**REVIEW OF REACTOR SAFETY ANALYSES
OF FAST AND LIQUID METAL
COOLED REACTORS**

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By

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Nuclear Safety Section
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REVIEW OF REACTOR SAFETY ANALYSES OF FAST AND LIQUID METAL COOLED REACTORS

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INTRODUCTION

Safety analysis reports on United States fast and liquid metal cooled reactors were reviewed to gain a better understanding of the safety philosophy applied to the design of these facilities. This information was compiled to help guide the design and safety analysis of the Fast Flux Test Facility. No attempt was made to draw conclusions concerning the relative merit of different approaches and philosophies used by different reactor design teams.

The facilities reviewed were:

Enrico Fermi Atomic Power Plant (FERMI)

Hallam Nuclear Power Facility (HALLAM)

Southwest Experimental Fast Oxide Reactor (SEFOR)

Fast Reactor Test Facility (FARET)

Experimental Breeder Reactor No. 1 (EBR-I)

Experimental Breeder Reactor No. 2 (EBR-II)

Fast Reactor Zero Power Experiment (ZPR-III)

The information gathered from the safety analysis reports is presented in tabular form under the following subdivisions:

Table I. A	Control and Safety Systems
Table I. B	Reactor Protection Systems
Table II	Backup Systems
Table III	Containment or Confinement Systems
Table IV	Inherent Reactivity Effects and Important Physics Parameters
Table V	Fuel and Fuel Handling
Table VI	Accidents Considered and Chemical Problems
Table VII. A	Site
Table VII. B	Exhaust Ventilation System
Table VII. C	Waste Effluents

TABLE I. A. CONTROL AND SAFETY SYSTEMS

<u>Name</u>	<u>Reactor Type</u>	<u>Elements</u>	<u>Total Strength</u>	<u>Individual Strength</u>	<u>Speed Of Insertion</u>
FERMI ⁽¹⁾	Fast breeder, Na-cooled	B ₄ C (boron enriched in 10B) safety—8 and control—2 rods; motor driven ^(1.a)	\$10.22 ^(1.a, g)	Safety = \$1.00-\$1.31 (max); Control = \$0.46 ^(1.a, g)	Safety: (scram), \$17/sec or 70 in./sec; (fast rundown), 10 ft/min and 1.6 in./min for last 6 in. ^(1.a)
Hallam ⁽²⁾	Thermal, Na-graphite	Vertical rods—19; combination shim—safety ^(2.a)	14% $\Delta k/k$ ^(2.a)	1.5 to 2% max ^(2.a)	0.9 sec ^(2.a)
SEFOR ⁽⁵⁾	Fast, Na-cooled	10 radial reflector segments surrounding core	\$14	\$1.40	Speed of Drop--Scram: \$10 @ \$20/sec; automatic rundown of "fine control" segments provided--rate not given.
FARET ⁽⁶⁾	Fast, Na-cooled	8 subassemblies—neutron-absorbing rods (probably B ₄ C).	Reference Zoned Core (RZC): 100% natural B = 0.04 Δk ; 75% natural B—25% ¹⁰ B = 0.07 Δk ; 50% natural B—50% ¹⁰ B = 0.091 Δk . Reference Small Core (RSC): 100% natural B = 0.029 Δk ; 50% natural B—50% ¹⁰ B = 0.056 Δk ; 25% natural B—75% ¹⁰ B = 0.065 Δk .	RZC: 100% natural B = 0.005 Δk ; 75%—25% = 0.00075 Δk ; 50%—50% = 0.0114 Δk . RSC: 100% = 0.0036 Δk ; 50%—50% = 0.007 Δk ; 25%—75% = 0.0081 Δk .	
EBR-I ⁽⁷⁾	Fast breeder, Na-cooled	12 vertical SS-clad natural uranium rods—8 serve as safety, 4 as fine control; entire outer blanket (Pb) or cup is raised or lowered rel. to core, hydraulically; tapered uranium safety plug—must be fully inserted before outer blanket can be raised to a critical position—pneumatically driven.	Pb cup: 5.25% $\Delta k/k$; safety rods: 0.18% $\Delta k/k$; safety plug: 0.06% $\Delta k/k$. Total: 5.49% $\Delta k/k$.	Safety rod: 0.028% $\Delta k/k$.	Addition Speeds: Control rods (4): 0.64 in./sec; safety rods (8): 0.64 in./sec; safety plug: 5.0 in./sec; cup (80 in. to 30 in.): 0.32 in./sec; cup (30 in. to 5.15 in.): 0.095 in./sec; cup (5.15 in. to 0 in.): 0.005 in./sec. Scram Speeds: (Total Time for Indicated Travel): safety rods (8), 0 to 16 in.: 0.38 sec; safety block, 0 to 6 in.: 0.35 sec; cup (0 to 12 in.): 0.56 sec; cup (0 to 80 in.): not given.

TABLE I. A. CONTROL AND SAFETY SYSTEMS (contd)

EBR-II ⁽⁹⁾	Fast breeder, Na-cooled	12 control rods (fail-safe); 2 safety rods; vertically operating; consist of modified movable fuel subassemblies with Na "voids."	0.06 $\Delta k/k$ (12 control); 0.015-0.020 $\Delta k/k$ (2 safety rods).	Control: $<0.006 \Delta k/k$; Safety: $\approx 0.0075 \Delta k/k$.	Normal operation limit: 5 in./min. Safety rod: 2 in./min.
ZPR-III ^(10, 11)	Fast, Al-simulated coolant; split-table machine	10 control-safety rods (horizontal) of fissionable material, 5 for each core half. Maximum worth when fully inserted. Each rod has 1/4 HP, reversible gear head motor with break, driving a pinion through a magnetic clutch. All rods pulled out of core by air pressure during scram. The 2 core halves are also moved apart at a speed of 30 in./min during scram reducing reactivity at a rate of 2-1/2%/sec. 8 safety rods are driven in before startup; 2 rods serve control function.	Rods: 8% $\Delta k/k$	Maximum of 1% $\Delta k/k$ each (or 0.0015 $\Delta k/k$ -in.); 0.002 $\Delta k/k$ -in. for Pu loading.	Limited to 4 in./min (0.07 in./sec) with 10 in. total travel.

TABLE I. A. CONTROL AND SAFETY SYSTEMS (contd)

<u>Name</u>	<u>Reactivity Addition Rate</u>	<u>Shutdown Margin</u>	<u>Accidents Considered</u>
FERMI	Safety; 8 rod rate: 1¢/sec max. Control; 2 rod rate: 1¢/sec max. (1. a)	@ 517 °F (startup) = \$9.30 @ op. temp. = \$9.90¢	Stuck safety rod failing to scram; cont. withdrawal of control (safety) rods at runaway speed. (1. g)
Hallam	0.03% $\Delta k/k$ -sec (2. a) (19 rods)	6% $\Delta k/k$ (2. a)	Control rod thimble leak; control rod withdrawal @ source, low and high power. (2. c)
SEFOR	Coarse Control Rod Drives--8: \$0.05/sec; Fine Control Rod Drives: \$0.01/sec.	At normal shutdown temp (350 °F): \$7.4; \$6.0 with one rod stuck.	1) Rod run-in starting at rated power (20 MW _t) 2) Rod run-in from source-level power (1 W) 3) Jamming of reflector rods.
FARET	Only rates given are associated with credible accidents; \$20/ sec max. for each core type.		Unplanned removal of control rod: a. Malfunction of control rod drives* b. Malfunction of fuel-handling machine* c. By manual means; max. withdrawal rate by 2 men; 3.3 in./45 msec or $\approx$ 6 ft/sec. *Both are rate limited so that excessive reactivity cannot be inserted by erroneous actions.
EBR-I	Control rods-4: 1.1×10^{-5} $\Delta k/k$ -sec per rod; safety rods- 8: 1.1×10^{-5} $\Delta k/k$ -sec per rod; safety plug: 4.9×10^{-4} $\Delta k/k$ -sec; cup (80 in. to 30 in.): not given; cup (30 in. to 5.15 in.): 3.75×10^{-4} $\Delta k/k$ -sec; cup (5.15 in. to 0 in.): 1.54×10^{-5} $\Delta k/k$ sec.		Control and safety rod failure-- simultaneous failure of any or all considered.
EBR-II	Control: <0.00006 $\Delta k/k$ -sec per rod; Safety: <0.0001 $\Delta k/k$ sec per rod; max. rate based on 2 rods: <0.00011 $\Delta k/k$ -sec.	0.05 $\Delta k/k$ @ operating temp	Safety rod run-in (both); single control rod run-in.
ZPR-III	$\Delta k/\Delta t \leq 5 \times 10^{-4}$ /sec for ²³⁵ U; $\Delta k/\Delta t = 1.6 \times 10^{-4}$ /sec for Pu.		Loss of electrical power resulting in de-energizing of electromagnetic clutches and stopping of drives.

