RL-4-7

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Cover Sheet for a Hanford Historical Document Released for Public Availability

Released 1994

**Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830**

**Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute**

DEC 13 1994

OSTI

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DECLASSIFIED

RL 4-7

Hanford Category C-65

Date 6-30-68

**RICHLAND FIVE-YEAR
02 R&D PROGRAM**

TARGET SPACE ENHANCEMENT

**RICHLAND OPERATIONS OFFICE
ATLANTIC RICHFELD HANFORD COMPANY
BATTELLE-NORTHWEST
DOUGLAS UNITED NUCLEAR, INC.**

MASTER

DECLASSIFIED

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DECLASSIFIED

RL 4-7

Classification Cancelled and Changed To

DECLASSIFIED

HANFORD CATEGORY C-65

By Authority of RM-Dten

CG-NMP-1, 8-8-94

By J E Savely 9-20-94

Verified By Jerry Moley 9-21-94

This document consists of 29
pages.

R I C H L A N D F I V E - Y E A R

O 2 R & D P R O G R A M

T A R G E T S P A C E E N H A N C E M E N T

June 30, 1968

RICHLAND OPERATIONS OFFICE
ATLANTIC RICHFIELD HANFORD COMPANY
BATTELLE - NORTHWEST
DOUGLAS UNITED NUCLEAR, INC.

This document contains restricted data
in accordance with the Atomic Energy Act of 1954. Its transmittal
or the disclosure of its contents in any manner to
any unauthorized person is prohibited.

P L E A S E S I G N B E F O R E R E A D I N G

Route To:	P.R. No.	Location	Files Route Date	Signature and Date
<u>J E Savely</u>	<u>30603</u>	<u>376</u>	<u>7-2-68</u>	<u>J E Savely 7-10-68</u>

DECLASSIFIED

R I C H L A N D F I V E - Y E A R
O 2 R & D P R O G R A M
T A R G E T S P A C E E N H A N C E M E N T

PRINCIPAL CONTRIBUTORS

P. A. Carlson	DUN
D. H. Curtiss	DUN
H. F. Tew	DUN

DECLASSIFIED

R I C H L A N D F I V E - Y E A R
O 2 R & D P R O G R A M

SUMMARY	RL 4-0
BASIC PRODUCTION	RL 4-1
COPRODUCT	RL 4-2
TRANSPLUTONIUM	RL 4-3
PLUTONIUM-238	RL 4-4
OTHER ISOTOPES	RL 4-5
ENRICHED FUEL PROCESSING	RL 4-6
TARGET SPACE ENHANCEMENT	RL 4-7
NUCLEAR SAFETY	RL 4-8
WASTE MANAGEMENT	RL 4-9
COLUMBIA RIVER	RL 4-10

DECLASSIFIED

DECLASSIFIED

TABLE OF CONTENTS

Page No.

RT TARGET SPACE ENHANCEMENT MISSION

INTRODUCTION

5

SCOPE AND OBJECTIVES

5

STATISTICAL SUMMARY SCHEDULE

7

INVENTIVES

7

PROGRESS DURING REPORT PERIOD

8

EVALUATION OF EFFORT

13

BUDGET PERIOD PLANS

14

PROGRAM SCHEDULE CHARTS

15

CHANNEL ENLARGEMENT - FIG. 1

17

HIGHLY ENRICHED FUEL - FIG. 2

18

HIGH POWER DENSITY FUEL - FIG. 3

20

ADVANCED TECHNOLOGY PROG. FIG. 4

21

MILESTONES

25

REFERENCES

27

STATISTICAL SUMMARIES

27

RL TARGET SPACE ENHANCEMENT MISSION

INTRODUCTION

This document contains the reports of progress and the plans for future work of Douglas United Nuclear, Inc., on the Target Space Enhancement Mission. The DUN research and development program is based on a long-range operating plan which recognizes a continuing need for the production of special nuclear materials in AEC facilities. Among these expected needs are increased requirements for non-defense plutonium, tritium, and other isotopes. The purpose of the target space enhancement mission is to establish an improved irradiation capability in the Hanford reactors to respond to these needs. Programs are included to reduce the unit costs of nondefense plutonium, to develop the use of Oralloys to meet future enrichment requirements, and to increase the flexibility of the reactors to produce isotopes such as plutonium-238 and uranium-233.

SCOPE AND OBJECTIVES

The prime objective of this mission is the development of fuel and reactor technology to establish an improved irradiation capability to produce special nuclear materials in the Hanford reactors. The mission includes many activities leading to improved production capability, reduced unit costs of nondefense plutonium, and increased product flexibility. These are concentrated in four programs which will be performed concurrently: 1) the channel enlargement program, 2) the development of highly enriched (Oralloy) fuels, 3) the development of high power density slightly enriched uranium fuels, and 4) the advanced technology program. The scope and objectives of these programs are as follows:

A. Channel Enlargement Program

The objective of this program is to develop the technology for enlarging the process channels at the single-pass reactors and operating these reactors with larger-diameter fuel elements. Emphasis will be placed on the development of rod-in-tube uranium fuel elements for nondefense plutonium production and integral fuel-target (coproduct) elements of the same geometry for the production of other isotopes. Both slightly enriched uranium and highly enriched fuel drivers will be developed for the latter application. The use of uranium-oxide fuels will be studied for plutonium production modes.

