APPENDIX B

JAERI-memo

57-238

TENTATIVE PROGRAM OF NSRR EXPERIMENTS FOR FY 1982

September 1982

Reactivity Accident Laboratory

日 本 原 子 力 研 究 所
Japan Atomic Energy Research Institute

編　　集　日本原子力研究所
印　　刷　㈱原子力資料サービス

JAERI-memo 57-238

Tentative Program of NSRR Experiments for FY 1982

Reactivity Accident Laboratory*
Division of Nuclear Safety Research,
Tokai Research Establishment, JAERI

(Received August, 1982)

The NSRR experiments started in October, 1975. A total of 566 tests were performed by July, 1982, using an atmospheric pressure capsule, a fuel observation capsule, a high temperature high pressure capsule and a loop.

The experiments of the fiscal year 1982 start in August, 1982 and will continue until June, 1983. A total of about 60 tests are planned during this period. This report describes the objectives and test conditions for each test series. The experiments are divided into eight categories as follows.

1. Standard fuel rod tests
2. Fuel design parameter tests
3. Coolant condition parameter tests
4. Defective fuel rod tests
5. Fuel motion observation tests
6. High temperature high pressure capsule tests
7. Loop tests
8. Miscellaneous tests

---

* T. Hoshi, S. Saito, T. Fujishiro, T. Inabe, S. Shiozawa, K. Ishijima, S. Tanzawa, T. Tsuruta, S. Katanishi, T. Yoshimura*1), M. Ochiai*1), N. Shirakawa*2), M. Uemura*3) and J.P. L'Heriteau*4)

*1) Ship Research Institute

*2) Nippon Atomic Industry Group Ltd.

*3) Computer Service Co.

*4) PHEBUS Program, France

CONTENTS

I. Outline of the NSRR Experiments for FY 1982

The program of the NSRR experiments is directed to provide detailed data on fuel behavior in reactivity initiated accident (RIA) conditions.

Since October, 1975, a total of 566 tests have been performed so far under high temperature and high pressure conditions as well as atmospheric pressure conditions. The threshold energy deposition for fuel failure, failure mechanism and failure consequences have been investigated in detail at ambient temperature and atmospheric pressure through numbers of experiments. The effects of coolant condition on fuel failure have been investigated with a high temperature high pressure capsule. And studies of the fuel behavior under PWR and BWR conditions with coolant flow were started last year with high temperature high pressure loop.

In the fiscal year 1982, extensive effort will be directed to the performance of high pressure capsule tests, loop tests and fuel behavior observation tests. And the preliminary studies of future NSRR experiments are also planned this year: irradiated-cladding fuel tests will be conducted as the preliminary experiments for future burn-up fuel tests, and fuel melt down tests are expected to give the basic data for future severe fuel damage tests. Atmospheric pressure capsule tests will be also continued to obtain detailed supporting data for high temperature high pressure capsule and loop experiments.

The planned NSRR experiments for FY 1982 consist of the following eight experiment groups.

1. Standard fuel rod tests (111 series)
2. Fuel design parameter tests (212, 214, 231 series)
3. Coolant condition parameter tests (240, 312 series)
4. Defective fuel rod tests (115 series)
5. Miscellaneous tests (104, 120, 206, 701 series, including irradiated-cladding tests and fuel melt down tests)
6. Fuel behavior observation tests (600 series)
7. High temperature high pressure capsule tests (1200 series)
8. High pressure loop tests (2200, 2300 series)

The summary of the planned tests and the test schedule are presented in Table I.1 and Table I.2, respectively. The objectives and conditions for each test series of the above eight experiment groups are described in the following chapters.

Table I.1 Summary of NSRR Test Program for FY '82 (Aug. '82 to June '83)

Test items	Test series No.	Objectives	Conditions	Number of tests	Remarks
(I) Standard Water Capsule Tests					
1. Standard fuel rod tests					
1.1 High energy deposition tests	111	• Study the effects of system pressure to mechanical energy conversion ratio	• energy deposition ~440 cal/g·UO_2 • system pressure 0.2 ~ 0.5 MPa	4	
2. Fuel design parameter tests					
2.1 Stainless steel clad fuel tests	212	• Study the effects of fuel rod diametral size and cladding material on fuel failure mode and threshold	• SS clad FBR size fuel	6	
2.2 Irradiated-cladding fuel tests	214	• Study the failure mechanism for burnup fuel (embrittlement of cladding due to irradiation)	• fuel rod with irradiated clad. and fresh pellet	4	
2.3 Pre-pressurized fuel tests under forced flow condition	231	• Study the effects of cooling condition on the failure of pre-pressurized fuel rods	• initial rod pressure 1.2 ~ 3.0 MPa • coolant velocity 0.5, 1.0 m/sec	5	

Table I.1 (Continued)

