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AEC
RESEARCH
and
DEVELOPMENT
REPORT

PROGRESS REPORT
FAST FLUX TEST FACILITY
REFERENCE CONCEPT

AUGUST 1967

BATTELLE-NORTHWEST

BATTELLE MEMORIAL INSTITUTE / PACIFIC NORTHWEST LABORATORY

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FAST FLUX TEST FACILITY
REFERENCE CONCEPT

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August 1967

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1.0 INTRODUCTION

The Pacific Northwest Laboratory (PNL), operated by Battelle Memorial Institute for the AEC, has been engaged since October, 1964 with studies and preparatory designs for a national fast neutron flux testing facility. A Fast Flux Test Facility (FFTF) had been envisioned for at least 5 years previously.

Initial feasibility studies performed by PNL in 1965 resulted in an FFTF study report⁽¹⁾ in September, 1965, and an Interim Reference Design⁽²⁾ in February, 1966. At the time the Interim Reference Design was completed, a Program Directive for FFTF Conceptual Design was issued by the AEC. The basic performance and testing criteria for the FFTF conceptual design are the objectives, capabilities, and requirements as outlined in the FFTF Program Directive. The directive criteria and the "reference design" were reviewed by four industrial contractors (Atomics-International, General Electric, Phillips Petroleum, and Westinghouse). Additional information pertinent to the FFTF criteria was obtained as the result of an intensive survey of FFTF functional testing requirements performed by seven laboratories and industrial contractors.

APDA

Atomics-International

General Electric

Idaho Nuclear

Los Alamos Scientific Laboratory

Pacific Northwest Laboratory

Westinghouse

The principal effort of PNL and its contractors in FFTF work has been the development of feasible design concepts for the different features of the facility. To assure that all significant candidate concepts had been identified, a task force was set up at PNL to review alternate concept possibilities. PNL sought and initiated conceptual design programs for

promising alternates to the "reference" concept to permit qualified design organizations to explore the advantages of each candidate concept to the fullest extent.

A rational method for the development and evaluation of alternate conceptual designs for the FFTF was established in a plan of action during the latter half of 1966. This was supplemented by a detailed evaluation criteria, and a comprehensive evaluation of the alternate concepts was carried out. This resulted in an evaluation report which served as a basis for agreement between PNL and the AEC on certain concept dependent FFTF characteristics.

The concept of the Fast Fuels Test Facility described in this document was developed to fulfill the objectives of:

- 1) Providing an adequately controlled environment in fast neutron flux for highly instrumented fuels and materials irradiation tests with capabilities for fuels testing to failure in dynamic sodium and for testing specimens for short duration (minutes).
- 2) Providing facilities for preirradiation testing to characterize the experiments for safety and performance, for interim nondestructive examination and for postirradiation examination.
- 3) Serving all U.S. fast flux needs consistent with the primary objective of fuels and materials testing.

This progress report was prepared to describe the current FFTF concept based upon the results of the agreements with the AEC on the major conceptual features, and the status of the continuing conceptual design effort.

REFERENCES

1. E. R. Astley. Progress Report - Conceptual Design - Fast Flux Test Facility, BNWL-CC-175. Pacific Northwest Laboratory, Richland, Washington, vol. 1, 2, and 3. August 1965.
2. E. R. Astley. Progress Report - Fast Flux Test Facility, BNWL-CC-400. Pacific Northwest Laboratory, Richland, Washington. February 1, 1966.

stainless steel vessel with a cover providing access to the driver and experimental positions via individual nozzles. These nozzles provide access for refueling and for instrument connections.

The coolant for the core is sodium. The heat transport system includes four independent parallel circuits consisting of a primary and secondary sodium loop and a modular air heat dump. The primary sodium covering from the reactor outlet passes through shell and tube Intermediate Heat Exchangers and is pumped back to the reactor inlet by free surface centrifugal pumps. The secondary sodium receives the thermal energy in the IHX's. The hot leg sodium is pumped through the forced air heat dumps and back to the IHX by the secondary pump. At the design point of 900 °F the full reactor power may be rejected through 3 of the 4 circuits providing one redundant circuit for improved plant availability. Receiving, storage and conditioning equipment is provided for the primary and secondary sodium and the inert cover gases.

Reactor refueling operations are accomplished in a shielded enclosure (hot cell) above the reactor. This enclosure, while normally flooded with air, can be inerted for special operations requiring oxygen free atmosphere. The fuel handling equipment in the hot cell performs operations needed in preparation for refueling, and the actual transfer of fuel and experiments into and out of the reactor. The fuel handling equipment is capable of maintaining fuel temperatures at required levels during transit to and from the reactor. The fuel handling equipment has special capabilities for preserving essential test information.

The operation of the reactor is under the surveillance and control of a centralized data handling and control system. The reactor safety system is designed to respond to signals

2.0 DESIGN CONCEPT

2.01 SUMMARY

The design concept for an integrated fast neutron irradiation-examination facility is described in subsequent sections of this report. The facility provides a broad spectrum of controlled irradiation testing environments (neutronic, chemical, thermal, and hydraulic) and provides capability for postirradiation examination for fast reactor fuels and materials. To assure early operation and continued availability for testing, the design utilizes, to the extent practicable, components and concepts of demonstrated performance.

A summary of the design and performance data for the FFTF is presented in Section 2.02.

The principal component of the facility is the Fast Test Reactor (FTR). It is a fast reactor designed to meet the process and handling requirements of multiple closed test loops. The core is formed by a hexagonal array of fuel subassemblies situated near the region of convergence in a split truncated cone. The subassemblies are tilted to provide space, in a vertical plane across the center of the core, for closed loop installation. The split core geometry permits the driver fuel flow ducts to be essentially in direct contact in the fueled zone, while they separate above the fueled zone to allow for coolant flow, fueling access, and piping connections above the reactor cover.

The approximately 1000 L core has 94 hexagonal lattice positions with lattice spacing of ~ 4.3 in. The expected maximum flux with the initial mixed $\text{PuO}_2\text{-UO}_2$ driver fuel is $\sim 0.7 \times 10^{16}$ n/cm²/sec at a core power of ~ 400 MW. The core, the reflector, the experimental facilities and various support structures along with hydraulic components are housed in a

from flow and temperature sensors in the primary cooling loop, flow sensors in individual fuel channels and neutronic instrumentation. Signals exceeding preset limits cause the control system to take corrective action through insertion of control rods. The reactor system operations including driver fuel and experimental facilities are monitored by a continuous on-line computer.

The closed loop test facilities represent the most important capabilities of the FFTF. These multimegawatt facilities provide isolated, recirculating coolant to a test channel in the reactor in which specimens are irradiated. The isolated cooling circuits allows variation of coolant chemistry, temperature and pressure level, and the use of coolants other than sodium. The largest of the test channels accommodates tests of 4 in. diam. Test powers range up to 6 MW and future designs will allow tests to 1400 °F maximum temperature. Packaged closed loops in reflector or core test positions are available for low power or materials tests.

Open test positions use the primary sodium for cooling test specimens. Test conditions are limited to those consistent with this limitation. The maximum test size is 5 in. diam. Both closed and open test positions can be fully instrumented. Short term tests (rabbit and trail cable facilities) are provided in core or reflector positions.

Capabilities for preirradiation inspection, flow testing, nuclear proof testing, and interim examination of specimens and subassemblies are provided. Interim examinations may be accomplished without dismantling the test and include mainly visual observations, dimensional checks and autoradiography. Two types of facilities are available for post-irradiation examinations. The underwater examination cells utilize the well developed underwater inspection technology for examining

high decay heat fuels and materials specimens not requiring rigorous environmental controls. Shielded, inert gas filled cells are used for examination of water reactive fuels and materials specimens. In these facilities equipment is provided for transfer, positioning and examination of the specimens. These facilities are designed to retrieve the maximum amount of test information.

The FFTF reactor building complex is a special concrete and steel structure. The gas tight reactor containment vessel is a welded steel structure of spherical shape. It houses the primary components of the reactor, the fuel handling equipment, and the closed loop cells. The vessel is capable of containing radioactivity and the energy released by sodium-air reaction or nuclear accident. The reactor and primary components are located in shielded vaults in the lower half of the sphere. These vaults have an inert atmosphere. Concrete provides the biological shielding. The upper part of containment houses the hot cell and work areas above the primary components and closed loop cells. The number of penetrations through containment are minimized. All penetrations are sealed.

The maintenance and decontamination facilities have access ports to the containment. These facilities are equipped with remote handling tools and equipment for decontamination of primary and reactor components. Fuel examination facilities are housed adjacent and connected to the containment via a transfer cell. Office, shop and laboratory facilities round out the building complex. The air heat dumps for the main and closed loop cooling systems are the major structures outside the reactor building complex.

2.02 DESIGN AND PERFORMANCE DATA

Tables 2.02-I and 2.02-II summarize the important features and characteristics of the FTR.

TABLE 2.02-I. FTR Experimental FacilitiesIn-Core Test Facilities

<u>Test Facility</u>	<u>Maximum Test Cross Section, In.</u>	<u>Number</u>	
		<u>Initial</u>	<u>Ultimate</u>
Closed Loop Fuel Tests	4	1	1
Closed Loop Fuel Tests	3 1/2	2	2
Closed Loop Fuel Tests	3	0	1
Closed Loop Fuel Tests	2 1/2	0	1
Packaged Loop Materials Tests	2 1/2	1	*
Open Test Positions	4 & 5	13	*
Control Rod Nosepieces	3 1/2	10	Undecided
Driver End Reflectors		**	**

Reflector Test Facilities

<u>Test Facility</u>	<u>Maximum Test Section, In.</u>	<u>Number</u>	
		<u>Initial</u>	<u>Ultimate</u>
Packaged Loop Materials Tests	2	1	*
Control Rod Nosepieces	3 1/2	Undecided	Undecided
Short Term Test Facilities		1	2
Reflector Test Holes	4	38	Undecided

* Large number possible. Packaged loops and/or open loops may be installed in any lattice position.

** Any number up to the number of driver fuel assemblies can be provided.

TABLE 2.02-II. Preliminary FTR Design and Performance DataPower (Including experiments)

MW	~400*
----	-------

Core

Type	Split-conical
Volume, liters	~1000
Length, in.	32-36*
Equivalent Diameter, in.	43.2-41.9*
Number of Core Positions	94
Total Peak Flux, n/cm ² -sec	~0.7 x 10 ¹⁶ *

Subassembly

Dimension Across Flats, in.	~4.3*
Shape, In-Core	Hexagonal
Shape, Above Core	Cylindrical
Shape, Below Core	Tapered Hexagonal or Tapered Cylindrical
Geometry	Rod Cluster
Number of Pins	169 to 217
Fuel Material	PuO ₂ -UO ₂ Oxide

Nuclear Control

Type	Poison Rods
Material	Enriched B ₄ C
Number of Safety Rods in the Core	4
Number of Shim Rods in the Core	6
Number of Rods in Reflector	Undetermined*

Neutron Shields

Radial Shield Material	Steel and Graphite
Upper Shield Material	Steel and Graphite
Lower Shield Material	Steel
Coolant Material	Nitrogen

Biological Shields

Primary Coolant Shield Material (Vaults and Cells)	Concrete
Shield Thickness, ft	~6

* Work in these areas is in progress and specific values cannot be specified now.

TABLE 2.02-II (contd)Primary Coolant

Coolant Fluid	Sodium	
	<u>Initial</u>	<u>Final</u>
Inlet Temperature, °F	600	800
Outlet Temperature, °F	900	1100
Flow Rate, lb/hr	$\sim 1.5 \times 10^7$	

Primary Loops

Number of Primary Loops	4
Pipe Diameter, in.	24 and 16
Power per Loop, MW	133

Primary Pumps

Number	4
Type	Vertical, Free Surface Centrifugal
TDH, ft	385
Motor Power, hp	~ 1500

Intermediate Heat Exchangers

Number	4
Type	Vertical, Shell-and- Tube
Shell Fluid	Primary Sodium
Tube Side Fluid	Secondary Sodium

Secondary Pumps

Number	4
Type	Vertical, Free Surface
TDH, ft	222
Motor Power, hp	~ 800

Reactor Heat Dump

Number	4	
Heat Sink	Ambient Air	
Secondary Sodium Temperature, °F	<u>Initial</u>	<u>Alternate</u>
Inlet	775	975
Outlet	475	675
Total Secondary Sodium Flow, lb/hr	1.5 x 10 ⁷	
Total Air Flow, cfm	3.3 x 10 ⁶	

2.03 PHYSICS DESIGN

PRELIMINARY NEUTRONICS DESCRIPTION OF THE SPLIT-CONE FTR REACTOR

The FTR core, consisting of driver and test regions, has a roughly conical shape. The nominal driver volume is ~ 1000 liters; the central gap (test region) volume is 150 liters. The core is surrounded (radially) by a 30 cm Inconel reflector.

Table 2.03-I shows the principal neutronics parameters of the FTR. All neutronics calculations were performed using a modified versions of the Russian 26-group cross sections. Cross section preparation was performed by the FCC-IV code; one-dimensional and two-dimensional computations were performed by the DTF-IV and 2DF transport codes, respectively.

Reactor control is provided by ten B_4C rods in the core and an undetermined number of B_4C rods in the reflector. Of the in-core rods, 4 are safety (scram) rods and 6 are shim rods. The safety rods are worth $\sim 0.02 \delta k$ each; the shim rods are worth $\sim 0.01 \delta k$ each.

The static control requirements for the FTR are large. Four control categories can be identified:

- Control to cover fuel burnup effects
- Control to cover temperature defect
- Control for reactor shutdown
- Control to accommodate "low-worth" test subassemblies.

Since the in-core breeding ratio is low (~ 0.5), reactivity decreases rapidly with fuel burnup. For 70 days at 400 MWt, the control margin required for burnup is of the order of $0.02 \delta k$.

The principal contributors to the cold-to-hot temperature defect are the Doppler, Na expansion, and fuel expansion

TABLE 2.03-I. *Parameters Pertaining to Reactor Physics*

Power	MWt	400
Driver Volume	liters	~1000
Total Core Volume	liters	~1150
Core Height	cm	85
Core Radius	cm	60
Inventory ($^{239}\text{Pu} + ^{241}\text{Pu}$)	kg	600
U/Pu Ratio	-	3.5
ϕ (Center point)	$\text{n/cm}^2\text{-sec}$	$\sim 0.7 \times 10^{16}$
ϕ (>0.1 MeV)/ ϕ	-	0.69
ϕ (>1 MeV)/ ϕ	-	0.15
Breeding Ratio	-	0.50
Reactivity Life ($\delta k = -0.02$)	days	70
Neutron Generation Time	sec	3.5×10^{-7}
β_{eff}	-	0.003
Doppler Coefficient	$T\left(\frac{dK}{dT}\right)$	-0.004
Doppler Coefficient (Na-out)	$T\left(\frac{dK}{dT}\right)$	-0.002
Clad (axial) Expansion	$\delta k/^{\circ}\text{C}$	-5.0×10^{-6}
Na (volume) Expansion	$\delta k/^{\circ}\text{C}$	-4.0×10^{-6}
Core Averaged ^{239}Pu Worth	$\delta k/\text{kg}$	+0.001
Total Na Worth	δk	+0.015

defects. Approximate numerical δk values are, in the above order, -0.0065, -0.0015, and -0.0020.

The amount of control margin required for shutdown is largely a safeguards question. The present design calls for a shim shutdown margin of 0.015 δk . If larger values are needed, some or all of the safety rods could be employed.

The large reactivity change needed to compensate for the introduction of large, low worth test assemblies into the core is provided by driver fuel inventory adjustment (shimming) rather than by reactivity capacity in the mechanical control system. Small reactivity perturbation, however, of the order of 0.02, is handled by the control system.

One would expect that the central test region--which contains little fissile fuel--would significantly affect the FTR nuclear performance. To assess this effect, the critical mass and center point flux were computed for a wide range of central gap volumes and driver volumes. The composition of the central gap was estimated using representative FBR fuel in the five test loops. The results are shown in Figures 2.03-1 and 2.03-2. Clearly, large central gaps significantly increase the critical mass, and, for a given total power, depress the central flux.

FIGURE 2.03-1. Total ^{239}Pu Critical Mass
Versus Central Gap Volume

FIGURE 2.03-2. Center Point Total Flux
Versus Central Gap Volume

2.04 REACTOR DESIGN

The FTR is a fast reactor that will initially operate with mixed uranium/plutonium oxide, stainless steel clad, driver fuel. The mission of the FTR is fast neutron irradiation of nuclear fuel and reactor construction materials. To this end, system optimizations aim toward high neutron flux, large and accessible in-core testing stations, and a high degree of experimental reliability.

The principal elements of the reactor vessel complex are the core; the reactor vessel with its internal tube-sheet, pressure plenums, thermal barriers, and coolant connections; and the reactor vessel cover with reactor cover nozzles. Sodium fills the reactor vessel to within a few inches of the underside of the reactor cover. The closed loop coolant piping connects to each closed loop tube above the reactor vessel cover.

The reactor core assembly is formed by fuel subassemblies situated near the region of convergence of a split, truncated cone. The driver fuel subassembly ducts are the essential structural elements of the core. They extend vertically as an expanding conical array. A bottom tube sheet, and guide tubes, attached to the top head, support and restrain the fuel ducts and closed loop tubes. The driver fuel ducts function as containers to locate the fuel subassemblies in the core. The ducts convey liquid sodium upward from a supply plenum, past the fuel to discharge into the sodium pool above the reactor core. The closed loop tubes isolate the experimental subassemblies from the primary reactor coolant.

To obtain a maximum generation of neutron flux at the high energy levels desired for fast neutron irradiation experiments, the FTR core includes an efficient neutron reflector to minimize neutron leakage.

A multi-element neutron shield surrounds the reactor vessel. The shield is made of concentric steel shells with steel-cased graphite filling the interstices. The neutron shield also functions as an energy absorbing medium in the event of a prompt critical nuclear excursion. Forced convection heat transfer to circulating helium (Figure 2.04-3) cools the shield.

REACTOR VESSEL AND CORE

The FTR has a compact core of high power density. The compact core has limited space for fuel handling equipment such as grapples, positioning apparatus, transfer arms, etc. In the FTR, these problems are compounded by the requirement for charging and discharging of test specimens. To retain the necessary compact core while obtaining an open tube array for free access to the reactor cover nozzles, the split core arrangement was adopted as the reactor design concept.

The split core geometry permits the fuel subassembly ducts to be essentially in direct contact in the active fueled zone while they are separated away from the fueled zone to allow for coolant flow, fueling access, and piping connection. In addition, the split core geometry permits installation of vertical closed loops for irradiation testing in a variety of reactor diametral core positions (Figures 2.04-1 and 2.04-2).

The reactor vessel design will permit changes in core configuration, as LMFBR program requirements may dictate, at any time during plant design or operation.

The structural members within the reactor vessel are either replaceable or shielded against large integrated flux doses of high energy neutrons. The fuel subassembly ducts are unprotected, replaceable, structural members. The reactor vessel is a shielded, nonexpendable structural

element. In general, structural members which are not easily replaceable will receive an exposure of less than 5×10^{21} nvt of damaging neutron fluence over a 20 yr period.

DRIVER SUBASSEMBLY DUCT

The driver fuel duct supports and locates the fuel subassembly in a confined stream of sodium coolant. This replaceable unit extends from the reactor cover downward to the high pressure coolant supply plenum at the lower end of the reactor vessel. The inlet end of the duct fits into aligned holes in the lower tubesheet.

Hydraulically, the duct functions as a high velocity sodium flow conduit between its inlet (lower) zone and the discharge (upper) zone just below the reactor vessel outlet nozzles.

NEUTRON SHIELD

Neutron shielding surrounds the bottom and sides of the reactor vessel as shown on Figure 2.04-3. This shield is formed by a series of nested steel shells in which the annular spaces between the shells are filled with circular tubes of diameter equal to the annulus width. The tubes are filled with graphite, serpentine, or boron carbide to moderate the neutron flux.

The neutron shield serves as blast-energy absorbing medium, and a radiation energy absorber. In the event of an accident, the shells and tubes become highly effective in absorbing the pressure pulses.

Helium is used for neutron shield cooling. Two circulator-coolers force the gas at high velocity through the neutron shield. The cooled gas discharges near the lower end of the radial shield.

REACTOR CONTROL MECHANISMS

The FTR is controlled by 18 poison type rods, positioned as shown in Figure 2.04-4. There are four safety rods near the core center, six in-core shim-scram rods, and eight peripheral shim rods. The rods operate approximately 2° to 8° from the vertical. The rods consist of a movable poison section, a drive section located above the reactor cover, and a drive extension section connecting the drive and poison sections. The drive mechanisms, extensions, and poison rods for the shim-scram rods and the peripheral shim rods are based on the FERMI design. The four central safety rods, worth between 5\$ and 6\$ each, provide "cocked" safety margin during reactor operation or refueling. The six in-core shim-scram rods, each worth 3\$ to 4\$, provide the reactivity control to compensate for fuel burnup and for the negative overall temperature coefficient. In addition, they provide the in-reactor subcritical shutdown margin during core loading. The eight peripheral shim rods, worth approximately 1\$ each, complement the shim function but are not equipped with the scram feature. One peripheral shim rod is used for automatic control of the reactor at a given power level.

Mechanical holddown for the driver fuel ducts is provided by the control rod shroud tubes. The control rods are located in core positions that allow these tubes to hold down adjacent subassemblies.

A hollow stainless steel extension piece is connected to the bottom of each safety rod. The extension piece is in the core when the safety rod is "cocked" and serves as a holder for long-term structural material test specimens. The lower end of the extension piece is a tapered section. It serves as the piston part of the snubber that absorbs the kinetic energy of the safety rod poison assembly after scram. The

stationary portion of the shock absorber is part of the control rod shroud.

The poison section of the safety and shim-scram rods is held to the drive extension section by a magnetically operated latch. A reactor safety circuit trip de-energizes the magnet, thus releasing the latch so that the poison section is driven into the core by an accelerating spring. The spring complements the gravitational acceleration to assure insertion in the core within the required time. Figure 2.04-5 illustrates rod operating sequence.

The operational safety of the reactor control system is enhanced by the following features:

- Only one unit at a time will operate in a direction that increases core reactivity.
- Rods can be withdrawn only with the safety circuit made up.
- The shim rods and shim-scram rods can be withdrawn only if the safety rods are fully withdrawn.
- The safety rods can be withdrawn only if all other rods are fully inserted.
- All drive units will drive to the rod "in" position whenever a safety circuit scram occurs. This inserts the maximum available amount of control system negative reactivity.
- All drives must be at the "in" limit to re-energize the safety circuit after a scram.

SHIM-SCRAM ROD DRIVE ASSEMBLY

The shim-scram rod drive assembly consists of two primary sections: the drive section, located in the top end of the rod shroud tube, and the drive extension which connects the drive section to the poison assembly. A shield plug is included as part of the drive extension. The complete assembly fits inside the rod guide tube.

The drive section consists of a drive head, a ball screw, a stepping motor, a selsyn position transmitter, and limit switches. There is a gear reducer between the motor and the ball screw.

The stepping motor can be rotated in a single step of 1.8° or in multiple steps at a maximum rate of 100 steps/sec. Since the stepping motor has a holding torque greater than the running torque, it serves the dual function of drive and electric brake. The drive is capable of exerting a maximum lifting force of approximately 1000 lb on the drive extension.

Position readout is provided by a selsyn transmitter-receiver system driven by a spur shaft on the drive motor. In addition, the pulses of the stepping motor can be counted to provide a second means of determining rod position.

Limit switches are used to provide drive "out" and drive "in" indication and control. The "in" limit is provided with a bypass and secondary "latch" limit to permit the overtravel required for latching the poison section to the drive extension section.

The electrical connector differs for each type of rod to prevent accidental interchange of interlock functions which are not common to all types of rods. In addition, the frame of the drive section only fits one type of rod shroud tube. The drive mechanism will be gas cooled.

DRIVE EXTENSION

The drive extension section is coupled at the drive head by a split collar. The scram mechanism, which is part of the drive extension, consists of a latching mechanism at the bottom for connecting to the poison section, a latch holding magnet at the top, and a latch operating rod between the two points. The latching rod is spring-loaded to assure unlatching of the poison section whenever the magnet is de-energized. Latching

is accomplished by moving the drive past its "in" limit so that the latch rod is pushed up by the poison section. When the top of the latch rod engages the magnet face a second limit stops the drive travel.

Stainless steel bellows are used as seals to prevent reactor coolant and sodium vapors from the reactor cover gas from entering the interior of the drive extension section. The seal design is shown in Figure 2.04-6. Limit switches are used to provide rod "latched" indication.

POISON ROD ASSEMBLY

The poison section is centered in the core when the rod is at the "in" limit. The bottom end of the poison is about 4 in. above the top of the fuel when the rod is fully withdrawn. The B_4C poison is contained in a group of pressure tubes and occupies approximately 30% of the cross-sectional area of the 4.5 in. rod shroud tube. The poison-containing tubes are enclosed in a load-bearing shell and are free to expand with respect to this shell as shown in Figure 2.04-6.

ROD SHROUD TUBE

The same basic shroud tube is used for all control rods. The rod shrouds are fastened to nozzles in the reactor vessel cover. The top cap forms a pressure closure that contains the drive and drive extension shield plug. The assemblies, including the cap and the attachment to the nozzle, are designed to withstand pressure surges. A shroud tube is shown in Figure 2.04-2 and Figure 2.04-6.

MATERIALS

Stainless Steel

The reactor will use one or more of selected 300 Series austenitic stainless steels, probably AISI 304 or AISI 316, as the basic construction material for all reactor parts which may be exposed to molten sodium.

The 300 Series stainless steels have been chosen because of good corrosion resistance and adequate mechanical properties at temperatures up to 1200 °F. These stainless steels have extensive operating experience in sodium systems.

Steel

Carbon and low alloy steel are suitable for use in many FTR parts which are not exposed to high temperature sodium. The inert gas atmosphere below the reactor vessel cover permits the use of carbon and low alloy steel (e.g. in the metallic parts of the neutron shield). Steel will perform equally well as jacketing material and sealing flanges for many of the connections to the lower primary containment vessel. Use of carbon steel for parts not exposed to either air or sodium vapor is expected to reduce costs without affecting the reliability of the reactor.

Nickel

Nuclear characteristics dictate a high nickel content for the reflector while environmental and structural requirements dictate choice of a material compatible with sodium and with adequate strength characteristics at FTR operating temperatures. The potential mass transfer of nickel to the relatively nickel-poor stainless steel reactor system requires cladding of the reflector.

Shield Materials

The shield materials considered for use are graphite or carbon and serpentine, with boron carbide being considered for specialized applications. Graphite is the primary candidate because it is a reasonably priced material which has been thoroughly characterized in reactor environments. Serpentine offers low cost and good neutron shielding characteristics which would allow use of a thinner shield. Boron carbide is a candidate for localized shielding.

