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TECHNICAL INFORMATION DIVISION
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CNLM-5713

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June 11, 1964

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From: G. U. Parks

cc: Messrs.
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R. I. Strough
E. R. Dytko
Files (3)

Subject: Visual Material Presented During the
NASA-AEC Meeting at CANEL on May 11-12,
1964.

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Listed below is an index of the Visual Material presented by CANEL personnel at the NASA-AEC Meeting at CANEL on May 11-12, 1964.

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II SNAP-50 Rankine Cycle Boiler Development					
III Materials Development					
IV High Temperature Instrumentation					
V Pump Development					

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GUP:kmr

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EFFECT OF POWER AND FUEL BURNUP ON REACTOR WEIGHT

	2 MW		8 MW	
	REFERENCE 3	REFERENCE 4		
BURNUP, %	1.5	1.0	1.5	4.9
PARAMETRIC WEIGHT, LBS	1300	1700	3985	1900

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REF ID: A63410

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SUMMARY OF HISTORY OF SNAP-50 REACTOR DESIGNS - UC/UN FUEL

	<u>POWER, MW</u>	<u>PARAMETRIC WEIGHT, LBS</u>	<u>FISSION GAS RELEASE, %</u>	<u>CLAD STRENGTH, PSI</u>	<u>MAXIMUM FUEL TEMPERATURE W/HCF, F</u>	<u>MAXIMUM FISSION BURNUP, % U</u>
PARAMETRIC DESIGN AND APPLICATION JULY 1962 TO OCTOBER 1963						
REFERENCE DESIGN 1, RADIATIVELY COOLED, EXTERNAL REFLECTOR	8	860	10	4000	3400	5.7
PARAMETRIC STUDIES	8	1100-2700	3-50	1200-6000	2300-3400	>4.0
PARAMETRIC AND PRELIMINARY FUEL DATA OCTOBER 1963 TO NOVEMBER 1963						
REFERENCE DESIGN 2	8	2000	10	1500	2500	4.3
REACTOR FUEL PARAMETRIC STUDIES NOVEMBER 1963 TO PRESENT						
PARAMETRIC STUDIES	8 2	2700-4200 1200-1900	10	750-2100	2300-2900	>1.5 >1.0
REFERENCE DESIGN 3	2	1500*	20	1500	2300	1.5
→ REFERENCE DESIGN 4	2	1800*	20	1500	2300	1.0 ←
*ESTIMATED ENGINEERED WEIGHT						

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SNAP-50 REACTOR AND SHIELD DESIGN SPECIFICATIONS

REACTOR

DESIGN POWER, MW(TH)	2.0
FULL POWER LIFETIME, HOURS	10,000
CORE COOLANT OUTLET TEMPERATURE, F	2000
CORE COOLANT TEMPERATURE RISE, F	100
REACTOR COOLANT ΔP , PSI	10
TYPE OF FUEL ELEMENT	PIN
TYPE OF CONTROL	MOVING REFLECTOR
REACTOR MATERIALS	
FUEL	UC/UN
STRUCTURE	Cb-1 Zr-0.1 C
FUEL CLAD	Cb-1 Zr-0.06 C
COOLANT	Li (99.9% Li ⁷)
REFLECTOR	BeO
FUEL CLADDING BARRIER	Ta OR W (0.005 INCH)
REFLECTOR COOLING	DIRECT THERMAL RADIATION TO SPACE

SHIELD

TOTAL DOSE*	
NEUTRON	10^{13} nvt >0.1 MEV
GAMMA	10^7 RAD
MATERIALS	
NEUTRON SHIELD	Li ⁷ H, NATURAL LiH
CLADDING	STAINLESS STEEL

*AT PAYLOAD, 42 FEET FROM REACTOR CORE MIDPLANE

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SNAP-50 REACTOR AND SHIELD DESIGN CONCEPT

03/7/2010

REF ID: A62110

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RESULTS OF REACTOR FUEL PARAMETRIC STUDIES

	FIRST GENERATION FUEL					SECOND GENERATION FUEL		
	PRESENT UC/UN	BACKUP		OTHER CASES FOR COMPARISON		60UC-W	80UC-W	80UO ₂ -W
		90UC-ZrC	UC-1W	UO ₂	UO ₂ -BeO			
PERFORMANCE ASSUMPTIONS STUDIED								
1. FUEL DENSITY, % THEORETICAL	95	95	95	95	95	95	95	95
2. MAXIMUM FUEL TEMPERATURE, F	2300	2300	2500	2300	2300	2500	2500	2700
3. FISSION GAS RELEASE, %	1,10	10	10	10	25	10	10	10
4. MAXIMUM BURNUP, %	1.0,1.5,2.0				3.0			
5. FUEL CLAD		Cb-1 Zr-0.06 C 1500 PSI 2200F				Cb-1 Zr-0.06 C T-222 4000 PSI 2200F		

RESULTS

6. PRESENT REACTOR DESIGN POSITION (REF. 4)

FISSION GAS RELEASE, % 20
 MAXIMUM BURNUP, % 1.0
 MAXIMUM POWER DENSITY, KW/CC 0.280
 ESTIMATED ENGINEERED WEIGHT, LBS 1800

7. BACKUP REACTOR DESIGN POSITION

MAXIMUM BURNUP, % 1.5 1.6 1.1 1.4
 MAXIMUM POWER DENSITY, KW/CC 0.38 0.44 0.24 0.15
 ESTIMATED ENGINEERED WEIGHT, LBS 1500 1350 1900 2200

8. HIGHER POWER LEVEL REACTOR EXAMPLES AT 8 MW

MAXIMUM BURNUP, % 4.5 5.0 4.0
 FUEL CLAD Cb-I Zr-0.06 C
 MAXIMUM POWER DENSITY, KW/CC 0.76 1.14 0.67
 ESTIMATED ENGINEERED WEIGHT, LBS 2600 2000 2500

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REFLECTOR CONFIGURATIONS CONSIDERED FOR SNAP-50 REACTOR

A = LAUNCH POSITION
B = START-UP POSITION
C = END OF LIFE POSITION

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REFERENCE REACTOR 4 DESIGN SPECIFICATIONS

THERMAL POWER LEVEL, MW	2
PIN CLAD STRENGTH, PSI	1500
REACTOR PRESSURE DROP, PSI	10
FUEL PIN MAXIMUM TEMPERATURE, F (WHCF)	2300
SIDE REFLECTOR TOTAL WORTH, % ΔK	20
REACTIVITY REQUIREMENT, STARTUP TO END-OF-LIFE, % ΔK	4.0
EXCESS REACTIVITY, WET/700F, % ΔK	6.0
URANIUM MASS LOADING, KG	100
FUEL ENRICHMENT, %	63
MAXIMUM FISSION BURNUP, % U	1.0
DESIGN FISSION GAS RELEASE, %	20
DESIGN HELIUM RELEASE, %	25
MAXIMUM FUEL POWER DENSITY AT STARTUP, KW	0.28
REACTOR DIMENSIONS, INCHES	
PIN CLADDING THICKNESS	0.015/0.025
PIN DIAMETER	0.25/0.35
EFFECTIVE CORE DIAMETER	11.8
CORE LENGTH	12.9
SIDE REFLECTOR THICKNESS	4.0
END REFLECTOR THICKNESS, EACH END	3.0
FISSION GAS VOID LENGTH	8.8/6.8
REACTOR PARAMETRIC WEIGHT, LBS	1700
REACTOR ESTIMATED DESIGN WEIGHT, LBS	1800

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REACTOR PRESSURE VESSEL AND CORE

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REACTOR FUEL PIN - 0.250 INCH DIAMETER

