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EXISTING REACTOR EXPANSION STUDY BASIS

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EXISTING REACTOR EXPANSION STUDY BASIS

H. W. Heacock
Reactor Modification Design
FACILITIES ENGINEERING SECTION

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By Authority of RLD CG-4

June 24, 1959

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EXISTING REACTOR EXPANSION STUDY BASIS

INTRODUCTION

The latest HAPO Five Year Program review, HW-59633, forecasts substantial increases in Pu production from the eight existing Hanford reactors over the next several years. These production increases would be attained by a combination of several methods which include increased reactor power levels resulting from higher process water flow rates and coolant bulk outlet temperatures, improved time operated efficiency, higher conversion ratios, 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 plant changes required to support these forecasted levels, to evaluate the economic and technical feasibility of achieving the process conditions, and to present an integrated program for achieving these objectives. This study program will necessarily consider the interrelated effects of a number of various facets of reactor and water plant process conditions, operational requirements, and proposed development programs.

The purpose of this document is to present a plan for the execution of the proposed study. Included in this outline are a review of the basic study considerations, problem assignments and schedules, and manpower and cost estimates for the performance of the study.

REVIEW OF STUDY BASIS

Increase in Pu production from the existing reactors may be achieved by several methods including increased reactor power levels, improved operational and process efficiencies, and higher conversion ratios. The achievement of increased reactor power levels will require consideration of four basic interrelated programs; which are:

1. Increased Process Water Flow Rates
2. Increased Bulk Outlet Water Temperature
3. Improved Fuel Element Performance
4. Installation of Zirconium Alloy Process Tubes

The achievement of increased operational and process efficiencies may be accomplished by a number of methods including zirconium alloy process tube installation, operational charge-discharge, improved reactor instrumentation and control systems, improved fuel element performance, reduced operational error, and improved maintenance techniques and programs. Since a number of these programs will proceed independently of any reactor power level increase on their own merits, consideration will be given in this study only to those items which are related to a general power level increase. This does not mean that consideration will be given only to the achievement of process flow and temperature increases, but rather that items of a purely operational or maintenance nature which have independent justification and are not directly related to increased power levels will not be included in the study. Also independent process improvement programs such as operational charge-discharge which are justified on their own merits will be excluded from the scope of this study.

Higher Pu conversion ratios may be achieved by several methods having a direct effect on reactor operating conditions, such as the use of zirconium alloy process tubes, fuel element design, and front to rear flattening.

These factors will necessarily be considered in any study or evaluation of increased reactor process conditions.

The items discussed in this section of the report are taken as the fundamental process variables which will be considered in the study program. There are a number of other process conditions which must be considered in a specific study case but are dependent variables of the basic variables. A number of the dependent items will be discussed in the following sections of this report.

It is recognized that it may be necessary to revise some of the specific study conditions as the study progresses and greater insight into various process limits is achieved. By the prosecution of a number of parallel study programs and the judicious selection of process conditions for final correlation, a reasonable evaluation of the short term potential of the existing reactors can be obtained within available time and manpower limitations. There are a number of other modifications of existing process conditions which potentially could be included within the scope of any long term reactor modification program such as overboring of the reactor graphite process channels; however, due to the limited technology which is available to support items of this nature they have been excluded from consideration in this study program. Several of the basic variables selected for use 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 considerations. 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 preliminary studies of the existing reactor process water system capabilities⁽¹⁾⁽²⁾ have indicated that a substantial increase in flow rates may be achieved for relatively modest expenditure of funds. However, little information is available regarding the feasibility of achieving additional flow increases beyond those previously studied. In order to more fully provide information regarding additional flow increases, process flow rates of up to approximately 120 percent of existing flow rates will be studied. The K reactors will not be included in this study program since substantial flow increases will be obtained by Project CG-775 which is currently underway. 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	85,000, 95,000 and 105,000 gpm
C	95,000 gpm	105,000, 110,000 and 120,000 gpm
KE-KW	188,000 gpm (Post CG-775)	Not Included

