Radioactive Waste Treatment. Radioactive wastes generated at the PUREX Plant are divided into five classifications according to the methods of handling or disposal and/or their potential radioactivity: gaseous, low-level liquid, high-level liquid, miscellaneous solid, and failed equipment. The general criteria requirements for the management of radioactive wastes are delineated in DOE Order RL 5820.2.[42] Design criteria for the gaseous and low-level liquid waste treatment and handling facilities were discussed in Section 4.3.3. Principal safety-related design criteria for the treatment and handling facilities for high-level liquid and miscellaneous solid wastes and failed equipment are described below. Onsite transfers of fissile and/or radioactive material comply with the requirements of DOE.[43,44]

- High-Level Liquid Wastes
  - Vessels containing concentrated, high-level waste solutions are provided with adequate cooling for the maximum expected heat generation rate as determined by tank capacity and fuel history (defined in Section 4.1.1).
  - Vessels containing high-level waste are provided with means of assuring a sufficient air supply (either purge air, sparge air, or other in-leakage) to dilute the hydrogen formed by radiolysis to a safe concentration.

- All pipelines used for transporting high-level waste solutions are contained either in a building or in a second, larger pipe or encasement, and are shielded to minimize the potential for radiation exposure to personnel and accidental releases to the environment.

- Miscellaneous Solid Wastes

  - Miscellaneous solid wastes, including small equipment items, are packaged, sealed, and shielded as necessary to prevent accidental spread of contamination or exposure of personnel.

  - Provision is made for segregating the solid wastes according to the transuranic element content.

  - The transuranic wastes are packaged in impervious, 20-yr retrievable containers, and stored in a retrievable storage area. Transuranic wastes are defined as containing greater than 10 nCi of transuranium elements (alpha-emitting radionuclides with half-lives greater than 100 yr, including ^{233}U and daughter products) per gram of waste matrix.

- Failed Equipment

  - Large-size failed equipment (e.g., large process equipment pieces such as dissolvers, towers, vessels, concentrators, etc.) is loaded on old rail cars and stored in the PUREX burial tunnels.

  - Materials of construction capable of sustaining combustion are kept to a minimum on both the rail car and the equipment containment envelope (if one is provided).

  - Intermediate-size failed equipment (e.g., tube bundles, process jumpers, pumps, etc.) is placed in noncombustible retrievable boxes that are capable of being sealed. The boxes are either stored on old rail cars in the PUREX burial tunnels or placed in concrete burial boxes and "buried" in a designated radiation burial ground in trenches covered by at least 8 ft of earth fill for radiation shielding.

4.3.7.3 PUREX Solid Waste Storage Facility. PUREX burial tunnel 2, described in Section 7.7.6.1, is used for storage of all large-size, failed equipment and, optionally, for storage of sealed boxes containing intermediate-size equipment. It is provided with a filtered exhaust system meeting the criteria of Section 4.3.2.2. A shielded containment door is provided at the entrance to the tunnel and is kept closed except when equipment is actually being transported into the tunnel.

4.3.8 Industrial and Chemical Safety

Operations of facilities in a manner to protect the general public, government and contractor personnel, as well as public and private property against potential health and safety hazards and excessive exposure to radiation is of primary importance to the continued operation of Rockwell facilities. One of the management control factors in obtaining the objective of a safe work environment is the application of recognized standards and codes in design, construction, and operation. The Rockwell Occupational Safety and Health Standards include applicable Safety Standards and Codes.(45) The provisions of DOE Order 5480.1A, Chapter I(46) and DOE Order 5483.1(47) are included.

A discussion of the design criteria implemented to avoid chemical hazards follows.

4.3.8.1 Flammable Materials and Oxidants. A list of design criteria implemented specifically to avoid damage by combustion-type mechanisms follows.

- Only nonflammable or flame-resistant materials are used in the construction of plant facilities to the extent practicable.
- All vessels in which solvent is stored or processed are provided with means for measuring and controlling the solution temperature.
- Equipment in areas where solvent aerosols might be generated are designed to minimize the probability of occurrence of sources of localized high temperature (e.g., sparks and hot bearings).
- Hydrogen is produced in the PUREX process during fuel decladding and by the radiolysis of process solutions. Capability is provided for dilution of hydrogen to a noncombustible concentration.
- Sufficient chemical storage capacity/space is provided so that oxidizing chemicals (e.g., nitric acid, potassium permanganate) can be isolated from combustible materials.

4.3.8.2 Thermodynamically Unstable Compounds. A list of design criteria for thermodynamically unstable compounds follows.

- Nitrated Organic Solvent

  Solvent/diluent nitration products can be formed by chemical reaction between the organic and nitric acid or heavy-metal nitrate solutions. These compounds are unstable and some can decompose violently if heated sufficiently. To prevent the formation of solvent/diluent nitration products, equipment is provided to remove organic from aqueous solutions by decantation

or steam stripping prior to concentration. In addition, instruments and controls are provided on all concentrators to ensure temperatures less than the safety boundary (135°C or 140°C depending on concentrator function).

- Nitrated Ion-Exchange Resin (not currently planned for use)

  Anion exchange resin reacts readily with concentrated nitric acid to form various nitrated organic compounds. The nitration reactions are enhanced by the presence of neptunium, plutonium radiation, and increased temperature. The compounds formed are unstable and will decompose violently and spontaneously with substantial energy release. The resin nitration reactions can be controlled at acceptable rates by controlling the temperature of the resin. Explosive decomposition can be prevented by providing adequate emergency venting of the system. Ion-exchange processing equipment is protected by instruments and equipment adequate to provide positive control of the temperature at less than 50°C and by an emergency venting system, including a rupture disk.

4.3.8.3 Physiological Irritants. Some process materials are harmful to man if inhaled, ingested, or contacted.

Vessels that might contain physiological irritants are provided with ventilation systems of sufficient capacity so that the maximum concentrations of irritants in air to be breathed by man are limited to the concentration levels shown in Table 4-8.

TABLE 4-8. Maximum Concentrations for Irritants in Air.

Irritant	Concentration (ppm parts of air)
NO_x	5
HNO_3	2
N_2H_4	1
HF	3
F_2	1

Systems containing chemicals that can injure people by contact (e.g., liquid oxygen or nitrogen, fluorine, hydrazine, nitric acid) are designed so that personnel need not contact the materials during normal operations or while flushing for maintenance.

Appropriate protective equipment (insulated or impervious clothing, face mask, etc.) is provided for the protection of personnel while coping with abnormal or potential accident conditions.

4.4 CLASSIFICATION OF STRUCTURES, COMPONENTS, AND SYSTEMS

When the PUREX Plant was designed and constructed, structures, components, and systems were not specifically classified as to safety function, seismic considerations, or quality assurance level. However, all process vessels were grouped into three classifications, according to location and use; descriptions follow:

- Class I

  All vessels normally located in the 202-A canyon process cells or subject to remote maintenance and operation

- Class II

  All vessels fabricated of stainless steel, located outside the 202-A canyon process cells, and subject to contact maintenance and operation

- Class III

  All vessels not included in classes I or II and normally fabricated of carbon steel.

Design criteria for the classes of process vessels described above are contained in the original criteria document.[9]

The structural design of the original 202-A building was based on the natural forces resistance requirements of UBC-1952 which specified minimum (life and limb) wind, seismic, and snow loadings.[1] Detailed design criteria are given in Section 4.2. Recent natural forces studies with risk-benefit analyses have resulted in planned structural upgrading improvements. Detailed design criteria for the improvements are given in Section 4.2.

Quality assurance levels, as such, were not specified for design and construction of the original PUREX Plant; however, a high-quality facility was realized by good design and construction practices. Quality assurance was formally instituted at the Hanford Site in 1974 by ERDA MC 0820[48] (superceded by DOE Order 5700.1)[49] and implemented in the chemical processing facilities in 1975 by the Rockwell Quality Assurance Manual.[50] The current Quality Assurance program is described in Section 10.7; all PUREX Plant modifications and improvements since 1975 have been designed and constructed using this program.

4.5 DECOMMISSIONING

The design of the original PUREX Plant contained no specific criteria to facilitate its future decommissioning. The requirement for incorporation of decommissioning criteria in federal facilities was instituted in 1972; the latest revision is contained in DOE Order 6430.[4] Four design principles were offered by the latter document for consideration, so that the facility could be decontaminated for future decommissioning; none of these principles were incorporated in the original design. In addition, due to the nature of the basic facility structural design, only one (i.e., minimization of radioactivity accumulations in soil columns) has been included in facility modifications and/or improvements.

Although it is recognized that the required structural design of the PUREX Plant does not lend itself to simple decontamination/decommissioning techniques, it is judged that its proposed startup and renewed operation will not render its ultimate decommissioning appreciably more difficult or costly.

Additional PUREX Plant decommissioning information, including planning and past experience, is presented in Section 10.6.

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CHAPTER 5.0 FACILITY DESIGN

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5.0 FACILITY DESIGN

5.1 SUMMARY DESCRIPTION

This chapter provides a description of the Plutonium-Uranium Reduction Extraction (PUREX) Plant buildings and related facilities. The design features discussed include those employed to:

- Withstand natural forces
- Ensure safe operation
- Provide personnel safety
- Ensure radiological protection.

The PUREX Plant was designed to chemically process irradiated fuel elements. Radiological containment and confinement features were incorporated in the various facilities and support systems to prevent exposure of plant personnel and the general public to excessive radiation. After plant production was initiated, the design was modified to improve the containment and confinement capability by the following:

- Provision of additional filtration of certain gaseous effluent streams
- Installation of additional fire protection systems
- Provision for reusing, reprocessing, or diverting the aqueous effluent streams to reduce radioactive discharges.

5.1.1 Site Location and Facility Layout

The Hanford Site is located in the southeastern part of the State of Washington (Fig. 3-1) about 45 mi north of the Oregon border. The site occupies about 570 mi^2 (365,000 acres) of arid land.

In the middle of the Hanford Site, on an arid terrace about 7 mi from the Columbia River, are the 200 East and 200 West Areas, where fuel and waste processing and waste storage facilities are located. The locations of the 200 Areas were chosen to provide the most isolation from the site boundaries and are the most remote from both surface and subsurface water. The groundwater table varies from 150 to 300 ft below the surface of the 200 Areas.

Other occupied portions of the Hanford Site include the 100 Areas along the Columbia River, where the production reactors are located; the 300 Area north of Richland, where the research and development laboratories and fuel production facilities are located; the 400 Area, or Fast Flux Test Facility

(FFTF) site, about 7 mi northwest of the 300 Area; and the sites of the nuclear power reactors (under construction) about 2 mi north of the 400 Area.

The area of the Hanford Site not included as one of the 100, 200, 300, or 400 Areas is designated the 600 Area. The support areas are shown in Figure 3-2. Each area, except the 600 Area, operates as an individual, fenced, and controlled, limited access area.

The PUREX Plant is a complex of several buildings and support facilities located within a fenced and controlled or limited area in the southeast corner of the 200 East Area. The support facilities are described in Section 5.1.2.5. Details of the roadways, railways, and associated facilities are given in Chapter 3.0.

The plant grade elevation is 708 ft above mean sea level (MSL). It is 300 ft above the underlying water table at 408 ft MSL, and 250 ft above the elevation of the Columbia River at 458 ft MSL. The river makes its closest approach 7 mi to the northwest of the plant site.

Truck transportation to and from PUREX is provided via the Hanford Site highway system connecting the state highways at three portals on the southeast, south, and west boundaries.

The Hanford Site railroad system provides rail transport directly into the main processing (canyon) building and connects to other areas within the site. Commercial railroad connections are with Burlington Northern and Union Pacific through the south portal at North Richland.

5.1.2 Principal Features

5.1.2.1 Site Boundary. The general location of the PUREX Plant on the Hanford Site is shown in Figure 3-2. The 21-acre PUREX Plant site is surrounded by a fence within the southeastern corner of the about 2,125-acre 200 East Area. The PUREX Plant fenced area is shown in Figure 3-3.

The plant site is managed as a limited area within the 200 East Area, which itself has limited access as a U.S. Department of Energy (DOE) security area. Security guards man the two entrances to the Hanford Site (two paved roads: one to the west at the Yakima Barricade and one to the south at the Wye Barricade). Only appropriately cleared personnel, or escorted tours with a need to enter either the 200 or the 100 Areas, are permitted to enter.

5.1.2.2 Limited Area. The definition of "limited area,"[1] is a security area in which guards or other internal controls can prevent access by unauthorized persons to classified material. This includes denial or removal of personnel and property from the area. In this sense, the 200 East Area (security area) and the Hanford Site (controlled area) are each considered a limited area.

5.1.2.3 Controlled Area. A controlled area is any area to which access is controlled to protect individuals from exposure to radiation and radioactive materials. The PUREX Plant site is a controlled area. Protection from radiation is achieved not only by control of access, but also through personnel training, procedures, regulations, management practices, and radiation monitoring systems and devices. Since only persons with appropriate clearance are passed through the Wye and Yakima Barricades, the greater part of the entire Hanford Site is also a controlled area.

5.1.2.4 Site Utility Supplies and Systems. Steam, water, and electrical utilities are provided from sources outside of, but adjacent to, the PUREX Plant site (see Section 5.4); compressed air is furnished from within the PUREX Plant. These sources may serve plants in other areas within the Hanford Site, or may serve only the facilities within the 200 East Area. Utilities are described in detail in Section 5.4.

5.1.2.4.1 Electrical. Normal electrical power is supplied via two independent, separately located 13.8-kV power lines from the 251-W primary electrical substation. The 251-W Primary Substation, located within the Hanford Site 4 mi northwest of the PUREX Plant, receives its electrical supply of 230 kV from the Bonneville Power Administration's (BPA) Midway Station 9.5 mi to the west on the south bank of the Columbia River below Priest Rapids Dam, and from the White Bluffs substation near Horn Rapids. See Figure 5-1 for an offsite supply, one-line diagram.

Standby electrical supply to the PUREX Plant is provided by diesel generators located on the north side of the 202-A building. A complete description of the electrical systems for the PUREX Plant is given in Section 5.4.2.

5.1.2.4.2 Water. Water for the 200 Areas is drawn from the Columbia River at the 100 B Area and is transported through a piping system known as the "export water system." Pumps at the 100 D Area are also tied into this system and serve a backup function.

Within the 200 East Area, the export water is pumped into the 282-E reservoir, which provides a 3,000,000-gal storage capacity. The water is pumped, as needed, directly to plants within the 200 East Area for use as "raw" water, or through the 283-E building for conversion into "sanitary" water by chlorination and filtration.

Raw and sanitary water are pumped by electric pumps (with steam-driven pumps for backup) to the PUREX Plant complex. The sanitary water system in the 200 East Area also includes the 2901-A, 50,000-gal elevated tank located 1400 yd east of the 283-E filtration plant. A complete description of the water systems for the PUREX Plant facilities is given in Section 5.4.5.

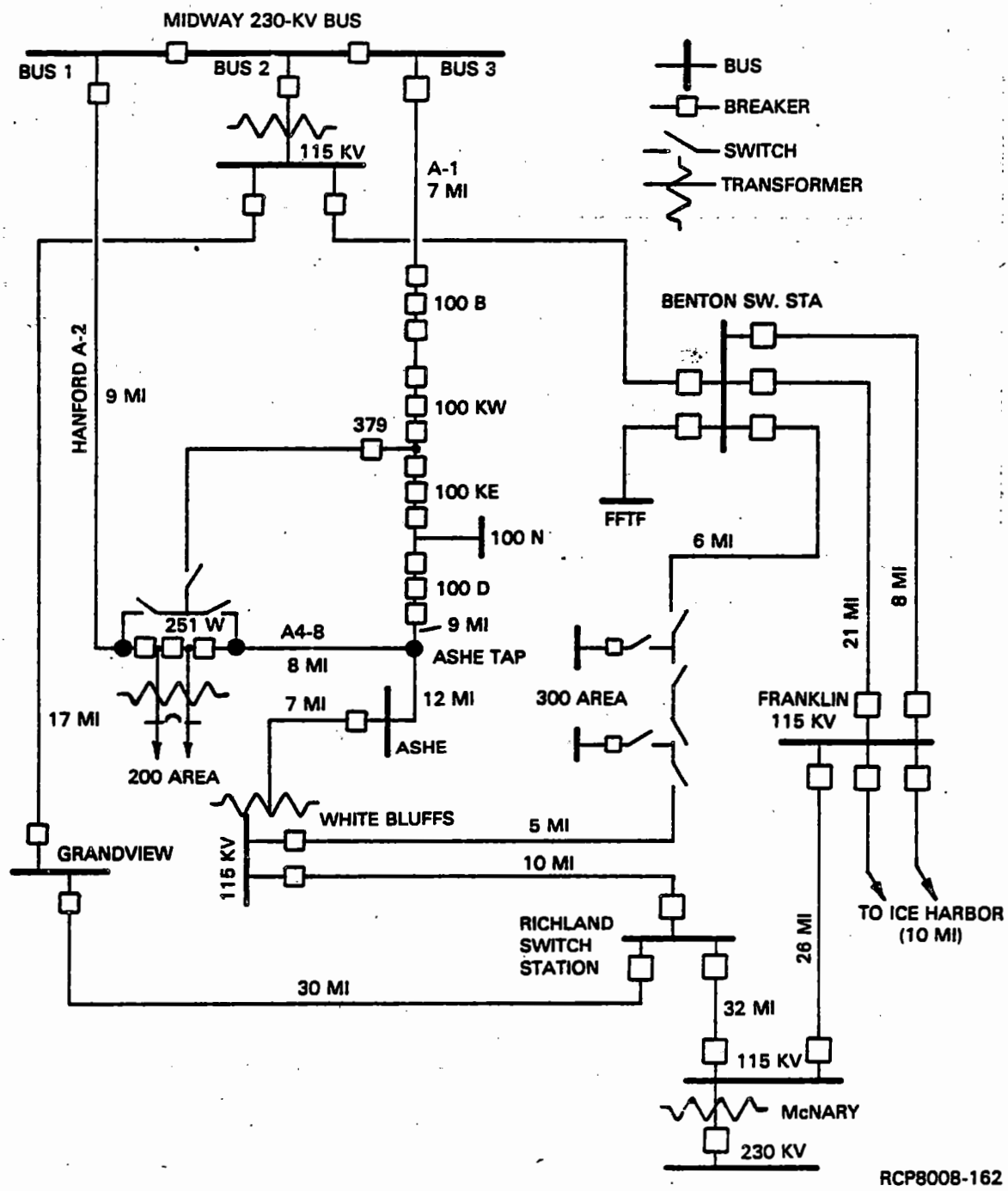


FIGURE 5-1. One-line Diagram Bonneville Power Administration Offsite System.

5.1.2.4.3 Steam. Steam is produced at the 284-E powerhouse by coal-fired boilers (five boilers available, with up to four on line and at least one on standby) and supplied to the PUREX Plant at 225 lb/in.^{2} gauge in an 18-in. overhead line. A loop header feeds the PUREX Plant from three lateral distribution points. A complete description of the steam system at the PUREX Plant is given in Section 5.4.4.

5.1.2.4.4 Air. Compressed air for instrumentation and control is produced in the PUREX Plant by three process air compressors, for process and instrument air, and one breathing air compressor. A complete description of the system is given in Section 5.4.3.

5.1.2.5 Auxiliary Facilities within the 202-A Controlled Area. The various structures located in the 202-A controlled area may be considered as two groups, based on geographical location around PUREX. Those structures south of the 202-A building are primarily for gaseous, liquid, and solid waste treatment and handling. Those north of 202-A are concerned primarily with chemical storage and handling. The auxiliary facilities are shown in Figure 5-2.

5.1.2.5.1 Facilities South of 202-A. A list of the facilities south of the 202-A building follows.

- 212-A Building

  This is a steel building for load-in and load-out of liquid wastes. The facility can handle casks as well as tank trailers. This facility is in shutdown status and there are no plans for its use.

- 213-A Building

  This is a steel building formerly used for liquid waste loading, now used for temporary storage of contaminated dry waste.

- 241-A Diversion Box

  This is a below-grade concrete enclosure equipped with remote jumpers and spare nozzles for routing waste solutions to tank farms.

- 291-A Structures

  These structures comprise the canyon exhaust air treatment and discharge facilities. Two underground concrete filter cells are operated in parallel, filtering the canyon exhaust air. A third filter cell is available for use in the event the other two cells become plugged. The air is pulled through the filter cells and an underground concrete tunnel by three, electrically driven exhaust blowers operating in parallel. A fourth, steam turbine-driven blower provides backup service. The blowers discharge via an underground concrete tunnel to a 200-ft-high concrete stack. The stack has a full-length, 7-ft-diameter, stainless-steel liner.

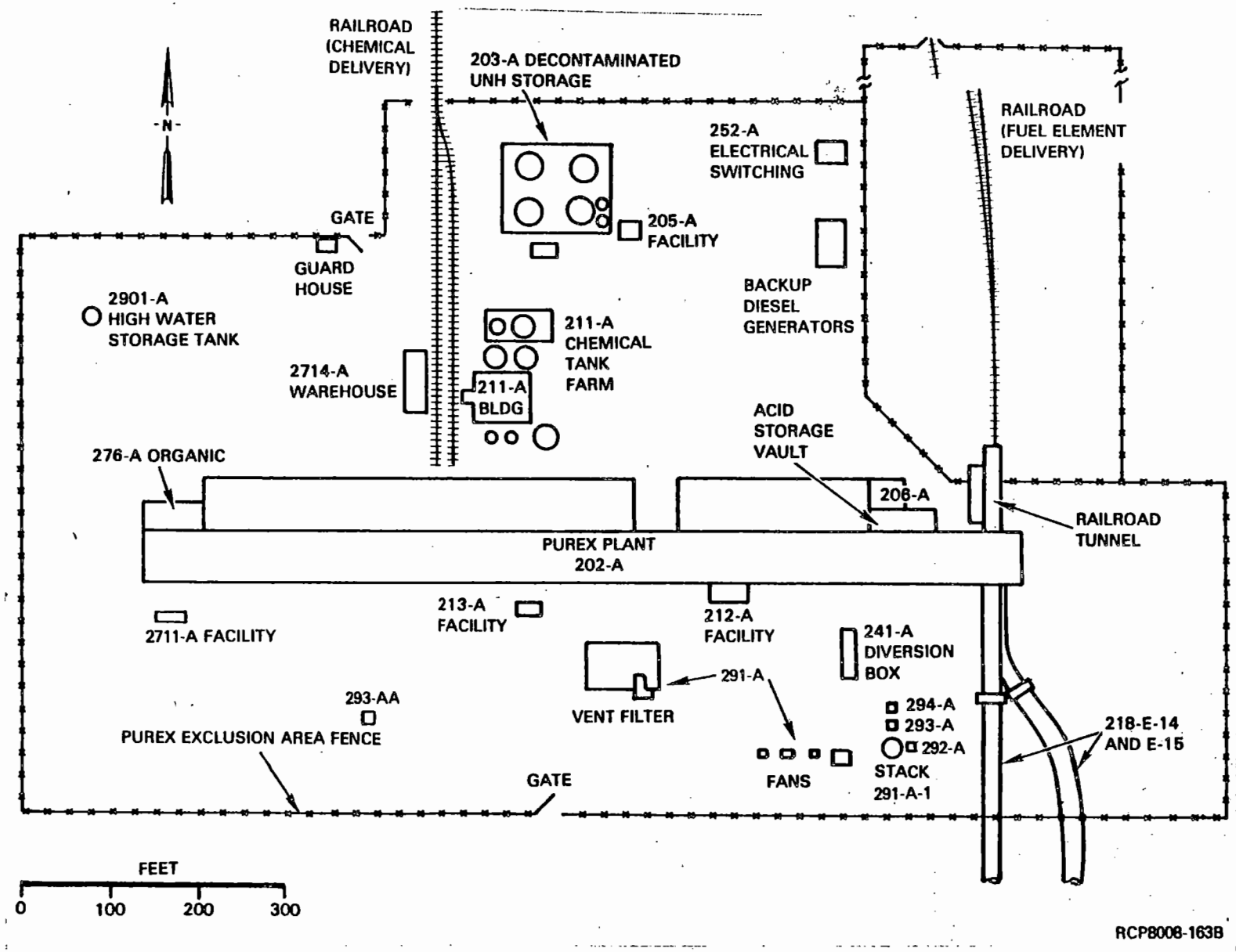


FIGURE 5-2. Auxiliary Facilities.

- 292-A Building

  This is a wood structure adjacent to the east side of the 200-ft stack housing stack monitoring and sampling equipment and stack flushing controls.

- 293-A Building

  This is a concrete structure with four processing cells on two levels. Housed inside are two absorption towers used to remove oxides of nitrogen and residual radioiodine from dissolver offgas (DOG).

- 293-A Storage Facility

  This is a concrete retention basin with a 13,000-gal capacity that contains three 10,000-gal aluminum tanks that are used to store 50 wt% hydrogen peroxide.

- 294-A Facility

  This is a small steel building above grade and three filter cells below grade. The 294-A facility is located north of 293-A and provides secondary filtration of DOG.

- 2711-A Facility

  This is a small steel building located near the southwest corner of the 202-A building. The 2711-A facility contains the equipment required to supply dry air to gloveboxes in the plutonium oxide production facility.

- 218-E-14 and 218-E-15 Tunnels

  These are two earth-covered tunnels extending southward from the east end of the 202-A building. The inactive, older tunnel (218-E-14) uses wood shoring; the new tunnel (218-E-15) is a concrete and corrugated steel structure.

5.1.2.5.2 Facilities North of 202-A. A list of the facilities north of the 202-A building follows.

- 203-A Tank Farm

  This facility includes a pumphouse, concrete pad enclosed and sectionalized with concrete dikes, containing four 100,000-gal tanks used for receipt, storage, and tank-trailer loading of uranyl nitrate hexahydrate in acidic solution (UNH) product solution. Also included are a 14,000-gal UNH concentration rework tank, two 7,300-gal tanks and one 13,800-gal tank for nitric acid recovered at the UO_3 Plant, and a 4,000-gal sumpwaste-collection tank.

- 205-A Facility

  This facility is comprised of a transite building housing the deactivated silica gel facility that was formerly used for uranium product treatment.

- 206-A Facility

  This is a concrete structure adjacent to U cell that contains a vacuum fractionator and associated equipment for concentrating in-plant and uranium oxide plant recycled nitric acid.

- 211-A Facility

  This is a steel and transite pumphouse and associated tank farm for receipt, storage, and bulk-handling of "wet" process chemicals. The process water demineralizer is located in the pumphouse. See Section 5.3.3.2 for further description.

- 2714-A Building

  This is a steel warehouse for receipt, storage, and transfer of process chemicals received in less-than-bulk quantities.

- Backup Diesel Generators

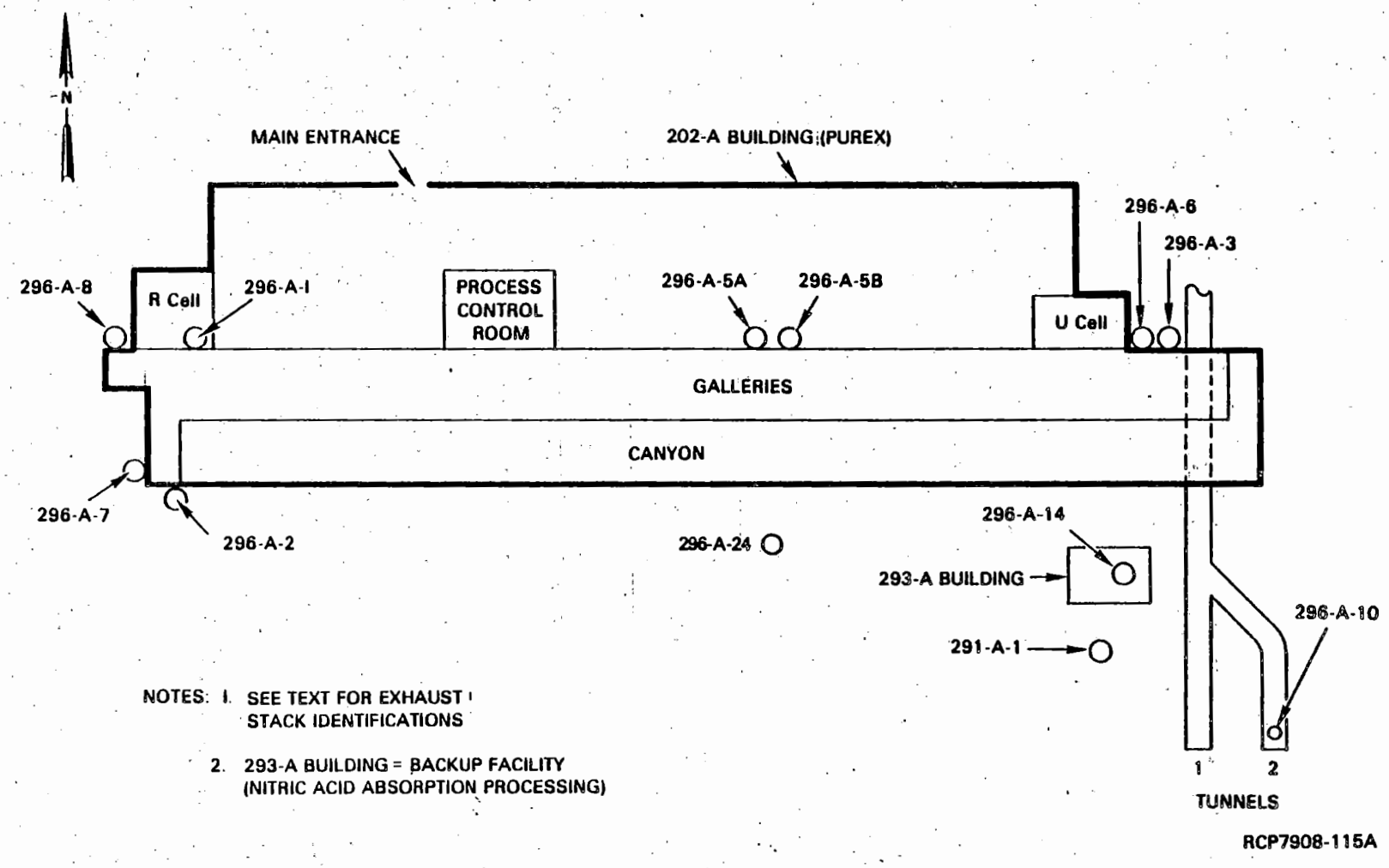
  These are the diesel generators that provide backup power for the plant.

- 252-A Electrical Switch

  This is an electrical transformer station that serves the PUREX Plant.

5.1.2.6 Stacks. There are 12 stacks (Fig. 5-3) exhausting to the atmosphere from the PUREX Plant. The largest, 291-A-1, is made of reinforced concrete, stainless-steel lined, 200 ft tall and handles the ventilation exhaust air from the processing cells. This stack is located near the southeast corner of the main canyon building (202-A). The remaining shorter stacks and the areas exhausted are as follows.

Stack number	Stack location	Area exhausted
296-A-1	Northwest corner of 202-A building	Filtered exhaust from N and Q cells and product removal (PR) room
296-A-2	Southwest corner of 202-A building	West sample gallery hood--filtered exhaust
296-A-3	Northeast corner (stairwell 13) of 202-A building	East sample gallery hood--filtered exhaust



NOTES: 1. SEE TEXT FOR EXHAUST STACK IDENTIFICATIONS

2. 293-A BUILDING = BACKUP FACILITY (NITRIC ACID ABSORPTION PROCESSING)

FIGURE 5-3. PUREX Exhaust Stacks.

Stack number	Stack location	Area exhausted
296-A-5A 296-A-5B	On roof of 202-A Laboratory Annex	Filtered air from rooms and hoods (east and west ducts)
296-A-6	Northeast corner (stairwell 13) of 202-A building	East sample gallery and U cell--filtered exhaust
296-A-7	Southwest corner of 202-A building	West sample gallery, N cell, PR corridors, and R cell--filtered exhaust
296-A-8	Northwest corner of 202-A building	White room--filtered exhaust
296-A-10	South end of 202-A building, equipment disposal tunnel 2	Filtered air from disposal tunnel 2
296-A-14	On roof of 293-A backup facility	Filtered exhaust from the 293-A building
296-A-24	South side of 202-A building	Filtered exhaust from ammonia offgas system

The locations of the various PUREX Plant stacks in relation to the PUREX Facility and other nearby facilities are shown in Figure 5-3.

The effluent streams from all of the exhaust stacks are all continuously sampled, and the samples are periodically analyzed for radioactive particulate content. In addition, the higher risk streams are continuously monitored for radioactive or noxious gas content.

5.1.2.7 Buried Piping, Encasements, and Ductwork. A complex of buried piping, encased piping, and buried ductwork services the PUREX Plant. The systems described here include high-level waste transfer lines, UNH solution transfer lines, the chemical sewer, steam condensate, process condensate, cooling water and ammonia scrubber waste condensate discharge lines, and the ductwork servicing the main filter and DOG systems.

Liquid waste from the east end of the 202-A building (D and E cells) is routed to underground waste storage tanks in the tank farm system via piping in the east waste encasement. A similar encasement and piping system routes waste from F, G, and R cells around the west side of the building to the tank farm system.

The UNH product transfer piping from K cell to the 203-A UNH storage tanks is in a similar encasement located on the north side of the building.

A buried, vitrified clay pipe located on the north side of the 202-A building serves as a chemical sewer handling the aqueous makeup (AMU) and chemical storage drainage, ventilation system steam condensate and cooling water from the acid fractionator overhead condenser. The stream discharges to the A-29 ditch and on to the 216-B-3 pond. The chemical sewer stream is provided with a continuous sampler/monitor, flow totalizer, and automatic diversion capability.

The cooling water discharge header is a buried carbon steel line located on the south side of the 202-A building. The header normally discharges to the 216-A-25 pond; however, continuous sampling/monitoring, flow totalizing, and automatic diversion capabilities are provided. The stream is automatically diverted to a retention basin (216-A-42) in case the cooling water discharge stream is contaminated.

The steam condensate header is also a buried, carbon steel line located on the south side of the 202-A building. The header drains from the east and west ends to a catch tank, and the steam condensate is pumped to the 216-A-30 crib. The header is equipped with a sampler/monitor station and a diverter station, which also diverts to the 216-A-42 retention basin.

The process condensate is discharged through lines located on the south side of the building to the 216-A-10 crib. A flow-proportional sampler and a monitor are provided for this stream.

Ammonia scrubber waste condensate is sent to the 216-A-36 crib located south of the 202-A building. A proportional sampler and a monitor are installed in this waste line.

On the south side of the building, buried concrete ductwork routes the canyon exhaust stream from the air tunnel to the 291-A buried filters to the 291-A plenum. The 291-A plenum is serviced by the exhaust fans, which discharge to a buried ductwork going to the 291-A stack. The stack drains to the buried 216-A-1 or 216-A-2 tanks, which in turn are jetted to the U3 tank (laboratory waste receiver) in the 202-A building.

The DOG lines are routed through a covered, concrete encasement to the 294-A offgas filter facility and then to the 293-A building. In the 293-A building, the offgas is routed either through or around the backup facility (depending on whether the dissolver is in a dissolving or cladding removal cycle) and to the 291-A stack.

The details of handling and measurement of waste streams are discussed in Chapter 7.0, monitoring of the streams is discussed in Chapter 8.0.

5.2 202-A PROCESS BUILDING

The design of the PUREX process facility provides for all of the processing operations to be within the 202-A building, except for areas for storing equipment and the area that houses the building services. These are the burial tunnels and the steel-and-transite annex. The burial tunnels extend south from the east end of the process building, and the annex is

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located at the north side of the building. The waste storage facilities are detailed in the waste management environmental statement[2] and are not included here.

5.2.1 Structural Specifications

The plant was built in the early 1950s (construction occurred between 1953 and 1956) and the criteria for establishing the structural design bases were those of the 1952 Uniform Building Code.[3] The code was followed, with the following modifications and interpretations:

- Under the provisions of the code, the building conformed to Type I construction, Group F occupancy[3]
- Reinforced-concrete construction followed building code requirements for reinforced concrete[4]
- Structural steel was designed in accordance with specifications of the American Institute of Steel Construction.[5]

The balance of the building and services was designed in conformance with codes recognized as guides by the Atomic Energy Commission.[6-8]

Earthquake resistance was provided for in accordance with Zone 2 earthquake regulations.[3]

The canyon portion of the building is reinforced-concrete construction with a poured concrete roof. Interior partitions are poured concrete. Metal doors are used throughout.

Two service area annexes, made of reinforced-concrete slab and steel girder construction, are attached to the north side of the canyon building. In general, partitions separating industrial-type or operating areas are poured concrete. Other areas with no contamination problem, such as offices, lunchrooms, and shops, are separated by metallic partitions of the demountable Hauserman type. All doors are metal or metal clad.

5.2.2 Building Layout and Facility Description

The 202-A building is 1,005 ft long and 119 ft wide, as shown in perspective in Figure 5-4. The building is 100 ft high, about 40 ft below grade and 60 ft above grade. Plan views of the building at various levels are shown in Figure 1-5, and a cross section is shown in Figure 1-4.

The canyon contains a single, 813-ft-long row of equipment cells. A heavy, 6-ft-thick, concrete shielding wall separates the cells from the galleries. The pipe trench outside wall is 5-ft 6-in.-thick concrete. Above the cells, the concrete shield wall is 4 ft thick, and the extension of this wall becomes the parapet wall of the shielded cab way (crane cab gallery) for the master cranes. A slave crane, which may be operated either directly and independently or remotely from either master crane, is provided on rails above the master crane level.

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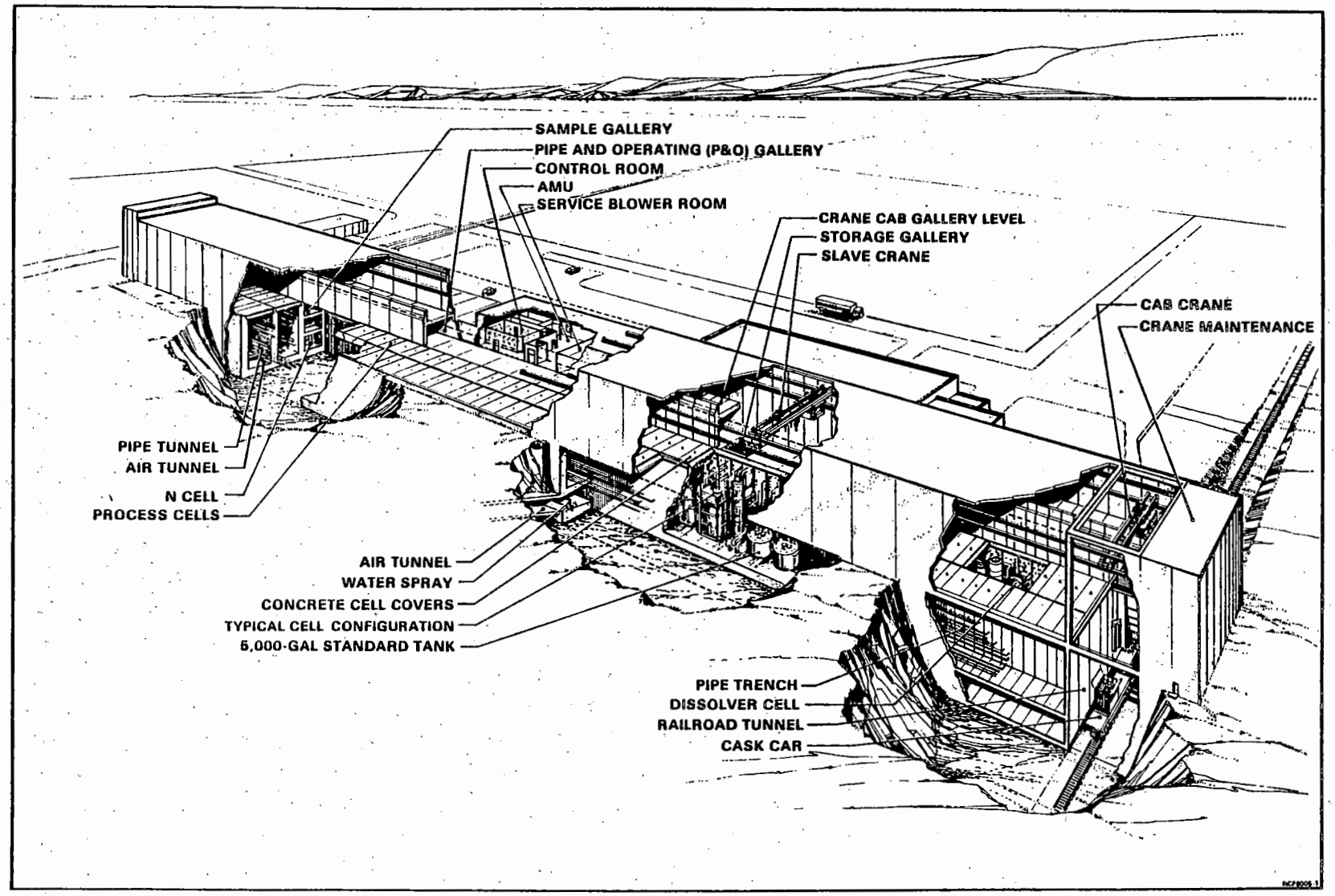

FIGURE 5-4. PUREX Building Perspective.

The pipe trench that parallels the cells is 30 ft 6 in. deep; this trench is 12 ft wide at the top and narrows to 11 ft as the wall between the cells and the pipe trench thickens from 1 ft 6 in. to 2 ft 6 in. The wall between the cells and the pipe trench supports one edge of the 3-ft-thick cover blocks that cover the cells and the 2-ft 6-in.-thick cover blocks that cover the pipe trench. The air tunnel, which lies directly below the pipe trench, is 11 ft wide and 7 ft 6 in. high. This tunnel exhausts the ventilation air from the cells to the outside filter cells and stack facility. The south wall of the canyon at the air tunnel and pipe trench levels is 5 ft 6 in. thick. From the canyon deck level to the master crane level, the south wall is 4 ft thick and again narrows to 2 ft 6 in. thick from the crane level to the roof. The roof is formed as a concrete beam, 2 ft 6 in. thick at the edges and 1 ft thick in the center. No internal truss work is used to support the ceiling of the canyon.

The railroad tunnel used for bringing in casks of irradiated fuel elements and removing equipment from the canyon runs north and south, forming a "T" at the east end of the canyon. On the east side of the railroad tunnel is a water-filled basin for storing irradiated fuel. The pool cell for storing "hot" equipment, the decontamination and storage cell, and the hot shop are located at the west end of the canyon at cell floor level. A 3-ft shield wall separates the hot shop from the decontamination cell.

The building is supported on a 5-ft 6-in.-thick concrete slab with reinforcement in the top half. Transverse expansion joints are provided at 90-ft intervals throughout the length of the building. All expansion joints in shielding walls and slabs are offset and keyed to ensure the necessary shielding requirements.

Five trap pits and two pump pits are attached to the south side of the building. The trap pits were built to handle the steam condensate from the process heating coils and steam chests. The pump pits were built to handle the trap pit drainage. The process steam traps are now located in the canyon.

5.2.2.1 Remote Process Cells. Process cells are located in-line on the longitudinal axis of the building between the pipe trench and sample gallery and are designated as follows:

Cells	Function
A,B,C	Metal dissolution
D	Metal solution storage
E	Feed preparation and cladding waste treatment
F	Waste treatment and process ventilation
G	Solvent treatment system 1
H	First decontamination system
J	Partition system
K	Uranium decontamination and concentration system
L	Plutonium decontamination and concentration system
M	Equipment decontamination and storage, plutonium nitrate storage

The listed cell designations are made according to the individual processing functions and do not indicate a physical partitioning of one cell from another. The actual locations of transverse partitions in the canyon were determined by ventilation and radiation criteria, rather than by functional cell boundaries.

All cells, excluding deep sumps and the 2A "doghouse," are 14 ft wide and 39 ft 6 in. deep from the bottom of the cover blocks, and vary in length. Cell dimensions are listed in Table 5-1.

The 2A doghouse consists of two special cover blocks that raise the canyon deck 5 ft for a distance of 13 ft 9 in., providing extra head room for the 2A column.

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TABLE 5-1. Process Cell Dimensions.

Cell	Dimension (length by width by height)*
A	35 ft by 14 ft by 42 ft 6 in.
B	35 ft by 14 ft by 42 ft 6 in.
C	35 ft by 14 ft by 42 ft 6 in.
D	65 ft by 14 ft by 42 ft 6 in.
E	71 ft by 14 ft by 42 ft 6 in.
F (beginning) to partition between TK-F12 and TK-F13	151 ft by 14 ft by 42 ft 6 in.
Partition to end of F	65 ft by 14 ft by 42 ft 6 in.
G	109 ft by 14 ft by 42 ft 6 in.
H (beginning) to partition in J between TK-J5 and TK-J6	117 ft by 14 ft by 42 ft 6 in.
Partition in J to partition in K between TK-K5 and TK-K6	111 ft 6 in. by 14 ft by 42 ft 6 in.
Partition in K to partition in L between T-L1 and T-L2	26 ft 11 in. by 14 ft by 42 ft 6 in.
Partition in L to end of L	33 ft 1 in. by 14 ft by 42 ft 6 in.

*To top of cell cover blocks.

The deep sumps (SH and SJ2) are two 8-ft wide by 10-ft long by 5-ft-deep holes. The sumps were dug in the PUREX canyon floor, after construction but before radioactive operation, to accommodate tall columns (HA and 1A). The 1A column was eventually removed and the neptunium solvent extraction "package" placed over the sump. The original HA column also has been replaced, and when that occurred, a stainless steel liner was installed in the SH sump with grout filling beneath it. The overall dimensions remain similar.

Design and arrangement of cell partitions and cover blocks are determined to a great extent by ventilation requirements. High-temperature equipment must be adequately cooled, the canyon air balance must be maintained, and cell exhaust air temperatures must be maintained below 125°F. These partitions are 12-in.-thick reinforced concrete, coated with various types of acid-resistant paint. The cells are made of reinforced concrete and coated with a protective paint to minimize absorption of radioactive solutions into the concrete. Dissolver cell cover blocks are designed to permit dissolver charging following the removal of only one block. This feature maintains ventilation flows and provides contamination control. The ventilation systems are designed to maintain between 1,500 and 13,000 ft^3/min airflow into a cell, depending upon the particular cell, when the cells are covered, and an additional 40,000 ft^3/min when a cover block is removed.

Any liquids released in a cell drain across the sloping cell floor to a small central trench, which in turn drains to a sump. The deep sumps are jetted out to the adjacent canyon floor and the solution is then jetted from the regular cell sump to the waste collection tank (TK-F18) for sampling and disposal. Procedures require periodic steam jetting of sump contents to TK-F18. Stainless steel liners cover the floors and 1 ft up the walls of L and M cells and in the H2, the A3, and the F6 positions. Otherwise, the floors and sumps of the process cell are concrete with a protective coating.

Table 5-2 references the instrument engineering diagrams of A through M cells and U cell. Typical instrument engineering diagrams are shown in Figure 5-5.

5.2.2.2 Hot Pipe Trench and Air Tunnel. Paralleling the process cells on the south side is the hot pipe trench, with varying levels of permanently installed (welded) transfer piping and spare routings supported by pipe racks. Overall dimensions of the pipe trench are 860 by 12 by 33 ft. Header piping is located at the bottom of the trench; built-in trench transfer piping is located above the header piping; piping terminating in connector heads to permit flexible routing is located at the top. The header and built-in-trench piping slope at least 1/32 in./ft and have nozzles at the low points so that the line can be drained. About 30% spare piping was provided and all critical lines and headers were spared. Jumpers are installed on the top level piping, and the trench is covered with cover blocks.

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TABLE 5-2. Instrument Engineering Diagram List.

Cell	References
A	H-2-63201 through -63205
B	H-2-63206 through -63210
C	H-2-63211 through -63215
D	H-2-63216 through -63219
E	H-2-63220 through -63226
F	H-2-63227 through -63243
G	H-2-63244 through -63251
H	H-2-63252 through -63256
J	H-2-63257 through -63268
K	H-2-63269 through -63274
L	H-2-63275 through -63280
M	H-2-63281
U	H-2-63282 through -63287

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Immediately below the pipe trench is the air tunnel through which exhaust air passes from the canyon through the cells to the filters and stack. The floors of the pipe trench and air tunnel are sloped to drain holes to allow escape of liquids. The hot pipe trench drains to the air tunnel, which in turn drains to the adjacent cell floor. The air tunnel is segregated by low parapet walls to segregate drainage by processing area. Overall dimensions of the air tunnel are 860 ft by 11 ft by 7 ft 6 in.

5.2.2.3 Gallery Section. Paralleling the process cells on the north side from top to bottom are the crane cab gallery, pipe and operating (P&O) gallery, sample gallery, and storage gallery. The shielding wall between the cells and galleries is 6 ft thick at cell level and 4 ft thick above cell level. The outside gallery walls are 3 ft thick. The crane cab gallery floor is 2 ft 3 in. thick and the P&O gallery and sample gallery floors are 1 ft 9 in. thick.

The parapet wall of the crane cab gallery provides a shielded area so that the cab, or the operator when entering or leaving the cab, is protected from direct radiation coming from the canyon. The cab way extends the full length of the crane cab gallery and is 20 ft wide. The distance from the crane cab gallery floor to the canyon roof is 39 ft 6 in. The slave crane rail is located 17 ft above the remote crane rail. The normal point of entry to the crane cab gallery and the remote crane is from stairwell 2 near the west end of K cell. Six emergency exit stairwells are distributed along the full length of the cab way. A person is never more than 100 ft from an emergency exit anywhere along the crane cab gallery.