TABLE I. B. REACTOR PROTECTION SYSTEMS

<u>Name</u>	<u>Primary Shutdown System</u>	<u>Neutron Flux Channels</u>
FERMI	Safety rod drop(1. a)	2 channels--source range (shutdown to 12 kW); (either channel scrams); 3 channels--intermediate range (1.2kW to 1200 MW); (2 out of 3 channels initiate scram); 6 channels--power range (2 MW to 300 MW on 5 of 6 channels; 14-1400 MW on 6th); (2 out of 3 channels initiate scram). (1. b)
Hallam	Safety rod drop(2. a)	I and II--source range channels (6×10^{-9} to $6 \times 10^{-4}\%$, rated power); III and IV--in intermediate range (6×10^{-5} to 10% rated power); V, VI and VII--power range protective system; VIII, IX--identical to V, VI and VII--provided for plant control (0.1 to 150% rated power). (2. a)
SEFOR	Inconel reflector dropped	1) "Source Range" or Startup: 2 channels 2) "Intermediate Range": 2 channels 3) "Wide Range": 3 channels
FARET	8 control rod assemblies	11 detector channels for: (2 out of 3 channels initiate scram) 1) monitoring and indicating neutron flux at all powers from source level to 300% of full power; 2) protecting against short reactor periods during startup and normal operation, and against excessive power levels; 3) generating a signal necessary for automatic control of reactor flux level.
EBR-I	8 safety rods driven from cup; pedestal and cup drop away	3 flux level trip circuits (1 on standby; either of the other 2 initiate scram); 2 period circuits; vibrating reed electrometer (startup); startup counter; galvanometer and automatic control
EBR-II	12 fuel-bearing control rods	Startup Range: 2 identical fission counter channels (1 and 2) (either will initiate scram); Log Power Range: Channels 3 and 4 are logarithmic level channels employing measurement of current from ionization chambers (either will initiate scram); Linear Power Range; Channels 5 and 6 are linear wide-range dc amplifier channels which measure current from ionization chambers (either will initiate scram); Channels 7, 8, 9, and 10 are identical in range and employ dc amplifiers which measure current from ionization chambers (2 out of 4 produce scram).
ZPR-III	10 control-safety rods and separation of core halves	1) 2 linear electrometer circuits 2) gamma log amplifier circuit 3) 2 proportional counter circuits 4) 3 trip level safety circuits 5) 2 period meter circuits 6) source neutron counter circuit

TABLE I. B. REACTOR PROTECTION SYSTEMS (contd)

<u>Name</u>	<u>Trips (Scram)</u>
FERMI	1) High power level 2) Excessive rate of power decrease 3) Short period 4) High Na temp 5) Na flow (2 out of 3 cooling circuits): 75% 6) 10 sec period or less (source range channels) 7) 20 sec period or less (intermediate channels) 8) Failure of one primary loop and secondary loop in another circuit 9) Loss of 28 V dc supply. (1. b)
Hallam	1) *High computed outlet temp (includes high neutron flux, low Na flow, and high inlet temp) 2) *High Na temp at fuel channel outlet 3) *High rate of change Na temp at fuel channel outlet 4) *Low reactor Na level 5) Loss of power to any main Na pump 6) *Low boiler H ₂ O level in any Na circuit 7) *High or low primary to secondary flow ratio in any Na circuit. (2. a) *Coincidence circuits (either 1 or 2 out of 3)
SEFOR	1) Scram producing conditions <ol style="list-style-type: none"> High neutron flux (1 out of 3) High-low neutron flux (scale indications) (2 out of 3) Short period (1 out of 2) High seismic activity Electrical power loss Low reactor Na level Very low reactor Na level High temp reactor Na Low flow main primary loop Low flow main secondary loop Low level secondary expansion tank Low pressure secondary expansion tank High temp main secondary cold leg High reflector temp High temp main primary pump winding (incl. power supply shutoff) Main load center electrical power loss 2) Automatic rundown conditions <ol style="list-style-type: none"> Low neutron flux High level secondary expansion tank 3) Ventilation valve isolation <ol style="list-style-type: none"> High radiation ventilation exhaust

TABLE I. B. REACTOR PROTECTION SYSTEMS (contd)

FARET	<ol style="list-style-type: none"> 1) With alarm: <ol style="list-style-type: none"> a. Source flux level--low b. Log count-rate level--high c. Log count-rate period--short/detector voltage--low d. Log N-period--short/detector voltage--low e. Linear level--high/detector voltage--low f. Automatic flux control rod down g. Power range above fixed level/above automatic flow set level/detector voltage--low h. Any control rod unlatched i. Any control rod not "full down" j. Control rod scram assist pressure--low k. Reactor inlet coolant flow--low l. Reactor inlet coolant flow rate of change--high m. Reactor outlet coolant temp--high n. Reactor outlet temp rate of change--high o. Primary pump motor power interruption p. Secondary pump motor power interruption q. Primary/secondary pump clutch reference voltage--low r. Main secondary heat exchanger power interruption s. Primary system coolant level--low t. Reactor blanket gas pressure--high u. Cell isolation trip (access lock open) v. Earthquake detection w. Manual scram 2) Alarm only: <ol style="list-style-type: none"> a. Linear level range setting interlock b. Main primary-secondary flow ratio--high/low c. Primary/secondary pump clutch temp--high d. Cell gamma radiation--high e. Cell atmosphere temp--high f. Cell differential pressure--high g. Smoke in cell, cavity, or vault
EBR-I	<ol style="list-style-type: none"> 1) Short negative period--2 channels 2) Short positive period--2 channels 3) Reactor coolant flow--low 4) Reactor inlet temperature--high 5) Reactor outlet temperature--high 6) Heat exchanger outlet temperature--high 7) Fuel rod temperature--high 8) Elevator leaves stops 9) Gravity tank outlet shutoff valve closed 10) Gravity tank drain valve open 11) Reactor overflow valve closed 12) Receiving tank overflow valve closed 13) High neutron flux--2 channels 14) Blanket rod temperature--high 15) Reactor assembly inlet valves (all internal valves not completely up or down) 16) Reactor assembly throttle valves (both internal valves not in correct position for series or parallel flow) 17) Compressed air supply to valve operators--low <p>2-Minute Delayed Shutdown Trips</p> <ol style="list-style-type: none"> 1) Pumped coolant flow low 2) Circulating gas flow low 3) Elevator hydraulic pressure low 4) Automatic control exceeds set points 5) Outer blanket cooling air (low flow) <p>In addition, 28 interlocks produce "alarm only."</p>

TABLE I. B. REACTOR PROTECTION SYSTEMS (contd)

EBR-II	<p>Safety trip provisions: a single period trip causes scram at any power level; a single high-level trip causes scram at levels up to about 50% power; 2 high-level trips (out of 4) cause scram in high power range.</p> <p>Scram (with alarm):</p> <ol style="list-style-type: none"> 1) Period too short 2) Power level, based on neutron flux level, too high 3) Loss of power to either main pump 4) Core inlet coolant flow rate too low 5) Blanket inlet coolant flow rate too low 6) Total reactor coolant flow rate, measured at reactor outlet, too low 7) Reactor tank cover unlocked 8) Coolant mean temp in reactor upper plenum too high 9) Coolant temp at selected reactor subassembly outlets too high 10) Coolant pressure in reactor upper plenum too high or too low 11) Temp differential between HX outlet Na and primary tank bulk Na too high 12) Primary tank bulk Na temp too high or too low 13) Primary tank bulk Na level too high or too low 14) Primary tank inert blanket gas pressure too high 15) Smoke in Reactor Plant
In addition, 106 other conditions will produce "Alarm Only."	
ZPR-III	<ol style="list-style-type: none"> 1) Scram Interlocks: <ol style="list-style-type: none"> a) Source leaves assembly b) Carriage retracts from closed position after having reached that position c) Airlock door opens or personnel counter indicates other than zero d) High power level (3 circuits) e) Short period (2 circuits) f) Low safety rod drive air pressure g) Air pressure becomes positive (gage) in assembly room h) Loss of high-voltage supply to period and power-level circuits (loss of line voltage also scrams these circuits) 2) Start Up Interlocks--reactor control console cannot be reset for startup under any of following conditions: <ol style="list-style-type: none"> a) Carriage is not fully retracted b) Personnel counter is not at zero or the airlock doors not closed c) Low safety rod drive air pressure d) Air pressure in assembly room is not negative (gage) e) All period and power level trip circuits not reset 3) Carriage Drive Interlocks--before carriage can be started: <ol style="list-style-type: none"> a) Loading platform must be out b) Control console must be reset c) Both neutron sources must be in reactor d) Neutron detection instrument must indicate neutrons are present

TABLE II. BACKUP SYSTEMS

Name	Secondary Shutdown	Coolant System Backup		Electrical Power System	
		Decay Heat Removal System	Loss of Coolant Protection	Primary Sources	Emergency Sources
FERMI ⁽¹⁾	None	Natural circulation. 3 independent circuits for each of primary and secondary coolant systems. ^(1.b)	1) Secondary containment 2) Siphon breakers 3) No drains in primary system 4) Reserve Na supply ^(1.b)	2 separate 120 kV transmission lines; 4800 V supply through 2, 600 kVA step down transformers. 4 separate 480 V distribution busses. ^(1.b)	Diesel gen. 250 kW @ 480 V. Battery power: 125 V with dc generator. One 6000 kVA transformer on standby ^(1.b)
Hallam ⁽²⁾	None	3 independent circuits--natural circulation or by pump. ^(2.a,c)	Na heat transfer piping within reactor cavity enclosed in guard piping. Outside cavity: steel-lined pipe tunnels and heat exchangers. ^(2.c)	Normal station transformer: 4160 V, 3 ϕ , 60 cycle. Reserve station (startup) transformer. ^(2.a)	500 kVA diesel-generator; battery power. ^(2.a)
SEFOR ⁽⁵⁾	None	Natural convection or an auxiliary coolant system.	1) Siphon breaker 2) Auxiliary system 3) Check valve 4) Turning off of pumps (low level trip) 5) Safety vessel in cup form around reactor vessel.	Local utility; 69 kV (3 ϕ) transmission line.	400 kW diesel-driven generator output for at least 8 hours. 3 battery systems.
FARET ⁽⁶⁾	None	Auxiliary coolant system designed to remove about 3 MW of heat by forced circulation; operating in parallel with main coolant system; primary loop coolant--Na; secondary loop coolant--NaK.	Outer reactor vessel wall designed to sustain Na load in event of failure of inner vessel wall. Void space in cavity is large compared to volume of Na above core in reactor vessel--in the unlikely event that both walls of vessel are violated simultaneously below core level, loss of coolant from core could occur. Reactor vessel and critical piping leading from cavity to process systems in vault will be of double-walled construction.	Single-circuit 13.8 kV pole lines originating from EBR-II area. Either line capable of supplying full FARET load upon failure of other.	1) Automatic transfer of 480 V motor control center to source of emergency power upon loss of normal utility power; one quick starting diesel generator set (cont. operation for 48 hr). 2) 120 V ac cont. power load center supplied by 3-machine, ac motor, dc motor generator set and 125 V, dc battery. 3) Battery powered, 125 V dc load center with motor-driven charger on battery sized to carry cont. 125 V dc load. 4) Portable battery-powered lighting units at all exits and occupied areas.

