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TITLE

OPERATING LIMITS
HANFORD PRODUCTION REACTORS

AUTHOR

By the Staff

Research & Engineering Operation - IPD

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OPERATING LIMITS
HANFORD PRODUCTION REACTORS

By the Staff

Research and Engineering Operation
IRRADIATION PROCESSING DEPARTMENT

November 5, 1963

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OPERATING LIMITS
HANFORD PRODUCTION REACTORS

OPERATING LIMITS
HANFORD PRODUCTION REACTORS

I. FACILITY IDENTIFICATION

These Operating Limits shall be applicable to the eight production reactor facilities, designated B, C, D, DR, F, H, KE and KW (hereinafter referred to as the Hanford Production Reactors) located at the Hanford site in the State of Washington.

II. REFERENCES TO DESCRIPTION OF FACILITIES

Hazards Summary Reports for the Hanford Production Reactors provide comprehensive descriptions of the process and facilities as well as analysis of the most severe potential hazards of the operation. These reports are as follows:

HW-74094, Hazards Summary Report - Six Oldest Hanford Reactors
- Vol. 1 - Hazards Evaluation and Accident Analysis
- Vol. 2 - Process Control and Technical Data
- Vol. 3 - Description of the Plants

HW-74095, Hazards Summary Report - Hanford K Reactors
- Vol. 1 - Hazards Evaluation and Accident Analysis
- Vol. 2 - Process Control and Technical Data
- Vol. 3 - Description of the Plants

The above reports are the technical references for this document, but are not considered a part of the Operating Limits.

III. OPERATING AND PERFORMANCE RESTRICTIONS[1]

A. Operating Parameter Limitations

1. Process tube outlet temperatures during operating conditions shall not exceed 150 C, or the instability temperature less 10 C, whichever is lower.

2. Process tube outlet temperatures during shutdown conditions shall not exceed 95 C except that coolant may be reduced or removed from process tubes during shutdown conditions as required for fuel discharge or maintenance purposes. Such interruptions to coolant flow shall be limited to time and duration such that there will be no melting of either fuel cladding or bond material.[2]

(1) As used in this document, the words "operating conditions" refer to the operating status as opposed to the shutdown status. "Operating conditions" apply whenever the reactor is critical or supercritical. The words "operation" or "operating" (when not followed by the word "conditions") refer to the reactor and auxiliary facilities under both operating conditions and shutdown conditions.

(2) The melting temperature of aluminum is 660 C and of the "Al-Si" bond material is 580 C.

[redacted]

3. Bulk outlet temperature during operating conditions shall not exceed 97 C.

4. Goal power levels of the reactors shall not exceed the following values:

Reactor	Power Level Limit - MW
B, D, DR, F, H	2090
C	2310
KE, KW	4400

In the event that power levels are noted to exceed the above values by three per cent or less, immediate action shall be taken to reduce reactor power. Whenever conditions result in power levels exceeding the above values by more than three per cent, the reactor shall be shut down immediately.

5. The calculated fuel surface heat flux during operating conditions shall not exceed 70 per cent of heat transfer burnout.

6. The maximum rate of power rise in the megawatt region shall be 15 per cent per minute of the power level limits listed in Item 4.

7. The startup period shall not be less than ten seconds.

B. Reactivity Control

1. The potential reactivity of the fuel loading[3] shall not exceed five per cent in the B, D, DR, and F Reactors and six per cent in the C, H, KE, and KW Reactors.

2. The minimum reactivity control margin shall be as follows:

a. Operating Conditions[4]

B, C, DR, F, and H Reactors

The operable primary safety system (vertical rods) shall be capable of inserting control equivalent to 2.0 per cent $\Delta k/k$ of reactivity poisoning.

(3) The fuel loading as used here specifically excludes safety and control rods and poisons in supplementary control devices, but includes target elements and water coolant in the process tubes.

(4) This control requirement is also permissible during shutdown conditions when the top-of-the-riser pressure is not less than 45 psig, coolant continuity is normal for operating conditions, and the secondary safety system (Ball-3X) is operable.

KE and KW Reactors

The operable primary safety systems (vertical rods) shall be capable of inserting control equivalent to 1.5 per cent $\Delta k/k$ of reactivity poisoning.

