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LINEAR POWER RATE-OF-RISE INSTRUMENTATION

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AUTHOR

B. W. Herrman
Reactor Design
FACILITIES ENGINEERING SECTION

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Reactor Design
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DESIGN CRITERIA
LINEAR POWER RATE-OF-RISE INSTRUMENTATION

1.0 INTRODUCTION

Studies ⁽¹⁾ of reactor safety considerations have demonstrated the need for automatic safety circuit action based on the measured rate of power increase in the power level range from 10^{-2} to 10^0 times equilibrium power level. Budget and Preliminary Engineering Studies ⁽²⁾ were performed.

2.0 PURPOSE

This document provides the design criteria for detailed design of the proposed Linear Power Rate-Of-Rise Instrumentation facilities and is applicable to any of the eight IPD reactors.

From the time that interest first developed in a power rate-of-rise system to the present time no equipment has been commercially available which could provide the necessary functions and performance. Also, there have been no sub-systems or components available which could be used in a building-block approach to provide a satisfactory system. IPD's Instrument and Electrical Development Operation (I&EDO) was therefore asked to develop a system to measure power rate-of-rise and automatically scram the reactor if the rate were too great. I&EDO was uniquely qualified to carry out this development because of their extensive background and specific experience in the fields of reactor instrumentation, Hanford reactor operational procedures and problems, reactor safety requirements, effluent water temperature measurement systems, reactor neutron flux measurement systems, and solid state trip (or comparator) circuits.

During the course of the development program, I&EDO investigated many possible techniques and developed prototypes of the two most promising systems. They then further refined the system requirements to produce the optimum design for Hanford reactors in terms of reliability, accuracy, operational safety, continuity of operation, and economy of equipment design.

After the extensive development and prototype testing, and definition of refined equipment and system performance criteria, I&EDO designed, built, and tested a production prototype which incorporated all of their accumulated experience. During this program every effort was made to reduce the equipment costs by obtaining competitive bids for such components as

-
- (1) HW-72555, HW-72591, HW-75672, HW-74904 Vol. I and HW-74095 Vol. I.
See Section 4.1
- (2) HW-76700 and HW-78840. See Section 4.1.

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meters, transformers, zener diodes, one percent tolerance resistors, high megohm resistors, switches, and telephone type relays.

The extensive testing of the production prototype has demonstrated that the design meets the requirements of Hanford reactors. This document presents the criteria for the production models and is based on our experience with the production prototypes. In many cases, the requirements were dictated by the system approach which was utilized. They acknowledge the capabilities and limitations of commercially available components and have been conscientiously screened to eliminate any over-specification which would unnecessarily increase cost.

3.0 DESCRIPTION OF PROPOSED PROJECT WORK

Three independent measuring channels will be installed in each reactor. Each channel will measure the rate of change of reactor power in the 10^{-2} to 10^0 times equilibrium power level range. Each channel will sense reactor power level by means of five pairs of RTD's arranged in a pattern similar to that shown in Figure 1 (page 7) so that a representative average reactor outlet water temperature can be obtained. A third (spare) RTD will be installed near each pair of RTD's. The new RTD's will be installed in Y fittings on the rear face of the small reactors and in special rear nozzle elbow fittings in KE Reactor. "Connectorless" RTD's with integral leads will be used. The leads will be terminated in a junction box located outside the rear face area. Cables from this junction box will connect to the control room instrumentation.

Three PRAAM (Power Rate Alarm And Monitor) chassis will be located in each control room. Each PRAAM channel will provide power to its RTD measuring circuits and include switches to replace failed RTD's with their installed spares. The PRAAM will derive the average power level from the RTD signals and display the level on a chassis-mounted meter. It will also differentiate the power level signal to determine the power rate, compare the measured rate with a preset trip setting, and initiate an alarm and trip function when the measured rate exceeds the trip setting. Two dual-indicating meters, having one pointer to show the trip setting and another to show the measured power rate, will be provided for each channel. One meter will be located on the PRAAM chassis and the other will be remotely located at the control console.

The trip circuits of the three channels will actuate a two-out-of-three logic matrix in the #1 Safety Circuit. Deactivation (e.g. switching to "calibrate") of a channel will produce the same effect as a high-rate trip. Simultaneous trips on two of the three channels will scram the reactor whether the trips are caused by excess power rate, erroneous trip setting, deactivation, equipment failure, or power failure.

A three-pen recorder, located near the instrument chassis, will record the power rate measured by each PRAAM channel.

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FIGURE 1

BLOCK DIAGRAM OF LINEAR POWER RATE-OF-RISE SYSTEM

A RAGE (RAMP Generator) test instrument will be installed in each control room. The RAGE will generate an electrical signal which changes at an adjustable rate. This signal can be introduced into the PRAAM channels to verify their calibration and to perform necessary trouble shooting.

4.0 REFERENCE DOCUMENTS

4.1 Hanford Reports

HW-72555 - Development and Application of Principles of Nuclear Safety Instrumentation, Research & Engineering Operation, February 1, 1962 - Confidential.

HW-72591 - Instrumentation Studies - Status Report, W. L. Stiede and D. I. Monnie, March 29, 1962 - Secret.

HW-75672 - Instrumentation Studies - Status Report II (High Level and Rate of Rise), W. L. Stiede and D. I. Monnie, November 28, 1962 - Secret.

HW-74094 - Vol. I - Hazards Summary Report, Vol. I, Safety Analysis and Hazards Evaluation Six Oldest Hanford Production Reactors, Process and Reactor Development Operation, June 21, 1963 - Secret.