Control Materials

Boron carbide is the primary control material since it has been used extensively, and is compatible with stainless steel and sodium. Tantalum is an alternate control material which burns out less rapidly than boron carbide.

HYDRAULIC CHARACTERISTICS

The specific design of reactor internals governs the internal hydraulics of the reactor vessel. In general, the sodium coolant zones in the reactor vessel are graded from a high pressure plenum, formed by the reactor vessel and bottom tubesheet, to a medium pressure zone around the driver fuel ducts, to a low pressure zone at the driver duct coolant outlet, and finally to a minimum pressure zone at the reactor vessel discharge nozzle. The reactor vessel can be pressurized with cover gas to provide added head to drive the primary sodium through the intermediate heat exchanger and piping.

Within the reactor vessel, thermal and flow baffles are arranged to minimize thermal shock upon a reactor power transient and to minimize thermally induced sodium circulation in the upper reactor vessel pool.

FIGURE 2.04-1. Reflector Details of Core Assembly

SK-3-12763

SK-3-12759

FIGURE 2.04-3. Neutron Shield Reactor Arrangement II

TENTATIVE INITIAL TESTING FACILITIES

- ⊗ REFLECTOR SHIM ROD (8)
- ⊗ SHIM ROD (6)
- SAFETY ROD (4)
- CLOSED LOOP (3)
- NEUTRON SOURCE (1)
- ~ OSCILLATOR (1)

- REFLECTOR (38)
- ⬢ DRIVER FUEL (76)
- ⬡ OPEN LOOP (11)
- ⬢ PACKAGE LOOP (2)
- ⬢ SHORT-TERM TEST (1)
- ⬢ VERTICAL OPEN LOOP (2)

FIGURE 2.04-4. Core Map

FIGURE 2.04-5. Safety Rod Operating Sequence

FIGURE 2.04-6. Safety Rod Split Core Reactor Arrangement I

2.05 FUEL SUBASSEMBLY DESIGN

The fuel subassembly is the basic power (neutron) generating member for the FTR core. The subassembly houses the fuel-containing fuel pins. It maintains the structural integrity of the fuel assembly, the position of the fuel within the core array, and is the core member which is fully removed and replaced during refueling.

GENERAL DESCRIPTION

The fuel subassembly consists of a hexagonal duct surrounding a close packed hexagonal array of fuel pins. Pin separation is provided by the wire wrap spacers which promote cooling for each pin and interchannel mixing. The stainless clad fuel pins are approximately 7 ft long. About half of that length contains $\text{PuO}_2\text{-UO}_2$. The fuel is compacted to a density sufficient to provide the required fuel loading while accommodating retained fission product swelling and providing relief of fission gases. Immediately above the column of mixed oxide pellets is a 6 in long nickel or high-nickel alloy rod which serves as a neutron reflector. The reflector has adequate clearance from the cladding for passage of fission gas. Approximately 3 ft of fission gas plenum is provided above the nickel reflector. The pins are assembled in an hexagonal array and are held at the base by the grid assembly. A slotted grid at the top of the assembly allows the pins to expand axially while lateral movement is restrained. The pin assembly is welded to the coolant duct at the lower end. Sodium coolant enters the subassembly through the bottom at a velocity of about 30 ft/sec. Core pressure drop is approximately 60 to 90 psi. The coolant temperature rise is 300 to 400 °F.

The design is based on a peak subassembly thermal duty of approximately 7 MW, at a peak burnup of 75,000 MWd/MT.

Fuel cladding deformation is constrained to 0.2% because of expected cladding embrittlement at peak exposures in excess of 1.3×10^{23} nvt fast fluence.

Preliminary hot channel factor analysis predicted a 3 σ deviation in the hottest channel of a 1.14 engineering power multiple.

The following table lists the operating characteristics of the FTR fuel subassembly.

TABLE 2.05-I. *FTR Fuel Subassembly Operating Characteristics*

Reactor

Reactor Power, MW:	
Thermal	350 to 400
Pin OD, in.	~0.250
Cladding ID, in.	~0.218
Pin Separation:	
Method	wire wrap, all pins
Center-to-Center Spacing	~0.281 in. triangular
Nominal Rod Separation	0.030 to 0.040 in.
Support Span	12 in.
Sodium Coolant:	
Flow Direction	up
Average velocity, ft/sec	~28
Core Pressure Drop, psi	~60
Linear Power, kW/ft	~30
Average	9.2
Maximum	15.4
Maximum, with OPF	19.2
Heat Flux, 10^6 Btu/hr-ft ² :	
Average	0.485
Maximum	0.845
Maximum with OPF	1.05
Power Peaking Factors:	
Nuclear:	
Axial	1.24
Radial	1.15
Engineering, Hot Spot- Hot Channel	1.20
Transient Overpower, Over Power Factor (OPF)	1.25
Overall	2.14

Fuel Subassembly Data:

Subassembly Length	~7 ft
Pins/Subassembly	169 to 217
Active Fuel Length	~3 ft
Fuel Pin Length	~7 ft
Plenum:	
Length, in.	~24
Location	top

Other Supporting Data:

Coolant Inlet Temp. (initial core)	
Inlet	500 to 600 °F
Outlet:	
Average	800 to 900 °F
Maximum (with hot channel)	1060 °F
Maximum (with OPF)	1200 °F

DETAILED DESCRIPTION OF THE FUEL SUBASSEMBLYSubassembly Coolant Duct

The duct is a hexagonal tube in which the fuel pins are housed. It is the structural member in the core and is the flow guide for the pin assembly. Design requirements and operating characteristics are:

Configuration	Tube with circular and hexagonal cross-sections
Size	
Hexagonal Portion	3.748 ± 0.005 to 4.236 ± 0.005 in. across inside flats
Circular Portion	4.328 ± 0.005 to 4.891 ± 0.005 in. ID
Condition	Fully annealed
Material	304 SS
Specification	Modification of ASTM A213-65 to permit above configuration. Carbon controlled to 0.04 to 0.06%. N.D.T. required to assure absence of defects ≥ 10% of the wall thickness
Operating Conditions	Temperature range 500 to 1200 °F

Fuel Pin

The pin consists of a 304 SS (cladding) tube, the fuel pellet column, reflector, gas plenum, and other internal pin hardware. The cladding contains the mixed oxide fuel, and

protects the fuel from the coolant. It provides the pressure vessel for containment of fission gases and serves as the structural member for the fuel pellet column. Design characteristics for a typical cladding tube and plenum are given below. Figure 2.05-1 shows the fuel pin details

Size	0.250 + 0.002 in. OD by 0.016 ± 0.001 in. wall
Length	
Fuel Column	34 to 37 ± 0.060 in.
Plenum Chamber	34 to 37 ± 0.060 in.
Material	304 SS
Fabrication	Seamless
Condition	Fully annealed
Specification	Modification of ASTM A213 to 65. Carbon controlled to 0.04 to 0.06%. N.D.T. required to assure defect level ≤ 0.001 in.
Operating Conditions	
Temperature	500 to 1100 °F (ID) (1250 °F with OPF)
Internal Pressure	1060 psi max. at 45,000 MWd/Te avg.
Pressure Stress	9300 psi at 1100 °F
Stress Limit	9300 psi at 1100 °F (based on 0.2% creep for 6500 hr)

Fuel Pellet Column

The column, approximately 3 ft long, consisting of nominally 1/4 in. long $\text{UO}_2\text{-PuO}_2$ pellets. The fuel operates to an average burnup of approximately 45,000 MWd/tonne. The plutonium in the fuel provides the primary fissionable material; the uranium is the dilution, absorbing, and conversion material (approximately half an atom of ^{239}Pu is formed from ^{238}U for every atom of ^{239}Pu burned). The design characteristics of the mixed oxide fuel are as follows:

Fuel Composition	$\text{UO}_2\text{-20 to 25 wt\% PuO}_2$
Fuel Form	Solid, right circular, cylindrical pellets
Tentative Fuel Structure	Solid solution
Tentative Fabrication Method	Cold press and sinter
^{240}Pu Content in Pu	10 to 15% (initial)

(Oxygen/Uranium plus Plutonium) Ratio	1.95 to 1.99
Pellet Density	92 to 93% TD
Pellet Column Length	~3 ft
Pellet Diameter, Cold	~0.212 in.
Pellet Length	~0.25 in.
Cold Smear Density	~88% TD
Cold Diametral Gap, Initial	~6 to 7 mils
Hot Diametral Gap, Initial	~4 mils
Hot Diametral Gap at Goal Burnup, 45,000 MWd/tonne, average	0
Maximum Fuel Surface Temp.	~1550 °F
Maximum Fuel Temperature	~4200 °F
Maximum Fuel Temperature, with OPF	~4850 °F
Fuel Melting Point; at Burnup, ~75,000 MWd/tonne, max.	~4850 °F (est)

Reflector

The nickel reflector, placed at the top of the fuel column, provides 6 in. of reflector for the core. This improves the neutron efficiency of the core and the power density of the upper core region. Design characteristics of the nickel reflector are as follows:

Size	0.212 ± 0.001 in. diam., 6.000 ± 0.032 in. long
Material	Nickel or high nickel alloy
Specification	ASTM B-160 Fully annealed
Operating Temperature	900 to 1500 °F

Wire Wrap Spacers

The spacer wires wrapped around the fuel pins, at a pitch of ~12 in. serve two functions. They maintain rigidity and spacing in the fuel pin array and promote interchannel mixing of coolant. The design characteristics for the wire wrap spacers are as follows:

Size	0.031 to 0.040 $\pm$ 0.001 in. diam
Material	304 SS Fully annealed
Type of Connection	TIG weld at each end
Specification	ASTM A 478-63, carbon controlled to 0.04 to 0.06%
Operating Temperature	500 to 1200 °F

The grids provide top and bottom support and restraint for the fuel pins. The bottom grid is welded to the subassembly duct. The fuel pins are welded to the bottom grid. The top grid provides lateral restraint and allows independent axial expansion of each fuel pin.

The lower grid support structure is fabricated from thin members to enable flexure of the fuel pins to be transmitted through the grid structure, thus reducing fatigue problems at the grid-pin interface. The design characteristics of the fuel pin grids are given below. Figures 2.05-2 and 2.05-3 show the fuel support grid details.

Material	304 SS Fully annealed
Specification	ASTM A 213-65, carbon controlled to 0.04 to 0.06%
Operating Temperature	500 to 1200 °F

Other Subassembly Components

Other subassembly components include; the depleted UO_2 pellets at the top and bottom of the mixed oxide fuel pellet column for thermal insulators.

2.05-7

BNWL-470

QTY.	PT. NO.	DESCRIPTION	MATL.	REF.
X	1	ASSEMBLY		
1	2	ROD .212 ± .001 DIA × 6 LONG	NICKEL	
1	3	END CAP - BOTTOM		
1	4	END CAP - TOP		
AR	5	FUEL PELLETS	UD ₂ -PuO ₂	
AR	6	WIRE .031 ± .001 DIA	304 SST	
1	7	TUBE .187 ± .002 OD × .014 WALL × 23.906 LG.	304 SST	
1	8	TUBE .250 ± .002 OD × .016 WALL × 74.250 LG.	304 SST	
1	9	SPRING		
2	10	PELLETS .212 ± .001 DIA × .500 ± .005 LONG	DEPLETED UO ₂

1 ASSEMBLY

H-3-27635

4 304 SST

3 304 SST

TYP PIECE MARK

SECT "B-B"

9 MATL NOTED

SECT "A-A"

GENERAL NOTES

ALL PARTS, UNLESS OTHERWISE SPECIFIED, SHALL CONFORM TO THE FOLLOWING:

1. TOLERANCES, FRACTIONAL $\pm \frac{1}{4}$ DECIMAL $\pm .005$ ANGULAR $\pm 0^\circ 30'$
2. REMOVE ALL BURRS AND BREAK SHARP EDGES TO $\frac{1}{4}$ MIN RADIUS, EXCEPT WELD PREP AREA (TUBE END & LIPS)
3. ALL MACHINED SURFACES $\sqrt{63}$ (ASA B 46.1-1962)
4. ALL MATERIAL TO BE AS SPECIFIED, OR APPROVED EQUAL QUALITY.
5. MATERIAL 304 SST TO BE ASTM SPEC, MODIFIED A 213-65 (CARBON 0.04-0.06)

SCOPE

FIGURE 2.05-1. Fuel Pin Assembly and Details

FIGURE 2.05-2. Driver Fuel Sub-Assembly Arrangement (1 of 2)

PART NO	"A"
3	4.006
5	3.444
6	3.163
7	2.882
8	2.601
9	2.320

PART NO.	"A"	"B"	"C"	"D"	"E"
20	3.871	13	3.653	1.858	14
21	3.309	11	3.091	1.577	12
22	2.747	9	2.529	1.296	10
23	2.185	7	1.967	1.015	8

MATL: 304 SST

(24) 304 SST

PART NO.	"A"	"B"
4	3.725	1.862
17	4.257	2.128

MATL: 304 SST

PART NO	"A"
10	3.870
11	3.589
12	3.308
13	3.027
14	2.746
15	2.467
16	2.184
18	4.121

(19) 304 SST

SCOPE

FIGURE 2.05-3. Driver Fuel Sub-Assembly Arrangement (2 of 2)

2.06 FUEL HANDLING SYSTEM

The fuel handling system handles driver and experimental fuel and other test specimens while they are in the FFTF. The equipment for this mission falls into three major categories:

- Nonirradiated fuel handling
- Reactor refueling
- Irradiated fuel handling.

During conceptual design the system functional requirements were developed, the sequence of major operations were defined, and the types of major equipment were identified.

The most complex portion of the fuel handling operations is reactor refueling. Several alternate refueling methods are under investigation, and a reference and backup scheme will be chosen as a result of current reevaluation efforts. The wet fuel handling machine described in this section was investigated extensively and is included here as only one of the possible approaches to reactor refueling.

SYSTEM FUNCTIONS

The basic "package" to be handled by the fuel handling system is the driver fuel subassembly. Figure 2.06-1 shows the current driver fuel subassembly concept being used for fuel handling conceptual design studies. Other core components of similar shape and size may also be handled by the same equipment.

Fuel is received at the FFTF as fuel elements or fuel subassemblies. Figure 2.06-2 shows schematically the flow of fuel through the facility.

Nonirradiated Fuel Handling equipment provides the capability for receiving, handling, storing and inspecting the fuel.

Reactor Refueling equipment provides the capability for performing the required handling functions inside the reactor hot cell.

Irradiated Fuel Handling equipment transports the irradiated fuel including experiments between the Reactor Hot Cell, and examination and storage facilities. In addition, it provides the equipment required to transport the fuel to reprocessing facilities.

NONIRRADIATED FUEL HANDLING

The Nonirradiated Fuel Handling System includes the equipment necessary to perform the following functions (Figure 2.06-3):

- Transports nonirradiated core subassemblies such as driver fuel, experiments, control rods, core reflector and shield subassemblies, rapid transit experimental tubes, package loops, in-core tubes or fuel elements, and hanger tubes between the receiving area, inspection area, NPTF and storage areas
- Inspects nonirradiated core components for shipping damage
- Connects driver fuel and experimental elements to hanger tubes
- Checks driver fuel and experimental subassembly instrumentation
- Performs preirradiation testing
- Stores core components as listed above
- Accounts for the components listed above.

UNLOADING

The unloading dock is equipped with equipment capable of unloading railway cars or trucks. The bridge crane is capable of handling various shipping containers ranging

in length from 15 to 40 ft, in a horizontal or vertical position. Core components are unpacked, visually inspected for shipping damage, and moved to storage via the bridge crane.

STORAGE

The following storage areas are provided for core components:

- Driver fuel, experimental element, and subassembly storage
- Hanger tube storage
- Loop and rapid transit tube storage
- Control rod storage.

Driver and experimental fuel element storage vault capacity is approximately 1 1/4 cores. The vault provides for vertical storage in a pattern that separates the subassemblies for nuclear and personnel safety.

Storage for approximately one core load of hanger tubes is provided on a storage rack. This rack is equipped with clamping devices to hold the hanger tubes.

Storage for approximately one core load of hanger tubes and control rods is provided near the hanger tube storage rack.

ASSEMBLY AND CHECKING

Driver fuel and experimental subassemblies are assembled from fuel or experimental elements and hanger tubes in a clean room that is equipped with vertical assembly equipment and work platforms.

The assembly equipment receives the fuel element and hanger tube in a vertical position and mates the two together to form a completed fuel subassembly. Routine checks of the driver fuel and experimental subassemblies include the following:

- Functional testing of the instrumentation
- Straightness, length, and diameter measurements
- Flow and pressure drop test

TRANSFER

The driver fuel and experimental elements and subassemblies are unpacked in the unloading and receiving area, and are transported in a vertical position to the fuel storage vault. Hanger tubes, control rods, and in-core tubes are also unpacked and transported to their respective storage racks.

A fuel transfer mechanism transfers the core subassemblies from the storage, assembly, and checking areas to and from the Nuclear Proof Test Facility or the Fuel Transfer Cell.

REACTOR REFUELING

The reactor refueling functions within the hot cell are closely related. Functional requirements for handling specimens and reactor core components are similar to the driver fuel handling requirements. A composite system for handling fuel, specimens, and components within the reactor hot cell has important relationships to the plant availability.

The Reactor Refueling System provides the capability for performing the following functions:

- Installation and removal of driver fuel subassemblies, test fuel, and test specimens
- Installation and removal of specified reactor core components
- Transfer of fuel and other core components of similar size and shape between reactor core, interim storage positions, and transfer stations.

DESIGN REQUIREMENTS

Safety

The fuel handling equipment must be designed to preclude criticality incidents while handling the fuel both in and out of the reactor. Hazardous nuclear conditions are not to result from nonstandard operation or malfunction of fuel handling devices. The fuel handling devices must be capable of remote operation from outside of the hot cell. Personnel safety includes both radiological safety and protection against blast and missiles.

System Availability

The availability of the fuel handling equipment is determined by both reliability and maintainability. To meet the 75% plant availability goal,⁽¹⁾ system equipment must complete fuel replacement in less than 25% of the total time which is available for outages. Some time is required for maintenance operations which cannot be performed concurrently with refueling.

Preventive and routine maintenance must be accomplished while the reactor is operating. Maintainability is achieved by use of installed spares and modular design. Emphasis is placed on replacement of failed components rather than repair in place.

Major Components

The reactor refueling system consists of the following major components located in the Hot Cell:

- Secondary gamma shield
- Auxiliary tool cask(s)

1. Milton Shaw. Unpublished Data. Battelle-Northwest Laboratory, Richland, Washington, January 28, 1966. (Memorandum to D. G. Williams, "FFTF Program Direction Attachment A")

- Fuel handling machine(s)
- Decay storage tank(s)

Secondary Gamma Shield

The secondary gamma shield provides a thermal and radiation barrier on top of the reactor. Provisions are made in the secondary gamma shield to allow access to the reactor top face for refueling and maintenance.

Auxiliary Tool Cask

Tools within the auxiliary tool cask prepare the reactor nozzles for refueling and secure them after refueling. Gas tight connections between the secondary gamma shield and the cask allow personnel to work near to the reactor nozzles.

Fuel Handling Machine

The Fuel Handling Machine (FHM) contains the fuel in the sodium-filled lower body of the FHM during handling. Sodium is drawn into the cask body by differential pressure through a retractable tube which extends into the reactor nozzle. Decay heat is removed from the fuel by natural convection of the sodium in the cask. A secondary NaK loop rejects the heat via an air blast heat exchanger to the Hot Cell atmosphere. Closed loop test subassemblies are replaced either by removal with the closed loop tube or independently. The FHM utilizes a wet closure valve at the bottom of the cask body with a sodium freeze seal as back-up against leakage.

Decay Storage Tanks

Decay storage under sodium is provided for the fuel during its initial decay period. Decay storage tanks are located inside the reactor hot cell near the top of the reactor. Storage capacity is at least one core load. The decay storage heat removal capacity is approximately 1 MW. Heat removal capability is provided by other systems.

IRRADIATED FUEL HANDLING

The Irradiated Fuel Handling System (Figure 2.06-4) performs the following functions:

- Transports irradiated core subassemblies such as driver fuel, experiments, control rods, neutron source, closed loop tubes between the reactor Hot Cell, examination and storage facilities.
- Receives nonirradiated core subassemblies
- Cools irradiated fuel during receiving, transfer, cleaning, storing, and handling
- Disconnects driver fuel elements and experiments from hanger tubes
- Reclaims hanger tubes for reuse where reclaiming is feasible and economical
- Cleans core subassemblies
- Packages hanger tubes, closed loop tubes, and other components for disposal
- Provides storage of fuel elements and experiments
- Loads driver fuel and experiments for shipment.

The Irradiated Fuel Handling System includes the fuel transfer cell, the irradiated fuel cleaning station, the underwater storage and loadout basin, and the irradiated material shipping equipment.

Fuel Transfer Cell

The Fuel Transfer Cell is a multipurpose cell equipped with manipulators, hoists, cranes, remote tools, fixtures, and a fuel transfer mechanism with cooling devices to perform the following activities:

- Receives irradiated driver fuel or experimental subassemblies from the reactor hot cell transfer port
- Changes subassembly coolant from liquid sodium to inert gas

- Provides cooling for the subassemblies during handling and transfer
- Separates the driver fuel and experimental elements from the hanger tubes
- Transfers driver fuel and experimental elements to the irradiated fuel cleaning station and/or to the examination facilities
- Disposes of hanger tubes, instrument packages, closed loop tubes, etc.
- Returns experimental subassemblies to the reactor.

Remote viewing equipment including lead glass windows, closed circuit television, periscopes, etc., are used for visual observation of handling operations. Manipulators and remotely controlled equipment and tools are used for handling and for performing operations within the cell.

A filtered, cooled and purified argon gas atmosphere is recirculated through the cell. Separate forced gas or sodium cooling systems are provided for cooling fuel bundles during cleaning, handling and storage.

A solid waste processing station is located within the fuel transfer cell. The station provides equipment for removal of hanger rods and instrument packages from subassemblies, for reduction of hanger rods and other core components to disposable lengths, and for packaging the waste hardware. A storage area is also provided for storage of components awaiting processing.

Irradiated Fuel Cleaning Station

The Irradiated Fuel Cleaning Station includes equipment for the removal of sodium from the driver fuel or experimental bundles prior to transferring them to underwater examination, underwater storage, and/or shipment to onsite or offsite fuel examination or reprocessing facilities.

The cleaning station is an enclosure that is sealed to contain any reaction between the cleaning medium and the sodium. The container is equipped with cleaning nozzles which allow only a measured amount of reactive material to enter during cleaning.

Underwater Storage and Loadout Basin

The Underwater Storage and Loadout Basin receives clean fuel from the irradiated fuel cleaning station and provides equipment to transport and store it underwater. An overhead handling system transports the driver fuel and experimental elements, pins, and specimens into the storage grid or loadout area. The underwater storage grid provides an arrangement for safe fuel storage.

A section of the storage basin is used for the handling and loading of shipping casks.

A heat exchanger and demineralized water supply is provided to dissipate the decay heat. Contamination control in the storage basin is provided by filters, ion exchangers, and vacuum cleaning equipment. Leaking fuel element and pins are packaged to prevent the spread of fission products and gases.

Irradiated Shipping Area Equipment

Shipping casks are required for offsite transport of irradiated material to fuel examination and/or reprocessing facilities. Shipping casks are also required for onsite transport of irradiated materials to facilities other than the FFTF.

Equipment is required for handling and decontamination of shipping casks.

SK-3-12604

FIGURE 2.06-2. Irradiated and Nonirradiated Fuel Handling Flow Sheet

FIGURE 2.06-4. Irradiated Fuel Handling Block Diagram

2.07 REACTOR HEAT TRANSPORT SYSTEM

The Reactor Heat Transport System provides cooling for the reactor driver fuel and reactor vessel internal parts other than closed loop test fuels which are cooled by separate systems. The system transfers reactor thermal power to a circulating liquid sodium coolant and wastes heat from the sodium to an air cooled heat dump. Figure 2.07-1 illustrates the process flow arrangement.

The overall system is comprised of four independent, parallel cooling circuits of equal power handling capability. Each of the four circuits is made up of a primary system loop, a secondary system loop, and an air heat dump.

The system design is optimized for dual operating requirements associated with:

- Initial reactor operation using a mixed oxide driver fuel having maximum coolant temperature limitations of approximately 900 °F, and
- Ultimate reactor operation using advanced, high temperature driver fuels.

The design provides a nominal 400 MWt power handling capability when operating any three of the four cooling circuits with a reactor outlet sodium temperature at 1100 °F. For initial reactor operation, the system capability is 400 MWt when operating all four of the cooling circuits with a reactor outlet sodium temperature above approximately 865 °F.

PRIMARY SODIUM SYSTEM

The primary sodium system performs direct contact cooling of driver fuel, reactor vessel, and other reactor vessel internal parts. Sodium circulation through the four closed

pipng loops, transports the reactor heat to intermediate sodium-to-sodium heat exchangers. The four loops have common flow paths through the reactor vessel but are otherwise independent in operation. Each loop includes one pump and one heat exchanger.

Heat is transferred from primary to secondary sodium systems within the intermediate heat exchangers. The heat exchanger tube bundles isolate activated primary sodium from the secondary system, thus serving as barriers preventing radioactive sodium and fission product transport out of the containment structure. This arrangement permits design flexibility for locating heat dump equipment outside of the containment structure in accessible unshielded areas.

Centrifugal type sodium pumps are located downstream of the heat exchangers. Variable speed pump drives adjust the sodium flow rate. The pumps are equipped with auxiliary pony motors to provide low flow conditions required during reactor refueling and standby operation. Energized from the plant emergency electric power supply; the pony motors provide backup cooling in the event of a normal power supply failure.

Pressure control of inert cover gas above the free surfaces maintains system operating pressure at the reactor vessel outlet. An overflow to a surge tank maintains fixed sodium level within the reactor vessel.

The relative elevation of reactor core and heat exchanger thermal centers establishes a driving head for natural convective sodium flow adequate for reactor decay heat cooling following an emergency reactor shutdown.

All reactor vessel nozzles are located above the top of the core. Siphon breaks are installed to prevent draining reactor sodium below the vessel nozzles in the event of a

pipng leak. Check valves in each pump discharge line prevent sodium backflow following a pump shutdown.

To minimize all potential sodium leaks, the design does not use permanently installed valves for system gravity drain. The system is drained by means of temporary dip tubes installed through openings located above normal reactor sodium level.

Primary system components, other than pump drive motors, are installed in shielded vaults below the main operating floor and adjacent to the reactor vault. Shielding is provided between primary system components and habitable building areas. An inert gas atmosphere minimizes fire hazards in the primary equipment vault.

The major primary system components are:

- Primary sodium pumps and electric motor drive equipment
- Primary side of intermediate heat exchangers
- Check valves for pump discharge
- Piping
- Pipe and equipment supports
- Thermal insulation
- System preheat equipment
- Control and surveillance instrumentation.