An equivalent amount of control shall be available from the secondary safety system (Ball-3X) should the primary safety system fail to function.

b. Shutdown Conditions

B, C, D, DR, F, and H Reactors

The reactor shall be maintained at least 2.0 per cent $\Delta k/k$ subcritical during shutdown conditions; for a maximum period of two hours immediately following the shutdown action, the shutdown margin may be 2.0 per cent $\Delta k/k$ less the gain in reactivity from cooling the fuel from operating to shutdown status.

KE and KW Reactors

The reactor shall be maintained at least 1.5 per cent $\Delta k/k$ subcritical during shutdown conditions; for a maximum period of two hours immediately following the shutdown action, the shutdown margin may be 1.5 per cent $\Delta k/k$ less the gain in reactivity from cooling the fuel from operating to shutdown status.

C. Control and Safety Systems

1. Primary Safety System (Vertical Rods)

a. The maximum allowable response time of the primary safety system to a trip of either the individual tube pressure-monitor system or high level flux-monitor system shall be 3.0 seconds. The response time to any other trip event actuating the primary safety system shall not exceed 3.5 seconds. The response time is defined as the interval between the trip event and 90 per cent downward travel of the vertical safety rods.

b. An operable vertical safety rod is defined as one having an insertion time not exceeding 2.8 seconds. Rod insertion time is defined as the interval between first movement and 90 per cent insertion.

c. The minimum number of operable vertical safety rods during operating conditions shall be as follows:

Reactor	Minimum Number of Operable Vertical Safety Rods
B,D,DR,F	22
H,C	35
KE, KW	35

The outer six vertical safety channels at the K Reactors are not considered as part of the primary safety system. There shall be no more than two adjacent inoperable rods at the B, D, F, KE and KW Reactors. There shall be no more than three adjacent inoperable rods at the C, DR, and H Reactors; no more than one of three adjacent inoperable rods shall be a peripheral rod.

d. The reactivity insertion rate afforded by vertical safety rod withdrawal shall be limited to less than .035 per cent per second for a cold startup.

e. The reactivity insertion rate afforded by vertical safety rod withdrawal shall be limited to less than .30 per cent per second for a hot startup.

2. Horizontal Control Rods

a. The reactivity insertion rate afforded by horizontal control rod withdrawal shall be limited to less than 0.05 per cent per second.

b. A horizontal control rod shall be replaced when its calculated control effectiveness is reduced by more than ten per cent due to poison burnout.

3. Secondary Safety System (Ball-3X)

Balls with a maximum diameter of 0.5 inch shall be available for insertion into the Vertical Safety Rod channels.

The effective average macroscopic 20 C neutron cross section of the balls insertable in each channel shall not be less than 2.4 cm^{-1}. The minimum number of operable Ball-3X columns shall be as follows:

Reactor	Minimum Number of Operable Ball-3X Columns
B,D,DR,F	22
H,C	35
KE, KW	35

The outer six vertical safety channels at the K Reactors are not considered as part of the secondary safety system. An operable column is one which is insertable by a manual trip from the control room and by an automatic trip during operating conditions. There shall be no more than two inoperable adjacent columns at the B, D, F, KE, and KW Reactors. There shall be no more than three adjacent inoperable columns at the C, DR, and H Reactors; no more than one of three adjacent inoperable columns shall be a peripheral column.

4. Supplementary Control Devices

Solid materials used in supplementary control devices, such as poison splines, poison column control facilities, or supplementary control columns may be used to facilitate reactor operating control and may be utilized in satisfying shutdown margin and total control requirements. Supplementary control devices which are used for nuclear safety purposes shall not have lost control effectiveness due to burnout calculated to be more than ten per cent. During operating conditions the rate of reactivity addition shall not exceed 0.05 per cent per second.

D. <u>Reactor Fuel Loadings</u>

1. <u>Production Fuel Loadings</u>

Production scale fuel loads which have not previously been approved for irradiation shall not be utilized in the reactors.

2. <u>Test Scale Loadings</u>

Test scale fuel loads shall not occupy more than ten per cent of the process tubes in each reactor. In addition, no test load shall result in an increase in potential reactivity of more than one per cent.