HW-74095 - Vol. I - Hazards Summary Report, Vol. I, Safety Analysis and Hazards Evaluation Hanford K Production Reactors, Process and Reactor Development Operation, June 28, 1963 - Secret.

HW-76700 - Linear Power Rate-of-Rise Instrumentation Budget Study FY 1965 and Revision of FY 1964, J. W. Ballowe, March 1, 1963 - Secret.

HW-78840 - Preliminary Engineering Study Linear Power Rate-of-Rise Instrumentation B, C, D, DR, F, H, and KE, B. W. Herrman, September 27, 1963 - Confidential.

4.2 Hanford Design Criteria, Specifications, and Standards

SDC-1.1 Standard Design Criteria

SDC-1.2 Standard Design Criteria for Codes, Standards, and Specifications

HWS-7200-S Standard Specification for Instrument Panel Piping and Wiring

DI-7200-S Instructions for Use of HWS-7200-S

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HWS-8002-S Standard Procurement Specification for Thermoplastic Insulated Wire and Cable - 600 Volt

DI-8002-S Instructions for Use of HWS-8002-S

DG-4041 Electronic Design Practice

D-20-1 Building and Process Wire and Cable - 600 Volt

D-20-5 Multiple Conductor Control Cable and Control Wiring

D-20-6 Construction and Wiring of Control Panels and Cabinets

D-20-10a System and Equipment Grounding Services, Panels and Conduits

D-20-23 15 amp. - 120 Volt Twist Lock Receptacle

D-20-24 15 amp. - 120 Volt Receptacle for Instrumentation

J-2-1 Instrument Panels

J-2-2 Instrument Panel Finish

J-2-7 Instrument Panel Nameplates

J-2-10 Panel Switch Cover

J-2-11 Instrument Panel for 19-inch Relay Rack Chassis

J-3-1a Space Behind Instrument Panels

HWS-7366 Procurement Specification for Three - Conductor
or
HWS-7363 Special Purpose Cable

HWS-6406 Procurement Specifications for Resistance Temperature
Rev. 1 Detector

HWS-8278 Procurement Specification for Cable to RTD Integral Assembly for all 105 Buildings

4.3 Military and Government Standards

MIL-T-945A, Rev. 2 - Test Equipment For Use with Electronic Equipment, General Specification

MIL-N-19900A - Nuclear Propulsion Control and Instrumentation.

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4.4 Industry Codes and Standards

National Electric Code NEFU No. 70.
Safety Rules for Installation and Maintenance of Electrical Supply
and Communications Lines - National Bureau of Standards Handbook H-81.
IEEE Standards and Recommended Practices.
ISA Recommended Practice.

5.0 DESIGN CRITERIA

5.1 Definitions

Throughout this document the following definitions apply.

- 5.1.1 System - The "system" consists of all of the assemblies and components which will be installed by or utilized for this project from the RTD's and their special mounting or installation fixtures through the relay(s) which will act in the safety circuit, the various readout devices, the annunciator functions, and the "RAGE" test instrument.
- 5.1.2 Assembly - The term "assembly" shall refer to equipment assembled by one manufacturer from numerous relatively basic components (such as resistors, capacitors, transistors, meter movements, transformers, light bulbs, switches, sheet metal, and hardware) and purchased as one unit.
- 5.1.3 PRAAM - The "PRAAM" is the assembly, located in the control room, to which the RTD's are connected.
- 5.1.4 Channel - A "channel" consists of all the primary sensors (RTD's) connected to a single PRAAM, that PRAAM itself, the integral and remote readout devices, and the associated inter-connections and relays in the safety circuit logic matrix.
- 5.1.5 Trip - A "trip" shall mean the opening of a set of contacts on a single PRAAM chassis which are in a matrix that normally energizes the windings of the master relays which in turn have contacts in the safety circuit.
- 5.1.6 Single Channel Trip - A "single channel trip" means a trip on one PRAAM channel without a concurrent trip on either of the other channels.
- 5.1.7 Scram - A "scram" shall mean the action of the master relays which are the output of a logic matrix receiving intelligence from all three PRAAM channels and whose contacts are connected directly into the safety circuit. This action shall initiate action to shut down the reactor.

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5.1.8 FSD - When referring to the Rate Meter, Rate Meter Circuits, or Rate Recorder, "FSD" (Full Scale Deflection) shall mean, depending on the context, either the amount the meter or recorder travels between indications of -300 and +300 (See Figures 2 and 3, Page 12) or the range of variation of some parameter (i.e. current or voltage) that is required to change the meter reading from -300 to +300. When referring to other meters "FSD" shall mean the complete range of the meter movement.

5.2 Performance Criteria

5.2.1 Power Sensors

The primary sensing elements, which measure a parameter that is proportioned to reactor power level, shall be RTD's procured to Specification HWS-6406, Rev. 1 (except for response time). These RTD's have already demonstrated satisfactory reliability in Hanford reactor installations.

5.2.1.1 The resistance vs. temperature characteristic of RTD's shall be that specified in HWS 6406 Rev. 1. Except for requirements noted herein, the RTD's shall comply with specification HWS-6406, Rev. 1.

5.2.1.2 Each RTD shall be fabricated with an integral cable meeting Specification HWS-7366 or 7363 and attached according to HWS-8278 so that no electrical connector is required in the reactor rear face area. The assembly of cable and RTD shall be hermetically sealed against moisture penetration.

5.2.1.3 The sensors shall be so located that the arithmetic average of their output shall be proportional to the total reactor power level with an accuracy of $\pm 10\%$ at equilibrium power level.

