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WESTINGHOUSE CLASS 3

WCAP-9210

RESEARCH AND DEVELOPMENT PROGRAM
FOR SELECTED COMPONENTS OF MIXED OXIDE
FUEL FABRICATION

MASTER

Quarterly Progress Report

for

the period ending June 30, 1977

by

John C. Limpert
Technical Coordinator

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INTRODUCTION

This quarterly report is the second in a series covering research and development for selected components of mixed oxide (MOX) fuel fabrication in support of LWR fuel recycle. The Westinghouse effort is one of several ERDA programs undertaken jointly with industry to assist in the commercialization of the LWR fuel cycle. This program, administered by the Savannah River Operations Office (SROO), consists of seven tasks on MOX fuel fabrication supporting both of ERDA's major near-term objectives: (1) the conceptual design of complete recycle facilities, and (2) the development of improved fuel cycle technology or resolution of uncertainties in that technology. The seven tasks currently authorized by SROO under Contract EY-77-C-09-0945 are listed below:

- **Task 1 — Application of Advanced Accountability Concepts in Mixed Oxide Fuel Fabrication**

The first part of this phased task was a study of the application of advanced material accountability concepts to a large-scale commercial mixed oxide fuel fabrication facility. Pending ERDA approval, Phase II will consist of installing, operating, and evaluating selected advanced material accountability systems in the Westinghouse Plutonium Fuels Development Laboratory (PFDL). As a result of new energy policies, an extension of the Phase I program has been initiated to evaluate the impact of alternate fuel cycle concepts on the proposed Phase II program.

- **Task 2 — Pneumatic Transport System Development**

Westinghouse will design, procure, install, test, and evaluate a pneumatic powder transport system for application in commercial fabrication processes.

- **Task 3 — Powder Batch Weighing**

This effort, involving the design, procurement, installation, test, and evaluation of a three-component powder batch weighing system, will be performed at the Plutonium Fuels Development Laboratory.

- **Task 4 — Planning Related to the Conceptual Design of a Large-Scale Mixed Oxide Fuel Fabrication Facility**

The first part of this phased task defined the actions and schedules required to develop and provide the technical base for a conceptual design of a mixed oxide fuel fabrication facility which would form a portion of a fuel reprocessing complex. A Phase II program will provide, in accordance with the plan developed under Phase I, technical data bases for the subsequent conceptual design — for instance, functional requirements, design criteria, and market information. A Phase III program will provide engineering support for the development of the conceptual design.

- **Task 5 — Residual Material Holdup and Powder Release**

This task consists of evaluation and testing to determine the location and probable quantities of residual material holdup in a large-scale MOX fabrication facility and to determine sites of powder accumulations if releases occur within containment.

- **Task 6 — Barrier Seal Development**

Westinghouse will conduct a barrier seal development program for a MOX rod loading system and develop appropriate functional specifications.

- **Task 7 — Mixed Oxide Fuel Fabrication Waste Management**

The first phase of this task involved a study defining the impact of waste management schemes on commercial recycle MOX fuel fabrication; the study included development of a test program, schedule, and cost estimates for the installation and evaluation of such a system at PFDL. If agreeable to ERDA, Phase II will authorize the actual procurement, operation, and evaluation of the selected systems identified in Phase I.

The reference commercial large-scale fabrication facility for these studies is the Westinghouse Recycle Fuels Plant (RFP), described in the RFP License Application, Docket Number 70-1432, published in July 1973. Many of the components of this plant represent new design concepts based on Westinghouse-sponsored development activity. Progress on each task is reported separately in the following sections.

SECTION 1

TASK 1 - APPLICATION OF ADVANCED ACCOUNTABILITY CONCEPTS IN MIXED OXIDE FUEL FABRICATION

Task Manager: J. J. Bastin

Principal Investigators: C. C. Randall
M. J. Jump
R. A. Lange

1.1 OBJECTIVES

This task is divided into two phases having separate but related objectives. The objective of Phase I is to perform a detailed study of the application of advanced special nuclear material accountability concepts, such as DYMAC,^[1] in a large-scale mixed oxide fuel fabrication process. The study will include an evaluation of the impact of alternative feed material — for example, coprocessed uranium-plutonium and uranium-thorium fuels — on the proposed Phase II plan.

The objective of Phase II will be to install, operate, and evaluate selected DYMAC systems in an operating commercial fuel fabrication facility (Westinghouse PFDL).

1.2 SUMMARY

Following ERDA approval of a Phase I extension in June 1977, work was initiated to evaluate the impact on the Phase II plan of processing alternative fuel forms, such as uranium-thorium and coprocessed uranium-plutonium feed. To date, a literature survey of the thorium-uranium fuel cycle has been completed.

1.3 TECHNICAL PROGRESS

A literature survey was conducted for information on the handling and processing of $^{233}\text{U-Th}$ fuels to provide a basis for determining the impact of substituting $^{233}\text{UO}_2\text{-ThO}_2$ for $\text{UO}_2\text{-PuO}_2$ in the Phase I plan (WCAP-9104). Based on the information obtained, it was determined that the current mixed oxide fabrication reference process would be similar for

1. DYMAC is the Los Alamos Scientific Laboratory acronym for Dynamic Materials Control.

the $\text{UO}_2\text{-ThO}_2$ fuel in that mechanical mixing, pelleting, and sintering operations would be used. However, some development is required to formulate current concepts into a commercially viable fabrication system. The present state of the art for the fabrication of $\text{UO}_2\text{-ThO}_2$ LWR pellet fuels is generally the result of development under ERDA Contract E(36-1)-CEN-14 by the Bettis Atomic Power Laboratory, which is explored in some detail in WAPD-TM-1244(L).^[1]

The review also identified additional studies needed to support a license amendment for the utilization of ^{233}U -Th fuels in the Westinghouse PFDL. Typically, the following would be required:

- Definition of ^{233}U enrichment - nuclear design
- Shielding requirements
- Criticality calculations
- Facility modifications
- Process equipment modifications and/or additions
- Analytical and chemical analysis equipment modifications and/or additions
- Health and safety
- Safeguards plan modification
- Environmental report update to reflect ^{233}U and impact analysis

1.4 FUTURE WORK

During the next reporting period, evaluations of the impact of coprocessed U-Pu and ^{233}U -Th feed materials will be completed and incorporated into the Phase I report.