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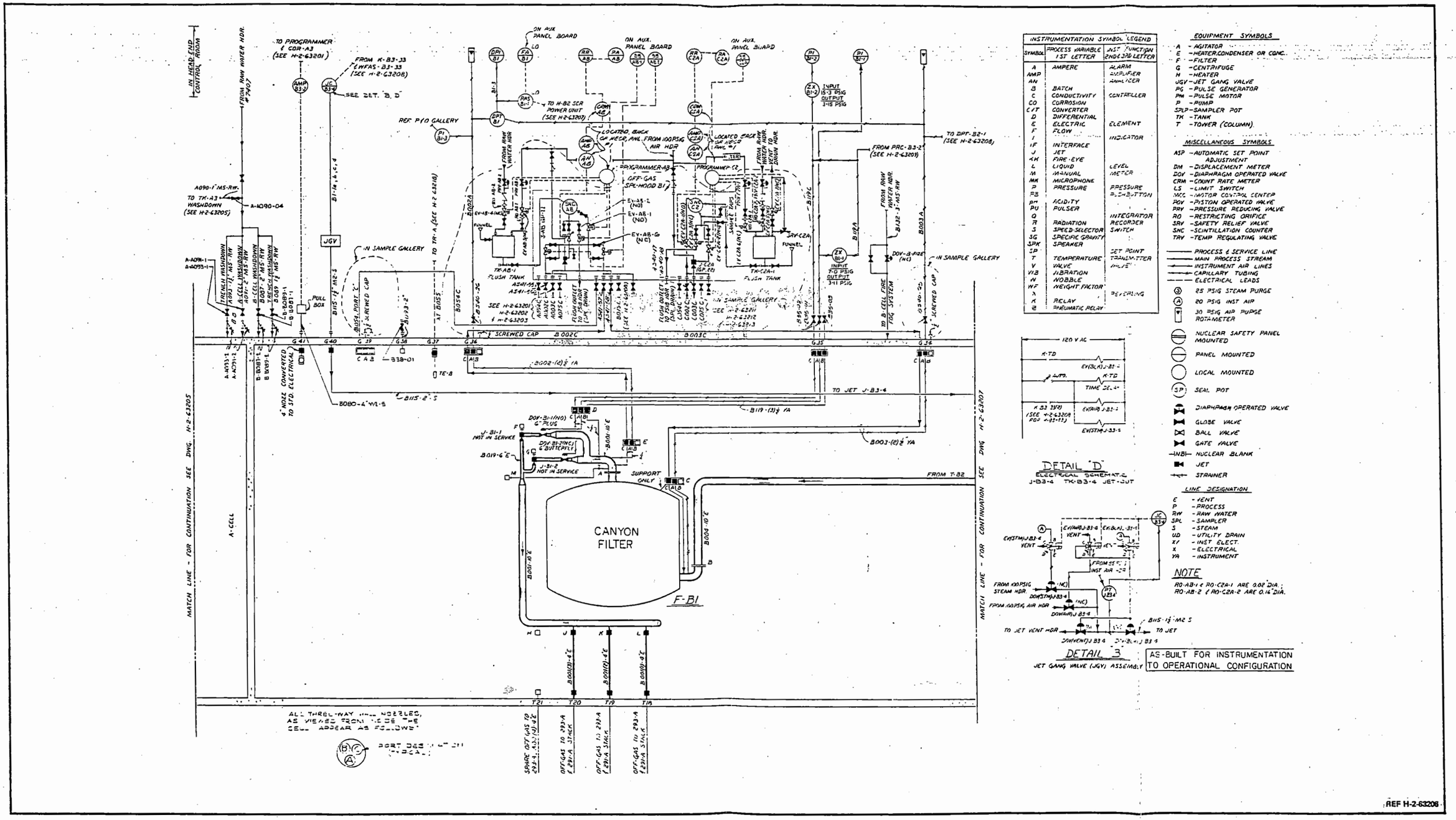

FIGURE 5-5. Typical Instrument B Cell Engineering Diagrams. (Sheet 1 of 5)

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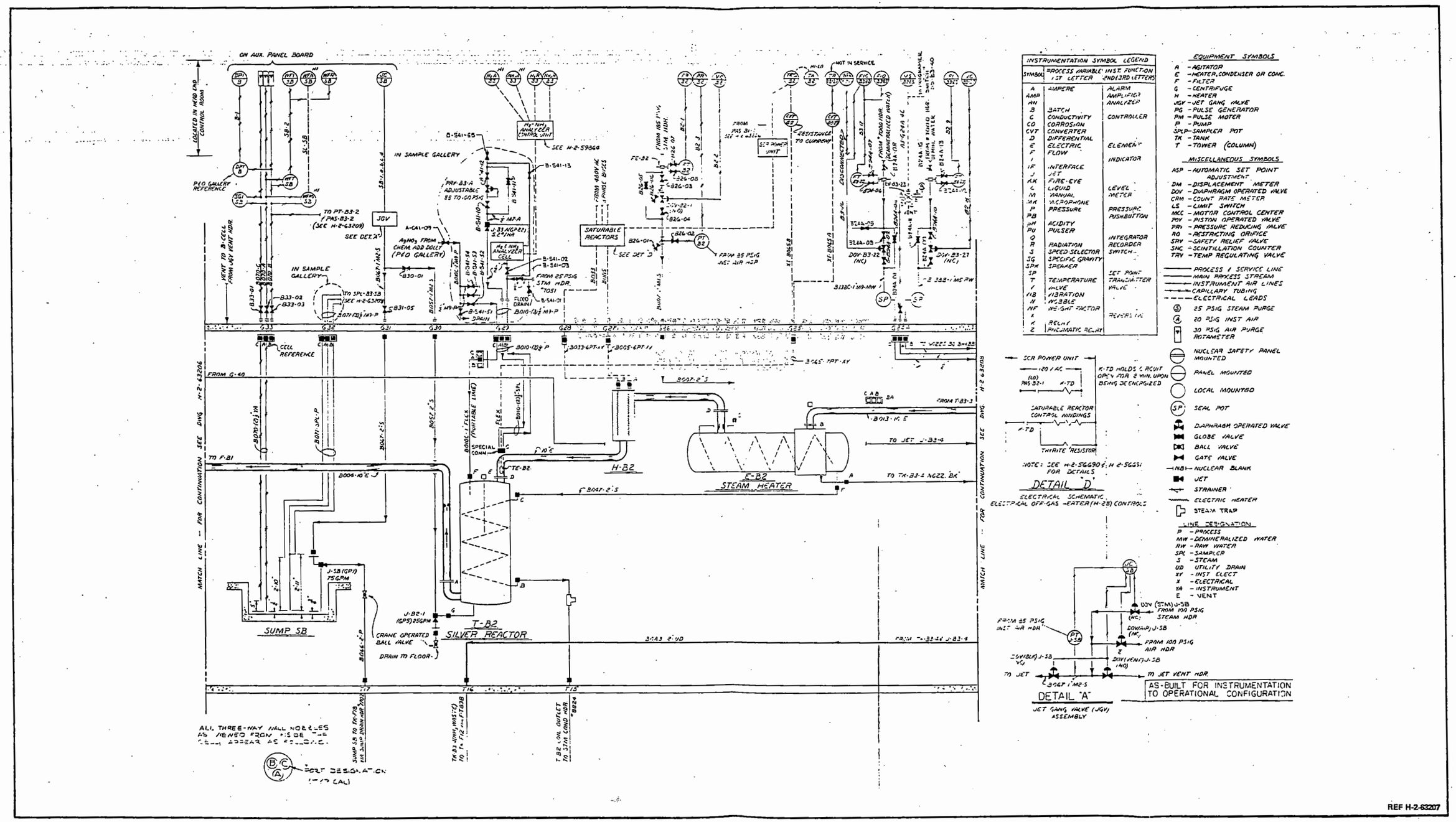

FIGURE 5-5. Typical Instrument B Cell Engineering Diagrams. (Sheet 2 of 5)

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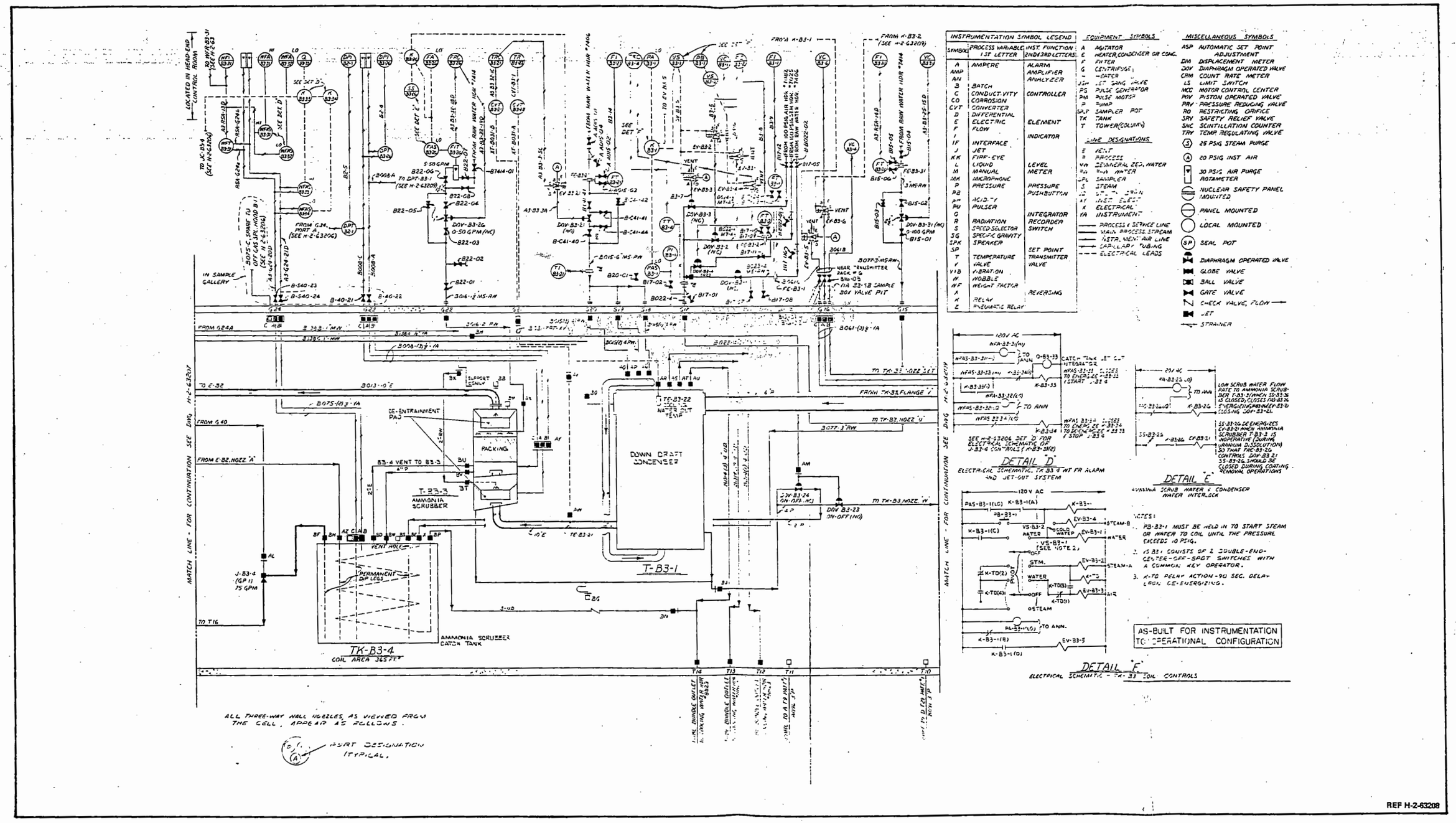

FIGURE 5-5. Typical Instrument B Cell Engineering Diagrams. (Sheet 3 of 5)

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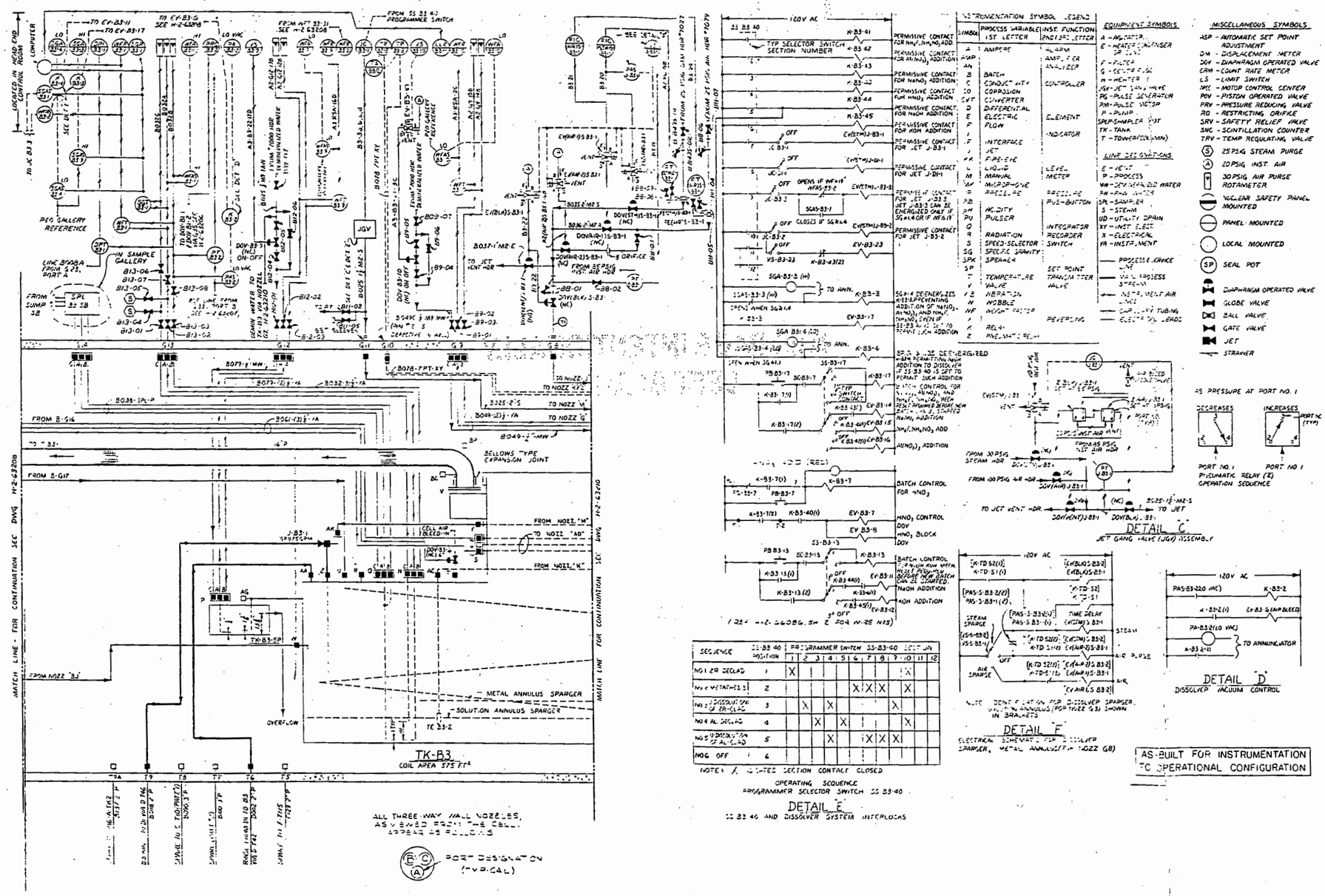

FIGURE 5-5. Typical Instrument B Cell Engineering Diagrams. (Sheet 4 of 5)

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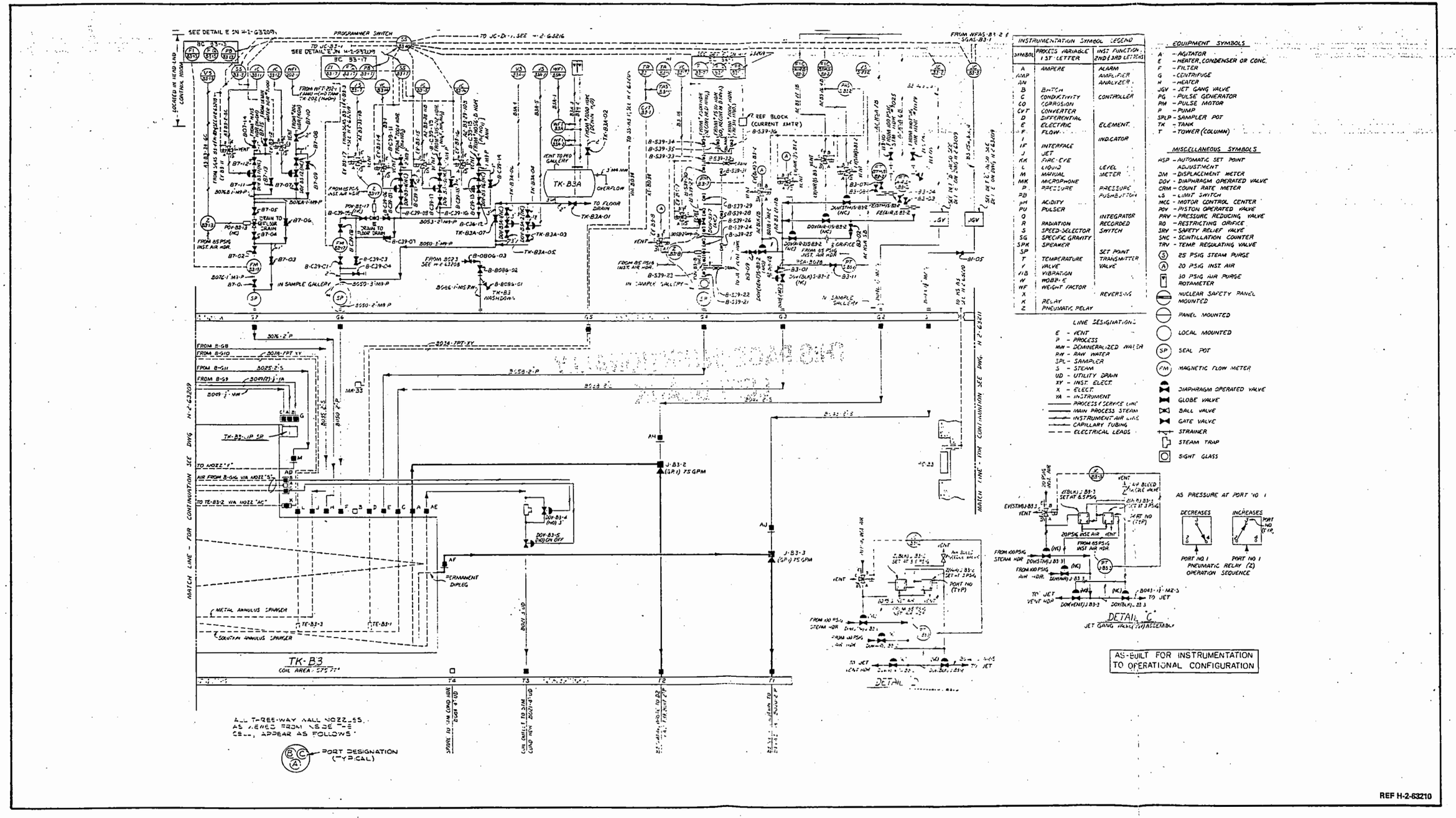

FIGURE 5-5. Typical Instrument B Cell Engineering Diagrams. (Sheet 5 of 5)

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The P&O gallery is located directly below the crane cab gallery and contains the nonradioactive piping and service headers, canyon motor control centers, instrument transmitters, and other related equipment. The P&O gallery also contains the steam pressure-reducing stations, reducing the steam pressure from 225 to 100 lb/in.^{2}. A mezzanine at the east end of the gallery contains the east crane maintenance platform (ECMP) change room; at the west end of the gallery is a canyon lobby. The ECMP is a building addition shown in Drawings H-2-57086, H-2-57087, and H-2-57088. The addition is described in Section 5.2.2.7.

The P&O gallery, extending the full length of the building, is 20 ft wide and 20 ft 3 in. high. Cold piping and services to cell equipment originate in this gallery and terminate at various levels in the cells. Operating equipment such as centrifuge bowl spray pumps, the organic blend tank, and dissolver drown-water tanks are located in the gallery. A high-pressure steam-reducing station is located at each end of the gallery in a ventilated area.

A 158-ft-long segment at the west end of the P&O gallery, called the "white room," is separated from the rest of the gallery by a 10-ft-high personnel control barrier. The controlled area was created shortly after plant startup due to a contamination spread.

The sample gallery extends the full length of the building below the P&O gallery. It is 19 ft 6 in. wide and 10 ft 3 in. high. A sample gallery shielded-pipe chase adjacent to the canyon wall provides shielding for process piping to the samplers, the sampler drain piping, and the recovered nitric acid and organic distribution piping to cell equipment. The sample gallery shielded-pipe chase has a permanent, concrete cover; facilities for water flushing; and floor drains to the cell sumps. A hood is installed adjacent to the shielded-pipe chase at B and F cells for sampling process offgases. A decontamination sink and hood are provided near the center of the gallery for cleaning of sampling equipment. The "A"- and "B"-type samplers are located along the gallery wall adjacent to the shielded pipe chase. The "C"-type samplers are located along the gallery wall near the shielded pipe chase. The A, B, and C designations refer to the amount of shielding and type of sampling equipment provided for solutions with decreasing radioactivity levels. Building air sampling compressors are installed in the west end of the sample gallery. Further details of the samplers are given in Chapter 6.0.

The stairway from the special work permit (SWP) lobby serves as the normal entrance to this level. To minimize the possibility of spreading contamination into the stairwell and the SWP change room, a personnel monitoring station is located at the stairwell entrance. At the west end of the gallery, the PR elevator provides entry from zones other than the SWP lobby, and a stairwell serves as an emergency exit. A stairwell located at the east end of the gallery can be used for personnel entrance to the railroad tunnel or for emergency exit from the sample gallery. The sample gallery is connected to the analytical laboratory by a stairwell and a dumbwaiter. The dumbwaiter is used for the delivery of sampling equipment to the gallery and samples to the laboratory.

The 19-ft 6-in.-wide by 25-ft-high gallery below the sample gallery, which also extends the full length of the canyon, is divided into five separate operating areas: the storage gallery at the east end, the PIV room in the center containing positive infinitely variable drive mechanisms for column pulsers, Q cell adjacent to the PIV room, the PR room adjacent to Q cell, and N cell at the west end of the gallery. The storage gallery is used for the storage of dry chemicals, spare instruments, and miscellaneous operating supplies. Just east of the PIV room, there is a seismically qualified and fail-safe light-water foam system that provides backup fire suppression capability for H and J cells. This system is discussed in Section 8.4.8.6. Sumps are provided along the outside wall of the storage gallery for collection of water. Individual sumps are emptied by a portable pump, which discharges to a collection header terminating in the AMU pipe chase. The PIV room houses the PIV-frequency motor alternator sets that supply electric power to the pulse generators, and the central exchange for the in-plant private automatic exchange (PAX) telephone system. The Q cell, PR room, and N cell operating facilities are described later in this chapter.

5.2.2.4 Trap and Pump Pits. The steam condensate from the process concentrator steam chest and coils is discharged through fixed piping in one of five trap pits attached to the south side of the building and then joins the steam condensate header. The buried steam condensate header discharges to the 216-A-30 crib. This condensate is continuously monitored and if the condensate becomes contaminated, it is automatically diverted to a retention basin (216-A-42).

Any solution (predominantly rain water) that accumulates in the bottom of trap pits 1 and 3 is routed to a French drain (see Section 5.2.2.15). The other trap pits drain to 43-ft-deep pump pits. Trap pit 2 drains to pump pit 6, and trap pits 4 and 5 drain to pump pit 7. Solution that collects in the pump pits is automatically pumped to the steam condensate header.

5.2.2.5 Fuel Receiving Facilities. Irradiated N Reactor fuel elements are received in the PUREX railroad tunnel located at the east end of the 202-A building. Railroad cars, casks, canisters, and crane devices are the equipment used in the fuel receiving process. The relative location of the railroad tunnel is shown in Figure 5-6.

5.2.2.5.1 Components. The railroad tunnel is 22 ft wide, 145 ft long, and 24 ft high. The tunnel extension permits initial spotting of three cars by the train crew and subsequent movement of cask cars by the crane operator, using a remotely operated car puller. A sliding metal ventilation cover at the canyon deck level provides an airlock when the tunnel outside door is open. The ventilation cover is electrically operated from the dispatcher's office. The railroad tunnel is accessible from the sample gallery, the outer tunnel door, and an outside door on the east side of the tunnel. A liquid collection sump and pump are provided to route liquids from the railroad tunnel to underground storage via TK-U3.

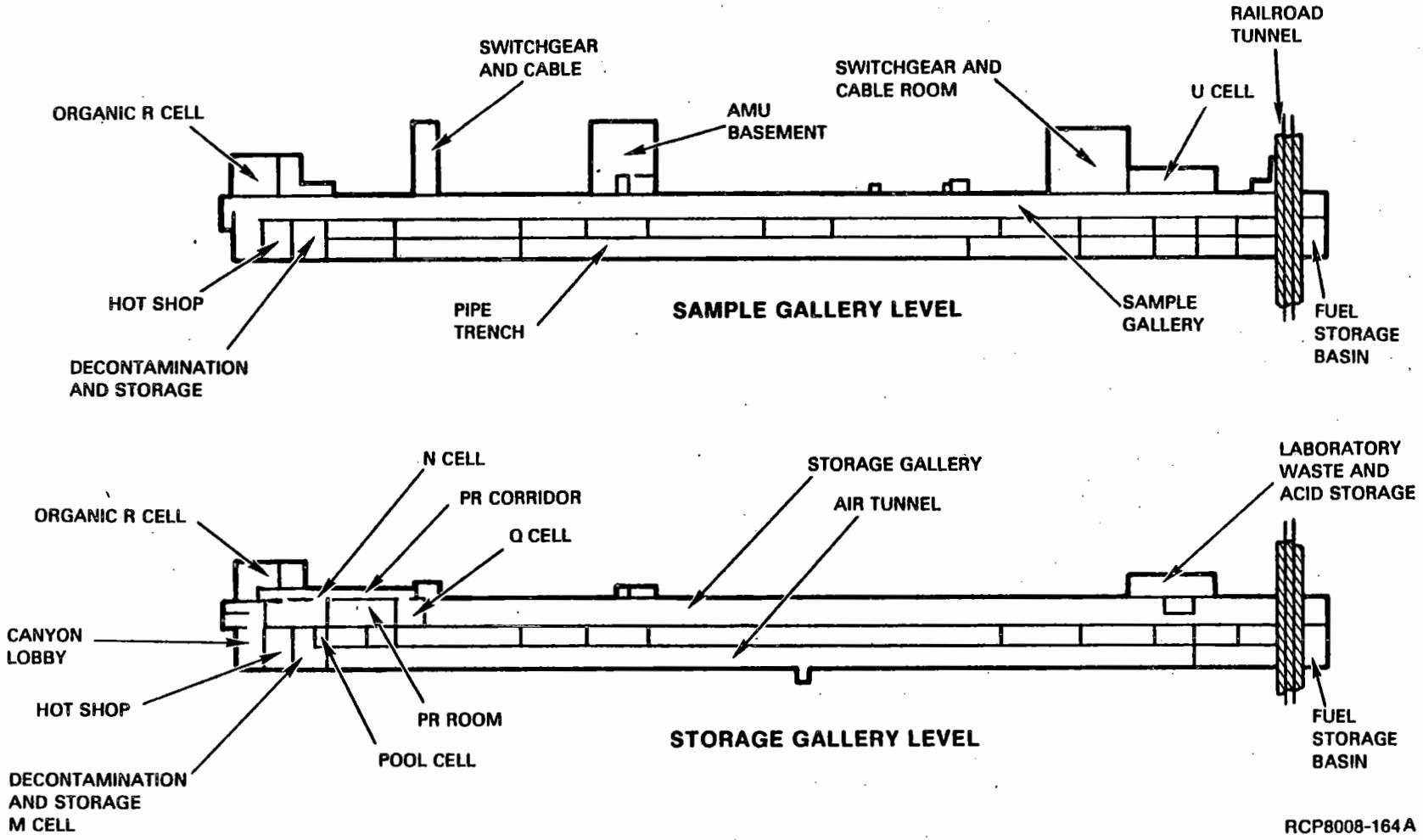

FIGURE 5-6. Relative Railroad Tunnel Location.

The cask cars are of two types: short cars that transport a single N basin cask and the long, underslung cars that transport three casks that can be used at both N and K basins. The short cars have a flatbed, with an overall length of 30 ft and a load capacity of 100 tons. The rectangular water tank has doors on top that are opened by a mechanism operated through a gearbox and a handwheel. The long car has an underslung frame, an overall length of 50 ft, and a load capacity of 200 tons. The load is carried by 4- or 6-wheel carriages, or "trucks." The water tanks on the long cars have handwheel opening mechanisms of the same type as on the short cars.

The N basin cask is 57 by 78 by 128 in. tall (outside dimensions) and weighs 51.85 tons. Tubes penetrate the lead shielding via bends to allow water circulation. The lead shielding is nominally 10 in. thick. The lid is held in place by locking dogs operated by a large impact wrench nut. The cask cavity is divided into four compartments by a special neutron-absorbing, stainless steel partition. The cavity holds 4 tall fuel canisters or 12 short fuel canisters.

The K basin cask is 57 by 59 1/4 by 74 3/4 in. tall (outside dimensions) and weighs 22 1/2 tons. Circulation tubes penetrate the lead shielding via bends. The lead walls are nominally 10 in. thick. The cask cavity is divided into three compartments, each of which holds a short fuel canister.

5.2.2.5.2 Function. The cask cars are placed in the railroad tunnel and attached by cable to the car puller, which permits remote positioning of cars by the crane operator. The railroad tunnel's outside door is closed for containment whenever a car is being loaded or unloaded. The overhead door to the canyon is opened remotely from the dispatcher's office, permitting access to the car from the canyon area. The cask lid is removed by the crane, and the canisters are individually removed from the cask by the canyon crane. A radiation-measuring device is installed in the railroad tunnel to gauge the relative activity of the material and also to verify the minimum cooling time since the reactor discharge during canister removal and transport to the dissolver. The canisters are then raised through the horizontal door to be taken to the dissolver cells. After the material in one car has been emptied, the empty canisters are placed in the cask wells, the cask lids are replaced, the car lids closed, and the car is decontaminated for return to the reactor car-loading facility.

5.2.2.5.3 Safety Considerations--Radiation Exposure. Extensive precautions are taken during fuel receipt and handling to keep personnel radiation exposure to as low as is reasonably achievable (ALARA). Radiation Monitoring personnel are present during all operations requiring personnel to be near loaded cars. Normal dose rates from the shipping cars are low due to the large amount of shielding. The water inventory is replaced and the inside of the shipping cars is flushed on a regular basis by UNC Nuclear Industries at the reactor basin to prevent buildup of contamination. Rockwell Radiation Monitoring personnel are required to authorize the release of the cask cars, when empty, for transport back to the reactor basin.

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Dose rates to personnel outside the canyon (service galleries) are low because of the 6-ft-thick concrete shielding wall at the process cell level and the 4-ft-thick concrete shielding wall at the level above the deck. The crane operator is protected by a shielded crane cab that travels behind a 4-ft-thick concrete parapet. To avoid charging operations while personnel are in the railroad tunnel and the vicinity of the canyon, the PUREX dispatcher controls access to the tunnel and canyon, controls operation of the horizontal door between the canyon and the tunnel, and maintains a logbook of personnel entering and exiting the tunnel and canyon. The vertical and horizontal doors of the railroad tunnel are interlocked to prevent opening both doors at the same time.

The railway approach to the railroad tunnel is through a railroad cut. This is a fenced, regulated area extending about 700 ft in front of the tunnel door. The railroad track in the cut has a slight "S" shape curve; there is an earthen berm on each side of the track and a concrete shield at the end of the cut. This arrangement prevents a direct shine to any area outside the cut enclosure from the tunnel door. Entrance to the railroad cut is from the railroad tunnel or through a dispatcher-controlled gate in the fence or the railroad entrance gate. Normal personnel access to the tunnel is from the sample gallery through a dispatcher-controlled door.

Equipment is located within the facility space to facilitate the decontamination of the railcars and track, should this be necessary. Facility ventilation pressure differentials are maintained to ensure that airflow is from the less potentially contaminated areas toward the more potentially contaminated areas.

5.2.2.6 Fuel Storage Basin. A storage basin (20 ft wide, 30 ft long, and 27 ft deep) is located east of the railroad tunnel at the canyon level (Fig. 5-7). The basin is open to the canyon and contains 12 ft of water. The storage area has a nominal capacity of 40 yoke-suspended buckets of aluminum-clad fuel* on one level, and a maximum capacity of 76 buckets on two levels. The basin is serviced by a raw-water fill line with overflow to the steam condensate header. A jet-out line discharges to the 216-A-30 crib via the steam condensate header. Liquid level is determined by visual inspection and weight factor instrumentation. The storage basin will not be used for storage of N Reactor fuel without further evaluation of the intended use. Inadvertent use of the basin for storage of N Reactor fuel will not occur as the yokes will not fit the N Reactor fuel canisters.

5.2.2.7 Crane Maintenance Facilities. The crane maintenance facilities, located at the east and west ends of the canyon (see Fig. 5-7), are used for repair and routine work on cranes. Each is a platform that extends across the canyon, with an installed bench for work on crane motors and other equipment. As a maintenance aid, a cross-building monorail hoist is installed in the raised section of the roof directly above each crane maintenance platform.

*From the deactivated, "low-pressure," production reactors.

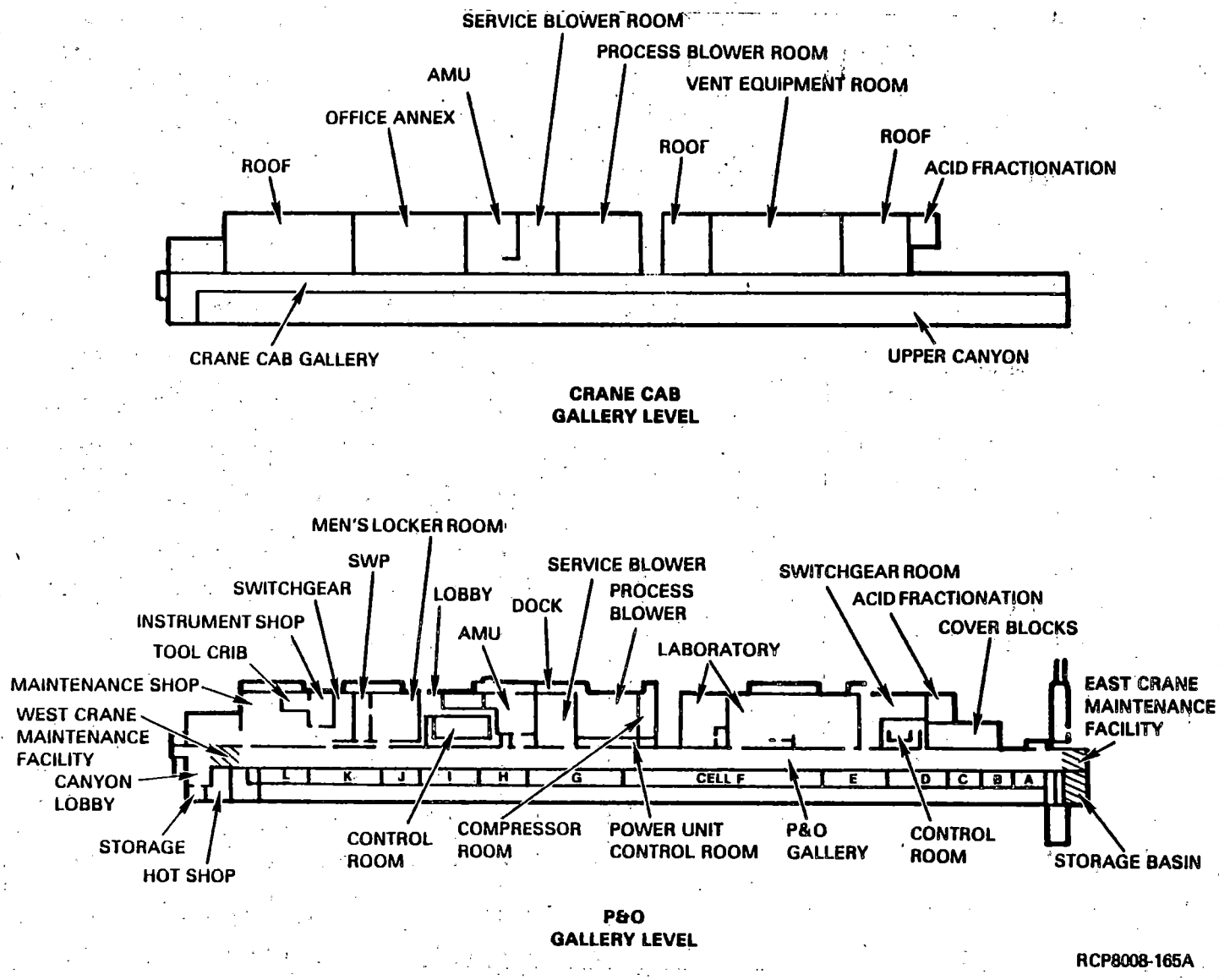

FIGURE 5-7. Relative Locations of the Storage Basin and Crane Maintenance Facilities.

The west crane maintenance platform (WCMP) is part of the original facility and is located above the canyon lobby and storage area. Access to the WCMP is via the crane way, or stairway, or (rarely) from the PR elevator at the west end of the building.

The ECMP is in an extension that was added to the existing 202-A building in 1957. The extension is 71 ft 3 in. tall, 36 ft wide, and 61 ft 6 in. deep, and is a reinforced concrete and steel-beamed structure. The three exterior sides are made of 2-in.-thick asbestos-cement board, which is in turn covered with 9-in. precast concrete panels above the 731-ft elevation and 4-in. pre-cast concrete panels below the 731-ft elevation.

Three interior, 3-in.-thick, steel plate shielding doors separate the canyon from the crane maintenance platform. Below the 731-ft elevation, 10 in. of concrete of the original building separate these structures. The roof is made up of coal-tar pitch, roofing felt, mineral-surfaced roofing, plastic-roofing cement, and roofing gravel. This addition serves as the containment vessel when the shielding doors are open.

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5.2.2.8 Contaminated Equipment Maintenance and Storage Areas. A decontamination and equipment storage cell (M cell), pool cell, and hot maintenance shop are located at the west end of the canyon (Fig. 5-8).

The M cell is "L" shaped. The main portion is 34 ft 6 in. long by 14 ft wide and the extended base is 20 ft long by 16 ft 6 in. wide. It is equipped with a stainless steel floor liner, wall spray nozzles, connectors, and flexible jumpers to facilitate remote decontamination of faulty canyon equipment. A vessel (TK-M1) is provided for cleanup of pumps, agitators, etc. Removable equipment storage racks are positioned on the wall. Personnel may enter the decontamination and storage cell by way of the hot maintenance shop. Oil-filled glass viewing windows in the wall separating the hot shop from the decontamination and storage cell allow visual observation of failed equipment. To conserve floor space, this concrete wall is constructed of high-density aggregate.

A portion of the north side of M cell, west of the pool cell, is partitioned for storage of concentrated plutonium nitrate product solution (see Fig. 5-8). The plutonium nitrate storage tanks (TK-M3, M4, M5, and M6) are part of the plutonium oxide production system and are further described in Section 6.8.2.

The pool cell (12 ft long, 14 ft wide, and 35 ft deep) is at the north east corner of M cell. The pool cell contains a stainless steel floor liner and is used for decontamination and/or storage of large equipment pieces.

The hot shop (30 ft long and 20 ft wide) is located to the west of M cell; it is used for maintenance of canyon equipment by semiremote and contact methods. That portion of the hot shop accessible from the crane is furnished with metal ventilation covers. The remaining portion of the hot shop roof is located below the canyon lobby. Handling of equipment in this

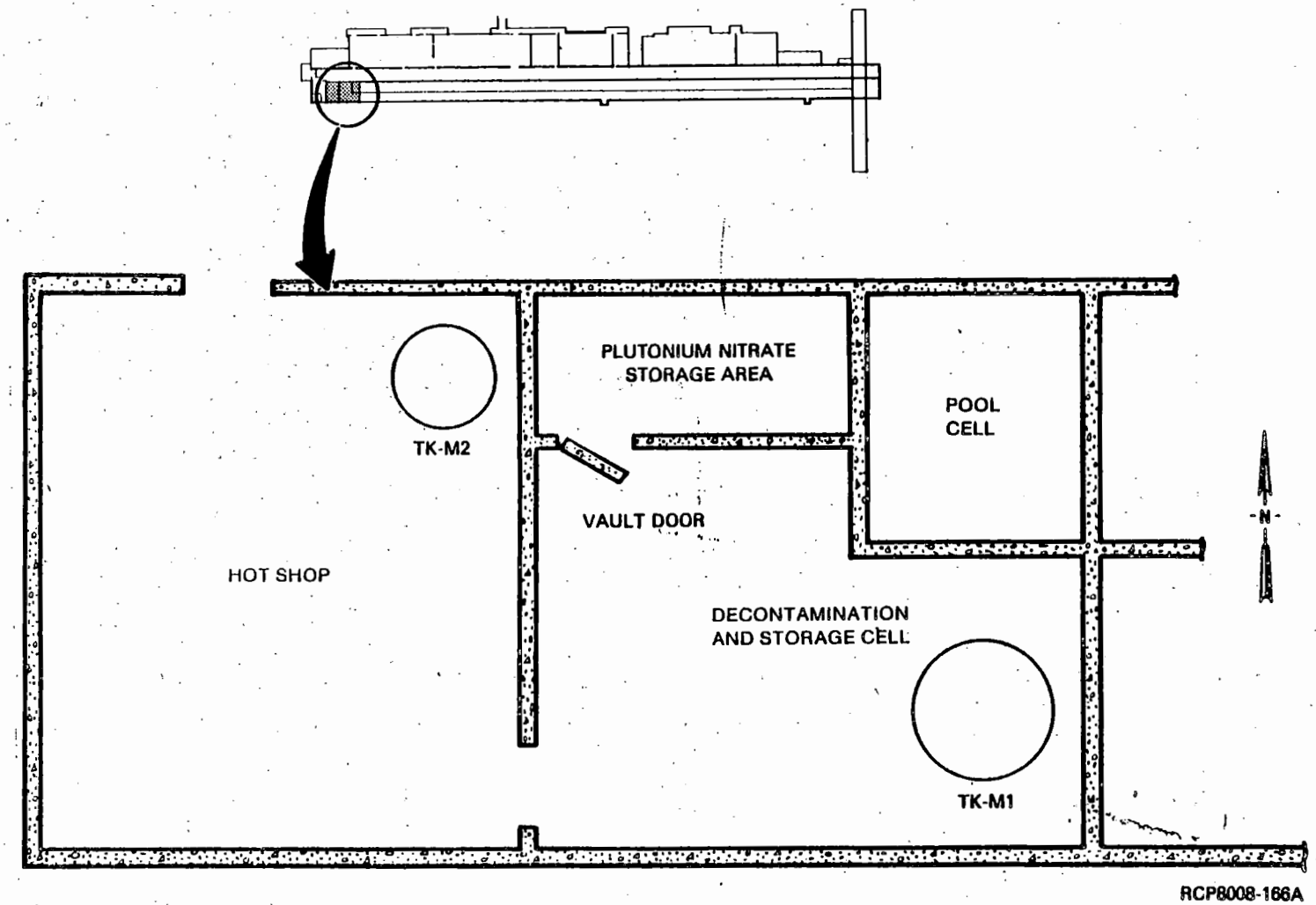

FIGURE 5-8. M Cell Contaminated Equipment Maintenance and Storage Areas.

area is accomplished by a monorail and a jib crane. A decontamination sink and hood are provided for cleaning small tools and equipment. A shielded vessel (TK-M2) is located in the hot shop to facilitate additional decontamination and disassembly of pumps and agitators.

An upgraded equipment decontamination and repair unit is being designed for installation in M cell, and the hot shop. High pressure water spray systems in M cell operated remotely from the hot shop or manually from within M cell and supplemented by chemical soaking will be used to decontaminate jumpers and other equipment pieces.[9]

5.2.2.9 Acid and Organic Recovery Vaults. The recovered acid and laboratory waste storage vault (U cell) is located along the north wall of 202-A building, just east of the headend control room. It is constructed below grade with removable concrete blocks extending above grade forming the roof. The cell has 1-ft 6-in.-thick reinforced-concrete walls and is 76 ft long, 20 ft wide, and 35 ft deep. Entrance to the vault is by way of a stairwell from the sample gallery through an electrically operated door and an airlock. U cell contains four large tanks: two for storing recovered nitric acid and two for collecting and sampling low activity laboratory waste. Tank volumes and dimensions are listed in Table 6-1. The recorders and controls for the associated equipment are located in the headend control room. The instrument diagrams for U cell are listed in Table 5-2.

The solvent recovery and storage vault (276-A or R cell) provides decontamination of organic solvent from the final uranium cycle and storage of the recovered solvent. Located below grade at the northwest corner of 202-A, this facility is operated from the central control room. Vessels located in R cell include a solvent washer (TK-R1), a scrub column (T-R2), an acid scrub recycle tank (TK-R2), a spare utility tank (TK-R5), a decanter (TK-R6), a treated-solvent storage tank (TK-R7), and an alkaline waste tank (TK-R8). These vessels are also listed in Table 6-1. The R cell is 65 ft long and 23 ft wide. Access is provided to the vault floor from the PR corridor and to the centrifuge platform by way of the sample gallery, The relative location of R cell is shown in Figure 5-9.

Because of similarity in structure and equipment, the following description applies to each of the two (R and U) vaults. (Equipment arrangements for the two cells are shown in Fig. 8-6 and 8-7.)

- The structure is reinforced concrete. The base of the vault is at the same elevation as the 202-A structural mat because of process hydraulics and equipment requirements. Curb and door sills are provided to confine leakage within specific areas. Removable concrete cover blocks at 2 ft above grade are designed to provide radiation shielding and to facilitate equipment replacement by motor crane. An emergency exit from U cell is provided via a caged ladder and escape hatch in the vault roof. The emergency exit from R cell is via the mezzanine door to the sample gallery.

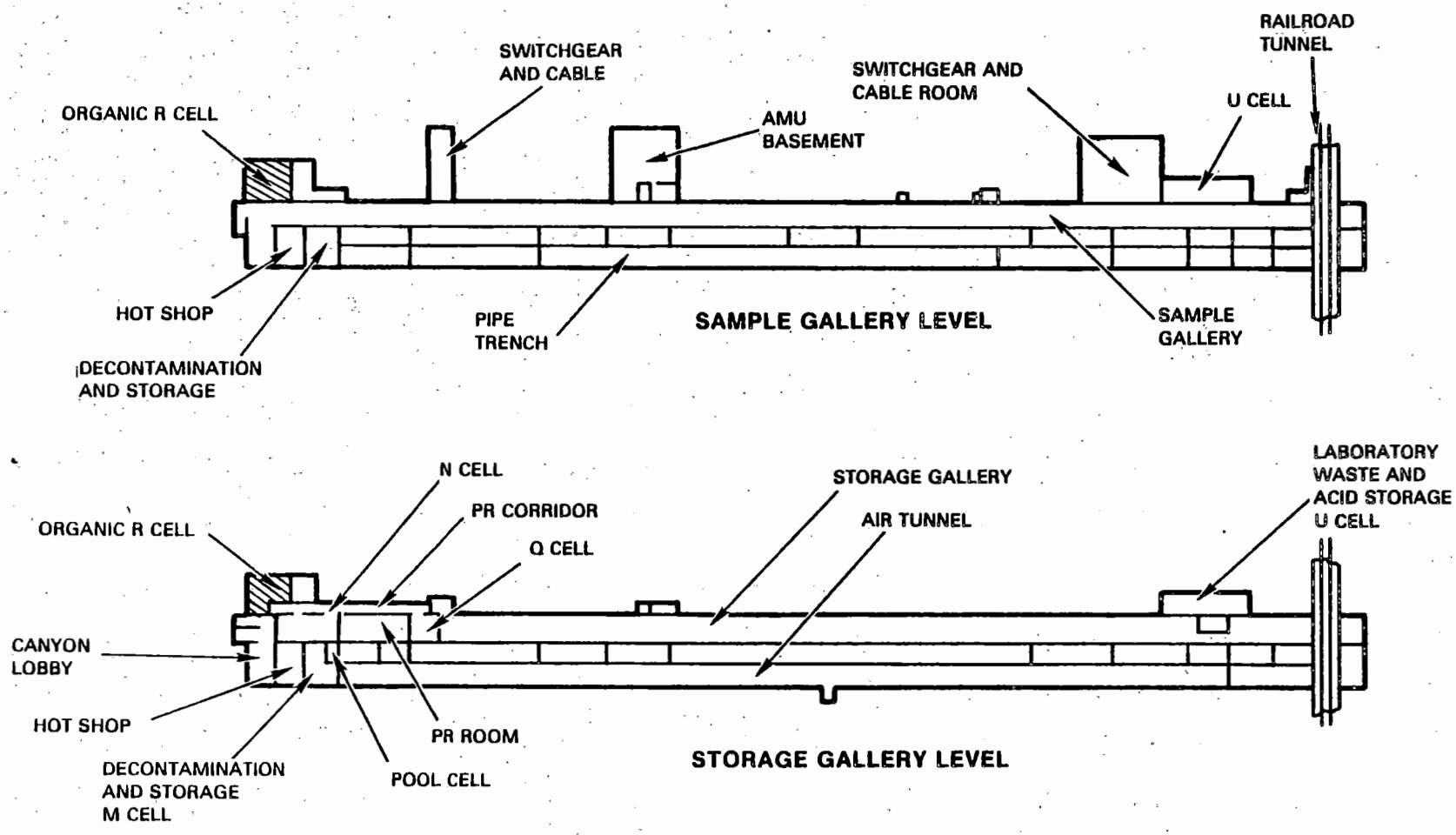

FIGURE 5-9. Relative Location of R Cell.

- The equipment, in general, is designed with the same physical dimensions as comparable canyon assemblies, but fabricated to commercial allowances with conventional flanges and supporting structures. All equipment maintenance is performed by contact methods under regulated work procedures.

5.2.2.10 Uranium Product Handling. The 203-A tank farm is used for storage and shipping of UNH product from the PUREX Plant. The UNH product is batch-transferred through a pipeline from TK-K6 in the PUREX canyon to one of four UNH storage tanks in the 203-A area. The 203-A area is described in Section 5.3.1.

5.2.2.11 Product Removal Room. The PR room is located in the west section of the storage gallery, north of L cell and separated from N cell to the west by a 6-ft-wide pipe chase. The PR room is 41 ft 2 in. long and 19 ft 6 in. wide and contains three concrete-shielded areas that isolate contained equipment from the working area. One area isolates the vacuum/rework tank (TK-L11) enclosed in a glovebox. Another area isolates the plutonium sampler tank (TK-L9) enclosed in a glovebox and the third area contains an empty glovebox that formerly enclosed another plutonium sampler tank (TK-L10). There are no plans, at present, to replace TK-L10. In addition, there is a load-out facility for shipping containers in the PR room, the L13-10 glovebox and load-out hood. A doorway from the PR room provides access to L cell for possible contact maintenance of the 2B column and third plutonium system. The PR room layout is shown in Figure 5-10.

Eventually the L13-10 glovebox and load-out hood will be replaced by an upgraded glovebox L14 that is designed to load out plutonium nitrate into the existing metal shipping containers or polyethylene bottle-type containers or load in from the same containers.[10]

5.2.2.12 Neptunium Purification Unit. The neptunium purification system, also known as Q cell, is located at the storage gallery level of the PUREX building between the west end of the PIV room and the PR room. As shown in Figure 5-11, Q cell includes a control room, a load-out room, an AMU level, a maintenance room and shielded maintenance hood, and a shielded hot cell. The AMU level is located above the control room. Access to Q cell is obtained through the PR corridor and SWP lobby, or, in emergencies, through the PIV room.

The Q cell was installed in the building, along with the neptunium recovery and decontamination facility in J cell (J cell package), to further purify the neptunium recovered in the J cell package prior to shipment offsite. The Q cell purification system is designed for batch operation. The current plan is to activate neptunium recovery and purification in the future. These operations will be described in an amendment to this report.

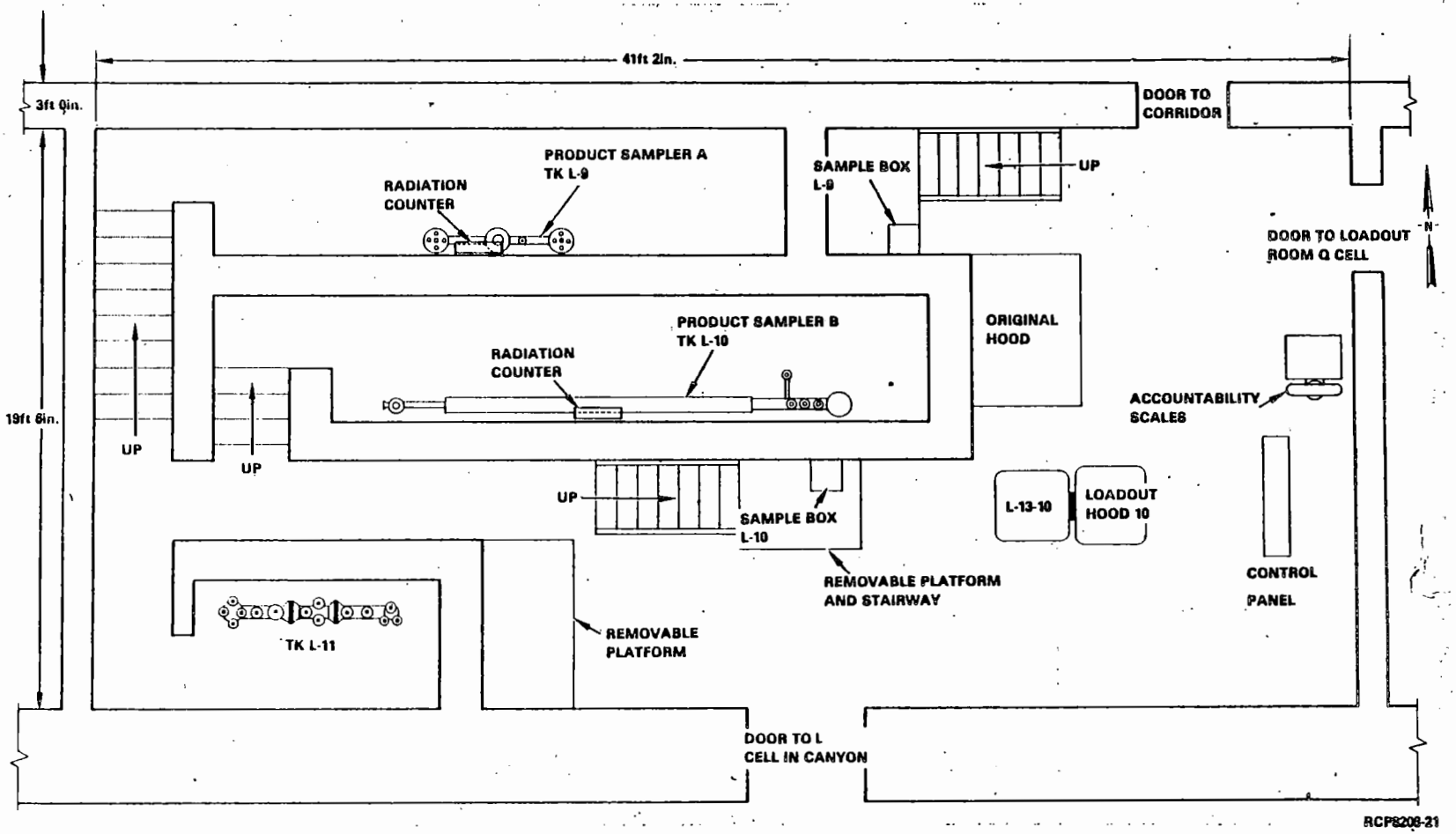

FIGURE 5-10. Product Removal Room--Plan View.

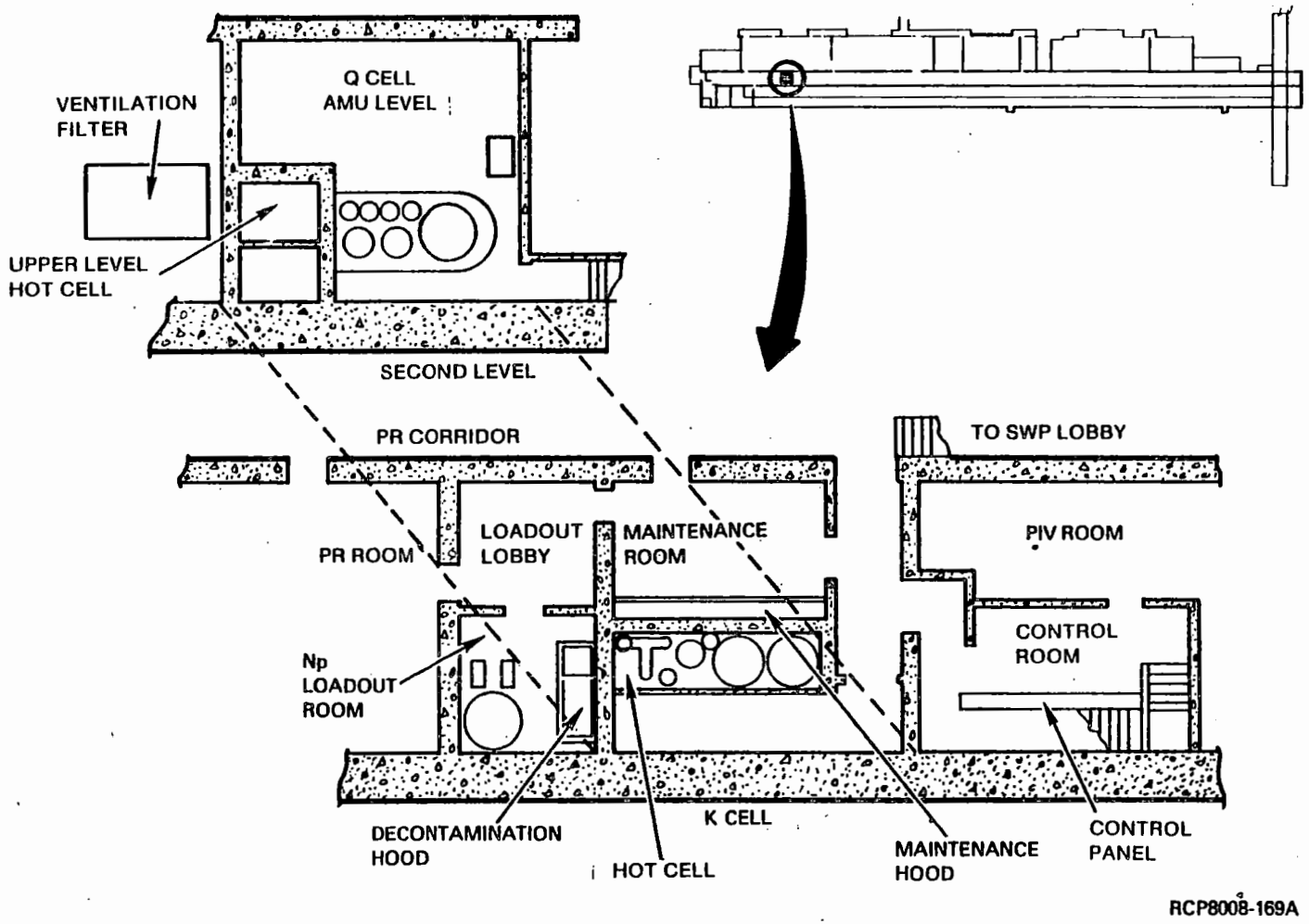

FIGURE 5-11. Q Cell Layout.