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REFLECTOR ASSEMBLY

TOP VIEW

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REFLECTOR ASSEMBLY

SIDE SECTION

UPPER REFLECTOR
SUPPORT CONE

SECTION A-A

SECTION B-B

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COMPARISON OF SNAP-50 REACTIVITY POSITION WITH OTHER SNAP REACTORS

	VALUES (ESTIMATES)		
	$K_{\text{effective}}$ SNAP-50*	SNAP-2/10A K_{eff}	SNAP-8 K_{eff}
MAXIMUM K_{eff} AT START-OF-LIFE	1.06	1.032	1.07
BARE CORE (DRY, COLD, NO REFLECTOR ASSEMBLY)	0.841	0.84	
BARE CORE (DRY, COLD, NO REFLECTOR ASSEMBLY) WITH ∞ WATER	1.006	1.035	
SHROUD AROUND CORE (DRY, COLD, NO REFLECTOR)	0.861	0.856	0.84
SHROUD AROUND CORE (DRY, COLD, NO REFLECTOR) WITH ∞ WATER	0.919	0.93	
REACTOR AND REFLECTORS ASSEMBLED FOR TEST (COLD, DRY)	0.886	0.988	0.907
	B/C SHROUD BETWEEN PYLONS	FILLER BLOCKS	
REACTOR AND REFLECTORS ASSEMBLED FOR TEST (COLD, DRY) WITH ∞ WATER	0.936	0.99	
REACTOR AND REFLECTORS ASSEMBLED FOR TEST (COLD, DRY) WITH ∞ WATER AND FLOODED INSIDE	1.0	1.056	
REACTOR AND REFLECTORS ASSEMBLED AND SAFEGUARDS REMOVED	0.934	0.955	
REACTOR AND REFLECTORS ASSEMBLED AND SAFEGUARDS REMOVED WITH ∞ WATER	1.046	1.06	

*REF. 4 REACTOR

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PRESENT SHIELD CONCEPT

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PRESENT WEIGHT ESTIMATE -
SNAP-50 REACTOR-SHIELD ASSEMBLY

REACTOR

PRESSURE VESSEL AND CORE	1060	
SIDE REFLECTOR	460	
CONTROL DRIVES, GEARING, SHAFT	270	
LIQUID METAL	40	
TOTAL		1830

SHIELD

LiH MAIN SHIELD	1250	
LiH PIPING PATCH SHIELD	100	
STRUCTURE AND CAN	490	
TOTAL		1840

REACTOR SUPPORT STRUCTURE		160
MISCELLANEOUS COMPONENTS (INSTRUMENTATION, WIRING, SAFETY DEVICES, INSULATION)		100
PIPING (INCLUDING Li)		80
TOTAL REACTOR-SHIELD ASSEMBLY		4010

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REACTOR OPTIMIZATION POSSIBILITIES

IMMEDIATE

1. POWER FLATTENING
2. REFLECTOR THICKNESS
3. MECHANICAL AND STRUCTURAL

LONG RANGE

1. FUEL
2. FUEL CLAD STRENGTH
3. HIGH STRENGTH STRUCTURAL ALLOY
4. TRANSLATING REFLECTOR

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PARAMETRIC STUDIES

FIRST GENERATION FUELS (PART I)

FUEL	UC	90 UC-10 ZrC	UC-1 W	
FUEL DENSITY	80-95	95	95	PERCENT
MAX. FUEL TEMP.	2100-2500	2300	2500	F W/HCF
FISSION GAS RELEASE	1, 10, 100	10	10	PERCENT
MAX. BURNUP	1, 1.5, 2	1.5	1.5	PERCENT
FUEL CLAD	Cb-1 Zr-0.06 C 1500 PSI			
COOLANT PRESS. DROP	5	5	5	PSI
FUEL-CLAD THERM. RESIST.	0.2×10^{-3}	0.2×10^{-3}	0.2×10^{-3}	HR-F/BTU

FIRST GENERATION FUELS (PART II)

FUEL	UC	90 UC-10 ZrC	UC-1 W	UN	
FUEL DENSITY	95	95	95	95	PERCENT
MAX. FUEL TEMP.	2300	2300	2500	2300	F W/HCF
FISSION GAS RELEASE	10-30	10-30	10-30	10	PERCENT
MAX. BURNUP	1, 1.5	1.5	--	1, 1.5, 2	PERCENT
FUEL CLAD	Cb-1 Zr-0.06 C 1500 PSI				
COOLANT PRESS. DROP	5-20	5-20	5-20	5	PSI
FUEL-CLAD THERM. RESIST.	$0.2-2.0 \times 10^{-3}$	$0.2-2.0 \times 10^{-3}$	$0.2-2.0 \times 10^{-3}$	0.2×10^{-3}	HR-F/BTU

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ADVANCED FUELS FOR 20,000 HOUR LIFETIMES

U-235 FUELS: UC, UC-1 W, 80 UC-20 W, 60 UC-40 W, UC₂

U-233 FUELS: UC, UC-1 W, 80 UC-20 W, 60 UC-40 W, UC₂

Pu-239 FUELS: PuC-1 W

FUEL DENSITY	95 PERCENT
MAX. FUEL TEMP.	2300F W/HCF
FISSION GAS RELEASE	10 PERCENT
MAX. BURNUP	NO LIMIT, EXCEPT FOR UC: 1.5, 2.0 PERCENT
FUEL CLAD	Cb-1 Zr-0.06 C 1500 PSI AND W-Re 4000 PSI
COOLANT PRESS. DROP	5 PSI FOR 2 MW
FUEL-CLAD THERM. RESIST.	0.2×10^{-3} HR-F/BTU

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VARIATION OF CALCULATED k_{eff} WITH TDC S_n
APPROXIMATION CCA-7 (12 X 12.4)

<u>S_n</u>	<u>FORWARD</u>	<u>ADJOINT</u>
S2	1.0282	1.0087
S4	1.0032	0.9931
S6	0.9992	0.9939
S8	0.9976	0.9929

10 X 10 MESH INTERVALS. LAMS-2543 16-GROUP
CROSS SECTIONS WITH CORRECTIONS TO Be (n,2n)
AND Cb (FXM-6606)

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COMPARISON OF CALCULATED AND EXPERIMENTAL
GAMMA HEATING VALUES FOR
CCA-7 (12 X 12.4; 1 C^b 4 B^e0)
(WATTS/CM³-WATT)

RADIUS (CM)	DISTANCE FROM MIDPLANE (CM)			
		0.86	6.75	16.9
18.7	CALC.	2.3×10^{-7}	2.1×10^{-7}	0.9×10^{-7}
	EXP.	2.4	2.2	1.02
21.6	CALC.	1.4×10^{-7}		
	EXP.	1.5		
24.1	CALC.	0.95×10^{-7}	0.81×10^{-7}	0.44×10^{-7}
	EXP.	0.83	0.80	0.39
26.7	CALC.	0.59×10^{-7}		
	EXP.	0.54		

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SNAP-50 REACTOR AND NEUTRON SHIELD MOCKUPS 30 INCH SHIELD THICKNESS

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SNAP-50 REACTOR. SHIELD. RADIATOR MOCKUP FOR RADIATOR SCATTERING CALCULATIONS

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HEATING RATE IN Li^7H PLUS NATURAL LiH SHIELD

REFERENCE DESIGN 2 REACTOR AT 2 MW

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EXPERIMENTAL ARRANGEMENT

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SNAP-50 FUEL ELEMENT OPERATION GOALS

10,000 HOURS, 1900F-2200F CLAD SURFACE

CLADDING: RESIST LI CORROSION

CONTAIN 20% FISSION GAS RELEASE (140 psi) WITH <2% DIAMETRAL GROWTH

WITHSTAND >2% DIAMETRAL GROWTH WITHOUT ENTERING THIRD STAGE CREEP.