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 probably require extensive alteration of the existing rear face piping and effluent system to provide some degree of pressurization⁽⁴⁾. There appears to be little long term incentive for the achievement of bulk outlet temperatures above the 110-120°C range due to fuel element corrosion rates and available technology will limit this temperature to a lesser value for the immediate future. The bulk temperature condition selected for study will provide for a review of the modification required to the reactor piping and effluent systems to support a further increase in bulk outlet temperatures and still be within reasonable extrapolations of current technology. The study of this condition will also provide an engineering evaluation of the physical changes required to support a further temperature increase at a later date. The increased effluent temperature conditions selected for study are as follows:

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

3. 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: reduction of process tube replacement outage requirements, the possibility of obtaining increased process water flow rates with present types of 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. A modest increase in process tube outside diameter may be achieved by replacement of the existing gunbarrels with thinner walled assemblies and utilization of a portion of the present gas gap between the process tube and the graphite for a tube of larger outside diameter. Any program for enlargement of the present process channels to permit the use of substantially larger process tubes is considered to be beyond the scope of this study. The study conditions may be summarized as follows:

Area	Base Case	Study Case	
	Aluminum	Aluminum	Zirconium
B, D, F, DR, and H	1.729" OD	Maximum OD in present channels	1.729" OD and Maximum OD in present channels
C	1.764" OD	" "	1.764
KE-KW	1.810	" "	1.810

4. Fuel Element

The successful attainment of any increase in reactor power level is highly dependent upon fuel element performance. Modest increases in reactor power levels will probably be achieved with only minor modifications to the present I&E types of fuel elements. It appears to be reasonable to base this study upon the use of self supported I&E types of fuel elements as reasonable extrapolations of current technology. Since overall reactor system economics are very dependent upon fuel performance, several levels of fuel performance will be evaluated.

<u>Base Case</u>	<u>Study Condition</u>
Supported-I&E Uniform Corrosion Present Quality	Self supported I&E Fuel performance evaluated at pessimistic and optimistic levels.

The above conditions describe the basic process conditions which will be considered in this study. A summary of these conditions is contained in Table I and a tabulation of specific study cases is presented in Table II.

The K areas have been included in this listing so as to provide for the evaluation of zirconium process tubes, bulk temperature increases, and fuel element performance although further expansion of the process water systems is not contemplated at this time.

There are a number of technical bases, process requirements, operational problems 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, the purpose of which is to provide a basis for the evaluation of manpower and time requirements for the performance of this study and the preparation of specific study assignments, is a summary and brief discussion of a number of these considerations. Any program recommendations resulting from this study will be an integrated program which considers all facets of operating requirements and process considerations.

The proposals presented at the end of this study program will necessarily be rather general in nature, with more detailed consideration given to the various items before any final project action is initiated.

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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 and 105,000 gpm	
C	95,000 gpm	105,000, 110,000 and 120,000 gpm	
KE-KW	188,000 (5 pumps) (Post CG-775)	Not Included	
2. Bulk Outlet Temperature	90°C	98°C, 105°C	
3. Process Tubes	Aluminum	Aluminum	Zirconium
B, D, F, DR, H	1.729" OD	Maximum OD in present channels	1.729" OD + maximum diameter in present channels
C	1.764" OD	" "	1.764 OD
KE-KW	1.810" OD	" "	1.810 OD
4. Fuel Element	Supported I&E Uniform Cor- rosion	Self supported I&E - 2 levels of performance	

