CONF-820704--38

DE83 008466

CONF-820704--38

Log 30

Session TS2

THE PFR/TREAT PROGRAMME:

OBJECTIVES, PROGRESS AND FUTURE WORK

C B Cowking, UKAEA, Risley, Warrington WA3 6AT, UK
H Alter, USDOE, Germantown, Washington DC 20545, USA
R Hewison, UKAEA, Dounreay, Thurso, Caithness KW14 7TZ, UK
S S Borys, ANL, Argonne, Illinois 60439, USA
M H Wood, UKAEA, Harwell, Didcot, Oxfordshire OX11 ORA, UK
G E Culley, HEDL, PO Box 1970, Richland, Washington 99352, USA
W J Woods, UKAEA, Winfrith, Dorchester, Dorset DT2 8DH, UK
A E Klickman, ANL, Argonne, Illinois 60439, USA

ABSTRACT

The PFR/TREAT collaborative programme of fast-reactor fuel testing is described and the objectives are illustrated in terms of the parameters selected for the irradiation of US and UK full-length fuel pins in PFR, followed by safety testing in TREAT. The measurements being made before, during, and after testing are outlined and the equipment and facilities being used in the UK and USA are described. An outline is given of the progress made and results obtained since the beginning of the collaboration in November 1979, together with future schedules for irradiation and testing. More-detailed results from the first two tests are given in a companion paper.

PROGRAMME OBJECTIVES

The PFR/TREAT programme is a collaborative undertaking between the UKAEA and USDOE established under the US/UK Fast Reactor Collaboration Agreement to combine the irradiation capabilities of PFR with the testing facilities of TREAT. In this way it is possible to obtain information required for validation of safety analysis codes for power producing fast reactors using test fuel pins which are as representative as possible, through having full-length designs very similar to those planned for power reactors and with irradiation before test in a fast neutron flux spectrum. The

MASTER

data acquired during the joint programme are expected to provide support and evidence that a majority of the accident paths will be terminated with limited core damage. The data will be beneficial in the licensing of the fast reactor, will ~~permit~~ assist the designer ~~to incorporate~~ in identifying features that ~~will~~ may mitigate the consequences of an accident, and will take advantage of better knowledge to reduce the conservatism in the design.

The PFR/TREAT agreement was signed in November 1979 and represents a major joint programme on fuel pins of both US and UK manufacture, covering a number of design variants and with ranges of pre-irradiation power and burnup followed by transient overpower (TOP) and transient undercooling plus overpower (TCUOP) safety tests. The response of the test fuel pins under the chosen conditions will give information ~~which~~ that will improve the safety analysis of a range of low-probability major faults in power reactors.

An international collaboration of this scope covers a wide range of technology at different establishments in the two countries. UK fuel pins are manufactured at Windscale. US fuel pins are manufactured at HEDL. The pins are assemblied into irradiation rigs at Windscale and the rigs are irradiated in PFR at Dounreay. Pin samples are cooled, cleaned and examined both non-destructively and destructively at Dounreay before selected pins are loaded into casks for shipment. Further PTE is carried out at AERE Harwell. In the USA, shipped pins are received at ANL facilities in Idaho and at HEDL, Washington and further PTE is carried out there. USDOE teams at HEDL and at ANL and UK teams at Winfrith and Harwell are responsible for test design and anslysis. USDOE teams at HEDL and ANL are responsible for test rig design and manufacture and post-test examination (PTE) of the fuel pins. Assembly of irradiated fuel pins into test rigs is done at HFEF in Idaho and the tests are conducted in TREAT.

Under a separate agreement CEA and KfK are associated with this project as junior partners to UKAEA and are receiving full details of the tests and results from the experiments using UKAEA-manufactured pins. This separate agreement is named CAPT.

TEST PARAMETERS AND MEASUREMENTS

The test pins for the programme are drawn from two sources. The UK pins are the standard annular-pellet design used for PFR with 5.8 mm cladding outer diameter, irradiated with grid supports in full size sub-assemblies and small cluster rigs. The US pins are of the same general construction with a lower gas plenum and the same length as standard PFR pins but have 6.6 mm diameter cladding and a variety of alternate internal designs of pellet geometry and density. They are wire-wrapped and are irradiated in central groups within special PFR sub-assemblies, surrounded by UK-made pins of the same dimensions.

The current matrix of tests in the programme is shown in Table I.

This matrix of tests is regularly under review as information obtained is evaluated and reactor safety needs are reassessed.

DESCRIPTION OF FACILITIES

The different facilities used to implement the programme in the UK and US can be conveniently described following the route of the fuel pins:

At Windscale in the UK, US-manufactured and UK pins are given final checks with detailed measurements, radiography and weighing before assembly into sub-assemblies and clusters for irradiation in PFR. Pins are built into gridded standard PFR sub-assemblies (UK) and special wire wrapped sub-assemblies (US) and also into small cluster rigs which fit into demountable sub-assemblies (US and UK).