1. "ThO₂ and ThO₂-²³³UO₂ High Density Fuel Pellet Manufacture for the Light Water Breeder Reactor," WAPD-TM-1244(L), January 1976.

SECTION 2

TASK 2 - PNEUMATIC POWDER TRANSPORT SYSTEM DEVELOPMENT

Task Manager: D. M. Batson

Principal Investigators: M. C. Skriba
C. K. Wu
E. E. Smeltzer
W. C. Yang

2.1 OBJECTIVES

The objective of this program is to perform an evaluation of the pneumatic transport of bulk nuclear fuel powders and provide design and performance criteria for the application of such a system in a large-scale commercial mixed fuel fabrication facility.

2.2 SUMMARY

A literature search for information on dilute phase pneumatic transport was completed and a draft report of the state of the art has been prepared. Revisions are being made to incorporate additional information on nonnuclear industrial operations and technologies which could be applicable to pneumatic transport of nuclear fine powder.

An overall test plan for the UO_2 dilute phase pneumatic transport tests was developed, and a detailed experimental program has been completed in draft form. The cost estimate in support of these test activities has been finalized.

Design of the pneumatic transport test loop at the Westinghouse Research and Development Center is continuing. A process flow diagram was prepared along with a general arrangement drawing showing the loops, components, and orientation of all equipment in the test facility. A detailed instrumentation drawing was prepared and specifications for the instrumentation are being written.

Purchase orders for the ThO_2 and depleted UO_2 test powders have been processed with respective acknowledged shipping dates of July 1977 and August 1977. Procurement on major loop components (long-lead-time items) has been initiated.

2.3 TRIPS AND VISITORS

On April 28 and 29, 1977, J. C. Limpert and M. C. Skriba visited the General Atomic Company to obtain information on pneumatic powder transport systems being developed under ERDA contract in support of HTGR fuel reprocessing.

On May 18, 1977, D. E. Braithwaite visited the BLH Corporation, Boston, a weighing system manufacturer, to discuss the application of load cells for monitoring powder transport rates.

2.4 TECHNICAL PROGRESS

The efforts in this second quarter have been directed at test plan development, transport loop test system definition, component design, and the preparation of a state-of-the-art summary.

2.4.1 State-of-the-Art Study

The available information on dilute phase pneumatic transport was reviewed and the state-of-the-art report was prepared in draft form. The information sources included (1) publications from scientific journals, meeting proceedings, and symposiums; university dissertations; and government agency research reports; and (2) user operating experience obtained from the Westinghouse pneumatic transport test loops for UO_2 powder at PFDL, Cheswick; Westinghouse Nuclear Fuel Division manufacturing facility, Columbia, South Carolina; General Atomics Corporation, San Diego, California; and National Research Laboratories. The literature search was conducted through the Westinghouse Research Laboratories Information Retrieval System, which scanned numerous articles in Chemical Abstracts (1970 to present), Engineering Index (1970 to present), National Technical Information Service (NTIS) (1964 to present), and Nuclear Science Abstracts (1967 to present). In addition, the manual search was extended back to 1950.

Generally, the state-of-the-art summary concludes that, despite many years of research in and study of pneumatic transport systems by manufacturers and users, the performance of dilute phase pneumatic transport systems is not theoretically predictable with a high degree of confidence. Verification testing utilizing plant-scale equipment has been the only reliable means to achieve the confidence necessary for the detailed design and installation of such systems in a remote or semi-remote recycle fuel process. The complexity of the pneumatic transport system can be readily appreciated by examining the dependent and independent variables of the pneumatic transport system:

- Material to be transferred and its properties in terms of size, shape, density, and surface roughness
- Solid loading or conveying rate

- Properties of the conveying fluid, such as its density and viscosity at the operating conditions
- Conveying velocity at the operating conditions
- Pipe size and interior surface finish

The dependent variables are the phenomena observed at different design and operating conditions, for example:

- Pressure drop in the transport lines
- Acceleration pressure drop and particle acceleration length
- Choking in the vertical transport and saltation in the horizontal transport
- Static electricity generation
- Agglomeration for fine particles
- Particle classification

2.4.2 UO₂ Phase Test Plan Development

A detailed experimental program plan for pneumatic transport study was developed and a document has been prepared for internal review. The plan consists of a series of 14 test runs conducted at the Westinghouse Research and Development Center Uranium Processes Engineering Laboratory. A description of the individual tests, including objectives, material requirements, and operation conditions, is given in table 2.1. This plan will be amended periodically as real data become available from actual operating experience. The experimental program will examine fine powder pneumatic transport in three phases, as described below.

2.4.2.1 Base System Performance Evaluation — Initially, the transport test loop will be operated at specific process conditions to simulate selected typical transports which are based on the Westinghouse Recycle Fuels Plant flow sheet. The performance of the base system will be evaluated for compliance with the functional requirements of the pneumatic transport system as well as the available design equations for a commercial MOX fuel fabrication facility.

2.4.2.2 Parametric Testing — The objective of the parametric testing is to establish an operating envelope extended from the present design point so that the capability and performance of the selected pneumatic transport system can be fully evaluated and optimized. The candidate powders for the experiments include UO₂, ThO₂/UO₂ mixtures, and three component mixtures which consist of UO₂, ThO₂, and recycle UO₂ powder derived from clean scrap. The linear gas velocity in the transport line will be varied, as will the gas-to-solid mass ratios.

