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FIVE-YEAR PROGRAM

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May 19, 1958

HANFORD ATOMIC PRODUCTS OPERATION
RICHLAND, WASHINGTON

Work performed under Contract No. W-31-109-Eng-52 between
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HANFORD ATOMIC PRODUCTS OPERATION
FIVE-YEAR PROGRAM

I. INTRODUCTION

The General Electric Company has prepared in past years numerous documents for the Atomic Energy Commission outlining in some detail its current and proposed programs at Hanford. Last year, at the request of the Commission, program types of information were consolidated into one document, the HAPO Five Year Program. That document was well received and useful to an extent that the General Electric Company was requested by the Commission to prepare another covering the fiscal years 1959 through 1963.

In outlining the five year program for the Hanford Atomic Products Operation, the General Electric Company has made assumptions regarding the US Atomic Energy Commission's current and future programs and Hanford's relationship to these programs. Two major objectives of the Commission were considered basic for future planning: first, to provide adequate atomic weapons for national defence; and second, to encourage and assist in the development of atomic energy for peaceful uses. The Hanford contributions to these objectives are conceived to include the acquisition and potential application of new technology in support of:

1. Increased production of plutonium, as nitrate solution, buttons, and as current and future shapes.
2. A program that will provide the technological capability to implement broad changes in the Commission's programs such as conversion of Hanford reactors to tritium production, the separation and packaging of mixed and specific fission products, the recovery of transuranic elements, the processing of power reactor fuels, and the provision of weapons assembly capability.

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3. Optimum costs, operating and capital.
4. New production reactor designs and concepts.
5. Use of plutonium as power reactor fuel.
6. Operation of nuclear reactors and associated plants with assured radiological protection of both workers and people and other forms of life in the environs.

During the last five years, the main line production technology at Hanford has been advanced such that plants are operating today substantially above the originally conceived requirements. During the past year, since the last five-year program document was published, the reactor levels have been increased 12 per cent, and reactor production for fiscal year 1958 has been increased 20 per cent over that for fiscal year 1957.

During the same period the separations plant throughput has increased around 30 per cent.

In the area of fuel element fabrication, fiscal year 1958 production was 22 per cent higher than that for fiscal year 1957. Over-all conversion costs of fuel elements were higher than in fiscal year 1957 because of the reactor requirements for the more expensive I & E fuel elements. However, there has been steady and substantial improvement in the cost of the I & E type of fuel element during fiscal year 1958, and in addition, considerable diversification in fuel element types was accomplished without increased manpower. Half the total production was diverted to several types of I & E elements and several types of enriched and depleted elements.

In effecting production and unit cost gains over a period of years, the General Electric organization at Hanford has acquired many specialized skills and facilities which are uniquely valuable to the accomplishment of the over-all Atomic Energy Commission Program. Perhaps the most important asset is the force of some 1400 scientific and technical personnel engaged in production and development work. Also there are research

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and development laboratories and semi-works facilities valued in excess of 35 million dollars. These facilities are capable of continued use, modification, and exploitation for development activities in atomic energy and related fields.

The production capability forecasts in this document are optimistic and are based on two assumptions: first, that the Atomic Energy Commission will continue to provide funds for research and development work as well as the necessary capital funds to install economically justified facilities; second, that interim considerations pertaining to nuclear safety will not be limiting to power and exposure levels.

It is not intended that this presentation be all-inclusive of Hanford's capabilities or that extension of the program to three, four or five years be considered firm. It is the belief of the General Electric Company that any program within the atomic energy field must be flexible enough to permit adaptation to newly discovered technologies, and the Hanford program is designed to be flexible to take advantage of technical break-throughs and new discoveries.

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II. SUMMARY

In view of past accomplishments and available facilities and skills at Hanford, the following five-year program is proposed in support of the broad objectives of the Atomic Energy Commission.

Production Capability

The program during the next five years is designed to increase substantially the production capacity of the existing reactors. Based upon plutonium production alone, product output might be increased approximately 60 per cent above the fiscal year 1958 level. These gains would result principally from a combination of power level increases and increases in operating efficiencies and conversion ratio. If both plutonium and tritium should be produced, the over-all production capability from existing reactors might be increased approximately 95 per cent above the FY 1958 level assuming tritium gram-atom equivalence to plutonium.

The achievement of these production goals will require expansion of the water plants at the K reactors as well as increases in the coolant flow rates at the other reactors. The installation of zirconium process tubes, use of superior fuel elements, installation of automatic charge-discharge equipment, and improvements in operational methods should increase the reactor operating efficiency. Such a program to increase the over-all production capability will require a continued high level of development work, technical breakthroughs and solutions to many complex problems, and capital expenditures on existing reactors. During FY 1959, studies will be made to determine the need for capital funds

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It must be recognized that the above program for existing reactors is designed to be optimistic to stimulate development work for potential production gains. It is not intended that the figures be considered firm, and there is of course no certainty that these production goals can be achieved. Some of the older reactors have operated for some time with several of them approaching fifteen years of service. Difficulties may develop that could limit their production capability. It is for this reason that new facilities probably should be considered in any Commission program requiring large additional production requirements.

A substantial proportion of the reactor production improvement will result from the ability to produce fuels that have irradiation capabilities superior to those used today. For the next several years a continual improvement in the internally and externally cooled fuel element is expected to implement the reactor improvement program. For the more distant future, the need for better and less costly processes may be indicated, and modest capital expenditures would be required to produce superior fuels.

The separations plants will meet their requirements through minor modifications made necessary because of increased plutonium throughput, enriched and power reactor fuels, and new weapon components. In establishing bases for advance planning, it has been assumed that an average exposure level of 800 MWD/ton will be attained in the Hanford fuels. However, it is recognized that changing Atomic Energy Commission programs may, from time to time, dictate either high or low exposure of fuel elements; this choice depending on uranium availability, weapons programs, need for incremental plutonium production, or other possible reasons. While the capability exists in separations facilities to process the predicted reactor outputs with fuel exposure of 800 MWD/ton, some plant modifications would be required to process the irradiated fuels at substantially lower exposures. Since additional solvent extraction capacity (beyond that available at the end of FY 1958) is not being provided at this time, an advance notice of 18 to 27 months will be necessary to accomplish any production program that calls for maximum reactor output at low fuel exposure.

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FIGURE 1
Production Trends

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FIGURE 2
Production Capability

Limited quantities of advanced weapons components are being produced and equipment is being installed to produce a significant fraction of the military needs. Plans are being developed to provide partial weapons assembly at Hanford, if desired by the Division of Military Application.

Improved Production Technology

In support of the production activity, it is assumed that the research and development at Hanford will be continued at the level necessary to permit a continuation of production and cost improvements.

The incentive for improved fuel element performance continues to be great and it is expected that a high level of metallurgical research and development will be an important supporting feature of the over-all production program. Improved fuel element capability will (1) improve the ability to take advantage of power level increases in the present reactors, (2) permit adjustment of exposure to optimum levels when power level increases are no longer feasible or economical, and (3) enhance the ability to produce fuel elements for new reactors that will place more stringent demands upon fuel element capability.

The objectives of the research and development program for the existing reactors are to increase over-all product output and reduce costs through (1) improved reactor power levels, (2) achievement of higher operating efficiency and improved continuity of production, and (3) improved utilization of fuel material. Maintenance and improvement of the operational safety of the reactors, as conditions of higher power level and higher production are attained, will continue to be an important objective of the research and development program. It is essential that development of major improvements in operational and maintenance techniques be continued, including charge-discharge procedures, reactor control systems, process tube replacement methods, and improved nuclear and process instrumentation.

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Separations development will continue to be directed toward assuring that reactor products can be separated and processed promptly, efficiently, and at ever-decreasing unit cost. The assignment of responsibility to Hanford for the processing of certain power reactor fuels has necessitated a rescheduling of development effort, with accelerated programs being adopted to develop processes for the dissolution of stainless steel jackets and alloy type fuels. The program to develop technology for the more certain containment of radioactive wastes is also being accelerated, and the program to recover certain fission products for productive use continued. Increased emphasis will be placed on developing the technology of nuclear safety, particularly in homogeneous and heterogeneous systems containing plutonium. The increasing volume of high exposure fuels requires that an improved technology be developed to provide adequate protection of personnel from neutron and gamma irradiation while converting the separated plutonium nitrate to buttons, weapons shapes, or assembled units.

Future Mix of Reactor Products

The Hanford program recognizes the possibility of changes in the Commission's requirements for product mix in the reactor product field. An increasing need for tritium could require that all or some Hanford reactors be diverted to tritium production in a relatively short period of time. In view of this potential change, the General Electric Company would expect Atomic Energy Commission authorization for continuing studies and development work relative to reactor fuels and separation requirements for diversion flexibility.

Research and Development for New Reactor Types

The broad objectives of the advanced reactor development program under Category II are to develop technology for replacement reactors, and to support prompt increases in production requirements should they occur. It has been assumed that Hanford will continue research, development and

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design programs in support of improved production or dual purpose reactors. Economic and feasibility studies have been conducted for pressurized water and organic cooled reactor systems. These studies will be extended to other advanced reactor concepts including gas cooling. At the request of the Commission, a design study was made for a New Production Reactor for a) production only, and b) production plus power recovery capability. Based upon the IPR studies, the pressurized water reactor was chosen for this preliminary design study. Authorization of the NPR study has required rescheduling of the IPR effort plus some incremental increases for the total research and development effort.

Research and Development on Use of Plutonium as Fuel

The research and development program includes the continuation of the Plutonium Recycle Program. This effort is aimed at the demonstration of the feasibility of using plutonium as an enriching fuel for a thermal heterogeneous reactor system. It has been presumed also that there will continue to be special development jobs in plutonium fuel metallurgy such as the current work on preparation of fuel elements for the Materials Test Reactor.

Research in Radiological Sciences

There is also indicated a continuation of the research programs in biology, biophysics and related studies of safe disposition of radioactive wastes.

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III. PRODUCTION PROGRAMS

A. Plutonium

1. Schedules

a. Reactor Forecasts and Assumptions

The over-all production capability of the Hanford reactors is the product of three distinct operating variables - total reactor power level, time operated efficiency, and conversion ratio. Product output can be increased by improving upon any of these variables. The data which follow are presented on the basis that all Hanford reactors will be operated at the highest achievable power levels consistent with maintaining or improving the present reactor safety status, and that reasonable progress will be made in the areas of improving conversion ratio and operating efficiency. Power and exposure level restrictions currently imposed by the Atomic Energy Commission would have the effect of restricting output to the FY 1958 level, although gains could be made through improvements in conversion ratio and operating efficiencies. These power and exposure level restrictions are considered to be temporary for the purpose of these discussions, and hence are not factored into this five-year program.

The existing reactors are targeted to be operated at the highest power levels economically attainable with a 98° C bulk outlet coolant temperature (nominal 100° C bulk temperature). Use of the I & E fuel elements in the central zone of the reactors is expected to permit goal exposures of 800-1000 MWD/ton, while solid elements in the fringe zones will be discharged on a variable goal exposure averaging 700 MWD/ton. For planning purposes, NPR authorization has been assumed, achieving beneficial production in FY 1963. This basic operating plan does not explicitly schedule large scale tritium production, although for comparison purposes, combined tritium and plutonium production capability has been included for the years FY 1960 through FY 1963.

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On the above bases, the average annual maximum relative power levels and the annual production capabilities are expected to be as follows:

TABLE I
HAPO REACTOR POWER LEVEL CAPABILITY
AS PER CENT OF FY 1957 BASE

Reactor	FY' 57	FY' 58	FY' 59	FY' 60	FY' 61	FY' 62	FY' 63
B	100	125	129	154	165	168	168
D	100	127	137	156	162	170	170
F	100	136	139	167	179	182	182
DR	100	123	125	146	157	162	162
H	100	118	130	148	158	158	158
C	100	104	125	143	152	152	152
KE	100	112	118	137	150	152	152
KW	100	112	118	137	150	152	152
NPR	-	-	-	-	-	-	(100)
Total	100	117	125	145	157	159	184

TABLE II
HAPO REACTOR PRODUCTION CAPABILITY
PER CENT OF FY 1957 BASE

	FY-57	FY-58	FY-59	FY-60	FY-61	FY-62	FY-63
	<u>a</u>	<u>a</u>	<u>a</u>	<u>a</u>	<u>b</u>	<u>a</u>	<u>b</u>
Present Reactors							
a. Plutonium	100	120	134	156	155	168	145
b. Tritium	0	0	0	0	13	0	48
NPR-Plutonium	-	-	-	-	-	-	-
Total	100	120	134	156	168	168	193

Column "a" assumes plutonium production only, and column "b" represents combined tritium and plutonium production capability.

See also Figure 2.

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The above power level and production capacity increases for the existing reactors are based upon the following technical assumptions:

- (1) Internally-externally cooled (I & E) fuel elements, tested during FY 1958, will be loaded into the reactors with adequate reactivity compensation on approximately the following schedule:

<u>Reactor</u>	<u>Date Central Zone Completely Loaded with I & E Fuel Elements</u>
C	December, 1957
KE & KW	April, 1958
D	October, 1958
H	December, 1958
B, DR and F	January, 1959

- (2) The bulk outlet water temperature will be 95° C during FY 1959, and 98° C will be attainable thereafter with minor modifications required for the effluent piping system without an extensive pressurization program.
- (3) Coolant flow rates will be increased as follows: Use of I & E fuel elements will result in flow rates of 75,000 gpm at B, D, F and H, and 73,000 gpm at DR during FY 1959 and FY 1960. Minor pump modifications could increase these flow rates to 80,000 gpm after FY 1960. Increased pump capacity and use of small diameter I & E fuel elements will result in 94,000 gpm at C Reactor in FY 1959 and FY 1960. Further pump modifications after FY 1960 could increase the C Reactor flow rate to 100,000 gpm. Use of I & E fuel elements and completion of project CG-775 will increase normal K Reactor flow rates to 175,000 gpm in FY 1963. Further minor modifications may increase this to 182,000 gpm in subsequent years.

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- (4) Enriched uranium (0.94 per cent U^{235}) will be utilized for
- (a) replacement of C metal, (b) additional reactivity required for I & E and/or E-N loadings, (c) compensation for shield protection and potentially for (d) shield blanket loading.
- (5) Operating efficiencies will be increased by reduction of operational losses. The present losses are sustained primarily from three types of reactor outages - fuel element failures, replacement of corroded process tubes, and charging fuel elements. Programs for reduction of such losses are as follows:
- (a) Replacement of solid, high power fuel elements with internally and externally cooled (I & E) elements to reduce or essentially eliminate uranium cleavage type failures.
 - (b) Replacement of aluminum process tubes with zirconium tubes to reduce losses from water leaks and tube replacement. Fuel element hot-spot failures will be reduced by centering of the fuel element in the tube. It is planned that zirconium tubes will be installed on the following approximate schedule:

<u>Reactor</u>	<u>Completion of Zirconium Tube Installation</u>
Two older reactors	July, 1961
Remaining reactors	January, 1963

- (c) Installation of automatic charge-discharge equipment to reduce fuel element charging losses.

It is assumed that with the above process improvements, the over-all efficiency of the existing reactors would be increased to 88 per cent.

- (6) Over-all conversion ratio will be increased by more efficient utilization of target and fuel elements by such methods as
- (a) increased resonance neutron capture
 - (b) reduced parasitic neutron capture

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- (c) reduced neutron leakage from the reactor by means of fringe tube poison
- (d) reduced plutonium burnout by use of enriched uranium.

b. Fuels Forecasts and Assumptions

The predicted fuel requirements of existing reactors for plutonium production has made it necessary that a variety of fuels be produced as the development of new fuel concepts can be utilized. The present forecast is based on the assumption that the natural uranium I & E fuel elements will permit exposure levels up to 800 MWD/ton, that enriched I & E fuel elements may be exposed to 1000 MWD/ton, and that the solid elements in the reactor fringe zones can be taken to a variable goal exposure level averaging 700 MWD/ton. With these exposure assumptions, the forecast indicates no substantial increases required in total fuel tonnages for plutonium production in existing reactors. The fuels plant modification currently approaching completion should permit a 4200 ton/year solid element production on a one shift, five day basis. This could be expanded to 12,500 tons/year on a three shift, five day basis or approximately 20,000 tons/year for round-the-clock operation. I & E element production on a tonnage basis would be approximately ten per cent less than that indicated for solid elements. Continuance of operation with the present manpower and production facilities could produce tonnage which will easily exceed the currently contemplated reactor demand for fuel elements in use at the present time.

In the following table, fuel element tonnages for solid, I & E, and 0.94 per cent enrichment are expressed as a percentage of the reactor tonnage throughput for FY 1958. Requirements for 1.2 per cent enrichment, lithium-aluminum, and NPR fuel are expressed as a percentage of the natural uranium solid fuel tonnages utilized in FY 1958.

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TABLE III
SUMMARY OF FUEL REQUIREMENTS

(Based on FY 1958 Reactor Fuel Element Tonnage Throughput)

	<u>FY 1958</u>	<u>FY 1959</u>	<u>FY 1960</u>	<u>FY 1961</u>	<u>FY 1962</u>	<u>FY 1963</u>
	a	a	a b	a b	a b	a b
8" Natural U - Solid	100	28	18 0	19 0	21 0	23 0
Natural U - I & E	100	384	435 435	462 0	510 0	451 0
0.94% Enriched U	100	172	148 406	159 1830	174 0	188 0
1.2% Enriched U	*	0	0 0	0 0	0 111	0 119
Lithium-Aluminum	*	0	0 0.3	0 1.2	0 2.3	0 2.5
NPR - Enriched	*	0	0 0	0 0	9.5 0	20.8 0
Total	100	90	90 87	95 81	112 90	114 97

* Natural uranium solid fuel tonnages for FY 1958 were used as the base for estimating future requirements.

Column "a" assumes plutonium production only, and column "b" assumes combined plutonium and tritium production.

Continued application of development programs promises a substantial improvement in plant productivity. During FY 1958, process improvements were incorporated which increased the production potential of the facility approximately 30 per cent. These included (1) improved welding techniques which provided superior weldments while reducing the weld cycle time from 22 seconds to nine seconds, and (2) reduction of required autoclaving from 40 hours to 20 hours. During FY 1959 efforts will be made to remove the last major bottleneck in the production process through substantial reduction of the canning cycle time. Thus by FY 1960 the limit will have been approached for the lead dip process. Research and development has indicated several new processes which promise improved products at markedly reduced costs. Process and plant design is currently underway which, if implemented, will permit a wider selection of fuel element designs to manufacture with considerable cost reductions. The incorporation of these processes will

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permit Hanford production of any fuel or target element proposed for present and currently contemplated Hanford reactors.

c. Separations Forecasts and Assumptions

Plans for providing production capacity in the separations plants are based on the assumption that the programs now in progress to accomplish routine discharges at 800 MWD/ton from all Hanford reactors will be successful and accomplished in accordance with the timetable established for the program. On this basis, it is not planned to provide any additional capacity in the solvent extraction separations plants after the expansion of Purex in June, 1958, to process uranium at 3.2 times the original design rate of the plant. Combined Purex and Redox capacity will then be 15 per cent above the total projected load for FY 1963, the heaviest production year foreseen in the five year period under study.

In the event that there should be reason to return to 500 MWD/ton uranium discharge levels, uranium separations capacity would be exceeded in FY 1961 and the years beyond. However, sufficient research and development work has been done to assure methods for expansion of the Purex plant production capability to 4.0 times original design rate. In addition, design for expansion of the Redox plant to Phase III rates exists "on the shelf". About 18 months would be required to complete Phase III Redox expansion, and about 27 months would be required to expand Purex capacity to a factor of 4.0. No estimates exist today for the time required to expand Purex beyond the 4.0 factor should it become feasible.

The following are projected throughputs for the separations plants during the next five years.

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TABLE IV

PER CENT OF TOTAL FY 1957 THROUGHPUT

	Enriched* Uranium	NPR* Fuel	Power Reactor Fuels*	Natural Uranium from Existing Reactors At 500 MWD/ton	At 800 MWD/ton
FY 1958	--	--	--	133	--
FY 1959	13	--	--	125	103
FY 1960	13	--	--	164	102
FY 1961	14	--	--	177	108
FY 1962	15	--	3	193	119
FY 1963	16	7	6	208	128

*These percentages do not represent actual tonnages, but rather estimates of the equivalent capacity for normal uranium displaced by the processing of these fuels plus the time required for switching from one type feed to another.

(1) Enriched Uranium Program and Special Handling Problems

Because of the higher value of the enriched uranium (0.94 to 1.25 per cent U^{235} prior to irradiation) it is planned to segregate this material through the solvent extraction separations plants and the UO_3 plant. New dissolvers are to be installed in order to assure nuclear safety during the dissolution of the enriched fuels. The new equipment is being designed for the lower enrichment, but can process the higher enrichment after slight modification or on a batch basis without modification. The first unit is scheduled for use in October, 1958, and the second by July, 1959. The Redox plant rather than Purex, has been selected to process the enriched uranium since the plant equipment is smaller and is more compatible with the amounts of material to be processed. Consequently, loss of product value and production capacity resulting from periodic flushing for segregation purposes is minimized.

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As indicated in the preceding throughput table, it is expected that small quantities of power reactor fuels will begin coming to Hanford for processing starting late in FY 1962. Under the basic 800 MWD/ton assumption the present solvent extraction plant capacities are sufficient to handle this additional load as well as that from the Hanford NPR. However, due to the new types of fuel elements (and cladding) expected from these sources, it will be necessary to provide special handling and dissolving facilities. This added capability is planned for installation in the now idle 221-U canyon, and items are carried in the FY 1959 and FY 1960 Budget for this and related construction. Due to the different U-235 content expected in spent power fuels, it probably will be necessary to provide segregation through the solvent extraction and UO_3 plants. Since power fuels are to be discharged at much higher MWD/ton levels (hence, higher Pu-240 content) than from the normal production reactors, it may eventually be necessary to segregate this product. Capability for segregation of various grades of plutonium will exist both in the solvent extraction and in the metal fabrication plants after the planned modifications are complete. Tests have shown that the dissolving time required for Weldon Springs "dingot type" uranium fuel elements may be as much as 25-50 per cent greater than for the present type fuels. The capacities of present dissolvers are such that no problem will be created by the use of this metal at thruputs presently planned, although a capacity limitation could be experienced if the 500 MWD/ton exposure is required.

(2) Purex Plant

It is expected that the Purex plant will be modified by June, 1958, such that only two solvent extraction cycles will be used for decontamination of products. Following a three month period at relatively low rates, as may be necessary to establish optimum

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two-cycle flowsheet conditions the plant is assumed to be capable of processing at a rate 3.2 times design capacity. This capacity is sufficient to process all of the natural uranium fuels if the planned 800 MWD/ton exposure is achieved. No further expansion of Purex plant capacity is contemplated at this time, but should there be changes in production programs requiring more capacity, the potential exists in Purex to increase capability to 4.0 times design capacity.

(3) Redox Plant

During the first quarter of FY 1959, while the Purex plant two cycle flowsheet is undergoing shakedown, the Redox plant will be used for normal uranium processing. Starting early in the second quarter of FY 1959, the Redox effort will be shifted to the processing of enriched uranium. Beginning about October, 1958 and continuing through to the end of the study period, Redox loads are expected to consist entirely of E metal, NPR fuels, power reactor fuels and other special fuels. The Redox plant will also serve as backup capability for normal uranium fuel processing in cases of long Purex outages or drastic changes in programs. Operating schedules for the Redox plant will be closely related to the production load in order to minimize labor costs and other fixed charges.

(4) Aging of Irradiated Uranium

It is assumed that iodine removal backup facilities, recently installed, will permit continued operation with a minimum metal cooling period of 90 days throughout the forecast period.

(5) UO₃ Plant

Experience to date with the continuous calciners indicates that, with moderate improvements as provided for by budgeted funds, there will be sufficient capacity to process forecasted production, including segregated products, through FY 1963.

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(6) 234-5 Facility

With the conclusion of the second improved Task I and II installation in June, 1958, (Project CG-691) sufficient capacity will be available in the purification and hydrofluorination steps to handle requirements anticipated through FY 1963. [

also provide the flexibility to permit the simultaneous but separate] In addition, capability will be available for segregated processing of high exposure plutonium as may be forthcoming from power reactor fuels and special request programs.

