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EXISTING REACTOR EXPANSION STUDY BASIS

by

H. W. Heacock

June 4, 1959

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EXISTING REACTOR EXPANSION STUDY BASISINTRODUCTION

The latest EAPO Five Year Program review, HW-59633, indicates that significant increases in Pu production from the eight existing Hanford reactors may be achieved. These production increases would be attained by a combination of several methods including increased process water flow rates, reactor coolant outlet temperatures, improved time operated efficiency, conversion ratio and reduced transient reactivity losses. In order to provide a realistic basis for budgeting to meet these or other increased production goals, it is necessary that a study program be undertaken to determine in general terms the more nearly optimum plant changes required and to evaluate the economic and technical feasibility of achieving future process conditions. This study program will necessarily consider the interrelated effects of a number of various facets of reactor and water plant process conditions, operating requirements, and proposed development programs.

The purpose of this document is to present a plan for the execution of the prepared study. Included in the study outline are the basic study consideration, problem assignments and schedules, required manpower estimates, and tentative cost estimates.

REVIEW OF STUDY BASIS

The items discussed below are considered to be the fundamental process parameters which will be considered in the study program. There are a number of other process variables which must be considered in the establishment of a particular study case but are dependent variables of the basic parameters. A number of the dependent items will be discussed in following sections of this report. It is recognized that it may be necessary to revise the study conditions listed for several of the basic parameters as the study progresses and greater insight into various process limits

is achieved. The parameters listed, if combined in all possible combinations, would result in an unusable number of study cases. However, by the prosecution of a number of parallel study programs and the judicious selection of parameters for final correlation, a reasonable evaluation of the potential of the existing reactors can be obtained within available time and manpower limitations. Several of the basic variables selected differ from those normally used in a reactor optimization study; however, since the fullest use will be made of existing process facilities, the capability of these facilities will have considerably more influence on the study results than more basic reactor process parameters. The basic variables selected for study are as follows:

1. Process Water Flows

At the present time, the reactor process water flow rates are approximately as follows:

B, D, F, DR, and H	-	80,000 gpm
C	-	95,000 gpm
KE-KW	-	175,000 gpm

Recent studies of the existing reactor process water system capabilities⁽¹⁾⁽²⁾⁽³⁾ have indicated that some increase in flow rates may be achieved for relatively modest expenditure of funds. Little information is available regarding the feasibility of achieving additional flow increases beyond these. Study conditions of approximately 110, 120, and 135 and 200 per cent have been selected to cover the range of possible flow increases. The flow rates selected for the specific reactors are as follows:

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	<u>Base Case</u>	<u>Study Condition</u>
B, D, F, DR, and H	80,000 gpm	35,000, 95,000, 110,000, and 150,000 gpm
C	95,000 gpm	105,000, 115,000, 125,000, and 150,000 gpm
KE-KW	188,000 gpm	Add 1 and 2 pumps to present 190 pump stations and 250,000 gpm

Some minor adjustment of the specific flow rates selected may be required during the progress of the study to make the fullest utilization of presently installed facilities.

2. Bulk Outlet Temperature

At the present time, the bulk outlet water temperature of the various reactors is approaching 93° C, with plans established to increase this limit to 95° C in the near future. Significant further bulk temperature increases will require extensive alteration of the existing rear face piping and effluent system to provide some degree of pressurization⁽⁴⁾. There appears to be little incentive for the achievement of bulk outlet temperatures above the 110-120° C range due to increasing fuel element corrosion rates. The bulk temperature conditions selected for study will encompass the temperature range from where only minor modifications to the existing piping and effluent system will be required to those requiring extensive alteration. One study case has been selected at the assumed maximum condition to determine cost trends. The study conditions selected are as follows:

	<u>Base Case</u>	<u>Study Conditions</u>
Bulk Outlet Temperature	95° C	98° C, 105° C, 115° C, and 125° C