TABLE 2.1
SUMMARY OF TEST SCOPE FOR PNEUMATIC TRANSPORT OF NUCLEAR FUEL

Test Series	Objective	Material	Diameter of Test Loop (in.)	Operating Conditions
BASE SYSTEM PERFORMANCE EVALUATION TEST PLAN				
001	To determine system throughput requirements and effect of time of operation on powder	UO ₂ powder from ADU or DCFB	2	Gas velocity = 90 ft/sec, S/G ^[a] = 2, solid rate = 400 kg/hr
011 ^[b]	Same as above	UO ₂ powder from ADU or DCFB	1	Gas velocity = 90 ft/sec, S/G = 2, solid rate = 80 kg/hr
013	Simulate pneumatic transport from the MC ₂ storage silo to the compactor	UO ₂ /ThO ₂ mixture	1	Solid rate = 80 kg/hr, transport velocity and S/G to be determined by parametric testing
PARAMETRIC STUDY TEST PLAN				
002	Determine system performance in terms of available design equations, line residuals, and filter performance	UO ₂ powder from ADU or DCFB	2	50 ft/sec at S/G of 1,2, and 4 65 ft/sec at S/G of 1,2, and 4 90 ft/sec at S/G of 1 and 2
003	Investigate system performance with a different UO ₂ powder	UO ₂ powder	2	Minimum of 3 test points selected from those tested in Test Series 002
004	Investigate system performance with a different powder -- UO ₂ /2% ThO ₂	UO ₂ /2% ThO ₂	2	Minimum of 3 test points selected from those tested in Test Series 002
005	Determine long-term powder accumulation and particle segregation in the line	UO ₂ /2% ThO ₂	2	One test point selected from the results of Test Series 004, minimum of 10 passes, system cleaned out after each pass
006	Investigate system performance with a different powder -- UO ₂ /4% ThO ₂	UO ₂ /4% ThO ₂	2	Minimum of 3 test points selected from those tested in Test Series 002
007	Investigate system performance with a different powder -- 3-component mixture	3-component mixture concentration to be determined	2	Minimum of 3 test points selected from those tested in Test Series 002

a. S/G = solid-to-gas ratio

b. Test Series 011B will be conducted in Parametric Testing.

TABLE 2.1 (cont)
SUMMARY OF TEST SCOPE FOR PNEUMATIC TRANSPORT OF NUCLEAR FUEL

Test Series	Objective	Material	Diameter of Test Loop (in.)	Operating Conditions
011B ^(c)	Determine system performance in terms of available design equations line residuals, and filter performance	UO ₂ powder from ADU or DCFB	1	50 ft/sec at S/G of 2, 4, and 8 65 ft/sec at S/G of 2, 4, and 8 90 ft/sec at S/G of 2 and 6
SYSTEM OPERATION AND COMPONENT PERFORMANCE EVALUATION TEST PLAN				
008	Study restart capability after involuntary shutdown	UO ₂ /2% ThO ₂	2	Minimum of 3 test points selected from those tested in Test Series 002
009	Investigate capability of continuous operation (continuous transfer from feeder to receiver and from receiver back to feeder)	UO ₂ /2% ThO ₂	2	Optimum test point selected from results of Test Series 004
010	Examine component reliability and performance under designed operating conditions based on test results (erosion, plugging, leak through, diverter valve, etc.)	UO ₂ /2% ThO ₂	2	Same as Test Series 009
012	Study restart capability after involuntary shutdown	UO ₂ /2% ThO ₂	1	Minimum of 3 test points selected from those tested in Test Series 011
014	Demonstrate the operation of the pneumatic transport loop at the designed operating conditions	To be specified later		

c. Test Series 011A will be conducted in the Base System Performance Evaluation.

2.4.2.3 System Operation and Component Performance — The final phase of the experiments consists of three parts: (1) evaluation of system operability and stability, (2) component performance assessment, and (3) demonstration runs. The tests will include simulation of involuntary shutdown and system restart capability after upset conditions. The effects on powder accumulation in transport lines, system failure due to line clogging, and erosion at bends will be analyzed. The performance of such components as the rotary air lock, diverter valve, blower, and filters as well as the control instrumentation will be evaluated. At the end of the program, a demonstration test series will be conducted to verify the system's applicability for the MOX fuel fabrication facility.

2.4.3 UO₂ Test Loop Design

To test the validity of theoretical calculation and engineering design equations, tests must be conducted in representative equipment and systems. Based on the state-of-the-art review and analysis, the projected test plan, and the design constraints, a loop has been designed for the conduct of the experimental test program.

2.4.3.1 General Constraints — Since the Westinghouse Recycle Fuels Plant flow sheet is used as the reference process, the constraints imposed by the functional requirements and design criteria for that process system were assumed to size and design the test loops. The two loops chosen for the simulation were the line from the powder blending operation to the storage silo, and the line from the storage silo to the compactor. These paths were chosen because they are widely different in their operating modes. The blender-to-silo transfer is an intermittent, high-capacity operation in a larger line; the silo-to-compactor transfer is nearly continuous at a lower level in a smaller line.

A line leak during powder transport would be a major problem in a positive pressure system, since it would spray powder into the containment. To prevent this type of failure, the system design was based on a negative pressure system using vacuum transport. From a design standpoint, a negative-pressure-driven system is less desirable because of the lower availability of driving potential, but the safety considerations take precedence.

Receiver vessel design is considered to be important, and two geometrically different vessels were deemed necessary. The silo receiver was selected in a slab geometry and the compactor receiver was selected in a cylindrical geometry. This was the initial design for those vessels in the plant, dictated by nuclear safety criteria.

2.4.3.2 Loop Description — A pneumatic transport test loop concept was developed; it is shown isometrically in figure 2.1. The test loop consists of three circuits: the 2-inch powder circuit, the 1-inch powder circuit, and the air circuit.

The loop is a closed loop system on the air side with a rotary positive displacement blower as the prime mover. The air loop was closed to allow maximum use of conditioned (-60°F dew point) air and reduce the load on the existing air dryer filter.

This air system is designed to provide the motive fluid for both the 1- and 2-inch powder transfer loops.

Blended powder is fed into a 2-inch-diameter pneumatic transport loop from the feeder through a rotary valve. This valve provides rate control to the solids flow so that design balances can be maintained on powder transfer rates and solid-to-gas ratios.

Pressure loss due to powder acceleration is anticipated from the outlet of the rotary valve over the initial 10 feet of line depth, around bends, in vertical and horizontal drops, at line elements, and, finally, at filters. Instrumentation has been provided to measure the differential pressure at each of these points.

In the 2-inch loop, provisions are made to return the transported powder from the silo back to the feeder while the loop is operating. In effect, this mode of operation can be continuous for extended test periods. Powder return is accomplished by rate feeding the powder from the silo through a rotary valve and then using a pressure-driven eductor to return the powder at a high solid-to-gas ratio to the feeder through a 1-inch return line.

The 2-inch line incorporates a diverter valve to enable a simulation of line switching. This simulation will allow a determination of functional performance and residuals in this important piece of equipment.