E. <u>Coolant Requirements with Irradiated Fuel in the Reactor</u>

1. During shutdown conditions the minimum flow shall be 1000 GPM at the B, C, D, DR, F, and H Reactors and 2000 GPM at the K Reactors, and there shall be a positive pressure differential on all tubes containing irradiated fuel except that coolant may be reduced or removed from process tubes as required for fuel discharge or maintenance purposes.

2. Coolant water shall be available from reservoirs during reactor operation to provide full normal flow for 15 minutes and a minimum of 24 hours of shutdown cooling including the shutdown transient.[5]

3. Each reactor shall have three independent, reliable sources of coolant supply as follows:

(5) Applicable water storage requirements at each of the reactors for flow conditions in July, 1963, were as follows:

	Water Storage (10^6 Gallons)		
	B,D,DR,F,H	C	KE, KW
Full normal flow for 15 minutes	1.36	1.58	3.15
24 hours of shutdown cooling including the shutdown transient	6.35	7.16	13.05
TOTAL	7.71	8.74	16.20

a. Primary Cooling System

The primary cooling system shall be operated to provide adequate process channel cooling during operating conditions.

b. Secondary Cooling System

The secondary cooling system shall be operated to provide adequate process channel cooling indefinitely immediately following a reactor scram from full level, assuming loss of power to the primary cooling system. The minimum demonstrated flow of this system for each of the reactors shall be as follows:

Reactor	Minimum Flow (GPM)
B,D,DR,F,H	20,000
C	25,000
KE,KW	50,000

The secondary cooling system shall be independent of both the primary and the last ditch cooling systems.

c. Last Ditch Cooling System

1) B, D, F, and H Reactor Areas:

The last ditch cooling system shall be operated to provide post-transient shutdown flow requirements indefinitely to any one reactor area assuming loss of power to the primary cooling system at all reactor areas and concurrent loss of flow from the secondary cooling system at any one of the reactor areas.

2) K Reactor Area

The last ditch cooling system shall be operated to provide post-transient shutdown requirements indefinitely to either reactor assuming loss of power to the primary cooling system at both K Reactors and concurrent loss of flow from the secondary cooling system at either K Reactor.

3) The minimum demonstrated flow of the last ditch system to any one reactor shall be:

Reactor	Flow (GPM)
B,D,DR,F,H	9,500 from the high tanks and 5,000 from the export system when the high tank supply is exhausted.
C	12,000 from the high tanks and 6,000 from the export system when the high tank supply is exhausted
KE,KW	29,000

[redacted]

4) The last ditch system shall be independent of both the primary and secondary cooling systems, including piping to the reactor coolant manifold.

All three coolant supply systems shall be in service during operating conditions, except that the last ditch system may be unavailable for a maximum of two hours.

No more than one of these systems shall be out of service during shutdown conditions.

The following definitions are appropriate for the interpretation of this specification:

a. Systems are independent of each other if failure or cause of failure in one system cannot induce failure of another system. In addition, failure of any single component within a system shall not be capable of rendering the system inadequate. In practice, certain selected valves, pumps, and piping may be qualified as exceptions in meeting the requirements of this specification.

b. Adequate cooling is defined, as a minimum, as that required to maintain reactor process channel components below the melting point of the fuel bond or jackets.

4. The reactor shall be shut down upon loss of primary coolant.

5. Emergency power shall be supplied by:

a. Coal-fired boilers supply steam to turbines driving coolant supply pumps at the B, C, D, DR, F, and H Reactors. The demonstrated maximum steaming rate of each of these boilers shall be at least 100,000 pounds of steam per hour. The minimum number of fired boilers shall be as follows:

Reactor Area	Two Reactors Operating	One Reactor Operating	No Reactors Operating
B, D	3 on line[6]	2 on line	1 on line and 1 banked
F, H	---	2 on line	1 on line and 1 banked

b. Oil-fired boilers supply steam to turbines driving electrogenerators and pumps at the K Reactors. The demonstrated maximum steaming rate of each of these boilers shall be at least 50,000 pounds of steam per hour. For each K Reactor, at least two boilers shall be on the line[7] during

(6) At the B, D, F, and H Reactor Areas, a boiler must be supplying steam at a rate of not less than 20,000 pounds per hour to be considered as "on line".
(7) At the K Reactor Area, a boiler must be supplying steam at a rate of not less than 12,000 pounds per hour to be considered as "on line".

operating conditions and one on the line during shutdown conditions. The last ditch coolant flow shall be provided for the K Reactors by an independent diesel-powered pumping station.