A new button production facility (RMC button line) is to be provided by July, 1959. This will provide parallel equipment for Tasks I, II, and III and provide the capacity to process the production loads forecast for the subsequent periods covered by this study. New weapons fabrication was initiated during March, 1958, by use of prototype equipment for production of Pit 65 cores. A new fabrication facility (RMC fabrication line) will be provided by December 1, 1958. Additional capability to fabricate new weapons cores through improved RMC line capacity and modification of the RMA line is planned to be achieved by January, 1960. This will provide fabrication capacity to meet existing weapons core schedules for Pit 65 production at HAPO [

] Interest has been expressed by the Division of Military Application in providing at Hanford, the facilities required to permit partial assembly of plutonium-bearing weapons. This program is considered to be intimately connected with the fabrication program discussed above [since the shipment of thin-shell weapons components] The initial steps to effect this program were taken under Project CG-745 in the amount

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of \$1,000,000 to provide limited facilities for Pit 65 production. An additional \$3,500,000 is being requested in the FY 1959 Plant Acquisition and Construction Budget to provide fabrication facilities for Pit 65, Pit 66 and possible future models. Another \$7,500,000 is being included in the FY 1960 Plant Acquisition and Construction Budget to provide a facility for weapons assembly.

2. Problems and Improvement Areas

a. Fuel Element Problems

Reactor power levels and operating efficiency are currently influenced by fuel element performance. Such performance is affected by two broad types of fuel element failures: the uranium cleavage failure (split core) and the corrosion induced failure (aluminum jacket failure). These problems will undoubtedly be of a continuing nature. As power and exposure levels are increased the goal will be to produce superior fuel elements which will satisfy the more rigorous performance requirements and maintain an economic balance between fabrication and material costs and the increased value of the new fuel in the production complex. Several approaches will be taken to obtain the solution to these problems, and are discussed in the Research and Development section of this report. Such problems as the following continue to receive detailed study: cleavage failures, flow stream unbalance, corrosion, coolant temperature limits, nuclear safety, conversion efficiency, fuel performance analysis, and long range fuel development.

Test experience to date indicates that an optimum type of the I & E fuel element may not limit reactor operation short of the projected power levels. Facilities will be available by the second quarter of FY 1959 for fabricating forecasted quantities of this promising fuel element type.

Programs for the mechanization of the existing process lines, application of non-destructive testing methods and other improvement which either enhance product quality or improve operating efficiency will continue.

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In addition, a more important long-range phase of our program will be extensive efforts to develop a less costly and more dependable cladding process. Extrusion cladding is a promising candidate for such a process having the inherent characteristics of simplicity and flexibility that should permit automation of the process and reduction of costly prefabricated materials. Equipment and facilities for piloting these improvements are now required by FY 1959.

b. The 100° C Bulk Effluent Problem

Studies have shown that reactor operation at bulk effluent temperatures higher than 100° C would create new engineering and materials problems, and might require extensive reactor modifications. The production rates were forecast on the basis that the reactors would operate with a maximum bulk effluent temperature of 95° C during FY 1959, increasing to 98° C thereafter, without major modifications for pressurization. The bulk effluent temperature at the C reactor will be increased to the range of 95-98° C early in FY 1959 for a short period to evaluate the effects of high temperature operation.

During FY 1959 a detailed engineering study will be made to evaluate the engineering and economic feasibility of pressurizing the effluent piping systems which would permit production capabilities higher than those now projected. Evaluation will be made of such problems as process tube life, graphite damage, measurement of graphite temperatures, shield damage, nuclear instrumentation, component improvements for the safety system, outlet coolant temperature limits, and nuclear safety.

c. Added Cooling Capacity for Reactors

(1) K Reactors

Economic and engineering evaluations have shown that a water plant expansion program for the K Reactors is well justified. A project to increase the K plant flow rates from 155,000 gpm per reactor to 175,000 gpm is budgeted for FY 1960, and will be completed

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in FY 1963. Modest modifications to the pumps may permit the K plant flow rates to be increased further to 182,000 gpm. This potential is being evaluated for future budget considerations.

(2) Older Reactors

During FY-1960, a design study will be made to assess the justification and costs of increasing the flow rates at the older reactors. This project should be integrated with the installation of zirconium process tubes and the use of I & E fuel elements. The design is included in the FY 1960 budget, and the expansion would be considered in the FY 1961 budget.

d. Increasing Operating Efficiency

As the reactor power levels increase, it becomes more difficult to maintain or improve the over-all operating efficiency, and thus efficiency becomes an increasingly important part of the reactor program. This effort involves the development of techniques and methods for more efficiently accomplishing routine, non-routine, and preventive maintenance; study of essential operating problems including charge-discharge; correcting abnormal conditions such as removal of ruptured fuel elements or corroded process tubes; and maintaining efficient start-up and steady state control of the reactor transients and flux distribution under the more severe reactivity limited, higher power level conditions. The goal is to attain an operating efficiency equal to 88 per cent of the projected power levels. Individual problems affecting the operating efficiency are discussed in detail in the Research and Development section.

e. Additional Potential Capacity of Existing Reactors Via Pressurization

Projected power levels do not rely upon reactor pressurization for capacity increases. However, extensive pressurization of the Hanford reactor cooling system has the potential of increasing production levels 30

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to 40 per cent above those shown in FY 1962. This potential could not be realized without superior fuel element performance and reactor component modifications to accommodate high graphite temperatures. An engineering study will be made to establish the economic incentives and the technical feasibility of pressurizing the reactors. These studies, and the results of tests to determine if the I & E fuel elements are capable of more rigorous service, will be used to determine if a large pressurization project should be included in future budgets. However, all studies to date show that such additional production is more economically obtained through new reactor plants which credit the sale of by-product power. Therefore, major development efforts which could exploit higher pressurization in existing plants will be diverted for the most part to new reactor systems.

f. Improved Production Reactor

The advanced age of the original reactors, which now have achieved fifteen years of service, suggests that additional capacity may be obtained more economically through the construction of a new Improved Production Reactor (IPR). At the direction of the Atomic Energy Commission, studies have been undertaken to develop such new reactor concepts. Preliminary studies have indicated that both pressurized water and organic cooled reactor systems would be efficient, economical plutonium producers. Research and development work has been conducted for both systems in the areas of materials compatibility, fuel elements, physics, heat transfer, component development, metallurgical studies, etc. Development work will be continued on each of these advanced reactor concepts, and in addition, other concepts such as the gas cooled, sodium cooled, homogeneous, etc., will be evaluated as to their plutonium producing potential.

In FY 1958, at the request of the Commission, a design study was prepared for a New Production Reactor (NPR) having dual purpose capabilities

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for economical production of plutonium and by-product electrical power. The concept chosen for this study was a graphite moderated, pressurized water system as developed under the IPR program. This reactor type represents a feasible extension of existing Hanford technology. In addition a considerable fund of technology is available from other pressurized water reactor programs. The primary problem for Hanford application is that of achieving a modest capital cost system which is an economical producer at high temperature when considering corrosion rates, pressure requirements, and design limitations imposed by the uranium-water reaction rates.

Authorization of NPR construction would require rescheduling of development and engineering phases of the IPR effort, and would require an incremental increase in the total effort. If the NPR were authorized in FY 1959, beneficial production would be realized in FY 1963, amounting to approximately 22 per cent of total FY 1957 production.

g. Nuclear Safety Problem

The general problem of reactor nuclear safety has received extensive study and review in recent years. In large measure the basic problem stems from the tentative and quite conservative safety criteria that were selected in 1954. The total reactivity control requirements for Hanford reactors required sufficient capacity to assure pile subcriticality under all catastrophic conditions. Considerable effort has been devoted to analysis of the problem and results show that the original criteria can be modified without sacrifice of nuclear safety. The modification has been reviewed with the AEC, ACRS, and other safety review groups and no adverse comment has developed. As a result the following minimum total control requirements are being adopted for present Hanford reactor operation with aluminum tubes:

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- (1) maintain the reactor subcritical under all conditions until the central zone process tubes have been rendered useless as cooling channels, and
- (2) guarantee that prompt criticality can never be attained under catastrophic conditions, including meltdown.

It should be recognized that the modified criterion will not allow reduced control system availability or maintenance; rather, it will permit elimination of the extra waiting periods that have been imposed at some reactors during cold start-up.

The improved production reactor design will eliminate the problem that exists at the older reactors by increasing the total available reactivity control and by providing a building integrity to permit controlled release of pressure build-up.

h. Separations Capacity Requirements

The solvent extraction plants are currently rated at uranium throughput capacities of 0.77 times Phase III rate for Redox and 2.5 times design rate for Purex. After conversion to two cycle operation in June, 1958, the Purex plant capability will be 575 tons uranium per month. The combined capacity is greater than the predicted uranium throughputs, when the 800 MWD/ton irradiation level is assumed. Planning will continue to define methods of providing the additional capacity which would be required if the fuels were exposed to only 500 MWD/ton.

On the basis of the 800 MWD/ton assumption, the operation of the plants on a part time basis becomes attractive. Before such a plan is adopted, however, ways must be found to minimize the problems associated with shutting down and starting up the continuous operations. During intermittent operation, equipment life tends to be shortened, waste losses tend to be higher, and off-standard products tend to be produced. These problems will be studied, with the view of placing one or both solvent extraction plants on a part-time schedule.

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It is recognized that changing Atomic Energy Commission programs and military requirements make built-in flexibility in separations capacity mandatory. The need for reverting to lower fuel element exposures could arise from weapons requirements, incremental plutonium production obtainable through this mechanisms, or other economic factors. Further expansion of the Redox or Purex plant should be undertaken within the very near future if any possibility continues to exist for discharging reactor fuels at the 500 MWD/ton exposure goal. Redox capacity could be increased to the Phase III rate at a cost of about \$650,000, while the Purex capacity could be increased to 4.0 times design rate at a capital cost of about \$3,000,000. The Redox expansion could be completed in about eighteen months after authorization, while the Purex expansion would require about twenty-seven months.

A prototype ion exchange system has been provided in conjunction with the Purex plant two-cycle process for final plutonium decontamination. The capacity of this unit appears to be adequate to match the rest of the plant. Action has been initiated to modify the unit to give the operational flexibility and reliability required.

1. Waste Disposal Facilities

The continued operation of the separations plants is dependent on the safe storage and/or disposal of the radioactive process wastes from these plants. Three distinct types of waste are involved: (1) radioactively contaminated, dissolved aluminum produced by the removal of jackets from fuel elements; (2) neutralized acid wastes from the solvent extraction process steps; and (3) aqueous wastes of relatively low radioactive content.

Coating wastes, which are non-boiling, are currently being stored in available space left in the older waste storage areas. Space available in the 200 West Area will serve Redox plant needs beyond the year 1970. The available space in 200 East Area will serve the Purex plant needs until January, 1964, assuming 500 MWD/ton metal exposure or until March, 1966, for 800 MWD/ton metal. It appears feasible, also, to pump coating

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wastes originating in the Purex plant to the 200 West Area through idle inter-area tie lines formerly used by the Metal Recovery Program.

The solvent extraction process wastes generate sufficient energy through radioactive decay to cause the wastes to boil, and advantage is taken of this boiling to reduce the volume of the waste stored. Net storage space currently required per ton uranium processed is approximately 450 gallons and 100 gallons for Redox and Purex, respectively. Each storage tank is filled only half full, however, to assure that the tank structure is not damaged by pressure surges caused by bumping of the boiling wastes. The maximum temperature to which the concrete tank is exposed is also a point of concern, as is the length of time the mild steel liner will be exposed to boiling wastes. These problems are being studied to improve the bases for operating limits to obtain optimum use of existing facilities. For long range planning, a more permanent method of containing the fission products would appear to be required.

On the basis of experience to date with boiling wastes and current limitations imposed on the use of tanks, new storage farms will be required as follows:

<u>New Tank Farms</u>	<u>500 MWD/ton</u>	<u>800 MWD/ton</u>
Redox (Sy)	Sept. 1961	Dec. 1964
Purex (Ax)	July, 1962	Aug. 1963

Low activity aqueous wastes, such as overheads from stored, boiling wastes, are discharged to underground sumps where ion exchange characteristics of the intervening soil are used to remove the low radioactive content before emergence into the water table. However, depletion of ion exchange capacity of the soil by overheads from Purex boiling wastes is now very rapid and underground sump replacement thus becomes a recurring expense item. It is, therefore, planned during FY 1959 to provide for returning the condensate from the waste concentration to the Purex plant for further decontamination.

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In the metal finishing area, plutonium-bearing process wastes have been traditionally dumped to underground sumps because the ion exchange characteristics of the soil are especially effective in removing and retaining plutonium. It now appears prudent to recover the plutonium from these wastes. Until the recovery facilities are provided, these wastes will be diverted to available permanent storage.

j. Plutonium Fabrication Capacity Needs

The present RMA line is deficient in the flexibility

] To meet this contingency a second (RMC) button line is being provided at a total cost of \$1,870,000 (Project CG-734). Beneficial use of the new line is expected about July, 1959, at which time two parallel systems, from purification through reduction, will have been effected.

The present RMA line is adequate only for the fabrication of conventional weapon cores, such as the 200 model, on a production basis. Limited capability for the production of Pit 65 parts has also been achieved on the RMA line through use of prototype equipment for the machining, inspection and packaging phase of the operation.

Project CG-745, at a cost of \$1,000,000, will provide the essential equipment for a second fabrication line (RMC) of limited capability as necessary to meet existing fabrication schedules for Pit 65's. It is expected that the RMC line modification will be completed by December, 1958. Additional fabrication facilities in both the RMC and RMA line are currently being planned at an estimated cost of \$3,500,000.

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The efficient fabrication and partial assembly of weapons components will require the resolution of many problems of personnel exposure which will be associated with higher reactor power levels and integrated exposures, and with the manufacture and handling [redacted] Studies are in progress to obtain a clearer definition of personnel exposure problems as related to shielding requirements and design, the need for and feasibility of remote operation, and throughput requirements and capability. Improved weapons technology is also predicted to require changes of operating equipment and procedures. Once these problems have been clearly defined and the mechanism for dealing with these problems developed, additional project funds will be requested for effecting the required improvements. The cost for providing the required facilities is estimates to be of the order of \$2,000,000 to be included in the FY 1963 budget.

Increased production rates on the fabrication facilities may require added capacity for product recovery operations as a result of the increased rate of scrap generation. Current information strongly indicates that the required increases of capability for slag, crucible, and powder dissolution and solvent extraction processing can be achieved by relatively inexpensive process and equipment improvements.

k. UO₃ Segregation and Improvement Needs

Segregated processing of the enriched uranium through the calciner facilities will be required to avoid loss of product value by dilution with uranium of lower U-235 concentrations. It is presently envisioned that the enrichment of Hanford fuels will be at levels which will not entail significant criticality problems in the continuous calciners and auxiliaries. More extensive modification of the calciner system will be required to process some of the power reactor fuels.

Initial UO₃ segregation capability will be achieved through use of the gas-fired pots at a cost of approximately \$150,000 by October, 1958. Further modifications are planned during FY 1960 to provide segregated processing of enriched metal through the continuous calciners at an estimated cost of about \$150,000.

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3. Plant Facility Capacities and Production Status

The following tabulation of plant facilities, their capacities and probable activity status are based on the assumption that the necessary funds will be available to complete programs outlined elsewhere in this document.

TABLE V
PLANT STATUS AND MONTHLY CAPACITY

<u>Facility</u>	<u>1959</u>	<u>1960</u>	<u>1961</u>	<u>1962</u>	<u>1963</u>
108-B	Standby	_____→			
105 Reactors	See Table under III, A, 1				
313	500 T I&E 400 T Solid	→ 900 T mixed products	_____→		
306 Semi-Wks	Small Quantities of I&E	→ Test Quantities of Fuels from mid-FY 1959 on	_____→		
BiPO ₄ B&T	70 T-U* each (Lay away)	→ Available for fission product recovery			
TBP U	Equipt Reno-	→ Power Fuels-Reprocessing vation Shop			
Redox	0.77 times Phase III Rate	_____→			
Purex	3.2 times Design Capacity	_____→			
UO ₃ Pots (Gas-fired)	100 T-U* enriched	_____→ 100 T-U Layaway		_____→	
UO ₃ Pots (Electric)	350 T-U* Layaway	_____→			
UO ₃ Calciners	124% **	→ 194%**		_____→	
234-5 (RMA Button (RMB	185%***	_____→			
		Start _____→ 185%***			
234-5 Fabric'n (See CLVI-400)					

* Tons of Uranium

** Of average monthly uranium load during FY 1957.

*** Of average monthly plutonium separations load during FY 1957.

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B. Other Products

1. Tritium Production

a. E-N Loading

It is recognized that there may be justification for increased tritium production in the future, and Figure 2 reflects the tritium production capability of the Hanford reactors. (Tritium production is expressed as the gram-atom equivalent of plutonium). Tritium production is feasible through several types of reactor loadings, and studies have indicated that the greatest combined productivity of tritium and plutonium could be achieved by means of enriched I & E fuel elements and lithium-aluminum target elements. It is projected that by FY 1963, full scale loadings in this manner would produce significant quantities of tritium per year, plus plutonium totalling 155 per cent of the FY 1957 plutonium production. Studies indicate that economic production of both tritium and plutonium could be accomplished using enrichment in the range of 0.94 to 1.2 per cent. The fuel element technology is developed and full-scale loadings can be effected at any time. The tritium production capability increases with increasing fuel enrichment, and the economics and fuel performance in the range of 1.5 per cent enrichment are being evaluated. In the event large scale tritium production is desired at Hanford, the E-N loadings would be preferable to the J-N or wraparound loadings discussed below.

b. J-N and Wraparound Slug Loadings

Tritium production utilizing U^{235} aluminum alloy fuel and lithium-aluminum target elements has been accomplished at Hanford in large scale irradiations in the DR and H Reactors using the J-N load. A second type of loading has been studied which utilizes a U^{235} aluminum alloy cylindrical shell with a lithium-aluminum target element centered within; coolant is supplied on each surface of the fuel shell. Each loading type would produce 40-45 kilograms of tritium per year, but would sacrifice plutonium production.

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The J-N load presents certain nuclear safety problems because of large reactivity gains possible upon complete loss of coolant followed by fuel element melting and dispersal through the lattice. The wraparound concept requires a considerable development effort prior to application. Major problems, brought about by the higher power levels, include high graphite temperatures and operational reactivity control. Mechanical chattering of the alloy fuel in the process tubes may also present problems. These problems would require thorough evaluation before proceeding with these types of loadings.

c. Tritium Separation

A study was made early in 1958 to determine the feasibility, costs and time required to reactivate the 108-B facility for tritium separation. The following conclusions resulted from the study:

1. Rehabilitation of the 108-B facility to an operating condition for processing solid N-type fuels would require 9 to 10 months and expenditure of \$200,000. Capacity: Equivalent to 1500 MW of continuous reactor power.
2. Rehabilitation of the 108-B facility to an operating condition for processing I & E N-type fuels would require 10 to 11 months and expenditure of \$250,000. Capacity: Equivalent to 3000 MW of continuous reactor power.
3. Rehabilitation of the 108-B facility to an operating condition for the processing of I & E N-type fuels with certain improvements made to permit sustained production levels equivalent to 5100 MW continuous reactor power would require about one year and an expenditure of \$450,000.
4. To carry out Item 3 and provide facilities for isotopic enrichment would require 18 months and an expenditure of \$1,065,000.

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5. If tritium separative capacity beyond the equivalent of 5100 MW continuous reactor power should be needed, a new facility would be required. Such a separations facility, including isotopic enrichment capability, would cost from \$6.5 million to \$8.5 million, depending on capacity, and would require 24-30 months to build.

2. Transuranic Elements

The recovery of neptunium-237 from irradiated Hanford fuels is currently under study. The most attractive plan developed thus far is dependent on the successful conversion of the Purex plant to a two-cycle flowsheet currently scheduled for July, 1958. Minor process changes would be made to route the neptunium with the plutonium, or the second cycle wastes' anion exchange equipment would be utilized to recover decontaminated neptunium from the chosen stream. The installation of this equipment is tentatively scheduled for FY 1960 at a cost of the order of \$100,000.

Prototypical equipment is expected to demonstrate the feasibility of this approach by recovering some neptunium during FY 1959. The study of neptunium recovery at Redox has been de-emphasized, since the bulk of the fuels is scheduled for processing at Purex and basic process changes are being considered for the Redox plant.

Should americium become a desirable product, the technology exists for recovering americium from aged plutonium by ion exchange techniques. The activation of this program is not planned, but could be effected at a relatively low capital expenditure. This recovery program could be associated with the rework of obsolete weapons shapes as a means of providing aged plutonium without unnecessary plutonium inventories.

3. Fission Product Recovery

The radioactive decay of fission products provides an energy source which is a liability under current operating procedures, but which could become an asset in the future. Specifically, isolated cesium or mixed fission products could supply a high intensity field of gamma radiation for

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food sterilization and other similar uses, and isolated cerium and/or strontium could be valuable as a heat source for specialized applications.

Plans are being developed to convert the inactive "221-B" plant facilities (formerly used to recover plutonium by the BiPO_4 process) to a fission product recovery facility. Based on the current status of process and equipment development, it is estimated that a pilot plant could be installed in "B" plant about 20 months after construction authorization for about \$1,500,000. This pilot plant would be capable of producing annually up to 11 megacuries of cesium, 11 megacuries of strontium, or 275 megacuries of cerium. Smaller quantities of two or more products could be produced by operating on an alternating basis. The operating reliability of such a unit would at first be questionable, since maximum use would be made of existing facilities which have not had recent use. One or two additional processing lines could subsequently be added for the simultaneous production of two or more products in 18 to 24 months for about \$850,000 to \$1,000,000 per line, with an earliest possible date of twelve months after the first line is completed. The incremental operating cost of the initial pilot plant line is estimated at about \$1,200,000 per year, excluding allocated plant overheads and amortization of capital investment.

A contract has been signed with the A. D. Little Company to conduct a market survey to determine market potential for radiation sources. This survey is expected to be completed by November, 1958. On the assumption that a demand for fission products is shown, either for government projects or industrial use, the detailed design for the "B" plant conversion is scheduled for completion during FY 1959. Construction can start when authorized, and subject to approval, is scheduled to start in FY 1959.

The recovery of krypton and xenon at Hanford is currently being evaluated at the request of the Division of Production. Current schedules indicate that about 1,500,000 curies of krypton-85 and about 2600 standard cubic feet of xenon-134 and -136 will be available annually in the Purex

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gaseous effluents. As currently conceived, the products would be recovered from the large-volume (about 1000 cfm) steam by low-temperature fractionation, or by ambient-temperature adsorption on moving charcoal beds. In either case, industrial technology would be employed, with little research and development work being required. Specific proposals for recovering the krypton and xenon will be made by November, 1958. The products are considered to be delivered as a "rough cut" grossly diluted with other gases, as relatively pure separate products, and as pure fractions after isotopic separation. While the basis of cost estimation is vague at the present time, the project cost of this installation is currently thought to be about \$1-2,000,000. The unit would probably require 18 to 24 months after authorization to install, and the project is tentatively scheduled for activation during FY 1959.

4. New Weapons and Weapons Assembly

The demand for new weapons shapes has continued during the past year. In response to this demand Hanford's program for development of improved fabrication technology has been very active.

_____ .n expenditure of \$1,000,000 (authorized in total in November, 1957) will provide production equipment for the fabrication of Pit 65 models. FY 1959 budget funds of \$3.5 million are planned to be used to provide additional fabrication facilities. An additional \$7.5 million has been submitted for the FY 1960 budget to provide facilities for routine weapon component fabrication and assembly.

5. Processing of Non-Production Fuels

It is currently predicted that the volume of irradiated fuels available for processing from the Reactor Development Program will reach the order of 500 to 1000 tons of low and intermediate enriched fuels per year before private industry will consider it wise to enter the field of chemical processing. The responsibility for processing these fuels during the interim

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period (say until 1965 or 1970) has been assigned to the Division of Production. The responsibility for processing the depleted and slightly enriched fuels has been delegated in turn to Hanford.