TABLE I

MATRIX OF TESTS

TRANSIENT OVER POWER TESTS

Ramp Rate	*Power Level*	*Fresh*		*Med*		*Goal*	
		US	*UK*	*US*	*UK*	*US*	*UK*
Low	*High*		*7*	*1,7*	*1,7*	*1,7*	*1,7*
Int	*High*			*1*			
High	*High*		*1,7*	*1*	*1,7*		*1,7*
High	*Int*		*7*		*1,7*		*1,7*

LOSS OF FLOW TESTS

CHANNEL	*Ramp Rate*	*Fresh*		*Med*		*Goal*	
		US	*UK*	*US*	*UK*	*US*	*UK*
Voided	*< nom*			*7*	*7*		
	nom		*7*	*7*	*7*	*7*	*7*
Unvoided	*< nom*			*1,7*			
	nom		*1*	*1,7*	*1,7*	*7*	*1,7*
Partially	*< nom*						
Voided	*nom*			*7*	*1,7*	*7*	*7*

1 = Single Pin Test

7 - Seven Pin Test

After irradiation in PFR and a period of cooling in irradiated fuel storage the pins are removed, cleaned of sodium, measured and radiographed in the PFR irradiated fuel cave. For destructive PIE examination some pins are removed to other examination caves at Dounreay and Harwell. The investigations made are shown in Table II.

TABLE II

PIE INVESTIGATIONS

Non-Destructive	
Pin length, weight	
Detailed visual examination	
Axial variation of clad diameter	
Axial variation of total gamma emission	
Neutron radiography	
Destructive	
Total fission gas release and composition	
Axial variation of	fuel outer radius
	fuel/clad gap
	columnar grain radius
	equiaxed grain radius
	central void radius
	fission gas retention
	fuel burn-up
Radial variation of	fission gas retention
	plutonium and caesium
	grain size
	porosity
	crack volume
Fuel clad transient burst tests	

Pins selected for testing are loaded in PFR cave into a basket and container which is shipped inside a shielded flask to HFEF at ANL facilities in Idaho.

At HFEF the pins are given further PIE examinations to confirm that the pin condition has not been affected by the shipment. The pins will then be directly loaded into either 7-pin or 1-pin test rigs. Several different TREAT test rigs will be used. Three initial single pin tests have been carried out in stagnant coolant capsules. Two further single pin tests will be carried out in a variant of the Mk III TREAT Loop (SPTL). The 7-pin tests are carried out in the TREAT Mk III loop.

Using shielded flasks the loaded test rigs are then moved to TREAT where preliminary, low-power heat balance tests to check instrumentation and the reactor/test fuel power coupling factor are conducted, followed by the safety test *proper. The control rods of TREAT are programmed to follow a sequence which will give the desired power-time history of a preheat phase followed by a transient overpower. In TUCOP tests the decrease of coolant flow is also preprogrammed by a determine rundown of the power to the induction pump.*

During the tests in TREAT instruments reocrd the reactor power, the temperature of the test section walls, the coolant temperature, the coolant pressure and the coolant flowrate. This information is recorded for later conversion into chosen physical units, graphical presentation and analysis. Information is also recorded from the TREAT hodoscope which is processed to produce a time-dependent spatial distribution of the fuel in the test section both before and after clad failure.

After test in TREAT the coolant is allowed to solidify and the rigs are returned to HFEF where they are neutron radiographed and initial PTE investigations are conducted. The test sections are shipped in whole or in part to other cave facilities a HEDL or ANL East, Chicago for completion of detailed PTE activities. The investigat are shown in TAble III.

TABLE III

POST-TEST EXAMINATION (PTE) INVESTIGATIONS

X-ray or neutron radiograph Axial variation of gamma emission Visual examination of the dismantled pins, and photographs Axial variation of cladding diameter, where the pins are sufficiently intact
Examinations on pins as appropriate:
Cladding dimensions and microstructure Axial extent of fuel movement within pin Fuel dimensions, outer diameter, central void diameter, melt radii Fuel microstructure, radial variation of porosity in solid and molten fuel Retained fission gas distribution
Examination and location of dispersed fuel and cladding:
Investigation and photomicrography of sections of dispersed material

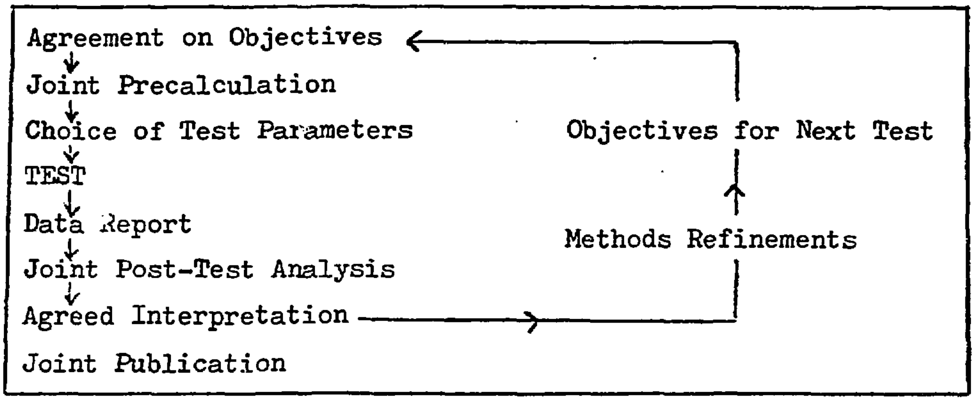
Data record tapes are distributed to the UK and US analytical teams and the hodoscope records are processed at ANL East.