B. Highly Enriched Fuel Program

The objective of this program is to develop highly enriched (Oralloy) fuels to be used as the sole fuel or in conjunction with slightly-enriched uranium fuel elements (spike concept) to produce a desired product mix in the reactors. Initial work will be directed toward development of the spike concept for the single-pass reactors with the objective of developing a loading using 95 or 72 Metal with highly enriched fuel to achieve up to 50 percent tritium production capability. The research and development areas to be explored include:

DECLASSIFIED

1. Reactor life effects from increased heat generation in the graphite moderator.
2. Nuclear safety studies to define fuel behavior following a loss of coolant.
3. Fuel and target design and fabrication development.
4. Development of both the supercell and the integral fuel-target irradiation modes.

C. High Power Density Fuel Program

The objective of this program is to develop enriched uranium (up to 2.1 percent U-235) fuel elements capable of operating at twice the tube powers obtained in weapons-grade plutonium production loadings. The program is directed toward the single-pass reactors with present-size process tubes. Achievement of this objective would provide the fuel technology to divert one-half of the existing reactors' irradiation space to target elements. The program will include development for utilization of either the supercell or integral fuel-target irradiation modes.

D. Advanced Technology Program

The basic objective of the advanced technology program is to develop the reactor and fuel technology necessary to attain 5600 Mwt - 1200 Mwe operation of the N Reactor.

To support this general objective, a number of programmatic objectives are established. Specifically:

1. Develop and demonstrate by mid FY-1971 the fuel and thermal hydraulic technology necessary to achieve reactor tube powers up to 7000 kw.
2. Develop and demonstrate by FY-1972 the instrumentation and control technology necessary to assure safe operation utilizing the trip-after instability philosophy to prevent boiling burnout during power transients.
3. Provide the necessary improvements and modifications to the control and heat dissipation systems on a schedule consistent with the attainment of maximum power operation with six cells and optimum boiling by mid FY-1972.
4. Perform engineering studies and transient analysis of interacting systems controls to verify their ability to adequately handle the various plant transients which are to be expected (e.g., reactor scrams, turbine tripoffs, loss of an electric power source, etc.).

DECLASSIFIED

The successful attainment of these goals will permit increased flexibility of operation between the extremes of 5600 Mwt - 1200 Mwe, and 4800 Mwt - 800 Mwe with up to 200 tubes diverted to isotope production.

STATISTICAL SUMMARY SCHEDULE

	Fiscal Year				
	<u>1969</u>	<u>1970</u>	<u>1971</u>	<u>1972</u>	<u>1973</u>
<u>Dollars (in Thousands)</u>					
DUN-N Reactor	400	700	600	625	650
DUN-CK Reactors	<u>450</u>	<u>500</u>	<u>600</u>	<u>625</u>	<u>650</u>
Total	850	1200	1200	1250	1300
<u>Man Years</u>					
DUN-N Reactor	9.3	13.1			
DUN-CK Reactors	<u>7.5</u>	<u>7.8</u>			
Total	16.8	20.9			

INCENTIVES

The programs described here are based on and are part of a long-range plan for the reactors which recognize a continued need for government production of special nuclear materials for at least the next 20 years with the Hanford reactors continuing to contribute significantly to this need. Expected needs in the production of tritium, nondefense plutonium, and isotopes such as Pu-238 and U-233 are recognized. Many activities leading to improved production capability, reduced unit costs of nondefense plutonium, and increased product flexibility are concentrated in the Target Space Enhancement Mission. It is primarily through the development and implementation of this mission that the production and cost reduction goals of the long-range plan will be achieved.

The increased power level capability obtained at N Reactor through development and implementation of the advanced technology program will, in addition to increasing total production, permit exploitation of the reactor's unique economic advantage--steam revenue. For example, increasing tube power by 40 percent from a nominal 5000 kw to 7000 kw would result in a reactor power level increase from 4000 Mw to 5600 Mw. The increase in power level could be used to increase electrical power capability with the associated increase in steam revenue. The effect would be a substantial increase in production and, with increased steam revenue, a dramatic decrease in unit cost. The same power level capability could be used to produce large quantities of isotopes while maintaining current reactor and electrical power levels. With a 7000 kw tube power capability, a significant portion of the reactor could be diverted to irradiation of nonheat-producing targets without attendant reduction of plutonium and steam production below current levels.

DECLASSIFIED

Successful development of high power density fuels would make it possible to increase the power output of a reactor process tube up to the limit of its cooling capacity. This would permit loading up to half the tubes with target material, loading the rest of the tubes with fuel, passing most of the reactor coolant through the fueled tubes, and maintaining current reactor power levels. This would produce a product mix including either weapons or nonweapons-grade plutonium if slightly enriched uranium fuels were used. The amount of plutonium production could be reduced with partial use of highly enriched fuels, and the reactors could be completely diverted to other isotopes by full reactor loadings using these fuels. A further incentive for the utilization of highly enriched fuels is the possibility that an inventory charge will be applied to slightly enriched uranium, thereby enhancing the highly enriched fuel economics.

