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ADVANCED FUEL SYSTEMS PROGRAM

ERDA-RRD BRIEFING
OCTOBER 14, 1976

MASTER

Rockwell International

Atomics International Division
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AGENDA

ADVANCED FUEL SYSTEMS PROGRAM

Herb Feinroth/Joe Leary Visit

October 14, 1976

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8:00 - 8:30	Introduction/Organization	G. W. Meyers
8:30 - 9:15	Program Background	J. E. Kinzer
9:15 - 9:45	Accomplishments to Date	L. Jones
9:45 - 10:15	Current Program Plan	L. Jones
10:15 - 10:45	Program Options	J. E. Kinzer
10:45 - 11:00	Break	
11:00 - 12:00	Tour of ATR/EBR-II Fuel Fabrication Area	A. C. Crawford
12:00 - 1:00	Lunch	
1:00 - 1:30	Travel to Santa Susana	
1:30 - 3:30	Tour of Advanced Fuel Systems Program Plutonium Facility and Supporting Facilities	R. Meyer/J. Carroll
3:30 - 4:00	Return to AI	
4:00 - 5:00	Discussions and Wrap-up	G. W. Meyers/ J. E. Kinzer

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FUEL & TEST FACILITY PROGRAMS

G.W. Meyers

G. W. MEYERS
DIRECTOR

S.F. Iacobellis

APPROVED:

S. F. IACOBELLIS

ADVANCED SYSTEM FUEL PROPOSED SCHEDULE

ADVANCED FUEL SYSTEM

RELATIVE PERFORMANCE BOUNDARIES OF OXIDES AND CARBIDES OR NITRIDES— CORE AVERAGE

EFFECT OF FUEL SWELLING ON DOUBLING TIME vs ROD DIAMETER

RESULTS OF BREEDING RATIO OPTIMIZATION STUDIES

ADVANCED FUELS PROGRAM HISTORY

MIXED CARBIDE PROPOSED DEVELOPMENT SCHEDULE

	GFY 1975			GFY 1976											
	Apr	M	J	J	A	S	O	N	D	J	F	M	A	M	Jun
<u>AIR 1</u>															
Fab. Hardware				AI											
Fab. Fuel				LASL											
Fab. Pins							LASL			AIR 1 Complete					
Prepare Data Package							AI								
<u>AIR 2</u>															
Design and Analysis							Design Review						Data Pkg. AIR 2		
Fab. Tubing				WARD/HEDL											
Fab. Hardware															
Fab. Fuel				Dev.			Production								
Fab. Pins													AIR 2 Complete		
<u>AIR 3</u>															
Design and Analysis													Design Rev.		
Fab. Tubing				WARD/HEDL											
Certification	Phase II						Phase IV			Phase IV					
Security	Design/Construct						Pellets			Pins					
							System Implemented								

ADVANCED FUEL SYSTEMS

GFY 1976 PROGRAM SCHEDULE - REVISED FEBRUARY 1976

ACTIVITY	FY 1976	TRANS
AIR-1		
FAB HARDWARE (AI)
FAB AIR-1 PINS (LASL)
PREPARE DATA PKG FOR AIR-1 (AI)
AIR-1 SURVEILLANCE (AI)
AIR-2		
DESIGN & ANALYSIS
FAB HARDWARE
PROCESS VERIFICATION		
FINALIZE PELLET FAB PROCESS
UPDATE PROCESS PROCED. & COMPLETE AGREEMENTS & COMMITMENTS
FUEL PIN PROCESS DEVELOPMENT

FUNDING HISTORY

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ADVANCED FUEL SYSTEMS PROGRAM
AI CAPITAL INVESTMENT

CURRENT COSTS

PRODUCTION EQUIPMENT	\$185,000
PLUTONIUM FACILITY MODIFICATIONS	81,000
SECURITY CONTROL CENTER BUILDING	35,000
SAFEGUARDS AND SECURITY INSTRUMENTATION AND INSTALLATION	30,000
SEISMIC IMPROVEMENTS	<u>24,000</u>
TOTAL	\$355,000

FUTURE COSTS

1977	\$50 TO 100 K
THEREAFTER	~ \$50 K PER YEAR

TABLE 2. Advanced Carbide/Nitride Fuels Phase I Irradiations

5/28/76

Experiment Identification			S/A Type	Respon- sible Cont- ractor	Goal Conditions			Element Design				Design Fuel Parameters				Design Cladding Parameters		
Matrix No.	Cont- ractor No.	EBR-II No.			Peak Center Element kW/ft	EBR-II Max. Clad Temp., °F	Burnup, at.%(a)					²³⁵ U Enrich., %	Pellet Dens., % TD	Dia. Gap, mils	Smear Dens., % TD	Type (d)	Dia., in.	Wall in.
A	K6A	X258	A-19B	LASL	23	1050	12	9 10	C	He	-	93	81 81	5 10	78 75	CW 316	0.310	0.020
B	K6B	X259	A-19B	LASL	23	1050	12	6 ^(e) 3 10	C	He	-	93	87 81 87	10 5 10	81 78 81	CW 316	0.310	0.020
C	C-6		A-19B	BCL	23	1050	12	5 4 5 5	N	He	-	93	81 81 87 87	10 5 10 5	75 78 81 84	CW 316	0.310	0.020
D	AIR-1	X276	A-19B	AI	23	1050	12	5 5 9	C	Na	1 2 None	93	98	(f) (f) 22	81 81 83	CW 316	0.310	0.015 0.015 0.020

(a) Interim examinations are planned at 8 at. % burnup for November 1978 decision point.