SECONDARY SODIUM SYSTEM

The secondary sodium system receives heat transferred from the primary side of the intermediate heat exchangers and transports the heat to the air heat dumps. There are no sodium interconnections between the four secondary system loops, thus permitting selective operation of individual loops. Located in the system cold leg piping, centrifugal pumps circulate the sodium coolant.

Expansion tanks accommodate sodium thermal expansion and establish the required pump net positive suction head for

secondary pumps. System operating pressure is maintained by control of inert gas makeup and vent to the expansion tanks. Sodium pressure at the intermediate heat exchangers is maintained above the primary system pressure in order to avoid radioactive contamination of secondary sodium in the event of a heat exchanger tube leak.

The physical arrangement of secondary system components promotes natural convective sodium flow adequate for reactor decay heat removal following a reactor shutdown.

Other than the secondary sides of the intermediate heat exchangers and piping connections at the heat exchangers, secondary system components are located in accessible, unshielded building areas outside of the reactor system containment vessel. Piping runs to the heat dumps are located outdoors and above ground level.

The major secondary system components are:

- Secondary sodium pumps and electric motor drive equipment
- Secondary side of intermediate heat exchangers
- Expansion tanks
- Valves as required for heat dump module isolation, sodium drain, and vent
- Piping
- Pipe and equipment supports
- Thermal insulation
- System preheat equipment
- Control and surveillance instrumentation.

HEAT DUMP SYSTEM

The heat dump system transfers heat from secondary system sodium to ambient air. The heat dumps are forced-draft type, using motor-driven blowers and fin-tube heat exchanger coils. Cooling rate is modulated over the reactor power range by controlling air flow. Heated air is discharged through exhaust

stacks. Stack heights are designed to promote natural draft adequate for reactor decay heat removal.

The heat dump exchangers are located in an outdoor area adjacent to reactor plant buildings.

The heat dump components are:

- Heat exchanger fin-tube coil sections
- Cooling air blowers and electric motor drives
- Coil casings, ductwork, breeching, and exhaust air stacks
- Structural supports
- Thermal insulation
- Preheat equipment
- Control and surveillance instrumentation.

SYSTEM PROCESS CONDITIONS

Table 2.07-I lists the general system design and performance conditions which typify the design for operation using advanced driver fuels. The tabulated conditions assume operation with three of the four available cooling circuits and 400 MWt total reactor power generation.

TABLE 2.07-I. *Process Conditions for Ultimate Operation Using Three Cooling Circuits (Data shown are for one of the three operating circuits.)*

Power Handling Capability, MWt	133
Sodium Temperatures, °F	
Reactor Vessel Outlet (IHX Pri. Inlet)	1100
Reactor Vessel Inlet (IHX Pri. Outlet)	800
Heat Dump Inlet (IHX Sec. Outlet)	975
Heat Dump Outlet (IHX Sec. Inlet)	675
Air Temperatures, °F	
Heat Dump Inlet	100
Heat Dump Outlet	500
Flow Rate, lb/hr	
Primary Sodium	5.02×10^6
Secondary Sodium	4.98×10^6
Heat Dump Air	4.42×10^6
Reactor Vessel Cover Gas Pressure, in. H ₂ O	<10
Primary System Pressure Loss, psi	
Reactor Vessel	120
Intermediate Heat Exchanger (shell side)	3
Piping System	20
Total Pressure Loss	143
Secondary System Pressure Loss, psi	
Dump Heat Exchanger	16
Intermediate Heat Exchanger (tube side)	2
Piping System	66
Total Pressure Loss	84
Nominal Pipe Diameters, in. OD	
Primary - Reactor Outlet to Pump Suction	24
Primary - Pump Discharge to Reactor Inlet	16
Secondary	16
Maximum Pipe Velocities, ft/sec	
24-in. Primary	9.3
16-in. Primary	20.6
16-in. Secondary	21.1

COMPONENTS

Tabulated design and performance data included with the component descriptions are based upon ultimate operating requirements at 400 MWt with the use of three of the four available cooling circuits.

Figures 2.07-2 and 2.07-3 show a conceptual layout of piping and equipment.

Intermediate Heat Exchangers

The four intermediate heat exchangers are vertical, shell and tube, counterflow type with primary sodium flow on the shell side and secondary sodium within the tubes. The units permit removal of tube bundles for repair or replacement without disturbing shells or primary piping connections. The shell section extends upward through the biological shield floor and shielding material is installed within the shell extension to attenuate radiation from the activated primary sodium.

To the maximum extent possible, the design will utilize applicable features and fabrication details proven through previous operating experience with units used at FERMI, EBR II, HNPF, and the ALCO unit currently under test at the SCTI Facility. Table 2.07-II shows the conceptual design and performance data for the intermediate heat exchangers.

TABLE 2.07-II. *Intermediate Heat Exchanger Design and Performance Data*

Number of Units	4
Duty per Unit, MWt	133
Shell Side (primary sodium)	
Inlet Temperature, °F	1100
Outlet Temperature, °F	800
Flow Rate, lb/hr	5.02×10^6
Velocity, ft/sec	4.7
Pressure Loss, psi	2.3
Sodium Volume, ft ³	329
Design Pressure, psig	75
Design Temperature, °F	1100
Tube Side (secondary sodium)	
Inlet Temperature, °F	675
Outlet Temperature, °F	975
Flow Rate, lb/hr	4.98×10^6
Velocity, ft/sec	6.7
Pressure Loss, psi	1.9
Sodium Volume, ft ³	185
Design Pressure, psig	150
Design Temperature, °F	1000
Overall Heat Transfer Coefficient, Btu/(hr)(ft ²)(F)	1020
Total Fouling Factor	0
Log Mean Temperature Difference, °F	125
Total Surface, ft ²	3570
Tube OD, in.	1.0
Tube Wall Thickness, in.	0.065
Tube Pitch (triangular), in.	1.375
Number of Tubes	908
Total Tube Length, ft	16
Effective Tube Length, ft	15

Primary Sodium Pumps

The four primary sodium pumps are electric motor driven, vertical shaft, single stage, centrifugal, free surface type similar to those used in the HNPF and FERMI reactor plants.

Eddy current drive couplings provide variable pump speed control. Auxiliary pony motors are also provided for pump operation at approximately 10-15% of rated pump speed.

The pumps are located in the cold leg piping downstream of the intermediate heat exchangers. An inert gas space is provided between the pump free surface sodium level and pump shaft seals. An overflow line from each pump barrel feeds back to the pump suction piping to maintain a constant pump sodium level. A loop seal in the overflow prevents cover gas from entering the pump suction. The pump gas spaces are interconnected with reactor vessel cover gas. The required pump NPSH is maintained by reactor cover gas pressure and static head difference between reactor vessel sodium level and the pump suction.

Shield plugs, located in the pump barrels above the cover gas, provide biological shielding. The shield plugs and pump internals are removable from the fixed pump tanks without disturbing primary piping connections. Table 2.07-III shows conceptual design and performance data for the primary system pumps.

Secondary Sodium Pumps

Except for biological shielding plugs and remote maintenance features of the four secondary pumps and associated drive equipment are similar to the primary pumps.

Sodium overflow from the pump barrel extensions is routed through the secondary system expansion tanks and then back to the pump suction piping. To avoid the possibility of vortex entrainment of cover gas, the pumps are installed external to

the expansion tanks with direct piping connections to pump suctions. The pump barrel gas spaces are interconnected with the expansion tank cover gas by external piping. The required pump NPSH is maintained by control of expansion tank cover gas pressure. Table 2.07-III show the secondary pump design and performance data.

TABLE 2.07-III. *Sodium Pump Design and Performance Data*

	<u>PRIMARY PUMPS</u>	<u>SECONDARY PUMPS</u>
Number of Units	4	4
Capacity Rating, gpm (minimum)	11,750	11,450
Total Dynamic Head, ft	385	222
Sodium Temperature at Rating, °F	800	675
Suction Pressure, psig	-1.3	5
Discharge Pressure, psig	142	89
Maximum Operating Speed, rpm	870	1170
Pumping Horsepower	1300	745
Motor Horsepower	1500	800
Shaft Length, ft	23	15 (approx)
Design Temperature, °F	1100	1000
Design Pressure, psig	175	150
Pipe Nozzle Sizes, in OD		
Suction	24	16
Discharge	16	16

Heat Dump Equipment

Heat from secondary system sodium is transferred to ambient air through forced-draft, sodium-to-air heat exchangers. The heat dump installations for each of the four cooling circuits are further subdivided into three or more heat exchanger modules. Each module is equipped with a heat exchanger coil

and blower arranged to permit operation independently of other modules. The modular design:

- Provides a broad capacity turndown ratio assuring stable operation at low power demands (by module shutdown).
- Reduces the physical size of heat exchanger coil sections thus simplifying fabrication, field erection, and maintenance.
- Minimizes damage and loss of plant capability in the event of a sodium fire leak.
- Reduces blower size requirements permitting use of commercially available equipment.

The heat exchanger sections are fin-tube type and are arranged for complete sodium drainage to permit maintenance. Motor-operated block valves are provided for isolating coil sections in the event of a sodium leak and to permit selective module shutdown during low load operation. The coil sections are installed in insulated steel casing enclosures.

Forced-draft equipment consists of electric motor driven blowers equipped with variable-position inlet vanes for capacity control. Positioning operators provide stepless modulation of inlet vane settings to maintain a preset reactor inlet sodium temperature throughout the reactor power range. Blower discharge louvers, with remote-manual operators, are also used to improve low load control stability and to isolate the blowers from heated air during system preheat or standby operations. Sound attenuators are provided to reduce noise levels.

Heated air is exhausted through steel stacks. Stack height and diameter are sized to permit natural draft adequate to assure reactor decay heat removal in the event of an electric power failure to the blower motors. The stack

tops are provided with remote-operated, low-leakage dampers or equivalent devices which serve to:

- Block cooling air flow following a reactor shutdown to prevent sodium freeze-up in heat exchanger coils.
- Reduce the air volume available for sodium-air reaction in the event of a sodium leak.
- Minimize heat loss due to air leakage through the unit during standby or preheat operation.

Electric resistance heating elements are installed in the air inlet plenums below the heat exchanger coils for preheating the coils prior to sodium fill and for maintaining sodium in a liquid state during standby operation. Table 2.07-IV shows design and performance data for each of the four heat dumps.

TABLE 2.07-IV. Heat Dump Design and Performance Data

Number of Units	4
Number of Modules per Unit	4
Duty per Unit, MWt	133
Outside Finned Surface, ft ²	197,000
Overall Outside Heat Transfer Coefficient, Btu/(hr)(ft ²)(F)	4.9
Log Mean Temperature Difference, °F	473
Fin-tube Data	
Total Number of Tubes	2944
Tube OD, in.	1.0
Fin OD, in.	2.25
Fin Thickness, in.	0.022
Fin Spacing, fins/in.	8
Overall Tube Length, ft	18
Effective Tube Length, ft	15
Number of Tube Passes	4
Number of Tube Rows/Pass	2

TABLE 2.07-IV. (contd)

Tube Side Conditions (sodium)

Inlet Temperature, °F	975
Outlet Temperature, °F	675
Flow Rate, lb/hr	4.98×10^6
Tube Velocity, ft/sec	8.5
Pressure Loss, psi	15.9
Sodium Volume, ft ³	485
Design Pressure, psig	150
Design Temperature, °F	1000

Shell Side Conditions (air)

Inlet Temperature, °F	100
Outlet Temperature, °F	500
Flow Rate, lb/hr	4.42×10^6
Pressure Loss (HX coil), in. H ₂ O	1.6

Blower Data

Number/Heat Dump Unit	4
Flow Rate, cfm	2.79×10^5
Speed, rpm	1170
Equivalent Pressure, in. H ₂ O	6.0
Efficiency, %	80
Blower Brake Horsepower	330
Motor Brake Horsepower	350

Piping

Sodium system piping is all-welded construction using full penetration butt welds for assembly. Long radius fittings or pipe bends are used. Flexibility to accommodate thermal expansion is provided by offsets and loops.

Piping is supported by a constant support, spring hanger system. Sway braces or equivalent flexible snubbers are used where necessary to minimize vibration.

All lines are sloped toward drain points permitting complete system drainage. Vents are provided where necessary to release trapped gas.

Structural design conditions are:

	<u>Pressure, psig</u>	<u>Temperature, °F</u>
Primary System - Reactor outlet to pump suction	75	1100
Primary System - Pump discharge to reactor inlet	175	1100
Secondary System	150	1000

Preheat Equipment

The heating equipment is provided for preheating pipe and equipment prior to sodium fill and maintaining sodium in a liquid state during standby. Heaters are electric resistance type attached directly to heated surfaces. Heaters are designed to assure a minimum sodium temperature of 500 °F. Redundant heaters are installed on equipment located in areas inaccessible for contact maintenance.

SK-3-12651

FIGURE 2.07-1. System Schematic
Reactor Heat Transport

SK-3-12750

FIGURE 2.07-2. Reactor Heat Transport System Arrangement Plan

SK-3-12751

FIGURE 2.07-3. Reactor Heat Transport
System Arrangement Sections (1 of 2)

SODIUM TO AIR HEAT DUMP

REACTOR SECONDARY Na EQUIP.

REACTOR PRIMARY Na EQUIP.

ELEVATION B-B - REACTOR HEAT TRANSPORT SYSTEM

SK-3-12750

SK-3-12751

FIGURE 2.07-4. Reactor Heat Transport System Arrangement Sections (2 of 2)

2.08 SODIUM AND INERT GAS SERVICE SYSTEMS

The Sodium and Inert Gas Service Systems provide the supporting services of storing, supplying, purifying and disposing of all of the liquid metal and inert gas to be used in the FFTF. These services include six sodium systems and seven inert gas systems.

Sodium is used in all liquid metal systems, except the NaK service cooling system. Three inert gases are used in the FFTF; argon, nitrogen and helium. Argon is used as a cover gas for low temperature liquid metal systems, as an atmosphere for irradiated fuel handling cells, and as an alternate cover gas for closed loop primaries and the fuel handling machine. Nitrogen is used as an atmosphere in radioactive sodium equipment rooms and helium is used as a cover gas for high temperature liquid metal systems.

SODIUM RECEIVING AND PROCESSING SYSTEMS

System Description

The Sodium Receiving and Processing Systems include the following:

- Fresh Sodium Receiving and Processing System
- Reactor Secondary Sodium Processing System
- Closed Loop Secondary Sodium Processing System
- Reactor Primary and Fuel Storage Sodium Processing System
- Closed Loop Primary Sodium Processing Systems
- Contaminated Sodium Processing System

Fresh Sodium Receiving and Processing System

The Fresh Sodium Receiving and Processing System receives, purifies, stores and distributes fresh sodium to the reactor and closed loop heat removal systems. The system flow diagram is shown on Figure 2.08-1. Fresh sodium is received in tank cars and melted by circulating heated oil through channels on the tank cars. The tank car is pressurized with inert gas to transfer the molten sodium through a heated

unloading line and filter to the fresh sodium storage tank. The fresh sodium recirculation and transfer pump circulates the sodium through an oxygen removal cold trap, a plugging meter and sodium sampler, and delivers fresh sodium to the reactor and closed loop primary and secondary heat removal systems and fuel storage facilities.

Reactor Secondary Sodium Processing System

The Reactor Secondary Sodium Processing System stores and processes sodium for the reactor secondary heat removal system. A system flow diagram is shown on Figure 2.08-2. The system includes a storage tank, recirculation and transfer pump, an oxygen removal cold trap, plugging meter and a sodium sampler. The storage tank maintains a reserve sodium supply for normal makeup to the reactor secondary heat removal loops and is sized to receive the entire contents of all four reactor secondary heat removal systems.

Sodium from storage or from the individual reactor secondary heat removal loops may be circulated by either the loop pump or the recirculation and transfer pump through the cold trap, sampler and plugging meter during purification operations. The recirculation and transfer pump may also transfer sodium from storage to the secondary heat removal systems and vice versa. Provisions are included for future addition of oxygen and carbon removal hot traps.

Closed Loop Secondary Sodium Processing System

A single sodium processing system stores and processes sodium for the secondary heat removal systems of all closed loops. A system flow diagram is shown on Figure 2.08-3. The system includes a storage tank, recirculation and transfer pump, oxygen removal cold trap, oxygen and carbon removal hot traps, plugging meter and a sodium sampler. The storage tank maintains a reserve sodium supply for normal makeup to the closed loop secondary systems and is sized to

receive the entire contents of all the closed loop secondary systems.

Sodium from storage or from the individual loop secondary systems may be circulated through the purification system by either the loop pump or the recirculation and transfer pump. The recirculation and transfer pump may also transfer sodium between the storage tank and the closed loop secondary systems.

Reactor Primary and Fuel Storage Sodium Processing System

The Reactor Primary and Fuel Storage Sodium Processing System serves both the reactor primary heat removal system and the fuel storage facilities. A system flow diagram is shown on Figure 2.08-4. The equipment includes a surge tank, storage tanks, recirculation and transfer pumps, oxygen removal cold traps, a plugging meter and a radioactive sodium sampler. Provisions are included for future installation of oxygen and carbon removal hot traps. Process piping and equipment is contained in shielded rooms. Provisions are included for remote replacement of contaminated equipment.

The surge tank provides capacity to accommodate sodium volume changes and maintains a reserve of hot sodium for makeup to the reactor in case of a primary system leak. Sodium is pumped continuously from the surge tank to the reactor and overflows from the reactor to the surge tank to maintain a constant reactor sodium level. The storage tanks are sized to receive the combined contents of the reactor primary system and fuel decay storage. The recirculation and transfer pumps recirculate sodium from the surge tank, storage tanks, or from fuel storage through the purification system, or transfer sodium between storage and the reactor primary system or fuel storage. Sodium overflow from the reactor and decay storage vessels removes impurities from the sodium surfaces.

Closed Loop Primary Sodium Processing Systems

Independent sodium processing systems, Figure 2.08-5, are provided for each closed loop primary system. The process piping and equipment are shielded. Process equipment for each loop includes a storage tank, recirculation and transfer pump, oxygen removal cold trap, plugging meter, radioactive sodium sampler, and oxygen and carbon removal hot traps. The storage tanks contain a reserve of sodium for makeup to the closed loop primary system.

Sodium is pumped continuously from the storage tank to the closed loop and overflows back to the storage tank. A bypass stream may be directed through the purification and sampling system. The storage tanks are sized to receive the contents of the closed loop primary systems. Recirculation and transfer pumps transfer sodium between storage and the primary systems. Provisions are included for remote replacement of contaminated equipment.

Contaminated Sodium Processing System

Figure 2.08-6 shows the Contaminated Sodium Processing System flow diagram. The system receives contaminated sodium from the reactor or closed loop primary sodium processing systems and from the maintenance cell and processes it for reuse or disposes of it.

The system components are shielded. Process equipment includes a storage tank, recirculation and transfer pump, oxygen removal cold trap, plugging meter and a radioactive sodium sampler. The sodium disposal equipment includes a tank in which the sodium is reacted with water and neutralized with acid, and a pump to transfer the neutralized waste solution to the Radioactive Waste System. An inert gas purge is provided to sweep out gases to avoid accumulation of hydrogen or radioactive gases or vapors.

INERT GAS RECEIVING AND PROCESSING SYSTEMS

System Description

The Inert Gas System includes the following:

- Helium Receiving and Distribution System
- Helium Purification System
- Nitrogen Receiving and Distribution System
- Argon Receiving and Distribution System
- Argon Processing System - Fuel Transfer and Fuel Examination Cells
- Radioactive Gas Decay and Vent System
- Vacuum System.

Helium Receiving and Distribution System

Figure 2.08-7 shows the Helium Receiving and Distribution System Flow Diagram. The system receives, stores and distributes fresh and purified helium to the following:

- Reactor primary heat transport system
- Closed loop primary heat transport system
- Fuel decay storage
- Fuel handling system
- Contaminated sodium processing system
- Short term irradiation facility.

The Helium Purification System provides the primary helium supply necessary to make up system losses. Pressure in each user system is maintained within preset ranges by supply and vent pressure controls. Vented gas is returned to the Helium Purification System.

Fresh helium is received in tank cars and transferred by pressure equalization to the high pressure storage tanks, then to low pressure storage through a pressure reducing station, and is finally supplied to the distribution header through a

second stage pressure reducing station. The second stage station includes a low capacity valve for normal makeup and a high capacity valve for large volume makeup which might be required during rapid cooling of the reactor.

Helium Purification System

The Helium Purification System receives and purifies helium vented from the user systems. Figure 2.08-8 shows the system flow diagram. Equipment includes an inlet and outlet filter, inlet sodium vapor trap, compressors, copper and copper oxide beds, molecular sieve beds and liquid nitrogen cooled cold traps. A dual system is provided to permit normal operation of half the system during regeneration of the other half.

The copper and copper oxide beds remove oxygen and oxidize hydrogen and carbon monoxide to water and carbon dioxide, which can be adsorbed by the molecular sieve beds. The cold trap removes the remaining impurities including methane, nitrogen, xenon and krypton. The copper and copper oxide beds are regenerated by heating in the presence of dilute oxygen in the copper bed and dilute hydrogen in the copper oxide bed. The molecular sieve bed and the cold trap are regenerated by heating under vacuum. Impurities released during regeneration are vented to the Radioactive Gas Decay and Vent System.

Nitrogen Receiving and Processing System

The Nitrogen Receiving and Processing System receives, stores and distributes nitrogen to the following user systems:

- Reactor primary sodium purification cell
- Reactor primary sodium storage cells
- Reactor access area
- Reactor hot cell
- Reactor primary equipment cells and reactor cavity
- Closed loop cells

- Maintenance and decontamination cell
- Helium purification system (liquid nitrogen).

As shown in the System Flow Diagram, Figure 2.08-9. liquid nitrogen is received and stored in a storage tank with integral vaporizer for converting the liquid to gas and gaseous nitrogen is piped directly to the Helium Purification System pressure control valves regulate system pressure. Liquid nitrogen is piped directly to the helium purification system for cooling the cold traps and the vapor is returned to the nitrogen gas system. Gas vented from the user systems is vented to the Radioactive Gas Decay and Vent System for disposal.

Argon Receiving and Distribution System

The Argon Receiving and Distribution System receives, stores and distributes argon to the following user systems:

- Reactor Secondary Heat Transport System
- Closed Loop Secondary Heat Transport System
- Fuel handling system
- Fuel Transfer Cell
- Inert Gas Cell Examination Facility
- Sodium Sampling and Analysis Facilities.

Figure 2.08-10 shows the System Flow Diagram. Liquid argon is received and stored in a storage tank with integral vaporizer for converting the liquid to gas. The argon gas is piped to the user systems where inlet and outlet pressure control valves regulate the system pressure. Argon gas purity within the user systems is maintained by feed and bleed or as described under the Argon Processing System for the Fuel Transfer and Fuel Examination cells. Gas is vented through the Radioactive Gas Decay and Vent System.

Argon Processing System: Fuel Transfer and Fuel Examination Cells

The Argon Processing System supplies, filters, cools, and removes oxygen and moisture from the argon atmosphere in

the Fuel Transfer and Fuel Examination Cells. Figure 2.08-11 shows the System Flow Diagram. Pressure controlled high and low flow supply valves, an exhaust valve and two oil seals for relieving gas over-pressure are provided. A recirculation system filters and cools the cell atmosphere to remove particulate contamination and heat from fuel, lights and in-cell equipment.

Oxygen and moisture concentrations are controlled. A compressor and receiver, drawing from the recirculation system, maintains a supply of compressed argon which is distributed to in-cell service outlets for operation of pneumatic equipment. Cooling of fuel elements during examination is also provided. Cell nitrogen concentration is controlled by feed and bleed.

Radioactive Gas Decay and Vent System

The Radioactive Gas Decay and Vent System receives and monitors activity of vented gases and discharges them directly to the building vent system or to holding tanks for controlled release to the atmosphere via the stack. The system flow diagram is shown on Figure 2.08-12.

Vacuum System

A vacuum system is provided for outgassing and filling sodium systems, for regenerating the helium purification system and for outgassing and filling the Short Term Irradiation Facility. Figure 2.08-13 shows the system flow diagram.

Two portable vacuum pumps are provided, one for radioactive systems and one for nonradioactive systems. Valved and capped connections which can be connected to the vacuum pump by flexible hoses are provided for systems requiring vacuum service. A vacuum exhaust header carries gas from radioactive systems to the Radioactive Gas Decay and Vent System.

FRESH SODIUM RECEIVING & PROCESSING

LEGEND

INSTRUMENT SYMBOLS

LETTER	POSITION IDENTIFICATION		
	FIRST	SECOND	THIRD
A		ALARM	
C			CONTROLLER
F	FLOW		
H			HI
I		INDICATOR	
L	LEVEL		LO
P	PRESSURE		
R		RECORDED	
T	TEMPERATURE		

NOTE: ALL SYSTEM ITEM NUMBERS SHALL BE PRECEDED BY SYSTEM NO. 81.

