Blowdown Test Facility CANDU LOCA Fuel Tests

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Canada

AECL
Atomic Energy of Canada Limited

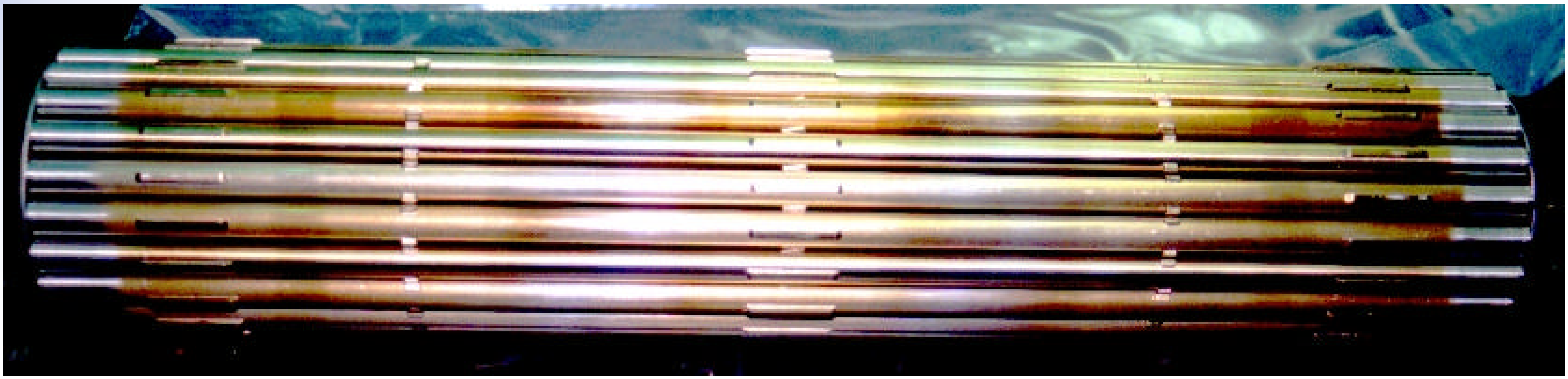
Outline

- CANDU Fuel Design
- Blowdown Test Facility Description
- Blowdown Test Facility Experiments
  - BTF-107
  - BTF-104
  - BTF-105A
  - BTF-105B
- Conclusions

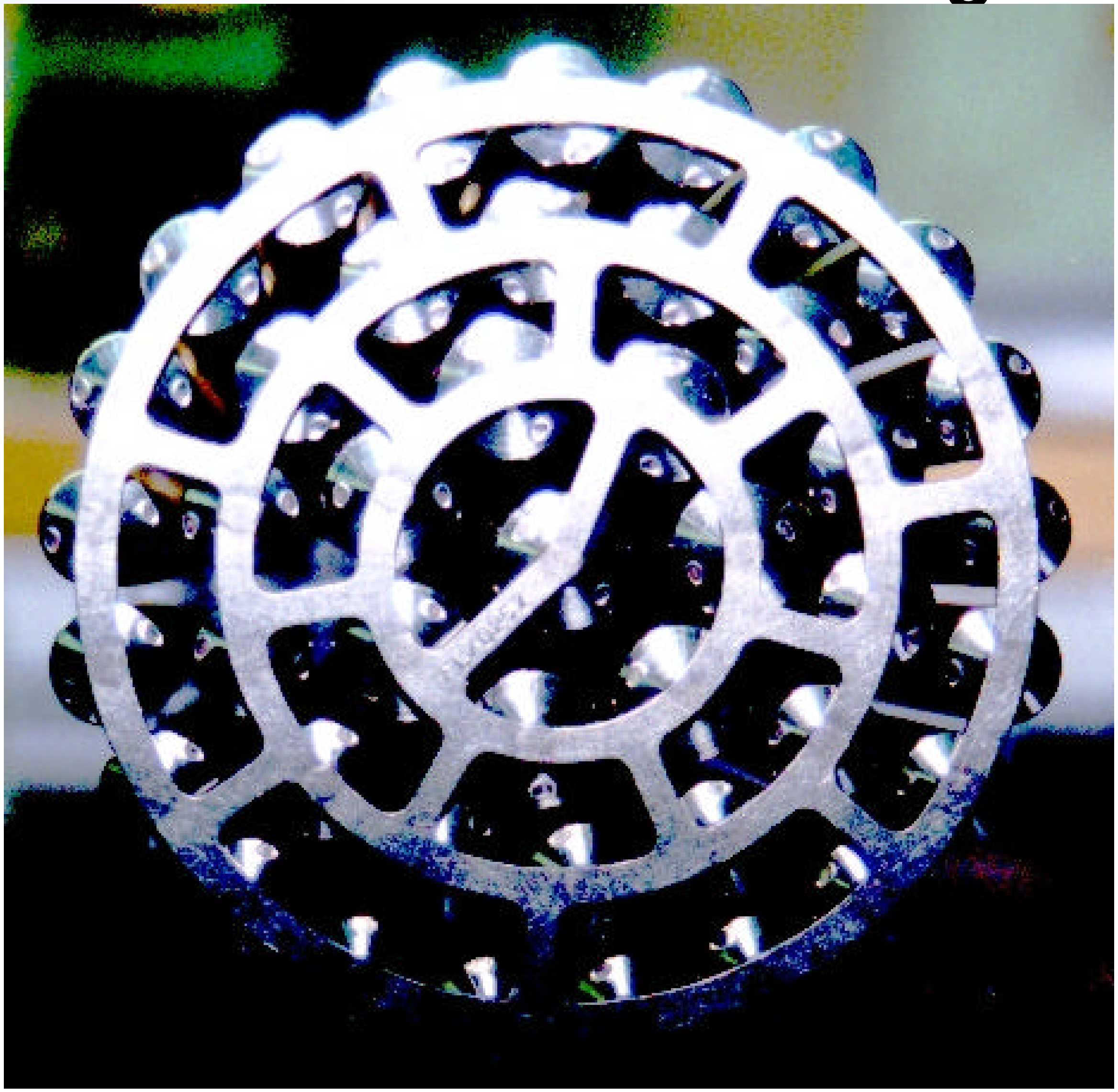
CANDU Fuel Design

- UO_2 fuel pellets clad with Zircaloy-4
- Pellet diameters:
  - 10.6, 12.6 or 14.2 mm, depending on bundle design
- Fuel cladding thickness: ~0.4 mm
  - Cladding collapses onto fuel pellets during normal operation to improve heat transfer
- Bundle length: ~0.5 m
- Fuel rods in bundle: 28, 37 or 43