(b) Pu/(U+Pu) = 0.20; C contains ~ 10 v/o M₂C₃ in MC unless stated otherwise; N is ~ 100 v/o MN.

(c) Shroud material is Type 316 stainless steel; Type 1 is ~ 20% cold-worked; Type 2 is solution-annealed.

(d) All 316 cladding is FTR Core-1 steel.

(e) Contains 0-2 v/o M₂C₃.

(f) Pellet diameter = 0.248 in.; shroud OD/ID = 0.258/0.252 in.

CURRENT IRRADIATION EXPOSURE

AIR-I

1050°F	CLAD TEMPERATURE	
23	KW/FT	
19	PINS	
0.310	DIAMETER	CURRENT BURNUP
8	SHROUDED ELEMENTS	3 ATOM PERCENT
11	UNSHROUDED ELEMENTS	
12	AT.% TARGET BURNUP	

U-5100

1200°F	CLAD TEMPERATURE	
22	KW/FT	
7	PINS	CURRENT BURNUP
0.310	DIAMETER	9 ATOM PERCENT
7	SHROUDED	
12	AT.% TARGET BURNUP	

FIGURE 1. PROJECTED SCHEDULE OF ADVANCED CARBIDE/NITRIDE FUEL IRRADIATIONS IN EBR-II

5/25/76

(a) An interim examination at 8 at. % is indicated for those experiments with a goal burnup of 12 at. %.

(b) Actual shipping date. (c) The U5100 and K4 elements will reach the goal burnup respectively in the first and second irradiation segments.

(d) Suggested for scoping purposes in estimating EBR-II test-space requirements.

BLDG. 55-PLUTONIUM GLOVE BOX LINE

ADVANCED FUELS PROGRAM GLOVE BOX LAYOUT

ADVANCED FUELS PROGRAM
GLOVE BOX LAYOUT CODE

<u>Identification (Refer to Previous Figure)</u>	<u>Glove Box Function</u>
1 & 1A	Air Entrance
2 & 2A	Inert Gas Entrance
3	Oxide Blending, Milling and Briquetting
3A	Batch Weighing
4	Carbothermic Reduction
5	Spex Mill and Ball Mill
6	Sintering
7	Automatic Briquetting (Future)
8	Pellet Pressing
12	Balance Box
13	Pellet Inspection
14	Pin Loading and Sodium Settling
15	Sample Dissolution and Pu and U Assay
15A	Analytical Sample Weighing
16	X-ray Diffraction and Fluorescence
17, 17A & 201	Emission Spectrographic Analysis
18	Carbon and Oxygen Analysis
19, 20, & M	Metallography
21	Nitrogen, Halogen, and Iron Analysis
22	Thermo-Gravimetric Analysis
24	Oxide Blending and Milling - Development
26	Carbothermic Red. and Sintering - Development
27	Briquetting and Pellet Pressing - Development
28	Transfer Box
30	Pin Welding
31	Sodium Loading
H	Hood - Pin Weld Trimming

ADVANCED FUEL SYSTEMS

MIXED CARBIDE PELLET PRODUCTION-PROCESS FLOW

ADVANCED FUEL SYSTEMS

TYPICAL CARBOTHERMIC REDUCTION CYCLE

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MIXED CARBIDE FUEL GRAPHITE/CARBON CONTENT

MIXED CARBIDE SYNTHESIS

W/O CARBON INPUT VS W/O CARBON IN PRODUCT

CHEMICAL ANALYSIS OF (Pu, U) CARBIDE FUEL

FUEL COMPOSITION	SPECIFICATION	BATCH NO. E-0190		BATCH NO. E-0100	
		AI	LASL	AI	LASL
URANIUM (WT %)		75.84		76.29	
PLUTONIUM (WT %)		18.68		18.49	
Pu/(Pu + U)	0.200 ± 0.005	0.198		0.195	
C + N ₂ + O ₂	5.00 ± 0.10	5.08		5.02	
CARBON (WT %)		5.02		4.92	
	LIMIT PPM				
NITROGEN	1000	790		790	
OXYGEN	1000	260		472	
ALUMINUM	300	35		35	
BORON	20	<1 D		<1 D	
BERYLLIUM	20	<0.5 ND		<0.5 ND	
CADMIUM	20	<1 D		<1 D	
CALCIUM	300	25		25	
CHLORINE	20	<1		2	
CHROMIUM	250	50		150	
COBALT	20	<5 D		<5 D	
COPPER	200	15		10	
FLUORINE	10	<1		<1	
IRON	500	100		150	
LEAD	200	10		8	
LITHIUM	10	3		2	
MAGNESIUM	200	<10 D		<10 D	
MOLYBDENUM	200	50		10	
NICKEL		1500		1500	
POTASSIUM	300	5		<5 D	
SILICON	100	25		25	
SODIUM	300	3		3	
TANTALUM	300	<200 ND		<200 ND	
TUNGSTEN	500	<250 D		<250	
VANADIUM	300	2		5	
ZINC	200	<50 D		<50 ND	
ZIRCONIUM	200	<200 ND		<200 ND	

APPROVED BY LASL AND RDD (SEE LAST COLUMN)