BARRIER: PREVENT GROSS REDUCTION OF FUEL TO U BY CLADDING.

FUEL: RELEASE <20% FISSION GAS AND UNDERGO <8% DENSITY CHANGE WITH 1% BURNUP.

RESIST GROSS REDUCTION TO METALLIC U IN THE EVENT OF CLAD FAILURE.

RESIST GROSS REDUCTION TO U IN THE EVENT OF BARRIER FAILURE

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REF ID: A66100

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STATUS OF UN AND UC PROPERTY STUDIES AT CANEL

	<u>UC</u>	<u>UN</u>
COEFFICIENT OF EXPANSION	100F TO 2800F	IN PROGRESS
HEAT CAPACITY	600F TO 2200F	600F TO 2400F
THERMAL CONDUCTIVITY	1650F TO 2900F	IN PROGRESS
VAPOR PRESSURE AND THERMODYNAMICS	3600F TO 4000F	3050F TO 3600F
HOT HARDNESS	1800F TO 2600F	1800F TO 2600F

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ADVANCED MATERIALS PROGRAM

FABRICATION

DEVELOP TECHNIQUES

UC, UN
UC, UN, UC-ZrC
UN-Cb, UN-W

SYNTHESIS
SINTERING AND HOT PRESSING

COMPATIBILITY

ESTABLISH BASIC BEHAVIOR

UC, UN, UC-ZrC
UC, UC, UC-ZrC
UC

Cb AND Cb-1 Zr
(W) Cb-1 Zr, W
(Ta) Cb-1 Zr

PROPERTIES

UC, UN
UC
UC, UN, UC-MC
UC
UC, UN

HEAT CAPACITY
COEFFICIENT OF EXPANSION
HOT HARDNESS
THERMAL CONDUCTIVITY
VAPOR PRESSURE, THERMODYNAMICS

IRRADIATION

UC, UN
UC-ZrC

ESTABLISH PRELIMINARY IRRADIATION BEHAVIOR
DEVELOP AND FABRICATE 3500F CAPSULE

OTHER

W-Re ALLOYS

INVESTIGATE EFFECT OF Re ON ELECTRON
EMISSION AND $\bar{\phi}$
ESTABLISH THERMAL DIFFUSION BEHAVIOR
ESTABLISH PHASE RELATIONSHIPS

UC_{1.1}
UN-ZrN

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URANIUM CARBIDE - COLUMBIUM-1 ZIRCONIUM
COMPATIBILITY COUPLE

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U₂C₃ MIGRATION IN HYPERSTOICHIOMETRIC UC FUEL TEST SPECIMENS (2200F, LITHIUM ENCAPSULATED)

<u>Specimen No.</u>	<u>% Carbon Pretest</u>	<u>Test Time, hr</u>	<u>Liner</u>	<u>Carbon Migration</u>	<u>Micro-Probe Fuel</u>
C202 ^(a)	4.92 5.08	1000	None	Yes	-- --
C203 ^(a)	4.92 5.08	3000	None	Yes	Cb --
C202 ^(a)	5.21 5.21	1000	Tantalum	None	-- --
C203 ^(a)	4.92 4.92	3000	Tantalum	None	-- --
C101 ^(a, b)	4.85 4.85	1000	None	None	-- --
C105 ^(a, b)	4.85 4.85	3000	None	None	-- --
170C	5.3	1000	None	None	--
150C	5.3	1000	None	None	--

- (a) Out-of-pile compatibility test, 2 pins per test
(b) Not lithium encapsulated
(c) Irradiation capsule control test, 3 pins for test

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UC_{1.0} VERSUS 1 MIL TUNGSTEN/Cb-1 Zr

2200F - 4000 HRS

1 MIL TUNGSTEN → | | ←

MAGNIFIED: 200X

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FUEL-CLADDING COMPATIBILITY AT 2200F¹ (SOUND PINS)

<u>FUEL</u>	<u>BARRIER</u>	<u>MAX. TEST TIME, HR</u>	<u>FUEL</u>	<u>EFFECT</u> <u>BARRIER</u>	<u>Cb-I Zr CLAD</u>
UC _{1.1}	NONE	9000	C LOSS	---	CARBURIZED
UC _{1.1}	Ta	9000	C LOSS	CARBURIZED	SL. CARBURIZED
UC _{1.0}	W	6000	NONE	NONE	NONE
UN	NONE	3000	NONE	---	NONE ²
UN	W	3000	NONE	NONE	NONE

¹Li ENCAPSULATED

²FREE U FORMED IN DIFFUSION COUPLE TESTS

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FUEL-CLADDING COMPATIBILITY AT 2200F¹ (DEFECTED PINS)

FUEL	BARRIER	MAX. TEST TIME, HR	FUEL	<u>EFFECT</u> BARRIER	Cb-I Zr CLAD	TIME U PENETRATE CLAD (HRS)
UC _{1.1}	NONE	9000	U	U	U	1000
UC _{1.1}	Ta	9000	U	U	U	3000
UC _{1.0}	W	6000	U	U	U	5000
UN	NONE	3000	NONE	-	4 MIL U	----
UN	W	3000	NONE	NONE	NONE ²	----

¹ IMMERSED IN Li

²U ATTACK IN UNPROTECTED REGIONS

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URANIUM NITRIDE COMPATIBILITY SPECIMEN

Cb-1 Zr ALLOY CLAD W BARRIER

SOUND (AND DEFECTED) PIN
3000 HOURS

LITHIUM ENCAPSULATED
2400F

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COMPONENTS - NAK SAMPLER

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UC AND UN IRRADIATION RESULTS

	<u>UC</u>	<u>UN</u>
NO. OF CAPSULES	14	8
NO. OF SPECIMENS	42	24
TEMP. RANGE, F		
CLADDING SURFACE	1850-2225	1525-2225
FUEL CENTER	2450-2875	1675-2850
FISSION BU RANGE, a/o U	0.31-1.83	0.05-2.34
POWER DENSITY RANGE, Kw/cc	1.17-1.93	0.37-2.22
TIME RANGE, HR.	670-3850	390-3000
NO. SPECIMENS FAILED	12	0

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REF ID: A66000

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FISSION GAS RELEASE VERSUS BURNUP FOR URANIUM CARBIDE

(1850-2225F CLAD, 2450-2875F FUEL CENTER)

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FISSION GAS RELEASE VERSUS BURNUP FOR URANIUM NITRIDE

- △ 32% ENRICHED
- 10% ENRICHED
- 93% ENRICHED

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SWELLING VERSUS BURNUP FOR URANIUM CARBIDE

(1850-2225F CLAD, 2450-2875F FUEL CENTER)

○ 174M

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SWELLING VERSUS BURNUP FOR URANIUM NITRIDE

(1875-2225F CLAD, 2375-2850F FUEL CENTER)

● 25 MIL CLAD

○ 35 MIL CLAD

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REF ID: A66021

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FUEL DENSITY DECREASE VERSUS BURNUP FOR URANIUM CARBIDE

(1850-2225F CLAD, 2450-2875F FUEL CENTER)

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FUEL DENSITY DECREASE VERSUS BURNUP FOR URANIUM NITRIDE

(1875-2225F CLAD, 2375-2850F FUEL CENTER)

○ 35 MIL CLAD

● 25 MIL CLAD

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FISSION GAS RELEASE VERSUS FUEL DENSITY DECREASE FOR URANIUM CARBIDE

- INTERGRANULAR POROSITY
- TRANSGRANULAR POROSITY

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FISSION GAS RELEASE VERSUS FUEL DENSITY DECREASE FOR URANIUM NITRIDE

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FUEL DENSITY DECREASE VERSUS BURNUP FOR UC AND UN

- UC (CANEL)
- UN
- △ UC (UNC 5080)

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FUEL DEVELOPMENT PROGRAM GOALS

DEMONSTRATE UC AND UN CAPABILITY UNDER 2 Mw SNAP-50 CONDITIONS
TO BURNUP OF 1.5 a/o U.