CANFLEX Fuel Design



CANFLEX Fuel Design

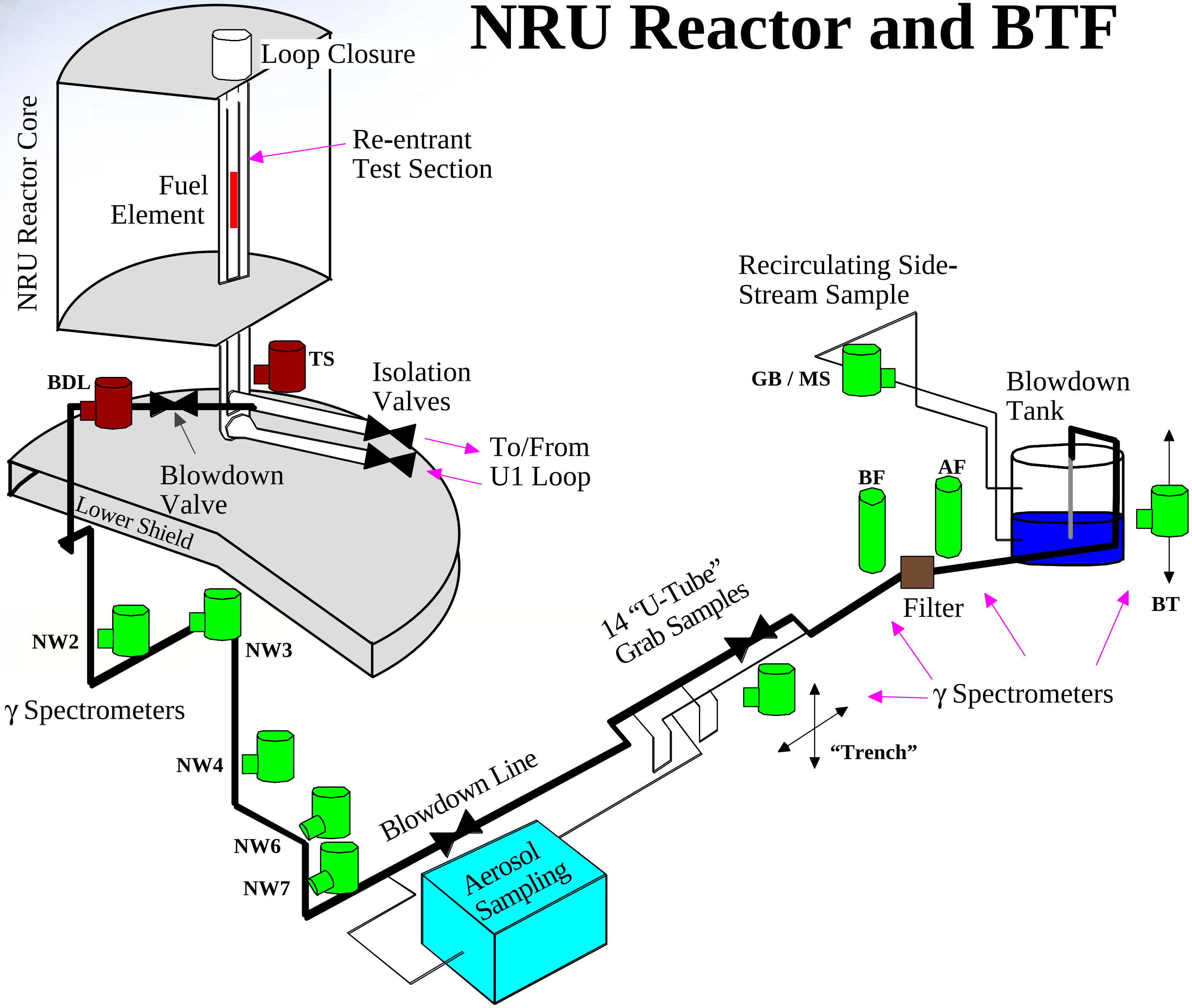


Blowdown Test Facility

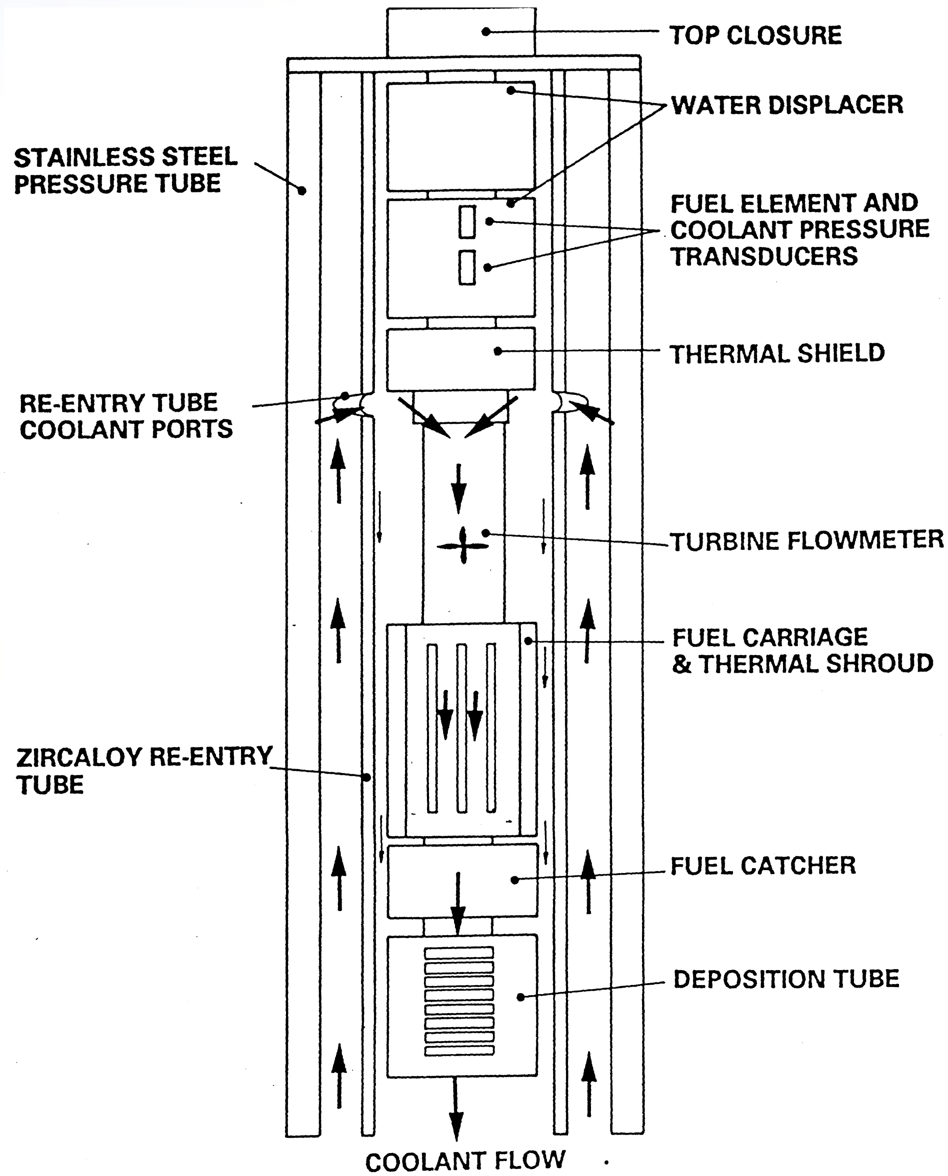
Research Program Goals

- Provide data from integral in-reactor experiments for use in the validation of computer codes used for safety analyses and licensing of CANDU reactors
- Verify our understanding of CANDU fuel behavior and FP release & transport under high temperature conditions representative of severe-fuel-damage accident scenarios