TABLE II. BACKUP SYSTEMS (contd)

EBR-I ⁽⁷⁾	None	<p>Gravity supply tank (2700 gal cap.) provides about 9 min of full coolant flow in event of primary pump failure. (2 min delayed shutdown assures most of tank cap. available for cooling). Throttling provides up to 8 hr of flow at sufficient rate to remove decay heat.</p> <p>A separate completely independent convection loop cooling system; heat is removed from loop coolant by means of a finned-tube NaK-to-air heat exchanger--although fan equipped, natural convection is sufficient for adequate heat removal.</p>	<p>All valves in coolant systems have welded double-bellows seals. Tandem arrangement of double-bellows means both must fail to cause coolant leak to atmosphere. All cells containing primary-system components are equipped with steel-lined floors with curbs sufficiently high to contain any leakage. If necessary (in case of leakage in primary-system components), the entire inventory of NaK may be rapidly drained into tanks located in lowest cells--except NaK in reactor and primary convection loops cannot be drained (guarantees reactor cooling will always be available for removal of decay heat). Reactor tank is double-walled and under little stress.</p>	<p>A diesel-driven 250 kW generator, which responds to power failure and assumes reactor building load within 30 sec; a much smaller unit provides power for emergency lighting. Both respond automatically to local utility power outage. Building also equipped with small battery-operated lighting units at strategic control and exit points.</p>	
EBR-II ⁽⁹⁾	None	<p>After shutdown: coolant flow is maintained through reactor by any one of: (a) Operation of one or both main pumps; (b) Operation of auxiliary pump; (c) Natural convection flow. Heat removal from Na leaving reactor can be accomplished by any of: (a) Heat can be transferred to secondary system; (b) Heat can be transferred to bulk Na in primary tank and then removed by "shutdown coolers."</p>	<p>The reactor and the entire primary coolant system, including HX, are contained in a large vessel (primary tank) and operate completely submerged in the coolant. Primary tank is double-walled, right circular cylinder. No external connections below the liquid Na level are permitted. The need for leak tightness of the primary coolant system piping is eliminated. Siphoning of primary tank is prevented by incorporation of surge tank in cold trap inlet line.</p>	<p>2 full capacity ties to NRTS 138 kV power loop. When in operation: the EBR-II 13.8 kV generator. (The 2400 V and 480 V auxiliary power requirements are furnished respectively through 13.8/2.4 kV and 13.8/0.48 kV full capacity auxiliary power transformers.</p>	<p>Automatic starting 480 V, 3ϕ, 60 cycle emergency diesel-generator set; arranged to operate only after sustained outage of the 3 primary sources (15 to 20 sec before full power is reached). Emergency lighting for entire facility is supplied from emergency 120 V bus of ac/dc distribution cubicle which is automatically transferred to station battery upon failure of normal ac supply. Station battery: 125 V with battery-charging motor-generator set included for trickle charging and equalizing charging of battery, and to relieve battery load during sustained emergency lighting service. During 15 to 20 sec outage battery power is available for primary coolant system auxiliary pump--for 30 min if necessary.</p>
ZPR-III ^(10, 11)	None				

TABLE III. CONTAINMENT OR CONFINEMENT SYSTEMS

Name	Type and Size	Design Basis		Containment Tests	
		Pressure, Temperature, Leakage Rates		During Construction	After Construction
FERMI ⁽¹⁾	Reactor Building: cylindrical vertical steel vessel with hemispherical top and semi-ellipsoidal bottom head; 72 ft diam, 120 ft high (51 ft below grade). (1.c) Reactor vessel: lower, 114 in. diam, dished elliptical 2 to 1 bottom head; upper, cyl., 174 in. diam with 115 in. diam rotating plug container extension atop it. (All stainless steel). (1.a)	Outer steel pressure vessel; steady state pos. internal pressure: 28 psig; steady state neg. int. pressure: 2 psig. Design temp: 460 °F. (1.c) Leakage rate: <500 scf/day. (1.d) Reactor vessel: steady-state pressure: 50 psig, and temp: 1000 °F. (1.a) Outer steel pressure vessel: designed to withstand an explosion equivalent to 1000 lb TNT. (1.g)		Reactor building penetrations--where practical welds were radiographed and checked for leakage with soapsuds solution. After leak rate tests, all remaining welds were radiographed, and either magnafluxed or dye penetrant checked. (1.c)	Another overload test and leak rate test similar to that during construction. (1.e)
Hallam ⁽²⁾	Steel reactor building (no containment feature); roof of steel decking; insulated; steel panel wall exterior (over steel frame). High bay area; 278 ft long, 80 ft wide, 75 ft high. Reactor vessel (Type 304 SS) of welded constr. (2.a)	Confinement: Reactor vessel: 30 psig below grid plate, 2 psig (reactor cavity, etc.); 700 °F below grid plate, 1050 °F above plate; allowable leakage rate: 3.4×10^{-3} cm ³ /sec (0.11 ft ³ /day--from reactor into building--calculated); reactor cavity: 1.37 ft ³ /day @ 6 in. H ₂ O @ 220 °F. (2.c) Reactor high bay area--design in-leakage rate: 3120 cfm @ -1/8 in. H ₂ O internal pressure. (2.a)			
SEFOR ⁽⁵⁾	First Containment Barrier (Nitrogen Cells and Refueling Cell): reactor cavity, reflector control drive cell, primary Na equipment cell, primary drain tank cell, and refueling cell above reactor. Second Containment Barrier: pressure vessel.	First Containment Barrier N ₂ Cell A Cell a. Pressure Design, max. psig 10 10 Design, min. in. H ₂ O -6 -6 Operation, in. H ₂ O $1/2 \pm 1/4$ $1 \pm 1/2$ or $-2 \pm 1^*$ *If and when the inside of the cell becomes alpha-contaminated. b. Temperature Design, max. °F 250 250 Normal operation, °F 120 120 c. Leakage rates--@ 10 psig <20% of contained volume over 24 hr period. (Concrete walls are sealed with a lining to minimize gas leakage from cells and prevent moisture seepage). Second Containment Barrier a. Pressure Design, internal: 30 psig Design, external: 1 psig (coincident with dead load only) b. Temperature Design rise: 250 °F (coincident with design internal pressure) Design max.: 370 °F. c. Leakage rates--2.5% of contained volume @ 30 psig over a 24 hr period.		Second C/B: all welds and seams radiographically examined; all welds and door gaskets soap-bubble tested for leaks.	First C/B: Pneumatically tested; integrated leak test. Final leakage tests on both barriers and periodic tests thereafter. Means are to be provided for introducing compressed air into each access lock and electrical penetration to test same for leak-tightness.

TABLE III. CONTAINMENT OR CONFINEMENT SYSTEMS (contd)

FARET(6)	Reactor building (not a containment vessel) is conventional structure fabricated of masonry wainscot, prefabricated metal siding and built-up roof. (Provides containment of activated gases released from reactor confinement structure). Confinement: a) cell; b) cavity; c) vault.	Confinement structures only: 1) pressure-- internal static pressure of 30 psig with overload factor of about 100%--60 psig max.; 2) Temperature--not given; 3) Leakage rates-- 5%/day @ 1 psi differential pressure and 70 °F (max. rate). An equivalent explosion of 40 lb TNT (bare charge) at the core would be confined.	
EBR-I(7)	Facility located entirely within single ordinary building of steel, concrete, and brick. Building has maximum height of 50 ft and lowest accessible floor lies approximately 25 ft below grade. Main body of building covers area 922 x 77 ft. Building not designed with any containment features. Reactor Tank Assembly: a 7-sided polygon in shape; tank and all piping leading from it through the shielding are double-walled. Portion of tank containing core and inner blanket is 28 in. in length and 15.87 in. in ID. Wall of lower portion of inner reactor loop is 5/16 in. thick; outer Inconel tank with wall thickness of 1/16 in. serves as emergency receiver for primary coolant in event of failure of inner tank.		
EBR-II(9)	Primary Containment System: Cylindrically shaped "pressure vessel" which surrounds primary tank. Building Containment System: Steel "building shell" enclosing entire Reactor Plant.	Primary Containment System: 75 psig; capable of withstanding (without rupturing) a 300 lb TNT equivalent energy release in the core. Building Containment System: 24 psig; 650 °F; 1000 ft ³ /day @ 20 psig internal pressure.	Radiographic examination of 10% of weld length was made, including all weld intersections. Stress relieving of shell as a whole was not contemplated. Shell was pneumatically pressure tested at 30 psig.
ZPR-III(10, 11)	High bay assembly room of reinforced concrete/one-story section containing control room, vault, etc., of concrete block exterior; vault has reinforced concrete walls and ceiling. Whole building has concrete slab floor. Dimensions of assembly room: 45-1/2 ft long, 42 ft wide, 29-1/2 ft high (75,000 ft ³); vault room: 29 ft long, 26 ft wide, 11-1/2 ft high.	Pressure: In a nuclear excursion building could be ruptured.	

