AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.

1 of 1

DECLASSIFIED

-1-

HW-75466 RD

This document consists
of 82 pages.

REACTOR INSTRUMENTATION AND SAFETY CIRCUIT
STATUS REVIEW AND PROGRAM DOCUMENT

HANFORD CODE C-44
AS SPECIFIED IN M-3679

Classified by [redacted] and Changed To
DECLASSIFIED

By Authority of CG-PR-2
RM Jen 3-15-94
By Jesse Maley 4-4-94
Verified By J E Sawley 4-15-94

J. L. Deichman
Reactor Design
FACILITIES ENGINEERING OPERATION

February 15, 1963

This document classified by

[Signature]

HANFORD ATOMIC PRODUCTS OPERATION
RICHLAND, WASHINGTON

NOTICE

This report was prepared for use within General Electric Company in the course of work under Atomic Energy Commission Contract AT(45-1) - 1350, and any views or opinions expressed in the report are those of the author only. This report is subject to revision upon collection of additional data.

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

DECLASSIFIED

[redacted]

DECLASSIFIED

-2-

HW-75466 RD

REACTOR INSTRUMENTATION AND SAFETY CIRCUIT
STATUS REVIEW AND PROGRAM DOCUMENT

DISTRIBUTION

1. T. W. Ambrose
2. E. R. Astley
- 3-4. J. W. Ballowe
- 5-6. R. S. Bell
7. V. G. Blanchette
8. J. L. Deichman
- 9-10. W. J. Ferguson
- 11-13. G. C. Fullmer
14. C. L. Goss
15. W. D. Hamilton
16. H. W. Heacock
17. B. W. Herrman
18. D. L. Hovorka
19. R. T. Jaske
20. R. T. Jessen
- 21-23. J. E. Kaveckis
24. L. M. Keene
- 25-26. A. R. Maguire
27. W. W. McIntosh
28. F. J. Mollerus
29. S. L. Nelson
30. R. Nilson
31. R. W. Reed
32. G. J. Rogers
33. G. E. Wade
34. C. N. Gross
35. 300 File
36. Record Center
37. Extra
38. Extra
39. Extra

DECLASSIFIED

DECLASSIFIED

-3-

HW-75466 RD

(COMMENT ISSUE)

REACTOR INSTRUMENTATION AND SAFETY CIRCUIT STATUS REVIEW AND PROGRAM DOCUMENT

	<u>Page</u>
<u>TABLE OF CONTENTS</u>	
I. INTRODUCTION	7
A. Purpose and Objective	7
B. Summary and Conclusions	8
II. DEVELOPMENT OF A NEW INSTRUMENTATION FUNCTIONAL CRITERIA	11
A. Classification of Reactor Instrumentation	11
B. Determination of Systems Design Philosophy	14
C. General Functional Criteria for Reactor Instrumentation and Safety Circuit Equipment	16
1. Instrumentation System Design Concepts Permitted	16
2. Reactor Operating Range Instrumentation Coverage	17
a. Low Level Reactor Operating Range	19
b. Intermediate Level Reactor Operating Range	20
c. High Level Reactor Operating Range	20
d. Safety Instrumentation Which is Not Dependent on Power Level	23
e. Process Equipment Monitoring Instrumentation	24
f. Process Monitoring Not Directly Safety Dependent	24
III. PRESENT REACTOR INSTRUMENTATION AND SAFETY CIRCUITS	25
A. Reactor Safety Circuit Instrumentation (Class I)	25
1. The 1XX Safety Circuit Instrumentation	28
2. The 2XX Safety Circuit and Associated Tripping Devices	31
3. The 3XX Safety Circuit and Associated Instrumentation	32

DECLASSIFIED

-4-

HW-75466 RD

TABLE OF CONTENTS (Continued)

B. Reactor Process Control Instrumentation (Class II)	33
1. Nuclear Instrumentation	33
a. Low Level Neutron Flux Monitor	33
b. Galvanometer System	34
c. High Level Neutron Flux Monitor	34
d. Octant Monitoring Systems	34
2. Temperature Monitoring	35
a. Effluent Water Temperature Monitoring	35
b. Moderator Temperature Monitoring	37
c. Thermal Shield Temperature Monitor	38
d. Miscellaneous Coolant Water Instrumentation	38
e. Gamma Monitor	38
f. Reactor Power Level Calculator	38
g. Reactor Atmosphere Instrumentation	39
C. Non-Process and Building Environmental Instrumentation (Class III)	39
1. Radiation Health Monitors	39
2. Reactor Confinement Instrumentation	39
3. Miscellaneous Instrumentation	41
D. Classification Summary of All Present Instrumentation	41
IV. INSTRUMENTATION SYSTEMS NEARING DEVELOPMENT COMPLETION	41
A. Intermediate Range Monitor	41
B. Power Rate of Rise Monitor	42
C. Incore Flux Monitoring	43
D. Power Rate Prediction Instrumentation	45
E. Flow Monitoring	47
F. Automatic Power Level Control	50

DECLASSIFIED

-5-

HW-75466 RD

TABLE OF CONTENTS (Continued)

G.	Reactor Inlet Gas Moisture Monitor	51
H.	Individual Tube Rupture Monitoring	53
I.	Dose Rate Telemetering	54
J.	Fixed Radiation Monitoring (Health Monitoring)	56
V.	REACTOR INSTRUMENTATION AND SAFETY CIRCUIT PROGRAM	57
A.	Reactor Safety Circuit Instrumentation (Class I)	58
1.	Primary Critical Instrumentation, Reactor Safety Circuit Instrumentation (Class IA)	62
a.	Intermediate Range (Nuclear) Monitoring System	62
b.	Linear Rate-of-Rise	64
c.	Neutron Flux Monitoring (High Level)	67
d.	Zone Temperature Monitoring - Six Old Reactors	68
e.	Temperature Monitoring - K Reactors	71
f.	Power Failure Detection	72
2.	Operating Instrumentation, Reactor Safety Circuit Instrumentation (Class I B)	73
a.	Flow Monitoring	73
b.	Seismoscope	74
B.	Reactor Process Control Instrumentation (Class II)	74
1.	Primary Critical Instrumentation, Reactor Process Control (Class II A)	74
a.	The Main Annunciator	74
b.	Low Level Neutron Flux Monitor	75
c.	Temperature Monitor	75
d.	Gamma Monitor and Effluent Monitor (107 Basin)	75

DECLASSIFIED

-6-

HW-75466 RD

TABLE OF CONTENTS (Continued)

e. Bulk Outlet Temperature Recorder	76
f. Miscellaneous Coolant Instrumentation	77
g. HCR, VSR, Ball 3X and Other Indicating Lights	77
2. Operating Instrumentation, Reactor Process Control (Class II-B)	77
a. Moderator Temperature Instrumentation	77
b. Thermal Shield Temperature Instrumentation	77
c. Reactor Atmosphere Instrumentation	77
d. Power Calculator	78
C. Non-Process and Building Environmental Instrumentation (Class III)	78
1. Radiation Health Monitors	78
2. Rear Face Beckman	79
3. Confinement Instrumentation	80
4. Miscellaneous Instrumentation	80
VI. REFERENCES	81
VII. ACKNOWLEDGEMENTS	81
VIII. DOCUMENT - HW-75657, "Logic for Reactor Safety Circuit Systems"	
C. L. Goss, January 11, 1963.	

DECLASSIFIED

-7-

HW-75466 RD

(COMMENT ISSUE)

REACTOR INSTRUMENTATION AND SAFETY
CIRCUIT STATUS REVIEW AND PROGRAM DOCUMENT

I. INTRODUCTION

A. Purpose and Objective

This document has been prepared for internal use by the General Electric Company to serve as a program for evaluating reactor instrumentation and safety circuit equipment needs. It is intended that this document be used as a guide for defining, planning and scheduling engineering effort; budgeting of capital money; and project planning for new instrumentation systems. Effort will be made to periodically evaluate the status of the programs presented and provide updating information accordingly.

After a plant has been built and operated for a number of years, it becomes apparent to operating and engineering personnel that certain modifications in controls and monitoring systems would provide both tangible and intangible benefits. Systems which were once thought to be the primary points of control shift in importance as others become recognized. As time passes this shifting spreads the main control focus from the central control desk to various other areas in the control room. Production rate increases cause instrument ranges and scales to be changed so that information on the process can still be obtained from existing equipment. Response times, sensitivity, limits, and time constants which were figured for one level must be used or revised for new levels. Further, it is discovered that the process monitoring points could be relocated or increased in number to provide more and better data on plant

DECLASSIFIED

-8-

HW-75466 RD

operation. New monitoring equipment is developed and installed to fill voids in information so production can continue meeting high standards for safety and process control. Equipment is fitted here and there in an already crowded control room, and some is even relocated to less advantageous positions to make available the necessary panel space.

This in brief, is the rather complex status of Hanford Production Reactor instrumentation today. Such situations are not unknown in other industries as they also approach the 10 and 20 year old mark. At such a point, an agonizing reappraisal of the whole instrumentation and control package is generally initiated to determine the proper course of action with respect to plant life and future plant operation. The objective of this report is to begin this appraisal and outline a course of action.

B. Summary and Conclusions

1. This instrumentation and safety circuit program is based on the following four assumptions and single hardware criteria:
 - a. There will be no major plant expansion program(s) to raise reactor power levels beyond the capability of present plant equipment.
 - b. Instrumentation installed in the future will be justified primarily on reactor and nuclear safety improvement needs and/or replacement of obsolete and difficult to maintain equipment.
 - c. Equipment concepts proposed in this document are applicable to the reactors as they exist today and will provide the necessary protection if an overbore or zirconium tube program materializes.

DECLASSIFIED

-9-

HW-75466 RD

- [REDACTED]
- d. As much of the existing equipment and concepts will be carried over into the proposed program as possible.
 - e. Instrumentation of either the front or rear faces of the reactors will be minimized with alternatives not involving these locations strongly recommended.
2. A two-out-of-three safety circuit system should be installed at all reactors. Safety circuits should be powered from station batteries. All Primary Critical or Continuity Sensitive Instrumentation should be supplied from these same batteries. Static inverters are recommended for conversion of D. C. to A. C. for instrument use. (System details are referenced to Figure 5, sheets 1 and 2).
3. Installation of three channels of Intermediate Range (Nuclear) Monitors is justified for reactor and nuclear safety improvement. Gamma compensated ion chambers would be installed in the top portions of the reactor to monitor exponential rate of power rise and power level. The power level monitoring will provide the same general protection to the immediate top section of the reactor as the present Neutron Flux Monitors (Beckmans) do for the lower section of the reactor.
4. Linear Rate of Rise Instrumentation.
- Three channels of linear power rate instrumentation will reduce dependence on operator procedures during reactor startup. Each of the three channels will have five pairs of RTD's located in each quadrant of the reactor with one pair in the center of the pile. An appropriate number of spare RTD's will be provided to allow replacement of failed units during plant operation. A two out-of-three tripping network will be used for scrambling the reactor.
- [REDACTED]

DECLASSIFIED

-10-

HW-75466 RD

5. Present Model RXG and R&G-2 Beckmans are being replaced with new units because of obsolescence and maintenance difficulties. The combination of these units and the level trip from the Intermediate Range (Nuclear) Monitoring System will provide adequate high level nuclear protection. The octant monitoring concept is dropped from further consideration at this time.
6. Zone Temperature Monitors are necessary to provide geometrical coverage of the reactor in addition to the Nuclear Monitoring from item 5 above. However, a reduced number of points can provide this protection compared to the present numbers at the old reactors with the addition of the Intermediate Range (Nuclear) Monitoring level trips in the top of the reactor. Three channels of Zone Temperature Monitor are suggested for an initial system composed of 22, 17 and 22 points respectively at the old reactors. The K Reactor would have a proportionate ratio if the High-Speed Scanning System does not materialize.
7. The present pumping power failure protection equipment is adequate except in the area of broken shaft protection. Differential pressure instrumentation is suggested to fill this area.
8. A detailed study of the adequacy and performance of the Pressure Monitor should be made to determine if pressure transients do exist in the reactor which cause spurious scrams. This study will also be needed as justification in the future if replacement of the Pressure Monitor is ever seriously contemplated.
9. The seismoscopes should be connected into a two-out-of-three tripping circuit. Presently, two channels are used in the safety circuit with a third for annunciation.