NRU Reactor and BTF



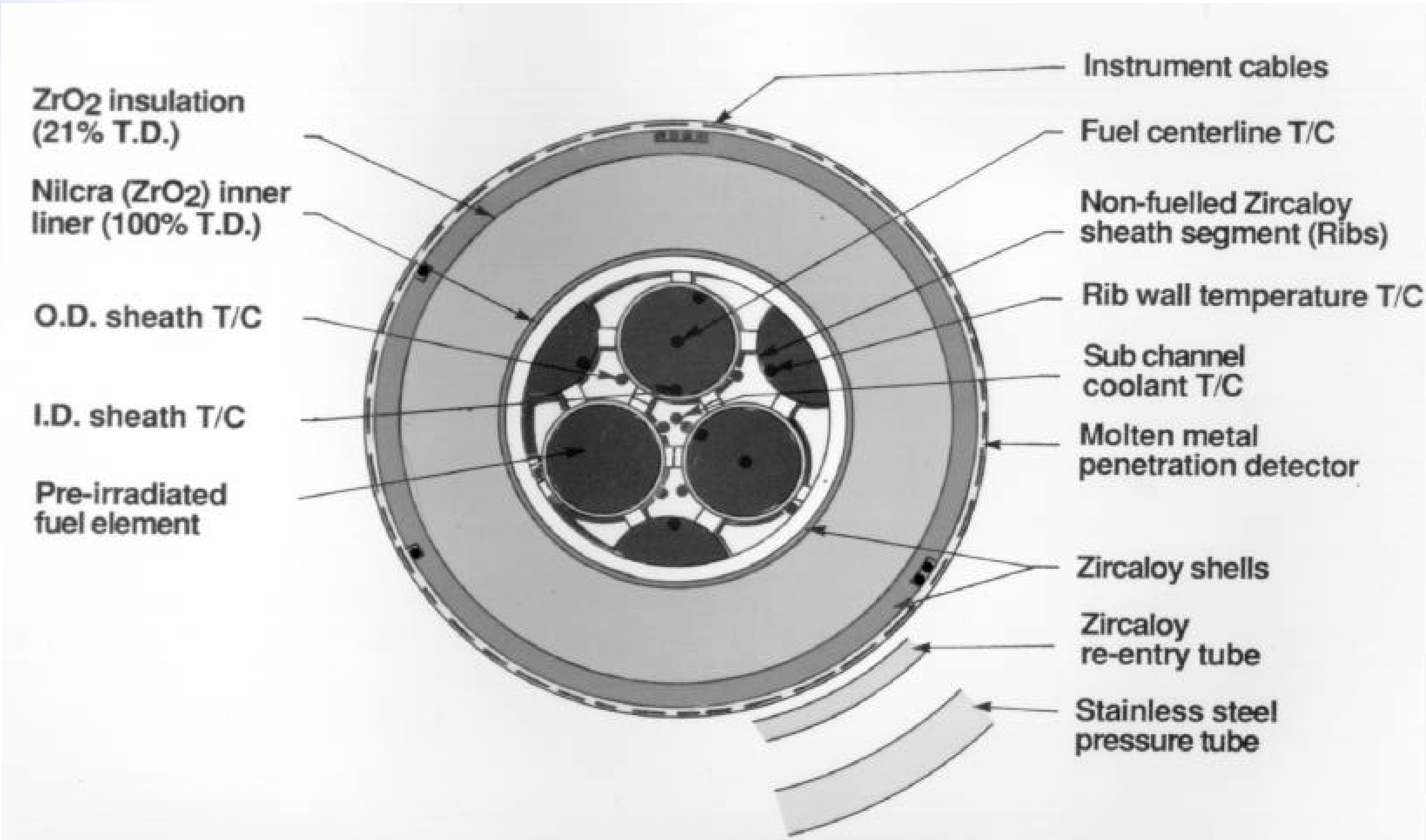
BTF Test Section



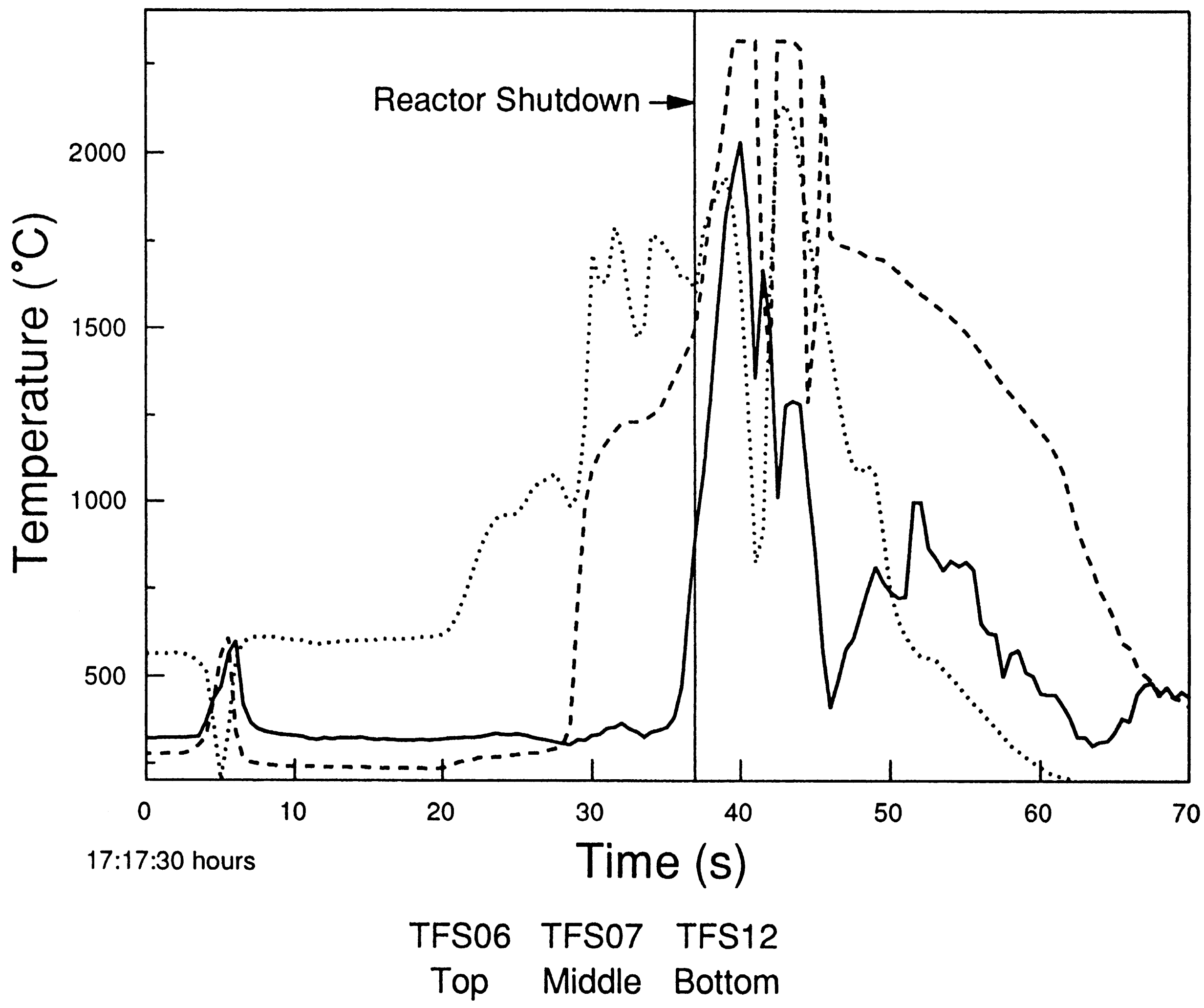
Summary of BTF Test Conditions

Parameter	BTF-107 Test	BTF-104 Test	BTF-105A Test	BTF-105B Test
Fuel elements	1 pre-irradiated, 2 fresh	1 pre-irradiated	1 fresh	1 pre-irradiated
Pre-transient cooling	Pressurized water	Saturated steam	Saturated steam	Saturated steam
Maximum fuel temperature (K)	= 2770 (peak)	~ 2100 (volume-average)	~ 2100 (volume-average)	~ 2100 (volume-average)
Transient duration (s)	~ 70	~ 2100	~ 2900	~ 4200
Time at high temperature after fuel failure (s)	~ 20	~ 1500	< 60	~ 2400

