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PRELIMINARY ENGINEERING STUDY
LINEAR POWER RATE-OF-RISE INSTRUMENTATION
B, C, D, DR, F, H AND KE

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B, C, D, DR, F, H AND KE

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PRELIMINARY ENGINEERING STUDY
LINEAR POWER RATE-OF-RISE INSTRUMENTATION
B, C, D, DR, F, H AND KE

1.0 INTRODUCTION

When the "stop-gap" rate-of-rise meter was installed on all 8 reactors by Amendment 1 to CGI-806 it was intended to replace it with a more satisfactory design when possible. Successful completion of the development program now permits installation of equipment of sufficient reliability to be utilized in the safety circuit.

2.0 PURPOSE

This document defines the program necessary to provide power rate-of-rise protection in the safety circuits of B, C, D, DR, F, H and KE Reactors, provides justification for the project, and presents estimates of the cost and schedule required to accomplish the program.

3.0 CONCLUSIONS

- 3.1 Three channels of PRAAM (Power Rate Alarm And Monitor) should be installed in B, C, D, DR, F, H and K E Reactors and incorporated into the safety circuits.
- 3.2 A RAGE (RAMP GEnerator) test instrument should be installed in each reactor.
- 3.3 Each channel should sense the output of five pairs of RTD's so located that they obtain a good geometric sample of the effluent temperature.
- 3.4 A two-out-of-three channel coincident trip circuit should be used in the safety circuit.
- 3.5 The present "stop-gap" rate-of-rise instrumentation should be removed.
- 3.6 GE should manage the program and perform the detail design of PRAAM, RAGE, and the safety circuit modifications. The AE should perform the installation design under GE's technical guidance.
- 3.7 Procurement of PRAAM and RAGE should be by competitive bids on detail design drawings and specifications.
- 3.8 Procurement of recorders should be by competitive bids to a functional specification.
- 3.9 Procurement of the RTD's should be by competitive bids to the latest HAPO functional specification.

- 3.10 The proposed program is estimated to cost \$450,000.
- 3.11 The proposed program is estimated to be completed 24 months after the AEC authorization of the project.
- 3.12 If the High Speed Scanner Project is approved for KE Reactor, KE should be deleted from this program.

4.0 DISCUSSION

4.1 STATEMENT OF PROBLEM

A study by R&EO of the basic considerations for providing reactor and nuclear safety protection from instruments that measure power level resulted in HW-72555, "Development and Application of Principles of Nuclear Safety Instrumentation." (1) This document discusses the function of level and rate instrumentation for the protection of Hanford reactors and describes the inter-relation of instrument safety systems, geometric considerations, and time response characteristics.

HW-72591(2) and HW-75672(3) the results of detailed R&EO studies, define actual limits on power rate and power level which are compatible with one another and which should be incorporated into an automatic protection system. These studies show that an adequate safety system must include both rate-of-rise and absolute power level protection in the heat generation region of operation (10^{-2} to 10^0 times equilibrium power level).

At the present time, no power rate instrument, operating in the 10^{-2} to 10^0 power level range, is utilized in the safety circuit and strict operating procedures (step by step resetting of the flux monitor trip points) are used to back up process control instrumentation to achieve the function of rate protection. By utilizing advanced technology now available, this reliance upon procedural control during operation can be eliminated as recommended in reference 1.

In KW Reactor the automatic rate protection will be provided by the High Speed Scanner, Project CGI-967. The program outlined herein provides automatic rate-of-rise protection for B, C, D, DR, F, H and KE Reactors. This program also provides continuous display of the power rate information at the operator's console which will not be provided by the High Speed Scanner. Both Systems provide for continuous recording of their rate signals.

4.2 BACKGROUND

4.2.1 Present Procedure

At the present time, rate-of-rise protection is provided in the heat generation range of reactor operation by procedural resetting of the flux monitor trip and by procedural monitoring of tube outlet temperatures. As flux distribution changes and as the power level changes, the trip points of the flux monitor are reset to 110% of the actual high level reading thereby minimizing potential rates-of-rise prior to a scram.

4.2.2 Development History

A more complete summary of the development history is contained in reference 4. The original criteria for a linear-rate-of-rise instrument were defined in 1957.⁽⁵⁾ Two experimental instruments based on this criteria were tested by EDO in 1958. One of these used the octant chambers and the other used RTD's as signal sources. While these instruments utilized the best amplifiers commercially available at that time, they did not meet the reliability requirements of reference (5).

In 1958, Revision I to Project CGI-806 initiated a "stop-gap" power rate-of-rise meter for all areas. As such it was to provide, as soon as possible, a means of obtaining rate information. It was never intended to be either a permanent installation or a component of the safety circuit. The "stop-gap" instrument used RTD's as a signal source and was installed in all areas except "C" by late 1960 and in C Area by late 1962. Operation of these instruments has been satisfactory with the majority of the problems centering in the RTD's and cables. The problems resulted from high moisture in the rear face environment, physical damage to the connectors during normal outage work, poor sealing of the RTD connector, and inadequate sealing and purging of the rear face RTD cable duct. Despite the existence of these problems, several of the older areas, by maintaining rigid maintenance practices, presently obtain satisfactory rate meter operation.