The 1-inch circuit is designed to run as an alternate system. It should be noted that the 2-inch and 1-inch circuits cannot be run simultaneously. Important differences between the 1- and 2-inch circuits are the length of run time and the inability to return the powder from the compactor hopper to the feeder on a continuous basis.

2.4.3.3 General Arrangement — The vessels are centrally arranged in a ventilated walk-in enclosure with the transport piping generally located around the vessels along the containment wall. The 2-inch and 1-inch circuits consist of approximately 200 feet and 100 feet of piping, respectively; both loops have horizontal and vertical linear runs of 25 feet.

Figure 2.1 Pneumatic Transport System General Arrangement

2.4.3.4 Control Instrumentation — The instrumentation package for the pneumatic transport test loop has been developed, and specifications are being written. Layout of a semi-graphic control panel has been completed and detail drawings necessary for the fabrication of the control panel have begun.

2.5 FUTURE WORK

During the next reporting period, detailed specifications for the instrumentation package and detail drawings necessary for the fabrication of the control panel will be completed.

Installation of the pneumatic transport test loop will be initiated and continue through the next quarter.

In addition, the state-of-the-art summary, currently in internal review, is expected to be in final draft form and issued to Westinghouse Technical Publications for printing in September.

SECTION 3

TASK 3 - POWDER BATCH WEIGHING

Task Manager: D. M. Batson
Principal Investigator: A. R. Marmo

3.1 OBJECTIVE

The objective of this task is to determine design and performance criteria for a powder batch weighing system suitable for use in a large-scale mixed oxide fuel fabrication facility. This will be accomplished by the development and demonstration of the operation of a three-component powder batching system at production plant throughput level under simulated conditions of remote operations.

3.2 SUMMARY

Accomplishments during this reporting period included preparing and releasing a request for quotation for the design and fabrication of a three-component powder batch weighing system. The procurement package included functional requirements, design criteria, system description, system process flow diagram, engineering flow diagrams, and a typical equipment arrangement drawing.

A test prospectus was completed defining the requirements for a test program to verify the system's compliance with the functional specification.

A market survey of powder batch weighing systems was conducted to determine the commercial state of the art and to identify potential suppliers. A report has been drafted summarizing the assessment and listing vendors with system design and fabrication capacity to supply a system for the unique requirements of a MOX powder batching system.

3.3 TRIPS AND VISITORS

On May 4, 1977, J. D. Kline and A. R. Marmo visited Packard Electric Company, Warren, Ohio, to view a multicomponent powder batch weighing system.

On May 19 and 20, 1977, J. D. Kline, S. J. Tyde, and A. R. Marmo visited weighing equipment manufacturers to discuss engineering and procurement aspects of the specification issued by Westinghouse for a batch weighing system for MOX powders, and to conduct a review of vendors' facilities.

3.4 TECHNICAL PROGRESS

Progress has been made in various aspects of the study, as described in the following paragraphs.

3.4.1 Procurement

A request for quotation was prepared for the design and fabrication of a powder batch weighing system. The procurement package was reviewed, finalized, and issued by Westinghouse PWR Purchasing. The package includes functional requirements, design criteria, system description, process flow diagram, engineering flow diagrams for the three component powders, and a typical equipment arrangement drawing.

3.4.2 Market Survey

A report has been drafted which summarizes commercially available technology in weighing systems as well as the vendors' capability to finish a complete system meeting the requirements of a MOX powder batch weighing system. The survey revealed that the technology exists to meet the technical requirements of a powder batching system suitable for operation in a large-scale mixed oxide fuel fabrication facility. However, there is little background or experience available in weighing systems for nuclear applications; consequently, vendors are not familiar with the radiation aspects of weighing system design.

The major design uncertainties and areas of concern to be resolved for commercial application of a batch weighing system to a nuclear facility involve weighing precision, material handling and residual levels, remote operation and maintenance, system reliability, radiation effects, and the ability to achieve required weighing accuracies.

Several batch weighing system vendors were identified and contacts were made to determine their ability to meet stated requirements for a mixed oxide batching system. Selected vendors were visited to view their facilities and discuss their backgrounds, expertise, and methods of doing business.

A trip was made to a commercial, multicomponent batch weighing installation to gain insight into actual operating experience and system performance under production conditions.

3.4.3 Test Prospectus

Functional testing of the fabricated powder batch weighing system will be performed at the vendor's facility prior to shipment to Westinghouse to assure compliance with the requirements of the functional specification (Westinghouse Specification SR-SP-2628). A test prospectus has been prepared to define to the vendor the requirements of a test program to demonstrate compliance.

Acceptance criteria defined in the test prospectus include the following:

- Performance criteria

- (1) Cycle time — The system must prepare a batch of powder in less than 4 hours.
- (2) Hopper discharge rates — Both feed hoppers and weigh hoppers must be capable of powder discharge rates as follows:
 - UO₂ hopper — 400 kilograms per hour
 - PuO₂ hopper — 48 kilograms per hour
 - MO₂ hopper — 200 kilograms per hour
- (3) Weighing accuracies — The powder weighing systems must have the capability to dispense the component powders to the following weighing accuracies:⁽¹⁾
 - PuO₂ — ± 0.05 percent of applied load
 - MO₂ — ± 0.1 percent of applied load
 - UO₂ — ± 0.1 percent of applied load
- (4) Repeatabilities — The powder hopper weigh cells must demonstrate a repeatability of 0.02 percent of maximum loads.
- (5) Tare weight — The system must automatically zero each hopper tare weight.
- (6) Calibration — The system must automatically apply calibration weights and calibrate each weigh cell, maintaining calibration within ± 0.1 percent of applied load.

1. These accuracies represent the commercial state of the art as determined from a vendor survey conducted as part of this task.

■ Process control criteria

- (1) Automatic mode — The batch weighing system must sequence automatically through the filling of the three weigh hoppers to the pre-selected weights, indicating a "weight acceptable" condition.
- (2) Manual mode — The entire batch weighing operation must be conducted manually from the control console.
- (3) Alarm system — The following alarms must be demonstrated:
 - Overweight (as defined under Weighing Accuracies, above)
 - Out of calibration
 - Excessive residual material
 - Cycle overdue (timer on cycle)
 - Scale moving (hopper losing powder)

■ Safeguards — The following safeguards must be demonstrated:

- (1) Upon loss of power, the system will fail safe.
- (2) Upon loss of air, the system will shut down in a fail-safe condition.
- (3) Failure or malfunction of a component or control element will stop the process in a fail-safe condition.