APPROVED BY LASL AND RDD PER

(1) TWX - CUNNINGHAM TO THORNE, JUNE 3, 1976 (6686AT)
 (2) LTR. - WATERBURY TO JONES, AUGUST 4, 1976 (10095AT)
 (3) LTR. - LEE TO JONES, SEPTEMBER 14, 1976 (12304 AT)

D = DETECTED
 ND = NOT DETECTED

**LOADING
CARBOTHERMIC
REDUCTION CHARGE**

AUTOMATIC PELLET PRESS

9071-1830CNA

**FUEL PELLET
SINTERING
FURNACE**

9071-1822CNA

Pu & U
COULOMETER
CELLS

CARBON ANALYZER

3-METER EMISSION SPECTROGRAPH WITH ARC-SPARK STAND IN BOX

FUEL ELEMENT FABRICATION FLOW DIAGRAM

FUEL ELEMENT FABRICATION FLOW DIAGRAM

(CONT)

AFS FUEL ELEMENT FABRICATION FLOW DIAGRAM (cont)

AFS END PLUG TO TUBE WELD DEVELOPMENT

WELD PARAMETERS

WELD CURRENT	28 amps
WELD TIME	9 sec
TOTAL CYCLE TIME	16 sec
WELD SPEED	10 rpm
GLOVE BOX ATM	75% He 25% Ar
TORCH GAS	100% Ar

AFS END-PLUG-TO-TUBE WELD DEVELOPMENT

WELD PARAMETERS

CURRENT	28 amps	SPEED	10 rpm
WELD TIME	9 sec	GLOVE BOX ATM	75% He, 25% Ar
CYCLE TIME	16 sec	TORCH GAS	100% Ar

SODIUM BOND CONTINUITY INSPECTION

DEVELOPMENT FUEL ELEMENT NO. II

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76-09-66-42

AFS COMPONENT PARTS AND SUBASSEMBLIES

9071-78A

AFS UPPER END PLUG ASSEMBLY

9071-70A

GB 31-THE SODIUM LOADING BOX

9071-72A

AFS SODIUM LOADING GUIDE

9071-77A

LOADING OF (U, Pu) Cx PELLETS INTO THE SHROUD

**LOADING THE FUEL AND SPACER
INTO THE CLADDING ASSEMBLY
(VIEWED FROM INSIDE THE GLOVEBOX)**

**LOADING THE FUEL AND SPACER
INTO THE CLADDING ASSEMBLY
(VIEWED FROM OUTSIDE THE GLOVE BOX)**

9071-59A

AFS SODIUM SETTLING FURNACE

9071-60A

AFS END PLUG TO TUBE WELD

9071-64A

AFS HELIUM LEAK DETECTOR

9071-69A

**AFS CENTRIFUGE-WITH ONE BUCKET
HELD IN THE OPERATING POSITION**

AFS SODIUM BOND CONTINUITY (EDDY CURRENT) TESTER

AFS TAG-GAS CAPSULE RUPTURE DEVICE

9071-65A

AFS AUTO RADIOGRAPH CASSETTE

9071-80A

AFS WIRE-TO-LOWER-END-PLUG WELD SETUP

9071-75A

AFS WIRE-TO-UPPER-END-PLUG WELD SETUP

AFS GAMMA SCANNER

9071-69A

AFS PLASTIC SEALER

9071-68A

APPLICATION OF POLICY & PROGRAM REQUIREMENTS

APPLICATION OF POLICY & PROCEDURES

ADVANCED FUEL SYSTEMS RELEASED DOCUMENTS

PROGRAM AND TEST PLANS	10
QA, INSPECTION, AND NDE PROCEDURES	30
HEALTH, SAFETY, AND RADIATION SERVICES PROCEDURES	32
ENGINEERING – SPECIFICATIONS AND REPORTS	55
DRAWINGS	26
CHEMISTRY AND METALLOGRAPHY PROCEDURES	12
OPERATING AND WELD PROCEDURES	53
	<hr/>
TOTAL	218

ADVANCED FUEL SYSTEMS

GFY1977 BASE PROGRAM SCHEDULE

ADVANCED FUEL SYSTEMS PROCESS IMPROVEMENT POTENTIAL

FIRST PHASE IMPROVEMENTS

- SAME BATCH SIZE OF PRESENT PROCESS (700 GRAMS)
- AUTOMATIC BRIQUETTING
- INCREASED CARBIDE MILLING CAPACITY
- AUTOMATIC PELLETIZING
 - ESTIMATED LABOR DECREASE – 40%⁽¹⁾

SECOND PHASE IMPROVEMENTS

- INCREASED BATCH SIZE (2100 GRAMS)
 - ESTIMATED LABOR DECREASE – 25%⁽²⁾
 - OVERALL LABOR DECREASE – 55%⁽¹⁾

(1) RELATIVE TO CURRENT PROCESS

(2) RELATIVE TO FIRST PHASE IMPROVEMENTS

ADVANCED FUEL SYSTEMS

GFY 1977 PROGRAM OPTIONS

ACTIVITY	1st QUARTER	2nd QUARTER	3rd QUARTER	4th QUARTER
CREEP PROPERTIES STUDY MATERIAL				
FAB & SHIP 20 MIXED CARBIDE PELLETS	■			
FRACTURE PROPERTIES STUDY MATERIAL				
FAB & SHIP 900 GRAMS MIXED CARBIDE	■			
AIR-4 (MATRIX III-B ASSEMBLY)				
DESIGN & ANALYSIS	■	■		■
PROCUREMENT OF SHROUD TUBING	■			
HARDWARE FABRICATION	■	■		
FUEL PELLET FABRICATION	■	■	■	■
FUEL PIN FABRICATION		■	■	■
SHIP 19 PINS TO EBR-II				△