TABLE II
EXPANSION STUDY CASE TABULATION

<u>Reactor</u>	<u>Process Tubes</u>	<u>Bulk Temperature</u>	<u>Process Flow</u>
B, D, DR, F, H	Aluminum	95°C	80, 85, 95,000 gpm
	Aluminum	98°C	80, 85, 95,000 gpm
	Zr (present OD)	95°C	85, 95, 105,000 gpm
	Zr (present OD)	98°C	85, 95, 105,000 gpm
	Zr (present OD)	105°C	95,000, 105,000 gpm
	Zr (max. OD)	95°C	95,000, 105,000 gpm
	Zr (max. OD)	98°C	95,000, 105,000 gpm
	Zr (max. OD)	105°C	95,000, 105,000 gpm
C	Aluminum	95°C	95, 105, 110,000 gpm
	Aluminum	98°C	95, 105, 110,000 gpm
	Zr (present OD)	95°C	105, 110, 120,000 gpm
	Zr (present OD)	98°C	105, 110, 120,000 gpm
	Zr (present OD)	105°C	110,000, 120,000 gpm
	Zr (max. OD)	95°C	110,000, 120,000 gpm
	Zr (max. OD)	98°C	110,000, 120,000 gpm
K	Zr (max. OD)	105°C	110,000, 120,000 gpm
	Aluminum	95°C	188,000 gpm
	Aluminum	98°C	188,000 gpm
	Zr (present OD)	95°C	188,000 gpm
	Zr (present OD)	98°C	188,000 gpm
	Zr (present OD)	105°C	188,000 gpm
	Zr (max. OD)	95°C	188,000 gpm
	Zr (max. OD)	98°C	188,000 gpm
	Zr (max. OD)	105°C	188,000 gpm

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STUDY PROBLEM ASSIGNMENTS

To evaluate the feasibility of attaining increased reactor power levels and to provide a basis for the performance of the design and economic studies the joint efforts of Facilities Engineering and Research and Engineering personnel will be required. The contributions of these groups will be in their particular fields of responsibility, and 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 a tabulation of problem assignments which will be included in the study program and which will be subject to some revision as the study progresses. The problem assignments have been grouped in general fields of interest 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 exercised in correlating the recommendations and conclusions presented in the individual reports for management consideration.

B. Basic Analytical and Engineering Studies

1. Engineering Evaluations

Evaluation of the technical feasibility of achieving the proposed increased reactor power levels in view of current reactor technology and planned development programs will be performed to provide a basis for management decision regarding any proposed project recommendations. Items which would be considered in these evaluations would include fuel element production and performance, graphite shifting and contraction, reactor life, reactor safety, ultimate specific tube powers, process tube integrity, nuclear stability, and basic operational philosophy.

2. Economic Analysis

It will be necessary to perform a number of economic analyses which will correlate the results of the process condition optimization, the proposed plant modification capital costs for the various study cases and the resulting operating cost changes in order to determine the more promising plant modifications from an economic standpoint and to develop justification for the proposed capital funds expenditure. This activity will necessarily be one of the later phases of the study program, but considerable early 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 of the various plant modifications which are proposed will be prepared, based upon the results of the various engineering studies.

4. Project Engineering

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

5. Basic Analytical Studies

A number of analytical studies of the proposed process conditions listed previously will be required to determine specific reactor performance criteria as a basis for the various engineering and economic studies which will be performed. Included in these studies will be basic physics evaluations, fuel element design and performance evaluation, variations in fuel exposure, enrichment, 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. Included in these studies as a specific item will be the evaluation of alternative enrichment patterns, such as spike vs. uniform enrichment, axial flattening as well as side-to-side flattening, and fringe blanket poisoning.

6. Reactor Transient Cooling Requirements

Reactor transient and shutdown cooling requirements will be established so as to provide a basis for the design of the process water system modifications and the evaluations of the various process water back-up systems.

C. Reactor Process Unit Studies

1. Nuclear Process Unit Studies

A problem becoming relatively more serious with increasing reactor power levels is that of reactor control. Evaluations of both operational and shutdown control system requirements will be made to determine the system modifications if any which will be required at the proposed power levels. Specific consideration will be given to the problem of total reactor control upon loss of water when zirconium process tubes are installed in the reactor. In establishing the necessary control system changes, consideration will be given to the

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use of auxiliary control systems such as poison columns, poison splines, and axial displacement columns for achieving adequate operational control and reducing transient reactivity losses. The development of speed of control requirements for reactor shutdown will be included in this problem assignment.