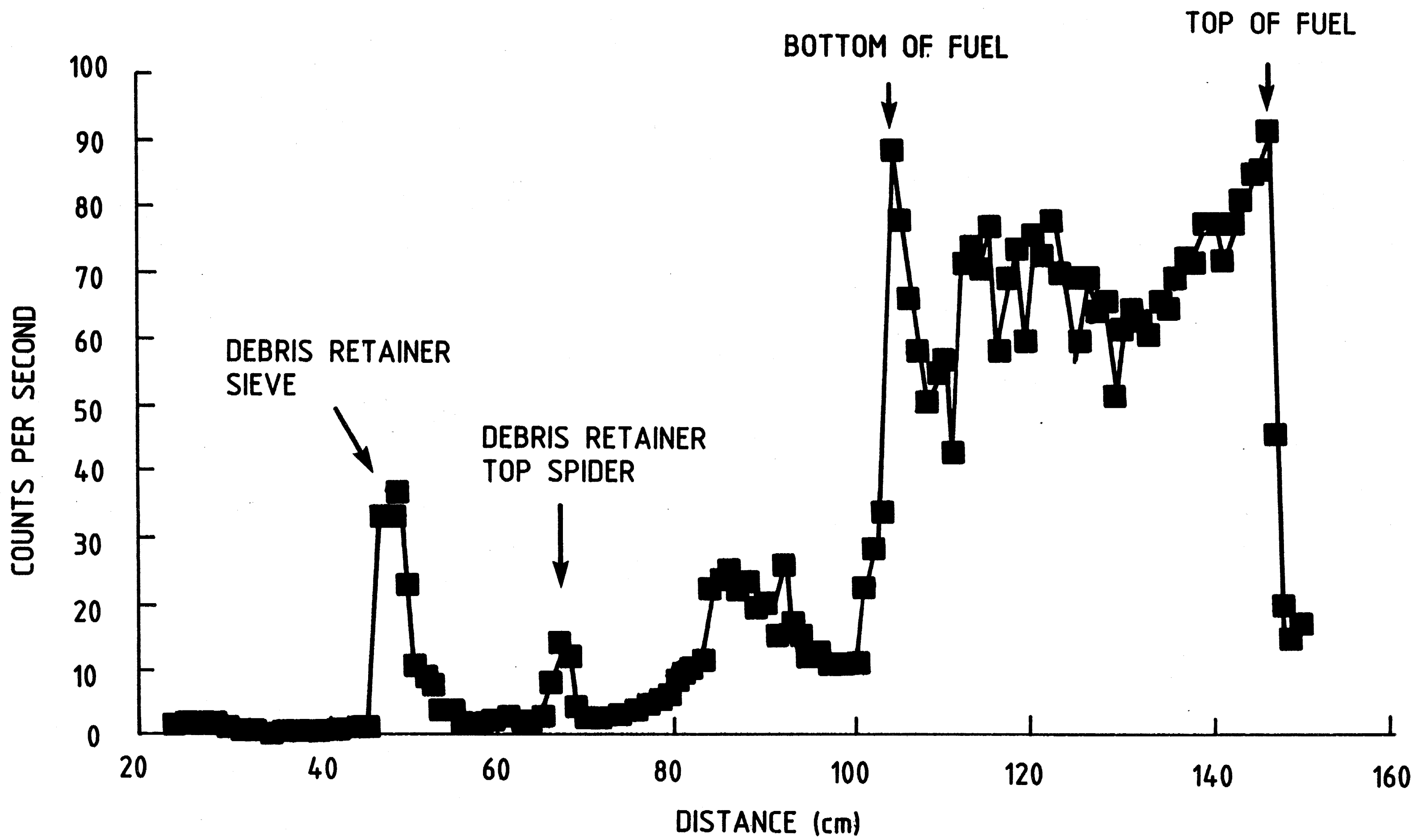
BTF-107 Fuel Assembly



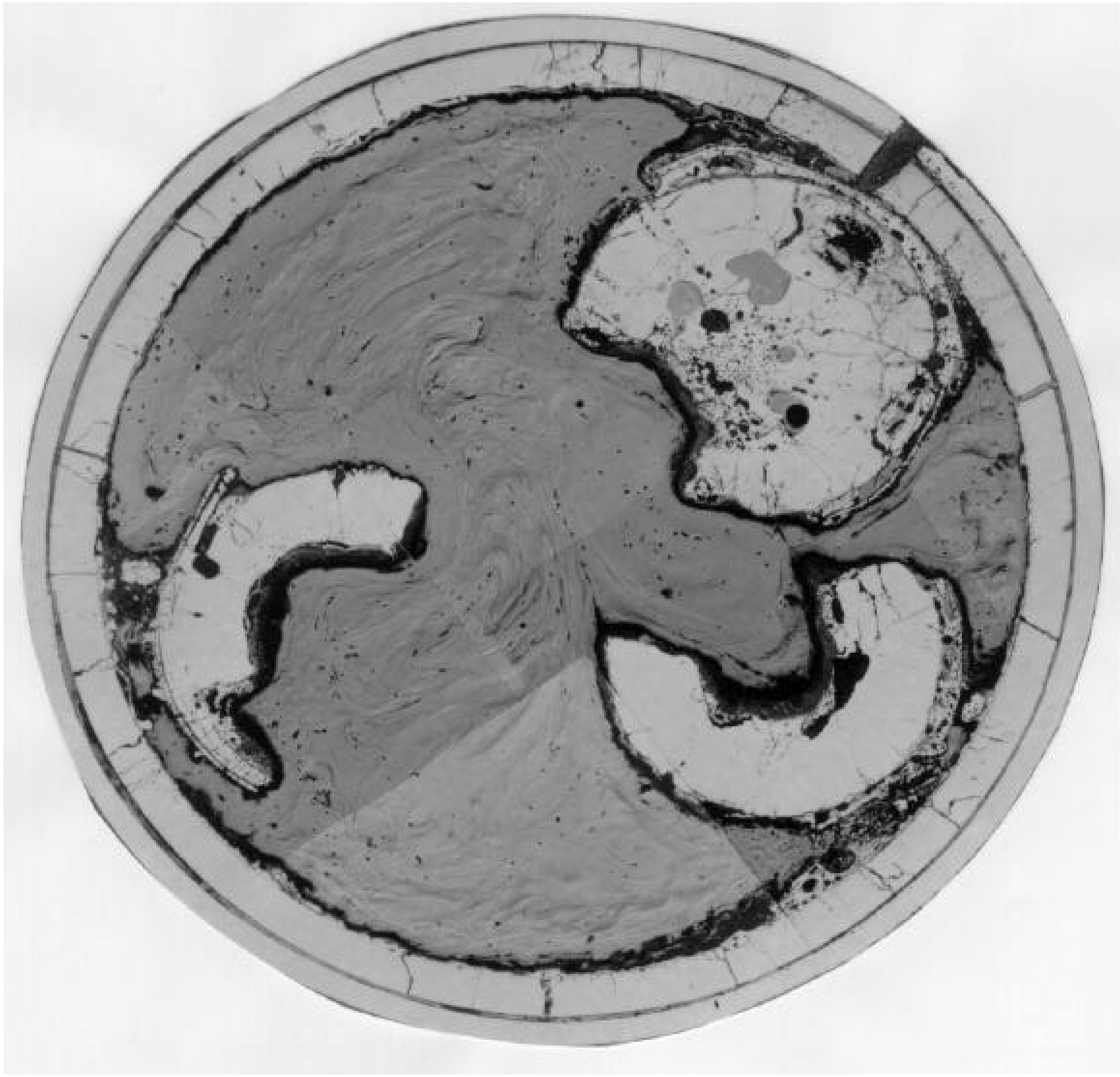
BTF-107 Cladding Temperatures



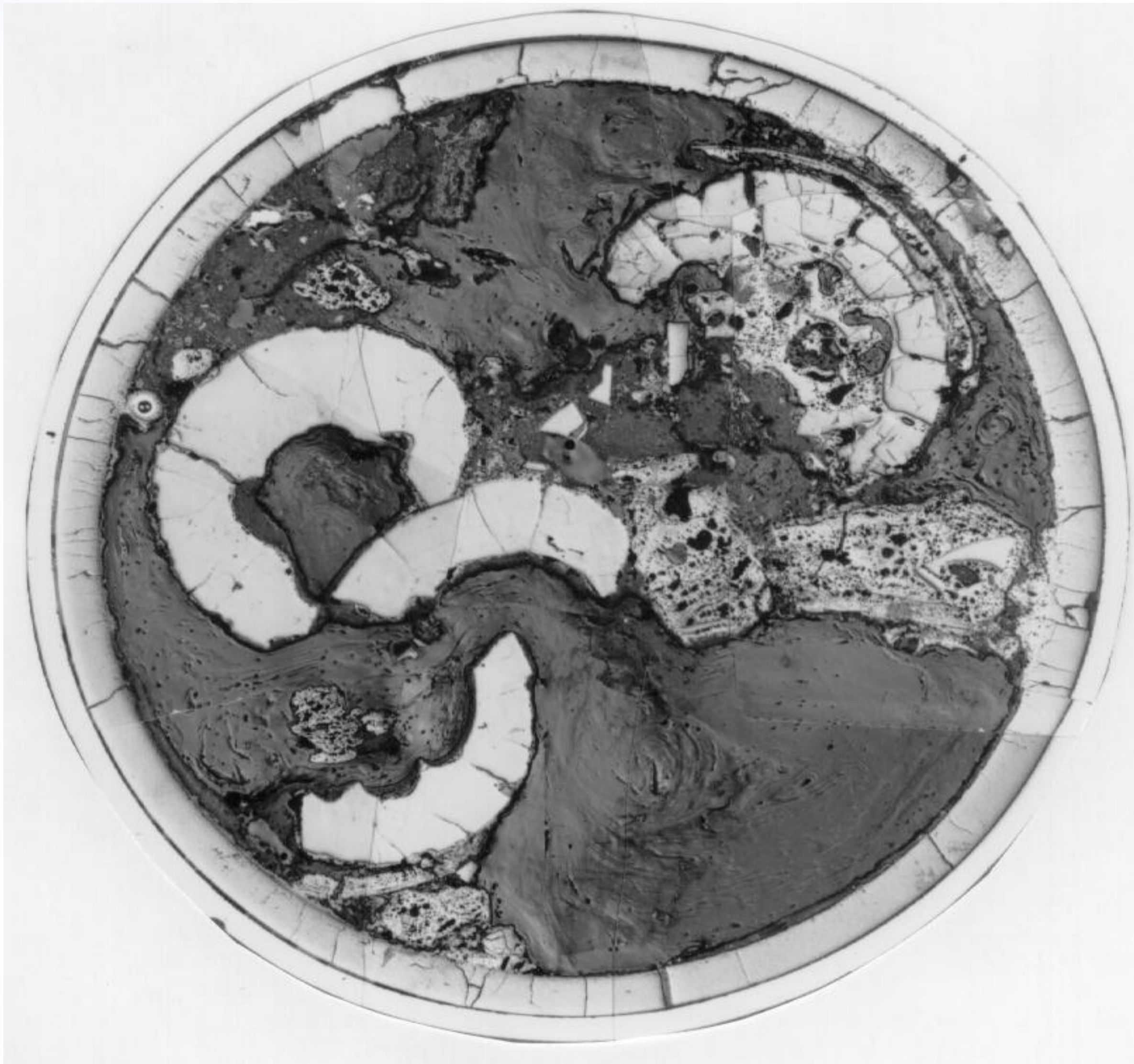
BTF-107 Post-Test ^{140}La Gamma-Scan



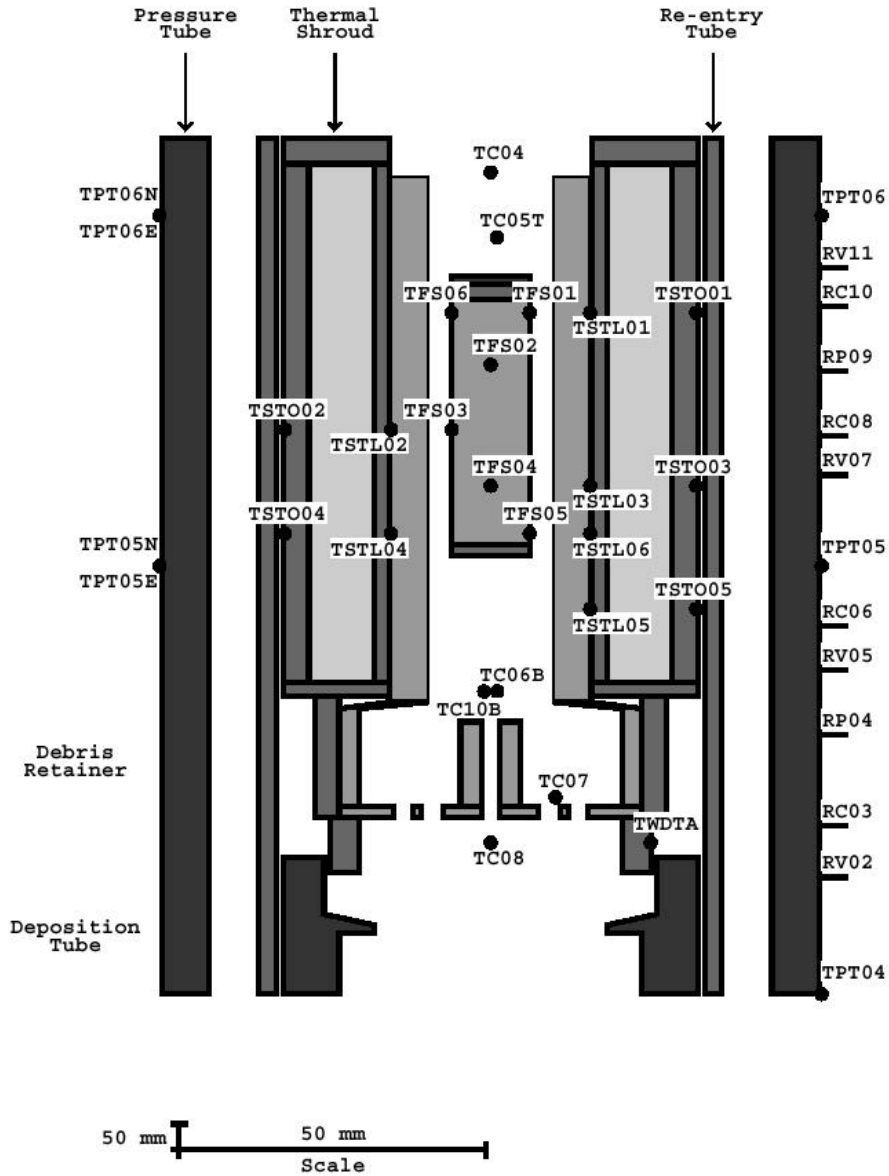
BTF-107 Post-Irradiation Examination (PIE)