Test items	Test series No.	Objectives	Conditions	Number of tests	Remarks
3. Coolant condition parameter tests					
3.1 Forced convection tests	240	• Two phase flow measurement	• 150 ~ 250 cal/g•UO_2 • coolant flow velocity 0.3 ~ 1.8 m/sec • coolant temp. 20 ~ 90°C • fuel type 10%E STD	3	
3.2 Bundled rod tests	312	• Fuel behavior of bundled rods under forced convection	• 190 ~ 230 cal/g•UO_2 • coolant flow velocity 1.0 m/sec • coolant temp. 20°C • fuel type 10%E, 20%E bundle	2	
4. Defective fuel rod tests					
4.1 Fretting corroded fuel rod tests	115	• Failure threshold for pre-pressurized, fretting corroded fuel rod	• initial fuel pressure 1.2 ~ 7.0 MPa • max. depth of defects 0.5, 0.3 mm	5	

Table 1.1 (Continued)

Test items	Test series No.	Objectives	Conditions	Number of tests	Remarks
5. Miscellaneous tests					
5.1 Fuel melt tests	104	• "Candling" or "melt-down" behavior as a consequence of fuel melting	• steady state operation (300 kW) or pulse operation (300 ~ 330 cal/g·UO_2) • adiabatic inner capsule	3	
5.2 Fuel rod down force measurement tests	120	• Measure the fuel rod down force and determine the effects of reactor periods and pellet stack length	• reactor period 4 ~ 20 msec • fuel stack length 100, 300 mm	5	
5.3 Cladding strain measurement tests	206	• Measure the cladding strain at high temperature	• 220 ~ 255 cal/g·UO_2	5	
5.4 Mixed oxide fuel tests	701	• Determine threshold energy deposition for rod fracture, rod failure and DNB occurrence • Study oxidation and deformation behaviors	• 140 ~ 300 cal/g·UO_2 • double capsule • $(U,Pu)O_2$ fuel	4	

Table I.1 (Continued)

Test items	Test series No.	Objectives	Conditions	Number of tests	Remarks
(II) Fuel Motion Observation Tests	600	• Ballooning • Melt-down behavior • Forced convection • Bundled fuel behavior	• 200 ~ 300 cal/g·UO_2	4	
(III) High Temperature High Pressure Capsule Tests					
1. Water logged fuel tests under HZP (Hot Zero Power) condition	1203	• Study the failure behavior under the hot-zero-power condition	• 200 cal/g·UO_2 • water amount: 100% • coolant condition pressure 16 MPa temp. 305 °C	1	
2. PCI-remedy BWR type fuel tests	1204	• Failure threshold evaluation for PCI remedy fuel rods	• BWR current type rod Zr-liner rod Cu-barrier rod • 260 cal/g·UO_2 • coolant condition pressure 7.2 MPa temp. 276 °C	1	3 rods irradiation in a capsule

Table I.1 (Continued)

Test items	Test series No.	Objectives	Conditions	Number of tests	Remarks
3. Pre-pressurized fuel tests	1205	• Study the failure threshold and its mechanism	• fuel rod 7 ~ 10 MPa pressurized • 210 ~ 260 cal/g·UO_2 • coolant condition pressure 16 MPa temp. 320 °C	1	3 rods irradiation in a capsule
4. LVDT calibration tests	1206 1207	• Calibrate the newly developed LVDTs	• 150 ~ 250 cal/g·UO_2 • coolant condition pressure 16 MPa temp. 320 °C	2	
5. System pressure effect tests	1208	• Study the heat transfer characteristics under various system pressure	• 1 ~ 16 MPa	1	1 to 2 tests will be performed in this year

Table I.1 (Continued)

Test items	Test series No.	Objectives	Conditions	Number of tests	Remarks
(IV) Water Loop Tests					
1. High temperature high pressure loop tests	2211	• Effects of flow and subcooling • Failure threshold	• 230 ~ 270 ± α cal/g·UO_2 • system condition: BWR flow rate:0.6 ~ 3.0 m/sec • fuel type 10%E STD	2	4 to 5 tests will be performed in this year
	2311	• Effects of fuel rod conditions • Failure threshold	• 190 ~ 250 ± α cal/g·UO_2 • system condition: BWR, PWR flow rate:0.6 ~ 3.0 m/sec • fuel type 10%E STD pre-pressurized Xe-gap gas	3	
			Total	61	

Table I.2 Tentative NSRR Experimental Schedule from Aug. 1982 to May 1983

Test Items	1982					1983				
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Atmospheric Pressure Capsule										
High energy deposition tests (111)				○	○○	○				
Stainless steel clad fuel tests (212)	○		○	○			○	○	○	
Irradiated-cladding fuel tests (214)							○	○	○	○
Pre-pressurized fuel tests under forced flow condition (231)	○		○○	○○						
Forced convection tests (240)	○		○		○					
Bundled rod tests (312)								○	○	
Fretting corroded fuel rod tests (115)			○	○	○	○	○			
Fuel melt tests (104)			○	○				○		
Fuel rod down force measurement tests (120)				○	○			○	○	○
Cladding strain measurement tests (206)			○	○		○	○	○		
Mixed oxide fuel tests (701)	○		○		○	○				
Fuel motion observation tests (600)		○	○			○			○	
High Temperature High Pressure Capsule										
Water logged fuel tests under HZP condition (1203)		○								
PCI-remedy BWR type fuel tests (1204)										○
Pre-pressurized fuel tests (1205)					○					
LVDT calibration tests (1206,1207)							○		○	
System pressure effect tests (1208,1209)								○		
Water Loop										
High temperature high pressure loop tests (2211,2311)			○	○		○			○	○

II. Standard Water Capsule Tests

1. Standard fuel rod tests

1.1 High energy deposition tests (111)

Objectives

The objectives of this test series are to clarify the mechanical energy generation procedure and to measure the mechanical energy conversion ratio at high energy deposition conditions. In this fiscal year, fuel failure modes and mechanical energy generation by fuel-coolant interaction are investigated under elevated pressure condition.