5.2.1.4 The response time of the RTD's shall be less than two seconds.

5.2.2 Power Sensor Readout

The RTD's resistances shall be measured by resistance bridges located in the PRAAM chassis.

5.2.2.1 Each bridge shall measure two RTD's. The RTD's shall be placed in opposite arms of the bridge. The pair of RTD's shall be physically located close to one another on the reactor face so that the temperatures they measure are essentially the same.

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FIGURE 2
RATE METER DIAL

FIGURE 3
RATE RECORDER SCALE

5.2.2.3 One installed spare RTD shall be located physically near each active pair of RTD's. A switch shall be provided on the PRAAM chassis to allow the spare to be substituted for either member of the pair. All three RTD leads must be switched so that the rejected RTD is completely isolated from the circuit.

5.2.2.4 Each bridge circuit of a channel shall be isolated from the others by at least 100,000 ohms.

5.2.2.5 Provision shall be made to compensate for the effect of temperature upon the resistance of the lead wire between the RTD's and the measuring circuits.

5.2.2.6 RTD bridges shall be linearized so that the linearity of the output voltage vs. temperature curve is better than $\pm 1/2\%$ of full scale over the range from 5°C to 130°C .

5.2.2.7 Bridge power supplies shall be of simple, all solid state, design with a nominal output of 16 volts. Their output characteristics shall be consistent with the overall system performance criteria, paragraph 5.2.11.

5.2.2.8 A switch shall be provided on the PRAAM assembly to permit removal of any one of the five bridges from the measuring circuit. At least four bridges shall be connected at all times to maintain broad geometric coverage of the reactor.

5.2.2.9 A push-button transient test switch shall be provided in each bridge circuit which will momentarily change the bridge balance. This feature will provide a quick check of all of the components in that bridge and all of the system's following computing circuits including a rough check of the over-all system gain and response times.

5.2.2.10 A low pass filter shall be provided between the output of each bridge and the averaging circuits to reduce sensitivity to "prompt neutron jump" and other short duration transient effects.

5.2.3 Averaging Circuit

A circuit shall be provided which averages the output of the five individual bridges, providing a signal proportional to reactor power level.

5.2.3.1 The circuit shall be capable of averaging the outputs of five or four bridges. Bypassing of a bridge shall not disturb the averaging function.

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5.2.3.2 A "level meter" circuit and meter showing the average voltage output of the bridges shall be provided on the PRAAM chassis for maintenance purposes. The meter circuit shall have continuously adjustable span and zero controls. The meter zero adjustment will allow correction to be made for such effects as the increase in effluent temperature (at zero reactor power level) which is caused by a rise in the inlet water temperature. The meter span adjustment will allow correction to be made for such effects as the increase in effluent water temperature which results (with no change in reactor power level) from an allowed reduction in process water flow. The effect of these adjustments shall be limited to $\pm 10\%$ of the full-scale span when both are adjusted to their midpoint setting.

5.2.3.3 With constant RTD resistances of approximately 90 ohms, drift of the output of the averaging circuit as a function of the ambient temperature of the instrument shall be less than 0.2% per degree C.

5.2.3.4 The averaging circuit shall not introduce an error into the indicated rate of more than $\pm 0.5\%$ of FSD.

5.2.3.5 The power level signal to the rate circuits shall have a span control with a range of about $\pm 8\%$ in conjunction with the step values available for the differentiating capacitors (see No. 5.2.4.2) will allow for continuous adjustment of the rate sensitivity of the rate measuring circuits over the entire range of adjustment and assure that all sensitivity values will be attainable despite variations in the capacitance of these capacitors within their manufacturing tolerances.

5.2.4 Rate Circuits

Circuits shall be provided which develop an output signal which is proportional to the rate of change of the power level signal.

5.2.4.1 The output signal from the power level (bridge averaging) circuits shall be passed through a low pass filter with a 0.4 second time constant before it is applied to the derivative taking (rate measurement) circuits.

5.2.4.2 Polystyrene capacitors rated for 100 volts shall be used in the derivative circuits. Provision shall be made so that suitable connections will provide capacitance values of 8, 10, 12, 14, 16, 18 or 20 microfarads. Polystyrene capacitors are required for this application because of their extremely high leakage resistance and their desirable dielectric absorption characteristics.

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- 5.2.4.3 The rate amplifier output shall be capable of driving at least two parallel-connected meters with one milliamperere movements. (See paragraph 5.27 for rate meter).
- 5.2.4.4 The rate meter zero shall be "live" and located at mid-scale.
- 5.2.4.5 Open or short-circuiting one of the rate meters shall not cause more than a 1% of FSD change in the rate indication of the other meter.
- 5.2.4.6 The rate amplifier shall be linear within $\pm 1\%$ of full-scale rate meter signal.
- 5.2.4.7 The rate amplifier's time constant shall be 1.5 ± 0.2 second. This value will help eliminate undesirable effects from the "prompt neutron jump" and also reduce the noise level in the amplifier.
- 5.2.4.8 The design of the "rate taking" circuit shall allow reduction of its time constant by as much as 0.8 second by simple substitution for one resistor. This change shall have no effect on the accuracy or stability of the PRAAM.
- 5.2.4.9 The amplifier's stability shall be consistent with over-all system stability requirements (see paragraph 5.2.11.).
- 5.2.4.10 Built-in current sources shall be provided to check the dc gain of the amplifier.
- 5.2.4.11 Circuit design shall make selection of transistors or electrometer tubes for special beta or transconductance values unnecessary and allow complete interchangeability between these components within the specified type numbers.
- 5.2.4.12 The performance of the circuit supplying the bias signal that is required to develop a "live" zero meter signal shall be consistent with the over-all operating requirements of the ratemeter with respect to temperature, humidity, line voltage variation, momentary loss of power, accuracy, and stability.
- 5.2.4.13 A rate signal output shall be provided which is suitable for operating a potentiometric recorder.
- 5.2.4.14 Shorting or grounding of the PRAAM's recorder output terminals shall not affect the accuracy of the trip function by more than 1% of FSD.