EQUIPMENT LIST

EQUIPMENT PIECE NUMBER	SYSTEM ITEM NUMBER	DESCRIPTION	SIZE (IN INCHES)	PRESS. (PSI)	END CONN.	MATERIAL	REMARKS
FRESH SODIUM RECEIVING & PROCESSING							
	F-1-1	FILTER, SODIUM					
	T-1-1	TANK, FRESH Na STG					
	P-1-1	PUMP, RECIRC & TFR					
	CT-1-1	COLD TRAP					
	HC-1-1	HEATER-COOLER					
	SS-1-1	SODIUM SAMPLER					
	SS-1-2	"					
	PM-1-1	PLUGGING METER					
	MFM-1-1	MAGNETIC FLOW METER					
	MFM-1-2	"					
	VT-1-1	VAPOR TRAP					
	FT-1-1	FREEZE TRAP					
	FT-1-2	"					
	TCH-1-1	TANK CAR HEATER					
	V-1	VALVE					
	V-2						
	V-3						
	V-4						
	V-5						
	V-6						
	V-7						
	V-8						
	V-9						
	V-10						
	V-11						
	V-12						
	V-13						
	V-14						
	V-15						
	V-16						
	V-17						
	V-18						
	V-19						
	V-20						
	V-21						
	LP-1-1	LEVEL PROBE					
	LAW-1-1	ALARM, HI					
	LAL-1-1	" LO					
	LI-1-1	INDICATOR					
	FI-1-1	FLOW INDICATOR					
	FI-1-2	"					
	TIC-1-1	TEMP IND CONTROLLER					
	TIC-1-2	"					
	TI-1-1	TEMP IND					
	TI-1-2	"					
	TI-1-3	"					
	TAW-1-1	ALARM, HI					
	TAC-1-1	REC CONTROLLER					
	PI-1-1	PRESS. INDICATOR					
	PI-1-2	"					
	FAL-1-1	FLOW ALARM, LO					

FIGURE 2.08-1. System Flow Diagram Fresh Sodium Receiving and Processing

FIGURE 2.08-2. Sodium Flow
Diagram Reactor Secondary Na
Receiving & Processing

[illegible]

FIGURE 2.08-3. System Flow
Diagram Closed Loop Secondary
Sodium Receiving & Processing

REACTOR PRIMARY SODIUM RECEIVING & PROCESSING

SK-3-12716

EQUIPMENT LIST CONTINUED						EQUIPMENT LIST									
EQUIPMENT PIECE NUMBER	SYSTEM ITEM NUMBER	DESCRIPTION	SIZE IN INCHES	PRESS. NORMAL	END CONN.	MATERIAL	REMARKS	EQUIPMENT PIECE NUMBER	SYSTEM ITEM NUMBER	DESCRIPTION	SIZE (IN INCHES)	PRESSURE (NORMAL)	END CONN.	MATERIAL	REMARKS
TRC-4-1A	TRC-4-1A	TEMP RECORDER-CONTROLLER						T-4-1A	T-4-1A	TANK, REACTOR PRIMARY NO STORAGE					
	TRC-4-1B							T-4-1B	T-4-1B	↓					
	TRC-4-2A							T-4-2	T-4-2	REACTOR PRIMARY NO SURGE					
	TRC-4-2B							P-4-1A	P-4-1A	PUMP, RECIRCULATION & TRANSFER					
	TI-4-1A	TEMP. INDICATOR						P-4-1B	P-4-1B	↓					
	TI-4-1B							CT-4-1A	CT-4-1A	COLD TRAP					
	TI-4-2A							CT-4-1B	CT-4-1B	↓					
	TI-4-2B							HC-4-1A	HC-4-1A	HEATER-COOLER					
	TI-4-3A							HC-4-1B	HC-4-1B	↓					
	TI-4-3B							SS-4-1	SS-4-1	SODIUM SAMPLER					
	TI-4-4A							PM-4-1	PM-4-1	PLUGGING METER					
	TI-4-4B							MFM-4-1A	MFM-4-1A	MAGNETIC FLOW METER					
	TI-4-5A							MFM-4-1B	MFM-4-1B	↓					
	TI-4-5B							VT-4-1A	VT-4-1A	VAPOR TRAP					
	TAH-4-1A	TEMP. ALARM HI						VT-4-1B	VT-4-1B	↓					
	TAH-4-1B							FT-4-1A	FT-4-1A	FREEZE TRAP					
	TAL-4-1A							FT-4-1B	FT-4-1B	↓					
	TAL-4-1B							FT-4-2A	FT-4-2A	↓					
	TAH-4-2							FT-4-2B	FT-4-2B	↓					
	LI-4-1A	LEVEL INDICATOR						RHX-4-1A	RHX-4-1A	REGENERATIVE HEAT EXCH.					
	LI-4-1B							RHX-4-1B	RHX-4-1B	↓					
	LI-4-2							VT-4-2	VT-4-2	VAPOR TRAP					
	LAH-4-1A	LEVEL ALARM HI						V-4-1A	V-4-1A	VALVE					
	LAH-4-1B							V-4-1B	V-4-1B	↓					
	LAH-4-2							V-4-2A	V-4-2A	↓					
	LAL-4-1A							V-4-2B	V-4-2B	↓					
	LAL-4-1B							V-4-3A	V-4-3A	↓					
	LAL-4-2							V-4-3B	V-4-3B	↓					
	FI-4-1A	FLOW INDICATOR						V-4-3C	V-4-3C	↓					
	FI-4-1B							V-4-3D	V-4-3D	↓					
	FAL-4-1A	FLOW ALARM LO						V-4-3E	V-4-3E	↓					
	FAL-4-1B							V-4-3F	V-4-3F	↓					
	PI-4-1A	PRESS. INDICATOR						V-4-3G	V-4-3G	↓					
	PI-4-1B							V-4-3H	V-4-3H	↓					
	PI-4-2A							V-4-3I	V-4-3I	↓					
	PI-4-2B							V-4-3J	V-4-3J	↓					
	PI-4-3A							V-4-3K	V-4-3K	↓					
	PI-4-3B							V-4-3L	V-4-3L	↓					
								V-4-15	V-4-15						
								V-4-16	V-4-16						
								V-4-17	V-4-17						
								V-4-18	V-4-18						
								V-4-19	V-4-19						
								V-4-20	V-4-20						
								V-4-21	V-4-21						
								V-4-22	V-4-22						
								V-4-23	V-4-23						
								V-4-24	V-4-24						
								V-4-25A	V-4-25A						
								V-4-25B	V-4-25B						
								V-4-26A	V-4-26A						
								V-4-26B	V-4-26B						
								V-4-27	V-4-27						
								V-4-28A	V-4-28A						
								V-4-28B	V-4-28B						

PRINCIPAL FLOW

INST. AIR LINE

INST. ELECTRICAL LINE

ELECTRIC HEATER

REMOVABLE SEPARATION

DIAPHRAGM OPERATED DAMPER

VALVE

TO T₁, T₂H

INERT GAS

FREEZE TRAP

TO P₁C, T₁, T₂H

INERT GAS

VAPOR TRAP

MFM

MAGNETIC FLOW METER

LEGEND

POSITION IDENTIFICATION

LETTER	FIRST	SECOND	THIRD
A		ALARM	
C			CONTROLLER
F	FLOW		
H			HI
I		INDICATOR	
L	LEVEL		LO
P	PRESSURE		
R		RECORDER	
T	TEMPERATURE		

LOCALLY MOUNTED

BOARD MOUNTED

NOTE:

ALL SYSTEM ITEM NUMBERS SHALL

BE PRECEDED BY SYS. NO. 31.

LEGEND

PRINCIPAL FLOW	INERT GAS	TO T1, TAH
INST. AIR LINE	TO GAS CLEAN-UP	FREEZE TRAP
INST. ELECTRICAL LINE	INERT GAS	TO T1, TAH
ELECTRIC HEATER	TO GAS CLEAN-UP	VAPOR TRAP
REMOVABLE SEPARATION		
DIAPHRAGM OPERATED DAMPER		
VALVE		
INSTRUMENT SYMBOLS		
POSITION IDENTIFICATION		
LETTER	FIRST	SECOND
A		ALARM
C		CONTROLLER
F	FLOW	
H		HI
I		INDICATOR
L	LEVEL	LO
P	PRESSURE	
R		RECORDER
T	TEMPERATURE	

NOTE:
ALL SYSTEM ITEM NUMBERS SHALL
BE PRECEDED BY SYS. NO. 81.

FIGURE 2.08-4. System Flow Diagram Reactor Primary Sodium Receiving & Processing

CLOSED LOOP PRIMARY Na RECEIVING & PROCESSING
TYPICAL FOR 6 LOOPS

SK-12718

L E G E

N D

EQUIPMENT LIST

PRINCIPAL FLOW
 INSTRUMENT AIR LINE
 INSTRUMENT ELECTRICAL LINE
 ELECTRIC HEATER
 REMOVABLE SEPARATION
 DIAPHRAGM OPERATED DAMPER
 GATE VALVE
 RESTRICTION ORIFICE

INSTRUMENT SYMBOLS

LOCALLY MOUNTED
 BOARD MOUNTED

POSITION IDENTIFICATION			
LETTER	FIRST	SECOND	THIRD
A		ALARM	
C			CONTROLLER
F	FLOW		
H			HI
I		INDICATOR	
L	LEVEL		LO
P	PRESSURE		
R		RECORDER	
T	TEMPERATURE		

ALL SYSTEM ITEM NUMBERS SHALL BE PRECEDED BY SYSTEM N° 81.

EQUIPMENT PIECE NUMBER	SYSTEM ITEM NUMBER	DESCRIPTION	SIZE (INCHES)	PRESS. (NORMAL)	END CONN.	MATERIAL	REMARKS
	T-5-1	TANK, CLOSED LOOP, PRIMARY NO. 5TG					
	P-5-1	PUMP, FILL, RECIRC					
	C-5-1	COLD TRAP					
	HC-5-1	HEATER-COOLER					
	RHX-5-1	REGENERATIVE HEATEXCH					
	OHT-5-1	OXYGEN HOT TRAP					
	CHT-5-1	CARBON HOT TRAP					
	SS-5-1	SODIUM SAMPLER					
	PM-5-1	PLUGGING METER					
	MFM-5-1	MAGNETIC FLOW METER					
	MFM-5-2	↓ ↓ ↓					
	VT-5-1	VAPOR TRAP					
	FT-5-1	FREEZE TRAP					
	FT-5-2						
	FT-5-3						
	FT-5-4						
	FT-5-5						
	V-5-1	VALVE					
	V-5-2						
	V-5-3						
	V-5-4						
	V-5-5						
	V-5-6						
	V-5-7						
	V-5-8						
	V-5-9						
	V-5-10						
	V-5-11						
	V-5-12						
	V-5-13						
	V-5-14						
	V-5-15						
	V-5-16						
	V-5-17						
	V-5-18						
	V-5-19						
	V-5-20						
	TRC-5-1	TEMP. RECORDER/CONTROLLER					
	TRC-5-2						
	TRC-5-3						
	TRC-5-4						
	TI-5-1	TEMP. INDICATOR					
	TI-5-2						
	TI-5-3						
	TI-5-4						
	TI-5-5						
	TI-5-6						
	TI-5-7						
	TI-5-8						
	TIC-5-1	↓ ↓ ↓					
	TAH-5-1	TEMP. ALARM HI					

EQUIPMENT PIECE NUMBER	SYSTEM ITEM NUMBER	DESCRIPTION	SIZE (INCHES)	PRESS. (NORMAL)	END CONN.	MATERIAL	REMARKS
	TAH-5-2	TEMP. ALARM HI					
	TAH-5-3	↓ ↓ ↓					
	LR-5-1	LEVEL RECORDER					
	LAL-5-1	LEVEL ALARM LO					
	FI-5-1	FLOW INDICATOR					
	FI-5-2	↓ ↓ ↓					
	FAL-5-1	FLOW ALARM LO					
	FAL-5-2	↓ ↓ ↓					
	PI-5-1	PRESSURE INDICATOR					
	PI-5-2	↓ ↓ ↓					
	LAL-5-1	LEVEL ALARM HI					

FIGURE 2.08-5. System Flow
Diagram Closed Loop Primary
Na Receiving & Processing.

CONTAMINATED SODIUM PROCESSING

SK-3-12720

EQUIPMENT LIST (CONT)							EQUIPMENT LIST								
EQUIPMENT PIECE NUMBER	SYSTEM PIECE NUMBER	DESCRIPTION	SIZE (IN INCHES)	PRESS. (PSI)	END CONN.	MATERIAL	REMARKS	EQUIPMENT PIECE NUMBER	SYSTEM PIECE NUMBER	DESCRIPTION	SIZE (IN INCHES)	PRESS. (PSI)	END CONN.	MATERIAL	REMARKS
	T-8-1	TANK, WASTE Na WATER REACTION								CONTAMINATED SODIUM PROCESSING					
	P-8-1	PUMP, TRANSFER								P-6-1					
	V-8-1	VALVE								CT-6-1					
	V-8-2									HC-6-1					
	V-8-3									SS-6-1					
	LI-8-1	LEVEL INDICATOR								PM-6-1					
	TI-8-1	TEMP								MFM-6-1					
	RN-8-1	REACTION NOZZLE								VT-6-1					
	PHM-8-1	pH METER								FT-6-1					
										FT-6-2					
										T-6-1					
										V-6-1					
										V-6-2					
										V-6-3					
										V-6-4					
										V-6-5					
										V-6-6					
										V-6-7					
										V-6-8					
										V-6-9					
										V-6-10					
										V-6-11					
										V-6-12					
										V-6-13					
										V-6-14					
										V-6-15					
										V-6-16					
										V-6-17					
										V-6-18					
										V-6-19					
										V-6-20					
										TRC-6-1					
										LAH-6-1					
										LI-6-1					
										LAL-6-1					
										PI-6-1					
										PI-6-2					
										TI-6-1					
										TI-6-2					
										TI-6-3					
										TIC-6-1					
										TAH-6-1					
										FI-6-1					
										FAL-6-1					
										T-7-1					
										V-7-1					
										V-7-2					
										V-7-3					
										LI-7-1					
										TI-7-1					

PRINCIPAL FLOW

INSTRUMENT AIR LINE

INSTRUMENT ELECTRICAL LINE

ELECTRIC HEATER

REMOVABLE SEPARATION

DIAPHRAGM OPERATED DAMPER

VALVE

RESTRICTION ORIFICE

INERT GAS

TO TI & TAH

TO INERT GAS CLEANUP

FREEZE TRAP

INERT GAS

TO PIC, TI, TAH

TO INERT GAS CLEANUP

VAPOR TRAP

MFM

MAGNETIC FLOW METER

INSTRUMENT SYMBOLS

LOCALLY MOUNTED

BOARD MOUNTED

POSITION IDENTIFICATION			
LETTER	FIRST	SECOND	THIRD
A	FLOW	ALARM	CONTROLLER
C			
F			
H			
I	LEVEL	INDICATOR	HIGH
L		LOW	
P			
R	PRESSURE	RECORDER	
T		TEMPERATURE	

ALL SYSTEM ITEM NUMBERS SHALL BE PRECEDED BY SYSTEM NO 51

FIGURE 2.08-6. System Flow Diagram Contaminated Sodium Processing

2.08-15

BNWL-470

FIGURE 2.08-7. System
Schematic Helium Receiving
and Distribution

SK-3-12781

SK-3-12782

FIGURE 2.08-8. System Schematic Helium Purification

FIGURE 2.08-9. System
Schematic Nitrogen Receiving
and Distribution

NOTE:
ALL SYSTEM ITEM NUMBERS SHALL BE PRECEDED BY SYSTEM NO.82. THUS: PCV-82-3-1
*REFER TO DESIGN STUDY 11, APPENDIX B, CSDD FOR SYSTEM 81

FIGURE 2.08-11. System Schematic
Argon - Fuel Transfer and Fuel
Examination Cells

SK-3-12785

FIGURE 2.08-13. System Schematic Vacuum Services

2.09 INSTRUMENTATION AND CONTROL

The FTR instrument safety and control system provides a highly reliable safety system designed to

- assure positive reactor safety shutdown when required
- provide a reactor-control characteristic that will cause least disturbance to the fuels and elements undergoing test
- provide high on-line availability for both the reactor and closed loop tests.

Sensors or transducers are used to convert different kinds of data such as temperature and pressure into electrical signals. These signals are amplified and displayed in the control room. Analog instruments and digital computers are used for safety, automatic control, data display, and data logging.

SAFETY CIRCUIT

A reliable safety circuit, patterned after the fail-safe reactor safety circuitry successfully demonstrated at EBR-II, SRE, and other reactors will be used. The best features of the latest safety circuitry are used in design of the FFTF safety circuit.

A typical safety circuit includes neutron flux detection chambers that transmit a flux level signal to an amplifier. From the amplifier the signal is transmitted to a controller that compares the signal to a trip set point. If the neutron flux level signal exceeds this set point, a contact is opened within the controller which trips a relay in the safety circuit. If two out of three such analog instruments open contacts, the final master safety trip relay is de-energized. De-energizing the master trip relay causes removal of electrical power from all safety rod holding coils causing insertion of the rods into the reactor at maximum speed. Similarly, other analog instruments initiate trip signals to scram or drive all rods into the reactor whenever safe operating conditions are exceeded. Operation of the safety rod

scram circuit is dominant over all other reactor operational or slower shutdown signals and will cause the reactor to shut down at maximum safe speed.

Trip inputs to the scram circuit Figure 2.09-1 are limited to those items that could be directly and immediately hazardous to the reactor. These trips include:

- Low level neutron flux period
- Intermediate range neutron flux period
- Power range flux level
- Power range power rate-of-change
- Individual reactor channel low flow
- Sodium bulk over-temperature on primary loop
- Sodium over-temperature on each individual reactor tube channel
- Loss of primary loop sodium flow
- Earthquake.

All these items will be covered by trip signals from analog instruments feeding to the safety circuit. A manual trip is also included. The above trips cover the reactor as a whole. In addition, there are safety circuit trips on the individual closed loops. These trips will include, but will not be limited to, the following trips for each closed loop:

- Low flow
- Over-temperature.

CONTROLLED SHUTDOWN

The "controlled shutdown" circuit is regulated by the computer. The control rods are driven into the reactor core at a rate which causes least disturbance to the fuel test specimens or the least damage to the reactor structure.

All noncritical trips are included in the controlled shutdown program which is executed by the computer. These trips monitor incidents (e.g., loss of a secondary pump, single power line failure, secondary loop over-temperature, and fire) which do not require a scram of the reactor with its attendant thermal shock.

Slower shutdown rates for noncritical reactor problems do not compromise the safety of the reactor because the scram safety circuit overrides the controlled shutdown circuit and shuts the reactor down rapidly if some parameter exceeds safe conditions during a controlled shutdown.

CENTRAL CONTROL AND DATA HANDLING SYSTEM

The basis of the central control and data handling system is a configuration with a minimum of three general purpose digital computers, as shown in Figure 2.09-2. One computer provides the process control function, the second controls the experimental facilities, and the third computer acts as a supervisory computer to the other two and is capable of taking over either of the two functional duties in event of failure. Each computer has other functions in the areas of data display, data handling, and back-up duties.

The nuclear safety system will be a separate and independent conventional analog configuration. The computer control system will initiate power setback and controlled shutdown.

Control Computers

The Experiment Computer will control the test loops and the experiments within the loops. Control functions that could cause interaction with the reactor as a whole will be coordinated with the Process Computer through the Supervisory Computer.

The Process Computer will have control of all functions related to the process facilities such as the reactor, main heat removal loops, etc.

Supervisory Computer

The Supervisory Computer performs four primary tasks:

- Computes setpoints as required and coordinates the control computers
- Checks the control computers

- Assumes the duties of either of the other computers if they fail
- Compiles records.

Setpoints and setback procedures will change as a function of power level, operating temperature, fuel burnup, etc. For example, as fuel burnup proceeds, the general operating setpoints will have to be changed. The Supervisory Computer normally makes the necessary calculations and updates the values as required. The new setpoint values or new operating procedures are placed in the mass storage unit of the proper control computer.

The Supervisory Computer reads the flux channels frequently and reads all other sensors less frequently but on a regular basis. The expected control response is calculated and compared with the actual output from either the automatic control device (if power level control is in the automatic mode) or the manual control station. Any out-of-tolerance discrepancy will be alarmed.

If either control computer fails, the Supervisory Computer can take over the control functions. A lock-out circuit disables the failed computer's outputs and enables those of the Supervisory Computer. The double switch multiplexer provides complete overlap of the inputs, allowing uninterrupted scanning. This technique allows maintenance personnel to check out the failed computer effectively on-line.

Records of relevant data will be kept in two separate files. Essentially, all data will be continuously stored on magnetic tape as a complete legal record of operations. Certain data (e.g., tube temperature maps or flux levels) will be held for a limited period of time on the Supervisor's magnetic disk memory. This information can be retrieved from the disk for comparison with current data or to display a trend.

MANUAL CONTROL SWITCHES

The manual control switches (or manual backup stations) which are associated with the critical process and experimental variables are located near the operator's console. These control switches directly operate the actuators to the final control elements. The capability, at the operator's option, to transfer control from the computer to manual (and, of course, back to automatic) is provided, and the status of control is displayed with suitable indicator lights. Each manual station provides indicators which display the process variable and the actuator position.

CONTROL CONSOLE

The control console includes the following functional hardware:

- Manual scram
- Startup channel bypass switches
- Rod operate switches
- Operating mode selector (manual, permissive, or automatic nuclear control)
- Rod selection and rod gang switch
- Annunciator
- Computer-directed CRT's for display of trend, matrix, and alpha-numeric data
- Typewriter for the digital system
- Manual input station for setpoint change, including memory protect or limited access key locks.

Panels located near the control consoles include the following functional hardware:

- Strip chart recorders, amplifiers, and power supplies for nuclear instrumentation
- Startup channels and bypass switches
- Period, level, rate of change, and error recorders
- Manual backup stations.

CONTROL MODES

Instrumentation and control devices which permit complete automatic control with manual backup are used. The reactor will be started up initially by manual control of rod movements. During subsequent operations, as detailed knowledge of the plant characteristics is accumulated, and as certain portions of the reactor control system demonstrate clearly that they can be controlled automatically without compromising reactor safety, these portions are switched to automatic control.

Startup Control

At startup both safety and control rods are completely inserted and the coolant inlet temperature is controlled at a preselected temperature above the sodium freezing point.

Neutron flux is monitored by the low level instrumentation as the safety rods are pulled. A neutron source is required to assure operation of the low level instrumentation. The regulating rods and the shim rods will then be withdrawn to approach criticality. As subcritical multiplication is increased, inverse multiplication plots will be calculated by the computer and displayed to the operator for use in determining the proper approach to criticality. When criticality has been achieved, the reactivity will be adjusted to maintain a prescribed reactor period. The intermediate range instrumentation will be used to monitor reactor period and power level as soon as sufficient flux is available at the flux sensors to provide a reliable indication.

In the power range (above 1% of design power), linear power level and rate-of-rise instrumentation take precedence over other nuclear channels.

Power Level Control

Three methods of power level detection are used for control purposes:

- Neutron flux (neutron chambers, etc.)

- Reactor tube outlet temperature
- Thermal power calculation from reactor tube differential temperature and flow rate.

Neutron flux measurements in the power range permit tight control of power level. Good reliability is achieved by use of multiple chambers and averaging-rationality check logic circuitry. The slower, but more accurate, thermal measurements are used effectively to maintain an accurate power level condition.

Manual Control

The operator, observing the indicating and recording instruments, can control the power level of the reactor by manually operating shim and regulating rod controls on the console. Other manual controls in the control room can be used to regulate sodium temperature, flow, pressure, level, and other pertinent reactor and test loop parameters.

Sodium Temperature Control

Significant transport lags exist between the heat source and the various heat sinks causing system instabilities unless relatively low controller gain settings are used. However, low controller gains result in sluggish control performance.

Considerable improvement in performance can be obtained by the use of a dead-time (transport) compensation model technique.⁽¹⁾ Further improvements are possible using the capability of the digital computer memory to represent the dead-time model. A direct digital control system includes these control improvements with no additional equipment complexity.

1. O. J. M. Smith. "A Controller to Overcome Dead Time," ISA Journal, vol. 6, no. 2. February, 1959.

Scram and Transient Behavior

The large differential temperature across the core, combined with a relatively low heat storage capacity, causes rapid changes in reactor outlet temperatures during scram. Reactor power level responses to reactivity disturbances are expected to be stable.

SENSORS AND INSTRUMENT SYSTEMS

Sensors located within the reactor vessel are subject to particularly hazardous environments such as gamma fields approaching 10^{10} R/hr in the reactor core, neutron fluxes approaching 10^{16} nv in and near the core and sodium temperatures of 1200 °F. These are more severe than those encountered in other reactors.

Programs have been established to develop and test instrumentation sensors or systems to meet FFTF requirements. The results of these developments will provide the basis for much of the instrument sensor and instrument systems design.

Neutron Flux

Since the dynamic range of the neutron flux from shut-down to full power is approximately 10^{10} , three complementary systems are used. An arrangement of the sensors in the neutron shield is shown in Figure 2.09(3). All neutron sensors are sensitive to thermal neutrons and are located in the neutron shield. Positioning mechanisms are provided for the more sensitive channels to increase their effective dynamic range. Suitable inorganic insulation materials are available for use in the sensors and leads to withstand the nuclear and thermal environments. A neutron source is used to support the subcritical neutron flux to a detectable level at all times.

Low Level

The system sensitivity is adequate to observe the relative neutron flux with all rods inserted in the core. Each channel consists of a fission counter type detector, log countrate meter, and period meter.

Intermediate Range

Each channel consists of gamma-compensated ion chambers, log-level amplifiers, and period meters, or fission chambers monitored with mean-square voltage instrumentation.

Power Range

Each channel consists of neutron sensitive ion chambers and linear dc amplifiers covering the top two decades of reactor power. Linear rate-of-rise information is derived from these signals for safety and for control.

In-Core Flux Distribution System

A system for making rapid spatial flux distribution measurements at several locations in the reactor core is required. Activational and ion chamber devices such as traveling wires, traveling balls ("Aero-ball") and traveling chambers are under consideration for this series. Neutron energy distribution measurements may also be performed with the same mechanical system using selective activational materials or threshold chambers.

Fuel Channel Instrumentation

The instrumentation associated with an individual sub-assembly such as flow, outlet temperature and sodium sampling for fuel failure detection are expected to be an integral part of the fuel subassembly. Figure 2.09-4 shows a fuel subassembly including a section for a magnetic flowmeter, a section for mixing the coolant prior to measuring outlet temperature and provisions for a sodium sample line. The

connectors needed at the top of the subassembly which allow remote disconnection of all electrical or fluid lines associated with the subassembly instrumentation are not shown on the drawing. In-vessel connectors located between the instrument sensors and the top of the subassembly may be used to reduce the length of the assembly which must be handled during refueling.

Fuel Failure Monitor

The Fuel Failure Monitor System involves the reactor cover gas, the four bulk primary heat removal loops, all closed test loops, and all open test loops and driver fuel channels. The fuel failure equipment cells are located within the main containment structure Figure 2.09-5.

Loop or channel coolant is monitored for fission product content in all cases by a combination of two techniques:

- Delayed neutron monitoring for fission debris is applicable only during reactor operation at power. Its use is dictated by the safety advantage of the short detection time compared to other available techniques.
- Fission gas monitoring is applicable during reactor operation at power or during shutdown. It is used because the delayed neutron monitoring is not applicable during shutdown conditions.

The delayed neutron monitor draws a sample of sodium and transports it to a shielded cell housing the neutron moderator and detection equipment. Primary loops are monitored continuously, but individual fuel channels are scanned by a valving system. Sample flow is measured to determine the age of the sample and permit appropriate corrective action. Back purging of lines with nonradioactive sodium reduces exposure levels for maintenance.

Closed loop delayed neutron monitoring systems are similar except the moderators and detectors are mounted directly on the loop piping, utilizing the full loop flow and the inherent shielding and flow control of the loop.

The fission gas monitoring system utilizes available gas samples from the reactor cover gas. The space above each reactor channel may also be usable as a collection volume. The presence of fission products in the sweeping gas may be detected by a gas chromatograph, or by an elastostatic precipitator that collects the solid daughters of noble fission gases. The reactor cover gas, each primary loop, and each closed loop are monitored continuously. Individual reactor channels are scanned.

Rod Position Indication

Rod position is indicated by both analog and digital means.

Temperature

Sodium coolant temperatures are sensed in most locations by thermocouples. In certain out-of-vessel applications, such as the measurement of thermal power level, redundant resistance elements are provided. Spare thermocouples are provided for critical applications, such as fuel channel coolant effluents, and heat removal system coolant temperatures. Strap-on or other nonpenetrating type sensors are used for applications where response time requirements permit and where accuracy requirements can be met with these methods.