Because of potential radiation problems associated with neptunium processing and the difficulty of contact maintenance, the Q cell equipment, except for the ion-exchange column, is of all-welded stainless steel construction, with major equipment pieces located within a shielded enclosure or hot cell (Fig. 5-11).

The piping penetrates the back shielding wall of the hot cell into a maintenance hood. This hood contains most of the replaceable mechanical, electrical, and operating equipment for handling the radioactive solution transfer between the major pieces of equipment in the hot cell. All equipment in the hood is flanged with standard stainless steel flanges. This hood is lined with stainless steel and has a 1-in. stainless steel front containing 1-1/2-in.-thick lead-glass viewing ports and glove ports. Primary control of the neptunium purification operations in Q cell is carried out on the graphic panel board in the control room; however, secondary control is carried out by hand in the maintenance hood.

Nuclear criticality safety for Q cell uses vessel geometry and upstream plutonium mass control. The vessels that are not of geometrically favorable design, including the 3-in. annular 3XF tank, are preceded by vessels Q1 and Q2 that are geometrically favorable. Multiple samples of the recirculating solvent extraction product stream are analyzed to ensure low plutonium content prior to diversion to Q cell.

5.2.2.13 Plutonium Oxide Production Facility. The original regulated shop and N cell area in the west end of the storage gallery has been modified to provide the process, transfer, maintenance, primary canning, secondary canning, control, and storage areas necessary to convert plutonium nitrate to plutonium dioxide and prepare the product for shipment to storage. A plutonium oxide rework facility is also provided in a single glovebox in the east end of the first floor of the N cell area. The relative location of the N cell area is shown in Figure 5-12. A perspective drawing of the plutonium oxide production facility is shown in Figure 5-13.

On the first floor, a concrete shielding wall separates the control room from the glovebox and product load-out areas. Access to the glovebox area from the control room is via an air lock. A stainless steel-clad, polyethylene shielding wall within the glovebox room separates the vessel and calciner gloveboxes from the powder load-out glovebox and the secondary canning area.

The second floor contains the upper portion of the vessel and calciner gloveboxes, maintenance gloveboxes, and the second floor control room. Access to the glovebox area is provided through an air lock from the control room.

The calciner glovebox is separated from the maintenance glovebox area by a stainless steel-clad, polyethylene shielding wall. Doors are located between gloveboxes for equipment access. Two shielding doors of the same composition as the walls on either side of the glovebox are provided for personnel access.

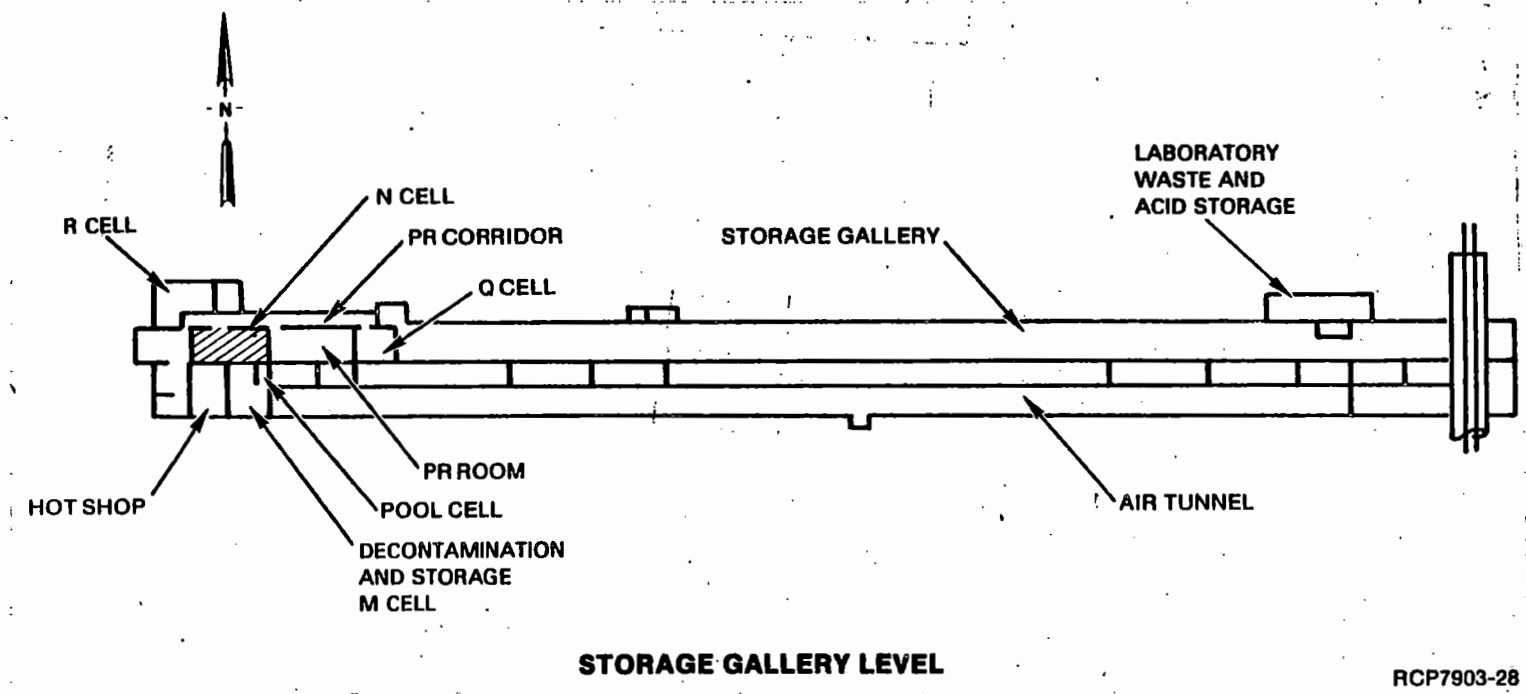

FIGURE 5-12. N Cell Location in the PUREX Plant.

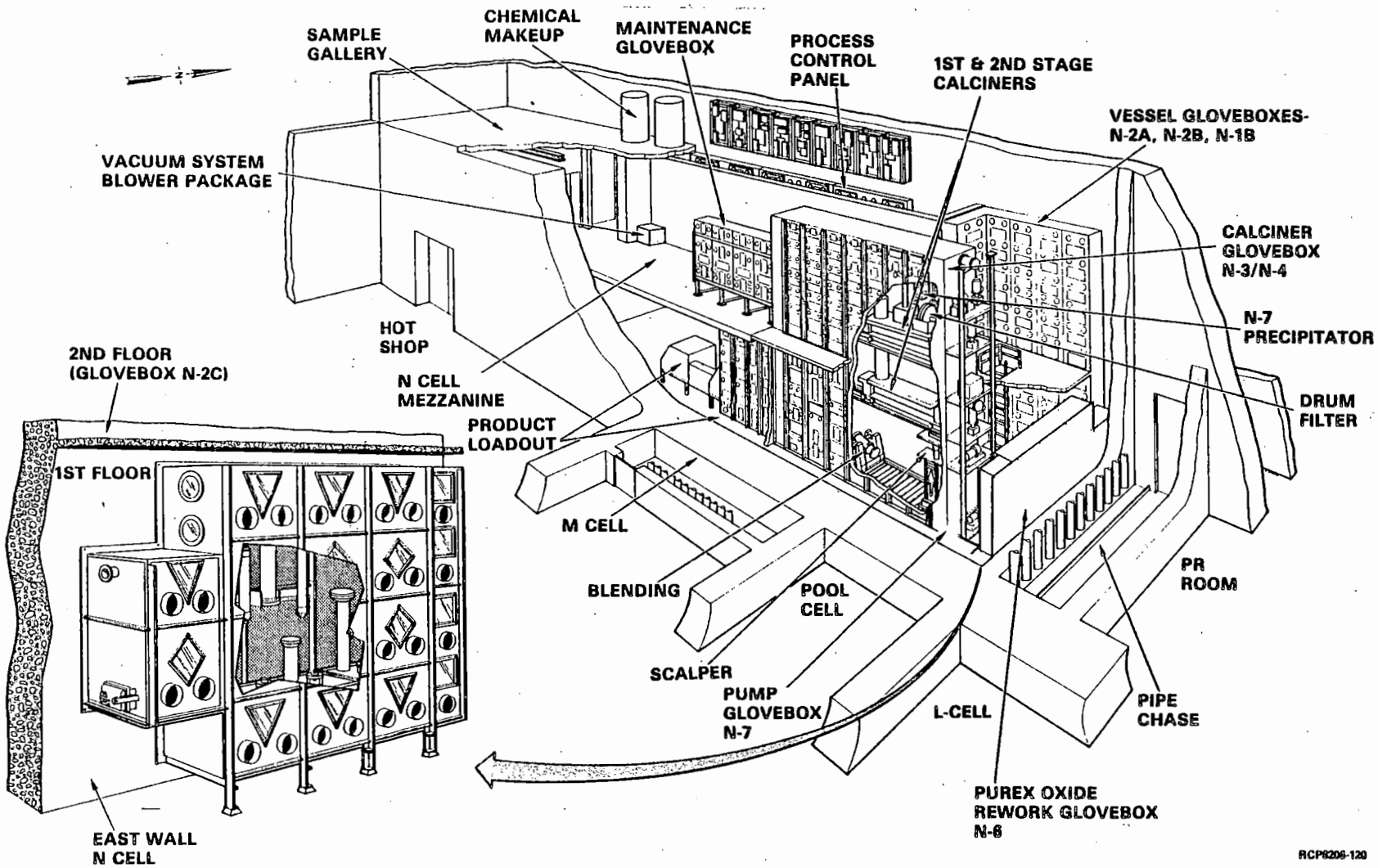

FIGURE 5-13. N Cell Showing Plutonium Oxide Production and Rework Facilities.

The plutonium rework glovebox, N-6, contains two glass dissolvers and associated tanks to convert off-specification plutonium oxide, clean out material, and plutonium oxalate to plutonium nitrate. The N-6 glovebox has a criticality drain to L cell that uses a common header between gloveboxes N-1B, N-6, and N-7 and L cell. The rework product is routed back into the process for purification.

Various tanks to support the N cell operations are located in a pipe chase to the east of N cell. A listing of these tanks and their function follows.

Tank	Service
N-15, -16	Filtrate holding tanks
N-21, -22	Condensate receiver tanks
N-39, -40	Vacuum dropout tanks
N-53	Rework storage tank

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Operations and controls are monitored directly through viewing windows. The thickness of the windows provides the shielding equivalence of the walls in which positioned.

The existing double doors at the west end of N cell are sealed, and a new door from the load-out room is located in the west wall to provide access into the elevator corridor. A new door provides access from the PR corridor and load-out room to the elevator and is located close to the foot of the new stairs.

A ladder opening at the east end of N cell provides (nonroutine) personnel access between the first and second floor glovebox areas. On the second floor, an equipment transfer hatch at the west end of N cell accommodates the use of a monorail hoist for equipment removal from N cell.

A section of M cell is partitioned with a new concrete shielding wall for housing four plutonium storage tanks. The M cell enclosure floor has a stainless steel liner turned up 8 in. at the walls to facilitate decontamination. Surfaces not lined received special protective coatings. Metal cover plates forming a ceiling over this area are gasketed to prevent entrance of moisture as are other wall openings from the M cell decontamination area.

In N cell, the concrete floors, walls, and ceiling surfaces were patched and smoothed prior to receiving special protective coatings.

5.2.2.13.1 Gloveboxes. All gloveboxes are similar in construction and follow the design of gloveboxes used in the plutonium facility at the Los Alamos National Laboratory (Drawing H-2-65350). Lead shielding, 1/4 in. thick, sandwiched between stainless steel plate, is an integral part of the maintenance and powder load-out gloveboxes only. All other gloveboxes are of single-wall construction. Separately supported, externally mounted,

neutron shielding is installed outside the primary canning glovebox, the calciner gloveboxes and the sections of the vessel gloveboxes in front of TK-N3, TK-N5, and TK-N6. Shielding over glovebox windows is fabricated of transparent acrylic-lead material. Shielding in other areas is fabricated of Benelex™, a woodfiber-phenolic resin composite. Additional 2-in.-thick movable shielding walls on tracks extend about 7 ft up from the floor on both sides of each calciner glovebox.

5.2.2.13.2 Piping. The engineering flow diagrams for piping and instrumentation are available in Drawings H-2-65483 through H-2-65498. All process and process instrument lines in the oxide production line are stainless steel and are fabricated, installed, tested, and inspected in accordance with ANSI B31.1.[11] Kynar piping and valves are used in the plutonium rework glovebox. The instrument lines in the heating, ventilation and air conditioning system are copper from the transmitters located in the glovebox room to the control room.

Access for maintenance, repair, and replacement of the equipment in the N cell gloveboxes is provided through glove ports and bag-in/bag-out ports. If it is necessary to replace vessels in a glovebox, an equipment access panel on the front of the glovebox can be removed. Although piping, welded fittings, flanged piping connections, tubing, and tubing compression fittings are all used for system assembly, all welded construction is used where feasible. Valves, pumps, filters, and other equipment have quick-disconnect capability to facilitate component removal.

The vessels in M cell and the piping to the vessels are of all-welded construction. The connections to N cell are through new penetrations in the wall.

The process equipment in N cell is designed and arranged so that the change from the oxalate process to direct denitration can be made by changing removable spool pieces in the process lines. Service lines to vessels not in use can be valved off. Provisions were made for flushing and draining vessels and piping prior to removal from service in making the process changeover.

All pressurized lines containing plutonium solution and located in personnel areas are encased. The filtrate holding tanks and the condensate receiver tanks are located in the pipe chase between N cell and the PR room. Piping to these tanks is welded. Both breathing air stations serving each of the glovebox rooms and 14 continuous air monitors (CAM) located in N cell are connected to existing piping.

5.2.2.13.3 Instrumentation. Control and readout instrumentation is of the conventional electronic type and is mounted in panels located in the first and second floor control rooms. Space limitations preclude access to the rear of the panels; consequently, the customary rear-of-panel auxiliaries, terminal strips, and interconnecting wiring are in configurations that permit maintenance and future modifications from the front of the panels.

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Transmitters, the direct-connected alarm switches, and purge airflow meters are mounted on open racks located in the P&O gallery in the vicinity of TK-R5A. This location was selected to reduce the possibility of migration of process fluid to the rack via the sensing lines.

Processing interlocks are provided as appropriate to facilitate process control or ensure safety. In addition, emergency shutdown buttons are located in the N cell upper control room, the PUREX dispatcher's office, and the guard house to activate an interlock system that will automatically bring the operation to a safe shutdown condition.

Fixed-filter particulate air samplers and CAMs with alarm systems are installed at selected locations in the N cell operating area, as well as in the first and second floor control rooms.

5.2.2.13.4 Normal Power. Normal electric power is supplied as 480-V, 3-phase power from existing Motor Control Center (MCC) 105, located in the P&O gallery, to three new panel boards: the process motor starter panel board (PMSP), product load-out motor starter panel board (PLMSP), and service distribution panel board (SDP). The new motor starter panel boards contain disconnect switches and combination motor controllers for branch circuit protection and control of 480-V, 3-phase motors and three transformers. A 25-kVA transformer provides 480/208/120-V, 3-phase power to panel board NPP, a 50-kVA transformer provides 480/120/240-V, 3-phase power to panel board HTR, and a 15-kVA transformer provides 480/208/120-V, 3-phase power to panel board LP (Drawing H-2-65271). Power at 120-V is supplied from the SDP panel board to loads such as room lighting, several fractional horsepower pumps, agitators, and motor-operated valves. Normal power is supplied to a welding receptacle at airlock 9 from the existing MCC 45, which is also located in the P&O gallery.

5.2.2.13.5 Emergency Power. Emergency (standby) electrical power is supplied at 480-V, 3-phase, from existing Motor Control Center 3, located in the P&O gallery, to a new emergency motor starter panel board (EMSP). The new motor starter panel board contains disconnect switches and combination motor controllers for branch circuit protection and control of 480-V, 3-phase motors and three transformers. A 3-kVA transformer provides 480/120/208-V, 3-phase power to the first stage calciner drive motor, a 3-kVA transformer provides 480/120/208-V, 3-phase power to the second stage calciner drive motor, and a 25-kVA transformer provides 480/120/208-V, 3-phase power to the emergency power panel board (EPP). Power at 120 V ac is supplied from the EPP panel board to loads such as emergency room lighting, motor-operated valves for the chemical addition process lines, vessel vent and vacuum systems, liquid transfer valves, the radiation monitoring system, the glovebox leak-detection system, the intercommunications system, the Halon fire-suppression system, safeguards and security equipment, and several fractional horsepower pumps and agitators.

5.2.2.13.6 Fire Alarm System. Building fire alarm gongs are installed in the following rooms:

- First floor control room
- First floor glovebox room
- Load-out room
- Second floor control room
- Second floor glovebox room
- Second floor maintenance room.

These alarms are connected to the building fire alarm system. Upon activation of any of the alarms located throughout the building, each alarm sounds, the actuated alarm is indicated on the fire alarm control panel near the central control room, an outside alarm is sounded, and an alarm at the central fire station is sounded.

5.2.2.13.7 Criticality Alarm System. Criticality detection devices are located throughout the facility. Criticality alarm howlers are located in the first and second floor control rooms, the powder load-out room, the first floor glovebox room, and the second floor glovebox room. The criticality alarm system is an extension of the present building criticality alarm system (see Section 8.3.4.2) with full compatibility.

5.2.2.13.8 Heating, Ventilating, Air Conditioning. Air is supplied by the existing sample gallery supply system. All previous ductwork in the N cell area was removed and a new duct configuration installed. New penetrations have been made between the sample gallery and N cell and between N cell and corridor 1 for supply ductwork. A steam reheat coil with controls is installed in the supply duct in N cell. Existing steam supply and condensate piping is used.

Part of the air supplied to the occupied spaces is exhausted through the west sample gallery exhaust system via an N cell exhaust duct. One stage of high-efficiency particulate air (HEPA) filters is installed in the room exhaust system. A second stage of HEPA filters is provided in the west sample gallery exhaust system prior to discharge to the atmosphere.

The remainder of the air supplied to the occupied spaces is used to supply air to most of the gloveboxes. The HEPA filters are provided on the inlet to these gloveboxes. The dry air system described in the next paragraph supplies the second stage calciner vacuum system, primary canning, and maintenance gloveboxes. Air from the second stage calciner glovebox is routed through the first stage calciner glovebox to the exhaust. Unfiltered air from the loadout room supplies the bagging, conveyor housing, and secondary canning gloveboxes.

The dry air supply system is located in the 2711-A building adjacent to the southwest side of the 202-A building. The system consists of a nonlubricated rotary compressor, filters, adsorption dryer, receiver tank, shutoff valves, and flow and pressure control valves. Moisture analyzers and alarm systems are provided to ensure dry air with a dew point of -40°F.

All glovebox exhaust is filtered at the glovebox with paralleled, dioctyl phthalate (DOP)-testable HEPA filters. The exhaust system ties into the PR exhaust system, which has an additional two stages of DOP-testable HEPA filters. Plenum modifications were made to ensure adequate filter capacity.

The process offgas is passed through two stages of DOP-testable HEPA filters prior to discharge to the PUREX canyon air tunnel for further filtration through the deep-bed fiberglass filters prior to discharge to the atmosphere. The system contains redundant exhausters with inlet vane dampers and has redundant HEPA filters. Offgases from the process vacuum lines, evaporator, and calciner are routed through a scrubber and a liquid retention trap prior to passing through the HEPA filters.

Ventilation for the new storage tank room in the M cell area is provided, using louvers to control the air entering the room from M cell and direct connection of the exhaust to the PUREX canyon air tunnel.

All air discharged to the atmosphere from the plutonium oxide production facility is monitored for radioactivity by existing equipment associated with one of three systems. All room atmospheres are monitored for radioactivity at selected locations. Glovebox exhaust is monitored and sampled between the first and second stages of HEPA filtration and downstream of the second-stage filters.

5.2.2.14 Building Annexes. Two service area annexes are attached to the north side of the 202-A building, as shown in Figure 5-14. The larger (west) annex houses AMU rooms, a switchgear room, ventilation supply rooms, a compressor room, a maintenance shop, dispatcher's office, central control room, change room and SWP lobby, offices, and a lunchroom. The smaller (east) annex contains the analytical laboratory, headend control room, and a switchgear room.

5.2.2.14.1 Aqueous Makeup Area. The main AMU area in the PUREX Plant is located in the west service annex. There are five levels comprising the AMU area. The first floor is used for all solids dissolution. First-floor makeup tanks are recessed in the floor for convenience in solids addition. Pumps for the first-level makeup tanks are located in the basement. Chemical and service piping and chemical makeup tanks and headers are located on the second level. The third floor contains head tanks and vessels for liquid makeup. A general utility head tank is located on the fourth floor in a regulated work area. For process tanks and safety-related details, see Section 5.3.3.

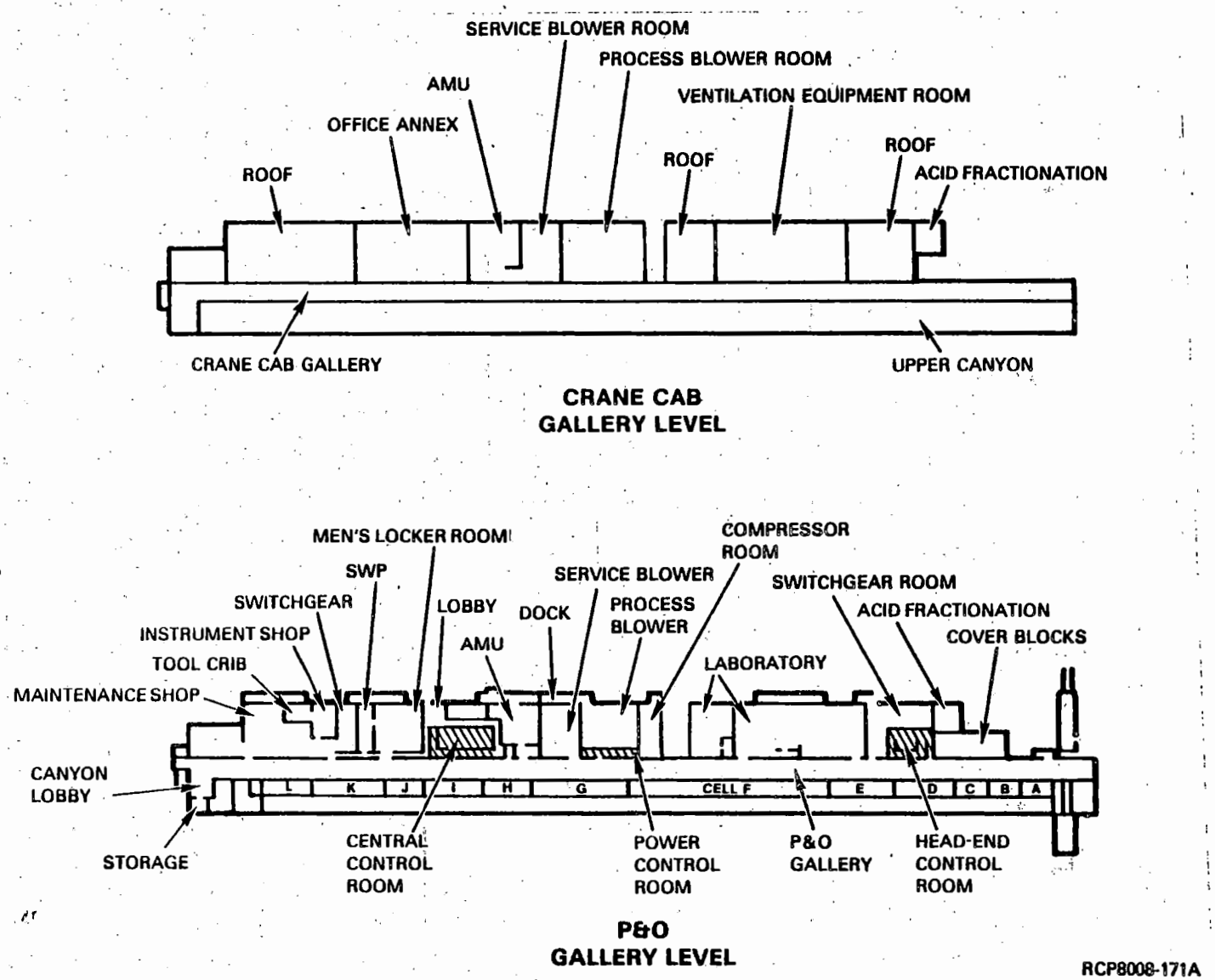

FIGURE 5-14. Relative Location of Control Rooms and Service Areas.

5.2.2.14.2 Electrical Switchgear Rooms. Switchgear for the electrical distribution system is located in the 2,400/480-V switchgear room, which is adjacent to the headend control room in the east annex and in the 480-V switchgear room near the maintenance shop in the west annex (Fig. 5-15).

The east 2,400/480-V switchgear room is 56 ft long and 60 ft wide; the west 480-V switchgear room is 20 ft wide and 42 ft long; both are located at the P&O gallery level. The east switchgear room contains a battery room with batteries to power switching equipment to convert from normal to standby power. Additional details for the electrical system are provided in Section 5.4.2.

5.2.2.14.3 Blower Rooms. The service blower room and process blower room are located immediately east of the AMU area. The two blowers for ventilation system 3 are located in the service blower room. The two blowers for ventilation system 1 and the two blowers for ventilation system 2 are located in the process blower room. The power control room is located at the south end of the process blower room.

5.2.2.14.4 Compressor Room. The compressor room is located next to the process blower room at the east end of the west annex. It houses compressors and dryers to produce instrument air, process air, and fresh breathing air.

5.2.2.14.5 Control Rooms. Five control rooms (the headend control room, central control room, power control room, N cell control room, and the inactive Q cell control room) containing graphic panel boards are provided for process and ventilation control. The control rooms are described in more detail in Section 6.6. The relative locations of the three control rooms in the service annexes are shown in Figure 5-14. Centralization of controls for a continuous process, in contrast to decentralized location and control, is of particular importance in prompt detection of instrument malfunctions and system upsets. This arrangement is of particular significance in a process with a high throughput and a small surge capacity between cycles. Pictorial graphic panels aid in quick appraisal of process difficulties, since the various pieces of operating equipment with interconnecting flow lines are portrayed in the correct relative positions. A false ceiling, with recessed direct lighting, is designed to eliminate reflection at eye level. Instrument repair in all but the N cell control room is performed at the rear of the panels in enclosed cubicles. The headend and central control rooms are rectangular in shape, with the primary panel boards installed along three walls in a modified U-shaped arrangement. Secondary panel boards are located along the fourth wall in both of these control rooms. The N and Q cells and power control rooms are rectangular in shape, with the panel boards arranged linearly along one wall.

The headend control room (42 ft long and 28 ft wide), located at the east end of the east service annex, contains the graphic panels for the batch-type fuel-decladding and dissolution processes and the acid concentration step, and is also located adjacent to the canyon area where those processes occur.

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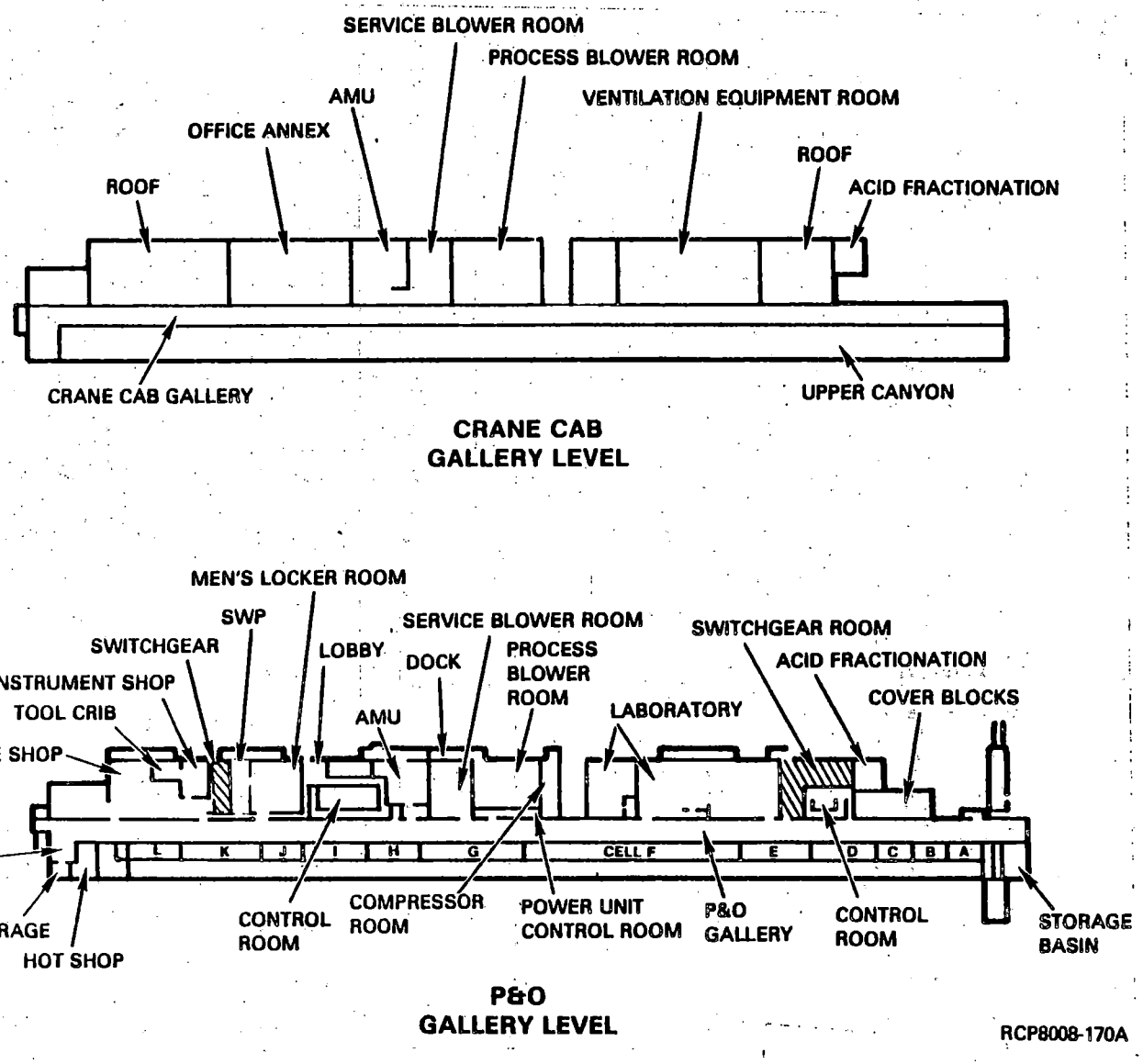

FIGURE 5-15. Relative Location of Electrical Switchgear Rooms.

The central control room (63 ft long and 26 ft wide) contains the graphic panels for some batch processes and the continuous portions of the process. The central control room, located in the middle of the west annex adjacent to the main lobby and the first floor of AMU, is centrally located with respect to the related processing operations.

The power unit control room (46 ft long and 12 ft wide) is located in the process blower room (see Fig. 5-14). The power unit control room contains controls for the building ventilation systems, laboratory ventilation systems, and compressor equipment; it also contains instrumentation for the utility services.

The N cell control room is located on two floor levels: the first level is 21 ft long and 6 ft wide and the second level is 44 ft long and 6 ft wide. It is part of the N cell processing area adjacent and to the west of the PR room (see Fig. 5-12), and contains the controls for the plutonium oxide production processing operations.

The Q cell control room (20 ft long and 10 ft wide), located at the storage gallery level adjacent to and east of the PR room (see Fig. 5-9), contains controls for neptunium purification processing operations. The relative location with respect to the rest of Q cell is shown in Figure 5-11.

5.2.2.14.6 Dispatcher's Office. The dispatcher's office is located across the hall from the central control room. The arrangement of the dispatcher's office is described in Section 6.6.1.5 and shown in Figure 6-76. The dispatcher's office is the main control center for communications in the plant. The dispatcher maintains log records for personnel entering controlled zones and controls the electrical door locks from the dispatcher's office. The dispatcher's office contains alarm panels, call bell system, the switch controls for the personnel access control doors, and PAX alarm system (described in Section 6.6.1.5).

5.2.2.14.7 Maintenance Shop. A centralized industrial shop, located at the P&O gallery level at the west end of the west annex adjacent to the switchgear room, is equipped to handle all normal building maintenance. A central tool crib and clerical office are provided for this area. All compressed-gas supply containers are grouped on the loading dock with a manifold piping system to the shop proper, the regulated and hot maintenance shops, and the crane maintenance platform. An overhead monorail system serves the loading dock and the valve, electrical, and instrument test benches. The dimensions are 67 ft wide (across the back), including tool crib, and 56 ft long. The location and layout are shown in Figure 5-16.

5.2.2.14.8 Special Work Permit Lobby. Adjacent to the men's and women's change rooms is the SWP lobby, or the radiation zone entry lobby. The lobby contains a supply room, cabinets stocked with protective clothing for radiation work, hampers for used protective clothing, Radiation Monitoring station, and step-off pads. The SWP lobby is adjacent to a stairwell that provides the main access to the radiation zones within the PUREX Plant. The stairwell services the crane gallery, sample gallery, and

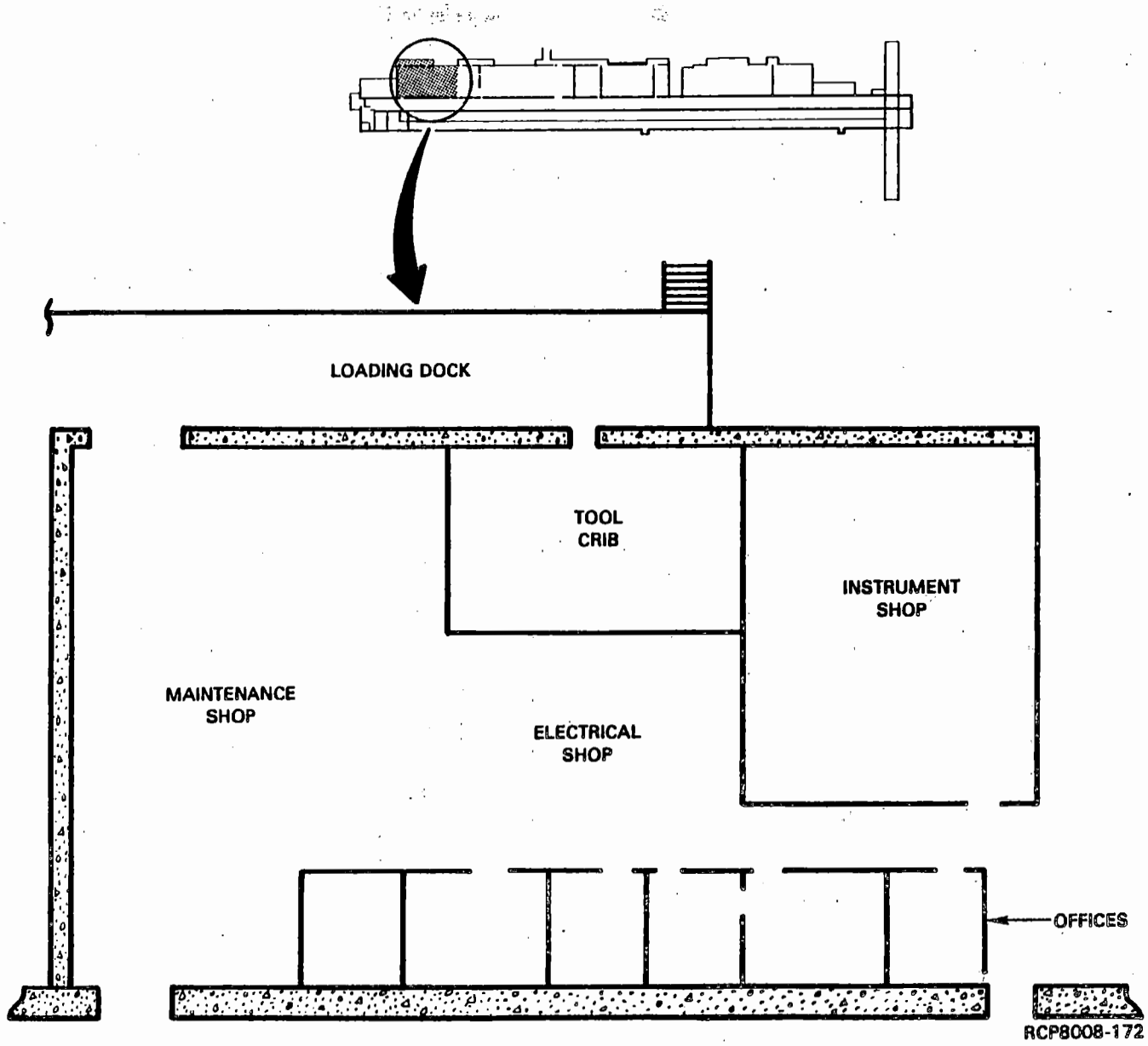

FIGURE 5-16. Maintenance Shop Layout.

PR corridor. A stairwell at the east end of the sample gallery provides entrance to the railroad tunnel and has an emergency exit door, opening directly to the outside of the building. The PR elevator and stairwell at the west end of the sample gallery and PR corridor serve as access to the canyon lobby and WCMP and also serves as an emergency exit. The PR corridor provides access to the Q cell, PR room, N cell, and the hot shop. Separate entry and exit doors connect the stairwell with the SWP lobby to minimize the possibility of spreading contamination. The door entering the SWP lobby from the stairwell is serviced by a step-off pad and Radiation Monitoring station.

5.2.2.14.9 Laboratory. The PUREX analytical laboratory, located in the western end of the east service annex, is 144 ft long and 34 ft high. The first floor, containing the laboratory work area and lunch and change rooms, is on the same level as the P&O gallery. The floor and walls of the first floor are made of reinforced concrete. The second floor, which houses the ventilation equipment and service piping, has concrete-asbestos panel walls.

The first floor of the laboratory contains the instrument repair shop, change rooms, lunchroom, and analytical equipment. The room requirements of the laboratory are given in Table 5-3. The floor plan of this area is shown in Figure 5-17.

TABLE 5-3. Room Dimensions--Analytical Laboratories.

Number	Type	Approximate size (ft)
2	Hot laboratories	20 by 24
1	Hot laboratory	24 by 28
2	Hot laboratories	15 by 28
1	Decontamination room	17 by 28
1	Counting room	20 by 30
1	Instrument repair shop	10 by 22
1	Sample storage room	10 by 18
1	Sample receiving room	14 by 17
1	Hot waste storage	8 by 18
3	Offices	10 by 12
1	Storage room	15 by 60
1	Personnel decontamination room	7 by 10
2	Hot change rooms	Varies
2	Cold change rooms	Varies

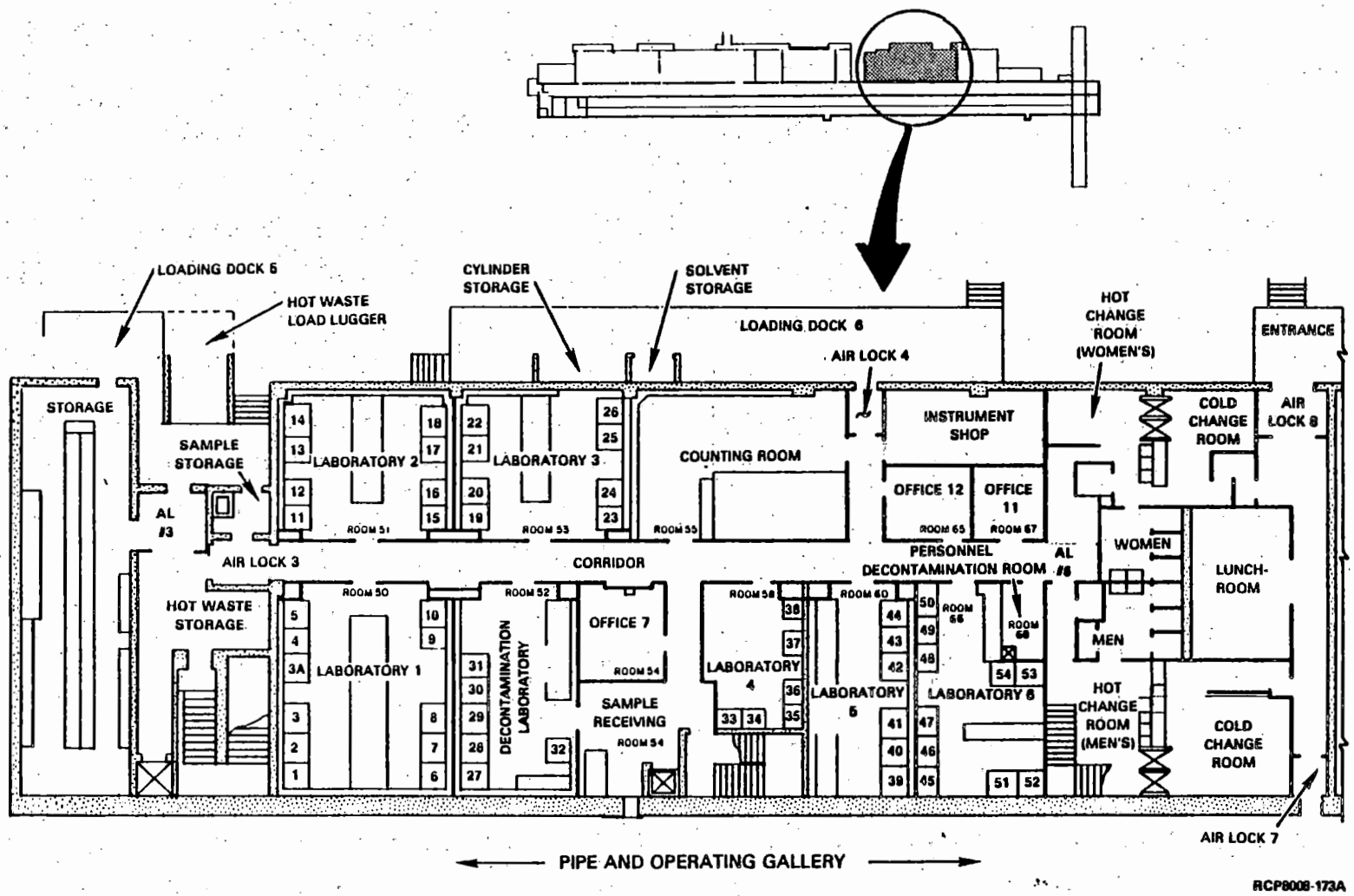

FIGURE 5-17. Layout--Analytical Laboratories.

The ventilation equipment room (ventilation loft) on the second floor of the laboratory houses all the piping, ventilation ductwork, and miscellaneous equipment for servicing the laboratory. Utilities and services are supplied to the laboratory through headers routed in common raceways located in the ventilation loft. Services to each room of the laboratory are brought through the ceiling and terminated at work stations. Service branches from the main building utilities include sanitary water, instrument air, 57% nitric acid, air sampling piping, and mask breathing air. A still and two vacuum pumps are located in the ventilation loft to provide distilled water and vacuum for the laboratory.

Laboratory sink drainage is collected in one of two 8,000-gal, stainless steel tanks (TK-U3 and TK-U4) located in U cell. The tank solution is sampled, made alkaline, and jetted to underground tank storage, with ultimate evaporation in the 242-A waste concentrator.

Radioactive liquid wastes accumulated in the decontamination room receiving and slurping hoods are routed to the acid waste accumulation tank (TK-F10) in the backcycle waste system. A water jet (aspirator) is used to slurp and dilute the waste.

5.2.2.15 French Drains. French drains are 10 ft (approximate) vertical sections of gravel located underground and normally surrounded by clay pipe. The six PUREX french drains listed have a potential for receiving contaminated liquid. In each case, the contamination levels are low (the existing floor contamination is difficult to measure) and, except for 216-A-26, the volumes are also low. Isolating the first five drains listed with installation of liquid-level detection capability, plus batch pump-out for disposal and rerouting the 291-A floor drain to an existing tank, is planned. However, since PUREX operation does not affect the releases significantly, the work will be completed following startup.

French drain	Liquid source	Contamination source
216-A-11	Trap pit 1 cover block seal leakage	Floor surface
216-A-12	Trap pit 3 cover block seal leakage	Floor surface
216-A-14	Vacuum filter pit and blower, pit floor drains (abandoned)	Floor surface
216-A-15	Leakage from abandoned process condensate sample station	Process condensate and floor surface
216-A-22	UNH truck apron sump (valved out)	UNH solution
216-A-26	291-A building floor drains	Floor surface

5.3 SUPPORT SYSTEMS

Auxiliary systems that support the PUREX Plant chemical processing systems include the following:

- Uranium product storage and handling facilities
- DOG backup treatment facilities
- Cold-chemical handling facilities
- Maintenance systems.

5.3.1 Uranium Product Storage and Handling Facilities

The uranium product storage and handling facilities are located in the 203-A area, and consist of four UNH storage tanks, a uranium recycle tank, a sump waste-handling tank, loading and unloading facilities, the associated pumps, and an inactive product decontamination facility (205-A building). The relative locations of the tanks are as shown in Figure 5-18. The 205-A building located near TK-P4 is not shown.

5.3.1.1 Uranium Storage and Handling--203-A Area. The 203-A area is used for storage and shipping of UNH product from the PUREX Plant. In addition, UNH waste solutions are received from the Uranium Oxide Plant (referred to as the UO_3 Plant) and accumulated for rework, and nitric acid recovered at the UO_3 Plant is received and stored in the 203-A tanks. The 203-A area is located about 100 yd north of the 202-A building, and contains four 100,000-gal, stainless steel tanks (TK-P1, -P2, -P3, and -P4) for UNH product storage and two 7,300-gal, stainless steel tanks (TK-13, and -14) and one 13,800-gal tank (TK-15) for UO_3-recovered nitric acid storage. A 14,000-gal tank (TK-P6), which contains a steam coil and vents to a condenser (E-P7), is used to receive and concentrate uranium-bearing liquid waste from the UO_3 Plant and the 203-A sump. Condensate from waste UNH concentration and 203-A sump waste is collected in a 4,000-gal tank (TK-P5), sampled, and disposed of as appropriate.

The storage tanks are mounted on concrete pads and are surrounded by a dike that provides a containment basin in the event of tank leaks.

The UNH solution is pumped from the 203-A storage tanks to tank trailers for shipment to the UO_3 Plant. The 203-A building, located outside the containment dike, houses the pumps and controls for solution transfers.

5.3.1.2 205-A Building. This structure is a transite shelter containing lead-encased silica gel beds formerly used for decontamination of UNH product. The facility, located inside the 203-A enclosure, is deactivated.

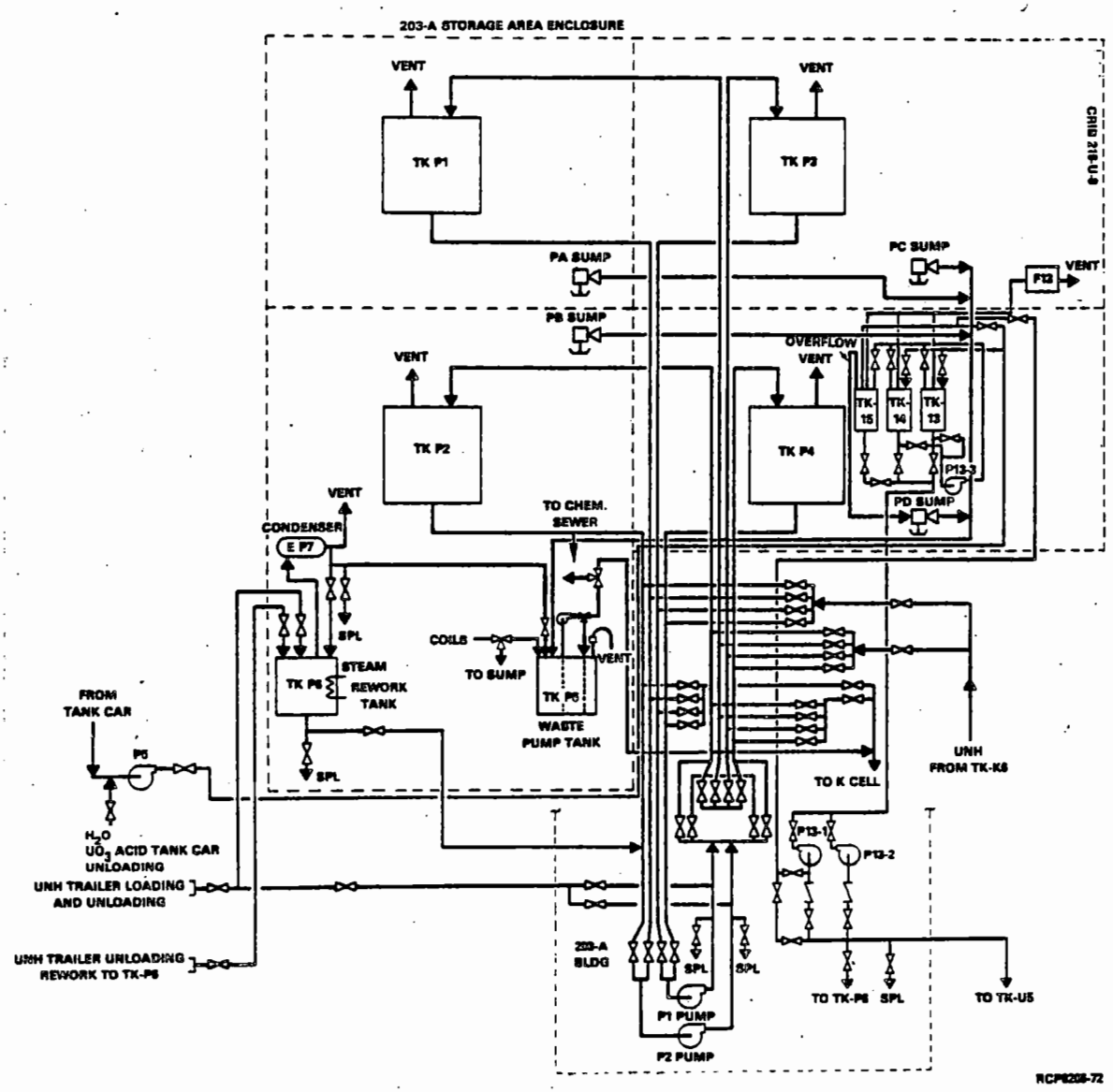

FIGURE 5-18. 203-A UNH Storage Area Process Piping and Flow Diagram.

5.3.2 Dissolver Offgas Backup Treatment Facilities

The DOG backup treatment facilities consist of an acid absorber facility (293-A) and individual backup DOG filters (294-A).

5.3.2.1 293-A Backup Facility. In the 293-A backup facility, the offgas from the dissolution step is processed to remove the oxides of nitrogen and residual radioiodine by two bubble-cap tray acid absorbers in series. The offgas is then discharged to the 291-A-1 main ventilation stack.

The 293-A backup facility is 33 ft 6 in. wide, 44 ft long, and 44 ft 6 in. tall and is made of reinforced concrete with concrete slab covers (see Fig. 6-61 for its relative location). The building cells and pipe pit are vented through a single-stage HEPA filter by a fan and are exhausted to a 50 ft stack (296-A-14).

The building contains four cells on two levels (the lower level is below grade and the upper level is above grade). It contains two acid absorption towers, two collection tanks, and the associated piping and pumps. The equipment is contact-maintained and large pieces of equipment can be replaced through the roof, whereas small pieces are carried in or out through the doors to the cells. For further functional and equipment descriptions of this facility, see Chapter 6.0.

5.3.2.2 294-A Building. The 294-A building, located north of the 293-A backup facility, consists of an above-grade steel shelter over a covered below-grade cell which contains three filters, one for each of the DOG streams from the 202-A building. Each filter is identical to the in-cell filter in this system and provides secondary filtration of the offgases prior to treatment in the 293-A backup facility or discharge to the 291-A-1 stack.

Each filter containment vessel is an insulated, dished-head, stainless steel tank, 9 ft in outer diameter (exclusive of insulation) by 8 ft 9 in. high. A 10-in. diameter flanged nozzle is located in the side wall near the bottom head and in the top head, for gas inlet and outlet, respectively. The Fiberglas filter (Type 115K) is in four layers of different densities held between screen-covered supports. Fiberglas Type 115K has a mean fiber diameter of 0.00115 in. The layers range in density from 1.5 lb/ft^3 at the bottom (gas inlet) with increasing density to 9 lb/ft^3 for the top (gas outlet) layer. The bottom layer is 1 ft 9 in. thick and the upper three layers are each 1 ft thick.

5.3.3 Cold Chemical Handling Facilities

The industrial chemicals used at PUREX are aqueous solutions or are made up as aqueous solutions. Two exceptions--the tributyl phosphate (TBP) and diluent, which comprise the process solvent--are immiscible with water. These solutions are known as "cold streams," as distinguished from process streams containing radioactive materials, known as "hot streams."

Some chemicals used at the PUREX Plant have potential hazards other than those of a radioactive or nuclear nature. These include physiological hazards and "disruptive" hazards that could damage the plant or equipment as a result of fire or explosion.

The disruptive hazards arise from violent reactions of imcompatible chemicals or the accidental combustion of dry chemicals or flammable mists and vapors.

The main AMU area in the PUREX Plant is located in the 202-A building annex. Here, the bulk of the "cold" aqueous chemical solutions required by the PUREX Plant process is prepared. This area is composed of four operating floors and a mezzanine, as shown in Figure 5-19. Two facilities located outside of the 202-A building and annex support this work area. The first is the chemical warehouse (2714-A) where packaged chemicals are stored. These chemicals may be either dry or liquid solutions. The second is the 211-A chemical tank farm where bulk, liquid chemicals are stored. A building at this location contains pumps to supply the main AMU area and demineralizer units for the preparation of process water.

Pipeline routings to and from the AMU vessels are designed and operated to minimize chemical hazards. This protection may be lost, however, by improper chemical makeup. Several solid chemicals of similar appearance are used in the plant and may be received in similar containers. For these reasons, strict identification of materials is maintained by administrative procedures and controls.

5.3.3.1 Aqueous Makeup Area. Approximately 30 "standard" chemical process streams and, occasionally, a few additional solutions for decontamination flushes or specialty processing operations are prepared in and distributed from the AMU area. In addition, two oxalic acid makeup tanks and a hydrogen peroxide tank are located in the sample gallery for use in the Plutonium Oxide Production Facility.

The chemical makeup operations are conducted in accordance with standard operating procedures provided for each batch preparation requirement. The procedures are well defined to provide chemical solutions that are accurately prepared.

