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RESEARCH AND DEVELOPMENT
IRRADIATION PROCESSING DEPARTMENT

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SEMIANNUAL REPORT
RESEARCH AND DEVELOPMENT
IRRADIATION PROCESSING DEPARTMENT

O. H. Greager
Research and Engineering

December 1, 1964

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SEMIANNUAL REPORT
RESEARCH AND DEVELOPMENT
IRRADIATION PROCESSING DEPARTMENT

INTRODUCTION

The 02 Research and Development program for the Irradiation Processing Department is contained in seven 189-forms, R-1 through R-6 and M-1 and M-2. The subprograms designated by R pertain to reactor research and development, and those designated by M pertain to the metallurgy or the fuels research and development. This report covers the progress in each of the subprograms on an individual basis and follows the format proposed by RL00. Although the reports are brief, the results are presented in a semitabular form and are essentially complete. Only the activities of the first four months of the fiscal year are included. It should be noted that the over-all IPD program is based on a nearly uniform expenditure of funds over the entire year and the expenditures to date reflect this general pattern. A number of items are listed in the reports on the subprograms that have been performed on product cost funds but were made possible by the research and development effort.

The next report in this series will be issued near the end of the fiscal year. At that time a better assessment of progress toward accomplishment of the fiscal year objectives will be possible. The report will also contain statements reflecting our judgment regarding the desirability program re-orientation and possible new programs which appear pertinent to IPD activities.

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Program: 02 Reactor IPD
Project: 02 50 10 10
Title: Radioisotope Reduction Reactor Effluent (R-1)
Responsible Manager: O. H. Greager
Responsible Investigator: R. G. Geier
Reporting Period: July 1, 1964, through October 31, 1964

	<u>Prior Year</u>	<u>FY to Date</u>	<u>Period</u>	<u>FY Estimate</u>	<u>Previous FY Estimate</u>
Costs (Thousands)	250	33.3	4 months	185	183
Scientific Manpower (Man-years)	4	0.5	4 months	3	3

I. Project Scope and Objective

The program is designed to develop processes for reducing the amount of radioisotopes present in the coolant leaving the Hanford reactors. Areas of study include finding methods for: (1) removing the parent materials responsible for radioisotope formation from the process water, (2) eliminating or reducing the time of adherence of parent materials to the in-reactor films by changes in the chemical constitution of water, chemical form of parent materials, or changes in the reactor film itself, and (3) treating the effluent to remove the radioisotopes after formation.

II. Major Accomplishments to Date

During the course of the program, several methods have been devised which are each capable of reducing the effluent activity by a factor of about two for the isotopes of most concern. The methods are:

1. Water treatment using high aluminum sulfate feed rates. This process has been in use since July 1961.
2. Water treatment using high aluminum nitrate feed rates with nitric acid for pH adjustment.
3. The addition of sodium silicate to treated water.
4. Passage of the reactor effluent through aluminum beds.

In addition, schemes for effluent disposal by an inland lake and by trenching were conceived.

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III. Progress During Report Period

1. It was demonstrated in single tube in-reactor testing that a combination iron and aluminum sulfate flocculating agent showed no improvement over aluminum sulfate as far as the concentration of P-32 in the effluent is concerned.
2. In-reactor testing using CO₂ for pH adjustment was initiated.
3. A half-plant test to define the effect of filter cycles was started.
4. A test to determine the effect of coolant pH on effluent activity was completed and showed only a minor pH effect.
5. The facilities to carry out a small-scale trenching experiment were installed.
6. A half-plant test demonstrated that there was no advantage in using purchased liquid alum vice bauxite alum from an effluent activity standpoint.
7. Preliminary planning was completed for a half-plant sodium silicate test.
8. A program of raw water and filter effluent analyses for parent materials was instituted.
9. A single-tube test to determine the effect of mechanical film removal during shutdown demonstrated essentially no reduction in radioisotope discharges.

IV. Evaluation of Effort to Date

The program has devised several methods for reducing effluent activity. However, each of the methods is expensive and particularly so when considered in light of the benefits which might be obtained. Continued work at approximately the same level of effort will be directed toward conceiving new and more economical processes, resulting in effluent activity reductions as well as improvements through optimization of the present process and its control.

V. Next Report Period Activities

1. The effluent activity effects of sodium silicate addition to process coolant will be defined on a half-plant scale.
2. Preliminary evaluation of the effluent activity and corrosion effects resulting from using CO₂ for coolant pH control will be completed.
3. An initial evaluation of the infiltration rates and effluent decontamination aspects will be obtained from the trench test at F Reactor.

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4. In-reactor studies using deionized water and chemical additions thereto will be continued.
5. The effect on effluent activity of the location of the point of acid addition for pH control will be determined.
6. The effect on effluent activity of continuous purging will be determined.
7. Filter effluent will be meticulously analyzed for particulate and chemical constituents so that filter performance can be determined.
8. Using the measure of filter performance as determined above differences in filter operation and make-up will be evaluated.
9. In-reactor tests using both raw river water and super-filtered water will be carried out.

VI. Topical Reports Issued

1. HW-49485, "The Origin of Certain Radioisotopes in Hanford Reactor Cooling Water," R. E. Ewing, April 24, 1957.
2. HW-52908, "The Depletion of Radioisotopes from the Columbia River by Natural Processes," J. M. Nielsen and R. W. Perkins, October 4, 1957.
3. "Interim Report on the Origin of Reactor Effluent Water Radioisotopes, Analysis of Turco Purge Material," R. W. Perkins, June 3, 1958.
4. HW-59029, "The Decontamination of Reactor Cooling Water with Aluminum," W. B. Silker, January 28, 1959.
5. HW-60154, "The Chemical Form of Phosphorus-32 in Hanford Reactor Effluent," W. B. Silker, April 24, 1959.
6. HW-61325, "Significance of Rupture Debris in the Columbia River," J. D. McCormack and L. C. Schwendiman, August 17, 1959.
7. HW-62874, "The Effect of Temperature and Flow Velocity on the Decontamination of Reactor Effluent Water with Aluminum," W. B. Silker, December 1, 1959.
8. HW-63633, "Kinetics of Arsenic Retention in Hanford Reactor Cooling Systems," W. B. Silker, February 11, 1960.
9. HW-64961, "Radioisotope Concentration in the Effluent from a Zircaloy-2 Process Tube," R. W. Perkins, May 2, 1960.
10. HW-68387, "Removal of Radioisotope Parent Material by Producing High Purity Process Water," R. W. Perkins, February 10, 1961.

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11. HW-69076, "A Method for Automatically Monitoring Radioarsenic in Effluent Streams," W. B. Silker, April 20, 1961.
12. HW-69083, "On the Origin of Radiophosphorus in Hanford Reactor Effluent Water," W. B. Silker, April 20, 1961.
13. HW-69060, "The Effect of Iron on Reactor Effluent Radioactivity," W. B. Silker, April 20, 1961.
14. HWSA-2192, "The Effectiveness of High Coagulant Feed in Reducing Hanford Reactor Effluent Radioisotope Concentrations," W. B. Silker, July 14, 1961.
15. HW-72215, "Pilot Scale Aluminum Bed Decontamination of Reactor Effluent," H. G. Rieck, March 1962.
16. HW-71583, "Mineral Adsorption of Phosphorus-32 from Reactor Coolant," D. W. Benson, March 1962.
17. HW-72926, "Optimum Alum Feed Rates at 100-K Reactors," W. B. Silker, March 7, 1962.
18. HW-73316, "Activity Buildup in New Process Tube Effluent," W. B. Silker, April 10, 1962.
19. HW-75782, "Reduction of the Effluent Water Radionuclides by the Addition of Sodium Silicate to Process Water," R. W. Perkins and D. E. Robertson, December 10, 1962.
20. HWSA-3147, "Variations in Elemental Concentrations in the Columbia River," W. B. Silker, July 22, 1963.
21. HW-79279, "Preliminary Measurement of the Adsorption of Reactor Effluent Water Radionuclides by Columbia River Particulate Material," L. L. Humphreys and R. W. Perkins, October 16, 1963.
22. HW-75976, "The Effect of Chemical Additives and Coating Materials on the Adsorption of Radionuclide Parent Elements on Aluminum Surfaces," R. W. Perkins and D. E. Robertson, December 26, 1963.
23. HW-80557, "Reduction of Radionuclides in Reactor Effluent Water: Final Report on the Effects of Chemical Additives and Coating Materials on the Adsorption of Radionuclide Parent Elements in Process Water on Aluminum Surfaces," D. E. Robertson and R. W. Perkins, December 23, 1963.
24. HW-80022, "A Concept and Proposed Field Test for Decontamination of Reactor Effluent," J. L. Nelson and G. J. Alkire, December 27, 1963.
25. HW-84182, "The Effect of Coolant pH on Phosphorus-32 Concentration in Small Reactor Effluent," R. G. Geier, September 22, 1964.

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Program: 02 Reactor IPD
 Project: 02 50 10 10
 Title: Nuclear Safety (R-2)
 Responsible Manager: O. H. Greager
 Responsible Investigator: T. W. Ambrose
 Reporting Period: July 1, 1964, through October 31, 1964

	<u>Prior Year</u>	<u>FY to Date</u>	<u>Period</u>	<u>FY Estimate</u>	<u>Previous FY Estimate</u>
Costs (Thousands)	187	40.5	4 months	167	161
Scientific Manpower (Man-years)	5	0.7	4 months	4	4

I. Project Scope and Objectives

The effort comprises a continuing nuclear safety program which has the prime objective of upgrading the safety status of the reactors and/or providing development as necessary to assure that deterioration of reactor components and proposed operating techniques and conditions do not reduce the safety of the reactors. The program consists of studies in both physics and engineering fields.