DECLASSIFIED

HW-75466 RD

10. Dual safety circuit tripping of the Pressure Monitor should be formally approved or disapproved for use in all reactors now that K Reactor systems have been demonstrated.
11. Reactor atmosphere instrumentation should be improved in four areas: 1) Moisture Monitoring, 2) gas analysis, 3) gas makeup equipment, and 4) remote and automatic control of the 115 Buildings.
12. Seismic and Flux Monitor trips should be added to the Ball 3X systems at the old reactors to provide the same level of protection as provided at the K Reactors. The same concept as used at the K Reactors should be employed.

II. DEVELOPMENT OF A NEW INSTRUMENTATION FUNCTIONAL CRITERIA

The initial step in appraising the status of instrumentation and safety circuits for the existing Hanford Production Reactors is to establish a new functional criteria as to what is needed to operate the plants safely and efficiently based on nearly 20 years operating experience and new reactor technology. This step includes categorizing instrument functions into basic types and performance reliability requirements. After these factors have been established, ranges and limits can be functionally described before specifying actual hardware.

A. Classification of Reactor Instrumentation

Reactor instrumentation categorizes itself into three basic classifications. The first division can be defined as Reactor Safety Circuit Instrumentation. Instruments in this classification provide information on the status of the process by visual readout devices and are connected directly into the reactor safety circuits for automatic shutdown if preset limits are exceeded. They are responsible for maintaining the standards of reactor and nuclear safety at all times. The second category is Reactor Process

DECLASSIFIED

-12-

HW-75466 RD

Control Instrumentation. These instruments provide information to operating personnel just the same as the instruments in the first classification but are not directly connected into the safety circuits; however, some of these instruments do require procedural shutdowns when certain levels are reached or exceeded. The third classification of instruments is Non-Process and Building Environmental Instrumentation. These are instruments used in the control of auxiliary work (other than direct operation of the nuclear reactor) and are positioned throughout the building in secondary functions such as monitoring building radiation levels. This report will be primarily devoted to the first two classes of instruments; however, the third will be mentioned where it affects the overall picture.

A further step in classifying instrumentation is the defining of the minimum required information functions needed during normal reactor operation, abnormal reactor operation, normal shutdown, abnormal shutdown, and emergency event conditions.*

*Definitions:

Normal Operation: Operation of the reactor under static power levels or startup conditions when neutron flux and heat distribution are relatively stable with normal operating limits in effect.

Abnormal Operation: Operation of the reactor under dynamic conditions of neutron flux and heat distribution movement and when operating limits, other than bulk outlet temperature and pile power level, are being approached possibly requiring shutdown. An example would be a severe heat cycle when TAI and graphite limits are being approached.

Normal Shutdown: Normal shutdown circumstances are those where the reactor is shut down and maintained in that state under controlled conditions.

Abnormal shutdown: Abnormal shutdown circumstances are those where the reactor is scrambled down. After the cause of the shutdown has been determined and the reactor is judged to be safe, then the shutdown can be considered normal. For example, if the reactor was scrambled due to an electrical power failure, the abnormal shutdown would last until BPA power was restored and primary pumping equipment returned to operation.

Emergency Event: An emergency event would generally be considered an abnormal shutdown accompanied by loss of one or more control systems, coolant supply systems, or emergency backup systems. An example would be complete loss of BPA power, accompanied by failure of the 184 boilers.

DECLASSIFIED

-13-

HW-75466 RD

[REDACTED]

The two extreme points of the spectrum are abnormal operation and emergency events when most information is needed to assure the safety of the plant, operating personnel, and the surrounding environs. Naturally, more information about the process status is needed during reactor operation than during shutdown. By providing the necessary continuous functions to assure efficient and safe reactor operation at startup through equilibrium power levels, the necessary functions will also be available for coping with an emergency event. The instrumentation required to control an emergency event is considered to be the absolute minimum and should be the most reliable and backed up in depth.

Therefore, two sub-classifications of instrumentation can be developed for each major classification. The first sub-classification, "Primary Critical Instrumentation", ^(1,2) is defined as the minimum instrumentation necessary to permit evaluation of an emergency event, guiding personnel to prudent action to minimize or eliminate possible personnel injury or property damage. Such an event may be so limited in extent that fission product release could be averted by appropriate personnel action. In this instance, the emergency event may be minimized only if the sufficient knowledge of the status of the process is available to the reactor personnel to permit continued assessment of the adequacy and responses of the coolant and reactivity control systems⁽¹⁾.

The second sub-classification of instrumentation, "Operating Instrumentation", is all remaining instruments necessary to maintain safe and efficient reactor operation. This is equipment which could possibly be out of service for short periods of time either during

[REDACTED]

DECLASSIFIED

-14-

HW-75466 RD

operation or shutdown and would generally not contribute to the minimizing of an emergency event. Examples of this type of instrument would be the Flexowriter portion of the Temperature Monitor or portions of the Moderator Temperature Instrumentation. These systems are too slow to be of much aid during an emergency event. In summary, reactor instrumentation can be categorized into the following classifications and sub-classifications:

CLASS I: REACTOR SAFETY CIRCUIT INSTRUMENTATION

- A. Primary Critical Instrumentation
- B. Operating Instrumentation

CLASS II: REACTOR PROCESS CONTROL INSTRUMENTATION

- A. Primary Critical Instrumentation
- B. Operating Instrumentation

CLASS III: NON-PROCESS AND BUILDING ENVIRONMENTAL INSTRUMENTATION

- A. Primary Critical Instrumentation
- B. Operating Instrumentation

B. Determination of Systems Design Philosophy

Before proceeding into the development of a general functional criteria, it is necessary to first develop a general overall philosophy for that criteria. There are two prime functions of instrumentation. The first function is to provide "continuous and reliable" signals to the safety circuits for initiation of automatic shutdowns whenever preset limits are reached or exceeded. The second function is to provide "continuous and reliable" information to operating personnel at all times on the status of the reactor.

Insuring continuity of process information (instrumentation) for

DECLASSIFIED

-15-

HW-75466 RD

[REDACTED]

safety reasons can provide some tangible returns through increased plant efficiency. The safety circuit can be stopped from crying "wolf" on false scrams, thus improving continuity of plant operation and unit production cost ratios. The crying "wolf" continuously has safety implications because operating personnel can get into a habit of regarding scrams with the wrong significance. If the ratio of false scrams to actual safety scrams is large, there is a risk that scrams will be treated with less importance than they should be. This statement is demonstrated by the past performance of the building radiation alarms. Because of the large number of times that these alarms have cried "wolf", there has developed a general apathy towards them with respect to immediate personnel evacuation of the alarmed area. Personnel sometimes walk from an area rather than run. The same thing can develop with respect to reactor safety instrumentation; operators may "walk" when "running" is called for.

There may be other psychological aspects which affect the trip settings of percentage trip instruments. If an instrument has a percentage trip and has the potential to "inconvenience" personnel by scrambling the reactor, then there could be a tendency to "fudge" and set the percentage "a little high" to reduce the chance of an "inconvenience" scram.

The use of coincidence and fixed limit trips can minimize these practices.

Section VIII contains a special report in its entirety, HW-75657

"Logic For Reactor Safety Circuit Systems", which objectively discusses the relationship of continuity of operation and nuclear safety as system logic (multiple channel monitoring of a single parameter point) is applied to Reactor Safety Circuits and Safety

[REDACTED]

DECLASSIFIED

-16-

HW-75466 RD

Circuit Instrumentation Systems. As stated in the report, six circuits were selected for study and analysis to determine what improvement in operating continuity and nuclear safety could be achieved by the application of logic to instrumentation and control system design.

The general conclusion of this report⁽³⁾ is that system logic, when conscientiously and properly applied through mathematical analyses to reactor instrumentation and safety circuit design, can significantly increase both operating continuity and reactor safety performance levels. The report also pointed out that the use of logic can sacrifice operating continuity or nuclear safety if not properly applied. The use of two channel logic can increase operating continuity and reduce nuclear safety or increase nuclear safety and decrease operating continuity over the present single channel system depending on the logic system chosen. The use of three and four channel logic can increase both operating continuity and nuclear safety over levels from single channel systems. Considering all factors presented in the report (HW-75657), it is concluded that the use of three channel system logic will provide the greatest return on investment with respect to continuity of operation and nuclear safety. Therefore, the systems design philosophy presented in this instrumentation program will be based upon a three channel system philosophy (exceptions are noted) employing a two-out-of-three channel tripping system.

C. General Functional Criteria For Reactor Instrumentation and Safety Circuit Equipment

1. Instrumentation System Design Concepts Permitted

- a. Fail-Safe: Single or multiple channel continuous monitoring.

DECLASSIFIED

-17-

HW-75466 RD

- b. Fail-Safe: Single or multiple channel continuous monitoring with self-testing.
- c. Non-Fail-Safe: Single or multiple channel monitoring using redundant, self-tested and self-healing circuits.
- d. Non-Fail-Safe: Scanning of a single or multiple set of transducers through a single set of redundant logic with self-testing and self-healing.

Non-fail-safe applications must equal or exceed the response times, system accuracies, and system reliabilities of alternative fail-safe systems to scram on demand.

2. Reactor Operating Range Instrumentation Coverage

Operating experience and nuclear engineering research ⁽⁴⁾ has shown that there are three distinct reactor operating ranges each of which requires a different type of information. If present equipment technology were such that instruments could be designed and installed which would have fixed trip settings and cover the entire range of reactor operation, then a single all-purpose instrument system could be installed to monitor all required functions. However, present technology does not indicate that a break through in the area of extended instrumentation ranges is forthcoming in the near future (10 years or so). Therefore, with known equipment and technology limitations, each of the three reactor operating ranges will be defined for the process monitoring functional requirements. Equipment can then be engineered for each of the requirements for each range.

Figure 1, Relationships of Reactor Power Level to Instrumentation Range Requirements, shows the ranges of each different instrumentation requirement as reactor power level is increased for a typical

DECLASSIFIED

-19-

HW-75466 RD

startup and equilibrium operating period. The total range of operation as shown is approximately 12 decades. The maximum range of present nuclear instrumentation is approximately 7 decades using logarithmic amplifiers and compensated ion chambers. Thermal instrumentation has a range of about 3 decades in the heat generation range of reactor operation at normal coolant flow rates.

a. Low Level Reactor Operating Range

By definition, the low level reactor operating range shall be from the 10^{-12} decade to 10^{-7} decades with one decade of overlap to 10^{-6} decades, totaling six decades span.

No automatic safety circuit action shall be required in this range provided that the next higher range (Intermediate Range) does initiate automatic safety circuit action to reverse any overshoot from the fastest possible ramp generated in the low level operating range before the total heat generation exceeds bulk temperature limits or individual tube power limits.

Trips shall be provided to alarm (audible and visual) for exponential power level rate increases having periods of 15 seconds or less. Trips and instrumentation ranges shall be fixed when the reactor power level is in this range (10^{-12} to 10^{-6}).

The response time* of the system shall be 4 seconds or less. Geometric distribution of transducers is relatively unimportant in this range.⁽⁴⁾ All transducers shall be located in one general area.

* See footnote on next page.

DECLASSIFIED

-20-

HW-75466 RD

b. Intermediate Level Reactor Operating Range

By definition, the intermediate level reactor operating range shall be from 10^{-7} decades to 10^{-3} decades with two decades overlap to 10^{-1} decade totaling six decades.

Automatic safety circuit action shall be required in this range.

Trips shall be provided to annunciate (audible and visual) and scram the reactor for exponential power level rate increases having periods of 15 seconds or less. Trips and instrumentation ranges shall be fixed when the reactor power level is in this range (10^{-7} to 10^{-1}). The response time* of the system shall be 4 seconds or less. Geometric distribution of transducers is not important in first four decades of this range (10^{-7} to 10^{-3}). All transducers shall be located in one general area to monitor the same power level.

c. High Level Reactor Operating Range

By definition, the high level reactor operating range shall be from 10^{-3} decades to 10^0 decades plus, totaling three plus decades span. In this range of operation, heat is generated in sufficient quantities to raise the coolant temperature at normal flow rates to a level which can result

* Response time is defined as the total time from a power level change to the opening of the LXX and LXXA relay contacts. The total time includes: 1) transit time (if applicable), 2) transducer response time, 3) instrument response time, 4) instrument delay time (if applicable), and 5) safety circuit response time, but does not include VSR drop time.