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5.2.4.15 The amplifier and ratemeter shall recover in less than 15 seconds from overloads caused by rates equal to 10 times those which would produce full-scale deflections in either the plus or minus directions.

5.2.5 Trip Circuit

A circuit shall be provided which will trip for rate signals above an adjustable set value.

5.2.5.1 The trip setting shall be continuously adjustable between the rates of $+100 \pm 10$ and $+295 \pm 10$ MW per minute. The 295 value is determined by reactor safety requirements and trip settings below 100 are unacceptable because excessive unnecessary scrams would result. Adjustment of the trip setting shall be by means of a potentiometer mounted on the front panel of the PRAAM assembly, adjacent to the rate meter. The potentiometer shall be secured against inadvertent shifting (see paragraph 5.6.5).

5.2.5.2 At the instant a trip action occurs, the trip setting and the measured rate which are indicated on the dual-indicating meters shall agree within 1% of the FSD. This quality of agreement is required to gain and maintain the reactor operator's confidence that, as long as he operates the reactor at indicated rates a reasonable margin below the indicated trip point, the system will not shut the reactor down unnecessarily.

5.2.5.3 The trip setting shall be stable within $\pm 2\%$ FSD.

5.2.5.4 A step change in the rate signal current (input to the trip function) from 0.9 times the trip current to 1.1 times the trip current shall effect a trip action in less than 0.1 second.

5.2.5.5 The trip unit shall be "fail safe" (i.e. shall provide a trip signal to the logic matrix) for normal component failures such as open resistors, open- and shorted-capacitors, diodes, etc., for a short across the element which holds the relay in its energized state, and for loss of power supply.

5.2.5.6 The trip relay shall be non-latching and shall reset with a signal hysteresis less than 0.4% of FSD.

5.2.5.7 The trip relay shall be a telephone type relay with a nominal 0.5 watt coil and four Form C contacts rated for a 4 ampere 450 watt ac resistive load current. One set of Form C contacts shall be used to energize indicating lamps on the PRAAM front panel. The other contacts shall be utilized for safety circuit or annunciation purposes. These relays were selected because of their previous satisfactory safety circuit performance in High Level Flux Monitor Controllers.

5.2.5.8 The trip setting shall be indicated at all times on both the PRAAM panel-mounted meter and on the meter at the reactor operator's console.

5.2.6 Annunciators and Trouble Lights

5.2.6.1 A trip on any PRAAM channel shall be annunciated and displayed on the reactor operator's annunciator panel and on the PRAAM panel (see 5.2.5.7 above).

5.2.6.2 Blown fuse indicators shall be provided for all fuses.

5.2.7 Power Rate Indicators

Each PRAAM channel shall include two panel meters to indicate the power rate - one located at the PRAAM chassis, the other at the control console.

5.2.7.1 Each meter shall consist of two co-axial meter movements - one to indicate the power rate and the other to indicate the trip setting. The deflection vs. current curves of the inner movements shall be linear (within $\pm 1.5\%$ of FSD) of the best straight line drawn through the plotted calibration data in the range from 50% to 100% of FSD.

5.2.7.2 The two meter movements shall have a tracking accuracy (including hysteresis of the movement driving the outer indicator) of $\pm 1\%$ of FSD everywhere in the range from + 80 to + 300 MW/Min. Tracking accuracy refers to the agreement between the reading of the two pointers when the two movements are driven by equal currents and can best be defined by the way it would be measured. A variable current source (and a current measuring system with at least one order of magnitude higher accuracy than that of the meter movements) would be used to slowly increase the current through the rate meter winding (driving the inner pointer) to a test value which produces a reading between + 80 and +300 MW/min. The meter reading would be recorded as R1. Next the current through the trip setting winding (driving the outer pointer) would be slowly increased to the same test value and the meter reading recorded as R2. Finally the current through the trip setting winding would be increased at least 10% of FSD above the test value and then slowly decreased to the test value. This meter reading would be recorded as R3. Tracking accuracy of $\pm 1\%$ FSD would mean that neither R2 minus R1 nor R3 minus R1 could be greater than $\pm 1\%$ of FSD.

The range from 80 to 300 MW/min covers the possible trip settings. The close agreement of the two indicators is required so that a reactor operator can be sure that, as long as he keeps the

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rate-of-rise a reasonable amount below the trip setting, he will not be shut down because of measuring system accuracy or tolerance problems. Only the increasing reading of the rate meter pointer is considered because a trip will always be approached from a lower power rate-of-rise.

5.2.7.3 The meters shall have nominal 1 milliampere (full scale) d'Arsonval moments.

5.2.7.4 The meters shall be nominal 3-inch diameter instruments with approximately 250 degree full-scale angular deflection.

5.2.7.5 The meter scale shall be black on white and conform to Figure 2 (page 12).

The locations of the primary markings expressed as a percent of the maximum rotation obtainable shall be as follows:

Point	%
Amplifier Zero	0
-300	10
-200	23 1/3
-100	36 2/3
0	50
+100	63 1/3
+200	76 2/3
+300	90
Test Red	100

5.2.7.6 Each meter movement shall be equipped with a mechanical zero adjustment.

5.2.7.7 The trip setting pointer shall be red and the rate measurement pointer shall be black.

5.2.8 Rate Recorder

A three-pen, potentiometric, strip-chart recorder shall be installed in each control room in close physical proximity to the PRAAM and RAGE chassis to provide a continuous record of the output of each PRAAM channel.