1. Process Tubes

Plans are currently under way for the trial replacement of a number of the presently installed aluminum process tubes with zirconium alloy tubes of the same outside diameter in several of the reactors. The installation of zirconium process tubes will provide several benefits, such as: elimination of process tube replacement, the possibility of obtaining increased process water flow rates with present fuel elements due to the larger flow area available, an increase in the conversion ratio and a reduction in enrichment requirements with the utilization of larger fuel elements. These potential benefits may be further increased by using the reactor process channels to accommodate larger diameter process tubes of either aluminum or zirconium. Preliminary study has indicated that it may be possible to increase the process tube O.D. approximately 200 mils by enlargement of the graphite channels and reduction of the gunbarrel wall thickness⁽⁵⁾. An additional increase in process tube diameter may be achieved by enlargement of the hole through the cast iron thermal shield and replacement of the shielding donuts. The feasibility of enlarging the process channel, and the increase in diameter which can be economically achieved, must be given further consideration. Initial review indicates that if channel enlargement is undertaken then the objective should probably be the achievement of the maximum increase possible. The study cases selected were based upon zirconium tube installation in the present process channels and aluminum or zirconium tube installation in enlarged process channels. Both cases of process channel enlargement are also considered. The study cases are as follows:

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Area	Base Case <u>Aluminum</u>	Study Case	
		<u>Aluminum</u>	<u>Zirconium</u>
B, D, F, DR, and H	1.729" OD	✓ 200 mils OD & max. feasible dia.	present OD, ✓ 200 mils OD and max. feasible dia.
C	1.810" OD	" " "	" " " " "
KE-KW	2.764" OD	" " "	" " " " "

4. Operational Charge-Discharge

Significant production gains may be achieved by the installation of operational charge-discharge equipment on the existing reactors. This system provides benefits due to an improvement in reactor time operated efficiency, achievement of optimum goal fuel exposure, and improved power level efficiency. It will be necessary to evaluate the reactor gains achieved with and without the installation of this equipment.

5. Fuel Element

This successful attainment of any increase in reactor power level is highly dependent upon fuel element performance. There are several types of fuel elements beyond the current I & E type which should be included in any evaluation as well as giving consideration to the achievement of improved I & E performance. It will be necessary to select a fuel element design for each of the proposed study cases which is nearly optimum for the specific tube power, tube diameter, and temperature considered. To provide for an evaluation of the effect of fuel performance on system economics, alternate cases will be studied with pessimistic and optimistic levels of fuel performance.

Base Case

I & E Uniform Conversion

Present Quality

Study Condition

Optimum for Each Case

2 Levels of Fuel Performance

6. Fuel Exposure

For every fuel element configuration, enrichment pattern, specific tube power and bulk outlet temperature there is an optimum goal fuel exposure. It will be necessary to determine the optimum fuel exposure for each study case for which an economic evaluation is prepared.

7. Fuel Enrichment

As with fuel exposure, it will be necessary to determine the optimum fuel enrichment resulting from variations in Ng/Nu , fuel exposure, power level, method of control, and enrichment pattern for each study case.

The above conditions describe the basic process parameters which will be considered in this study. A summary of these parameters is contained in Table I.

There are a number of technical bases, process requirements and plant modifications which must be reviewed and evaluated in any study regarding the achievement of increased reactor power levels. The following section of this report, whose purpose is to provide a basis for the evaluation of manpower and time requirements for the performance of this study, is a summary and brief discussion of a number of these considerations.

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TABLE I
EXPANSION STUDY BASIC PARAMETERS

<u>Item</u>	<u>Base Case</u>	<u>Study Conditions</u>	
1. Process Water Flow			
B, D, F, DR, H	80,000 gpm	85,000, 95,000, 110,000, 150,000 gpm	
C	95,000 gpm	105,000, 115,000, 125,000, 150,000 gpm	
KE-KW	188,000 (5 pumps)	Add 1 pump - 190; Add 2 pumps - 190 250,000 gpm	
2. Bulk Outlet Temperature 95° C		98° C, 105° C, 115° C, 125° C	
3. Process Tubes	Aluminum	Aluminum	Zirconium
B, D, F, DR, H	1.729" OD	1/2 200 mils OD max. dia.	present OD 1/2 200 mils OD 1/2 max. dia.
C	1.764" OD	" " "	" " "
KE-KW	1.810" OD	" " "	" " "
4. Operational Charge- Discharge	Not installed	Operational in all areas	
5. Fuel Element	I & E Uniform Corrosion	Optimum for each case - 2 levels of performance	
6. Fuel Exposure	Optimum for case fuel element and tube power		
7. Fuel Enrichment	Optimum for case Ng/Nu fuel exposure, and power level		