Also, in order to confirm the validity on the mechanical energy evaluated according to the piston model, the mechanical energy is evaluated by elastic stress of spring.

Experimental plan

Test conditions of the experiments planned are listed in Table II.1.1.

Instrumentation

Following instruments will be installed.

(1) Water pressure sensor
(2) Cover gas pressure sensor
(3) Water column velocity sensor
(4) Cladding surface temperature (Pt/Pt-13% Rh T/C)
(5) Capsule water temperature (C-A T/C)
(6) Fuel rod break off sensor

Table II.1.1 Test conditions

Test No.	Fuel type	Energy deposition ($cal/g \cdot UO_2$)	Capsule	Remarks
111 - 43	10%E STD type	440	φ60 inner capsule	Compressed cover gas (0.2 ~ 0.5 MPa)
111 - 44	ditto	440	φ60 inner capsule	Dynamic loading by piston (0.2 ~ 0.5 MPa)
111 - 45	20%E FBR type bundle	400	φ120 STD capsule	——
111 - 46	10%E STD type	440	ditto	——

2. Fuel design parameter tests

2.1 Stainless steel clad fuel tests (212)

Objectives

Determine the thermal behavior and failure threshold of small diameter fuel rods clad with stainless steel (rod O.D.: 6.3 mm).

Experimental plan

Planned test conditions are given in Table II.2.1.

Table II.2.1 Test Conditions

Test No.	Test Fuel	Energy Deposition ($cal/g \cdot UO_2$)	Test Objective
212 - 62	Stainless steel clad FBR type fuel (10%E)	200	Clarify the thermal response of small diameter rods.
212 - 63		250	
212 - 64		280	
212 - 65		310	Determine the fuel failure threshold.
212 - 66		330	
212 - 67		350	

2.2 Irradiated-cladding fuel tests (214)

Objectives

Study the effects of irradiation of the cladding to fuel failure.

Experimental plan

Four test fuel rods composed of pre-irradiated cladding and fresh fuel pellets are subjected to the energy deposition of near failure threshold.

Planned test conditions are listed in Table II.2.2.

Table II.2.2 Test Conditions

Test No.	Fuel No.	Pellet - Clad Gap Width	Energy Deposition	Neutron Fluence** (nvt)
214 - 101	001	0.095 mm	240 cal/g·UO_2	2.7×10^{21}
214 - 102	031	0.050 mm	*	2.3×10^{21}
214 - 111	002	0.095 mm	240 cal/g·UO_2	1.2×10^{21}
214 - 112	033	0.050 mm	*	1.4×10^{21}

(Note)

*) Energy deposition will be determined based on the tests of 240 cal/g·UO_2.

**) Cladding tubes were irradiated in JMTR.

2.3 Pre-pressurized fuel tests under forced flow condition (231)

Objectives

To investigate the effect of coolant flow rate on the failure of pre-pressurized rod under RIA condition.

Experimental plan

As shown in Table II.2.3, three tests to study the effect of coolant flow rate on pre-pressurized rod behaviors have already been performed. In this year, the effects of pressure of flow shroud and higher coolant flow rate will be studied.

Planned test conditions and instrumentation are listed in Table II.2.3 and II.2.4, respectively.

Table II.2.3 Test Conditions

Test No.	Initial Rod Pressure (MPa)	Coolant Velocity (m/s)	Shroud Inner Dia. (mm)	Energy Deposition (cal/g·UO_2)	Remarks
231 - 51	1.2	0.5	20	216	Cladding Rupture
231 - 52	1.2	0.5	20	200	Cladding Rupture
231 - 53	1.2	1.0	20	199	Uniform Ballooning
231 - 54	1.2	1.0	20	215	Failure Threshold
231 - 55	1.2	0.0	20	1)	Effect of flow shroud
231 - 56	3.0	1.8	16	2)	Failure Threshold
231 - 57	3.0	1.8	16	3)	Failure Threshold
231 - 58	3.0	0.0	16	2)	Effect of flow shroud

(Note)

1) The same condition as Test 231-24

2) The same condition as Test 231-12

3) To be determined after Test 231-56

Table II.2.4 Instrumentation

Test No.	Cladding Temp.	Rod Pressure	Flow Rate	Coolant Temp.
231 - 54	○	○	○	○
231 - 55	○	○	○	○
231 - 56	○	○	○	○
231 - 57	○	○	○	○
231 - 58	○	○	○	○

3. Coolant condition parameter tests

3.1 Forced convection tests (240, 312)

Objectives

The objective of this test series is to investigate the fuel behavior under forced convection in the atmospheric pressure capsule. Although the test conditions are limited to ambient pressure and low coolant flow rate, the tests are very useful for the preliminary ones for the loop experiments due to its easy handling capability.