DECLASSIFIED

-21-

HW-75466 RD

in damage to the effluent piping system if left unchecked.

Automatic safety circuit action shall be required of this range. There shall be good geometric coverage of the process by protective instrumentation.⁽⁴⁾

Level Instrumentation:

Fixed level and/or percentage level trips shall be provided to annunciate and scram the reactor for power levels above a certain level.

A system response time* of 8 seconds maximum shall be permitted for good geometric protection of a reactor divided into 16 zones or more having a fixed level trip. A system response time* of 4 seconds maximum shall be permitted for geometric protection of a reactor divided into two, four or nine zones having percentage trips.

Each zone shall be so defined as to provide information representative of the neutron flux levels along the total axial direction of the reactor within the flattened portion of the reactor. Figure 2, Division of a Reactor Into Zones, shows an example of a two, four, nine and sixteen zone reactor. A single high level system may be used if it divides the reactor into nine or more zones and has a response time* of 4 seconds or less with fixed or percentage level trips.

A high level system may be used with an 8 second or less time response* with fixed level trips, if it has 16 or

* See previous footnote - page 19.

UNCLASSIFIED

- 22 -

HW 75466 RD

FIGURE 2
Division of a Pile Into Zones

UNCLASSIFIED

DECLASSIFIED

-23-

HW-75466 RD

more zones and is backed up by a two zone system with a 4 second response time* and fixed or percentage level trips. The number of monitoring points per zone shall be three or more based on the system design philosophy concepts in Section II B (Page 14) and III C (Page 39).

Rate Instrumentation

Fixed linear rate trips shall be provided to annunciate and scram the reactor for power level rate increases.

A system response time* of 12 seconds shall be permitted for geometric protection of a reactor divided in 5 zones or more having a fixed rate trip. Axial and radial flux levels must be summed to protect against front-to-rear distortions during power level increases.

d. Safety Instrumentation Which is Not Dependent on Power Level

Because of the nature of the process, certain safety monitoring functions are required which are not a function of reactor power level or reactor operating status.

Protection against loss of primary cooling pumping capacity shall be required to scram the reactor and automatically start secondary equipment to assure continuous coolant flow to the reactor.

Protection against loss of bulk coolant flow to the reactor and individual tube coolant flow shall be required.

Protection against disabling the primary safety control system shall be provided and operation of a backup safety control system shall be automatic in case of failure of the primary system.

* See previous footnote - page 19

DECLASSIFIED

-24 -

HW-75466 RD

e. Process Equipment Monitoring Instrumentation

It is necessary to monitor certain parameters of the process equipment to control damage or deterioration of parts or materials which affect the life of a reactor. Instruments used for this application are classed as "Operating Instruments" and need be only single channel monitors.

The moderator and thermal shield shall be monitored for temperature level. The moisture content in the moderator atmosphere shall be monitored.

f. Process Monitoring Not Directly Safety Dependent

The following process parameters of an operating reactor shall be monitored.

Individual tube temperatures shall be logged for process control and accountability information. Effluent shall be monitored to determine when fission products from failed fuel elements are being released into the coolant.

Reactor moderator atmosphere shall be controlled to provide certain mixtures of inert gases. This shall be done to protect the moderator from being oxidized and carried off by the atmosphere and to permit closer control of the process.

Temperature and flow of HCR coolant shall be monitored to protect against damage of the primary control equipment. Also display of the position of the control equipment (HCR's and VSR's) is necessary to operating personnel.

Total process power level is necessary to control reactor operating levels and for production accountability.

DECLASSIFIED

-25-

HW-75466 RD

General Comment: The design of all systems should consider and be compatible with present concepts for automatic reactor control.

III. PRESENT REACTOR INSTRUMENTATION AND SAFETY CIRCUITS

The present instrumentation and safety circuits have evolved from the original B,D,F systems of 1943 through experience and knowledge gained in operating the Hanford Reactors and through continued engineering research in the nuclear sciences. Before discussing new instrumentation or presenting a program for future action, it is necessary to establish a common base from which to work. That base is the present installed equipment.

The following discussions will be limited to a generalized or typical presentation realizing that variations in equipment exist between reactors. However, where system concepts vary from reactor to reactor, each concept will be discussed. Instrumentation will be presented according to the classifications as defined in Section II-A (Page 11). Particular attention is given to the whole system {i.e. power supply, transducer, the instrument itself, control function (safety circuit monitoring or readout device) and pertinent comments}.

A. Reactor Safety Circuit Instrumentation (Class I)

There are three separate and complete safety circuits at each production reactor. Figures 3 and 4, Typical Block Diagram of the Three Safety Circuits at the six old reactors and at the K Reactors respectively show the system concept of the present safety circuits.

The 1XX and 2XX Safety Circuits at B, D, and F Reactors are A.C., while the 3XX Safety Circuit is D.C. All three safety circuits are D. C. at the other reactors.

UNCLASSIFIED

Number One
Safety Circuit
(1XX)

FIGURE 3

Typical Block Diagram of the Three Safety Circuits at the 6 Old Reactors

Legend

LP	Low Pressure
VLP	Very Low Pressure
ELP	Extra Low Pressure
ZTM	Zone Temperature Monitor
PF	Power Failure
CX	Seismoscope
BX	Flux Monitor
PSR	Pressure Monitor
TD	Time Delay

* Note:
Signal in Line With Arrow
Will Block Signal At If It Arrives First.

UNCLASSIFIED

FIGURE 4

Typical Block Diagram of the Three Safety Circuits at the K Reactors

DECLASSIFIED

-28-

HW-75466 RD

1. The LXX Safety Circuit Instrumentation

The LXX Safety Circuit scrams the vertical safety rods (VSR's) and the horizontal control rods (HCR's); however, only the negative reactivity of the VSR's is counted for reactivity control for this safety system. In most instances (exceptions are noted in subsequent paragraphs), relays are used in parallel with contacts connected in series to provide high reliability to trip on demand.

Manual Trip

A manual scram pushbutton is located on the reactor control console and is readily accessible to the reactor operator.

Pressure Monitor

The Pressure Monitor System (sometimes called the "Panellit") monitors coolant flow continuity in each individual process tube (2004 at the old reactors and 3220 at the K Reactors). A venturi or orifice is located at the inlet nozzle of each tube. A single hydraulic sensing line extends from the venturi or orifice to the reactor control room and a pressure gauge. This gauge consists of a coiled Bourdon tube which rotates a dial through mechanical linkages. The trip points (high and low) are set by two magnets rotating on the dial which operate an electric switch as they pass and attract a metal "flag", thus opening the switch contact(s).

The K Reactors are equipped with double pole, single throw switches which are connected into individual row and column tripping circuits using two relays in series per circuit. These relays are located at the opposite ends of the respective rows or columns. Concurrent tripping of both the row and column

DECLASSIFIED

-29-

HW-75466 RD

circuits is required to scram the reactor. Identification of the first gauge to trip is through the coordinate row and column relays and is presented by indicating lights.

The C and H Reactors are equipped with the same double pole, single throw switches; however, they are to be connected into multi-row series circuits (approximately 15 rows per circuit) and multi-column series circuits (approximately 15 columns per circuit) rather than by individual rows and columns as in the K Reactors. This has an advantage in that the total number of components is significantly reduced improving the reliability of the system. Concurrent tripping of both the row and column circuits will produce a scram. Identification will be provided by Project CGI-966 through the use of static-magnetic switching devices. The modifications leading to this system are presently underway.

The B, D, DR, F Reactors presently have a single pole double throw switch whose contacts are summed into individual rows by single row relays. These systems are scheduled to be changed to be standard with the C and H system concept by about July 1964.

Comment: As the modifications of the electrical portion of the Pressure Monitor near completion, it will be relatively easy to determine whether the so-called coincidence tripping feature will reduce spurious scrams as justified in the MJA's or whether an additional problem area, that of pressure transients, must be analyzed. Engineering effort in the study of origin and control of pressure transients will be the only area to produce a significant reduction of spurious scrams. To outline a program for such a study is beyond the scope of this report;

DECLASSIFIED

-30-

HW-75466 RD

however, it is strongly believed that such a study is needed simply because pressure transients in the system have been measured throughout the entire piping network and the Pressure Monitor is capable of responding to these transients which apparently have no safety significance. An additional point is that if the Pressure Monitor is ever going to be replaced in the future, documentation should proceed immediately because such a study done properly will probably take two engineers working full-time a minimum of two years.

Neutron Flux Monitor (EX & EXA)

The Neutron Flux Monitor System, commonly referred to as the "Beckmans", is composed of four picoammeters, ion chambers, and controllers for setting safety circuit trip points. The four ion chambers are located in instrument risers beneath the reactor and are positioned for equilibrium power level calibration. The effective range of operation is approximately the top four decades of the twelve decade range of neutron flux. The instrument scale ranges from 10×10^{-13} to 10×10^{-8} amperes. Trip settings are controlled by procedure and are a controlled percentage (10 percent) above the instrument reading. In some reactors, one instrument is set up with a bucking voltage circuit to extend its effective range to approximately five decades.

Both the high and low level trips are connected into the LXX Safety Circuit. Any two Beckmans in the tripped position will scram the reactor. Interlocks are provided so that bypassing two or more Beckmans at the same time will automatically scram the reactor. The EX and EXA relays are time-delayed

DECLASSIFIED

-31-

HW-75466 RD

three to seven cycles (dependent on the reactor) to permit amplifier recovery from short BPA power transients.

A "Beckman-Panellit" interlock is provided to automatically unbypass the Pressure Monitor when the reactor is above 2 megawatts. This circuit uses static switching devices in a one-out-of-four Beckman tripping circuit to unbypass the Pressure Monitor. Additional discussion of the Beckmans appears in Section II B 1 c (Page 17).

Seismoscope

Each reactor is equipped with three seismoscopes. Two are connected in coincidence in the DDX Safety Circuit and are set to trip and annunciate on a modified Mercalli Scale of 5. The third seismoscope is primarily used as an information device and is set on a modified Mercalli Scale of 3. This unit annunciates only.

The design of the seismoscopes has a non-fail-safe characteristic which makes the two-out-of-two coincidence circuit very questionable from a reactor safety standpoint.⁽⁵⁾

Power Failure Detection

Detection of either pumping or electric power failure is accomplished through relaying located in the 190 Buildings. The relaying is based on either undervoltage, reduced power flow or reversed power flow to the motors plus normal motor protection relaying.

2. The DDX Safety Circuit and Associated Tripping Devices

The DDX Safety Circuit scrams the horizontal control rods only. There are three entries to the DDX Safety Circuit; 1) Manual

DECLASSIFIED

-32-

HW-75466 RD

[REDACTED]

pushbutton located on the control console, 2) the upper limit switches from each VSR connected through the SN and SNA relays (at the old reactors) and through the SNX relays (at the C and K Reactors) to scram the HCR's if a VSR inadvertently drops into the reactor, and 3) the HCR/VSR Interlock so that the VSR's cannot be withdrawn from the reactor if the HCR's are not inserted in the reactor.

3. The 3XX Safety Circuit and Associated Instrumentation

The 3XX Safety Circuit drops boron-steel balls into the VSR channels. The signal is from a set of Mercoid pressure switches located in each inlet riser. There are three switches located in each inlet riser. There are three settings used: Low Pressure (LP), Very Low Pressure (VLP), and Extra Low Pressure (ELP). The LP and VLP trips are set to scram the Ball 3X system upon a pressure decay rate greater than a certain value. This is accomplished by a time delay coincidence trip of the LP and VLP switches. The ELP trip will automatically drop the "balls" when the pressure drops below a fixed minimum.

At all reactors but C, there are two complete systems in the 3XX circuit. Two batteries, two sets of pressure switches, and two latching solenoid mechanisms will allow failure of a single system without the consequence of a "ball drop". A manual pushbutton is located centrally in each control room to trip both systems, thus dropping the balls. Modifications are presently underway at C Reactor to install a dual system similar to the other reactors.

[REDACTED]

DECLASSIFIED

-33-

HW-75466 RD

B. Reactor Process Control Instrumentation (Class II)

Instrumentation beyond that used for safety circuit action is necessary if the reactor is to be operated and controlled effectively and efficiently. In some instances, Process Standards require manual scrambling of the reactor when indicated readings reach predetermined levels.