II. Major Accomplishments to Date

1. Computer codes have been acquired or developed, codes have been grouped into chains, and codes have been modified to provide a useful and highly efficient library of codes applicable to nuclear safety studies.
2. Theoretical work of significance has been accomplished in the field of scattering kernels, multigroup diffusion theory, exponential pile data reduction, reactor kinetics, reduced delayed neutron constants, control rod calculations, fission product buildup, and physics-engineering aspects of reactor design. Significant completed studies involved scattering law calculations by exact treatment of two resonances and modified gas model studies for graphite-uranium and graphite-plutonium systems.
3. Basic kinetic investigations have been used to quantitatively establish operating parameters for the automatic instrument package currently under development which will cover all levels of operation.
4. A comprehensive review and evaluation of safety control criteria and requirements have been initiated to evaluate safety system serviceability in view of moderator distortion. The physics work will serve as a bases for establishing firm control requirements and for determining adequacy of various alternative courses of action.

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5. Important lattice parameter data, temperature coefficient data, reactivity data, and control system data were obtained during K startups. These data have served useful purposes in improving understanding of the physics of the reactors.
6. Resonance neutron capture in uranium rods was measured in the Hanford Test Reactor yielding early information basic to the knowledge of Doppler coefficients in the Hanford reactors.
7. Comprehensive exponential pile measurements of the multiplicative properties of enriched uranium-water lattices have provided basic critical mass data of importance to safe fuel storage.
8. Comprehensive theoretical and experimental work has been carried out over a number of years to enable evaluation of the consequences of the loss of coolant accident in the Hanford reactors. The work has included void coefficient measurements in many lattice arrangements, boilout measurements, safety system response determinations, analog and digital computer analyses, and establishment of basic control criteria.
9. Hazards Summary Reports for the production reactors have been prepared.
10. Measurements were made on the control worth of splines and how the worth varied with boron depletion and spline corrosion. These measurements have enabled more economic use of splines.
11. A comprehensive analytical review of instrumentation protection has been completed which, for the first time, establishes quantitatively and realistically technical bases for upgraded reactor instrumentation systems.
12. Reliability studies have been carried out for the Panellit and Beckman systems. Improvements have been developed in the seismoscope systems based on analytical review. All safety systems and circuits receive continual review.
13. A fundamental laboratory program of cross section measurements has been partially supported over the past years. Knowledge of cross sections of important reactor materials is fundamental to reactor safety.
14. Unstable boiling and burnout conditions for Hanford process tubes under a large variety of possible operating situations have been identified. Most recent studies have been directed toward characterizing the behavior of self-supported fuel element designs.

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15. The behavior of the fuel columns during flow-loss and power-surge accidents, including experimental investigations of front connector failures, loss of pumping capability, and sudden plugging of the process tube system, have been established.
16. The effect of fuel eccentricity on the burnout heat flux has been determined.
17. The effect of local disturbances in the coolant flow passage, such as self-supports or bumpers on the fuel surface, on the conditions resulting in local boiling in the fuel column have been evaluated.
18. The effort to improve the understanding of and compensate for moderator contraction has resulted in the following achievements:
 - a. Efficient channel broaching techniques have been developed.
 - b. Projections of future stack distortion have been obtained from experimental irradiations.
 - c. A probe was developed which provides accurate measurement of channel dimensions and distortion.
 - d. A flexible safety rod which can follow channel curvature has been developed.
19. A prototypical in-core flux monitor has been installed on-reactor.

III. Progress During Report Period

1. Comprehensive hazards analyses of the enriched uranium-thoria reactor loading for U-233 production were completed and supplements to the principal Hazards Summary Reports for the IPD reactors were issued.
2. Work continued on basic nuclear safety studies and computer code development. Principal emphasis has been toward new fuel-and-target lattice, particularly the U-233 producer.
3. The evaluation of control requirements and adequacy of alternate solutions to the present control systems was continued.
4. The design of a reactor process tube mockup to be used to study heat transfer characteristics at higher tube power has been completed and components are on order.
5. The analysis to determine the mechanisms which cause distortion of the K Reactor moderator stacks has been completed.
6. The loss of 3X balls in the separations between graphite blocks in the stack has been defined and some ball hoppers have been removed from service to minimize the possibility of balls lodging in the voids and causing a permanent reactivity loss.

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7. An effort to develop methods of filling the voids in the moderator stack was initiated.
8. The installation of flexible vertical safety rods and channel broaching maintained the operability of all vertical safety rods within the specified limits.
9. Laboratory operation of the high-speed scanner prototype continued to accumulate sufficient hours of operation for system evaluation.
10. Reactor operating data were accumulated on the in-core flux monitor.

IV. Evaluation of Effort to Date

The research and development effort in support of reactor safety has always been considered of primary importance, and a continuous program has been in progress. The fact that the Hanford reactors are operating at many times their design basis without nuclear incident is conclusive proof of the value of the program. An analysis of the safety of new reactor loadings and the safety impact of changes due to reactor aging or operating modifications can be made efficiently and satisfactorily. In order to insure maintaining these capabilities, a similar level of effort is anticipated for FY-1966.

V. Next Report Period Activities

1. The effort on basic nuclear safety studies and computer code development will continue.
2. The evaluation of control requirements and the adequacy of alternate solutions to the present control systems will continue.
3. Nuclear safety studies directed toward establishing the feasibility of: (1) plutonium burning, (2) major lattice modifications to maximize production of alternate products, and (3) the use of higher enrichment fuels will be carried out.
4. Measurements will be made to determine the reactivity effect of coolant loss in enriched fuel lattices.
5. The fabrication of the heat transfer mockup will be completed, and tests to demonstrate the feasibility of operation up to fuel column powers of 3800 kw will be initiated.
6. Stack distortion mechanism studies will be refined to permit a better estimation of the forces which must be resisted by vertical safety rod channel liners.
7. In-reactor testing to determine feasibility of methods for filling safety rod channel separations to prevent loss of 3X balls will be initiated.

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8. Tests will be performed on a prototypical control system designed to replace 3X balls in selected regions of K Reactor.
9. Laboratory operation of the high-speed scanner for system evaluation will continue.
10. Performance evaluation of the in-core flux monitor will continue.

VI. Topical Reports Issued

1. HW-36825, "Temperature Coefficients of Heterogeneous Reactors - I," G. W. Stuart, May 25, 1955.
2. HW-37158 PT 2, "K Pile Startup Experiments, Part II, Measured Temperature Coefficients of Reactivity," J. H. Brown, June 14, 1955.
3. HW-37766, "Resonance Capture of Neutrons by Uranium Cylinders," M. V. Davis, August 18, 1955.
4. HW-37158 PT 1, "K Pile Startup Experiments, Part I, Critical Size Determination of Lattice Characteristics," C. L. Miller, November 1, 1955.
5. HW-39587, "Nuclear Safety Summary - Natural Uranium Loadings," J. H. Brown, et al., December 27, 1955.
6. HW-40930, "Exponential Pile Measurements in Water Moderator Lattices with Enriched Uranium Rods," E. D. Clayton and H. Neumann, January 16, 1956.
7. HW-42302, "Reactivity Effect of Large Volume Expansions," A. W. Thiele, March 29, 1956.
8. HW-37158 PT 3, "K Pile Startup Experiments, Part III, Reactivity Effects of Fuel and Target Materials," C. L. Miller, April 2, 1956.
9. HW-37158 PT 4, "K Pile Startup Experiments, Part IV, Evaluation of Safety and Control System Capacities," C. L. Miller, July 2, 1956.
10. HW-50284, "Total Control Requirement - Hanford Piles," J. H. Brown, May 21, 1957.
11. HW-51659, "Specification A-020 Process Tube Instability Limits," K. W. Hess, July 22, 1957.
12. "Process Tube Boilout Experiments," D. C. Pound and G. J. Busselman, August 23, 1957.
13. HW-52339, "Speed-of-Control in Hanford Reactors," J. C. Peden, et al., September 16, 1957.

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14. HW-52282, "Graphite Temperature Coefficient of Reactivity vs. Fuel Exposure - KE Reactor (Final Report, PT-105-600 A)," R. O. Gumprecht, et al., September 20, 1957.
15. HW-53221, "Special Hazards Report - I&E Fuel Loads," J. H. Brown, et al., October 15, 1957.
16. HW-53523, "PT-IP-126-C, Comparison of Ball 3X Column and VSR Reactivity Effects," D. E. Simpson, November 8, 1957.
17. HW-53693, "Review of the Speed-of-Control Criterion," J. H. Brown, November 22, 1957.
18. HW-54188, "Total Control Problem - Hanford Reactors," J. H. Brown, December 16, 1957.
19. HW-54516, "Measurements of K-Pile Lattices in the PCTR," R. I. Smith, January 13, 1958.
20. HW-56621, "Experimental Results of Tests Simulating Plugging of a K Tube with I&E Slugs," D. E. Fitzsimmons and G. M. Hesson, July 7, 1958.
21. HW-57616, "Experimental Results of Tests Simulating Plugging of a C Tube Charged with I&E Fuel Elements," G. M. Hesson, et al., October 1, 1958.
22. HW-58148, "Use of Delayed Neutron Data in Reactivity Measurements," D. E. Simpson, November 7, 1958.
23. HW-58813, "Full Reactor E-N Load Review of the Hazards from a Chemical Viewpoint," W. R. DeHollander, December 22, 1958.
24. HW-59133, "Chemical, Physical and Reactivity Changes in a Full Reactor E-N Meltdown," R. Nilson, February 9, 1959.
25. HW-59164, "The Effect of Hafnium or Increased Boron in the 3X Balls," R. Nilson, February 9, 1959.
26. HW-59703, "Individual Process Tube Flow Protection Low Pressure Operation of K Reactors," F. W. Van Wormer, April 23, 1959.
27. HW-60164, "Results of Reverse Flow Experimental Tests for C Operational Charge-Discharge Tube at Low Tube Powers," D. E. Fitzsimmons, April 30, 1959.
28. HW-60287, "Interim Report on Laboratory Experiments Investigating Consequences of Failure of Front Fittings," D. E. Fitzsimmons, et al., May 6, 1959.
29. HW-60495, "Relative Ball 3X VSR Reactivity Strength - DR Reactor Interim Report of PT-IP-126-C," D. E. Simpson, June 1, 1959.