Plans are being made to receive and process these fuels at Hanford, making optimum use of existing facilities. Since the estimated useful life of the facilities provided specifically for this work is estimated at five to ten years, capital expenditures will be minimized at the expense of some increase in operating cost. As currently conceived, some new facilities will be required to receive, unload, and decontaminate cask cars from off-site. New facilities will also be required to perform a partial disassembly of the fuel elements unless this function is performed at the reactor sites. The 221-U plant facilities (formerly used for the recovery of uranium from stored waste solutions) are expected to be revised to permit the interim storage of fuel elements prior to processing. New equipment is to be developed, designed, constructed, and installed in 221-U to effect the dissolution of the fuel elements. The solution is then to be transferred via a new pipe line to the Redox plant, where the fissile materials will be recovered and decontaminated in existing equipment. Some of the low-enrichment fuels may be stored and dissolved in the Redox plant as an economical means of obtaining added capacity.

If the uranium product solution has an enrichment of less than 1.25 per cent U-235, it can be calcined to UO_3 in existing equipment at the 224-U Plant. Uranium of higher enrichment will be converted to UO_3 , UO_2 , or UF_4 in new equipment designed for nuclear safety, the choice of Hanford product depending on future needs of reactor and Commission organizations. The plutonium is to be converted to buttons by blending with normal production, by processing separately in existing operating equipment on a campaign basis, or in new, small scale equipment. The final choice will depend on the degree of segregation required, other product commitments, and the resolution of personnel exposure problems associated with the handling of high exposure plutonium.

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While some aspects of the plans for processing the non-production fuels at Hanford are being modified with continued study, it is believed that the projected work can be completed within the \$6,300,000 budgeted for this work. Design work is scheduled to start in early FY 1959, with the goal of having operable facilities early in FY 1962. The facilities provided should be adequate for the processing of several hundred tons of irradiated fuels per year.

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IV. RESEARCH AND DEVELOPMENT PROGRAMS

Continuing research and development programs are necessary to provide assurance that the production requirements of future military and industrial programs can be met safely and economically. An actively functioning research and development organization is thus to be regarded as a major national resource in the development and maintenance of the nation's security and well-being. A close alliance between current development and production efforts is required to assure that pertinent technology needs are promptly identified, developed, and applied to meet the constantly changing requirements of the military and industrial programs.

A significant increase of applicable technology is required to achieve the production gains and diversification outlined in Section III, above. In most cases, intensive research and development programs are already in progress to supply the needed technology. In addition, the General Electric organization plans to make significant contributions to the technology supporting the broad programs of the Atomic Energy Commission, including many advancements of simultaneous benefit to military production and civilian application programs.

The scope of the Hanford research and development effort includes exploratory and applied research, process and equipment development, design development, prototype testing, and engineering and economic evaluations directed toward new and improved processes. Concurrently the engineering and operating technology is developed to provide an increased knowledge of nuclear and chemical safety parameters, improved reactor systems, improved materials of construction, equipment design, process control methods (both analytical procedures and in-plant instrumentation), and techniques for contamination control. Results of these efforts provide firm bases for modifications to existing plant equipment and processes and for potential new plant construction. The Hanford development programs take advantage of development at other sites whenever practicable.

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Summarized in the following table are the estimated direct professional manpower requirements and costs of the research and development programs for the next five years necessary (1) to support the production program and achieve the advances described in the preceding section, (2) to continue present research and development programs for the Division of Military Application, Reactor Development, and Biology and Medicine, and (3) to conduct certain additional research and development programs for the Division of Reactor Development and Research which appear suitable to the over-all Hanford program. It must be recognized that many of the programs mutually support each other. For example, fuel cladding techniques for the IPR may be applicable to the plutonium recycle program, and much of the advanced technology in weapons manufacture was obtained in the Whitney work. Therefore, the manpower and dollar estimates must be looked upon as "allocable" rather than being a strict measure of direct costs. The deletion of any one program might not effect a cost reduction equal to the allocated costs, and might have deleterious effects on others unless a portion of the deleted program is completed by the remaining programs.

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TABLE VI
ESTIMATED MAGNITUDE OF RESEARCH AND DEVELOPMENT EFFORT

Source of Support	Program	FY 59		FY 60		FY 61		FY 62		FY 63	
		Men ⁽¹⁾	\$MM ⁽²⁾	Men	\$MM	Men	\$MM	Men	\$MM	Men	\$MM
Division of Production (2000)	Subtotal	286	10.3	284	10.6	285	10.6	283	10.5	283	10.5
	Category I	182	7.0	185	7.1	185	7.1	183	7.0	183	7.0
	Category II	104	3.3	99	3.5	100	3.5	100	3.5	100	3.5
Division of Mil. Appl. (3000)	Subtotal	15	1.2	18	1.5	20	1.6	20	1.6	18	1.3
	Category I	7	0.7	10	1.0	12	1.1	12	1.1	10	0.8
	UCRL(Whitney)	8	0.5	8	0.5	8	0.5	8	0.5	8	0.5
Division of Reactor Dev. (4000)	Subtotal	110	6.1	117	6.1	122	6.9	119	6.9	113	6.6
	Plutonium Recycle	86	4.3	88	4.5	94	5.2	91	5.3	86	5.0
	A-M Gas Loop	4	0.6	5	0.2	5	0.2	5	0.2	5	0.2
	Pu and U-233 Fuel Elements ⁽³⁾	8	0.6	8	0.6	8	0.6	8	0.6	8	0.6
	Gas Cooled Reactor Studies	7	0.3	7	0.3	6	0.4	6	0.3	5	0.3
	Fixation of Radio-active Wastes	3	0.1	7	0.3	7	0.3	7	0.3	7	0.3
	Swelling of Fission-able Metals	2	0.2	2	0.2	2	0.2	2	0.2	2	0.2
	Subtotal (Washington Designated Program)	9	0.5	9	0.5	9	0.5	9	0.5	9	0.5
	Subtotal	66	2.1	68	2.3	69	2.3	69	2.3	69	2.3
	Subtotal	66	2.1	68	2.3	69	2.3	69	2.3	69	2.3
Total for All Programs ⁽⁴⁾		486	20.2	496	21.0	505	21.9	500	21.8	492	21.2
Total for Authorized Programs		456	18.9	472	19.5	432	20.4	477	20.4	470	19.8

- (1) Includes direct professional personnel only.
(3) Assumes similar work in plutonium metallurgy.

- (2) Budget estimates are 1959 dollars without escalation.
(4) Includes items in submitted budget proposal, HW-54976 and other submitted proposed supplemental items. All are described in this document.

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A. Division of Production

The efforts in support of the production program consist of two programs - Category I and Category II. The Category I program is directed toward the technological improvement of process cycles at the existing facilities which will result in increased product output. Category II is directed toward the development of broad areas of technology for replacement reactors and for the support of accelerated production requirements should they occur.

The magnitude of projected production increases from existing facilities is shown in Figures 1 and 2. It should be recognized that these projected increases are based on optimistic assumptions, and the achievement of such levels cannot be guaranteed but are contingent upon significant technological progress on all phases of the process cycles. Rigorous research and development programs must be continued in order to approach the indicated production capabilities. The individual problem areas requiring development are discussed in the following sections.

1. Fuels Preparation

The fuel development program for the existing reactors for the next five year period is planned to produce a fuel element compatible with the general requirements of (1) reducing over-all cost of plutonium production, (2) being sufficiently rupture resistant to both core and corrosion failures that fuel element performance will not be a reactor operating limit (3) being sufficiently stable dimensionally that they will not lodge in the process tube, and (4) being compatible with the operation of the separations plants.

The ramifications and, in some cases, the contradictory nature of some of the above requirements are not readily discernible. For example, a small change in the geometrical shape designed to reduce thermal stresses during irradiation will also affect operating costs, reactor reactivity, compatibility with charge-discharge techniques and process tube geometry, resistance to corrosion type failure, dimensional stability of the fuel element,

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and the operating conditions in the separations plants. Thus the research and development effort required to effect what appears to be the slightest of changes must continue to be studied from all aspects - technical, economic, and operational.

a. I & E Fuel Elements

The internally and externally cooled fuel element, now in production, shows promise of removing the reactor operating restriction imposed by fuel element core performance. Continued utilization will permit production gains equivalent to 45 million dollars per year. While the differential total cost is \$.70 per pound of canned uranium higher than that of solid elements, it is expected that the difference can be substantially reduced through improved fabrication techniques now in the intermediate stage of evaluation. The potential production gains more than compensate for the present increased cost.

b. Increased Corrosion Resistance

A majority of the current fuel element failures can be characterized as corrosion-induced failures in that the jacket is penetrated from without by the cooling water. Many of these failures result from excessive corrosion at local "hot spots", and the higher coolant temperatures anticipated will tend to increase corrosion rates. It is anticipated that a change in jacket material will be required to meet the goal reactor condition planned for FY 1961. An aggressive alloy development program is currently entering the stage of reactor testing.

(1) Tru-Line Feature

Approximately 35 per cent of all fuel elements produced during FY 1958 possessed true-line features and by year end, two-thirds of the produced fuel elements were so equipped. Evaluation of the true-line feature in production usage continues for this geometry and is intended to alleviate the incidence of "hot spot" failures caused by cocked slugs. However, similar effects can be traced to several

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other causes including fuel element column bowing. Pre-irradiation testing of the self-supporting type fuel element, which should eliminate both slug cocking and column bowing, is underway. Reactor evaluation of the most promising of these designs will be undertaken as rapidly as possible.

(2) Intergranular Corrosion Resistant Jackets

Corrosion induced failures resulting from intergranular attack ("hot spot" type) may be alleviated by the use of appropriate aluminum alloys such as 8001 (formerly designated as M-388). From laboratory tests and a limited amount of in-reactor experience, this alloy has been found to possess greater resistance to intergranular corrosion than 1245 and has demonstrated uniform corrosion rates that are about equal to 1245. Although quantitative in-reactor data are not available, lot quantities of I & E fuel elements clad with the 8001 alloy are under test, and no evidence of extensive intergranular attack on these fuel elements has been found.

Because of the higher coolant temperatures planned for the reactors, aluminum alloys with improved resistance to uniform corrosion and intergranular corrosion will be required for jacketing materials. Investigations are continuing to develop such alloys.

c. Quality Control

Significant improvements in fuel element performance continue to be realized through the application of stringent quality control. Many of the fuel element failures which occur during irradiation are thought to result from inherent defects in material or in the fabrication process. Therefore, there is strong incentive for identifying these characteristics or defects which are potential causes of fuel element failure. Having identified an undesirable characteristic, it is imperative that methods be developed for testing and eliminating undesirable characteristics prior to irradiation. To be effective, the test must be non-destructive and performed on all production

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elements so that all acceptable elements are retained for reactor use. The non-destructive testing program will be implemented by the procurement and installation of applicable equipment.

d. Improved Cladding Technique

The impact of adjustments in fuel jacket properties, particularly increased stiffness which results from alloying, on the properties of the clad can bond must be evaluated. Continued research and development into cladding techniques, uranium fabrication, and heat treatment are needed to proceed from the present porous, relatively weak, frangible bond now obtained to a dense, strong, ductile bond that will prolong the service lives of those fuel elements that will be exposed to extraordinary corrosive conditions.

The technology for cladding fuel elements continuously in an extrusion press has been developed ~~off-site~~ to the point where ~~provisional~~ submission for a production facility has been made in the FY 1960 Plant Acquisition and Construction Budget.

available early in FY 1960 It is anticipated that ^{pilot plant} facilities for extrusion work on-site ^{will} be obtained in FY 1959. Such a facility will be capable of producing ~~not only~~ fuel elements of the present solid design, but also would be capable of ^{not} producing ^{tubular configurations} clusters, plates and ~~probably I & E~~ elements with several cladding materials.

e. Continuation of Other Current Development Programs

Savings of 4 - 8 million dollars per year may be realized through the application of chipless fabrication techniques for uranium fuel elements. Initial results indicate that direct pressure casting is feasible. ^{Reactor evaluation} During ~~FY 1959~~ ^{then} sufficient quantities of the material will be available for initial reactor evaluation.

Although present performance of the I & E fuel element is extremely promising, the severe operating conditions at the higher projected power levles may show characteristics of these elements to be limiting. For this

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reason, a continuing program of producing superior fuel elements must be carried forward. Primary candidates under this program are the wafer and washer type fuel elements. Because of their geometric configuration, these fuel element types may alleviate some of the major difficulties associated with dimensional stability, heat transfer, and water-uranium reaction rates. Preliminary testing and evaluation of these designs should be completed within the next two years.

Although it may be necessary to resort to fuel elements that are segmented in order to cope with the more severe operating conditions, there remain tremendous cost incentives for producing large massive fuel elements which will perform satisfactorily. Fundamental problems associated with irradiating massive fuel elements at high specific power lie principally in the fields of dimensional stability, thermal conductivity, chemical reaction between uranium and water, and irradiation effects. Fundamental and applied research in these fields is being carried out at Hanford continually.

2. Reactor Operation

The objective of the Category I program is to improve the operational performance of existing reactors in order to increase production and reduce conversion cost. The operational levels of several reactors have been extended to the point where increased production may require major plant modification. During FY 1959 an engineering study will be made to establish the economics and operational feasibility of providing further increases in production capabilities of existing reactors by such methods as pressurization or increased coolant capacity. These studies will evaluate the effect of such changes on all phases of the reactor system, and will establish the continued objectives and direction for the Category I programs. Individual problem areas requiring development are discussed in the following sections.

a. Fuel Element Performance

Superior fuel element performance is a major contributing factor to increased product output of the reactors. Without improved fuel elements

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the productive capacity will essentially be that which was attained in FY 1958. Evaluation of fuel element requirements is not limited to performance, but includes also those factors contributing to over-all production capability. Such factors as conversion ratio, reactor reactivity, resistance to corrosion and cleavage failures, compatibility to charge-discharge techniques and process tube geometry, and dimensional stability are to be considered in the design and engineering of fuel element types.

During FY 1958 it was demonstrated that the I & E fuel element is a major step toward development of a fuel element having superior performance and which possesses appropriate nuclear characteristics. Several technological areas will require continued development.

(1) Performance Analysis

Fuel element ruptures are difficult to categorize unerringly because of many contributing variables, and because post-rupture examination in full metallurgical detail is difficult or impossible. For these reasons the dependence of rupture rates upon reactor parameters such as power, exposure, coolant temperature, core temperature, and position in the reactor, is not completely understood. Cleavage failures are better understood than corrosion induced failures. General conclusions drawn from selected data have proven to be dangerous. An exhaustive data processing and analysis program is being carried forward and will be continued as an essential part of the study to improve our understanding of the causes of failures and to define the reactor variables contributing to each failure type. Basic fuel element performance data will be obtained to pilot the conditions anticipated at higher power levels.

(2) Cleavage Failures

It now appears both on experimental and analytical grounds, that I & E fuel element geometry will have adequate resistance to cleavage failure to operate without difficulty from this mechanism

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at goal power and exposure levels. With natural uranium and present economic criteria, there is little incentive to extend goal exposures of the I & E fuel elements beyond 800 - 900 MWD/ton. With enriched uranium, either as reactivity support for maintaining high efficiency or as a fuel for isotope production programs, there is a strong incentive to demonstrate that exposures up to 1500 - 2000 MWD/ton are possible without reaching limiting rupture conditions.

The use of I & E fuel elements have generated several unique reactor problems which will require time and effort to overcome, but none appear insurmountable. The most salient of the problems in reactor technology include the following:

(a) Flow Stream Unbalance

In order to proportion the flow of cooling water inside and outside of the I & E fuel elements, the outer diameter of this element has been made slightly greater than that of the solid element. The reactor process tubes, however, contain ribs for horizontal support of the fuel elements. These ribs are fixed in height for solid fuels, and the use of I & E elements results in an eccentric position of fuel in the channel. This eccentricity results in higher coolant temperatures, more rapid jacket corrosion, and nearer approach to localized boiling at the top of the channel. Precise temperature balance is not required, but is desirable to obtain more efficient reactor operation. Under active consideration are the use of "mixing pieces" to mix coolant from the internal and external channels; development of a fast, positive and reliable method of in-pile rib height reduction; reduction of the thickness of the fuel element jacket - especially the thickness of the Al-Si bonding layer; and development of self-supported fuel elements for use in ribless tubes. The self-supported fuel element offers flexibility to adapt the

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configuration of the I & E fuel elements to changing reactor conditions without complications arising from eccentricity. However, costly alterations to reactor nozzles, charging machines, and installation of ribless process tubes will be required to make use of self-supported fuel elements. A continuing long-term development program will be undertaken to achieve highest beneficial utilization of the I & E fuel elements with minimum cost for major reactor component modifications.

(b) Coolant Temperature Limits

Each process tube assembly contains a Panellit pressure monitor which automatically shuts down the reactor as conditions leading to flow instability develop; that is, a trip before flow instability sensitivity is maintained. The I & E fuel column substitutes two parallel flow channels for the one monitored in a solid fuel load, resulting in a reduction of sensitivity to changes of flow in either channel. Sensitivity to bulk flow changes is not significantly affected. The current trip before or after instability limits will be applicable to tube outlet temperature in excess of 100° C. An aggressive program is now being followed to determine the conditions under which adequate protection against component melting is provided if the reactor shutdown is initiated after conditions possibly leading to flow instability are reached. The results are encouraging in that the dual coolant channel arrangement continues to provide considerable cooling in the event one of the two channels undergoes plugging.

(c) Nuclear Safety

Nuclear safety problems are somewhat more severe with I & E fuel loadings than for solid fuel loads because the reactivity gain upon loss of water is somewhat greater. Analysis of this problem has indicated that neither the potential nor the severity of a water loss disaster would be markedly changed with I & E fuel element loadings.

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(d) Conversion Efficiency

To permit balanced flow streams in the dual coolant channels of the I & E fuel loading, the I & E fuel elements contain about eight per cent less uranium than the standard solid element. However, because of neutron moderation in the interior cooling channel with resultant increase of resonance neutron capture in the fuel element the conversion ratio is essentially unaffected. There is an incentive to increase the amount of uranium in the fuel elements in order to increase the conversion ratio above existing values, but this must be accomplished without sacrificing heat transfer. Engineering and economic studies will be made during FY 1959 to evaluate the incentives for increasing conversion ratio by various methods including boring out of the graphite channels to accommodate larger diameter process tubes and fuel elements.

(3) Corrosion Failure

Planned increases in reactor power levels will require that solid and I & E fuel elements operate at high surface temperature and with high heat loads. Uniform corrosion rates of aluminum cladding alloys are increased, and the inevitable presence of at least minor alignment and surface irregularities can be expected to produce further elevation of surface temperatures, resulting in the so-called "hot-spot" failures in areas of high heat flux. This is particularly true for the eccentric cooling annulus with I & E elements. Aluminum alloys which resist the onset of intergranular corrosion attack at these high temperatures are being developed, and a continued development program to define optimum alloy fabrication techniques and compositions is required.

b. Operation at 100° C Bulk Effluent

The reactor power levels were projected on the basis that the reactors would operate with a maximum bulk effluent temperature of 95° C during FY 1959, and increased to 98° C thereafter. These bulk outlet temperatures

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correspond to maximum individual tube outlet temperatures of 125 - 130° C. Reactor operation at outlet temperatures in the range of 95 - 100° C will require minor modifications to permit modest pressurization of portions of the rear face coolant system. These high temperatures, and the attendant increases in power level, will create new engineering and materials problems.

(1) Materials Development for 100° C Bulk Effluent

(a) Process Tubes

Aluminum tubes are subject to relatively rapid corrosion rates in high temperature process water. The problem is that of extending the life of the process tube either through control of the corrosion rates or by means of new process tube materials. It is projected that aluminum tubes will be used in the fringe process channels, and that zirconium alloy tubes will be used for the central zone. Present process tube material has been specified as 1100 or 6063 aluminum alloy. Development efforts will continue to evaluate aluminum corrosion under various conditions of pH adjustment. New aluminum alloys will be evaluated which show improved strength and corrosion resistance to provide superior performance at high temperatures.

Economic and engineering studies have shown it feasible to install zirconium alloy tubes in the central zone of all reactors. It is anticipated that installation of zirconium tubes will be completed in the existing reactors in FY 1963. During FY 1960 a pilot lot of 300 tubes will be installed in one of the older reactors, and retubing of two older reactors completed early in FY 1962.

These zirconium tubes will have a thinner wall than aluminum tubes, thus permitting an increased flow rate and higher power level. The tubes will be sized to accommodate I & E fuel elements, and better fuel element performance is anticipated. The larger coolant channels may require minor water plant modifications to provide the increased flow rates.

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(b) Graphite

Projected power level increases will result in graphite temperatures in the range of 700 - 800° C. An extensive graphite monitoring program is being carried out routinely to monitor distortion, burnout, and stored energy effects as power levels and temperatures are increased. Experimental studies will continue in order to gain a better understanding of the changes in the physical properties of the graphite as a function of irradiation and temperature. As the graphite temperature is increased, emphasis will be placed on improved methods of temperature monitoring, and the chemical reactions of water, carbon dioxide, nitrogen, and oxygen with graphite. Graphite technology at temperatures to 1500° C and at fluxes to 10^{15} neutrons/sq cm/sec will be obtained at the MTR and ETR to support development required for the IPR program or pressurization of existing Hanford reactors.

(c) Shield Damage

The biological shield of the six older reactors is subject to thermal deterioration of masonite layers, and will require remedial action to maintain shield life or effectiveness at the higher power levels. Fringe zone poisoning, which involves the use of compensating enrichment elsewhere in the reactor, appears to be the only practical remedial action short of limiting the reactor power level. The schedule and program for shield protection is included as a part of the over-all enriched uranium program. Augmentation of the shield through external construction will be evaluated through engineering and design studies as a method of compensating for the appreciable masonite deterioration rates that may be experienced at higher power levels even with fringe poisoning.

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(d) Component Improvements

Operation of the reactors at the projected higher power levels will result in graphite temperatures in the range of 700 - 800° C. These high temperatures will increase the severity under which other reactor components must operate, and new materials may be required for the proper functioning of some components. Those systems which may require improved materials include the control rods, Ball 3X, thermocouples or other graphite temperature monitoring devices, electrical lead wires, insulation, and seals and gaskets.

In addition, improvements in design of the tube-nozzle joints may be required to accommodate the thermal stresses to be encountered at the higher operating temperatures.

(2) Engineering Development Problems

(a) Outlet Coolant Temperature Limits

A major program of flow and power transient studies has demonstrated the safety of operation under the "trip-after-flow instability" limits. Experimental assurance has been obtained from the full-scale mock-up facility that the transient dynamics of the coolant caused by flow or power anomalies are such as to shut down the reactor before melting of fuel jackets occurs when the time responses of all components are conservatively considered. Studies currently being evaluated indicate that tube outlet temperature limits of 130° C will permit safe operation for I & E fuel loadings. These studies will be extended during FY 1959 and FY 1960 to evaluate the temperature limit requirements for tritium producing loadings. Experimental tests and studies have indicated that the present process monitoring system is adequate, and that a supplementary system of flow, pressure, or temperature monitoring instrumentation would not add significantly to the operational safety of the reactor.

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(b) Nuclear Instrumentation and Safety Circuitry

All aspects of nuclear instrumentation are being improved, including octant monitoring systems, power rate meters, coolant flow monitors, outlet water temperature monitors, passive scanner data monitors, and others. Development or installation of these improved systems will be completed in FY 1961, except the passive scanner system which will be completed in FY 1962.

(c) Effluent Systems

Some effluent system problems will be encountered as the 100° C bulk outlet temperature is approached. Most of these are associated either with vapor evolution in low static pressure regions or inadequate mixing of the higher and lower temperature coolant streams. During FY 1959, instrumentation will be placed on the effluent piping system at one of the reactors to establish the severity of the riser and downcomer problems as the outlet temperature is raised step-wise to a limiting temperature of approximately 100° C bulk outlet. Data will be obtained to establish limitations imposed by transient flow conditions. Also, extensive out-of-pile experiments will be performed in FY 1959 in which process tube and crossheader geometries are mocked up with prototypic flow conditions. The results of these full-scale tests will be used to establish the modifications required to permit the higher bulk outlet temperatures. It is anticipated that modifications will be required in rear crossheader orificing, downcomer venting, rupture detection system, and effluent line venting. A study will also be made to evaluate the feasibility of supplying cold water to the effluent system to maintain the bulk outlet coolant at a temperature less than 100° C.