F. <u>Reactor Confinement</u>

Each reactor shall be operated with a confinement system. This system shall be designed primarily for the removal of particulate fission products and halogens from the ventilation exhaust air which might be released as a result of a minor accident such as burning of a few fuel elements. The system shall consist of a ventilation system, particulate filters, charcoal filters, and a fog spray system.

Exhaust air from the reactor building shall pass through the confinement system filters; a minimum of one filter cell shall be on the line during all phases of operation. The filter cells shall have demonstrated a capability of removing at least 90 per cent of the halogens and 95 per cent of the particulates.

As a minimum, one exhaust fan[8] shall be maintained on the line and one shall be available as backup, except that the backup fan may be unavailable for a maximum period of 24 hours. Power to the backup fan shall be steam at the B, C, D, DR, F, and H Reactors and direct-drive diesel motors at the KE and KW Reactors. These diesel motors shall have sufficient fuel available to operate for a minimum of five days.

The fog spray system shall discharge from the top of the rear face area, shall have demonstrated a minimum flow rate of 400 gallons of water per minute, and shall be activated either automatically by an increase in the I^{131} content in the exhaust air or manually.

G. <u>Code Compliance</u>

Wherever applicable in the design, procurement, construction, alteration, maintenance, and operation of plant facilities, the intent of national codes and standards shall be observed as minimum standards to the extent required in Engineering Standards adopted by the General Electric Company and in use at the Hanford Atomic Products Operation. In those cases where national codes and standards are not applicable, the design, procurement, construction, alterations, maintenance and operation shall be guided by safe and uniform designs consistent with the use intended and with sound engineering principles.

(8) The ratings of the exhaust fans at the reactors are as follows:

Reactor	Flow, cfm	Exhaust Fan Head Inches of Water
B,D,F	50,000	10-1/2
DR	42,500	11
C,H	75,000	11
KE,KW	67,500	11

[redacted]

H. Safety Instrumentation and Set Points[9]

Nuclear and process control instrumentation shall be provided to shut down the reactor automatically when certain process limits are exceeded. The following specifies the instrumentation and trip set points for each function which is required to shut down the reactors automatically.

1. Neutron Flux Level

Approach to critical shall be monitored by at least one neutron flux monitor which has demonstrated sensitivity to a fission-induced power level of 500 watts or less. Exceeding power trip settings on two out of a minimum of three flux monitors, failure of two monitors, failure of one monitor and exceeding the power trip setting on one monitor, or fewer than three flux monitors in the safety circuit, shall actuate the primary safety circuit. During operating conditions with no process tube outlet temperature in excess of 80 C, power trip settings on three safety channels shall be no more than two decades above the operating signal, or 120 per cent of the expected signal at full operating power, whichever is lower; with process tube outlet temperatures in excess of the 80 C, the power trip setting shall not exceed the following values:

Maximum Process Tube Outlet Temperature (°C)	Trip Setting - % of Operating Signal
80 - 90	150
90 - 100	140
100 - 110	130
Above 110	120

2. Low Reactor Coolant Pressure

A primary safety circuit trip shall result when supply riser water pressure drops below normal operating pressure more than 60 psig. Trip of the flow detection device for individual process channels as noted under item 4, "Process Channel Coolant Adequacy", shall provide this protection.

3. Rapid Loss of Reactor Coolant Pressure

Secondary safety circuit trip shall result when a process water pressure decay rate from operating conditions is sustained in the front risers which is greater than 40 psig per second for a total pressure loss

(9) Safety circuit activation shall result in automatic control action as follows:
a. Primary safety circuit - insertion of vertical safety rods.
b. Secondary safety circuit - insertion of poison balls into the vertical safety channels (ball-3X system).

exceeding 300 psig. The system may be manually bypassed for repair or for resetting trips for a maximum period of eight hours.