Pressure

Pressures in the primary and secondary loops, and other vessels with a gas blanket, are sensed at a tap in the gas blanket region. Sensing lines are vapor trapped and means are provided for back purging with clean gas. It is necessary to measure liquid sodium pressure at the discharge of loop pumps and at the reactor inlet plenum. Sensors for this service require development.

Sodium Level

Sodium levels are sensed in the reactor vessel, surge tanks, pump tanks, and other locations as required. For some applications narrow span or single point level sensors are adequate (e.g., induction type probe). Redundant sensors are provided for critical applications and severe environments such as reactor vessel level.

Flow

Magnetic flowmeters are used for most sodium flow measurements in the main reactor piping and in the auxiliary circuits. Magnetic flowmeters are standard items available from several manufacturers and should present little difficulty except for initial calibration on the larger size flowmeters. Magnetic flowmeters are installed in each primary loop as close to the reactor vessel as practical. Multiple sensing connections and lines are utilized to provide redundancy for flow loss monitoring and flow control circuits. Magnetic flowmeters and a differential pressure type flow device are installed in each secondary loop. The differential pressure device provides means for checking calibration of the primary and secondary magnetic flowmeters.

Flow measurement in reactor tubes is more difficult, mostly due to the high neutron flux, high gamma radiation, relatively high temperature (for transducers), and small available space. A cylindrical magnetic flowmeter is the reference design. However, turbine flowmeters or eddy current flowmeters may be feasible if the magnetic flowmeter fails to meet requirements.

Leak Detection

Sodium leaks in the heat removal equipment will be monitored by detectors appropriate for the individual applications. Smoke detectors will be used to monitor for airborne sodium vapors while gamma detectors will be used for

detection of leaks from the primary sodium system to the secondary sodium. Leaks from the primary piping will be monitored using thermocouples or resistance sensing devices.

FUEL HANDLING MACHINE INSTRUMENTATION

The instrumentation and control systems, Figure 2.09-6, were made for a wet fuel handling machine concept. This drawing is typical of the instrumentation required for a wet fuel handling machine.

Instrumentation is provided to indicate and control all major fuel handling machine parameters. These include: sodium level, grapple position, atmosphere control in cask, heat removal from sodium pool, cooling and heating of cask, cask lifting system, machine positioning system, purge system, and seal leak detection system.

NONIRRADIATED FUEL HANDLING SYSTEM

The instrumentation is provided for mechanical check out of incoming fuel and to determine flow and pressure drop characteristics of completed fuel subassemblies.

An automated data handling system is provided to store fuel nuclear and physical properties as determined in this receiving inspection. In addition this data handling system provides a complete fuel accountability system.

Radiation Monitoring

A radiation monitoring system includes:

- Airborne particulate monitors for personnel protection and for process monitoring of gaseous effluents
- Beta-gamma activity monitors for personnel protection and for process monitoring of activity build-up on filter or traps
- Effluent monitors for process monitoring and control of liquid effluent streams
- Halogen monitors for monitoring gaseous effluent streams

The system also includes criticality monitors, personnel monitors, neutron detectors, and filter counters.

Gas Analytical System

The reactor cover gas is monitored for chemical impurities and for fission gases. Gas is drawn from a number of reactor points and taken via sample lines to a gas analysis room. The gas is sampled by a programmer which runs the gas samples to a gas chromatograph. Different chromatographs are used in the radioactive and nonradioactive gas systems.

Water analyzers are used to monitor for water at the purifier output and at the input to the reactor sodium systems. Continuous oxygen analyzers measure oxygen content at the inlet to each system. The nitrogen and argon in the inert gas filled spaces are monitored for chemical impurities.

Oxygen Analyzer

Each sodium loop in FFTF is equipped with a plugging meter. A continuous reading model will be used for this application if proven versions are available.

An electrochemical oxygen probe is being developed and will be used for specific oxygen impurity measurements if operation in radioactive sodium is proven. Below 700 °F the oxygen probe can be used directly. A heat exchanger will be used on installations exceeding 700 °F to limit sample sodium temperature to about 600 °F.

Carbon and Hydrogen Analyzers

A proven in-line carbon analyzer is not now available. A promising device is undergoing advanced laboratory testing at United Nuclear Corporation. This device depends on diffusion of carbon through a metallic membrane at about 1400 °F for subsequent measurement. Installation of these devices is planned in all coolant systems except the reactor secondary system when proven models are available.

In-line hydrogen monitors are not required to measure water in-leakage since steam generators will not be used. In-line hydrogen monitors should be installed, if proven models are available, whenever refractory metals are in contact with sodium coolants at temperatures ≥ 900 °F.

SK-3-12691

FIGURE 2.09-5. Building Plan XVI
at Elevation +23 ft 0 in.

FIGURE 2.09-6. Instrumentation Engineering Diagram for Wet Fuel Handling Machine

2.10 IRRADIATION TESTING FACILITIES

The FFTF can accommodate a variety of irradiation testing facilities with flexibility to locate tests in essentially any lattice position. Testing facilities that can be installed are:

- Closed Loops
- Package Loops
- Open Test Positions
- Short-Term Test Facilities
- Reflector Test Holes
- Axial Positioners.

Arrangement of the initial testing facilities is shown in Figure 2.10-1.

CLOSED LOOPS

A closed loop is a system which provides an isolated, recirculating coolant to an in-reactor tube for testing fuel and material specimens at conditions other than those provided or permitted by the reactor coolant. Coolant flow through the in-reactor section may be re-entrant or single pass.

A closed loop facility provides coolant quality control and heat removal capabilities tailored to special testing requirements. Coolants other than sodium may be used. Choice of construction materials is optional in closed loop tube internals. Power-temperature limits are set by testing requirements and material limitations. Closed loop systems are designed to accept vented fuel, and fuel clad failures during testing without harm to the reactor and/or contamination of the primary cooling system.

The FFTF is designed with six closed loop equipment cells. The initial split-conical core can accommodate five vertical closed loops in the central split region. Initially three sodium cooled closed loops are installed in their locations designated A-1, B-1 and B-2 on Figure 2.10-1. These loops are sodium cooled. The main functional testing capabilities of the initially installed loops are indicated in Table 2.10-I.

Future Closed Loop Facilities

It is planned that two additional closed loops will be installed in the central split region of the core in the locations noted as C-1 and C-2. The characteristics of these loops will be based on the results of further testing requirements studies. Position C-1 is proposed as the location of an advanced design, sodium-cooled facility, and position C-2 as a helium-cooled facility. Table 2.10-II shows tentative design characteristics for these closed loops. Other alternate coolants may be used in future closed loops with appropriate development and within safeguards limitations.

A sixth closed loop can be installed at some other undefined lattice position if testing requirements indicate this need. Alternately, the sixth closed loop cell can be used as a spare cell for installation of new out-of-reactor closed loop equipment to minimize closed loop changeout time.

CLOSED LOOP COOLING SYSTEM

Each closed loop has a separate cooling system with primary and secondary sodium circuits and with final heat dissipation to air via finned tube, air blast heat exchangers. Essential features of the closed loops are shown in the engineering flow diagram, Figure 2.10-2. Table 2.10-III summarizes operating conditions and design data.

TABLE 2.10-I. *Initial Closed Loop Facilities*

<u>Type</u>	<u>Closed Loop A-1</u>	<u>Closed Loop B-1</u>	<u>Closed Loop B-2</u>
Number	1	1	1
Maximum test diameter, in.	4	3 1/2	3 1/2
Maximum test length above core, ft	15	15	15
Maximum test length below core, ft	3 1/2	2	2
Total power, MW	0.7-5	0.6-5	0.6-5
Flux, n/cm ² /sec	~0.6x10 ¹⁶ *	~0.5x10 ¹⁶ *	~0.5x10 ¹⁶ *
Coolant Fluid	Na	Na	Na
Inlet Temp, °F	500-1100	500-1100	500-1100
Outlet Temp, °F**	800-1200	800-1200	800-1200
Test Section ΔT, °F**	20-400	20-400	20-400
Inlet Pressure, psig	20-150	20-150	20-150
Outlet Pressure, psig	20-50	20-50	20-50
Test Section, ΔP, psi	1-130	1-130	1-130
Flow, gpm	70-600	70-600	70-600

* Consistent with a nominal maximum reactor flux of 0.7×10^{16} n/cm²/sec

** Bulk Coolant Temperature. Within safeguards limits, there are no inherent limitations on local channel temperatures that may be achieved by orificing, etc.

TABLE 2.10-II. *Potential Future Closed Loop Facilities*

<u>Type</u>	<u>Closed Loop C-1</u>	<u>Closed Loop C-2</u>
Number	1	1
Maximum Test diameter, in.	3	2 1/2
Maximum Test Length Above Core, ft	15	15
Maximum Test Length Below Core, ft	3 1/2	3 1/2
Total Power, MW	0.4-6*	0.4-4
Flux, n/cm ² /sec	0.4 x 10 ¹⁶	0.4 x 10 ¹⁶
Coolant Fluid	Na	He
Inlet Temp, °F	500-1200	500-1200
Outlet Temp, °F**	800-1400	800-1500
Test Section, ΔT	20-500	20-600
Inlet Pressure, psig	20-150	50-1500
Outlet Pressure, psig	20-50	50-1500
Test Section, psi	1-130	1-100
Flow	40-600 gpm	12,000 #/hr

* Requires advanced design of cooling system.

** Bulk Coolant Temperature. Within safeguards limits, there are no inherent limitations on local channel temperatures that may be achieved by orificing, etc.

Separate purification, purity monitoring, storage sampling, and handling of primary sodium is provided in each of the equipment cells. Purification equipment includes cold traps, zirconium packed hot traps (for oxygen removal), and stainless steel packed hot traps (for carbon removal). Sodium purity is monitored by plugging temperature indications. Storage capacity is provided to contain all primary sodium, including that in the purification system and the backup supply. A common purification, storage, and service system is used for secondary systems.

Purified helium gas (with argon optional) is used to pressurize the pump expansion and storage tanks. It serves as purge gas for rupture (fission gas) monitoring, and as general cover gas for sodium surfaces. For primary system service the gas is circulated at low flow and static helium atmospheres are maintained over sodium in the secondary system pump expansion and storage tanks.

Filling of the primary system may be done automatically or manually from the primary expansion tank; while drainage is performed manually. Provision is made for evacuation of the primary system prior to filling. Provisions are made for decontamination of the primary system to remove rupture debris and to reduce radiation levels.

The loops are instrumented for operational control, safety, and test data collection. Instrumentation also includes audio and visual sensors to monitor system operation. The safety circuit instrumentation incorporates two-out-of-three coincidence trip action with intermediate alarms used to gain advance warning of offstandard conditions.

PRIMARY SYSTEM DESIGN FEATURES

In-Reactor Loop Tube

The in-reactor loop tube is either a U-tube or re-entrant design. The tubes differ in OD and configuration below

TABLE 2.10-III. *Typical Closed Test Loop Operating Conditions and Design Data*

PRIMARY SYSTEM

Coolant

sodium

Design flow (max)

600

Design flow (normal), gpm

500

TDH, psi

175 at 600 gpm

Piping

Design temperature, °F

1250

Design pressure, psig

225

Pipe Material

Austenitic Stainless
Steel

Pipe size, in.

3 or 4

Intermediate Heat Exchanger

Type

Single Pass
Counterflow

Design duty, MW

5

Main Circulating Pump

Type

Helical rotor
(vertical centri-
fugal free surface
pump as alternate.)

Flow rate, gpm

600

TDH, psi

175

Motor, hp

~100

TABLE 2.10-III. (contd)Service Pump

Type	ac Electro-magnetic Induction
------	-------------------------------

Flow rate, gpm	50
----------------	----

TDH, psi	60
----------	----

SECONDARY SYSTEM

Coolant fluid	Sodium
---------------	--------

Design flow (max)	600
-------------------	-----

Design flow (normal), gpm	500
---------------------------	-----

TDH, psi	100
----------	-----

Piping

Design temperature, °F	1150
------------------------	------

Design pressure, psig	150
-----------------------	-----

Pipe material	Austenitic Stainless steel
---------------	----------------------------

Pipe size, in.	4
----------------	---

Main Circulating Pump

Type	Vertical, Centrifugal, Free Surface
------	-------------------------------------

Flow rate, gpm	1250
----------------	------

TDH, psi	100
----------	-----

Main motor, hp	50
----------------	----

Emergency Pump

Type	ac Electro-magnetic Induction
------	-------------------------------

Flow rate, gpm	100
----------------	-----

RDH, psi	40
----------	----

Air Blast Heat Exchanger

Type	Enclosed, Finned Tube
------	-----------------------

Design duty, MW	5
-----------------	---

the core depending upon the core position. For all configurations, the outer pressure bearing tube is insulated by an inert gas gap to maintain thermal stresses at an acceptable level.

The re-entrant tube design, shown in Figure 2.10-3, permits removal of the in-reactor tube without disconnecting piping from the nozzle spool piece. The design also permits the replacement of the spool piece alone or the spool piece with attached inlet and outlet piping.

A U-tube can be readily installed in the two outermost loop positions. As shown in Figure 2.10-4, a U-tube can be placed in the center position by dividing the coolant inlet tube. A U-tube arrangement does not appear feasible in the two intermediate positions. All U-tube arrangements require a special reactor nozzle arrangement.

Pumps and Expansion Tanks

The main primary pumps are of the helical rotor type with centrifugal free surface pumps as alternates. Either type uses integral shield plugs. Two pumps are used for redundancy.

Expansion tanks are sized to handle the maximum volume fluctuation of the system. Gravity overflow of sodium to the primary storage tank is provided. The arrangement of pumps and other Closed Loop primary system components in the closed loop cell is shown in Figure 2.10-5.

Intermediate Heat Exchangers

The intermediate heat exchangers are vertical, counterflow, internal floating head, shell and tube design similar to the Fermi units. The primary coolant is on the shell side of the exchangers.

Primary Sodium Storage

The primary storage tank is designed to contain the entire contents of the primary system plus a normal backup

supply. The storage tank is located on the floor of the primary equipment cell. Storage tank contents may be routed to sampling, purification, primary system filling, or to waste or external purification by an electromagnetic pump. Cover gas pressure in the storage tank is the same as that in the main primary system expansion tank.

SECONDARY COOLING SYSTEMS

Pumps and Expansion Tanks

The secondary system pumps are of the free surface centrifugal type with integral expansion tanks. Each expansion tank has its own liquid level control since it may not be desirable to operate the secondary pumps with a common gas over pressure. There is no gravity overflow from the secondary expansion tanks. An electromagnetic emergency pump is installed on a bypass line around each main pump.

Secondary Sodium Storage

Common sodium purification, sampling, auxiliary service, and storage are used for all closed loop secondary systems. Stagnant cover gas is used in the main storage tank. The storage and service tank serving the closed loop secondary systems is sized to contain the contents of three secondary systems plus a normal backup supply.

AIR BLAST HEAT EXCHANGERS

Final heat dissipation from the secondary systems is to air via individual, finned-tube, air-blast, heat exchangers located above grade in the heat dump area. Coils are fabricated of stainless steel with stainless steel fins. Each unit contains means for system heating.

The blower capacity of each heat exchanger is split between two fans. Each fan has a stack to discharge the heated air above the surrounding structures and to create

natural draft. The stacks are equipped with shut off dampers actuated by a smoke-detection alarm system.

EMERGENCY AND BACKUP COOLING

Electromagnetic pumps are used on bypass lines around the main pumps in the secondary systems for emergency cooling. Emergency pumping capability is adequate to cool a fuel subassembly following loss of normal power.

The possibility of a rupture in primary or secondary system piping requires injection of backup coolant at a location as close to the process tube as possible. For backup cooling, a continuously running service pump provides the coolant supply near the reactor top face.

PACKAGE LOOPS

The FTR core can accommodate a large number of package loops in both core and reflector lattice positions. There are two types of package loops:

- The natural convection loop which dissipates small amounts of heat to the reactor coolant by means of natural circulation within the tube.
- The forced convection loop with a pump and heat exchanger built into its top end for heat dissipation to a heat dump or to the reactor coolant.

Initially, one package loop will be installed in the core and one in a reflector position. These natural convection loops are designated as NC-1 and NC-2 and their proposed location is indicated on Figure 2.10-1. Major functional characteristics of these initial, natural convection loops are listed in Table 2.10-IV

OPEN TEST POSITIONS

An open test is an experiment, directly cooled by the reactor primary coolant. Coolant flow and temperature control are possible by orificing, auxiliary heating and internal flow channeling. Since all core lattice positions have full instrumentation capability, any position is available for open loop testing.

Initially, 13 open loop test positions are provided: two in the central split region in the locations designated C-1 and C-2, three in average flux regions in the core, and eight in core edge positions.

Table 2.10-V gives the major functional testing capabilities of the initially-installed open loop test positions.

SHORT-TERM TEST FACILITIES

Facilities for testing small specimens for less than one reactor cycle without shutdown may include:

- a pneumatic or hydraulically-operated shuttle with rapid insertion and removal rates ("Rabbit" type facility),
- a mechanically-driven shuttle with slower insertion and removal rates but with the potential for handling somewhat larger test specimens ("trail-cable" type facility).

Heat removal may be either by reactor coolant or by an auxiliary liquid metal or gas system.

A typical gas-driven and gas-cooled rapid transit facility, schematically shown in Figure 2.10-6, is located in a reflector position. The facility accommodates a specimen carrier or at least 2 in. diam and 2 in. length. The irradiation position is controllable from 0 to 10 ft above the core mid-plane to provide variable test fluxes. The coolant gas temperature, at the specimen location, is controllable from 200 to 1200 °F. Transport times are less than a minute.

TABLE 2.10-IV.*Initial Package Loop Facilities*

<u>Type</u>	<u>Package Loop NC-1</u>	<u>Package Loop NC-2</u>
Number	1	1
Maximum test diameter, in.	2 1/2	2
Maximum test length above core, ft	15	15
Maximum test length below core, ft	2	2
Power, MW	0.2-0.6	0.2-0.5
Flux, n/cm ² /sec	0.2x10 ¹⁶ - 0.7x10 ¹⁶	0.2x10 ¹⁶
Coolant fluid	Na	Na
Inlet temp, °F	900 to 1000	900 to 1000
Outlet temp, °F	1200 to 1400	1200 to 1400
Test ΔT, °F	300 to 500	300 to 500

TABLE 2.10-V. *Initial Open Test Positions*

<u>Type</u>	<u>Position^(a)</u> <u>D-1</u>	<u>Positions</u> <u>C-1 and C-2</u>
Number	11	2
Maximum test cross section, in.	4 ^(b)	5
Maximum test length above core, ft	15 ^(b)	15
Maximum test length below core, ft	3 1/2 (tapered)	3 1/2 (tapered)
Maximum power, MW	~10	~10
Flux* n/cm ² /sec	0.3x10 ¹⁶ - 0.7x10 ¹⁶	0.4x10 ¹⁶
Coolant fluid	Reactor Na	Reactor Na
Inlet temp, °F ^(c)	600	600
Outlet temp, °F ^(d)	800 to 1000	800 to 1000
Test ΔT, °F	200 to 400	200 to 400

-
- (a) May replace any driver fuel subassembly.
 (b) Must conform to driver fuel subassembly envelope dimensions.
 (c) Reactor inlet temperature, initial = 600 °F.
 (d) Reactor outlet temperature, initial = 900 °F, and the initial bulk outlet temperature of the open loops = reactor outlet temperature ±100 °F.

* Dependent upon test location.

Additional short-term test facilities may be located anywhere in the core or reflector and either pneumatic or mechanical shuttles may be used.

REFLECTOR TEST HOLES

The initial core is surrounded by a single ring of replaceable reflectors. These reflector positions may be occupied by a variety of test facilities. All reflector positions, not otherwise occupied, may contain capsules or directly-cooled test specimens.

AXIAL POSITIONERS

An axial positioner is a mechanical device for programmed positioning of specimens. The characteristics and features of axial positioners are similar to those of control rod drives. Positioners can be provided for use with selected tests in closed loops, open loops, and reflector test holes to permit precisely controlled "steady-state" irradiations, cyclic testing, and transient testing. The drives can accommodate test specimens up to about 200 lb weight (including hanger rods, snubbers, etc.) Positioning accuracy is within 0.1 in. for "steady-state" testing, 0.2 in. for cyclic testing, and 0.4 in. for transient testing. Speeds are at least 2 in./min for "steady-state" and cyclic tests. For transient tests the speeds are at least 10 in./sec, up, and 60 in./sec, down (single transient).

- ⊗ REFLECTOR SHIM ROD (8)
- ⊗ SHIM ROD (6)
- ⊙ SAFETY ROD (4)
- CLOSED LOOP (3)
- NEUTRON SOURCE (1)
- ~ OSCILLATOR (1)

- REFLECTOR (38)
- ⬢ DRIVER FUEL (76)
- ⬡ OPEN LOOP (11)
- ⬢ PACKAGE LOOP (2)
- ⬢ SHORT-TERM TEST (1)
- ⬢ VERTICAL OPEN LOOP (2)

FIGURE 2.10-1. Tentative Initial Testing Facilities

NOTES

1. BASIC PIPING SHOWN ONLY. ALL INSTRUMENTATION OMITTED.
2. HELICAL-ROTOR TYPE PUMPS WOULD BE ARRANGED IN SERIES, WORKING WITH ONE SURGE & EXPANSION TANK AS SHOWN.
3. CENTRIFUGAL FREE SURFACE PUMPS WOULD BE INSTALLED IN INTEGRAL SURGE & EXPANSION TANKS, & ARRANGED IN PARALLEL (ALTERNATE SCHEME).

FIGURE 2.10-2. Engineering Flow Diagram-III for General Purpose Closed Loop

FIGURE 2.10-3. Closed Loop
 Re-Entrant Tube Arrangement

SK-3-12788

FIGURE 2.10-4. Closed Loop U-Tube Arrangement

FIGURE 2.10-5. Closed Loop Piping for 5 MW Loop Arrangement V

- HOLD EQUIPMENT LIST -

EQUIPMENT PIECE NUMBER	SYSTEM PIECE NUMBER	DESCRIPTION	SIZE (INCHES)	PRESS. (NORMAL)	END CONN.	MATERIAL	REMARKS
B-68-1		BLOWER, EXHAUST					
B-68-2		BLOWER, GAS					
E-68-1		EXCHANGER, COOLANT					
E-68-2		EXCHANGER, GAS					
MF-68-1		MAGNETIC FLOW METER					
P-68-1		PUMP, COOLANT					
P-68-2		PUMP, VACUUM					
T-68-1		TANK, COOLANT SURGE					
EV-68-1		VALVE, SOLENOID					
EV-68-2							
EV-68-3							
EV-68-4							
EV-68-5							
EV-68-6							
EV-68-7		GATE					
EV-68-8							
EV-68-9							
EV-68-10							
EV-68-11							
EV-68-12							
EV-68-13							
EV-68-14							
EV-68-15							
EV-68-16							
EV-68-17							
EV-68-18		DOV					
EV-68-19		DOV					
EV-68-20		DOV, SOLENOID					CONTAINMENT VALVE
EV-68-21							
EV-68-22							
EV-68-23							
EV-68-24		GATE					
FAL-68-1		FLOW ALARM, LO					
PI-68-1		PRESSURE INDICATOR					RANGE
PI-68-2							
PI-68-3							
PI-68-4							
PI-68-5							
LIA-68-1		LEVEL IND. & ALARM (H & L)					
TIA-68-1		TEMP. INDICATOR ALARM (H)					
TIA-68-2							
TIA-68-3							
TIA-68-4		RESIST. TEMP. DETECTOR					

NOTES

1. LEAK DETECTION PROBES SHALL BE INSTALLED AT ALL MECHANICAL JOINTS & CONNECTIONS.
2. ALL CONTAINMENT VALVES WILL HAVE POSITION DETECTORS WITH REMOTE INDICATION ON RABBIT PANEL IN CONTROL ROOM.
3. ALL SOLENOID OPERATED VALVES WILL BE CLOSED IN THE UNENERGIZED POSITION.

LEGEND

- PRINCIPAL FLOW
- AUXILIARY FLOW
- INSTRUMENT PRIMARY LINE
- ELECTRICAL LINE
- DIAPHRAGM OPERATED VALVE
- ELECTRIC SOLENOID VALVE
- GATE VALVE
- REMOTE DISCONNECT (SEE NOTE 1)
- MAGNETIC FLOW METER

2.11 STRUCTURE AND UTILITIES

FFTF REACTOR BUILDING

The FFTF reactor building is a highly specialized concrete and steel structure. Its design is integrated with the design of the reactor systems, the fuel handling system, fuel examinations facilities, and test loop facilities. The building functions are to provide:

- Shelter space for the reactor and allied equipment, including maintenance and operating functions
- Radioactive contamination control and protection of personnel from excessive amounts of radiation
- A pressure containment vessel that will retain released radioactive materials and gases resulting from any incident in the reactor or its cooling system
- For the safe collection and disposal of contaminated wastes and to minimize the hazard to personnel operating the waste facility
- Storage space for unirradiated and irradiated fuel and materials and a work area for certain operations including examination of fuel and materials
- Utilities, office space, and shops as required to meet the minimum needs of operation and maintenance.

The FFTF building consists of four principal functional spaces:

- A gas tight reactor containment vessel
- Fuel handling and examination areas
- An auxiliary equipment area (Secondary Heat Transport System Equipment)
- Administration and service areas.

Figures 2.11-1 through 2.11-12 show the building plans, sections, and elevations.

A gas tight, all welded steel pressure vessel, the containment vessel houses the reactor, its primary cooling system, the closed test loop system, the inert gas system, the reactor hot cell, fuel handling machine, and storage space for irradiated fuel and primary sodium. It is designed to contain radioactive gases and particles released in the event of sodium-air reactions or nuclear incidents. All containment vessel utility penetrations are sealed or otherwise closed in such a manner that the leak tight integrity of the vessel is not compromised. One personnel air lock for normal access and one emergency air lock are provided.

Adjacent to the reactor containment vessel, the fuel handling area includes the fuel transfer and cleaning cells, the fuel storage and load out basin (water), the underwater and inert gas examination facilities. It also houses the non-irradiated fuel handling facilities, the equipment maintenance and decontamination (M&D) cell, and the radioactive waste handling and storage facilities. The Nuclear Proof Test Facility (NPTF) is located below grade in this area.

The maintenance and decontamination cell includes facilities for removing the fuel handling machine and large equipment and components (pump, heat exchangers) from the containment vessel. Crane coverage over this area affords transfer of the fuel handling machine, fuel shipping casks, and large equipment. This area has railroad and truck access for receiving and shipping fuel, waste, and equipment.

Adjacent to the fuel handling area are the sodium analytical laboratory, the change room, and the maintenance shop.

The auxiliary equipment for the NPTF, the inert gas examination facility, the underwater examination facility, and the operating galleries for the M&D cell are located below grade, under the fuel handling area. Also included in this area is the control room, the change room, the fuel storage vault, work area, and equipment space required for the NPTF.