3.5 FUTURE WORK

Efforts during the next reporting period will be directed toward evaluation of vendor proposals for design and fabrication of the powder batching systems, awarding of a contract, and initiation of the conceptual design of a system.

SECTION 4

TASK 4 - PLANNING RELATED TO THE CONCEPTUAL DESIGN OF A LARGE-SCALE MIXED OXIDE FUEL FABRICATION FACILITY

Task Manager: E. R. Rubbo

Principal Investigators: G. D. Childs
L. M. Coco
H. H. Crain
C. D. John
W. G. Tope

4.1 OBJECTIVE

The objective of the second-quarter work effort for Task 4 was to initiate the work scheduled through April 30 under the contract extension agreement and to provide written functional requirements, operating philosophies, design criteria, and design bases as defined by the action diagram presented in the Phase I report.

4.2 SUMMARY

The contract extension required submittal of reports on the following subjects:

- Fuel cycle service supplier-utility purchaser commercial relationships
- Preliminary criteria for the design of a fuel assembly facility
- Preliminary criteria, description, and examples of a QA/QC program plan required for operation of a large-scale MOX facility
- Westinghouse review of SRL's technical data summary
- Representative nonproprietary feed and product specifications
- Specialized fabricating equipment for the manufacture of mixed oxide fuels

Draft reports have been completed and are currently in internal review.

Reports on functional requirements, operating philosophies, design criteria, and process design bases are being prepared, and a schedule has been transmitted to SRL for comment. The flow of data will extend into FY 78; the data will be provided according to a schedule agreed upon by Westinghouse and ERDA.

4.3 TRIPS AND VISITORS

On May 26, 1977, Messrs. W. B. Wilson and W. Shaeffer (ERDA) and T. Gould, T. Rankin, R. Herries, and R. Huntoon (DuPont) visited Westinghouse Nuclear Fuel Division (NFD) and met with Advanced Fuels and Process Development personnel on the status of ERDA-Westinghouse programs. Progress on the Design Integration Study (DIS) was included as part of the meeting agenda.

4.4 TECHNICAL PROGRESS

Progress has been made in various aspects of the study, as described in the following paragraphs.

4.4.1 IFRC-MOX Product Mix, Fuel Supply Requirements, and Interfacing Fuel Cycle Service Supply Activities

A study was conducted and a report prepared describing typical fuel cycle service supplier-utility purchaser commercial relationships and providing data on the following issues:

- The representative BWR-PWR reactor product mix (types, sizes)
- Typical fuel supply requirements for the reactor product mix
- Identification of specific interfacing fuel cycle service supply activities

These data are provided for the 1986 time frame, which is the operational reference for the Integrated Fuel Reprocessing Complex — Mixed Oxide Fuel Fabrication Facility (IFRC-MOX).

Assessments have been made of the size of the total potential reload market, projected IFRC-MOX capacity, representative PWR-BWR product mix (by type and size) to be produced by IFRC-MOX, and typical fuel supply requirements for that mix. The report also contains a discussion of interfacing fuel cycle service supply activities, from both the design and manufacturing standpoints.

4.4.2 Preliminary Criteria for the Design of a Fuel Assembly Facility

Preliminary criteria for the design of a fuel assembly facility as an integral part of the IFRC mixed oxide fuel fabrication facility have been evaluated and a draft report prepared.

The report provides a description of a fuel assembly, fuel rods, and a fuel assembly structure. The structure discussion includes descriptions of the top and bottom nozzles, guide and instrument thimbles, and grid assemblies.

4.4.3 A Typical QA/QC Program for the Operation of a Large-Scale Mixed Oxide Fuel Fabrication Plant

The manufacture of mixed oxide fuel must conform to the criteria established in 10CFR, Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants." The scope of Appendix B ranges from the planning, designing, construction, and operation of a total nuclear power plant to the design, procurement, testing, and operation of basic materials and components of construction and operation. An explanation of how and why Appendix B applies to the operation of a fuel fabrication plant and to the manufacture of nuclear fuel and components is provided.

Appendix B to 10CFR, Part 50, composed of 18 criteria, establishes by law the quality assurance requirements for the design, construction, and operation of nuclear power plant safety-related structures, systems, and components; it applies directly to the nuclear power plant owners.

The most-often-used practice of nuclear power plant owners is to delegate the establishment and execution of the required quality assurance programs to others (such as reactor designers and fuel fabricators). However, the total responsibility for complying with Appendix B remains with the plant owners.

In this study, a suggested assignment of the various criteria of Appendix B to various participants in the mixed oxide fuel cycle has been provided. The criteria assigned to the fabricator of mixed oxide fuel form the basis for the QA/QC program described.

The report presents a description and provides examples of a typical QA/QC program required to comply with the criteria of Appendix B assigned to fuel fabrication plants.

4.4.4 Westinghouse Comments on DPSP-LWR-77-18, "LWR Recycle and Conceptual Design Considerations"

Westinghouse has reviewed the SRL technical data summary for the IFRC-MOX facility and issued comments, which are currently under review by SRL.

4.4.5 Westinghouse NFD Listing of Feed and Product Specifications

Westinghouse has compiled specifications for PWR fuel products, such as PuO_2 , UO_2 , pellets, fuel rods, tubing, rod components, and assembly hardware. It has been recommended that the industrial specifications be used for conceptual design purposes which require the application of feed and product material information. For those cases in which Westinghouse uses industrial specifications as published, these have also been provided.

4.4.6 Identification of Specialized Fabricating Equipment for the Manufacture of Mixed Oxide Fuels

An equipment list for a large MOX fuel fabricating facility was compiled from a review of the reference process and identification of the major pieces of process equipment. Most of the required items must be custom-designed. They would normally be procured by initiating a design-and-build contract based on functional specifications, or by supplying detailed design drawings and specifications to a fabricator.