Channel enlargement would also greatly increase the flexibility of the single-pass reactors and provide for reductions in the unit costs for producing nondefense plutonium. In addition, an overbored reactor could be more easily adapted to the use of uranium oxide or highly enriched fuels. A further incentive for channel enlargement in the single-pass reactors is the increased reactor safety attained through an increase in the fuel-to-graphite ratio, thereby eliminating the autocatalytic response to a loss of coolant accident which is now characteristic of these reactors.

Thus, the economic incentives to develop the technology in fuel and associated disciplines is large. The capability to produce a number of isotopes individually or in concert enhances the flexibility of AEC to respond to market demands (quality as well as cost), to assess alternate (commercial) means of production and to attain maximum utility of government facilities.

PROGRESS DURING REPORT PERIOD

Channel Enlargement Program

The 44-tube one-inch overbore pilot installation was completed at C Reactor during January 1968.

Essentially the work went as planned. No significant problems developed in overboring the graphite or installing the channel hardware. Examination of the process channels before and after overboring showed the graphite to be in good condition and that the blocks were not significantly damaged by the machining operations. The block contains six ribbed aluminum process tubes, three guide-rail Zircaloy tubes, and 34 smooth-bore Zircaloy tubes. One channel was left bare and a thermocouple train installed to measure graphite temperatures.

The objective of initial operation of the block is to demonstrate plutonium production modes. The tubes were charged with rod-in-tube fuel elements containing uranium cores with 0.8 weight percent U-235. This enrichment was chosen for initial operation of the block to provide a base for evaluating reactivity and production characteristics of the overbore lattice. Future basic loadings of the block will consist of mixtures of 95 and 72 Metal fuel elements. Tube powers average 2250 kw, which is 50 percent higher than those normally experienced in the C Reactor.

DECLASSIFIED

At the end of FY-1968, the fuel had reached an average exposure of 700 MWD/T without incident.

An analysis of the graphite temperature data being obtained in the block demonstrated that significant moderator temperature reductions can be achieved by overboring. At current C Reactor tube power levels, the graphite temperature would be about 200 C less in the overbored reactor than in a normal lattice primarily because of the increased surface area for graphite heat removal.

The irradiation of a column of natural uranium rod-in-tube fuel elements was completed in the KER facility at about twice the normal C Reactor tube power levels. The fuel was discharged because of a fuel failure at 1140 MWD/T. The failure was judged to have resulted from excessive corrosion of the fuel supports. This problem was also encountered in normal fuel columns at high exposure in the K Reactors. A heavier support system with improved corrosion resistance was developed to remedy the problem and is being tested.

The irradiation of a column of simulated coproduct fuel elements was also completed in the KER facility. This fuel consisted of a natural uranium tube containing an aluminum rod. The purpose of the test was to obtain a preliminary evaluation of the inner support system proposed for coproduct fuels. The elements were discharged at 656 MWD/T without incident. Visual examinations indicate that the inner support system was satisfactory. Evaluation is continuing.

Preliminary work to define the requirements for overboring the K Reactors was completed. It appears that the present tooling and techniques for overboring will have to be modified for the K Reactors to prevent eventual tube flattening due to graphite distortion. The modification is required because the K stack operates at higher powers and therefore is contracting at higher rates than the C Reactor graphite. Various methods are being studied to obtain satisfactory tube life characteristics.

The hydraulic designs of 210 E-N coproduct fuel elements and highly enriched (Oralloy) fuel elements for testing in the overbore block were completed. These designs are being studied by Physics to establish lithium-6 and Oralloid concentrations needed to obtain the desired test conditions.

The installation of a mockup of an overbore channel was completed in the Thermal Hydraulics Laboratory to study the heat removal characteristics of this system. Steady-state hydraulic demand curves for tube powers up to 3400 kw were completed as the first phase of this program.

PCTR tests were completed to determine reactivity and production characteristics and behavior following water-loss or flooding of the one-inch overbore lattice. These data will be normalized using data obtained from operation of the C overbore pilot installation.

High Power Density Fuel Program

A demonstration consisting of 81 columns of 125 Metal fuel elements operating at 150 percent of the base specific power level was successfully completed. An

DECLASSIFIED

initial segment of the test which contained 20 columns of 501 (standard) uranium alloy cores was discharged at about 950 MWD/T after two failures, attributed to core cracking, had occurred. Evaluation of data from a prior high power density alloy test (PTA-040) supported use of a uranium alloy containing increased amounts of silicon. The second segment of the test was therefore fabricated with 801 alloy (350 Fe, 350 Si, 800 Al). Uranium performance was acceptable although two fuel failures were incurred in the second segment of the test, the first attributed to mechanical damage of the cladding and the second was an internal cladding failure. However, average exposures in the second segment of the test reached 2000 MWD/T.

Six columns of the test material discharged at about 1300 MWD/T have been examined and measured to determine dimensional behavior of the fuel. Satisfactory dimensional stability during irradiation was demonstrated by OD and ID changes of +0.003 and -0.003 inches, respectively. Fuel lengths increased up to 0.030 inches, and average warp was less than 0.002 inches. Maximum weight loss was six grams with some 0.010-0.020-inch deep groove corrosion being incurred.