5.2.8.1 The chart width shall be 4" minimum and 12" maximum.

5.2.8.2 The sensitivity and calibration shall be such that the signal driving the rate meters is recorded with an accuracy of $\pm 1/2\%$ of full-scale deflection.

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- 5.2.8.3 The recorder shall incorporate "differential" input design allowing both input terminals to each recorder channel to be floated at least 50 volts away from ground potential.
- 5.2.8.4 The three recorder channels shall be independent and there shall be no interaction between them.
- 5.2.8.5 The scale and chart graduation shall be as shown in Figure 3 (page 12).
- 5.2.8.6 Chart speeds of 2 inches/hr. and 1/2 inch/min. shall be available. Changing of chart speed shall be simple and rapid such as by throwing a switch or moving a lever. Replacing of gears shall not be required. The slower speed was selected to provide adequate definition on a continuous recording while permitting a reasonable chart replacement schedule. The faster speed was selected to provide useful traces for such test cases as time constant determinations and observations of the reactor short term (transient) power excursions.
- 5.2.8.7 The ink capacity of the pens shall be sufficient for 30 days operation.
- 5.2.8.8 At least 4 inches of "history" shall be visible without unrolling the chart.

5.2.9 Safety Circuit Action

A scram signal from the logic matrix shall de-energize the Linear Rate Master Relays (see Figure 4, page 20) thus breaking the Number 1 safety circuit to scram the reactor.

- 5.2.9.1 The logic shall be accomplished by proper interconnection of the trip circuit output relays of the three individual PRAAM channels (Ref. Sec. 5.2.5.7)
- 5.2.9.2 Arc suppression shall be provided to protect the relay contacts used in the safety circuits. Techniques used shall be those which have been demonstrated to be satisfactory by HAP0 development and operational experience.
- 5.2.9.3 To the maximum extent possible, failure of components shall not result in an unsafe (i.e., failure to scram on demand) operating conditions.
- 5.2.9.4 Relays shall always be used so that the de-energized position is equivalent to a trip or scram signal.

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A, B, & C - Contacts on the Trip Relays of PRAAM Channels A, B, & C respectively. These contacts are closed during normal operation and open when the channel trips.

BP - Contacts on the Bypass switch. Open during normal operation, closed on "Bypass".

INT - Interlock contacts. Open when power level is greater than 2 MW. Closed below 2 MW.

LRR & LRRA - Linear Rate Master Relays.

IXX and IXXA - #1 Safety Circuit Master Relays

FIGURE 4

SCHEMATIC DIAGRAM OF LOGIC MATRIX AND
SAFETY CIRCUIT CONNECTIONS

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5.2.9.5 The action of the logic circuit shall be to interrupt the current to the Linear Rate Master Relays which shall have contacts in the Number 1 safety circuit and to thereby initiate a scram when two of the three PRAAM channels are tripped at the same time.

5.2.9.6 A trip on a single PRAAM channel without a concurrent trip on one of the other channels shall not cause a scram.

5.2.9.7 When a tripped channel resets for any reason (i.e., measured rate drops below the trip setting, a bypass is removed, the set point is changed, etc.), the logic circuits shall reset so that a subsequent single channel trip on another (or the same) channel shall not cause a scram signal.

5.2.9.8 The Master Relays shall be specific models which have previously demonstrated suitable reliability in Hanford reactor safety circuits.

5.2.9.9 Design of the Safety Circuit modifications shall be consistent with the requirements of CGI-966 - Safety Circuit Trip Identification and shall permit identification of exactly which two of the three channels caused the scram.

5.2.10 RAGE (Ramp GEnerator)

An instrument (RAGE) shall be provided to test the performance of the individual PRAAM channels.

5.2.10.1 The output of the RAGE shall be a changing voltage signal suitable for use in the PRAAM as the input to the averaging circuit instead of the output of the bridges.

5.2.10.2 The range of the output voltage of the RAGE shall be from -2.5 volts to 0 volts.

5.2.10.3 The rate of change of the output voltage shall be continuously adjustable between zero and ± 4 mv/sec.

5.2.10.4 At constant ambient temperature, the ramp rate, once adjusted and after a half hour warmup time, shall be stable within $\pm 1 \frac{1}{2}\%$ of FSD.

5.2.10.5 In order to obtain precise, repeatable selection of values, the rate shall be set with a ten-turn potentiometer equipped with an indicating dial.

5.2.10.6 An adjustment shall be provided to allow the ramp to commence at any voltage level between -2.5 volts and 0 volts.

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5.2.10.7 Provision shall be made to interrupt the ramp at any time with a push-button switch. This feature provides a convenient means of determining the time constants of the PRAAM circuits. Release of the button shall allow the ramp to continue from the voltage at which it was interrupted.

5.2.10.8 A meter shall be provided which shows the voltage at the output of the RAGE. The pointer shall move from left to right as the voltage increases from more negative (lower equivalent power level) values to more positive ones.

5.2.10.9 The meter shall be graduated in terms of actual output voltage rather than equivalent power because the relationship between power level and voltage is not fixed but changes as a function of the individual reactor under consideration and of the inlet water temperature and the coolant flow rate.

5.2.11 Composite System

5.2.11.1 The rate zero, as indicated by the Recorder, shall not drift more than $\pm 1\%$ of FSD because of environmental changes with the limits defined in Section 5.4 with the exception of paragraph 5.4.3.5 (intermittent loss of power).