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(3) Increased Cooling Capability

The K reactors will each be provided with an increased flow rate of 20,000 gpm by FY 1963 based on five-pump operation. After installation of zirconium tubes and I & E fuel elements, it may be feasible to increase the cooling capability at the other reactors by making modest modifications to the water plant and pumping system. The feasibility of such modifications will be established in an engineering study to be completed in FY 1959 for increased power levels for all reactors.

(4) Increased Operating Efficiency

The following major problems and areas of effort are involved with the attainment of improved operating efficiency:

(a) Reactivity and Flux Control Problems

As power levels are raised, the reactivity transients become larger and increase the operational control problem. The xenon transient, and the moderator and metal temperature coefficients of reactivity are such that the power and flux distributions are more difficult to control. Also, the excess reactivity is reduced at higher power, placing limitations on the amount of variable control that can be placed in-pile and adversely affecting the ability to recover from outages without being compelled to accept an extended outage. Development will be continued on methods of using spike enrichment to augment low reactivity, as will equipment and techniques to augment the limited capacities of the control rod systems. Additional control schemes include poison column control facilities, neutron absorbing splines, poison column displacement facilities, and pile atmosphere manipulation to simplify the general flux control problem.

(b) Tube Replacement Problem

Replacement of process tubes is necessary in order to alleviate outages caused by water leakage from corroded tubes. The long-range goal is to replace the aluminum tubes in the central zone of the existing reactors with zirconium tubes. It is anticipated

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that this large-scale tube replacement program will be completed during FY 1963. Thereafter the program will consist of replacement of aluminum tubes in the fringe zones and replacement of zirconium tubes if required. The zirconium tube replacement program will be initiated in FY 1960 with installation of 300 zirconium tubes in one of the older reactors, and retubing of two older reactors will be completed in FY 1962. Methods and equipment will be developed to achieve a high tube replacement rate in FY 1960 for the other reactors. During FY 1959 - 1960, the aluminum tube replacement program will be continued at a normal rate of approximately 30 tubes per day.

(c) Rupture Discharge

Development of tools and techniques for rapidly discharging ruptured fuel elements will be continued. Also, methods of more quickly identifying the tube containing the rupture and discharging remotely are under development to minimize outage recovery time.

(d) Charge-Discharge

Charge-discharge during reactor operation is an integral part of the long-range objectives of the present reactors where it can be shown that such a program is economically feasible. On the basis of current production the project would seem marginal at the older reactors with three-year pay-off. During FY 1958, the 112-tube system was installed on C Reactor under Project CG-651 to demonstrate operability of the system. A significant part of the charge-discharge incentive hinges upon discharging ruptured fuel elements during operation. The demonstration of a superior fuel element or more economical methods of accomplishing rapid rupture removal might reduce the justification for full reactor installations. However, for any large scale enriched loading program, charge-discharge during operation would prove advantageous.

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(e) Advanced Maintenance Techniques

The program of improving maintenance techniques and equipment will be continued throughout the period. In general, capital expenditures to support this essential effort are from the equipment and/or operating budgets. Improved methods will be developed for reduction of personnel exposure to radiation during maintenance work. These include a remote manipulator for rear face maintenance operations, power operated maintenance tools, development of efficient rear face decontamination methods, and development of more efficient tube replacement techniques.

(5) Improving Safety Conditions

During the next five year period, continued emphasis will be placed on the development of appropriate nuclear safety criteria, and the range of studies will support existing reactors and specific IPR concepts. The nuclear safety criteria established to date are summarized as follows: (1) continuity of cooling is a critical factor and emphasis should be placed on water plant reliability; (2) loss of cooling should not result in melted reactor components while the reactor is critical, and (3) the reactor must remain subcritical following a loss of coolant and subsequent melt-down.

(a) Power Excursions

Calculated power excursions based on conservative assumptions have indicated that, if higher power levels are to be obtained, accelerated safety rods would be required to maintain the energy release within acceptable limits. However, recent calculations and laboratory tests have indicated that reactor safety would not be compromised if the limiting criteria were established as the melting point of uranium rather than aluminum jacket melting. Acceptance of this concept would eliminate the requirement of accelerated safety rods (and an installation cost of \$5, 000, 000) at limiting power levels appreciably beyond those at present.

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(b) Total Control Requirement

The nuclear control system will have sufficient capacity to maintain the uncooled reactor subcritical until an appreciable fraction of the process tubes have been rendered useless (by melting) and to maintain the reactor below prompt-critical thereafter.

The criterion on the speed of control appears to be unnecessarily restrictive since from the point of view of offsite hazards it should be sufficient to require that the reactor be shut down prior to the melting of uranium fuel elements instead of aluminum fuel element jackets.

The power increases, forecast in this five year plan, are based upon the assumption that the speed of control criteria can be based upon the melting of uranium instead of the melting of aluminum if the latter becomes restrictive to power levels.

(c) Supplementary Cooling

Methods of cooling the reactors independently of the primary cooling system have been scoped and estimated at about \$14,000,000 for all reactors. This study has been transmitted to the Atomic Energy Commission for their consideration and inclusion in future budgets at their discretion.

(d) Radiological Safety

The study of the effects of radioactivity discharged to the Columbia River will be continued with emphasis on the effects upon river, plant, and animal life, downstream utilization of water, the environment, and the well-being of people. Particularly because of recent and anticipated increases in coolant water flow, programs will be inaugurated to reduce the concentration of the critical radioisotopes in reactor effluent water. Two isotopes

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presently receiving emphasis are arsenic-76 and phosphorous-32. Water treatment additives will be carefully studied as sources of trace inert elements required to produce the critical isotopes found in effluent water. Understanding of the importance of film formation, corrosion, target element hold-up time, temperature, power levels, and other variables in isotope formation will be amplified. The release of critical isotopes to the river will be continuously monitored.

Radiation exposure to personnel will be lowered through the development of methods to decontaminate internal surfaces of reactor piping and remote techniques and equipment. Better personnel monitoring instruments and techniques will be developed to effect more efficient utilization of manpower in radiation zones.

Methods of controlling both local and widespread deposition of radioactivity under unusual reactor process conditions will be evaluated experimentally.

(e) Containment

Hanford experience to date discloses a minimum of fission product releases from reactors. These were operational nuisances requiring special procedures for limited times to prevent exceeding allowable personnel radiation limits. No incidents have occurred which would have endangered people outside of the Hanford Site. However, a small but finite probability exists that a fission product release would endanger people beyond the Hanford exclusion area.

Continued efforts will be directed toward assessing the types of incidents which could result in fission product releases of significant magnitude, determining the mechanisms for release of fission products, estimating the rates and magnitudes of the possible fission product releases and estimating the offsite hazards which would be associated with each type of accident.

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Studies will be continued to evaluate the methods and feasibility of effecting total containment or controlled release of fission products in the event of a major reactor disaster. Containment may be accomplished by several methods. The first line of containment is the clad, cooled metallic uranium fuel element. Primary emphasis is placed on providing and maintaining an adequate supply of coolant. In addition to continuous monitoring of proposed and accomplished changes in the coolant supply system, a comprehensive review of the assurance of the continuity of the coolant supply will be made during the next two or three years. This will include detailed studies of the adequacy of the water plant from river to river including the emergency backup coolant systems, and the electric and steam power supplies.

The second line of containment for fission products is the reactor block within the shielding and the adjacent cooling piping. This containment feature will be studied as indicated in the section on release of fission products.

The third line of containment would be provided by chimney stack filters to remove fission products from the effluent ventilation air stream. Engineering studies to determine suitable filter media and their effectiveness are being made.

Additional containment could be provided by sealing the reactor building, or by providing a low pressure (2 psi) shell over the reactor building. An engineering study of the cost of providing various degrees of containment is being presented to the AEC.

It is anticipated that some degree of containment beyond that now provided by the fuel elements and reactor block may be required for the existing reactors.

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In an effort to increase our knowledge of fission product release mechanisms and, hence, improve estimates of the rate and magnitude of potential fission product releases from the Hanford reactors, basic studies will be conducted, supported, or followed in the following fields:

- (1) Release of fission products from molten uranium as a function of temperature and reactor atmosphere;
- (2) Fission product retention in graphite as a function of fission products and graphite temperatures;
- (3) Formation and characteristics of U-Al intermetallic alloys as a function of temperature and atmosphere;
- (4) Chemical reaction rates of U-Al alloy with various gases including oxygen and steam;
- (5) Chemical reaction rates of metallic uranium with various gases including oxygen and steam.

An aggressive program will be continued for the reducing and minimizing of reactor hazards. Major emphasis will be placed upon the following problem areas: (1) Improving instrumentation used for reactor control during the approach to critical and during operation; (2) improving the safety circuitry and shutdown mechanisms; (3) improving the reliability of the water supply complex and integrating it more closely with the reactor; and (4) investigating the feasibility of providing additional physical containment for fission products released from the reactors.

c. Improved Product Yield

An active program will be undertaken to increase the over-all product yield of the existing Hanford reactors by more efficient utilization of fuel and target materials. The present process can be improved by several fundamental approaches in the production of both plutonium and tritium. (a) Resonance

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capture can be increased. It is desirable to increase the resonance capture if possible, since neutrons captured at resonance energies in U^{238} to form plutonium are not subject to waste losses from absorption in graphite, water, and aluminum. (b) Parasitic neutron capture can be reduced. By a reduction of flux level, the neutron losses to graphite, water, and aluminum can be reduced. This can be accomplished without power level reduction by using enriched uranium fuel. The use of enrichment, however, implies the use of a poison to absorb the excess neutrons, and such poisons must produce useful product. (c) Losses to control elements can be converted to useful isotopes. Control rods and flattening columns used for reactor control can produce useful product by substituting lithium for the present non-productive poisons. (d) Neutron leakage from the reactor can be decreased by charging productive poisons in the fringe tube and supporting the reactivity with slightly enriched uranium. (e) Plutonium burn-out can be reduced. The rate of product burn-out can be decreased by increasing the amount of material in the reactor competing for thermal neutron absorption. Thus, by increasing the uranium enrichment, the plutonium has less chance of absorbing neutrons due to competing U^{235} cross sections. Studies will be continued in these areas to determine the most effective fuel element and target loadings consistent with the product requirements of the Atomic Energy Commission.

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3. Separations

The research and development programs in support of the production effort are currently centered in five major areas. These areas include (1) the processing of current nuclear feeds for the recovery of fissile materials with improved safety of operation, decreased operating costs, and increased production capability and continuity; (2) the containment of biologically hazardous fission products with increased certainty; (3) the processing of non-production nuclear fuels with the same goals as listed in (1) and (2) above; (4) the recovery of by-products of value to the military and to industry; and (5) the innovation of new processes and technology permitting the construction of future facilities at a fraction of the cost of existing facilities.

An exact definition of the research and development efforts being applied to each of the individual areas is virtually impossible. The technology evolved by research and development in solvent extraction and ion exchange processes, process equipment and materials, instrument and analytical control methods, and radiation and control techniques have wide applicability, even though development is initiated to meet a recognizable immediate need of a specific program. In the subsequent discussion, specific programs are described in connection with the most immediate need, recognizing that in most cases the programs would have been justified in a few years by other foreseeable needs.

a. Improved Performance of Existing Operations

Experience has shown that the level of effort in support of current operations tends to remain relatively constant, although the pattern of specific effort is constantly changing. This situation is a natural consequence of the continual introduction of improved processes and equipment into the producing complex. Thus, the development effort in support of established operations becomes minimal, while the emphasis shifts successively to the new operating problems created by the recently adopted technologies.

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The operation of the Purex plant has undergone dramatic improvement with the successful plant use of the organic-continuous extraction column with the zebra scrub cartridge (alternate sections are aqueous and organic continuous), an improved solvent regeneration process utilizing an alkaline permanganate wash, improved instrumentation for interface control and further application of in-line instrumentation. The continuous anion-exchange system for plutonium decontamination and concentration has also shown considerable promise, reducing the metallic impurities in the plutonium buttons by a factor of two, and reducing the fission product content to the limits of analytical detection. Continued research and development are planned, with the objective of improving the versatility and reliability of the system. These improvements will result in lower conversion costs in the immediate future and will provide a technology which will permit dramatic capital cost savings in the construction of subsequent extraction plants for military or industrial use.

New solvents hold promise for improved performance of the Redox plant. Although the present flowsheet and equipment have been satisfactory, increased flexibility would be desirable to meet the operating needs of the future. The goal of this new development effort is to permit the use of higher acidities in process solutions (eliminating the hazard of the hexone-nitric acid reaction and permitting greater flexibility of feed compositions), the elimination of the head-end ruthenium volatilization step with its attendant problem of contamination control, and a reduction in the solids content of the wastes to be contained. A minimum of plant revision is described.

A small effort will also continue to obtain a better understanding of the fundamental and engineering limitations of solvent extraction performance. Studies will be conducted in a laboratory "profile column" to gain a better insight into fission product behavior. The use of the analog computer will be studied to ascertain its ability to simulate solvent extraction phenomena. It is possible that this technique can reduce future development costs by reducing the experimental work required to define a given situation.

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A minor problem exists in the dissolution of uranium manufactured by the "dingot" process. Current data show that this material requires 25 to 50 per cent longer to dissolve than does "ingot" type uranium under comparable conditions. The economic incentive for using the "dingot" is recognized. Modified dissolution processes are being developed which will dissolve "dingot" material more rapidly yet not cause undue corrosion of the dissolver vessels.

The development programs to provide improved processing equipment are designed to be of general benefit. Pump developments will include screw pumps for the transfer of slurries or boiling solutions, and deep-well turbine and canned motor pumps for submerged operation while pumping process solutions. The possible application of ceramics as journal bearings will be explored. Materials of construction suitable for halide systems (such as Hastalloy F, titanium, etc.) will be studied for application in process equipment and instruments. Linear polyethylene and radiation-resistant plastics will be studied for use in the flexible jumpers and other applications in plant radiation zones.

Development of ceramics for research and manufacturing application is needed to meet those demands not filled by metallic components. Emphasis will be placed on the use of high purity materials, such as calcium fluoride either for the ceramic body or as a coating. Ceramics suitable for molten salt baths and for porous electrolytic bridges will be explored.

Continuing research and development programs for improved analytical procedures and instrumentation are required to supply the separations plant with the rapid and accurate process information needed for high efficiency. Major prototype instruments scheduled to be demonstrated during FY 1959 include an organic-phase densitometer that will permit operations of a Purex HA column at optimum solvent saturation, an in-tank pH measuring unit, and magnetic flowmeters for 100 per cent UNH solution. New developments to be explored include the application of semi-conductors as alpha contact monitors, and the application of new scintillation-detecting

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techniques to the detection of beta, gamma or alpha radiation. Instrumental methods for monitoring wastes and other streams will be explored using polarography, chromopotentiometry, derivative coulometry, chelation separation and other methods. The development of an improved analyzer for alpha energy will be completed. Emphasis will be placed on improving the analysis of plutonium in dissolver solutions of the varying compositions anticipated for non-production fuels. More reliable, more rapid and less costly methods for the determination of plutonium, neptunium, americium and curium in chemical samples are expected as a result of research to be carried out on new chelation and anion exchange separations methods. The possible development of a completely instrumented method for determining plutonium in the process waste streams will be explored.

b. Plutonium Processing Technology

The major operating problem of protecting 234-5 process personnel from neutron and gamma radiation is now serious and will become progressively worse in the next few years unless corrective measures are found. This problem is a cumulative result of ever increasing throughputs of plutonium isotopes, coupled with the increasing complexity of weapons shapes requiring more contact operations. While some of the operating problems are a part of the 3000 program, the development efforts within the 2000 and 3000 programs must integrate to obtain optimum results. Development efforts therefore are concentrated on methods of reducing personnel exposure both before and after the reduction of plutonium to the metallic state. A plutonium trichloride process is being developed to replace the plutonium tetrafluoride step currently used, thereby effecting a reduction of the neutron flux. The neutron flux from the alpha-neutron reaction would be reduced about 100 fold, and the total gamma plus neutron flux would be reduced at least 25 per cent by such a substitution. The use of a continuous reduction step promises to reduce personnel contact with process materials and thereby reduce the exposure problem. Design modifications will be developed

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to obtain optimum shielding while retaining operational flexibility. Emphasis will continue on the elimination of fission products to the greatest practicable extent, and processes and equipment will be developed to permit the segregated handling of high exposure plutonium as may be required by the production programs of the future.

The use of high temperature chemical purification techniques such as oxide slagging will be explored as a means of purifying molten plutonium metal and recovering fabricated plutonium parts without employing wet chemistry techniques. The program for preparation of pure plutonium metal will be continued. When the ultimate capability of the present process has been tested, new processes for producing metal containing impurity concentration an order of magnitude lower will be started, using techniques such as electrorefining.

c. Nuclear Safety

An improved definition of nuclear safety parameters is required in order that the conflicting requirements of maximum safety and high processing capability can be reconciled intelligently. This reconciliation is required so that existing facilities can be used to best advantage in the processing of the slightly enriched fuels from military and reactor development programs. Engineering studies and nuclear activity tests will be performed to obtain better definition of homogeneous and heterogeneous systems. The use of soluble poisons will be evaluated as a potential means of safely utilizing high-capacity equipment which is not safe by geometry. The construction of a criticality laboratory to define the reactivity of plutonium-bearing systems is an integral part of this program, and the first phase of this construction is scheduled for FY 1959. While the most pressing need for data from this type facility currently lies with production requirements at Hanford, the data will have broad applicability to the over-all programs of the Division of Production. Specific attention is being given to ways in which this facility can best serve other production sites.

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d. Waste Containment and Disposal

The program for improved containment of high level waste will be accelerated with the intent of obviating the construction of another conventional tank farm. Flowsheet revisions will be defined for the reduction of non-volatile materials such as iron and aluminum in the wastes from the separations plants. These revisions imply the possible use of uranium (IV) as a reducing agent and the use of a volatile salting agent in the Redox plant. Calcination methods for converting Purex type wastes to inert solids for storage will be explored. Engineering studies will be made to determine optimum methods for nitrate removal prior to calcination, for heat removal during storage of solids, and for assurance of physical and chemical stability during storage. The technical bases required for design will be developed during FY 1959, and prototype demonstrations of pertinent process steps will be performed.

The desirability of using submerged combustion for the reduction of coating wastes volumes by a factor of 3 to 5 will be determined. The use of gels in the disposal of waste solutions will be evaluated and the program extended or dropped.

A program to define the silver-iodine system more completely will be pursued to provide a basis for improved operation and reliability of the silver reactors. A prototype silver reactor will be constructed with the goal of obtaining increased life between regenerations and the ability to clean and re-use the basic structures.

A program of soils evaluation will continue to obtain optimum selection and use of crib sites for the ground disposal of low-level waste. A program to define the position of fission products currently held in the soil will be initiated in order that a verification inventory can be made. A survey of real estate resources for ground disposal will be completed.

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In addition it has been proposed to the Commission that a study be made by geophysical seismic means of the geologic features of the Hanford area in order that the behavior of radioactive wastes in the ground can be better predicted and determined. Complete reliance on well drilling for such data is not only a matter of concern, but involves slow and costly methods that are adequate only if the wells can be accurately positioned to provide the maximum data. Geophysical work can provide the guides for more accurate positioning than now possible. This study would be made by an outside concern. It is estimated the cost would be about \$150,000 in each of FY 1959 and 1960.

e. The Processing of Non-Production Fuels

The development efforts to support the processing of non-production fuels include studies of mechanical disassembly techniques, the zirflex process, alternate processes for the dissolution of stainless steel, and waste containment problems created by the increased quantity and variety of the ions to be stored. These problems are similar to those created by the fuels being considered for production use, and the development efforts undertaken in behalf of non-production fuels would have been scheduled in a few years in support of production. It is anticipated that the level of effort in this area will peak during FY 1959 and 1960, and will diminish thereafter as the techniques are applied in a production effort.

Studies of mechanical disassembly will include techniques of sawing and chopping, to be conducted either in air or under water. Efforts in this area will be limited in scope, since the intent is to dejacket the fuel elements by chemical means.

The zirflex process will be studied on a semi-works scale. In this process, zirconium is dissolved in ammonium fluoride for storage separate from the solvent extraction wastes. Problems requiring further study include the control of the hydrogen evolution to minimize the combustion hazard, a

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better definition of the effect of process variables on dissolution rate, and the control of uranium-plutonium losses in the coating wastes.

The dissolution of stainless steel in dilute aqua regia will be demonstrated on a semi-works scale. While the basic chemistry has been defined at ORNL, some engineering information remains to be defined as a basis for plant design. An alternate process is under development for the dissolution of fuels in HNO_3 -HF mixtures. This chemical system promises to dissolve most of the fuels assignable to Hanford, but has a major drawback of also dissolving most of the available materials of construction. Hastelloy F having a low carbon content (0.01%) shows promise of containing this chemical system and is being studied intensively.

Alternative processes will be explored as potential means of minimizing uranium inventory requirements during the conversion of enriched uranyl nitrate to UO_3 , UO_2 , or UF_4 while maintaining segregation of the fuels of different enrichments. Fluidized bed reduction to UO_3 or UO_2 , chemical precipitation of UF_4 , and electrolytic reduction to UF_4 will be evaluated.

The engineering aspects of transporting the irradiated fuels to Hanford and charging these materials into Hanford facilities are being studied. Starting in FY 1959, the design of required Hanford facilities will be developed, and any required prototypical demonstrations will be performed. Analytical procedures will be developed and tested for the new ions encountered, and accountability procedures and techniques will be defined.

f. By-Product Recovery

Considerable interest has been indicated by the military and industry in the recovery of potentially valuable by-products from the chemical processing plants. The required technology will be developed with particular emphasis placed on the demonstration of flowsheets for recovering cesium-137, cerium-144, strontium-90, and neptunium-237. Multicurie laboratory tests

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and bench-scale tests will provide firm flowsheets for cesium recovery, isolation and packaging. An integrated prototype installation for the hydrolysis of $\text{Cs}_2\text{ZnFe}(\text{CN})_6$ and conversion to cesium chloride will be constructed, operated, and made available for use in the projected cesium recovery facility in B Plant. Multicurie tests on a liter scale will be made to demonstrate a cerium and strontium recovery flowsheet and to develop integrated flowsheets for consecutive recovery of cesium, cerium, strontium, and possibly other fission products.

Flowsheets for achieving the desired routing of neptunium through the Purex plant will be firmed and tested on a plant scale. The recovery of neptunium from the Purex plant is scheduled for demonstration on a prototype basis during FY 1959. It is now intended that anion exchange be employed to recover the neptunium from the concentrated second cycle wastes as they are back cycled to the first decontamination cycle.

Alternate processes for the recovery of noble gases will be evaluated and costs estimated for implementing their recovery. The bulk of any required research and development will be conducted on a contract basis to obtain maximum benefit from existing industrial technology.

