UNCLASSIFIED

OFFICIAL USE ONLY

BNWL-595

3-

FAST FLUX
TEST FACILITY
PROJECT REPORT

FFTF CRITICALITY SAFETY SYSTEM 72 -
UNDERWATER EXAMINATION FACILITY
CONCEPTUAL DESIGN EVALUATION

C. L. Brown and L. A. Lawrence

OCTOBER 1967

AEC RESEARCH &
DEVELOPMENT REPORT

Route to	P.V. No.	Location	Remarks

OFFICIAL USE ONLY

BATTELLE

NORTHWEST

BATTELLE MEMORIAL INSTITUTE

PACIFIC NORTHWEST LABORATORY

3000 STEVENS DRIVE, P. O. BOX 999, RICHLAND, WASHINGTON 99352

UNCLASSIFIED

BNWL-595

INFORMATION CONCERNING USE OF THIS REPORT

~~CONFIDENTIAL~~

This document type, when it is transmitted in advance of patent application, is made available in confidence solely for use in performance of work under contract with the U. S. Atomic Energy Commission. This document is not to be published nor its contents otherwise disseminated except for purposes other than specified above before patent approval for such release or use has been secured, upon request from the Patent, Chicago Patent Group, U. S. Atomic Energy Commission, 9800 So. Cass Ave., Argonne, Illinois.

PRELIMINARY REPORT

This report contains information of a preliminary nature prepared in the course of work under Atomic Energy Commission Contract AT(45-1)-1830. This information is subject to correction or modification upon the collection and evaluation of additional data.

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

PACIFIC NORTHWEST LABORATORY

RICHLAND, WASHINGTON

operated by

BATTELLE MEMORIAL INSTITUTE

for the

UNITED STATES ATOMIC ENERGY COMMISSION UNDER CONTRACT AT(45-1)-1830

PRINTED BY/ FOR THE U.S. ATOMIC ENERGY COMMISSION

UNCLASSIFIED

BNWL-595

3 3679 00060 7087

FFTF CRITICALITY SAFETY
SYSTEM 72 - UNDERWATER EXAMINATION FACILITY
CONCEPTUAL DESIGN EVALUATION

By

C. L. Brown and L. A. Lawrence

Critical Mass Physics Section
Reactor Physics Department

October, 1967

Approved by

P. L. Hofmann

PACIFIC NORTHWEST LABORATORY
RICHLAND, WASHINGTON

UNCLASSIFIED

12-6-67

TABLE OF CONTENTS

INTRODUCTION	1
SUMMARY.	1
DISCUSSION	2
Assumptions	2
Critical and Safe Parameters	3
Recommended Limits and Controls	4
REFERENCES	7

FFTF CRITICALITY SAFETY
SYSTEM 72 - UNDERWATER EXAMINATION FACILITY
CONCEPTUAL DESIGN EVALUATION

C. L. Brown and L. A. Lawrence

INTRODUCTION

Each FFTF system that is to involve the handling, storage, or transporting of fissile material will be evaluated for criticality safety during the conceptual, preliminary, and final design stages.⁽¹⁾ Wherever necessary, special controls will be recommended to assure criticality safety. This report reviews the conceptual design of the Underwater Cell Examination Facility (System 72) and gives guidelines for criticality safety in this facility.

SUMMARY

Controls necessary to assure criticality safety in the Underwater Cell Examination Facility (System 72) have been established. In the fuel bundle* disassembly operation, it is recommended that at least two of the following three methods be used: (1) geometry control, in which mechanical devices are utilized to confine the pins to a safe cylinder diameter (6.1 in.); (2) geometry control, in which the pins are removed from the bundle in rows, one row at a time; and (3) neutron poison control, in which at least 3 g B/liter (0.59 g ¹⁰B/liter) in the form of sodium borate, is added to the cell water. Once fuel pins are removed from bundles, it is recommended that subsequent transfer, handling, examination and packaging operations be limited to batches not exceeding 40 pins, with a spacing of at least 12 in. between batches at all times. Fuel bundles may be stored in rows (one, two, or three bundles high) with at least a 12 in. spacing horizontally and vertically between the bundles in a

* A bundle is a subassembly minus instrumentation and hanger tube.

row and a 6 ft spacing laterally between rows. These limits will be reviewed periodically in the FFTF project and broadened, if feasible, as new criticality data become available.

