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OPERATING LIMITS
HANFORD PRODUCTION REACTORS

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OPERATING LIMITS
HANFORD PRODUCTION REACTORS

By the

Research and Engineering Operation
IRRADIATION PROCESSING DEPARTMENT

Compiled by

G. F. Owsley

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OPERATING LIMITS
HANFORD PRODUCTION REACTORS

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OPERATING LIMITS
HANFORD PRODUCTION REACTORS

I. FACILITY IDENTIFICATION

These Operating Limits shall be applicable to the eight operating production reactor facilities, namely 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

Basic descriptions of the reactor facilities are contained in the following early HAPO reports.

HDC-2225, C431-B Scope Document, 105-C Reactor Plant, E. L. Hollister, 6-1-51.

HDC-2524, Basic Design Specifications for "X" Pile No. 1.10 (Twin K Reactors), G. M. Roy, 3-11-52.

HW-25892, Summary Report of Reactor Hazards for Twin 100-K Area Reactors, G. M. Roy, G. L. Locke, E. L. Armstrong, C. Sege, 10-10-52.

HW-44708, Vol. I Rev., Hazards Summary Report, Projects CG-558 and CG-600 Reactor Plant Modifications, R. E. Trumble, 3-6-57.

HW-44708, Vol. II, Hazards Summary Report, Projects CG-558 and CG-600 Reactor Plant Modifications, R. E. Trumble, 12-21-56.

Hazards Summary Reports for all existing Hanford Production Reactors have been updated and revised, and provide more complete descriptions of the process and facilities than contained in the above. 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

None of the above reports is to be considered a part of these Operating Limits.

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III. OPERATING AND PERFORMANCE RESTRICTIONS

A. Operating Parameter Limitations

1. The process tube outlet temperature limit during steady state operating conditions shall be 150 C or the saturation temperature at the end of the fuel charge, whichever is lower.

2. The process tube outlet temperature limit during shutdown conditions shall be 95 C. Coolant may be 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.(1)

3. The bulk outlet temperature limit during steady state operating conditions shall be 95 C.

4. The 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

5. The calculated fuel surface heat flux during steady state operation shall not exceed 70 per cent of heat transfer burnout, based upon established burnout correlations.

6. The linear rate-of-rise shall not exceed 25 per cent per minute of the limiting power level, as determined from four above.

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

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

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B. Reactivity Limitations

1. The potential reactivity of the water-cooled loading(2) 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 control margin for the water-cooled reactor shall be as follows:

a. Operating Control

The operable vertical rod system shall be capable of inserting control equivalent to 2.0 per cent $\Delta k/k$ of reactivity poisoning. An equivalent amount of control shall be available from the Ball 3X system should the vertical rod system fail to function.

b. Shutdown Control

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.

c. Operating Readiness Control(3)

There shall be 2.0 per cent $\Delta k/k$ of control available from the vertical rod system or the reactor shall be 2.0 per cent $\Delta k/k$ subcritical.

3. Reactivity and operating limitations imposed by Total Control or Speed-of-Control requirements will be applicable when more restrictive. (See page 16 for statements of the Total Control and Speed-of-Control criteria.)

C. Control and Safety Systems

1. VSR System

a. The maximum allowable response time of the No. 1 Safety System to a

(2) The water-cooled loading as used here specifically excludes control rods and poisons in supplementary control devices.
(3) This control requirement is permissible when the top-of-the-riser pressure is not less than 45 psig, coolant continuity is normal for operating conditions, and the Ball 3X system is operable.

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Panellit system or a high level fluxmonitor trip shall be 2.6 seconds. The response time to any other trip event actuating the No. 1 Safety System shall not exceed 3.0 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. The maximum allowable insertion time of the vertical rods shall be 2.4 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 shall be as follows:

Reactor	Minimum Number of Operable Vertical Safety Rods	Minimum Calculated Reactivity Poisoning Effect
B,D,DR,F	21	$>$2.0 per cent $\Delta k/k$
H,C	35	
KE,KW	30	

The outer six rods at the K Reactors are not considered as part of the Safety System. There shall be no more than one inoperable rod adjacent to another inoperable rod at the B, D, and F Reactors. There shall be no more than one inoperable rod adjacent to two inoperable rods at the C, DR, H, KE, and KW 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 0.02 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 0.25 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. Ball 3X System

Metallic or ceramic balls with a maximum diameter of 0.5 inch shall be available for insertion into the Vertical Safety Rod channels.

The average macroscopic 20 C neutron cross section of the balls insertable in each channel shall not be less than 2.4 cm^{-1}. At least 50 per cent of the balls must meet this cross section limitation which is equivalent to 0.75 w/o natural boron in steel. The minimum number of operable Ball 3X columns shall be as follows:

Reactor	Minimum Number of Operable Ball 3X Columns	Minimum Calculated Reactivity Poisoning Effect
B,D,DR,F	20	
H,C	30	$>$2.0 per cent $\Delta k/k$
KE, KW	32	

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 one inoperable column adjacent to another inoperable column at the B, D, and F Reactors. There shall be no more than one inoperable column adjacent to two inoperable columns at the C, DR, H, KE, and KW 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

[redacted]

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 these purposes shall have lost a calculated control effectiveness due to burnout of not more than ten per cent. Reactivity insertion increments with supplementary control devices shall not exceed 0.2 per cent, and the rate of reactivity insertion, averaging for two or more increments the time to effect such increments and the time interval between increments, shall not exceed 0.005 per cent per second.