EXTEND BURNUP LIMITATIONS OF UC AND UN BASE FUELS BEYOND 1.0 a/o U.

MINIMIZE FUEL PIN RUPTURE AND BARRIER FAILURE EFFECTS.

DEVELOP IMPROVED CLADDING FOR UC AND UN.

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SNAP-50 FUELS IRRADIATION CONDITIONS

	<u>REACTOR DESIGN</u>	<u>IRRADIATION TEST</u>
TEMPERATURE (F)	2200	2200
TIME (HRS)	TO 10,000	TO 10,000
FLUX	FAST	THERMAL
ENRICHMENT % U ²³⁵	85	10
POWER DENSITY (Kw/cc)	0.4	0.4

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SNAP-50 UC AND UN IRRADIATION SUPPORT PROGRAM

CLAD TEMP, F		2000			2200		CLAD	BARRIER
TIME, HRS	3000	6000	10,000	3000	6000	10,000		
BURNUP a/o U	0.45	0.9	1.5	0.45	0.9	1.5		
TOTAL NO. OF CAPSULES	4	4	--	4	4	--	Cb-1 Zr	2 AND 5 MIL W
(DATE)	(10/64)	(4/65)	--	(12/64)	(6/65)	--		
	4	4	4	4	4	4	Cb-1 Zr- 5 MIL W	
	(5/65)	(11/65)	(8/66)	(7/65)	(12/65)	(9/66)	0.6 C	

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BURNUP LIMIT EXTENSION PROGRAM

(2200F CLADDING SURFACE TEMPERATURE)

<u>PURPOSE</u>	<u>FUEL</u>	<u>NO. CAPSULES</u>	<u>POWER DENSITY (Kw/cc)</u>	<u>TIME, (HR)</u>	<u>DESIGN BURNUP a/o U</u>	<u>DATE</u>
ALLOY STRENGTHENING	UC-10 m/o ZrC	2*	1.5	2500	1.5	1/65
	UC-1 w/o W	2*	1.5	2500	1.5	2/65
DENSITY VARIATIONS	81-93% DENSE UC	4*	1.5	2500	1.5	2/65
MEAT LENGTH VARIATIONS	UC AND UN, L/D = 18	16	0.4	3000	0.3	10/65
				6000	0.9	5/66
				10,000	1.5	4/66
FUEL GEOMETRY	UC AND UN WITH CENTER HOLE, L/D = 18	16	0.4	3000	0.3	10/65
				6000	0.9	5/66
				10,000	1.5	4/66

*AT NRTS

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FUEL-CLAD COMPATIBILITY AND BARRIER EVALUATION PROGRAM

	<u>NO. OF TESTS</u>	<u>10,000 HR. DATA</u>
EFFECT OF LI ON FUEL-CLAD COMPATIBILITY	130*	6/64-6/65
EVALUATION OF COATED FUELS	32	12/65
ADVANCE ALLOY EVALUATION		12/65
TANTALUM-BASE ALLOYS	20	
TUNGSTEN-BASE ALLOYS	8	3/65

* 40 IN TEST

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FUEL CLAD OBJECTIVES

FABRICABLE (HIGH QUALITY, WELDABLE)

STRONG (1500 PSI/2200F/10,000 HRS RUPTURE)

DUCTILE (8% RUPTURE DUCTILITY)

COMPATIBLE WITH LITHIUM (2200F/10,000 HRS)

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FUEL CLAD MATERIALS

<u>ALLOY</u>	<u>EXTRAPOLATED RUPTURE STRENGTH, PSI 2200F/10,000 HR</u>
Cb-I Zr-0.02C (REFERENCE)	700
Cb-I Zr-0.065C	1500
Ta-9.5 W-2.5 Hf-0.01C	--

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STRESS VERSUS RUPTURE TIME
Cb-1 Zr-0.065 C FUEL PIN TUBING
(MANSON-HAFERD PARAMETER)

- 2900F/1 HR + 5% C.W. + 2200F ANN'L (RUPTURE TEST)
- 2900F/1 HR + 5% C.W. + 2200F ANN'L (DISC. TEST)
- 2900F/1 HR + 2200F ANN'L (RUPTURE TEST)
- 2900F/1 HR + 2200F ANN'L (DISC. TEST)

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MECHANICAL PROPERTIES EVALUATION PROGRAM

DETERMINE

EFFECT OF HEAT TREATMENT
EFFECT OF ASSEMBLY SEQUENCE

THROUGH

RUPTURE TESTS: 2200F Li/100-3000 HRS

SELECT -

HEAT TREATMENT SEQUENCE SIZE

DETERMINE

RUPTURE STRENGTH AND CREEP AT DESIGN CONDITIONS

THROUGH

STRESS RUPTURE AND CREEP TESTS OF FUEL CLAD WITH
AND WITHOUT BARRIERS
1900F-2600F/1000-10,000 HRS

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STABILITY OF FUEL CLAD IN LITHIUM

DETERMINE

EFFECT OF 2200F Li ON STABILITY OF CLAD ALLOY IN Cb-1 Zr LOOP

THROUGH

RUPTURE TESTS AND CHEMICAL ANALYSES

STATUS

Cb-1 Zr-0.065C

SPECIMENS:	2	EXPOSED 1000 HRS	ON RUPTURE TEST
	2	EXPOSE 1000 HRS	START - 5/64
	2	EXPOSE 1000 HRS	START - 11/64
LOOPS:	1	Cb-Zr-C HOT LEG, SCHEDULED 3000 HRS - (1966 HRS - 5/4)	
	1	Cb-Zr-C HOT LEG, SCHEDULED 3000 HRS - START 7/64	

Ta-9.5 W-2.5 Hf-0.01C

SPECIMENS:	2	EXPOSE 1000 HRS	START - 7/64
LOOPS:	2	T-III HOT LEG, SCHEDULED 3000 HRS - 8/64	

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STRUCTURAL ALLOY OBJECTIVES

FABRICABLE (DIE FORGINGS, PIPE, SHEET)

STRONG (6000 PSI/10,000 HRS/2000F/STRESS RUPTURE)
(3000 PSI/10,000 HRS/2000F/<1% CREEP)

COMPATIBLE WITH -

LITHIUM
POTASSIUM
VACUUM - SPACE
TEST STAND
RADIATION

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STRUCTURAL ALLOY MATERIALS

<u>ALLOY</u>	<u>EXTRAPOLATED 1% CREEP STRENGTH, PSI 2000F/10,000 HRS.</u>
Cb-1 Zr - 0.02C (EXTRUDED - 2300F)	2000
Cb-1 Zr - 0.1C (EXTRUDED - 2900F)	5800
Cb-3 Zr - 0.3C (EXTRUDED - 3100F)	5000

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ADVANCED STRUCTURAL ALLOYS CREEP RATE VERSUS STRESS (MANSON-HAFERD PARAMETER)

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PRESSURE VESSEL TEST PROGRAM

DEMONSTRATE

CREEP CORRELATION
FABRICATION
CONTAINMENT

THROUGH

10 INCH VESSEL TESTS/2000F Li/3000 HRS
IN 10^{-8} TORR VACUUM

CONDITIONS

	<u>Cb-1 Zr</u>	<u>Cb-1 Zr-0.1C</u>	<u>Cb-3 Zr-0.3C</u>
1-5% CREEP	3	3	3

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REQUIREMENTS FOR LITHIUM CONTAINMENT

LOW O ₂ IN Cb-I Zr	< 300 ppm UNANNEALED
	< 3000 ppm ANNEALED
LOW O ₂ IN ENVIRONMENT	< 10 ⁻⁷ TORR O ₂ /10,000 HRS.
	< 0.1 ppb O ₂ IN He/10,000 HRS.