Items which are commercially available have been identified by supplier and model number where applicable, and the address of the supplier has been provided. Although items of equipment are identified specifically by model number, various degrees of modification may be expected. Alterations due to remote operation, containment of product, material handling equipment, and specialized maintenance will probably be required, along with special controls and instrumentation to assure their safe, reliable operation and control.

Where items of equipment are described as being fabricated to design drawings and specifications, the list indicates that a workable design exists from experience in uranium process lines or development programs, or that the equipment follows a reference process for a specific design (for example, loading of Westinghouse design PWR 17 x 17 final assemblies).

Items of equipment which will be designed and fabricated to functional specifications are not considered to require highly advanced technology in the nuclear fuel fabrication discipline. Upon establishment of functional requirements, operating philosophies, design criteria, and the process design bases for a MOX fuel fabrication facility, these items may be fabricated by specialists in the particular fields (for instance, conveyor systems, storage tanks).

4.5 FUTURE WORK

Phase II of Task 4 will include development of the technical design base for the MOX facility. Westinghouse will provide technical data on an agreed-upon schedule and in discrete packages which follow the format presented in the Phase I planning document. Westinghouse will also review and comment on ERDA documents, drawings, and so forth which utilize these data.

SECTION 5

TASK 5 - RESIDUAL MATERIAL HOLDUP AND POWDER RELEASE

Task Manager: D. M. Batson
Principal Investigators: H. C. Woodsum
C. K. Wu

5.1 OBJECTIVES

The objectives of this task are (1) to determine the residual holdup of material containing mixed oxide^[1] in storage vessels, transfer mechanisms, and processing equipment specifically designed for MOX fuel fabrication under conditions of remote or semi-remote handling, and (2) to examine various release modes and determine from the quantities released how much MOX ultimately reaches the final filters and how much is retained locally (in the glove box, local filters, and duct work), so that accountability determinations can be made.

5.2 SUMMARY

Design and construction of the metal surface/powder adherence test apparatus has been completed and mechanical shakedown tests are being conducted.

Experiments to determine the electrostatic charge effect on powder mixtures have been initiated for two types of powders: UO_2 with 3 weight percent ThO_2 and ADU-derived UO_2 . The first series of test results obtained in a grounded metal column showed insignificant charge buildup. Resistivity measurements on the powder mixture ingredients indicate that pure thorium (ThO_2) has much higher resistivity than urania (UO_2).

The clean scrap recovery system (CSRS) has been disassembled and cleaned out in preparation for the CSRS residual and release tests. The containment hood has also been cleaned out, and an aerosol sampling test fixture has been fabricated.

1. Mixed oxide here refers to a nominal composition of 2 to 4 weight percent PuO_2 and 96 to 98 weight percent depleted UO_2 , with a maximum PuO_2 content of 6 weight percent.

Design and construction of the powder processing test system at PFDL is continuing. The Westinghouse slab blender has been sent to an offsite vendor for modifications before installation in the test system. All materials for the containment box to be constructed in the Uranium Processing Area at PFDL have been received, and the exhaust system has been cleaned out and made operational.

The Experimental Program Plan (Phase I — UO_2), which details plans for the residual holdup tests utilizing UO_2/ThO_2 , has been issued. The UO_2/PuO_2 residual holdup measurement test plan (Phase II) has been completed in draft form, and cost estimates in support of these plans have been prepared.

The report entitled "State of the Art Survey of Residual Holdup in a 200 MT/Year MOX Fuel Fabrication Facility" has been sent to the Technical Publications group for final editing and printing.

5.3 TRIPS AND VISITORS

A status report of progress to date and future plans for Task 5 was presented to the Savannah River Operations Office and Savannah River plant personnel by the principal investigators, H. C. Woodsum and C. K. Wu, at an overall program review held on May 27 in Pittsburgh.

5.4 TECHNICAL PROGRESS

A detailed experimental program plan for residual holdup measurements (Phase I) utilizing UO_2 and ThO_2 powders to simulate mixed oxide has been completed and issued. The Phase I plan involves six sets of tests, as shown in table 5.1. Three of these tests will be repeated in Phase II utilizing MOX powder; a detailed experimental plan has also been prepared for these tests. The overall experimental program network is illustrated in figure 5.1.

The current status of these experiments is described in some detail below.

The first series of experiments to determine the electrostatic charge effect on powder mixtures has been initiated. Two types of powders (BNFL UO_2 with 3 weight percent ThO_2 and ADU-derived UO_2) were tested in a grounded metal column under fluidized conditions. A pulsing voltage of 0.5 to 1 volt was measured with a high impedance electrometer at a gas flow of 3 scfm for both powders. The voltage level remained fairly constant during the 100-minute test. To compare charge effects in a conducting and insulated vessel, the test was repeated in a glass column. At 3 scfm gas flow, the voltage generated was above 100 volts. The voltages when the gas flow was lowered to 0.5 and 1 scfm were 25 and 95 volts,

respectively. The results of these tests show that charge buildup in an insulated glass column is significantly different from that in a grounded steel column. The impact of this effect on powder adherence has not been determined at this time.

Resistivity measurements have been performed on the constituent powder mixture materials. Preliminary data indicate that thorium (ThO_2) has a much higher resistivity than the uranium (UO_2) matrix. These measurements will also be performed on the UO_2/ThO_2 mixture, and all electrostatic charge and resistivity measurements will be repeated with MOX as part of the Phase II experiments at the Plutonium Fuels Development Laboratory (PFDL).

TABLE 5.1
SUMMARY OF PHASE I (UO_2) RESIDUAL MATERIAL
HOLDUP TESTS PLANNED FOR 1977

Westinghouse R&D Center Tests	
■	Metal Surface/Powder Adherence Characteristics ^[a]
■	CSRS Vessel Residual Measurement
■	Sintered Metal Filter Holdup
■	Powder Mixture Dielectric Characteristics ^[a]
Plutonium Fuels Development Laboratory (PFDL) Tests	
■	Powder Processing System Residuals ^[a]
■	Pellet Grinder Residuals and Releases

a. These tests will be repeated in Phase II, utilizing MOX powder instead of UO_2 and/or UO_2/ThO_2 powder.