D. Reactor Fuel Loadings

1. Production Scale Loads

Production scale fuel loads shall consist of fertile and/or fissionable material supplemented with enriched uranium fuel containing not more than 0.96 per cent U-235. The fuel elements shall be metallic uranium enclosed in metallic aluminum cans. Production scale fuel loads which have not previously been approved for irradiation shall not be utilized in the reactors without prior approval of the General Electric Company and the Commission.

2. Test Scale Loads

Test scale fuel loads shall be limited in size such that the additional potential reactivity of the test load could not cause an increase of more than one per cent in the gross pile reactivity.

3. Blanket Loadings

It shall be permissible to load not more than two lattice units adjacent to the reflector with enriched lithium-aluminum poison pieces, and to provide additional enriched columns of 0.96 per cent U-235 to supply

[redacted]

reactivity for reactor operation.

E. Coolant Requirements with Irradiated Fuel in the Reactor

1. During shutdown conditions the minimum flow shall be 1000 GPM at the B, C, D, DR, F, and H Reactors and 2000 GPM to the K Reactors, and there shall be a positive pressure differential on the top fuel tubes.

2. Coolant water shall be available from reservoirs during reactor operation to provide the following coolant capacities:

	Available Water Storage - 10^6 Gal.		
	B,D,DR,F,H	C	KE,KW
Full normal flow for 15 minutes	1.40	1.58	3.15
Transient shutdown plus minimum of 24-hour shutdown cooling	6.35	7.17	13.10
TOTAL	7.75	8.75	16.25

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

   a. Primary Cooling System

   The primary cooling system shall be designed to:

   1) Be capable of providing adequate process channel cooling during all phases of normal reactor operation and shutdown.

   b. Secondary Cooling System

   The secondary cooling system shall be designed to:

   1) Be capable of providing adequate process channel cooling indefinitely immediately following a reactor scram from full level, assuming instantaneous loss of power to the primary cooling system. The minimum design flow of this system shall be as follows:

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

2) Be independent of both the primary and the last ditch cooling systems.

c. Last Ditch System

The last ditch cooling system shall be designed to:

1) For the B, D, F, and H Reactor Areas - be capable of providing post-transient shutdown flow requirements indefinitely to any one reactor area assuming instantaneous loss of power to the primary cooling system and concurrent loss of flow in the secondary cooling system at that one reactor area.

For the K Reactor Area - be capable of providing post-transient shutdown requirements indefinitely to any one reactor assuming instantaneous loss of power to the primary cooling system and concurrent loss of flow in the secondary cooling system at that one reactor.

The minimum design flow of this system shall be:

Reactor	Flow (GPM)
B,D,DR,F,H	10,000 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	30,000

2) Be independent of both the primary and secondary cooling systems, including piping to the reactor coolant manifold.

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

Two of these systems shall be in 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, common use of 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 as indicated in Table I.

5. Emergency power shall be supplied by:

a. Coal-fired boilers supplying steam to turbines directly driving coolant supply pumps at the B, C, D, DR, F and H Reactors. The designed maximum firing rate 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	2 on line	1 on line and 1 banked
F, H	--	2 on line	1 on line and 1 banked

b. Oil-fired boilers supplying steam to turbines driving electrogenerators at the K Reactors. The designed maximum steaming rate 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 during operating conditions and one on the line during shutdown conditions. The last ditch cooling system shall be provided for the K Reactors by an independent diesel powered pumping station.

F. Reactor Confinement

Normal practice at each reactor shall be to operate 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 and a fog spray system.

Exhaust air from the reactor building shall pass through the ventilation system filters; normally a minimum of one bank of filters shall be on the line during operating and shutdown conditions. The ventilation system shall be designed to remove at least 50 per cent of the halogens reaching the filters and 90 per cent of the particulates reaching the filters. Normal practice shall be to maintain, as a minimum, one exhaust fan on the line and one available as backup. 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 for a minimum of five days' operation.

The fog spray system shall discharge from the top of the rear face area, shall have a minimum design 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. Test Facilities

Irradiation Test Facilities installed in the Hanford Production Reactors shall be operated in accordance with the Administrative procedures described in Section IV agreed to by the General Electric Company and the Commission.

H. Code Compliance

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, economical, uniform designs consistent with the use intended and with sound engineering principles.

I. Safety Instrumentation and Set Points[1]

Nuclear and process control instrumentation shall be provided to automatically shut down the reactor when preset control 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 is sensitive 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 No. 1 Safety Circuit. 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 110 per cent of the expected signal at full operating power, whichever is lower.