DEMONSTRATED BY:

NO ATTACK

CAPSULE TESTS:	300 - 3000 ppm O ₂ (ANNEALED)
PRESSURE VESSEL TESTS:	10,000 HRS - 1 10 INCH VESSEL
2000F LITHIUM	4 4 INCH VESSELS
LOOP TESTS:	5000 HRS - 1 Sn-Al COATED
2000/1000F LITHIUM	1000 HRS - 1 Sn-Al COATED
	1 Ta WRAPPED

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STRUCTURAL ALLOY CORROSION EVALUATION

DEMONSTRATE

OXYGEN STABILIZATION (WELDS)

CONTAINMENT (Li - 10,000 Hrs/2200F)

SYSTEM MATERIALS COMPATIBILITY

THROUGH

CAPSULE TESTS: OXYGEN LIMITS

LOOP TESTS: CONTAINMENT AND COMPATIBILITY

CONDITIONS

CAPSULES - OXYGEN LEVELS: 2000 - 10,000 ppm

ANNEAL: 2000 - 2400F

LITHIUM: 2200F

LOOPS: LITHIUM - 2200/1900F 3000 - 10,000 HRS

POTASSIUM - 1900/1600F 3000 HRS.

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Cb-1 Zr ALLOY IRRADIATION DATA

	<u>TEMP, F</u>	<u>STRESS, PSI</u>	<u>FLUX</u> <u>nv (> 1 Mev)</u>	<u>TIME , HRS</u>	<u>DOSE</u> <u>nv t (> 1 Mev)</u>	<u>RESULTS</u>
ORNL RUPTURE TESTS	1800/2000	$1-3 \times 10^4$	$\sim 10^{13}$	1-600	$10^{17}-10^{19}$	NO SIGNIFICANT EFFECT
P&WA-CANEL FUEL PIN CLAD- DING	1500/1750	----	1.6×10^{13}	10,000	3.6×10^{20}	] NO LOSS IN BEND DUCTILITY
	1950/2180	----	1.3×10^{13}	2720	1.3×10^{20}	
	1750/2090	----	$2.1 \times 10^{14*}$	1000	6.8×10^{20}	

* ETR CORE

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STRUCTURAL ALLOY EVALUATION IN VACUUM ENVIRONMENT

DEMONSTRATE:

ALLOY STABILITY (10^{-7} - 10^{-10} torr)

LITHIUM CONTAMINATION (10^{-7} - 10^{-8} torr)

THROUGH:

- 1) OXIDATION RATE TESTS
- 2) CARBON STABILITY TESTS
- 3) LOOP TESTS

CONDITIONS:

OXIDATION: 10^{-5} - 10^{-8} torr O_2 ; 2000, 2200F UP TO 1000 HOURS

CARBON STABILITY: 10^{-7} - 10^{-9} torr O_2 ; 2000, 2200F; 500, 1000, 3000 HOURS

CONVECTION LOOP: 2000/1900F Li; 1000 HOURS; 1.2×10^{-6} torr O_2 PRESSURE
5000 HOURS; 4.0×10^{-7} torr O_2 PRESSURE

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CORRELATION OF OXYGEN PRESSURE WITH CONTAMINATION OF C^b-1 Z_r ALLOY

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PRELIMINARY RESULTS OF CARBON STABILITY TESTS IN VACUUM

POSSIBLE REACTION:

<u>MATERIAL</u>	<u>TEST CONDITIONS</u>	<u>RESULTS</u>
ORNL		
Cb-1 Zr	2700F; 1×10^{-9} ; 512 HRS	OXYGEN DECREASED CARBON UNCHANGED
Cb-1 Zr	2700F; 5×10^{-7} ; 512 HRS	OXYGEN INCREASED CARBON DECREASED
CANEL		
Cb-1 Zr-0.08C	2000F; 2×10^{-9} ; 816 HRS	WEIGHT UNCHANGED OXYGEN INCREASED CARBON UNCHANGED
Cb-3 Zr-0.3C	2000F; 1×10^{-9} ; 1000 HRS	WEIGHT UNCHANGED

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REFLECTOR SUPPORT STRUCTURE

REQUIREMENTS:

PREHEAT: 1000F AIR/1000 HRS

SERVICE: 500 PSI, 1% CREEP/2400F/10,000 HRS VACUUM

PROGRAM:

STABILITY: Sn-Al COATED Cb-I Zr

1000F AIR/1000 HRS/87% YS

STRENGTH: CREEP AND RUPTURE TEST AFTER PREHEAT

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REFLECTOR MATERIAL

OBJECTIVES:

EFFICIENT, LIGHT WEIGHT

RADIATION STABILITY - 10^{21} nvt (>1 MEV)

1900F-2400F

$<10^{-9}$ torr

MATERIAL:

BeO - SMALL BLOCKS

TENTATIVE IRRADIATION PROGRAM:

EFFECT OF: TEMPERATURE, DOSE, DOSE RATE,
DENSITY, GRAIN SIZE

ON: SWELLING,
THERMAL CONDUCTIVITY,
EMISSIVITY

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NEUTRON SHIELD REQUIREMENTS

NEUTRON SHIELD MATERIAL MUST BE:

EFFICIENT (LARGE SCATTERING AND CAPTURE CROSS-SECTIONS)

STABLE (MAINTAIN GEOMETRY AND COMPOSITION, $1000F/10^{20}$ nvt)

COMPATIBLE WITH SUPPORT STRUCTURE (1000F/10,000 HRS)

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NEUTRON SHIELD MATERIALS

HIGH FLUX REGION

σ/A^*

Li^7H (99.99 A/o Li^7)

0.25

MINIMUM HEAT GENERATION

Be

0.11

IMPROVED THERMAL CONDUCTIVITY

LOWER FLUX REGION

LiH (NATURAL Li)

0.25

LOWER COST

*REMOVAL CROSS SECTION PER NUCLEON

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SUMMARY OF LIH TECHNOLOGY

FABRICATION: REINFORCED CASTINGS PRODUCED 20-INCH DIAM (AI DATA)

STABILITY: IRRADIATION - NO PRESSURE RISE;
 NO SWELLING OR CRACKING;
 1000F/181 HRS/ 10^{19} nvt (GE DATA)

 MECHANICAL - NO CRACKING OF REINFORCED CASTINGS
 VIBRATION, SHOCK, THERMAL CYCLING (AI DATA)

COMPATIBILITY: 300 SERIES - NO CHANGE IN TENSILE STRENGTH
 STAINLESS AFTER 4000 HRS/1200F LIH. (AI DATA)

 POSSIBLE REDUCTION IN 1000 HR/1100F RUPTURE
 STRENGTH IN LIH. (GE DATA)

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LiH EVALUATION PROGRAM

DETERMINE:

STABILITY (IRRADIATION, MECHANICAL)

COMPATIBILITY WITH CANNING ALLOY

THROUGH:

IRRADIATION TESTS

HYDROGEN MIGRATION AND PERMEATION TESTS

MECHANICAL PROPERTIES TESTS

CONDITIONS:

IRRADIATION: 10 CAPSULES, 400 - 1000F $\text{Li}^7\text{H}/10^{20}$ nvt

GAS RELEASE, SWELLING

HYDROGEN: 400-1100F, 100 - 3000 HRS.