A more advanced prototype, utilizing octant chamber signals and including high level trip channels and two experimental rate circuits was installed in KE in July, 1962. Data from this system⁽⁴⁾ indicate that a system which could meet the requirements for inclusion in the safety circuits would require at least two additional octant chambers at each corner of each reactor. (Sixteen additional chambers per reactor, minimum.) While this alternative is technically feasible, it is impractical economically.

Equipment Development therefore concentrated further work on a system utilizing RTD's. Summarizing all of their development experience to that time, EDO established new, more rigorous, and more detailed design criteria for an RTD type rate meter. After considerable laboratory proof testing, a prototype of one complete channel was installed in 105-DR and by April of 1963 had clearly demonstrated its fine performance.

Culminating this effort, a prototype was fabricated by EDO which incorporated the features that they had found were required in an instrument to be installed on production reactors. This prototype was essentially completed in March 1963 and has since been subjected to continuous proof testing in 1713-D and on-reactor. It presently is running continuously in 1713-D accumulating endurance time. On September 26, 1963, it had operated 5800 hours without a malfunction.

4.3 PROPOSED SOLUTION

4.3.1 Physical Description of the Proposed System

In each reactor, three independent channels will monitor the rate at which power level is changing in the 10^{-2} to 10^0 (equilibrium) power level range. Each channel will utilize five pairs of RTD's; arranged in a pattern similar to that shown in Figure 1 (page 3) so that a representative outlet water temperature is obtained. For each pair of RTD's, a third RTD would be installed as a spare. The PRAAM will include switches to replace any failed RTD with its installed spare.

In each reactor a RAGE test instrument will be installed in the control room to provide signals which change at adjustable rates. These test signals could be plugged into any one of the three PRAAM channels to verify or adjust their calibration and to perform necessary trouble shooting.

Each channel of PRAAM will have a trip circuit which will alarm above a pre-determined power rate-of-rise and two dual-indicating meters - one on the chassis and the other remotely located at the control console. One meter pointer will indicate the trip setting and the other will indicate the measured power rate.

The trip circuits of the three channels will be connected through a two-out-of-three logic matrix into the #1 safety circuit. Simultaneous trips on two of the three channels would therefore scram the reactor whether the trips were caused by excess indication, by-passing, or equipment or power failure.

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HW-78840 RD

FIGURE 1

BLOCK DIAGRAM OF LINEAR POWER RATE-OF-RISE SYSTEM

The outputs of all three PRAAM channels will be recorded on a three-pen potentiometric recorder located near the instrument chassis.

New RTD's will be installed in Y fittings on the rear face of the six old reactors. In KE extra RTD's will be installed in special nozzle elbow fittings for the 45 tubes selected. "Connector-less" 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 PRAAM chassis in the control room.

4.3.2 Procurement Plan

The most critical procurement items will be the PRAAM and RAGE instruments. Detail design drawings (schematic and physical layout) and specifications for these items will be prepared by GE Engineering based on the design developed and proven by the Instrument and Electrical Development Operation. Competitive bids will then be asked for parts to the drawings and specification. Since the articles will not be designed by the vendor, performance can not be specified as a vendor responsibility.

A production prototype of both PRAAM and RAGE should be obtained, tested, and approved by I&EDO before the balance of the order is released to production. Source inspection by GE field inspectors and by representatives of I&EDO and Reactor Design during the fabrication of the production prototype shall be required to assure that proper fabrication, assembly and testing techniques are utilized. After approval by GE of the prototype instruments, no changes would be allowed during the fabrication of the rest of the order without written approval of GE engineering.

The recorders will be purchased by competitive bids on a functional specification.

New RTD's will be purchased by bids to the latest applicable HAP0 specification.

4.3.3 Responsibility Plan

Because of the intimate and detailed knowledge which will be required to complete the detailed design of PRAAM and RAGE and because of the critical nature of the resulting interconnection into the safety circuit, it is planned to have Reactor Design perform the detail design of these instruments and circuits with the consultation of I&EDO. Installation design will be provided by the AE under GE's technical direction. Overall project management will follow the usual project procedures. Research and Engineering will be responsible for selecting the specific process tubes in which the 45 RTD's are to be located in each reactor.

5.0 JUSTIFICATION

Studies (1,2,3) 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} times equilibrium power level to equilibrium power level. The reason for this need is as follows:

There are finite time lags in the power sensing equipment and in the response of the safety circuit and safety system mechanisms. For this reason, a trip at a given power level by itself does not provide sufficient protection. As power level is increasing, safety action is initiated when it reaches the trip point. However, because of the finite response times in the measurement and safety systems, the power level overshoots the trip point before the corrective action takes effect. The amount of this overshoot is a function of the rate at which power was increasing at the time the trip occurred. In order to protect against the worst possible case, power level trips would have to be set low enough so that even with the highest conceivable rate of power increase the overshoot would not exceed predetermined specific heat generation limits above which fuel element melting and fission-product release would be threatened.