With process tube temperatures in excess of 80 C, the power trip setting shall not exceed the following values:

(1) Safety circuit activation shall result in automatic control action as follows:

a. No. 1 Safety Circuit - insertion of Vertical Safety Rods.

b. No. 2 Safety Circuit - insertion of Horizontal Control Rods.

c. No. 3 Safety Circuit - insertion of poison balls into the Vertical Safety Rod channels (Ball 3X System).

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 No. 1 Safety Circuit trip shall result when process water riser pressure drops below normal operating pressure more than 60 psig at C, KE, and KW Reactors and 130 psig at B, D, DR, F, and H Reactors. This trip may have substituted for it the trip of the flow detection device for individual process channels as noted under item 4, "Process Channel Cooling"; thus manual bypass may be available.

3. Rapid Loss of Reactor Coolant Pressure

A No. 3 Safety Circuit trip shall result when a process water pressure decay rate is sustained which is significantly greater than the pressure decay rate which occurs following electrical power failure in the Primary Coolant System. Manual bypass may be available.

4. Process Channel Coolant Adequacy

All process channels containing fuel materials shall be equipped with pressure sensing flow detection devices. Trip points actuating the No. 1 Safety Circuit, shall be set such that flow reductions and/or power level increases in individual process tubes will not result in melting of fuel bond or jackets. The operating pressure span between the high trip and the low trip shall not exceed 100 psig. These flow detection devices may 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 bypassable when the reactor power level exceeds approximately 0.1 per cent of the normal operating power level.

5. Earthquake

Seismoscopes shall be set to trip upon detection of an earthquake having an intensity of four on the Modified Mercalli Scale. Exceeding trip settings on two out of three seismoscopes shall actuate the No. 1 Safety Circuit. Manual bypass may be available.

6. Electrical Power Loss

Electrical power failure shall actuate the No. 1 Safety Circuit.

7. In-Reactor Test Loops

Special procedures shall be provided for operation of in-reactor test loops. Instrumentation and set points will be variable depending on function and complexity of the loop. Set points will be provided to shut down the reactor under conditions established by Administrative Procedures.

J. Control Criteria for Hanford Production Reactors

1. Total Control

The operation of the Hanford reactors shall be 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 consequences of the accident.

2. Speed-of-Control

The operation of the Hanford reactors shall be 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.

IV. ADMINISTRATIVE PROCEDURES

The General Electric Company shall establish and place into 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 as 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. 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.

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 when, in the best judgment of qualified and responsible technical and operating personnel, such deviation will not result in increased hazard or reduced pile life. Copies of Process Change Authorizations are transmitted to the Commission for information.

4. Production Test Authorization

A test which has the prime objective of developing engineering or technological data 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 technical and operating components signify that the risks are known, understood and reasonable. Copies of Production Test Authorizations 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 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 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 such modifications require changes in the Operating and Performance Restrictions or may involve an Unreviewed Safety Question. Copies of the Project Authorizations shall be transmitted to the Commission for final authorization.

8. Standard Operating and Maintenance Procedures

Methods, procedures, and check lists for process operations with nuclear hazard potential are prepared 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. Special operating and maintenance procedures are provided for in-reactor test facilities.

B. Training Programs

The General Electric Company shall maintain a program under which qualified employees will receive formal certification that they have the required capabilities, skills and job knowledge to operate or supervise the operation of the control console of a Hanford Production Reactor. The requirements for certification shall be as follows:

1) The employee must meet physical and general health requirements, and
2) The employee must possess the required reactor knowledge and operating capability as indicated by his successful completion of both written and oral examinations which will be administered by the General Electric Company.

C. 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.

D. Reports and Records

In addition to those otherwise provided within these Specifications, the

General Electric Company shall make the following reports:

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

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

V. AUTHORIZATION FOR CHANGES

A. The Hanford Production Reactors shall be operated by the General Electric Company in accordance with the Operating and Performance Restrictions and the Administrative Procedures as defined in these Operating Limits.

B. General Electric Company may (1) make changes in the reactor facilities, (2) make changes in the procedures described herein, and (3) conduct tests or experiments utilizing the reactor facilities, provided the change, test, or experiment does not involve a change in the Operating and Performance Restrictions, and does not involve an Unreviewed Safety Question.

C. A proposed change, test, or experiment shall be deemed by the General Electric Company to involve an Unreviewed Safety Question if (1) the probability of occurrence of a type of accident analyzed in the referenced Hazards Summary Report may be significantly increased; or (2) if the

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consequences of any type of accident analyzed in the referenced Hazards Summary Report.

D. If a proposed change, test, or experiment involves an Unreviewed Safety Question, or involves a change in the Operating and Performance Restrictions as defined in these Operating Limits, it may not be carried out unless authorized by the Commission and approved by General Electric Company. General Electric Company shall submit a written request to the Commission for such authorization, accompanied by an appropriate hazards report with respect to any change, test, or experiment which must be authorized. The Commission may approve such change, test, or experiment, and in such case shall so notify General Electric Company in writing.

GFO:mm