The auxiliary equipment area is adjacent to the containment vessel on the side opposite the fuel handling area. It is a multi-story structure housing the reactor secondary heat transport system equipment, liquid metal handling and secondary sodium cleanup facilities, and other support facilities. Only the access galleries physically connect the auxiliary equipment area to the main building.

Located adjacent to the containment-vessel, the administration and services areas are connected to all major portions of the facility by corridors or tunnels to provide personnel, utilities service, instrumentation, and control access. The basement of the administration structure houses mechanical and service equipment and storage spaces. The structure houses reactor control room, auxiliary instrumentation rooms, offices, conference room, and lunch room.

A service area houses maintenance shop facilities, sodium laboratory, heating and ventilating and other service equipment.

The FFTF building is arranged to separate areas of different radioactive contamination potential. Personnel enter all potentially radioactive areas through change rooms.

The heating and ventilating system gives effective control of airborne radioactive contamination. Pressure levels are set to produce air flow from lower to higher regions of radioactive contamination. Exhaust air passes through high efficiency and halogen filters before discharge to the atmosphere through an exhaust stack. Activity monitors and integrating gas samplers are provided downstream from the filters.

MATERIALS OF CONSTRUCTION

The substructure is reinforced concrete. The superstructure is structural steel framing and insulated metal siding. Roof construction is built-up asphalt and gravel roofing over poured vermiculite concrete on corrugated metal decking.

CONTAINMENT VESSEL

Constructed of carbon steel plate, the containment vessel is a 200 ft diam gastight sphere designed and built in accordance with the ASME Boiler and Pressure Vessel Code, Section III. The containment vessel design pressure is in the range of 30 psig. The major cause of pressure loading on the containment vessel is expected to be a sodium-air reaction. The nominal thickness of the sphere is 1 1/4 in.

Reinforced concrete walls and slabs subdivide separate closed functional spaces. The concrete structures support the equipment, provide biological shielding, and protect the containment vessel from direct missile damage.

The exterior surfaces of the vessel not protected by adjoining building structure are insulated to reduce the air conditioning loads and to prevent condensation.

A sealed equipment access, usable only under reactor shutdown conditions, affords transfer of major items in and out of the containment vessel without going through the maintenance and decontamination cell.

All containment vessel penetrations are sealed or otherwise closed in a positive manner to assure the leak tightness of the vessel.

Table 2.11-I lists the major containment vessel penetrations. In addition to the major penetrations, a number of smaller penetrations will be necessary for instrumentation, electrical, and miscellaneous utilities.

The reactor hot cell and the containment work area are on the operating floor. Above the hot cell is the heating and ventilating equipment. Located beneath the operating floor, in shielded gas and pressure tight compartments, are the reactor, primary heat transfer system, primary sodium system, inert

gas system, closed test loops, and instrumentation areas. A peripheral operating gallery, beneath the operating floor, provides personnel access to all compartments, except the reactor cavity. Directly beneath the operating gallery is the service gallery.

TABLE 2.11-I. *Major Containment Vessel Penetrations*

<u>Penetrations</u>	<u>Number Required</u>	<u>Approximate Size, ft diam</u>
Personnel Airlock	1	10
Emergency Airlock	1	5
Fuel Handling Machine and Equipment Transfer Port	2	8
Ventilation Supply and Exhaust	2	2.5
Secondary Coolant Piping	8	2.5
Closed Loop Piping	20	1.25
Fuel Transfer Ports	1	1.5
Instrument	10	1
Electrical	10	1

The hot cell contains the fuel handling machine, a bridge crane, and equipment for refueling and remote handling operations. Viewing windows in the walls permit visual observation of operations from the surrounding work area. The reactor is situated beneath the hot cell, in the centrally located circular reactor cavity. Six closed test loop cells and other equipment cells are arranged in a radial pattern around the reactor cavity. Equipped with a crane, a containment work area surrounds the reactor hot cell.

Steel liners in the hot cell and all equipment cells containing primary system sodium protect the concrete and assure a gas tight compartment. Sodium storage cells may be only partially lined with steel plate as required to contain sodium in case of tank rupture.

Reactor Hot Cell

The approximate dimensions of the rectangular reactor hot cell are 48 by 114 by 80 ft high. Type 304 SS lines the hot cell to protect the concrete from sodium air reaction, provide gas tightness, and facilitate decontamination. Personnel normally gain access through a main personnel airlock. Provisions are made for suited entry under emergency conditions. An airlock provides an emergency exit. Equipment enters through a sealed equipment door, or through the maintenance and decontamination cell. Sealed transfer ports in the cell floor connect the hot cell to the fuel transfer cell and the maintenance and decontamination cell. The reactor, the reactor vault, and the fuel decay storage pots are located below the hot cell floor.

Reactor Vault

The circular reactor vault cavity is about 45 ft inside diameter, and about 37 ft deep. Steel lined and thermally insulated, the reactor vault is designed to withstand the design basis accident, sodium fire reactions, and the operating temperatures. A gas cooled neutron shield protects the concrete from direct neutron irradiation. Cooling coils attached to the outside face of the steel liner protect the concrete from overheating. Concrete shielding permits contact work to be performed in the adjacent equipment cells during reactor shutdown. Access to the vault is through a sealed port in the reactor hot cell floor. The cell atmosphere is inert gas.

Closed Loop Cells

The six closed loop cells (15 by 37 by 27 ft high) circle the reactor vault. The gastight cells are lined with carbon steel and designed for sodium-air reaction conditions. The

cells have an inert gas atmosphere during operation. During installation and maintenance periods the atmosphere changes to air. The cells are accessible through sealed cover blocks in the ceiling and through shielded gas tight doors from the operating gallery. Concrete shielding permits full 8 hr occupancy for installation of equipment or maintenance with adjacent cells operating.

Primary Equipment and Sodium Cleanup Cells

Two primary equipment cells (approximately 28 by 38 by 48 ft high) stand on opposite sides of the reactor vault. Adjacent to each primary equipment cell are cells containing sodium cleanup traps. Located below these are the primary sodium cleanup equipment cells.

Gas tight and lined with carbon steel, the primary equipment cells and the cleanup cells have an inert gas atmosphere capability with provision for changing to air. The cells can withstand sodium air reactions. Access to the cells is through sealed cover blocks in the ceilings and through doors from the operating gallery.

Sodium Storage

Two shielded cells (approximately 28 by 32 by 16 ft high) store about 50,000 gal of primary sodium, are located adjacent to the decay storage pots and beneath the rupture monitoring equipment cells.

A 5,000 gal contaminated sodium dump tank stands in a shielded cell (approximately 44 ft diam by 12 ft high) beneath the reactor cell.

Partially lined with carbon steel, all storage cells have a normal air atmosphere, with provision for changing to inert gas.

Rupture Monitor Equipment Cells

Two rupture monitoring cells, one on each side of the fuel decay storage, have gas monitoring equipment that is shielded by a 1 ft thick concrete wall. Partially steel lined, the cells (approximately 29 by 37 by 14 ft high) have an air atmosphere. Access to the cells is through gas tight shield plugs in the operating floor and through personnel doors from the operating gallery.

Operating Gallery and Service Gallery

Situated under the operating floor and connected to it by a stairway, the peripheral operating gallery provides access to the equipment cells. This gallery has viewing windows to observe remote maintenance operations in the primary heat transfer and the closed loop cells. Directly under the operating gallery is the service gallery. Concrete shielding permits continuous personnel access to both galleries. Specially treated concrete surfaces facilitate decontamination. The atmosphere is air.

FUEL HANDLING AND EXAMINATION AREA

A major portion of the FFTF building, the fuel handling and examination area consists of an integrated arrangement of the following facilities:

- Underwater examination cell
- Fuel transfer cell
- Inert gas examination cells (4)
 - Subassembly cleaning and storage cell
 - Disassembly-reassembly and interim examination cell
 - Equipment storage and transfer cell
 - Fuel and material specimen examination cell.
- Storage area for inert gas cells
- Decontamination area for inert gas cells

- Nonirradiated fuel storage vault
- Irradiated fuel storage and load-out basin
- Sodium analytical laboratory
- Nuclear proof test facility
- Maintenance and decontamination cells.

Two independent examination facilities are provided: an underwater basin and an inert gas cell bank for examination of fuel and materials.

Underwater Examination Cells

The underwater examination cell (approximately 18 by 10 by 32 ft deep) consists of a stainless steel lined water basin with fuel and material transfer access to storage and load-out basin and transfer cell.

One side of the basin has an operating gallery at the -32 ft elevation with lead glass windows and manipulators. A traveling catwalk operates on top of the basin walls.

Inert Gas Examination Cells

A bank of in-line cells is attached to one side of the fuel transfer cell opposite the underwater examination cell and the storage and load-out basin. The first is a deep cell approximately 27 by 16 by 55 ft high providing space for cleaning, storage, disassembly, reassembly and interim examination of fuel and material subassemblies. The remainder of the cell bank consists of an equipment storage and transfer area about 16 by 16 by 20 ft deep and a fuel and material specimen examination area about 34 by 16 by 20 ft deep.

Cell walls are high density concrete about 5 ft thick. Stainless steel lines the interior surfaces of the cell bank, and all cell penetrations are sealed.

Operating stations with viewing windows are provided on opposing walls at three levels in the deep cell area and at one level in the remainder of the cell bank.

Remotely operated, partially shielded doors isolate the inert gas cell bank from the fuel transfer cell and the equipment storage and transfer cell from the remainder of the cell bank. The three cell areas have through-wall transfer devices and personnel access locks.

"Warm" Storage Area

A "warm" storage area near the inert gas cell bank is used for the storage and for maintenance of contaminated equipment. Access to the area is controlled.

Decontamination Area for Hot Cells

The area under the inert gas cells includes stations for decontamination of hot cell equipment before transfer to the adjacent warm storage area. A transfer cell below the equipment storage affords access to the decontamination area for removing equipment from the cells. The cell walls are ordinary concrete. The decontamination station has stainless steel lining and the transfer cell has a stainless steel floor and wainscot.

Nonirradiated Fuel Storage Vault

A locked fuel storage vault located adjacent to the fuel handling area stores unirradiated fuel. The storage vault is approximately 25 by 30 ft in the plan view. The floor is recessed to permit installation of fuel storage sleeves. The top of the storage sleeves are flush with the main floor level. Each sleeve is fitted with a cap. The storage sleeves are arranged on about 16 in. center-to-center grid pattern. Constructed of reinforced concrete, the fuel vault can hold 170 subassemblies. Provisions are made to preclude flooding of the vault.

Irradiated Fuel Storage and Load-Out Basin

An underwater fuel storage and load-out basin of approximately 1100 ft² area and about 40 ft deep is located adjacent to the

receiving and shipping area. Connected to the fuel transfer cell by a transfer canal, the basin is equipped for underwater transfer of subassemblies between the storage basin and the transfer cell and underwater examination cell. The basin has fixed storage positions for about 160 irradiated subassemblies. The storage racks assure positive spacing of the subassemblies. The remaining storage basin area is utilized for loading shipping casks.

The basin walls extend approximately 3 ft above the main floor level. Lined with stainless steel, the basin is equipped with underwater lighting, an ion exchange cleanup system, and heat exchangers.

Sodium Analytical Laboratory

The building includes an analytical laboratory of approximately 2400 ft² floor area for analysis of sodium samples from the reactor systems. The laboratory located on the main floor level is accessible from the fuel handling area, and the exterior of the building. Figure 2.11-1 shows the laboratory location.

The laboratory is divided into five functional areas:

- Hot cell
- Radiochemistry
- Counting Room
- Emission Spectrograph
- Nonradioactive Chemistry.

Hot Cell Area

The Hot Cell is a two compartment, 15 in. thick cast iron shielded cell. One compartment has an inert gas atmosphere, the other has air. A transfer gas-lock is provided between the compartments. Each compartment has viewing windows and manipulators. The inside dimensions are 5 by 12 by 6 ft high. A monorail system handles casks containing samples of radioactive sodium.

Radiochemistry Area

The radiochemistry area contains hoods and laboratory equipment for final chemical separations of radioactive samples for counting.

Counting Room

The counting room has instruments for qualitative and quantitative identification of alpha, beta, or gamma activities. The room is shielded to provide a low background for counting.

Emission Spectrograph Area

An emission spectrograph provides semi-quantitative and routine analysis for metallic impurities in sodium. This area also has a darkroom for film developing, one hood, and laboratory equipment.

Nonradioactive Chemistry Area

Space and equipment is provided for analysis of secondary system sodium, preparation of calibration standards, and routine wet chemistry analyses. Two hoods, a vacuum dry box, glove box, and laboratory equipment are provided in this area.

Nuclear Proof Test Facility

Figures 2.11-4 and 2.11-5 show the nuclear proof test facility. It consists of a reactor cell, control room, work area, fuel storage vault, change room, and equipment and storage area, which are located below the main floor level adjacent to the inert gas cell bank.

About 1200 ft² in plan and about 40 ft deep, the reactor cell is shielded by 4 ft thick walls of concrete. Normal entry to the cell for personnel is provided at the -20 ft level. The control room, work area, and fuel storage vault are located

at the same level. Access is also provided at the cell floor level from the equipment room. Test fuel and material subassemblies are transferred into the cell vertically from the fuel handling area.

The reactor cell is a steel lined gas tight containment structure designed for the NPTF design basis accident. All penetrations into the reactor cell are sealed.

An equipment room of approximately 1500 ft² on the -40 ft level is provided for switchgear, mechanical equipment, and storage of experimental gear. A work area located adjacent to the reactor cell provides approximately 800 ft² of floor space for special experimental equipment storage, and assembly of equipment and test materials. A fuel storage vault stores nuclear proof test reactor fuel.

The change room gives entry to the work area. It is approximately 200 ft² and contains eight lockers, clothing bins, toilet and shower facilities, and personnel decontamination and monitoring facilities.

The control room, located adjacent to the change room, is approximately 350 ft² in plan. Contamination control requires that personnel enter the reactor cell through the change room.

Maintenance and Decontamination Cell

The Maintenance and Decontamination (M&D) cell is comprised of three sections: radioactive maintenance, decontamination and contact maintenance cells. Adjacent to the containment vessel, the radioactive maintenance cell is connected to the vessel by two 8 ft diam transfer ports. The radioactive maintenance cell dimensions are approximately 16 ft by 125 ft by 65 ft deep. The cell top and walls are ordinary concrete. Type 304 SS lines the inside of the cell. All

penetrations into the cell are sealed. All items are transferred vertically into and out of the cell and horizontally within the cell.

Operations performed within the cell are by remote methods. Viewing windows and manipulators are installed in the cell walls at each operating level. The cell is designed for either air or inert gas atmosphere.

The decontamination cell (approximately 12 by 16 ft by 65 ft deep) is in line with the radioactive maintenance cell. A contact maintenance cell (approximately 24 by 32 by 65 ft deep) is attached to one side of the Maintenance and Decontamination Cell.

AUXILIARY EQUIPMENT AREA

The auxiliary equipment area is a multistory, reinforced concrete structure that houses secondary sodium pumps, drain and storage tanks, cleanup facilities, NaK cooling systems and associated equipment. One side of the structure is designed to rupture in the event of a major sodium fire. The structure is 50 by 120 ft in the plan.

A crane is provided for pump and equipment maintenance. The structure houses the following:

- Reactor secondary pumps
- Closed loop secondary pumps
- Expansion tanks
- Secondary sodium system cleanup equipment
- NaK cooling system
- Operating galleries for the all sodium and gas cleanup system
- Operating galleries for secondary sodium system pumps
- Electrical gallery and switch gear
- Maintenance space

ADMINISTRATION AND SERVICE AREA

The administration and service building is a single-story structure with a basement. The substructure is reinforced concrete and the superstructure is insulated metal siding on a structural steel frame. The administration and service area is comprised of the following:

- Reactor Control Room
- Instrument and Electrical Equipment Room
- Offices
- Change Room
- Maintenance Shop
- Service Equipment Area
- Heating and Ventilation Equipment Room.

With approximately 4000 ft² of area, the reactor control room provides space for operating consoles and data collecting equipment. A visitors' viewing room allows visual observation into the control room, but not a direct access.

The instrument and electrical equipment room is located directly below the control room and contains about 4000 ft² in area. This area houses electrical and instrument equipment, cable trays, and switchgear.

Offices are provided for administrative personnel as well as a conference room, toilet facilities, and a lobby.

The change room (approximately 2000 ft²) is the main personnel access to the operating areas. It houses the equipment and facilities necessary for proper control of personnel. This includes the necessary toilets, showers, lockers, and decontamination control equipment.

The maintenance shop (approximately 4300 ft²) provides facilities for maintenance of nonradioactive equipment. An air-lock is provided for transfer of equipment from the reactor building into the shops.

The auxiliary equipment and storage area (approximately 12,500 ft²) houses miscellaneous equipment and provides storage space for operating supplies.

HEATING, VENTILATING, AND AIR CONDITIONING

Figure 2.11-13 shows the heating, ventilation, and air conditioning flow diagram.

The system functions are:

- Control air temperature, humidity, and cleanliness
- Provide contamination control by maintaining proper airflow direction
- Control release of contaminants to atmosphere by filtration of exhaust air and discharge to atmosphere through a stack
- Provide for air purging spaces in the facility which normally operate with inert atmosphere.

The building is divided into four basic ventilation zones as described below and shown in Figures 2.11-14 through 2.11-19.

Zone I: Primary Radiation Zone (Containment Zone)

Zone I includes the ventilated spaces within the containment zone which operates with an air atmosphere. Zone I-A includes the Hot Cell.

Ventilation is supplied on a once-through basis from the central supply system with continuous single filtration of the exhaust through the control filter facility prior to discharge from the stack. The rate of air change provided in this zone is a minimum of one change per hour.

The containment vessel is maintained at a negative operating pressure, with respect to adjacent areas. Quick closing valves are provided on supply and exhaust penetrations.

Recirculating refrigeration units provide air conditioning in the containment vessel. These same units are capable of providing supplemental heat, and they may be used for the cleanup following containment.

Zone I-A: Primary Radiation Zone (Containment Zone)

Zone I-A includes those spaces within the containment zone which may be maintained either in air or inert gas atmosphere. All spaces except the Reactor Hot Cell are normally maintained in an inert atmosphere. The pressure in these spaces is maintained lower than the surrounding spaces.

Individual recirculating cooling units provide the temperature control in this zone. Ventilation is independent of the main ventilation system except for valved purge connections to the exhaust system.

All cells in this zone are filtered at the cell exit and at the central filter facility. A "Booster" exhaust system overcomes the additional resistance of the cell filters and increases flow during maintenance operations.

Zone II: Secondary Radiation Zone (No Containment)

Zone II includes those process spaces, outside containment, that are normally accessible but potentially contaminated. The central supply system furnishes air on a once-through basis. The air is continuously filtered before discharge through the stack. The minimum air change rate is that required for contamination control.

The spaces are maintained at temperatures suitable for personnel. The pressures are maintained to provide air flow direction as required for contamination control.

Zone III: Normal Access Zone (No Containment)

This zone includes normally accessible spaces where the potential for contamination release is extremely small.

Ventilation for this zone is supplied from the central supply system on a once-through basis with exhaust directly to atmosphere via roof ventilators. The air change rate and temperature conditions in this zone are for personnel comfort and equipment requirements. The pressure in this zone is essentially atmospheric conditions.

Zone IV: Unlimited Access (No Containment)

This zone includes clean nonprocess areas which are physically separated from process areas.

A separate ventilation system is provided for this zone which exhausts directly to atmosphere. The air change rate and temperature in this zone are maintained for personnel comfort and for instrumentation cooling requirements. Refrigerative cooling is provided for this zone. The pressure in this zone is essentially atmospheric.

Ventilation Zone Pressures

To assure proper direction of airflow between building zones, the pressures in Zones I and II are maintained at a negative pressure relative to the atmosphere. Zone I-A (inert gas) is maintained at a pressure slightly lower than the surrounding Zones I and II. Zone III and IV pressures are manually set.

Tentative zone pressures are as follows:

Zone I	Minus 0.50 in. water
Zone I-A	*
Zone II	Minus 0.15 in. water
Zones III and IV	Atmospheric

Heating and Cooling Temperature Requirements

Table 2.11-II shows the nominal air temperature requirements for the Ventilation Zone.

* Pressure not determined

TABLE 2.11-II. *Air Temperature Requirements*

<u>Zone</u>	<u>Space</u>	<u>Summer, °F</u>	<u>Winter, °F</u>
I	Containment Vessel (ventilated spaces)	80	70
I-A	Inert Atmosphere Cells	--	--
II	Operating Galleries	80	70
	Equipment	100	--
III	Equipment	100	--
	Personnel	80	70
IV	Administration Area	80 (max)	75

Table 2.11-III shows the exhaust air treatment provided.

TABLE 2.11-III. *Exhaust Air Treatment*

<u>Zone</u>	<u>Air Treatment</u>	<u>Exhaust System</u>	<u>Discharge</u>
I	Single Filtration	Central	Stack
I-A	Double Filtration	Central	Stack
II	Single Filtration	Central	Stack
III	None	Individual	Roof
IV	None	Individual	Roof

Electrical Power Supply

Normal power with emergency power backup operates certain exhaust and supply fans, refrigeration compressors, and spray pumps. This is required to maintain contamination control during normal power outages.

Zones I Through III Supply Systems

Three supply units are provided, each designed for 50% of the total requirements of the zones served with the spare equipment provided to maintain 100% capacity at all times except emergency conditions. Each supply unit consists of the following:

- Screen and/or louvers
- First preheat coil, ethylene glycol type
- Dry filters, roll type
- Second preheat coil, ethylene glycol type (if required)
- Air washer and/or cooling coil
- Reheat coil, ethylene glycol type
- Supply fan, nonoverloading, centrifugal type with inlet damper for modulation of airflow
- Discharge damper, to prevent backflow, where required
- Filters in ducts serving spaces requiring better than normal quality air conditions.

Zone IV Supply System

One 100% capacity, central air conditioning unit serves Zone IV. Multiple compressor-condensing air conditioning units provide cooling.

Exhaust Filters

A reinforced concrete underground structure houses central exhaust filter banks. The design permits replacement of highly radioactive filters. The structure consists of three physically separate filter sections each capable of handling 50% of the normal Zones I and II exhaust. Each section has airtight, motor-operated closures at the inlet and the outlet ends to permit isolation of each filter section for filter replacement while still maintaining the system flow rate at 100% capacity. The filter bank design permits individual filter replacement or remote replacement of an entire bank.

Stack

After filtration, the exhaust air from Zones I, I-A, and II is discharged through a 200 ft high, single region, reinforced concrete stack.

Containment Valves

The ventilation systems for the respective zones maintain the containment integrity of that zone. The ductwork and the containment valves exposed to the zone pressure are capable of withstanding the maximum pressure of that zone. Containment valves are automatically closed.

INSTRUMENTATION

The instrument controls for the Heating and Ventilating Systems are a pneumatic, "fail-safe" type. Instrumentation is provided to control or indicate the following:

- Zone Pressure
- Humidity in Zones I and I-A and the Control Room
- Zone Temperature Instrumentation
- Pressure Drops across Filters
- Equipment Operation
- Airflows in the Main Supply and Exhaust Headers
- Air and Filter Radioactivity.

ELECTRICAL

Power

Two 115/13.8 kV transformers, furnished by others, supply the source of normal power. Each has a power rating of 12/16/20 MVA. A circuit breaker connects each substation to a 13.8 kV bus. A normally open bus tie breaker connects the two 13.8 kV buses.

Four outdoor distribution transformers rated 13.8 to 2.4 kV supply power to the indoor 2.4 kV switchgear. This switchgear serves four primary and four secondary pumps, sixteen sodium to air heat exchanger blowers, and two transformers which provide power to sodium hot trap heaters. Figure 2.11-21 shows this system.

Outdoor transformers rated 13.8 kV to 480 V supply power to indoor 480 V switchgear housed within the reactor building.

The 480 V switchgear is located at approximate centers of load and directly serves major loads. They also serve motor control centers and circuit breaker panels which in turn serve other than major loads. Two sections of 480 V switchgear are provided with emergency power in addition to the manual sources. Two gas turbine driven generators provide emergency power , one to each emergency bus. Figure 2.11-20 shows this system.

All switchgear is the metal enclosed, dead front, draw-out type. Air circuit breakers are used and control power will be dc. Power feeds from the switchgear to motor control centers. Feeders are sized to allow for future load additions of approximately 30%.

Local dry type indoor transformers feed panels to supply lighting, communications, alarm equipment, and control. No transformers are connected either to normal or to emergency 480 V sources, depending on the load requirements.

Distribution voltages in the building are three phase, 480, and 208/120 V wye. Instrument panels are served by voltages not exceeding 150 V to ground. The control and instrument power supply voltage is regulated by means of electronic voltage regulator or in special cases, by harmonically filtered, regulated battery fed solid state inverters.

The trip settings of breakers which control power to vital equipment are adjusted to provide maximum safety to the reactor where uninterrupted power supply is critical to the safety. Trip settings for breakers protecting control circuits and instruments will not exceed 10A. Breakers set at trips less than 10A subdivide and protect critical circuits.

Batteries are provided for switchgear operation, dc lighting, dc instruments, dc safety circuit, and dc to ac inverters. Nonaging static battery chargers are used. Batteries will not be tapped for odd voltages. Three 125 V batteries, two for

large loads and one for safety circuit and backup services, are used. Each battery has a charger and switching to transfer chargers and loads between the batteries.

The normal electrical power system is separated into two independently operating sections to achieve maximum reliability. Critical loads within the building are connected so that if one half of the electrical power system fails, the remaining half of the power system continues to supply power.

Two gas turbine generators provide emergency backup electric power. Each generator operates independent of the other. Load connections are split so that if one generator fails, the remaining generator furnishes power to critical loads.

Any three of the four power supplies and/or their loads could fail and the reactor would have adequate shutdown power.

Grounding

Each building grounding system has a ground mat with ground electrodes and connections to adjacent nonstainless steel water piping systems on the site. Galvanized steel grounding conductors, rods, and other parts are installed outdoors, in the earth, in concrete, or in wet locations. Grounding materials located indoors and in dry locations are made of copper. The connections between the indoor copper and outdoor galvanized steel are exposed.

Each supporting building, facility, tank, stack, equipment enclosure, and metallic fence has a separate perimeter grounding system. The grounding systems are cross-connected and bonded to each other to form a plant-wide grounding grid.

The neutral conductor for each single phase wye connector transformer is grounded at the transformer. Transformers that supply lighting or other loads are connected to the panel neutral bus. All switchgear, grouped motor controls, metal enclosed bus systems, and metallic cable trays have a ground bus which is connected to the plant ground grid. Equipment

grounding conductors are in conduit, raceway, or enclosure with the energized conductors.

Lighting

Fluorescent lights are used, wherever relamping is not a problem, to reduce glare and maintenance. Mercury vapor or equivalent lighting is used in the cells. Mercury vapor Lucalox, or high intensity fluorescent lighting, is used in high ceiling areas. Emergency lighting provides lighting for process shutdown and for safe exit from the building.