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76-09-66-51

TABLE 4. Advanced Carbide/Nitride Fuels Phase II Irradiations

5/28/76

Experiment Identification			S/A Type	Responsible Contractor	Goal Conditions			Element Design				Design Fuel Parameters				Design Cladding Parameters			
Matrix No.	Cont-actor No.	EBR-II No.			Peak Center Element kW/ft	EBR-II Max. Clad Temp., °F	Burnup, at.%(a)	Init. Load.	Element Design			235U Enrich., %	Pellet Dens., % TD	Dia. Gap, mils	Smear Dens., % TD	Cladding Parameters			
									Fuel (b)	Bond	Shroud Type (c)					Type (d)	Dia. in.	Wall in.	
A/F	AIR-2/3	X277	L-19	AI	30	1100	12	5 4 5 5	C	Na	1 2 1 2	72	98	(e)	81	CW 316 CW 316 PE16 PE16			
B	WSA-32	-	L-19	WARD	30	1100	12	5 4 5 5	C	He	-	79	81 87 81 87	11 11 6 11	76 81 78 81	CW 316 CW 316 (f) CW 316 CW 316	0.370	0.020	
C	K9	-	L-19	LASL	21	1210	8	4 3 4 4 4	C	Na Na He He He	1 2 - - -	40	98 98 81 81 87	(e) (e) 11 6 11	81 81 76 78 81	CW 316	0.370	0.015 0.015 0.020 0.020 0.020	
D	K10	-	L-19	LASL	21	1210	8	4 5 5 5	C	He	-	40	87	11 11 11 6	81 81 81 84	CW 316 CW 316 (f) PE16 PE16	0.370	0.020	
E	WSA-33	-	L-19	WARD	30	1100	12	3 4 4 4 4	C	He	-	79	87 87 87 87 81	11 11 6 11 6	81 81 84 81 78	CW 316 PE16 PE16 PE16 PE16	0.370	0.020 0.020 0.020 0.015 0.020	
G	C-8	-	L-19	BCL	30	1210	12	4 4 4 4 3	N	He	-	70-75 (g)	87 87 87 87 87	(h) (h) (h) (h) (h)	6 6 6 6 11	84 81 84 81 81	CW 316 CW 316 PE16 PE16 PE16	0.370	0.020
H	C-9	-	L-19	BCL	30	1210	12	5 4 5 5	N	Na	1 1 1 2	70-75 (g)	95	(i) (c) (i) (i)	85 78 85 85	CW 316 CW 316 PE16 PE16	0.370	0.015	

(a) Interim examinations are planned at 8 at. % burnup (or less) for those experiments with a goal burnup of 12 at. %, for the November 1978 decision point.

(b) Pu/(U+Pu) = 0.20; C contains ~ 10 v/o M₂C₃ in MC; N is ~ 100 v/o MN.

(c) Shroud material is Type 316 stainless steel; Type 1 is ~ 20% cold-worked; Type 2 is solution-annealed.

(d) All 316 is FTR Core-4 steel unless otherwise specified.

(e) Pellet diameter = 0.303 in.; shroud OD/ID = 0.312/0.306 in.

(f) FTR N-lot steel.

(g) To be finalized.

(h) 0.070 in. ID annular pellet.

(i) Pellet diameter = 0.316 in.; shroud OD/ID = 0.325/0.319 in.

TABLE 5. Advanced Carbide/Nitride Fuels Proposed Phase III Irradiations

5/28/76

Experiment Ident.		Goal Conditions		Type of Test	Recommended Priority ^(a)	References
Current Matrix No.	Former Matrix No.	kW/ft	Clad Temp., °F			
A	A	-	-	Restructuring test of carbide and nitride	3	1, 2, 3
B	B	30	1100	Na-bonded C in 0.370 in. dia advanced alloy cladding	1	1, 4
C	E	14	1200	He-bonded N in 0.310 in. dia CW 316 cladding	2	1, 3
D	G	30	1200	He-bonded annular N in 0.370 in. dia CW 316 cladding	3	1, 3
E	H	-	-	Microstructural variations of carbide	3	1, 2
F	F	23	1100	He-bonded dished and annular C in 0.310 in. dia advanced alloy cladding	1	1, 5
G	-	23	1100	He-bonded dished and annular C in 0.310 in. dia CW 316 cladding	1	5
H	-	14	1200	He-bonded dished and annular C in 0.310 in. dia advanced alloy cladding	2	5
I	I	23	1100	Na-bonded N in 0.310 in. dia advanced alloy cladding	2	1, 3
J	L	23	1100	He-bonded N with fuel processing variables in 0.310 in. dia CW 316 cladding	3	3

^(a) Based on RATG discussions summarized in references 6 and 7.