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30. HW-60518, "K Reactor Pannellit Protection Against Plugging Incidents with Low Front Header Pressures," D. E. Fitzsimmons and G. M. Hesson, June 1, 1959.
31. HW-56655 PT 1 REV, "Calculation of Supplementary Disaster Control Requirement - Hanford Piles, Part I, Basis and Procedures," D. E. Simpson, June 15, 1959.
32. HW-56655 PT 2 REV, "Calculation of Supplementary Disaster Control Requirement - Hanford Piles, Part II, Data," D. E. Simpson, June 15, 1959.
33. HW-60439, "Operational Reactivity Accounting by One-Group Theory," G. R. Parkos, June 18, 1959.
34. HW-61849, "Report of Preliminary Laboratory Experiments Investigating Consequences of Failure of Front Hydraulic Fittings in K Reactor Geometry," G. M. Hesson, et al., September 10, 1959.
35. HW-57867, "Results of Tests Investigating Pannellit Protection to a D Process Tube Without a Rear Pigtail," G. M. Hesson, et al., September 24, 1959.
36. HW-61478, "Safety Circuit and VSR Delay Times," P. C. Althoff, October 12, 1959.
37. HW-62541, "Impact of Power Level Increases on Flux Cycling and Effect of Nuclear Safety," W. S. Nechodcm, et al., October 29, 1959.
38. "Sub-Cooled Burnout in K Reactor Geometry," G. M. Hesson, October 29, 1959. (Undocumented)
39. HW-62494, "An Analysis of the Time Sequence of Events Following a Complete Loss of Cooling Water to a Hanford Reactor," W. F. Ekern, et al., November 5, 1959.
40. HW-62884, "Hanford Safety System Capacities by 'Square Pile' Approximations," G. R. Parkos, December 4, 1959.
41. HW-63904, "Energy Release Per Fission in the Hanford Reactors," W. C. Morgan, et al., February 12, 1960.
42. HW-64027, "Recommendations to Apply the Square Pile Total Control Concept," C. E. Bowers, February 25, 1960.
43. HW-64436, "The Effect of Bond Defects on Temperatures Within I&E Fuel Elements During Irradiation," F. R. Zaloudek, March 18, 1960.
44. HW-64560, "Hydraulic Demand Curves for Standard BDF Geometry at Low Tube Powers," E. D. Waters, et al., March 24, 1960.

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45. HW-64632, "Xenon and Samarium Reactivity Effects Associated with Coolant Loss," R. E. Heineman and D. E. Wood, April 5, 1960.
46. HW-61760, "Potential for Process Tube Burnout During Transient Conditions," P. A. Carlson and S. S. Jones, April 22, 1960.
47. HW-65438, "Subcooled Burnout Relative to Hanford Reactors," P. A. Carlson and R. E. Trumble, May 31, 1960.
48. HW-66123, "Hydraulic Demand Curves for K Reactor Geometry at Low Tube Powers," E. D. Waters, et al., July 20, 1960.
49. HW-67450, "Determination of Power Rate Meter Response Final Report of PT-IP-261-C," C. E. Bowers, November 18, 1960.
50. HW-67460, "Technical Summary Enlarged Outlet Fittings - Old Reactors," P. A. Carlson, November 23, 1960.
51. HW-67139, "Laboratory Data for Review of Outlet Water Temperature Limits for BDF Type Reactors," E. D. Waters, et al., December 11, 1960.
52. HW-68214, "Heat Transfer Experiments Simulating a Failure of the Inlet Piping to a K Reactor Process Tube," E. D. Waters and D. E. Fitzsimmons, January 20, 1961.
53. HW-68250, "Total Control Aspects of Fringe Poison Loadings," A. D. Vaughn, January 26, 1961.
54. HW-68273, "Heat Transfer Experiments Simulating Front Header Pressure Reductions to a K Reactor Process Tube," E. D. Waters, et al., February 20, 1961.
55. HW-64398 1, "Hydraulic Demand Curves for BDF Geometry with Enlarged Outlet Fittings - 25 psig Rear Header Pressure," E. D. Waters, et al., May 15, 1961.
56. HW-69628, "Fractional Heat Generation Rates in Hanford Reactors After Shutdown," R. Nilson, et al., May 17, 1961.
57. HW-63157, "Parametric Analysis of Hanford Speed-of-Control Criterion," R. Nilson, et al., July 17, 1961.
58. HW-70769, "Heat Transfer Experiments Simulating a Failure of the Inlet Piping to a BDF Reactor Process Tube," E. D. Waters, et al., August 16, 1961.
59. HW-71074, "Experimental Boiling Burnout Conditions for Hanford Production Reactors," E. D. Waters, et al., September 20, 1961.
60. HW-71119, "Power Excursion in a Hanford Reactor Due to a Positive Reactivity Ramp," E. D. Jones, September 20, 1961.

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61. HW-71377, "Possibilities for Relaxing Process Tube Flow Trip Requirements for Hanford Reactors," E. D. Waters, et al., November 6, 1961.
62. HW-71075, "Results of Laboratory Heat Transfer Experiments for C Reactor Overbore Fuel Channels," E. D. Waters, et al., November 10, 1961.
63. HW-68763 REV, "Analysis of the Stored Energy Distribution in D Reactor," W. C. Morgan, November 15, 1961.
64. HW-71925, "Measurement of Control Spline Worth for K-Reactors," K. R. Birney and D. E. Wood, December 6, 1961.
65. HW-72653, "Recommended Total Control Requirements for Disaster Planning Studies," A. D. Vaughn, February 8, 1962.
66. HW-73167, "Reliability Analysis of Beckman System," N. T. Hildreth, et al., March 27, 1962.
67. HW-72591, "Instrumentation Studies - Status Report," W. L. Stiede, et al., March 29, 1962.
68. HW-73596, "Flow Effects Following the Failure of a Front Van Stone Flange," E. D. Waters, May 8, 1962.
69. HW-73956, "Examples of the Changes in Temperature, Pressure and Flow Following a Reactor Power Surge," M. R. Kreiter, et al., June 7, 1962.
70. HW-74247, "Flow Tests of K-V-NS Fuel with Zr-2 Process Tube and Associated Fittings," E. D. Waters, July 10, 1962.
71. HW-74248, "Basis for Establishing Minimum Support Height for KVN Fuel Elements," P. A. Carlson, July 11, 1962.
72. HW-72374, "Preliminary Hazards Review Overboring Hanford Reactors," R. Nilson and P. A. Carlson, July 25, 1962.
73. HW-74669, "Results of Laboratory Heat Transfer Experiment for K Reactor Fuel Channels," M. R. Kreiter and J. E. Hammond, October 9, 1962.
74. HW-74247 2, "Flow Tests of K-V-NS Fuel with Zr-2 Process Tube and Revised Fittings," E. D. Waters, October 20, 1962.
75. HW-75523, "Instability Limits for Smooth-Bore Process Tubes," P. A. Carlson, November 6, 1962.
76. HW-75672, "Instrumentation Studies Status Report II (High Level and Rate-of-Rise)," W. L. Stiede, November 28, 1962.

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77. HW-74094 VOL 3, "The Staff of the Irradiation Processing Department. Hazards Summary Report. Volume 3. Description of the 100-B, 100-C, 100-D, 100-DR, 100-F, and 100-H Production Reactor Plants," J. W. Ballowe, April 1, 1963.
78. HW-74095, "Description of the 100-KE and the 100-KW Production Reactor Plants," Staff of Irradiation Processing Department, Hazards Summary Report, Volume 3, April 15, 1963.
79. HW-74094 VOL 2, "Hazards Summary Report, Volume 2, Process Control and Technical Data, Six Oldest Hanford Production Reactors," J. W. Ballowe, May 15, 1963.
80. HW-74095 VOL 2, "Hazards Summary Report, Volume 2, Process Control and Technical Data - Hanford K Production Reactors," Staff of Research and Engineering Operation, IPD, May 22, 1963.
81. HW-74094 VOL 1, "Hazards Summary Report, Volume 1, Safety Analysis and Hazards Evaluation - Six Oldest Hanford Production Reactors," T. W. Ambrose, June 21, 1963.
82. HW-74095 VOL 1, "Hazards Summary Report, Volume 1, Safety Analysis and Hazards Evaluation - Hanford K Production Reactors," T. W. Ambrose, June 28, 1963.
83. HW-78356, "Neutron Lifetimes in the Hanford Lattices," R. E. Tiller, July 23, 1963.
84. HW-78368, "Effective Delayed Neutron Fractions and Decay Constants in the Hanford Production Reactors," R. E. Tiller, July 24, 1963.
85. HW-78551, "Possible Consequences of Operation with KIVN Fuel Elements in K Zircaloy Process Tubes," P. A. Carlson, August 6, 1963.
86. "Neutron Rethermalization in Graphite and Water," Nuclear Science and Engineering, 17, 131, R. A. Bennett, September 1963.
87. HW-79054, "Scattering Law for Water II, Physics Research Quarterly Report - July, August, September 1963," C. W. Lindenmeier, October 15, 1963.
88. "The Modified Heavy Gas Equation and Graphite-Moderated Systems, Physics Research Quarterly Report - July, August, September 1963," K. B. Stewart and C. W. Lindenmeier, October 15, 1963.
89. "Quasi-Elastic Scattering by Room Temperature Light Water," Inelastic Scattering of Neutrons in Solids and Liquids, Vol. I, 373-382, IAEA, Vienna, D. A. Kottwitz and B. R. Leonard, Jr., and R. B. Smith, 1963.