Lighting distribution voltages are 208/120 V wye and 480/277 V. Figure 2.11-22 shows the schematic diagram of ac power supply to the lighting system. Switching is done at panelboards, or through contractors for large areas. Wall switches are used in the operating galleries, basin areas, offices, in rooms infrequently used, and for in-cell lighting.

Lighting Levels

Table 2.11-IV shows the lighting levels.

TABLE 2.11-IV. *FFTF Lighting Levels*

	<u>Lighting Level, maintained footcandles</u>
Control Room	
Vertical Panels	50
Control Desk (adjustable)	125
General Area	60
Offices, Laboratories, Conference Room	100
Corridors	30
Change Rooms	70
Shops	70
Mechanical, Electrical, Instrument and Equipment Rooms	70
Storage Rooms	30
Reactor Containment Area	100
Work Area	70

TABLE 2.11-IV. (contd)

	<u>Lighting Level, maintained footcandles</u>
Operating Galleries	70
Service Galleries	70
Closed Loop Cells	100
Shielded Hot and Work Cells	300
Basins	
Underwater: Load Out	200
Underwater: Examination	700
General Room Area	70
Piping and Pump Rooms	50
Outdoor	
General Area	2
Main Entrance	20
Main Walkway	5
Loading and Unloading Docks	20
Substation	20

Special Lighting

Lighting for the control room is fluorescent luminous ceiling type, designed to minimize glare or reflection from meter and instrument enclosures. Dimming control of fixtures over control desks is provided.

The work area has high bay lighting. Fixtures mounted beneath the crane provide better illumination.

Sectionalized switching of fixtures in the operating galleries outside cell viewing windows prevents reflections when observing from the cold side.

Special mercury vapor or Lucalox fixtures are provided in the cells. Hot cell lights are changed with remote manipulators or long shielded sealed connectors extending through the cell walls. Through cell wall wiring is sealed. Switching is controlled from outside the cells.

Underwater lighting for the basins allows unrestricted visibility for fuel examination, load-out, and storage. Special provisions are made for relamping underwater lighting.

Emergency Lighting

Individual emergency lighting units provide sufficient illumination for safe exit from the building. These lights turn on automatically when ac power fails. The control room, important instrument and electrical switchgear locations have an emergency ac voltage or a battery source.

Communications

A few large, wide-coverage systems handle the communications. Figures 2.11-23 through 2.11-27 describe this system.

Telephone System

The existing dial-type Hanford Plant Telephone Exchange provides connections within the plant and to offsite telephones via General Telephone and Bell System connections.

PAX System

A dial-type private exchange telephone system provides automatic dialing features between the instruments. It is a two wire system of the "private line" type. About 10 circuits have amplifiers with speakers for public address and paging purposes. Speakers are strategically located and equipped with individual volume control.

The PAX System automatically uses prerecorded messages for public address instructions in the event of an alert, attack

warning, criticality, or fire. The System also provides dictation recorders for use with a master stenographic pool.

The System accommodates 100 dial telephone numbers, initially 75 numbers with 25 spares, and is rated to provide for at least 10 simultaneous conversations.

Intercommunications System

The Intercommunications System consists of a completely separate and independent dial-type system with 100% trunkage.

Each dial-type telephone has a plug-in type connector to accommodate a trailing cord with a headset. Special stations and controls are provided for locations where the operator may be wearing heavy gloves and special clothing, including headsets in breathing masks. The system provides progressive dialing type conference features.

Alarm System

Actuation of an alarm system energizes alarm signals distinctive to the system and a prerecorded message is transmitted over the PAX public address system.

Table 2.11-V lists the emergency conditions and their respective types of alarm signals.

TABLE 2.11-V. *Types of Alarm Signals*

<u>Emergency Condition</u>	<u>Type of Signal Simulated</u>
CRA Critical Radiation Alarm (High gamma at certain building locations)	Motor Driven Howler
AAA Attack Warning	Wailing Siren
AAA Alert	Steady Siren
FAS Fire	Stroke Type Gong

A fire alarm system detects local alarms and sends coded signals to the existing Hanford fire alarm system.

Radio Radiation Telemetry System

Portable radiation exposure meters and radio transmitters carried by personnel transmit radiation dosage signals to a master radiation monitoring station.

Portable Radio System

By means of portable transceivers wired antennas enable radio communications to be conducted between various shielded locations. The Radio Radiation Telemetry System can also use these antennas.

TV System

Camera stations for closed circuit TV, either color or black and white, are located at strategic indoor and outdoor locations. Each station has a camera with pan, tilt, zoom, and focus controls from the communications console in the control room. Five monitoring locations are provided, including the communications console in the control room.

Noise Monitoring

Each test cell, fuel examination cell, and certain other pertinent locations are wired (without equipment) for future noise or special one-way audio monitoring equipment using microphones. An isolated system of empty conduits is provided between each amplifier location and the control room communications console.

Microwave Radio System

Facilities are provided to accommodate the future installation of equipment connections to the Hanford microwave radio facility.

SERVICE PIPING

The Service Piping System provides the following conventional piping services common to one or more systems:

- Compressed air
- Vacuum

- Water
- Steam
- Bottled Gas
- Sanitary Sewer
- Process Sewer
- Coolant Fluid Piping.

Table 2.11-VI shows the Service Piping System data. Figure 2.11-28 shows flow diagrams for compressed air, water and steam systems.

TABLE 2.11-VI. *Service Piping Data*

<u>Equipment</u>	<u>Characteristics</u>
<u>Compressed Air</u>	
Central Station *	
No. Units	3 @ 75% (1 unit is a spare)
Type	Oil-free (carbon ring)
Capacity	500 scfm/unit
Pressure	100 psig
Instrument Air	
Flow Rate	300 scfm
Pressure	100 psig
Temperature	Dewpoint minus 20 °F
Bottled Gas Back-up	Approximately 2200 psig
Breathing Air	
Flow Rate	100 scfm
Pressure	20 psig
Temperature	60 °F
Plant Air	
Flow Rate	250 scfm
Pressure	100 psig
Temperature	Ambient
<u>Vacuum</u>	
Room Air Monitoring	
No. Units	1
Flow Rate	10 scfm/ head
Vacuum	minus 20 in. H ₂ O
	with filter in place
Temperature	Ambient
Building Vacuum	
No. Units	1
Vacuum	minus 26 in. Hg
Temperature	Ambient

* The central station supplies Instrument air, Breathing air, and Plant air

TABLE 2.11-VI. (contd)

<u>Equipment</u>	<u>Characteristics</u>
<u>Water</u>	
Sanitary	
Flow Rate	200 gpm sanitary, 1000 to process
Source	300 Area System
Process	
Flow Rate	1000 gpm total
Source	Sanitary
Pumps	3 at 50% capacity (1 pump is a spare)
Demineralized	
Flow Rate	250 gpm
Distilled	
Flow Rate	~5 gpm
<u>Steam</u>	
Flow Rate	40,000 lb/hr

Compressed Air Service

Compressed air is provided for instrument, breathing, and utility uses. Two 100% capacity compressors, discharging to two receivers, provide the required compressed air for the FFTF. A third unit is provided as an installed spare.

The compressors are the oil-free type (carbon ring) powered by electric motors. After coolers remove moisture from the compressed air. The utility air service is separated from the breathing and instrument air services just downstream of the air receivers. Automatic valving shuts off utility air on low air pressure. Filters remove particles 10 μ and larger from the instrument and breathing air. The line is divided into the instrument and breathing lines downstream of the filters. Critical components are served by the instrument air service. Dryers are installed to reduce the instrument air dew point to a maximum of minus 20 °F.

Emergency electrical power is provided so that one compressor will operate on loss of normal power.

Vacuum Services

An air monitoring service developing 20 in. of water gage monitors room air. Sampler heads are located throughout the facility where air-borne contamination levels are expected to exceed 1/10 of the International Commission on Radiological Protection, ICRP Publication No. 2, values. The evacuated air is filtered through high efficiency filters located upstream of the vacuum pump. The evacuated air is discharged through a filtered ventilation exhaust system.

A vacuum service, developing a negative pressure of 26 in. Hg, is provided for laboratory use as required. A vacuum tank minimizes pulsations and provides a vacuum reservoir. High efficiency filters are installed upstream of the vacuum tank. The evacuated air and gases are discharged through a filtered ventilation exhaust system.

Water Services

Water for process, fire protection, and potable needs is provided from the 300 Area Sanitary Water System.

Process water is provided for equipment, cooling, and other uses where a contamination potential exists. Water from the sanitary system discharges to a reservoir through an air gap. Two electrically driven 50% capacity pumps distribute water to use locations. A third pump is provided as an installed spare. Emergency electrical power is provided so that at least one pump is operational on loss of normal power.

Two 100% capacity demineralizer units, operating in parallel, provide demineralized water for basins and laboratory uses. A water still provides distilled water for the sodium analytical laboratory. Sanitary water is provided for the Fire Protection System. Safety showers are supplied directly from the fire main system. The sanitary water service also provides hot and cold water for sanitary and potable needs such as wash-room and toilet facilities, showers, utility sinks, drinking fountains.

Steam Service

Steam is supplied for building heat, decontamination of equipment, removal of sodium from fuel elements and equipment, and other uses.

Bottled Gas Services

Bottled gas storage and a distribution piping system provides oxygen, acetylene, and other gases for laboratory and shop use.

Sanitary Sewer Service

The building sanitary sewer system collects and disposes sanitary wastes to a septic tank and tile field.

Process Sewer Service

The building process sewer system collects and disposes of nonradioactive process wastes to the Columbia River.

FIRE PROTECTION

Fire protection for FFTF is provided on the basis of the dual criteria of compatibility with the facility processes and compliance with AEC requirement of "improved risk" level of fire protection. To meet both criteria, the following types of protection systems are provided:

- In all zones where water is compatible with materials or equipment, automatic sprinklers are used.
- Where the possibility of sodium-water reactions precludes the use of automatic water sprinklers, products-of-combustion detectors, inerting, or other suitable extinguishing methods are used.
- In areas where costly electronic gear is located, inert gas, dry chemical systems, or high expansion foam actuated either by products-of-combustion detectors or by hand are installed.

- Backup of installed systems is provided by conventional hand operated first aid extinguishers such as carbon dioxide, dry chemical, Met-L-X, are also provided at appropriate locations.

Each extinguishing or detecting method referred to above incorporates the conventional electrical circuitry with alarms, signals, and supervisory panels.

RADIOACTIVE WASTE DISPOSAL

Facilities for the disposal of radioactive wastes insure that release of radionuclides to the environs is minimized. Four general categories of radioactive wastes require disposal: sodium waste, liquid wastes, solid wastes, and gaseous wastes. All liquid and gaseous effluents are monitored prior to release

Sodium Waste

Waste sodium metal depending on volume, activity, and origin is stored in drums or oxidized by reaction with water or steam. The reaction solution is stored in underground storage tanks or released to a retention crib depending upon the amount of radioactive material present.

Liquid Wastes

Only those liquid process wastes routinely containing no radionuclides are discharged to the river or to ground areas adjacent to the river. Continuous radioactivity monitors and integrating samplers are provided on liquid waste streas discharging to the river.

Intermediate level liquid wastes, $>5 \times 10^{-5} \mu\text{Ci}/\text{cm}^3$, are transported to cribs located at established disposal sites. High level wastes, $>100 \mu\text{Ci}/\text{cm}^3$, are stored in underground storage tanks.

Figure 2.11-29 shows the liquid waste disposal system flow diagram. Liquid wastes from the fuel cleaning cells and inert gas examination hot cells are collected in one of two ~2500 gal stainless steel waste tanks. After sampling and neutralization, the waste, depending on its activity level, is transferred to one of three 5000 gal stainless steel holdup tanks. Liquid wastes from the maintenance-decontamination cell, the six closed loop cells, and the miscellaneous equipment drains (gas system) are collected in a 3500 gal stainless steel tank. After sampling and neutralization, the waste, depending on its activity level, is transferred to one of the three holdup tanks. From the holdup tanks the waste is shipped by truck or rail to a disposal site for cribbing or storage in underground waste tanks. If the activity level of waste streams is low, $<5 \times 10^{-5} \mu\text{Ci}/\text{cm}^3$, it is discharged after retention via the process sewer to the ground or the river.

Liquid waste from the analytical laboratory, the personnel decontamination stations, the contaminated floor drain system, and miscellaneous equipment drains is collected in a separate 5000 gal tank. The waste, depending on its activity, is transferred to one of the above three 5000 gal holdup tanks, to the river via the process sewer, or to the load-out station for truck or rail shipment to crib.

All tanks in the system are connected through a radioactive vent system to a condenser. Condenser off-gas is discharged through the radioactive gas cleanup system. Each drain and holdup tank in the system has liquid level indication, high liquid level alarm, remote sampling devices, and a steam jet or transfer pump.

Each drain tank has a chemical solution addition line for pH control. The 2500 gal and 3500 gal drain tanks are equipped with steam sparging nozzles.

Solid Wastes

The principal sources of solid radioactive waste are:

- Fuel hanger rods, process tubes, etc.
- Miscellaneous wastes (paper, rags, gloves, and small tools)
- Particulate filters
- Ion-exchange resins
- Hot and cold traps.

Shielded storage vaults provide temporary storage. Access to the fault is through cover blocks on the main floor level.

Solid contaminated wastes are disposed of at established burial sites. Known plutonium-containing solid wastes are segregated from other wastes and buried near the Hanford Separations Plants. Facilities are provided to remove metallic sodium from waste before it is shipped to the burial ground.

Gaseous Wastes

Gaseous wastes are held for decay as required and disposed of via a stack after passing through high efficiency particulate and halogen filters. Activity monitors and integrating gas samplers are provided downstream of the particulate and halogen filters. The waste gas disposal system is described in Section 2.08.

OUTSIDE FACILITIES AND UTILITIES

Figure 2.11-30 shows the 300 Area site plan. The outside facilities are the final heat dump (sodium to air), the stack including a gas sampling station, an exhaust filter vault, the emergency power generators, 13.8/2400 V substation and

switchgear, the waste holdup tank, a sodium disposal facility, fuel oil storage tank, railroad spur, and roads including parking areas. The principal utilities are: electrical power, transportation, steam, water systems, and sewer systems.

Electrical Power Supply System

The 300 Area Substation, served from Bonneville Power Administration 115 kV line, has automatic, motor operated, sectionalizing switches. If a permanent fault occurs on the line, the system automatically sectionalizes the line and restores power service in approximately 1 minute.

One source of power is the Benton to Richland 115 kV line. A second 115 kV line extends from the Benton Switching station to the site (Figure 2.11-31). Figure 2.11-32 shows the 13.8 kV switchgear and the local 13.8V feeders and transformers. An underground duct system is provided from the substation.

Railroad

A Hanford plant railroad spur goes to the building receiving and shipping area. Car spotting and unloading stations are provided for helium, sodium, and fuel oil. All unloading stations accommodate both rail and truck shipments.

Roads

Asphalt surface access roads run to the site from the plant highway systems (Figure 2.11-30).

Steam

Approximately 40,000 lb/hr of 100 psig steam is required. Three sources of supply are being evaluated: the 300 Area "Central" steam plant, package boilers at the facility, and waste heat from the reactor heat dump.

Sanitary and Process Water

Approximately 200 gal/min of water for sanitary use and 1800 gal/min of water for process use are produced from the 300 Area fire and sanitary water system via a 10 in. pipe loop extension. The sanitary and process water systems are isolated to prevent the possibility of backflow. The process water is delivered to a reservoir and pumped to the process system.

Process Sewer

The FFTF process sewer is a 15 in. vitrified clay tile line extending from the facility to the Columbia River. The sewer discharges through an underwater line extending approximately 150 ft into the river mainstream.

Sanitary Sewer

A septic tank and tile field at the site disposes of the sanitary wastes.

Fencing

The 300 Area site is within the Hanford Works restricted area. An exclusion area is not required. Security control is maintained at the building entrances. Access control fencing runs around the electrical substation, transformer banks, sodium disposal facility, and other facilities.

300 AREA SITE

The FFTF is located west of the 300 Area about 4200 ft from the west bank of the Columbia River (Figure 2.11-30). The site offers relatively level ground at an elevation well above the estimated 100 year maximum flood stage. This location is convenient with respect to services such as electrical power, water, waste disposal, and transportation. Hazards to the immediate surroundings are minimized by means of containment, reactor design, appropriate instrumentation, controls, and procedures.

SK-3-12690

FIGURE 2.11-1. Building Plan XVI
at Elevation 0 ft 0 in.

SK-3-12692

FIGURE 2.11-3. Building Plan XVI
at Elevation +40 ft 0 in.

SK-3-12693

FIGURE 2.11-4. Building Plan XVI at Elevation -20 ft 0 in.

SK-3-12694

FIGURE 2.11-5. Building Plan XVI
at Elevation -40 ft 0 in.

0 10 20 FT.
SCALE: $\frac{3}{32}'' = 1'-0''$

SK-3-12695

FIGURE 2.11-6. Building Plan XVI
at Elevation -55 ft 0 in.

2.11-47

BNWL-470

N O R T H E L E V A T I O N

E A S T E L E V A T I O N

SK-3-12699

FIGURE 2.11-10. Building Plan XVI Elevations

S O U T H E L E V A T I O N

W E S T E L E V A T I O N

0 16 32 FT
 $\frac{1}{16}'' = 1'-0''$

FIGURE 2.11-13. Ventilation Flow Diagram

FIGURE 2.11-14. Building Ventilation Zones
at Elevation +40 ft 0 in.

NOTE: See Figure 2.11-19 for Legend

FIGURE 2.11-15. Building Ventilation Zones at Elevation +23 ft 0 in.

NOTE: See Figure 2.11-19 for Legend

2.11-52

BNWL-470

FIGURE 2.11-16. Building Ventilation Zones
at Elevation 0 ft 0 in.

NOTE: See Figure 2.11-19 for Legend

2.11-53

BNWL-470

FIGURE 2.11-17. Building Ventilation Zones at Elevation -20 ft 0 in.

NOTE: See Figure 2.11-19 for Legend

2.11-54

BNWL-470

LEGEND

Zone	Symbol	Classification
I		Primary Radiation Area, Containment Zone (Air)
IA		Primary Radiation Areas, Containment Zone (Inert or Air)
II		Secondary Radiation Area, No Containment
III		Normal Access Area No Containment
IV		Unlimited Access Area No Containment

FIGURE 2.11-19. Building Ventilation Zones at Elevation -55 ft 0 in.

FIGURE 2.11-20. One Line Diagram of 480 V Switchgear for Reactor Facility

SK-3-12339 1/0

SK-3-12339

FIGURE 2.11-21. One Line Diagram of 2.4 kV Switchgear for Reactor Facility

PART	DESCRIPTION
1	TV RECEIVER, ENTRANCE MONITOR
2	TELEPHONE, ENTRANCE MONITOR
3	TELEPHONE, SUBSTATION MONITOR
4	REMOTE CONTROL PUSHBUTTON STATION, ENTRANCE DOORS-ELEC. LOCKS
5	NAMEPLATE, 'ENTRANCE MONITOR'
6	TV RECEIVER, SUBSTATION MONITOR
7	NAMEPLATE, 'SUBSTATION MONITOR'
8	ANNUNCIATOR, FIRE ALARM
9	REMOTE CONTROL PUSHBUTTON STATION, SUBSTATION DOORS-ELEC. LOCKS
10	TV RECEIVER, PLANT SITE SURVEY
11	TV CAMERA CONTROL-PAN, TILT, ZOOM, ETC.
12	TV RECEIVER, FUTURE
13	GENERAL PLANT TELEPHONE (GPT)
14	TELEPHONE DIRECTORY STORAGE
15	PAX DIAL TELEPHONE
16	INTERCOM DIAL TELEPHONE
17	TV RECEIVER, OPERATIONS, ETC. MONITOR
18	ROTARY FILE-200 NUMBERS
19	ALARM SYSTEMS PUSHBUTTON CONTROL STATIONS
20	ANNUNCIATOR, CRITICALITY ALARM

NOTE
THIS DRAWING INDICATES FUNCTIONAL ARRANGEMENT ONLY, AND DOES NOT IMPLY DETAILED DESIGN.

NOTES:

1. TYPICAL - NOT MORE THAN ONE TELEPHONE PER OFFICE, SHOP OR FACILITY SHOWN.
2. TERMINAL BOX GROUPINGS ARE CONCEPTUAL.
3. EXECUTIVE RIGHT-OF-WAY TELEPHONE SHOWN THUS:

NOTES

- 1. THIS DRAWING INDICATES FUNCTIONAL ARRANGEMENT ONLY, AND DOES NOT IMPLY DETAIL DESIGN.
- 2. RESERVE 4 FT. FLOOR SPACE ON LEFT SIDE FOR PORTABLE VIDEO TAPE RECORDER.
- 3. RESERVE 4 FT. FLOOR SPACE ON RIGHT SIDE FOR AUDIO AMPLIFIERS AND TAPE RECORDERS.
- 4. LOCATE GENERAL PLANT TELEPHONE (GPT) ON SEPARATE DESK OR WALL IF REQUIRED.

TYPICAL FOR -
1. RADIATION TIMEKEEPING OFFICE
2. FULL EXAMINATION FACILITIES
3. TEST CELL MONITORING
4. TEST LOOP PANELS

PART NO	DESCRIPTION
1	TV RECEIVER
2	PAN, TILT, ZOOM & WIPER CONTROL
3	PAX DIAL TELEPHONE
4	INTERCOM DIAL TELEPHONE
5	ROTARY FILE - 200 NUMBERS
6	FUTURE TV RECEIVER

NOTES
1. EACH SYSTEM SHOWN IS TYPICAL ONLY AND DOES NOT REPRESENT ACTUAL DESIGN OR QUANTITIES.

ALARM SYSTEMS
(HANFORD STANDARD HNS-8210.5)

LEGEND

- AAA WARNING ALARM - SIREN --- ALERT ALARM (STEADY SIGNAL)
FUT. FUTURE
CRA CRITICALITY ALARM - MOTOR-DRIVEN HOWLER
--- ATTACK WARNING ALARM (WAVERING SIGNAL)

COMPRESSED AIR SYSTEM

SERVICE WATER DIAGRAM

2.11-67

BNWL-470

SCOPE

SK-3-12701

FIGURE 2.11-30. Building Plan XVI Site Plan

SK-3-12627

FIGURE 2.11-31. Transmission Line Map of FTF Interties

FIGURE 2.11-32. One Line Diagram and Plot Plan
of 115 and 13.8 kV Electrical Power and Relaying
(1 of 2)

FIGURE 2.11-33. One Line Diagram and Plot Plan of 115 and 13.8 kV Electrical Power and Relaying (2 of 2)

2.12 EXAMINATION FACILITIES

The examination facilities serve FFTF experimentors by providing shielded space, equipment, and techniques for prompt nondestructive examination of experiments. The care and skill exercised during the removal of an experiment from the reactor and during subsequent cleaning, handling and examination operations directly affect the condition of the experiment and the test information acquired. Examined objects include irradiated fuel subassemblies and pins (from open and closed loop positions), irradiated material samples (from core and peripheral test hole positions, short term irradiation specimens, and reactor core components.

GENERAL DESCRIPTION

The function of the Fuel Examination Facilities is to provide a nondestructive examination capability for early inspection of FFTF driver and test subassemblies, pins, capsules and specimens. Preservation of data is a prime objective. Included in the facilities is remote handling and inspection equipment capable of performing the following phases of examination:

- Inspection without disassembly of subassemblies and return to the reactor during a scheduled outage.
- Inspection, disassembly and reassembly of test subassemblies and return to the reactor after one or more operating cycles.
- More complete inspection, disassembly and packaging of subassemblies whose irradiation is complete.

Remote controlled equipment is provided to perform the above examination. Examination is conducted under high decay heat output, alpha contamination and radiation levels.

Vertical handling of long subassemblies and forced gas cooling during handling, disassembly and reassembly are provided for data preservation purposes.

Figures 2.12-1 and 2.12-2 present a summary of the examination facilities in the form of a flow sheet. Dual examination lines consisting of both underwater and inert gas facilities are shown for processing material samples and fuel subassemblies. An Inert Gas Cell Examination Facility is provided, since vented and aqueous reactive fuels are expected as test specimens. An Underwater Cell Examination Facility is provided to take advantage of well developed underwater inspection technology. High decay heat output fuels can be handled more easily under water and many materials experiments do not require strict environmental control.

INERT GAS CELL EXAMINATION FACILITY

The Inert Gas Cell Examination Facility provides for interim and final nondestructive examination of FFTF fuel and test subassemblies and reactor components. The inert gas cells, support facilities and interface systems are arranged to ease handling and transfer operations. Fuel or test subassemblies for inert gas cell examination are transferred from the reactor via the Fuel Transfer Cell as shown on Figure 2.12-2.

Examination Cell

The inert gas cell examination facility consists of an in-line cell bank divided into three distinct working areas, as shown on Figure 2.12-3. A deep cell area approximately 27 x 16 x 55 ft high provides space for cleaning, storage, disassembly, reassembly and interim examination of the long fuel and material subassemblies. The remainder of the cell bank consists of an equipment storage and transfer area about 16 x 16 x 20 ft high and a fuel and material specimen examination area about 34 x 16 x 20 ft high.

Cell walls are high density concrete, about 5 ft thick. The interior surfaces of the cell bank are lined with stainless steel, and all cell penetrations are sealed. Remotely changeable absolute filters, mercury vapor and fluorescent lights are provided throughout the cell bank.

Operating stations with viewing windows and master-slave manipulators are provided on opposing walls at three levels in the deep cell area and at one level in the remainder of the cell bank. Width of the cell bank permits simultaneous operations at opposing in-cell work stations and provides sufficient space in the center of the cell for material and equipment handling. Viewing windows are oil filled-lead glass type with alpha seal plates. Master-slave manipulators are the sealed type.

Remotely operated, partially shielded doors isolate the inert gas cell bank from the Fuel Transfer Cell and isolate the equipment storage and transfer cell from the remainder of the cell bank. Throughwall transfer devices and personnel access locks are provided for the three cell areas.

A filtered, cooled and purified argon gas atmosphere is recirculated through the inert gas cell bank. Separate forced-gas cooling systems are provided for cooling of fuel subassemblies and bundles during cleaning, storage, handling, disassembly, reassembly and inspection. Sodium vapor control equipment is provided to prevent sodium vapor deposition on viewing windows and in-cell equipment.

Equipment is provided for handling and inter-cell transfer. Full length fuel and test subassemblies are transferred and positioned with two in-cell cranes and two bridge type electromechanical manipulators. Redundant cranes and electromechanical manipulators are provided for simultaneous operation in

different cell areas and for pushing or towing failed units to the storage and transfer cell. Crane and manipulator rails extend the length of the cell bank and into the Fuel Transfer Cell. Fuel and test bundles and heavy disassembly tools are handled with post type electromechanical manipulators located in the lower part of the deep cell area.