DISCUSSION

ASSUMPTIONS

The criticality safety evaluation of System 72 is based on the assumptions given below.

1. The most reactive fuel bundle that will be encountered in the facility will be as described below:

Fuel and Enrichment:	35 wt% PuO ₂ -UO ₂
²⁴⁰ Pu in Plutonium :	10%
²³⁵ U in Uranium :	0.22%
Fuel Diameter :	0.190 in.
Pin Diameter :	0.216 in.
Fuel Length :	37 in.
Pin Length :	72 in.
Clad :	Stainless Steel
Fuel Density :	10.0 g/cm ³ (90% TD)
No. Pins/Bundle :	217 (max)

2. Operations in the facility will be the transfer, storage, examination, and disassembly of driver and test fuel bundles; and the transfer, storage, examination, and packaging of fuel pins removed from bundles.
3. All operations will be underwater.
4. The smallest unit of driver or test fuel in the facility will be the "pin".
The pins will not be shorter than about 72 in.

5. The pins will be whole; the pins will not be cut; and the fuel will not be released from the pins.*
6. An accidental meltdown of fuel in System 72, if considered credible, will be evaluated in a later report.

CRITICAL AND SAFE PARAMETERS

Calculated critical and safe parameters for driver fuel pins in water are given in Table I.⁽²⁾ Safe masses are one-third of the critical masses; safe volume is one-half of the critical volume; and safe dimensions are three-fourths of the critical dimension.**

TABLE I. Critical and Safe Parameters
for 35 Wt% PuO₂-UO₂ Fuel Pins in Water^(a)

	<u>Critical</u>	<u>Safe</u>
<u>Mass--Spherical Geometry</u>		
No. Bundles at Pin Spacing in Bundle	6.2	2
No. Pins at Optimum Spacing	63	21
<u>Mass--Cylindrical Geometry</u>		
No. Bundles at Pin Spacing in Bundle	9.7	3
No. Pins at Optimum Spacing	114	40
<u>Volume, liters</u>	15.5	7.8
<u>Infinite Cylinder Diameter, in.</u>	8.1	6.1
<u>Infinite Slab Thickness, in.</u>	3.5	2.6
Mass/Area, pins/ft ²	26	13

(a) These limits may be increased as more reliable criticality data become available.

* There may be instances where a pin is accidentally cut or broken, or a failed pin is not discovered in a bundle prior to transfer to the water basin. These instances are assumed to be the exception and will be covered by special procedures.

** As new criticality data become available, higher operating limits may be permitted.

RECOMMENDED LIMITS AND CONTROLS

Storage of Fuel Bundles

It is recommended that fuel bundles be stored in rows. A row of bundles could be located along a wall, or in a special rack perpendicular to a wall. A row may be one, two, or three bundles high; however, there must be at least 12 in. of water between bundles, both vertically and horizontally, at all times. The lateral spacing between rows must be at least 6 ft. Precautions must be taken to assure that in the event of an accident the storage array will not collapse, or that other fuel will not fall onto or against the array.

Disassembly of Fuel Bundles

A tentative function of the Underwater Cell Examination Facility is to disassemble driver and test fuel bundles. This function would involve removing the outer steel duct and extraneous hardware from the pin bundle, selectively cutting away the grid that holds each row of pins together at the ends of the bundle, and then removing the pins in that row. The pins will be removed individually, or in fixed rows, depending on the technique developed and the design of the subassembly. If removed in rows, the individual pins will be extracted from the rows in a subsequent operation.

The underwater disassembly operation presents a unique criticality safety problem. Calculations show that a 217-pin driver fuel bundle, in which the pins are close-packed (undermoderated), represents only about 1/5th of a critical mass.⁽²⁾ At a spacing between pins for optimum neutron moderation (0.7 in.), however, the 217 pins in a bundle represent two critical masses! This means that in the disassembly of a driver fuel bundle (or bundle with similarly high fissile material content), if the 217 pins were allowed to spread apart in an uncontrolled manner, criticality could result.