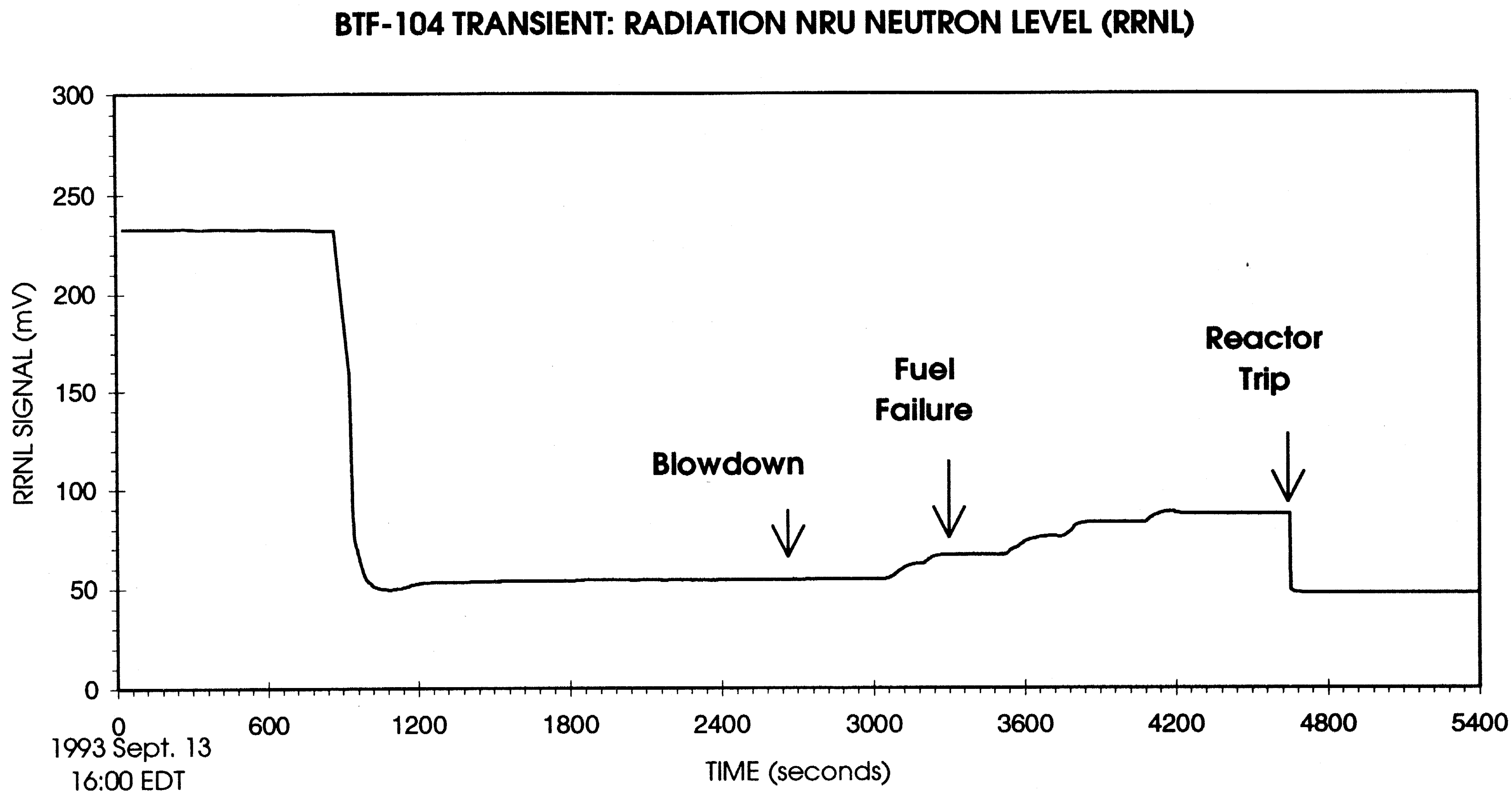
BTF-107 PIE



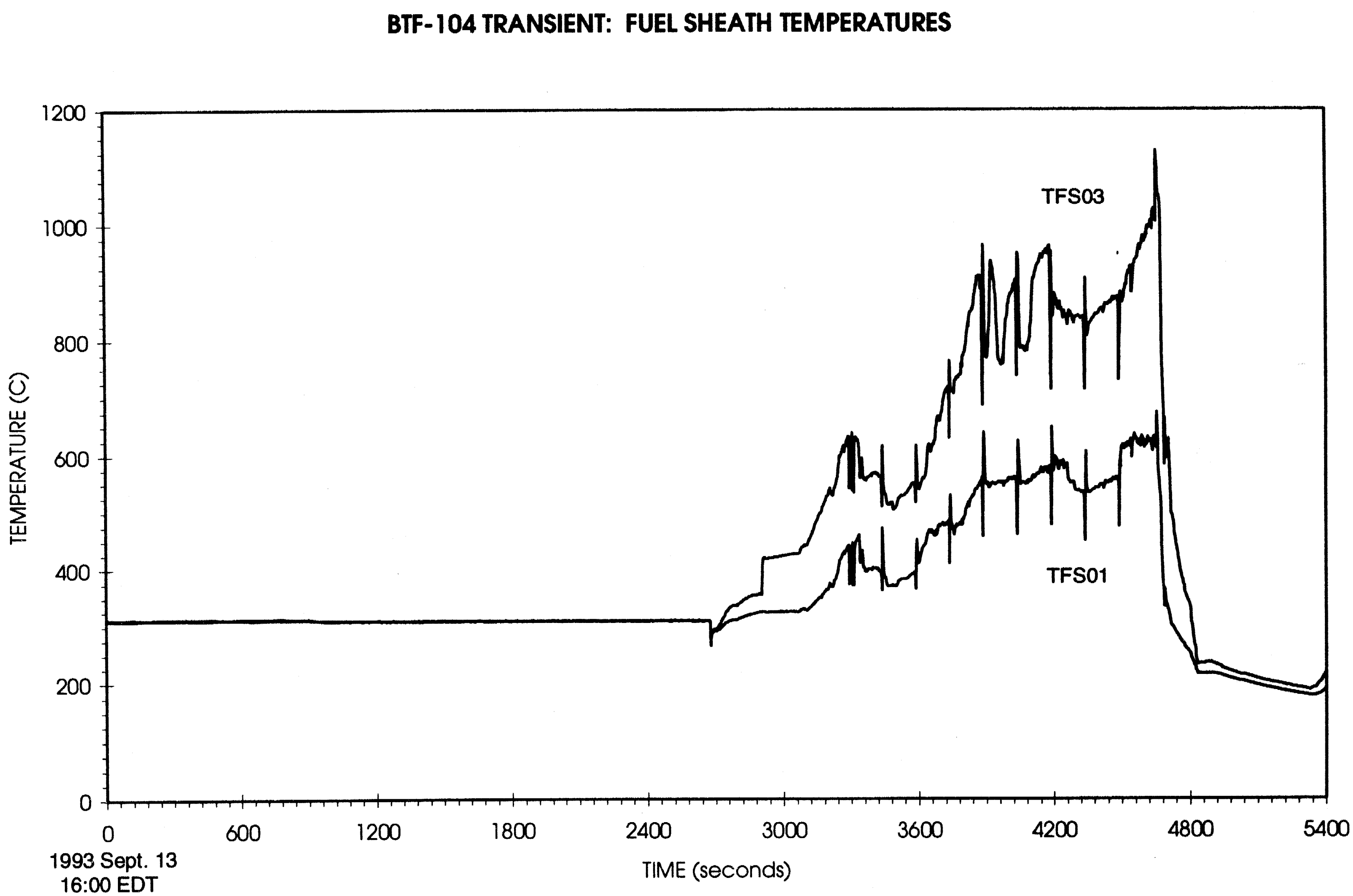
BTF-104 Fuel Assembly



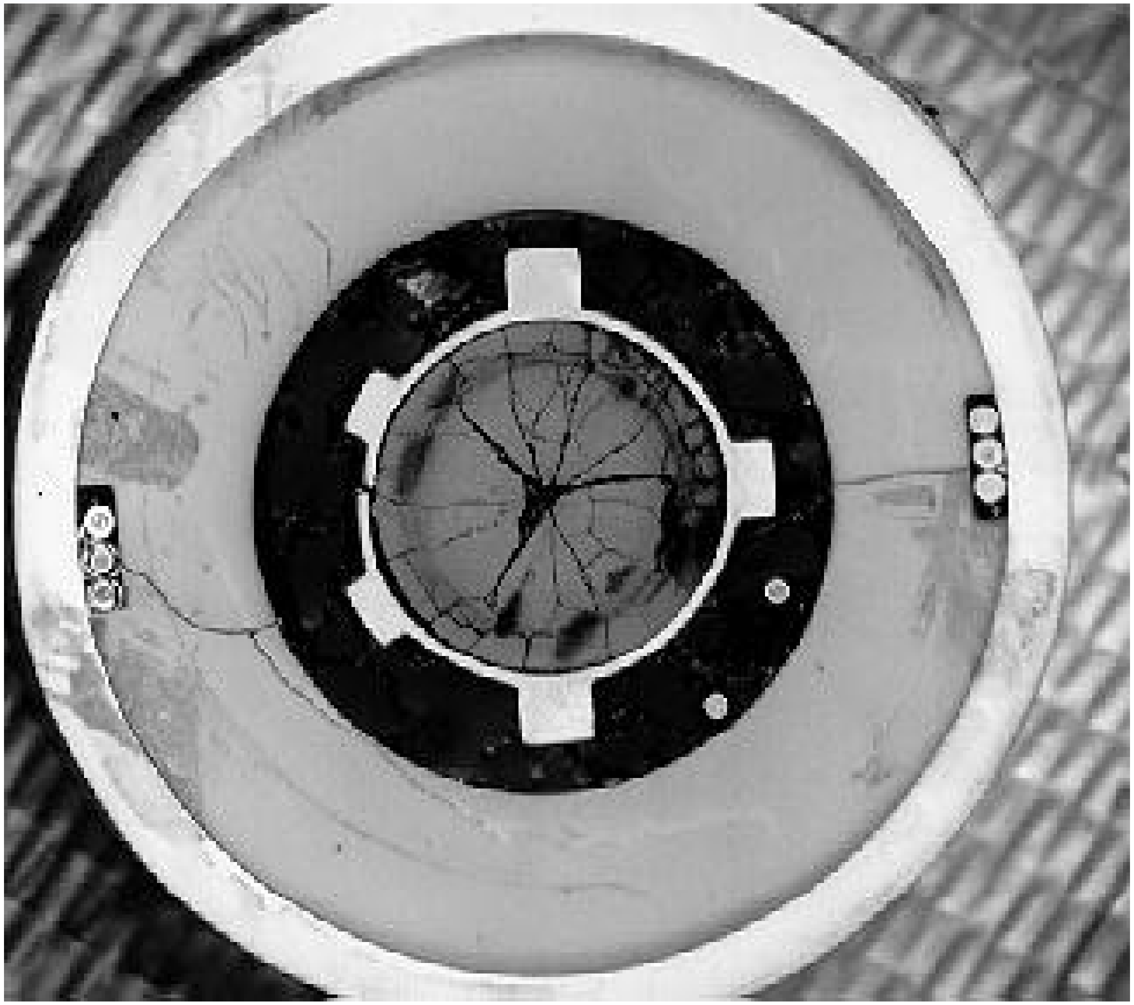
BTF-104 Reactor Power