Each cell operating station is equipped with electrical, instrument and other services for remote operation of in-cell equipment. General cell services are routed to the cell through sealed cell wall penetrations. Specialized services are routed through removable, sealed plugs located in the operating face and cell floor. Remote indicating radiation sensors are installed in the three cell areas. Microphones are located in areas where cutting or machining work is performed to assist control of these remote operations.

Cleaning and Storage

The cleaning and storage areas are the first in-line stations for processing irradiated subassemblies. Their functions are to remove residual sodium from the subassemblies and provide interim storage for the examination cell. Cleaning equipment must be compatible with forced gas cooling of fuel subassemblies and preservation of data.

Disassembly, Reassembly, and Interim Inspection

The dismantling, inspection, reassembly and interim inspection of subassemblies and bundles is performed at the next in-line stations. Equipment provided for interim and final inspection of subassemblies include the following:

- Two periscopes
- Binoculars and cameras
- Equipment for overall bundle dimensional measurement
- Equipment for interpin dimensional measurements
- Equipment for dismantling and assembling subassemblies in a vertical position.

- Equipment for reassembly of pin bundles
- Equipment for disconnecting and reconnecting instrument tubes
- Neutron radiography equipment
- Gamma scanning equipment
- Pin hole camera.

Transfer and Equipment Storage Cell

A transfer and equipment storage cell is provided for removal of cell equipment and storage of the electric manipulators and cranes. A large gaslock, located in the floor of the storage cell, permits transfer of large equipment into a shielded decontamination area below. A shielded plug gaslock transfer station, installed in the top of the cell, permits removal of the electric manipulator or crane trolleys for maintenance. Waste, collected in containers is also removed through this transfer plug for burial.

An air atmosphere cell, located below the Transfer and Equipment Storage Cell, provides for transfer of in-cell equipment to a decontamination chamber. The gaslock provides for transfer of items from the air atmosphere cell into the inert gas storage and transfer cell. Decontamination hoods and chamber are located adjacent to the air cell. Provisions are made for suited personnel entry into the air cell for contact decontamination and maintenance.

Fuel and Material Specimen Inspection

After disassembly, components such as pins, specimens, capsules are transferred to the last in-line cell area for nondestructive inspection. The following examination equipment is included in this cell.

- Periscopes, binoculars and cameras for visual inspection and photography
- Pin and specimen dimensional measuring equipment
- Balance

- Leak test equipment
- Bond test equipment
- Density measuring equipment
- Fission gas measuring and collecting equipment
- Milling machine and cutting equipment
- Packaging equipment
- Shielded specimen storage

Equipment located in the deep cell bank area for radiography, gamma scanning, gamma autoradiography (pin hole camera) is also used for inspection of pins, specimens and capsules.

UNDERWATER CELL EXAMINATION

The Underwater Cell Examination Facility provides for the handling, transfer, disassembly, nondestructive inspection, identification, short term storage and packaging of selected fuel and test bundles. The examination cell and operating areas are arranged with adjacent irradiated fuel cleaning, storage and inert gas examination facilities to ease transfer and handling operations.

The sequence of material flow from reactor decay storage to the examination basin is shown in Figure 2.12-1. Subassemblies are transferred from decay storage to the Fuel Transfer Cell for dismantling; then bundles are transferred to the Irradiated Fuel Cleaning Station for sodium removal and transfer into the basin.

Examination Cell

The examination cell provides the underwater work area for inspection, disassembly, packaging and handling operations. The general arrangement of the basin and associated equipment is shown in Figures 2.12-4 and 2.12-5. One side of the stainless steel lined cell serves as an operating face and has two

operating stations. One station is for inspection of pins, capsules and specimens; the other is for inspection and disassembly of bundles. Each station is equipped with a viewing window and master-slave manipulators. A periscope is provided for use at either station. Adjustable work tables are located on the water side of each viewing window.

The traveling catwalk, located over the basin, serves as an above water operating station. Operating space is provided around the basin curb and along the sidewall operating face.

Services required for operation of the facility are provided at service panels located on the operating face. Signal leads from control boxes and consoles at the operating face are routed to outlets along the top of the basin curb and from there to remote controlled underwater equipment. Direct service outlets are also provided at the basin curb for general lighting, water treatment system operation and above water operation.

General underwater lighting is supplied by portable lights. Sealed underwater light fixtures installed above each viewing window provide increased illumination needed for inspection and visual control of remote operations.

Inspection

Equipment is provided for visual inspection, photography and dimensional measurement of pins, capsules and specimens. Visual inspection equipment consists of viewing windows, a through-wall periscope, and a portable periscope and borescope. A periscope or borescope may be attached to the traveling catwalk for operation from above water.

Optical equipment is provided with photographic attachments for data recording purposes. A macrocamera is used for direct photography through the viewing windows.

Direct reading gages mounted on remote positioning devices are used for measurement of pins, capsules and specimens. Bundle measurements are made by direct reading gages which are attached to the disassembly equipment.

Disassembly

The disassembly work station provides for disassembly of bundles and test capsules and for general cutting operations. The underwater bandsaw and milling machine are used for disassembly operations. Removal of miscellaneous hardware extraneous to the fuel region is performed with the bandsaw. The milling machine is used for the precision removal of fuel pins from bundles, specimen capsule disassembly and bundle duct removal.

Disassembly fixtures are designed to insure that identification of disassembled components is maintained. Use of the milling machine positioning and feed control features for measurement operations is also provided. Remote operation and control of the disassembly equipment is performed from the side wall operating station.

Packaging and Storage

The underwater packaging station provides for preparation of components for shipment. Remote-operated packaging equipment is used to seal and/or close the loaded containers. The containers are sized to be compatible with the fuel storage racks. The storage racks provide for short term storage of bundles and components. Size and spacing of storage components is based on criticality control requirements. Storage rack inserts (baskets) are provided to

facilitate transfer, handling, and identification of components. Tool and equipment racks are provided adjacent to work stations for storage of small tools and equipment accessories.

Handling and Transfer

Handling and transfer equipment is provided for equipment and component movement within and adjacent to the examination basin. The equipment includes the catwalk hoists, master-slave manipulators, adjustable work tables, the examination-to-cleaning cell transfer device, and miscellaneous handling tools and probes.

Underwater operations which require minimum visual control are performed from the curb level operating station using long probes and the catwalk hoists. Operations requiring maximum visual control and more complex handling and remote equipment operation are performed from the side wall operating stations using the catwalk hoists and through-wall master-slave manipulators. Adjustable work tables at the underwater stations are positioned vertically to support and position components and equipment during examination.

The examination-to-cleaning cell transfer device transfers components between the cleaning cell transfer port and the water basin floor. The basin gate is used for emergency underwater transfer of irradiated material to the storage and load-out basin. An overhead bridge crane is used for interbasin transfers, removal and installation of basin equipment, and waste cask handling.

WATER TREATMENT SYSTEM

The Water Treatment System processes and handles the water inspection medium of the Underwater Cell Examination Facility. The recirculation subsystem clarifies, decontaminates,

and cools the basin water. The drain and overflow subsystem is utilized to drain and clean the basin. The supply and makeup subsystem provides for filling the basin and assists in criticality control. The process flow diagrams for the subsystems are shown on Figures 2.12-6 and 2.12-7.

Recirculation

The water recirculation subsystem removes turbidity, soluble fission products, and heat from the water. Process equipment includes a recirculating pump, mechanical filter, mixed bed demineralizer and heat exchanger. The recirculating pump draws water from the basin through the mechanical filter and discharges the water through the heat exchanger and demineralizer into the basin. Portable resin supply and disposal tanks charge and discharge the demineralizer resin.

Drain and Overflow

A mechanical filter, trap, pump, and floor sweeper provide for routine cleanup of residue and for cleanup and draining during major maintenance outages. During routine cleanup operations, water drawn through the filter and trap is returned to the basin to reduce the volume of liquid waste generated. Located underwater for shielding purposes, the filter and trap can be replaced remotely.

Overflow drains above the normal water level drain off during basin filling and when casks, equipment, etc., are introduced into the basin. The overflow drains also serve as outlets for removal of water surface film.

Supply and Makeup

The water supply and makeup subsystem fills the basin with neutron poisoned demineralized water. Process equipment includes a concentrated poison supply tank, mixer,

metering valve and liquid level sensors. To assist criticality control, concentrated neutron poison (sodium borate) is added to the demineralized water. Addition of sodium borate to the water also reduces the algae control problem. Provisions are made to prevent filling the basin with nonpoisoned water and for monitoring the poison concentration.

FIGURE 2.12-1. Material Flow Chart for Underwater Cell Examination

FIGURE 2.12-2. Material Flow Chart for Inert Gas Cell Examination

SK-3-12566

FIGURE 2.12-3. Inert Gas Examination Plan and Sections

SK-3-12564

SK-3-12562

FIGURE 2.12-5. Basin Equipment for Underwater Examination

EQUIPMENT LIST						
EQUIPMENT PIECE NUMBER	SYSTEM PIECE NUMBER	DESCRIPTION	SIZE (INCHES)	PRESSURE (NORMAL)	END CONNECTION	MATERIAL
RECIRCULATION						
	F-1-1	FILTER				WOOL
	P-1-1	PUMP				
	HE-1-1	HEAT EXCHANGER				VARIABLE (40 GPM MAX)
	MBD-1-1	DEMINERALIZER				MIXED BED, 4 Cu. Ft.
	ORT-1-1	DEPLETED RESIN TANK				C. STL.
	RST-1-1	RESIN SUPPLY TANK				SST
	VI-1-1	VACUUM INDICATOR				0-30" Hg.
	TI-1-1	TEMP. INDICATOR				0-200° F
	TI-1-2	TEMP. INDICATOR				0-200° F
	TA-1-1	TEMP. ALARM-HI				~ 85° F
	PM-1-1	POISON MONITOR				0-30g. B ¹⁰ /LITER
	PA-1-1	POISON ALARM-LOW				
	FM-1-1	FLOWMETER				0-50 GPM
	FM-1-2	FLOWMETER				0-20 GPM
	QD-1-1	QUICK DISCONNECT				
	QD-1-2	QUICK DISCONNECT				
	QD-1-3	QUICK DISCONNECT				
	QD-1-4	QUICK DISCONNECT				
	QD-1-5	QUICK DISCONNECT				
	V-1-1	VALVE, FOOT				SST
	V-1-2	VALVE				
	V-1-3	VALVE				
	V-1-4	VALVE				
	V-1-5	VALVE				
	V-1-6	VALVE				
	V-1-7	VALVE				
	V-1-8	VALVE				
	V-1-9	VALVE				
	V-1-10	VALVE				
	V-1-11	VALVE				
	V-1-12	VALVE				
	V-1-13	VALVE				
	V-1-14	VALVE				
	V-1-15	VALVE				
	V-1-16	VALVE				
	V-1-17	VALVE				
	V-1-18	VALVE				
	V-1-19	VALVE				SST

EQUIPMENT PIECE NUMBER	SYSTEM PIECE NUMBER	DESCRIPTION	SIZE (INCHES)	PRESSURE (NORMAL)	END CONNECTION	MATERIAL	REMARKS
DRAIN & OVERFLOW							
	QD-2-1	QUICK DISCONNECT				SST	REMOTELY OPERABLE
	QD-2-2	QUICK DISCONNECT					
	QD-2-3	QUICK DISCONNECT					
	QD-2-4	QUICK DISCONNECT					REMOTELY OPERABLE
	T-2-1	TRAP					50 MESH
	F-2-1	FILTER					50 MICRONS
	P-2-1	PUMP					SUBMERSIBLE
	OD-2-1	OVERFLOW DRAIN				SST	
	V-2-1	VALVE, FOOT				SST	
	V-2-2	VALVE					
	V-2-3	VALVE					
	V-2-4	VALVE					SAFETY LOCK
	FS-2-1	FLOOR SWEEPER				SST	SWIMMING- POOL TYPE
SUPPLY & MAKEUP							
	PST-3-1	POISON SUPPLY TANK				SST	
	M-3-1	MIXER					
	LLS-3-1	LIQUID LEVEL SENSOR					
	LLS-3-2	LIQUID LEVEL SENSOR				SST	
	LLA-3-1	LIQUID LEVEL ALARM-LO					
	LLI-3-1	LIQUID LEVEL INDICATOR					
	EV-3-1	SOLENOID VALVE				SST	N.C.
	EV-3-2	SOLENOID VALVE					N.C.
	MV-3-1	VALVE, MIXING					METERING PUMP MAY BE REQUIRED
	V-3-1	VALVE					
	V-3-2	VALVE					
	V-3-3	VALVE					SAFETY LOCK
	V-3-4	VALVE					SAFETY LOCK
	QD-3-1	QUICK DISCONNECT				SST	

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LEGEND

	HEAT EXCHANGER
	ALARM
	FLOW METER OR INDICATOR
	INDICATOR
	PUMP, CENTRIFUGAL, OR OTHER ROTARY
	AGITATOR, MIXER
	LIQUID LEVEL INDICATOR
	FLOOR SWEEPER
	MIXING VALVE
	QUICK DISCONNECT
	VALVE
	SOLENOID VALVE
	CHECK VALVE, OR FOOT VALVE
	LLS
	ELECTRICAL LINE

NOTES

1. PIPING SHOWN ON SHEET 2, TO BE ALL WELDED CONSTRUCTION WITH MECHANICAL JOINTS AT EQUIPMENT CONNECTIONS.
2. SOLENOID VALVES EV-3-1 & EV-3-2 ARE OPERATED IN SERIES BY SERIES WIRED LIQUID LEVEL SENSORS LLS-3-1 & LLS-3-2.

SK-3-12561

FIGURE 2.12-6. Process Flow
Diagram for Underwater Cell
Examination Water Treatment
System (1 of 2)

RECIRCULATION

SK-3-12561

DRAIN & OVERFLOW

SUPPLY & MAKEUP

FIGURE 2.12-7. Process Flow Diagram for Underwater Cell Examination Water Treatment System (2 of 2)

2.13 NUCLEAR PROOF TEST FACILITY

The initial nuclear design of the FTR relies heavily on critical mockup experiments to perfect design methods, to provide nuclear design data and to verify nuclear design features. Continuing nuclear analysis effort is required in support of operation. A zero-power, critical facility--the Nuclear Proof Test Facility (NPTF) is used in this nuclear analysis effort.

Conceptual design work is currently under way to define the features of the NPTF. It is expected that this facility will include capabilities to simulate .

- Overall reactor geometry and fuel loading features
- Fuel Geometry and burnup
- The nuclear effects of the coolant
- Control features.

The NPTF is housed in a closed structure designed to control the release of radionuclides to the atmosphere following its design basis accident.

Figure 2.13-1 shows a vertical core assembly for the Nuclear Proof Test Machine.

VERTICAL CORE ASSEMBLY

FIGURE 2.13-1. Nuclear Proof Test Machine

2.13-2

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2.14 OPERATIONS AND MAINTENANCE FUNCTIONS

REACTOR OPERATION

An on-line efficiency of 75% is the goal used for FFTF conceptual studies. The operating cycle selected consists of alternate 9 week operating and 15 day shutdown periods. The distinguishing features of FFTF operating cycles are the high burnup rate and the operation of multiple loops. A burnup rate of $\sim 0.07\% \Delta k/\text{day}$ is estimated depending upon the reactor power level. Adjustment in large-worth rods is a daily requirement. The startup swing is approximately $1.5\% \Delta k$ depending upon operating sodium and fuel temperatures. Small worth regulating rods are utilized for short term control.

Indicators, dials, video monitors, and strip chart recorders are arranged near the reactor operating console for convenience and ease of observation. The operator observes the indicating and recording instruments, controls the power level of the reactor by operating large worth shim and small worth regulating rod controls on the console. Each of the rods has a separate control. Other controls in the control room are used to regulate sodium temperature, flow, pressure, and level for the reactor and test loops.

Instrumentation and control devices are designed to permit either manual or automatic control. The reactor is started up initially by manual control. As detailed knowledge of the reactor is accumulated, certain portions of the reactor control system can be by automatic control without compromising reactor safety.

Two types of reactor shutdown modes are used. One is the fast scram mode where the reactor is shutdown as fast as possible. The other is a "controlled shutdown" mode in which control rods are driven into the reactor core automatically at a rate which

causes least disturbance to the fuel test specimens or the reactor. All noncritical trips which do not require maximum reactor shutdown rates are included in the controlled shutdown program. These trips monitor loss of a secondary pump, single power line failure, secondary loop overtemperature, and fire.

The closed loops may be operated at temperatures different from the core coolant. Coolant purity limits may differ between the primary and closed loop coolants and between individual closed loops. Different coolants may be employed in the loops. These factors necessitate frequent sampling, analysis, and adjustment of coolant purities by the operating staff.

During operation of the reactor, it is expected that rebuilding of one or more loops will occur as one customer terminates his test program and another prepares to test. Final tie-ins to the core will take place during outages. The examination facilities included in FFTF are in use during reactor operation as well as during outage periods.

Outage Operations: On-Line Efficiency

The FTR reference core consists of 94 in-core positions (plus 38 similar positions in the reflector) which are allocated as in Table 2.14-I.

TABLE 2.14-I. *FTR Core Positions*

	<u>Core</u>	<u>Reflector</u>
Closed Loop-Fuel	3	0
Closed Loop-Material	2	0
Open Test Positions	13	0
Driver Fuel	76	-
Control and Safety Rods	10	8
Short Term Irradiation Tests	0	1
Neutron Source	0	1
Reflector Test Positions	0	38

Assuming a 45,000 MWd/tonne average exposure and 400 MW operation, 15 to 17 driver fuel subassemblies are replaced during each 15 day outage following a 9 week operation period. Several loops, are recharged or the subassemblies are removed for interim examination and recharged during the outage. Material samples from various test holes are also handled during outages. Table 2.14-II shows a tentative shutdown schedule.

TABLE 2.14-II. *Tentative FTR Shutdown Schedule*
[Outage Length: 15 days (45 shifts)]

Shutdown, prepare for refueling	2 1/2 shifts
Refuel 15 to 17 driver tubes	12 shifts
Refuel 3 open test positions	2 shifts
Refuel 2 closed loops	3 shifts
Transfers for interim examinations	3 shifts
Startup preparation and tests	3 shifts
Balance allotted for maintenance, loop adjustments, delays, other	20 shifts (7 days)

The cycle of a 9 week operation and a 15 day shutdown may be something different after startup. Aside from scrams and other unplanned outages, optimization of fuel burnup and rod strengths may affect the cycle chosen. The nature and number of tests imposes variations on the operating cycle. The validity of the 75% on-line efficiency goal depends on the ability to perform maintenance and loop adjustments in the 7 days allotted.

Reactor primary pumps, heat exchangers, and control rods are similar to counterparts in the EFFBR, EBR-II, HNPF, and SRE reactors and it is assumed equal operating efficiency can be attained.

The presence of sodium test loops, operating at 1400 °F and ultimately 1×10^{16} n/cm² - sec neutron fluxes, are features that create uncertainties regarding the on-line goal percentage. At the central peak flux of 1×10^{16} n/cm² -sec, a fuel tube or closed loop will achieve an exposure of 2.3×10^{23} nvt by the end of 1 year at full power operation. In-core components

require replacement on a 1 year cycle for neutron exposure reasons. The replacement rate averages one per shift, therefore 20 days or 1/3 of the total maintenance and loop outage time allowance is used for this type of replacement. Additional outage time is needed for maintenance of loop piping, pumps, heat exchangers, and other components.

A major factor affecting on-line efficiency will be the nature of tests performed in the open test positions and closed loops. Failure of coolant purity controls of test assemblies may cause frequent shutdowns and unscheduled outages. The presence of five loops with safety circuit tie-ins also creates potential on-line efficiency penalties.

RADIOACTIVE MAINTENANCE

The Radioactive Maintenance System provides the capabilities and equipment necessary for remote and/or contact maintenance of the contaminated or radioactive components. The functions of the system include:

- Remote handling
- Remote maintenance
- Remote decontamination
- Contact maintenance.

Figures 2.14-1 through 2.14-4 show the basic handling sequences for major equipment maintenance operation. Radioactive maintenance also provides the capabilities within the reactor hot cell for nonroutine maintenance operations.

The system consists of the following:

- Maintenance Hot Shop
- Portable Hot Shop
- Radioactive Maintenance Cells
 - Component Transfer
 - Component Decontamination
 - Remote Maintenance
 - Contact Maintenance

- Reactor Hot Cell Maintenance

Maintenance Hot Shop

A radioactive maintenance hot shop is provided for repair and preventive maintenance of low level radioactive and contaminated components. The areas within the hot shop are equipped for localized alpha and radioactive contamination confinement. The hot shop consist of the following:

- Machine shop
- Instrument shop
- Electrical shop
- Manipulator repair area
- Hood or glove box welding facilities

Portable Hot Shop

The portable hot shop provides tools and equipment which can be transported to the specific work area for in place maintenance.

Radioactive Maintenance Cells

The radioactive maintenance cells provide the capability for decontamination, disassembly, repair, assembly, modification, and preventive maintenance on major radioactive or contaminated equipment and components.

Component Transfer Cell

The component transfer cell connects with the Reactor Hot Cell, and the contaminant work area with the high bay area outside of containment. The cell provides the capability to transport large radioactive and/or contaminated components between these areas.

The cell is equipped with the following:

- Lead glass viewing windows
- Binoculars and cameras
- Periscopes

- Master-slave manipulators
- Television cameras with monitors in the operating gallery
- Overhead transfer system
- Access ports
- Cell service plugs.

Component Decontamination

The component decontamination cell provides sodium and alpha decontamination capabilities for large equipment and components.

The cell is equipped with the following:

- Lead glass viewing
- Binoculars and cameras
- Periscopes
- Master-slave manipulators
- Television cameras with monitors in the operating gallery
- Decontamination tanks
- Remote overhead crane
- Access ports
- Cell service plugs.

Remote Maintenance Cell

The remote maintenance cell provides for maintenance of components or equipment which do not permit contact maintenance. This cell permits repair of primary sodium pumps, control rod poison sections, closed loop components, etc.

Equipment necessary to perform the cell functions include:

- Lead glass viewing windows
- Binoculars and cameras
- Periscopes
- Master-slave manipulators
- Sidewall electro-mechanical manipulators
- Television cameras with monitors in the operating gallery
- Overhead crane

- Elevating work platforms
- Miscellaneous fixtures, jigs and tools
- Cell service plugs.

Contact Maintenance Cell

The contact maintenance cell receives components or equipment that has been decontaminated in the decontamination cell. In this cell components and equipment are repaired by contact methods, radiation levels permitting. The contact maintenance cell may be converted for remote maintenance operation with limited biological shielding, if needed.

Reactor Hot Cell Maintenance

The reactor hot cell maintenance capability is provided by the radioactive maintenance system within the reactor hot cell. These functions include:

- Remote maintenance of equipment within the cell
- Remote removal of closed loop cross-piping
- Remote reactor core changeout
- Remote cleanup from sodium spill or contamination release.

Containment Work Area

The containment work area is used for handling and performing contact maintenance on components and equipment located within this area.

High Bay Area

The high bay maintenance area located above the radioactive maintenance cell is used to handle the following:

- Component handling cask
- Components and/or equipment
- Waste removal cask(s) and/or container(s)
- Shipping casks

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FIGURE 2.14-1. Maintenance and Decontamination
Typical Flow Sequence

NEUTRON SHIELD GAS CIRCULATOR

F. H. M. INTERNALS

INTERMEDIATE HEAT EXCHANGER

DISTRIBUTION28 AEC, Washington

Division of Reactor Development & Technology
M. Shaw, Director, RDT
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Analysis & Evaluation Branch, RDT:NS
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Asst Dir for Plant Engineering Branch, RDT
Applications & Facilities Branch, RDT:PE
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Systems Engineering Branch, RDT:PE
Asst Dir for Program Analysis, RDT
Asst Dir for Project Management, RDT
Liquid Metals Projects Branch, RDT:PM
FFTF Project Manager, RDT:PM (3)
Asst Dir for Reactor Engineering
Control Mechanisms Branch, RDT:RE
Core Design Branch, RDT:RE
Fuel Fabrications Branch, RDT:RE
Fuel Handling Branch, RDT:RE
Reactor Vessels Branch, RDT:RE
Asst Dir for Reactor Technology
Chemistry & Chemical Separations Br, RDT:RT (2)
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J. R. Boldt
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D. C. Boyd
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J. E. Brown
W. L. Bunch
C. A. Burgess
M. P. Burns
C. P. Cabell
J. J. Cadwell
D. S. Cameron
J. R. Carrell
W. E. Cawley
W. L. Chase
T. D. Chikalla
T. T. Claudson
P. D. Cohn
D. L. Condotta
R. R. Cone
R. M. Crawford
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D. R. de Halas
R. F. Dickerson
D. R. Doman
G. E. Driver
R. V. Dulin
S. L. Engstrom
J. F. Erben
P. L. Farnsworth
S. L. Fawcett
L. M. Finch
J. K. Flickinger
C. D. Flowers
C. J. Foley
G. L. Fox

Battelle-Northwest

J. C. Fox
E. E. Garrett
R. L. Gibby
S. M. Gill
S. Goldsmith
A. L. Gunby
V. W. Gustafson
J. W. Hagan
W. L. Hampson
J. E. Hanson
H. Harty
R. A. Harvey
J. J. Hauth
K. D. Hayden
B. R. Hayward
J. W. Helm
L. G. Henke
R. J. Hennig
J. Herb
G. M. Hesson
C. W. Higby
P. L. Hofmann
M. T. Jakub
B. M. Johnson
H. G. Johnson
R. L. Junkins
W. S. Kelly
F. J. Kempf
R. L. Knecht
D. J. Lagrou
D. D. Lanning
H. D. Lenkersdorfer
C. W. Lindenmeier
H. E. Little
W. W. Little, Jr.
R. J. Lobsinger
G. L. Locke
C. E. Love
J. F. Lubeck
M. K. Mahaffey
C. A. Mansius
W. R. Markillie
W. B. McDonald
K. R. Merckx
M. H. Meuser
D. J. Meyers
M. K. Millhollen
D. M. Nero
R. E. Nightingale
J. C. Noakes

Battelle-Northwest

W. M. Noble
A. Padilla
R. S. Paul
M. G. Patrick
C. E. Peckinpaugh
L. T. Pedersen
L. A. Pember
J. A. Perry
R. E. Peterson
F. G. Richards
W. A. Richmond
W. E. Roake
M. O. Rothwell
G. H. Salzano
J. R. Samuel
J. D. Schaffer
D. P. Schively
F. H. Shadel
D. W. Shannon
B. O. Shaver
D. E. Simpson
R. J. Squires
C. C. Steele
W. F. Stevenson
G. H. Strong
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M. T. Walling
G. R. Waymire
J. H. Westsik
R. G. Wheeler
L. A. Whinery
R. D. Widrig
E. F. Witeck
M. R. Wood
F. W. Woodfield
D. C. Worlton
H. H. Yoshikawa
Technical Information Files (3)
FFTF Record File
FFTF Reference File