Process development will be conducted for the recovery of americium and/or curium from aged plutonium without resorting to aqueous dissolution. Such a development would permit the low cost recovery of these products from obsolete weapon components. Thereby providing these products without necessitating a large inventory of plutonium.

g. Ion Exchange

Ion exchange technology will be expanded in order that the processing plants can make optimum use of this technology. Firm flowsheets will be demonstrated for the efficient recovery of plutonium from the Purex IWW raffinate, for the recovery of plutonium from Recuplex feeds and wastes, and for the coupling of an anion exchange cycle with a single solvent extraction

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cycle for decontamination of plutonium from uranium and fission products. Research will be initiated on organophosphorus resins which may serve as a tail-end purification step for the uranium stream after one-cycle solvent extraction. Absorption kinetics studies will be completed with respect to plutonium and continued with respect to other complex ions. A research program will be initiated in late FY 1959 to determine the mechanisms by which anion resin is damaged by radiation and to investigate means by which the service life of these resins may be extended. The development of alternative ion exchange contactors suitable for remote operation in radiation zones will be continued, and a prototype unit for plutonium recovery from Purex IWW will be constructed.

h. Electrochemical Processes

The applicability of electrochemical processes to Hanford requirements will be determined. Prototypes will be tested to demonstrate the electrolytic reduction of uranium (VI) nitrate to uranium(IV) nitrate and the production of a uranium (IV) fluoride by the Flurex process. The electrolytic reduction of plutonium from chloride systems will be studied in the laboratory.

i. Pyrochemical Processes

Exploratory research of a pyrochemical process suitable for a low capital investment reprocessing plant will be continued. The feasibility of using the $KAlCl_4$ or another promising system will be demonstrated during FY 1959 in a series of tracer-level and full level laboratory tests.

j. Engineering Studies

Engineering studies are conducted on a continuing basis to provide a realistic integration of the theoretical aspects of research and development with the practical requirements of design, construction, and operation. These studies employ the most recent developments available from all sources, and seek to evaluate the technical, engineering, and economic feasibility of alternative plans. A basis is thereby established upon which the research and development efforts are guided for optimum return.

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4. Improved Reactor Concepts

At the request of the Atomic Energy Commission a program has been established at HAPO leading to the design and development of technology applicable to an Improved Production Reactor (IPR). The evaluation of several candidate reactor concepts under this program has been supported from Category II funds. The objective of this program is to develop a reactor concept which will retire one or more HAPO reactors within ten years following the start of detailed design. In FY 1958 a design study was prepared for a New Production Reactor having dual purpose capabilities for the economical production of plutonium and by-product electrical power. Two alternate approaches were considered for the study: 1) the pressurized water-cooled, graphite moderated, metallic uranium fueled concept, and 2) the organic-cooled, graphite moderated, metallic uranium fueled concept. The organic-cooled concept is attractive because high temperatures ($\sim 300^{\circ}\text{C}$) are achievable at low pressures, corrosion rates are low for a wide range of materials including magnesium, aluminum and carbon steel, and the reaction of the organic with metallic uranium is not severe. However, the technology necessary to adapt organic coolants to a production reactor system is currently under-developed, and the organic testing facilities at Hanford are not adequate to support a large-scale development program on the desired time schedule. On the other hand, the pressurized water system represents a feasible extension of existing Hanford technology, and a considerable fund of technology has already been developed for other pressurized water reactor systems. The primary problem for Hanford application is that of achieving a modest capital cost system which is an economical producer at high temperature when considering corrosion rates, pressure requirements, and design limitations imposed by the uranium-water reaction rates.

Selection of a pressurized water system for the NPR will require an accelerated engineering and component development program to satisfy the NPR design requirements. Assuming authorization of the NPR various phases of the development program will continue through FY 1962, requiring

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funds in the order of \$7.2 million over and above forecasted 2000 program costs for the Category I and Category II programs. Following is a brief description of the various programs which will receive major development emphasis for the NPR. It should be noted that the results of these development programs will be applicable to the Improved Production Reactor concepts in general, but must be accelerated to satisfy NPR requirements.

a. Physics

The reactor physics studies will be directed toward 1) the determination of appropriate lattice parameters to assure efficient neutron utilization for the NPR and for other organic or gas-cooled concepts, and 2) the determination and evaluation of transient and other operational problems in a high temperature, recirculating coolant, power-producing reactor system.

(1) Neutron Utilization

From calculations and experimental measurements in exponential piles and the Physical Constants Test Reactor, the optimum lattice configurations for the NPR or other IPR concepts will be determined during FY 1959. Measurements will be made to determine enrichment requirements, isotope build-up, moderator temperature coefficients, reactivity, neutron temperature, neutron cross sections, and other parameters necessary for optimization of the NPR lattice or other organic or gas-cooled systems. These studies will be conducted for several fuel element types to ascertain the lattice arrangement which possesses safe and efficient neutronics when considering restraints imposed by heat transfer, hydraulics, fuel design requirements, and economic considerations.

(2) Operational Problems

Reactivity transients in new reactor concepts will be studied, and laboratory measurements will be conducted to determine both wet and dry moderator coefficients for virgin and irradiated metal. Results from reactivity and transient studies will be used to evaluate

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the control and nuclear response characteristics of the high temperature recirculating reactor with by-product power recovery. Analog simulator studies will be made to evaluate transient and feedback control problems. These studies will include temperature coefficients and system stability as a function of system design, and nuclear stability as affected by plutonium inventory and coolant boiling. Completion of these studies may require additional experimental facilities.

b. Fuel Element Development

The fuel development program for the New Production Reactor is emphasizing a metallic core, ~~aluminum or zirconium~~ jacketed element compatible with a high temperature water system. The various fuel element types and configurations are being tested in-pile in the KER Loop facilities, ~~These irradiation facilities are inadequate and must be modified for testing under NPR conditions.~~

The NPR fuel element development program consists essentially of six problem areas, each of which requires proper solution for achievement of the required fuel element characteristics.

(1) Cladding Material

Two types of cladding material are being developed for the first loading of NPR fuel elements - aluminum and zirconium. It is anticipated that final decision between these two cladding types can be deferred until mid FY 1960, and the development programs for these two concepts will run concurrently with equal emphasis until that date.

(a) Aluminum Cladding

—If the choice of cladding material is aluminum - and the low cost of aluminum makes this approach attractive - it is first necessary to determine that aluminum alloys of appropriate

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corrosion resistance can be formulated and that fabrication technology for aluminum components can be developed to ensure consistent low corrosion rates. It must be determined that a strong, uniform, diffusion barrier layer having high strength and integrity during irradiation can be formed. The aluminum-nickel-uranium bonding system is being tested, and other aluminum-uranium bonding systems with properties superior to those now under development are conceivable. The two major problems - corrosion resistance and bond integrity - must be satisfactorily solved if aluminum is to be used as the cladding material.

(b) Zirconium Cladding

The use of zirconium as a cladding material is attractive for two reasons, e. g. , zirconium exhibits negligible corrosion in high temperature water, and the co-extrusion process for fabrication of the elements produces a strong, sound, continuous bond between the zirconium and the uranium. The principle objection to this cladding process is the high cost of zirconium products. However, simultaneous forming and cladding of the element represents a saving in process cost which partially offsets the high cost of the cladding material. Irradiations of zirconium-clad uranium will be completed in FY 1959, from which evaluations of corrosion and bond performance may be made.

(2) Fuel Element Failure

The major problem in a high temperature water-cooled reactor loaded with uranium metal is the gross physical distortion of the fuel element that occurs if the cladding fails. The fuel element must be designed to minimize the effects of failures, such as blockage of coolant flow in the process channel and damage

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to the zirconium process tube. To arrive at an optimum design for the geometry of the fuel element and to specify the required properties of the cladding and bonding system, the development programs will include large numbers of deliberate tests to failure under controlled conditions in order to isolate specific mechanisms or sequence of events following failure. The testing program, involving both potential cladding materials and bonding systems, various fuel element configurations, and slightly alloyed uranium as well as the unalloyed metal, will be continued through the development period. Testing of uranium oxide fuel elements will also be continued. An important part of the program will be to establish the effect of various modes of failure on devices being developed for detection of failure.

(3) Fuel Element Support in Process Tube

The NPR fuel element will probably be self-supported in a ribless tube, and methods of support must be developed which are consistent with other process variables such as coolant flow rates, heat transfer, and reactor physics.

(4) Irradiation-Induced Swelling

It has been shown that in certain temperature and exposure ranges uranium suffers a reduction in density. Gaseous fission products form in minute bubbles, expand and swell the metal. Gross swelling may produce a strain in the cladding, causing it to fail and to admit water into the fuel element core. Development programs will be continued in the KER and MTR loop facilities to provide data to evaluate the effects of this problem.

(5) Cleavage Failures

Many Hanford-type fuel element failures have been the result of a splitting core. The lack of appropriate physical property data does not permit an accurate evaluation of this potential failure type

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under NPR temperature and irradiation conditions. An important phase of the fuel element development program will be the continuation of experiments for determining the mechanical and physical properties of uranium as a function of temperature and exposure. Experiments will be performed with each candidate fuel element type to determine the cause and effects of cleavage failures.

(6) Fabrication Technology

Process development for the manufacture of each of the possible generic designs of fuel elements - clusters, rods, or tubes - will be required to assure efficient, high volume, low cost production. This program will be conducted concurrently with design of these fuel element types. The production process and process specifications must be established at least two years before production of the first loading is initiated - early in FY 1960. Thus, a part of the over-all NPR fuel development program is a major effort involving extensive process developments in the areas of aluminum cladding and co-extrusion technology, development of new processes for welding and forming end seals, and development of adequate methods of inspection to assure proper quality of fuel elements delivered to the reactor.

c. Materials Development

The materials program is directed toward development of zirconium process tubes and graphite which will perform satisfactorily under the high temperature conditions. During FY 1958 development of zirconium tube fabrication methods proceeded at an accelerated rate, and a large number of finished tubes will be available for testing during FY 1959. Based upon results of the tube development program to date, it is indicated that with continued intensive effort, procurement of the zirconium tubes for the NPR should offer no major problem. Basic studies will be continued to determine the creep and mechanical properties of the zirconium tubes in high temperature service, and the limitations placed upon the use of the tubes by the reactor atmosphere or process water.

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The operating conditions of the NPR may result in graphite temperatures beyond those now experienced in the existing reactors. Graphite irradiation tests are being conducted at HAP0 and in the MTR and ETR to obtain physical property data at temperatures to 1500° C. Studies will be made on steam-graphite-metal reactions at temperatures in excess of 1000° C to simulate conditions which would prevail in the event of a process tube rupture. It is necessary to determine the upper graphite temperature limit so that the NPR can be designed to operate under normal conditions without a graphite temperature limitation.

A major incentive exists to make maximum utilization of carbon steel in the reactor system in order to reduce capital costs. A program was initiated in FY 1958 to develop the process water conditions and chemical decontamination methods adequate for use in the carbon steel system. Data will be obtained from the KER loops and several recirculating out-of-pile loops.

The material program will continue to concentrate on developing economical systems with satisfactory high temperature and corrosion performance. In-reactor components require the development of zirconium and aluminum alloys, and thin, high strength, stainless steel tubes. Considerable effort will be placed upon economic design of the hydraulic and coolant systems. Experimental data will be used to evaluate the use of untreated Columbia River water as heat exchanger coolant.

d. Engineering Development

Intensive engineering and design studies will be made to provide a reactor system advanced in design and efficient in operation. The following exemplify major specific areas of required technical and engineering development:

- (1) Heat transfer, unique hydraulic problems, coolant instrumentation, reactor operating limitations, and interaction between the primary and secondary coolant loops.

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- (2) Development of accurate temperature and pressure monitoring methods over the range of conditions to be encountered.
- (3) Development of control systems with emphasis on safety and high operating efficiency, including increased control system capacity with useful isotope production, and improved instrumentation and safety circuitry throughout.
- (4) Development of improved charge-discharge systems, and development of improved maintenance techniques for reducing reactor outages.
- (5) Development of efficient, temperature-resistant shields.
- (6) Development of reactor components including nozzles, seals, and pumps, that are capable of severe, maintenance-free, high temperature operation.
- (7) Development of new technology and designs which will increase the nuclear safety of the new reactor design.

e. Safety

A summary of NPR hazards was completed in FY 1958, with the conclusion that no unusual hazardous conditions will result from operation of the reactor. Hazard studies will be continued for the Improved Reactor concepts to integrate the operational, design, and nuclear safety requirements of the system. Particular emphasis will be placed on control instrumentation, coolant back-up, interaction of reactor and electrical generation systems, and containment.

f. Processing of IPR Fuels

The improved-reactor program postulates the use of slightly enriched metal or metal-oxide fuel elements clad in aluminum or zirconium alloy. The program outlined in support of currently forecast production is believed to be adequate to permit the processing of the aluminum-clad fuels without

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additional development. Recent research data indicate that zirconium cladding can be dissolved in ammonium fluoride-hydroxide without damage to stainless steel equipment. The research and development work required to demonstrate this new processing technique sufficiently for plant application will be complete in about nine months. The problems unique to the storage of raffinates from the processing of non-production fuels will be evaluated. Problems currently recognized include an increased volume of precipitated materials, the presence of large quantities of ammonia and fluoride ion, and the slow precipitation of radioactive zirconium from the Zirflex wastes.

g. Major Facility Requirements

Four KER in-pile loops are being operated to obtain data appropriate to the design of high temperature pressurized water system. These loops are supplemented by existing or scheduled small irradiation test facilities at HAPO, the MTR and the ETR. The HAPO loop facilities and the existing heat transfer and hydraulic testing equipment, have restricted capacity and are not adequate for operation under NPR conditions. The capital and prototype equipment and facility needs include extrusion facilities, KER loop modifications, additional fuel test facilities, metallurgical and equipment development facilities, and heat transfer and hydraulic test equipment. These facilities would cost approximately \$4.3 million more than has been included in previous budget schedules.

Data obtained from these modified or additional facilities would support the NPR design and provide technology upon which to base the fabrication of the initial NPR fuel load. Additional irradiation facilities, perhaps in the form of a Fuel Element Test Reactor should be considered for performing large-scale irradiations required to critically evaluate advanced fuel element designs, both for the NPR and the existing reactors.

Following are the major new and modified facilities required for Category II development programs: KER Modifications, Heat Transfer Facilities, Rupture Test Facility, Uranium Metallurgy Test Facility,

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Metallurgical Development Facility - 306 Building Addition, Zirconium Tube Rupture Facility, Cooling Loop Prototype, Corrosion Test Facility, Organic Coolant Test Loop, and Full Scale Physical Constants Test Reactor.

h. Other Advanced Development Efforts

As noted previously, authorization of the NPR would require major rescheduling of Category II effort to support development of pressurized water technology through FY 1962.

However, a modest program will be continued during this period to develop technology and criteria applicable to various Improved Production Reactor concepts. The organic-cooled graphite moderated concept is an attractive alternate to the pressurized water system, and will receive considerable emphasis under this program. With lesser priority, still more advanced concepts will be evaluated through advanced engineering and design concept studies. Concepts to be considered in these studies include heavy water moderation with organic, heavy water, or light water cooling; homogeneous and/or fast breeder. As a result of these studies, active development will be programmed for the most economically attractive long-range concepts for production of plutonium and/or tritium.

Evaluations of materials for an organic-cooled system will be maintained at a relatively low level until the pressurized water development program is essentially completed. Continued operation of existing organic loops will aid in 1) determining the thermal and radiation induced decomposition rates for various candidate organic coolants, and 2) evaluating performance of hydraulic systems, valves, pumps, components, etc., necessary to establish design requirements of an organic system. Chemical research will be continued on stabilization and clean-up of recycled organic coolants. An in-reactor organic loop will be installed in FY 1959 capable of irradiating small fuel element specimens at high coolant

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temperature (~800° F). The continued development progress of organic coolant technology for the IPR schedule will be in direct ratio to the facilities available for organic studies.

Physics studies, evaluation of engineering and materials requirements, and development of specific areas of technology required to support advanced reactor concepts will be programmed as required or as funds are available through FY 1963.

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B. Division of Military Application

1. Support of Current Production

The plutonium metallurgy research and development program in support of current plutonium production for the period of this forecast will deal with the problems of producing radically new designs of plutonium weapon components. Since there are a variety of designs involving different types of plutonium no single process will be adequate for all types of weapon designs. The program will involve substantial investments in experimental fabricating equipment some of which will ultimately be usable in production. Because of the size of some of this equipment it will probably be necessary to provide some additional space to house it. In addition to fabrication problems vital problems of metallurgical stability, oxidation and corrosion resistance, and stress relaxation will require basic research. Work along these lines of basic research is being done in the program of assistance to Project Whitney.

2. Assistance to UCRL (Project Whitney)

Hanford assistance to Project Whitney began in 1954. In this work through FY 1957 Hanford made special plutonium weapon device parts.

The FY 1958 budget is \$475,000 for operating expenses and \$100,000 for capital equipment.

These have included tensile strength, yield strength, elongation, modulus of rupture, hardness, compressive yield strength, elastic modulus under compression and plastic deformation in compression. This part of the program will continue and be extended

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to include creep properties, tensile impact strength and Charpy impact strength.

It is planned that this program will continue at the present level through FY 1960 and probably beyond.

3. Assembly of Weapons Components

The assembly of weapons components would require the use of techniques and equipment new to Hanford.

These techniques will have to be modified, however, to permit high volume production of plutonium components while maintaining adequate protection of personnel. The neutron and gamma radiation emitted by the fabricated pieces are such that personnel protection or limited working time is mandatory to comply with nationally recommended limits on radiation exposure. Simultaneously the extreme precision required.

Requires a very high degree of operator skill attainable only by continuous practice. A high operating efficiency would thus appear to be best attained by utilizing a minimum force of highly skilled artisans. This approach in turn requires that specialized techniques and equipment be developed to permit the operations to be conducted through transparent shielding barriers with a minimum of direct operator contact with the plutonium pieces.

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C. Division of Reactor Development

1. Plutonium Recycle Program

The objective of the Plutonium Recycle Program is to develop the technology needed for safe, economical use of plutonium as a fuel in thermal heterogeneous power reactors. The name of the program refers to a system of reprocessing discharged fuel elements and returning the "by-product" plutonium to the reactor feed stream where it provides a significant increase in power obtainable from a given amount of natural uranium. While the technical feasibility of such operations is generally accepted, the economics have not been established. This factor receives primary attention in the nine sub-divisions of the program discussed below.

In order to carry out this program several major facilities are of particular importance. These must perform the obvious tasks of producing test fuel elements, irradiating them under appropriate conditions, examining the irradiated elements, and recovering the plutonium either in a decontaminated form or as reconstituted fuel elements. The first of these tasks will be accomplished by the new Plutonium Fabrication Pilot Plant. This facility will be equipped for efficient fabrication of test reactor quantities of fuel elements by a variety of fabrication methods. Construction was started in March, 1958. Beneficial occupancy is scheduled for June, 1959. The second task will make use of the new Plutonium Recycle Test Reactor (PRTR) which is designed with the flexibility necessary to investigate a wide range of physics variables and fuel element designs at operating conditions (specific power, coolant temperature, and pressure) to be expected in power reactors. This test reactor has been designed as a heavy-water cooled and moderated reactor utilizing 85 vertical pressure tubes. It will have a heat dissipation capacity of 70 megawatts. Construction of the reactor was started in March, 1958. Start-up is scheduled in 1960. The third task, examination of irradiated fuel elements, poses major disassembly problems which are still under study to determine what additional facilities will be necessary. Funds for this

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appear as a tentative budget item (Radiometallurgy Building Addition) for FY 1961. The fourth task listed above, recovery of plutonium, can probably be done with only minor changes to existing facilities since it involves straightforward dissolution and decontamination; reconstitution of fuel elements without extensive decontamination, however, may require special facilities.

a. Plutonium Fuels Development

Plutonium fuel elements for spike enrichment and for uniform enrichment applications will be developed which satisfy the criteria of (1) in-reactor stability, (2) low fabrication costs, and (3) freedom from personnel hazards in fabrication operations in spite of the toxic nature of plutonium. To attain these objectives it is regarded as necessary to explore a variety of fuel design concepts and fabrication methods. Concepts surviving preliminary screening will be subjected to a thorough program of evaluation and development. It appears likely that the more fruitful concepts will be those susceptible to a high degree of remote fabrication.

(1) Aluminum-Base Spike Enrichment Elements

Plutonium-aluminum fuel elements have been under study since the inception of this program and work to date indicates that this fuel composition in a Zircaloy-clad, rod-cluster design is technically feasible. Determination of performance will be accomplished in the PRTR which will be fueled with several loadings of this design from mid-1960 to mid-1962. Study of fabrication methods for determination of economic feasibility will proceed concurrently. In this regard pneumatic and pressure injection casting have shown promise. The plutonium Pilot Plant will include equipment for formation of Pu-Al from PuO_2 by the Canadian cryolyte bath method and direct injection casting of the fuel into long zirconium fuel sheathing in a single operation. Injection into other sheathing materials and into annular as well as cylindrical shapes will be studied. Prior to PRTR

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start-up, extensive irradiation testing of the 19-rod cluster design will be performed in MTR, ETR, and Hanford facilities. Problems of weld closure, corrosion of fuel and cladding, bond formation, fuel assembly, and pre-irradiation testing will need to be solved.

A second fuel composition of interest for spike element use at intermediate coolant temperatures (ca. 300° C) is PuO_2 dispersed in aluminum. Fabrication processes to be evaluated include (1) cold pressing or isostatic compaction of mixed PuO_2 and aluminum powder followed by coextrusion of cladding and fuel, and (2) swaging of pre-clad powder mixtures.

(2) Ceramic-Type Spike Enrichment Elements

Studies are in progress or planned on several fuel designs which are not limited by surface temperatures obtaining in water-cooled power reactor systems. These are: (1) PuO_2 or $\text{PuO}_2\text{-UO}_2$ dispersed in a porous graphite matrix, (2) PuO_2 or $\text{PuO}_2\text{-UO}_2$ dispersed in a porous Al_2O_3 or MgO matrix and (3) PuO_2 or $\text{PuO}_2\text{-UO}_2$ diluted with Al_2O_3 or MgO in a sintered compact. Elements cited under (1) and (2) are formed by imbibition of nitrate solution into the evacuated porous matrix and ignition to the oxide in situ and may be susceptible to recovery by simple leaching followed by reuse of the porous matrix core.

Another concept to be evaluated is the "self-shielded" element, consisting of a small rod of plutonium or plutonium alloy imbedded in a heavy cladding jacket. The "blackness" of plutonium to neutrons effectively limits fission to the periphery of the fuel which is progressively consumed. In concept this design permits high accumulative power generation in a single fuel loading without exceeding specific power limitation at any time. The long residence time in the reactor thereby reduces unit fuel cladding costs.

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Still another concept to be evaluated is that of simply canning a loose powder mixture of PuO_2 diluted with natural or depleted UO_2 or other material.

All of the above concepts will be explored in respect to technical and economic feasibility in preliminary small-scale studies conducted over the next two years. Three concepts of greatest promise will be subjected to further, large scale fabrication development and irradiation testing. One or more of these fuel designs is expected to warrant testing in the fringe regions of PRTR during FY 1961 and 1962.

(3) Fuel Elements for Uniform Enrichment

For this purpose fuel designs to be studied are (1) high density PuO_2 - UO_2 fuels of both rod-cluster and concentric tubular geometry fabricated by extrusion or cold pressing followed by sintering, (2) high density PuO_2 - UO_2 fuels fabricated by swaging, and (3) metallic U-Pu fuels. In respect to (1) and (2) above, work has been started with uranium alone. During FY 1959 preliminary fabrication and irradiation testing will be conducted. In FY 1961 and 1962, utilizing the Plutonium Fabrication Pilot Plant, extensive fabrication development and further irradiation testing will be conducted. By FY 1963 and 1964, large scale testing of one or both of these concepts will be conducted in PRTR.

Evaluation of metallic-type Pu-U fuels is planned, but the pattern of study has not been determined and will await observation of studies conducted by Argonne National Laboratory on Pu-U systems and studies on metallic uranium fuels for high temperature use conducted at HAPO, SRP and elsewhere. It appears probable that during FY 1961, studies on these systems will commence and significant fabrication and irradiation data will be obtained by FY 1964.

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(4) Remote Fabrication Operations

It is expected that near the end of the period under review, two or three fuel designs and associated fabrication processes will appear particularly attractive. At that time, taking into account results obtained in the chemical processing program, pilot plant fabrication equipment will be revised to perform these operations as nearly as possible on a wholly remote basis, and to the extent possible, to perform them on recycled plutonium that has been only partially decontaminated from fission products.