5.2.11.2 The rate error, as calculated from the following tests, shall not exceed $\pm 2\%$ as a result of the environment changes delineated in 5.2.11.1 above. The error in the average amplifier output shall be determined by replacing the RTD's with dummy resistors of 100 ohms each, varying the environment and measuring the changes in the average amplifier's output. The error in the rate amplifier output shall be measured by driving the rate amplifier input with a full scale ramp, varying the environment, and measuring the rate amplifier output.

5.2.11.3 The overall system incorporates several design features to facilitate adjustment of the time constants of the various sub-systems. The overall system time constant will, therefore, also be variable. The range of adjustment of the system time constant shall be from 4 seconds to 7.5 seconds.

5.3 Reliability and Operational Life

The mean time to failure of the system, exclusive of the RTD's and their integral cables, shall be greater than 10,000 hours. Assemblies shall be designed and components selected for an expected life, with a 90% confidence level, of at least 15 years. These figures are exclusive of failures of replaceable filamentary devices such as indicating lights and allowed electron tubes. The only allowed electron tubes shall be one electrometer tube each in the PRAAM channels and the RAGE. The RTD and cable assemblies shall have a design life of

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5 years; i.e., choice of materials, design parameters, etc., shall be based on 98% survival of all units for a period of 5 years under the conditions specified.

The reliability required of the equipment specified herein is in part defined by an applicable portion of Mil-N-19900A extracted:

"3.1.1 Reliability

It is imperative that reliability of operation be considered of prime importance in the design and manufacture of the equipment. The manufacturers shall employ all reasonable methods possible in the process of manufacture which will assure quality and maximum reliability consistent with the state of the art. In the functional application of parts of equipment circuits, adequate factors of safety shall be provided by suitable deratings from the part specification values where required in order to insure high equipment reliability under all service conditions. The design shall include all possible features which will result in reliable and stable operation with reduced requirements for adjustment and alignment, reduced frequency of failure, reduced requirements for maintenance, and simplified maintenance; thus reducing requirements for highly skilled maintenance personnel."

5.3.1 Component Derating

The allowed electrometer tubes shall be derated from the manufacturer's specification, exclusive of filament requirement, at least 50% on power requirement and 25% on voltage and current. All capacitors shall be derated from the manufacturer's voltage specification by at least 50% except electrolytics which shall be derated by at least 20%. All resistors shall be derated from the manufacturer's nominal specified power ratings by at least 50%. All transistors, diodes, and other solid state components shall be derated at least 40% of both voltage and current ratings.

5.3.2 Component Quality

All components shall comply with the specification requirements of Mil-T-945A, Revision 2; however, no source inspection of components is required.

5.3.3 Plug-In Modules

Plug-in modules shall use redundant pin connections for all terminals. As a minimum the following sub-assemblies shall be fabricated as separate modules:

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1. PRAAM averaging amplifier
2. PRAAM rate amplifier
3. PRAAM output reference channel
4. RAGE amplifier

5.3.4 Construction Practice

The equipment, including all parts and accessories, shall be constructed and finished in a thoroughly workmanlike manner. Particular attention shall be paid to neatness and thoroughness of soldering, wiring, impregnation of coils, marking of parts and assemblies, plating, painting, riveting, machine-screw assemblage, welding and brazing, and freedom of parts from burrs and sharp edges.

5.4 Environment

The performance criteria of Section 5.2 shall be met with any combination of the physical and electrical environments of this section unless specifically excepted.

5.4.1 Temperature

5.4.1.1 Operating Ambient Temperature: 20°C (68°F) to 50°C (122°F).

5.4.1.2 Storage Temperature (non-operating): -30°C (-22°F) to 60°C (140°F)

5.4.1.3 Integral Cabled RTD Operating Temperature: 20°C (68°F) to 150°C (302°F).

5.4.2 Humidity

Relative humidity operating or non-operating: 10% to 80%, except for RTD and its integral cable which shall be 10% to 100%.

5.4.3 Power Supply

The system shall operate from a nominal 117 volt, single phase, 60 cps supply. The criteria shall be met for any combination of the following deviations unless specifically excepted.

5.4.3.1 Gradual (slower than 1 volt per minute) voltage excursions of 8 volts to -12 volts from 117 volts ac during a 24 hour day.

5.4.3.2 Gradual (rates-of-change of frequency less than 0.5 cps per minute) frequency deviations from 60 cps of +0.5 cycle per second to -1.5 cycle per second.

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5.4.3.3 Line voltage transients consisting of step changes of 5 volts to (and from) any voltage value in the range from 105 to 125 volts.

5.4.3.4 Line voltage transients of 50 volts or less (plus or minus) which have a duration of one millisecond or less.

5.4.3.5 Intermittent (less frequent than once per minute) loss of ac power supply for periods of 4 cycles (67 milliseconds) or less shall not cause the individual channel alarm functions to trip if the following conditions existed prior to the power interruption:

- a) Power rate of change was zero.
- b) The trip setting of the alarm function was set at 100% of the positive full-scale rate.

The system should meet all performance and accuracy requirements within 30 seconds after such a power interruption.

5.4.4 Electrical Interference

The system shall be designed to operate satisfactorily without spurious alarm indications in the presence of radiated and conducted electrical interference such as encountered in the vicinity of portable electric hand tools and heavy electrical noise when the electrical equipment and tools are using the same power source. It shall comply with Mil-N-19900A as extracted:

" 3.3.62 Susceptibility

The equipment shall be designed to minimize susceptibility to interference from other sources. The enclosing case construction shall be designed not only to minimize interference propagation, but also to minimize pickup from external sources. Where conducted energy on the power leads or any external leads might cause interference, the leads shall be isolated from other leads to avoid coupling and where necessary, shall have line filters or capacitors at their entry into the enclosing case. Low level signal circuits shall preferably be of low impedance or of balanced (to ground) design so that coaxial or other shielded lines can be used to insure an interference free installation. Routing of low level signal circuits within the equipment shall be so designed and installed that interference is not picked up from power or control leads due to common conductive paths with other circuits, or with the enclosing case ground path."