TABLE III. CONTAINMENT OR CONFINEMENT SYSTEM (contd)

<u>Name</u>	<u>Shielding</u>
FERMI	(1) Primary Shield: uranium blanket, SS thermal shield, rotating plug (biological shield) and graphite shield; (2) Secondary Shield; (3) Biological Shields: operating floor shield, biological shield outside reactor building; (4) Special Purpose Shields: primary coolant piping shields, etc.; (5) Shields for Service Buildings.(1. c)
Hallam	Reactor vessel surrounded by thermal shield--2 concentric, carbon-steel cylinders. Reactor outer vessel is carbon-steel tank. Reinforced-concrete loading face shield; welded, steel-plate (1/2 in. thick) cavity liner surrounded by concrete biological shield. Shielding for accessible high bay areas designed to limit radiation to 0.75 mr/hr (plugs in place) with 7.5 mr/hr max. in plug clearance void areas.(2. a)
SEFOR	(1) Primary (Radial)--12 ft OD cylinder enclosing reactor vessel and radial reflector--material includes boron carbide and serpentine (16 wt% H ₂ O of hydration in serpentine for moderation and absorption). An additional 2 in. B ₄ C layer in steel containers surrounds the reflector. Additional serpentine layers: 6 in. and 20.5 in. thicknesses separated by nitrogen coolant gaps (3). (2) Bottom Shield Plug--combined neutron shield and thermal column in form of cylindrical container filled with serpentine and B ₄ C (instrumentation plug--flux reading); biological shield (lower section) consists of concrete and steel (gamma shield). (3) Shielding between cells containing radioactive Na and accessible areas is 4 to 6.5 ft of regular concrete (or equivalent high-density concrete or steel). (4) Radiation Levels: a. <0.75 mr/hr in all areas of unrestricted access during reactor operation; b. <2.5 mr/hr on operating floor; c. <10 mr/hr in areas of restricted access below operating floor; d. <100 mr/hr in areas of limited access 2 days after reactor shutdown; e. ²⁴ Na activity during 20 MW _t operation: 0.1 curies/cm ³ . Highest possible surface flux of a volume containing Na of this activity is 3.46 x 10 ¹¹ MeV/cm ² -sec. 6.5 ft of regular concrete is sufficient to drop flux level to 8.39 x 10 ² MeV/cm ² -sec or 1.5 mr/hr (shielding for Na pipes and tanks).
FARET	Reactor vessel to be surrounded by borated-graphite neutron shield. All other shielding details of containment structures not detailed.
EBR-I	Located immediately outside the heavy Pb outer blanket is an annular layer of graphite, 18 in. thick and 35 in. high. On the outside of the graphite is a 4-in. cast iron course followed by 8-3/4 ft of standard concrete. The bottom of the cup is shielded by 4-1/2 ft of steel. The coolant and rod extensions absorb most upward emitted radiations. Two shields atop the reactor further attenuate these radiations; lower shield consists of 2 ft of scrap-filled concrete; upper shield consists of 8 in. of iron and masonite laminae. (Both are easily handled by a 20-ton overhead crane).
EBR-II	Neutron Shield: Surrounds the outside of the reactor vessel on all sides and is submerged in bulk Na of primary tank. Shielding material is graphite and graphite impregnated with 3 wt% natural B and is canned in SS. Shield is composed of 3 sections: (1) Total graphite thickness of radial neutron shield is 24-3/4 in. of which 8-1/4 in. is borated and 16-1/2 in. is plain graphite; (2) Bottom shield consists of 5 layers (alternate borated and plain graphite) which is 20-5/8 in. thick, of which 12-3/8 in. is plain and 8-1/4 in. is borated graphite; (3) Top shield contains 6 layers of cans filled with either 3% borated graphite or boron carbide with total thickness 24-3/4 in. Biological Shield: In combination with the primary structure this forms a "pressure vessel" surrounding primary tank; constructed of ordinary concrete 6 ft thick, reinforced with continuous hoops of rods. Missile Protection: For protection against missiles, which conceivably could originate within the top closure, a missile shield (14 in. thick) of reinforced concrete lines the cylindrical section of building shell from operating floor up, and false ceiling (missile shield) of same construction joins the former and completes enclosure. (Also, a 14 in. thick wall of reinforced concrete or equivalent steel plate thickness is provided for missile protection at personnel air lock opening and freight door opening).
ZPR-III	(1) Assembly room: Reinforced concrete; shielding wall between assembly room and control room is 5 ft thick up to 12 ft above floor and 3 ft thick the remainder of distance to roof. North wall is 2 ft thick, west and south walls 1 ft thick. Partial wall between assembly room and passageway and ventilation equipment mezzanine is 4 ft thick up to 12 ft high and 2 ft thick remainder of distance to roof. Roof has 6 in. of concrete poured atop corrugated steel deck. (2) Vault: Walls and roof of 9 in. thick reinforced concrete. (3) Reactor: Personnel shield arranged and available if tests in first stages of operation prove it necessary.

TABLE IV. INHERENT REACTIVITY EFFECTS AND IMPORTANT PHYSICS PARAMETERS

Name	Temperature Coefficients		Coolant/Moderator Void Coefficient	Doppler Effect	Kinetics Parameters	
	Fuel	Moderator			Neutron Lifetime (l)	Delayed Neutron Fraction (β), Δk/k
FERMI(1)	-6.16 x 10 ⁻⁶ Δk/k-°C(1. a)			-2.59 to -2.47 x 10 ⁻⁶ Δk/k-°C(1. a)	1.4 x 10 ⁻⁷ sec(1. a)	Effective: 0.0066(1. a)
Hallam(2)	-1.85 x 10 ⁻⁵ /°F(2. f)	1.55 x 10 ⁻⁵ /°F(2. f)		1.5 x 10 ⁻⁴ /°C (0.83 x 10 ⁻⁴ /°F)(2. f)	2.8 x 10 ⁻⁴ sec(2. c)	0.0069(2. c)
SEFOR(5)	Total: -4.8 x 10 ⁻⁶ Δk/k-°C			-0.0083 (temp. coeff.): Isothermal: @ 1295°K (20 MW _t) -6.4 x 10 ⁻⁶ Δk/k-°C; @450°K (zero power): -18.0 x 10 ⁻⁶ Δk/k-°C.	0.36 x 10 ⁻⁶ sec	Effective: 0.0033
FARET(6)	RZC (expansion whole reactor core): -3.21 x 10 ⁻⁶ Δk/ΔT-°C; RSC (expansion): a) Core: -4.13 x 10 ⁻⁶ *b) Region I: -0.97 x 10 ⁻⁶ Δk/ΔT-°C; *c) Region II: -3.16 x 10 ⁻⁶ Δk/ΔT-°C. *Radii: Region I (0-10 cm); Region II (10-18.796 cm); entire core equivalent diam 152.4 cm.			RZC @ 750 °F (Driver, Buffer, and Test Zones): -2.72 x 10 ⁻⁶ Δk/ΔT-°C; RSC @ 750 °F: a) Core: -0.33 x 10 ⁻⁶ Δk/ΔT-°C; *b) Region I: -0.05 x 10 ⁻⁶ Δk/ΔT-°C; *c) Region II: -0.28 x 10 ⁻⁶ Δk/ΔT-°C.	Prompt : a) RZC: 8.90 x 10 ⁻⁷ sec; b) RSC: 6.55 x 10 ⁻⁷ sec.	
EBR-I(7)	>-3.01 x 10 ⁻⁶ Δk/k-°C			<0.5 x 10 ⁻⁶ Δk/k-°C	Prompt: 4. x 10 ⁻⁸ sec	0.00296
EBR-II(9)	-3.6 x 10 ⁻⁵ Δk/k-°C			(Avg): 0.04 x 10 ⁻⁵ Δk/k-°C	Prompt: 8 x 10 ⁻⁸ sec	
ZPR-III(10, 11)				Maximum: 5 x 10 ⁻⁶ Δk/°C at room temp. (Pu-C fuel); integrated Doppler effect from room temp. to vaporization would amount to 0.0026 to 0.004 Δk. +50. x 10 ⁻⁶ /°K (U fuel).	≈10 ⁻⁹ sec	a. ²³⁹ Pu loadings: .0022; b. ²³⁵ U loadings: .0069