(5) Basic Studies

To support the fuel element development program, basic data will be derived if they are not available from other sources. Examples are the vapor pressure, thermal conductivity, and sintering characteristics of PuO_2 - UO_2 mixtures.

b. Uranium Fuels Development

Uranium fuel development is conducted within the Plutonium Recycle Program for two reasons. First, uranium may be used to advantage as a stand-in for plutonium in the early stages of development of plutonium - bearing fuels, and second, methods are needed for fabricating, inexpensive, stable, uranium-bearing fuel elements for use in reactors operating on plutonium recycles in which the uranium and plutonium fuels are separate, i. e., in two region, uranium-spike plutonium loadings. During FY 1957 and 1958, the Uranium Fuels Development program has pioneered design of the nested tubular UO_2 fuel assembly and made many improvements in the fabrication processes for high density sintered oxide elements that have improved quality and lowered cost. During FY 1959 these studies will continue in order further to simplify core fabrication methods, to solve remaining problems of weld closures and mechanical design of the fuel assembly, and to obtain additional irradiation data. In addition, a fuel charge will be fabricated for the first loading of the PRTR.

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Another very promising method of fabricating high density UO_2 elements is that of swaging UO_2 powder within a closed Zircaloy tube. Further studies will be conducted to define optimum fabrication conditions and to disclose any deleterious irradiation behavior resulting either from the absence of sintering or the different thermal expansion coefficients of UO_2 and Zircaloy. If favorable results are obtained, the second PRTR loading will be of this type, probably in a rod shape.

The feasibility of novel and unorthodox fuel designs, compositions and operating conditions will continue to be explored. Two examples are the "wheel" fuel element in which clad UO_2 powder is compacted by isostatic pressing to about 70 per cent of theoretical density, and an element consisting merely of loose powder poured into a fuel sheath and sealed off. These studies are of great importance as "stand-ins" for later exploitation with plutonium compositions. Other fuel materials such as uranium carbide, uranium nitride and cermets will also be explored. No schedules for pilot plant scale evaluation can be estimated at this time.

Throughout the period under review a strong program of basic studies will be maintained. Better knowledge is required in respect to items such as the effects of temperature and radiation on the thermal conductivity of UO_2 , the phase behavior of UO_2 at very high temperatures, variables affecting fission gas release, and variables affecting sintering behavior. These studies will not only support the previously described fuel element studies but may provide the key to a major increase in the present conservative central temperature limits set for UO_2 elements. Relaxation of these limits could yield a major reduction in nuclear power costs.

After start-up of the PRTR it may be expected that a substantial part of the uranium fuels program will be determined by results of PRTR testing. Defective elements must be examined, hypothesis developed to explain the defects, and special elements fabricated to test the hypotheses. The course and extent of this work cannot be predicted in detail, but past experience at Hanford and elsewhere in the development of fuel elements of various kinds indicates that such work will inevitably be necessary.

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c. Materials Development

Materials development activities in support of the Plutonium Recycle Program during FY 1959 will be largely devoted to development of, and technical assistance in the procurement of, specialized reactor materials needed for the construction of the PRTR, and jacket materials for the first several fuel loadings. These specialized reactor materials include: Zircaloy-2 process tubes, thin-wall ribbed Zircaloy fuel cladding, and irradiation-resistant thermocouples and elastomeric materials for insulation and hydraulic and gas seals. This work will be supplemented by proof testing of the above components, by out-of-reactor corrosion and hydraulic testing of prototype fuel assemblies, by programs to develop improved process tube and fuel cladding alloys (including new zirconium and aluminum alloys) with higher strength properties and better corrosion resistance, and by radiometallurgical studies of irradiated reactor structural and fuel materials being developed as part of the over-all PRP.

Specification of reactor materials for PRTR construction will be completed by the beginning of FY 1960, and materials development emphasis will shift to lowering procurement costs for components such as fuel jacket tubing and to the development of materials capable of operation at higher temperature and flux conditions. Attention will be given to reducing fabrication costs of Zircaloy hardware components, testing better alloys and non-metallic reactor materials, the demonstration of new aluminum alloys capable of high-temperature water service in high-flow inhibited systems, and continuing post-irradiation examination in the Radiometallurgy facilities.

The varied in-reactor testing programs conducted during the three year period from FY 1961 to 1963 as part of the over-all Plutonium Recycle Program are expected to create a continuing need for better reactor structural and nonmetallic materials. This will require continual testing programs supplemented by fundamental irradiation damage studies. The evolutionary

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development of better plutonium and uranium-bearing fuels will require expanded effort in radiometallurgical examination. New fuel element concepts will require new jacket components in varied shapes, and the new designs will be subjected to out-of-reactor loop tests to appraise service characteristics.

d. Chemical Research and Development

Chemical and engineering studies are planned as part of the Plutonium Recycle Program to develop the technology necessary to define low-cost separation techniques and facilities for Pu-U mixed or separate fuel cycles. In addition, a necessary adjunct to other sub-programs is the provision of chemical methods, equipment materials, and possible service processing in the Hot Semiworks facility of fuel elements irradiated in the Recycle Test Reactor.

In FY 1959, the methods and facilities to be used in PRTR fuel processing will be selected and scoped. Pilot scale plutonium recovery processing studies will be initiated, and engineering flowsheets of the Zirflex process will be prepared. Process requirements for conversion of plutonium to metal and oxide forms will be established. New and advanced fuel reprocessing concepts will be evaluated for economics and engineering feasibility, and basic engineering experimental programs supporting these concepts will be initiated. Fundamental research will be continued on new separation processes with low inherent cost and specific applicability to Pu fueled reactors.

In FY 1960 project action for service reprocessing of PRTR fuels will be initiated. Flowsheets will be developed leading to scaled-up prototype tests of low-cost close-coupled processes. Laboratory studies of irradiated elements will be conducted in the High-Level Radiochemistry Facility. Engineering, laboratory and pilot plant studies of advanced reprocessing methods, particularly non-aqueous, will be continued. PRTR radioactive wastes will be studied.

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In FY 1961 service reprocessing of PRTR fuels will begin, including establishment of routine recovery and reprocessing of the plutonium. Laboratory, semiworks and High-Level Radiochemistry Facility studies on alternate and improved processes will be continued, together with studies of PRTR effluents.

In FY 1962 laboratory and engineering work on various fuel cycle concepts will be continued, as will service reprocessing. The most promising separations processes unique to the PRP will be tested on a pilot-plant scale.

In FY 1963 service reprocessing and engineering evaluation of basic alternate processing methods will be continued. The study of effluent disposal will be completed. Technical concepts as developed will be reported, or alternatively the studies and services required by developments in the over-all program will be extended and continued as required. Plans for full-scale separation methods utilizing the new technology will be developed.

e. Physics Research and Development

The objective of the physics portion of the Plutonium Recycle Program is to provide sound and adequate bases for examining any thermal heterogeneous reactor from the standpoint of its performance in a plutonium recycle situation. Work in this portion of the program will be closely integrated with the cycle analysis subprogram (i).

It is planned to expose plutonium producing fuels and plutonium containing fuels in the PRTR; to measure the amounts of plutonium produced or consumed with exposure; to determine the isotopic composition of the discharged material; to observe the reactivity effects in the PRTR; to measure reactivity effects of recovered plutonium in well controlled situations in the PCTR; and to carry on a program in reactor theory to interpret the results and apply them to the main objective mentioned above. It is also planned to carry out experiments in the PCTR to aid in translation of the results from one moderator to another.

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This work will be supported by a continuing effort in the measurement of nuclear cross sections of fissionable isotopes and of other materials of interest in reactor work. This cross section work is currently supported jointly by 2000 and 4000 program funds. The theoretical physics and cross section work will be utilized directly in the development and refinement of the computing codes to be described in section (i) on the fuel cycle analysis subprogram. Some work will be done in the investigation of the physical mechanism of radiation damage to materials to supplement results of off-site work in this field and apply them to special problems which may arise in the recycle program.

Other activities will include provision of improved instrumentation for special situations expected in the operation of the PRTR and some work in nuclear safety in conjunction with development of recycle processes.

It is not now expected that any additional major equipment or facilities will be required for this program. However, this expectation is based upon having available a critical mass laboratory to deal with problems in this area which will arise in developing recycle processes.

f. Design Development

Within this subprogram the principal effort has been the preparation of the design scope for the Plutonium Recycle Test Reactor. Although formal design criteria were completed for PRTR at the end of FY 1957, design scoping studies have continued and may be expected to continue through FY 1958 and 1959. In the course of detail design work, experimental design verification testing, and continuing analytical studies of the reactor design and its safety and operability new information will be developed which suggests improved basis of design. These potential improvements must be reviewed and the scope altered when this is in the balanced best interests of functional utility of the reactor, adherence to cost bogeys, and maintenance of schedule.

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Other tasks which must be performed prior to start-up include preparation of acceptance test procedures, preparation of process specifications for the reactor, and further physics studies of lattice parameters insofar as these affect process specifications.

It is expected that reactor start-up will disclose a minimum of design defects; however, some will probably occur and corrective design changes must be made as required. During the period of about April, 1960 to January, 1961, design-development personnel may be expected to be extensively involved in following reactor performance to compare this performance with design expectations, to define necessary process or equipment design changes and to revise process specifications as necessary.

In FY 1962 and 1963, PRTR operation should permit design-development efforts to be reoriented. As experimental data on plutonium fuel cycle technology are obtained, it is necessary that these data be broadly interpreted and translated to apply to other types of reactors. An important and final part of this generalization of the results of the Plutonium Recycle Program will involve conceptual design studies in conjunction with Physics and Cycle Analysis effort. In these studies the nature of design modifications or characteristics needed to optimize various types of reactors for plutonium fuel utilization will be scoped in sufficient engineering detail to permit useful estimates of capital cost factors.

g. Reactor Engineering Development

Inasmuch as the Plutonium Recycle Program is primarily a fuel cycle program rather than a reactor development program, the efforts in the field of reactor engineering will be auxiliary and supporting in nature. Three principal functions of the program are:

- (1) Experimental testing of critical equipment and process features of the PRTR design in order to assure proper performance of the test reactor.

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- (2) Continuing provision of specialized functional assistance to other parts of the Plutonium Recycle Program in the fields of heat transfer, fluid flow, prototype testing of components and systems, and shielding technology.
- (3) Provisions of engineering assistance following start-up of the PRTR as required to assure safe and efficient operation and to make such changes in process and components as may be required during the course of the over-all program.

h. Test Reactor Operation

This subprogram comprises the safe and efficient operation of the PRTR within the limits of prescribed process specifications.

At the beginning of FY 1959, all exempt personnel of the operations crew will have been recruited. During FY 1959 design liaison work will continue in respect to safety and operational respects of the reactor design, a training program will be developed for reactor technicians and operators, and the preparation of descriptive operating manuals will be partially completed.

In FY 1960 the preparation of manuals will be completed, a complete reactor operating force will be set in place, and a training program will be conducted for operators. In addition, close liaison will be maintained with personnel responsible for formulation of the sequence of research and development tests to establish detailed operational plans. Also during this period the operations force will participate in acceptance testing of the reactor and will perform "pre-startup shakedown" and the critical loading of the reactor.

In FY 1961 and subsequent years the reactor will be operated to provide maximum service to the Plutonium Recycle Program. In so doing the objective will be to achieve maximum continuity of operation and minimum operating costs without compromising conservative standards in regard to reactor life and safety.

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i. Fuel Cycle Analysis

The fuel cycle analysis subprogram seeks to characterize the economics of utilization of plutonium fuels in thermal heterogeneous power reactors so as to identify reactor types which are most efficient for operation with recycled plutonium. In FY 1959 and FY 1960 the plutonium utilization economics will be determined for a wide variety of heterogeneous thermal reactor types. Intensive analyses will be carried out for appropriate specific cases during this period and in FY 1961. Methods of analysis and of data presentation will be refined and improved in the course of the program. By FY 1962 enough data should be developed by other phases of the program to justify revision and updating of the general survey and specific case analyses. Lesser efforts will therefore be necessary in FY 1962 and 1963 to continue this aspect of the program.

A key function of the cycle analysis work is the integration and interpretation of data from the other fields within the over-all program. This not only forms the basis for technical and economic evaluations of cycle performance but serves to guide the direction of effort in the other subprograms into the most rewarding and significant channels. The cycle analysis and physics programs will be particularly closely related, insofar as both are jointly concerned with the utilization and improvement of certain computational techniques for the interpretation and prediction of experimental results, and for the evaluation of comparable idealized models of reactor and fuel-cycle behavior.

2. Army and Maritime Gas Loop

The Loop is being jointly sponsored by the Army Reactor Branch and the Maritime Reactor Branch of the Division of Reactor Development. It will be used for irradiation tests concerning the fuel element performance, structural materials, and the operating characteristics of their respective gas cooled systems.

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During FY 1958 the following items were accomplished:

1. The necessary design modifications were made to make the facility compatible with helium operation as well as the original basis of nitrogen operation.
2. The specialized compressors, using gas lubricated bearings, were developed by the General Engineering Laboratory.
3. The full-scale installation of the Loop equipment and piping was started.

The construction of the Loop will be completed during the second quarter of FY 1959. Performance tests of the Loop components and the integrated facility will be completed by the third quarter of the fiscal year. In-pile studies in support of Army Reactor Branch Program will start during the third quarter and will continue for the remainder of FY 1959.

In early FY 1960, the Loop will be converted to operation with helium as the coolant. This conversion will require approximately two months. The Loop will then be placed into operation in support of the Maritime Reactor Branch Program and it is anticipated that these studies will continue for the remainder of the five year period.

3. Plutonium and U-233 Fuel Element Fabrication

In October, 1957, Hanford was asked to undertake on a "crash" basis the fabrication of a loading of plutonium fuel assemblies and shim rod assemblies for the MTR. (The work was formally authorized November 25, 1957. Original authorization was for \$223,000. This was subsequently increased to \$312,000 and currently an increase to \$500,000 is being requested.) This job required adaptation and refinement of fabrication methods that had been used elsewhere for making similar uranium fuel assemblies for the MTR. Hanford is the only place in the country where facilities exist to do this job with plutonium on the scale required. As a result of inspection of some of the components of the assemblies and

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taking into account considerations of possible failure of a plutonium assembly in the MTR, the specifications for the assemblies were made more stringent than originally proposed. The present schedule calls for a complete charge of plutonium assemblies to be prepared by June 10, 1958.

On February 20, 1958, the preparation of a full charge of uranium-233 assemblies and shim rods was authorized at a cost of \$126,800. Some work has been done to provide shielding and otherwise prepare equipment for this job. Actual work with uranium-233 is expected to start late in May, 1958. Preparation of a complete charge of assemblies is scheduled for sometime in July, 1958.

The work described above is requiring a finite, short term effort. In view of the increasing interest in use of plutonium and uranium-233 as fuels, however, it is reasonable to expect that there will be further requirements for application of these particular capabilities at Hanford.

4. Gas Cooled Reactor Studies

a. Graphite Studies

One of the promising power reactor types for the future is the high temperature, gas cooled, graphite moderated reactor. In such a reactor the temperature of the moderator would be in the range of 450 - 600° C. Little information is available on pertinent aspects of graphite behavior at these temperatures. Graphite temperatures in the Calder-Hall reactors are relatively low (~350° C), thus operational information on behavior of the moderator is of limited value in the design and operation of a more advanced reactor at the higher temperatures.

A proposal is being submitted to the Commission for a study at Hanford to secure improved knowledge of the reaction of gas coolants with protected and unprotected graphites over a range of conditions of practical interest for gas-cooled power reactors. This study would take a broad, fundamental approach directed toward understanding the effect of each variable, rather than simply be empirical testing under conditions

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expected in a reactor but not yet firmly established. For example, improved fundamental knowledge about the reverse of the oxidation reaction, $2 \text{CO} = \text{C} + \text{CO}_2$, in the presence of radiation, may aid in the development of a practical system or operating practice for higher temperature. Water vapor is known to react with graphite at a rate comparable to CO_2 . Since high pressure steam is a common medium for converting reactor heat to electric power, the effects of potential leakage of water vapor into the coolant of a gas-cooled reactor need to be investigated.

It is proposed that a number of other items should be investigated to determine if and to what extent a problem exists. Examples of such items are: graphite contraction above 300°C , graphite development and procurement, stored energy, thermal conductivity, strength and oxidation monitoring.

Conduct of this study would take advantage of Hanford experience in graphite technology, particularly recent and current studies of graphite conducted in support of operation of the Hanford reactors.

A program for a five year period is envisioned. Annual expenditures for conducting the work would be \$175,000 to \$300,000. In addition equipment and capital expenditures over the period might be about \$1,000,000, most of this for an ex-reactor loop and an in-reactor loop for the experimental work. Four or five professional people would be used in the work.

b. Physics Studies

A program has been proposed for experimental reactor physics to support the design of a gas-cooled, graphite-moderated reactor currently proposed by Kaiser Engineers and American Car and Foundry. This work is necessary as a check on the calculated reactivity of the proposed lattice and control rod system and the reactivity held in the fuel temperature coefficient. The program will make use of the prototype Physical Constants Testing Reactor (PCTR) in making the experimental measurements. In addition the program will be directed toward obtaining reactor lattice data applicable to more general types of reactors fueled with clusters of uranium oxide fuel and evaluating the use of the PCTR in obtaining the strengths of control rod systems.

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These studies will require the efforts of two or three professional men and funds of about \$125, 000 in FY 1959 and \$100,000 in FY 1960. It is expected that the information in direct support of the Kaiser-ACF gas-cooled reactor will be supplied in FY 1959. It is not unreasonable to expect that information obtained in this study will show the need to extend experimental physics work for gas-cooled reactor systems or other thermal heterogeneous systems beyond FY 1960.

5. Fixation of Radioactive Wastes

In exploratory work at Hanford during FY 1958 on methods of fixing radioactive wastes it has been shown that certain liquid radioactive wastes could be jelled with sodium silicate or dried with earth materials and sintered to a porcelain or fused to a glass. This and similar work done at ORNL indicate the possibility of developing processes suitable for ultimate disposal of radioactive wastes. It has been proposed in the Hanford budget submission for FY 1960 that the scale-up to a pilot plant operation be conducted at Hanford where high level waste solutions are readily available in a wide variety of composition and where space and environment are eminently suitable for the application of this method of disposal. The work contemplated would be the laboratory study of locally available raw materials; the thermal aspects of self-sintering through heat generated by the radioactivity; design and construction of a reaction pit, of the off-gas treatment pit and of the related instrumentation, and finally, the operation of the facility with simulated and actual wastes. This work would require three professional men in FY 1959, and about twice this number in FY's 1960, 1961, and 1962. Actual operation of a pilot plant on radioactive wastes should be achieved in FY 1962 and continued in process development work in FY 1963.

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6. Swelling of Irradiated Fissionable Metals

Although use of metallic uranium fuels at the elevated temperatures characteristic of power reactor operation mitigates the familiar problem of preferential dimensional instability, it introduces a new major problem: that of general swelling and volume expansion. Existing data on the quantitative dependence of this effect on temperature, flux, fuel composition, exposure and other variables are incomplete and contradictory.

In order to permit metallic fuel elements intended for high temperature use to be designed in a rational manner, basic data on the temperatures at which swelling becomes a severe limitation and data on the rates at which fuels swell under given temperature and flux conditions must be obtained.

It is proposed to undertake a theoretical and experimental study of the swelling phenomenon as it applies to fuels of metallic uranium and uranium alloy compositions. The results should be applicable to a large segment of the reactor and fuels development programs sponsored by the AEC.

Mechanical models intended to predict the manner in which voids are nucleated and the rate at which these voids expand have been developed based on the scant available data. These models can be evaluated by controlled temperature irradiations of unrestrained fuel samples in carefully selected fluxes.

Irradiations must then be carried out to determine whether the in-pile behavior of the uranium or uranium-rich alloy is in keeping with that predicted by the swelling models.

The goal of the program will be to develop such a model to the point that behavior of uranium under given conditions of flux, temperature, and exposure can be predicted. A longer range goal will be the determination of methods by which the swelling behavior of unalloyed uranium or uranium-rich alloys can be controlled, thereby increasing maximum possible exposures of fuel elements.

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This study can effectively use the efforts of two professional men over a period of five years. It is anticipated that valuable information will be obtained throughout this period.

7. Other Programs

The foregoing paragraphs indicate both approved programs being conducted under Division of Reactor Development sponsorship and certain other specific programs that have been proposed and are under discussion. In addition to these described programs, consideration is being given to other research and development work that might be undertaken at Hanford to contribute further to the over-all Division of Reactor Development Program, perhaps particularly to the Civilian Power Reactor Program, or to the purposes of the programs of the Division of Research or other divisions. Examples of areas now being considered are shielding evaluation, non-destructive testing of fuels and other materials, heat transfer, plutonium metallurgy, reactor physics and fundamental chemistry.

The summary data on level of research and development effort in Table VI, page 50 shows a slight increase in total effort from FY 59 to FY 61 and then a slight decrease to FY 63.

The research and development proposals in this document and the budgetary and manpower estimates are consistent with the general level of effort concept. Expansion of manpower beyond the totals shown in the summary table is not presently contemplated.

It is to be noted, however, that the investment in research and development facilities is presently about \$35,000,000. With the completion of the additional approved facilities indicated in this document, this investment will be about \$56,000,000 by FY 60. If other proposed facilities also described here are built, by FY 63 the investment will be about \$68,000,000. To assure that the most effective use is made of this sizable investment, for the benefit of the Commission's objectives, it will be desirable that the programs for the use of the equipment and the manpower requirements for the programs be reconsidered periodically.

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D. Division of Research

(Washington Designated Programs)

The following four programs will be conducted at Hanford by request directly from the Division of Research.

1. Computation and Statistical Analyses
2. Radiochemical Analyses
3. Isotopic Analyses

Work on the first three of these is part of an AEC-wide program. Analyses will be made as requested by the Division of Research. It is presumed that this work will continue at about a constant level through the five year period.

4. Test Programs on Irradiated Metals

The purpose of this program is to study the effect of neutron radiation on structural metals. A need for basic correlation of fast flux with radiation effects has motivated this work. The work will also include a study of the annealing kinetics of radiation damage.

In FY 1958, irradiated specimens of copper, nickel, titanium, zirconium, iron, molybdenum, and 347 stainless steel were transferred from KAPL to Hanford. Initial stages of testing, which will include determination of tensile properties, hardness, electrical resistivity, density, and X-ray diffraction parameters, have started.

In FY 1959, measurements of tensile properties, hardness, electrical resistivity, density, and X-ray diffraction parameters for the control specimens and the irradiated specimens will be complete. The annealing of irradiated copper, nickel, titanium, zirconium, iron, molybdenum, and 347 stainless steel will continue through the year. Property measurements will be made as the annealing schedule allows. Testing will be completed in the early part of FY 1960. Reports will be completed and issued during the remainder of the year.

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E. Division of Biology and Medicine

1. Biology

The program in biology at Hanford is currently designed to contribute to the improvement and validation of radiation protection practices at Hanford. A considerable portion of this basic objective simultaneously provides benefits on a national level. In addition, to a limited degree, some programs primarily of national rather than Hanford interest are appropriately included. The basic research methods of radiation biology are employed but work is programmatic and applied to the outstanding questions that must be answered in an expanding economy of atomic power development. The following exposition is organized in a manner intended to indicate the objectives, both short range and long range, of the continuing research program in biology. The effort in biology research will continue through the five year period at a stable level with 30 to 35 professional men and an annual budget of about \$1,200,000.

a. Effects of Specific Radioactive Materials

(1) Plutonium

Several years ago, Hanford contributed importantly to the relaxation of the permissible limit of plutonium in drinking water by noting a lowered coefficient of plutonium absorption and deposition in rats and pigs. Continuation of the research has recently produced evidence that very young animals, however, may absorb and deposit up to 80 times more plutonium from drinking water than mature animals. This phenomenon must be thoroughly investigated and the implications of this on permissible concentrations of plutonium in drinking water must be assessed. The research along this line is progressing and will probably continue for several years.

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Within the last year it has been shown that the gut cannot be considered as a critical organ for alpha emitters. This conclusion was derived from biological experimentation and is serving to remove the doubt that the earlier permissible limit for plutonium, which was based on bone deposition, should not be revised downward because of gut irradiation.

Various decontaminating agents have been used for removing plutonium from the skin of workers. It has recently been found that a plastic trade produce, "Aeroplast", is superior to all other standard methods employed. When a coating of this material is sprayed on the skin and then peeled off, it removes some of the dead skin and practically all of the plutonium. It is planned to continue to seek improved skin decontaminating agents.