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90. "The Scattering Law for Room Temperature Light Water," Inelastic Scattering of Neutrons in Solids and Liquids, Vol. I, 359-372, IAEA, Vienna, D. A. Kottwitz and B. R. Leonard, Jr., 1963.
91. HW-80942, "Results of Thermal-Hydraulic Experiments with KVNS Self-Supported Fuel in a Zircaloy Tube - K Reactor," E. D. Waters and M. E. Shockley, March 2, 1964.
92. HW-80600, "Hazards Summary Report - Hanford Test Reactor - 305 Pile," R. Nilson, April 1, 1964.
93. HW-83869, "K Reactor Moderator Distortion Study," W. K. Alexander and A. Russell, June 22, 1964.
94. HW-83152, "Ball Drop Implications at K Reactor, Operational Physics Analysis," A. D. Vaughn, June 30, 1964.
95. HW-81660, "An Evaluation of the Experimental Determination of the Effects of Burnout and Corrosion on Spline Worth," W. A. Blyckert, July 13, 1964.
96. "Boilout of Process Tubes with Thoria Fuel Elements," G. M. Hesson, July 30, 1964. (Undocumented)
97. HW-61929, "Results of Tests Investigating Panellit Protection to C and K Process Tubes without Rear Pigtaills," B. R. Cremer, et al., September 15, 1964.
98. HW-83870, "Hydraulic Supply and Demand Characteristics of Thorium Target Elements in B, C, D, and K Process Tubes," C. W. Angle, September 15, 1964.

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Program: 02 Reactor IPD
 Project: 02 50 10 10
 Title: Personnel Radiation Exposure Reduction (R-3)
 Responsible Manager: O. H. Greager
 Responsible Investigator: P. C. Jerman
 Reporting Period: July 1, 1964, through October 31, 1964

	<u>Prior Year</u>	<u>FY to Date</u>	<u>Period</u>	<u>FY Estimate</u>	<u>Previous FY Estimate</u>
Costs (Thousands)	60	19	4 months	95.5	36
Scientific Manpower (Man-years)	2	0.4	months	6	6

I. Project Scope and Objective

The program comprises a broad spectrum of studies directed toward minimizing the exposure of personnel to radiation. It includes reducing high dose rate conditions, minimizing the number of personnel required at the job site, warning personnel when appreciable dose rates are encountered, and minimizing contamination spread.

II. Major Accomplishments to Date

1. In the area of reactor decontamination, great progress has been made. Decontaminating agents have been developed which are compatible from the standpoint of corrosion with the various reactor components. The use of decontaminating techniques has markedly reduced exposure during maintenance activity.
2. In the area of fixed radiation monitoring instrumentation, a log picoammeter was developed which appears to far surpass anything in the line of area radiation monitoring equipment produced to date. Prototypes have been produced by several vendors.
3. Progress has been made in the development of pocket sized alarm devices to warn personnel that a certain level of radiation dose rate or dose has been exceeded.
4. A dose rate telemetering system has been developed to a good state of refinement. The unit has the capability of integrating dose rate information to dose. Specifications to permit off-site procurement of a prototype have been completed.

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III. Progress During Report Period

1. Work on reactor decontamination was limited to that which will be applied to the deactivation of reactors. The effort in this regard is being engineered for implementation at the time the reactors are shut down.
2. The improvement of fixed radiation monitoring systems has been implemented by project action to install the improved equipment at the two K Reactors and KER. Project action for the installation of improved equipment at the three older reactors, which will continue operation, is pending.
3. A Mark I prototype of a dose rate alarm device was developed and fabricated. It was field tested at the reactors. A Mark II prototype is currently being designed which will incorporate improvements to the original prototype and seek to reduce costs involved in the fabrication of production models.
4. A pocket sized dose alarm device developed at the Chalk River plant was received and evaluated for application at Hanford. The design of the device was modified to better suit IPD's needs by the substitution of components and the incorporation of a printed circuit board.
5. Negotiations for procurement of a dose rate telemetering system prototype continued. Negotiations resulted in a firm bid from Tracerlab, Inc. Bid reviews are currently being reviewed by the AEC.

IV. Evaluation of Effort to Date

The success of the program to date is evidenced by the following:

1. The decontamination of reactors has reduced the dose rates received by personnel working in the discharge area during outages by up to a factor of four.
2. Completely satisfactory equipment has been made available for replacing outmoded and worn out fixed radiation monitoring equipment at all the reactors.
3. Three satisfactory instruments have been developed for warning personnel of high dose and dose rate conditions. The use of these instruments, plus the radiation alarm systems scheduled for installation, should go a long way in alleviating the need for radiation monitor coverage to monitor changing dose rate conditions for radiation work performed by operating and maintenance personnel.

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V. Next Report Period Activities

1. Development work associated with reactor decontamination will continue with attention directed to those areas requiring special application.
2. The engineering and design effort required to incorporate a remote readout function into the fixed radiation monitoring project will be completed.
3. The fabrication and testing of the Mark II dose rate alarm prototype will be completed.
4. A contract will be placed for the procurement of a dose rate telemetering system, and testing will be initiated.

VI. Topical Reports Issued

1. HW-56001 I, "Interim Report No. 10, Chemical Decontamination Activities, 105 Reactors During the Period July 1962 Through October 1963," H. F. Jensen, November 11, 1963.
2. HW-79712, "Project Proposal - Replacement and Improvement of Fixed Gamma Radiation Monitoring Instrumentation - Existing Hanford Production Reactor Areas (Project CGI-125)," T. H. Lyons, December 26, 1963.
3. HWS-5991, "Procurement Specifications for a Logarithmic Radiation Monitor, Project CGI-125, Revision No. 3," G. L. Erickson, March 5, 1964.
4. HWS-7397, "Radiation Dose Rate Telemetry and Integration, Revision No. 1," P. J. Horvath, April 15, 1964.
5. HWS-7371, "Dose Rate Telemetering System, Revision 2," P. J. Horvath, April 17, 1964.
6. HW-82369, "Radiation Monitoring of Personnel by Dose Rate Telemetering," M. L. Smith and P. J. Horvath, May 22, 1964.
7. HW-SA-3560, "Reactor Decontamination and the Health Physicist," L. R. Wallis, M. L. Smith and F. E. Owen, June 1964.
8. I&EDO Memo 64-08, "Dose Rate Preset Alarm Development," P. J. Horvath, July 27, 1964.
9. HW-84269, "Reactor Plant Deactivation, Decontamination Guide," H. C. Copeland, September 25, 1964.

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Program: 02 Reactor IPD
Project: 02 50 10 10
Title: Cost Reduction and Reactor Life (R-4)
Responsible Manager: O. H. Greager
Responsible Investigator: T. W. Ambrose
Reporting Period: July 1, 1964, through October 31, 1964

	<u>Prior Year</u>	<u>FY to Date</u>	<u>Period</u>	<u>FY Estimate</u>	<u>Previous FY Estimate</u>
Costs (Thousands)	420	76.2	4 months	274.5	272
Scientific Manpower (Man-years)	10	1.7	4 months	6	6

I. Project Scope and Objective

A base level of research, development, and testing is maintained for the production reactors for the purposes of reducing the cost of operation and assuring that reactor and component deterioration is minimized as necessary to maintain reactor life. Detailed examination is made of the factors which affect reactor life, and a course of corrective action is recommended, based on technical and engineering facts as they can best be determined. Included are basic engineering and physics studies providing a broad base of reactor knowledge necessary for operational improvements consistent with nuclear safety requirements and for seeking solutions to phenomena threatening reactor life.

II. Major Accomplishments to Date

1. Smooth-bore Zircaloy tubes were developed for use in the Hanford reactors. The development program resolved the following problems:
 - a. The establishment of a commercial source of satisfactory tubes.
 - b. The determination of the hydraulic characteristics of smooth-bore tubes charged with self-supported fuel elements.
 - c. The evaluation of the corrosion and irradiation characteristics of Zircaloy tubes under irradiation conditions.
 - d. The techniques required for tube installation which would minimize graphite damage and tube distortion.
2. Graphite oxidation due to oxygen from air in-leakage into the reactor gas atmosphere has been substantially reduced through improvements in gas system instrumentation and operation.

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3. The determination that the oxidation of graphite by CO₂ was lower than anticipated permitted graphite temperature limits to be relaxed at those reactors using a He-CO₂ atmosphere.
4. Basic lattice physics measurements over a wide range of fuel-to-moderator ratios have been carried out. The studies have well characterized the cold lattice physics parameters of Hanford type reactors, have enabled the construction of physics models, and have led to better understanding of the neutronic processes.
5. Basic theoretical physics investigations, both with regard to neutron reactions and with regard to models and calculational aids, have led to efficient, useful computer codes. The codes have been extremely useful in the rapid evaluation of complex reactor problems so that the effects of proposed programs can be fully evaluated prior to actual reactor demonstrations.
6. A five-year program for demonstrating the concept and equipment parameters required for automatic distribution control was completed. The self-feedback concept, applied with on-off circuitry activated by high and low deadband limits, was successfully demonstrated in the D Reactor during equilibrium operating conditions and following limited deliberate upset tests.
7. A xenon override technique was developed and successfully tested on-reactor.
8. A broad, basic assessment of the modern role of the Ball 3X system in reactor safety has been carried out. A new philosophy, which recognizes reactor safety improvements, which realistically assesses certain accident probabilities, and which takes into consideration the present condition of the reactor stacks, has been established. Implementation of this philosophy through proposed circuit changes is believed to be capable of significantly reducing the potential of an inadvertent, and perhaps serious, ball drop.
9. Studies of alternate control methods have defined minimum system requirements and have identified specific backup control methods, such as chains, which show merit in further development.
10. Corrosion studies have broadened the understanding of the effects of coolant composition on aluminum corrosion. Increased process tube life at a coolant pH of 6.6 and the adequacy of reduced inhibitor concentration has been demonstrated on a full reactor basis.