In this test period, the parametric tests are to be continued to obtain the basic data on the two phase flow behavior and the bundled configuration.

Experimental plan

Five tests are planned for this test period as shown in Table II.3.1. Measurement of average coolant velocity and void ratio at test channel exit is attempted in Test 240-13, -16 and -17 with a newly developed two phase instrumentation. Test 240-17 is to be conducted under the condition of 10°C subcooling. In these three tests, a single fuel rod is to be repeatedly irradiated at various energy depositions and coolant flow velocities.

Two bundled rod tests are to be conducted with five rod cluster at the energy deposition below failure threshold under coolant velocity of 1.0 m/s.

Table II.3.1 Forced Convection Test Plan

Test No.	Energy Deposition ($cal/g \cdot UO_2$)	Fuel Type	Flow Condition		Objectives
			Flow Velocity (m/s)	Coolant Temp. (°C)	
240-13-1	150	Std. 10%E	1.8	20	Two phase flow measurement
-2	150		1.0		
-3	250		1.8		
240-16-1	150	Std. 10%E	0.6	20	Two phase flow measurement
-2	150		0.3		
-3	250		1.0		
240-17-1	150	Std. 10%E	1.0	90	Two phase flow measurement under low subcooling
-2	150		0.6		
-3	250		1.0		
312-42	190	5 rods 10%E & 20%E	1.0	20	Fuel behavior of bundled rods under forced convection
312-43	230	5 rods 10%E & 20%E	1.0	20	Fuel behavior of bundled rods under forced convection

4. Defective fuel rod tests

4.1 Fretting corroded fuel rod tests (115)

Objectives

The objective of this series is to obtain general information about the effects of cladding defects due to fretting corrosion on fuel rod failure behavior at RIA conditions.

In this fiscal year, the pre-pressurized fuel rods with defective cladding will be tested to investigate the effect of initial rod pressure on fuel failure threshold energy, and the effect of defect shape on fuel failure behavior.

Experimental plan

The pre-pressurized fuel rods whose cladding have artificial pitting defects or vertical defect at center position of active region will be tested. Experimental conditions and measuring items are listed in Table II.4.1.

Table II.4.1 Experimental Conditions and Measuring Items

Test No.	Experimental Conditions			Measuring Items
	E ($cal/g \cdot UO_2$)	P_f (bar)	Depth of Defects (mm)	
115 - 38	167	12	0.5	Clad. Temp. Fuel Pres. Capsule Pres. Water Level
- 39	182	12	0.3	
- 40	140	30 ~ 70	0.5	
- 41	160	30 ~ 70	0.3	
115 - 51	180 ~ 250	12	0.5 U, 10 mmℓ	Clad Temp. Fuel Pres. Capsule Pres. Water Level

5. Miscellaneous tests

5.1 Fuel melt tests (104)

Objectives

Fuel rod behavior under a steam, helium or air atmospheric condition will be studied to simulate a LOCA without ECCS or a severe fuel damage accident. UO_2-Zircaloy chemical reaction and fuel melting behavior will be examined with a specific emphasis. The data is expected to be applied to future severe fuel damage tests.

Experimental plan

Three tests are scheduled to observe the fuel rod melting behavior. One is to study UO_2-Zircaloy chemical reaction under an isothermal condition which can be established by a steady-state reactor operation for ~10 min. The atmosphere surrounding the test rod is kept air during the test. Expected cladding temperature is approximately 1800°C, but below Zircaloy melting temperature of ~1850°C, in which melting due to UO_2/β-Zircaloy reaction is presumed to occur and develop.

The other two tests will be subject to a pulse irradiation at an energy deposition of ~300 and ~330 cal/g·UO_2 in an air or steam atmosphere. After the pulsing, fuel becomes molten and molten fuel will be maintained for several minutes, resulting in "candling" or meltdown to a bottom structure.

In this test series, specially-fabricated "adiabatic capsule" will be supplied to keep hot condition for a long time. Test conditions are summarized in Table II.5.1.

Table II.5.1 Test Conditions

Test No.	Energy deposition (cal/g·UO_2)	Test fuel rod and capsule	Approximate expected cladding temperature (°C)	Main behavior to be examined	Instrumentation
104-9	300 kW steady state operation for ~10 min.	Standard fuel rod and almost adiabatic inner capsule* filled with steam, helium or air under atmospheric condition	1800	UO_2-Zircaloy reaction and melting behavior	fuel pellet center-line temperature and cladding surface temperatures
104-10 -11	~300 & ~330		above melting point	"candling" or meltdown behavior as a consequence of fuel melting	fuel pellet center-line temperature and bottom structure temperature if fuel meltdown occurs

* An inner capsule with ZrO_2 insulator is specially fabricated for this test.