5.4.5 Radiation

The system assemblies and components shall meet all performance criteria while subjected to the maximum dose rates tabulated below and after receiving the total accumulated dosages tabulated below:

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	Max. Dose Rate		Total Dose	
	Gamma	Neutron	Gamma	Neutron
	(R/hr)	(nv)	R	(nvt)
RTD's	2000	10^6	10^8	10^{12}
Cable in Integral RTD-Cable Assy.	200	10^6	10^7	10^{12}
Cable Between Junction Box and Control Room	0.1	10^4	10^4	10^9
Assemblies and Components Located in the Control Room	0	0	0	0

5.4.6 Mechanical Shock

Neither the system's performance nor the PRAAM or RAGE assemblies' performance shall be affected if these assemblies are shocked by raising any one side of the chassis, from its normal operating plane, three inches above a concrete floor or slab and dropping it. Meter movements are excluded from this requirement.

5.5 Safety

5.5.1 Fail Safe Philosophy

To the maximum extent possible, failure of any component or circuit of a channel - whether by short circuit, open circuit, by change of component characteristics, or by any other reasonably possible event or effect - shall result in the same trip action as would be produced by an over-limit power rate-of-rise.

5.5.2 Equipment Protection

Since the system is to be incorporated into the safety circuit, special attention should be given to the design of protective covers and incorporation of necessary fuses and circuit techniques to minimize the possibility of accidental damage to the equipment or circumvention of its functional intent.

5.5.3 Personal Safety

5.5.3.1 All equipment shall be so constructed that personnel cannot come into accidental contact with voltages in excess of 24 volts while operating or putting the equipment into operation.

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- 5.5.3.2 Safety covers and warning notices shall be provided for exposed potentials in excess of 24 volts at all locations except the undersides of the PRAAM and RAGE chassis.
- 5.5.3.3 Plugs and chassis connectors, when disconnected, shall not expose "hot" leads.
- 5.5.3.4 All control shafts and shaft bushings shall be grounded.
- 5.5.3.5 Three-wire, grounded 120 volts ac power connections shall be used and shall be color coded: green-ground, black-hot, white-neutral. Power connections shall be in accordance with Hanford Standard D-20-24, 15 amp-120 volt receptacle for instrumentation.
- 5.5.3.6 Chassis bottom covers shall be provided on the PRAAM and RAGE which can be removed when they are extended (on chassis sliding assembly) while mounted in their 19-inch racks. In addition, dust covers must be provided over any portions of the chassis where accumulations of dust might, in time, effect the performance of the system or an electrical shock hazard exists.
- All covers shall be held in position by a minimum number of screws which screw into captive nut assemblies mounted on the chassis. Access holes must be provided through chassis bottom covers and/or top dust covers as required so that routine (less than thirty days) calibrations and adjustments can be made without the removal of any covers.
- 5.5.3.7 Good construction practice (see 5.3.4) shall be followed to minimize the possibility of cuts, scratches, or other injuries to personnel.

5.6 Electronic Assembly Mechanical Design Criteria

5.6.1 Panel Size

The PRAAM and RAGE assemblies shall be suitable for mounting in a standard 19 inch instrument rack.

5.6.2 Panel Layouts

Front panel layout of rack-mounted equipment shall be designed for simplicity of operation.

5.6.3 Finish and Engraving

The normally visible front panel of rack-mounted equipment, excluding meters, control accessories, etc., shall have smooth

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non-gloss finish which will remain in good condition for ten years when exposed to the environmental conditions of Section 5.4.

In addition, all front panel markings shall be engraved and filled with an enamel which contrasts with the front panel finish. The use of standard abbreviations on the front panel to indicate switch or control functions shall be consistent with usual Hanford practice.

5.6.4 Chassis Mounting

The PRAAM and RAGE chassis shall be constructed to use -- and shall be equipped with -- chassis slide assemblies for mounting in a standard 19 inch rack which will allow the following:

- a) The chassis to be pulled straight out for a minimum distance of 16 inches for service and adjustments without detachment from the 19 inch rack or cable connectors.
- b) A quick disconnect feature which will allow the assemblies to be removed from the 19-inch rack chassis slide assembly directly at the point of use after disconnecting the attached cables.

5.6.5 Controls and Adjustments

All chassis-mounted controls or adjustments shall be accessible from the top or side of the chassis and their adjustment shall not require the removal of more than one dust cover or removal of the assembly from its 19 inch sliding rack mountings. In addition, all adjustments shall be secured against inadvertent shifting. This may take the form of switch detents or friction shaft locks.

The function of all controls and adjustments shall be identified as to their function by permanent marking on the chassis or panel, immediately adjacent to their location.

Zero or calibration adjustments shall not be adjustable by the use of fingernails, thin dimes, etc., but shall require the use of some standard tool. A recessed screwdriver adjustment is acceptable.

5.6.6 Maintenance Features

5.6.6.1 Test points shall be provided for the logical testing and trouble shooting of assemblies. All test point and major components such as receptacles, transformers, tubes

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transistors and components of special significance shall be identified adjacent to the part. All printed circuit boards shall either be accessible from both sides for trouble shooting and component replacement or shall be of the plug-in module type using redundant pin connections (see Sec. 5.3.3).