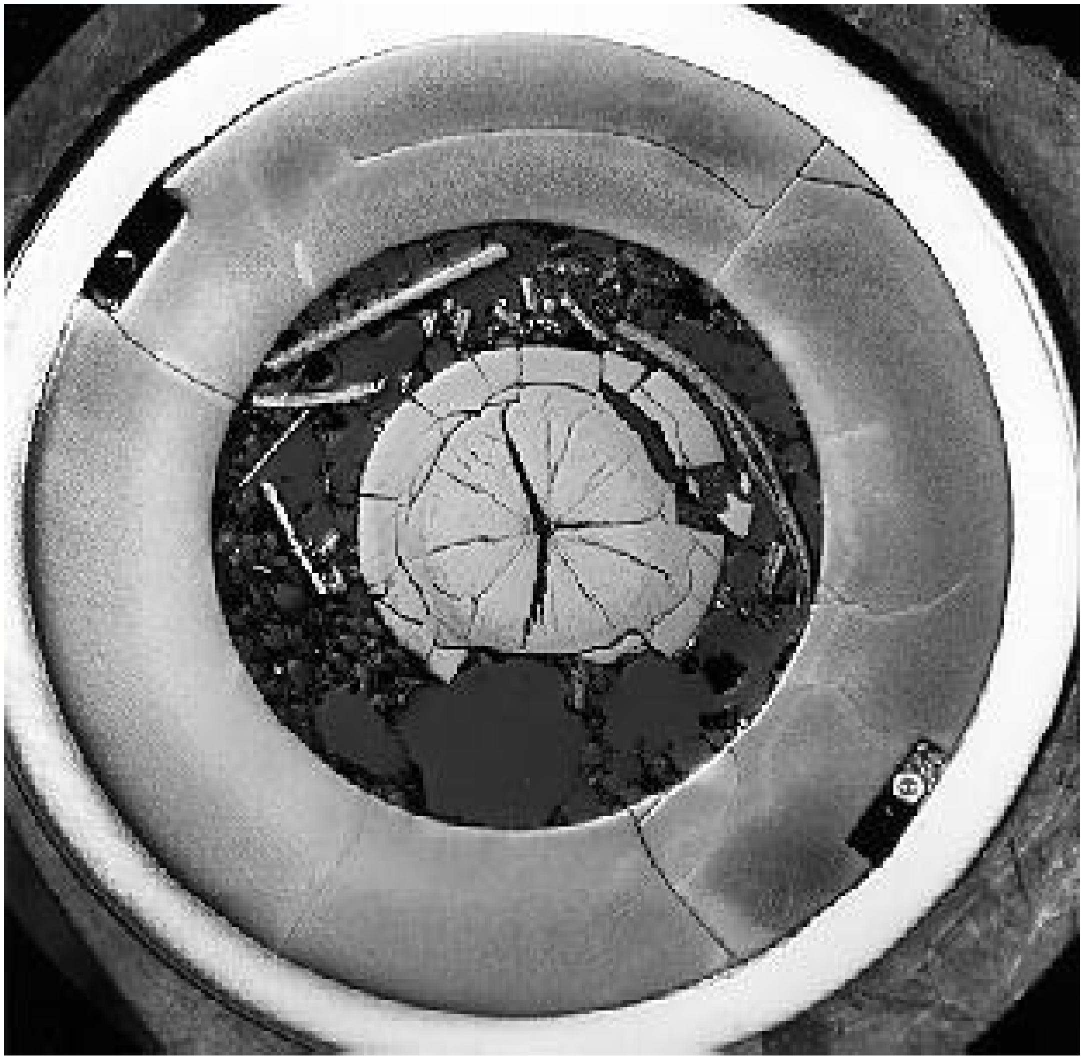
BTF-104 Fuel Cladding Temperature



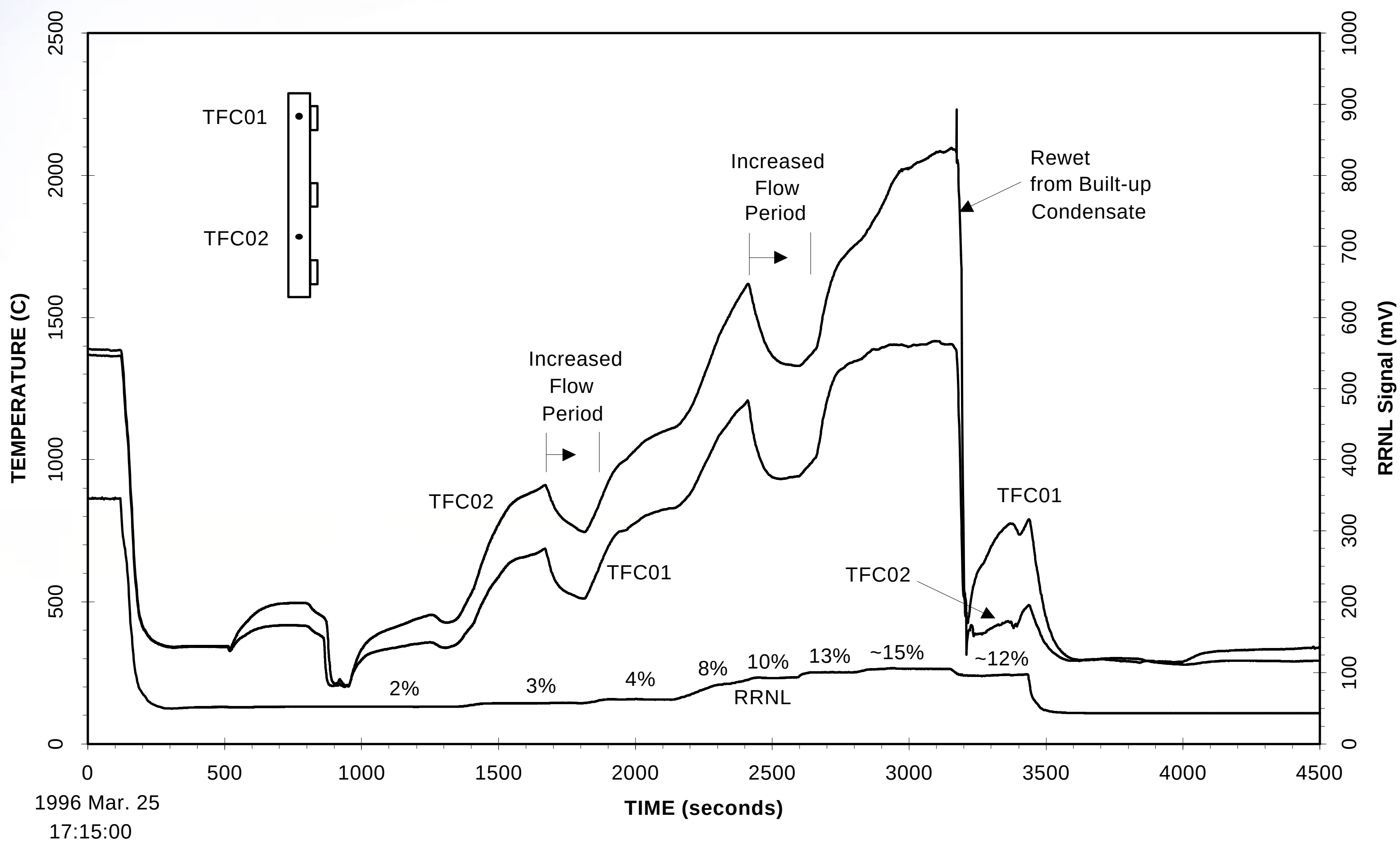
BTF-104 PIE, Elevation 252 mm



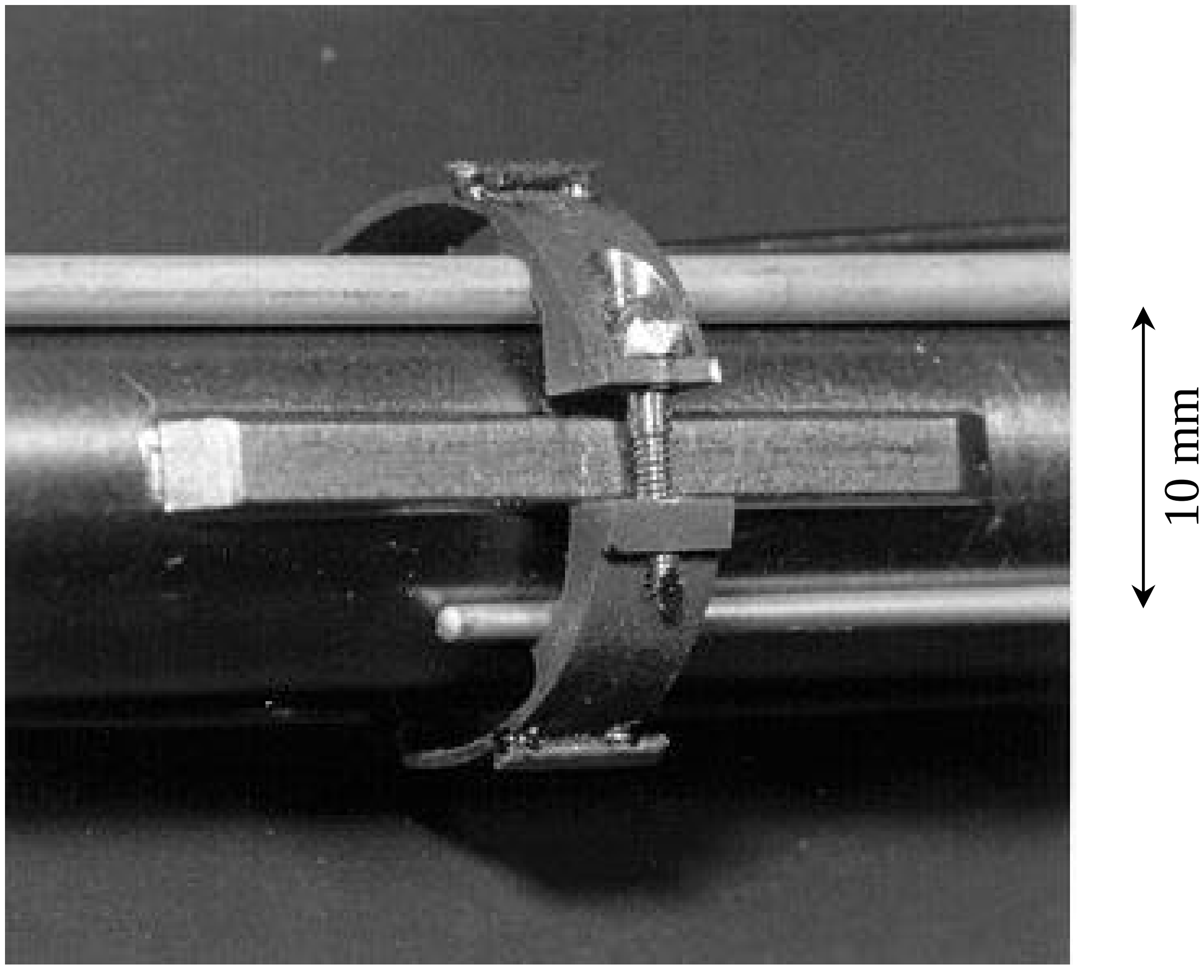
