ENCLOSURE A

Draft

NSRR Severe Fuel Damage Experiments Plan

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Reactivity Accident Laboratory

Division of Nuclear Safety Research

Japan Atomic Energy Research Institute

NSRR SFD Experiment Plan

General Objectives

(1) Determine nature of fuel rod damages (cladding oxidation, ballooning to rupture and fuel liquefaction) and fission products release from fuel resulting from wide-ranged SCD events.

(2) Characterize debris formation by reflood quenching.

(3) Study coolability of debris.

EXPERIMENT PROGRAM

PHASE I:

PRELIMINARY AND SCOPING TESTS SIMULATING CORE UNCOVERY ACCIDENT EVENT.

PHASE II:

DETAILED TESTS SIMULATING WIDE-RANGED SCD EVENTS USING MODIFIED NSRR AND DEVELOPED TEST TRAINS.

PHASE I AND PHASE II EXPERIMENTS PROGRAM

	Period	Accident type to be simulated*	Reactor power	Peak fuel temperature (°C)		Pre-irradiation of test fuel rod (burn up fuel)	Remarks
				quasi-steady state	transient		
Phase I	1982 ~ 1984	Core uncovery transient and Reflood phase	Pulse or Steady-state	~1600	~3000	no	Using present NSRR and test equipments
Phase II	1986 ~	PCM & ATWS in addition to above	Controlled power to simulate any types of accidents	~2500	~3000	yes	Using modified NSRR and developed test trains

* Fuel temperature will be simulated mainly.

Experiment Program in Phase I

1. Objectives

(1) Fuel Behavior Test & Debris Formation Test

(i) Extent and type of fuel rod damage and possible flow blockage resulting from a range of core uncovery transient.

(ii) Corresponding amount of fission products release from fuel.

(iii) Fuel fragments size after reflood quenching.

(iv) Kinetics of Zircaloy-steam and-UO_2 reactions including effect of environmental gas and cladding inner surface oxidation.

1. Objectives (Cont'd)

(2) Coolability Test

- Thermal-hydraulic characteristics of debris beds.

2. Test Samples

(1) Fuel Behavior & Debris Formation Tests

Zircaloy-4 clad UO_2 fuel (14 x 14 PWR type)

- unirradiated (fresh) rod
- single rod (or 5-rod cluster*)

(2) Coolability Test

- Fuel fragments from Fuel Debris Formation Tests

  (size and shape: uncontrolled)

- Fuel fragments from NSRR RIA Tests

  (size: controlled, shape: uncontrolled)

- Specially-fabricated fuel and cladding chunks

  (size and shape: controlled)

* A simulated control rod with low-melting poision materials may be replaced in the center in some cases.

3. Test Conditions

(1) Irradiation (ramping of power)

- Steady-state power
  - — expected peak fuel temperature: ~1600°C
  - — heating rate : 0 ~ 10°C/sec (variable)
- Pulsing power
  - — expected peak fuel temperature: ~3000°C
  - — heating rate : very fast (not variable)

(2) Cooling (termination of test)

— slow (0 ~ 50°C/sec) or quench

(3) Coolant (environment of test fuel)

— atmospheric pressure of water, steam, air, helium or their mixtures

4. Test Parameters

(1) Heating rate

VERY QUICK (PULSE OPERATION)

SLOW 0 ~ 10°C/SEC (STEADY-STATE OPERATION)

(2) Temperature of fuel or cladding

PEAK : 1000 ~ 3000°C (PULSE OPERATION)

1000 ~ 1600°C (STEADY-STATE OPERATION)

HOLDING TIME: 0 ~ 10 MIN (STEADY-STATE OPERATION ONLY)

(3) Cooling condition (Termination of test)

SLOW (0 ~ 50°C/SEC) OR QUENCH

(4) Environment gas

STEAM, HELIUM OR MIXTURE

5. Test Data

(1) Transient

(I) Temperatures of fuel centerline, cladding surface, debris and environment gas

(II) Fuel displacement

(III) Differential pressure across debris bed

(IV) Fuel motion observation

(2) Post-irradiation examination

(I) Dimensional Measurement

(II) Metallography and ceramography

(III) Hydrongen and fission products analysis

(IV) Sieve analysis (to dermine fragments size)