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III. Progress During Report Period

1. A monitoring program has been established to evaluate the long-term performance of the K Reactor Zircaloy tubes.
2. A Zircaloy overbore tube has been removed from C Reactor and is undergoing metallurgical and physical testing.
3. A program has been initiated to develop ribbed Zircaloy process tubes. The feasibility of using a seam-welded tube with the ribs attached to the inner surface by electron beam welding is being investigated.
4. The graphite oxidation monitoring program continued to show minimum oxidation of graphite due to in-leakage of air.
5. Fabrication of drilling equipment to remove graphite core samples from HCR, VSR, and process tube channels was essentially completed. The cores will assist in assessing the reduction in graphite strength.
6. An in-reactor test is in preparation to investigate graphite oxidation by CO_2 at higher graphite temperatures.
7. An experimental apparatus for laboratory study of the reaction between graphite and water vapor has been built.
8. Continued effort in Monte Carlo techniques has enabled the combining of several Monte Carlo computer codes. The result will be useful in solving complex reactor problems.
9. A prototype chain control system for Ball 3X replacements in ball channels having voids has been developed and tested successfully.
10. An additional reduction in aluminum corrosion rate was demonstrated in a half-reactor test when using coolant having a pH of 6.2 vice 6.6.
11. The feasibility of using electrical resistance probes for monitoring in-reactor corrosion was demonstrated.
12. In-reactor tests to determine the corrosion effect of using CO_2 for coolant pH adjustment were initiated.
13. Out-of-reactor test facilities have been designed and fabricated, and testing of resistance temperature detectors has been initiated to determine the cause of stem corrosion.

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IV. Evaluation of Effort to Date

The studies ascribed to this program have for many years been part of reactor research and development. The effort has been eminently successful in providing the technology required to reduce costs, increase productivity and extend the useful life of the Hanford reactors. Examples of more recent achievements include:

1. The installation of 5000 Zircaloy tubes in the K Reactors was completed on schedule for 70 per cent of the originally estimated cost.
2. Corrosion studies resulted in defining the conditions which would markedly increase process tube life.
3. The lattice physics effort in providing improved understanding of reactor neutronics has provided a means of rapidly determining the effects of changes proposed for cost reductions or increased life.

It is anticipated that a similar level of effort will be required in FY-1966.

V. Next Report Period Activities

1. The K Reactor Zircaloy tube monitoring program will continue.
2. The development of the ribbed Zircaloy tubing will have been carried to the point of making full length tubes.
3. In-reactor tests of the graphite-CO₂ reaction will be concluded, and a basis for graphite temperature limit will be established.
4. Laboratory tests of the graphite-water reaction will be initiated.
5. The revised Ball 3X philosophy will be translated into new 3X-circuit designs. These circuits will employ coincidence techniques.
6. Effort in Monte Carlo techniques to solve complex reactor physics problems will be continued and actual problems of practical interest will be investigated.
7. Testing of the effects of further inhibitor reduction will be initiated on a half-plant basis.
8. The assessment of the corrosion effects from adding sodium silicate to process coolant will be initiated on a half-plant basis.

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9. The single-tube testing of CO₂ for coolant pH adjustment will be completed.
10. The evaluation of nonchromium inhibitors will be completed.
11. The testing and evaluation of the resistance temperature detectors will continue.

VI. Topical Reports Issued

1. HW-20213, "Zirconium Tubes for Present Hanford Piles," W. K. Woods and W. R. Lewis, January 1951.
2. HW-31999, "Exponential Pile Measurements in Graphite-Uranium Systems," E. D. Clayton, June 1, 1954.
3. HW-34012, "Final Report - Production Test 105-168-P, Supplements A through I, Replacement of Pile Helium Atmosphere with Carbon Dioxide," S. S. Jones, December 13, 1954.
4. HW-38738, "Determination of Lattice Parameters from Experimental Neutron Distributions in Rod Fuel Elements at KW Pile Startup Part I, Natural Uranium," W. E. Niemuth, June 15, 1955.
5. HW-34544, "The Effects of Water Quality on Pile Operation, Final Report Production Test No. 105-525-E," N. R. Miller, September 23, 1955.
6. HW-45942, "C Pile Graphite Burnout Experiment - Final Report," J. C. Fox, August 31, 1956.
7. HW-46117, "Preliminary Report on Lattice Parameter Measurements on Massive Slugs," R. Nilson, February 15, 1957.
8. HW-49799, "The Parameters of Some Large Process Tube Lattices Determined from PCTR Measurements," D. D. Lanning, et al., April 24, 1957.
9. HW-50133, "Uniform Aqueous Corrosion of Aluminum - Effects of Various Ions," V. H. Troutner, June 10, 1957.
10. HW-54092, "The Economics of Zirconium Process Tubes," L. W. Lang, December 20, 1957.
11. HW-52834 REV, "Lattice Parameters Derived from Neutron Distributions," R. Nilson, February 18, 1958.
12. HW-46118, "Experimental Lattice Parameters for Cluster Type Fuel Elements - Interim Report," R. Nilson, April 10, 1958.

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13. HW-57708, "Ribbed Zircaloy-2 Process Tubes for Production Reactors," D. H. Curtiss and J. W. Riches, October 10, 1958.
14. HW-57854, "Radiation Effects on Aluminum Corrosion in Hanford Process Water," R. B. Richman, October 31, 1958.
15. HW-58678, "Correlation of Exponential and PCTR Measurements on Cluster Fuel Elements with Theory," G. D. Joanou, December 31, 1958.
16. HW-59007, "Final Report on PT-105-630-A - Pile Power Distribution Control at the K Piles," R. O. Brugge, February 18, 1959.
17. HW-62541, "Impact of Power Level Increases on Flux Cycling and Effect of Nuclear Safety," W. S. Nechodom and R. Nilson, October 29, 1959.
18. HW-62273 REV 2, "Graphite Burnout - Interim Report on PT-IP-25-A," B. A. Ryan and D. R. de Halas, March 15, 1960.
19. HW-67094, "Lattice Parameter Measurements for a Concentric Tube Fuel Element," D. E. Wood, et al., December 1, 1960.
20. HW-69084, "Xenon Instability in Graphite Reactors," G. C. Fullmer, February 1961.
21. HW-69525, "Material Buckling Measurements on Graphite-Uranium Systems at Hanford: A Summary Tabulation," D. E. Wood, May 1961.
22. HW-69695, "A Study of an Elementary Two-Zone Reactor by Analog Simulation," C. D. Swanson and B. E. Dozer, May 23, 1961.
23. HW-71709, "Relative Xenon Instability in the Hanford K and N Reactors," D. K. McDaniels, November 16, 1961.
24. HW-71809, "Production Test IP-467-C, Reducing Minimum Downtime," J. F. Jaklevik, December 6, 1961.
25. HW-71957, "Reducing Minimum Downtime - A Nuclear Safety Analysis," J. F. Jaklevik and G. F. Owsley, May 9, 1962.
26. HW-73930, "Production Test IP-467-C, Supplement B, Reducing Minimum Downtime - K Reactors," R. A. Chitwood, June 6, 1962.
27. HW-74663, "A Review of the Reaction of Nuclear Graphite with Carbon Dioxide," R. E. Woodley, August 17, 1962.
28. HW-73906, "Design Criteria, Modifications for Use of Zirconium Tubes: 100-K Reactors," M. H. Schack, August 20, 1962.

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29. HW-SA-2661, "Corrosion of Aluminum-Clad Fuel Elements," D. R. Dickinson, R. J. Lobsinger, and R. B. Richman, August 24, 1962.
30. HW-75072, "A Review of the Reactions of Nuclear Graphite with Oxygen and Water Vapor," R. E. Woodley, September 27, 1962.
31. HW-75126, "Final Report, PT-IP-383-C - Test of Experimental Control Logic and Design Parameters," W. L. Stiede, October 3, 1962.
32. HW-75206, "Interim Report, Production Test IP-467-C, Supplement A, Horizontal Rod Calibration at B Reactor During Xenon Override Startup," A. D. Vaughn, October 9, 1962.
33. HW-67333, "A Discussion of Monte Carlo Principles and Associated Nuclear Data Currently Being Used in Lattice Physics Investigation," R. D. Cahoon, October 10, 1962.
34. HW-74104, "Technical Criteria and Bases for a Zirconium Tubed K Reactor," D. H. Curtiss, October 19, 1962.
35. HW-75368, "An Analysis of the Frequency of Ledge Corrosion Attack Observed on Fuel Elements," M. A. Clinton, October 24, 1962.
36. HW-76332, "Summary of K Reactor Graphite Treatment for the Zirconium Tube Program," K. D. Couchren, February 8, 1963.
37. HW-76625, "Development and Testing of Reactor Automatic Distribution Control System," R. Sherrard, February 19, 1963.
38. HW-76642, "Radiation Effects on Aluminum Film and Corrosion," R. B. Richman, February 20, 1963.
39. HW-77121, "Interim Report Experience with PT-IP-467-C Reducing Minimum Downtime," J. R. Fredsall, March 29, 1963.
40. HW-74359 REV, "Erosion Corrosion of Aluminum Alloys," R. L. Dillon and R. S. Hope, April 1963.
41. HW-77196, "An Analysis of the Frequency of Groove Corrosion Attack Observed on Fuel Elements," R. G. Geier, April 4, 1963.
42. "Design Change No. 672, Installation of Zirconium Process Tubes - 100-K Reactors," M. H. Schack, et al., April 30, 1963.
43. HW-77610, "Corrosion of Experimental Aluminum Alloys," R. B. Richman, May 10, 1963.
44. HW-78912, "Technical Criteria and Bases - Supplemental Reactor Safety Control - IPD Reactors," R. Nilson, September 13, 1963.