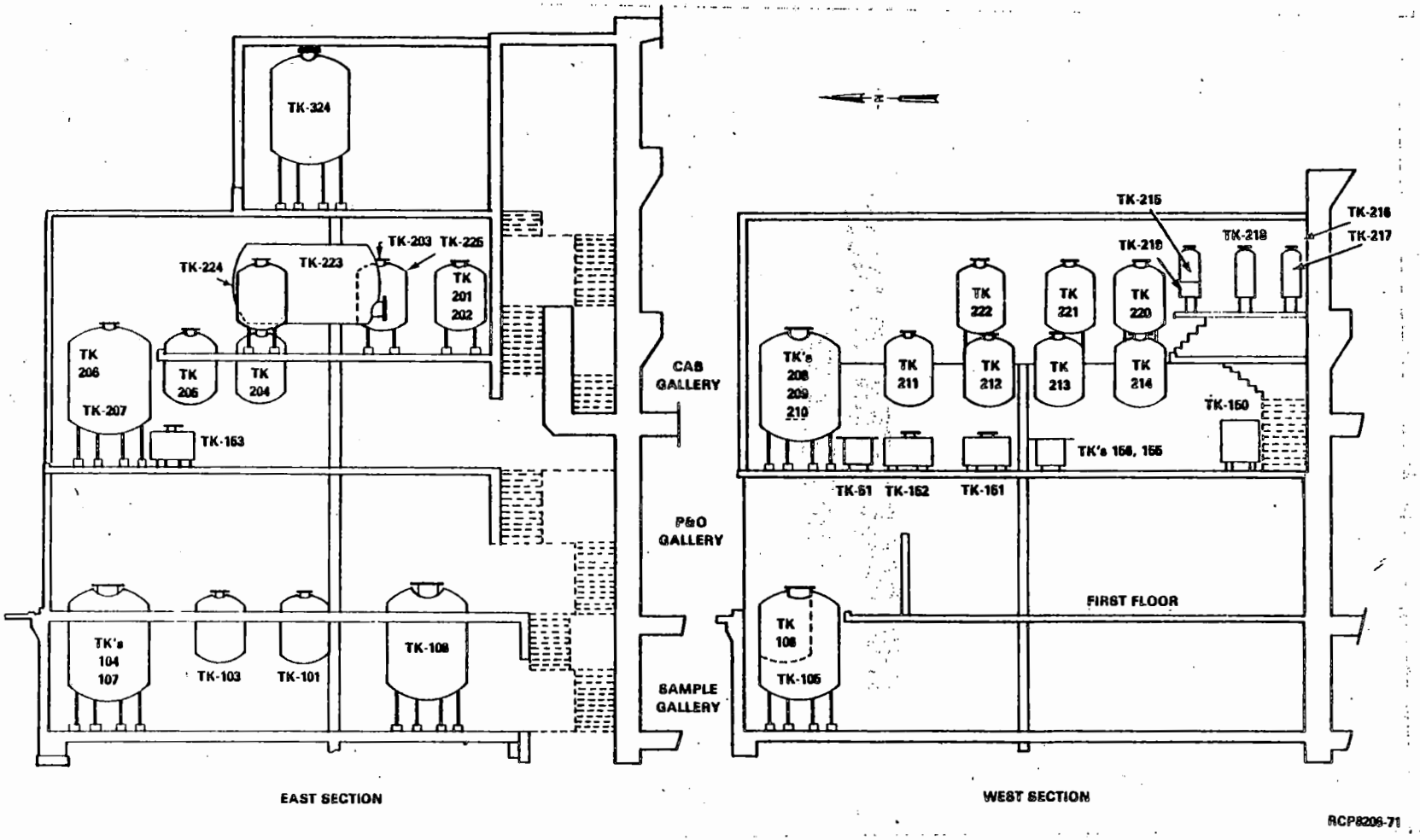

FIGURE 5-19. AMU Area Elevations.

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The first level of the main AMU area contains large tanks for mixing aqueous solutions of dry, solid chemicals plus certain concentrated liquid materials. The dry materials are generally received in bags or drums and are transported by forklift from the chemical warehouse to the appropriate makeup tank. First-level tanks and uses are listed as follows.

First-level tanks	Service
101	Ferrous sulfamate makeup
103	Hydroxylamine nitrate
104	Sodium nitrate makeup
105	Utility; used for mixing chemical solutions used in equipment decontamination, etc.
106	Sodium nitrite makeup
107	Sodium carbonate (Na_2CO_3)-potassium permanganate ($KMnO_4$) mixture
108	Utility; used for mixing chemical solutions used in equipment decontamination, etc.

The completed chemical solutions in the first-level makeup tanks are transferred by pumps positioned on the basement level to head tanks located on the second, third, and fourth levels of the AMU area. However, the fourth level contains only one, multipurpose tank. The elevation of the tanks on the upper levels provides sufficient liquid head pressure for transferring the chemical solutions to various process points. Solutions of 50% sodium hydroxide, 57% nitric acid, and demineralized water are pumped directly to the head tanks from the 211-A area. A list of the head tanks and uses follows.

Second-level tanks	Service	Remarks
150	3BX makeup, HNO_3	Makeup tank for 3BX solution routed to feed tank, TK-155
151	$Cd(NO_3)_2$ makeup and feed	Made up and routed to the PR room; used as the motive fluid for transferring rework plutonium solution from TK-L11 to TK-E6

Second-level tanks	Service	Remarks
152	$NaNO_2$	Filled from TK-106; routed to the HA column ($HA-NO_2$) (inactive), TK-J5 ($2AF-NaNO_2$)
153	NaOH	Filled from TK-20 (211-A); serves all process locations using NaOH, except the dissolver systems (i.e., waste neutralization, solvent wash solutions, etc.)
155	3BX feed	Head tank for routing 3BX solution to the 3B column; filled from TK-150
156	3AS feed	Head tank for routing 3AS solution to the 3A column; filled from TK-211
51	Resin wash tank	Used for the conversion of anion exchange resin to the nitrate form prior to addition to the neptunium purification anion exchange column (inactive)

Third-level tanks	Service	Remarks
201, 202, 203	NaOH	Not in service
204	Sugar makeup and feed	Head tank for making up and routing sugar solution to the waste concentration and treatment system for nitric acid destruction (waste denitration)
205	$[AL(NO_3)_3 \cdot 9\ H_2O]$	Filled from TK-42 (211-A); routed to the dissolvers and E cell for complexing fluoride during Zirflex processing
206	KOH feed	Filled from TK-21 (211-A); routed to TK-D1 for metathesis of UF_4 in the dissolvers during Zirflex processing

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Third-level tanks	Service	Remarks
207	NH_4F-NH_4NO_3	Filled from TK-11 (211-A); routed to the dissolvers for fuel element jacket removal during Zirflex processing
208	Na_2CO_3 $KMnO_4$ mixture	Filled from TK-107; organic wash solution routed to TK-G1 and TK-R1
209, 210	1BX solution HNO_3, FeSA and SA	Head tanks for making up and routing solutions to the 1BX partitioning column; HNO_3 added from TK-215, FeSA added from TK-216, SA added as a solid
211	3AS solution HNO_3	Makeup tank for 3AS solution; routed to TK-156
212	$NaNO_2$	Filled from TK-104; used for adding $NaNO_2$ to waste solutions
213, 214	2BX solution HN N_2H_4	Head tanks for making up and routing 2BX solution to the 2B column. HNO_3 added from TK-215, N_2H_4 added from drums, HN added from TK-219
215	57% HNO_3	HNO_3 addition tank serving TK-209, -210, -211, -212, -213, and -214
216	FeSA	FeSA addition tank; filled from TK-101; serves TK-209, -210, and -211
217	N_2H_4	Makeup from drums; serves TK-K1 (2DF-N_2H_4) stream
218, 219	HN	Filled from TK-103; routed to T-K2 (2DIS-HN); TK-219 is also used as a scale tank for HN addition to the 2BX makeup

Third-level tanks	Service	Remarks
	2NS solution, HNO_3 FeSA, and N_2H_4	Head tanks for making up and routing 2NS solution to the 2N column; HNO_3 added from 211-A, FeSA added from TK-101, N_2H_4 added from drum via T/C 220/221A
222	57% HNO_3	Filled from fresh HNO_3 headers (TK-12); serves numerous process points requiring continuous acid flow
223	Demineralized water	Filled from TK-30; serves all process cells and AMU tanks
224, 225	2PX solution and HNO_3	Head tanks for making up and routing 2PX solution to the 2P column; HNO_3 added direct via addition port

Fourth-level tank	Service	Remarks
324	Utility	Filled from TK-105 and -108; serves most sections of the PUREX Plant process as a utility addition tank

Sample gallery tanks	Service	Remarks
N34-1	H_2O_2	Head tank for making up and routing 12 wt% H_2O_2 to the TK-N5 prereduction tank via the TK-N4 metering tank.
N35-1, N36-1	$(COOH)_2$ $2H_2O$	Head tanks for making up and routing 1M $(COOH)_2$ to the plutonium precipitator, TK-N7.

5.3.3.2 211-A Chemical Tank Farm. The 211-A chemical tank farm (Fig. 5-20) is located north of the 202-A building. A listing of tanks, their use, capacities, and materials of construction follows.

Tank	Service	Capacity (gal)	Materials of construction
TK-10	57% HNO_3	4,600	Type 309 stainless steel
TK-11	NH_4F-NH_4NO_3	100,000	Type 304L stainless steel
TK-12	57% HNO_3	100,000	Type 304L stainless steel
TK-20	50% NaOH	30,000	Carbon steel
TK-21	45% KOH	30,000	Carbon steel
TK-30	Demineralized water	50,000	Aluminum
TK-40	Hydrocarbon diluent	65,000	Carbon steel
TK-41	TBP	30,000	Carbon steel
TK-42	$Al(NO_3)_3 \cdot 9H_2O$	7,850	Types 347 and 304L stainless steel
TK-50	93% H_2SO_4	8,400	Carbon steel

A chemical warehouse (2714-A) is located north of the 202-A building. This separate storage building is located away from the main plant as a safety precaution in the event of a fire.

5.3.3.3 Safety Considerations of Cold Chemicals.

5.3.3.3.1 Nuclear Criticality Safety. It is extremely unlikely that a criticality incident in any of the PUREX Plant processing zones could cause physical harm to anyone in the AMU area. However, the emergency procedures require complete evacuation from the building and area in the event of a criticality alarm. There are, however, nuclear safety implications in the work performed in AMU. The three circumstances that follow are examples of ways in which the AMU operation has direct impact on nuclear criticality prevention in the plant.

- The addition of oxidizing agents or precipitating agents to certain process streams could result in the refluxing or precipitation of plutonium and, thus, cause plutonium mass limits to be exceeded.

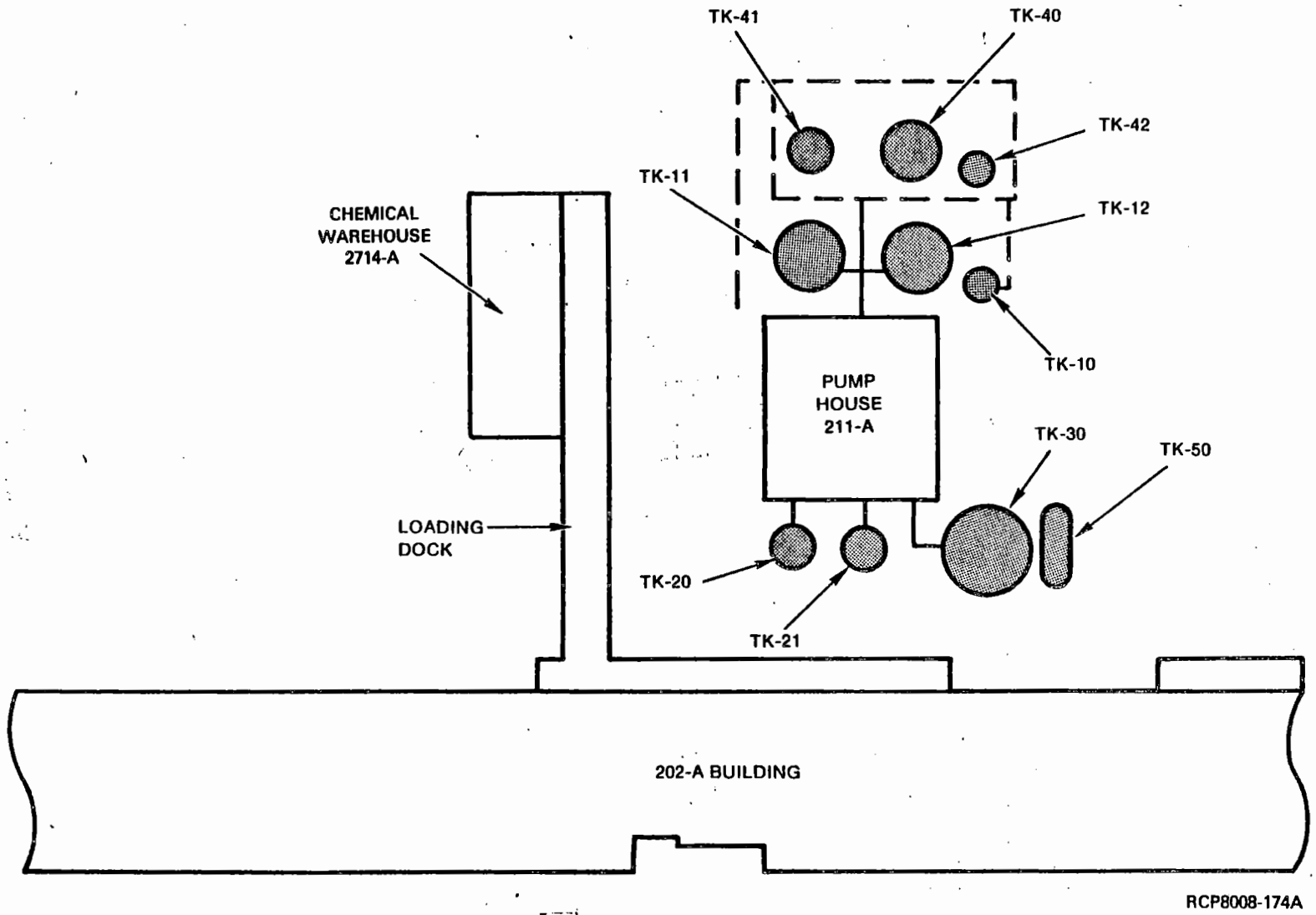

FIGURE 5-20. Chemical Tank Farm.

- The cadmium in TK-151 makeup serves as a neutron absorber during the transfer of plutonium rework solution. Rework plutonium transfers frequently require the dilution and neutron absorption afforded by this stream to reduce the nuclear reactivity of the plutonium to an always-safe value.

- Partitioning cycle operation, which separates the plutonium from uranium, depends upon the presence of a reductant in 1BX. Excessive reductant could feasibly result in the concentration of plutonium, by internal reflux, to an unsafe value. A safe ferrous ion concentration is ensured by laboratory analysis prior to use.

5.3.3.3.2 Chemical Hazards. Hazards associated with each chemical used in the PUREX process are described in the next section. Many of the chemicals received in drums or sacks are either strong oxidants or strong reductants. The major hazard involved in storing these chemicals is the possibility of a vigorous oxidant-reductant reaction occurring due to a leaking drum or other means. To minimize this potential, specific chemicals are stored in clearly designated areas of the 2714-A chemical warehouse per approved procedures. Proper storage is verified by periodic audit. Use of the wrong drummed or sacked chemical in a makeup is a remote possibility because each container is clearly marked. Also, due to the types of makeups used, the consequences of errors of this type are minor. Bulk liquid chemicals received in tank car or truck trailer lots are routed only to specific tanks in the 211-A area and from there to specific tanks in the AMU area.

5.3.3.3.3 Descriptions of PUREX Chemicals.

- Aluminum Nitrate Nonahydrate [$Al(NO_3)_3 \cdot 9\ H_2O$]

  In combination with certain other materials, Aluminum Nitrate Nonahydrate (ANN), an oxidizing agent, can be explosive. The dry salt has been known to start fires. The ANN at the PUREX Plant is, therefore, received and handled in a liquid form, and the fire hazard is greatly reduced. The ANN is received at the PUREX Plant in truck trailer lots and is stored in the 211-A area, TK-42.

- Ammonium Fluoride-Ammonium Nitrate (NH_4F-NH_4NO_3)

  The soluble fluorides are very irritating to the skin, eyes, and mucous membranes. The solution as received at the PUREX Plant is alkaline. The solution is poisonous and ingestion results in systemic poisoning. The material is received at the PUREX Plant in tank truck lots at a concentration of 36 wt% ammonium fluoride, 7 wt% ammonium fluoride-ammonium nitrate (AFAN). It is stored in the 211-A area, TK-11.

- Cadmium Nitrate, $Cd(NO_3)_2$

  Cadmium is poisonous, and ingestion of cadmium salts causes effects that resemble those of food poisoning. The illness is serious, but seldom fatal, with symptoms appearing 15 or 30 min

after ingestion. As with other nitrates, cadmium nitrate is an oxidizing agent and is kept separate from reducing agents. It is received at the PUREX Plant as a 45 to 50 wt% solution in 55-gal drums and is gravity-fed into the cadmium nitrate tank in AMU from an upper level.

- Diluent (Normal Paraffin Hydrocarbon)

Normal paraffin hydrocarbon (NPH) is a petroleum diluent with a flash point of 155° to 160°F and is a moderate fire hazard. The range of concentration for flammability of vapor in air is from 0.6% to 6.0%. Solvent aerosol flammability may occur, however, at much higher concentrations and at all process temperatures up to 194°F (in closed containers), at which temperature mist flammability is limited by lack of sufficient oxygen in the mixture.

The NPH is classed as a physiological hazard and, under some conditions, may become anesthetic. Inhalation of the vapor causes irritation of the mucous membranes of the eyes and nose. Early symptoms of exposure are impairment of mental and physical faculties and dizziness. The NPH is received at the PUREX Plant in railroad tank car lots and stored in the 211-A area, TK-40.

- Ferrous Sulfamate, $Fe(NH_2SO_3)_2$ [FeSA]

Ferrous sulfamate is a moderately acute local irritant. It is not seriously hazardous upon contact, provided that body areas contacted are promptly flushed with water. At elevated temperatures (417.6°F), the sulfamate may decompose with the evolution of oxides of sulfur that are toxic and irritating. Ferrous sulfamate is received at the PUREX Plant as a green, viscous liquid in 360-lb containers of 50 wt% solution and stored in 2714-A.

- Hydrazine, N_2H_4

Hydrazine is a strong reducing agent received at PUREX in 55-gal drums as a 35 wt% (11.3M) aqueous, nonflammable solution and stored in 2714-A. Hydrazine is a skin irritant and systemic poison. It is an explosive at high concentration; it self-ignites with nitric acid.

- Hydrogen Peroxide, H_2O_2

Hydrogen peroxide is a powerful oxidant. Contact with greater than 35 wt% solution can cause blistering of the skin. Highly-concentrated solutions are explosive when heated. It is received at PUREX as 50 wt% solution in truck trailer lots or as 13 to 15 wt% solution in 55-gal drums. The 50 wt% solution is stored in three 10,000-gal aluminum tanks in the 293-A storage facility. These tanks are inside a concrete retention basin that has a

capacity of 13,000 gal. The drums are stored in 2714-A. The concentrated hydrogen peroxide is used as a 50 wt% solution in the 293-A acid absorbers and the dilute solution is used in the Plutonium Oxide Production Facility.

- Hydroxylamine Nitrate, $NH_2OH \cdot HNO_3$

  Hydroxylamine nitrate is a strong reducing agent. The 1.4M to 2.05M solution used in the PUREX Plant is more stable than the anhydrous salt. Handling and storage precautions and health hazards are similar to those required for hydrazine. These drums are also stored in 2714-A.

- Mercuric Nitrate, $Hg(NO_3)_2$

  Mercuric nitrate is an oxidizing agent. With nitric acid and alcohol, the highly-explosive mercury fulminate is formed. With ammonia, unstable mercury diamine salts may be formed. Mercuric nitrate is very poisonous, and smoking or eating is not permitted in areas where mercury or its compounds are used; individuals are instructed to wash thoroughly after handling this agent. Mercuric nitrate is received in crystalline form in bottles of 2 1/2-lb capacity and is stored in a vented and filtered cabinet located on the first floor of AMU.

- Nitric Acid, HNO_3

  Nitric acid is a powerful, oxidizing agent. In combination with wood or cotton, it forms cellulose nitrates, the basis for several nitrate explosives. Nitric acid produces a characteristic brown compound on contact with the skin. With concentrated solutions, severe skin burns will occur in a short time. Nitric acid is received at the PUREX Plant in truck trailer lots at 57 wt% concentration and is stored in the 211-A area, TK-12.

- Oxalic Acid $(COOH)_2 \cdot 2H_2O$

  Oxalic acid produces a strong, local, caustic action on skin and mucous membranes and can be fatal if ingested. Oxalic acid is received at the PUREX Plant in a white crystalline form in bags and stored in 2714-A.

- Potassium Hydroxide, KOH

  Potassium hydroxide is extremely caustic and may cause severe and even fatal burns. Hot caustic will cause almost instant destruction of body tissue. All forms, even solutions as dilute as 1%, can produce serious injury on short contact. Ingestion of 2 g is usually fatal. The dusts or mists of solution are irritating to the respiratory organs, but because of pain to the nose, concentrations that might damage the lungs will not usually

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be inhaled. Potassium hydroxide is received at the PUREX Plant in railroad tank car lots of 45 wt% solution and stored in the 211-A area, TK-21.

- Potassium Permanganate, $KMnO_4$

Potassium permanganate is a powerful oxidizing agent. It is explosive when treated with sulfuric acid and in contact with alcohol, ether, or flammable gas. Dust of permanganate acts as a lung irritant and prolonged exposure causes pneumonia and bronchitis. Potassium permanganate is received at the PUREX Plant and stored in 2714-A in metal drums of 110-lb capacity. It is a dark purple, crystal form with a blue, metallic sheen.

- Silver Nitrate, $AgNO_3$

Silver nitrate is a powerful oxidizing agent and a fire hazard. The crystals react vigorously with reducing solids. Ingestion of silver nitrate results in a poisoning caused by absorption in the blood, followed by deposition in various body tissues. A fatal dose for an adult is 3 g. Silver nitrate is received as a white crystalline salt at the PUREX Plant and stored in the basement of AMU in a locked metal cabinet in containers of 1,000-oz capacity.

- Sodium Carbonate (Soda Ash), Na_2CO_3

Sodium carbonate is alkaline in reaction and may cause caustic burns. If ingested in significant quantities, it will cause pain in the mouth, throat, and stomach followed by nausea, vomiting, weakening pulse, and collapse. Death usually occurs within 24 h. Sodium carbonate is received at the PUREX Plant as a white, odorless, crystalline powder in paper bags of 100-lb capacity that are stored in 2714-A.

- Sodium Fluoride, NaF

Sodium fluoride is a poisonous material and must be handled with extreme caution. Inhalation of the powder can destroy mucous membrane and tissue. Large doses can damage the gastrointestinal and nervous systems and bone structure. The lethal dose by ingestion is 60 mg. Care should be taken to avoid contacting sodium fluoride with acids. Sodium fluoride is received at the PUREX Plant and stored in N cell as a finely pulverized, white powder in 4-oz plastic packets.

- Sodium Hydroxide, NaOH

Sodium hydroxide is extremely caustic and may cause severe and, even fatal, burns. Hot caustic will cause almost instant destruction of body tissue. All forms, even solutions as dilute as 1%, can produce serious injury on contact. Ingestion of 2 g is usually fatal. The dusts or mists of solutions, even in dilute quantities, are irritating to the respiratory organs. These

concentrations that might damage the lungs should not be inhaled. Sodium hydroxide is received at the PUREX Plant in railroad tank car lots of 50 wt% solution and stored in the 211-A area, TK-20.

- Sodium Nitrite, $NaNO_2$

  Sodium nitrite is a powerful oxidizing agent and compares to sodium nitrate as a fire and explosion hazard. Ingestion results in a drop in blood pressure, respiratory failure, and, occasionally, heart failure. It is received at the PUREX Plant and stored in 2714-A as white granular solids in bags.

- Sugar

  There is no associated toxicity with sugar during plant use. The reaction with oxidizing agents can be vigorous, so it is stored separately from such agents in 2714-A. Sugar is received in 100-lb bags.

- Sulfamic Acid, NH_2SO_3H

  The hazards of handling sulfamic acid are the same as those associated with ferrous sulfamate. It is received at the PUREX Plant as white granular solid in bags and stored in 2714-A.

- Sulfuric Acid, H_2SO_4

  Sulfuric acid is a strong oxidizing and dehydrating agent, dangerously reactive with water or organic materials, and highly corrosive to most metals. Sulfuric acid is particularly hazardous because of its ability to cause burns. The concentrated acid has such an affinity for water that it will char wood, paper, or flesh. Death may result from severe skin burns. The acid liberates heat on mixing with water, and may erupt explosively if improperly mixed. The acid should always be added slowly to water; never add water to the concentrated acid. Sulfuric acid is received in 9-lb bottles as chemically pure grade for use in the analytical laboratory. Sulfuric acid is purchased as commercial-grade in tank truck lots and stored in TK-50 in the 211-A area for use in regenerating the water demineralizer beds.

- Tartaric Acid, $HOOC(CHOH)_2COOH$

  Tartaric acid is a moderate fire hazard with a flash point of 410°F. There are no physiological hazards identified with handling tartaric acid. It is stored away from strong, oxidizing agents in 2714-A. It is received at the PUREX Plant as colorless-to-white crystalline material in 100-lb bags.

- Tributyl Phosphate, $(C_4H_9)_3PO_4$

  The chemical tributyl phosphate (TBP) is a moderate fire hazard with a flash point of 295°F. A physiological hazard is the dissolving of natural oils from the skin that causes dryness, cracking of the skin, and irritation. The vapor pressure of TBP is very low, and the breathing of vapors at ordinary temperatures is not known to produce toxic effects, but fumes from fires of organo-phosphates are reported to be very toxic. The TBP is received at the PUREX Plant in railroad tank car lots and is stored in TK-41 in the 211-A area.

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5.3.4 Maintenance Systems

Process equipment located in the canyon has been designed, as much as possible, to give trouble-free service and to require minimal maintenance. Two shielded master cranes and a nonshielded slave crane have been provided to replace the process equipment when it fails, in addition to performing process functions.

Preventive maintenance of the equipment in the radioactive processing cells is not economically feasible. Rotating equipment is, therefore, run until failure and then replaced, meaning that replacement or removal will occur only when complete failure is noted.

Specially designed connectors and tie-down nuts, operated by impact wrenches hung from the master cranes, permit the removal and replacement of equipment, process lines, and electrical lines remotely from the master cranes. Cell jumper lines connect process line nozzles mounted on the cell walls to the equipment.

Equipment, once removed from the cell by cranes, can be taken to the railroad tunnel for removal to the burial grounds or burial tunnel, or can be taken to the decontamination cell or hot shop for any necessary decontamination and repairs.

5.3.4.1 Cranes. Two master cranes and one slave crane, each with an individual capacity of 40 tons, are located in the 202-A building canyon and depicted in perspective in Figure 5-21. A general description of these cranes follows.

- Master Cranes

  The master cranes do most of the routine remote work involving vessels, rotating equipment, pipe jumpers, and cell cover blocks. Charging the dissolvers is performed by the master cranes. These cranes also perform all activities requiring impact wrenches, grabbers, and viewing aids.

  Crane operations are observed from the cab by two variable-power monocular periscopes mounted on either side of the crane bridge. The objective lens of each periscope may be moved across the

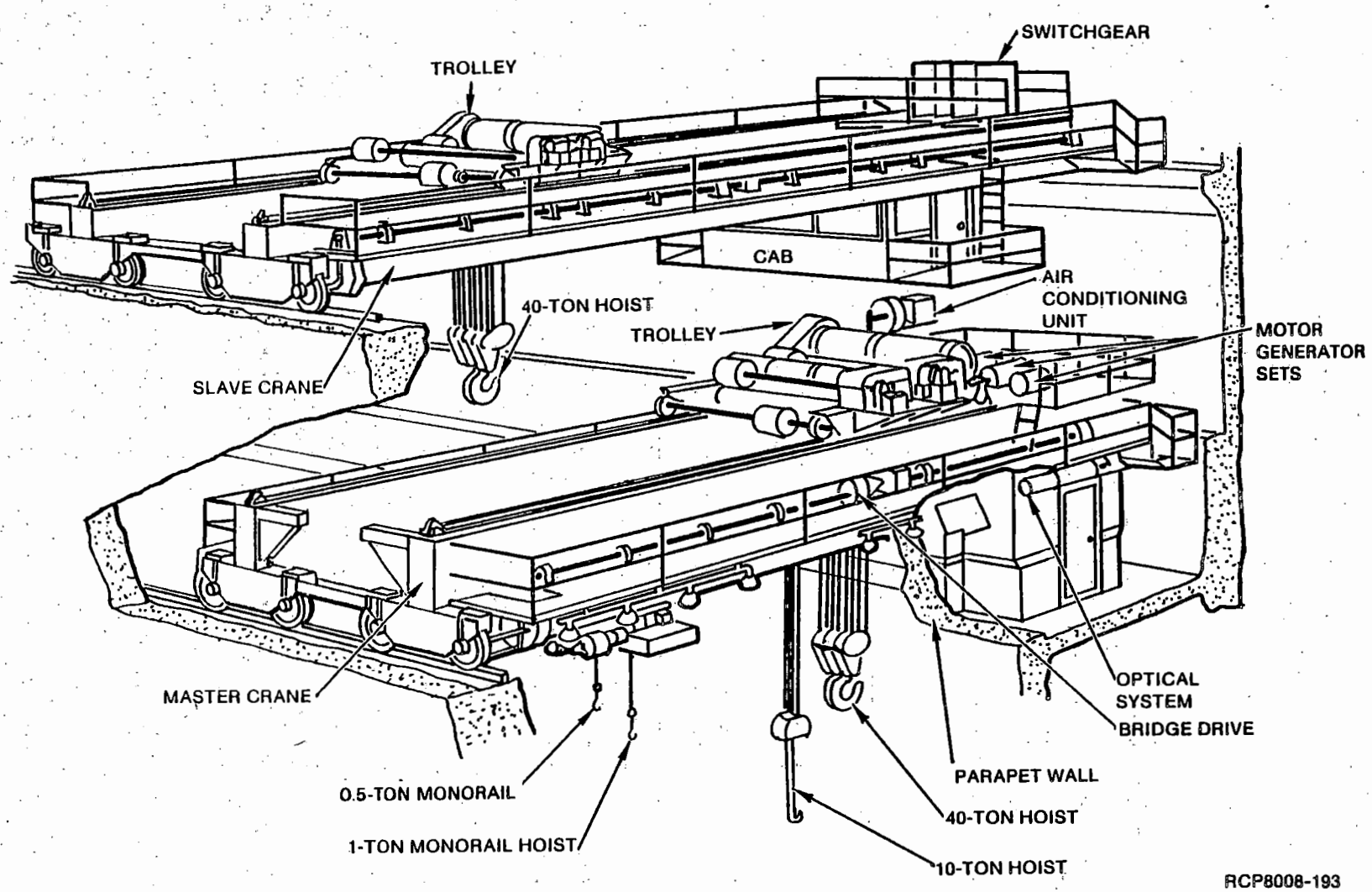

FIGURE 5-21. Canyon Cranes.

canyon and rotated about its axis to allow direct vision. Both cranes can travel the full length of the canyon; however, one is serviced in the east crane maintenance facility, and the other is serviced in the west crane maintenance facility.

Process functions and remote maintenance activities require the master crane to operate almost continuously.

When the crane is in contact with a short section of rail conductor near the railroad tunnel, the operator in the master crane can control the car puller. The car puller positions railroad cars in the railroad tunnel. A second control station for the car puller is located at the track level in the tunnel.

An intercommunication system (speaker and receiver) is mounted on the console of the master crane cab, allowing voice communication between the cab, the dispatcher's office, and the railroad tunnel. A wall-type dial telephone is mounted on the cab wall and connected to the building telephone system by way of collector shoes and trolleys. The microphone of the public address system is in the master crane cab. The system's two speakers are located on the crane bridge.

For safety and contamination control, the master cranes are operated from a totally enclosed, steel-shielded cab that travels behind a 4-ft concrete parapet wall. A fire suppression system using bottled Halon-1301 is provided in each crane cab. In the event of a fire, the system is activated and an alarm is sounded in the dispatchers office. The alarm system is tested daily (readout only) and a buzzer also sounds if the system is tampered with. An annual test of the entire system is conducted by the vendor field engineer.

- Slave crane

The slave crane has been provided to assist the master crane for those operations in which two cranes are required for removal and installation of tall equipment, such as the solvent-extraction columns and the large, single-piece concentrators and to perform maintenance operations over areas where radiation levels are low. While assisting the master crane in high-radiation-level work, the slave crane is controlled from the cab of the master crane. The slave crane is controlled from the master crane by a 75-ft-long electric cable that is plugged into a receptacle on the slave crane. When the slave crane is used for low-radiation-level work, it can be controlled from its own cab.

The height of the slave crane places its cab above the concrete wall used to shield the master crane cab. Since the slave crane is only operated from its own cab for low-radiation-level work, sufficient radiation protection is provided by the cab walls and shatterproof glass windows. When operated from the enclosed cab,

air is supplied by wearing a fresh air-supplied mask. Otherwise, the slave crane is operated from the master crane cab. The slave crane has limit switches to prevent bridge, trolley, and hoist over-travel. Rail stops are also provided on the bridge and trolley.

- Hooks and hoists

  All hooks have three directions of movement: the bridge travels the length of the canyon, the monorail trolleys travel across the canyon, and the hoists travel vertically.

- Grabber

  The grabber is a clamshell bucket device for handling small pieces of equipment that cannot be picked up by the crane's hooks. The jaws of the grabber are used to grasp loose nuts and other small items. Piping may be picked up by special attachments on the grabber.

- Power system

  The cranes are powered by amplidyne variable voltage, variable-speed direct current (dc) drive systems that provide high torque at low speed. Each driving motor, with the exception of those operating the cross-canyon monorail trolleys under the master crane, has a separate motor-generator set. One set supplies the power for both monorail trolleys. Both trolleys cannot be used at the same time.

5.3.4.2 Contaminated-Equipment Maintenance. Maintenance areas are provided at the west end of the process building to decontaminate, inspect, or repair hot equipment after removal from the canyon. Tanks, pumps, agitators, and other equipment are first moved to the decontamination cell and then to the hot shop.

Equipment removed from the 202-A canyon area for repairs, inspection, or disposal is replaced immediately to maintain as close to continuous operation as possible. Because of the high cost in time and money to decontaminate equipment prior to repair work, it is generally more economical to install new equipment, rather than repair old equipment. Disposal of contaminated equipment is covered in Section 7.7.1.1.

The decontamination cell, referred to in Section 5.3.4, is equipped with a stainless steel floor with an 8-in.-high flashing around the walls. The cell is also equipped with electrical outlets and piping to supply breathing air, compressed air, steam, and decontamination solutions. A tank to flush and decontaminate rotating equipment is located in the cell.

The east one-third of the hot shop is accessible from the canyon. Partially decontaminated equipment from the decontamination cell can be lifted into the shop by either canyon crane for contact maintenance work or

further decontamination. The remaining portion of the hot shop is covered. The covered area contains racks to store one of each size or type pump and agitator used in the canyon. A 20-ft-diameter shielded tank for pump and agitator work and a centrifuge test stand are located in the open area.

5.3.4.3 Diversion Boxes. Diversion boxes (Fig. 5-22) are provided to congregate radioactive liquid waste transfer lines in a single location for convenience in changing piping routings, adding new lines, detecting leaks at junctions, and reducing duplication of piping.

5.4 DESCRIPTION OF SERVICE AND UTILITY SYSTEMS

The following are service and utility systems that support PUREX Operation:

- Building ventilation
- Electrical power
- Compressed air
- Steam
- Water
- Sewer systems
- Communications
- Fire protection.

Four ventilation systems (Fig. 5-23) provide air to process and personnel areas, confine radioactive contamination, and treat offgases. The systems are designed to maintain airflow from areas of lesser contamination to areas of greater contamination. Electrical power, compressed air, steam, and water are supplied for operations, process control, and safety systems. The sewer systems dispose of both sanitary and chemical (nonradioactive) wastes from PUREX operatons. The plant telephone system, an internal PAX system, a paging system, and emergency alarms provide communications. Fire protection is provided by automatic systems in the plant and by the Hanford Fire Department.

5.4.1 Building Ventilation

The building ventilation systems are used for control of radioactive contamination by maintaining four distinct and selective static pressure zones (Fig. 5-24) and to control ambient temperatures affecting the process and personnel. The systems are designed and pressures are maintained to ensure that the airflow is always from the less or potentially less contaminated zone to the more or potentially more contaminated zone.

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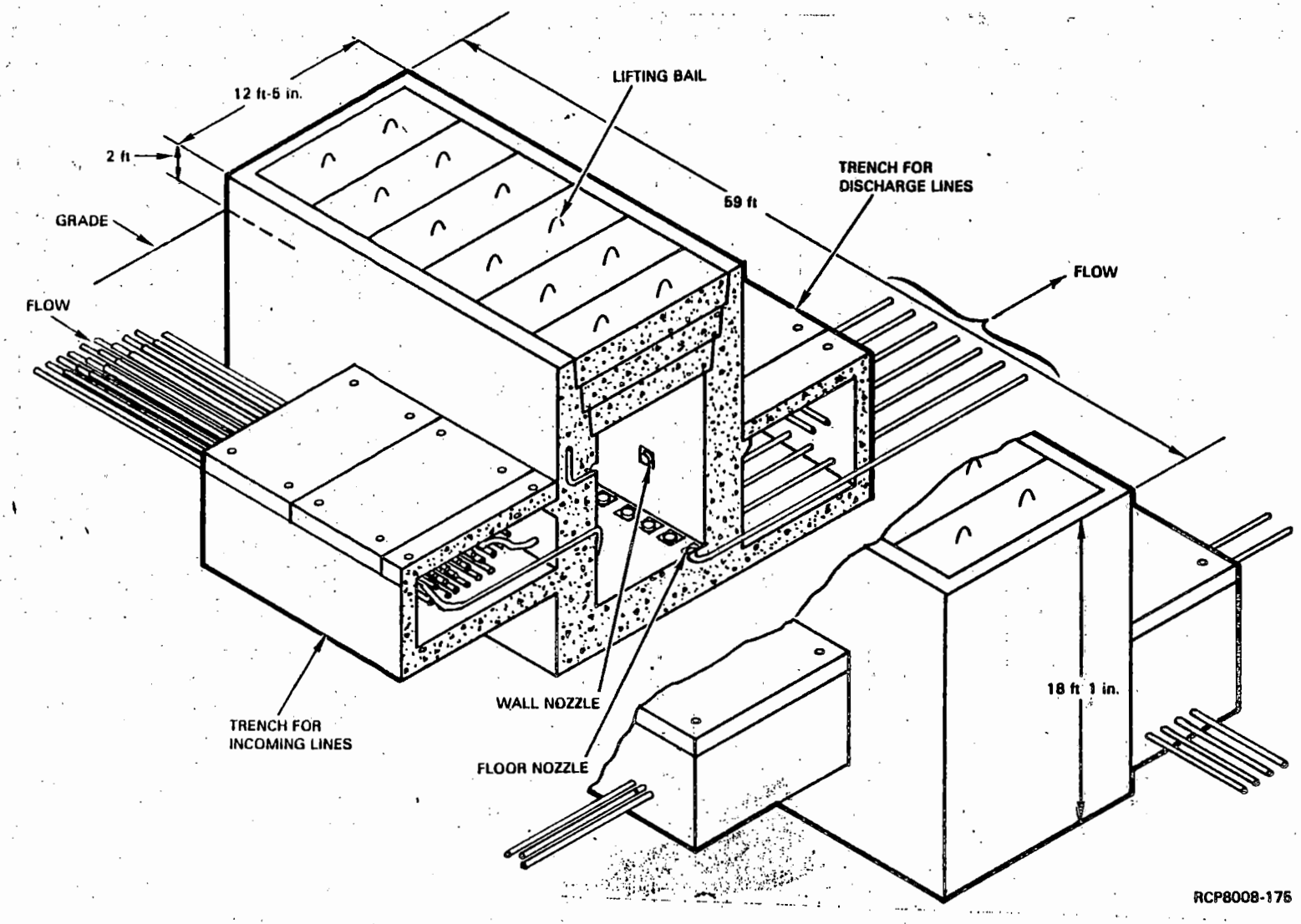

FIGURE 5-22. Typical Diversion Box.

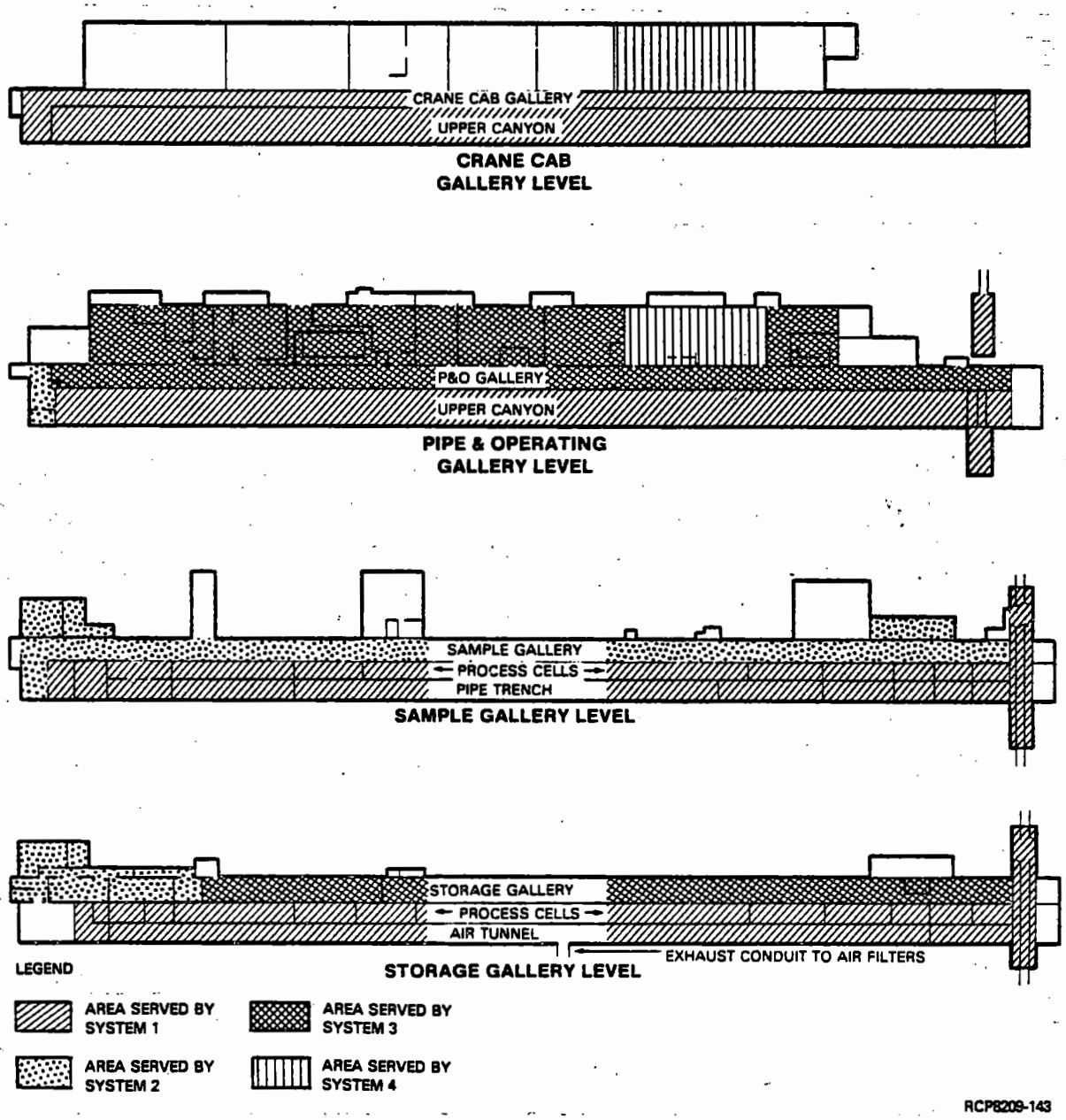

FIGURE 5-23. Areas Served by Ventilation Systems 1, 2, 3, and 4.

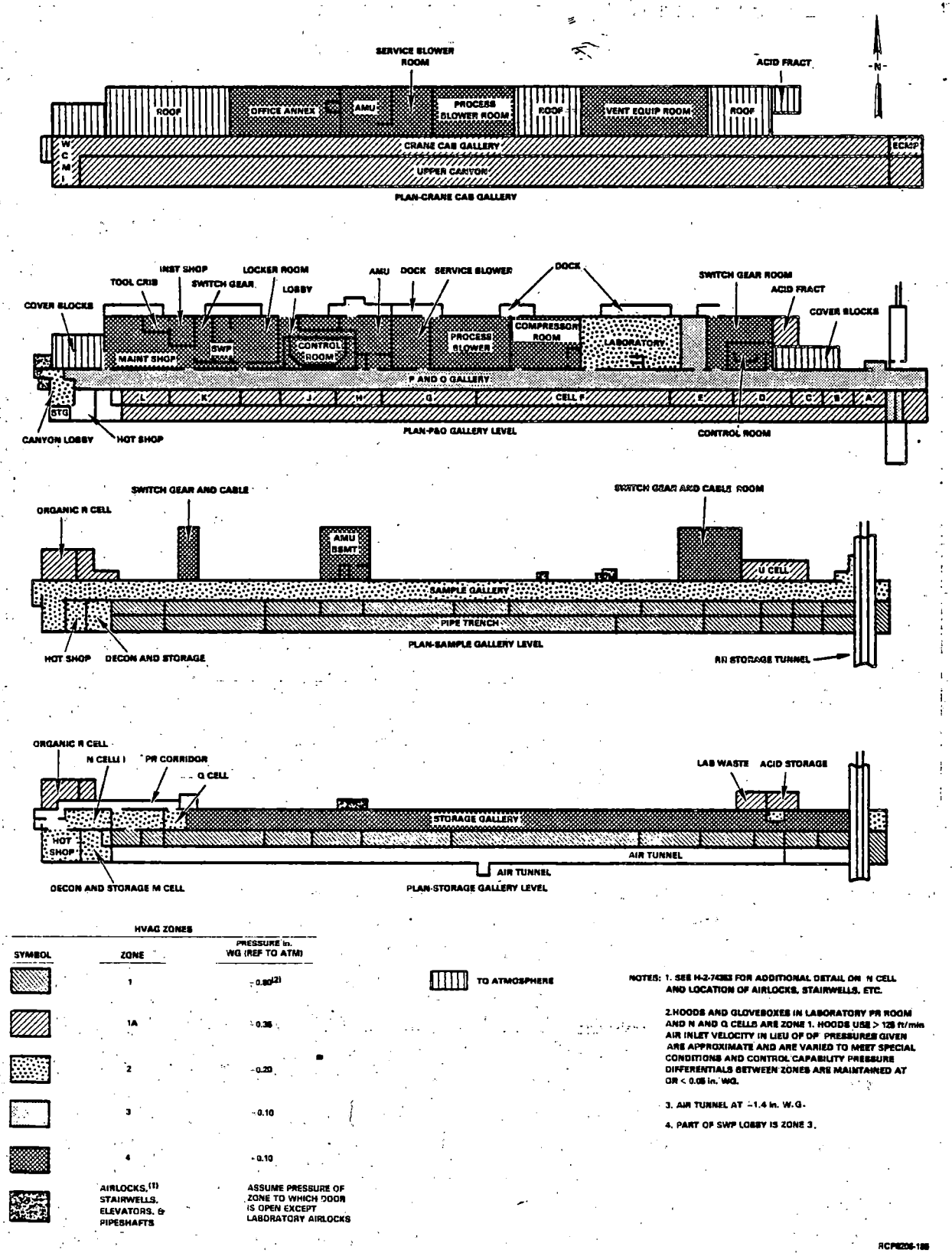

FIGURE 5-24. Plan Views and HVAC Zones of the 202-A Building.

Positive control of contamination is accomplished through the use of airlocks and pressure-monitoring instrumentation. All radioactively contaminated or potentially contaminated* air is filtered to remove radioactive particulates before it is released to the environment.

Safety analyses of the ventilation systems are based on the description presented in this section. Four systems provide ventilation for the 202-A building: system 1, canyon ventilation; system 2, sample gallery ventilation; system 3, service area ventilation; and system 4, laboratory ventilation. See Chapter 7.0 for waste management criteria.

The four ventilation systems supply and exhaust air at 325,000 ft^3/min. Most of the instrumentation and control of the 202-A building ventilation is located in the power control room in the west annex near the process blower room. The ventilation systems are designed to maintain air velocity of at least 125 ft/min through all process area openings to minimize reverse flow of potentially contaminated air. A general cross-sectional view of ventilation system 1 is shown in Figure 5-25. The gallery levels with room locations and HVAC zones are shown in Figure 5-24. The principal points of discharge from the 202-A building are shown in Figure 5-3.

5.4.1.1 Ventilation System 1--Canyon Ventilation. This system serves the canyon and process cells, ECMP area, hot shop, and M cell. Figure 5-26 is a flow diagram of ventilation system 1. A listing of fans and ratings for this system is given in Table 5-4.

5.4.1.1.1 Flow. Two supply fans, SF-1 and SF-1A, deliver air from the outside to the crane cab gallery. The fans are rated at 73,000 ft^3/min each, but are operated in parallel to supply about 126,000 ft^3/min. Before entering the supply fans, the air is filtered, heated (as necessary), washed, and humidified. The fans discharge into a common "inlet duct" from which the air is distributed, via several air grilles, throughout the length of the crane cab gallery. The air flows from the crane cab gallery through the upper canyon, down through the process cells and pipe trench, into the exhaust air tunnel, and through the exhaust filters to the exhaust air plenum. Exhaust Fans EF-1-1, -2, -3, and -4 discharge the exhaust air plenum to the atmosphere through the 291-A-1 stack, which is 7 ft in diameter and 200 ft high.

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*Part of the P&O gallery exhaust, which has a potential for contamination from a suck-back and line rupture, is not routinely filtered. Detection of airborne contamination by two or more CAMs automatically shuts down the unfiltered exhausters, causing the air to be drawn through the filter in the white room exhaust or into the east crane maintenance service areas which are exhausted to the canyon. This concept was adopted based upon a cost benefit analysis that indicated that it was the most effective method to minimize possible airborne radionuclide releases from the P&O Gallery. The overall occupational radiation exposure would not increase significantly as a result of the possible contamination spread during the air rerouting because of the early warning provided by the CAM, the small quantity of radionuclides available for transport, and the highly effective decontamination procedures that would be employed in this area. The storage gallery exhaust is discussed in Section 5.4.1.3.

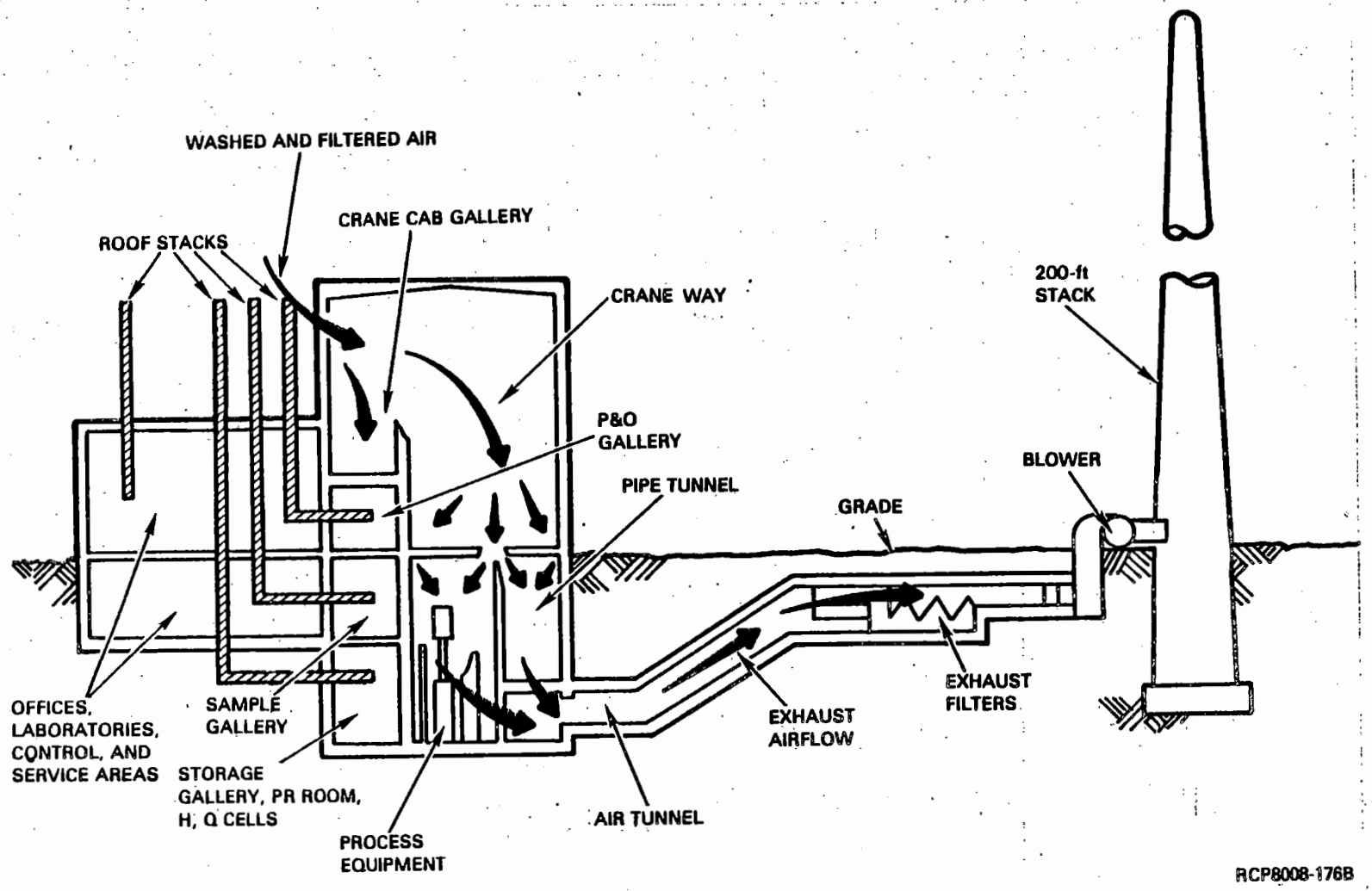

FIGURE 5-25. Cross-Section and Schematic Diagram, Ventilation System 1.