An evaluation of both fuel and target performance was completed in a preliminary 210 E-N irradiation during the year. The demonstration was terminated at an average exposure of 1900 MWD/T when a test fuel element failed due to severe corrosion and subsequent failure of the supports. The standard alloy (501) uranium cores in which the silicon concentration had been increased to 170 ppm for grain refinement exhibited good dimensional stability. Weight losses to a maximum of 12.5 grams followed predictions. Both the lithium-aluminum alloy targets and the solid and hollow lithium aluminate (pellet) target elements performed satisfactorily.

A core alloy test consisting of a total of 160 columns of 301, 601, and 801 uranium alloy test fuels and controls of 501 (standard) alloy fuels was initiated in C Reactor. Solid and hollow induction heat-oil quench heat treatments are being evaluated in the test. The test is designed to evaluate fuel behavior in high exposure irradiations up to 3500 MWD/T, the test duration and level of exposure being dependent upon incremental discharges and examination of the test material.

Studies continued in evaluation and development of fuels surface coatings and treatments to improve corrosion behavior of the aluminum cladding. Work thus far has led to an anodic etch pre-treatment of the fuels to enhance the bonding of nickel plate to the aluminum. Fuels treated by this process have withstood preliminary testing by bubble test, caustic solution, and thermal cycling without separation of the nickel plate. Additional testing and evaluation is under way prior to the initiation of irradiation testing of the plate.

Development and evaluation of candidate aluminum cladding alloys proceeded with the preparation of test quantities of the alloys. Tests of the corrosion behavior and working properties of the alloys were initiated. Corrosion tests included both high temperature screening tests in a static system and flow testing under simulated reactor conditions. In addition to specific aluminum alloys being tested, a dual alloy cladding concept was included in the evaluation and testing operations. The dual alloy concept involves cladding by the hot-die-sizing process with an inner layer of high silicon-aluminum alloy

DECLASSIFIED

and an outer layer of 8001 alloy, the total system metallurgically bonded. The outer layer of 8001 alloy is intended to serve as a sacrificial anode to protect the inner cladding from galvanic corrosion.

Zircaloy-clad and aluminum-clad fuel elements were fabricated for irradiation testing of full length columns at 150 percent power in a K reactor. The production test authorization was in place at the end of the fiscal year and the fuel elements will be charged at the first opportunity in FY-1969.

Highly Enriched Fuels Program

A safety analysis was written to establish criticality limits for highly enriched fuels containing up to 7.1 percent by weight U-235 (reference 6).

A research and development program was designed to develop highly enriched fuels for the production of tritium in the Hanford reactors three years after initiation of the program (reference 7). Preliminary evaluation of the major problem areas lead to the conclusion that all are solvable without too much of an extrapolation from current technology. The cost of the program to develop highly enriched fuels for all the Hanford reactors was projected to total \$4.2 million over the three-year period.

Preliminary calculations using the MOFDA computer code were made to investigate tritium production in the K reactors using highly enriched fuels containing about 35 grams of Oralloy in aluminum per foot of charge (reference 8). The analysis further showed that the reactivity gain on coolant voiding should be acceptable on the basis of current criteria for loadings containing up to 50 percent highly enriched fuel.

Tests were completed in the PCTR to determine the reactivity and water-loss characteristics of highly enriched fuel-target loadings. Lattices consisting of 1) Oralloy fuel drivers and lithium targets, and 2) Oralloy and 95 Metal fuel drivers with lithium targets (spike concept) were studied. The experimental data obtained are currently being analyzed.

A production test was written and the fuel prepared to investigate aluminum cladding corrosion characteristics at high surface heat fluxes using uranium-aluminum fuel elements containing 7.1 and 4-1/8 weight percent U-235. The test will be performed after the completion of PCTR tests described above for which the fuel elements were required.

A uranium-aluminum fuel design in the I&E geometry was developed for use in a reactor test to define graphite heating and physics parameters. Preparations were made to order the fuel so that the test could begin by mid FY-1969.

DECLASSIFIED

Advanced Technology Program

An engineering feasibility study of the advanced technology program was completed in early CY 1968. The results indicated that tube powers of 6000 to 7200 kw would be achievable in the N Reactor with tube-in-tube fuel in the range of 22 to 28 pounds of uranium per foot. The combination of higher weights and powers would require boiling in the subchannels of the higher powered fuel columns.

As a result of the feasibility study, the scope of development of boiling technology can and will be confined to the following potential problem areas associated with net steam generation in fuel column subchannels.

1. Void-reactivity feedback
2. Hydrodynamic stability among subchannels
3. Fuel hot spot considerations
4. Safety factors in boiling burnout heat flux
5. Control of manufactured dimensions
6. System response during rapid transients

By the end of FY-1968, it is expected that all analysis will be complete in preparation for a single-tube demonstration of subchannel boiling. Work accomplished thus far is as follows:

1. Instrumentation and measurement requirements have been determined.
2. Mark I fuel selected for the test has been tested in an out-of-core loop to determine flow distribution to subchannels.
3. A computer code was developed to investigate the hydrodynamic stability characteristics of the fuel subchannels.
4. Technical interchange has been established with the Chalk River Nuclear Laboratories of the AECL to follow their progress in conversion of NPD to a boiling water reactor.
5. Preliminary results indicate the feasibility of utilizing acoustical methods to detect boiling.