5.6.6.2 Provision shall be made to prevent damage to equipment or injury to personnel resulting from accidental grounding of test points by terminating all test points with pin jacks.

5.6.6.3 All adjustments must be labeled as related to their function alongside the adjustment in the chassis and alongside any access hole provided on any removable covers.

5.6.6.4 A reference number, such as the electrical schematic drawing number or the CVI (Certified Vendor Information - previously called BPF) file number shall appear on the front panel of the PRAAM and RAGE assemblies to facilitate location of reference data when maintenance is required.

5.7 Bypass

One bypass switch shall be provided. It shall be a key-locked switch located on the control room's by-pass panel. Its contacts, in series with the interlock contacts (see paragraph 5.8 below), shall bypass all of the contacts of the logic matrix. Its contacts shall be normally open and shall be closed when the switch is in the bypass position. See Figure 4, page 20. Operation of any control switches which can effectively bypass a PRAAM channel shall produce an effect in the logic matrix equivalent to a trip of that channel.

5.8 Interlocks

An interlock shall be provided (see Figure 4) to negate the effect of the bypass switch when the reactor power level is greater than 2 MW. It shall function in the same manner as the present flux monitor-pressure monitor interlock and shall utilize contacts on the relays which presently prevent passing of the pressure monitor trips contacts above 2 MW.

5.9 Installation Criteria

5.9.1 RTD's (With Integral Cable)

5.9.1.1 RTD's shall be so located that neither they nor their integral cables interfere with the normal reactor rear face operations or maintenance.

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5.9.1.2 Each RTD shall be installed in a fitting in the effluent water system so that it measures the temperature of effluent from a single process tube.

5.9.1.3 Leakage between a fitting and its properly installed RTD shall be less than one drop per five minutes of 95°C water with a static test pressure of 30 psig.

5.9.1.4 The installation shall permit replacement of RTD's without opening any other joint in the effluent water system.

5.9.1.5 The RTD shall be so oriented that the cable leaves the installed RTD in a generally downward direction so that water falling on the assembly drains away from the junction between the cable and RTD.

5.9.1.6 The cable, after looping down from the RTD, shall proceed to the top of the reactor in the space between the reactor rear face and the rear cross headers and then leave the rear face area through a suitable penetration above the top of the reactor.

5.9.2 Junction Box and Signal Cables

5.9.2.1 The integral RTD cables shall be terminated on terminal boards in a junction box located near the top of, but outside of, the rear face work area. Provision shall be made to keep the interior of this junction box and any ducting to it clean and dry.

5.9.2.2 Cables from the junction box to the control room shall be terminated with connectors which plug directly into the PRAAM chassis. No other unsoldered connections will be permitted. Cables and individual wires shall be marked with permanent identification code letters and/or numbers at both their control room and junction box termination.

5.9.2.3 Cables to the control room shall not be installed in the same ducts with power circuits. The installation shall be designed to minimize the pickup of radiated interference by the RTD signal cables.

5.9.2.4 The sensing circuits shall be designed as an ungrounded system. The installation shall minimize the potentiality for inadvertent system grounding either by accident or wear. After installation, the resistance to ground of each RTD circuit when measured at the connector which normally plugs into the PRAAM chassis shall be greater than 500 megohms when measured with a 50 volt dc power source.

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5.9.3 PRAAM and RAGE

5.9.3.1 In addition to the requirements of Section 5.6, the components shall be so arranged that adequate clearance is available for servicing (including replacement of complete assemblies) both in front and behind the panel.

5.9.3.2 If possible, all assemblies should be mounted in the same relay rack and in any case the three PRAAM chassis shall be contiguous vertically.

5.9.4 Console Meters

5.9.4.1 The physical arrangement of the console meters with respect to one another should be the same as that of the PRAAM chassis.

5.9.4.2 The meters shall be so arranged that they are well lighted and easily viewed by the console operator.

5.9.4.3 Physical arrangement shall allow replacement of any of the three meters without disturbing either of the other two meters or other console equipment.

5.9.5 Recorder

The recorder shall be installed close to the PRAAM chassis. The installation shall comply with applicable Hanford Standards (see Sec. 4.2).

B. W. Herrman

B. W. Herrman
Reactor Design
Design Engineering Subsection
Facilities Engineering Section

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DESIGN CRITERIA
LINEAR POWER RATE-OF-RISE INSTRUMENTATION

PREPARED BY

B. H. Herrman

Reactor Design
Design Engineering
Facilities Engineering Section

APPROVED BY

E. H. De

Supervisor, Reactor Design
Design Engineering
Facilities Engineering Section

Date 12-27-63

PROGRAM REPRESENTATIVES CONCURRENCE

Date: Dec. 20, 1963

B. H. Herrman

Reactor Design
Facilities Engineering Section

R. M. Long

Instrument and Electrical Development
Facilities Engineering Section

C. Simsen

Project Engineering
Facilities Engineering Section

N. T. Hildreth

Reactor Physics
Research and Engineering

H. D. Hamilton

Plant Engineering - Instruments
Manufacturing Section

DESIGN COUNCIL CONCURRENCE

Date: 1-16-64

H. De

FACILITIES ENGINEERING SECTION

O. H. Greager

RESEARCH AND ENGINEERING SECTION

Q. H. Greager

MANUFACTURING SECTION

AEC CONCURRENCE

Date: 6-18-64

C. R. Qualheim

R. L. Plum, Chief
Production Reactor Operations Branch
Production Division

for

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DATE

FILMED

8/4/94

END