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45. HW-SA-3087, "Neutron Measurements for Corrosion Studies in Large Reactors," R. B. Richman, September 23, 1963.
46. HW-78745, "Aluminum Alloy Corrosion in Treated River Water," R. B. Richman, November 1963.
47. HW-80893, "Interim Report - RTD Corrosion Studies," D. B. Lovett, January 1, 1964.
48. HW-80875, "Status Report - Research and Engineering Moderator Distortion Program," W. K. Alexander, et al., February 14, 1964.
49. HW-SA-3393A, "Continuous Measurement of Corrosion with Resistance Probes," R. B. Richman, March 1964. (Presented at the 13th Annual AEC Corrosion Symposium.)
50. HW-80543, "Corrosion of Resistance Temperature Elements," D. F. Davis and R. B. Richman, March 1964.
51. HW-81947, "Graphite Temperature, An Important Economic Parameter," R. E. Baars, R. D. Shimer, and H. G. Spencer, April 22, 1964.
52. HW-SA-3599A, "Continuous On-Reactor Measurement of Instantaneous Corrosion Rates," R. B. Richman, June 1964.
53. HW-82450, "Final Report of Production Test IP-578-C, Automatic Control Experiment, Part II, Phase II (Trial of Developmental Test System)," W. L. Stiede, June 1, 1964.
54. HW-82333, "K Reactor Zirconium Tube Program, Summary Report," R. S. Bell, June 9, 1964.
55. HW-83201, "Stress Corrosion of Stainless Steel RTD Models," R. B. Richman and R. D. Henry, July 1964.
56. RL-REA-14, "Increased Graphite Temperature Limit - F Reactor," A. Russell, October 19, 1964.
57. HW-80343, "Continuous Corrosion Measurement in a Nuclear Reactor," R. B. Richman, November 1964.
58. HW-80555, "Static Tests of Corrosion Inhibitors for Aluminum and Carbon Steel," R. B. Richman, November 1964.
59. HW-84500, "Aluminum and Steel Corrosion in Low pH Water at D Reactor," R. B. Richman and V. F. Fitzpatrick, November 1964.

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Program: 02 Reactor IPD
 Project: 02 50 10 10
 Title: Production of Clean U-233 (R-5)
 Responsible Manager: O. H. Greager
 Responsible Investigator: W. K. Woods
 Reporting Period: July 1, 1964, through October 31, 1964

	<u>Prior Year</u>	<u>FY to Date</u>	<u>Period</u>	<u>FY Estimate</u>	<u>Previous FY Estimate</u>
Costs (Thousands)	282	174	4 months	477	563
Scientific Manpower (Man-years)	6	2.2	4 months	6	6

I. Project Scope and Objective

The program is designed to develop and demonstrate the technology required to optimize a process for the large-scale production of uranium-233 containing low amounts of uranium-232 contaminant. It includes studies to define low cost methods of fabricating thorium target elements for irradiation, intensive investigation of the reactor physics and the reactor engineering related to thorium loadings in Hanford reactors and the chemical and isotopic analyses of irradiated specimens.

The research and development required to define a thorium dissolution process, a chemical reprocessing scheme, and the conversion of uranyl-233 nitrate and thorium nitrate to other forms is covered in a separate program (Project 02-50-10-15-1, Subprogram 12, "Separations - Innovation and New Business").

II. Major Accomplishments to Date

1. The rate of formation of U-232 and U-233 in the core of a small Hanford reactor has been established by small-scale irradiations, and the feasibility of producing U-233 containing only 1 ppm of U-232 has been demonstrated.
2. Theoretical calculations analyzing the effect of different reactor environments, e.g., small versus K Reactors, and central versus fringe locations, on U-233 production were performed.
3. The ratios of enriched uranium fuel to thorium targets required to provide proper reactivity balance were demonstrated in three different reactor locations on a scale involving several dozen tubes.

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4. The effect on U-232 production by thorium-230 contamination of thorium-232 has been established. Photoneutron effects contributing to U-232 formation were observed and evaluated.
5. Thoria specifications were developed, and an economical method of fabricating target elements was developed.

III. Progress During Report Period

1. The 20-week irradiation of one ton of thoria in the fringe tubes of a small reactor was completed.
2. The five-week irradiation of two tons of thoria in the core of a K Reactor was completed.
3. Representative irradiated thoria targets were isolated and set aside for dissolution and analysis. Analytical work was initiated on four elements and completed on eight previously irradiated one gram samples.
4. Reactor physics calculations were reviewed and refined as necessary to remain consistent with experimental results.
5. Thoria canning facilities were designed and installed to permit production scale fabrication of target elements.
6. The evaluation of fuel power, jacket corrosion, core temperatures, and coolant flow balance resulted in the definition of driver and target element designs for both fringe and core loadings.
7. Hazards summary reports containing a comprehensive review of the potential for nuclear and mechanical accidents which are unique to thoria loadings were issued.
8. The initial reactor loadings required for the production of 100 kg of U-233 were completed.

IV. Evaluation of Effort to Date

A complete evaluation of the program must await the results of the 100 kg production effort which will not be available until FY-1966. However, initial results indicate that the effort has been quite effective as evidenced by the present ability to fabricate target elements on a production scale and analytical results which confirm that U-233 containing small quantities of U-232 can be produced in Hanford reactors.

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V. Next Report Period Activities

1. The chemical processing of the six tons of thoria already irradiated will provide large-scale information expected to verify the data obtained from small experiments.
2. The irradiation of about 100 tons of thoria will be completed and analysis of the data will establish a solid technological base for subsequent reactor loadings.
3. Studies will be directed toward the development of methods for obtaining higher thoria densities in target elements.
4. Preliminary data will be obtained on the feasibility of irradiating thoria to higher U-233 concentrations if higher U-232 concentrations should be acceptable.

VI. Topical Reports Issued

1. HW-76847, "Production of U-233 and Program Proposal," L. W. Lang, et al., March 21, 1963.
2. HW-78590, "Production of 'Clean' U-233," W. K. Woods, August 8, 1963.
3. HW-78789, "Production Test IP-614-A, Irradiation of Thorium Target Elements," K. L. Hladek, et al., August 29, 1963.
4. HW-78959, "Analysis of Irradiating Thorium Oxide (Series I - Development Test IP-588-D)," W. Y. Matsumoto, et al., September 17, 1963.
5. HW-78959 SUP 1, "Analysis of Irradiated Thorium Oxide (Series II - Development Test IP-588-D)," W. Y. Matsumoto, et al., October 7, 1963.
6. HW-79233, "Production Test IP-627-A, Irradiation of Thorium Oxide Elements," K. L. Hladek, et al., October 16, 1963.
7. HW-78989, "Thorium Irradiation Calculations," H. H. Van Tuyl, November 1963.
8. HW-80289 REV, "Production of Clean U-233 - Process Parameters and Limits," L. W. Lang, et al., January 31, 1964.
9. HW-80828, "Production Test IP-659-AC - Evaluation of a Thorium Oxide Loading," R. D. Carter, et al., February 28, 1964.
10. HW-81964, "Beta-Gamma Dose Rates from U-232 in U-233," F. E. Owen, April 1964.

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11. HW-82789, "Production Test IP-695-AC - Thorium Oxide Irradiation-K Reactors," P. D. Gross, et al., July 7, 1964.
12. HW-80960, "Analysis of Irradiated Thorium Metal and Thorium Oxide Target Elements - Production Tests IP-614-A and IP-627-A," M. R. Weiler.
13. "Preliminary Hazards Evaluation for Enriched Uranium-Thoria (E-Q) Loading - Hanford IPD Reactors," R. Nilson, et al., July 23, 1964.
14. HW-74094 SUPP1, "Hazards Summary Report Supplement 1, Slightly Enriched Uranium-Thoria Loading, Six Smaller Hanford Production Reactors," Staff of Irradiation Processing Department, September 1, 1964.
15. HW-74095 SUPP1, "Hazards Summary Report Supplement 1, Slightly Enriched Uranium-Thoria Loading, Hanford K Production Reactors," R. Nilson, et al., September 15, 1964.

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Program: 02 Reactor IPD
 Project: 02 50 10 10
 Title: Product Development Studies (R-6)
 Responsible Manager: O. H. Greager
 Responsible Investigator: T. W. Ambrose
 Reporting Period: July 1, 1964, through October 31, 1964

	<u>Prior Year</u>	<u>FY to Date</u>	<u>Period</u>	<u>FY Estimate</u>	<u>Previous FY Estimate</u>
Costs (Thousands)	36	18	4 months	86	70
Scientific Manpower (Man-years)	2	0.4	4 months	3	3

I. Project Scope and Objective

The objectives of this program are to develop the technology for efficient production of specific isotopes, particularly exploiting the unique advantages of the Hanford production reactors, and to develop the technological basis for producing a wide variety of products. Irradiation techniques receiving consideration are different fuels -- higher enriched metallic uranium, enriched uranium-aluminum alloys, and plutonium-aluminum alloys; the production of plutonium of high Pu-240 content from irradiation of depleted uranium; the creation of a high flux zone in a reactor for materials testing and rapid product formation; and the use of test hole facilities for special irradiations.

II. Major Accomplishments to Date

1. Fundamental studies of Np-237 production in the Hanford reactors have led to quantitative understanding of the formation rates of this isotope in nonrecycle fuel. Similar studies of Np-237 production in recycle fuel while not yet yielding the same degree of understanding have established the advantages of recycle.
2. Preliminary calculations have provided some encouraging information concerning the safety aspects of using plutonium fuels in the Hanford production reactor lattices.
3. Results of irradiations of uranium depleted to 0.2 per cent U-235 performed in 1958 established the correctness of calculations which stated that such irradiations could produce plutonium high in Pu-240.

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4. Emphasis on diversification has been responsible for many studies on production of isotopes. Important among those isotope studies are Co-60, Po-210, Tm-170, Cm-242, Cm-244, Am-241, and U-233. The studies, which are continuing, have been instrumental in critically assessing the flexibility of the IPD reactors and have led to new irradiation techniques of significant importance.
5. An optimum E-N lattice has been developed through successive E-N irradiations in H Reactor. This loading, which produces tritium and plutonium, has proved to be safe and significantly more productive than a normal plutonium producing loading (at least 11 per cent).
6. A comprehensive study on the physics of an overbore lattice has been carried out. Nuclear safety advantages and improved product yields (including Np-237) have been identified and demonstrated in experimental tests. Laboratory measurements verified that, at 500 mils overbore, the lattice is fail safe on coolant loss. In-reactor conversion ratio tests verified expected gain in plutonium conversion, Np-237 production, and higher isotope yields.