Time Schedule for NSRR Experiments

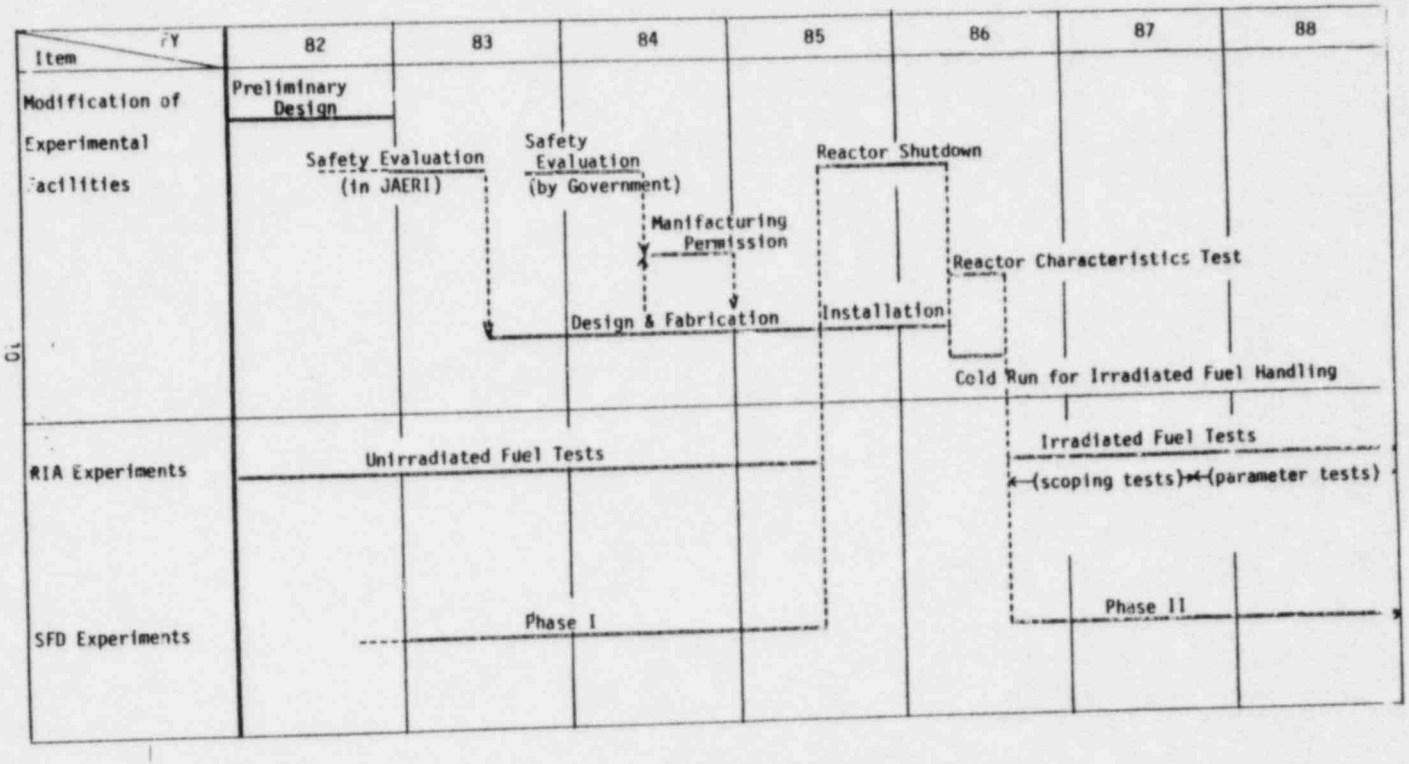

Table 1 Summary of NSRR SCD Phase I Experiments

Test Designation	Specific Objectives	Key Test Parameters
Fuel Behavior Test	1. Determine nature of fuel rod damages 2. Study Zry-H_2O and -UO_2 reactions 3. Determine amount of FP release	· Peak fuel temperature: 1600 ∿ 3000°C (pulse irradiation only, no heating rate controlled) · Environmental gas: He, air, steam or their mixtures · Cooling rate: slow or very slow · Holding time at peak temperature: 0 ∿ 10 min (max, peak temperature ∿ 1600°C · Heating rate: 0 ∿ 10°C/sec (up to 1600°C)
Debris Formation Test	1. Characterize debris formation by reflood quenching 2. Determihe amount of FP release	· Same as above (Water is injected under above conditions)
Coclability Test	1. Study thermal-hydraulic characteristics of debris beds upon reflooding	· Fuel temperature before water injection: 500∿1000°C · Debris bed depth: 5, 10 (15) cm · Particle size : 1 10 m approximately

Table 2 Fuel Behavior & Debris Formation Tests (1/3)

Heating rate during ramping (°C/sec)	Peak fuel temperature (°C)	Holding time at peak temperature (°C)	Cooling rate	Environmental gas before reflooding	Test date	Status of fuel
Very high (pulse irradiation)	1600	—	slow	He	1983. 1	Cladding and fuel slightly molten due to UO_2-Zry reaction
			quench	He	1983. 6	
	1800	—	slow	He	1983. 1	Cladding and fuel partially molten due to UO_2-Zry reaction unless severe oxidation occurs
			quench	He	1983. 9	
			slow	mixture	1983. 3	
			slow	steam	done (104-7)	
	2000	—	slow	He	done (104-10)	metalic cladding molten and liquified fuel formed
			very slow*	He	1984. 1	
			slow	steam	done (104-6)	
			quench	steam	1983. 9	

Table 2 Fuel Behavior & Debris Formation Tests (2/3)

Heating rate during ramping (°C/sec)	Peak Fuel temperature (°C)	Holding time at peak temperature (°C)	Cooling rate	Environmental gas before reflooding	Test data	Status of fuel
very high (pulse irradiation)	2500	—	slow	air	1983. 2	large amount of liquified fuel formed
			quench	air	1983. 11	
			slow	He	1983. 3	
			very slow	He	1984. 1	
	3000	—	slow	air	done (104-4)	fuel molten, but fuel fragmentation may occur.
			slow	He	1983. 4	

A total of ~5 tests will be added for unspecified quench experiments to study debris formation upon reflood quenching.