4. Process Channel Coolant Adequacy

All process channels containing fuel materials shall be equipped with pressure sensing flow detection devices. Trip points actuating the primary safety circuit shall be set such that flow reductions or power level increases in individual fuel tubes which result in insufficient cooling for safe operation will result in reactor shutdown. Shutdown shall occur within sufficient time to prevent melting of fuel bond or jackets provided adequate coolant is supplied to cool the tubes during shutdown conditions. The operating pressure span between the high trip and the low trip shall not exceed 100 psig. These flow detection devices shall also be used to actuate the No. 1 Safety Circuit for the condition of low reactor coolant pressure. Normal operating practice will permit bypassing individual pressure monitor trips when the coolant pressure or exit temperature of the affected channel is under continuous surveillance. The system shall not be bypassed when the reactor power level exceeds 0.5 per cent of the normal operating power level.

5. Earthquake

Seismoscopes at each reactor shall be set to trip in the event of an earthquake having an intensity of four or more on the Modified Mercalli Scale.

Exceeding trip settings on two out of two or more seismoscopes shall actuate the primary safety circuit. The system may be manually bypassed for repair or for resetting trips for a maximum period of 24 hours.

6. Electrical Power Loss

Loss of primary electrical power shall actuate the primary safety circuit.

I. Control Requirements for Hanford Production Reactors

Reactivity and operating limitations imposed by the total control and the speed-of-control requirements will be applicable when more restrictive than other limits specified in the Operating and Performance Restrictions Section.

1. Total Control Requirement

The Hanford reactors shall be operated such that in the event of any credible combination of events, and including complete and permanent loss of coolant, the total control strength will be sufficient to ensure that no reactivity state will develop which would significantly increase the consequence of the accident.

No reactivity state shall be allowed to develop in the dry reactor (following the scram and any excursion which may have accompanied the accident) which would decrease the probability of restoring coolant to the reactor; i.e., a delayed neutron critical state shall not be permitted until after a significant number of process tubes have been rendered useless as coolant channels. A prompt critical state shall never be permitted.

2. Speed-of-Control Requirement

The Hanford reactors shall be operated such that in the event of a power excursion resulting from any credible combination of events, and including complete and permanent loss of coolant, the response of the reactor safety control system will be sufficient to ensure that no energy state will develop during the excursion which would significantly increase the consequences of the accident.

Maximum reactivity insertion rates shall be such that in the event of an excursion and a failure to manually scram the reactor, an automatic scram would limit any power rise to one of a magnitude such that no melting of fuel bond or cladding would occur.

The energy generated in any excursion associated with coolant loss shall be insufficient to cause the surface temperature of the fuel elements at any point in the reactor to reach the melting point of uranium until the power generation at that point returns to its pre-accident equilibrium value.

IV. ADMINISTRATIVE PROCEDURES

The General Electric Company shall establish and maintain in effect specifications, process controls, reviews, approvals, and other administrative procedures designed to assure safety of the reactor process during all phases of reactor operation. These procedures shall include the following:

A. Process Control Procedures

The General Electric Company shall establish and maintain in force a system of administrative control of reactor operation including the eight features defined below. These control methods shall include written technical and operating guides directed toward safety of the reactor process during all phases of reactor operation and shall be authorized by qualified and responsible General Electric Company management. The procedures or limitations developed shall not be less restrictive than the limitations imposed by the Operating and Performance Restrictions, and they shall not authorize operation under conditions which involve an Unreviewed Safety Question.[10]

(10) A proposed change, test, or experiment shall be deemed to involve an Unreviewed Safety Question (1) if the probability of occurrence of a type of accident analyzed in the referenced Hazards Summary Reports may be significantly increased; or (2) if the consequences of any type of accident analyzed in the referenced Hazards Summary Reports may be significantly increased; or (3) if such change, test, or experiment may create a credible probability of a nuclear accident of a different type than any analyzed in the referenced Hazards Summary Reports.