5.2 Fuel rod down force measurement tests (120)

Objective

A model calculation indicates that the rapid expansion of fuel rods may cause large down forces and the forces may affect the core support structure when fuel rods are subjected to rapid energy insertions during RIA. This test series is aimed at obtaining the data to evaluate these down forces.

Experimental plan

The down forces are supposed to be proportional to the acceleration of fuel pellet axial expansion and the reactor periods. Tests are conducted with reactor periods and fuel stack length as parameters.

Test conditions, measuring items and schematic of test hardware arrangement are shown in Tables II.5.2, II.5.3 and Figure II.5.1.

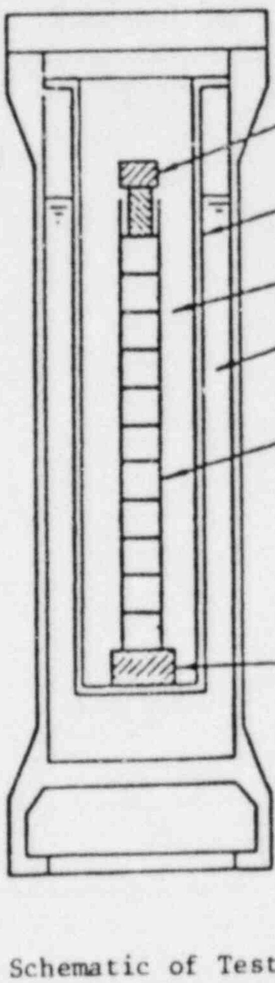

Fig.II.5.1 Schematic of Test Hardware Arrangement

Table II.5.2 Test Conditions

Test No.	Reactivity ($)	Reactor Period (ms)	Fuel Stack Length (mm)	Test Objectives
120 - 3	1.2	20	100	Determine the effect of reactor periods.
120 - 4	∫	∫		
120 - 5	2.0	4		
120 - 6	2.0	4	300	Determine the effect of pellet stack length.
120 - 7				

Table II.5.3 Instrumentation Requirements

Test No.	Measuring Items
120 - 3	∘ Fuel rod down force.
	∘ Fuel pellet acceleration.
∫	∘ Cladding strain.
120 - 7	∘ Cladding temperature.

5.3 Cladding strain measurement tests (206)

Objectives

The objectives of this test series are to obtain useful informations for the development of pellet expansion model including pellet cracking effect, and to get basic data for the future burnup fuel rod tests.

In the previous tests, the rods with various gap widths were tested, and transient cladding strain histories were measured.

Adhesive to fix strain gage used in the previous tests lose its ability above 70°C. Therefore, in this fiscal year, more advanced adhesive will be used to measure cladding strains at higher temperature more exactly.

Experimental plan

Measuring Items:

1) Cladding surface temperature
2) Cladding strain
3) Pellet and cladding axial elongations

Experimental conditions and instrumentation are listed in Table II.5.4 and II.5.5, respectively.

Table II.5.4 Experimental Condition

Test No.	Teat Fuel	Energy Deposition	Remarks
206 - 40	10%E Standard	220 cal/g·UO_2	
206 - 41	10%E Wide-Gap.	220 cal/g·UO_2	
206 - 42	10%E Narrow-Gap.	220 cal/g·UO_2	
206 - 43	10%E Standard	220 cal/g·UO_2	With Cd sheaths at both pellet stack ends
206 - 44	10%E standard	255 cal/g·UO_2	

Table II.5.5 Instrumentation

Test No.	Cladding Surface Temperature	Cladding Strain	Axial Elongation	
			Pellet	Cladding
206 - 40	○	○	○	○
206 - 41	○	○		
206 - 42	○	○		
206 - 43	○	○	○	○
206 - 44	○	○		

5.4 Mixed Oxide Fuel Tests (701)

Objectives

General fuel rod behaviors will be studied for uranium and plutonium mixed oxide ($(U,Pu)O_2$) fuel rods in comparison with the behaviors of uranium oxide (UO_2) fuel rods. Especially, the incipient failure threshold energy and its mode will be determined through a total of 10 tests.

Experimental plan

Four tests were already finished in FY 1981, therefore six tests will be conducted in this fiscal year. The test schedule and condition are shown in Table II.5.6.

Table II.5.6 Test Conditions

Test No.	Test fuel rod	Capsule	Energy deposition (cal/g·MO_2)	Specific objective	Instrumentation
701 - 5	$(U,Pu)O_2$ fuel	Double Capsule*	300	to determine threshold energy deposition for rod fracture	Cladding surface temperatures and Coolant water temperature
701 - 6 - 7			260 ~ 290	to determine threshold energy deposition for rod failure	
701 - 8 - 9			140 ~ 160	to determine threshold energy deposition for DNB occurrence	
701-10			200	to study oxidation and deformation behaviors	

* I-N-D type atmospheric pressure capsule with water at room temperature.

III. Fuel Motion Observation Tests (600)

Objectives

Optical instrumentations have been developed to observe the fuel behavior during rapid transient. The inpile tests are directed to investigate the fuel failure mechanism and to produce useful data for the modelling of fuel behavior.