2. Water Quality Requirements

Reactor process water quality requirements at the proposed operating conditions will be established so as to provide a basis for the design of the water treatment system modifications. The water quality requirements will reflect fuel element performance and process tube and effluent system piping corrosion problems.

3. Graphite Problem

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

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 of available instrument system suitability will be performed. This will include consideration of nuclear instrumentation, rupture detection, process flow monitoring, graphite thermocouples, and other process-type instrumentation systems. The evaluation of the present instrumentation system will necessarily reflect the problems encountered with present reactor instrumentation.

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 the effluent system. This study will also include an evaluation of downcomer flow capabilities under non-pressurized conditions. A specific problem which will be considered in this study is the flow vibration and instability problems which are currently being encountered in the reactor rear face piping systems.

7. Process Tube Assembly

The development of a new process tube assembly for use with zirconium process tubes will be required. This assignment will also include a determination of the maximum process tube OD which can be accommodated in the present process channels, without channel enlargement, by the use of thinner walled gunbarrels and reduction of the gas gap distance between the process tube and graphite. Consideration will be given in the design of a new process tube assembly for the elimination of as many of the deficiencies of the presently installed equipment as is possible. The process tube assembly is considered to include the entire assembly including front and rear pigtails.

8. Fuel Handling Equipment

Consideration will be given to the changes required in presently available equipment for the routine handling of the proposed fuel element designs. Although the installation of full pile operational charge-discharge equipment is considered to be beyond the scope of this study, the correction of deficiencies in presently installed equipment and systems will be considered.

D. Process Water System Studies

1. River Studies

Currently, temperature stratification, dichromate and radioactive contamination problems are being encountered with present methods of 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 will be performed. These studies will include the consideration of alternate methods of effluent disposal by means of cribbing, inland lakes, etc. The objective of this assignment will be the establishment of a basis for the design of any required effluent disposal system.

2. Effluent System

Within the basic system philosophy and requirements developed in the previous assignment, consideration will be given to methods of modifying the present effluent systems to accommodate the increased process water flows and temperatures. This assignment will consider the problem of effluent hold-up by means of retention basins or other suitable structures and any special treatment of the effluent which may be required.

3. Process Water Pumping Systems

Alterations to the presently installed process water pumping stations (181, 183, 190) will be required in support of increased process water flows significantly beyond those presently achieved. These studies

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will determine the changes which are required in the various pumping stations of all areas except 100-K Area for each of the process water flows selected for evaluation. These studies will include consideration of shutdown and back-up system requirements. Consideration will be given to the maximum feasible utilization of present facilities and equipment.

4. Process Piping System

At present process water flow rates the velocities in portions of the water plant piping systems are considerably above normal industrial practice. Studies will be performed to evaluate this problem and determine the corrective action necessary to provide a basis for determining the process piping modifications 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. At increased process water flow rates, the available storage capacity will be inadequate to meet the requirements of present criteria. A reevaluation of this philosophy will be made to establish a water storage criteria for use in this study. This assignment will also include the design of such additional water storage facilities as may be determined to be required.

6. Process Water Back-Up Systems

Certain basic criteria and philosophy regarding process water back-up systems have been proposed for application to the existing reactor process water systems. Studies of this criteria and the modified process water systems will be performed to evaluate the adequacy of the modified systems in terms of the criteria, to determine the applicability of these criteria to these systems and the system modifications which are required. Rather extensive alterations of the present back-up systems may be required to meet this criteria.

7. Water Treatment Facilities

Some modifications to the presently installed water treatment facilities will be required in support of 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 plant changes required to support the proposed flow rates and water quality requirements.

8. 151 and Electrical Distribution Systems

The 230/13.8 kv electrical systems are generally loaded near their maximum capacity at the present time. Extensive alteration of these

and the intra-area distribution systems will be required in some areas in support of 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 Electrical 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 present system capabilities in order to determine the alterations required in support of the increased loads resulting from the proposed plant modifications and at the same time provide adequate system reliability.