1. Nuclear Instrumentation

The nuclear instrumentation range requirement is from normal background or shutdown levels to approximately 10^{-11} times normal background for equilibrium power levels. Because instrumentation is not presently available with this large a range, nuclear instrumentation is divided into different systems which monitor reactor operation in various parts of this 11 decade range.

a. Low Level Neutron Flux Monitor

At background or shutdown levels, the Low Level Neutron Flux Monitor System (Sub-Critical Monitor) is used. This system is comprised of two separate and identical channels, each composed of a chamber mounted on a screw drive mechanism and an amplifier-counting circuit indicating period and level. The system is set to provide visual and audible alarms when a 15 second rising period is reached. The primary use of this system is to determine when the reactor achieves criticality and indicate the magnitude of the rising period during low power level reactor operation. The range of each channel is a nominal 5 decades with an effective 4 decades. During startup the channels are used in tandem with overlapping range settings to extend the system range (both channels)

DECLASSIFIED

-34-

HW-75466 RD

to approximately 9 decades. This is accomplished by positioning the chambers on the screw drive mechanism in steps from their full-in location at the moderator fringe.

b. Galvanometer System

The Galvanometer Systems operate from signals supplied from one to eight ion chambers depending on the reactor. Two galvanometers are connected in series; one providing a signal (current) proportional to the neutron flux power level and the other showing deviation from a preset level. The equipment, including shunts and potentiometers, is built into the control console.

c. High Level Neutron Flux Monitor

The high level nuclear monitoring system is the "Beckmans" previously discussed in the section on Safety Circuit Instrumentation. The B, C, and the K Reactors use the Model V Beckman picoammeters currently in production, while the D, DR, F, and H Reactors still have the RXG-2 Beckmans which have been out of production for about nine years. Engineering effort is currently underway to changeout the RXG-2's for Model V's. Readout information is in the form of indicating meters and recorders, remote and adjacent to the instrument.

d. Octant Monitoring Systems

The C and K Reactors are equipped with an Octant Flux Monitoring System. The DR and H Reactors have holes in the shielding for the chambers; however, the instrumentation has never been installed. The octant concept is similar to the Beckman system concept; however, there are eight channels instead of four and

DECLASSIFIED

HW-75466 RD

they are positioned to monitor each corner of the pile from holes on the near and far sides.

2. Temperature Monitoring

One of the primary reactions in the fissioning of U-235 is the generation of heat. It is therefore of prime importance to know that adequate removal of this heat is being maintained in all sections of the reactor. Temperature monitoring divides into three categories of instrument systems: effluent water temperature monitoring, moderator temperature monitoring, and thermal shield temperature monitoring. There are many different methods for displaying this information to operating personnel; however, generally the main temperature monitoring functions are similar in concept at each reactor.

a. Effluent Water Temperature Monitoring

A thermocouple (RTD's at the K Reactors) is installed at the outlet of each process tube to measure the temperature of the cooling water leaving that tube. Each temperature transducer is connected to a central control board and a series of stepping relays is used to scan the transducers by rows in process format. The control board is used to manually select individual tubes for recording data at various forms. Two recorders are provided for individual tube temperature trend recording, and for traversing the temperatures in process format. A "cornpopper" function is provided which scans a preselected number of tubes by regions or zones in the reactor.

The stepping relays select the transducers in reactor format

DECLASSIFIED

-36-

HW-75466 RD

sequence by rows for presentation on the traverse recorder or on an electric typewriter. An analog to digital converter (ADC) changes the analog signal from the transducer to a digital signal for the typewriter. Project CGI-939 has been authorized to change the present ADC's to solid state electronic systems from the present shaft driven encoders at the six old reactors. Project CGI-967 has been authorized to install a High-Speed Scanning Type Temperature Monitoring System at KW Reactor to replace the present temperature monitoring and data logging system.

An interim Linear Power Rate-of-Rise System operates from 10 RTD's distributed in a uniform pattern over the rear face of the reactor. The circuit averages the signals of the RTD's to show an average linear increase or decrease in power level in megawatts per minute. This system has numerous disadvantages which are being resolved through development effort for a final system.

Zone Temperature Monitoring Systems were installed under Project CGI-666 at the six old reactors to provide safety circuit action for "hotspot" control. This system is composed of RTD's (resistance temperature detectors), controllers, and a visual readout display. The RTD's measure the temperature of the outlet water from the center process tube of a 3 by 3 tube cell or zone. A special wye fitting was installed between the spiral connector and the Parker fitting to house the RTD.

DECLASSIFIED

-37-

HW-75466 RD

The reactor is divided into 211 different cells or zones covering all process tubes. Each controller has an adjustable level trip setting ranging from 85 C to 140 C.

The system has been used wholly as an information system since installation. A readout device using an en masse adjustable level control on an approach to trip basis indicates "hotspots" with lights representing each zone tube.

The system was never put into the safety circuit because of various problem areas; however, at the writing of this document, the Zone Temperature Monitor is being upgraded and readied for this function.

b. Moderator Temperature Monitoring

Thermocouples were embedded in the moderator at construction to measure the distributed heat in the graphite. Because a large percentage of these original thermocouples have ceased to function, it became necessary to provide an alternate means for obtaining this information. Strings of thermocouples (11 at the old reactors and 13 at the K's) were inserted into process tube channels at the old reactors and in the side-to-side channels at the K Reactors. Originally these "stringers" were contained in beads of graphite for better heat conduction; however, a new method has been recently devised to use sheathed thermocouples without the graphite beads. The temperature information is presented on a profile recorder or can be readout directly on a trend recorder.

DECLASSIFIED

-38-

HW-75466 RD

c. Thermal Shield Temperature Monitor

Thermocouples are distributed in the thermal shield to maintain temperature control of the shield. It is important that the temperature of the shield be kept optimized to reduce deterioration from high temperature.

d. Miscellaneous Coolant Water Instrumentation

There are many miscellaneous pressure gauges in the control room which indicate the pressures at various points in the primary, secondary and last ditch coolant systems. Included in these measurements are: top of riser pressure, crossheader pressures, top of downcomer pressure, control rod coolant pressures, and high tank level and pressure.

e. Gamma Monitor

The Gamma Monitor System detects fuel element ruptures by continuously monitoring effluent water from each rear cross-header. A gamma sensitive ion chamber is revolved past the respective continuous streams and measures the magnitude of the gamma emission. Visual and audible alarms annunciate if the trip points are exceeded. The radiation profile of the cross-headers is plotted on multipoint recorders.

f. Reactor Power Level Calculator

The total power level of the reactor is computed using total flow to the reactor from the 190 Building and the bulk outlet and inlet temperatures. The total power level is recorded on a circular chart and power deviation is recorded from a preset power level value.

DECLASSIFIED

-39-

HW-75466 RD

g. Reactor Atmosphere Instrumentation

Reactor atmosphere instrumentation consists of flow rate, temperature, moisture content, gas pressure, and make-up flow rate equipment. In the old reactors this equipment is located in the 105 control rooms and the 115 Building. At the K Reactors, the equipment is mostly in the control room.

C. Non-Process and Building Environmental Instrumentation (Class III)

Instrumentation is required in parts of the reactor building to support work which is not directly associated with the nuclear reactor process.

1. Radiation Health Monitors

Radiation health monitoring equipment is positioned around the reactor building and associated areas to monitor radiation levels and control access to these areas. The health monitors consist of RXG, RGX-2, and Model V Beckman picoammeters and gamma sensitive ion chambers. Depending on the location and the purpose for which the monitor is used (either health or criticality monitoring), the instruments are set to trip and alarm at 30 mr to 3000 mr. Audible alarms sound to warn personnel when set limits are exceeded. In some cases the health monitors serve a dual function; that is to measure building level radiation and the intensity of certain radioactive materials as they are prepared for disposition.

2. Reactor Confinement Instrumentation

Reactor confinement facilities were installed to control the release of radioactive material from the reactor building in the event of a nuclear incident. The instrumentation monitors the pressure and air balance in various sections of the building and the radiation level and spectrum of the air exhaust.

TABLE I
INSTRUMENTATION SYSTEM CLASSIFICATION

HW-75466 RD

MAJOR REACTOR INSTRUMENTATION SYSTEMS	INSTRUMENTATION SYSTEM CLASSIFICATION					
	CLASS I REACTOR SAFETY CIRCUIT INST.			CLASS II REACTOR PROCESS CONTROL INST.		
	I-A. Primary Critical	I-B. Operating Instruments	Power Level	II-A. Primary Critical	II-B. Operating Instruments	Power Level
Neutron Flux Monitor (Beckmans)	X		High			
Power Failure Detection Relays	X		n.a.			
Ball 3X System	X		n.a.			
Pressure Monitor		X	n.a.			
Seismoscope		X	n.a.			
Safety Circuit Relays		X	n.a.			
Main Annunciator				X		n.a.
Low Level Neutron Flux Monitor				X		Low
Temperature Monitor System (all)				X		High
Galvanometer				X		Hi. & Int.
Gamma Monitor				X		n.a.
Bulk Outlet Temperature Recorder				X		High
Misc. Coolant Instrumentation				X		n.a.
Top of Riser Pressure				X		n.a.
Export System Pressure				X		n.a.
High Tank Level				X		n.a.
High Tank Pressure					X	n.a.
High Tank Temperature					X	n.a.
Top of Downcomer Pressure					X	Hi. & Int.
HCR Coolant Pressure & Temperature					X	n.a.
Crossheader Pressure				X		n.a.
HCR, VSR, Ball 3X Lights					X	n.a.
All Remaining Indicating Lights					X	High
Octant Monitoring System					X*	High
Zone Temperature Monitor	X*				X	High
Interim Linear Power Rate-of-Rise					X	High
Moderator Temperature Instrumentation					X	High
Thermal Shield Temperature Instrumentation					X	n.a.
Reactor Atmosphere Instrumentation					X	High
Power Calculator				X		n.a.
Effluent Monitor (107 Basin)					X	n.a.
All Control Relaying						
Radiation Health Monitors						X**
Rear Face Beckman						X
Reactor Confinement Instrumentation						X**

POWER LEVEL LEGEND

High: 10^{-3} to 10^0 decades
of operation
Intermediate: 10^{-1} to 10^{-2}
decades of operation
Low: 10^{-12} to 10^{-6} decades
of operation
n.a. (not applicable: These
instruments' functions
are needed to some de-
gree at all times
whether the reactor is
up or down)

DECLASSIFIED

* When the Zone Temperature Monitor is upgraded and connected in the safety circuit, it will be classified I-A.
** Selective monitors will be in each category.

DECLASSIFIED

-41-

HW-75466 RD

3. Miscellaneous Instrumentation

This report acknowledges that there are other instrumentation equipment in the various reactor buildings used for specific work; however, this remaining equipment will be classified as miscellaneous at this point because it does not carry the level of importance that the above equipment does.

D. Classification Summary of All Present Instrumentation

Table I, Instrumentation System Classification, categorizes and summarizes all major reactor instrumentation systems into the classifications per Section II A (Page 11) and shows the power level at which the instrumentation was designed to function (if applicable to a certain power level range.)

IV. INSTRUMENTATION SYSTEMS NEARING DEVELOPMENT COMPLETION

The following discussion is limited to instrumentation which is nearing development completion and will be ready for application within six months to three years. Recently developed systems already in project status are discussed elsewhere in this document (Section V)

A. Intermediate Range Monitor

A laboratory and on-reactor evaluation of three commercial Intermediate Range Monitors has been completed. Although none of the instruments evaluated have all the features desired for a reactor process instrument, at least one of the instruments will satisfy the requirements with minor modifications.

A typical Intermediate Range System for reactor safety circuit use could consist of three Intermediate Range Monitors with log-level and reactor period readout and trips, through compensated ion chambers and associated power supplies and three reactor hole facilities with shield plug, bonnets, etc.

DECLASSIFIED

-42-

HW-75466 RD

A program to evaluate compensated ion chambers is continuing; more information is needed to describe chamber performance under varying reactor conditions and to obtain maximum performance. Sufficient information is available at this time; however to assure the minimum performance required for intermediate range use.

A comparatively inexpensive molded iron-epoxy shield plug and bonnet assembly is being evaluated in 105-DR. Results to date have been satisfactory.