In addition, much of the work accomplished under Mission 1 - Basic Production is directly applicable to the development of the advanced technology program. Among the significant items are:

1. Studies of the in situ application of protective coatings on graphite and/or process tube outside surface.

DECLASSIFIED

2. Improved fuel performance resulting from alloy modifications, support design, and changes in manufacturing process.
3. Studies on the feasibility of process control by an on-line computer.
4. Initiation of the Mark IV fuel development program.

EVALUATION OF EFFORT

Installation and initial operation of the 44-tube overbore pilot facility was successfully demonstrated on schedule. Reactor and fuels operating data are being compiled in preparation for studies and tests involving the use of alternate uranium alloys, higher enrichment fuels, and combined fuel-target assemblies.

Fuel and reactor technology have been demonstrated supporting operation of the single-pass reactors at tube powers 50 percent higher than those obtained in natural uranium loadings to provide six percent Pu-240 plutonium. Tests are in progress to investigate slightly enriched uranium fuel behavior at the exposures required to produce nondefense plutonium. Tests at higher power levels were not begun because of delays in obtaining approvals for the enriched fuel cores needed for the program, problems in scheduling and fabricating the uranium cores, and a shift in emphasis to highly enriched (Oralloy) fuels.

The development work of neither the fuel-coating processes nor the alternate aluminum alloy(s) progressed to the point where irradiation testing was justified; however, technology in each of these areas of study was advanced during the period. Active investigations are continuing to provide sufficient test data to support a decision concerning irradiation testing of the treated fuels.

The highly enriched fuel program was initiated and preliminary physics and fuel development work completed. Safety studies were completed and documented to establish criticality limits for these fuels. These studies clear the way for the handling of test quantities of highly enriched fuel in Hanford facilities.

The study of the engineering feasibility of the advanced technology modes at N Reactor has shown the program to be entirely feasible. A range of fuel weights and operating modes have been defined which cover the range between the extremes of maximum plutonium and maximum electrical production. The studies have shown that the operating level of N Reactor can be readily increased to 5600 Mwt with modest capital expenditure for plant modifications, and that the heat dissipation system would be capable of supplying sufficient steam, at a suitable pressure, for the generation of 1200 Mwe by WPPSS. Modest additional increases in reactor power above 5600 Mwt are also shown to be feasible although probably not justifiable because of the increased capital costs and higher technical risks.

The study shows that, although feasible, operation with net steam generation would probably be unnecessary at the 5600 Mwt power level. Thus, the major technical problem will be the development of the technology required to permit sub-channel boiling only.

DECLASSIFIED

There are, of course, other problems of a substantial nature to be solved prior to the attainment of the optimum mode of operation, e.g., reactivity control, systems control, reactor life considerations and safety considerations. Studies have already been initiated under Mission 1 - Basic Production and 8 - Nuclear Safety to resolve many of these problems.

The feasibility study has shown that all major systems will be adequate for the higher power operation, although minor equipment modifications will be necessary. The really major capital expense will be third turbine-generator necessary to exploit the additional steam capability, which would accrue to WPPSS account.

BUDGET PERIOD PLANS

Channel Enlargement Program

The demonstration of plutonium production modes will be completed in the 44-tube overbore pilot installation. Coproduct fuels will be developed employing both slightly enriched uranium and highly enriched oralloy drivers with lithium-aluminate targets and their irradiation stability demonstrated. Operation and testing in the overbore facility will include the use of natural uranium and 0.95 w/o U-235 enriched uranium fuels for basic loadings. The use of alternate uranium alloy cores, uranium oxide cores, and as-extruded uranium cores will be evaluated.

Overbore tooling and hardware will be developed for the K Reactors and up to four channels overbored to demonstrate the integrity of the reactors' graphite. Graphite distortion behavior will be projected from experimental data to provide a basis for K overbore tooling development.

Physics and thermal hydraulics tests and analyses will be completed to establish the basic reactivity, water-loss and flooding characteristics and coolant instability and burnout limits of the overbored reactors. Detailed engineering and safety studies will be made of the single-pass reactors operating with enlarged process channels and larger diameter fuel elements.

A program chart outlining the steps leading to a program to overbore the single-pass reactors beginning in July 1972 is shown in Figure 1.

Highly Enriched Fuel Program

The effort in this program during the budget period will concentrate on the development and demonstration of the spike fueling concept for tritium production in the single-pass reactors. A preliminary engineering and safety analysis of highly enriched fuel loadings will be completed to better define the areas requiring research and development. The tests in the Physical Constants Test Reactor, initiated in FY-1968, will be completed and the results analyzed. An irradiation test will be performed to obtain physics and graphite heating data. Graphite temperature limits will be defined and the effects of Oralloy fuel operation on reactor life established.

Fuel development studies including the development of alternate fuel diluents, fuel support systems, and fabrication processes will be continued. Particular

DECLASSIFIED

PROGRAM SCHEDULE - CHANNEL ENLARGEMENT
FIGURE 1

emphasis will be placed on the development of an integral fuel-target design for current process tubes to increase safety in refueling operations at the reactors.

A program chart outlining the steps required to develop the spike concept so that a demonstration loading may be performed in the K reactors in FY-1972 and the steps required to develop full reactor loadings using highly enriched fuels are shown in Figure 2.