TABLE V. FUEL AND FUEL HANDLING

Name	Type of Fuel	Quantity and Size of Fuel Elements	Charge and Discharge Methods
FERMI ⁽¹⁾	1) Core Region: U-10 wt% Mo; 0.35 wt% ²³⁵ U; 2) Axial Blanket Region: U-3 wt% Mo; 0.35 wt% ²³⁵ U; 3) Radial Blanket Region: U-3 wt% Mo; 0.35 wt% ²³⁵ U. (1. a)	1) Core Section: 140 pins per subassembly with 105 subassemblies; round pin, U diam 0.148 in., U length, 30.5 in.; 2) Axial Blanket Section: 32 round rods per subassembly with 210 subassemblies; U diam, 0.395 in., U length, 14 in.; 3) Inner and Outer Radial Blanket Section: 25 round rods per subassembly with 531 subassemblies; U diam, 0.395 in., U length, 61.75 in.; subassembly dimensions for all sections: cross section-square; outside dimension, 2.646 in.; wall thickness, 0.096 in. (1. a)	New fuel is transferred from storage by means of transfer cask car. From cask car, subassemblies are deposited in transfer rotor of the reactor vessel through an exit port. Exchange of subassemblies between transfer rotor and reactor is accomplished by use of the rotating shield plug and offset handling mechanism. Removal of spent subassemblies from reactor is this procedure in reverse. (1. c)
Hallam ⁽²⁾	U-10 wt% Mo alloy; 3.6 wt% ²³⁵ U. (2. a)	137 elements (18 rod cluster); 224 kg (U-Mo)/element and 30,700 kg U-Mo alloy (total) of which 27,600 kg is U. Size of rods: 0.590 in. diam, 3 to 12 in. long in Type 304 SS tube. Total active fuel length: 13.5 ft. Tube: 0.660 in. OD x 0.010 in. wall thickness x 18 ft long. (2. a)	Fuel handling machine consists of a shielded cylinder with two internal hoists and grapple mechanisms to raise and lower core components. Machine supported and transported by trolley which rides on a gantry crane. Maximum speed of trolley: 80 ft/min. Cooling system provided for fuel element in machine. Television cameras employed. (2. a)
SEFOR ⁽⁵⁾	Pelletized, mixed PuO ₂ -UO ₂ (17% PuO ₂ ; 83% natural UO ₂)	763 rods (includes BeO and dummy); 7 rods/assembly which implies 109 channels; approx. 654 fuel rods. Active core height: 33.8 in.; 1 in. diam, stainless steel (SS) clad; channel material--Type 316 SS.	Refueling cell facility (concrete and steel) situated over reactor vessel--part of containment barrier. An in-cell bridge crane provides the primary means of transporting objects about the refueling cell. Crane: 5-ton capacity drum hoist on double-bridge-mounted trolley. (Entire vessel head is raised). All manipulations of crane are made by remote control (windows, etc.).
FARET ⁽⁶⁾	(hexagonal subassemblies); RZC: a) Test Zone: (Pu-U)O ₂ ; ²³⁹ Pu enrich., 12.5%; ²³⁸ U (276 kg); ²³⁹ Pu (39 kg); b) Buffer Zone: depleted UO ₂ ; ²³⁵ U enrich., ~0.4%; ²³⁵ U (3 kg); ²³⁸ U (763 kg); c) Driver Zone: enriched uranium-fission alloy; ²³⁵ U enrich., 67%; ²³⁵ U (462 kg); ²³⁸ U (233 kg); RSC: (Pu-U)C; ²³⁹ Pu enrich., 34%; ²³⁸ U (142 kg); ²³⁹ Pu (73 kg)	RZC: a) Test Zone: 7 elements/subassembly; rod length: 91.4 cm; fuel OD: 1.331 cm; tube OD: 1.509 cm; tube wall thickness: 0.084 cm; b) Buffer Zone: 37 elements/subassembly; rod length: 91.4 cm; fuel OD: 0.576 cm; tube OD: 0.688 cm; tube wall thickness: 0.030 cm; c) Driver Zone: 61 elements/subassembly; rod length: 91.4 cm; fuel OD: 0.450 cm; tube OD: 0.561 cm; tube wall thickness: 0.030 cm. Total Number of Subassemblies: 161 total in core: Test-37; Buffer-82; and Driver-42. RSC: 61 elements/subassembly, 37 total in core; fuel pin length: 37.6 cm; fuel OD: 0.500 cm; tube, OD: 0.579 cm; tube wall thickness: 0.038 cm.	Remote-controlled operations. All core subassemblies will enter or leave containment structure through access hatch in ceiling of fuel transfer area. New fuel subassemblies in separate disposal containers will be lowered through access hatch into container-carriage assembly. Assembly will traverse tunnel leading to fuel transfer port in floor of cell. Removal of subassembly from container, and subsequent transfers within cell, will be effected by a fuel-handling machine or manipulator.

TABLE V. FUEL AND FUEL HANDLING (contd)

EBR-I ⁽⁷⁾	wt% Pu, 98.59%; Al, 1.25% and impurities, 0.16%	60 rods per subassembly with 7 subassemblies in core; Zircaloy-2 jacket OD, 0.299 in.; jacket ID, 0.257 in.; 3 equispaced Zircaloy-3 ribs (each 0.049 in. in height) run longitudinally along active portion of rod; fuel slug diam, 0.232 in. (37.9 kg Pu-max. load); subassemblies are hexagonal; of 2.875 in. width and 108 15/16 in. length. Fuel portion of rods consists of 4 Pu-Al alloy slugs, each 2.121 in. long, giving total core height of 8.484 in.	Fuel and blanket rods are transferred directly from opened reactor to a 10-ton Pb coffin which is held in place over reactor top with building crane. A fuel rod is pulled upward into the coffin through a trapdoor arrangement at bottom. Trapdoor is shut and coffin moved to wash-pit area. Access to top of opened reactor is made possible by effective shielding of the coolant, rod extensions, and upper support structure. Inleakage of air is prevented by continuous flow of argon from upper tank region.
EBR-II ⁽⁹⁾	(Initial loading); Fuel Alloy Comp. (fissium): 95.0 wt% U, 2.5 wt% Mo, 1.5 wt% Ru, 0.5 wt% Pd, 0.3 wt% Rh, 0.2 wt% Zr; Fuel Alloy (enriched U-fissium): 49% ²³⁵ U enrichment. (Subsequent loadings were to be Pu-U alloys).	47 hexagonal subassemblies in core; 91 fuel elements/subassembly. Fuel elements (Pin-Type, Na-bonded); pin diam: 0.144 in.; pin length: 14.22 in.; fuel tube (SS) OD: 0.174 in.; fuel tube wall thickness: 0.009 in. Total core loading is 363 kg of fuel alloy.	"Fuel handling" includes: removing subassembly from reactor, transferring it to the storage rack, and after a 15-day cooling period, removing it to the disassembly cell. System consists of reactor gripper, mechanism, hold-down mechanism, transfer arm, storage rack and disassembly cell gripper mechanism. Reactor gripper mechanism and holddown mechanism are located in the small rotating plug which is in turn eccentrically located in the large rotating plug. Rotation of the two plugs is employed to position the gripper over the desired location in the reactor, and to position the gripper at "transfer position." The reactor cover is also supported by the small plug, rotates with it, with the gripper mechanism and holddown mechanism operating through the cover. (Excellent detailed description given of entire operation in Ref. 9).
ZPR-III ^(10, 11)	1) Pu-plates alloyed with Al; 4.5% ²⁴⁰ Pu; 0.5% ²⁴¹ Pu; 0.04% ²⁴² Pu; $\approx$ 95% ²³⁹ Pu. 2) ²³⁵ U, depleted uranium	1) Pu-Al; core sizes: 0.085 x 1.765 in.; lengths: 0.925, 1.925, 2.925 in. Core plates are inclosed in a jacket of 0.012 in. Type 304-L SS; closed by end plugs of same material welded in place. Maximum of $\approx$ 230 kg Pu in core. 2) ²³⁵ U, depleted U: drawers placed in array of square tubes, 2 in. sq., 33 in. long, and 0.040 in. wall thickness. Drawers in core are 15 in. long loaded with slugs 2 in. x 1/8 in.; 1/2 in., 1 in., 2 in., and 3 in. long (²³⁵ U and depleted U); 17 in. drawers in end blanket section loaded with slugs 1 in. x 1 in.; 2 in., 3 in., and 5 in long (depleted U). A combination of above drawer sizes and slugs are used in intermediate blanket section (depleted U only). (SS and Al slugs are also in drawers).	Drawers loaded in separate work room, brought into assembly room on a special cart (carrying $\leq$ 2 drawers) and placed in position in reactor.* Crane service in assembly room itself is furnished by a 5-ton capacity bridge crane having a vertical lift of 24 ft; controlled by pendant push buttons and has 5 operating speeds. A 5-ton capacity monorail hoist with motor driven trolley operates between loading platform through freight door across passageway and into assembly room; has 13 ft lift and variable speed control. *Entire procedure done by men in contact with or near drawers, from vault to loading or vice versa.

TABLE V. FUEL AND FUEL HANDLING (contd)

Name	Fuel Storage
FERMI	New Fuel Handling and Storage Facilities are in NE corner of Fuel and Repair Bldg (100 ft N of Reactor Bldg). New fuel storage vault is comprised of a room containing 209 sleeves embedded in floor in a 19-row by 11-row array in a 14 in. sq. pattern. Top of each sleeve is covered and fits flush with floor. Storage tubes, into which new subassemblies are placed, are fitted into floor sleeves. Access area or upper compartment is approx. 17 ft wide by 25 ft long by 18 ft high. Walls are 10 in. thick reinforced concrete. Lower compartment is approx. 16 ft wide by 24 ft long by 13 ft high. Walls of variable thickness of reinforced concrete. Decay pool contains permanent storage rack consisting of single tier with spaces for 344 spent subassemblies on a spacing of 14 in. 513 additional (temporary) storage spaces can be made available for entire core unloading. (1. c)
Hallam	Storage cells consist of 40.5 ft long thimbles, provided with plugs and cover plates, suspended into 3 vaults below reactor room floor. Vault I: 111 thimbles (dry); Vault II: 187 thimbles (filled with water as required; Vault III: 85 thimbles (filled with water for cooling--new and spent fuel only). (2. a)
SEFOR	1) Spent: Na-filled rectangular tank in refueling cell. Stores 1-1/2 core loads and 6 instrumented fuel assemblies in Na coolant. 2) New: New fuel hanging racks in storage vault (in-cell). See PSSR, Part II, pp. 5-46.
FARET	New fuel subassemblies will be stored in thimbles embedded in concrete floor of rear cell area. Irradiated fuel will be stored in wet fuel storage tank located near pressure vessel. Tank will be of double-walled construction and filled with Na. (Heat removal provided for tank). Both storage facilities to be designed to prevent accidental loading to criticality.
EBR-I	Prior to storage or inspection, rods are lowered from coffin through access holes in ceiling of wash room, where they are rinsed in successive baths of alcohol, water and acetone. The fuel rods are stored in a rod form which consists of pipe thimbles embedded in a concrete shield, the top of which is at an elevation corresponding to main floor of bldg. No special provisions have been made for cooling (1 MW-full power). Natural circulation and radiation to shielding are sufficient to remove decay heat.
EBR-II	Storage rack is a tank-shaped structure providing 70 storage locations in 3 concentric rows. The rack is suspended by a shaft extending through the disassembly cell, with its drive mechanism mounted on the ceiling of the cell. The rack can be rotated as well as raised to different levels in the primary tank. An empty storage location is positioned below the subassembly, which is suspended from the transfer arm, by rotation of the storage rack. By elevating the storage rack, the subassembly is inserted into a storage location and at the end of upward movement, it is lifted from holding device upon release of transfer arm locking bar. To assure proper vertical movement of rack, a transfer-indicating device is used: a sensing rod extending vertically from disassembly cell ceiling directly to the transfer position.
ZPR-III	Fuel slugs stored in vault on racks in special "birdcage" type containers which limit storage density to 2 kg of ^{235}U /ft ³ .