Preparations are being made for coring a reactor shield mockup and then coring one hole in a reactor shield.

Specifications are being prepared for the purchase of Intermediate Range Monitors. It is planned to require a production prototype prior to the acceptance of production quantities.

B. Power Rate-of-Rise Monitor

A linear power rate-of-rise instrument suitable for safety circuit use in all the existing reactors has been developed. This instrument requires 10 RTDs per channel for active signal elements and 5 RTDs for spares.

A Power Rate System connected in a reactor safety circuit would consist of the following:

1. Three power rate computers.
2. Three magnetic amplifier trip circuits.
3. Forty-five (45) RTDs (30 active RTDs and 15 spares).
4. Associated circuits such as bridge circuits, power supplies, RTD switching circuits, calibration generators, etc.

The rate amplifier and associated circuits use solid stated circuitry throughout with the exception of one reliable and conservatively rated vacuum tube. The rate system has been tested in the laboratory and

DECLASSIFIED

-43-

HW-75466 RD

on-reactor to assure that it has reliability, fail-safe features, stability with line and temperature variations and ease of maintenance required of a quality reactor process instrument.

A final mechanical prototype of the power rate meter has been constructed and is undergoing tests prior to on-reactor testing.

Following completion of testing, it is planned to prepare electrical and mechanical drawings and specifications for the purchase of "chinese copies" of this prototype on any subsequent project action.

C. Incore Flux Monitoring

The object is to obtain a continuous display of reactor axial (front to rear) flux distribution at selected radial locations. The output signals should also be capable of driving recorders and be of sufficient magnitude, accuracy, and reliability to actuate safety circuits when desired.

Four general chamber designs are being developed:

1. The first design (referred to as IFM-1) consisted of aluminum gamma sensitive chambers with aluminum triaxial, aluminum-oxide insulated, cable in the active zone. A set of five chambers was installed in KW Reactor and proved to be quite unsatisfactory. The signals were too small (in the order of 10 to 25 microamperes at equilibrium power level) to be used without amplification. The output was grossly (about 300 times) more sensitive to changes in the voltage difference between the center electrode and the guard than to changes in reactor power level. Because of internal shorts all five chambers were virtually useless 3 months after they were installed in the reactor.

DECLASSIFIED

-44-

HW-75466 RD

2. The second design (IFM-2) consists of stainless steel, neutron sensitive, ion chambers with integral (stainless steel, aluminum oxide or magnesium oxide insulated) cables in the active zone. A set of five chambers has provided trouble free operation for over thirteen (13) months and their useful life should be greater than 3 years.
3. The third design (IFM-3) features five stainless steel gamma sensitive chambers, three with coaxial and two with triaxial mineral oxide insulated cables. These chambers were installed in the reactor on February 1, 1963. Test data from these chambers should indicate whether the ratio of the gamma chamber signal current to the coaxial cable leakage current can be increased to a value which would make guarded (triaxial) construction unnecessary. Testing should also indicate if sufficiently large gamma chamber currents are attainable to reliably operate the desired equipment. Gamma chambers should have considerably longer life than fission (neutron sensitive) chambers because fission chambers burn out in time. This, of course, would be a decided economic advantage.
4. The fourth program (IFM-4) was to design a higher current gamma sensitive chamber. This was carried through conceptual design and drawings were prepared. The decision to pursue this program through fabrication and test awaits further analysis of test data from IFM-2 and IFM-3

Conceptual design of the graphic display of the incore chamber data for control room operational information is complete. A prototype readout display will be built to demonstrate the value of the continuous axial and radial display of reactor flux. This display will also be

DECLASSIFIED

-45-

HW-75466 RD

used for the final on-pile prototypic system which will be installed to demonstrate the feasibility of incore flux monitoring as an operating and safety monitoring device.

The traveling wire flux monitor (TWFM) must be repaired so that independent measurements of the flux level in the process tube containing the neutron sensitive in-core flux monitor (IFM2) chambers can be obtained to calibrate and determine the sensitivity of the chambers. The burnout rate of the IFM2 chambers must be determined to establish their useful economic life. Cross calibration tests of TWFM, IFM2, and spline traverses must be made to verify the calibration data and determine whether TWFM would be necessary in a complete reactor installation or whether splines alone could be used for calibration.

D. Power Rate Prediction Instrumentation

Preliminary exploratory work has been done concerning the possibility of using the "prompt jump" in power level or neutron flux following an increase in reactivity in a reactor as a source of information for the control and protection of a reactor. A number of simplified calculations (assuming time and space variables separable and one group of delayed neutrons) indicated that the first derivative of the flux (or power level) was very large in the first instant of time after a reactivity change is made. Data from IHM runs of a 1 node, 6 delayed group model was examined. These data showed similar results although the values were less than those of the earlier more crude approximations.

These data looked encouraging but not definitive since the mathematical model of the differentiator did not include a time lag for the filtering that is necessary in a real instrument.

DECLASSIFIED

-46-

HW-75466 RD

[REDACTED]

A test at KE using octant chambers as a signal source had two differentiators on the total ion current, one of which had a built-in variable time lag. This time lag was decreased and the behavior qualitatively observed during startups and operation. Signals were observed to be generated with each rod movement and very large signals were recorded at times. It was difficult to ascertain exactly what action occurred in-reactor to develop these signals since they occurred at irregular times and no observers were present to correlate events with the signals.

A multichannel differentiator was built and installed on individual channels of the KE octant system. The analysis of these data is not complete but they generally show (a) rod motions, (b) considerable 60 cycle noise, and (c) the invalidity of the assumption that the space and time variables in a reactor are separable, at least for the small transients occurring.

It must be kept in mind; however, that the transients being observed at KE were normal operational and startup phenomena, the type that would be rejected (not cause operation) by a safety circuit device. These data were recorded merely as a by-product of normal reactor operating procedures. Signals of the type of interest for safety circuit actuation could be tested only under a well considered, specially controlled, approved production test.

Since no priority has been established, this work is done on a fill-in basis only. Last work on this problem was done during May, 1962.

The concept appears attractive as considerable additional safety factor would be available if instrumentation is feasible. However, additional studies are needed to establish the feasibility. These studies would include:

[REDACTED]

DECLASSIFIED

-47-

HW-75466 RD

1. Calculation (digital, analog) of output with a one lag differentiator for various reactivity inputs and various differentiator lag constants.
2. Cogitation of the above results. Create those incidents which would cause the desired trip action and trip levels.
3. Study and testing of the methods of attenuating the 60 cycle hum and other electrical noise that appears in octant chamber leads without loosing the fast response time required.
4. Simulation (or calculation) of various reactor transients with a multi-node, multi-group reactor model to determine the spatial distribution of a localized transient. These data should show the minimum number of ion chambers necessary to adequately protect the reactor. These runs would also provide a basis for safety assurances necessary before a production test could be authorized.
5. Build up prototype instrument and test (a) on analog simulator, and (b) on reactor.

E. Flow Monitoring

The following will outline an all-static component differential pressure process tube flow monitor development program that is believed to be achievable in approximately three years and will be competitive with present mechanical gauges (Panellit) when operating and replacement costs of Panellit gauges are considered.

The development of differential pressure monitoring systems started before reorganization in 1956 and has continued on a semi-continuous basis. Early developments were concerned primarily with both electronic and mechanical type monitors. Initial results on electronic systems were not encouraging. Break throughs have been noted after

DECLASSIFIED

-48-

HW-75466 RD

[REDACTED]

the development of a mechanical type flow monitor suitable enough for PRTR application was completed. This upturn of events was due to combining the Barton differential pressure element with an electrical transducer that had sufficient output to make electronic monitoring feasible. Other requirements such as that of the NRD Reactor which required remote en masse set of low flow trip point (and later high trip point) favored the use of electronic systems rather than conventional mechanical means.

At present the Barton-Metrisite transducer unit and the electronic monitoring system (Avien) used in the NRD Reactor could be applied to the older reactors successfully. However, the cost is in excess of \$1000 per channel monitored.

During the final phase of N flow monitoring development, there were two "break throughs" which alter the cost picture considerably. First truly static (or nearly so) transducers became available but in restricted ranges and of doubtful reliability because of lack of experience in the materials and manufacturing process used to manufacture them.

The second break through was that of proving that high speed data acquisition systems (Scanners) could be procured for process monitoring with sufficient inherent reliability and functions to fulfill process safety monitoring requirements.

From various vendor inquiries, it appears that both static transducers and semi-conductor scanning systems (for limit monitoring of transducers) will be procurable after development is complete at a cost of less than \$100 for the transducer and approximately \$100 per point monitored for the scanning system. These figures apply to full scale systems.

[REDACTED]

DECLASSIFIED

-49-

HW-75466 RD

Transducers

A number of manufacturers have been surveyed with preliminary specifications for the transducers. Three general types of transducers appear to be available in the pressure range and with sufficient output to be used for a high speed scanning system.

1. Semiconductor strain gauge type.
2. Variable mu iron capsule, differential transformer.
3. Diaphragm directly coupled to differential transformer or variable inductance.

Of the three types, the second type "variable mu" is truly a static device. It utilizes the variable mu characteristics of certain arrangements of iron alloys to unbalance the magnetic paths of a differential transformer in proportion to differential pressure. In essence, it has no moving parts.

The first type, semiconductor strain gauge transducer, would contain two diaphragms exposed to the differential pressure. The differential pressure would then be transmitted to a beam rigidly mounted between the diaphragm and the strain would be ready by semiconductor strain gauges with a very high gauge factor (300-400). This transducer is not truly static, the diaphragms will move a few milli-inches but there will be no complicated and/or expensive bellows, torque tubes or linkages.

The third type transducer is very similar to the first type except the slug of a linear differential transformer or variable inductance is mounted on one diaphragm and the coils of a differential transformer or inductance coil of a variable inductance is mounted on the other diaphragm. Differential pressure is then sensed by the relative movement between the coil and slug.

DECLASSIFIED

-50-

HW-75466 RD

Each of the above types of devices are predicted to have an acceptable reliability. There are several confirmed sources for development of strain gauge type of transducers. Ordering of prototypes has been postponed temporarily because of price. The variable mu transducer is undergoing final development by International Resistance Company and a proposal for prototype has been promised in the near future. The diaphragm mounted differential transformer is already in production by the T. A. Edison Company and sells for a price less than \$100 each. Edison is preparing a proposal on a specific prototype in the required static pressure and differential pressure range.

Procurement of prototypes and evaluation is expected to be complete on at least two types in approximately 12 to 18 months after higher priority work is completed.

Monitoring System

The application of the high speed scanning technique has been thoroughly investigated and possess no particular problems except three proven sources must be available. One source already exists, two additional sources can be developed in approximately 24 months after higher priority work is completed.

At present the program is being pursued on a "fill-in" basis only.

The logical time for completion of the above program is approximately three years from now when Panellit gauges may have to be rebuilt.

The program will be continued on a fill-in basis until it is deemed necessary to raise the priority.

F. Automatic Power Level Control

The subject system is an automatic system for detecting deviations from a manually established base and controlling reactor flux distribution relative

DECLASSIFIED

-51-

HW-75466 RD

to the desired base. Power level or average flux in a zone is measured by means of a resistance temperature detector (RTD) located in the effluent stream from a selected process tube. Each measured temperature is compared to a manually set base temperature. If the measured temperature is above or below this base temperature, the system selects the proper control rod and moves it to correct the deviation. The system contains logic to determine which rod should be moved and the direction of movement.

The present developmental system is a demonstration system and is designed to be installed in 105-D and to control flux distribution at or near equilibrium. The system also was designed so it could be modified to control both flux distribution and power level. The justification for the present system is experimental to prove a principle and is sponsored jointly by Research and Engineering Operation and Instrument and Electrical Development Operation.

If the demonstration system is successful, the principles and some of the actual control system will be applicable to the automatic control of all Hanford Production Reactors including 105-N.

G. Reactor Inlet Gas Moisture Monitor

A prototype gas moisture monitor has been assembled and is being tested. The water analysis is made by use of an electrolytic cell. The sample flow is controlled by a differential pressure regulator which is controlled by the pressure drop across a porous plug flow restrictor. Tests have been made with various porous media. A sintered stainless steel disc is currently being tested.