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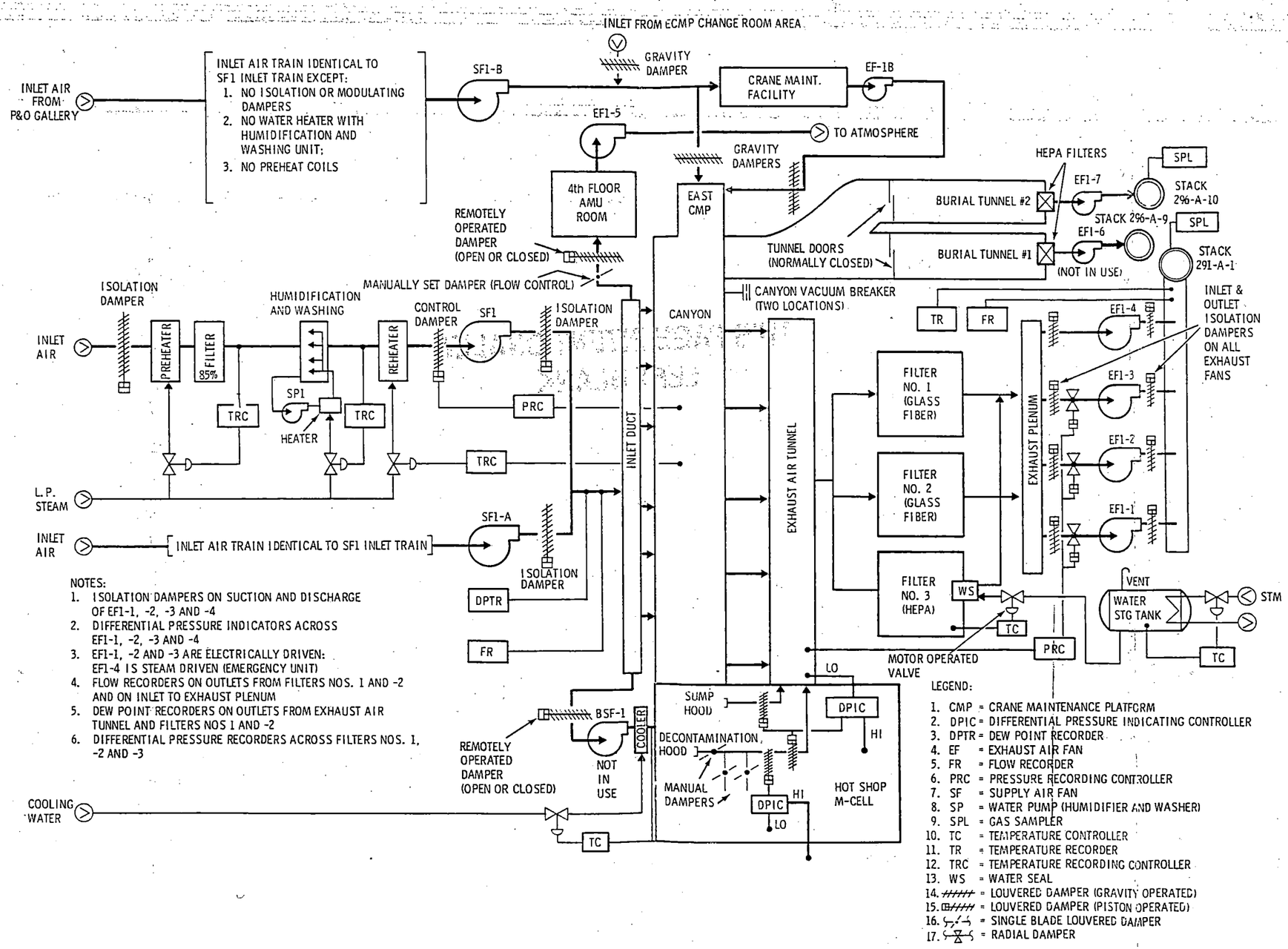

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FIGURE 5-26. Flow Diagram--Ventilation System 1.

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TABLE 5-4. Ventilation System 1 Fans.

Designation	Service	Location		Rating		Drive description
		Fan	Drive control	ft^3/min	TDH[a] (in. WG)	
SF-1	Canyon supply	Process blower room	Power control room Process blower room	73,000 57,750	2.0 4.5	Electrical, 75 hp, 440 V, 01 A, 60 cycle
SF-1-A	Canyon supply	Process blower room	Power control room Process blower room	73,000 57,750	2.0 4.5	Electrical, 75 hp, 440 V, 91 A, 60 cycle
SF-1-B	Crane maintenance facility and ECMP supply	Crane maintenance facility (change room)[b]	Power control room Change room in crane maintenance facility[b]	19,130	2.0	Electrical, 10 hp, 440 V, 60 cycle
BSF-1	Hot shop/M cell supply	Storage room in canyon lobby	Power control room Canyon lobby	6,640	1.0	Electrical, 1,445 rpm fan, 2 hp motor, 1,750 rpm, 3/60/440
EF-1-B	Crane maintenance facility exhaust	Crane maintenance facility (change room)[b]	Power control room	1,000	1.5	Electrical, motor 440 V, 3 phase, 60 cycle
EF-1-1	Canyon exhaust	291-A area[c]	Power control room 291-A area[c]	42,000	15.0	Electrical, 1,150 rpm fan, 200 hp motor, 1,770 rpm, 3/60/2,300
EF-1-2	Canyon exhaust	291-A area[c]	Power control room 291-A area[c]	42,000	15.0	Elecrical, 1,150 rpm fan, 200 hp motor, 1,170 rpm, 3/60/2,300
EF-1-3	Canyon exhaust	291-area[c]	Power control room 291-A area[c]	42,000	15.0	Electrical, 1,150 rpm fan, 200 hp motor, 1,700 rpm, 3/60/2,300
EF-1-4	Canyon exhaust emergency standby	291-area[c]	Automatic emergency controls in 291-A area Manual turn-off in power control room Manual turn-on and off in 291-A area	63,000	9.0	Steam turbine-type BH-1, fan speed, 876 rpm, overspeed trip setting, 4,972 rpm, full load hp @ max load, 156, full load rpm @ max load, 4,386/876, steam/h @ 156 hp, 7,566 lb/h, @ 171 hp - 8,037 lb/h
EF-1-5	4th floor AMU head-tank room	Room above AMU room	Power control room AMU roof	1,385	0.8	Electrical, belt, 1 hp, 440 V, 1,725 rpm motor, 1,775 rpm fan

[a]Total dynamic head.
[b]Crane maintenance facility is addition on east end of PUREX Facility.
[c]219-A is south of PUREX Facility.

Specially designed openings at the peripheries of the process cell cover blocks allow the correct amount of air to flow through each process cell. Small openings at the bottom of the south wall of each process cell, which allow the air to flow from the process cells into the exhaust air tunnel, are designed to restrict airflow through the process cells at those times when the cell covers are removed.

The 73,000-ft^3/min supply of one fan is adequate for canyon ventilation under reduced airflow conditions with all cell blocks installed, and therefore, allows one fan to be down when necessary for required maintenance. Airflow is about 126,000 ft^3/min when the PUREX Plant is operating and about 85,000 ft^3/min when in standby.

Two glass-fiber filter units and one HEPA filter unit, installed in parallel, filter the canyon ventilation exhaust air before it is released to atmosphere (see Fig. 5-26). Each unit was designed to handle the full canyon ventilation airflow. However, solids accumulated on filter 1 (glass-fiber) have reduced its capacity, so that the filter is no longer able to handle the full canyon airflow without excessive pressure drop. The present allowable flow configurations through these units follow:

- Parallel flow through glass-fiber filters 1 and 2
- Single-path flow through glass-fiber filter 2.

Glass-fiber filters 1 and 2 were designed to remove 99% of the radioactive particles from the exhaust ventilation air; recent tests have shown efficiencies greater than 99.95%. The filters are 85 ft long by 52 ft wide by 13 ft deep. In these filters, the air flows sequentially through two glass-fiber filters. The first unit or prefilter consists of a 7-ft-deep bed of "free packed" type 115 K glass-fiber for filter 1 and five separate layers packed with different densities of glass-fiber for filter 2. The second unit or cleanup filter consists of 132 American Air Filter, "Deep-Bed" filter units, each of which is packed with 1/2 in. of AA Fiberglass (1.2 lb/ft^3 density) and 1/2 in. of B Fiberglass (1.4 lb/ft^3), each with a total area of 50 ft^2. The design pressure drop is 2.0 in WG at superficial velocities of 50 ft/min through the prefilters and 20 ft/min through the cleanup filters. There is a bypass channel and provisions for the air ducts to direct the air through either or both filter units. The air flows downward through the prefilter bed in filter 1 and upward in filter 2. Airflow is upward through the cleanup filter cell in both glass-fiber filter units (Fig. 5-27).

During previous operations, a large quantity of ammonium nitrate accumulated on the prefilters of both units. Tests conducted by Hazards Research Corporation (HRC) in the fall of 1978 and spring of 1979, with filter media containing several times the estimated concentrations in the actual prefilters, support the conclusion that this ammonium nitrate is safe under any credible accident conditions.

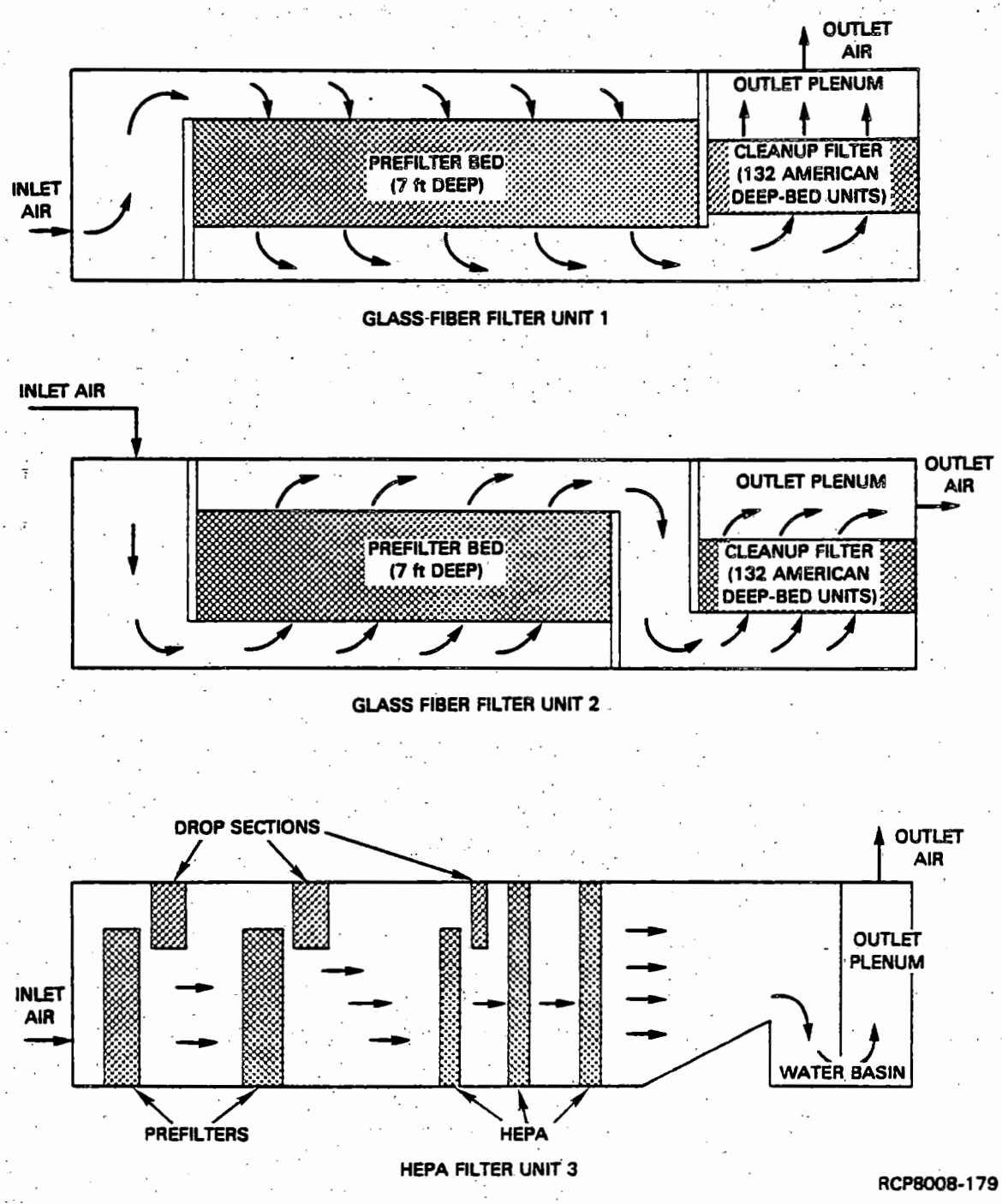

FIGURE 5-27. Ventilation System 1 Exhaust Air Filters.

The significant findings of the HRC study are listed below.[12]

- The ammonium nitrate occluded on the prefilters could not sustain a detonation and would not be capable of thermal runaway reaction even if subjected to high temperatures (170°C, which is the melting point of NH_4NO_3) for extended periods (24 h) in stagnant air.

- Irradiation of the organic (plant solvent condensed in the filter) results in decomposition into lighter, volatile products which diffuse rapidly out of the prefilter beds, further reducing the possibility of reaction.

- Even under high confinement and initiating energy conditions much more severe than are credible in the PUREX prefilters, about 8.7 times the ammonium nitrate estimated in prefilter 1 would be required to sustain a detonation. (A separate system, described in Chapter 7.0, is provided to handle ammonia-containing gases in the future).

- The prefilter matrix will not detonate, even with shock loadings orders of magnitude greater than could be attained mechanically as a result of a solvent fire.

- Pressures of about 3 kg/cm^2 and temperatures of about 240°C are required for a thermal explosion of ammonium nitrate sensitized with wax (hydrocarbon) or chloride. These conditions are not credible in the PUREX filters.

- Sustained sudden impingement of very high temperature vapor/air or flames would only melt and decompose the ammonium nitrate even at concentrations 7.5 times the estimated value.

- Although the filter media directly exposed to an acetylene/air torch flame (10 min) was embrittled, the properties of the remaining filter media were essentially unaffected.

Exhaust filter 3 (HEPA), currently in standby, is designed to remove greater than 99.97% of the radioactive particles from the exhaust ventilation air. The facility is about 50 ft long by 20 ft wide by 16 ft deep. In this facility, the air flows sequentially through five vertical filter stages: the first two are prefilters and the last three are HEPA filters (see Fig. 5-27). The first three stages can be bypassed by lowering the upper two rows of filters.

Filter 3 (HEPA) is used as emergency backup only. The required number of HEPA filter elements is available in the PUREX storage gallery. However, these elements will not be installed in the frames until the filter is placed in service. The exhaust air filters are located just south of the east end of the PUREX Building in the 291-A area. Filter 3 is currently on standby.

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A horizontal, 10,000-gal water-storage tank is located just south of the east end of the PUREX Building in the 291-A area. Water is maintained in this tank for filling the water seal basin in canyon exhaust air filter 3 (HEPA). The water is automatically released to the water seal basin whenever a high temperature is detected within filter 3 (HEPA), indicating a possible fire. The water can also be released manually, using controls located nearby in the 291-A area. To make sure that freezing will not prevent the system from working in the winter, a steam coil within the tank is set to automatically maintain a minimum tank-contents temperature of 35°F, and the transfer line from the tank to the water seal basin is steam-traced.

A pump will be used to remove the water when it becomes necessary. Installation of the pump and removal of the water will be done in accordance with approved procedures, which will include provisions for disposing of the water.

Four exhaust fans installed in parallel are located near the base of the 291-A-1 stack. The exhaust load is normally 126,000 ft^3/min carried by the three electrically driven fans, EF-1-1, -2 and -3, each rated at 42,000 ft^3/min at 15 in. WG. These fans are backed up by an automatic, emergency steam turbine-driven fan, EF-1-4, which can maintain an adequately safe, minimum canyon exhaust flow rate of 63,000 ft^3/min at 9 in. WG.

The main ventilation stack is 200 ft tall, rising 140 ft above the roof level of the 202-A Building. The stack is constructed of reinforced concrete and contains a 7-ft-diameter, stainless steel liner through which the filtered exhaust air is discharged to the environment at a velocity of about 3,300 ft/min. The annulus between stack and liner is capped at the top. The bottom of the liner has a dished head that drains to a collection tank. The inlet breaching for the ventilation air is baffled and welded to the liner at an upward angle of 45 degrees. Six 8-in. nozzles enter the liner below the ventilation air breaching: three are for routing DOG to the stack, and the other three are spares.

The booster pump and wash system to spray the stack are located in the sample house. There are spray rings at the 50-, 100-, 150-, and 200-ft elevations. The stack is flushed periodically under conditions of (1) less than 15 mi/h wind velocity, (2) no dissolving activity, (3) all cover blocks in place in the canyon, and (4) stack flow rates throttled to the minimum flow rate attainable with no supply fans on and only one electrical exhaust fan on. The stack is flushed with a 10-min, 20-gal/min spray at the 150-, 100-, and 50-ft levels (the use of the 200-ft elevation is optional). The flushing liquid drains to a collection tank. The spray system, drain line, and collection tank are stainless steel.

Effluent sampling, monitoring, and flow measuring/totalizing capability for the 291-A-1 primary exhaust stack is described in Section 8.6.1.1.1. The operating characteristics for this subsystem are given in Table 5-5.

TABLE 5-5. Typical Operating Characteristics for Canyon and Process Cells Ventilation (approximate values).

Characteristics	Production mode[a]	Standby mode[b]
Normal canyon airflow range (ft^3/min)	110,000 to 136,000	85,000 to 95,000
Normal airflow through process cells, cover blocks in place (ft^3/min)	1,600 to 14,000	1,000 to 7,300
Airflow through open process cells, cover blocks removed (ft^3/min)	40,000	30,000
Emergency condition canyon airflow (EF1-4 capacity) (ft^3/min)	63,000	63,000
Upper canyon vacuum range (in. WG)	0.2 to 0.45	0.2 to 0.45
Exhaust air tunnel vacuum range (in. WG)[c]	1.0 to 1.7	1.0 to 1.7
Upper canyon temperatures (°F)	68	68

[a]PUREX process operating; two canyon air supply fans and three electric exhaust fans operating.

[b]PUREX process not operating; all process material removed from the process equipment and one canyon air supply and two exhaust fans operating.

[c]The openings between the cell and wind tunnel restrict the airflow values shown whenever three or more cover blocks are removed.

- East Crane Maintenance Platform and Service Area Ventilation. Supply fan SF-1B delivers air via separate air ducts to the crane maintenance service area and the ECMP. About 11,000 ft^3/min of air is cascaded from the east end of the P&O gallery into supply fan SF-1B. Before entering the supply fan, the air is filtered and heated (as necessary).

  The ECMP is normally open to the PUREX upper canyon. Ventilation air enters the platform through a gravity damper and flows continuously into the upper canyon. In the upper canyon, the air joins with the primary canyon ventilation air. The combined air stream is ultimately filtered and released to the atmosphere through the 291-A-1 stack. Most of the air delivered by supply fan SF-1B (10,000 ft^3/min) flows through this platform area.

  The balance of supply fan SF-1B output flows to the equipment rooms, the change room, and the locker room. Exhaust fan EF-1B exhausts the change room, locker room, lavatory, and decontamination area to the ECMP via exhaust grills and ductwork. Each area can be manually isolated from the exhaust via manual dampers at the exhaust location. Fan EF-1B can be operated from the power control room or locally in the east change room. Fan EF-1B is electrically interlocked to assure the exhaust fan does not operate unless supply fan SF-1B is operating. Air may infiltrate into the canyon from the equipment rooms and the switchgear room, located adjacent to the locker room and change room.

  The airflow will be toward the canyon, since it is kept at a lower pressure. The doors to the equipment rooms and switchgear room are normally closed and Radiation Monitoring is notified prior to opening the doors. The decontamination hood is radiation zone I, the upstairs area is zone IA, the equipment rooms and switchgear rooms are zone II, and the remaining areas are zone III.

  The normal operating conditions for this subsystem follow:

Characteristic	
Normal air supply	15,000 ft^3/min
Maintenance facility airflow	4,000 ft^3/min
ECMP airflow	11,000 ft^3/min
Maintenance facility pressure, slight positive	0.05 to 0.10 in. WG
ECMP vacuum	0.20 to 0.45 in. WG
Inlet-air temperature	70°F

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- Hot Shop and M Cell Ventilation

The hot shop and M cell, located at the west end of PUREX on the storage gallery level, are used for the decontamination and maintenance of radioactively contaminated equipment. Consequently, there is a high potential for airborne radioactive contamination.

Booster fan BSF-1 delivers air from the canyon inlet duct through a water cooler to the hot shop and M cell. The air flows from the hot shop and M cell through decontamination and sump hoods to the exhaust air tunnel, where it combines with the canyon exhaust air. The filtered air is then released through the 291-A-1 stack. The normal operating conditions for this subsystem follow.

Characteristic	
Normal airflow	6,300 ft^3/min
Hot shop/M cell vacuum	0.25 in. WG
Pressure difference, hot shop/ M cell to exhaust air tunnel	1.25 normal in. WG 0.25 minimum in. WG
Inlet-air temperature	70°F

- AMU Ventilation

The fourth floor AMU room houses TK-324, which is used for feeding nonradioactive chemicals to the PUREX process by gravity. The room ventilation air is supplied from the inlet duct and is discharged unfiltered by exhaust fan EF-1-5, to the environment. The normal operating conditions for this system follow.

Characteristic	
Normal airflow	1,300 ft^3/min
Room pressure, vacuum	0.10 in. WG
Inlet-air temperature	68°F

- Burial Tunnel Ventilation

Two railroad (burial) tunnels, extending in a southerly direction from the east end of the PUREX Plant, are used for long-term storage of bulky and highly radioactive PUREX solid waste, such as failed processing equipment. The entrances to these tunnels

are closed to avoid interaction with the canyon ventilation system, except when access is required. Whenever the tunnel entrances are open, the horizontal canyon door must be closed. Burial tunnel 1 is inactive and filled with solid waste so that access will not be required. Some storage space is still available in tunnel 2, necessitating infrequent access to this tunnel. Both the exhaust fan and the HEPA filter for tunnel 1 are blanked off. In addition, the door is sealed with caulking so that the air in tunnel 1 is stagnant. When tunnel 2 doors are closed, exhaust fan EF-1-7 maintains a slight vacuum in the tunnel and discharges HEPA-filtered air to the atmosphere. When the doors are open, EF-1-7 maintains inward airflow through the open door.

- Process Offgas

  The process offgas systems (except for DOG and ammonia offgas systems) discharge to the air tunnel and are handled in ventilation system 1. The DOG are routed through separate filters and an acid recovery facility (see Section 7.4.2.), and discharged to the 291-A-1 stack. The ammonia offgas is discharged through separate filters and through a separate stack, 296-A-24 (see Section 7.4.3.).

5.4.1.1.2 Ventilation System 1 Control Objectives. Ventilation system 1 prevents escape of airborne radioactivity and controls ventilation by automatically maintaining preestablished, slightly negative pressures in the upper canyon and the exhaust air tunnel. The exhaust air tunnel pressure is set lower than the upper canyon pressure so that airflow will always be toward the exhaust. The difference between these two pressures is selected to assure that the air flowing through the system is adequate. Under steady-state operation, the supply and exhaust airflow rates are not equal. There is some difference in flow rate caused by air in-leakage, withdrawal of some ventilation air for the fourth floor AMU room, and introduction of exhaust ventilation air from the crane maintenance facility.

When operating normally, ventilation system 1 instrumentation and air-control devices automatically maintain the ventilation airflow, temperature, pressure levels, and humidity in the PUREX process areas without allowing release or escape of airborne radioactivity. The mechanisms through which the power operators establish the system operating conditions and the start/stop devices for the operating equipment (e.g., fans) are located either on a graphic panel board in the power control room or in local panel boards conveniently located in the PUREX Facility. In addition, selected system operating conditions are displayed and out-of-normal operating range alarms are mounted in these panel boards to assist the power operators in monitoring and maintaining proper system operation.

Normally, all process cell cover blocks will be in place and all canyon doors that can affect airflow will be closed (i.e., the canyon horizontal door though which irradiated fuel elements enter the canyon and the burial tunnel doors).

Some operations require removal of cover blocks from the process cells and/or opening of canyon doors (e.g., cell maintenance or irradiated fuel element charging operations). The outside, vertical door in the railroad tunnel and the overhead door between the tunnel and the canyon are never open at the same time; however, the system airflow pattern might be disturbed. Power operators will be forewarned of such activities, so that the system operating conditions can be modified to maintain ventilation and radioactive contamination control.

Whenever more than three cell cover blocks are removed from position, the airflow pattern will change. Special precautions are defined in the appropriate operating procedures to assure airborne contamination control.

Since the PUREX canyon is maintained at a lower pressure than its environs, airflow will be toward the canyon. However, should the canyon vacuum be lost, for any reason, a gravity damper will close, preventing release of contaminated canyon air through the maintenance platform area.

To prevent a high vacuum from overstressing the canyon roof, two vacuum breakers are installed in stairwells to the canyon. The vacuum breakers are located on the north and south sides of the canyon on the eastern portion of the building. One breaker is mounted inside the canyon proper on the north wall just west of the ECMP. The other is mounted on the south wall of the canyon proper across from C cell.

Should supply fan SF-1B stop operating, another gravity damper will open, allowing untreated air to enter the system, so that ventilation of the maintenance platform can continue until the supply fan is operating again.

The hot shop and M cell are automatically maintained at a somewhat higher pressure than the exhaust air tunnel, so that airflow will always be toward the tunnel. The pressure in the hot shop and M cell is somewhat lower than atmospheric so that any air leakage will always be from the atmosphere into the hot shop and M cell.

Two dampers control airflow through the inlet air duct to the fourth floor AMU room. One damper, a remotely operated, pneumatic unit, is either open or closed. The other damper is a manual unit set to allow the amount of airflow that maintains a very slight vacuum in the fourth floor AMU room.

5.4.1.1.3 Ventilation System 1 Control. Inlet air treatment for ventilation system 1 consists of the following:

- Filtering for dust removal
- Heating for temperature control
- Washing and humidifying for control of ventilation air moisture content and for additional dust removal.

Temperature controllers and steam valves control heat and moisture added to the ventilation supply air during the winter months. During the summer months when no heating is required, the supply air is evaporatively cooled by the water-spray washer.

The minimum ambient humidity and temperature within the process cells are automatically maintained at values desirable for process operations. The air flowing through each process cell removes the heat from the process equipment so that cell temperatures do not become too high; descriptions of ventilation control follow.

- Canyon and Process Cell Ventilation Control

  Direction of airflow is maintained by static pressure control. Design static pressures in equivalent inches of water are -0.35 canyon, -0.8 cells, and -1.4 air tunnel. The canyon deck static pressure controller on the graphic power panel controls the inlet-modulating dampers on supply fans SF-1 and SF-1A. This controller modulates the inlet dampers to hold a design static pressure in the upper canyon.

  The exhaust air tunnel pressure is kept slightly lower than the canyon pressure, so that the ventilation air will flow from the crane cab gallery toward the exhaust air tunnel. This pressure is maintained by control dampers located at the inlets of exhaust fans EF-1-1, -2, -3. Under normal operations, the openings of these dampers automatically change whenever the atmospheric and exhaust air tunnel pressures differ from the setpoints.

  Exhaust fan EF-1-4 automatically starts whenever there is an unplanned shutdown or failure of an exhaust fan (EF-1-1, -2, or -3). The capacity of EF-1-4 is about one-half of the normal ventilation system 1 airflow. Therefore, the inlet to EF-1-4 does not have a control damper, nor is the exhaust air tunnel pressure automatically controlled (by instrumentation) whenever only EF-1-4 is operating.

  Should both supply fans (SF-1 and SF-1A) stop operating, all dampers (isolation and control) in the air supply train automatically open so that the exhaust air fans can continue to draw air through the PUREX canyon.

  Ventilation system 1 has been designed to provide sufficient flow of air through each process cell to assure contamination control under normal operating conditions. With all cover blocks in place, engineered openings in the cover block seating gaskets provide the correct flow of air. With three or more cover blocks removed, the openings between the cells and the wind tunnel restrict the airflow to prevent "starving" of the closed cells for air.

- ECMP and Service Area Ventilation Control

  - The exhaust air fan (EF-1B) and the supply air fan (SF-1B) are interlocked so that the exhaust fan cannot operate unless the supply fan is operating.

  - Gravity dampers in the ECMP inlet air ducts are weighted to allow, under normal pressure differences, the correct amount of airflow to the platform, but to prevent backflow to the service area when the pressure difference is not adequate.

- Hot Shop/M Cell Ventilation Control

  Ventilation air leaves the hot shop and M cell through the decontamination and sump hoods and flows through two ducts to the exhaust air tunnel. Ventilation air also flows into parallel exhaust openings into the ductwork directly. Dampers in each of the hood exhaust ducts are in the open position whenever the hot shop and M cell pressure exceeds the exhaust air tunnel pressure by 0.25 in. WG. Whenever this pressure difference drops to this value, these dampers automatically close and the booster supply fan (BSF-1) stops operating. Whenever this pressure difference increases beyond this value again, the dampers automatically reopen, but the booster fan must be restarted manually.

  Another damper, located in the decontamination hood exhaust air duct, automatically maintains a hot shop and M cell pressure which is slightly lower than that of its surrounding atmosphere (i.e., about 0.25-in.-WG vacuum).

- Fourth Floor AMU Room Ventilation Control

  This room is ventilated from the canyon inlet air duct. Since there is no external contamination in the room, ventilation air from this room is exhausted directly to the atmosphere by a small roof-mounted fan (EF-1-5). The air entering the room passes through two dampers. One is manually set and locked in a position which allows the appropriate airflow. The other, a remotely operated damper, is interlocked to open automatically whenever the exhaust fan (EF-1-5) is operating and to close when it is not operating. The damper is also interlocked to close when the canyon supply fans (SF-1 and -1A) are not operating. This damper can also be opened by manual override switches whenever the exhaust fan (EF-1-5) is not operating, should it become desirable to do so.

5.4.1.1.4 Ventilation System 1 Interlocks. The system is instrumented to maintain control of radioactive contamination and a minimum ventilation airflow rate if abnormal events or upsets should occur. For example, should electric power fail, the steam-driven exhaust fan (EF1-4) will start automatically and the dampers in the inlet-air supply duct lines will remain open, allowing the system to continue operating at about one-half capacity.

Should the instrument air system fail, the supply fans (SF-1 and SF-1A) will stop operating, the dampers in the inlet air ducts will remain open, the isolation dampers will close on the electric exhaust fans, and the turbine will come on to maintain canyon ventilation. Should a fire occur or be suspected in the HEPA exhaust air filter 3, water will automatically flow into the water-seal basin on the HEPA outlet. If only filter 3 is in service, the ventilation supply fans will stop operating, shutting off the ventilation exhaust fans, and avoiding pressurization of the PUREX Canyon.

Operating equipment, control devices, and system instrumentation are interlocked (mechanically and/or electrically) to permit only those automatic operating modes that provide effective ventilation and prevent escape or release of ventilation air contaminated with airborne radioactivity. These interlocks are functionally described as follows.

- If neither supply fan (SF-I or SF-1A) is operating:
  - The isolation dampers for both fans will be open 1
  - Steam will flow to the preheat coils
  - The remotely operated inlet damper to the fourth floor AMU room will be closed
  - The remotely operated damper to the hot shop and M cell will be fully open
  - The supply fans will not start unless there is a minimum vacuum in the canyon of about 0.30 in. WG; therefore, the exhaust fans must be operating before the supply fans can start
  - The control (intake) dampers to the supply fans must be operating in response to signals from the canyon pressure controller.
- If one supply fan (SF-I or SF-1A) is operating:
  - The isolation dampers of the nonoperating fan will be closed to prevent the operating fan from discharging to the atmosphere through the nonoperating supply fan. It should be noted that this is the only time that the supply fan isolation dampers close. They are open at all other times
  - The remotely operated inlet damper to the fourth floor AMU room will be closed
  - The remotely operated inlet damper to the hot shop and M cell will be fully open.
- If both supply fans (SF-1 and SF-1A) are operating:
  - The isolation dampers for both supply fans will be open

- The control (intake) dampers of each supply fan will be operating to automatically maintain the canyon pressure within 0.02 in. WG of its set value, about 0.35 in. WG vacuum

- The remotely operated inlet damper to the fourth floor AMU room will be open

- The remotely operated inlet damper to the hot shop and M cell will be at its minimum opening

- The preheaters and reheaters will be operating: the preheater will maintain a minimum temperature of 45°F ± 2°F at its outlet; the reheater is set to maintain 68°F ± 2°F within the canyon.

- If only the electrically driven exhaust fans are operating:

  - The isolation dampers (suction and discharge) on each electrically driven fan will be open

  - The isolation dampers (suction and discharge) on the steam-driven unit will be closed

  - The control dampers in the suction of each electrically driven unit will be operating to automatically maintain the exhaust air tunnel pressure at about 1.0-in.-WG vacuum in standby mode, and about 1.4-in.-WG vacuum in production mode

  - The steam-driven unit can be manually placed in service to maintain ventilation capacity whenever an electrically driven unit must be removed from operation (e.g., maintenance)

  - The differential pressure (DP), dew point, and flow instrumentation will be operating

  - The 291-A-1 stack radioactivity monitor will be operating to detect any unusual radioactivity releases

  - The HEPA filter water-seal basin will be filled with water or the water-storage tank will be filled with water and in a state of readiness for flooding of the HEPA filter water-seal basin.

- If only the steam-driven exhaust fan is operating:

  - The isolation dampers in the steam-driven fan will be open

  - The isolation dampers in the electrically driven fans will be closed

  - Since there is no control damper in the suction line to the steam-driven fan, it will operate at full capacity, about 63,000 ft^3/min

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- The exhaust system DP, dew point, flow, and 291-A-1 stack monitoring instrumentation will be operating

- The HEPA filter water-seal basin and the water-storage tank for flooding will be in the same stage of readiness as when the electrically driven fans are operating.

5.4.1.1.5 Abnormal Event or Upset Condition Operation.

- Electrical Power Failure

  - In the event of a total electrical power failure at PUREX, the steam-driven exhaust fan (EF-1-4) will start up automatically and all electrically driven equipment will stop. The latter includes the supply air fans (SF-1, -1A, and -1B), the electrically driven exhaust fans (EF-1-1, -2, and -3), the fourth floor AMU room exhaust fan (EF-1-5), the crane maintenance facility exhaust fan (EF-1B), and the booster fan (BSF-1) for the hot shop and M cell

  - The status of the supply air equipment will be the same as when neither supply air fan (SF-1 or SF-1A) is operating, except that the spray-water pump will not operate. The control dampers (intake) to the supply fans will continue to operate as long as instrument air is available. When instrument air is no longer available, these dampers will fail in the open position

  - The status of the exhaust air equipment will be the same as when only the steam-driven fan is operating

  - It is remotely possible for the electrical fans and the steam-driven exhaust (steam turbine) fan to be out of service at the same time resulting from two or more independent failures. In this event, process operations would cease. The canyon would remain at, or slightly below, atmospheric pressure as a result of natural draft through the 291-A-1 stack.

- Instrument Air Failure

  - Should the instrument air pressure fail, the steam-driven exhaust fan will start up and the electrically driven fans (supply and exhaust) will stop operating

  - The status of both the supply and exhaust air equipment will become the same as if an electrical power failure had occurred.

- High Pressure in the PUREX Canyon

  - If the canyon pressure rises to an unsafe level, the supply air fans (SF-1 and -1A) will stop operating and the supply air equipment status will become the same as the "no supply-fan operating" status. This occurs when the canyon pressure rises to 0.05 in. WG vacuum and remains at this value or higher for at least 10 s.

5.4.1.2 Ventilation System 2. This system serves the sample gallery, Q cell, PR room, neptunium loadout room, PR corridor, N cell, canyon lobby, R cell, and U cell. Figure 5-28 is a flow diagram of ventilation system 2. Table 5-6 describes the fans and characteristics for this system. This system serves essentially all zone 2* areas; therefore, all exhaust air from this system passes through at least one stage of HEPA filtration to remove airborne radioactive particles before the air is released.

All HEPA filters used at the PUREX Plant are efficiency-tested in place at least once a year. The decision to change out a filter can be based on low particle retention as measured by the efficiency test. Evidence of activity breakthrough is measured by high activity in downstream samples or by a low DP reading and is cause for a filter change-out. High DP readings across HEPA filters are also cause for change-out.

5.4.1.2.1 Flow. There are two ventilation system 2 air supply fans (SF2 and SF2-A) in the process blower room. The capacity of each fan (38,000 ft^3/min) is large enough to satisfy the total system air requirement. Normally, one unit operates while the other is maintained in readiness, should the operating unit stop. The inlet air is filtered and washed to remove airborne dust that would otherwise deposit on the HEPA exhaust filters and thereby increase the replacement frequency. Steam preheaters, located between the inlet air filters and water-spray washers, make sure that the air entering the washers (in the winter) is warm enough (45°F $\pm$ 2°F) to avoid freezing the water in the washers. There are inlet and outlet louver dampers on each supply fan unit. Those on the idle unit are closed to prevent the operating supply fan from discharging to the atmosphere through the idle unit. Radial dampers at the inlet of each supply fan are manually set to establish the system air throughout.

The outlet air from the operating supply fan flows through four parallel ventilation branches. The airflow rate through each branch is established by manually setting louver and/or diversion dampers in the air ducts leading to each branch.

*The contamination control zones are defined in Section 4.3.2.2.

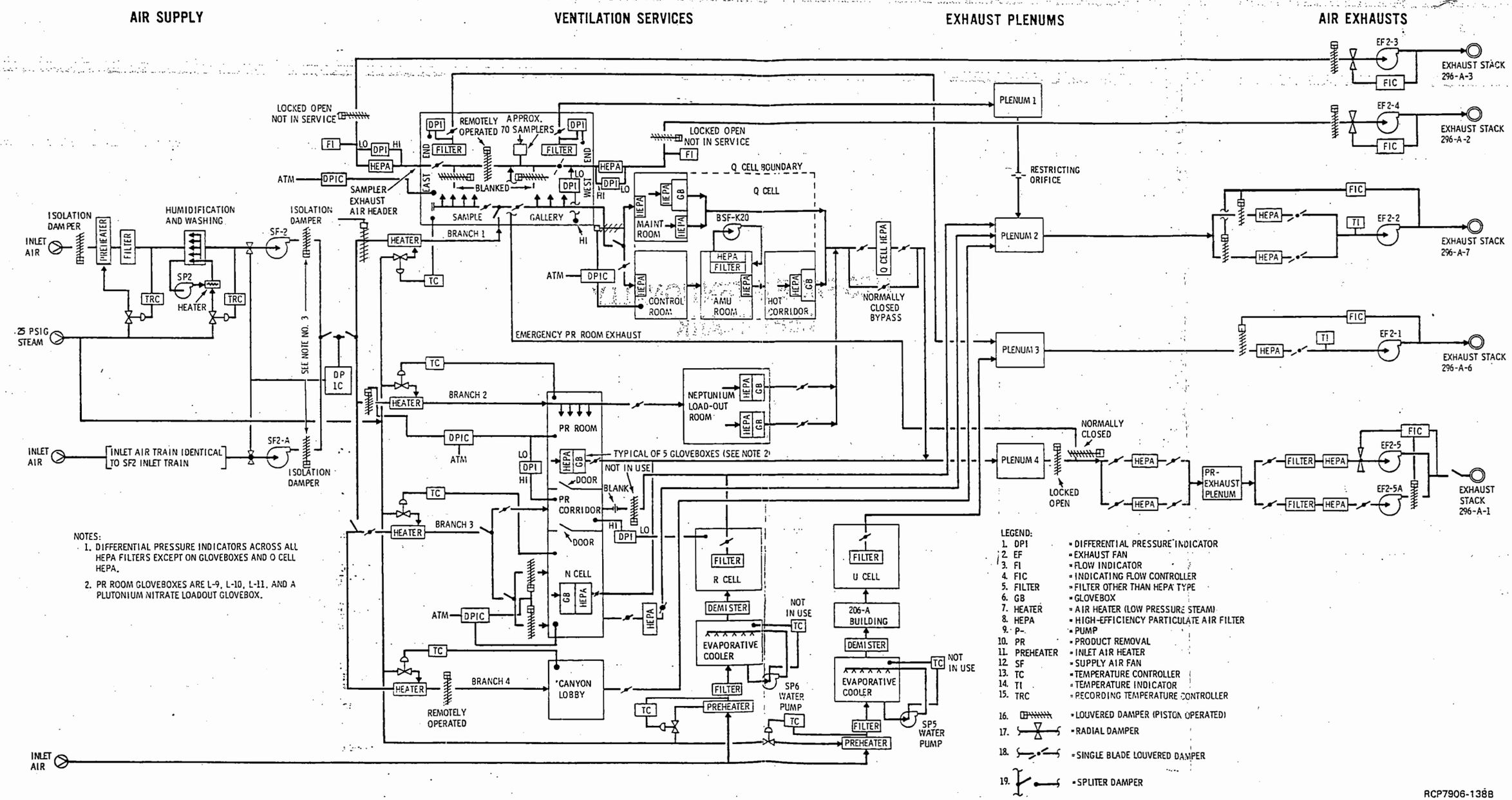

FIGURE 5-28. Flow Diagram--Ventilation System 2.

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TABLE 5-6. Ventilation System 2 Fans.

Designation	Service	CVI Drawing	Location		Rating		Drive description
			Fan	Drive control	ft^3/min	TDH[a] / rpm[b]	
SF-2	Ventilation system 2 supply	8302 / H-2-52416	Process blower room	Power control room, process blower room	38,365	3.5 / 734	Electrical, 40 hp, 440 V, 49 A, 60 cycle, 1,750 rpm
SF-2-A	Ventilation system 2 supply	8302 / H-2-52416	Process blower room	Power control room, process blower room	38,365	3.5 / 734	Electrical, 40 hp, 440 V, 40 A, 60 cycle, 1,750 rpm
EF-2-1	Plenum 3 exhaust (east sample gallery and U Cell)	8302 / H-2-64905	Northeast of PUREX building (outside)	Power control room, outside near EF-2-1	19,130	2.0 / 665	Electrical belt, 30 hp, 440 V, 35.6 A, 60 cycles, 1,750 rpm
EF-2-2	Plenum 2 exhaust (west sample gallery, N cell, canyon lobby, and R cell	8302 / H-2-64905	West of PUREX building (outside)	Power control room, outside near EF-2-2	27,625	2.0 / 645	Electrical, 50 hp, 440 V, 58 A, 60 cycle, 1,745 rpm
EF-2-3[c]	Sampler exhaust header (east sample gallery hoods)	8302 / H-2-52416	Northwest of PUREX building (outside)	Power control room, outside near EF-2-3	4,600	6.0 / 2,432	Electrical, belt, 7 1/2 hp, 440 V, 10 A, 60 cycle, 1,730 rpm
EF-2-4[c]	Sampler exhaust header (west sample gallery hoods)	8302 / H-2-52416	Southwest of PUREX building (outside)	Power control room, outside near EF-2-4	4,600	6.0 / 2,432	Electrical, belt, 7 1/2 hp, 440 V, 19 A, 60 cycle, 1,730 rpm
EF-2-5[c]	Plenum 4 exhaust (PR room, neptunium load-out room, and Q cell)	17064 / H-2-52416	On R cell roof (outside)	Power control room, outside near EF-2-5	7,600	14.0 / 1,485	Electrical, 15 hp, 440 V, 60 cycle, 1,800 rpm
EF-2-5A[c]	Plenum 4 exhaust (PR room, neptunium load-out room, and Q cell)	8302 / H-2-52416	On R cell roof (outside)	Power control room, outside near EF-2-5A	6,080	6.0 / 2,385	Electrical, 10 hp, 440 V, 60 cycle, 3,450 rpm
BSF-K20	Recirculate Q cell air	H-2-59555	Above Q cell control room	In PIV room, near BSF-K20	30		

[a]Total dynamic head, inches of water.
[b]Revolutions per minute.
[c]On backup (emergency) power bus.

Human comfort temperatures are automatically maintained in the ventilated areas by steam heaters in the ventilation branch inlet air ducts. The PUREX work areas ventilated by each ventilation system 2 branch follow:

- Branch 1 (sample gallery and Q cell)
- Branch 2 (PR Room and neptunium load-out room)
- Branch 3 (PR corridor and N cell)
- Branch 4 (canyon lobby).

With the exception of some air that discharges through the process sampler hoods located in the sample gallery, ventilation system 2 exhaust air flows sequentially through exhaust air plenums, HEPA filters, and exhaust air fans. This air is released to the atmosphere above the PUREX building roof through several discharge stacks attached to the sides of the building. There are four exhaust plenums; descriptions follow.

- Plenum 1 receives exhaust air from the west end of the sample gallery and Q cell vessel vent system.
- Plenum 2 receives exhaust air from plenum 1, R cell, N cell, and the canyon lobby. The PR corridor also discharges into this plenum. A restricting orifice limits airflow from plenum 1 to plenum 2.
- Plenum 3 receives exhaust air from the east end of the sample gallery and U cell.
- Plenum 4 receives exhaust air from Q cell, the neptunium load-out room, the PR room, gloveboxes and load-out hood, and the N cell gloveboxes.

Exhaust fan EF-2-2 draws air from plenum 2 through two parallel HEPA filters and discharges to the atmosphere through the 296-A-7 stack. Exhaust fan EF-2-1 draws from plenum 3 through a HEPA filter and discharges through the 296-A-6 stack. The airflow rates of these streams are automatically maintained by louvered dampers located downstream of the HEPA filters. Indicating flow controllers automatically change these damper openings whenever the airflow rates, which are measured downstream of the exhaust air fans, vary from the controller setpoints.

One of two exhaust fans (EF-2-5 or -5A) discharges plenum 4 air to the atmosphere through the 296-A-1 stack. The capacity of each fan is large enough to satisfy plenum 4 exhaust air requirements. Because of the nature and degree of contamination of the plenum 4 exhaust air, it passes in series through two HEPA filters that are upstream of the exhaust air fans. There are two parallel HEPA filtration branches with enough isolation dampers to permit filter changing without interrupting airflow. However, the two parallel, second-stage HEPA filters are paired with the exhaust fans. To replace

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a second-stage HEPA filter without interrupting airflow, it is necessary to operate with the alternate exhaust fan (EF-2-5 or -5A) as well as with the alternate second-stage filter. There are non-HEPA-type prefilters upstream of each second-stage HEPA. The nonoperating exhaust fan (EF-2-5 or -5A) will start automatically whenever plenum 4 vacuum becomes inadequate (at about 3.0-in.-WG vacuum). Standby emergency electrical power is supplied to exhaust fans EF-2-5 and -5A. Low vacuum in plenum 4 will cause fan EF-2-5A to operate on standby electrical power whenever normal electrical power is not available. Exhaust fan EF-2-5 may be manually switched to standby power if necessary.

Stack 296-A-1 is monitored with an alpha monitor placed above a fixed filter in a sample head through which a sidestream is continuously drawn. The results are recorded in the control room and indicated in the dispatcher's office with both a visual and audible alarm to signal higher-than-normal values. The fixed filter is changed on an established schedule (weekly) and a determination of the gross alpha and gross beta content is made using appropriate counting instruments. Stacks 296-A-2 and -3 are sampled with a sidestream drawn through a fixed filter. Stack 296-A-2 is continuously monitored for alpha and beta-gamma and 296-A-3 is monitored for beta-gamma.

- Branch 1

  Branch 1 ventilates the sample gallery and Q cell. The air is delivered to the center of a sample gallery distribution duct from which air is dispersed through manually adjustable louvers throughout the length of the sample gallery. There is a "take-off" from the west end of the distribution duct that is used to conduct ventilation air to Q cell. Manual dampers in the distribution duct and the Q cell take-off are set for the desired air distribution. The temperature of branch 1 air is thermostatically controlled from the sample gallery.

  Ventilation air leaves the sample gallery through separate east-end and west-end exhaust air ducts and from both the east and west ends of the sampler hood exhaust air header. Air leaving the east and west exhaust air ducts passes through non-HEPA-type filters (to reduce the particulate loading on the downstream exhaust HEPA filters), manual dampers, HEPA filters, and remotely operated, louvered dampers. The manual dampers are set to establish the flow through each exhaust duct; the remotely operated dampers are modulated to control constant flow. The west exhaust duct discharges to plenum 1 and the east duct to plenum 3. Gauges (DP) downstream of the non-HEPA filters are useful in monitoring pressure loss through the filters (the filters must be replaced when pressure loss becomes too great) and for setting the manual dampers.

In the sample gallery, there are about 70 process solution sampler stations. The design allows for sampler airflow from the sample gallery, through the sampler station, and into the sampler hood exhaust air header: exhaust fan EF-2-3 draws air from the east end of the header, through a HEPA filter, and discharges to the atmosphere through stack 296-A-3; exhaust fan EF-2-4 draws from the west end of the header, through a HEPA, and discharges through stack 296-A-2. Manual dampers upstream and flow indicators downstream of the HEPA filters are used to establish and monitor the airflow of each of these exhaust air streams. There are DP indicators across each of these HEPA filters for monitoring the pressure loss through the filters and for determining when they need to be replaced. Remotely operated, louvered dampers downstream of these HEPA filters are normally open but may be closed and the damper in the center of the sampler hood exhaust header may be opened to direct flow to the operating fan if either fan fails or is removed from service.

The Q cell (the PUREX neptunium processing area) is partitioned into four discrete functional areas: a room containing a maintenance glovebox, a control room, an AMU room, and a hot corridor containing a neptunium processing glovebox. The ventilation air passes through Q cell in two parallel paths, always flowing toward increasingly contaminated or potentially contaminated areas. In one path, the air flows through the maintenance room; in the other, it flows sequentially through the control room, the AMU room, and hot corridor. The exhaust air from both the maintenance room and the hot corridor is combined with the exhaust air from the neptunium load-out room (branch 2). This combined stream flows through another HEPA filter, identified as the "Q cell HEPA," into plenum 4. Some of the ventilation air leaves the maintenance room through the maintenance glovebox; from the hot corridor, the ventilation air leaves through the neptunium processing glovebox. Several HEPA filters have been installed in Q cell to prevent airborne radioactivity upstream of and within Q cell, should a reverse flow of the ventilation air occur. These HEPA filters are located at the inlets to the maintenance room, the control room, both the maintenance and neptunium processing gloveboxes, and at the outlets from both the maintenance and AMU rooms. Fan BSF-K20 circulates the AMU room air through a prefilter and a HEPA to continuously remove particulates from the AMU room air. Manual dampers in the Q cell inlet duct are set to proportion the airflow through the two Q cell airflow paths. There are manual dampers upstream and downstream of the Q cell HEPA and in its bypass duct, so that the HEPA can be replaced without interrupting the flow of air through branch 1.

A remotely operated, normally open, louvered damper located in the sampler hood exhaust header isolates the suctions of exhaust fans EF2-3 and -4. Should either of these fans fail, the damper in the suction duct to the failed fan closes, allowing the operating fan to then service all of the samplers at a reduced capacity per sampler until the failed fan is operating again.

Remotely operated, normally closed, louvered dampers downstream of the HEPA filters in each sample gallery room exhaust duct will close when a predetermined low-flow condition is reached (i.e., EF2-1 or -2 fail to operate). The damper in the duct serviced by the failed fan will close and the sample gallery will be exhausted at a reduced capacity by the fan which continues to operate.

- Branch 2

Branch 2 ventilates the PR room and the neptunium load-out room, both of which are located in the west end of the PUREX building at the storage gallery level. The ventilation air is dispersed in the PR room from an inlet air duct through several manually adjustable (dampered) outlets. An extension of the inlet air duct, also containing a manual damper for controlling airflow rate, is used to conduct ventilation air to the neptunium loadout room. All ventilation exhaust air leaves the PR room through four plutonium processing gloveboxes: one is a plutonium nitrate load-out glovebox; the other three are identified as the L-9, -10, and -11 gloveboxes. There are manual dampers downstream of each of these gloveboxes. These dampers are used to control the rate of airflow through each glovebox. The exhaust air from these four gloveboxes is combined with the outlet airstream from the Q cell HEPA filter and flows to plenum 4. The ventilation exhaust air leaves the neptunium load-out room through two neptunium nitrate load-out gloveboxes, one of which is also used for small-item neptunium decontamination. Downstream manual dampers are used to control the rate of airflow through these gloveboxes. The neptunium load-out room exhaust air is combined with the Q cell exhaust air upstream of the Q cell HEPA. The ventilation air enters the PR room and neptunium load-out room processing gloveboxes through HEPA filters. The temperature of branch 2 ventilation is thermostatically controlled from the PR room.

An intertie air duct, containing a normally closed manual damper, connects the sampler exhaust air header to the outlet from plenum 4. Should both exhaust fans (EF-2-5 and -5A) fail to operate, the manual damper in this duct can be opened so that ventilation air can be temporarily exhausted from the PR room, neptunium loadout room, and Q cell through the sample gallery header by exhaust fans EF-2-3 and -4. Conversely, the sample gallery can be temporarily exhausted by either fan EF-2-5 or -5A, should fans EF-2-3 and/or 2-4 stop operating.

The plutonium purification processing is conducted in L cell, in the west end of the PUREX building at the storage and sample gallery levels. The L cell is adjacent to the PR room. On the rare occasions when contact maintenance in L cell is necessary, entry is made through a door in the wall that separates L cell from the PR room. Normally, this door is closed and its periphery is sealed to prevent the spread of airborne contamination from L cell

to the working areas in the PR room. In addition, the pressure in the PR room is maintained about 0.5 in. WG higher than that in L cell, so that any possible air leakage or flow (e.g., when the door is opened for L cell entry) will always be from the PR room to L cell. The DP between the PR room and L cell is recorded in the central control room (P&O gallery level) and indicated in the PR room.

- Branch 3

Branch 3 ventilation air flows, in parallel, to the PR corridor and N cell, both of which are located in the west end of the PUREX building at the storage gallery level.

The PUREX plutonium oxide production facility has been installed in N cell, which has been expanded to include the entire regulated shop. Air is supplied to the N cell control rooms.

A portion of room air is supplied to all gloveboxes, except the second-stage calciner glovebox, the primary canning glovebox, and the maintenance glovebox. These "dry" gloveboxes are supplied with dry air from compressors located in a new building (2711-A) located on the south side of the canyon building. The room air is exhausted through a HEPA filter into plenum 2. The gloveboxes are exhausted through plenum 4 to the PR stack. A DP is maintained between N cell rooms and gloveboxes to allow supply air to flow from the rooms to the gloveboxes, and to prevent the spread of airborne contamination from the gloveboxes to the control rooms.