References

1. Letter, L. A. Neimark to J. O. Barner, et al, Minutes of January 13 and 14, 1976 ITG Meeting, February 12, 1976.
2. Letter, J. O. Barner to J. H. Kittel, March 9, 1976.
3. Letter, A. A. Bauer to J. H. Kittel, March 12, 1976.
4. Letter, J. E. Kinzer to RATG and ITG Attendees, "Advanced Fuel Systems Program; Action Item Resulting from Requirements Analysis Task Group Meeting, LASL, April 27 & 28, 1976," May 17, 1976.
5. Letter, A. Boltax to J. H. Kittel, "W-ARD Recommendations for WSA-31, WSA-33 and Phase III Tests of Helium-Bonded, Annular and Dished Mixed-Carbide Fuel," May 12, 1976.
6. Letter, J. H. Kittel to A. A. Bauer, et al, "Summary of Discussions, Advanced Fuels Requirements Analysis Task Group Meeting, Los Alamos, New Mexico, April 27 & 28, 1976," May 27, 1976.
7. Letter, J. H. Kittel to A. A. Bauer, et al, "Summary of Discussions, Advanced Fuels Requirements Analysis Task Group Conference Telephone Call, May 21, 1976," May 28, 1976.

ADVANCED CARBIDE FUEL PHASE III-B IRRADIATION
EXPERIMENT AIR-4 (K-12) (d)

Goal Conditions			Element Design				Design Fuel Parameters					Design Cladding Parameters		
Peak Center Element kw/Ft	EBR-II Max Clad Temp.	Burnup at %	Init. Load	Fuel (a)	Bond	Shroud Type (b)	²³⁵ U Enrich %	Pellet Diam. in.	Pellet Dens. % TD	Dia. Gap. mils	Smear Dens. % TD	Type	Dia. in.	Wall in.
30	1100	12	6	C	Na	--	72	0.310	98	30	81	PE 16	0.370	0.015
		8	5	C	Na	--	72	0.319	98	21	86	PE 16	0.370	0.015
		12	4	C	Na	1	72	0.310	98	30 (c)	81	PE 16	0.370	0.012
		12	4	C	Na	2	72	0.310	98	30 (c)	81	PE 16	0.370	0.012

(a) $Pu/(U + Pu) = 0.20$; Carbide Contains ~ 10 v/o M_2C_3

(b) Shroud Material is Type 316 Stainless Steel; Type 1 is $\sim 20\%$ Cold-Worked; Type 2 is Solution Annealed

(c) Shroud OD/ID = 0.321/0.315 in.

(d) Subassembly Type L 19

FIGURE 1. PROJECTED SCHEDULE OF ADVANCED CARBIDE/NITRIDE FUEL IRRADIATIONS IN EBR-II

5/25/76

(a) An interim examination at 8 at. % is indicated for those experiments with a goal burnup of 12 at. %.

(b) Actual shipping date. (c) The U5100 and K4 elements will reach the goal burnup respectively in the first and second irradiation segments.

(d) Suggested for scoping purposes in estimating EBR-II test-space requirements.

ADVANCED FUEL SYSTEMS

FTR SODIUM BONDED CARBIDE PIN FABRICATION SCHEDULE

76-08-66-44

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FTR MIXED CARBIDE DRIVER FUEL ASSEMBLY

SCHEDULE ACTIVITIES

1. OBTAIN CONCURRENCE OF HEDL ON TECHNICAL FEASIBILITY

2. OBTAIN ERDA APPROVAL IN PRINCIPLE

FURNISH COST RECOVERY INFORMATION

ENGINEERING

1. PREPARE PRELIMINARY TEST DESIGN DESCRIPTION (TDD - VOLUME I)

ESTABLISH TEST REQUIREMENTS

ESTABLISH PROGRAMS AND SCHEDULES

PERFORM CONCEPTUAL DESIGN

PERFORM PRELIMINARY SAFETY ANALYSIS

PREPARE QA PROGRAM PLAN

2. COMPLETE FINAL DESIGN AND TEST DESIGN SPECIFICATIONS (TDD - VOLUME II)

COMPLETE DESIGN DESCRIPTION

CONFIGURATION

IRRADIATION CONDITIONS

10-8-76

INSTRUMENTATION

THERMAL-HYDRAULIC PERFORMANCE EVALUATION

STRESS AND STRAIN ANALYSIS

DEVELOPMENT TEST RESULTS

SPECIFICATIONS

MATERIALS

FABRICATION SPECIFICATIONS

FINISHED PRODUCT/INTERFACE REQUIREMENTS

PRE-IRRADIATION CHARACTERIZATION REQUIREMENTS

GAS TAGGING REQUIREMENTS

QUALITY ASSURANCE

QA PROGRAM INDEX

TASK RESPONSIBILITIES

SUBCONTRACTOR CONTROLS AND HOLD POINTS

FABRICATION AND ASSEMBLY INSPECTION AND TEST PLAN

ENGINEERING DRAWING LIST

COMPLETE TEST PROCEDURES, CERTIFICATIONS, FINAL SAFETY ANALYSIS
(TDD - VOLUME III)

INTERIM AND POST-IRRADIATION REQUIREMENTS

REQUALIFICATION REQUIREMENTS (IF INTERIM EXAMINATION IS REQUIRED)