The prototype electrical chassis associated with the flow control chassis contains a linear concentration readout having three ranges (0-50-500-5000 ppm by volume at 50 cc/min. sample flow rate),

DECLASSIFIED
-52-

HW-75466 RD

[REDACTED]

a logarithmic readout on one scale (5-5000 ppm) with recorder output, calibration circuits for the log readout, cell voltage test point, associated power supplies and the controller for the thermostat containing the log diodes and the porous plug flow restrictor. Space was reserved for a high moisture alarm circuit but this has not been built, being considered an accessory whose need is yet to be demonstrated.

Additional Work Necessary

Recently the flow-pressure drop characteristics of the stainless steel element shifted abruptly and the cause of this shift must be determined and steps taken to prevent its recurrence. Plugging of the pores in the restrictor is a likely cause, but some effort must be expended to verify this.

The porous plug element was built into an easily replaceable unit unit which fits into the thermostated housing. Difficulty has been experienced with gas leakage around the associated "O-ring" seals. An improved seal will have to be provided, or a less easily replaceable flow restrictor accepted.

When the final design of the flow restrictor is completed and in operation, its flow-pressure drop characteristics for air, CO₂ He, N₂, CO₂-He mixture and N₂-He mixtures must be measured. The theoretically predicted variations of flow with the absolute pressure at the porous plug must be verified at several points. The accuracy of the analyzer must be tested at several known moisture concentrations. After passing bench tests, the analyzer will be installed in a reactor gas system to check its in-use performance.

An electrolytic cell will be tested for its life. One manufacturer of these cells states that there is a limit to the total current time integral

[REDACTED]

DECLASSIFIED

HW-7546c

beyond which the cells will not operate. Other manufacturers do not admit to this limit.

Following the laboratory tests and the on-reactor experience, an evaluation of the performance will be made and a listing of critical parameters provided so that additional monitors may be purchased or on-site fabricated for routine reactor application.

H. Individual Tube Rupture Monitoring

The goal of this program is to develop a method of fuel element rupture confirmation and individual process tube identification which is economically applicable to existing reactors. To this end, the following measurements of the operating characteristics of the He-3 neutron spectrometer have been made:

1. Sensitivity and resolution to monoenergetic neutrons in the 400 Kev to 1 Mev energy range.
2. Its sensitivity to thermal neutrons and background gamma rays.
3. Its response to an operating reactor rear face neutron and gamma background.

These measurements have shown that it may be feasible to make a neutron monitoring system which would be sensitive to the fission product delayed neutrons on an operating reactor's rear face yet insensitive to the background photo-neutrons, thermal neutrons, and gamma radiation.

Work yet to be done involves the following:

1. Additional on-reactor measurements with the He-3 detector to confirm existing measurements.
2. Mounting the He-3 detector and preamplifier on the KE remotely operated flapper carriage for confirming ruptures.

DECLASSIFIED

-54-

HW-75466 RD

3. Making neutron measurements on 105-H downcomer with He-3.
4. Proceed with rupture simulation experiment on 105-H utilizing all existing rupture monitor equipment systems - He-3 delayed neutron BF-3 delayed neutron systems and gross gamma system.
5. Determine the availability and operating characteristics of neutron energy threshold fission detectors which use Np^{237} , Pa^{231} and U^{236} as the fissionable material.
6. Evaluation of new solid state neutron detectors and neutron spectrometer
7. Assist reactor operating personnel in rupture confirmation to gain an insight into operational rupture confirmation problems.
8. Procure or develop a low noise high radiation resistant proportional counter preamp capable of operating continuously in a reactor rear face area.
9. Based upon the results of the above tests and measurements, a prototype rupture confirmation and individual process tube fuel rupture identification system is planned for installation on an operating reactor.

I. Dose Rate Telemetering

The dose rate telemetering development work was recently divided into two approaches. Each approach will use a different means of acquiring the same end result, that of obtaining a completed prototype system. The first approach, started some time ago and currently active, will follow a plan of fabricating a prototype system on plant with the use of available radio-telemetering components. The second approach will follow a plan of off-site procurement using detector circuitry and other information developed earlier in the first approach. Enough information

DECLASSIFIED

-55-

HW-75466 RD

has been gained about problems inherent to this application of radio-telemetering that a prototype system can be specified for off-site procurement.

On-Site Fabrication:

Initial tests on a single channel dose rate telemetering system indicated that radiation monitoring by radio telemetry is feasible. Fabrication of a five channel system was started. A detector count rate circuit used in a commercially available radiation area monitor was modified and miniaturized for use. Receivers were fabricated. Discriminators that had been excessed from another government operation were obtained. Sub-carrier oscillators for use in the detector-transmitter package were purchased. Two channels of the five channel system were fabricated and tested. Satisfactory results were obtained in signal transmission tests. Test results indicated that excessive temperature drift was occurring in high voltage power supplies and sub-carrier oscillators. Also, excessive drift has been observed in the discriminators. Further tests are necessary for positive identification of the problem. A high voltage power supply and a sub-carrier oscillator, both temperature stabilized, have been purchased for evaluation in an improved system.

It is planned to fabricate a single detector-transmitter package using newly acquired components. Tests will be performed to determine system accuracy. Satisfactory operation is expected of all components except, possibly, the discriminators. If satisfactory discriminator

DECLASSIFIED

HW-75466 RD

operation is not obtained, the commercial market will be investigated further for possible solutions to discriminator problem. After a single channel has tested satisfactory, a six channel system will be completed. Receivers, which were fabricated previously, will be tested to determine if receiver selectivity is adequate for narrow band operation as required for present frequency assignments.

Off-Site Procurement

A preliminary specification for off-site procurement of a six channel dose rate telemetering system has been written and a market survey has been initiated to learn of vendors qualified to fabricate the prototype system and to obtain an idea of cost and delivery.

After completing the market survey, a final draft of the specification will be prepared for purchasing use. If satisfactory proposals are obtained, a demonstration system will be purchased.

J. Fixed Radiation Monitoring (Health Monitoring)

A specification for logarithmic picoammeter was written and two prototype instruments were purchased from four different vendors through a negotiated purchasing procedure. All four vendors have completed their prototypes and currently are testing for performance. On plant arrival of the prototype picoammeters is expected by March 1, 1963.

Work in progress or being planned for:

1. Assist AEC Purchasing as required and requested to insure the delivery of instruments for evaluation March 1, 1963.
2. Test and evaluate vendors prototype log picoammeter as per HWS-5991, Rev.
3. Provide development support if required to make vendors prototypes meet specification requirements.
4. Issue final evaluation and report.

DECLASSIFIED

HW-75466 RD

V. REACTOR INSTRUMENTATION AND SAFETY CIRCUIT PROGRAM

The following instrumentation and safety circuit program is based on four assumptions with respect to future plant operation. First, there will be no major expansion programs to raise power levels beyond the capability of present plant equipment. Second, instrumentation installed in the future will be justified primarily on reactor and nuclear safety improvement needs and/or replacement of obsolete and difficult to maintain equipment. The third assumption is that the equipment concepts proposed are applicable to the reactors as they exist today and will provide the necessary protection if an overbore or zirconium tube program materializes. The fourth assumption is one of economics which is stated only for clarification purposes; as much of the present existing equipment and concepts will be carried over into the proposed program as possible.

A single criteria for economic plant operation and reduced maintenance expense is that instrumentation on either the front or rear faces of the reactors will be minimized with alternatives not involving these locations strongly recommended. The severe environment of rear face applications accompanied by the inadvertent and often unavoidable damage to the equipment during major tube outages and other rear face work makes the operation and maintenance costs of such equipment very high. Elevator time is generally required for this maintenance, and normally elevator work governs the length of outages and establishes the time operating efficiency (TOE) of the plant.

The following discussion is the proposed instrumentation and safety circuit program by classification (Section II A).

DECLASSIFIED

HW-75466 RD

A. Reactor Safety Circuit Instrumentation (Class I)

Before discussing the instrument systems, it is necessary to discuss safety circuits and power supply concepts for these instrumentation systems because they must be closely integrated into the overall system approach. Figure 5 (Sheets 1 and 2) Reactor Safety Circuit and Critical Instrumentation Power Supplies, shows the two-out-of-three channel safety circuit and instrumentation system concept in elementary circuit form. Sheet 2 shows the three sub-safety circuits and the power supplies for all critical and safety circuit instrumentation. It should be pointed out that an alternate A.C. power source (BPA, backed up from plant generation facilities) should be provided to each instrument for maintenance purposes and power supply flexibility. This feature was not shown because it was believed that it would complicate an already complex drawing and could be covered adequately by this short explanation.

Sheet 1 shows the summation of the sub-safety circuit relaying on the VSR power supply battery and the latching circuit. Also shown is the Ball 3X System which is patterned after that now operating at the K Reactors.⁽⁵⁾ These two sheets cover basically the entire reactor safety instrumentation power supply, and safety circuit system program concept. The following discussion will reference these sheets. Document HW-72312, "Safety Circuit Relaying Study"⁽⁶⁾ provides the technical backup and explanations for the design development of the system relaying concepts employed and the use of static inverters for a separate and isolated power source for all critical and continuity sensitive instrumentation.

The critical instrumentation power supplies are based on the use of station batteries and conversion of D.C. to A. C. through static

190 Building
(Typical for 558 Areas)
Same Principle Can Be
Used at C, KZ, & KW Reactors.

AC Power Source
#1

PROPOSED REACTOR SAFETY CIRCUIT AND CRITICAL INSTRUMENTS

UNCLASSIFIED

PROP

LEGEND

1. Last Letter "W" Stands for Auxiliary Relay
2. PR1: Pressure Monitor Row Relay, First Section
3. PR2: Pressure Monitor Row Relay, Second Section
4. PR3: Pressure Monitor Row Relay, Third Section
5. PC1: Pressure Monitor Column Relay, First Section
6. PC2: Pressure Monitor Column Relay, Second Section
7. PC3: Pressure Monitor Column Relay, Third Section
8. PF: Power or Pumping Failure Relay
9. 74: Auxiliary Relay Code Number
10. IRM1: Intermediate Range Rate Monitor (Channel #1)
11. IRM2: Intermediate Range Rate Monitor (Channel #2)
12. IRM3: Intermediate Range Rate Monitor (Channel #3)
13. LRR1: Linear Rate of Rise (Channel #1)
14. LRR2: Linear Rate of Rise (Channel #2)
15. LRR3: Linear Rate of Rise (Channel #3)
16. CX1: Solenoscope (Channel #1)
17. CX2: Solenoscope (Channel #2)
18. CX3: Solenoscope (Channel #3)
19. NT1: Neutron Flux Monitor, Top (Channel #1)
20. NT2: Neutron Flux Monitor, Top (Channel #2)
21. NT3: Neutron Flux Monitor, Top (Channel #3)
22. NB1: Neutron Flux Monitor, Bottom, (Channel #1)
23. NB2: Neutron Flux Monitor, Bottom, (Channel #2)
24. NB3: Neutron Flux Monitor, Bottom, (Channel #3)
25. NB4: Neutron Flux Monitor, Bottom, (Channel #4)
26. BP - Bypass Contact
27. Electrical Ground
28. Indicating Lights
29. Breaker
30. Battery
31. Relay
32. Relay Contact
33. Fuse
34. Coil
35. Audible Alarm
36. Ground Test Switch

ROW SECT/1
PRESS
USING CYP

COLUMN 5
PE
USING CYP

-60-

FIGURE 3 - SHEET 2

PROPOSED REACTOR SAFETY CIRCUIT AND CRITICAL INSTRUMENTATION POWER SUPPLIES

ROW SECTION OF DUAL TRIPPING
PRESSURE MONITOR
USING CYPAK TRIP IDENTIFICATION

COLUMN SECTION OF DUAL TRIPPING
PRESSURE MONITOR
USING CYPAK TRIP IDENTIFICATION

1002 SAFETY CIRCUIT AND
INSTRUMENTATION POWER SUPPLY

1003 SAFETY CIRCUIT AND
INSTRUMENTATION POWER SUPPLY

-60-

HW 75466 RD

POWER SUPPLIES

1X03 SAFETY CIRCUIT AND INSTRUMENTATION POWER SUPPLY

1X04 SAFETY CIRCUIT AND INSTRUMENTATION POWER SUPPLY

1X05 SAFETY CIRCUIT AND INSTRUMENTATION POWER SUPPLY

UNCLASSIFIED

DECLASSIFIED

-61-

HW-75466 RD

[REDACTED]

inverters. This conversion is necessary because all present instrumentation is A.C. and replacement of same would be most expensive. New equipment should be D. C. so as to eliminate the necessity for this conversion.