STUDY PROBLEM ASSIGNMENTS

To evaluate the feasibility of attaining increased reactor power levels and to provide a basis for the performance of the parametric and economic studies the joint efforts of Facilities Engineering and Research and Engineering personnel will be required. Since the contributions of these groups will be in their particular fields of responsibility, the services and facilities available in other HAPO components will also be utilized to some extent. The following items as listed are not proposed to be an all inclusive listing, but rather as an indication of general types of problem assignments which may be subject to some revision as the study progresses. The problem assignments have been grouped in general fields of activity rather than by a functional activity type of listing.

A. Report Preparation

It is expected that topical reports will be prepared upon each of the various study assignments as the work progresses. However, the rather extensive task of editing and compiling the information generated in this study into a final summary report will necessarily be performed after completion of the various individual assignments. Considerable judgment will have to be experienced in compiling recommendations and conclusions based on the data from the individual reports for management consideration.

B. Basic Analytical and Engineering Studies

1. Engineering Evaluations

It will be necessary to evaluate the technical feasibility of achieving the proposed increased reactor power levels. Items which would be considered would include fuel element production and performance, graphite shifting and contraction, reactor life, over-all reactor safety, ultimate specific tube powers, process tube integrity, nuclear stability, and basic operational philosophy.

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2. Economic Analysis

It will be necessary to perform a number of economic analyses of the parametric study results, plant modification costs and resulting operating cost changes in order to determine the more promising study cases from an economic standpoint. This will necessarily be one of the later phases of the study program, but considerable effort will be required in developing basic data for use in these studies.

3. Cost Estimates

To provide a basis for the economic analysis, cost estimates will be required for the various plant modifications which are proposed.

4. Project Engineering

As part of the economic analysis consideration will have to be given to the reactor outage time required for the performance of the proposed modifications and the scheduling of the same. The estimates of outage time will have considerable effect on over-all program economics and thus must be given sufficient attention to ensure that the estimates prepared are realistic.

5. Process Condition Optimization

It will be necessary to conduct a number of parametric studies of the process conditions listed previously in order to determine the more optimum process conditions. Included in these studies will be basic physics evaluations, fuel element design and performance assumptions, variations in fuel exposure, enrichment, Ng/Nu , process channel diameter and process tube materials, specific tube powers, flux density, moderator temperatures, fuel

costs and product values, conversion ratio, and other items of a similar nature. Suitable computer programs are generally available for the performance of these studies or programs are available which can be adapted to the study requirements.

6. Fuel Element Design and Evaluation

Attention will be given to the preparation and evaluation of fuel elements designs which are suitable for the proposed operating conditions. Considerations will also be given to the changes required in FPD and their suppliers' facilities for the production of the proposed fuel materials.

7. Enrichment Pattern

Due to the large effect on over-all process economics the several available methods of reactor enrichment will have to be evaluated in view of the proposed process conditions. These evaluations will include spike vs. uniform enrichment, axial flattening as well as side-to-side flattening, and fringe blanket poisoning.

8. Reactor Transient Cooling Requirements

Consideration will be given to the present transient and shutdown reactor cooling requirements to determine their applicability to the proposed conditions. These requirements are basic to the design of the process water system and will have considerable effect on the costs of these systems.

C. Reactor Process Unit Studies

1. Nuclear Control

A relatively serious problem is that of reactor control. Evaluations of the operational and shutdown control system requirements will be made to determine the system modifications if any are required. In establishing the required changes, consideration will be given to the use of auxiliary

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control systems such as poison columns, poison splines, axial displacement columns for achieving adequate operational control. The development of shutdown speed of control requirements will be included in this problem assignment.