BTF-104 PIE, Elevation 36 mm



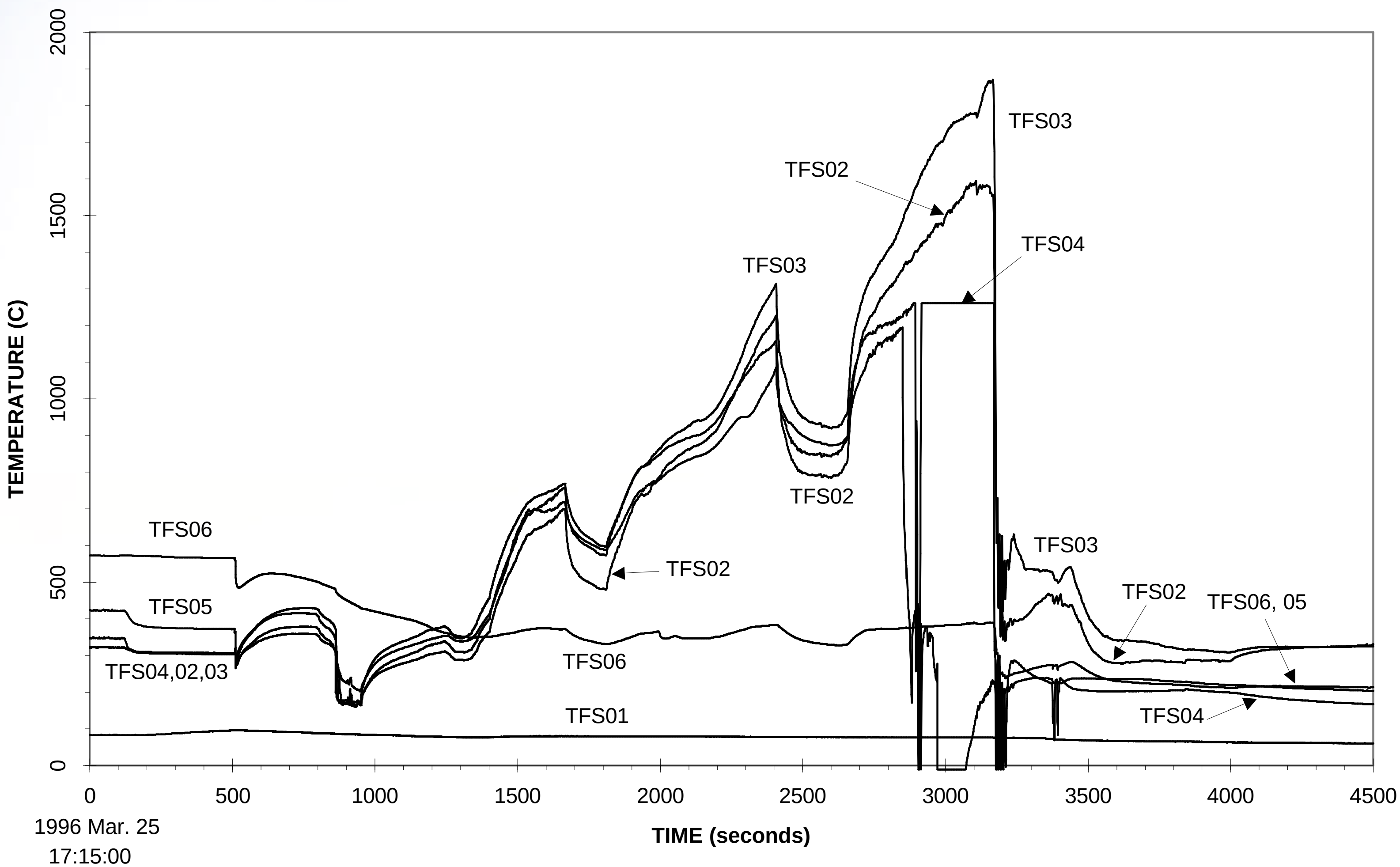
BTF-105A Fuel Centerline Temperatures



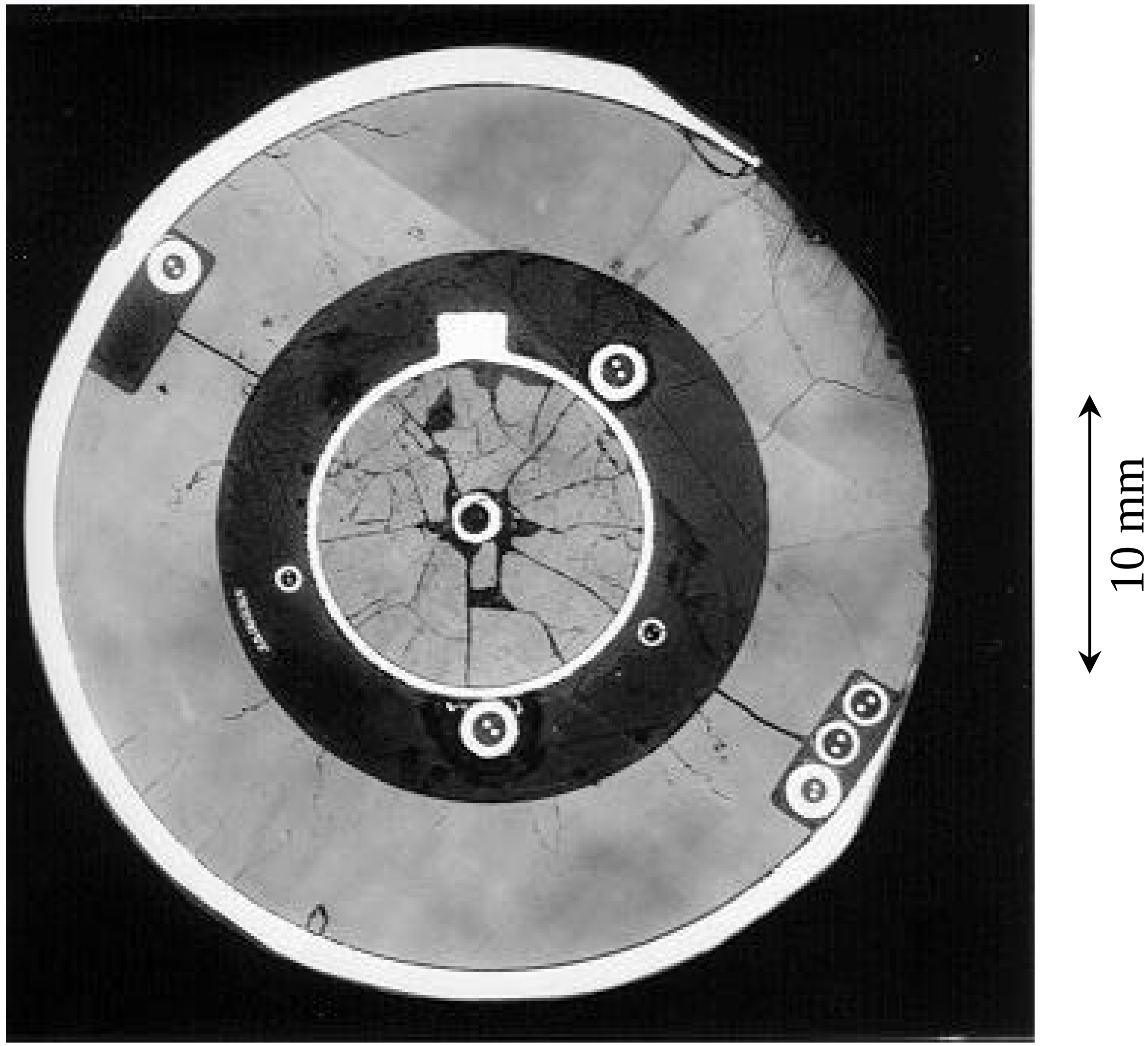
Thermocouple Clamp