The two most widely recognized agents for removing internally deposited plutonium are zirconium citrate and EDTA. Neither one of these is effective if administered a day or so after the internal contamination occurred. Recent work has shown that DTPA (diethylenetriaminepentaacetic acid) is more effective than either of the previous two agents. Further tests of this substance will continue because of its important promise for practical treatment of plutonium deposition. Also other agents will be investigated in the hope that an even better treatment may be found.

The permissible body burden of plutonium is based on a mixture of calculations and a few biological experiments performed elsewhere. It is planned to contribute better data toward establishing the permissible plutonium burden by determining its toxicity in pigs as part of the Sr^{90} toxicity program. Attempts will be made also to relate body burdens of plutonium to excreta concentrations of plutonium for assistance in interpreting bioassay results of exposed workers.

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(2) Fission Products

The fission product which has received most attention at Hanford is I^{131} . The research in this field is the first that biologically determined the safe daily intake to large animals for any radioactive material. This work with sheep and pigs is drawing to a close rapidly; however, some of the animals will be retained for their effective life times in order to observe long term effects that may develop slowly. To replace the I^{131} study, approval has been received from the Division of Biology and Medicine to engage in a major investigation of the toxicity of St^{90} . It is expected that this work will require many years to produce definitive results. Pigs and other animals will be fed daily doses of Sr^{90} and radium. The latter element will be used for comparative purposes, since its toxicity to humans is known better than that of any other radioactive element.

Permissible limits for other fission products important to atomic energy production will continue to be investigated. As with all work on permissible limits, the effect of age and size of the animal will be studied in order to establish permissible limits for humans more firmly.

(3) Radioelements from Neutron Activation

Important activation product from plutonium manufacture and weapons tests include the radionuclides of Co, Fe, Mg, P, and Zn. Zinc and phosphorus, the two radioelements of greatest hazard significance in the Columbia River, are currently being investigated. From recent work, it appears that the permissible limits for both of these substances are in error. It is anticipated that the correct limits for these will be derived during the next year or two.

Since these radioelements are incorporated into the biosphere, their transfer from soil into plants and the ecological implications of their presence in natural communities will also be investigated in the coming five-year period.

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(4) Radioactive Particles

Probably less is known about the hazards due to radioactive particles than any other form of radioactive material. In past research, Hanford work has shown that some types of radioactive particles remain in the lungs for a relatively long time. Others, which are ordinarily insoluble, are removed from the lung with surprising rapidity. It had also been observed that oxides of plutonium and radoruthenium can cause lung cancers in experimental mice, although the dose and the length of time required to do this are yet unknown. To assess the particle hazard more thoroughly, mice and larger animals (dogs and possibly pigs) will be used in a study which is expected to require five to eight years. The purpose of the work is to establish permissible limits for the many types of radioactive particles that may be encountered in atomic industry, and to relate body burdens resulting from inhaled particles to concentrations in the excreta.

Another hazard of radioactive particles, which is largely unknown, is that of particles lodging on the skin. Continued investigation of this hazard is planned. Attempts will be made to relate the area of skin exposed to the incidence of late pathological effects such as skin cancer.

b. Biological Mechanisms and Effects

(1) Gonad as Critical Organ

With the recent emphasis on the importance of possible genetic changes that may occur in future human populations as a result of atomic energy production and atomic weapons tests, exposure of the gonads to ionizing radiation has become a critical problem. During the coming five years it is planned to relate gonad burdens of important internal emitters to environmental contamination. This will include fission products, neutron activated elements, and radioactive particles.

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(2) Relative Biological Effectiveness

Some years ago a new technique for measuring the biological effectiveness (RBE) of one type of ionizing radiation as compared to another was developed at Hanford. This was found to save considerable time and yet be compatible with RBE's determined in animal experiments, which are far more tedious. In addition, the technique promised to afford a means for determining the RBE of alpha particles. Work along these lines will be continued in order to find experimentally RBE's for the several types of radiations. These measurements are needed to establish more firmly the permissible body burdens of internal emitters.

(3) Mechanisms of Radiation Damage

Learning more of how ionizing radiations exert their damaging effects in biological materials is one of the most important and intriguing problems in radiation biology. Knowledge of these mechanisms is relatively poor. Recent contributions toward elucidating these mechanisms include noting that the gut is insensitive to alpha emitters and that certain classes of enzymes in the gut are largely accountable for the damaging effects of beta emitters there. The relative radiosensitivities of the various critical organs in the body are largely unknown. For interpreting hazards of radiation and for interpreting the importance of environmental contamination, more must be learned of the mechanisms of radiation damage. These will be investigated by means of microbiological and animal physiological techniques over the coming five years.

(4) Mechanism of Uptake and Deposition

Some of the most important work to come from Hanford within the last year concerns the Sr^{90} to Ca relationship. In brief, it has been found that earlier concepts regarding this relationship are not correct and will lead to errors in interpreting the Sr^{90} hazard from fallout. Because of the national and international importance of this

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problem and because of past Hanford contributions to it, it is planned to conduct intensive work toward finding more about the relationship of Sr^{90} to Ca by means of metabolism experiments in plants and animals.

In line with this work are efforts toward elucidating the environmental factors that control the uptake and transfer of Sr^{90} among living materials. Because of the great variation in ecology that the State of Washington offers, special sampling and analysis methods will be used to study the relationship of transfer of Sr^{90} to the ecological environment from which samples are obtained.

The mechanisms of uptake and deposition of plutonium, and other important radioelements in plants and animals also will be investigated in order to provide improved means for hazard control.

(5) Effect of Age on Biological Coefficients

It was noted above that the age of the experimental animal is very important in determining the amount of a radioelement which can deposit in a critical organ. Other laboratories have shown a marked increase in radiosensitivity in very young animals. It is intended to investigate the effect of age on the deposition and metabolism of radioelements in order to find whether special rules for exposure of the very young will have to be established.

(6) Mixed Exposures

Atomic energy workers may carry minor amounts of radioelements deposited in their bodies. An important factor to be determined is the limit of external radiation to which they may then be exposed. By means of exposing animals to both internal emitters and to external radiation it is planned to establish the relationship of hazards due to a mixture of internal and external exposures.

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2. Instrumentation

The work in instrumentation is concerned with the development and application of new and improved techniques and devices for detection and measurement of ionizing radiation for survey and personnel monitoring . The work meets the demands for special devices required in support of plant operations and other research and development programs. Such instrument devices are not commercially available. Usually only one of a kind is desired. Work in this field is of continuing necessity to activity in nuclear research and development and production operations. Major effort will be directed toward the development of a line of portable, transistorized monitoring instruments with interchangeable components. It is planned that the work will proceed with three professional people in FY 1959 with a budget of \$124, 000. Increase of the level of effort by one or two men in subsequent years may be warranted.

3. Dosimetry

The program in dosimetry is concerned with the development of techniques and devices for measuring radiation to which personnel may be exposed. Nationally there is an increased concern with exposure of personnel to radiation both in nuclear industry plants and in the general population. The subject of correct measurement of radiation has become of such importance that the National Committee for Radiation Protection in 1956 enlarged its scope to include that field and changed its name to the National Committee for Radiation Protection and Measurement. A trend at the national level is toward establishment of somewhat more restrictive permissible limits of radiation exposure. A significant part of the work in the Hanford dosimetry program is directed to more accurate measurement particularly of smaller radiation doses. It is considered desirable and necessary to continue the present level of effort in this field and expand it during FY 1959 by one professional man. With the increase to six professional persons in this work during FY 1959, the budget will be \$187, 000. It is planned that work will continue at this level.

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4. Biophysics Program

The purpose of the biophysics program is to carry out research and development in the physical sciences fundamental to radiological protection. Specifically, the studies are in low level analytical chemistry and counting, geology, hydrology, micromeritics, soil chemistry and physics, and instrumentation. While the findings have broad application at all AEC sites, they have more direct application at Hanford, since in general, Hanford materials, processes and facilities are used in the work.

Specific problems of interest within the program includes such items, for example, as the development of instruments and methods for low assay effluents and for continuous and in-line monitoring; analytical techniques to support biology experimentation; origins, mechanisms of formation, and chemical relationships of radioisotopes in reactor effluent water; factors related to release of gaseous materials; quantitative techniques in study of soil adsorption and waste stratification; possible use of seismic studies of geology; waste gelling techniques; soil percolation rates; character of radioactive particulates, and the like.

As the problems, methods and techniques are worked out to assure continued adequate routine control of Hanford radiological hazards from plant effluents, longer range studies are to be instituted to find even safer and more economical waste disposal means; methods of handling wastes from contemplated new processes and plants; design of research for geologic application at other than Hanford sites; and technical assistance to other sites with waste disposal problems.

The Biophysics Program during FY 1959 is expected to utilize 14 professional employees and is budgeted at approximately \$450,000 including all overhead costs. With development of the longer range studies and applications, 16 professional employees and a budget level of \$550,000 is planned for FY 1960 and subsequent years.

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5. Environmental Sciences Program

The Environmental Sciences Program studies are concerned with environmental contamination arising from Hanford Plant operation with specific studies relating to spread of effluents by atmospheric means and by underground and limnological processes.

The studies in atmospheric physics embrace a wide range of problems which are normally grouped together under the heading of atmospheric pollution. The primary objective in these study areas is to determine the capacity of the lower atmosphere to transport and disperse contaminant materials emitted continuously or sporadically from point or area sources which are located at the ground or at some height above the ground. From such knowledge long- and short-period concentrations and dosages may be calculated for various distances from the source and for a wide variety of meteorological and environmental conditions. Our knowledge of the atmosphere's capacity to diffuse and transport airborne material is at present inadequate. The Hanford Works is ideally suited for a comprehensive research and development program in the field of atmospheric disposal of contaminants from nuclear energy plants. A wide variety of meteorological and terrain conditions are available for experimental purposes and the relative isolation from heavily populated areas permits an unusual degree of flexibility and freedom in field measurements. The results of such a program will provide specific answers to specific problems at the Hanford Works and additionally will provide basic knowledge required for offsite problems. One of these specific problems now under study is estimation of the degree of vulnerability of the Wahluke Slope to reactor incidents.

The applicability of results to non-Hanford problems has elicited the interest of the Air Force and it is expected that a proposal will be received to increase somewhat the scope of our program to provide results which can also be directly applied to situations of interest to the Air Force. Financial support for the expansion would be provided by the Air Force. The expanded

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program would entail acquisition of additional experimental equipment and increase in the number of non-exempt assistants employed. Addition of one professional meteorologist is also contemplated. The budget for FY-1959 will be \$158, 000 not including the possible expansion of scope mentioned above.

A second group of studies in environmental sciences is concerned with the spread of Hanford effluents in the environs by means of underground and limnological processes. General objectives are the assurance of safety of plant personnel and neighboring populations, preservation of environmental resources, and the utilization of Hanford experience for the definition of safeguards in future nuclear developments. Specifically, these studies are concerned with the location of radioactive materials that have been disposed to the ground to demonstrate the acceptability of ground disposal techniques for low level wastes. This research problem is visualized as a continuing long-range effort involving the construction of special wells and drill holes, the development and application of special analytical techniques and monitoring instrumentation.

These underground and limnological transport studies are expected to utilize two professional employees at a total cost of \$60, 000 to \$100, 000 annually.

6. Integrated Exposure Study

Historically, at Hanford, the contributions to radiation exposure in the environs from several different sources have been sufficiently low that their sum could be seen to be below the appropriate limits.

In a recent survey of off-site exposures in preparation for waste disposal hearings it is seen that this condition is no longer assured. The situation arises from a combination of increased production with proportional releases, from substantial reductions in permissible limits, and from improved analytical prowess.

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A concerted new attack on this situation is needed to be led by an individual with broad conceptual skills in all phases of the radiological sciences. Such a study is currently being initiated. It is expected to lead to a proposal for a specific program increment which has not been included in our forecasts to date. The magnitude and degree of urgency of this work is not clearly defined at this time.

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F. Research and Development Staff and Facilities

1. The Research and Development Staff

When the General Electric Company assumed responsibility for the operation of Hanford in September, 1946, personnel with research and development backgrounds were limited to a small group of scientists and engineers engaged mainly in plant assistance work. Plans had already been formulated, however, for major Hanford expansion projects and for the operation of Hanford on a long-term basis. Recognizing the need for a strong technical organization to support these projected activities, an active recruiting program was initiated in late 1946.

The first field of research and development to undergo a major expansion was that of chemical process research and development and associated analytical research which by the beginning of 1949 had attained about the same scale of effort as that maintained today. The stimuli for this very abrupt expansion were the early target dates for the design, construction and start-up of the Redox Separations Process, the Metal Recovery Process and the Plutonium Metal Fabrication Process. In the area of reactor research and development, expansion was more gradual, manpower reaching a peak in 1952 and declining slightly since that time. In the field of metallurgy, only a moderate expansion occurred prior to late 1951. At that time, however, it became evident that the continuity of programs of increased reactor power levels, fuel exposure and coolant temperatures was in serious danger of foreclosure by excessive fuel element rupture rates. In consequence of this a major expansion of metallurgy activities took place in 1952 and 1953. Considering all branches of Hanford research and development, very nearly the present manpower level had been attained by January 1, 1952.

In view of the extreme youth of the nuclear industry as a whole, the Hanford organization must thus be regarded as relatively mature and seasoned. On the Hanford staff are several men who are recognized among their technical and scientific colleagues throughout the country and internationally as outstanding persons in their field. These persons and other senior

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HANFORD ATOMIC PRODUCTS OPERATION COMPONENTS ENGAGED IN RESEARCH & DEVELOPMENT AND ALLIED ENGINEERING

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HW-55767 **DEL****RESEARCH AND DEVELOPMENT FACILITIES****SUMMARY****DISTRIBUTION BY PROGRAM**
(Approximate)

<u>R & D Program</u>	<u>Orig. Cost</u>	<u>Space</u>
Support of Existing Plant		
Reactor	\$ 5,130,000	58,300 sq. ft.
Metallurgy	4,845,000	82,300
Separations	11,791,000	152,045
Improved Production Reactor		
Reactor	4,944,000	56,600
Metallurgy	2,168,000	48,330
Assistance to UCRL (Whitney Proj.)	250,000	5,300
Plutonium Recycle Program (1)	771,000	19,190
Radiological Sciences (2)	4,970,000	88,907
	<u>\$34,869,000</u>	<u>510,972</u>

DISTRIBUTION BY AREAS

<u>Orig. Cost (Dollars)</u>	<u>100</u>	<u>200</u>	<u>300</u>	<u>600</u>	<u>Total</u>
Structure	4,177,000	1,704,000	12,513,000	189,000	18,583,000
Equipment	5,460,000	4,055,000	6,676,000	95,000	16,286,000
Total	<u>9,637,000</u>	<u>5,759,000</u>	<u>19,189,000</u>	<u>284,000</u>	<u>\$34,869,000</u>

Floor Space (Sq. Ft.)

Work Area	5,700	13,400	87,277	0	106,377
Laboratory	46,650	17,950	60,400	730	125,730
Supporting	30,050 (2)	5,400 (2)	198,780	400	234,630
Office	5,600	3,995	33,740	900	44,235
	<u>88,000</u>	<u>40,745</u>	<u>380,197</u>	<u>2,030</u>	<u>510,972</u>

(1) Not including the Plutonium Recycle Test Reactor and Plutonium Fabrication Pilot Plant now under construction at estimated costs of \$15,000,000 and \$4,000,000 respectively.

(2) Supporting space in buildings not primarily R & D is omitted.

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RESEARCH AND DEVELOPMENT FACILITIES

300 Area

(Figure 3)

TEST REACTOR (305)

<u>Description:</u>	Graphite reactor with power levels up to 600 watts		
<u>Function</u>	Uranium and graphite testing and determination of reactor constants.		
<u>Statistics</u>			
Use Date	1944		
Cost	Structure	\$273,000	
	Equipment	850,000	
			<u>\$1,123,000</u>
Floor Space	Work Area	8,100 sq. ft.	
	Supporting	3,900	
	Office	260	
	Total		<u>12,260 sq. ft.</u>

PHYSICAL CONSTANTS TEST REACTORS (305-B)

(Figure 4 and 5)

<u>Description:</u>	Two critical, very low power, uncooled reactors, the Physical Constants Test Reactor and Thermal Test Reactor. The PCTR has an enriched lattice surrounding a test cavity. The TTR is a small graphite reactor with a controlled, elevated temperature thermal column.		
<u>Function</u>	Determination of reactor constants. Specifically: PCTR - K Infinity TTR - Danger coefficients; also source of medium intensity thermal neutrons		
<u>Statistics</u>			
Use Date	March, 1955		
Cost	Structure	\$ 98,000	
	Equipment (est.)	130,000	
	Total		<u>\$ 228,000</u>
Floor Space	Work Area	2,100 sq. ft.	
	Supporting	260	
	Total		<u>2,360 sq. ft.</u>

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METALLURGICAL SEMI-WORKS (306)

(Figure 6)

Description: Metallurgical equipment and fuel element pilot plant. Standard machine metal finishing and forming tools, heat treating, welding and metallographic equipment.

Function Development and fabrication of experimental fuel elements

Statistics

<u>Use Date</u>	February, 1955	
<u>Cost</u>	Structure	\$ 785, 000
	Equipment (est.)	1, 400, 000
	Total	\$2, 185, 000

<u>Floor Space</u>	Work Area	16, 000
	Supporting	14, 500
	Office	3, 000
	Total	33, 500 sq. ft.

METALLURGICAL ENGINEERING (314)

Description: Corrosion testing, metallurgical, and mechanical equipment, including a mock-up of a PRTR tube assembly. Converted production space.

Function Corrosion studies, mechanical development.

Statistics

<u>Use Date</u>	August, 1953 (as R and D Facility)	
<u>Cost</u>	Structure	\$547, 000
	Equipment (est.)	200, 000
	Total	\$ 747, 000

<u>Floor Space</u>	Work Area	15, 800 sq. ft.
	Supporting	1, 900
	Office	460
	Total	18, 160 sq. ft.

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HW-55767

DEL

COLD CHEMICAL SEMI-WORKS (321)

Description: Chemical processing canyon and supporting facilities. Solvent extraction apparatus as process demonstration and scale-up units. Test stands for studying process equipment.

Function Improve existing and develop new chemical processes and equipment.

Statistics

Use Date

1944

Cost

Structure

\$ 839,000

Equipment (est.)

1,536,000

Total

\$2,375,000

Floor Space

Work Area

11,000 sq. ft.

Supporting

6,500

Office

1,250

Total

18,750 sq. ft.

RADIOCHEMISTRY (325)

(Figures 7 and 8)

Description: Forty-five laboratories with 100 radiochemical hoods, a Cobalt-60 source and many instruments such as emission and mass spectrometers. A new radiochemistry cell with four foot thick concrete walls has been approved for design.

Function Chemical process research
Ceramic fuel element research
Analytical service and development
Coatings and corrosion research

Statistics

Use Date

January, 1954

Cost

Structure

\$4,121,000

Equipment (est.)

800,000

Total

\$4,921,000

Floor Space

Laboratory

20,300 sq. ft.

Supporting

91,300

Office

6,200

Total

117,800 sq. ft.

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DEL

PHYSICS AND METALLURGY (326)

(Pile Research and Development)*

(Figures 9 and 10)

Description: Physics and metallurgical laboratories with such research apparatus as an electron microscope, exponential piles, an analog computer and laboratory scale metallurgical machinery.

Function Nuclear physics research
Metallurgy research
Non-metallic reactor materials studies
Fuel element coatings and corrosion research
Non-destructive test methods development

Statistics

<u>Use Date</u>	January, 1954	
<u>Cost</u>	Structure	\$2,388,000
	Equipment (est.)	650,000
	Total	<u>\$3,038,000</u>

<u>Floor Space</u>	Laboratory	22,300 sq. ft.
	Supporting	26,600
	Office	9,300
	Total	<u>58,200 sq. ft.</u>

RADIOMETALLURGY (327)

(Figure 11)

Description: Deep water-filled storage and viewing basin, dry storage unit, five cast iron cells and a number of lead-brick shielded installations and auxiliary facilities.

Function Remote metallurgical physical testing of irradiated material.

Statistics

<u>Use Date</u>	January, 1954	
<u>Cost</u>	Structure	\$ 839,000
	Equipment (est.)	870,000
	Total	<u>\$1,709,000</u>

<u>Floor Space</u>	Laboratory	6,200 sq. ft.
	Supporting	14,600
	Office	500
	Total	<u>21,300 sq. ft.</u>

*Official designation

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**RESEARCH AND DEVELOPMENT MANAGEMENT
AND TECHNICAL SHOPS (328)**

(Mechanical Development Building)*

Description: Offices and technical shops. Shops include electronic, machine, electrical, carpentry, paint, welding and glass shops.

Function Research and development management
Shop assistance to engineering and scientific effort

<u>Statistics</u>									
<u>Use Date</u>	September, 1953								
<u>Cost</u>	<table border="0"> <tr> <td>Structure</td> <td>\$ 617,000</td> </tr> <tr> <td>Equipment (est.)</td> <td>300,000</td> </tr> <tr> <td>Total</td> <td><u>\$917,000</u></td> </tr> </table>	Structure	\$ 617,000	Equipment (est.)	300,000	Total	<u>\$917,000</u>		
Structure	\$ 617,000								
Equipment (est.)	300,000								
Total	<u>\$917,000</u>								
<u>Floor Space</u>	<table border="0"> <tr> <td>Shop</td> <td>17,300 sq. ft.</td> </tr> <tr> <td>Supporting</td> <td>10,800</td> </tr> <tr> <td>Office</td> <td>6,600</td> </tr> <tr> <td>Total</td> <td><u>34,700 sq. ft.</u></td> </tr> </table>	Shop	17,300 sq. ft.	Supporting	10,800	Office	6,600	Total	<u>34,700 sq. ft.</u>
Shop	17,300 sq. ft.								
Supporting	10,800								
Office	6,600								
Total	<u>34,700 sq. ft.</u>								

BIOPHYSICS (329)

Description: Forty-five physical and radiochemical research and development, and service laboratories equipped with a wide range of counting apparatus including scintillation and current measuring equipment.

Function Radiological physics
Radiation protection instrument development
Radioanalysis
Radiological chemical analyses

<u>Statistics</u>									
<u>Use Date</u>	December, 1952								
<u>Cost</u>	<table border="0"> <tr> <td>Structure</td> <td>\$ 1,195,000</td> </tr> <tr> <td>Equipment (est.)</td> <td>57,000</td> </tr> <tr> <td>Total</td> <td><u>\$1,252,000</u></td> </tr> </table>	Structure	\$ 1,195,000	Equipment (est.)	57,000	Total	<u>\$1,252,000</u>		
Structure	\$ 1,195,000								
Equipment (est.)	57,000								
Total	<u>\$1,252,000</u>								
<u>Floor Space</u>	<table border="0"> <tr> <td>Laboratory</td> <td>11,600 sq. ft.</td> </tr> <tr> <td>Supporting</td> <td>20,400</td> </tr> <tr> <td>Office</td> <td>3,270</td> </tr> <tr> <td>Total</td> <td><u>35,270 sq. ft.</u></td> </tr> </table>	Laboratory	11,600 sq. ft.	Supporting	20,400	Office	3,270	Total	<u>35,270 sq. ft.</u>
Laboratory	11,600 sq. ft.								
Supporting	20,400								
Office	3,270								
Total	<u>35,270 sq. ft.</u>								

*Official designation

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DEL

GRAPHITE SHOP (3730)

Description: Shop for machining experimental quantities of reactor graphite shapes; and an experimental shop for examining irradiated graphite.

Function Graphite machining; irradiated graphite examination

Statistics

<u>Use Date</u>	August, 1956		
<u>Cost</u>	Structure	\$ 150,000	
	Equipment (est.)	48,000	
	Total		\$198,000

<u>Floor Space</u>	Shop	2,700 sq. ft.	
	Supporting	420	
	Total		3,120 sq. ft.