High Power Density Fuel Program

The irradiation tests of full length columns of Zircaloy-clad and aluminum-clad fuel elements at 150 percent tube power in the K reactors will be completed. Initiation of tests at higher powers up to the 200 percent level will depend on the availability of funds and priority with respect to highly enriched fuels. It is expected that power level limits based on failure potential will be established for both Zircaloy-clad and 8001-F aluminum-clad fuels.

Uranium alloy irradiations will be completed at exposures up to 3500 MWD/T. Based on the results of these irradiations, an alloy will be selected to replace the now standard 501 alloy for the single-pass reactors.

With the objective of providing an aluminum-clad fuel having capability of withstanding more severe corrosion environments, development and testing of nickel-plated fuels processes is expected to be completed and an irradiation test of a selected fuel element plating initiated in FY-1969. During the period, work will continue on the technical and economic feasibility of using thin Zircaloy cladding for single-pass reactor fuel elements.

It is likely that funding and manpower will be limited for this program because of emphasis on the other programs in the mission. A program chart outlining the steps required to complete the program is shown in Figure 3 on the basis that the program will continue to gain support.

Advanced Technology Program

DECLASSIFIED

Subchannel boiling tests will be conducted in early FY-1969 using the Mark I fuel. The results of this initial experiment will set the tone of the later tests, which will be performed using the Mark IV fuel, by defining the conditions and providing the basis for the further study of boiling technology.

Two-phase pressure drop experiments will be performed using the Mark IV fuel. The results will be correlated with the results from the Mark I and Mark II experiments.

The technical basis leading through design studies to installation of equipment will be developed for such diverse systems as in-core power monitoring, automatic process control via a hybrid computer, and supplemental reactivity control.

Fuel development studies, including alloy development, clad thickness reduction, and development of novel end closures and support systems, will be continued. The studies are expected to yield a fuel design which will have the thermal,

DECLASSIFIED

PROGRAM SCHEDULE - HIGHLY ENRICHED FUEL PROGRAM
FIGURE 2

DECLASSIFIED

PROGRAM SCHEDULE - HIGH POWER DENSITY FUEL
FIGURE 3

hydraulic and irradiation characteristics required by the advanced operational modes and be in the 26 to 27 pound per foot weight class. The phenomena of hot spot failure experienced with the Mark II fuel will be thoroughly investigated and the results factored into the design of this high-performance fuel.

Detailed steady-state and transient analyses of existing systems will be performed to determine their capability for operation at the higher power level. Interacting systems and controls will be analyzed to verify their ability to adequately handle the various plant transients which could occur. Where systems are found to be inadequate, design studies will be performed and supported by the required research and development effort to provide the equipment modifications necessary to upgrade the systems. Implementation of the design changes is expected to be essentially completed by late FY-1972.

A program chart outlining the steps leading to the completion of the advanced technology program and attainment of the optimum operating mode are shown in Figure 4. Naturally, many of the less important steps have been omitted. However, significant developments in the other missions are included to provide an insight to the total N Reactor program.

DECLASSIFIED

DECLASSIFIED

ADVANCED TECHNOLOGY PROGRAM

FIGURE 4

MILESTONES

Channel Enlargement Program

Complete PCTR tests - plutonium production mode.	July 1968
Complete 210 E-N coproduct fuel development.	December 1968
Complete demonstration of plutonium production mode.	January 1969
Charge initial 2-3 tubes test of highly enriched U-Al fuel.	March 1969
Define K Reactor graphite distortion characteristics.	March 1969
Overbore 2-4 K Reactor channels to demonstrate graphite stack integrity.	April 1969
Complete laboratory thermal hydraulics program.	July 1969
Complete uranium-aluminum fuel development in the overbore geometry.	August 1969
Complete physics tests of coproduct fuels.	September 1969
Complete demonstration irradiation of 210 E-N fuels.	January 1970
Establish K Reactor overbore equipment and techniques.	January 1970
Charge highly-enriched (U-Al) fuel demonstration test-spike loading concept.	February 1970
Complete highly enriched fuel spike loading.	January 1971
Charge highly enriched fuel-target demonstration test.	February 1971
-Safety Analysis Reports complete.	January 1972
Initiate channel enlargement in lead reactor.	July 1972

Highly Enriched Program

Spike Fuel Loadings

Complete preliminary safety analysis of highly enriched fuel models.

November 1968

DECLASSIFIED

Define graphite heating and physics parameters.	January 1969
Establish graphite temperature limits.	July 1969
Define fuel design for spike program.	December 1969
Design loading for tritium production.	July 1970
Complete thermal hydraulics and physics programs.	December 1970
Complete fuel and target fabrication development.	July 1971
Complete final engineering and safety analyses.	July 1971
Fabricate fuel and targets for demonstration loading.	November-December 1971
Charge demonstration loading.	January 1972
Spike concept demonstrated for tritium production mode.	October 1972

Full Reactor Loadings

Define materials criteria for advanced fuel loadings.	January 1972
Complete design of advanced fuel for test loadings.	March 1972
Initiate irradiation tests of advanced fuel.	November 1972
Complete physics and thermal hydraulic tests of advanced fuel loadings.	January 1973
Complete advanced fuel development.	December 1973
Design production fuel.	July 1974
Fission product release studies.	FY-1973-1974
Safety Analysis Report.	FY-1974
Demonstration loading.	FY-1974