PLANS AND PROCEDURES

AS-BUILT RECORDS AND CERTIFICATIONS

QA PROGRAM FINALIZED

SAFETY ANALYSIS

NORMAL OPERATION

ABNORMAL OPERATION

CLADDING FAILURE ANALYSIS

CRITICALITY CONSIDERATIONS

FABRICATION

MATERIALS PROCUREMENT AND RECEIVING INSPECTION

PE-16 CLADDING TUBE

PE-16 ROD END CAP MATERIAL

PE-16 WIRE WRAP

STAINLESS STEEL SHROUD AND PIN INTERNALS MATERIAL

TYPE 302 SS, RDT E-13-12, HOLD-DOWN SPRING MATERIAL

TAG GAS CAPSULES

PuO_2

UO_2

GRAPHITE

POWDER PRESSING LUBRICANT

SODIUM

PROCESS DEVELOPMENT AND PROCEDURE REVISION

BATCH SIZE SCALEUP

COMBINATION SCALEUP

AUTOMATIC PELLET PRESSING

PE-16 WELDING

PE-16 WIRE WRAPPING

FUEL PELLET PRODUCTION AND INSPECTION

FUEL PIN ASSEMBLY AND INSPECTION

END CAP MACHINING

SPRING ASSEMBLY

PIN LOADING AND CLOSURE

WIRE WRAPPING

PACKAGING AND SHIPMENT

SHIPPING SPECIFICATIONS

DESIGN AND MANUFACTURE SHIPPING CONTAINERS

PACKAGE FOR SHIPPING

SHIPPING SCHEDULE

SECURITY MODES OF OPERATION

- CURRENT OPERATING CONDITIONS
 - MINIMAL SECURITY GUARD COVERAGE
 - MAXIMUM OF FORMULA QUANTITY AT SANTA SUSANA
 - ▲ WEIGHT OF U-235 + (2.5) (WEIGHT OF Pu) ≤ 5 kg
 - ▲ ALLOWED IN BLDG. 055 – APPROXIMATELY 3.8 kg OF MIXED CARBIDE
 - ASSUMED FOR FY 1977 AND AIR-4 FABRICATION
- LICENSE POSSESSION LIMIT
 - FULL SECURITY GUARD COVERAGE – \$300 K/YEAR
 - MAXIMUM OF 3.5 kg OF Pu IN BLDG. 055
 - MAXIMUM OF 2.0 kg OF Pu IN GLOVE BOX LINE
 - ▲ EQUIVALENT MIXED CARBIDE – APPROXIMATELY 10 kg
 - ASSUMED FOR FTR FUEL PIN FABRICATION
- INCREASED POSSESSION LIMIT
 - REQUIRES CHANGE TO A PRODUCTION LICENSE
 - MINIMUM 1 YEAR NEGOTIATION TIME + PROBABLE FACILITY MODIFICATIONS
 - APPLICATION FEE – \$135 K
 - FULL SECURITY GUARD COVERAGE – \$300 K/YEAR

ADVANCED CARBIDE/NITRIDE FUELS PROGRAM

PRINCIPAL MILESTONES

STEADY-STATE IRRADIATION TESTS

FABRICATION OF FUEL AND FUEL ELEMENTS

OFF-NORMAL IRRADIATION TESTS

ELEMENT PERFORMANCE MODELING

SYSTEMS STUDIES

FUEL PROPERTIES STUDIES

TEST REACTOR UTILIZATION

PROGRAM COORDINATION

CALENDAR YEAR				
1976	1977	1978	1979	1980
	1	2	3	4 5
6		7 8	9	
10	11	12	13 14	15
	16	17	18	19
20 21	22 23	24 25	26	27 28
29 30	31	32	33	34
35 36		37	38	39
39		40		

ADVANCED CARBIDE/NITRIDE FUELS PROGRAM

Principal Milestones 1976-1980

1. Begin EBR-II irradiations with advanced cladding alloys
2. Evaluate PIE results at 8 at. % burnup
3. Complete EBR-II Phase I irradiation tests
4. Begin CLIRA and non-CLIRA irradiations in FTR
5. Complete EBR-II Phase IA and II irradiation tests
6. Complete certification of fabricators
7. Begin fabrication of CLIRA tests in FTR
8. Begin fabrication of non-CLIRA tests in FTR
9. Ship initial FTR tests
10. Begin TOP tests in TREAT
11. Begin LOB tests in EBR-II
12. Begin postincident operation tests
13. Begin TUC tests in TREAT loops
14. Begin RBCB tests in EBR-II
15. Begin CLIRA tests in FTR
16. Complete development of sodium-bonded options for UNCLE-I
17. Document UNCLE-T

18. Complete development of UNCLE-II
19. Complete development of advanced UNCLE-T
20. Issue recommended CSDT definition
21. Complete initial evaluation of designs with advanced cladding alloys
22. Issue initial report on consistent comparison of breeding performance of LMFBRs fueled with carbide, nitride, and oxide
23. Complete initial evaluation of element spacer concepts
24. Develop bases for plant cost analyses
25. Complete fuel management, safety, and operating environmental studies of advanced fuel in CRBR
26. Issue initial cost evaluation for 1200 MWe plant
27. Issue initial cost evaluation for 2000 MWe plant
28. Evaluate CRBR duct design for advanced fuels partial loading
29. Issue initial critically-reviewed tabulation of fuels properties
30. Begin yield and fracture studies
31. Issue report on unirradiated fuel-clad compatibility Test B series
32. Complete measurements of thermal transport properties on unirradiated fuel

33. Complete vapor pressure measurements on carbide with simulated fission products
34. Complete measurements of unirradiated fuel properties
35. Obtain Approval of Technical Feasibility for FTR tests
36. Issue report on safety and operational considerations of large amounts of advanced fuels in EBR-II
37. Complete final design and safety analysis of FTR Mark I duct
38. Complete final design and safety analysis of FTR Mark II duct
39. Prepare Program Summary
40. Decision on most promising and on back-up fuel element design