2. Water Quality Requirements

Process water quality requirements must be established in order to provide a basis for the design of the water treatment system. These requirements will reflect fuel element, process tube, and effluent system piping corrosion problems.

3. Graphite Problems

An evaluation of reactor graphite distortion, contraction, venting requirements, and similar problems under the proposed operating conditions will be required. This study will also touch upon the basic problem of ultimate reactor life. The establishment of gas system requirements will also be a responsibility of this study.

4. Thermal and Biological Shields

A study of the current biological shield deterioration and deflection problems under the proposed operating conditions will be made to determine if corrective action is required. Consideration will also be given to thermal shield heating and process block base concrete deterioration to determine if corrective action is required.

5. Reactor Instrumentation

An evaluation of reactor instrumentation requirements for the proposed operating conditions and an evaluation of available instrument system

[REDACTED]

suitability will be required. This will include consideration of nuclear instrumentation, rupture detection, process flow monitoring, graphite thermocouples, and other process-type instrumentation systems.

6. Process Piping Systems

Preliminary designs will be prepared for the front and rear face process piping changes required to accommodate the increased process flows and temperatures. This study will include all reactor piping from the valve pit to effluent system. Included in this study will also be an evaluation of downcomer flow capabilities under non-pressurized conditions. An additional problem to be considered is the flow vibration and instability problems which are currently being encountered in some instances.

7. Process Channel Enlargement

One of the most basic problems to the proposed expansion program is the development of suitable methods for enlargement of the present process tube channels. This study will include the determination of the maximum diameter to which the channel may be enlarged and the costs, methods, and equipment for performing the enlargement. Consideration will also be given to the feasibility of enlargement of the hole in the thermal shield and replacement of the shielding donuts. It is expected that actual drilling tests will be performed as part of this assignment.

8. Process Tube Assembly

In conjunction with the process channel enlargement study the development of a new process tube assembly for use in the enlarged process channel will be required. This will include the use of a thin wall gunbarrel or the elimination of the gunbarrel for support of the thermal shield. The revised

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process tube assembly will provide for the elimination insofar as possible of the deficiencies of the presently installed equipment.

9. Fuel Handling Equipment

The development of continuous charge-discharge system equipment and improved shutdown metal handling systems designs will be required to provide a basis for the comparative evaluation of the two systems. The systems proposed will be suitable for the use of several different types of reactor fuel elements. Consideration will also be given to the problem of metal handling in support of the charge-discharge operation.

D. Process Water System Studies

1. River Studies

Currently, temperature stratification and contamination problems are being encountered with reactor effluent disposal in the Columbia River. Studies of the effect of increased reactor power levels on this problem and the determination of methods of alleviating these difficulties are required. The studies will include consideration of alternate methods of effluent disposal by means of cribbing, inland lakes, etc.

2. Effluent System

Within the basic system philosophy developed above, consideration will be given to methods of modifying the present effluent systems to accommodate the increased process water flows and temperatures. This assignment will also consider the problem of effluent hold-up by means of retention basins or other suitable structures.

3. Process Water Pumping Systems

Extensive alterations to the presently installed process water pumping stations (181, 183, 190) will be required in support of increased process water flows. These studies will determine the changes which are required in the various areas' pumping stations for each of the process water flows selected for evaluation. These studies will include shutdown and back-up system requirements. Consideration will be given to the maximum utilization of presently installed facilities.

4. Process Piping System

At present process water flow rates the piping velocities employed are generally considerably above normal industrial practice. Studies will be made to determine the flow velocities which can reasonably be employed, in order to provide a basis for determining the extent of the process piping modifications which are required in support of increased process water flow rates. These studies will also include an evaluation of the adequacy of certain non-process but vital auxiliary piping systems.

5. Water Storage Requirements

Present plant philosophy requires the on-hand storage of considerable quantities of treated process water for back-up purposes. Under the increased process water flow rates the presently available storage will be inadequate under the present philosophy. A revaluation of this philosophy will be required to determine the water storage requirements to be used in this study.