The potential for airborne radioactive contamination in the PR corridor is significantly less than in the adjacent rooms. Therefore, the PR corridor is maintained at a higher pressure, so that air leakage will always be from the PR corridor to the adjacent rooms. A manual damper in the PR corridor inlet air duct and two PR corridor DP indicators are used to establish and monitor the PR corridor airflow and pressure level. One DP indicator shows the difference in pressure between the PR corridor and the PR room; the other DP indicator shows the difference in pressure between the PR corridor and R cell.

The temperature of branch 3 ventilation air is thermostatically controlled from N cell.

- Branch 4

Branch 4 ventilation air flows through the canyon lobby to plenum 2. Exhaust airflow rate is established with a manual damper located in the lobby exhaust air duct. Inlet airflow is controlled by a remotely operated, open-or-closed, louvered damper in the inlet duct, and the temperature of the air is thermostatically controlled from the canyon lobby.

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The canyon lobby, located at the west end of the PUREX building at the P&O gallery level, can be entered either from the P&O gallery, the stairway or elevator at the west end of the building, or through a door to the outside of the building. There is an entry from the lobby through an airlock onto the deck of the PUREX upper canyon (above the process cell cover blocks).

The R and U cells are located at the storage gallery level of the PUREX building: R cell in the west end and U cell in the east end. The R cell is used for regenerating and storing the organic solvent used in the uranium extraction cycle. The U cell is used to concentrate and store nitric acid and to store liquid laboratory waste.

Both R cell and U cell ventilation air is exhausted by ventilation system 2 exhaust fans through HEPA filters: R cell by fan EF-2-2 through plenum 2 and U cell by fan EF-2-1 through plenum 3. The exhaust air leaves each cell through dust filters and manual dampers that are set to provide the desired airflow and vacuum levels in each cell. The inlet air to both of these cells flows sequentially through a preheater, a dust filter, spray washers, and a water demister. In the case of U cell, the inlet air flows through and ventilates the 206-A building before entering U cell. There are no supply air fans for either R or U cells; the inlet air motive power in each case is provided by exhaust fan and the vacuum in the cell.

5.4.1.2.2 Control Objectives and Operating Characteristics. Ventilation system 2 is designed to prevent airborne contamination in those worker-occupied operating areas where personnel become more closely associated with radioactive materials than is the case with the totally isolated and remote process operations occurring within the canyon process cells. These are the areas where process samples are obtained, process operations are conducted in gloveboxes, maintenance is performed on slightly contaminated equipment, entries are made to the upper canyon, etc.

In these areas, the equipment and operations have been designed so that there always is a barrier between the radioactive material and both the personnel and work area. The flow of air is controlled to move the air from zones with low radionuclide concentrations to zones with higher radionuclide concentrations.

The air within these areas is normally free of airborne contamination. However, because mishaps resulting in the release of radioactivity are not completely ruled out, these areas are regarded as zone II areas. The hazard represented by this classification is much lower than the zone I[11] classification assigned to the nearby canyon itself (ventilation system 1). Thus, the pressure in ventilation system 2 areas is lower than atmospheric pressure, but higher than the canyon pressure. Therefore, air leakage will always be from the atmosphere either to ventilation system 1 or to ventilation system 2 areas, and from ventilation system 2 to ventilation

system 1. The pressure in ventilation system 2 decreases progressively through the system from the high point at the discharge of the supply fans to the low points at the inlets to the exhaust fans.

Should a mishap occur in which radioactivity is released in any ventilation system 2 areas, the system is designed to localize the released radioactivity as much as possible and to prevent release to the atmosphere. For this reason, each work area receives ventilation air from the supply fans and discharges (through a plenum) to the exhaust system. Thus, should a radioactive release occur in any ventilation system 2 work area, there is no downstream work area to which it can be transmitted. Air flowing through the contaminated locality is channeled (through a plenum) to the exhaust system where the radioactive particles are removed by HEPA filtration and the air is then released to the atmosphere.

With the exception of the small amount of air flowing through the process sampler hoods (in the sample gallery), ventilation system 2 air is discharged through plenums 2, 3, or 4. Those work areas with the greatest potential for radioactivity release hazard (e.g., the PR room, Q cell, etc.) are discharged through plenum 4. Air leaving this plenum passes through two HEPA filters before release to the atmosphere; air leaving plenums 2 and 3 passes through one HEPA filter before release to the atmosphere.

It is particularly important to prevent loss of vacuum in the potentially highly contaminated process sampler hoods (in the sample gallery), the PR room, Q cell, and the neptunium load-out room.

When necessary, the alternate exhaust duct between the sample exhaust header and the outlet from plenum 4 can be opened so that the PR room, Q cell, and the neptunium load-out room can be temporarily exhausted by fans EF-2-3 and -4 should fans EF-2-5 and -5A stop. Conversely, the duct can be used temporarily to exhaust the process samplers using fans EF-2-5 and -5A should fans EF-2-3 and/or -4 stop.

Approximate airflow rates and vacuum levels for the PUREX building areas ventilated by system 2 are given in Table 5-7. The table also contains ventilation fan throughputs and thermostatic temperatures. These order-of-magnitude flow rates and vacuum levels are presented here only to characterize the system.

5.4.1.2.3 Ventilation System 2 Control. Ventilation system 2 prevents radioactive particles from escaping either to the environs or to the worker-occupied areas that it services by adhering to the design principles identified in Chapter 4.0. That is, the areas serviced by this system are maintained under slight vacuums and air flows toward areas of increasing radioactive contamination or potential for such contamination. In addition:

- Radioactive particles are removed by HEPA filtration from all air released from ventilation system 2 to the atmosphere

TABLE 5-7. Ventilation System 2 Typical Operating Characteristics.

Service	Airflow (ft^3/min)	Vacuum level (in. WG)	Temperature (°F)
Supply flow (one fan operating)	36,500	-	-
To sample gallery	25,200	0.20	70
To Q cell	1,350	-	-
To PR room	3,300	0.20	70
To neptunium load-out room	250	0.20	-
To PR corridor	800	0.10	-
To N cell	2,500	0.10	70
To canyon lobby	2,660	0.10	70
To R cell	6,350	0.35	-
To U cell	7,300	0.35	-
Exhaust fan EF-2-1	15,000	-	-
Exhaust fan EF-2-2	20,000	-	-
Exhaust fan EF-2-3	4,400	-	-
Exhaust fan EF-2-4	4,400	-	-
Exhaust fan EF-2-5	5,000	-	-
Exhaust fan EF-2-5A	5,000	-	-

- To prevent the contamination of normally clean areas serviced by this system by reverse airflows or airflow eddy currents, transitions from the normally clean areas to contaminated areas (e.g., gloveboxes) or to areas of significantly greater potential for contamination (e.g., sample hoods and Q cell) are through HEPA filters or at high air velocities

- Leakage of air from contaminated PUREX areas into adjacent ventilation system 2 worker-occupied areas is prevented by maintaining slightly higher pressures in the worker-occupied areas (e.g., PR room pressure is about 0.5 in. WG higher than L cell pressure)

- Air is not allowed to flow from areas with potential for radioactive contamination into areas where personnel are allowed.

Fundamentally, ventilation system 2 is automatically controlled as described below:

- Equipment component interlocks which ensure only those operating modes (including failure and abnormal event modes) which prevent contamination spread or release

- Air supply to areas modulated based on static pressures

- Plenums 2, 3, and 4 exhaust airflow rate controls (constant exhaust flow rate)

- Inlet air temperature controls for each parallel branch of the system (see Fig. 5-28).

A description of the basic concept in establishing and maintaining the normal operating pressure levels and airflow rates throughout the system follows.

The desired flow rates are set on plenums 2 and 3 exhaust airflow controllers. These flow rates are determined from the necessary flows through those parts of ventilation system 2, including R and U cells that exhaust through plenums 2 and 3.

The total capacity of each supply fan (SF-2 and -2A) is large enough to provide the total ventilation system 2 air requirement. The supply airflow rate is manually controlled by adjusting the opening of the isolation discharge damper of the operating supply fan, SF-2 or -2A (see Fig. 5-28), as needed, to maintain the required DP between the sample gallery and the atmosphere (i.e., sample gallery vacuum). The isolation dampers are opened and closed by pneumatically (instrument air) operated actuators. The position of the movable element in these dampers (i.e., the degree to which the dampers are open or closed) depends upon the instrument air pressure (range 0 to 15 lb/in.^{2}) applied to the actuators. Two small manual instrument air valves (one for each isolation discharge damper) are mounted on the graphic panel board for controlling the actuator air pressure. The percentage of the full-open position of each isolation damper is displayed on the graphic panel board, just above each manual instrument air control valve. The DP between the sample gallery and the atmosphere is also displayed on the graphic panel board, so that the power operator can (for the operating air supply fan) set the isolation damper opening that maintains the desired sample gallery vacuum, about 0.20 in. WG.

If either sample hood exhaust header fan (EF-2-3 or -4) stops, the suction damper of the nonoperating fan will close and the damper in the center of the sample hood exhaust header will open. The operating fan will service all of the sample hoods (at a reduced capacity per hood) until the nonoperating fan is back in service. Reverse flow through the nonoperating fan will be prevented by the closed suction damper and the full capacity of the operating fan will be available for the sample hoods.

If all exhaust fans stop operating, the suction dampers for fans EF-2-3 and -4 (the sample hood exhaust header) will open and the main sample gallery exhaust dampers will close. The PR room exhaust fan (EF-2-5 and -5A) suction damper will open and the supply fan (SF-2 or -2A) is shut down by an electrical interlock. The arrangement provides the following:

- Continues airflow from the sample gallery through the sample hoods
- Continues airflow through Q cell, the PR room, and the neptunium load-out room in the normal direction [i.e., through plenum 4 exhaust system (including HEPA filters) to the atmosphere].

If exhaust fan EF-2-2 (the west main sample gallery exhaust) stops, the damper in the canyon lobby supply duct will close. The PR corridor exhaust duct is blanked off. This damper arrangement prevents the east main sample gallery exhaust fan (EF-2-1) from drawing exhaust ventilation air from these locations through plenum 2 into the sample gallery.

The east and west main sample gallery exhaust dampers open and close automatically whenever exhaust fans EF-2-1 and -2 start and stop, respectively.

Electrical interlocks prevent the main sample gallery exhaust fans (EF-2-1 and -2) from operating unless one of the sampler hood exhaust fans (EF-2-3 or -4) and one of the plenum 4 exhaust fans (EF-2-5 or -5A) are operating. This operating restriction prevents the main sample gallery exhaust fans from drawing air from higher potentially contaminated areas (the sample hoods, PR room, neptunium load-out room, and Q cell) into the sample gallery, a worker-occupied area of lower contamination potential.

An electrical interlock prevents simultaneous operation of more than one supply fan (SF-2 or -2A). The combined capacity of both supply fans is greater than the total exhaust fan capacity. With both supply fans operating, it would not be possible to maintain ventilation system 2 under slight vacuum. This interlock can be manually bypassed if special circumstances require operation of both supply fans.

Electrical interlocks prevent the supply fans (SF-2 and -2A) from operating unless one main sample gallery exhaust fan (EF-2-1 or -2) is operating. When a supply fan is operating, the exhaust fan capacity will not maintain ventilation system 2 under slight vacuum unless one of the main sample gallery exhaust fans is operating.

Electrical interlocks prevent the R cell spray-water pump (SP-6) from operating unless the main sample gallery exhaust fan (EF-2-2) is operating; electrical interlocks also prevent the U cell spray-water pump (SP-5) from operating unless exhaust fan EF-2-1 is operating.

5.4.1.2.4 Abnormal Event or Upset Condition Operation.

- Electrical Power Failure

  Exhaust fans EF-2-3, -4, -5, and EF-2-5A are provided with standby electrical power. Exhaust fan EF-2-5 may be manually switched to standby power if necessary. Should the PUREX primary power system fail, the standby electrical system will automatically power fans EF-2-3 and -4. All other ventilation system 2 fans will stop. The supply fan (SF-2 and -2A) isolation dampers will open, and the inlet dampers to the regulated shop and canyon lobby will close. In addition, when plenum 4 vacuum becomes low enough (about 3.0 in. WG), exhaust fans EF-2-5 and -5A will also operate automatically on the standby electrical power system. This arrangement continues airflow through the contaminated areas (e.g., gloveboxes) and areas of highest potential for such contamination

(e.g., Q cell, the process samplers, etc.) through the use of standby electrical power until the primary electrical system is returned to service.

- Instrument Air Failure

Should instrument air become unavailable, ventilation air will flow through the same ventilation system 2 pathways as it would if the primary electrical power system failed and standby electrical power remained operational. The supply fans (SF-2 and -2A) will not operate and the isolation dampers will open. Exhaust fans EF-2-3 and -4 and either EF-2-5 or -5A (whichever is operating when the instrument air failure occurs) will continue to operate. The suction dampers for exhaust fans EF-2-3 and -4 will remain open. The inlet dampers to the regulated shop and the canyon lobby will close, and the main sample gallery exhaust dampers (east and west) will close.

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5.4.1.3 Ventilation System 3--Service Area. This system ventilates those areas within PUREX assigned to activities where personnel must be free to move about without concern for exposure to radiation or airborne radioactivity. These areas* (zones III and IV) are sufficiently isolated from the radionuclide processing and handling areas so that, under normal conditions, there is no radiological hazard. The areas ventilated by this system include the administrative and supervisory offices, lunchrooms, maintenance shops, control rooms, change rooms, restrooms, etc. Most of these areas are located in the PUREX annex. However, the storage and P&O galleries in the main concrete canyon structure are also included in this ventilation system.

This system supplies air to seven separate service areas from a common supply plenum. One or more exhaust fans discharge unfiltered ventilation air into the atmosphere from each of the areas.

The zones III and IV service areas are maintained at slightly higher pressures than the surroundings, so that air leakage will always be from the service areas either to the atmosphere or to the PUREX areas serviced by the other ventilation systems. Access to these areas is not normally through air locks. Personnel entering ventilation system 3 areas from those PUREX areas where the potential for radiological hazard has been judged to be significant are surveyed for freedom from radioactive contamination prior to entry.

Supply air entering this system is heated, cleansed (by filtration and washing), and humidified for human health and comfort. Low-pressure, steam-to-air heaters are located in the supply ducts for temperature control. During the cold seasons, a low-pressure steam heater, ahead of the inlet filter, prevents ice formation in the water-spray unit. During the hot and dry seasons, the inlet air is cooled and humidified for personnel comfort in

*The contamination control zones are defined in Section 4.3.2.2.

ventilation system 3 work areas by the evaporation of water in the water-spray unit. Grilles and diffusers* have been installed in the ductwork to properly balance and distribute the flow of air.

Figure 5-29 is a flow diagram of ventilation system 3, and Table 5-8 provides a summary description of the system fans, the fan characteristics, and the areas serviced. Figure 5-29 is arranged to give some concept of the service area floor plans and air distribution ductwork.

5.4.1.3.1 Airflow. There are two ventilation system 3 air supply fans (SF-3 and -3A) in the service blower room. Each fan is capable of delivering 71,000 ft^3/min of air at a DP of 3 3/4 in. WG. These fans are turned on and off manually and can operate either singly or simultaneously, according to the airflow requirements of the areas serviced by ventilation system 3. Louvered dampers on the inlet and discharge sides of each supply fan automatically open when a fan is operating and close when the fan is not operating to prevent backflow of air.

The supply fans discharge into a supply air plenum (also located in the service blower room) that has four, splitter-type, outlet dampers set to proportion the supply air among five air ducts. These ducts, three of which subdivide into three additional ducts (making a total of eight), distribute the air to seven independently ventilated areas (two ducts supply air to the P&O gallery). The PUREX areas to which these ducts conduct ventilation air are identified as follows (see Fig. 5-29 for distribution duct numbers):

Duct	Area	Location
1	East switchgear room, headend control room, battery room, restroom	First floor annex, east end of PUREX
2,3	P&O gallery, white room, and pressure reducing valve (PRV) room	First floor annex
4	Service and process blower rooms	First floor annex
5	Supervisors' offices, main control room, maintenance shops, locker rooms, etc.	First floor annex
6	Administrative offices, lunch and conference rooms	Second floor annex
7	Storage gallery and PIV Room	Lowest level PUREX building
8	AMU rooms	Basement and levels 1, 2, and 3 in PUREX annex

*Diffusers are small, radial-type dampers with circular louvers downstream of the damper vanes, and are usually installed as discharge devices in overhead ducts to control the flow rate at which air is released from the ducts. The desired opening is obtained by manually adjusting the diffuser radial vanes. The circular louvers reduce the velocity of the air as it leaves the air ducts and diffuses it over a wider area.

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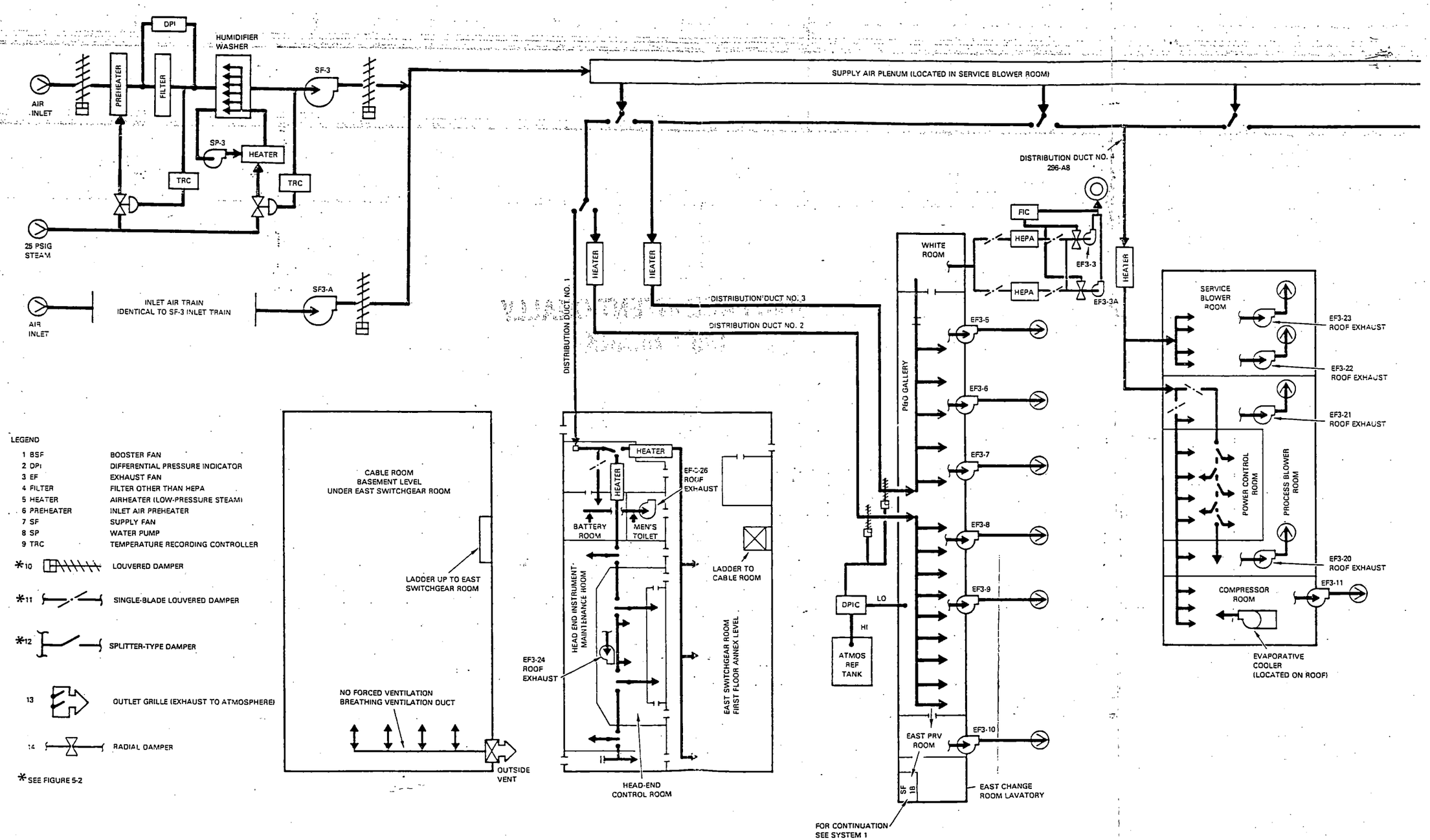

FIGURE 5-29. Flow Diagram--Ventilation System 3. (Sheet 1 of 2)

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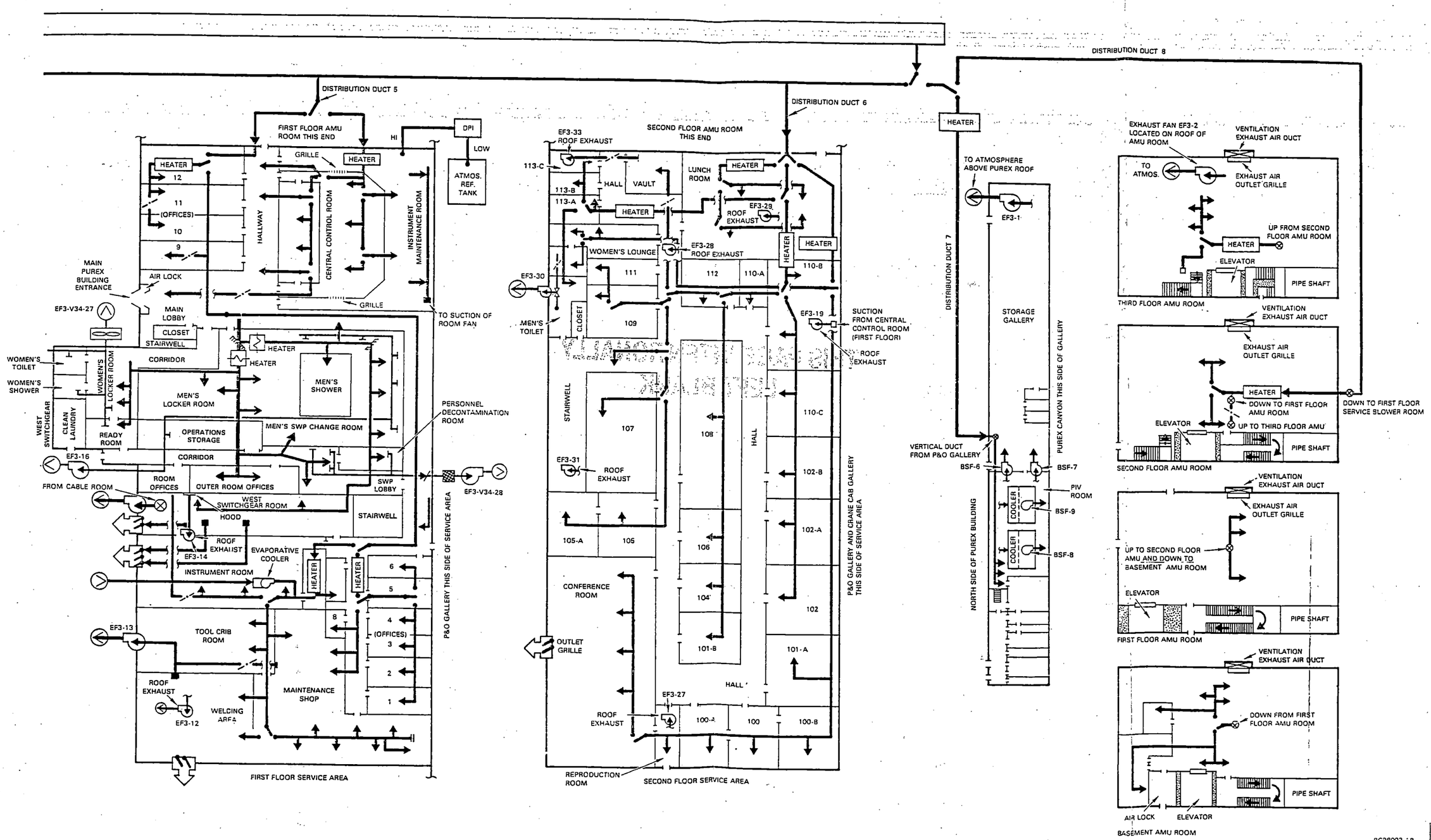

FIGURE 5-29. Flow Diagram--Ventilation System 3. (Sheet 2 of 2)

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TABLE 5-8. Ventilation System 3 Fans. (Sheet 1 of 5)

Designation	Service	Location[a]		Rating		Drive description
		Fan	Drive control	ft^3/min	TDH[b] / rpm	
SF3	Ventilation system 3 supply	Service blower room	1. Power control room 2. Service blower room	71,060	3.75 / 686	Electric, 75 hp, 460 V, 93 A, 3 phase, 60 cycle, 1,730 rpm, belt drive
SF3-A	Ventilation system 3 supply	Service blower room	1. Power control room 2. Service blower room	71,060	3.75 / 686	Electric, 75 hp, 220/440 V, 182/91 A, 3 phase, 60 cycle 1,750 rpm, belt drive
EF3-1	Storage gallery exhaust	Extreme east end of storage gallery	1. North wall of storage gallery 2. Power control room	13,160	0.75 / 686	Electric, 5 hp, 440 V, 3 phase, 60 cycle, 1,800 rpm, belt drive
EF3-2	AMU room exhaust	AMU roof	Power control room	17,080	0.625 / 853	Electric, 7-1/2 hp, 220/440 V, 20/10 A, 3 phase, 60 cycle, 1,750 rpm, belt drive
EF3-3 and EF3-3A	White room exhaust	Outside, north of west end of PUREX building	1. Power control room 2. Next to fan	22,500	6.25 / 1,750	Electric, belt drive, 30 hp, 480 V, 3 phase, 60 cycle, 1,750 rpm
EF3-5	P&O gallery exhaust	P&O gallery near ceiling, between columns 10 and 11	North wall of P&O gallery below fan	6,730	0.25 / 690	Electric, 3/4 hp, 440 V, 3 phase, 1,750 rpm, belt drive
EF3-6	P&O gallery exhaust	P&O gallery near ceiling, between columns 20 and 21	North wall of P&O gallery below fan	6,730	0.25 / 690	Electric, 3/4 hp, 440 V, 3 phase, 1,750 rpm, belt drive
EF3-7	P&O gallery exhaust	North wall of P&O gallery near ceiling, between columns 27 and 28	North wall of P&O gallery below fan	6,730	0.25 / 690	Electric, 3/4 hp, 440 V, 3 phase, 60 cycle, 1,750 rpm, belt drive
EF3-8	P&O gallery exhaust	North wall of P&O gallery near ceiling, between columns 37 and 38	North wall of P&O gallery below fan	6,730	0.25 / 690	Electric, 3/4 hp, 440 V, 3 phase, 60 cycle, 1,750 rpm, belt drive

TABLE 5-8. Ventilation System 3 Fans. (Sheet 2 of 5)

Designation	Service	Location[a]		Rating		Drive description
		Fan	Drive control	ft^3/min	TDH[b]/rpm	
EF3-9	P&O gallery exhaust	North wall of P&O gallery near ceiling, between columns 40 and 41	North wall of P&O gallery below fan	6,730	0.25/690	Electric, 3/4 hp, 440 V, 3 phase, 60 cycle, 1,750 rpm, belt drive
EF3-10	East steam PRV room exhaust	East steam PRV room	East wall of east steam PRV room near door	3,420	0.25/870	Electric, belt drive, 1/2 hp, 440 V, 3 phase, 60 cycle, 1,750 rpm
EF3-11	Compressor room exhaust	North wall of compressor room	North wall of compressor room below fan	8,160	0.25/806	Electric, 1/2 hp, 440 V, 3 phase, 60 cycle, 1,725 rpm, belt drive
EF3-12	Maintenance shop welding area (hood) exhaust, exhaust through welding area roof	Above welding table near ceiling	North wall in northeast corner of welding area	630	2.5/1,610	Electric, 3/4 hp, 440 V, 3 phase, 60 cycle, 1,800 rpm belt drive
EF3-13	Maintenance shop (tool crib) exhaust	Tool crib room inside exhaust duct near north wall and near ceiling	North wall in northeast corner of welding area	2,790	0.25/1,128	Electric, 1/2 hp, 440 V, 3 phase, 60 cycle, 1,750 rpm, belt drive
EF3-14	West switchgear room, hood fume exhaust	Instrument shop, northeast corner near ceiling, exhausts through roof	North wall of instrument shop, northeast corner	630	1.0/1,128	Electric, 1/3 hp, 440 V, 3 phase, 60 cycle, 1,800 rpm, belt drive
EF3-15	SWP change room exhaust	North wall of SWP room	North wall of SWP room below fan	2,390	0.25/1,725	Electric, 1/3 hp, 440 V, 3 phase, 60 cycle, 1,725 rpm, direct drive
EF3-16	Exhaust from men's shower, women's locker room, first floor corridor	Men's locker room, northwest corner near ceiling	North wall of men's locker room below fan	3,540	0.500/1,092	Electric, 1 hp, 440 V, 3 phase, 60 cycle, 1,750 rpm, belt drive
EF3-17	Men's locker room exhaust	North wall of men's locker room	North wall of men's locker room below fan	2,050	0.25/1,725	Electric, 1/3 hp, 440 V, 3 phase, 60 cycle, 1,725 rpm, direct drive

TABLE 5-8. Ventilation System 3 Fans. (Sheet 3 of 5)

Designation	Service	Location[a]		Rating		Drive description
		Fan	Drive control	ft^3/min	TDH[b]/rpm	
EF3-18	West switchgear cable room exhaust	Inside exhaust duct near north wall of west switchgear room	North wall of west switchgear room below fan	1,400	0.50/1,725	Electric, 1/2 hp, 440 V, 3 phase, 60 cycle, 1,725 rpm, direct drive
EF3-19	Process control room exhaust	Roof	1. South wall of room 110-B 2. Circuit breaker box on second floor outside room 108	3,620	0.25/1,140	Electric, 1/2 hp, 440 V, 3 phase, 60 cycle, 1,140 rpm, direct drive
EF3-20	Process blower room exhaust	Process blower room roof	North wall of process blower room	3,850	0.125/850	Electric, 1/3 hp, 440 V, 3 phase, 60 cycle, 850 rpm, direct drive
EF3-21	Process blower room exhaust	Process blower room roof	North wall of process blower room	3,850	0.125/850	Electric, 1/3 hp, 440 V, 3 phase, 60 cycle, 850 rpm, direct drive
EF3-22	Service blower room exhaust	Service blower room roof	East wall of service blower room	2,440	0.125/850	Electric, 1/4 hp, 115 V, 1 phase, 60 cycle, 850 rpm, direct drive
EF3-23	Service blower room exhaust	Service blower room roof	East wall of service blower room	2,440	0.125/850	Electric, 1/4 hp, 115 V, 1 phase, 60 cycle, 850 rpm, direct drive
EF3-24	Headend control room exhaust	Headend control room roof	On wall in east switchgear room next to west door to headend control room	2,140	0.100/850	Electric, 1/6 hp, 115 V, 1 phase, 60 cycle, 850 rpm, direct drive
EF3-26	Headend control room toilet and battery room exhaust	South wall of toilet room	West wall of battery room next door	600	0.125/1,140	Electric, 1/20 hp, 115 V, 1 phase, 60 cycle, 1,140 rpm, direct drive

TABLE 5-8. Ventilation System 3 Fans. (Sheet 4 of 5)

Designation	Service	Location[a]		Rating		Drive description
		Fan	Drive control	ft^3/min	TDH[b]/rpm	
EF3-27	Second floor corridor exhaust	Corridor ceiling over reproduction room	Corridor wall below fan	3,510	0.125/850	Electric, 1/3 hp, 115 V, 1 phase, 60 cycle, 850 rpm, direct drive
EF3-28	Second floor corridor exhaust	Corridor ceiling outside lunchroom door	1. Corridor wall near lunchroom door 2. Circuit breaker box on second floor outside room 108	3,510	0.125/850	Electric, 1/3 hp, 115 V, 1 phase, 60 cycle, 850 rpm, direct drive
EF3-29	Lunchroom	Lunchroom ceiling	North lunchroom wall	2,625	0.125/850	Electric, 1/4 hp, 115 V, 1 phase, 60 cycle, 850 rpm, direct drive
EF3-30	Second floor men's and women's restroom exhaust	Men's restroom ceiling	North restroom wall	660	0.125/1,140	Electric, 1/20 hp, 115 V, 1 phase, 60 cycle, 1,140 rpm, direct drive
EF3-31	Main lobby stairwell exhaust	In ceiling above main lobby stairwell (stairwell 3)	North wall of PUREX annex, second floor service area corridor	2,590	0.125/850	Electric, 1/4 hp, 115 V, 1 phase, 60 cycle, 850 rpm, direct drive
EF3-33	Room 113 exhaust, second floor service area	Above false ceiling in room 113	Northeast corner of room 113	655	0.25/1,605	Electric, 1/20 hp, 115 V, 1 phase, 60 cycle, 1,605 rpm, direct drive
EF3-34	Decontamination hood exhaust, SWP survey room, first floor service area	Northwest corner SWP survey room near ceiling	Northwest corner of SWP room below fan	1,000	0.75/700	Electric, 3/4 hp, 440 V, 3 phase, 60 cycle, 1,750 rpm, belt drive
BSF-6	PIV room exhaust	East wall PIV room near ceiling	1. Power control room 2. On PIV room west wall near door	6,800	0.25/700	Electric, belt drive 3/4 hp, 440 V, 3 phase, 60 cycle, 830 rpm

TABLE 5-8. Ventilation System 3 Fans. (Sheet 5 of 5)

Designation	Service	Location[a]		Rating		Drive description
		Fan	Drive control	ft^3/min	$\frac{TDH^b}{rpm^c}$	
BSF-7	PIV room exhaust	East wall of PIV room near ceiling	1. Power control room 2. On PIV room west wall near door	6,800	$\frac{0.25}{700}$	Electric, belt drive 3/4 hp, 440 V, 3 phase, 60 cycle, 830 rpm
BSF-8	PIV room booster	West end PIV room on top emergency control room	1. Power control room 2. North PIV room wall 1/4 distance from west end	4,050	$\frac{0.25}{1,080}$	Electric, belt drive 2 hp, 440 V, 3 phase, 60 cycle, 1,750 rpm
BSF-9	PIV room booster	West end PIV room on top emergency control room	1. Power control room 2. North PIV room wall 1/4 distance from west end	4,050	$\frac{0.25}{1,080}$	Electric, belt drive 2 hp, 440 V, 3 phase, 60 cycle, 1,750 rpm

[a]See Figure 5-25 for room locations.

[b]TDH = total dynamic head, (inches of water)

[c]rpm = revolutions per minute.

A network of ducts in each of the seven areas serviced by ventilation system 3 distribute the ventilation air throughout each area. These networks contain manual dampers, grilles, and diffusers that are set to achieve proper ventilation by controlling the rates at which the air is released through the grilles and diffusers. The approximate locations of these distribution networks, the manual flow control dampers, and the air release points are indicated in Figure 5-29.

Several exhaust fans that discharge the ventilation air to the atmosphere are located on the roofs and outside walls of the ventilated areas. In addition, louvered grilles are on the outside walls of the west switchgear room, maintenance shop instrument room, welding area, and PUREX conference room, through which ventilation air also exhausts to the atmosphere. The approximate locations of these exhaust fans and exhaust grilles are indicated in Figure 5-29. With the exception of the white room and the air supplied to the ECMP area from the east end of the P&O gallery, ventilation system 3 air is released to the atmosphere unfiltered and in the immediate vicinity of the exhaust fan and exhaust grille outlets.

During hot, dry seasons, the compressor room is cooled by a small evaporative cooler located on the roof of the compressor room. After passing through the compressor room, this evaporatively cooled air is exhausted, along with the ventilation air that flows to the compressor room from the supply plenum, by a fan mounted on the north wall of the compressor room.

Ventilation air flows from the supply plenum to the PIV room and is exhausted into the west end of the storage gallery by two wall fans in the partition between the two rooms. The ventilation air is then exhausted unfiltered from the east end of the storage gallery by an exhaust fan which discharges above the PUREX roof.

The cable room, which is located below the east switchgear room, is vented to the east switchgear room through a ceiling duct.

The P&O gallery and white room have a slightly higher possibility of contamination than the other ventilation system 3 areas and are classified as zone III areas (0.10 $\pm$ 0.05 in. WG vacuum). The other ventilation system 3 areas are classified as zone IV[11] areas (0.10 $\pm$ 0.05 in. WG positive pressure). About 11,000 ft^3/min of air from the east end of the P&O gallery is routed to the ECMP as described in Section 5.4.1.1.1. The remaining P&O gallery air is exhausted by fans EF-3-5, -6, -7, -8, -9, and -10 via gravity dampers to atmosphere. The white room has been partitioned from the remainder of the P&O gallery and the direction of airflow is always from the P&O gallery into the white room. The white room ventilation air is exhausted via EF-3-3 or -3a through a HEPA filter and a stack (296-A-8) extending above the building roof. The P&O gallery exhaust fans and EF-3-10 (east steam PRV room) automatically shut off if radiation is detected by a unit CAM monitoring gallery exhaust. Air is then pulled through the white room by EF-3-3 or the east crane maintenance service areas by EF-1B (EF-1B exhausts to the canyon).

5.4.1.3.2 Control Objectives. The primary control objectives for ventilation system 3 are those that are usually controlled for the health and comfort of personnel (i.e., temperature, airflow, humidity, and dust). Since this system is associated with a radionuclide processing facility, however, and the areas serviced are normally occupied by personnel, the very small potential for radiological hazard within these areas cannot be ignored. The pressure levels maintained in the areas serviced by ventilation system 3 are slightly higher (except the P&O gallery and white room) than those in the areas ventilated by the other PUREX ventilation systems. Thus, any airflow between areas is toward the areas serviced by ventilation systems having higher radiological risk.

5.4.1.3.3 Operating Characteristics (Approximate). The ventilation system 3 operating capacity and the distribution of air through the eight separate circuits are occasionally changed to account for the influences of the seasons of the year and the operating status and activity within the building. Table 5-9 shows a comparatively high flow rate material balance and the approximate pressure level which is maintained in each distribution circuit. This material balance, representing somewhat more than 90% of the capacity of both supply fans, indicates the amount of flow that can be obtained through each distribution circuit. The heaters in this system are thermostatically set to maintain comfortable (65°F to 70°F) temperatures during the cooler seasons. Summer temperatures are limited to those that can be achieved by the evaporative effect of the inlet air spray units.

5.4.1.3.4 System Control. Airflow rates, distribution, and pressure levels in the areas serviced by ventilation system 3 are established and controlled manually.

The airflow from each supply fan (SF-3 and -3A) is established by setting its discharge damper manually. Both fans are operated simultaneously when the total required airflow is greater than the capacity of one fan. The total airflow requirement must be known, within reasonable limits, before the operating mode of the fans is decided. Each supply fan must be set for the same discharge flow whenever both are operated simultaneously.

The PUREX process operating status is a major factor affecting the airflow requirements from ventilation system 3. When the plant is operating, the process steam pipes located in the P&O gallery radiate substantial heat and correspondingly more ventilation air is required to remove it. When the plant is not operating, the flow of ventilation air through the P&O gallery can be reduced.

The distribution of air among the seven service areas is accomplished by manually setting the splitter dampers that are at the supply plenum outlets and in the supply distribution ducts. The diffusers and outlet grille louvers, through which ventilation air is released into each service area, are also set manually so that all parts of each service area are adequately ventilated. Once a properly balanced flow of air through all service areas is obtained, these devices should not have to be reset, unless a major rebalancing of air distribution becomes necessary.

TABLE 5-9. Ventilation System 3--Typical Operating Characteristics.

Service	Airflow (ft /min)	Pressure level (in. WG)
Total supply	131,300	-
Duct 1 (east switchgear room)	5,485	0.10
East switchgear room	2,880	-
Headend control room	340	-
Headend instrument maintenance room--north	1,675	-
Headend instrument maintenance room--south	200	-
Battery room	390	-
Duct 2 (P&O gallery--east)	22,550	-0.10
Duct 3 (P&O gallery--west)	22,550	-0.10
Duct 4 (power control and equipment rooms)	19,740	0.10
Power control room	500	-
Service blower room	4,640	-
Process blower room	6,830	-
Compressor room	7,770	-
Duct 5 (first floor service area)	20,580	0.10
Office (12 @ 300 ft^3/min average)	3,600	-
Central control room	2,150	-
Central control room instrument maintenance room--north	550	-
Central control room instrument maintenance room--south	750	-
Main lobby	600	-
Corridor	670	-
Instrument shop	1,820	-
Welding shop	600	-
Tool crib	1,040	-
Maintenance shop	3,380	-
West switchgear room	1,340	-
SWP lobby	590	-
SWP change room	1,150	-
SWP supply room	180	-
SWP laundry room	180	-
Women's locker room	180	-
Men's locker room	1,040	-
Men's shower	760	-
Duct 6 (second floor area)	11,170	0.10
Conference room	1,360	-
Lunchroom	2,500	-
Restroom--men's	345	-
Restroom--women's	365	-
Offices (24 @ 275 ft^3/min average)	6,600	-
Duct 7 (Storage gallery and PIV room)	12,960	0.10
Duct 8 (AMU rooms)	16,265	0.10

Two DP gauges are located in the power control room on the ventilation system 3 graphic panel board. One gauge displays the pressure difference between the atmosphere and the P&O gallery; the other displays the pressure difference between the first floor service area and the atmosphere. The service area sensor is located in the central control room. The P&O gallery pressure is maintained at about 0.10 in. WG below atmospheric by turning individual P&O gallery exhaust fans on or off as required. These fans (EF-3-5, -6, -7, -8, -9, and -10) are operated from the power control room, and the change in DP can be observed whenever one of the fans is turned on or off. The first floor service area is maintained at about 0.10 in. WG above atmospheric by turning exhaust fan EF-3-16 on or off as required. This fan, which also has a pushbutton on the ventilation system 3 graphic panel board, exhausts air from the locker rooms, shower, and first floor service area corridor. The capacity of this fan is about 3,500 ft^3 min, but the operating flow can be reduced by partially closing the inlet damper. The second floor service area is always open to the first floor service area through the stairwell, so that this pressure control services both areas. All accesses to the P&O gallery and storage galleries from the PUREX annex are through air locks or through normally closed, small (single) doors so that the slight vacuum in the galleries is always maintained.

In the winter, ventilation system 3 service areas are heated for comfort by 17 thermostatically controlled steam-to-air heaters. These heaters are installed in the air distribution ducts.

The temperature and humidity of the supply air can be varied by changing the setting on the recording temperature controller that modulates the flow of steam to the humidifier-washer water heater.

- Interlocks

  Each supply fan (SF-3 and -3A) is electrically interlocked with its suction and discharge dampers, so that the dampers are open when the fan is operating and closed when it is idle.

- Electrical Power Failure

  Should electrical power fail, all ventilation system 3 fans stop operating and the supply fan suction and discharge dampers close. A 22,500-ft^3/min exhauster fan located at the west end of the white room, operating on standby electrical power, provides backup ventilation for the P&O gallery.

- Instrument Air Failure

  Instrument air failure does not affect operation of ventilation system 3 fans.

5.4.1.4 Ventilation System 4--Laboratory. Ventilation system 4 services that portion of the east annex which houses the PUREX analytical laboratory. The design prevents airborne particulate radioactivity from escaping to the laboratory work areas or to the environment.

The laboratories are located in the PUREX annex, toward the east end of the building at the P&O gallery level. There are four accesses to the laboratory, all of which are through airlocks: one is from the P&O gallery, one from a storage area at the west end of the laboratory, and two on the north side of the laboratory from the outside (one from loading dock 6 and one is the main laboratory entrance). The ventilation system 4 operating equipment is located in a large room (the ventilation equipment room) just above the laboratory.

The PUREX process samples contain a relatively small quantity of radionuclides. The primary potential mechanisms for release of airborne radioactivity within the laboratory are sample spills during transport and air releases from the open-faced hoods. The PUREX samples are well confined in rugged containers whenever transported, and are only transported under approved procedures. The ventilation system is designed to provide a continuous, high-velocity, inward flow of air through all open-faced hood openings. All air leaving the hoods passes through HEPA filters to remove radioactive particulates before the air is released to the environment.

Figure 5-30 is a general schematic of ventilation system 4 (see Fig. 5-17 for a plan view of the laboratory) and Table 5-10 provides a summary description of the system fans and characteristics.

Each area or room within the PUREX laboratory is classified as either a regulated or nonregulated area. Typical nonregulated areas are offices, lunchrooms, lavatories, etc. The regulated areas are those in which activities involving radioactive materials are conducted, but are normally free of airborne radioactive contamination and in which radioactivity exposure levels are typically less than 1 mr/h. The regulated areas in the PUREX laboratory include the laboratory rooms in which radioactive materials are analyzed, the decontamination laboratory, the counting room, and the sample receiving room. The presence of radioactive materials in these rooms slightly increases the possibility of airborne radioactivity. Personnel entering the regulated areas may be required to observe special precautions.

5.4.1.4.1 Airflow. There are two ventilation system 4 air supply fans (SF-4 and -4A) located in the laboratory ventilation equipment room. This room is one of the nonregulated laboratory rooms and is above the laboratory rooms shown in Figure 5-17.

The hood openings are reduced in size so that the capacity of one supply fan is sufficient to ensure at least 125 ft/min air velocity through the openings of all of the hoods in service when the PUREX Plant is in operation.

Inlet air to each supply fan is preheated, filtered, and washed. The filtration and washing operations remove airborne dust that would otherwise deposit on the hood-exhaust HEPA filters, thereby increasing replacement frequency. The inlet steam preheaters assure that the inlet air is warm enough in the winter to avoid freezing the water in the washers.

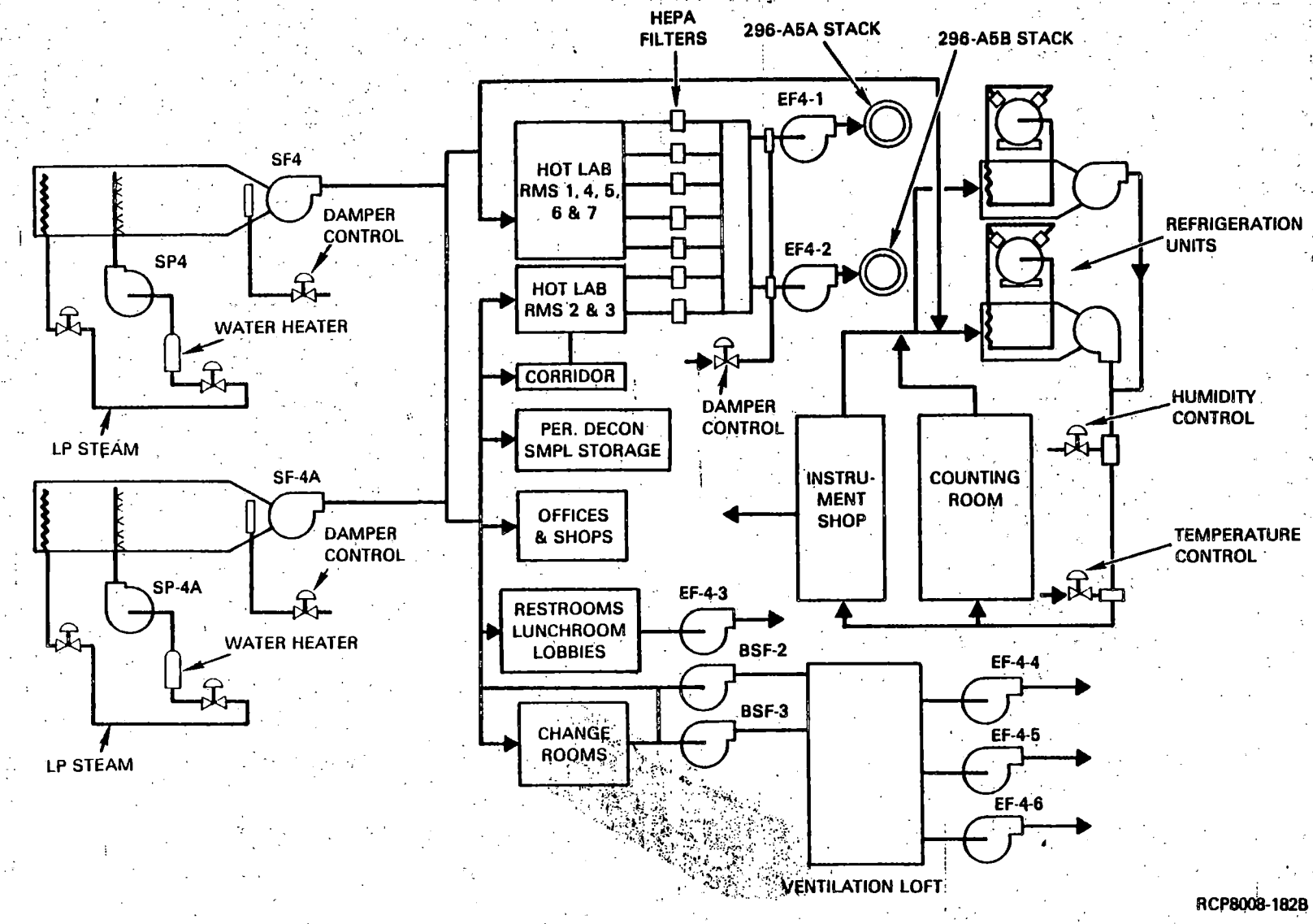

FIGURE 5-30. Schematic of Ventilation System 4.

TABLE 5-10. Ventilation System 4 Fans.

Designation	Service	Location		Rating		Drive description
		Fan	Drive control	ft^3/min	$\frac{TDH^a}{rpm^b}$	
SF-4	Ventilation system 4 supply	Ventilation equipment room	1. Power control room 2. Ventilation equipment room	31,060	$\frac{3.25}{650}$	Electrical, belt, 30 hp, 1,750 rpm, 3 phase, 60 cycle, 220/440 V, 74/37 A
SF-4A	Ventilation system 4 supply	Ventilation equipment room	1. Power control room 2. Ventilation equipment room	31,060	$\frac{3.25}{650}$	Electrical, belt, 30 hp, 1,750 rpm, 3 phase, 60 cycle, 220/440 V, 74/37 A
BSF-2	Ventilation equipment room supply booster	Ventilation equipment room (near ceiling)	1. Power control room 2. Ventilation equipment room	3,585	$\frac{0.5}{1,488}$	Electrical, belt, 1/2 hp, 1 1/2 hp, 1,725 rpm, 3 phase, 60 cycle, 440 V
BSF-3	Ventilation equipment room supply booster	Ventilation equipment room (near ceiling)	1. Power control room 2. Ventilation equipment room	3,585	$\frac{0.5}{1,488}$	Electrical, belt, 1 1/2 hp, 1,725 rpm, 3 phase, 60 cycle, 440 V
EF4-1	Regulated area exhaust	Ventilation equipment room	1. Power control room 2. Ventilation equipment room	21,600	$\frac{6.0}{1,017}$	Electrical, belt, 40 hp, 1,750 rpm, 3 phase, 60 cycle, 440 V, 40 A
EF4-2	Regulated area exhaust	Ventilation equipment room	1. Power control room 2. Ventilation equipment room	21,600	$\frac{6.0}{1,017}$	Electrical, belt, 40 hp, 1,750 rpm, 3 phase, 60 cycle, 400 V, 40 A
EF4-3	Lavatory and lunchroom exhaust	Women's lavatory	Women's lavatory	1,870	$\frac{0.25}{1,140}$	Electrical, direct drive, 1/2 hp, 1,140 rpm, 3 phase, 60 cycle, 114 V
EF4-4	Ventilation equipment room exhaust	Roof of ventilation equipment room	1. Power control room 2. Ventilation equipment room	2,420	$\frac{0.125}{850}$	Electrical, direct drive, 1/4 hp, 850 rpm, 3 phase, 60 cycle, 115 V
EF4-5	Ventilation equipment room exhaust	Roof of ventilation equipment room	1. Power control room 2. Ventilation equipment room	2,420	$\frac{0.125}{850}$	Electrical, direct drive, 1/4 hp, 850 rpm, 3 phase, 60 cycle, 115 V
EF4-6	Ventilation equipment room exhaust	Roof of ventilation equipment room	1. Power control room 2. Ventilation equipment room	2,420	$\frac{0.125}{850}$	Electrical, direct drive, 1/4 hp, 850 rpm, 3 phase, 60 cycle, 115 V

[a]Total dynamic head; (inches in water).
[b]Revolutions per minute.

The SF-4 and -4A supply fans discharge into a supply air plenum from which the air is distributed to the ventilation ducts.

The distribution duct from the air supply plenums divides into two primary branches: one distributes air to only regulated areas and the other distributes air to regulated and nonregulated areas, as shown in Figure 5-30. The regulated rooms supplied by the regulated supply duct are hot laboratory rooms 1, 4, 5, 6, and 7. The other duct supplies air to hot laboratory rooms 2 and 3, the personnel decontamination room, the sample receiving room, the laboratory corridor, offices, instrument shop, lobby, and to the following nonregulated areas:

- Air locks
- Stairwells
- Restrooms
- Lunchroom
- Old change rooms
- Ventilation equipment room.

Ventilation air is not filtered as it leaves the nonregulated areas. Laboratory air locks, unlike those in the remainder of the plant, are supplied with air to minimize dust infiltration. The air locks and stairwell 6 discharge directly to the outside. The lavatories, lunchroom, and laboratory lobby are also exhausted to the outside by fan EF-4-3.

The ventilation air from stairwell 7, the offices, the women's lounge, and the instrument shop flows into the laboratory corridor. The exhaust air from the corridor is distributed among the hot laboratories.

The exhaust air from the change rooms plus some additional air from the regulated area inlet distribution duct is used to ventilate the ventilation equipment room. Booster fans BSF-2 and -3 assist delivery of ventilation air to the equipment room, and fans EF-4-4, -5, and -6 exhaust the room air directly to the atmosphere.

Air from the sample receiving room is exhausted into the nonregulated corridor and decontamination room. The counting room air is recirculated through refrigeration air conditioners. The only air leaving the room is a small amount of leakage when the door is opened.

Constant airflows are maintained through the decontamination laboratory and through hot laboratories 1, 2, 3, and 5. Ventilation air leaves these laboratories through room exhaust ducts and through open hoods. Louvered dampers in the room exhaust ducts automatically control the exhaust airflow through these ducts whenever the laboratory's hoods are opened or closed. Whenever hood openings are reduced, the damper openings increase, allowing

more air to flow through the room exhaust ducts. In hot laboratories 4 and 6, all air leaves through open hoods. The rate of airflow through these two laboratories is not kept constant. Air from the personnel decontamination room is exhausted via the hot laboratory 6 hood exhaust duct. All regulated area ducts discharge into the exhaust plenum. Exhaust fans EF-4-1 and -2 discharge the exhaust plenum above the PUREX roof through exhaust stacks 296-A-5A and -5B.