MECHANICAL: CANNED LiH, 1100F, PRESSURE 87% YS, TO 5000 HRS.

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CO-LINEAR CONTROL DRIVE. CONTAINED

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DUTY CYCLE

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HIGH TEMPERATURE CONTROL COMPONENT EXPERIENCE

<u>COMPONENT</u>	<u>TESTS</u>	<u>HOURS</u>	<u>CONDITION (F)</u>
ANTI-FRICTION BEARINGS	62	59,000	600
	6	5,000	800
HARMONIC BEARINGS	19	11,000	600
GEARS	9	10,500	600
ELECTRICAL COMPONENTS	21	24,000	600 - (800)

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CONTROL DRIVE COMPONENT PERFORMANCE OBJECTIVES

CONTROL UNIT

A. MOTORS

B. BEARINGS

C. POSITION TRANSDUCERS

D. GEARING

10,000 HOURS LIFE - 2000 HOURS UNDER
CYCLIC CONDITIONS - 800F 10^{19} nvt

FLEXURE PIVOTS

10,000 HOURS 1000F 10^{20} nvt
 10^{-9} - 10^{-10} torr

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SUMMARY OF SNAP-50 RANKINE CYCLE BOILER DEVELOPMENT AT CANEL

PRIOR TO THE SNAP-50 PROJECT, CANEL HAD BEEN ENGAGED IN THE DEVELOPMENT OF LIGHTWEIGHT, HIGH PERFORMANCE, RELIABLE HEAT EXCHANGERS FOR VARIOUS HIGH TEMPERATURE LIQUID METAL REACTOR SYSTEMS. A BASIC HEAT EXCHANGER CONCEPT EVOLVED FROM THIS WORK.

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HEAT EXCHANGER

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MANY HOURS OF DESIGN, COMPONENT AND FULL-SCALE TESTING, SUPPORT THIS CONCEPT. THE NON-NUCLEAR SYSTEMS TEST NOW RUNNING, WHICH HAS BEEN OPERATED FOR MORE THAN 6300 HOURS IN LITHIUM AT 5 MW - 2000F REPRESENTS THE COMBINED RESULTS OF THIS EFFORT.

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NON-NUCLEAR SYSTEMS TEST

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NEW RELEASED

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TWO Cb-1 Zr ALLOY HEAT EXCHANGERS LIKE THE ONES SHOWN ON THE NEXT
SLIDE AS WELL AS OTHER DEVELOPMENT COMPONENTS ARE IN THIS SYSTEM.

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REF ID: A66703

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ANALYSIS OF THE SNAP-50 BOILER REQUIREMENTS INDICATED THAT THE BOILER PROBLEM WAS BASICALLY THE SAME AS THE HEAT EXCHANGER PROBLEM WITH THE ADDED REQUIREMENT OF TWO-PHASE ZERO-GRAVITY OPERATION. TWO-PHASE OPERATION INDICATED TWO PROBLEM AREAS (1) DEVELOPMENT OF A ZERO-GRAVITY HEAT TRANSFER MATRIX (BOILER TUBE) AND (2) DEVELOPMENT OF TECHNOLOGY REQUIRED TO DESIGN AND OPERATE A ONCE-THROUGH 100 PERCENT VAPOR QUALITY TWO-PHASE SYSTEM. THE APPROACH TO THE TUBE PROBLEM WAS AS FOLLOWS.

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BOILER TUBE SELECTION PROGRAM

<u>HEAT TRANSFER</u> 1,2,3	<u>PRESSURE DROP</u> 1,2,3,4	<u>FABRICATION</u> 4	<u>PACKAGING</u> 4
TEMPERATURE DIFFERENCE	SINGLE PHASE	QUALITY	DIMENSIONAL CONTROL
FLOW RATE	TWO PHASE	INSPECTION	SUPPORT
PRESSURE		COST	VOIDS
QUALITY		TIME	STRUCTURAL
BOILING INITIATION		DEVELOPMENT	
BOILING STABILITY			

EXPERIMENTAL APPARATUS

- 1 SINGLE TUBE LIQUID METAL TESTS
- 2 WATER SCREENING TESTS
- 3 TWO-LOOP LIQUID METAL SYSTEM TESTS
- 4 FULL SCALE SHELL SIDE FLOW MODEL

UNCLASSIFIED

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TWO-PHASE POTASSIUM, TUBE SIDE EXPERIMENTAL HEAT TRANSFER AND PRESSURE DROP DATA
WERE OBTAINED AS A FUNCTION OF VAPOR QUALITY FOR PARAMETERS OF INTEREST.

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FORCED CONVECTION LOCAL BOILING HEAT TRANSFER COEFFICIENT, VERSUS LOCAL QUALITY - TWO-PHASE POTASSIUM

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COMPARISON OF EXPERIMENTAL FORCED CONVECTION LOCAL BOILING PRESSURE COEFFICIENT WITH MARTINELLI-LOCKHART PRESSURE DROP CORRELATION

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HAYNES 25 BOILING POTASSIUM HEAT TRANSFER RIG

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OVER-ALL TWO-PHASE POTASSIUM HEAT TRANSFER AND PRESSURE DROP DATA WERE
OBTAINED ON THREE FULL LENGTH TUBE SHAPES.

DECLASSIFIED

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OVERALL HEAT TRANSFER COEFFICIENT, U FOR THE POTASSIUM PREBOILER IN THE P&WA BOILING POTASSIUM HEAT TRANSFER TEST

DECLASSIFIED

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MANY TUBE SHAPES OF INTEREST WERE FABRICATED AND TESTED IN WATER TO
DETERMINE THEIR RELATIVE HEAT TRANSFER AND PRESSURE DROP PERFORMANCE.

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BOILER TUBE SAMPLES

SINE WAVE TUBE

INTEGRAL HELICAL
FIN TUBE

DUAL DIAMETER TUBE

PERFORATED TWISTED
RIBBON TUBE

TWISTED RIBBON TUBE

HELICAL INSERT TUBE

ORIFICED TUBE

0.127 INCH I.D. TUBE

0.190 INCH I.D. TUBE

COMPARISON OF LOCAL HEAT TRANSFER COEFFICIENTS FOR VARIOUS BOILER TUBE GEOMETRIES WITHIN A GIVEN PRESSURE DROP RANGE

ΔP 10-20 INCHES OF WATER AT 100 STEAM QUALITY

BOILING PRESSURE : 5 PSIG

DISTANCE BETWEEN PRESSURE TAP : 16 INCHES

HEAT FLUX, $Q/A = 6300 \text{ BTU/FT}^2$

MASS FLOW RATE, $G = 26,500 \text{ LB/HR FT}^2$

RESTRICTED

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A FULL-SCALE BOILER MODEL INCORPORATING THE SERPENTINE TUBE SIZED IN ACCORDANCE WITH TEST DATA WAS MADE TO DEMONSTRATE FABRICATION AND PACKAGING TECHNIQUES. SHELL SIDE FLOW TESTS TO DETERMINE DISTRIBUTION AND PRESSURE DROP WERE PLANNED FOR THIS MODEL.

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REF ID: A66666

FULL-SIZE SERPENTINE TUBE BOILER MODEL

REF ID: A66666

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SINE WAVE BOILER ASSEMBLY

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THE TWO-PHASE SYSTEM OPERATIONAL PROBLEM WAS INVESTIGATED IN CONJUNCTION WITH THE HEAT TRANSFER AND PRESSURE DROP TESTS ON THE TWO-LOOP, FULL-LENGTH TUBE SYSTEMS.