As stated in HW-72312, ⁽⁶⁾ the concept of batteries supplying instrumentation through inverters was applied in the design of DR, C, H and the K Reactors using rotary inverters. However, operator errors and the level of maintenance on this equipment made it less reliable than direct BPA operation which is now used at all reactors. The system concept as presented here divides the instrumentation into three separate and isolated sections permitting complete failure of a power source and the associated instrumentation without loss of function or operating continuity of the other equipment. The use of static inverters instead of rotary inverters should overcome most of the maintenance problems previously encountered because of the higher reliability of these units.

There are many different static inverter models and concepts presently available on the market. The power capacities range from 250 volt-amperes to 10 KVA. Some have switching characteristics which can transfer the power source between two different A.C. supplies or in case of complete A.C. failure will transfer to the inverter function in less than 2 cycles without frequency shift or variation, with a voltage drop during these two cycles of 20 percent or less.

Presently, a separate study of static inverters is being conducted within Facilities Engineering Section to verify these manufacturer's specifications and determine the final scope of work in this area.

[REDACTED]

DECLASSIFIED

-62-

HW-75466 RD

1. Primary Critical Instrumentation, Reactor Safety Circuit
Instrumentation (Class I A)

a. Intermediate Range (Nuclear) Monitoring System

The Intermediate Range Monitor is presently in the final stages of development and is nearly ready for application at all production reactors. This system is justified on the basis of reactor and nuclear safety improvement. (The details of this justification will be presented in the Project Proposal and Preliminary Engineering Documents.)

The system should be designed for a seven decade nominal range with a hoped for 6.5 decade effective operating range.

There will be three complete and independent operating channels each supplied from one of the three instrumentation and sub-safety circuit batteries through a static inverter. Each operating channel will consist of a gamma compensated ion chamber and a seven-decade or more logarithmic amplifier.

There should be two safety circuit tripping functions:

- 1) Fixed exponential rate trip (15 second period) and 2) Adjustable level trip.

The three chambers will be located near each other so as to provide the same relative information. At B, D, DR, F, and H Reactors they should be installed in the top of the reactor.

Holes should be bored to place the chambers on the centerlines of the VSR pattern as shown in Figure 6. By installing these chambers on top of the reactor, the level trip function of this instrument can be used to monitor the top-half of the reactor in the same manner as the present Beckmans now monitor

-63-

B, D, DR, & F VSR PATTERN
(Partial View) H VSR PATTERN
(Partial View)

FIGURE 6

LOCATION OF INTERMEDIATE RANGE
(Nuclear) MONITOR ION CHAMBERS
IN THE VSR PATTERNS -B,D,DR,F,H
REACTORS

DECLASSIFIED

HW-75466 RD

[REDACTED]

the lower section of the reactor. This also permits a reduction in the number of Zone Temperature Monitor points (to be discussed later). Because new holes must be bored or present holes bored to size in most reactors to install these chambers, it seems appropriate to take advantage of the level tripping function of this instrument to provide level trips in the top of the reactor instead of on the side where such trips will not be as useful.

At the C and K Reactors, the top shield would offer a challenge to bore holes in the VSR pattern without running into cooling tubes, ball hoppers and channels, structural steel, etc.

These reactors are equipped with octant holes in the sides.

To overcome the boring problem, it is proposed that four channels of instrumentation be installed at these reactors, one channel in each top octant hole. The reason four channels was chosen is that these holes are far enough apart that each channel can be monitoring a relatively different flux condition as demonstrated by present octant monitoring experience. A any two-out-of-four trip network will be employed for this case for both rate and level trips.

b. Linear Rate-of-Rise

Development effort is nearing completion. Linear rate-of-rise should be ready for application to all production reactors in 6 months. Justification is based on reactor and nuclear safety improvement which will be delineated in the Project Proposal and Preliminary Engineering documents.

[REDACTED]

DECLASSIFIED

-65-

HW-75466 RD

The reactor is started from critical and maintained on an exponential rate-of-rise (period) until approximately 10^{-3} power level. At this point, the rate of power level increase should be changed from an exponential rate to a controlled linear rate.

This is done to prevent overshooting level limits as equilibrium is approached. Also, the reactor must be sampled uniformly for the "heat" distribution in this range of power levels.

Therefore a Linear Rate-of-Rise Instrumentation System should be installed to monitor the rate(linear) at which the power level is being increased in the 10^{-3} to 10^{-0} range. It will be a three channel system with signal coming from RTD's distributed uniformly across the rear face of the reactor.

Ten (not including provision for spares) RTD's shall be used in each of the three channels totaling 30 RTD's. The RTD's shall be located in groups of twos in a pattern as shown in Figure 7. A spare RTD is installed for each group of

FIGURE 7
RTD LOCATION FOR A SINGLE CHANNEL OF LINEAR RATE-OF-RISE

- Denotes active RTD
- Denotes spare RTD

DECLASSIFIED

-66-

HW-75466 RD

[REDACTED]

two RTD's. The spare can be connected in place of a failed RTD in its area. Because there will be three groups of two RTD's in each location (because a three channel system is used), this does not imply that there must be one spare for each group of two. The same spare could be assigned to all six in that location or one spare could be assigned to each group of two. This means that 35 to 45 RTD's would be required for the linear rate-of-rise system.

The RTD's will run from the rear face (through a junction box not in the rear face) to a bridge circuit. Each two RTD's of the same channel and location will be connected in opposite legs of the bridge circuit. The five bridge circuits will supply a signal to an averaging circuit. The averaging circuit should be adjustable to average 5,4,3,2 or 1 bridge circuit to produce an output signal to the rate instrument. The rate instrument should have an adjustable-fixed rate trip. The trips from the three channels will be connected in a two-out-of-three trip network.

A recorder and a rate meter should be located at the instrument with a remote rate meter located at the control desk.

The linear rate system should be interlocked to bypass the exponential rate trips of the Intermediate Range Monitor after a power level of 10^{-1} has been reached. This will reduce the possibilities of a failure in the Intermediate Range Monitor period function causing a spurious scram when the instrument is no longer needed for exponential rate protection.

[REDACTED]

DECLASSIFIED

-67-

HW-75466 RD

c. Neutron Flux Monitoring (High Level)

In order to divide the reactor into two zones or regions of nuclear type monitoring, the four present Beckmans shall be kept (as upgraded by Design Change 209)⁽⁷⁾ to monitor the bottom half of the pile. As previously mentioned, the level trip from the Intermediate Range Monitor will be used to monitor flux levels in the top of the pile. Each system (top and bottom) should have trip contacts independent as shown in Figure 5. Level trips would not need to be set for "cold" and "hot" startups as presently done because the Beckmans will not be required for rate control after the Intermediate Range Monitor and Linear Rate-of-Rise equipment is installed. These level trip limits can be fixed at or near equilibrium power levels for reactor startup and then adjusted to the proper percentage trips as the reactor approaches equilibrium.

The present Beckmans will be retained as the bottom neutron flux monitors in the "any two-out-of-four" tripping network. The level trips of the Intermediate Range Monitor will be in a two-out-of-three network at the B, D, DR, F, and H Reactors where three channels will be installed. An "any-two-out-of-four" tripping network should be used at C and the K Reactors. The octant flux monitoring concept will be abandoned from all planning considerations at this time for use as a high level monitoring system except where such systems presently exist. It should be acknowledged that the function of such a system is approached with the above system (combinations of Intermediate Range Monitors and present Beckmans without the

DECLASSIFIED

-68-

HW-75466 RD

[REDACTED]
additional capital outlay for a separate system.)

Incore Flux Monitors are still in the development stage with possibly as much as two years remaining (depending on assigned priorities) before the chambers will be perfected for application to the production reactors. In light of the present business climate it is doubtful if this system should be required as a reactor control or safety instrument. However, engineering development should not be stopped on this basis because climate changes have been known to occur. Development of this system should be carried through to a full reactor prototypic installation.

The incore system as originally proposed would install five chambers in each of five process tube channels. The channels were selected in the center of each quadrant, and the fifth channel was to be located in the center of the reactor. This system as proposed has a disadvantage of requiring elevator time (front and rear) for maintenance.

Estimated cost of the system for eight reactors has been placed in the range of \$1,000,000 to 1,300,000.

A sizable reduction in capital investment for this system may be realized if "spline" monitoring proves satisfactory for calibrating the incore chambers. This would eliminate the need for the Traveling Wire Flux Monitor (TWFM).

d. Zone Temperature Monitoring - Six Old Reactors

Because of the addition of the top neutron flux monitoring system in the form of the level trip of the Intermediate Range Monitor, adequate protection can be still maintained with a reduced Zone Temperature Monitor (especially when considering [REDACTED])

DECLASSIFIED

-69-

HW-75466 RD

that this function has never been previously required for nuclear safety). The present Zone Temperature Monitors at the six old reactors should be revised from a 211 point single monitoring system to three monitoring systems, each consisting of 22, 17, and 22 points respectively. All points will lie within the enrichment fuel ring only. This totals 61 points which is a 70 percent reduction in total points from the present 211 point concept.

It should be realized with this reduction in points, that a smaller number of total points may be permitted out-of-service during reactor operation than for the full 211 point system. However, it is estimated that at least one point per row can be by-passed as long as it is not adjacent to a bypassed point in the rows immediately above and below. This will permit about 11 points to be bypassed during operation. Failures beyond 11 RTD's should be tripped (in scram position) permitting the reactor to operate as long as these tripped points are not in adjacent rows which will then scram the reactor.

The tripping network will be designed to scram the reactor when single point(s) in two adjacent rows exceed a temperature level of 125 C. A second trip circuit will be designed to scram the reactor when any four or more rows have points tripped. This feature can be easily obtained by wiring an additional set of contacts into the safety circuit from the relays required to provide the two adjacent row tripping network. This later tripping function serves an "en masse" coverage if the reactor is affected by a single large "hot" spot or multiple small "hot" spots.

DECLASSIFIED

- 70 -

HW-75466 RD

FIGURE 8
ZONE TEMPERATURE MONITOR SYSTEM
POINT LAYOUT
(61 Points Total)

LEGEND:

- Denotes approx. E-ring position.
- 1,2,3 Denotes which of the three channels that point belongs to.

Figure 8, Zone Temperature Monitor System Point Layout, shows the location of the RTD's for each of the three channels. It should be noted that all points were selected on the basis of the original ZTM layout and should not require much re-location effort to achieve this layout pattern. This layout pattern is considered to be the absolute minimum configuration which will permit reactor operating with monitoring points in a failed condition.

e. Temperature Monitoring - K Reactors

An approved project (CGI-967) will install a High Speed Scanning Type Temperature Monitor at the KW Reactor. It will provide the level and linear rate protection of the Zone Temperature Monitor and the Linear Rate-of-Rise Instrumentation. The justification⁽⁸⁾ for the KW system was approximately 60 percent safety and 40 percent for increased production through improved operating efficiency.

The tentative planning at the time the KW system was approved called for a similar second system to be installed at KE Reactor after completion of the KW system. Under the present business "climate" which calls for no production increases, the justification for a KE system must be based primarily on safety. This means the justification for a KE system would be 40 percent short using the same justification approach as used for KW Reactor. Also with a reduced Zone Temperature Monitor system proposed for the old areas, it is appropriate to reduce the alternative cost as compared to that used in the justification for the KW scanning system. Because of these changes in business climate and proposed

DECLASSIFIED

-72-

HW-75466 RD

instrumentation philosophy, it would be prudent to reconsider planning for the KE Reactor and install a new Zone Temperature Monitor, Data Logging System, and Linear Rate-of-Rise System at less capital cost (approximately \$400,000 less). It should also be noted that if Zone Temperature Monitoring is required in the old reactors, then decisions and actions should begin immediately to provide the K Areas with this protection.

f. Power Failure Detection

Present power failure (pumping and electrical failures) appears to be adequate from a safety standpoint except in the area of broken shaft protection. From a continuity standpoint, the power failure detection equipment is probably over sensitive, scrambling the reactor needlessly at times. However, to make this system less sensitive, from a continuity standpoint would also be less sensitive from a safety standpoint which cannot be permitted. The effect on operating continuity of this system causing spurious scrams is relatively very small when compared to the spurious scrams caused by the Pressure Monitor. Therefore, if continuity is to be attacked, the largest gains can be achieved in the Pressure Monitor. The spurious scram ratio between these two systems is estimated to be greater than 20 to 1.