5.4.1.4.2 Control Objectives. Ventilation system 4 is comprehensively designed to provide all of the PUREX laboratory ventilation needs independent of the other PUREX building ventilation systems.

Ventilation system 4 is designed, first, to ensure control of airborne contamination and, second, to provide for the health and comfort of personnel working in the laboratory. Within the laboratories, a cascade of static pressures maintains airflow toward areas of higher contamination potential (i.e., nonregulated to regulated areas). The zone IV(11) nonregulated areas are maintained at slightly positive static pressures (0.05 to 0.15 in. WG) with respect to the atmosphere, so that contamination-free air always flows out of these areas. The zone III(11) nonregulated change room area pressures are maintained at a slightly negative pressure (-0.05 to 0.15 in. WG) with respect to the atmosphere. The regulated areas are maintained at slightly more negative pressures (0.15 to 0.25 in. WG) with respect to the atmosphere, so that any air exchange with nonregulated areas will always be toward the regulated areas. Regulated areas are regarded as zone II(13) areas. The exhaust air plenum, which is downstream of the laboratory hoods, is maintained at a significantly lower pressure (about 3.0 in. WG vacuum) than the regulated areas, so that air will always flow from the laboratory rooms into any open laboratory hoods at velocities high enough to prevent escape of radioactive particulates from the hoods into the rooms. The pressure differences across the HEPA filters downstream of the laboratory hoods must be monitored frequently so that the filters can be replaced before flow resistance increases enough to prevent adequate air velocities through the hood openings. There are DP indicators across each HEPA filter for this purpose.

The system capacity is large and the airflow patterns are designed to prevent the laboratory air from becoming stagnant. During warm weather, the washer-humidifiers not only remove dust from the hot, dry, inlet air, but also evaporatively cool and humidify it. Nine thermostatically controlled steam heaters maintain comfortably warm temperatures throughout the laboratory during cool weather.

Since ventilation air is supplied to both the regulated and nonregulated areas from a common supply plenum and, in some cases, from common supply ducts, it is important to prevent air from flowing from the regulated areas (high potential contamination) to the nonregulated areas (lower potential contamination) through the common plenum and ducts. This is done by maintaining, at all times, a higher pressure in the plenum and ducts than in the regulated and nonregulated areas (i.e., 1.0 in. WG positive in the plenum, 0.05 to 0.1 in. WG positive in the nonregulated areas, and 0.05 to 0.15 in. WG negative in the regulated areas).

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Ventilation system 4 is instrumented so that it can fulfill these four requirements under normal, abnormal, standby, and shutdown laboratory or PUREX operating modes.

5.4.1.4.3 Operating Characteristics (Approximate). The operating characteristics for ventilation system 4 are given in Table 5-11.

5.4.1.4.4 System Control. Ventilation system 4 maintains pressure levels, airflow rates, and airflow patterns that prevent escape or release of airborne radioactive contamination from the contaminated areas (laboratory hoods) to the worker-occupied areas or to the environment. Both manual and automatic control devices are used to achieve this objective. Ventilation in those nonregulated areas that exhaust directly to the PUREX laboratory environs is controlled independently of the regulated areas.

Airlocks at each PUREX laboratory access prevent excessive interchange of air between the laboratory and the surroundings, and prevent excessive disturbance of the laboratory pressure level whenever a laboratory entrance or exit is made. Air lock 3 is at the west end of the laboratory corridor (the access from the storage area); air lock 4 is at the access from loading dock 6; air lock 7 is at the access from the P&O gallery; air lock 8 is the main laboratory entrance (see Fig. 5-17). These laboratory accesses interface with nonregulated laboratory areas, so that the potential for escape of airborne radioactivity through the air locks is negligible. In addition, access to the main laboratory corridor from each change room is through air lock 6. This air lock maintains the pressure differential between the main laboratory corridor and the rooms on the high-pressure side of the air lock (i.e., the change rooms, lunchroom, and lavatories), and further reduces the already low risk of airborne contamination in the rooms on the high-pressure side of the airlocks.

The primary ventilation system 4 airflow circuit is from the supply fans (SF-4 and SF-4A) through the supply air plenum to the nonregulated areas, most of which exhaust through doorways into the laboratory corridor. From the corridor, the air flows through doorways to the regulated areas (hot laboratories) and from there via air ducts through HEPA filters, the exhaust air plenum, the exhaust fans (EF4-1 and -2) and the exhaust stacks (296-A-5A and -5B) to the atmosphere. In addition, some air flows directly to each regulated area from the supply air plenum through air ducts. There are manual dampers in all inlet air ducts to the regulated areas, except for those through which air flows to hot laboratories 4 and 6. This circuit is controlled as follows.

- The driving force for maintaining a comparatively constant airflow through the laboratory is a DP between the supply and exhaust air plenums of about 4.0 in. WG. Two pneumatic, recording pressure controllers located on the graphic panel board in the power control room are used to maintain this pressure difference. One of these controllers automatically maintains constant air pressure in the inlet air plenum. It does so by varying the openings of dampers located at the inlets to the supply air fans in response to variations in the output from the supply air plenum pressure sensor.

TABLE 5-11. Ventilation System 4--Typical Operating Characteristics.

Pressure levels	
Service	**Inches of water**
Supply plenum (positive)	0.7
Nonregulated areas (positive)	0.1 to 0.2
Regulated areas (vacuum)	0.1 ± 0.05 Zone 3 0.2 ± 0.05 Zone 2
Exhaust plenum (vacuum)	1.8 min
Counting room	Ambient atmosphere pressure
DP across HEPA filters:	
Normal	1.5 to 3.5
Maximum	4.0

Airflow[a,b]	
Service	**ft^3/min**
Nonregulated area supply	13,250
Hot laboratory 2	2,300
Hot laboratory 3	3,000
Personnel decontamination room	150
Sample storage	100
Change rooms	3,100
Lunchroom, restrooms, and lobbies	1,400
Air locks	300
Ventilation equipment room	2,900
Regulated area supply	14,450
Hot laboratory 1	3,750
Hot laboratory 4	2,500
Hot laboratory 5	2,000
Hot laboratory 6	2,500
Decontamination room	2,500
Counting room makeup	100
Sample receiving	700
Stairwells	400
Total system flow	27,700

Temperature levels	
Time period	**Temperature**
Winter	65°F to 70°F
Summer	As obtainable by evaporative cooling
Minimum preheater air outlet temperature	45°F ± 2°F

[a]One supply fan and one regulated area exhaust fan operating.

[b]The minimum inlet velocity for open-faced hoods is 125 ft/min.

Similarly, the other pressure controller automatically maintains the exhaust air plenum pressure by varying the openings in the exhaust air from inlet dampers in response to variations in the output from the exhaust plenum pressure sensor. Normally, the inlet plenum pressure controller is set for a positive 1.0 in. WG pressure and the exhaust plenum pressure controller for 3.0 in. vacuum. These controls are designed to maintain the set point pressures plus or minus 0.3 in. WG.

- Airflow distribution through this circuit ensures that all areas are adequately ventilated and maintenance of correct pressures for contamination control are achieved by setting manual dampers in the inlet air ducts to both regulated and nonregulated areas.The functional locations of these dampers are shown in Figure 5-30.

- Airflow control through the regulated areas is discussed briefly in Section 5.4.1.4.1. Reasonably constant airflows are maintained through the decontamination laboratory and hot laboratories 1, 2, 3, and 5 (see Section 5.4.1.4.1).

Some ventilation air leaves each of these laboratory areas through the "room exhaust ducts" (Fig. 5-31). The balance of the air flows through laboratory hoods (there are several hoods in each laboratory) and leaves through individual "hood exhaust ducts." All of the exhaust ducts (room exhaust plus hood exhaust) from each area discharge into a "common duct" (one common duct for each regulated area). All of the ventilation exhaust air from these regulated areas flows through HEPA filters installed in the common ducts. Constant flow rates are automatically maintained in the common ducts, and consequently through the regulated areas. Flow-indicating controllers cause openings in pneumatically operated, louvered dampers (located in the room exhaust ducts) to increase or decrease whenever flow sensors detect changes in the airflow through the common ducts. Thus, changes in the hood exhaust airflow resulting from the opening or closing of hoods is automatically compensated by changes in the flow through the room exhaust ducts. The set points on the flow-indicating controllers represent the desired flow through each of these regulated areas. Approximate flows through these areas are given in Table 5-11.

The flow-indicating controllers are monitored to assure there is always adequate airflow through each laboratory. Low-flow alarms are located in the normally occupied power control room.

There are manual dampers in each hood exhaust duct and also downstream of each HEPA filter (in the common ducts). The hood exhaust dampers are set to make sure that inlet air velocity through all hood openings is at least 125 ft/min, the minimum velocity for avoiding airborne contamination of the laboratory rooms by preventing eddy current or reverse airflows through the hood openings. The manual dampers in series with the HEPA filters are used to maintain constant airflow resistance in the common ducts. The openings of these dampers must be increased from time to time to compensate for increases in filter resistances caused by deposition of particulate matter

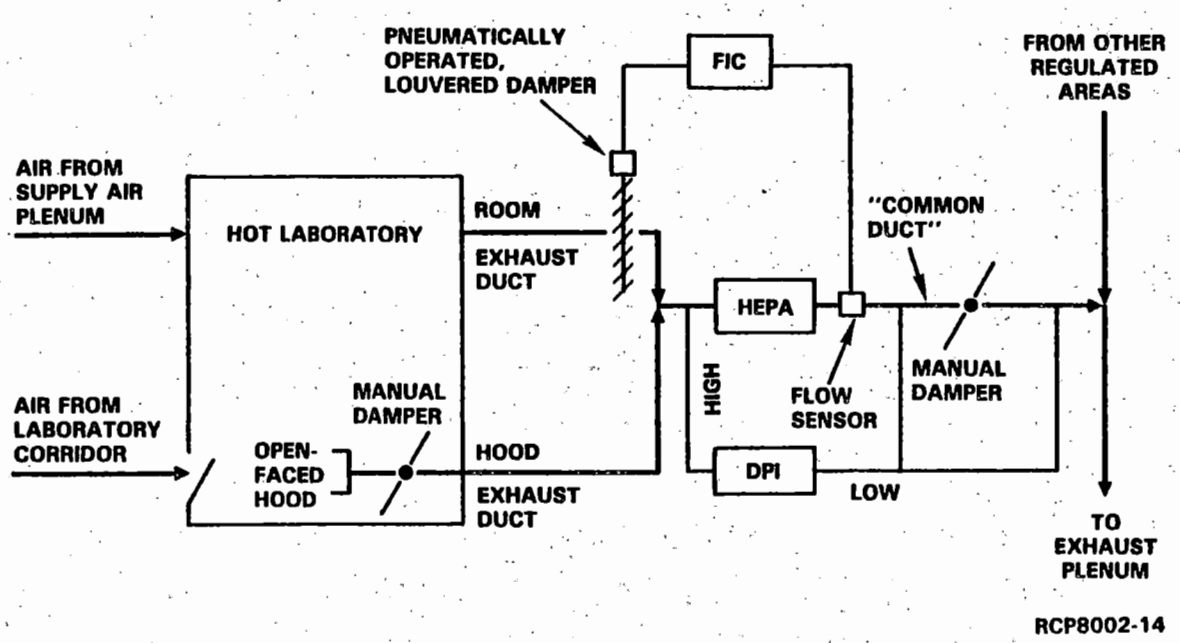

FIGURE 5-31. Room Exhaust Ducts--Laboratory.

on the filters. There are DP indicators around each filter so that the filter resistances can be monitored periodically. These filters are replaced before the resistances become large enough to restrict airflow through the common ducts when the dampers are wide open.

In ventilation system 4, the laboratory hoods are the primary source from which airborne radioactivity can escape into the worker-occupied areas of the laboratories. Since these hoods are open faced and because the room and hood exhaust ducts join together without intervening HEPA filtration, the exhaust plenum vacuum is maintained at all times.

There are three unfiltered ventilation system 4 air releases. These releases are from nonregulated areas that are physically isolated from the regulated areas. Except for the ventilation equipment room, the potential for environmental contamination via these releases is negligible. The precautions for containing contamination are developed in the following paragraphs. The areas exhausting ventilation air via these three nonfiltered release systems follow:

- Air locks 3, 7, and 8
- The lunchroom and both lavatories
- Both change rooms and the ventilation equipment room.

Air locks 3, 7, and 8 are supplied, via air ducts, from the supply air plenum. The air pressure in these air locks is somewhat higher than it is just outside of each door. When the doors are closed, a small amount of air continuously leaks out around each door. Although a significantly larger amount of air flows out of these air locks for the short time when a door is opened, the amount of air flowing though each air lock is very small (see Table 5-11) and limited. The amount of air available to each of these air locks is established by setting manual dampers in the inlet ducts. These dampers are reset, if necessary, whenever the ventilation system is balanced. Air is not ducted from the supply air plenum directly to air lock 4, the access to and from loading dock 6. A very small amount of air can flow from the atmosphere into the air lock when the outer door is opened and from the air lock to the nonregulated corridor when the inner door is opened.

Fan EF-4-3 exhausts unfiltered ventilation air to the atmosphere from the lunchroom and lavatories. Physical isolation of these rooms from the regulated laboratory areas makes the potential for airborne contamination in these areas so low that HEPA filtration of the exhaust ventilation air is unnecessary. Access to the regulated areas from the lunchroom and lavatories is through the change room and air locks. Fan EF-4-3 is located in the women's lavatory. The supply air plenum pressure is always maintained high enough to make sure that air does not reverse from the regulated areas to the lunchroom and lavatories through this plenum and the supply air distribution ducts.

The ventilation equipment room, in which ventilation system 4 equipment is installed, is a large room above the PUREX laboratory. Its entrance is at the top of the stairs in the men's change room (see Fig. 5-17). Equipment located in this room includes: seven hot laboratory exhaust HEPA filters; an exhaust plenum, exhaust fans EF-4-1, -2, -4, -5, and -6; booster fans BSF-2 and -3, counting room air conditioners, and supply fans SF-4 and -4A. The room is supplied with ventilation air from two sources: the exhaust from both change rooms and the supply air plenum. A remotely controlled, pneumatically operated, louvered damper in the change room exhaust duct is set to maintain slightly positive change room pressures for airborne contamination prevention while allowing an adequate flow of air through the change rooms for proper ventilation. A similar damper in the duct from the supply air plenum restricts airflow from this source to the incremental amount needed to satisfy the ventilation requirements of the equipment room. Downstream of these dampers, booster fans BSF-2 and -3 elevate the supply air pressure sufficiently to ensure that the ventilation room pressure can be maintained slightly higher than the pressure within the HEPA filter enclosures. The HEPA filters and inlet ducts are the only sources of significant potential for airborne contamination in the ventilation equipment room. These filters are installed in sealed enclosures, and the contaminated interiors are maintained under slight vacuum by exhaust fans EF-4-1 and -2. The ventilation room pressures must always be slightly higher than the pressure within the HEPA filter enclosures to ensure that air leakage will always be from the room into the filters. Three roof fans (EF-4-4, -5, and -6) exhaust the ventilation air unfiltered from the equipment room to the atmosphere. These fans are not capable of creating as much suction vacuum as the regulated area exhaust fans (EF-4-1 and -2).

5.4.1.4.5 Ventilation System 4 Interlocks. Similar to ventilation systems 1 and 2, the ventilation system 4 operating equipment, control devices, and instrumentation are also interlocked, permitting only those operating modes that effectively ventilate the PUREX laboratory and that prevent release or escape of ventilation air contaminated with particulate radioactivity. The following sections provide an understanding of the possible operating modes, the interlock systems, and the status of the ventilation equipment and components in each mode.

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- Supply Air System

1. If neither supply fan (SF-4 or SF-4A) is operating:

   a. The isolation dampers for both fans are open

   b. The control dampers for each fan respond to signals from the supply air plenum pressure controller, finally moving to the open position as the plenum pressure dissipates

   c. Steam flows to the inlet air preheaters, but not to the spray-water heaters

   d. The spray-water pumps (SP-4 and SP-4A) operate to provide additional cleansing of any inlet air or airborne dust that would necessarily deposit on the HEPA filters downstream of the laboratory hoods

   e. At least one main exhaust fan (EF-4-1 or EF-4-2) will be operating.

2. One supply fan (SF-4 or SF-4A) is operating:

   a. The nonoperating fan isolation dampers are closed to prevent the operating fan from discharging air to the atmosphere through the nonoperating fan. Normally, this is the only time that supply fan isolation dampers are closed

   b. The operating supply fan control damper responds to signals from the supply air plenum pressure controller, maintaining 1.0 $\pm$ 0.3 in. WG pressure in the plenum

   c. Steam flows to the inlet air preheater and spray-water heater on the operating fan

   d. The spray-water pump on the operating fan will operate

   e. At least one main exhaust fan (EF-4-1 or -2) will be operating.

3. Both supply fans (SF-4 and SF-4A) are operating. (Normally, electrical interlocks prevent both supply fans from operating simultaneously. There is, however, a manual bypass switch on the graphic panel board for avoiding this restriction. Administratively, simultaneous operation of both supply fans requires proper authorization and approved special procedures):

   a. The isolation dampers to both fans are open

   b. The control dampers respond to signals from the supply air plenum pressure controller, maintaining 1.0 ± 0.03 in. WG pressure in the plenum

   c. Steam flows to the inlet air preheaters and spray-water heaters on both fans

   d. The spray-water pumps on both fans will be operating

   e. Both exhaust fans (EF-4-1 and -2) will be operating.

- Exhaust Air System

There are six ventilation system 4 exhaust fans. Most of the ventilation system 4 air flows through the regulated areas and is exhausted by fans EF-4-1 and -2. These two fans are regarded as the main or primary exhaust fans for this system with capacities (about 21,500 ft^3/min each) much larger than those of the other four exhaust fans. Fan EF-4-3 is a small fan (about 1,900 ft^3/min) that exhausts clean, unfiltered air from the laboratories and lunchroom. Fans EF-4-4, -5, and -6 are small roof fans (about 2,400 ft^3/min each) that exhaust clean, unfiltered air from the equipment ventilation room.

A 3.0 ± 0.3 in. WG vacuum is automatically maintained in the exhaust plenum. This vacuum, developed by the suction action of the main exhaust fans, is the vacuum source for controlling airflow and airborne contamination in the ventilation system 4 regulated areas. Therefore, at least one main exhaust fan is in operation at all times.

1. If neither main exhaust fan is operating:

   a. Ventilation system 4 will be shut down

   b. The supply fans (SF-4 and -4A) will be idle. Electrical interlocks prevent the supply fans from operating unless at least one main exhaust fan is in operation

c. The isolation and flow-control dampers for both supply fans and for both main exhaust fans will be open

d. The supply air and exhaust air plenums will both be at atmospheric pressure

e. The booster fans (BSF-2 and -3) and the lavatory exhaust fan (EF-4-3) will be idle. The booster fan suction dampers will be closed.

2. If one main exhaust fan is operating:

a. The isolation dampers of the operating exhaust fan will be open and the control damper (suction side of the fan) will seek (in response to signals from the exhaust plenum pressure controller) to maintain 3.0 in. WG vacuum in the exhaust plenum

b. The idle fan isolation dampers will be closed. Otherwise, the flow of air into the exhaust plenum through the idle exhaust fan and its exhaust stack (296-A-5A or 296-A-5B) may prevent the operating fan from maintaining the exhaust plenum vacuum

c. The standby electrical power system will automatically supply the operating exhaust fan, should the primary power system fail. Return to the primary electrical system for power is automatic, once it is restored to service.

3. If both exhaust fans are operating:

a. An electrical switch on the graphic panel board must be positioned for overriding the electrical interlock, which prevents simultaneous operation of the main exhaust fans

b. The isolation dampers for both exhaust fans will be open and both control dampers will be responding to the exhaust plenum pressure-controller signals

c. The standby electrical power system automatically supplies both of the main exhaust fans should the primary electrical power system fail. The fans automatically return to the primary power source once it is returned to service.

4. Booster fans (BSF-2 and -3):

a. The booster fans will not operate unless the supply air plenum pressure is at least 0.6 in. WG

b. The booster fans will stop if the instrument air system fails

c. The automatic booster-fan suction dampers are closed when the booster fans are not operating.

5. Lavatory exhaust fan (EF-4-3):

The lavatory exhaust fan will not operate unless at least one booster fan is operating. This prevents the lavatory fan from causing airflow from the change room to the lunchroom and lavatories.

- Abnormal Event or Upset Condition Operation--Electrical Power Failure

1. The supply fans will not operate.

2. The supply isolation dampers will be open.

3. The supply control dampers will become wide open when the supply air plenum pressure becomes low enough.

4. Steam will flow to the preheaters.

5. The washer-humidifiers (water pump and heater) will not be operating.

6. The main exhaust fans (EF-4-1 and -2) will automatically operate on standby power and continue in the same mode as before the power failure.

7. Exhaust controls and isolation dampers will continue as before the failure.

8. All other exhaust fans and booster supply fans will not operate.

9. If the standby electrical power system also fails, the ventilation system will assume the same status as described below.

- Abnormal Event or Upset Condition Operation--Instrument Air Failure

1. No fans (supply or exhaust) will be operating.

2. The isolation and control dampers for the supply fans and the main exhaust fans (EF-4-1 and -2) will be open; the booster-fan suction dampers will be closed.

3. The supply air and the exhaust plenums will be at atmospheric pressure.

4. The fan motor and freon compressor for the counting room air conditioning units will be off; the automatic dampers in the makeup duct, return air duct, and fan discharge of the air conditioning units will be closed.

5.4.2 Electrical

5.4.2.1 Major Components and Operating Characteristics. Normal electrical power to the PUREX Plant is obtained from the Northwest Power Pool at the 251-W substation that is located about 4 mi to the northwest of the PUREX Plant area. The 251-W substation is supplied by the Midway Substation at Vernita, Washington and by the White Bluffs Substation near Horn Rapids by 230-kV overhead lines equipped with static wire protection. Power is, thus, provided from two sources, with either line capable of providing the necessary power demand. The 230-kV power is reduced to 13.8 kV by two separate transformers, rated at 18.75 and 15 MVA with either transformer capable of carrying the entire 200 Areas' demand load (20 MVA) for a limited period of time (2 to 3 d).

Electric power from the 251-W substation to the PUREX Plant switching station is transmitted by two independent 13-kV overhead lines. If one line is inoperative, the load is switched in the PUREX Plant by the 2,400-V switchgear. Other 13.8-kV lines can be switched to carry the PUREX load, should the need arise. The 2,400-V standby power supply is described in Section 5.4.2.2.

The distribution of electrical lines at the PUREX Plant is shown in Figure 5-32. Power from the switching station is supplied via two, 13.8-kV lines which run underground to two, 3.75-MVA, 13.8/2.4-kV transformers at the northeast end of the 202-A building. One of these transformers is capable of carrying the total load for PUREX. Each transformer supplies power at 2,400 V to one of the main buses. The two systems are interlocked so that a failure of one of the supplies will activate circuit breakers connecting the two systems. The number 2 bus is normally tied to the standby (emergency) bus and provides power to a few key loads through it. The standby bus is energized by the diesel generators if the normal power supply is lost. The standby generator programmable controller starts the generators and switches to standby power only after the normal power has had time to isolate one feeder and close the bus tie, a delay of 3 s. Figure 5-33 is a typical, one-line, electrical distribution system diagram for the PUREX Plant; details of the system are available in Drawing H-2-54350.

Some equipment, such as the exhaust fans for ventilation system 1, are powered directly from the 2.4-kV buses. Generally, lower voltage loads in the west half of the building are powered through the west switchgear room and in the east half through the east switchgear room. Each 2.4-kV bus supplies power to a 2,400/480-V transformer at each switchgear room, which, in turn, energizes a 480-V bus. Each switchgear room has two 480-V buses, energized by separate transformers, that can be interconnected if the power supply to one fails. Key electrical loads in either half of the building are connected to a common bus, the west (or east) 480-V backup bus, which is

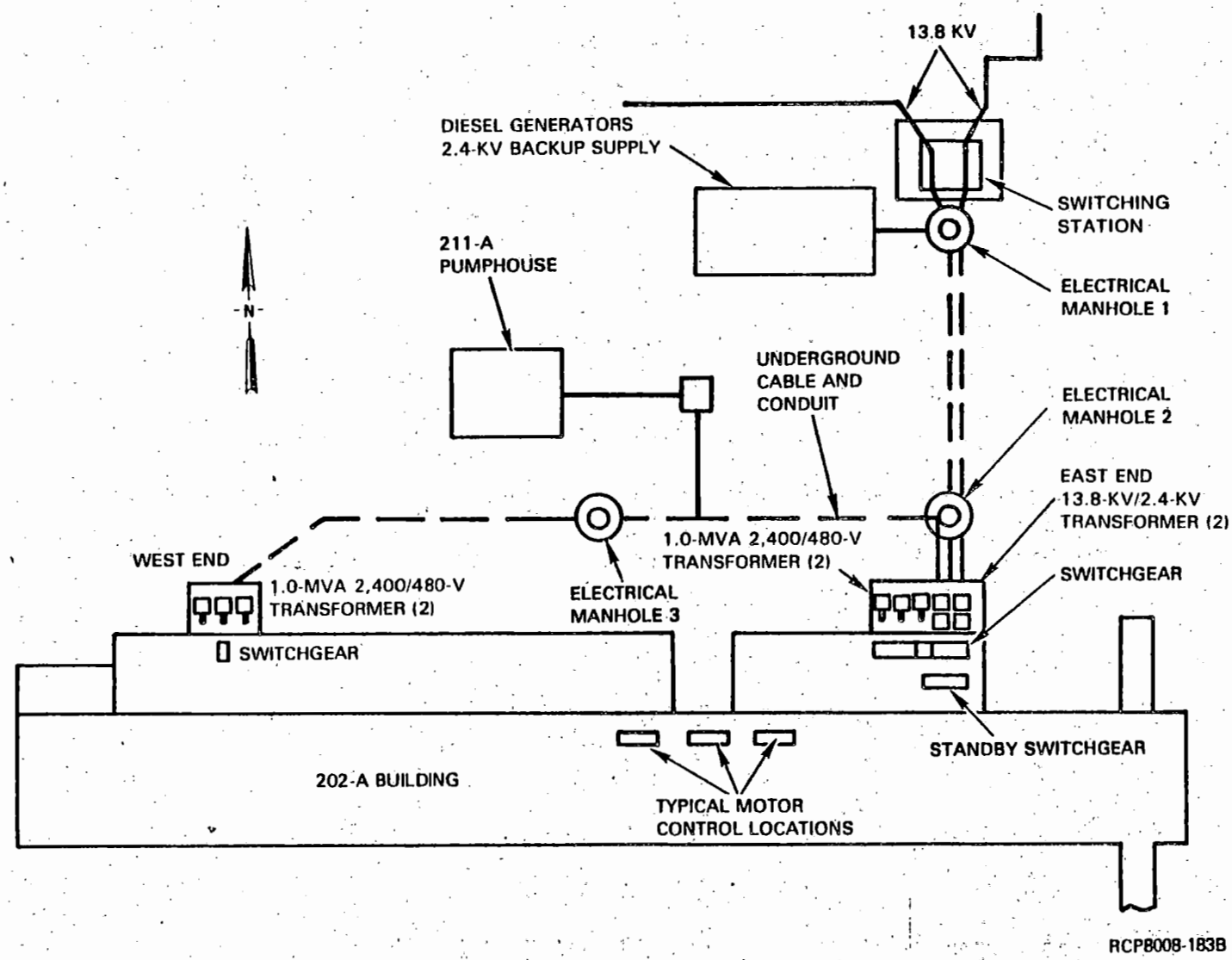

FIGURE 5-32. Physical Layout of the Electrical Power Transmission Lines at PUREX Plant.

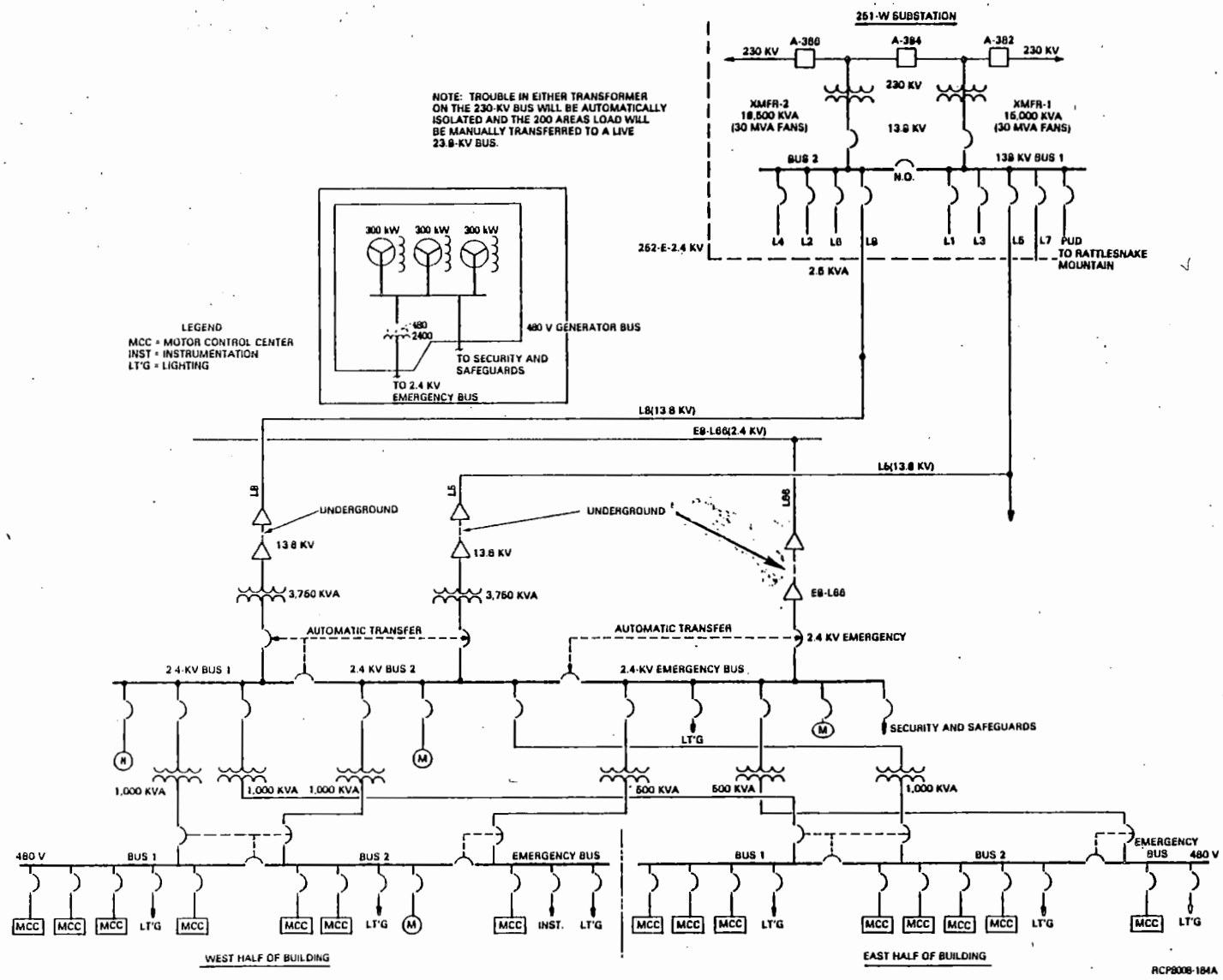

FIGURE 5-33. Typical One-Line Electrical Diagram.

routinely energized by the corresponding number 2 480-V bus. If the normal power supply is lost, the two 480-V backup buses are energized by the 2.4-kV/backup/bus through 0.5-MVA, 2,400/480-V transformers in each switchgear room.

Distribution to electrical apparatus from the 480-V system is through MCC located throughout the building as close to loads as possible.

5.4.2.2 Safety Considerations and Controls. Standby power is available from diesel generators at PUREX.

If the normal power supply to the 284-E 2.4-kV bus fails, an electrical outage of about 15 s will occur until the diesel generators reach full load speed, at which time the backup circuits are automatically reenergized. Batteries, located in the battery room, supply power for transferring the switchgear to the backup supply during the 15-s outage.

Three 375-kW generators provide backup power to PUREX. Two generators will supply the necessary power to maintain the plant in a safe status if normal power is lost. The third generator will be in standby. The generators supply electric power at 480 V to a bus that distributes power to the security and safeguards systems and, through a 480/2,400-V step-up transformer to the 2.4-kV backup bus.

About 20% of the building lighting, all the perimeter lighting, and the instrument power panels are connected to the backup power system. In addition to this load, motors in ventilation and agitation service, totalling a connected load of 435 hp, are supplied from the backup electrical system.

The backup circuits are listed as below.

- From the backup generator 480-V bus:
  - Security and safeguards system
  - Step-up transformer T1, 480/2,400 V.
- From the 2.4-kV backup bus-bar:
  - Fence and lighting
  - Plant air compressors (one of two)
  - East 480-V backup bus (via 2,400/480-V transformer)
  - West 480-V backup bus (via 2,400/480-V transformer).
- From the east 480-V backup bus:
  - East sample gallery hood exhaust fan
  - Laboratory exhaust fans (one of two)
  - Breathing air compressor
  - Lighting
  - Instrument power

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- Agitator A-F16, A-U5, A-U7
- 216-A-42 diversion facility MOV
- Pumps P-U5-1, P-U5-2, P-U8-1, and P-U8-2.

- From the west 480-V backup bus:

  - West sample gallery hood exhaust fan
  - PR room exhaust fan (one of two)
  - Air sampling vacuum pumps (one of two)
  - Lighting
  - Instrument power
  - Pump P-R5-1
  - White room exhaust fan.

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5.4.3 Compressed Air

The compressed air requirements of the PUREX facility are supplied by three separate compressed air systems. Descriptions of the compressed air systems follow (Fig. 5-34).

- Process/Instrument Air System

  This system supplies compressed air for two functions. Process compressed air requirements are for air jets, the jet air blow system, process coil purging, air sparger systems, air-operated tools, etc. Instrument air requirements are for pneumatic signal transmission, purge air in instrumentation, air motor controls on ventilation equipment and for specialized calibration requirements.

- Breathing Air System

  This is a special system for the distribution of clean air for regulation and use in breathing air masks. The areas of service are the sample gallery, laboratory, N cell, railroad tunnel, decontamination cell, hot shop, PR room, 276-A building, crane maintenance platform, acid storage vault, canyon area, and laboratory ventilation equipment room.

- Oxide Line Compressed Air System (Dry)

  This system supplies compressed air to N cell for use as forced ventilation of the gloveboxes. A separate system was dedicated to the oxide line due to the low moisture requirements of the materials handled in the gloveboxes.

5.4.3.1 Major Components and Operating Characteristics.

- Process/Instrument Air System

  Compressed air is supplied by three oil-lubricated, water-cooled, single-stage enclosed-package rotary-screw compressors. The compressors have a rated capacity of 1240 ACFM.

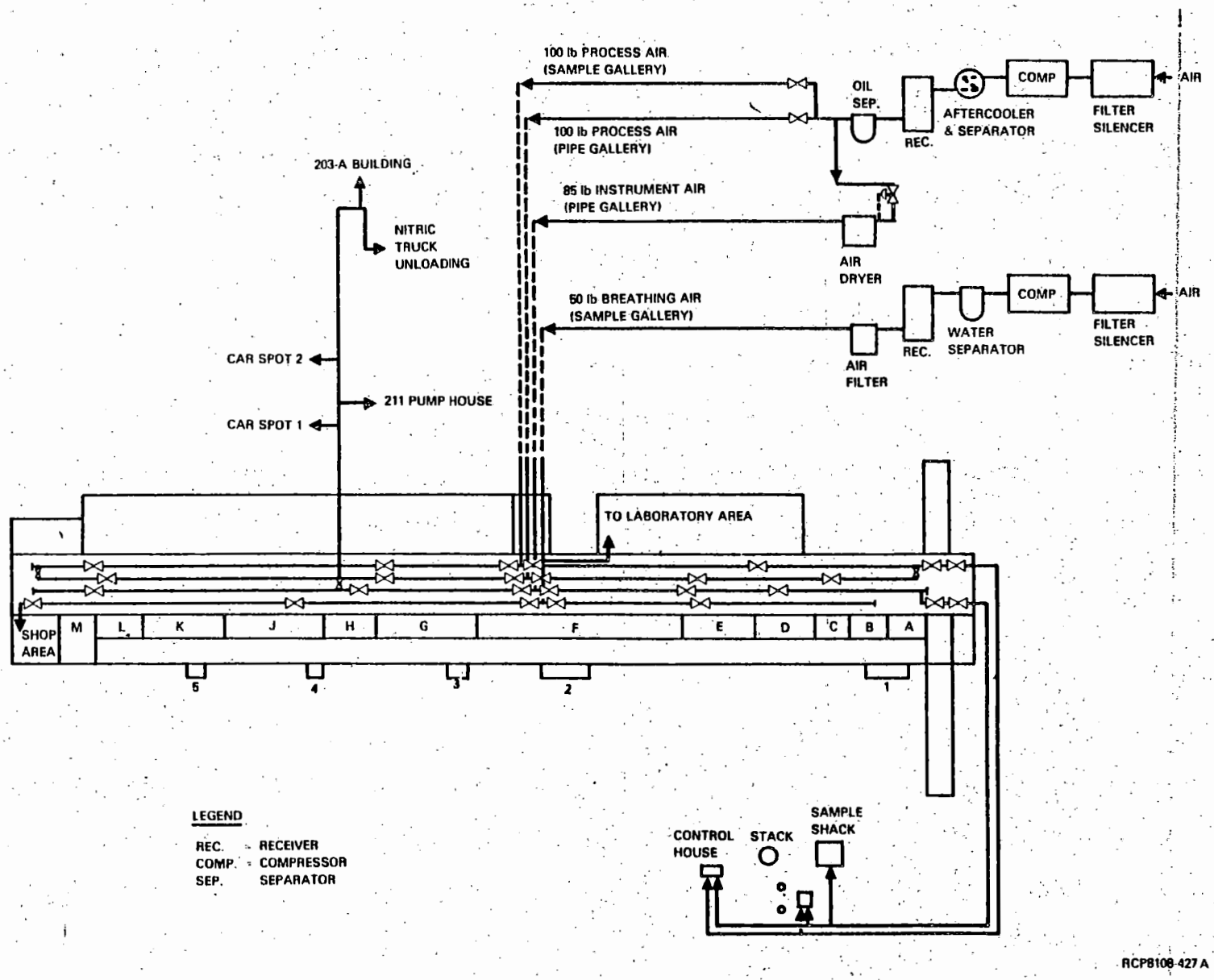


FIGURE 5-34. Schematic of Process, Instrument, and Breathing Air Headers--202-A Building.

The compressors are operated in a lead-lag-standby mode. The three compressors are interlocked so that each compressor operates or modulates on plant demand. One of the three compressors is designated as the lead compressor, one is designated as the lag compressor and one is in standby. The lag compressor is idling, but does not compress air until the lead compressor is operating at 100%. Pressure switches in the receiving tanks load and unload the compressors as plant demand requires.

Three 10-in. lines supply filtered outside air to the process/instrument air compressors. Filtration is accomplished by drawing the outside air through an oil filter/silencer. In addition to the oil filter/silencer, each compressor filters intake air with a dry filter capable of removing 99.9% of all particles greater than 10 μm in diameter.

Air flows from the process/instrument air compressor to an aftercooler and into a receiving tank. From the air receiving tank, compressed air flows to two oil separator tanks to remove entrained and vaporized oil. Process air is supplied at 100 lb/in.^{2} g to a 6-in. line that serves the P&O gallery and a 4-in. line that serves the sample gallery. These headers run the length of the respective galleries with numerous subheaders and feeders.

Compressed air to be used as instrument air flows from the oil separator tanks to a PRV station. At the PRV station 100 lb/in.^{2} g air is reduced to 85 lb/in.^{2} g. From the PRV station, the air passes through an oil filter and into the instrument air receiving tank. A pressure sensing device on the instrument air receiving tank is interlocked with a diaphragm-operated valve (DOV) to control the downstream pressure. Pressure indicators and low pressure alarms are located in the power, central, and headend control rooms.

From the receiving tank, the air goes to a refrigerated liquid-to-air, water-cooled air dryer. The maximum inlet temperature is 110°F and the air is dried to a maximum of 35°F dew point. After leaving the dryer, the air goes into a 4-in. header that branches into two 3-in. headers in the P&O gallery. Several 1/2-in. lines drop off these main headers to service the instrument racks in the P&O gallery. Several subheaders furnish instrument air to heating and ventilating controls; 291-A control house; headend, power, and central control rooms; instrument shop; test benches; PR room instrumentation; N cell; sample gallery; storage gallery; AMU; 203-A; and 211-A.

- <u>Breathing Air System</u>

Breathing air is supplied by an oil lubricated single stage, enclosed package rotary screw air compressor. The breathing air compressor is rated at 190 actual ft^3/min at 125 lb/in.^{2}.

Air supply to the breathing air compressor is drawn from inside the compressor room. The air intake filter is a dry type with 99.9% removal of particles 10 μm or greater in diameter. Each breathing air compressor has a filter package capable of delivering Compressed Gas Association Bulletin 7.1 Grade E breathing air.[14] The filter package consists of a prefilter and two activated charcoal filters. The prefilter removes particles greater than 5 μm in diameter. The activated charcoal filters remove odors and converts carbon monoxide to carbon dioxide.

Breathing air is monitored for carbon monoxide greater than 5 ppm. Concentrations greater than 10 ppm activate alarms in the power control room and dispatcher's office.

Breathing air passes from the compressors through a water separator and into the breathing air receiver tank. A pressure-sensing device on the tank operates the compressor motor if the motor is in the automatic mode. The pressure signal also regulates a DOV on the compressor air recycle, so that the downstream pressure is controlled. If the pressure in the receiving tank falls below a set point, an audio-visual alarm activates in the dispatcher's office and power control room.

After leaving the tank, the air passes through another filter and into a 3-in. header that branches into two other headers in the P&O gallery. One branch is a 2-in. header that supplies the laboratory areas. The other branch is a 2-in. header that supplies the P&O gallery. The main header continues to the sample gallery, where it branches to two other headers: the west branch is 2 in. and the east branch is 1 1/2 in.

The header that goes to the hot laboratories also has service drops in the ventilation equipment room and decontamination and storage cell, as well as each hot laboratory. The P&O gallery header has manifolds with quick-disconnect fittings throughout the gallery. One line serves the east craneway. The sample gallery header also services U cell, R cell, N cell, Q cell, L cell, the PR room, and the hot shop.

- <u>Oxide Line Compressed Air System</u>

Compressed air is supplied by two electric-powered, oil-lubricated, water-cooled, enclosed-package, rotary-screw compressors manufactured by Sull Air Co. The compressors and associated equipment are located in building 2711-A on the southwest end of the 202-A building. Each compressor is rated at 285 ft^3/min at 100 $lb/in.^2$.

The compressors are operated in an "on standby" mode. During normal operation one compressor is operating and the second is in a standby mode. Low header air pressure automatically starts the standby compressor. The compressors do not have standby electrical power.

Supply air to the compressors is modulated with compressed air demand. Prefilters remove oil and moisture from the supply air. Once compressed, the air passes through an after-filter into one of two air dryers. Each dryer consists of two parallel columns packed with alumina for moisture removal. One column of alumina drys the air and the other column regenerates dry alumina every 10 min. The columns are alternated between drying and regeneration. The dryers supply air at -40°F dew point. From the dryers the air fills the compressed air receiver and passes into the main supply header.

Most of the compressed air is supplied at 100 lb/in.^{2} for use as forced ventilation of the N cell gloveboxes. A PRV station supplies a header with 20 lb/in.^{2} air for use as instrument air to piston-operated valves (POV). These POV fail in the safe position in response to an instrument air loss.

5.4.3.2 Safety Consideration and Controls. Standby electrical power for one of the air compressors is automatically supplied by three 300-kW diesel generators located at 202-A building.

The breathing air system requires assurance that it can provide clean breathing air with good reliability. The air is monitored for carbon monoxide concentrations greater than 5 ppm. Alarms sound in the power control room and dispatcher's office for concentrations greater than 10 ppm carbon monoxide.

5.4.4 Steam Supply and Distribution

Steam used in the 200 East Area is produced in the 284-E powerhouse by three 80,000-lb/h and two 90,000-lb/h automatic stoker-fired boilers at 250 lb/in.^{2}. Each facility anticipating a significant increase in steam usage must notify powerhouse personnel 4 h in advance to enable the necessary boilers to be placed in operation to meet the demand. Under maximum steam demand conditions, one boiler is available on a standby basis. The coal feeder drive is equipped with both electric and steam drives. The boiler feed water is monitored and sounds an alarm in the event of low water pressure. A manually operated emergency water supply is available to prevent boiler tube damage. Steam produced in this building is also available to operate an automatic starting, steam turbine-driven, 750-kW generator located in the 284-E powerhouse. This generator provides standby electrical to 200 East Area facilities other than PUREX.

5.4.4.1 Major Components and Operating Characteristics. The 284-E powerhouse supplies 225 lb/in.^{2} g steam (superheated to 450°F) to an 18-in. overground line. Steam enters the PUREX building at three points via an aboveground header system. The north loop is an 8-in. line that enters the building at the service blower room to supply steam service for building ventilation and heating requirements. This loop also supplies the 203-A, 211-A, and AR vault areas prior to entering the building.

The south loop is a 16-in. line that branches into two 14-in. lines near the west end of the building. One branch enters the building at the west PRV station. The other branch supplies steam service to the 291-A, 212-A, and 201-A storage tank areas prior to entering the building at the east PRV station.

A 2-in. line connects the east PRV station to the service blower room station, which supplies 225-lb/in.^{2} g steam service for the silver reactors and heaters in the dissolver (A, B, C cells) and F cells.

With the exception of the 2-in. high-pressure line supplying steam to the canyon silver reactors, all distribution of steam within the process building is at 100 or 25 lb/in.^{2} g. The PRV stations are located at each end of the P&O gallery (Fig. 5-35). These stations are sized so that either can supply the entire demand load. The two PRV stations are connected by a 16-in. header in 100-lb/in.^{2} g service and a 2-in. header in 25-lb/in.^{2} g service, which supply steam to the cells and service areas.

Steam at 100 lb/in.^{2} g is used for process transfer jets. Steam to concentrators passes through local PRV and is used in the canyon at 29 lb/in.^{2} g (39 lb/in.^{2} g on acid concentrators and fractionators).

The 25-lb steam service header supplies low-pressure steam to ventilation zone reheaters, canyon spargers, and canyon and gallery service "drops" for steam cleaner service.

Isolation valves are installed throughout the steam distribution header system for system isolation, with minimum process shutdown, during periods of header maintenance.

5.4.4.2 Safety Considerations and Controls. High-pressure (225 lb/in.^{2} g) steam to the 291-A exhaust turbine is supplied by the mentioned 14-in. line to the 291-A area.

The 291-A exhaust turbine and the DOG heaters have first priority on high-pressure steam. This priority is accomplished by controllers in the east and west PRV stations, which maintain a minimum pressure of 185 lb/in.^{2} g in the north and south loops outside the building at the expense of the process requirements. This system is used to maintain the turbine at maximum speed and to maintain continuity of the silver reactor offgas treatment during emergency periods without unduly overloading the powerhouse facilities.

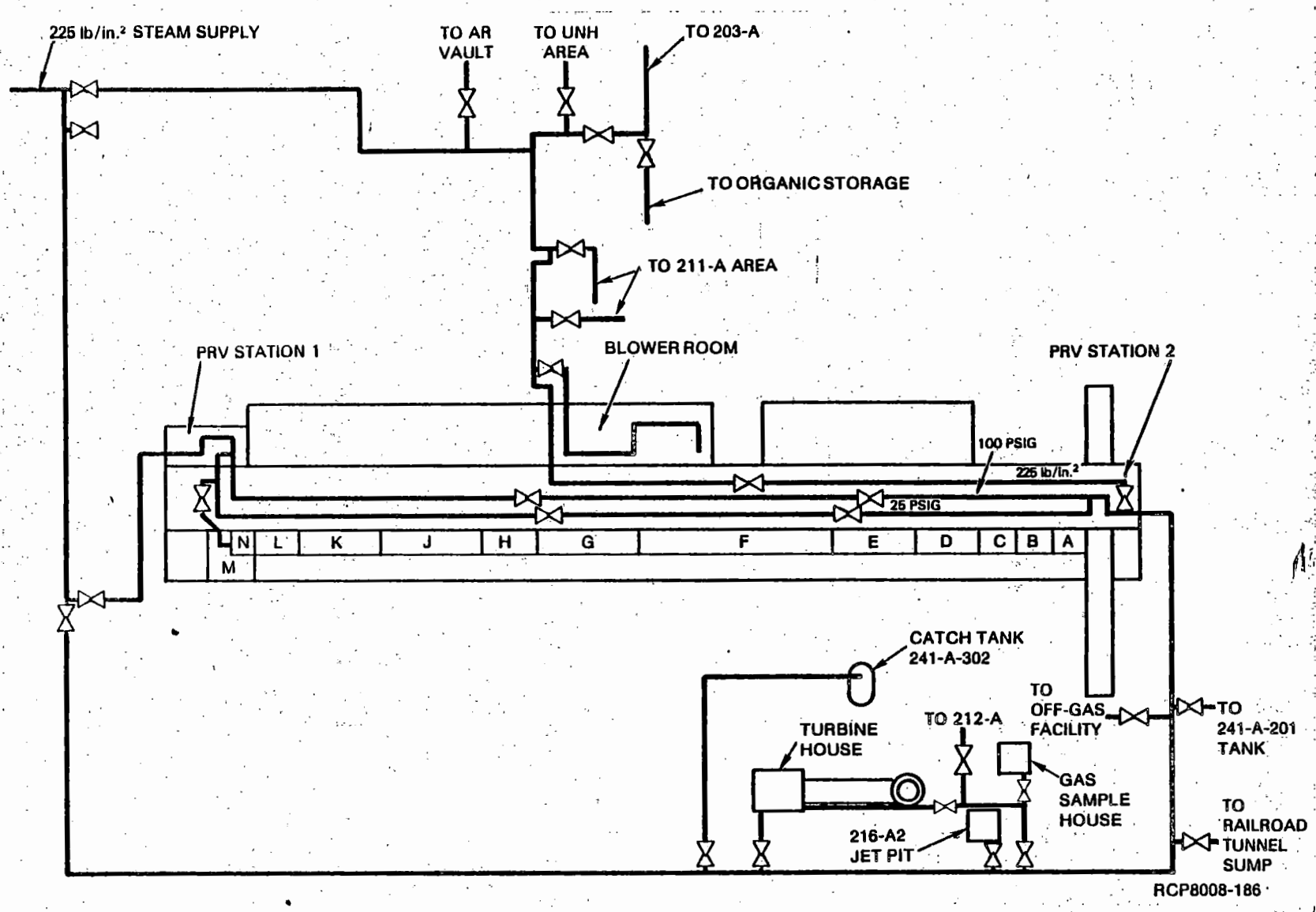


FIGURE 5-35. Schematic of Steam Header System--202-A Building.

The main steam supply for the PUREX Plant buildings (inside) is controlled by two steam stations: one at the east end of the P&O gallery and the other located over R cell. Both stations have automatic controllers that regulate DOVs to maintain desired pressure in the medium steam header. It is necessary that one of the steam stations be placed on manual control so the steam load can be distributed between the two stations. The east end steam station controls (Fig. 5-36) permit manual control yet, at the same time, have the advantage of automatically switching to the controller, if necessary. In case of building shutdown, this station would be placed on automatic control. This allows the controller to control header pressure.

5.4.5 Water Systems

The PUREX Plant water demands, as well as most of the Hanford Site's water needs, are met by pumping water from the Columbia River. Characteristics of this water source are discussed in detail in Section 3.4. The facilities in the 200 East Area, including PUREX, require about 10,000 to 11,000 gal/min, with peak demands in the 12,000 to 13,000 gal/min range. These water needs are met by pumping river water through an underground, export water piping network and into the 200 East Area reservoir at the 282-E building. From here, the water is filtered, treated, processed, and/or pumped to the various areas that have an established water requirement.

5.4.5.1 River Pumping Stations. River water is pumped at both the 100-B and 100-D reactor sites. At 100-B (the primary water source), eight pumps, with a total pumping capacity of 84,000 gal/min, deliver river water from the 181-B pumphouse into a 25 million-gal reservoir. The 182-B pumphouse contains five pumps, with a total capacity of 30,000 gal/min that deliver water from the reservior into the underground, export water pipeline. At 100-D (the backup or reserve water source), five pumps, with a total capacity of 65,200 gal/min, deliver river water from the 181-D pumphouse into a 15 million-gal reservoir. From this reservoir, two pumps, with a total capacity of 12,000 gal/min, deliver water from the 182-D pumphouse to the export water system.

The dual-pumping feature offers the backup necessary to assure an uninterrupted water supply as long as the export water pipeline is intact.

5.4.5.1.1 Emergency Water Supply. The safety-related characteristics and/or controls come from the backup units of the 181-D and 182-D pumphouses. These two pumphouses are on standby in case of electrical failure of the primary 181-B and 182-B pumphouses. In case of electrical failure in both areas, there are two diesel pumps rated at 3,000 gal/min in the 182-B pumphouse, and one diesel pump rated at 7,500 gal/min in the 181-B pumphouse. The one diesel pump in 181-B pumps raw water to the reservoir to the PUREX (202-A) building. As stated earlier, this dual backup system assures a water supply as long as the export water pipelines are intact.