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RANGE OF HEAT TRANSFER DATA TAKEN ON STAINLESS STEEL BOILING POTASSIUM LOOP NKSS-B

0.311 I.D. TUBE 5 FEET LONG WITH HELICAL INSERT

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A HAYNES-25, TWO-PHASE POTASSIUM SYSTEM CONTAINING A 70 KW 10-TUBE BOILER (FULL-SCALE TUBES) AND A MULTI-TUBE CONDENSER IS BEING FABRICATED TO INVESTIGATE SYSTEM AND COMPONENT PROBLEMS OVER A WIDE RANGE OF OPERATING PARAMETERS.

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TWO-PHASE POTASSIUM SYSTEM X-585

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AREAS OF INVESTIGATION TWO-PHASE POTASSIUM 70 KW SYSTEM TEST

1. STARTUP CHARACTERISTICS OF A HIGH TEMPERATURE LIQUID METAL MULTI-TUBE TWO-PHASE SYSTEM. (CONTINUATION OF INVESTIGATIONS STARTED UNDER CONTRACT NAS3-2335 BY P&WA EAST HARTFORD.)
2. CONTROL MODES OF A HIGH TEMPERATURE TWO-PHASE SYSTEM AS INFLUENCED BY THE ACCUMULATOR, POTASSIUM THROTTLE VALVE, CONDENSER, AND I^2R HEATER INPUT.
3. THE LIQUID POTASSIUM PREHEAT AND SUPER-HEAT REQUIRED TO INITIATE AND MAINTAIN STABLE OPERATION.
4. THE REQUIREMENTS FOR AND PERFORMANCE OF A GAS SEPARATOR TO REMOVE NON-CONDENSIBLES.
5. DEVELOP A PRACTICAL UNDERSTANDING OF A TWO-PHASE BOILING SYSTEM WHICH , WOULD BE USED TO CONSTRUCT AN ELECTRICAL ANALOG OF THIS SYSTEM AND OTHER SPACE TYPE SYSTEMS SUCH AS SNAP-50/SPUR.

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AUXILIARY MATERIALS PROGRAMS

<u>COMPONENT</u>	<u>ENVIRONMENT</u>	<u>TENTATIVE MATERIALS</u>
<u>PUMP</u>		
METAL-CERAMIC JOINT	1000F Li	Cb-1 Zr; BeO; Ti-8.5 Si
BEARINGS	OR	WC-8 Mo-2 CbC
	1000F NaK	Mo-20 CbC
SHAFT		Cb-10 W-1 Zr-0.1 C
<u>RADIATOR SYSTEM</u>		
CONDENSER	1350F K	Cb-1 Zr
	1250F NaK	
RADIATOR	1250F NaK	TYPE 316 SS
<u>THERMOCOUPLES</u>		
CLAD	2200F Li	Cb-1 Zr
INSULATION	OR	Al ₂ O ₃
WIRE	2400F VACUUM	W-5 Re; W-26 Re

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PROCESS SENSOR DEVELOPMENT

SUPPORTS CANEL REQUIREMENTS FOR:

REACTOR TEST

GENERAL DEVELOPMENT TESTING

ADVANCED MATERIALS PROGRAM

COLUMBIUM FABRICATION

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PROCESS SENSOR DEVELOPMENT

<u>PRIMARY EFFORT</u>	<u>APPLICATION</u>
THERMOCOUPLES	REACTOR AND PROCESS CONTROL FUELS IRRADIATION PROGRAM
LIQUID METAL LEVEL PROBES	PROCESS CONTROL
RADIATION DETECTORS	REACTOR CONTROL CRITICAL EXPERIMENTS IRRADIATION TESTING

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REF ID: A66100

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EFFECT OF INTERNAL CONTAMINATION ON LIQUID METAL
LEVEL PROBES FOR OPERATION IN LITHIUM

FAILED AFTER
75 HR. AT
1000F IN Li

COLD END
UNSEALED

COLD END
HERMETICALLY
SEALED

SATISFACTORY AFTER
6600 HR. AT 1000F
IN Li

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REF ID: A66100

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PROCESS SENSOR DEVELOPMENT

Cb-I Zr CLAD THERMOCOUPLE TESTS

COMPLETED

<u>TYPE</u>	<u>QUANTITY</u>	<u>TEMPERATURE, F</u>	<u>TIME, HR</u>	<u>ENVIRONMENT</u>	<u>POST-TEST ACCURACY</u>	<u>PERCENT SURVIVING</u>
CHROMEL/ALUMEL	20	1950	10,000	INERT GAS	1%	100
W-5 Re/W-26 Re	16	1950	10,000	INERT GAS	1%	100

IN PROGRESS

<u>TYPE</u>	<u>QUANTITY</u>	<u>TEMPERATURE, F</u>	<u>SCHEDULED TIME, HR</u>	<u>TIME TO DATE, HR</u>	<u>ENVIRONMENT</u>	<u>ACCURACY</u>	<u>PERCENT SURVIVING</u>
W-3 Re/W-25 Re	9	1950	10,000	4600	INERT GAS	1%	100
Mo/Cb	10	1950	10,000	2300	INERT GAS	NOT DEFINED	100
Mo/W-26 Re	7	1950	10,000	9500	INERT GAS	NOT DEFINED	100

IN PROCESS OF BUILD-UP

<u>TYPE</u>	<u>QUANTITY</u>	<u>TEMPERATURE, F</u>	<u>SCHEDULED TIME, HR</u>	<u>ENVIRONMENT</u>
CHROMEL/ALUMEL	6	2200	10,000	NaK
W-5 Re/W-26 Re	12	2200	10,000	NaK
W-5 Re/W-26 Re	70	2200-2400	1000-10,000	LITHIUM
W-5 Re/W-26 Re	100	2200-2500	10,000	INERT GAS
W-3 Re/W-25 Re	40	2300-2500	10,000	INERT GAS
CHROMEL/ALUMEL	20	2200	10,000	INERT GAS
Mo/Cb	20	2300-2500	10,000	INERT GAS
W-5 Re/W-26 Re	20	2500	10,000	VACUUM

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PROCESS SENSOR DEVELOPMENT

LIQUID METAL LEVEL PROBE TESTS					
COMPLETED					
<u>CLAD</u>	<u>QUANTITY</u>	<u>TEMPERATURE, F</u>	<u>TIME, HR</u>	<u>ENVIRONMENT</u>	
Cb	2	1000	6600	LITHIUM	
IN PROGRESS					
<u>CLAD</u>	<u>QUANTITY</u>	<u>TEMPERATURE, F</u>	<u>SCHEDULED TIME, HR</u>	<u>TIME TO DATE,HR</u>	<u>ENVIRONMENT</u>
Cb	2	900	10,000	6000	LITHIUM
316 SS	3	1000	10,000	6000	LITHIUM
316 SS	3	800	10,000	6000	NaK
Cb	6	1000	10,000	9800	LITHIUM

PRESSURE TRANSMITTER TESTS					
IN PROGRESS					
QUANTITY	TEMPERATURE, F	SCHEDULED TIME, HR	TIME TO DATE, HR	ENVIRONMENT	
2	600	10,000	6000	LITHIUM	
7	600	10,000	6000	NaK	

FLOWMETER TESTS		
COMPLETED		
<u>QUANTITY</u>	<u>POLE FACE TEMPERATURE, F</u>	<u>TIME, HR</u>
2	200	10,000
1	900	6,600
IN PROGRESS		
<u>QUANTITY</u>	<u>POLE FACE TEMPERATURE, F</u>	<u>TIME, HR</u>
2	200-300	6000