* Fuel temperature will be kept high with well-desiged thermal insulator(s) or auxiliary electric heater installed.

Table 2 Fuel Behavior & Debris /Formation Tests (3/3) (Steady state Reactor Operation)

Heating rate ramping (°C/sec)	Peak fuel temperature (°C)	Holding time at peak temperature (°C)	Cooling rate	Environmental gas before reflooding	Test date	Status of fuel
< 0.5	1600*	10	slow	He	1983. 10	cladding and fuel slightly molten due to UO_2-Zry reaction
∿ 3	1600*	10	slow	He	1983. 10	
> 5	1600*	1	slow	He	1983. 11	
			slow	steam	1983. 11	
			quench	steam	1983. 12	
			slow	mixture	1983. 12	
—	1800**	not specified			1984. 1∿	∿10 numbers of tests

* As high as possible with thermal insulator(s) installed.

** As high as possible with thermal insulators(s) and auxiliary electric heater(s) installed.

Table 3 Coolability Test

Fuel Temperature before Water Injection	Particle size (mm)	Debris Bed Depth (cm)	Debris Bed Diameter (cm)	Environmental Gas before Reflooding	Heat Generation during Reflood	Test Date
800°C	1	10	5	Steam	Steady State Reactor Ope.	1983. 4
	5	10				1983. 4
	7	10				1983. 5
	*	5				1983. 9
						1983. 10
1800°C	*	*	5	Steam	None (Pulse Ope.)	1983. 11
1600°C	*	*				1983. 12
1000°C	*	*				1983. 11

* To be determined based on previous tests

FIG. 1 TEST TRAIN OF FUEL BEHAVIOR & DEBRIS FORMATION TESTS

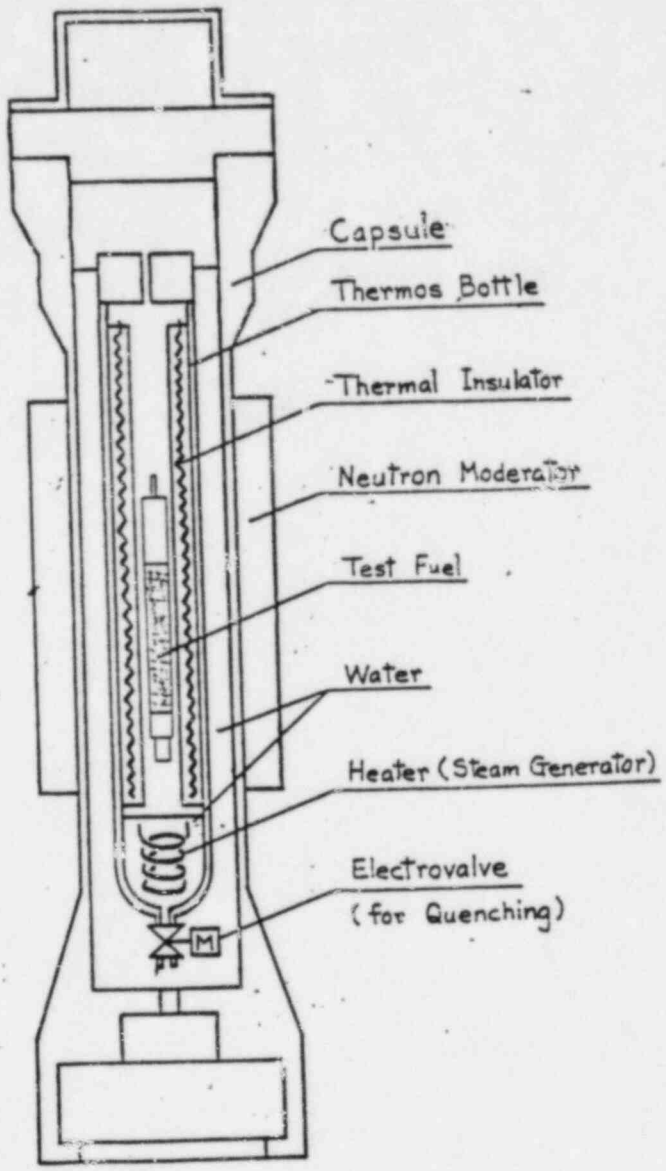

Fig.2 Test Train of Coolability Test