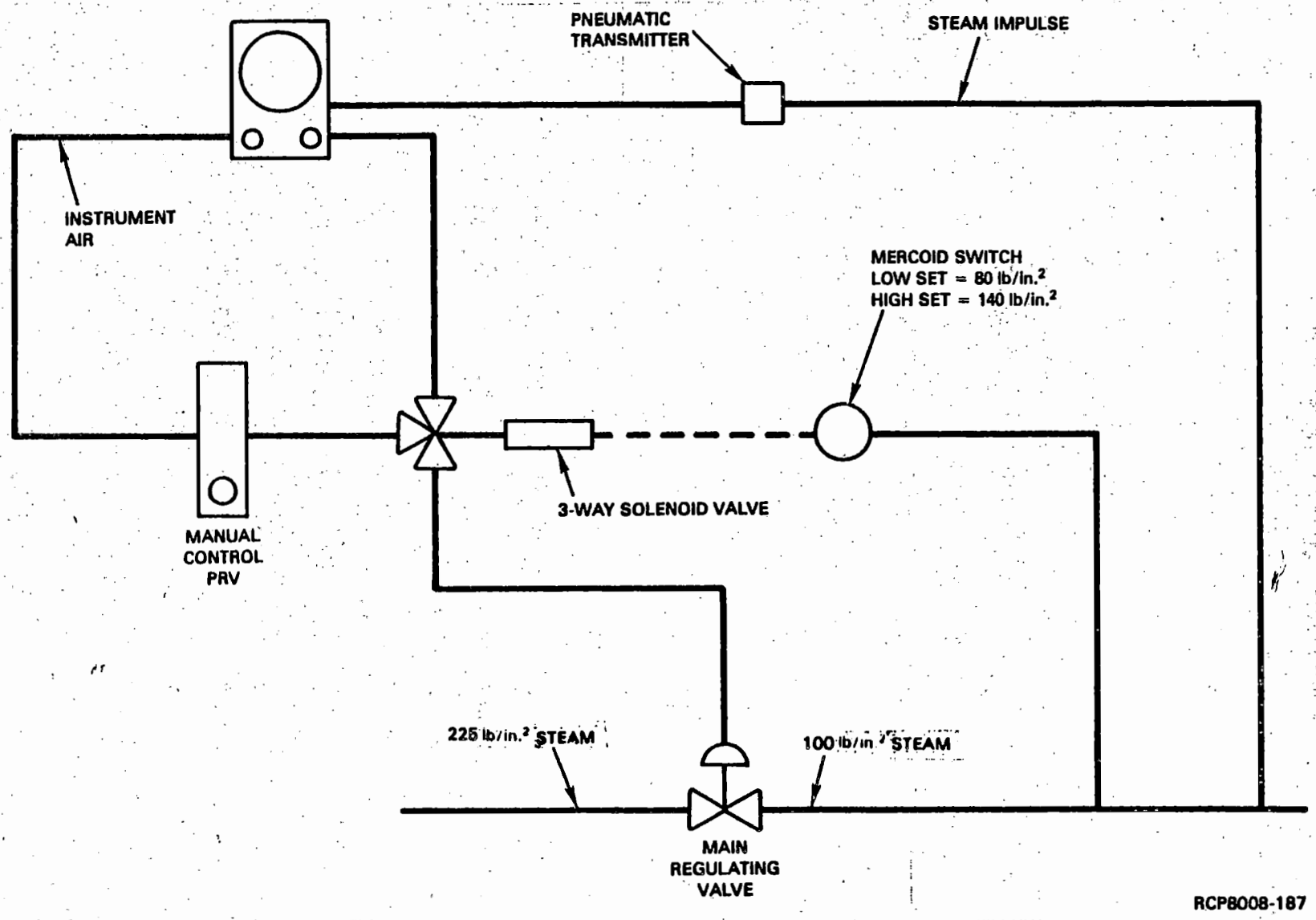


FIGURE 5-36. Typical Schematic of Pressure Reducing Valve Station Steam Supply--202-A Building.

5.4.5.2 Export Water Pipelines. Water enters a 42-in. underground concrete pipeline at the 182-B pumphouse. This line proceeds generally eastward to the 1901-Y area where it joins with a similar pipeline proceeding southward from the 182-D pumphouse. Both of these lines contain valves on each end that are capable of shutting off the flow and isolating the pumphouses/reservoirs and/or the pipelines. This ensures a source of water to the 1901-Y area. Water flows through two 30-in. lines, one concrete and one steel, to the 2901-Y area. Both of these lines also have shutoff valves on each end to provide a loop and facilitate isolation in the event of line failure.

Water is divided at the 2901-Y area to provide the 200 Areas with the necessary quantities. Two 24-in. waterlines run to the 282-E reservoir and one 24-in. line runs to the 282-W reservoir.

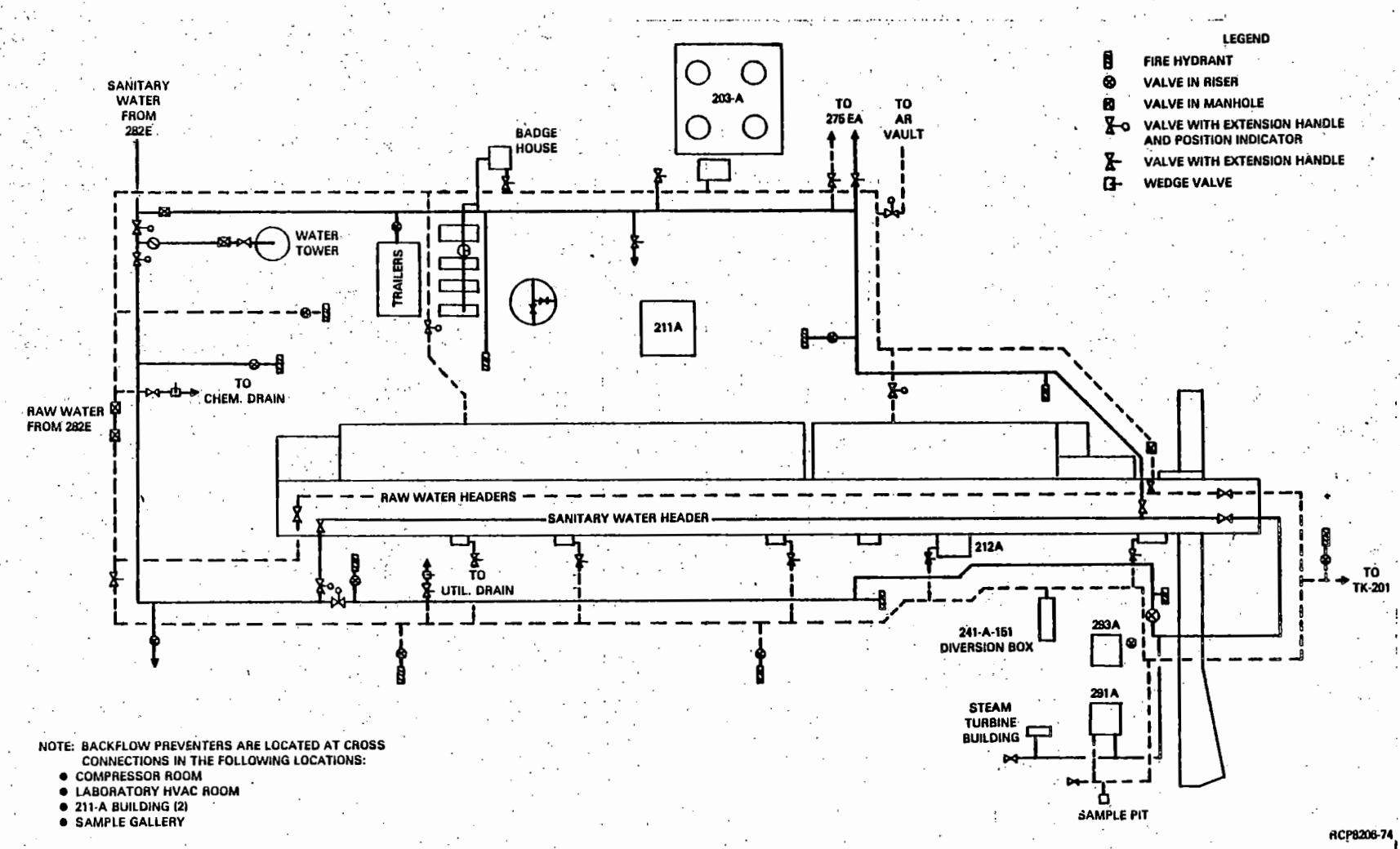
5.4.5.3 Water Distribution within the 200 East Area. The primary water storage facility in the 200 East Area is the 3-million-gal 282-E reservoir. From this reservoir, water is pumped as "raw water" by four electric pumps and one standby steam pump. Each of the five pumps has a 6,000-gal/min capacity at 250-ft head pressure.

5.4.5.4 Sanitary Water System. Sanitary water is produced in the 283-E filter plant, where raw water is filtered and chlorinated and a 400,000-gal supply is maintained in an underground, clear-well system containing two 200,000-gal concrete tanks. The water is then pumped by four electric pumps of 3,200-gal/min total capacity, and two steam turbine pumps (standby status) with a 1,200-gal/min total capacity. The water travels through a 12-in. pipe to supply the PUREX Plant.

A schematic of the PUREX sanitary water header system is shown in Figure 5-37. The 12-in. supply line from 283-E divides northwest of the PUREX (202-A) building into two 8-in. lines forming a loop that parallels the raw water loop around the building. The north loop serves facilities within the PUREX exclusion area north of the 202-A building and then enters it at the northeast corner near the raw waterline.

Filtered (sanitary) water is used to supply some fire hydrants and in the 202-A building for safety showers, drinking, toilet facilities, for making demineralized water for process use, and as an emergency backup for fire fighting. Included in the system is a 50,000-gal, high tank, located just northwest of the PUREX building. PUREX Plant sanitary water requirements typically average about 250 gal/min, but occasionally reach 1,000 gal/min. Approximately 90% is used for process and operational purposes and 10% for nonoperational (fountain, toilet, etc.) purposes.

Backflow preventers are installed at connections of the sanitary and raw water systems at the locations listed on Figure 5-37. The backflow preventers are tested upon installation or completion of maintenance work and, as a minimum, annually. Every 5 yr the units are opened for inspection and overhauled. Although the PUREX sanitary water supply is sampled and



NOTE: BACKFLOW PREVENTERS ARE LOCATED AT CROSS CONNECTIONS IN THE FOLLOWING LOCATIONS:

- COMPRESSOR ROOM
- LABORATORY HVAC ROOM
- 211-A BUILDING (2)
- SAMPLE GALLERY

FIGURE 5-37. Schematic Header Diagram--Raw and Sanitary Water Systems.

analyzed monthly to assure receipt of acceptable quality drinking water, the backflow preventer testing program is relied upon to ensure subsequent contamination does not occur.

5.4.5.4.1. Demineralized Water System. As received, the sanitary water contains relatively large quantities of dissolved ionic impurities. To be suitable for process use, water must be purified before it is suitable for process use in the PUREX Plant. Water is purified in the demineralizers located in the 211-A chemical tank farm.

Demineralization, or deionization, is a chemical exchange and adsorption process in which undesirable dissolved salts are removed from water. Adsorbents are selective with respect to either cations or anions; hence, a complete demineralization process includes contacting the water with both cation- and anion-exchange materials. In both cases, removal of salts is effected by exchange of an ion in the adsorbent structure for another in the solution being treated. In the PUREX Plant, an acidic adsorbent (Dowex Cation EX*) removes cations, and a basic adsorbent (Amberlite IRA-93**) removes anions.

Three cation and three anion columns are used to meet the demand for PUREX process water. Sanitary water that has been filtered enters the top of the cation columns and is routed from the bottom of the cation columns to the top of the anion columns. After contacting the resin bed of the anion exchanger, the water flows out the bottom of the column to the demineralizer water header and to the demineralized water storage tank (TK-30).

With use, the resin beds gradually become less effective for deionizing water, and must be regenerated. Sulfuric acid is used to regenerate the cation units and sodium hydroxide is used to regenerate the anion units. Routine demineralizer operation consists of regenerating one cation unit and one anion unit after each has processed approximately 200,000 gal of sanitary water. A special regeneration manifold permits the isolation of the columns to be regenerated while the other columns remain on-line and continue to produce demineralized water.

Table 5-12 summarizes the demineralizer operating parameters and time cycles.

5.4.5.4.2 Distilled Water. High-purity water required for plutonium product purification is provided by a 100-gal/h distillation system consisting of the tin-lined still (having three parts: evaporator, condenser, and aftercooler), the distilled water storage tank, the distilled water pump, and associated piping. This equipment is located in the service blower room just east of the first floor AMU area.

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*Dow Chemical Co., Midland, Michigan.

**Rohm and Haas Co., Philadelphia, Pennsylvania.

TABLE 5-12. Demineralizer Operating Parameters.

Operating mode	Cation flow rate (gal/min)	Time cycle	Anion flow rate (gal/min)	Time cycle
Maximum desired flow rate of demineralized water	150	--	110	--
Normal service flow	125	48 h	85	72 h
Back wash	100	15 min	25	15 min
Regeneration	75	40 min	25	30 min
Slow rinse	25	10 min	20	10 min
Fast rinse	100	50 min	75	50 min

Feed to the still is demineralized water. Raw water is used to first cool the distilled water in the after-cooler and then condense the distilled water vapor in the condenser. Steam in the evaporator coils converts the demineralized water into pure dry steam, which goes through deentrainment baffles to the condenser. The condensed distilled water flows by gravity through the after-cooler to the storage tank. The water may be pumped to one of five AMU tanks (150, 211, 212, 213, and 214), but it is used only in TK-150 for chemical makeup of the 3BX process stream.

The still is automatic in operation once initial adjustments to feed streams and controls are performed. As the liquid level lowers in the storage tank, the storage tank Vaporstat* controller closes the electric circuit to the still. The closed circuit opens the cooling water solenoid valve and also closes (activates) the still feed-water circuit. With the feed-water circuit closed, the liquid level in the still regulates the flow of feed water into the still. The cooling-water line pressure downstream of the solenoid regulates the operation of the steam DOV and the still drain DOV. As the line pressure increases (cooling water flowing to the condenser), the steam DOV opens and the still drain DOV closes.

When the storage tank fills, the tank Vaporstat opens the electric circuit and the still shuts down. The cooling water flow ceases, which in turn stops the steam flow and opens the still drain. The open electric circuit also stops the feed water flow.

After every 4 h of operation, the still electric circuit is opened by a timer and the still is shut down, independent of consumption. This occurs to prevent scaling conditions from being created by overconcentration of the feed water in the evaporator.

*Honeywell Co., Fort Washington, Pennsylvania.

5.4.5.5 Raw Water System. Raw water is used at PUREX for condenser and tank coil cooling water, for all sprays, for operating area washdowns, for coolant for the air compressors, for fire protection, and in the fuel storage basin. A schematic of the PUREX raw water header system is shown in Figure 5-37.

5.4.5.5.1 Major Components and Operating Characteristics. Raw water is pumped from the reservoir via a 24-in. line to the PUREX Plant. The 24-in. line branches just west of the 202-A building. A 20-in. line forms a north loop around the building, serving the north service area, and enters the 202-A building on the northeast end of the railroad tunnel. A second 20-in. line proceeds southward and branches into an 18-in. line that enters the southwest corner of the PUREX building and a 6-in. line that serves the south service area and eventually enters the east end of the building.

An 18-in. line in the P&O gallery completes the loop by connecting the 20-in. north service loop entering near the railroad tunnel with the 18-in. line entering at the southwest corner of the building.

Normal raw water usage is about 8,000 gal/min during plant operation and about 1,000 gal/min during shutdown periods. As an operability feature, all raw-water lines are adequately supplied with sectionalizing valves for segment isolation during periods of maintenance.

5.4.5.5.2 Safety Considerations and Controls. Failure of raw-water supply would require an immediate, orderly shutdown of all processing operations. The chemical reactions in the dissolvers can be quenched, and the solutions cooled as necessary, by the addition of demineralized water from the dissolver drown tanks. The sanitary water, including the high-tank inventory, can be connected to the building sprinkler headers to provide fire protection. The high tank water supply system is activated when the sanitary water line pressure decreases to 75 lb/in.^{2} g. Cooling for those vessels containing large inventories of radionuclides would be provided by adding demineralized water directly to the vessel contents to prevent boiling to dryness. Calculations based upon heat content of 180 d cooled fuel show that no vessel would boil to dryness for at least 3 d if no water were added.

5.4.6 Sewer Systems

See Figure 5-38.

5.4.6.1 Sanitary Sewage. The PUREX Plant uses sanitary water at an estimated rate of about 1.3 x 10^8 gal/yr. Approximately 10% of this amount serves fountains, toilets, showers, sinks, lunchroom, and other nonradiation-zone outlets. This is discharged via the sanitary sewer system to a septic tank-tile field disposal area about 1,500 ft north of the 202-A building.

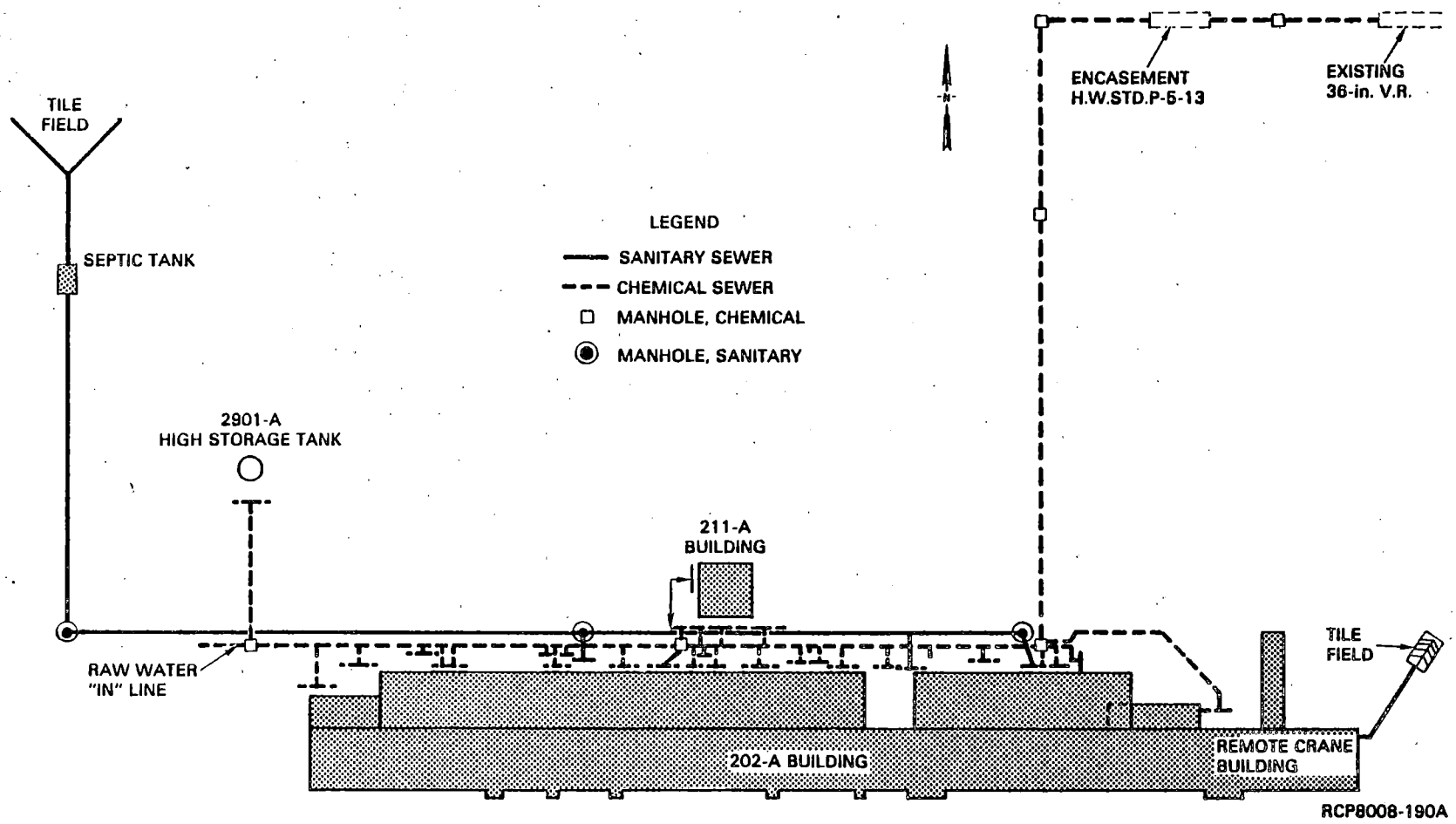

FIGURE 5-38. PUREX Plant Sewer Systems.

5.4.6.2 Chemical Sewage. The chemical sewer system includes floor drainage from nonradioactive areas in the service side of 202-A building and from chemical makeup tank overflows. This material is collected in a header at the north side of the building and disposed of to the 216-B-3 pond. Untreated waste released via the chemical sewer to the 216-B-3 pond contains small amounts of process chemicals from spills, floor flushes, discharges in chemical preparations, etc., and from regeneration of the water demineralizers. Should the chemical sewer stream become contaminated, it would be automatically diverted to the retention basin (216-A-42).

5.4.7 Communications Systems

The PUREX Plant communications system consists of (1) plant or "outside" telephone system, (2) internal PAX dial-type telephone system, (3) internal paging system and secondary "teletalk" system, (4) call bell system, (5) emergency evacuation or air-raid warning audible alarm system, (6) fire alarm system, and (7) criticality alarm system. The drawings for these systems are listed in Table 5-13.

TABLE 5-13. PUREX Communication and Emergency Systems.

System communication drawing	
Plant and PAX phone	H-2-54539 H-2-54542 H-2-54543
Secondary "teletalk"	H-2-65287 H-2-65288
Call and emergency	
Paging	H-2-74909
Call bell, emergency siren	H-2-54540 H-2-54544 H-2-54545
Fire alarm	H-2-75817
Criticality	H-2-65129 H-2-65130

5.4.7.1 Major Components and Operating Characteristics.

5.4.7.1.1 Plant or "Outside" Telephone System. The PUREX facility is served by a telephone cable that provides outside communication for all primary control locations, as well as offices allocated to operating and utility personnel within the PUREX facility.

5.4.7.1.2 Internal Dial-Type Telephone System. A PAX telephone system provides communication within the facility. This system is sized to accommodate 120 stations. For most efficient utilization and plant coverage, two types of installation are used. Dial-type phones equipped with jacks are located in strategic positions where maintenance will be routinely accomplished. Phone jacks are located throughout the processing areas at points where personnel entrance is infrequent. Portable, hand telephone sets with 50-ft extension cables are available for "plug in" service to the jacks.

5.4.7.1.3 Paging System. A paging system that utilizes the speaker system installed for the criticality alarm system is available for use from selected phones in the PAX telephone system. This system is designed not to interfere with a criticality alarm in the event that alarm system was activated.

Secondary teletalk systems are available between the dispatcher's desk and other areas in the plant.

5.4.7.1.4 Call Bell System. A call bell system is installed in the 202-A Building, providing audible code signal transmission for use in locating key personnel throughout the facility. The 27 bells used in this system are located throughout the facility and have a characteristic tone in order to be distinguished from other building signals. Signals are initiated from the dispatcher's office.

5.4.7.1.5 Emergency Evacuation or Air-Raid Warning Audible Alarm System. Evacuation, "siren," audible alarms are located in 58 places inside and outside the 202-A building for complete facility coverage during periods of emergency. This alarm system is controlled by a switch at the dispatcher's control desk.

The evacuation sirens produce a steady sound of constant pitch. The required response to this alarm is to proceed immediately to the main lobby of the building for further instructions.

5.4.7.1.6 Fire Alarm System. Fire alarm boxes for the building fire alarm system are located as follows:

- Master alarm box, with an auxiliary, located outside the main entrance to the 202-A building
- Master alarm box outside the main entrance to the laboratory, with auxiliary boxes located in the corridor and lobby

- Master alarm box located on the south side of the building between 291-A and 151-A diversion box

- Standard coding alarm box located at the east end of 211-A.

Each of the 18 fire zones described in the Building Pre-Fire Plans has a local alarm, an alarm to the dispatcher's office and/or main entrance lobby in PUREX, and, with the exception of the Halon systems located in the crane cabs, an alarm to the Hanford Fire Department 200 Areas station. "Local" fire alarms for process cells F, G, H, J, K, L, and R are in the central control room.

5.4.7.1.7 Criticality Alarm System. A criticality alarm system, which adheres to DOE requirements,[15] is installed in the building. Although the criticality alarm system does not meet the single-channel failure alarm state specified by DOE, an exemption to this requirement has been obtained from DOE. Areas requiring criticality detector coverage are listed below.[16,17] Detector locations are covered by three detectors to allow the use of a "two-out-of-n" logic system.[18]

Area	Number of Locations
M cell	1
N cell	2
Q cell	2
PR room	5
Corridor 1	1
Corridor 1A	1
West canyon lobby	1
Hot shop	1
Sample gallery	1
Elevator shaft	1

A total of 48 individual criticality alarm detection monitors (CADM) and 9 criticality alarm logic modules (CALM) are installed. The locations of these detectors are shown in Figures 8-14 and 8-15 and discussed in Section 8.3.4.2.

5.4.7.2 Safety Considerations and Controls. The PUREX facility is served by three two-way communication systems and by five additional call or emergency alarm systems (see Table 5-12). These systems are designed to allow internal and external communications at all normal operating stations, and to allow maximum coverage in infrequently used stations by the judicious installation of jacks for portable phone service. Emergency audible alarms are strategically located inside and outside the building for complete area coverage. The electrical circuitry is backed up by the standby electrical system, as described in Section 5.4.2.2.

5.4.8 Fire Protection

The fire protection systems of the PUREX Plant are described in the following sections. Systems provided include standard wet and dry automatic sprinkler systems, a light water aqueous-film forming sprinkler system, Halon suppression systems, and a carbon dioxide system. Smoke detectors, heat detectors, and manual pull boxes are located in appropriate areas of the facility. A proper number of portable fire extinguishers and fire-hose stations are located strategically throughout the facility. Fire hydrants are located both north and south of the 202-A building at a distance of 60 to 150 ft. The Hanford Fire Department, which is specifically trained for fighting fires in nuclear processing facilities, responds to a building alarm with Engine 2 from the 200 Area, Engine 1 from the 100 Area, and, if warranted, with Engine 1 from the 100 Area.

5.4.8.1 Fire Types. Types of fires that could indirectly or directly affect safety-related structures, systems, and components are as follows:

- Electrical failures involving equipment and/or wiring
- Thermally hot surfaces, such as heaters, rotating equipment (friction), open flames, etc.
- Pyrophoric metals
- Spontaneous ignition of oil-soaked rags, resins, etc.
- Use or generation of and handling of highly flammable materials, such as hydrogen, solvents, flammable gases, etc.
- Maintenance operations that produce heat (such as welding and burning)
- Use and handling of strong, oxidizing agents, such as nitric acid and sodium nitrate.

A discussion of the potential for these types of fires and the preventive measures included in the plant design follows.

5.4.8.1.1 Electrical. All electrical equipment is designed and installed in conformance with the National Electrical Code requirements for handling class III solvents. Sparking devices (e.g., switches, relays, and fuses) are installed in zones where solvent vapors are essentially absent (e.g., outside the solvent-containing cells).

In-cell lighting fixtures are guarded to prevent accidental breakage and the resultant possibility of short circuiting. Fire barriers are installed between the transformers in both the east and west transformer banks.

Fire detectors of the photoelectric-type are installed in the canyon cranes. The detectors sound an alarm in the dispatcher's office. The crane electrical panels are enclosed and provided with a Halon-1301 extinguishing system connected to the fire alarm system. The electrical switchgear and cable rooms are provided with fire (smoke) detectors.

5.4.8.1.2 Thermally Hot Surfaces. Enclosures are provided for heating elements of furnaces, ovens, hotplates, or other heating devices, and high-temperature cutoff safety circuits are provided independently of normal controls. By administrative control and safety rules, heat-producing devices (e.g., motors, ovens, hotplates, soldering irons, and direct-flame devices) must be used and located away from combustible materials.

5.4.8.1.3 Pyrophoric Metals. Zirconium alloy (a reactor fuel cladding material) and uranium metal are pyrophoric under certain conditions. Fines produced during processing could ignite spontaneously in air. Fuel elements are continuously covered with aqueous solutions, except for short periods while decladding wastes, rinses, or uranium salt solutions are jetted from the dissolver. The dissolvers are equipped with temperature alarms. Drown tanks are available to provide water in the event of fire.

5.4.8.1.4 Spontaneous Ignition. Fires arising from spontaneous combustion of class A materials are not expected to be a significant problem due to the limited quantities of stored fuel or packaged waste. Fire protection systems provided are described in Section 5.4.8.6.

5.4.8.1.5 Use and Handling of Highly Flammable Materials.

- Hydrogen

  Hydrogen is generated during the Zircaloy decladding process, but the quantity produced is drastically reduced by the addition of ammonium nitrate to the decladding solution. The hydrogen and ammonium nitrate react to produce ammonia and water, the reaction proceeding to about 94% completion. The remaining hydrogen is diluted below flammable limits in the DOG. The hydrogen concentration is monitored by an in-line analyzer and additional dilution air may be added manually. Hydrogen may also be formed by the radiolytic decomposition of water in some systems. Hydrogen is diluted with air to less than 2 vol% (lower flammable limit is 4%) and removed via the process vent system.

- Ammonia

  Ammonia is formed in the dissolvers during the Zircaloy decladding process and during the metathesis process. Ammonia is also evolved in large quantities when the decladding waste solution is reacted with caustic solution in E cell, using the reverse strike procedure in which waste is slowly added to the caustic. Ammonia vapors are not flammable in processing vessels due to the high moisture content of the offgas. To minimize downstream hazards; such as silver

azide formation in the silver reactors, the dissolver and E cell offgas ammonia scrubbers are operated at a low temperature with a saturated water-air mixture for effective and safe removal of ammonia. A separate offgas system, including condenser, steam heater, prefilters, final filters, blower, and stack, is provided for the exhaust from E cell decladding waste tanks and the concentrator, which is used to reduce the volume of spent ammonia scrubber solutions. Ammonia offgas streams are equipped with ammonia analyzers and temperature control is provided for tanks containing ammoniacal solutions.

- Organic Solvents

  The TBP/NPH mixture used in the solvent extraction columns is prepared batchwise in TK-R1A, which is located in the white room of the P&O gallery. The solvent is then added to G or R cell. The G and R solvent systems supply organic solvent to the extraction columns located in H, J, K, and L cells. Fire protection systems for these cells are also described in Section 5.4.8.6.

- Compressed gases

  Flammable and oxidizing compressed gases used by the analytical laboratory or the shops are stored in small quantities outside the main building. Gases are piped into areas where needed from the outside area. These storage areas are protected by standard dry-pipe automatic sprinkler systems.

5.4.8.1.6 Maintenance Operations. Maintenance operations can introduce unusual heat sources and cause the accumulation of quantities of flammable material in an otherwise controlled area. Operational procedures are developed to help prevent these circumstances.

5.4.8.1.7 Use and Handling of Strong Oxidizing Agents. Bulk storage of strong oxidizers (liquids such as nitric acid) is outside in aboveground tanks that are diked to control any spillage. These materials are pumped into tanks in the AMU room for usage. These oxidizers are handled in closed piping systems from receipt through the entire process. In the process, special controls are effected to limit temperatures and concentratrations in contact with hydrazine and organic materials. Solid, oxidizing, and reducing agents are physically separated during storage at a nearby warehouse.

5.4.8.2 Fire Characteristics. The characteristics of fires in plant areas that have combustible materials and are associated with safety-related structures, systems, and components are discussed in the following sections. None of the types of fires described could initiate and develop to peak burning without activating automatic or manual fire-fighting measures. However, discussions of these potential events are presented to indicate potential fire intensities and the possible effects on adjacent areas.

5.4.8.2.1 Electrical. A fire originating in the conventional, flame-retardant, heat-resistant, thermoplastic insulation of electric cable could produce a fire of sufficient intensity to extend to adjacent cables. Conventional types of flame-retardant, heat-resistant, thermoplastic insulation will burn (once ignited) and become self-sustaining and accelerating under maximum fire conditions, producing smoke and toxic contaminants. Products of combustion may include carbon monoxide, carbon dioxide, hydrogen chloride, and water.

The electrical switchgear rooms are of reinforced-concrete construction that would limit fire spread to the immediate area. Certain types of malfunctions in electrical cables in the switchgear room might result in a fire of sufficient intensity to involve some of the power, instrumentation, and control wiring in this area.

A fire originating in the electrical insulation in the control room should be of limited intensity, with little or no flame, and of short duration due to the limited amount of fuel. Cabinets are of all-metal construction with both vertical and horizontal separations or fire barriers. Although the fire might spread to other circuits in the same rack, it would most likely be limited to the cabinet of origin. The potential quantity of smoke and toxic contaminants would be minimized by subdivision of components, fire compartmentalization, and electrical protection of circuits. The physical separation of cabinets will help minimize spreading of a fire. Smoke generation would be high, hampering extinguishment, but there would be no extension of fire to adjoining areas due to construction safety features.

5.4.8.2.2 Solvent. A fire involving solvent is considered to be the fire of greatest significance that can occur in the facility. Solvent fires can reach major burning rates (if initial temperature is high) in a minimum of time and will liberate on the order of 20,000 Btu/lb of fuel consumed. At the same time, dense clouds of heavy, black smoke will be emitted.

The net effect is a fire of intense radiant heat, fast flame spread over a spill, and rapid involvement of any combustibles in the area. The fire offgases include toxic contaminants (carbon monoxide) that will vary with ventilation rate and completeness of combustion.

The use of reinforced-concrete construction in galleries and process cells prevents structural involvement and limits fire spread. Exhaust ventilation throughout all areas of the facility provides for removal of toxic gases and smoke without recirculation and prevents the spread of heat and fire gases to other parts of the facility. The ventilation tunnel is provided with an automatically actuated spray system.

5.4.8.2.3 Pyrophoric Metals. Zirconium fragments from the hulls and uranium fragments from the fuel could be generated in the fuel handling and dissolver cell during processing of fuel elements. Although these materials could ignite simultaneously in air if the zirconium and uranium were sufficiently fine, the extent would be severely restricted by the amount of

available metals. With limited fuel available, any fire would be of short duration and its intensity of no significance insofar as spread to other areas is concerned. The operations involving the dissolving of zirconium and uranium are confined to A, B, and C cells. Heavy, reinforced shielding walls would act as fire barriers and confinement.

5.4.8.2.4 Miscellaneous Combustible Materials. Potential fires involving miscellaneous combustible materials would be small because of the controls that limit the quantity of such materials outside metal containers. Manual fire-fighting measures would be adequate even with delayed detection. The fire should not extend beyond the room or area of origin because of the fire-resistant nature of the structure, sprinklers, and the limited amount of fuel available at any single location.

5.4.8.3 Building Features. The facility arrangement and the structural design elements include the following features to provide for fire prevention, fire extinguishment, fire control, and control of hazards created by fire.

- Buildings and support facilities are separated to limit fire spread and to aid in control and extinguishment.
- Fire-resistant or noncombustible materials are used.
- Potential fire areas are isolated by using fire dampers, fire walls, and fire doors to contain and isolate hazardous materials and operations. For example, fire dampers are installed between the two sections of R cell. Fire doors are installed from the PR corridor to R cell and between the two sections of R cell. Fire dampers and fire doors are also installed between the pulse generator electrical supply room and the remainder of the storage gallery.
- Vertical openings (e.g., stairways, elevator shafts, pipe ways, etc.) are enclosed to prevent fire spread to upper floors.
- Exhaust ventilation systems are designed with high fire integrity and the canyon exhaust is equipped with a water spray system.
- Electric service and distribution systems utilize approved components and are designed and installed to minimize any contribution to ignition of flammables where special fire hazards are present.
- Adequate means of exit are provided for personnel so that safe egress is assured for all anticipated fire events.
- Fire extinguishers are located throughout the occupied areas of the plant.

- Fire alarm pull boxes are located throughout high-occupancy areas. Telephones may be used to summon the Hanford Fire Department, which can reach the area in 6 min. Automatic or manual actuation of any sprinkler system also automatically summons the Hanford Fire Department.

5.4.8.4 Seismic Design. The construction of the original plant was based on the 1952 Uniform Building Code.(3) A discussion of the seismic design requirements is given in Section 4.2.5.

5.4.8.5 Water Supply. There are two fire protection-related water supply systems at the PUREX Plant. The sanitary water system supplies some yard hydrants, and the raw water system supplies all sprinklers, cell fire fog nozzles, and some yard hydrants. The general layout of these water lines with respect to PUREX is shown in Figure 5-37.

The water supply systems are described in detail in Sections 5.4.5. A 50,000-gal tank 100 ft above grade is connected to the sanitary water system and located within the fenced area of the PUREX Plant for emergency backup. Provision is also made to cross-connect the raw and sanitary water systems in the PUREX Plant. Backflow preventers are installed at the cross-connection points. The Hanford Fire Department pump trucks can also be used to provide water to the systems.

5.4.8.6 Fire Protection Systems. The fire protection systems in the 202-A building are shown in Figure 5-39. Automatic sprinkler protection on standard, wet and dry pipe systems have been installed in essentially all of the normally occupied or hazardous areas of the PUREX Plant in accordance with Factory Mutual Research Corporation recommendations. All sprinkler installations are low-activation temperature, closed-head systems, utilizing standard spacing and pipe sizes. Control is mostly by readily accessible valves, post-indicator valves, or outside screw and yoke valves in safe areas. Activation of a sprinkler system results in both local and 200 Areas central fire station alarms.

Areas covered by sprinkler protection include the hot shop, east and central storage gallery, N cell, Q cell, the PR room, extreme east end of sample gallery and the 202-A annex, including the laboratories, laboratory storage area, AMU area (two floors), offices, shops, and change rooms. Additional sprinklers are being installed throughout the sample gallery.* A standard dry pipe automatic sprinkler system is provided for the loading dock, laundry storage room, gas cylinder storage area, and power transformers, which are located on the exterior of the facility along the north wall. A carbon dioxide system is provided for the in-line monitor equipment room that contains a great deal of sensitive electronic gear. A fire suppression system using bottled Halon 1301 is provided in each crane cab.

*Work may not be complete at startup.

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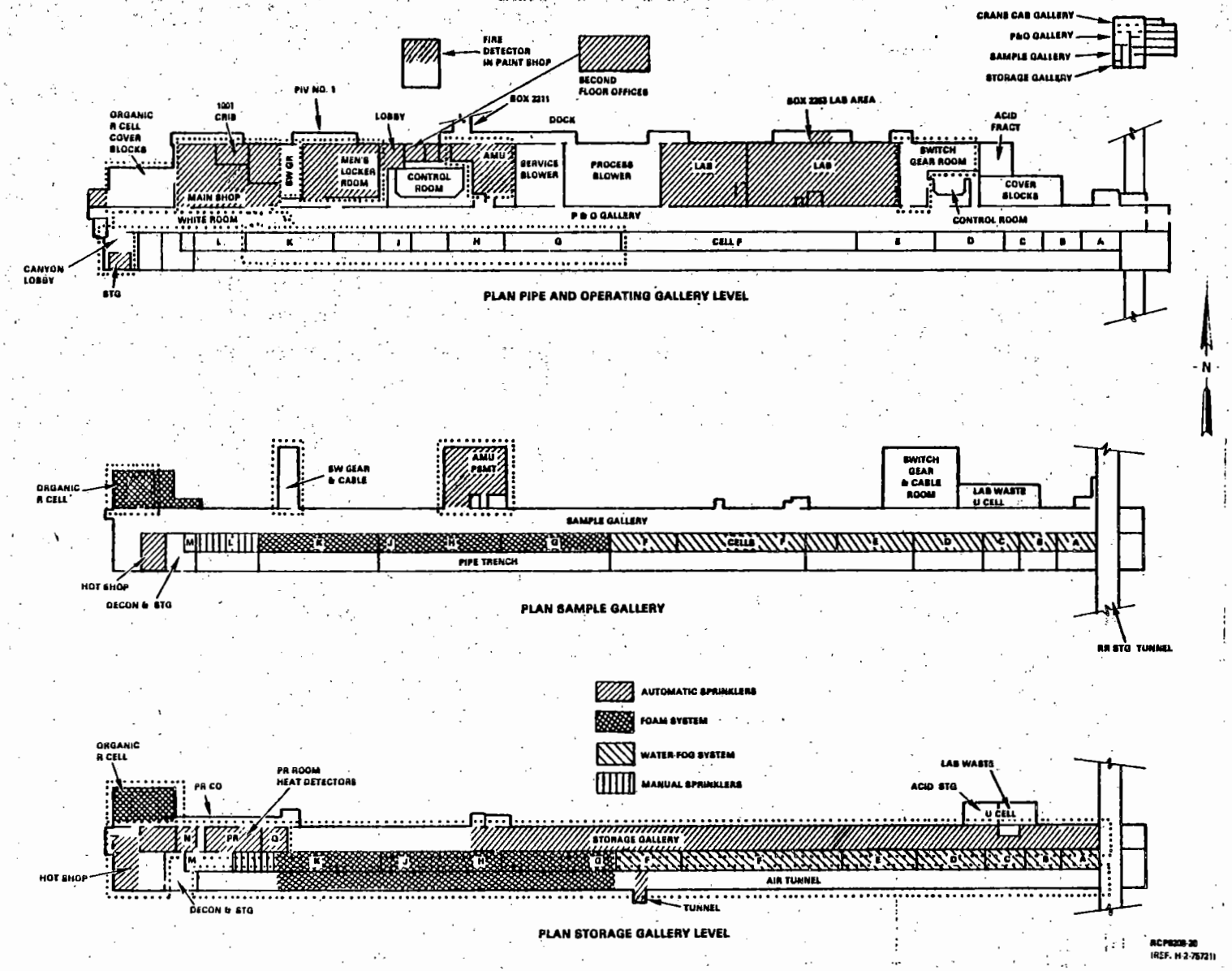

FIGURE 5-39. 202-A Fire Protection Systems.

Fire screens (stainless steel mesh with 1/8-in openings) are installed in the exhaust duct manifolds in each analytical laboratory room and glovebox and the main manifolds of the PR room and Q cell gloveboxes to prevent burning material from reaching the HEPA filters. The prefilters in the N cell glovebox exhausts also act as combination fire screens and mist eliminators.

Automatic wet-pipe sprinkler protection is provided in all normally inhabited room areas of N cell: the control rooms and air locks, load-out room, and room areas surrounding gloveboxes. The storage tank area in M cell is not provided with sprinkler protection, as no combustibles are in the area. The sprinkler system was designed and installed in accordance with the extra hazard occupancy classification requirements.(19) The system is supported and braced for earthquake protection. The sprinkler heads are temperature-rated(19) and have nominal 1/2-in. orifices. The heads are located judiciously in rooms containing gloveboxes to minimize direct impingement of water spray on glove ports or other "soft" openings into the glovebox. Sprinkler piping is sized in accordance with extra-hazard pipe schedules(19) and is routed to minimize interference with removable walls and decks. Sprinkler heads located under the removable deck in the glovebox area are designed to accommodate deck removal without impairing the normal operation of the remainder of the sprinkler system. If the sprinkler system is activated, the movable shielding is automatically rolled away from the gloveboxes to eliminate a potential chimney effect.

All process, powder handling, and maintenance gloveboxes in the plutonium oxide production facility are provided with Halon 1301, full-flooding, fire-suppression systems. Each glovebox has an individual, automatic, fire-suppression system designed to provide a minimum agent concentration in the glovebox atmosphere of 6% by volume, at 70°F, for a minimum period of 10 min. The systems were designed and installed in accordance with Reference 20. Activation of a system is by a thermally activated fire detector mounted in a stainless-steel well affixed to the glovebox. Fire detectors have an adjustable temperature set point with the initial setting at 140°F. Detectors are located in relation to glovebox and equipment arrangement to provide reliable fire detection and to minimize inadvertent activation from operational heat sources. Activation of a detector will automatically shut off incoming air supply to the affected glovebox and activate both local and remote fire department alarms. Halon discharge will begin after a 3-s delay to allow damper closure and airflow coast-down.

Fire protection in the nonsolvent-containing canyon process cells (A through E) is provided by a system of peripherally mounted spray nozzles controlled by manual gate valves. The nozzles were installed at the time of construction and are mounted at 9- and 12-ft spacing in the cells.

Manual actuation of the systems is dependent upon the detection of abnormal conditions by cell temperature heat detectors, set about every 50 ft throughout the cells. The headend detection units activate alarms in the headend control room. The F and L cell heat detectors activate alarms in the central control room and in the dispatcher's office.

Criticality considerations restrict the amount of water that may be added to L cell and PR room gloveboxes. Therefore, L cell is protected by manually controlled spray nozzles, and use of this system is administratively controlled to limit the amount of fire-fighting water that may be added. The PR room gloveboxes have criticality drains that, together with limited water addition, restrict the depth of solution.

Cells G, H, J, K, and R and TK-R1A are protected by the light-water foam system described below, which automatically sprays foam into the alarming cell and the adjoining ventilation tunnel.

To provide backup protection to the canyon exhaust filter in the event of an in-cell solvent fire and the concurrent failure of the light-water foam system, the ventilation tunnels are equipped with automatically actuated water sprays for removal of heat from the air stream. Actuation is by heat detectors in the east, west, and south tunnels. The system may also be actuated manually from its control panel in the central control room.

The light-water foam system protects cells G, H, J, K, and R and TK-R1A in the white room, and is designed to include the following features:

- Dual heat detectors in the processing cells that contain significant quantities of organic solvent
- Automatic relay of a fire alarm to the Hanford Fire Department
- Automatic or manual operation of the fire foam spray to the process cells and air tunnel
- Fire foam flow for 1 min after the system is reset by cooling of the detectors
- While the foam system is operating due to an alarm condition, the foam spray may be manually stopped by placing the manual operation switch in the "Spray Stop" position momentarily. If after a preset delay (0.5 to 5 min) the heat detectors have not cooled, the foam discharge will automatically resume
- Water will discharge from the foam nozzles after the foam is depleted. Foam will flow for about 5 min.

The light-water foam system is activated either automatically by heat-detection devices in the process cells or manually from the central control room by switches located on panel B-12. (The TK-R1A system is activated manually from the white room.) Automatic activation of the system will result if both heat detectors on a jumper in G, H-J, K, and R cells are energized or if one detector near TK-R1A is energized. If the heat detectors in the air tunnel are energized, or if only one of the dual heat detectors in the canyon is energized, an alarm will annunciate on the control panel and at the 200 Areas central fire station, but foam will not be sprayed into the cell.

Electrical alarm systems for both the sprinkler and light water systems are provided with battery backup. The automatically actuated valves on the light water system also are provided with battery backup. The schematic of the system, which is located in the P&O gallery is shown in Figure 5-40.

A seismically qualified and fail-safe light-water foam system is located in the storage gallery just east of the PIV room to serve as a backup for fire suppression in H and J cells. The system is activated only when the primary system fails to respond. The backup system and piping are structurally hardened to withstand the safe shutdown earthquake. Operation and arrangement of the backup system are similar to that of the primary system as discussed in the preceding paragraph and displayed in Figure 5-40.

5.4.8.6.1 System Evaluation.

- General

  - Entry

    There are two main entrances and multiple other entrances to the first floor on the north side of the 202-A building. There is one entry on the west end of the building. There is one entry on the east end, giving access to the ECMP and the P&O gallery.

  - Electrical Service and Hazards

    The east and west switchgear rooms have 2,400-V services and are essential to maintain the proper airflow. Entrance to these areas is restricted due to the possibility of an accidental shutdown.

  - Toxic Gases and Hazardous Chemicals

    Heavy concentrations of contained chemicals are distributed throughout the building proper. Several areas of contained, concentrated acids and volatile liquids also are present.

  - Protective Clothing

    "Turnouts," as worn for fire fighting, are required. Prescribed breathing apparatus will be worn.

  - Rescue

    The main entrances, laboratory entrance, and any door in the sevice area may be used. Victims in the office area on the second floor could be taken out of the door at the west end of the hall onto the roof and from there lowered to ground level.

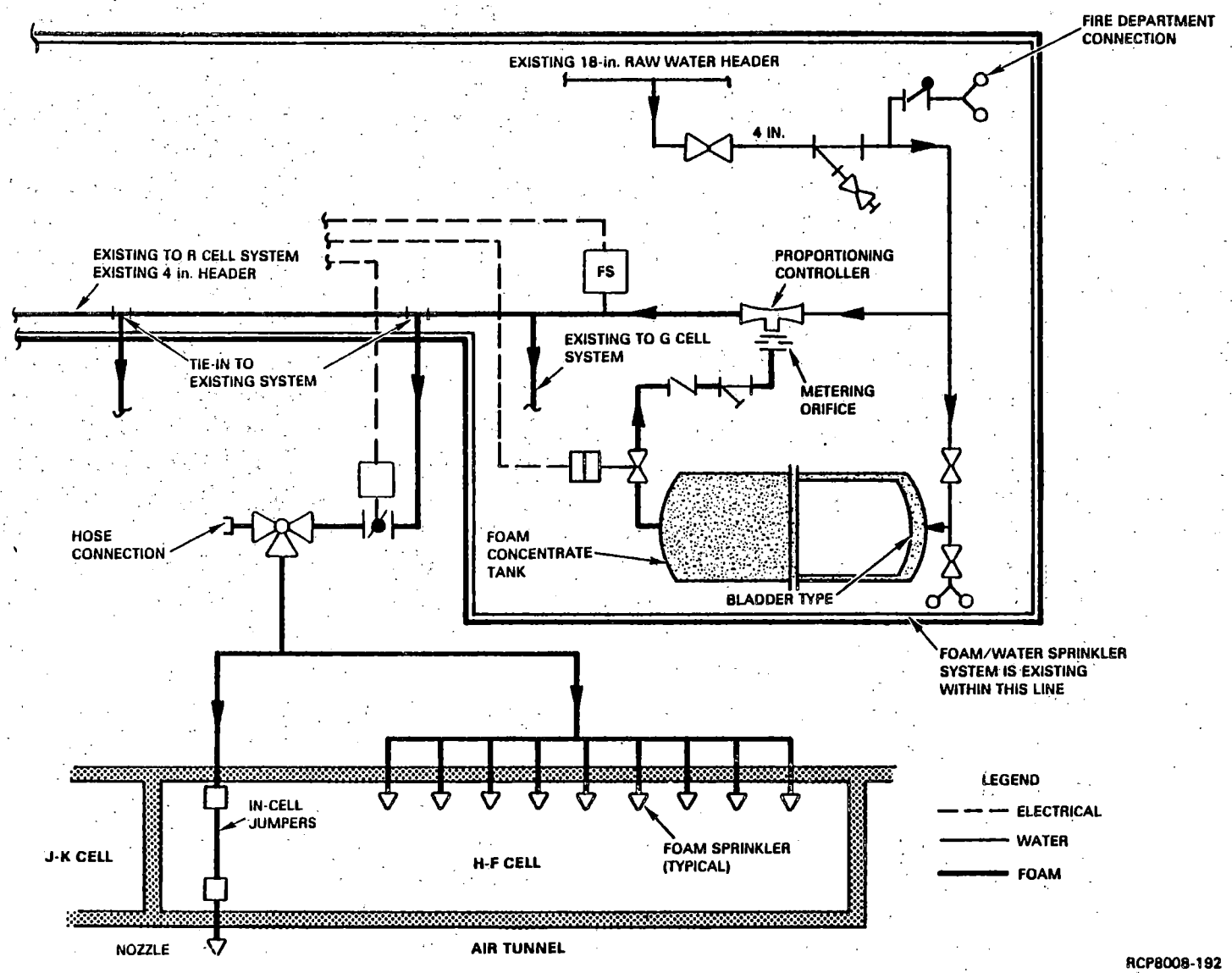

FIGURE 5-40. Typical Fire Foam Sprinkling System.

- Combustibles

  Most all types and mixtures of combustible materials can be expected in the PUREX Plant area.

- Ventilation

  The office area would have to be ventilated through the door at the west end of the hall with smoke ejectors. The other zones of the building can be ventilated with the building ventilation system.

- Salvage operations

  Normal salvage operations should be sufficient, with the exception of areas where electrical and other equipment damage might be done with application of dry chemical powders.

- Fire Protection Zones. For fire control, detection, and alarm purposes, the 202-A building complex is divided into 18 administrative fire protection zones. The location and discussion of each of these building zones with respect to specific hazards and methods to be used for fire control is found in the 202-A building prefire plans. Outside buildings are included in these zones.

- Alarm and Annunciator Systems. Fire protection zones 1 through 6 have sprinkler systems, heat detectors, and smoke detectors connected to alarm box 2211 located at the 202-A building main entrance. The annunciator panel at this location is the only annunciator panel for alarm box 2211.

  Alarm box 2213 monitors the laboratory area, ventilation fan room, main and upper floors, and supply room. This box has a supervisory bell at the hallway entrance. The zone indicator and trouble audible alarm are just inside the main entrance.

- System Inspections. Fire protection engineers are on the plant staff. Fire protection systems are periodically inspected. Certain critical systems are also periodically tested. Minimum inspection and testing frequencies are given in standard 6 of Reference 21.

- Fire Fighting--Criticality Accident Prevention Considerations. Water is the most efficient, general-purpose agent for fighting fire in the PUREX facilities. In some of the areas where plutonium is processed, however, the use of water should be carefully controlled because of the potential for a criticality accident. A criticality during a fire would endanger personnel and would greatly complicate the fire fighting. The probability that a criticality accident could be caused by adding water to PUREX Plant facilities depends on the quantities and nature of the

fissile materials present. There are four Hanford criticality accident probability categories (A, B, C, and D). The PUREX Plant has categories A, B, and C, but not D.

Category	Probability of criticality due to water addition
A	Zero. The addition of water to the facility cannot cause a criticality accident because fissile materials present are less than a minimum critical mass.
B	Minimal. The likelihood of a criticality accident resulting from fighting this fire with water is very small. Although fissile materials are normally present in quantities exceeding a minimum critical mass, the fissile materials are in very dilute solutions or are distributed in space such that a criticality accident cannot occur.
C	Finite. Under credible conditions, the addition of water could cause a criticality accident. This category embraces two types of areas. The first type includes those process areas in which fissile materials are normally present in quantities exceeding a minimum critical mass. As in category B, the fissile materials are normally held in such a manner that the addition of water would not cause a criticality accident. Under reasonably foreseeable conditions, however, the fissile materials could be rearranged so that the addition of water could cause a criticality accident. For example, equipment failure could allow an accumulation of process materials on a floor; a collapsing structure could distort a vessel or reduce the spacing between plutonium inventories. The addition of water to any of these rearranged systems could cause a criticality accident. In addition, a forceful, direct stream of water could move fissile materials into a critical configuration. The second type includes the personnel-working areas immediately surrounding category D facilities. Although the amounts of fissile materials in these working areas are normally small, such areas are of concern during a fire because of the probability that the barriers confining a category D area may be breached.
D	High. Fissile materials are normally present in a configuration that could be made critical by the addition of water, or the configuration is very likely to be changed by fire such that the addition of water could cause a criticality accident.

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For fire fighting in the PUREX Plant, each plant area has been classified into one of the preceding criticality probability categories. The assignments of plant areas to these categories are listed as follows (all plant areas not specifically mentioned are in category A):

Category B

- All process cells, except those listed in category C
- Analytical laboratory
- PR can storage areas
- M cell (except plutonium nitrate storage area)
- Hot shop
- Railroad tunnel.

Category C

- L cell
- PR room
- HEPA filters in plutonium service
- N cell plutonium oxide production facility
- M cell plutonium nitrate storage area.

Category D

None of the PUREX facilities are classified as category D.

5.5 REFERENCES

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