Experimental plan

A test fuel rod is installed in a capsule with a lamp and a periscope, and the transient behavior of a rod is recorded by a high speed movie camera.

Seven tests have been performed so far changing energy deposition in a fuel rod and internal pressure of a rod. The slow motion films recorded clearly a Cerenkov glow, violent film boiling, cracking and deformation of the cladding quenching, bubble formation, etc.

Following experiments are planned to observe the ballooning of the cladding, fragmentation of fuel and melting behavior of stainless steel cladding, and also to investigate the effect of forced convection.

The planned tests are shown in Table III.1 and instrumentation are listed in Table III.2.

Table III.1 Test Condition for Fuel Motion Observation Tests

Test No.	Test Conditions		Objectives
	Energy Deposition ($cal/g \cdot UO_2$)	Remarks	
600 - 10	200	Initial fuel rod internal pressure; 2 MPa Dry Condition	Ballooning
600 - 11	200	Dry Condition	Meltdown Behavior
600 - 12	300	Fluid velocity; 2 m/sec	Forced Convection
600 - 13	250	3 FBR-sized fuel rods	Bundle Fuel Behavior

Table III.2 Instrumentation for Fuel Motion Observation Tests

Test No.	Optical instrument	Cladding Surface temp.	Water temp.	Fuel rod internal press.	Capsule press.
600 - 10	○	○	○ (Air)	○	○
600 - 11	○	○	○ (Air)		○
600 - 12	○	○	○		○
600 - 13	○	○	○		○

IV. High Temperature High Pressure Capsule Tests (1200)

1. Waterlogged fuel test under hot-zero-power condition

Objectives

The waterlogged fuel rod test series so far have revealed the mechanism and the threshold energy of such a defective fuel rod. All the tests, however, have been performed under the cold-stand-by condition. Therefore, it is necessary to perform a waterlogged fuel rod test in a HTHP capsule in order to study its failure behavior under the hot-zero-power (HZP) condition.

Experimental plan

It is not so difficult to predict the failure behavior of a waterlogged fuel rod under the HZP condition to be high-temperature-burst, which is not followed by mechanical energy release, since all waterlogged fuel rods so far have shown such a type of failure when their cladding temperature is over 200°C. Therefore a single experiment in a HTHP capsule is planned in this period. Table IV.1.1 and IV.1.2 show the test condition and instrumentation, respectively.

Table IV.1.1 Test Condition for a Waterlogged Fuel Rod Test

Test No.	Energy deposition $(cal/g \cdot UO_2)$	Water amount (%)	Temp. (°C)	Press. (kg/cm^2)	Test fuel
1203	200	100	305	157 (347)*	STD

* temperature of a pressurizer

Table IV.1.2 Measuring Items for a Waterlogged Fuel Rod Test

Test No.	Cladd. Temp.	Water Temp.	Internal Press. of a Capsule	Internal Press. of a rod
1203	○ (2 pairs)	○	○	○

2. PCI-remedy BWR type fuel tests

Objectives

To determine failure threshold and study the effect of Cu barrier and Zr liner. The specific objective of this test is to confirm whether the failure threshold energy changes or not for PCI remedy fuel rods.

Experimental plan

Three types of GE fuel rods, which consist of a conventional BWR type and two PCI remedy rods with Cu barrier and Zr lined cladding, will be tested. Test conditions are shown in Table IV.2.1.

Table IV.2.1 Test Conditions

Test No.	Energy deposition	Test fuel rod		Coolant condition	Approximate expected cladding temperature (°C)	Main behavior to be expected	Instrumentation
		Type	Enrichment (%)				
1204	260	GE-reference GE-Cu barrier GE-Zr lined	10 10 10	BWR (276 °C 7.2 MPa)	near melting temperature	failure threshold	cladding surface temperatures only

3. Pre-pressurized fuel tests

Objectives

To learn the effect of pre-pressurization of the test fuel rod using PWR type fuel rods, since the previous test results showed lower cladding temperature by 300-400°C in the fuel rod previously-pressurized to 7.0 MPa at an energy deposition of ~200 cal/g·UO_2.

Experimental plan

Test conditions are shown in Table IV.3.1.

Table IV.3.1 Test Conditions

Test No.	Energy deposition	Test fuel rod		Coolant condition	Approximate expected cladding temperature (°C)	Main behavior to be expected	Instrumentation
		Type	Enrichment (%)				
1205	260	Standard	20	PWR (320 °C, 16 MPa)	near melting point	failure threshold and its mechanism	cladding surface temperatures and fuel rod internal pressure
	260	7.0 MPa pre-pressurized	20		1600 - 1700		
	210	10.0 MPa pre-pressurized	10		~1500		

4. LVDT calibration tests

Objectives

Measure the pellet and cladding elongations using the newly developed LVDTs, and examine their responses under high temperature and high pressure environment.

Experimental plan

Planned test conditions and instrumentation requirement are given in Tables IV.4.1 and IV.4.2.