ELECTRON ACCELERATOR (3745A)

Description: Two Mev Van de Graaff electron accelerator

Function Calibrations
Primarily not R. and D. but available for special studies requiring a wide range of monoenergetic electrons

Statistics

<u>Use Date</u>	1949		
<u>Cost</u>	Structure	\$ 45,000	
	Equipment (est.)	67,000	
	Total		\$112,000

<u>Floor Space</u>	Work Area	1,277	
	Total		1,277 sq. ft.

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POSITIVE ION ACCELERATOR (3745B)

(Figure 12)

<u>Description:</u>	Two Mev Van de Graaff positive ion accelerator		
<u>Function</u>	Variable energy fast neutron source for special irradiation studies.		
<u>Statistics</u>			
Use Date	May, 1954		
Cost	Structure	\$ 56,000	
	Equipment (est.)	118,000	
	Total		\$174,000
Floor Space	Work Area	1,600 sq. ft.	
	Supporting	400	
	Total		2,000 sq. ft.

HANFORD LABORATORIES MANAGEMENT AND TECHNICAL
INFORMATION (3760)

(LIBRARY AND FILES BUILDING)*

<u>Description:</u>	Management offices. Technical library and classified files.		
<u>Function</u>	Management and Technical Information.		
<u>Statistics</u>			
Use Date	November, 1952		
Cost	Structure	\$560,000	
	Equipment (est.)	150,000	
	Total		\$710,000
Floor Space	Work Area	11,400 sq. ft.	
	Supporting	7,200	
	Office	2,900	
	Total		21,500 sq. ft.

*Official designation

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HOT SEMI-WORKS (201-C et al)

(Figure 13)

Description: Chemical process type building containing three process cells; several auxiliary buildings. (In standby as of July 1, 1957)

Function Demonstration of chemical separation flow plans on radioactive material. Process improvement and prototype studies.

Statistics

<u>Use Date</u>	April, 1952	
<u>Cost</u>	Structure	\$1,400,000
	Equipment (est.)	3,325,000
	Total	<u>\$4,725,000</u>

<u>Floor Space</u>	Work Area	13,400 sq. ft.
	Supporting	4,800
	Office	1,000
	Total	<u>19,200 sq. ft.</u>

REDOX LABORATORY (222-S)

Description: Radiochemical laboratories with two heavy-walled 20 curie cells occupy about 20% of the laboratory space in this analytical control building.

Function Chemical Separation Process Development

Statistics

<u>Use Date</u>	September, 1952	
<u>Cost</u>	Equipment (est.)	\$ 190,000
	Total	<u>\$ 190,000</u>

<u>Floor Space</u>	Laboratory	2,750 sq. ft.
	Office	435
	Total	<u>3,185 sq. ft.</u>

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EARTH SCIENCES LABORATORY (222-U)

Description: Soils and radiochemical laboratories, and hydrology laboratory.

Function Soils studies for waste disposal.

Statistics

<u>Use Date</u>	1947	
<u>Cost</u>	Structure	\$304,000
	Equipment (est.)	40,000
	Total	<u>\$344,000</u>
<u>Floor Space</u>	Laboratory	6,000 sq. ft.
	Supporting	600
	Office	760
	Total	<u>7,360 sq. ft.</u>

PLUTONIUM METALLURGY RESEARCH ANNEX (231)

Description: Laboratory space in the former production Plutonium Isolation Building adapted for plutonium metallurgy research and development.

Function Plutonium metallurgy research and development

Statistics

<u>Use Date</u>	November, 1955	
<u>Cost</u>	Equipment (included in 234-5) (est.)	
<u>Floor Space</u>	Laboratory	4,000 sq. ft.
	Office	1,300
	Total	<u>5,300 sq. ft.</u>

PLUTONIUM PROCESSING DEVELOPMENT LABORATORY (234-5)

Description: Laboratory and pilot plant facilities

Function Purification of plutonium by aqueous and dry processes
Development of metal reduction processes
Development of scrap recovery processes
Development of improved ceramic materials

Statistics

<u>Use Date</u>	1951	
<u>Cost</u>	Equipment (est.)	\$200,000
<u>Floor Space</u>	Laboratory	3,500 sq. ft.
	Office	500
	Total	<u>4,000 sq. ft.</u>

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DEL

PLUTONIUM METALLURGY RESEARCH LABORATORY (234-5)

Description: This facility in a process building provides highly specialized shielded radiometallurgical equipment.

Function Plutonium metallurgy research

Statistics

<u>Use Date</u>	1951	
<u>Cost</u>	Equipment (est.)	\$500,000 (incl. 231 Bldg.)
	Total	<u>\$500,000</u>

<u>Floor Space</u>	Laboratory	5,200 sq. ft.	
	Office	500	
	Total		<u>5,700 sq. ft.</u>

METEOROLOGY FACILITY (622 et al)

Description: A 400' tower with associated buildings such as a balloon release building and a blimp hangar. Recording thermometers and wind velocity gauges at fifty foot levels of the tower telemeter readings to the office building.

Function Basic and applied meteorological studies for stack gas dispersal.

Statistics

<u>Use Date</u>	1944	
<u>Cost</u>	Structure	\$189,000
	Equipment (est.)	95,000
	Total	<u>\$284,000</u>

<u>Floor Space</u>	Laboratory	730 sq. ft.	
	Supporting	400	
	Office	900	
	Total		<u>2,030 sq. ft.</u>

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METAL EXAMINATION FACILITY (105 C)

(Figure 14)

Description: Attached to a reactor building, four large water-filled concrete basins, special underwater periscopes, decanners and metallurgical tools.

Function Underwater examination and physical property measurements of irradiated fuel elements.

Statistics

<u>Use Date</u>	July, 1956		
<u>Cost</u>	Structure	\$250,000	
	Equipment (est.)	700,000	
	Total		<u>\$950,000</u>
<u>Floor Space</u>	Laboratory	1,650 sq. ft.	
	Office	120	
	Total		<u>1,770 sq. ft.</u>

THERMAL HYDRAULICS LABORATORY (189-D)

Description: Laboratories for heat transfer and fluid flow studies; pressurized mock-up process tubes and accessory apparatus.

Function Heat transfer and fluid flow studies

Statistics

<u>Use Date</u>	1951		
<u>Cost</u>	Structure	\$ 420,000	
	Equipment (est.)	1,000,000	
	Total		<u>\$1,420,000</u>
<u>Floor Space</u>	Laboratory	10,500 sq. ft.	
	Supporting	9,300	
	Office	420	
	Total		<u>20,220 sq. ft.</u>

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NEUTRON SPECTROMETERS (105-DR AND 105-KE)

Description: In the DR and KE Reactors. The crystal neutron spectrometers cover a range of .01 ev to 10 ev.

Function Measure neutron cross section.

Statistics

<u>Use Date</u>	DR - 1950; KE - 1958	
<u>Cost</u>	Equipment (est.) DR	\$100,000
	Equipment (est.) KE	183,000
	Total	<u>\$283,000</u>

<u>Floor Space</u>	Laboratory	1,000 sq. ft.
		<u>1,000 sq. ft.</u>

KAPL-120 LOOP (105-H)

Description: Located in the H Reactor, the loop operates at 2300 psi and 620 F.

Function Fuel element performance, corrosion and water chemistry evaluation

Statistics

<u>Use Date</u>	July, 1955	
<u>Cost</u>	Equipment (est.)	\$400,000
	Total	<u>\$400,000</u>

<u>Floor Space</u>	Laboratory	2,000 sq. ft.
	Office	100
	Total	<u>2,100 sq. ft.</u>

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COOLANT TESTING FACILITY (1706 KE-KER)

Description: Eight single pass tubes, 10 out-of-reactor loops, 16 steam heated mock-up tubes, and 4 in-reactor loops.

Function Evaluation of fuel elements, reactor materials and equipment

Statistics

<u>Use Date</u>	May, 1955		
<u>Cost</u>	Structure	\$1,380,000	
	Equipment (est.)	2,600,000	
	Total		\$3,980,000

<u>Floor Space</u>	Laboratory	15,400 sq. ft.	
	Supporting	5,800	
	Office	740	
	Total		21,940 sq. ft.

BIOLOGICAL LABORATORY (108-F)

(Figure 15)

Description: Laboratories for biological and biochemical studies.

Function Animal research for permissible limits; contamination transfer from soil to plants; mechanism of biological effects of radiation.

Statistics

<u>Use Date</u>	1949		
<u>Cost</u>	Structure	\$1,261,000	
	Equipment (est.)	400,000	
	Total		\$1,661,000

<u>Floor Space</u>	Laboratory	10,800 sq. ft.	
	Supporting	8,500	
	Office	2,300	
	Total		21,600 sq. ft.

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EXPERIMENTAL ANIMAL FARM (141-F et al)

Description: Animal and storage barns and auxiliary facilities for experiments with large animals.

Function Determination of MPC for I^{131} and other radioisotopes in large animals. Exposure studies on large animals for radioactive particle inhalation.

Statistics

<u>Use Date</u>	1949	
<u>Cost</u>	Structure	\$361,000
	Equipment (est.)	30,000
	Total	<u>\$391,000</u>

<u>Floor Space</u>	Work Area	5,700 sq. ft.
	Supporting	2,200
	Office	870
	Total	<u>8,770 sq. ft.</u>

AQUATIC BIOLOGY (146 FR)

Description: Three biology laboratories and a tank room for exposure of aquatic life to different toxic materials, including reactor effluent.

Function Evaluate toxicity of reactor effluent and absorption and toxicity of radioelements in aquatic organisms.

Statistics

<u>Use Date</u>	September, 1952	
<u>Cost Date</u>	Structure	\$426,000
	Equipment (est.)	200,000
	Total	<u>\$626,000</u>

<u>Floor Space</u>	Laboratory	4,000 sq. ft.
	Supporting	4,200
	Office	800
	Total	<u>9,000 sq. ft.</u>

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PHARMACOLOGY (141-FS, 1705-F)

Description: Two small buildings housing radio-biological laboratories.

Function Evaluate toxicity of radioactive particles in lungs of small animals.

Statistics

Use Date
Cost

1948

Structure

\$ 80,000

Equipment (est.)

30,000

Total

\$110,000

Floor Space

Laboratory

1,300 sq. ft.

Supporting

50

Office

250

Total

1,600 sq. ft.IN-REACTOR IRRADIATION FACILITIES

Description: Approximately 62 test holes with tubes leading through reactors. Number per reactor varies from four in older ones to 15 in new ones.

Function Special high flux thermal neutron irradiations.

DATA PROCESSING FACILITIES (703)

Description: IBM-702 and accessory equipment.

Function Primarily accounting; scientific and engineering data processing on limited basis.

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**MAJOR LABORATORIES WITH PRIMARY FUNCTIONS
OTHER THAN R & D OR R & D SUPPORT**

<u>Name</u>	<u>Bldg. & Equip. Cost</u>
Laboratory Section - 3706	\$ 60,000
Laboratory Section - Purex (202A)	1,256,000
Redox Laboratory - 222S	5,154,000 (a)
Laboratory Section - 234-5	600,000
Bioassay - 747	135,000

(a) includes R & D

OFF-SITE FACILITIES AT ARCO

HANFORD FACILITIES AT NATIONAL REACTOR TEST STATION

ARCO, IDAHO

MATERIALS TESTING REACTOR

(Figure 16)

Description: Accessory equipment for material in reactor tests. Test facility space limited.

Function Test reactor and other materials.

Cost \$50,000 (est.)

ENGINEERING TEST REACTOR

Description: Test loops in two test positions.

Function In-reactor testing of fuel elements.

Cost \$1,200,000 (est.)

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FACILITIES UNDER CONSTRUCTION
PLUTONIUM RECYCLE TEST REACTOR

(Figure 17)

Description: Demonstration reactor and auxiliaries, in support of Plutonium Recycle Program.

Function Demonstrate operation of compatible plutonium and uranium fuel elements. Experimentation on plutonium recycle concept; recycle operation feasibility and economics.

Status Construction started March, 1958. Criticality scheduled for early 1960.

Estimated Cost \$15,000,000

PLUTONIUM FABRICATION PILOT PLANT

(Figure 18)

Description: Laboratory and pilot plant building with associated offices

Function Fabricate plutonium-bearing experimental fuel elements.

Status Construction started March, 1958. Beneficial occupancy scheduled for late 1959.

Estimated Cost \$4,000,000

GAS LOOP - 105-DR

Description: To be operated at 1250 F outlet temperature and 200 psi base pressure using nitrogen, then helium as coolant.

Function Study fuel element and structural material performance and operating characteristics of gas system.

Status Start-up scheduled for January, 1959.

Estimated Cost \$900,000

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FIGURE 3
300 Area

400-00 BICHLAND, WASH.

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FIGURE 4
Physical Constants Test Reactor - 305-B Building

REF ID: A61440

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FIGURE 5

Thermal Test Reactor - 305-B Building

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FIGURE 6
Fuel Element Pilot Plant Canning Line - 306 Building

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FIGURE 7

High Level Solvent Extraction Facility - 325 Building

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FIGURE 8
Ceramics Laboratory - 325 Building

AFU GE RICHLAND, WASH.

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FIGURE 9

Hot Stage Metallograph - 326 Building

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FIGURE 10

Out-of-Reactor Zirconium Gas Reaction Apparatus - 326 Building

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FIGURE 11
Radiometallurgy Canyon - 327 Building

FIGURE 12
Positive Ion Accelerator - 3745-B Building

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FIGURE 13

Hot Semi-Works - 201-C Building

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105 METAL EXAMINATION FACILITY

FIGURE 14

ARC 35 RICHARD WARD

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FIGURE 15
Biology Facility - 100-F Area

466-06 HIGHLAND, WASH.

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FIGURE 16
MTR Pressure Loop

FIGURE 17
Plutonium Recycle Program Reactor

V. ACQUISITION AND CONSTRUCTION PROGRAMS

Following is a summary of major Plant Acquisition and Construction work anticipated in support of the programs outlined above. Orientation is by fiscal years as follows:

- A. By the fiscal year from which Plant Acquisition and Construction budget funds are proposed (HW-55678, dated April 15, 1958) to be derived for work to be started through FY 1960.
- B. By the fiscal year in which major and sustained design and design and construction activity is expected to start for prospective work beyond FY 1960.

Equipment not in Construction Projects and "General Plant Project" type of work is not included in this summary. It is forecasted that Equipment not in Construction Projects will range from 3 to 8 million dollars per year, and that General Plant Projects will range from 1.5 to 2.5 million dollars per year. In some cases, major expenditures are foreseen as potentially required to maintain safe production, but the probability of need is judged to be low. Some items of this nature are included in this presentation as "contingency" items, but have not been included in requests for funds through FY 1960.

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SUMMARY OF MAJOR PROJECTS

<u>Budget Study No.</u>	<u>Title</u>	<u>Project Cost Estimate (Million of Dollars)</u>	<u>Primary Justification</u>	<u>Estimated Completion Period</u>
<u>FY-1958 AND PRIOR YEARS</u>				
<u>FUEL PREPARATION FACILITIES</u>				
58-b-4	Modification of 306 Pilot Plant	0.7	Evaluation of recently devel- oped extrusion processes	April, 1959
<u>IRRADIATION FACILITIES</u>				
B-5790	Nuclear Instrumentation for Reactor Safety and Control - All Reactors (Includes Octant Monitors and Power-Rate-of- Rise Systems)	.7	Improved Nuclear Safety	March, 1960
B-5768	High Speed Scanning Instru- mentation - 100-K (Phase I)	.2	Increased Process Safety and Control	June, 1959
CG-706	Installation of Improved Reactor Gas Instrumentation	.3	Maintain Continuity of Operation, Increase Pro- duction, and Reduce Gas Consumption	March, 1960
B-5922	Reduced Personnel Exposure Remote Manipulator	.2	Reduced Personnel Exposure and Continuity of Operation	June, 1960
	Cap Removers, 100-K Area	.6	Reduced Personnel Exposure and Continuity of Operation	December, 1959
CG-775	100-K Water Plant Expansion (Design)	.3	Increased Production	October, 1959
CG-707	Improvements to Reactor Nuclear Instrumentation, All Reactors	.7	Improved Nuclear Safety	December, 1959

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<u>Budget Study No.</u>	<u>Title</u>	<u>Project Cost Estimate (Million of Dollars)</u>	<u>Primary Justification</u>	<u>Estimated Completion Period</u>
<u>FY-1958 AND PRIOR YEARS</u>				
<u>SEPARATIONS FACILITIES</u>				
CG-772	E-Metal Dissolvers, Redox	0.6	New product, nuclear safety	October, 1959
CG-767	Miscellaneous Improvements, UO ₃ Plant	0.6	Maintain continuity of operations; reduce unit cost.	November, 1959
57-a-5 6024	Additional Waste Disposal Facilities, Purex	4.0	Continuity of operation	January, 1962
<u>FACILITIES IN SUPPORT OF RESEARCH AND DEVELOPMENT</u>				
CG-731	Critical Mass Laboratory	1.8	Development of basic critical mass data	October, 1959
CA-744	Metallurgical Development Facilities - 306 Bldg.	2.6	Development of improved fuel elements and reactor structural components.	July, 1960
CA-747	Plutonium Fabrication Pilot Plant	4.0	Pilot plant production of plutonium fuel elements to develop plutonium fabrication technology.	April, 1961
CA-749	High Level Radiochemistry Facility	1.1	Radiochemical research work on highly radioactive materials (i.e., fission product recovery, power reactor fuels separation, etc.)	June, 1959
AEC-167	Plutonium Recycle Test Reactor	15.0	Demonstration of plutonium recycle concept	November, 1960
	Additions to the Radiometallurgy Building (Including Proj. CGH-790 "High Level Radioactive Material Receiving and Storage Addition - 327 Building" for \$375,000.	0.6	Increased capacity, shielding and handling facilities to allow metallurgical examination of highly irradiated, massive fuel elements.	December, 1959

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<u>Budget Study No.</u>	<u>Title</u>	<u>Project Cost Estimate (Million of Dollars)</u>	<u>Primary Justification</u>	<u>Estimated Completion Period</u>
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FY-1959

FUEL PREPARATION FACILITIES

None

IRRADIATION FACILITIES

B-5923	Tube Replacement Facilities	1.8	Increased Production, Reduction of Operating Costs, and Reduced Personnel Exposure	December, 1961
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SEPARATIONS FACILITIES

CG-718	Fission Product Isolation Phase I	1.5	Value of fission products; to decrease waste storage problems	July, 1960
59-3	Power Fuels Processing, Phase I	5.0	AEC need for facility	18 - 24 months
9300 59-2	Weapon Program, Fabrication	3.5	Weapon equipment and product operating continuity	July, 1961
59-2	Purex Off-Gas Recovery	1.0 - 2.0	AEC need for production	18 - 24 months

FACILITIES IN SUPPORT OF RESEARCH
AND DEVELOPMENT

None

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Budget Study No.	Title	Project Cost Estimate (Million of Dollars)	Primary Justification	Estimated Completion Period
FY-1960				
<u>FUEL PREPARATION FACILITIES</u>				
GE-6024	Facilities for Improved Type Fuel Element	2.3	Reduction of operating cost and increased production	April, 1961
<u>IRRADIATION FACILITIES</u>				
B-02-I	Nuclear Instrumentation for Reactor Safety and Control (Includes log ion trip systems, Octant Monitors)	1.3	Improved Nuclear Safety	June, 1961
B-01-I	High Speed Scanning Instrumentation (Phases II and III)	.8	Increased Process Safety and Control	September, 1961
B-03-I	Effluent System Modifications	1.2	Continuity of Operation	June, 1961
B-07-I	Rear Face Crossunder Lines, B, C, D, DR, F, and H	.5	Reduced Personnel Exposure and Continuity of Operation	September, 1960
B-08-I	Water Plant Expansion, 100-K Area (Construction)	5.0	Increased Production	March, 1963
B-010-I	Revision of HCR's for By-Product Production, 105-C, KE and KW	.7	Increased Production	October, 1960
<u>SEPARATIONS FACILITIES</u>				
6022	Fission Product Isolation, Phase II	1.7	New and Improved Products; increase capacity.	18 - 24 months
59-3	Power Fuels Processing, Phase II	1.3	AEC need; increased flexibility and capacity.	18 - 24 months
9300	Weapon Program,	7.5	Weapon equipment and product; operating continuity.	30 - 36 months
6033	Assembly			
6021	Shielding Program, 234-5	1.2	Radiation control; reduced operating cost	24 - 30 months
B-09-C	Building			

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<u>FACILITIES IN SUPPORT OF RESEARCH AND DEVELOPMENT</u>				
B-04-H	Effluent Technology Addition to the 329 Bldg.	0.5	Development of safer and more economical methods for dis- posal and storage of radioactive wastes and effluents.	24 - 30 months *
B-01-H	Modifications to the Hot Semi- Works for Service Processing PRTR Fuels	1.5	Recovery, isolation, and storage of irradiated PRTR fuels to perform the out-of- reactor portion of the cycle.	October, 1960
B-05-H	Full Scale Physical Constants Test Reactor	0.9	Development of advanced reactor concepts leading to increased production and improved safety for production reactors	December, 1960
B-02-H	Hydroformer and Rolling Mill- 231-2 Bldg.	1.1	Development of techniques for fabricating advanced weapon shapes.	November, 1960
<u>FY-1961</u>				
<u>FUEL PREPARATION FACILITIES</u>				
	Administration Building Area	0.8	Maintaining efficiency of employees	7 - 12 months
<u>IRRADIATION FACILITIES</u>				
B-06-I	Reduced personnel Exposure, All Reactors	3.0	Reduced Personnel Exposure and Continuity of Operation	June, 1963
B-011-I	Continuous Charge-Discharge, 105-C	3.0	Increased Production and Continuity of Operation	September, 1962
	Increased Water Capacity, 100-B, C, D, DR, F, and H Areas	5.0	Increased Production	June, 1963

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<u>Budget Study No.</u>	<u>Title</u>	<u>Project Cost Estimate (Million of Dollars)</u>	<u>Primary Justification</u>	<u>Estimated Completion Period</u>
<u>SEPARATIONS FACILITIES</u>				
	Additional Waste Disposal Facilities	4.5	Maintain continuity of operation	12 - 30 months
	Low Activity Waste Processing	0.6	Contamination control; reduction of future capital costs	15 - 20 months
<u>FACILITIES IN SUPPORT OF RESEARCH AND DEVELOPMENT</u>				
	Radiometallurgy Bldg. Addition	2.0	Metallurgical examination of PRTR fuel elements	July, 1962
<u>FY-1962</u>				
<u>FUEL PREPARATION FACILITIES</u>				
	Modification of Production Facilities	1.0	Provide improved product flexibility and reduced costs	12 - 24 months
<u>IRRADIATION FACILITIES</u>				
	Charge-Discharge - K Reactors	4.0	Increased Production and Continuity of Operation	March, 1963
	Effluent System Modifications (This is an extension of B-03-I - FY-60)	1.0	Continuity of Operation	September, 1963
<u>SEPARATIONS FACILITIES</u>				
	Automatic In-Line Instrumentation	1.0	Maintain continuity of operation; reduction of operating costs; nuclear safety	24 months
	Replace Ventilation Filter, Purex	0.8	Maintain continuity of operations	18 - 24 months

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<u>Budget Study No.</u>	<u>Title</u>	<u>Project Cost Estimate (Millions of Dollars)</u>	<u>Primary Justification</u>	<u>Estimated Completion Period</u>
<u>FACILITIES IN SUPPORT OF RESEARCH AND DEVELOPMENT</u>				
	Replacement of PRTR Core and/or Conversion to Organic Coolant	1.5	Design Improvements	July, 1963
<u>FY-1963</u>				
<u>FUEL PREPARATION FACILITIES</u>				
None				
<u>IRRADIATION FACILITIES</u>				
	Storage Basin Cleaning Facilities	.5	Reduced Personnel Exposure and Continuity of Operation	December, 1963
<u>SEPARATIONS FACILITIES</u>				
	Additional Waste Disposal Facility	4.0	Maintain continuity of operation	24 - 36 months
	Equipment Modifications - Technology	2.0	AEC need for product and improved personnel protection	12 - 14 months
<u>FACILITIES IN SUPPORT OF RESEARCH AND DEVELOPMENT</u>				
None				

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