1. Process Standards

The Process Standards are mandatory written instructions, prepared by an independent component having no line responsibility for reactor operation or production efficiencies. The Process Standards specify, for the reactor process and vital auxiliary plants, the process limits, conditions, and materials where such specification is necessary to safeguard against nuclear hazards.

2. Equipment Maintenance Standards

The Equipment Maintenance Standards are mandatory written instructions, prepared by an independent component having no line responsibility for reactor operation or production efficiencies. The Equipment Maintenance Standards specify, for the reactor process and vital auxiliary plants, the equipment and component specifications, methods and frequency of performing functional tests, and maintenance procedures where such specification is necessary to safeguard against nuclear hazards.

3. Process Change Authorization

The Process Change Authorization is a method of providing for reactor operation under temporary waiver of Process Standards in a manner such that the deviation will not result in significantly increased hazard. Process change authorizations are prepared by an independent component having no line responsibility for reactor operation or production efficiencies. Copies of Process Change Authorizations involving nuclear hazards are transmitted to the Commission for information.

4. Production Test Authorization

A test which has the prime objective of developing engineering or technological data or producing special materials may be conducted under a Production Test Authorization. Such tests may be conducted outside the conditions authorized by Process Standards or Equipment Maintenance Standards. Authorizing documents describe the risks and hazards involved in the test so that formal approval by the same technical and operating components authorizing Process Standards signifies that the risks are known, understood and reasonable. Copies of Production Test Authorizations involving nuclear hazards are transmitted to the Commission for information immediately upon issuance.

5. Process Improvement Transition Authorization

A test which has the prime objective of piloting the application of knowledge or techniques to the reactors on a large scale may be conducted under a Process Improvement Transition Authorization. Such tests may be conducted outside the conditions authorized by Process Standards or Equipment Maintenance Standards, and require authorization similar to Production Test Authorizations. Copies of Process Improvement Transition Authorizations involving nuclear hazards are transmitted to the Commission for information immediately upon issuance.

6. Development Test Authorization

Development work utilizing reactor facilities which can be accomplished without deviation from Process Standards or Equipment Maintenance Standards is permitted under a Development Test Authorization. Authorization requirements are similar to but less restrictive than those for Production Test Authorizations.

7. Authorizations for Facility Modifications

Major modifications to the plant facilities may be accomplished under the provisions of a Project Authorization, and minor modifications may be accomplished under a Design Change. When modifications require changes in the Operation Limits or involve an Unreviewed Safety Question, the authorizing document shall be transmitted to the Commission for approval.

8. Standard Operating and Maintenance Procedures

Methods, procedures, and check lists for process operations with nuclear hazard potential are prepared and approved by the components having line responsibility for the operation to ensure that execution of maintenance work, process functions, inspections, functional tests of critical equipment, reactor startup preparations, and reactor operations are conducted in accordance with Process Standards and Equipment Maintenance Standards.

B. Audits and Inspection of Reactor Operation and Maintenance

The General Electric Company shall maintain in force organizational and procedural arrangements which provide for frequent and periodic checks of (1) degree to which the facilities are operated in accordance with the limits specified in the Process Standards, (2) facility maintenance, particularly in those areas of equipment and components critical to reactor safety as specified in the Equipment Maintenance Standards, and (3) adequacy of training of reactor operators and maintenance personnel.

The General Electric Company shall also provide for investigation of any unusual or unpredicted reactor conditions which might affect safe reactor operation, such investigation to be by a competent body of the General Electric Company including personnel not having direct responsibility for operation or maintenance of the facility in question. A report of each such investigation shall be transmitted to the Commission.

C. Reports and Records

In addition to those otherwise provided within these Specifications, the General Electric Company shall make the following reports:

1. The General Electric Company shall immediately report to the Commission in writing any change in the physical or operating characteristics of the Hanford Production Reactors that might affect the safe operation of the reactors.

2. The General Electric Company shall advise the Commission in writing of changes, tests, or experiments involving nuclear safety, judged to be of informational interest to the Commission.

3. The General Electric Company shall transmit to the Commission an annual report of operating experience pertinent to reactor safety.

4. The General Electric Company shall maintain records for demonstrating compliance to procedures and limitations within the Operating Limits.

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