A summary of the study assignments discussed above is given in Table III following.

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TABLE III
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. Basic Analytical Studies
 - 6. 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 Tube Assembly
 - 8. Fuel Handling Equipment
- D. PROCESS WATER SYSTEM STUDIES
 - 1. River Studies
 - 2. Effluent System
 - 3. Process Water Pumping Systems
 - 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 Electrical System

SCHEDULES AND MANPOWER ESTIMATES

The schedules and manpower estimates presented in this section of the report are based upon the following dates which have been established from budget preparation requirements:

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

The schedules and manpower estimates given in the following section are based upon the estimated scope of the various study assignments and the expected availability of manpower within Facilities Engineering and Research and Engineering Sections. In addition to the estimated manpower requirements indicated, the services of additional personnel will be utilized in some phases of the study programs. This additional effort will be primarily in individual fields of responsibility or technical competence. It is expected that the work performed by these individuals will be accommodated within normal work loads and not require specific diversion of effort to this study.

It is expected that some readjustment of time spans and manpower requirements for the individual study assignments will be required as the program progresses; however, the overall schedule and manpower estimates are felt to be generally valid.

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FIGURE 1

PROPOSED STUDY SCHEDULE AND MANPOWER ESTIMATES

		July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
A	Study Recommendation and Report Preparation							1 1	1 1	
B-1	Engineering Evaluations						1 1/2	1 1/2	1	
B-2	Economic Analysis					1 1/2	1 1/2	1 1/2		
B-3	Cost Estimates			() (1)	() (1)	() (2)	() (2)			
B-4	Project Engineering				1	1	1	1		
B-5	Process Condition Optimization	2 1	2 1	2 1	2 1/2					
B-6	Transient Cooling	1								
C-1	Nuclear Control			1/2 1	1/2 1	1/2 1				
C-2	Water Quality		1/2							
C-3	Graphite Problems				1 1/2	1 1/2				
C-4	Thermal and Biological Shields		1/2 1	1/2 1						
C-5	Reactor Instrumentation		1 1/2	1 1/2	1/2 1	1/2 1				
C-6	Process Piping Systems		1	1	1	1				

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PROPOSED STUDY SCHEDULE AND MANPOWER ESTIMATES (Continued)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
C-7 Process Tube Assembly	1	1							
C-8 Fuel Handling			1	1					
D-1 River Studies	1/2	1/2							
D-2 Effluent System	1/2	1/2							
D-3 Process Water Pumping	(1)(2)	(1)(2)	(1)(2)	(1)(2)					
D-4 Process Piping									
D-5 Water Storage					(1)(2)	(1)(2)			
D-6 Process Water Back-up									
D-7 Water Treatment									
D-8 151 and Electrical Distribution			(1)(1)	(1)(1)	(1)(1)	(1)(1)			
D-9 230 kv System									

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TABLE IV
EXISTING REACTOR EXPANSION STUDY
ESTIMATED MANPOWER REQUIREMENTS

	<u>JULY</u>	<u>AUGUST</u>	<u>SEPTEMBER</u>	<u>OCTOBER</u>	<u>NOVEMBER</u>	<u>DECEMBER</u>	<u>JANUARY</u>	<u>FEBRUARY</u>	<u>TOTAL MAN MONTHS</u>
Research and Engineering	3 1/2	4 1/2	4	4	3	2	3	2	26
Facilities Engineering	3 1/2	4	7	8	6	1 1/2	3	1 1/2	35 1/2
Construction Engineering ⁽²⁾	2	3	4	4	5	2			20

NOTES:

1. Exempt liquidators only, included in above estimates.
Drafting, technicians, and other supporting manpower requirements not shown.
2. CEU manpower includes Architect Personnel on loan.

DECLASSIFIED

END

DATE
FILMED

21/7/93