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PROCESS SENSOR DEVELOPMENT

NUCLEAR SENSOR TESTS

COMPLETED

<u>TYPE</u>	<u>MANUFACTURER</u>	<u>QUANTITY</u>	<u>TEMPERATURE, F</u>	<u>TIME, HR</u>	<u>ENVIRONMENT</u>
ION CHAMBER	REUTER-STOKES	1	400	2200	INPILE - 1×10^{11} NV (TH)
FISSION COUNTER	REUTER-STOKES	1	400	2300	INPILE - 2×10^9 NV (TH)
FISSION COUNTER	GENERAL ELECTRIC	1	400	2300	INPILE - 2×10^9 NV (TH)
FISSION COUNTER	GENERAL ELECTRIC	1	400	3000	INPILE - 2×10^9 NV (TH)

IN PROGRESS

<u>TYPE</u>	<u>MANUFACTURER</u>	<u>QUANTITY</u>	<u>TEMPERATURE, F</u>	<u>SCHEDULED TIME TO TIME, HR</u>	<u>DATE, HR</u>	<u>ENVIRONMENT</u>
ION CHAMBER	REUTER-STOKES	1	400	10,000	8900	INPILE - 4×10^9 NV (TH)
FISSION COUNTER	REUTER-STOKES	1	400	10,000	8200	INPILE - 1×10^9 NV (TH)
ION CHAMBER	GENERAL ELECTRIC	1	400	10,000	8800	INPILE - 3×10^9 NV (TH)
ION CHAMBER	GENERAL ELECTRIC	1	400	10,000	8700	INPILE - 4×10^9 NV (TH)
ION CHAMBER	REUTER-STOKES	3	400	10,000	7400	OUT-OF-PILE
FISSION COUNTER	REUTER-STOKES	3	400	10,000	100	OUT-OF-PILE
ION CHAMBER	GENERAL ELECTRIC	2	400	10,000	4200	OUT-OF-PILE

PREAMPLIFIER TESTS

IN PROGRESS

<u>TYPE</u>	<u>QUANTITY</u>	<u>TEMPERATURE, F</u>	<u>SCHEDULED TIME, HR</u>	<u>TIME TO DATE, HR</u>	<u>ENVIRONMENT</u>
CANEL	2	250	3,000	600	INPILE - 3×10^7 NV (FAST)
CANEL	11	250-350	10,000	3200	OUT-OF-PILE

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PROCESS SENSOR CAPABILITY

<u>MEASUREMENT</u>	<u>SENSOR</u>	MAXIMUM ENVIRONMENT TEMPERATURE, F			
		<u>AIR</u>	<u>INERT GAS & VACUUM</u>	<u>L.M.</u>	<u>LITHIUM</u>
TEMPERATURE	CLAD THERMOCOUPLES				
	a) 316 SS CLAD C/A	1500*	2000*	2000 1800*	800*
	b) Cb-I Zr CLAD C/A	--	2200 2000*	2200	2200
	c) Cb-I Zr CLAD W-Re	--	2600 2000*	2600 2000*	2400 1000*
LIQUID LEVEL J & I PROBES					
	a) 316 SS CLAD	--	--	2000 1800*	800*
	b) Cb-I Zr CLAD	--	--	2600 2000*	2400 1000*
PRESSURE	TRANSMITTERS, DIAPHRAGM TYPE, 316 SS	MAXIMUM DIAPHRAGM TEMPERATURE, F			
		<u>AIR, INERT GAS, VACUUM, L.M. LITHIUM</u>			
			1000 600*		800 600*
FLOW	PERMANENT MAGNETS	MAXIMUM MAGNET TEMPERATURE, F			
		<u>AIR, INERT GAS</u>			
		800			
RADIATION	FISSION AND IONIZATION CHAMBERS	MAXIMUM ENVIRONMENT TEMPERATURE, F			
		<u>AIR, INERT GAS</u>			
		700 400*			

*PROVEN LONG TERM PERFORMANCE

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SUMMARY OF LIQUID METAL PUMP DESIGN EXPERIENCE AT CANCEL

<u>ANP PROGRAM</u>						
<u>MODEL</u>	<u>FLUID</u>	<u>MAX. TEMP, F</u>	<u>FLOW RATE, GPM</u>	<u>HEAD RISE, FT.</u>	<u>SHAFT SPEED, RPM</u>	<u>TYPE DRIVE</u>
NJ-2B	NaK-44	1200	8500	500	4350	AIR TURBINE
TP-1	NaK-44	1300	3000	440	8000	AIR TURBINE
PW-19-1	NaK-44	1500	47	120	4500	ELECTRIC MOTOR
TP-2	NaK-44	1342	8500	540	7150	AIR TURBINE
<u>LCRE PROGRAM</u>						
LP-1	LITHIUM	1600	195	115	4500	ELECTRIC MOTOR
NP-1	NaK-78	1200	394	143	4580	ELECTRIC MOTOR
RP-1	NaK-78	700	175	106	4300	ELECTRIC MOTOR
<u>SNAP-50/SPUR PROGRAM</u>						
LP-2	LITHIUM	1877	341	130	11,400	ELECTRIC MOTOR
KP-2	POTASSIUM	1103	43	339	11,400	ELECTRIC MOTOR
NP-2	NaK-78	1080	131	60	11,400	ELECTRIC MOTOR

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RESTRICTED

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SUMMARY OF LIQUID METAL PUMP DEVELOPMENT EXPERIENCE AT CANEL

<u>MODEL</u>	<u>FLUID</u>	<u>TEMPERATURE, F</u>	<u>FLOW RATE, GPM</u>	<u>HEAD RISE, FT</u>	<u>LONGEST TEST, HRS</u>	<u>TOTAL OPERATING HOURS</u>
LP-1	LITHIUM	1600 MAX. 1000 NOM.	195	140	10,292 10,112	40,205
NP-1	NaK-78	1200 MAX. 700 NOM.	394	143	8,113	19,689
TP-1	NaK-44	1300 MAX. 1200 NOM.	3000	440	1,332	4,408
PW-19-1	NaK-44	1500	47	120	911	2,640
S-1	NaK-44	1335 MAX. 1000 NOM.	400	127	1,000	2,326
S-2	NaK-44	1200	400	127	70	70
					TOTAL	69,338

MAY 8, 1964

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PUMP

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SNAP-50/SPUR REACTOR COOLANT PUMP

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DECLASSIFIED

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SNAP-50/SPUR CONDENSATE PUMP

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~~DEFENSE INFORMATION~~

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SNAP-50/SPUR CONDENSER COOLANT PUMP

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~~DEFENSE INFORMATION~~

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HYDROSTATIC BEARING CONFIGURATIONS

4-POOL, ORIFICE-COMPENSATED

DIA. = 2.375 IN.

$L/D = 1$

$L/D = 1.5$

0000000000

HYDRODYNAMIC BEARING CONFIGURATION

DIA. = 2.375"

L/D = 1.5

024558703

WATER THRUST BEARING TEST UNIT

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0340507030

DYNAMIC SEAL IMPELLERS FOR WATER TEST

DS - 11

DS - 12

DS - 10

DECLASSIFIED

INTERFACE ON DYNAMIC SEAL

DECLASSIFIED

OSCILLOSCOPE TRACES OF SINGLE HYDROSTATIC
WATER BEARING TEST UNIT

1000 RPM

6040 RPM

7290 RPM

9060 RPM

REF ID: A66000

MACHINED IMPELLERS FOR INITIAL REACTOR COOLANT PUMP

Cb-1 Zr

STAINLESS STEEL

REF ID: A66000

MACHINING OF THE NaK PUMP IMPELLER

POSITIONING SEQUENCE

CUTTING SEQUENCE

0001 022810

IMPELLER AND SCROLL MATCHING TEST UNIT FOR
INITIAL REACTOR COOLANT PUMP

0001 022810

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