To avoid a criticality hazard in the disassembly operation and assure safety with all fuels, three methods of control may be considered:

- (a) Geometry control, utilizing mechanical devices to assure a safe cylindrical geometry
- (b) Geometry control, utilizing controlled removal of pins from the bundle
- (c) Neutron poison control, utilizing addition of a soluble neutron poison (boron) to cell water

The first method (a) is recommended as the primary means of criticality safety control. Criticality cannot occur with the 217 pins in one bundle if the pins are confined to a cylindrical diameter not exceeding 6.1 in.* Mechanical devices, such as pincers around the bundle, a metal sheath around the bundle, or a system of yokes or collars around the bundle, would serve this purpose. The important feature of the device would be to limit the expansion of the pins to 6.1 in. diam in the event the pins are freed and tend to spread apart. Consideration must be given also to preventing the holding device from slipping off the bundle, or the pins slipping out from under the device. On the other hand, the device must leave the pins loose enough to be removed individually or in rows.

The second method (b) is recommended as a backup to the first method. As mentioned above, the current subassembly design permits the pins to be removed from a bundle a row at a time. After a row is removed, it would be placed a safe distance away from the bundle (at least 12 in.) and the pins separated. The remaining pins in the bundle would be held in close-packed

* This limit may be increased as more reliable criticality data become available.

arrangement and could not separate until the bundle was completely disassembled. This procedure could be considered as the primary criticality safety control, or as an added control to the first method (a).

If it is decided that criticality safety cannot be assured by methods (a) and (b), then it is recommended that the third method of control (c) - boron as a soluble neutron-poison in the cell water - be used. The recommended minimum concentration of boron is 3 g/liter (0.59 g ^{10}B /liter. This boron concentration is sufficient to assure criticality safety during the disassembly operation, regardless of how far apart the pins in the bundle spread.⁽³⁾

If soluble neutron poison is used for criticality control, additional secondary controls will be required to be certain that the poison is always present. At least two independent checks must be utilized to assure that the boron is present in the water at the proper concentration. For example, water samples could be taken for boron analysis; and an in-line boron monitor could be installed in the water recirculation system, with an alarm to signal a low boron level.

The boron compound recommended for use in the basin water is sodium borate, such as produced by the United States Borax and Chemical Company under the trade name FR28. Sodium borate is available in commercial quantities as a readily soluble powder containing about 66% B_2O_3 or about 20.5% boron. Sodium borate can be dissolved to give a clear solution containing nearly 30 g B/liter; the pH would be 8.0 to 8.5, depending on concentration. No corrosion problem is expected with either the metal components of the cell or the cover glass of the lead viewing windows.⁽⁴⁾

It should be pointed out that the addition of 3 g B/liter to the cell water will assure criticality safety in the fuel bundle disassembly operation, and

subsequent operations involving finite numbers of fuel pins; but will not necessarily assure subcriticality for a large number of fuel bundles in uncontrolled geometry. Calculations indicate that in order to effectively poison the water such that any number of bundles would be safe side by side, at least 30 g B/liter would be required.⁽³⁾ This action is not considered necessary and is not recommended.

Handling, Storage, and Packaging Fuel Pins

Once fuel pins have been removed from a bundle, it is recommended that the number of pins accumulated together at one place at one time not exceed 40; and that the spacing between 40-pin batches be at least 12 in. This limit applies to all transfer, handling, and storage operations involving loose pins.

For transfer and storage operations, either portable or stationary racks could be designed. It is possible that with a proper rack design, several racks could be side by side for storage or transfer; however, detail design information is needed to make this evaluation. Variables to be considered are the spacing between pins and the potential accident conditions.

It is difficult at this stage of design to establish a safe, reasonable number of pins for a shipping package. The limit can be at least 40 pins. With proper package design, the limit could be 80 or more pins. For the time being, it is recommended that the 40-pin limit be used for planning purposes; and a higher limit will be considered later in the project.