TABLE VI. ACCIDENTS CONSIDERED AND CHEMICAL PROBLEMS

Name	Maximum Credible Accident (Design Basis)	Accidents Analyzed	Operating Experience		Chemical Reactions Considered
			Accidents	Equipment Failures	
FERMI ^(1,8)	Melting of some or all of the fuel in one core subassembly, due to either complete or partial plugging of the nozzle of that subassembly, or to a flow restriction within the subassembly due to radiation damage which resulted because the subassembly in question was left in the reactor too long as the result of an administrative error. (No in-plant or public hazard). ^(1.g)	Credible Accidents - Not Resulting in Fuel Failure: Primary Na system leaks; loss of plant electric power except battery power; dropping of core subassembly during reloading; secondary Na system leak; feedwater pipe rupture; steam generator failure; control maloperation. - Involving Fuel Mismanagement: Outer and inner subassembly handling error; reirradiation of a core subassembly. - Due to Subassembly Plugging and Swelling: Partial blockage of flow; full and sudden blockage of flow. Hypothetical Accidents: Flow failure without scram, but with pony motor operation; and without pony operation; loss of coolant from primary system; hypothetical meltdown design accident. ^(1.g)	5 Oct 66: An undetermined number of fuel elements melted upon start-up to full power. ⁽⁸⁾		Tests conducted: Na-H ₂ O reaction in Na shell side of steam generator to determine size of pressure relief diaphragm needed; Na and air burning reaction to determine design temperature and pressure for reactor building. ^(1.e)
Hallam ⁽²⁻⁴⁾	Dropping of one slug (or its equivalent in smaller pieces) from fuel handling machine. Calculated dose rates (1 hr) at site boundary are: Direct radiation, 6.8 mr; Iodine, 8 x 10 ⁻² mrad; and noble gases, 4 x 10 ⁻⁵ mr. ^(2.c,d)	Meltdown of one element; core meltdown; fuel rupture in wash cell; fuel handling incidents (includes MCA); pressurization of inert atmosphere; Na spill (small; large spill following core meltdown); radioactive Na fire (small, large); steam generator leak; control rod thimble leak; gas leakage through loading face shield (1% failed fuel rods, core meltdown); gas leakage from primary pump; loss of reactor heat sink. ^(2.c,d)	During shutdown-Na fire in auxiliary bay of reactor building (12-62); carbon trap cell fire. ⁽³⁾	(9-64); Na in-leakage to 7 SS-clad graphite moderator cans. ⁽⁴⁾	Oxygen and hydrogen present in Na as impurities would be absorbed by the Zircaloy-2; energy released is insignificant. Carbon present in Na will cause only slight carburization of stainless steel at 950 °F. Moderator can failure--Na invades porous graphite causing intracrystalline physical expansion of about 2%. No significant amounts of energy released. Na fire in IHX cell. ^(2.c)
SEFOR ⁽⁵⁾	(Maximum Hypothetical Accidents): 1) Rapid melting of core resulting from insertion of reactivity by Fast Reactivity Excursion Device, and loss of coolant flow; followed by compaction of core into supercritical mass; 2) Rapid insertion of reactivity in excess of a dollar by FRED when core is already well above design maximum temperature.	1) Excessive reactivity addition with reflector segments (rods) 2) Reactivity addition with coolant system (cold Na "accident") 3) Reactivity additions during refueling 4) Moderator addition to core 5) Fuel rod bowing 6) FRED malfunctions 7) Reactivity insertions with oscillator rod 8) Loss of coolant pumping power 9) Loss of pumping power coincident with planned prompt excursion 10) Local loss of coolant flow 11) Mechanical failures in Na coolant system 12) Reactor vessel failure 13) Loss of N ₂ cooling system 14) Loss of argon cooling system 15) Ventilation system malfunction (none) 16) Loss of instrument and breathing air systems			(Cases considered): 1) Na-air reaction at a time when O ₂ -depleted air (5 vol% O ₂) blankets the cells within First C/B and normal atmospheric air blankets the operating space in the region between the First and Second Barriers. Result: 24 psig (peak) within Second C/B. 2) Same as 1) with additional reaction of Na with Freon from the three N ₂ cell coolers. Result: ≈ 29 psig (peak) within Second C/B. 3) Na-air reaction at a time when normal atmospheric air blankets the entire volume within the Second C/B, including the region within First C/B. Result: ≈ 31 psig (peak) within Second C/B. (All peaks occur within 0.1 hr after reactions commence). (Na-SS reaction not considered).

TABLE VI. ACCIDENTS CONSIDERED AND CHEMICAL PROBLEMS (contd)

FARET ⁽⁶⁾	<p>May be either partial loss of coolant or coolant flowrate which results in the gravitational collapse of a molten core, or the dropping of fuel subassembly.</p> <p>Either event could, though not necessarily, lead to nuclear accidents involving a high explosive energy equivalent of 25 to 30 lb of TNT.</p>	<p>Fuel Handling and Storage Accidents:</p> <ol style="list-style-type: none">1) Reactor vessel cover removal2) Loss of power during fuel handling operations3) Jamming of a spent fuel subassembly4) Dropping of a fuel subassembly5) Criticality of wet fuel storage tank <p>Failure of Primary and Secondary Coolant Systems; Core Meltdown Studies; Release of Fission Products to Atmosphere</p>	<ol style="list-style-type: none">1. $\text{Na} + \text{H}_2\text{O} \rightarrow \text{NaOH} + \frac{1}{2} \text{H}_2 + \text{Q}$ (34 kcal);2. $2\text{Na} + \frac{1}{2} \text{O}_2 \rightarrow \text{Na}_2\text{O} + 104 \text{ kcal.}$ <p>Cell atmosphere is normally low-moisture, inert gas with <5% O₂ content. But normal air may be present in cell from time to time, which with a violent ejection of Na into cell would cause Na fire. Postulated peak pressure in cell after Na-air reaction: 20 psig. Theoretical: 97 psig.</p>	
EBR-I ⁽⁷⁾	<p>A ramp insertion rate of 20% Δk/k-sec with Doppler effect included; corresponds to a burst of approximately 9×10^{17} fissions. Entire plutonium core melts and 8 kg Pu vaporizes. Core boundary will accelerate to a maximum velocity of approximately 220 ft/sec. Reactor tank system may rupture. NaK and Pu fires are probable, including general contamination of reactor building. Total energy release: 27.7 MW-sec.</p>	<ol style="list-style-type: none">1) NaK leakage and fire2) Steam-generator failure3) Coolant pump failure4) Failure of shutdown cooling system5) Reactor tank failure6) Failure of cell ventilation7) Failure of outer blanket cooling8) Hydraulic system failure (platform elevator carrying outer blanket and control safety rod drives)9) Outer blanket failure (uranium blanket--not lead blanket used with Mark IV loading)10) Fuel slumping11) Fuel element cladding failure12) Loading errors	<p>Nov 55: Partial meltdown of core during a transient experiment carried out without main coolant flow; caused by mechanical design of Mark I and II fuel rods and core structural, rod bearing points.</p>	<ol style="list-style-type: none">1) NaK leakage in either the primary or secondary coolant system when operating at high temperature will likely result in fire. Smoke-detection system will sound alarm.2) Under steam-generator failure, Na-water or Na-steam reaction may result in moderate explosion of design "blow-out" panels. In case of over-design pressure in secondary system, a rupture diaphragm allows discharge of NaK to a point outside building.3) NaK leakage in reactor tank could result in major fire in elevator room with ²⁴Na being passed through stack to atmosphere.
EBR-II ^(9, 3)	<p>No one accident is termed "the" maximum accident. However, the design basis accident is an energy release equivalent to 300 lb TNT within the core, although it is stated that the primary containment system could probably contain a release considerably greater. This energy is considered to have originated with partial core meltdown and gravity drop of fuel into a more reactive configuration.</p>	<ol style="list-style-type: none">1) Six cases are considered where the reactor is at delayed critical, and either at zero or operating power, when either the control fuel subassembly is loaded or falls at various rates, the two safety rods are driven in, in an uncontrolled manner, or a single control rod is driven in, in an uncontrolled manner.2) Loss of all pumping power under three different conditions.3) Hypothetic containment rupture.4) Bowing of fuel elements.	<p>Two of eleven control rods failing to scram; cause: failure of lower linear ball bushing in oscillator drive shaft housing (40 of original 105 balls recovered--others remain in primary tank). Reason: Carbon steel model bushing was unknowingly substituted for specified SS model during reactor construction.⁽³⁾</p>	<p>Na exposure to atmosphere:</p> <ol style="list-style-type: none">1) Stagnant pool--results in only small pressure increase within secondary containment shell;2) Pressurized spray--results in 38 psig peak pressure within reactor shell;3) Explosive ejection exposure--could result only from a serious nuclear excursion. Only under the most severe conditions would a peak pressure approaching 75 psig result--highly improbable. <p>Na exposure to water: Water or other highly reactive material will not be permitted within reactor building in sufficient quantity to constitute a potential hazard.</p>
ZPR-III ^(10, 11)	<p>Fire in which large part of Pu inventory was oxidized, damage to sealing of building occurred, and Pu in quantity of about 200 g was released from building.</p>	<ol style="list-style-type: none">1) Action by personnel in assembly room2) Action by personnel in control room3) Natural catastrophes4) Loss of control of fissionable materials5) Possible autocatalytic characteristics6) Sabotage7) Collapse of matrix8) Failure of nuclear instrumentation9) Startup accident resulting from mechanical failures.		