DECLASSIFIED

High Power Density Fuel Program

Technology complete for fuel operation at 150 percent power conditions.	July 1968
Complete Zircaloy-clad fuel evaluation at 150 percent power conditions.	December 1968

Initiate tests at 200 percent power	January 1969
Define uranium alloy for improved high exposure performance.	March 1969
Establish subcooled burnout correlations.	July 1969
Define Zircaloy-clad fuel power limits.	August 1969
Define aluminum-clad fuel power limits.	December 1969
Charge test to demonstrate high power density fuels at 175-200 percent power.	January 1970

Advanced Technology Program

Start retubing of steam generators.	1967
Initiate installation-effluent control project.	July 1967
WPPSS decision for third turbine-generator.	July 1968
Initiate Mark IV boiling tests.	July 1968
Initial charging Mark IV production fuel.	October 1968
Increase power level to 4400 Mwt.	July 1969
Complete steam generator retubing.	July 1970
Initial charging optimized Mark IV fuel.	July 1970
Full core boiling demonstration - Mark IV fuel.	July 1970
Complete effluent control project.	July 1970
Increase power level to 4800 Mwt.	July 1970
Initiate Mark VI fuel development.	July 1970
Initiate plant capital modifications.	July 1970
Complete Mark IV boiling tests.	January 1971
Initiate Mark VI tests.	January 1971
Increase power level to 5200 Mwt.	April 1971
Initiate full reactor boiling tests with optimized Mark IV fuel.	April 1971

DECLASSIFIED

Complete capital improvements.	December 1971
Increase power level to 5600 Mwt.	January 1972
Initial charging Mark VI production fuel.	July 1972
Complete Mark VI boiling tests.	October 1972
Complete transition to Mark VI fuel.	July 1973
Start normal operation at 5600 Mwt-1200 Mwe	January 1974

DECLASSIFIED

REFERENCES

1. RL 3-7, "Richland Five-Year O2 R&D Program - Target Space Enhancement," by Richland Operations Office, et. al., dated 6/30/67. (SECRET)
2. DUN-3214, "PTA-103, Operation and Evaluation of a 44-Tube Reactor Modernization Facility in 105-C," by W. K. Alexander, R. E. Baars, and J. C. Nosler, dated 12/8/67. (SECRET)
3. DUN-3213, "Production Test Authorization - 102 - Installation of 44-Tube Reactor Modernization Test Facility at 105-C," by C. E. Bonham and W. K. Alexander, dated 1/12/68. (UNCLASSIFIED)
4. R. E. Baars, "One-Inch C Reactor Overbore Facility Hydraulics Data," dated 2/1/68. (CONFIDENTIAL)
5. DUN-4003, "44-Tube Overbore Reactor Modernization Test Facility - 105 C Building - Outage Summary Report," by R. G. Knirck, dated 3/19/68. (SECRET)
6. DUN-3800, "Criticality Safety Analysis Report - Uranium-Aluminum Fuel Elements (7.1 Percent by Weight U-235)," by A. K. Hardin, dated 2/19/68. (UNCLASSIFIED)
7. DUN-3810, "Highly Enriched Fuel Development Program," by P. A. Carlson, H. E. Jackel, and R. D. Shimer, dated 4/17/68. (SECRET)
8. DUN-3530, "Tritium Production Using Highly Enriched Fuel," by R. L. Miller, dated 12/18/67. (SECRET)
9. DUN-3222, "Use of 170 Metal for High Power Density Testing," by T. W. Ambrose, dated 10/13/67. (SECRET)
10. DUN-3262, "Support Corrosion Problem," by P. A. Carlson and L. H. Rice, dated 10/19/67. (SECRET)
11. DUN-3037, "PTA-098, High Exposure G3E Core Alloy Test," by G. L. Smith, dated 12/7/67. (SECRET)
12. BNWL-CC-1660, "Examination of High Power Density Fuels from PTA-040," by J. W. Weber and J. W. Goffard. (To Be Issued)
13. DUN-3896, "Metallurgy Examination of 125 Fuel Element Failure in KW Reactor, PTA-067," by R. W. Toivenen, dated 2/26/68. (SECRET)
14. DUN-4145, "125 Mechanical Damage Failure - KW Reactor, PTA-067," by R. W. Toivenen, dated 4/10/68. (SECRET)
15. DUN-3853, "Design Test No. 1394 - Results of Flow Calibration of Venturi- Orifice Flowmeters," by W. N. Adachi, dated 4/26/68. (SECRET)

DECLASSIFIED

References (Cont.)