Figure 5.1 Residual/Release Experimental Program Network

The jaw crusher containment hood has been cleaned out and an aerosol sampling test fixture has been designed and fabricated for measurement of aerosol concentrations produced by a release of powder. The test apparatus for this release test will consist of pellet crusher, powder mill, and hopper (figure 5.2). The release experiments will be initiated as soon as a new HEPA filter, to be placed in the containment hood ventilation system, has been received and installed. The powder derived from the crushed pellets will then be utilized for residual holdup tests with the clean scrap recovery system (CSRS) reactor.

The CSRS has been disassembled and cleaned out, and modifications have been made to fill in instrumentation ports in the reactor which could cause excessive, atypical residual holdup. The reactor has also been reassembled in preparation for the upcoming residual holdup tests.

The metal surface/powder adherence characteristics test apparatus has been constructed as shown schematically in figure 5.3. Mechanical shakedown tests have been initiated with UO_2 powder. As a result of these shakedown tests, modifications were made to the apparatus to (1) reduce the solid/gas mass ratio of the aerated powder stream, (2) provide adequate control of the powder feed rate, and (3) increase test duration run time to approach the design goal of 5 to 6 minutes. The Phase I series of tests with UO_2 powder has been initiated.

A detailed test plan to assess the effects of powder holdup on sintered metal filters has been formulated as part of the Phase I residual holdup measurements program. This plan is described briefly below.

The apparatus consists of a fluidized bed column, a powder recirculation loop, and a filter plenum. A schematic diagram is provided in figure 5.4. The candidate filters are made of 316 stainless steel, with 10-micron pore size, and of cylindrical geometry. The filter thickness and surface area are 1/16 inch and 1 square foot, respectively. The effect of four parameters on the pressure drop across the filters and the powder holdup on the filters will be determined by a factorial experiment at two levels. This will require 16 test runs to investigate the four parameters: filter type, blow-back pressure, face velocity, and duration of runs. It is expected that these tests will determine which of these four parameters will have the greatest effect, if any, on residual holdup and/or pressure drop. Subsequent testing with the most critical factors could then be used to determine filter life.

Preparation for the pellet grinder residuals and releases tests are proceeding on schedule. The reworked grinder has been returned to the PFDL at Cheswick. Materials for the glove box containment have been received, and construction of this containment has been initiated.

NOTE: A.S. = AIR SAMPLE PICKUP

Figure 5.2 Schematic Diagram of Powder Release Study Apparatus
at Westinghouse R&D Center

Figure 5.3 Schematic Diagram of Test Apparatus for Metal Surface/Powder Adherence Measurements

Figure 5.4 Schematic Diagram of Filter Blow-Back Test Apparatus

Design and construction of the powder processing test system at PFDL is continuing. A review of the design status indicates that (1) design of the blender vessel modifications is complete; (2) mechanical design of the storage silo, powder feed hopper, and glove boxes has been completed; and (3) procurement of long-lead-time items, which include the rotary valve, air blower, line components, and control instrumentation, is in progress. The Westinghouse slab blender has been sent to an offsite vendor for modifications in preparation for installation in the test system. All materials for the containment box to be constructed in the Uranium Processing Area at PFDL have been received, and the building exhaust system has been cleaned out and made operational.

5.5 FUTURE WORK

During the next quarterly period, the powder mixture dielectric characteristics tests will be repeated with mixed oxide powder, and the Phase I metal surface/powder adherence tests will be continued with thorium and UO_2/ThO_2 blend powders. The sintered metal filter residual holdup and CSRS release and residual holdup experiments also will be initiated during this period.

Construction of the powder processing test system at PFDL will continue with assembly of the containment box and support structure for the blender. Installation of the blender will be initiated, and installation of the ventilation exhaust system is expected to be completed.

SECTION 6

TASK 6 - BARRIER SEAL DEVELOPMENT

Task Manager: D. M. Batson
Principal Investigator: W. L. Johnson

6.1 OBJECTIVES

The objective of this task is to complete the evaluation of barrier seal mechanisms applicable to mechanization of mixed oxide pellet encapsulation. Upon completion of the engineering evaluation, a single seal type will be selected and tested in accordance with the specified functional requirements.

6.2 SUMMARY

Authorization of funding for Westinghouse Mechanical Research and Development Division's (MRDD) participation in a vendor survey and an engineering evaluation of barrier seal candidates was received in May 1977.

The functional specification for this barrier seal was issued to Westinghouse MRDD and a project orientation meeting was held on May 4, 1977.

A detailed catalog search of commercial seal manufacturers, environmental chamber manufacturers, ordnance machinery manufacturers, and medical equipment manufacturers was completed. Candidate suppliers were identified and discussions initiated to determine product technical specifications and product adaptability.

6.3 TECHNICAL PROGRESS

Work on this project was initiated in May with authorization for Westinghouse MRDD's support of a vendor survey and engineering evaluation.

A detailed catalog search of commercial seal manufacturers, environmental chamber manufacturers, ordnance machinery manufacturers, and medical machinery manufacturers was made. Equipment and component manufacturers who were identified as potential suppliers of a barrier seal are being contacted.

Several commercial seal manufacturers identified in the survey were contacted and discussions initiated to determine product specifications and willingness to participate in a prototype development program. Engineering information, technical specifications, and product brochures are being collected in order to complete the evaluation and selection of the candidate seal type for cold (UO_2) test.

6.4 FUTURE WORK

During the next reporting period, the vendor survey will be completed and feasible designs will be evaluated to select the seal system which best meets the NFD specification. The test program, seal procurement, assembly, and test schedule will be established.

The Phase II program plan (single rod prototype hot test) at PFDL will also be defined.

SECTION 7

TASK 7 - MIXED OXIDE FUEL FABRICATION WASTE MANAGEMENT

Task Manager: D. M. Batson

Principal Investigators: R. E. Olson

J. Goodman

7.1 OBJECTIVE

A detailed study of approaches to mixed oxide fuel fabrication waste treatment, including those approaches currently under study and development by ERDA, will be made. The study will analyze the needs for and impacts of the application of the most promising waste management systems to a commercial mixed oxide (MOX) fuel fabrication facility. Also included will be the development of a test program, schedules, and cost estimates for the installation, operation, and evaluation of selected waste treatment systems in the Westinghouse Plutonium Fuels Development Laboratory (PFDL) to determine their impact on the manufacture of mixed oxide fuel.