Table IV.4.1 Test Conditions

Test No.	Test Fuel	System Condition (Pressure/Temperature)	Energy Deposition ($cal/g \cdot UO_2$)
1206 - 1 1206 - 2 1206 - 3	10%E STD Fuel	7.2 MPa / 276°C	150 200 250
1207 - 1 1207 - 2 1207 - 3	10%E STD Fuel	16 MPa / 320°C	150 200 250

Table IV.4.2 Instrumentation Requirement

Test No.	Fuel Instrumentation
1206 and 1207	∘ Thermocouples for cladding surface temperature ∘ LVDT for pellet elongation ∘ LVDT for cladding elongation

5. System pressure effect tests

Objectives

The effects of system pressure on heat transfer characteristics and fuel behavior will be studied at the pressure range from 1 MPa to 7 MPa under stagnant coolant condition. The data will be used for the verification of heat transfer correlations of RIA fuel behavior analysis code.

Experimental plan

Three independent rods, i.e. standard, pre-pressurized and Xe filled rods, are irradiated simultaneously at the system pressure of 1 MPa (Test 1208) and 3 MPa (Test 1209), at the energy deposition of 200 cal/g·UO_2.

To examine the effect of coolant subcooling, each set of test rods are irradiated repeatedly at different coolant subcooling from 80°C to 5°C.

Test conditions for each test are listed in Table IV.5.1.

Table IV.5.1 Test Conditions

Test No.	Energy Deposition (cal/g·UO_2)	System Pressure (MPa)	Coolant Subcooling (°C)	Fuel Rods	Instrumentation
1208 - 1	200	1	80	• Standard rod • Pre-pressurized to 0.8 MPa • Xe filled at 0.1 MPa	• Cladding Surface Temperature • Coolant Temperature
1208 - 2			20		
1208 - 3			5		
1208 - 4			80		
1209 - 1	200	3	80	• Standard rod • Pre-pressurized to 2.4 MPa • Xe filled at 0.1 MPa	
1209 - 2			20		
1209 - 3			5		
1209 - 4			80		

V. Water Loop Tests

1. High temperature high pressure loop tests (2211, 2311)

Objectives

The objectives of these test series are to study the fuel behavior and failure threshold under the simulated cooling condition of PWR and BWR.

Experimental plan

Total of 10 tests are planned as the HPHT loop tests, which are composed of 2 test series, i.e. series 2211 and 2311. In test series of 2211, a single fuel rod will be tested to study the effect of cooling condition, and in test series of 2311, 3 different types of the fuel rods which have independent flow shrouds will be tested at the same time to study the effect of fuel design parameter.

The major test conditions and measuring items are shown in Table V.1 and V.2, respectively. The first test, Test No.2211-1, was performed last year. This year, 4 or 5 tests will be performed.

Table V.1 Test Conditions

Test No.	Energy (1) Deposition ($cal/g \cdot UO_2$)	Coolant Condition: Pressure (2) (MPa)	Coolant Condition: Temperature (3) (°C)	Coolant Condition: Flow rate (4) (m/s)	Fuel Type	Objectives	Note
2211-1-1	190	7.2	276	3	STD × 1	Power calibration and scoping	Performed
-2	190			0.7			
2211-2-1	230	7.2	276	3	STD × 1	Scoping (effect of flow rate)	
-2	230			1			
-3	230			0.7			
22-1-3-1	230	7.2	206	1	STD × 1	Scoping (effect of subcooling)	
-2	230		246	1			
-3	230		276	1			
2211-4	270	7.2	276	0.7	STD × 1	Failure Threshold	
2211-5	270 ± α	7.2	276	0.7	STD × 1	ditto	
2311-1-1	190	7.2	276	3	STD	Power calibration and scoping	
-2	190			1	He 3MPa		
-3	190			0.7	Xe 3MPa		

Table V.1 Test Conditions (continued)

Test No.	Energy Deposition (1) (cal/g·UO_2)	Coolant Condition: Pressure (2) (MPa)	Coolant Condition: Temperature (3) (°C)	Coolant Condition: Flow Rate (4) (m/s)	Fuel Type	Objectives	Note
2311-2	230	7.2	276	1	STD He 3MPa Xe 3MPa	Fuel parameter (effect of gap heat transfer)	
2311-3	230	15.8	325	1	ditto	ditto	
2311-4	250	7.2	276	1	STD He 3MPa BWR Type	Failure Threshold	
2311-5	250 ± α	7.2	276	1	ditto	ditto	

1) Energy Deposition is including the initial enthalpy, and might be exchanged by the result of pre-analysis or power calibration.

2) At an outlet of circulation pump.

3) At a heating tank.

4) At a test section.