TABLE VII. A. SITE

Name	Exclusion Area Radius	Distance to Population Centers	Doses at Exclusion Area Radius and Low Population Zone Boundary Accident Conditions
FERMI ⁽¹⁾	(minimum): 3280 ft ^(1.f)	Monroe (23,000), Mich., 8 mi SW. 30 mi from Detroit and 25 mi from Toledo (down- town areas), Stony Pt. (915), 1.5 mi SSW ^(1.f)	(Max. Hypothetical Accident-Core Meltdown): (1 yr doses); EAR:I dose to thyroid:163 rem; γ dose from MHA plume:2.0 rem; direct γ dose from Reactor Bldg.: 5.6 rem; Sr-90 dose to bones: 5.7 rem; LPZB: 6 mi- no dose rates given. ^(1.g)
Hallam ⁽²⁾	Site boundary: 1/4 mi ^(2.b)	Nearest population center (264), 1 1/2 mi S from site. Nearest small town (3546), 10 mi to NW. Largest cities in area are 19 mi N (129,000) and 19 mi S (12,000). ^(2.b)	(MCA-dropping fuel element); under most unfavorable weather conditions (@site boundary): 4.1×10^{-5} mr (noble gases), 7.8×10^{-5} rads (Iodine); direct radiation to site boundary:6.8 mr. (All doses during first hour). (33% core meltdown): TID @ site boundary: 820 mr (1% per 24 hr). (Primary Na fire): TID @ site boundary: Cloud Dose: 63 mr; Ground Deposition: negligible; Direct Radiation: 16 R; Max. Ground Deposition (1.75 mi): 2.2 R. Various TID's at site boundary and in reactor building have been calculated for radioactive cover gas release. ^(2.c)
SEFOR ⁽⁵⁾	0.4 mi	1) Nearest village: (pop. <30), 2 mi due west. 2) Nearest cities: Fayetteville, (pop. 20,000), 16 mi NNE; Fort Smith (pop. 53,000), 29 mi SSW.	EAR:0.042 rem (total); LPZB: 0.00096 rem (total); whole body doses.

TABLE VII. A. SITE (contd)

<u>NAME</u>	<u>Exclusion Area Radius</u>	<u>Distance to Population Areas</u>	<u>Doses at Exclusion Area Radius and Low Population Zone Boundary - Accident Conditions</u>
FARET ⁽⁶⁾	4000 ft; distance from EBR-II	30 mi due west of Idaho Falls, Idaho	<p>1) TID (inhalation) from stack release-inversion conditions and total cell leakage fraction ($L_t = 1.0$): EAR: 0 rem (thyroid); 0 rem (bone); 0 μgm ^{239}Pu; 0 μgm ^{240}Pu; 0 μgm ^{241}Pu; LPZB (14.4 mi downwind): 72 rem (thyroid); 0.003 rem (bone); 3.0×10^{-5} μgm ^{239}Pu; 5.6×10^{-6} μgm ^{240}Pu; 1.9×10^{-6} μgm ^{241}Pu.</p> <p>2) TID (inhalation) at EAR (EBR-II) from stack release-neutral lapse conditions ($L_t = 1.0$): 28.8 rem (thyroid); 0.0012 rem (bone); 1.2×10^{-5} μgm ^{239}Pu; 2.2×10^{-6} μgm ^{240}Pu; 7.6×10^{-7} μgm ^{241}Pu.</p> <p>3) Whole-body gamma dose from fission product cloud ($L_t = 1.0$): EAR: 9.4 rad (neutral lapse cond's); LPZB (14.4 mi downwind): 23.6 rad (inversion cond's).</p> <p>4) TID (inhalation) at EAR from ground level activity release ($L_t = 0.04$): Inversion: 538 rem (thyroid); 43 rem (bone); 0.45 μgm ^{239}Pu; 0.082 μgm ^{240}Pu; 0.029 μgm ^{241}Pu. Neutral lapse: 1.2 rem (thyroid); 0.1 rem (bone); 1×10^{-3} μgm ^{239}Pu; 1.9×10^{-4} μgm ^{240}Pu; 6.6×10^{-5} μgm ^{241}Pu.</p>
EBR-I ⁽⁷⁾	Same as ZPR-III	Nearest residential areas: Arco (pop. 1600), 17 mi WNW and Atomic City (pop. 230), 12 mi SE	Total inhalation dose in fallout area (under stable-inversion conditions): at Highway 20 (2800 m): 155 μgm Pu; at Central Facilities (5600 m): 33 μgm Pu (highest quantities given). Ground contamination at Highway 20 and Central Facilities (stable conditions): at Highway 20: 5.6×10^4 μgm Pu/m ² ; at Central Facilities: 1.2×10^3 μgm Pu/m ² .

Name	Exclusion Area Radius	TABLE VII. A. SITE (contd) Distance to Population Centers	Doses at Exclusion Area Radius and Low Population Zone Boundary Accident Conditions
EBR-II ⁽⁹⁾	0.6 mi (site boundary)	Atomic City, 11 mi. With exception of Arco, and a few towns with populations of over 100, surrounding communities are more than 35 mi distant. All other sites at NRTS are more than 12 mi distant (with exception of TREAT).	Hypothetical container-rupturing disaster of 10^{20} fissions assumed after reactor had been operating at 60 MW for 135 days with no fuel element removal. It was arbitrarily assumed the core contained 125 kg of ^{239}Pu . EAR: (airborne fission product activity); fumigation conditions, ave. windspeed: 397 rep (β -dose); 6.20×10^3 R (γ -dose); (External hazard from activity deposited on ground; external $\beta + \gamma$ dose during first 3 hr after disaster): 1.0×10^6 rep under high windspeed and total instantaneous washout; (amount of radioisotope which could be accumulated in critical organ by inhalation under daytime conditions-those resulting in overdose): 3.44×10^2 μCi (^{131}I) to thyroid; 0.774 μCi ($^{106}\text{Ru} + ^{106}\text{Rh}$) to kidneys; 540 μCi (^{89}Sr) to bone; 9.05 μCi ($^{90}\text{Sr} + ^{90}\text{Y}$) to bone; 421 μCi ^{91}Y to bone; 217 μCi ($^{95}\text{Zr} + ^{95}\text{Nb}$) to bone; 574 μCi ^{95}Nb to bone; 839 μCi ($^{140}\text{Ba} + ^{140}\text{La}$) to bone; 48.7 μCi ^{140}La to bone; 96.3 μCi ($^{144}\text{Ce} + ^{144}\text{Pr}$) to bone; 236 μCi ^{143}Pr to bone; 1.98 μCi ^{239}Pu (soluble) to bone; 1.32 μCi ^{239}Pu (insoluble) to lungs. LPZB (assumed to be about 11 mi): (airborne fission product activity); fumigation conditions, ave. windspeed: 25 rep (β -dose), 386R (γ -dose); (External hazard from activity deposited on ground; external $\beta + \gamma$ dose during first 3 hr after disaster): 4.5×10^3 rep under high windspeed and total instantaneous washout; (amount of radioisotope which could be accumulated in critical organ by inhalation under daytime conditions-overdoses): 2.74 μCi ^{131}I to thyroid; 4.30 μCi ^{89}Sr to bone; 3.36 μCi ^{91}Y to bone; 6.69 μCi ($^{140}\text{Ba} + ^{140}\text{La}$) to bone.
ZPR-III ^(10,11)	2360 ft (adjacent to EBR-I @ NRTS).	Control Facilities, $3\frac{1}{2}$ mi due E; Atomic City, 12 mi SE; Arco, 18 mi NW	Long exposure: @ 5500 ft for turbulent conditions; <300R @ 10 mi for stable conditions.