7.2 SUMMARY

Based on information obtained from a review of the literature and visits to various ERDA sites, an initial draft of the state-of-the-art review of waste management applicable to MOX fabrication facilities has been prepared and is currently undergoing internal review.

The report, which defines the expected waste material types and quantities from a large commercial MOX fuel fabrication facility, is complete and is being prepared for publication.

An analysis of alternative MOX fuel fabrication waste management approaches has been initiated in preparation for a study to assess the impact of the most probable treatment systems for a large-scale commercial MOX facility in the mid-1980s.

Test programs are currently being developed to identify program scopes, schedules, and cost estimates required for the installation, operation, and evaluation of selected waste treatment systems at PFDL.

Various scrap recovery schemes have been evaluated to analyze the impact which these schemes would have on overall process flow in relation to the generation of additional waste in a large MOX facility.

7.3 TRIPS AND VISITORS

On April 26, 1977, D. M. Batson, J. C. Limpert, and M. C. Gilchrist met with HEDL personnel in Richland, Washington, to discuss the HEDL waste management program and status of the acid digestion process.

On April 27, 1977, D. M. Batson, J. C. Limpert, and M. C. Gilchrist met with Battelle PNL personnel in Richland, Washington, to discuss electropolishing, incineration, and other waste management topics.

D. M. Batson and M. C. Gilchrist visited Rockwell's Atomics International Division, Canoga Park, California, on April 28 to review and discuss all aspects of the molten salt combustion process used there.

Mr. J. Goodman attended a symposium in Atlanta, Georgia, entitled "Management of Low-Level Radioactive Waste," on May 22-26, 1977.

7.4 TECHNICAL PROGRESS

Progress has been made in various aspects of the study, as described in the following paragraphs.

7.4.1 State-of-the-Art Assessment

An initial draft of the state-of-the-art report was prepared for internal review after visits to ERDA sites and an in-depth review of the literature. The major effort in the first quarter concentrated on volume reduction of combustible solid wastes.

During the second quarter the effort was directed toward the following:

- Evaporative process — Evaporation and evaporation crystallization, drying, and calcination
- Nonevaporative and liquid decontamination treatment options — Reverse osmosis, flocculation, filtration, and ion exchange
- Stabilization — Cementing, glassing, metal matrixing, and hot pressing
- Packaging — Drumming and crating for retrievable storage and burial
- Decontamination of solid equipment items — Electrolytic techniques
- Disposal options — Shallow land burial, retrievable storage, and terminal storage
- Instrumentation — Methods for solid waste assay and characterization

7.4.2 Impact Assessment

Studies have been initiated to evaluate comparative economic values for those approaches to waste collection and treatment, waste shipping, and terminal storage for a commercial MOX plant which have been identified as most probable.

Figure 7.1 shows one type of waste with its subsequent treatment and disposal alternatives. Costs are currently being developed to analyze the probable process operational and cost impact on the production of fuel in a commercial MOX facility. Typical of the assumptions being made are the following (for the cyclone incinerator currently being developed by Mound Laboratory):

- 8,000 ft³/year (56,000 pounds) of waste
- All combustible waste incinerated at MOX plant
- Ash concreted in 316 stainless steel drums
- Drums shipped from South Carolina to New Mexico for salt bed burial

7.4.3 Test Program

A draft of a test program identifying program scopes, schedules, and cost estimates was prepared for Phase II work at the Westinghouse PFDL, and issued to ERDA for review. The key proposed activities and objectives of this program are as follows:

- Confirm the potential applications of reduction of liquid waste volumes by evaporation to representative waste streams in a mixed oxide fabrication facility and the benefit of recovery of additional plutonium values from the waste concentrate
- Evaluate electrolytic techniques for the cleanup and decontamination of equipment items representative of commercial mixed oxide fabrication hardware. Specific areas of consideration include (1) development of an operational procedure for equipment items, (2) testing and evaluation of treatment conditions for decontamination, (3) comparison with manual techniques for effectiveness and cost, and (4) waste type and quantity generated.
- Evaluate the commercial applicability of the various volume reduction systems for combustible materials and identify potential problem areas. Specific areas to be evaluated will include licensability aspects as well as performance and economic considerations.

Figure 7.1 Combustible Waste Treatment and Disposal Alternatives

- Demonstrate a method of treatment of representative organic wastes from a mixed oxide fuel fabrication facility. Specific areas will include the recovery of plutonium values, the safe in-plant handling of these waste streams, and the stabilization of representative organic streams by means other than combustion systems.
- Design, implement, and evaluate a radioactive waste measurement system operating with ^{235}U and Pu at the PFDL that would have direct application to a full-scale MOX facility

7.4.4 Scrap Recovery Schemes (Impact on Waste Management)

Various scrap recovery schemes have been evaluated to determine the impact which these schemes would have relative to waste management considerations in a large commercial MOX facility.

The Westinghouse Recycle Fuels Plant (RFP) design was used for the evaluation. The RFP base plant provides the capability for dirty scrap storage only, although space exists for scrap recovery operations.

Dry process schemes such as molten salt electrolysis, pyrolysis, and fluoride volatility were disregarded because they were judged insufficiently developed for commercial application. Traditional wet recovery schemes were selected because of their reliability and the advanced level of technology development. These schemes included dissolution, solvent extraction, and ion exchange purification and conversion. Nitric acid dissolution, copurification by solvent extraction, and conversion by coprocessing methods were selected and used for this evaluation.

The addition of a scrap recovery system to a large commercial MOX facility would have the obvious benefit of improved material accountability and the cost advantage of in-house versus contracted scrap reprocessing. The negative aspects are as follows:

- Increase in process equipment capital cost
- Increase in operational labor and chemical costs
- Increase in liquid waste quantities handled in the RFP liquid waste treatment (LWT) system

The increase in liquid wastes to be treated by the LWT system was determined to be approximately 1,500 liters per year of liquid waste to be concentrated and approximately 700 liters per year of excess weak acid to be solidified in concrete. The shipping and storage (disposal) of this waste (about 8 additional drums) is the major impact.

7.5 FUTURE WORK

During the next reporting period, the work effort will be concentrated on completing all the required studies and analyses defined within the Phase I work scope. Development of proposed scopes, schedules, and cost estimates relative to Phase II test programs will be completed.