Since such a setting (based on the worst conceivable rate of rise) would enforce uneconomically low power limits, it is preferable to set higher power level trip points and to concurrently limit the rate of power increase to those values which would ensure adequate safety trip action at the higher selected trip level.

Other studies⁽⁷⁾ have demonstrated that to obtain maximum reliability of tripping on demand while maintaining maximum freedom from false trips, a two-out-of-three coincident trip circuit should be used. This means that there would be three independent measurement and alarm circuits or channels which could trip from an excess rate of power increase. Each channel would utilize fail-safe design to the maximum extent possible (i.e., the circuits would be so arranged that component failures would produce the same effect as a rate greater than the trip setting). A trip on one channel would be annunciated but would not initiate a scram. This would permit location and replacement of failed components in an individual channel without interrupting reactor operation. Trips (whether caused by excessive power rate, by by-passing, or by faulty operation) on two channels at the same time would initiate a scram.

The present procedural type of power rate protection (see paragraph 4.2.1) injects the element of human reliability into the system. Improper adjustment of the level trip setting could result in either inadequate protection (from too high a setting) or unnecessary shutdown (from too low a setting). Automatic limiting of the rate of rise will allow use of a fixed trip setting for both the power level and the power rate trips and will completely eliminate the procedural element during operation.

The present "stop-gap" rate meter has experienced many resistance-to-ground problems (see paragraph 4.2.2). The instrument proposed is much less sensitive to these problems. The improvement is by a factor of five or more.

6.0 ALTERNATIVE SOLUTIONS

- 6.1 The alternative of modifying and upgrading the present "stop-gap" indicating system was rejected because the present components can not be made to meet the accuracy, stability, or reliability criteria that apply to safety circuit components. As paragraph 4.2.2 (above) and reference 4 point out, the present equipment was installed to provide additional information only and with the intention of removing it when safety circuit grade equipment could be developed.
- 6.2 One alternative which was considered was that of using octant chambers to provide the power level input signal to the PRAAM. As discussed in paragraph 4.2.2 above, prototypes of this type system were evaluated. The alternative was rejected because the cost of providing three complete channels of octant monitors would be prohibitive.
- 6.3 The only other alternative which has been developed to the point of demonstrated reactor-grade equipment is a High Speed Scanning system such as that which will be installed in KW Reactor by Project CGI-967. This alternative was rejected since its high cost could not be justified on the basis of providing power rate protection alone. In KW it will also provide individual tube temperature monitoring, zone temperature protection, approach-to-limit alarms and power setback control and alarm.
- 6.4 Another alternative which was considered was the use of in-core flux monitor chambers for the power level input signals. However, the development program on this type of equipment has not progressed to the point where project action can be recommended.
- 6.5 Another alternative considered was a system using the present galvanometer's input signal. C & KE's galvanometers are driven by the octant chambers which are discussed above in 6.2. In the other reactors the galvanometer is actuated by a single chamber. Such a signal would provide inadequate geometric representation and insufficient reliability for safety circuit systems. This alternative was therefore rejected.
- 6.6 A sixth alternative considered was a system using the average output obtained by connecting a number of thermocouples in parallel as the power level signal. This alternative was rejected because of the low signal level obtainable and the poor averaging characteristics of paralleled thermocouples.
- 6.7 A seventh alternative was to use the power calculator's bulk temperature input signal as the input to the rate meter. This system was rejected because the slow response of the bulk effluent RTD circuit would require uneconomically low maximum power level settings to keep the maximum temperature attainable on transient overshoots from exceeding operating limits.

7.0 PROPOSED SCHEDULE

	<u>Start</u>	<u>Finish</u>
Detail Design	2 months ADA*	10 months ADA*
Procurement	2 months ACA**	10 months ACA**
Installation	6 months ACA**	18 months ACA**

* ADA - After Design Authorization

** ACA - After Construction Authorization

8.0 ESTIMATED COST ⁺

Construction Cost

315 Rear Face Y Fittings	38,500
315 RTD's w/lead wire	56,500
21 PRAAM Channels	84,000
7 RAGE Units	10,500
42 Meters w/set Point	24,800
7 3-channel Recorders	10,500
7 Wiring and Miscellaneous Materials	35,000
7 Plant Forces Safety Circuit Work	9,100
Project Management	15,000

Total \$283,900

Supervision of Construction (Title III)	20,000
Contingency	86,000
General Overhead	9,700
Detail Design Title II	50,400

Total Project Cost \$450,000

9.0 ACKNOWLEDGMENTS

The author wishes to acknowledge the assistance of W. D. Hamilton, C. A. Simsen, N. T. Hildreth and R. R. Cone in editing and correcting this document.

† This estimate was made by the author not by Estimating Operation. However, it is based on Estimating Operation's data for the Budget Study. (6)

Special acknowledgment is given to the work of R. R. Cone and M. L. Peterson of the Instrument and Electrical Development Operation for conceiving, developing, proving, and engineering the PRAAM power rate meter, the trip circuits, and the RAGE test ramp generator.

The author assumes full responsibility for the acronyms PRAAM and RAGE.

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