16. DUN-3576, "Advanced Technology Engineering Feasibility Study," by N Project Engineering Staff, dated 1/18/68. (CONFIDENTIAL)
17. DUN-3170, "Number of Fission Chambers in Graphite Coolant Tubes Required to Accurately Measure Peak-to-Average Power Ratios at NPR," by G. R. Correll and R. M. Schein, dated 9/27/67. (CONFIDENTIAL)
18. DUN-3562, "Alternative Systems for Complete In-Core Flux Monitoring at N Reactor," by T. E. Dabrowski, dated 1/3/68. (UNCLASSIFIED)
19. DUN-4121, "Summary of Advanced Technology Engineering Feasibility Study," by C. W. Kuhlman, to be issued. (CONFIDENTIAL)

DECLASSIFIED

RICHLAND
OPERATIONS OFFICE

RESEARCH AND DEVELOPMENT STATISTICAL SUMMARY

02 PROGRAM

HAN- _____

1. MISSION NO. AND TITLE <u>7 - Target Space Enhancement</u>		2. BUDGET ACTIVITY NO. <u>02-50-10-5</u>	
MISSION SUB-PROGRAM TITLE _____		<u>02-50-10-10</u>	
3. CONTRACTOR AND	A. <u>DUN (N)</u>	4. PERSON IN CHARGE: <u>J. W. Riches</u>	
CONTRACTOR	B. _____	INVESTIGATOR: <u>M. Lewis</u>	
NUMBER	C. _____	INVESTIGATOR: <u>R. H. Shoemaker</u>	
	AT (45-1)-1857		

FIVE YEAR FORECAST

	CURRENT BUDGET YEARS *		FY 1971	FY 1972	FY 1973	5 YEAR TOTAL
	FY 19 69	FY 19 70				
5. MAN-YEARS						
A) SCIENTIFIC AND TECHNICAL	6.2	8.8				
B) OTHER	3.1	4.3				
TOTAL	9.3	13.1				
6. COSTS (\$000'S)	\$ 191	\$316.2	\$	\$	\$	\$
A) DIRECT LABOR (INCL. COST OF SERV.)						
B) MATERIALS, TECH. SERV., SUB CONTRACTS						
C) SPONSORED WITH BNW	160	298				
TOTAL DIRECT	351	614.2				
D) INDIRECT EXPENSES	49	85.8				
TOTAL OPERATING COSTS	400	700	600	625	650	2975
E) EQUIPMENT (NEW)	0	0				
F) IRRADIATION UNIT COSTS						

7. COMMENTS:

DECLASSIFIED

U. S. ATOMIC ENERGY COMMISSION

RICHLAND
OPERATIONS OFFICE

RESEARCH AND DEVELOPMENT STATISTICAL SUMMARY

02 PROGRAM

HAN- _____

1. MISSION NO. AND TITLE <u>7 - Target Space Enhancement</u>		2. BUDGET ACTIVITY NO. <u>02-50-10-5</u>	
MISSION SUB-PROGRAM TITLE _____		<u>02-50-10-10</u>	
3. CONTRACTOR AND A. <u>DUN (CK)</u>		4. PERSON IN CHARGE: <u>TW Ambrose</u>	
CONTRACTOR B. _____		INVESTIGATOR: <u>PA Carlson</u>	
NUMBER C. _____		INVESTIGATOR: _____	

FIVE YEAR FORECAST

	CURRENT BUDGET YEARS *		FY 1971	FY 1972	FY 1973	5 YEAR TOTAL
	FY 1969	FY 1970				
5. MAN-YEARS						
A) SCIENTIFIC AND TECHNICAL	6.3	6.4				
B) OTHER	1.2	1.4				
TOTAL	7.5	7.8				
6. COSTS (\$000'S)	\$	\$	\$	\$	\$	\$
A) DIRECT LABOR (INCL. COST OF SERV.)	170	175				
B) MATERIALS, TECH. SERV., SUB CONTRACTS	34	26				
C) SPONSORED WITH BNW	190	240				
TOTAL DIRECT	394	441				
D) INDIRECT EXPENSES	56	59				
TOTAL OPERATING COSTS	450	500	600	625	650	2825
E) EQUIPMENT (NEW)	0	0				
F) IRRADIATION UNIT COSTS						

7. COMMENTS:

DECLASSIFIED

DISTRIBUTION

RICHLAND OPERATIONS

1-24. D. G. Williams

ATLANTIC RICHFIELD HANFORD COMPANY

25. B. M. Dobbs/J. Christy	31. H. P. Shaw
26. J. B. Fecht	32. A. E. Smith
27. B. B. Field	33. P. W. Smith
28. W. M. Harty	34. W. G. Smith
29. H. C. Rathvon	35. M. J. Szulinski
30. L. M. Richards/R. P. Corlew	36. R. E. Tomlinson/R. E. Esacson
	37. ARHCO Files

BATTELLE-NORTHWEST

38. F. W. Albaugh	46. J. J. Fuquay
39. J. M. Batch	47. R. E. Nightingale
40. C. A. Bennett	48. H. M. Parker
41. R. E. Burns	49. A. M. Platt
42. F. G. Dawson	50. W. D. Richmond
43. D. R. deHalas	51. C. A. Rohrmann
44. E. A. Eschbach	52. E. E. Voiland
45. E. A. Evans	53. R. G. Wheeler
	54. D. C. Worlton

DOUGLAS UNITED NUCLEAR, INC.

55. T. W. Ambrose	65. N. R. Miller
56. P. A. Carlson	66. W. S. Nechodom
57. D. H. Curtiss	67. R. Nilson
58. G. C. Fullmer	68. G. F. Owsley
59. R. G. Geier	69. R. W. Reid
60. C. D. Harrington	70. J. W. Riches
61. C. W. Kuhlman	71. R. K. Robinson
62. M. Lewis	72. O. C. Schroeder
63. W. M. Mathis	73. C. H. Shaw
64. J. M. McMahon	74. R. H. Shoemaker
	75. J. T. Stringer

DECLASSIFIED