CHRONOLOGY OF AN EXPERIMENT

As illustrated above, the experimental programme requires extensive physical movement of fuel between facilities. There is a parallel need for planning, analysis and interpretation work. This is a shared US-UK exercise needing joint agreement and activities, leading eventually to publication of the results. In the course of the feedback of test data and PTE from individual tests to the design of further experiments, the methods and computer codes in both countries are refined and improved in their ability to make safety analyses of power reactors.

The sequence of steps for the execution of tests is shown in figure 1.

FIGURE 1



The design stage of experiments within this sequence needs careful consideration because there are limitations on the match that can be achieved between a test rig and the conditions within a real fast reactor.

These dissimilarities mean that it is important that ~~non-representation~~ *non-representative* features should be properly identified and their effect quantified so that the appropriate adjustments can be made when transferring results from the experiments to predictions for the reactor.

The driver core of TREAT has a limited transient energy capability which sets a maximum on the energy that can be generated in the test fuel, hence it is difficult to achieve a true steady state before the test transient. In addition the TREAT thermal neutron spectrum unavoidably introduces a radial flux depression in the fuel pin or bundle under test. This affects the radial distribution of fuel temperature in single pin tests and introduces azimuthal asymmetry into the peripheral pins of a 7-pin bundle. These in turn affect the progression into fuel melting and the release of fission gas. The test section is limited in size to a number of pins much less than in a real sub-assembly and the flow resistances and thermal capacities of the test vehicle are not representative; for example, the thermal capacity of the steel is too high and that of the recirculating coolant is too low. The design of the experiments has to take account of all these factors as best possible in order to obtain information which can be used for safety analysis and analytical model refinement with as little uncertainty as possible.

PROGRESS TO DATE

At the time of writing in June 1982 the programme is well under way with most of the key activities already demonstrated.

Fresh fuel pins, for UK zero burn-up tests in TREAT and for US pre-irradiations in PFR have been shipped between the countries.

US pins are undergoing irradiation in PFR.

Irradiated UK pins have been shipped successfully to the US.

Extensive PIE has been conducted on pre-irradiated UK pins.

Six tests have been planned and carried out in TREAT.

PTE on these tests is in progress in US examination facilities.

Test analysis is in progress for the 6 tests performed.

Details of the tests completed are as follows:

TABLE IV

COMPLETED PFR/TREAT TESTS

Test No.	Test Date	Type of Test	Test Rig Design	Test Pin Design	Burn-up	Result
C01	Nov '80	TOP 5 $/sec	1-pin capsule	UK St'd	Fresh	Failure near peak power at 2 axial locations
L01	Nov '80	TOP 5 $/sec	7-pin loop	US-made UK replicas	Fresh	Failure after peak power with fuel movement
C02	Nov '81	TOP 5 $/sec	1-pin capsule	UK St'd	4%	Failure before peak power at $\frac{3}{4}$ height
C03	Dec '81	TOP 5 $/sec	1-pin capsule	UK St'd	9%	Failure at peak power below mid-height
L02	Mar '82	TOP 5 $/sec	7-pin loop	UK St'd	4%	*Failure just before peak power, in the vicinity of mid-height*
L03	May '82	TOP 10 c/sec	7-pin loop	UK St'd	4%	*Failure at 2.9 Po at 0.8 height followed by significant fuel dispersal*

TABLE V

NEAR-TERM TEST SCHEDULE

Date	Test	Type	Design	Burnup
Jun '82	C04	Slow TOP	1-pin loop	4%
Aug '82	C06	TUCOP	1-pin loop	4%
Oct '82	C05	Slow TOP	1-pin loop	9%
Nov '82	L04	TUCOP	7-pin loop	4%
Jan '83	C07	TUCOP	1-pin loop	4%
Mar '83	L05	TUCOP	7-pin loop	4%
May '83	L06	TUCOP	7-pin loop	Fresh

(C04, C06, etc to be moved to TABLE IV as appropriate at deadline)

Irradiations of US fuel in PFR will provide pins ready for test following the TREAT Upgrade in 1983, as scheduled below:

TABLE VI

US PIN IRRADIATIONS IN PFR

Sub-Assembly	Rating	Peak Burnup % ha	End of Irradiation
1	High	3½	Feb '83
2	Low	3	Oct '83
5	High	7	Nov '84
4	Low	5	Apr '85
3	High	10½	Feb '86
6	Low	7	Feb '86

After the end of irradiation a period of about 12 months is needed for cooling, cleaning, examination and shipping of pins followed by mounting in rigs for

TREAT testing. Tests on the last pins to complete irradiation will therefore begin in 1987 and final PTE and interpretation will be some years later, making the total programme timescale about 10 years. This major collaborative exercise is expected over this period to bring many improvements in the understanding of the behaviour of prototypical fuel pins with corresponding benefits in the analysis of safety of fast reactor power stations.