REFERENCES

1. C. L. Brown. FFTF Out-Of-Reactor Criticality Safety Objectives and Criteria, BNWL-576. Pacific Northwest Laboratory, Richland, Washington, September, 1967.
2. C. L. Brown. Unpublished Data. Pacific Northwest Laboratory, Richland, Washington, 1967. (Preliminary Report)

3. C. L. Brown and L. A. Lawrence. System 72 - Feasibility of Using a Soluble Poison for Criticality Control, BNWL-594. October, 1967.
4. K. M. Harmon. Unpublished Data. Pacific Northwest Laboratory, Richland, Washington, July 7, 1966. (Personal Communication)

DISTRIBUTION

- 28 U. S. Atomic Energy Commission
 Division of Reactor Dev & Tech
 M Shaw, Director, RDT
 Asst Dir for Nuclear Safety
 Analysis & Evaluation Br, RDT:NS
 Environmental & Sanitary Engrg
 Br, RDT:NS
 Research & Development Br, RDT:NS
 Asst Dir for Plan Engrg, RDT
 Applications & Facilities Br, RDT:PE
 Components Br, RDT:PE
 Instrumentation & Control Br, RDT:PE
 Systems Engineering Br, RDT:PE
 Asst Dir for Program Analysis, RDT
 Asst Dir for Project Mgmt, RDT
 Liquid Metals Projects Br, RDT:PM
 FFTF Project Manager, RDT:PM (3)
 Asst Dir for Reactor Engrg
 Control Mechanisms Br, RDT:RE
 Core Design Br, RDT:RE
 Fuel Fabrication Br, RDT:RE
 Fuel Handling Br, RDT:RE
 Reactor Vessels Br, RDT:RE
 Asst Dir for Reactor Tech
 Chemistry & Chemical Separations
 Br, RDT:RT (2)
 Fuels & Materials Br, RDT:RT
 Reactor Physics Br, RDT:RT
- 1 AEC Chicago Patent Office
 GH Lee, Chief
- 1 AEC Idaho Operations Office
 CW Bills, Director
- 4 AEC Richland Operations Office
 FFTF Project Office
 JH Krema (2)
 Engineering & Construction Div (1)
 RK Sharp - Patents
- 1 AEC San Francisco Operations Office
 Director, Reactor Division

DISTRIBUTION, Continued

- 4 AEC Site Representatives
 - Pacific Northwest Laboratory
 - PH Holsted (2)
 - LR Lucas
 - AD Toth
- 4 AEC Site Representatives
 - Argonne National Laboratory
 - Atomics International
 - Atomic Power Development Assoc.
 - General Electric Co.
- 2 Argonne National Laboratory
 - RA Jaross
 - LMFBR Program Office
- 2 Atomics International
 - LE Glasgow
 - RW Dickinson
- 1 Atomic Power Development Assoc.
 - BVD Farris
- 2 Babcock & Wilcox & Wilcox Co.
 - Atomic Energy Division
 - SH Esleeck
 - TP Farrell
- 2 General Dynamics Corp.
 - D Coburn
- 4 General Electric Co.
 - Dr Karl Cohen (3)
 - Bertram Wolfe
- 1 Idaho Nuclear Corporation
 - DR deBoisblanc
- 1 Stanford University
 - Dr R Sher
- 5 Westinghouse Electric Corp.
 - Dr JCR Kelly

DISTRIBUTION, Continued104 Battelle Northwest

GE Akre	WW Little
WG Albert	CE Love
SO Arneson	DE Mahagin
ER Astley	WB McDonald
JM Batch	MH Meuser
RA Bennett	RA Moen
JR Boldt	CA Munro
CL Boyd	DM Nero
DC Boyd	MG Patrick
CL Brown (10)	JA Perry
WL Bunch	RE Peterson
CP Cabell	WE Roake
AC Callen	JD Schaffer
JR Carrell	FH Shadel
WE Cawley(2)	DW Shannon
WL Chase	DE Simpson
TT Claudson	CRF Smith
PD Cohn	RJ Squires
DL Condotta	GH Strong
JH Cox	CD Swanson
JM Davidson	JC Tobin
VA DeLiso	KG Toyoda
DR Doman	M Vogel
GE Driver	DM Walley
RV Dulin	JH Westsik
JF Erben	LA Whinery
LM Finch	RD Widrig
RC Free	NG Wittenbrock
EE Garrett	MR Wood
SM Gill	FW Woodfield
RA Harvey	FFTF File (2)
BR Hayward	Tech. Info. File (3)
JW Helm	
RJ Hennig	
GM Hesson	
PL Hofmann	
JE Irvin	
BM Johnson	
HG Johnson	
RN Johnson	
RL Junkins	
JH Kinginger	
WC Kinsel	
DD Lanning	
LA Lawrence (10)	
HD Lenkersdorfer	
CW Lindenmeier	
HE Little	