6. Process Water Back-up Systems

Certain basic criteria and philosophy have been proposed for adoption as

applying to the back-up requirements of the existing reactor process water systems. Studies of this criteria and the modified process water systems will be required to evaluate the adequacy of the modified systems in terms of the criteria and to determine the applicability of these criteria to the modified systems. Rather extensive alterations of the present back-up systems may be required to meet this criteria.

7. Water Treatment Facilities

Alteration of the presently installed water treatment facilities will be required to support the increased process water flow rates. Since the quality requirements of the process water are being established as a separate study, this study will be primarily concerned with the required water treatment plant changes to support these flow rates.

8. 151 and Electrical Distribution Systems

The 230/13.8 kv electrical systems are generally loaded too near their maximum capacity at the present time. Extensive alteration of these and the intra-area distribution systems will be required in support of the increased process pumping loads. These studies will determine the changes required in each of the various areas in support of increased process pumping loads.

9. 230 kv System

The addition of a large block of load to the present 230 kv electrical system will probably require that major alterations be made to the presently installed system. Studies will be performed of the alterations required to support the increased loads resulting from the plant modifications and at the same time provide adequate system reliability.

The study items listed above are summarized in Table II following.

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TABLE II
STUDY PROBLEM ASSIGNMENT SUMMARY

- A. REPORT PREPARATION
- B. BASIC ANALYTICAL AND ENGINEERING STUDIES
 - 1. Engineering Evaluations
 - 2. Economic Analysis
 - 3. Cost Estimates
 - 4. Project Engineering
 - 5. Process Condition Optimization
 - 6. Fuel Element Design and Evaluation
 - 7. Enrichment Pattern
 - 8. Reactor Transient Cooling Requirements
- C. REACTOR PROCESS UNIT STUDIES
 - 1. Nuclear Control
 - 2. Water Quality Requirements
 - 3. Graphite Problems
 - 4. Thermal and Biological Shields
 - 5. Reactor Instrumentation
 - 6. Process Piping Systems
 - 7. Process Channel Enlargement
 - 8. Process Tube Assembly
 - 9. Fuel Handling Equipment
- D. PROCESS WATER SYSTEM STUDIES
 - 1. River Studies
 - 2. Effluent System
 - 3. Process Water Pumping Systems

D. PROCESS WATER SYSTEM STUDIES (Continued)

4. Process Piping System
5. Water Storage Requirements
6. Process Water Back-up Systems
7. Water Treatment Facilities
8. 151 and Electrical Distribution Systems
9. 230 kv System

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SCHEDULING

The schedule presented in this section of the report is based upon the following dates which are essentially fixed by budget preparation requirements:

Start of Study Program	July 1, 1959
Completion of Final Report and Engineering Evaluation	March 1, 1960
Completion of Engineering Study	December 1, 1959
Completion of Final Cost Estimates	January 1, 1960
Completion of Final Economic Analysis	February 1, 1960

The schedule dates given for the various specific studies are based upon the assumption that reasonable amounts of suitable manpower will be made available for the performance of the various studies. If adequate manpower is not available, either reductions in the depth of the study or an extension of the completion will result. Generally, information regarding the tentative results of the study will be available prior to the December 1 engineering study completion. The time spans shown for each of the individual study items are preliminary and subject to revision upon further review; however, the over-all schedules are felt to be valid.

PROPOSED STUDY SCHEDULE

	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
A	Study Recommendation and Report Preparation								
B-1	Engineering Evaluations								
B-2	Economic Analysis								
B-3	Cost Estimates								
B-4	Project Engineering								
B-5	Process Condition Optimization								
B-6	Fuel Element Design								
B-7	Enrichment Pattern								
B-8	Transient Cooling								
C-1	Nuclear Control								
C-2	Water Quality								
C-3	Graphite Problems								
C-4	Thermal and Biological Shields								

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PROPOSED STUDY SCHEDULE

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