TABLE VII. B. EXHAUST VENTILATION SYSTEM

<u>Name</u>	<u>Independent Systems</u>	<u>Filtering and Monitoring Arrangements</u>	<u>Stack</u>
FERMI	2: above reactor operating floor and below same. Supply and exhaust fans in Ventilation Bldg. provide 150 to 200 cfm of fresh air to above floor region of Reactor Bldg. Lower region: 95% N ₂ , 5% O ₂ . (30,000 cfm flow). (1.c)	Absolute filter used in N ₂ supply system. (1.c) Monitors: On 6 in. exhaust pipe from Reactor Building, watertight γ scintillation detector (10^{-6} to 10^{-1} μ Ci/cm ³); on 3 in. exhaust pipe from machinery dome, γ - scintillation detector; in lower reactor building ventilation ducts: 2 GM counters (10^{-2} to 10^3 mr/hr). (1.d)	200 ft high, made of 1/4 in. plate steel; ID of 6 ft for lower 15 ft and 3 ft for remainder of height. (1.c)
Hallam	3: I. Reactor Area; II. Service Area; III. Control and Steam Generator Area. (2.a)	Reactor Area (-1/8 in. H ₂ O throughout): 3 filter banks (2 in operation). Each bank contains 36 roughing filters, 36 pre-filters, and 36 final filters. Dry scrubber included for hot exhaust during fire. Service area inlet air filters similar to those in Reactor Area. Control and Steam Generator Area-conventional air conditioning system in Control Area (slightly above atmospheric). Reactor atmosphere monitor: scintillation detector and single-channel differential analyzer; range: (10 to 10^6 cpm). Control room atmosphere detector (part of an 8-unit system); has range of 0.01 to 10 mr/hr. (2.a)	100 ft above grade with 5 ft ID; exhausts air at rate of 82,500 scfm. (2.e)
SEFOR	2: Reactor and Operations	Makeup air is introduced ahead of filter-cooling coil section of recirculation system thereby filtering and dehumidifying the air. 12 independent monitoring channels.	110 ft high (ventilating). Radiation monitor will ensure that release limits are not exceeded in accordance with AEC Regulations 10CFR20.
FARET	2: support wing and reactor bldg. Support wing system will be designed to effect required air changes and maintain a slightly positive pressure with respect to outside atmosphere. Reactor building ventilation and exhaust systems are once-through type. Atmospheric pressures are regulated to ensure positive air flow from zones of low contamination to those of higher suspect (e.g., rear cell and high-bay areas).	Exhaust air will be monitored prior to discharge through 200 ft stack. If high activity levels are detected, system will automatically de-energize air supply fans, reduce exhaust fan speed, and bypass exhaust gas through absolute filters prior to discharge to stack.	200 ft high

TABLE VII. B. EXHAUST VENTILATION SYSTEM (contd)

EBR-I	4 systems: Reactor air supply, outer-blanket-cooling, shield-cooling systems (interconnected); bldg. ventilation system; cell-ventilation system associated with primary cooling system cells; and cell-ventilation concerned with elevator room and outer-blanket-handling cells.	Particulate matter in intake side of reactor supply system is removed by means of an electrostatic precipitator. The cooling air for the reflector and shield and outer-blanket-cooling system is passed through high-efficiency filters prior to release up the exhaust stack. Exhaust-air-activity monitor consists of an ionization chamber and linear amp. having range of 10^{-12} to 10^{-10} A. Amp. output is registered on a Brown strip chart recorder located in the control room. To effect proper discrimination against general background, activity of exhaust air is compared on same chart with activity of air sampled from bldg.	Mounted on roof of main building (height not given)
EBR-II	4 systems: Reactor Plant; Laboratory Bldg., and Process Plant (2)		
ZPR-III	At least 2: assembly (reactor) room and vault.	Assembly room: Supply system takes outside air through an emergency, compressed-air operated intake damper, a 2 in. thick fiber glass filter, 2 finned steam heating coils in series and a 12,000 cfm blower. Exhaust system takes air from ceiling of assembly room and passes it through a 2 in. thick fiber glass prefilter and 1 1/2 in. thick Chemical Warfare Service absolute filter. (Exhaust fan is rated at 13,000 cfm @ 5 in. H_2O . Vault: Air supplied through grill from supply blower, filter, converter unit in boiler room; exhaust system consists of prefilter of fiber glass, C. W. S. absolute filter and 300 cfm fan.	25 ft; mounted on roof of assembly building

TABLE VII. C. WASTE EFFLUENTS

Name	Quantity of Wastes			Disposal Systems	Monitoring System
	Gas	Liquid	Solid		
Fermi	9800 scf/month ^(1.c)	Subassembly cleaning: 2600 gal/mo; low-level decontamination operations: 350 gal/mo; laundry (if installed): 5000 gal/mo; laboratory sinks: 1500 gal/mo. ^(1.c)	Abs. filters: 16 ft ³ /mo; pre-filters: 2.7 ft ³ /mo; misc. wastes: 25 ft ³ /mo; 1 ion-exchange resin tank: 3 ft ³ /mo. Total: 46.7 ft ³ /mo. ^(1.c)	1) Gas: Maximum concentration of activity at stack: 2 x 10 ⁻⁶ μCi/cm ³ or 2.45 curies/day maximum total discharge; >1 x 10 ⁻³ μCi/cm ³ : gas shunted to holdup (decay) tanks (2) in alternate use. 2) Liquid: System provides for substantial holdup capacity (3-2500 gallon SS waste surge tanks) permitting continuous discharge; wastes are diluted and discharged to lagoon and thence Lake Erie (if < 8 x 10 ⁻⁹ μCi/cm ³ activity). 3) Solid: Temporarily stored in Fuel and Repair Building-a section of maintenance pit. Offsite shipment of accumulated wastes made in ICC approved 55-gal drums. No permanent onsite solid waste disposal. ^(1.c)	1) Gas: Scintillation type gas sampler-controller positioned after absolute filters in collection header-determines whether gas is shunted; monitors either at base of or at top of stack: 4 scintillation type gas samplers, 2 air particulate monitors. 2) Liquid: Flow of waste liquid to turbine condenser discharge pipe is monitored by scintillation counter (Range: 1 x 10 ⁻⁵ to 1 μCi/cm ³). Duplicate set of continuous water monitors is located near point where turbine condenser overflow pipe enters lagoon (5 x 10 ⁻⁵ μCi/cm ³ maximum sensitivity). Sampling system used for both gas and liquid decay tank monitoring. ^(1.c, d)
Hallam	If <10 ⁻³ μCi/cm ³ , gas is sent to stack (80,000 scfm). If >10 ⁻³ μCi/cm ³ gas is sent to decay tanks. Fuel wash cells: 3040 ft ³ /yr; reactor vents: 290 ft ³ /yr; fuel handling machine: 200 ft ³ /yr. ^(2.c)	Fuel wash cell: 200 gal/yr; fuel handling machine wash: 40 gal/yr; decontamination room: 4,469 (total) gal/yr; maintenance: 250 gal/yr; laundry: 16,380 gal/yr; pump wash cell: 300 gal/yr. ^(2.c)	Operating experience needed before making estimate of solid wastes. ^(2.c)	1) Gas: If activity is above 10 ⁻³ μCi/cm ³ , through vent suction tank and compressors to radioactive gas decay tanks. 2) Liquid: <2 x 10 ⁻⁶ μCi/cm ³ , to leaching field diluted with sanitary sewage or to ash pit to be diluted with effluent from coolant tower blowdown. Higher activity liquids are evaporated and concentrated with subsequent dilution of distillate into leaching field or concentrate packaged. ^(2.a)	3-Unit System is used to monitor vent gases. (Range in mr/hr corresponding to 10 ⁻² to 10 ⁻⁵ μCi/cm ³ of ¹³³ Xe in air). Gas monitor used for effluent gases before stack release. (Range in mr/hr corresponding to 10 ⁻² to 10 ⁻⁵ μCi/cm ³ of ⁸⁵ Kr in air). A continuous gas monitor for effluent gases upon release and to prevent high level release from radioactive vent tank. (Range is 0 to 500,000 cpm). Radiation level of a liquid waste being transferred to sanitary sewage leaching field continuously measured by a single unit radiation monitor. (Range same as stack gas monitor). Continuous gas monitor used for effluent gases leaving radioactive waste facility. (Range same as 2 preceding monitors). ^(2.a)

TABLE VII. C. WASTE EFFLUENTS (contd)

SEFOR	Reactor cover gas (75 cf/batch); fuel storage tank cover gas (75 cf/batch); primary drain tank vent (2000 cf/batch); refueling cell argon loop vent (24,000 cf @ 100 cfm/batch); man lock vent (400 cf/batch); and N ₂ system vent (10 cfm). (Decay tank capacity-total: 20,000 scf gas).	System is composed of the following tanks: 500 gal, 200 gal; 500 gal holding; 500 gal dilute waste; and 2000 gal waste storage.	1) Gas; facilities provided to collect, store, filter, dilute and disperse—long term (60 days) plant operation without gas release and no direct routing to atmosphere. (Once-through type system). 2) Liquid: compact flexible system of storage tanks. 3) Solid: collection area onsite; when appropriate, transfer is made to licensed disposal agency for offsite disposal.	Routine monitoring of small waste batches (liquid) before combining with other wastes. (RRA) Radiation Alarm provided at sewer inlet. See Exhaust Ventilation System; Filtering and Monitoring Arrangements and Stack.
FARET			1) Gas: Vented to atmosphere via absolute filters and through stack if levels acceptable, otherwise it is compressed and stored pending decay to permissible limits for release to atmosphere. 2) Liquid: All lab water from contamination suspect areas routed to shielded storage tanks for retention and analyses to determine ultimate mode of disposal—either onsite leaching field or pumping to authorized tank trucks for transport to offsite processing and disposal areas. 3) Solid: Nonfueled subassembly scrap will be canned in the cell and removed in shielded containers for subsequent disposal at NRTS burial grounds.	A process gas radiation level detection system will monitor the activity levels in waste gas from the Na system argon blanket gas and argon atmosphere in cell, vault, and cavity. Gas samples monitored by scintillation type detector. Output fed to count-rate meter which feeds alarm circuit. Samples of stack gas effluent will be taken continuously and monitored for particulate and gaseous activity.
EBR-I				
EBR-II	Excess make-up argon gas is vented directly through filters to the exhaust stack or to a retention tank for subsequent disposal.	Recirculating cold trap system is used for continuous primary Na purification. Cold trap consists of 500 gal tank filled with Type 304 SS wire mesh to provide supplementary surface area to enhance Na crystallization and deposition.		Argon vented to the stack is continuously monitored for activity. If the activity exceeds the tolerable level, the gas is pumped into a retention tank and held until it decays sufficiently for safe disposal.
ZPR-III				

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