Improved detection of pump shaft breakage should be installed for safety circuit action. The Pressure Monitor does provide a degree of protection in this area, but pressure decay time to the Pressure Monitor may be slow allowing boiling in the downcomer before initiation of a scram signal. The Ball 3X System will not protect for a single broken shaft. Pressure or differential pressure instrumentation should be applied to

DECLASSIFIED

HW-75466 RD

each pump to protect against shaft failures in critical pumping facilities in addition to the present electrical power failure detection equipment.

2. Operating Instrumentation, Reactor Safety Circuit Instrumentation (Class IB)

a. Flow Monitoring

Adequate flow monitoring must be maintained at all times to assure that heat removed is commensurate with heat generated in each process tube. The present Flow Monitor is basically a mechanical device which has been historically replaced (rebuilt, modified, and improved) every five years at an average cost of more than \$50 per point. Interim maintenance costs are not discussed here but are recognized as being of sufficient magnitude that they should be cranked into all economic studies concerning Pressure Monitor replacement. With known operating costs acknowledged to be in excess of \$17 per year per point (this cost is believed conservative by a factor of two at a minimum), engineering development effort should be concentrating on producing an alternative system to replace the Pressure Monitor when the next replacement is due (approximately 1965-66). Also, this replacement system should eliminate the undesirable features of monitoring flow as a function of pressure as previously discussed (Page 29) to eliminate spurious scrams from pressure transients. The target date for completing development on such a flow monitor should be about June, 1964 so that sufficient time will be available for engineering evaluation and project proposal preparation.

DECLASSIFIED

HW-75466 RD

b. Seismoscope

The seismoscope should be changed to a two-out-of-three tripping system.⁽⁵⁾ Three channels are presently installed with one used for annunciation only. The three channels should be all in the safety circuit.

Two proposals are made here for action. One, set all three channels to trip on a modified Mercalli Scale of 5. Or, two, set two channels to trip on a modified Mercalli Scale of 5 and the third to trip on a modified Mercalli Scale of 3 to provide annunciation of a low intensity earthquake.

A relay tripping circuit has been proposed by Manufacturing⁽⁹⁾ to eliminate the use of the electronic amplifier which exhibits non-fail-safe characteristics. This relay circuit is suggested for use on the basis of its simplicity. Presently this circuit is undergoing testing in order to verify the engineering by laboratory tests.

B. Reactor Process Control Instrumentation (Class II)

Reactor Process Control Instrumentation provides information only on the status of the reactor mainly during plant operation. However, when discussing instrumentation regarding coolant flow, one must remember that the water plant must maintain adequate coolant to the reactor 100 per-cent of the time.

1. Primary Critical Instrumentation, Reactor Process Control (Class II A)

a. The Main Annunciator

Provision should be made to enlarge the main control room annunciators at most reactors. Presently, this work has been started or completed at B, F, and the K Reactors. The

DECLASSIFIED

-75-

HW-75466 RD

annunciator modifications should include provision for operation from the primary critical power supply, the same as the safety circuit instrumentation because the annunciator is an extension of all other reactor instrument systems combined to alarm at one location.

b. Low Level Neutron Flux Monitor

This instrument is the only instrument in the reactor which is capable of determining if the reactor is sub-critical, critical, or increasing in power level at low power level operation. The Sub-Critical Monitor, as it is often called, should be on the battery power supply as shown in Figure 5 (Page 59).

c. Temperature Monitor

Certain elements of the temperature monitoring equipment are very useful to operating personnel during emergency conditions to determine the heat generation rates in the reactor. Provision should be made to supply these elements from the battery power supply. Because it is difficult to determine prior to an emergency event just what elements would be most useful, it is recommended that the entire system be capable of being operated from the battery source. Normal operation should be from BPA because of the total load considerations of the temperature monitor systems.

d. Gamma Monitor & Effluent Monitor (107 Basin)

Further improvements to the fuel element rupture monitoring beyond the present project action for all eight reactors (the K Reactors are now being added) will probably not be

DECLASSIFIED

-76-

HW-75466 RD

[REDACTED]

necessary. It is recognized that system maintenance (from minor work to major replacements) will be required on a periodic basis; however, general improvements will probably be made as they apply to maintenance efforts.

After present project work is completed no major efforts should be required for at least five years. This system should be supplied from the battery source as there are safety implications to both personnel and the reactor itself if the instrumentation is lost under certain emergency conditions.

In line with the philosophy of monitoring the effluent for fuel element ruptures, the 107 Basin Effluent Monitor should be operated from the battery source. This could serve as an alternative to having the Gamma Monitors battery-operated of the load from the Gamma Monitor is too large for the capacity of an inverter and a battery.

e. Bulk Outlet Temperature Recorder

The bulk temperature recorder can serve as a backup to the power calculator in case of failure of that system. It is also a very useful tool in measuring total heat generation of reactor. Design changes 643 and 644 (10) will install recorders independent from the present system which is tied to the power calculator. This system is planned to have its own self-contained power source (built-in Nickle-Cadmium Battery) to function in case of an A.C. power failure. The purpose of the design changes is to install an automatic device to lockout the HCR "Deadman" Switch and lockout the PCCF systems.

[REDACTED]

DECLASSIFIED

-77-

HW-75466 RD

f. Miscellaneous Coolant Instrumentation

On a general overall basis, instrumentation installed appears adequate. Any instrumentation showing system continuity for the primary, secondary, and last ditch systems which is dependent on electric power should be placed on the battery source.

g. HCR, VSR, Ball 3X and Other Indicating Lights

Indicating lights should all be D.C. and operated from the same battery as the annunciator.

2. Operating Instrumentation, Reactor Process Control (Class II B)

a. Moderator Temperature Instrumentation

The use of sheathed thermocouples as stated in Design Change 584 is suggested for adoption in all reactors (presently approved by B,C,F, H, KE and KW Processing). As technical advancements are made, they should be incorporated as replacements are made.

b. Thermal Shield Temperature Instrumentation

The present instrumentation concept is adequate

c. Reactor Atmosphere Instrumentation

There are four general areas of improvement for reactor atmosphere instrumentation:

The first area is moisture monitoring. Modifications are being made under an engineering program to upgrade the present Moisture Monitor Equipment (Dew Cells). The last step in the program is the installation of new 100 point recorders at the old reactors. This work should be completed by June 1963. Also, inlet and existing moisture monitoring equipment will be provided to record continuously the moisture in the atmosphere.

DECLASSIFIED

-78-

HW-75466 RD

The second area of improvement is gas analysis. Gas chromatographs and oxygen analyzers should be installed at all reactors. This will provide continuous composition monitoring and permit better control of moderator life.

The third area is gas makeup equipment. Propositional makeup equipment is badly needed to give better control of gas composition. Presently, gas cannot be added according to the desired ratio, but is added as one gas or the other. Often, this inability to control gas composition to the desired ratio has caused heat cycles which make reactor operation most difficult.

All instrumentation and controls for the reactor atmosphere should be designed to provide for the possibility of future remote operation of the 115 Building.

In general, this philosophy has been incorporated in all of the above programs, which makes the final step automation of the dryers. This can be accomplished by a cycle timer.

d. Power Calculator

The present instrument appears to be adequate for the life of the reactor.

C. Non-Process and Building Environmental Instrumentation (Class III)

Non process and building environmental instrumentation are positioned throughout the building to monitor secondary functions and auxiliary work.

1. Radiation Health Monitors

Initial engineering effort was initiated about a year ago⁽¹¹⁾ to provide new radiation health monitors and criticality alarms

DECLASSIFIED

-79-

HW-75466 RD

[REDACTED]

in the reactor buildings. The reactor buildings were surveyed and the number and location of these monitors was established in an engineering concept report.⁽¹¹⁾ Presently, instruments are being procured for testing to determine if they will meet specifications for performance as both radiation health monitoring and criticality monitoring instruments.

In general the number of instruments required at the old reactors was about 30 while the K Reactors required over 50 each. Only a percentage of these instruments are required to operate in the Primary Critical Class. During emergency events, when electric power (BPA and 184 generator) is lost, certain areas need not be monitored as access to these areas is either not required or can be controlled. The overlapping protection of a number of instruments in the building can be used to advantage by selectively connecting only the minimum number required for minimum protection to the battery power supply. The remainder can be connected to BPA and backed up by 184 generation. The principle reason for not connecting all instruments to the battery is that the total load requirements of these instruments plus the alarming equipment would be higher than all other reactor instrumentation combined.

2. Rear Face Beckman

The rear face Beckman is a good indicator of whether the reactor is operating or not. This instrument serves in about three capacities: 1) Rear face health monitor 2) rupture and discharge monitor, and 3) indication of power level. Information from this instrument can be most valuable under certain situations.

[REDACTED]

DECLASSIFIED

HW-75466 RD

It should be supplied from the battery supply through a static inverter.

3. Confinement Instrumentation

A most likely situation when the confinement equipment will be called upon to operate is during an emergency event when normal A.C. power has been lost. Therefore, all confinement instrumentation should be classed as Primary Critical and supplied from station batteries through static inverters.

4. Miscellaneous Instrumentation

In each reactor, there is numerous miscellaneous equipment which must be considered on its own merits as far as classifying it for power supply purposes. Most principle equipment has been covered at this point, and in general, equipment not discussed can be operated from its present supply.

Reactor Design
FACILITIES ENGINEERING

DECLASSIFIED

-81-

HW-75466 RD

VI. REFERENCES

1. HW-75010, Power Backup Requirements for Reactor Instrumentation, B. R. Cremer, et. al. October 1, 1962.
2. Letter, H. W. Heacock to S. M. Graves, Comments on HW-75010, Power Backup Requirements for Reactor Instrumentation, October 24, 1962.
3. HW-75657, Logic for Reactor Safety Circuit Systems, C. L. Goss, January 11, 1963.
4. HW-72555, Development and Application of Principles of Nuclear Safety Instrumentation, G. C. Fullmer, February 1, 1962 (Confidential)
5. HW-74975, Review of Hanford Reactor Seismoscope System, S. W. Nechodom, October 3, 1962.
6. HW-72312, Safety Circuit Relay Study, V. G. Blanchette, et. al. January 24, 1962.
7. Design Change 209, Replacement of Flux Monitor Amplifiers D, DR, F, and H Reactors, W. D. Hamilton, October 16, 1962.
8. HW-70655 Rev. 1, Engineering Conceptual Study Report, High Speed Scanning Temperature Monitoring System For 105-KW Reactor, J. L. Deichman, March 30, 1962.
9. Letter, W. D. Hamilton to J. R. Spink, Seismoscope Circuit Test, December 5, 1962.
10. Design Changes 643 and 644, Bulk Outlet Temperature Lockout for The HCR "Deadman" Switch and PCCF System, All Reactors, J. L. Deichman (not yet issued).
11. HW-72131, Replacement and Improvement of Fixed Radiation Monitoring Instrumentation, Engineering Concept and Study Report, H. C. Copeland, February 27, 1962, and Supplement No. 1.

VII. ACKNOWLEDGEMENTS

The author would like to thank all those who have contributed their knowledge and experience to produce this overall instrumentation program. Special thanks is given to B. W. Herrman, Reactor Design Operation, for proof reading and commenting on the final copy. W. D. Hamilton, Plant Equipment Engineering Operation, is also recognized and acknowledged for

DECLASSIFIED

-82-

HW-75466 RD

his comments and efforts in representing the Manufacturing Section's viewpoint on instrumentation.

Section IV of this document was prepared and written by J. E. Kaveckis, et. al., Instrument and Electrical Development Operation, to present and summarize the document status of new instrument systems. Their work is greatly appreciated.

C. L. Goss, Reactor Design Analysis, prepared a study document (HW-75657 - attached) to determine the optimum safety circuit logic. This document has been used as the basis for the overall program presented in Section V. A special thanks is given to Carolyn for her long hours of effort.

DATE

FILMED

7/29/94

END