TASK 1: STEADY-STATE IRRADIATION TESTS

- I. HELIUM-BONDED CARBIDE
 - A. STAINLESS STEEL-CLAD
 - B. ADVANCED ALLOY-CLAD
- II. SODIUM-BONDED CARBIDE
 - A. STAINLESS STEEL-CLAD
 - B. ADVANCED ALLOY-CLAD
- III. HELIUM-BONDED NITRIDE
 - A. STAINLESS STEEL-CLAD
 - B. ADVANCED ALLOY-CLAD
- IV. SODIUM-BONDED NITRIDE
 - A. STAINLESS STEEL-CLAD
 - B. ADVANCED ALLOY-CLAD

TASK 1: STEADY-STATE IRRADIATION TESTS

Milestones

1. Begin irradiation of void-deployment experiments (K6A and K6B) in Core-1 steel cladding.
2. Begin firm planning of Phase III experiments.
3. Begin irradiation of high-power low-temperature void-deployment experiment (K7) in N-lot steel cladding.
4. Begin irradiation of low-power high-temperature void-deployment experiment (K8) in N-lot steel cladding.
5. Begin irradiation of high-power low-temperature void-deployment experiment (WSA-32) in Core-4 steel cladding.
6. Begin irradiation of low-power high-temperature void-deployment experiment (K9) in Core-4 steel cladding.
7. Begin firm planning of initial FTR tests.*
8. Evaluate performance of K6A and K6B at 4 at.% burnup.
9. Evaluate performance of K7 at 4 at.% burnup.
10. Evaluate performance of WSA-32 at 4 at.% burnup.
11. Evaluate performance of K6A and K6B at 8 at.% burnup.
12. Evaluate performance of K8 and K9 at 4 at.% burnup.
13. Evaluate performance of K7 at 8 at.% burnup.

*The advanced fuel element designs tested in FTR will depend upon selection in November 1978 of the most promising candidates.

14. Evaluate performance of WSA-32 at 8 at.% burnup.
15. Evaluate performance of K6A and K6B at goal burnup (12 at.%).
16. Evaluate performance of K8 and K9 at 8 at.% burnup.
17. Evaluate performance of K7 at goal burnup (12 at.%).
18. Evaluate performance of WSA-32 at goal burnup (12 at.%).
19. Begin CLIRA and non-CLIRA tests in FTR.*
20. Evaluate performance of K8 and K9 at goal burnup (12 at.%).
21. Complete analysis of all void-deployment results in stainless steel cladding.
22. Begin irradiation of low-power high-temperature void-deployment experiment (K10) in advanced alloys and in N-lot and Core-4 steel cladding.
23. Begin irradiation of high-power void-deployment experiment (WSA-33) in advanced alloys and in Core-4 steel cladding.
24. Begin irradiation of high-power void-deployment experiment (WSA-31) in advanced alloys and in N-lot steel cladding.
25. Evaluate performance of K10, WSA-31, and WSA-33 at 4 at.% burnup.
26. Evaluate performance of WSA-33 at 8 at.% burnup.
27. Evaluate performance of K10 and WSA-31 at 8 at.% burnup.
28. Evaluate performance of WSA-31 and WSA-33 at goal burnup (12 at.%).
29. Evaluate performance of K10 at goal burnup (12 at.%).

* The advanced fuel element designs tested in FTR will depend upon selection in November 1978 of the most promising candidates.

30. Complete analysis of all void-deployment results in advanced alloy cladding.
31. Begin irradiation of high-power low-temperature shroud-variables experiment (AIR-1) in Core-1 steel cladding.
32. Begin irradiation of low-temperature experiment (K7) in N-lot steel cladding.
33. Begin irradiation of high-temperature experiment (K8) in N-lot steel cladding.
34. Begin irradiation of high-power low-temperature shroud-variables experiment (AIR-2) in Core-4 steel cladding.
35. Begin irradiation of low-power high-temperature experiment (K9) in Core-4 steel cladding.
36. Evaluate performance of U5100/K4 elements at 8/5 at.% burnup.
37. Evaluate performance of AIR-1 and K7 at 4 at.% burnup.
38. Evaluate performance of AIR-2 at 4 at.% burnup.
39. Evaluate performance of U5100/K4 elements at goal burnup (12/9 at.%).
40. Evaluate performance of K8 and K9 at 4 at.% burnup.
41. Evaluate performance of AIR-1 and K7 at 8 at.% burnup.
42. Evaluate performance of AIR-2 at 8 at.% burnup.
43. Evaluate performance of AIR-1 and K7 at goal burnup (12 at.%).
44. Evaluate performance of K8 and K9 at 8 at.% burnup.