III. Progress During Report Period

1. Controlled irradiation tests of recycle enriched fuel in the reactors have started to better characterize the conversion of U-236 to Np-237.
2. All Np-237 production data from previous irradiation tests were analyzed and correlated with a theoretical model. Neptunium-237 buildup studies were thus established to permit Np-237 production studies.
3. A Pu-238 optimization model, developed jointly with the AEC, was successfully programmed and used to determine optimum blend assays for uranium recycle.
4. Theoretical studies on the utilization of plutonium fuels were carried out. Calculations based on available physics data have been encouraging to the point of establishing that more refined theoretical models should be developed.
5. Experimental studies were performed in the Physical Constants Test Reactor to evaluate the flux rise in a lattice cell surrounded by 0.947 per cent enriched fuel. Thulium target was employed, and the tests showed a flux rise in substantial agreement with calculated values. Furthermore, the tests, as applicable to irradiations of thulium to produce the radioisotope Tm-170, demonstrated that flux amplification by such irradiation techniques can be sufficient to produce Tm-170 having a useful specific power.

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6. Preliminary studies were completed on Po-210 production. Yields up to 6 kg/small reactor-year look achievable with 1000 mil overboring.
7. Comprehensive studies are in progress on the usefulness of a small reactor as a general isotope producer.
8. Measurements were made in the 305 Hanford Test Reactor to determine natural uranium equivalents of fuel-target arrangements for several target materials. Materials were LiAl, ThO₂, Bi, and depleted uranium.
9. The reactor design code MOFDA was modified to permit study of supercell lattices.
10. Analysis of conversion ratio data from fuel discharged from the C overbore facility was completed. The data were characterized by high plutonium yields, high neptunium yields, and increased yields of transplutonium isotopes. Agreement between observed data and predicted values using present physics methods was good.
11. An optimum fuel canning cycle for the production of depleted uranium target elements was developed, and 7500 elements were successfully fabricated. Ten tons of depleted uranium were charged into a small reactor and 12 tons into a K Reactor to demonstrate the production of plutonium having a high concentration of Pu-240. The elements have been irradiated to an average exposure of 600 MWD/T without incident.
12. Preliminary fuel element designs were determined for 1.25 wt% U-235 enriched uranium fuel elements for both the small and K Reactors based on potential use as driver elements for fuel and target loadings at current reactor power levels.

IV. Evaluation of Effort to Date

The program has been successful in establishing incentives in many areas of diversification. Three programs -- the tritium producing E-N load, the overbore facility, and Np-237 production are quantitatively understood. Others are in various stages of development. Substantial work to define both the physics, engineering, and economic parameters of the new processes is anticipated in future years.

V. Next Report Period Activities

1. Experimental work on Doppler and voiding effects in plutonium-graphite lattices will be started as the need develops.
2. A theoretical feasibility study of the use of plutonium fuel in the IPD reactors will be completed.

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3. The conversion of U-236 to Np-237 in recycle fuel will be characterized from test results.
4. A theoretical study of maximizing Po-210 production in a small IPD reactor will be completed.
5. The 22-ton test irradiation of depleted uranium will be completed. An evaluation of the irradiation behavior of the fuel and the operating characteristics of the load will be completed.
6. Studies on the production of other isotopes will continue.
7. A test irradiation of 1.25 per cent enriched uranium having current fuel geometry will be completed to permit engineering and physics evaluations.

VI. Topical Reports Issued

1. HW-48783, "Bucklings in Lattices with Enriched Uranium and Li-Al Alloy Target Material," R. C. Lloyd, February 26, 1957.
2. HW-58304, "Calculation of Plutonium Buildup in Depleted Uranium," W. E. Niemuth, December 1, 1958.
3. HW-58817, "The Effective (n,2n) Cross Section for U-238," R. Nilson, January 9, 1959.
4. HW-58917, "Final Report, Production Test IP-2-A - Enriched Uranium Conversion and Stability Test," L. W. Lang, January 16, 1959.
5. "Isotopic Analysis of the Depleted Uranium Load," C. R. Richey, August 7, 1959. (Undocumented)
6. HW-63668, "Conversion Ratio Incentive for Using Black Mint in an E-N Load," R. Nilson, January 28, 1960.
7. HW-67208, "Technical Bases for C Pile Overbore Test," D. H. Curtiss, et al., November 3, 1960.
8. HW-68066, "Conversion Ratio Consideration in the E-N Fringe Loading," C. E. Bowers, January 9, 1961.
9. HW-68697, "Comparative Return for Overbore and E-N Loadings; B, D, F, and DR Reactors," W. S. Nechodom, March 22, 1961.
10. HW-69566, "Physics of E-N Load Compared to Natural Uranium Load at H Reactor," D. I. Monnie, May 10, 1961.

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11. HW-70528, "A Qualitative Discussion of the Conversion Ratio Aspects of Overboring the 8-3/8 Inch Lattice Hanford Reactors," R. Nilson, July 24, 1961.
12. HW-73291, "RIP CODE, Radioisotopic Power Code," R. C. Liikala, April 6, 1962.
13. HW-73615, "Technical Evaluation of E-N Demonstration Loading (Interim Report, PT-IP-350-C)," R. D. Carter, et al., May 11, 1962.
14. HW-73613 SUP3, "Final Report on E-N Conversion Ratio Data, Production Test IP-350-C," R. D. Carter and W. A. Blyckert, December 18, 1962.
15. HW-77202, "Proposal to Produce Transuranium Isotopes in Hanford Production Reactors," L. E. Kusler and R. O. Gumprecht, April 12, 1963.
16. HW-78320, "Overbore Program Exponential Experiments," D. L. Johnson, July 11, 1963.
17. HW-78525, "HAPO Isotope Program - Po-210 Production," L. W. Lang, et al., August 7, 1963.
18. HW-78782, "Higher Isotope Case Study," L. E. Kusler, et al., August 29, 1963.
19. HW-79037, "Material Buckling Measurement of a Supercell Using Enriched and Natural Fuel," D. L. Johnson, September 23, 1963.
20. HW-79593, "Preliminary Survey Reactor Formation of Rhenium-Tungsten Alloy," R. H. Meichle and L. W. Lang, November 11, 1963.
21. HW-80867, "Alternative Production Methods for Polonium-210," R. E. Tomlinson, et al., February 14, 1964.
22. HW-81680, "Analysis of Additional 1963 E-N Yield Data," R. D. Carter, April 1, 1964.
23. HW-80826, "Hanford Production of Thulium-170," R. H. Meichle and L. W. Lang, April 17, 1964.
24. HW-81861, "Thulium Oxide Irradiation," L. E. Kusler, April 17, 1964.
25. HW-81569, "C Reactor Overbore Test Facility Review," R. Nilson and P. A. Carlson, April 24, 1964.
26. HW-72075, "Np-237 Production in the IPD Reactors," R. Nilson, May 27, 1964.

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27. HW-84308, "Operating Physics Aspects of E-N Loading," E. L. Conner and A. DePino, July 1, 1964.
28. HW-83940, "Three-Kilogram Polonium Production Study," L. E. Kusler, et al., September 4, 1964.
29. HW-84102, "Reactivity Measurements of Cored Lithium-Aluminum Cylinders," W. A. Blyckert, September 15, 1964.

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Program: 02 Metallurgy IPD
 Project: 02 50 10 05
 Title: Alternate Cladding Process (M-1)
 Responsible Manager: J. T. Stringer
 Responsible Investigator: H. F. Tew
 Reporting Period: July 1, 1964, through October 31, 1964

	<u>Prior Year</u>	<u>FY to Date</u>	<u>Period</u>	<u>FY Estimate</u>	<u>Previous FY Estimate</u>
Costs (Thousands)	380.5	121	4 months	302	302
Scientific Manpower (Man-years)	4	1.6	4 months	4	4

I. Project Scope and Objective

Attractive fuel manufacturing incentives and payout exist for replacing the present -AlSi process with an alternate hot-die-sizing process. Other advantages of the hot-die-sizing process are: (1) increased flexibility in fuel geometry and length, (2) amenability to mechanization, (3) ease of control, and (4) it produces a more uniform and higher quality fuel which will satisfy current or more severe reactor conditions warranted by product diversification programs.

This program will advance the technology of the hot-die-sizing process. Areas being investigated include: (1) the effects of process variables on fuel quality and irradiation stability, (2) simplification of process techniques, (3) establishing the technology to use tubular and potentially more corrosion resistant high-silicon aluminum alloy cladding components, and (4) developing techniques for producing self-supported fuel with integral ribs.

II. Major Accomplishments to Date

1. Laboratory-scale equipment was installed for the development of the hot-die-sizing process.
2. Improvements in uranium core surface pretreatment and plating rack design have provided an electro-deposited nickel plate with excellent adhesion properties, uniform thickness, and relatively free of defects.
3. Process parameters have been developed and provisional specifications have been issued to produce fuel elements with high integrity uranium-nickel-aluminum diffusion bonds.

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4. Approximately 1800 hot-die-sized fuel elements have been reactor charged with AlSi control pieces.
5. Post-irradiation data show that average diameter of hot-die-sized fuel elements increases six to eight mils more at mid-point than the AlSi control pieces. Investigation of this problem indicates that it may result from end bonding and uranium heat treating variables or a combination thereof.
6. Because of the inherent advantages of induction over resistance end bonding, equipment was installed and test quantities of induction end bonded fuel elements have been fabricated for irradiation in an effort to resolve the fuel diameter growth problem. Tests designed to investigate the effect of uranium heat treating variables have also been reactor charged.
7. Fabrication techniques were developed and process feasibility has been demonstrated for the assembly of hot-die-sized fuel elements in more economical tubular cladding components.
8. Limited tests indicate the diffusion bonds obtained with high-silicon alloy cladding are at least equivalent to those obtained with standard 8001 aluminum alloy cladding.
9. The feasibility of producing integral ribbed fuel elements having a rib configuration which closely approaches the collapsibility features of the standard bridge-rail for self-supported fuel, has been demonstrated.

III. Progress During Report Period

1. Hot-die-sized fuel elements were fabricated and reactor charged to determine the effects of induction end bonding and uranium heat treating variables on in-reactor growth behavior.
2. A preliminary irradiation test showed that induction end bonding provided only a minor benefit over resistance end bonding in terms of fuel diameter growth. If, in fact, end bonding is a major source of this problem, subsequent induction end bonding innovations are expected to yield a greater improvement in fuel stability.
3. A series of tests were run to establish tentative process parameters for the use of high-silicon aluminum alloy tubing components.
4. Work was continued on the development of tooling and component dimensions for the production of both four and eight integral-ribbed fuel elements in the die sizing operation.