Table V.2 Measuring Items

Test No.	Cladding surface temperature	Coolant temperature	Fuel internal pressure	Inlet of test section		Outlet of test section		
				Flow rate	Pressure	Flow rate	Density	Pressure
2211-1-1~2	6	4	——	——	——	——	——	——
2211-2-1~3	6	4	——	1	1	1	1	1
2211-3-1~3	6	4	——	1	1	1	1	1
2211-4	6	4	1	1	1	1	1	1
2211-5	6	4	1	1	1	1	1	1
2311-1-1~3	8	4	——	——	——	——	——	——
2311-2	8	4	——	3	1	3	1	1
2311-3	8	4	——	3	1	3	1	1
2311-4	8	4	2	3	1	1	1	1
2311-5	8	4	2	3	1	1	1	1

1-10-83
Draft
from
NRC

ROSA-IV AGREEMENT
BETWEEN JAERI AND USNRC

I. USNRC would be willing to provide JAERI the following support for the ROSA-IV program.

A. USNRC would send two to three qualified resident engineers to JAERI for the ROSA-IV program support. These engineers would have expertise in one or more of the following areas: test facility design, facility operation, experimental program planning, experimental pretest and post-test analysis, data qualification and data analysis. The USNRC sponsored engineer expertise would be [illegible]termined by the activities on the ROSA-IV program, JAERI [illegible]s and USNRC capability to obtain the desired expertise. U[illegible] would provide all costs associated with transportat[illegible] salary and living expenses of the engineers while at JAERI. JAERI would provide suitable office space, required computer cost and all other items required to perform the assigned tasks. USNRC and JAERI would agree on the workscope and assignment prior to the engineer being assigned to JAERI.

B. USNRC would agree to supply advance instrumentation to the ROSA-IV program at the rate consistent with the following funding:

FY 1982

FY 1983

FY 1984

FY 1985

FY 1986

This funding would be used to provide, to the extent possible, four spool pieces, of length 720 mm, 207 mm ID contain five two-phase flow instruments (SP-1), three spool piece of length 720 mm, 87.3 mm ID containing four two-phase flow instrumentations (SP-2), four free-field drag disks, four single beam gamma-densitometers, and two optical probes.

The above instruments would be provided, taking full advantage of the available instrumentation and electronics that have been provided under 2D/3D program for SCTF and CCTF. Software data reduction would be provided consistent with definitions specified in the 2D/3D program except that USNRC would be willing to provide additional support to JAERI for modification to the data reduction program as required.

All the above instructions would be on a loan basis to the JAERI (similar to the 2D/3D program agreement) for the time period covered by the agreement and disposition would be determined after the expiration of the ROSA-IV agreement.

C. USNRC would provide JAERI with calculational assistance and code modifications for the USNRC code to be used on ROSA-IV program analysis effects. The code should be mutually agreed on by USNRC and JAERI. This assistance would be provided at the rate consistent with the following funding:

FY 1983

FY 1984

FY 1985

FY 1986

Calculations to be performed by USNRC should be mutually agreed on a year in advance for the time that the calculations are to be performed. The number of calculations to be performed would be consistent with the funding shown above.

USNRC would provide all the calculated results and the computer codes used in the analyses to JAERI. The analysis results should be published with the coauthor(s) of JAERI personnel or should be published after the publication of the experimental results in a technical journal by JAERI.

D. JAERI would be able to send engineers to the U.S. national laboratories that are performing code modifications and ROSA-IV program calculations to receive training and to aid in performing analysis of the ROSA-IV experiments. JAERI would fund all travel expenses, salary and living costs for their engineer and USNRC would provide suitable office space, required computer cost and all other items required to perform the agreed on task. These assignments and scope of work would be mutually agreed on by USNRC and JAERI prior to the engineer being assigned to the national laboratory.

II. USNRC would like to have JAERI provide to the following items such that USNRC can make full use of the ROSA-IV program experimental data.

A. A complete set of engineering drawings, manuals and system descriptions for both TPTF and LSTF. These should be in enough detail that a complete evaluation of data and computer code modeling of these facilities would be possible.

B. A complete set of test procedures for the tests to be performed in TPTF and LSTF.

C. A draft test matrix for TPTF and LSTF should be developed in a joint effort between USNRC and JAERI. It is recognized that JAERI would have full control of both TPTF and LSTF test matrix, but that USNRC's request to perform specific experiments to resolve technical issues common to the U.S. and Japan would be accommodated to the extent possible.

too specific

D. A joint meeting would be held at least twice a year to discuss the scope of work for the ROSA-IV program, test matrix for

anticipate "Summit" status

TPTF and LSTF, any problems associated with the ROSA-IV program, and experimental results. Time and place for this meeting would be agreed on by USNRC and JAERI.

E. Experimental results from TPTF and LSTF experiments would be provided to the USNRC in a timely manner. Results obtained from the ROSA-IV program would be held by USNRC and would not be released outside of USNRC without prior approval. A list of USNRC contractors that would be using the data to make code modifications and assessments would be sent to JAERI for approval. It is expected that USNRC would request that INEL and LANL would receive the data and the proper protection procedures would be established.

F. Experimental results for selected experiments that have been jointly decided on by JAERI and USNRC should be provided on a magnetic tape to be included in the INEL data bank. These data would be "password" protected to insure that it would not be used by unauthorized personnel.

It is our intent that the above items be discussed in detail such that a formal agreement can be drafted by the end of January 1983. It is expected that the agreement would be signed by the director of the Office of Nuclear Regulatory Research and JAERI management. USNRC would like to use the 2D/3D Program Agreement as a basis for the ROSA-IV program agreement.