45. Evaluate performance of AIR-2 at goal burnup (12 at.%).
46. Evaluate performance of K8 and K9 at goal burnup (12 at.%).
47. Complete analysis of shroud effectiveness in stainless steel cladding.
48. Begin irradiation of high-power low-temperature shroud-variables experiment (AIR-3) in advanced alloys and in Core-4 steel.
49. Evaluate performance of AIR-3 at 4 at.% burnup.
50. Evaluate performance of AIR-3 at 8 at.% burnup.
51. Evaluate performance of AIR-3 at goal burnup (12 at.%).
52. Evaluate relative effectiveness of shrouds in stainless steel and advanced alloy cladding.
53. Begin irradiation of high-power low-temperature void-deployment experiment (C-6) in Core-1 steel cladding.
54. Begin irradiation of high-power high-temperature void-deployment experiment (C-7) in N-lot steel cladding.
55. Evaluate performance of C-6 at 4 at.% burnup.
56. Evaluate performance of C-7 at 4 at.% burnup.
57. Evaluate performance of C-6 at 8 at.% burnup.
58. Evaluate performance of C-7 at 8 at.% burnup.
59. Evaluate performance of C-6 at goal burnup (12 at.%).

60. Evaluate performance of C-7 at goal burnup (12 at.%).
61. Complete analysis of all void deployment results in stainless steel cladding.
62. Begin irradiation of void-deployment experiment (C-8) in advanced alloys and in Core-4 steel cladding.
63. Evaluate performance of C-8 at 4 at.% burnup.
64. Evaluate performance of C-8 at 8 at.% burnup.
65. Evaluate performance of C-8 at goal burnup (12 at.%).
66. Complete analyses of results from all void-deployment and strong cladding restraint experiments.
67. Evaluate performance of X163 at 4 at.% burnup.
68. Evaluate performance of K4 elements at 5 at.% burnup.
69. Evaluate performance of X163 at 8 at.% burnup.
70. Evaluate performance of K4 elements at goal burnup (9 at.%).
71. Evaluate performance of X163 at goal burnup (12 at.%).
72. Begin irradiation of high-power high-temperature shroud-variables experiment (C-9) in advanced alloys and in Core-4 steel cladding.
73. Evaluate performance of C-9 at 4 at.% burnup.
74. Evaluate performance of C-9 at 8 at.% burnup.
75. Evaluate performance of C-9 at goal burnup (12 at.%).
76. Evaluate relative effectiveness of shrouds in stainless steel and advanced alloy cladding.

TASK 2: FABRICATION OF FUEL AND FUEL ELEMENTS

I. EBR-II TESTS

A. PHASE I

B. PHASE IA

C. PHASE II

D. PHASE III

II. TREAT TESTS

A. OFF-NORMAL

B. SAFETY

III. FTR TESTS

A. CLIRA

B. NON-CLIRA

TASK 2: FABRICATION OF FUEL AND FUEL ELEMENTS

Milestones

1. Ship AIR-1 elements
2. Ship C-6 elements
3. Ship K7 elements
4. Ship K8 elements
5. Ship C-7 elements
6. Ship WSA-31 elements
7. Ship AIR-2 elements
8. Ship WSA-32 elements
9. Ship K9 and WSA-33 elements
10. Ship K10 elements
11. Ship AIR-3 elements
12. Ship C-8 elements
13. Ship C-9 elements
14. Order Phase III cladding
15. Begin Phase III fabrication
16. Ship III-C and III-D elements

17. Ship III-E and III-D' elements
18. Ship III-B elements
19. Ship III-F and III-G elements
20. Ship III-A elements
21. Ship III-J and III-K elements
22. Ship III-H and III-I elements
23. Ship mockup and HC-1 capsule
24. Ship HC-4 capsule
25. Ship SC-1 capsule
26. Ship SC-2 capsule
27. Ship HN-1 capsule
28. Ship HC-2 capsule
29. Ship SC-3 and SC-4 capsules
30. Ship LOB experiment
31. Ship HN-2 capsule
32. Ship HC-3 capsule
33. Ship HN-3 capsule

34. Ship Na-C elements for MFCI test
35. Ship He-C elements for SAF-1 subassembly
36. Ship He-C elements for TOP or TUC test
37. Ship Na-C elements for SAF-2 subassembly
38. Ship Na-C elements for TOP or TUC test
39. Ship He-N elements for SAF-3 subassembly
40. Ship He-C elements for TUC/B test
41. Ship elements for initial SLSF test
42. Order cladding for FTR tests
43. Begin fabrication of initial CLIRA test
44. Ship elements for initial CLIRA test
45. Begin fabrication of initial non-CLIRA test
46. Ship elements for initial non-CLIRA test

SWELLING COMPARISONS

COMPOSITIONS OF STRUCTURAL ALLOYS

	Fe	Cr	Ni	C	Ti	Al	Nb	Co
AISI 316	66	17	12	0.04	-	-	-	0.12
A 286	53	15	26	0.05	2.15	0.2	-	0.26
AISI 330	43	19	35	0.05	-	-	-	0.35
INCONEL 706	40	16	41.5	0.03	1.75	0.2	2.9	0.41
NIMONIC PE 16	33	16.5	43.5	0.05	1.2	1.2	-	1.43

STATUS
FACILITIES AND PRODUCTION

PLUTONIUM FACILITY MODIFICATIONS COMPLETE

PRODUCTION EQUIPMENT OPERATIONAL

SAFEGUARDS FACILITY COMPLETE

SAFEGUARDS INSTRUMENTATION INSTALLED AND OPERATIONAL

BUILDING 064 VAULT UPGRADED FOR LARGE PU KG DEPOT

BUILDING 100 VAULT ROOM ADAPTED FOR CENTRIFUGE EQUIPMENT

ALL CERTIFICATIONS SCHEDULED FOR COMPLETION BY MID-DECEMBER 1976