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5. More economical fuel assembly tooling and transfer devices were developed for the preheat and die sizing operations.
6. A study of nondestructive testing methods for hot-die-sized fuel indicates existing equipment is satisfactory, except for the need of further basic development in bond testing to distinguish between mechanical and metallurgical Ni-Al bonds.
7. Chemical research studies showed that substitution of an H_2SO_4 -HCl solution for the conventional H_3PO_4 -HCl anodic etch solution will reduce nickel plate pore density by a factor of about 20.

IV. Evaluation of Effort to Date

Engineering and development studies encompassed by the effort to date have demonstrated the feasibility and versatility of the hot-die-sizing process for fuel production. Although an unforeseen fuel diameter growth problem has been experienced during irradiation, early resolution is expected from tests under way to evaluate the effects of process variables.

Definition of process parameters required to support the conversion of fuel manufacturing facilities to the hot-die-sizing process is progressing on schedule. It is anticipated that research and development findings will be ample to warrant project action by FY-1966.

V. Next Report Period Activities

1. Priority will be given to early resolution of the fuel element diameter growth problem experienced during irradiation. If the process variables tests under way do not yield a solution, a production test is planned to evaluate the effects of additives (Fe, Si and Al) and the heat treating variables on the irradiation behavior of hot-die-sized fuel cores.
2. Process parameters will be further optimized and process specifications will be issued for all regular fuel models to permit pilot-scale production and irradiation of up to 5000 fuel elements per month, starting in January 1965.
3. A run-to-rupture test will be prepared and reactor charged to compare the rupture resistance of hot-die-sized and AlSi bonded fuel.
4. A preliminary irradiation test will be completed on hot-die-sized fuel elements clad in tubing components, and transition will be made to pilot-scale evaluation.

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5. Ex-reactor corrosion tests will be completed on samples of high-silicon aluminum alloy cladding components, and in-reactor testing will be initiated to compare corrosion resistance of the selected alloy with standard 8001 alloy cladding.
6. Hydraulics tests will be completed on integral-ribbed hot-die-sized fuel, rib design will be modified as required to meet reactor requirements, and irradiation testing will be initiated.

VI. Topical Reports Issued

1. HW-72848, "Technology, Economics and Incentives for a Solid State Diffusion Bonding Process - Hot-Die-Sizing," C. A. Burgess, March 1, 1962.
2. HW-76858, "Interim Report on Hot-Die-Sizing Variables Test," C. A. Strand, May 20, 1963.
3. HW-77683, "Provisional Specifications for the Hot-Die-Sizing Process," Process Development Unit, Production Fuels Section, IPD, May 20, 1963.
4. HW-75465, "Production Test IP-546-A, Irradiation of Hot-Die-Sized Diffusion Bonded Fuel Elements," K. L. Hladek and C. A. Burgess, June 27, 1963.
5. HW-78960, "Production Test IP-616-A, Irradiation of Enriched Hot-Die-Size Diffusion Bonded Fuel Elements," K. L. Hladek, September 17, 1963.
6. HW-75465 C, "Fabrication of Hot-Die-Sized Diffusion Bonded Fuel Elements for Production Test IP-546-A," C. A. Strand, October 10, 1963.
7. HW-79706, "Development Status and Incentives for the Hot-Die-Sizing Process," W. A. Blanton, November 20, 1963.
8. HW-80281 RD, "Post-Irradiation Measurements of PT-546-A Fuel Elements," R. R. Bloomstrand, January 1964.
9. HW-78869, "End Closure of Hot-Die-Size Diffusion Bonded Fuel," C. A. Strand, January 4, 1964.
10. HW-81015, "Production Test IP-665-A, Evaluation of Hot-Die-Sized End Bonding Process," K. L. Hladek, March 30, 1964.
11. HW-82472, "Production Test IP-684-A, Hot-Die-Sized Parameters Evaluation," K. L. Hladek, July 16, 1964.

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12. HW-79706 A, "Development Status and Incentives for the Hot-Die-Sizing Process - Supplement A - Case V, Incentives for Five Operating Reactors," W. A. Blanton, August 14, 1964.
13. HW-83454, "Production Test IP-708, Oil-Quenched Hot-Die-Sized Element Evaluation," K. L. Hladek, August 24, 1964.
14. HW-83454 D, "Fabrication of Hot-Die-Sized Diffusion Bonded Fuel Elements from Oil and Water-Quenched Cores for Production Test IP-708-A," C. A. Strand, September 15, 1964.
15. HW-83770, "Interim Report, High-Silicon Aluminum Cladding for Hot-Die-Sized Fuel Elements," C. A. Strand, September 17, 1964.
16. HW-81840, "Production Test IP-677-A, Evaluation of Tube Cladding for Hot-Die-Sized Elements," K. L. Hladek. (To be issued.)

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Program: 02 Metallurgy IPD
Project: 02 50 10 05
Title: Fuel Development (M-2)
Responsible Manager: J. T. Stringer
Responsible Investigator: J. T. Stringer
Reporting Period: July 1, 1964, through October 31, 1964

	<u>Prior Year</u>	<u>FY to Date</u>	<u>Period</u>	<u>FY Estimate</u>	<u>Previous FY Estimate</u>
Costs (Thousands)	246	34.0	4 months	149	149
Scientific Manpower (Man-years)	2	0.2	4 months	2	2

I. Project Scope and Objective

A major part of the funds for this project will be used in the "C" basin examination of fuel irradiated under development programs. The remaining funds will be used for: (1) basic studies of uranium additives and heat treatment to provide the technology for producing relatively stable fuel elements of longer length and to withstand more severe service under product diversification programs, (2) investigation of cladding alloys offering potentially improved corrosion resistance, (3) search for a better means of fuel identification than length, and (4) any basic studies required to resolve fuel quality or performance problems.

II. Major Accomplishments to Date

1. Fuel evaluation studies show a strong correlation between fuel element warp, total bond count, and the rupture resistance of nonbumper fuel to accelerate corrosion "hot spot" failures.
2. An evaluation of induction heat-treated, oil-quenched uranium cores showed no significant difference in the dimensional behavior of this material and standard salt heat-treated, water-quenched cores.
3. An initial test to compare the dimensional stability of water-quenched six-inch and ten-inch enriched fuel cores showed no significant difference in average warp (about five mils) and only minor differences in diameter change. An evaluation of 12-inch natural fuel cores was unsuccessful because of excessive warp during canning, which was attributed to mechanical straightening of the core blanks after heat treating.

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4. Advances in basic technology have resulted in improved reproducibility and accuracy of the nondestructive testing equipment.
5. Static and dynamic corrosion tests on a series of aluminum alloys, having iron and nickel as the major constituents, indicate their corrosion resistance is only equivalent or slightly better than the present 8001 fuel cladding alloy. High-silicon alloys being evaluated in conjunction with the alternate cladding process are the only alloys showing potential at this time.
6. Techniques and equipment have been developed to size and control the support height of self-supported fuel models.
7. A stronger arch-rail has been developed, and is being evaluated in-reactor as an alternate for the present collapsible bridge rail.

III. Progress During Report Period

1. Post-irradiation measurements were continued in "C" basin in support of research and development programs.
2. Post-irradiation data showed no appreciable difference in the warp and diameter change of salt heat-treated, water-quenched six-inch and ten-inch enriched fuel cores. A test has been prepared to compare the dimensional behavior of oil-quenched ten-inch and six-inch fuel cores.
3. Studies thus far of techniques for identifying fuel enrichment by other means than length differences have been unsuccessful.

IV. Evaluation of Effort to Date

Advances in basic technology falling within the scope of this program have resulted in improved fuel quality and performance. Further progress can be made in fuel uniformity or grading with respect to performance. The development of stable fuel elements of longer lengths will lead to lower fuel fabrication costs.

V. Next Report Period Activities

1. "C" basin examinations will continue in support of fuel development programs on a priority basis.
2. The evaluation of longer fuel lengths will be gradually expanded to pilot-scale quantities. Incentives for the use of longer fuel will be established on the basis of potential reactor usage.

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3. Studies will be made in cooperation with feed-site to determine the effect of uranium core blank dimensions prior to heat treating on core surface hydrogen, fuel element braze porosity, and irradiation warp.
4. Pilot-scale evaluation of induction heat-treated, oil-quenched uranium will be resumed.
5. Limited effort will be continued to establish a feasible means of identifying fuel models other than by present length differences.

VI. Topical Reports Issued

1. HW-76293, "Post-Irradiation Data from the Quality Certification Program," R. R. Bloomstrand and J. L. Jaech, January 18, 1963.
2. HW-77610, "Corrosion of Experimental Aluminum Alloys," R. B. Richman, May 10, 1963.
3. HW-78745, "Aluminum Alloy Corrosion in Treated River Water," R. B. Richman, November 1963.
4. HW-78759, "Production Test IP-610-A, Evaluation of Induction Heat-Treated Fuel Cores," K. L. Hladek, November 19, 1963.
5. HW-80089, "Increased Length Fuel Elements," D. A. Snyder, December 27, 1963.
6. HW-SA-3319, "Oxide Dissolution in Aluminum Corrosion," D. R. Dickinson, January 14, 1964.
7. HW-80468, "Production Test IP-654-A, Evaluation of Ten-Inch Enriched Uranium Fuel Elements," K. L. Hladek, February 2, 1964.
8. HW-81231, "Process Improvement Transition Authorization IP-29-I, Evaluation of Induction Heat-Treated, Oil-Quenched Uranium Cores," N. E. Fuller, March 6, 1964.
9. "Analysis of Data from PT-654," R. R. Bloomstrand, September 17, 1964. (Undocumented)
10. HW-84328, "Analyses of Quality Certification Data," R. R. Bloomstrand, October 9, 1964.

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