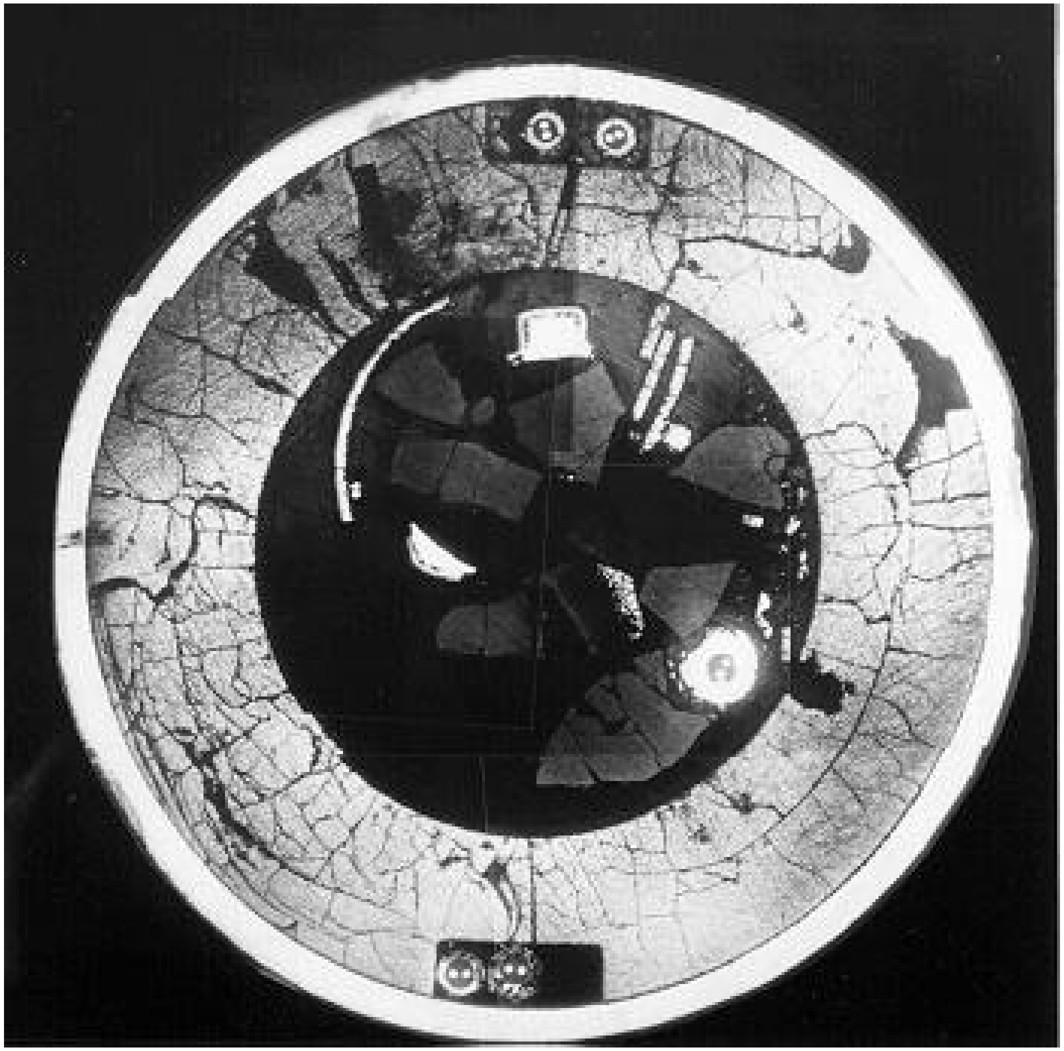
BTF-105A Fuel Cladding Temperatures



BTF-105A PIE, Elevation ~400 mm

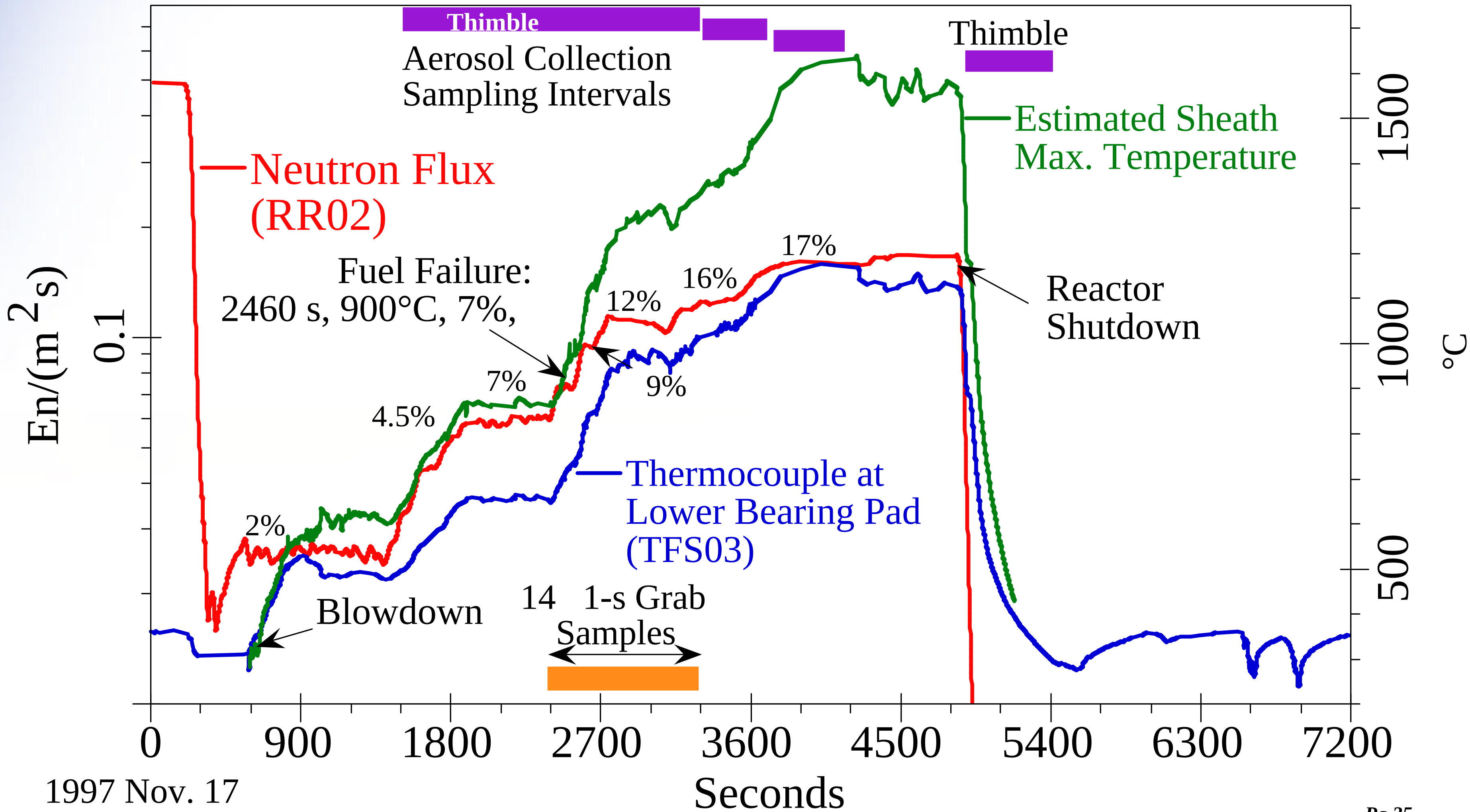


BTF-105A PIE, Elevation ~250 mm



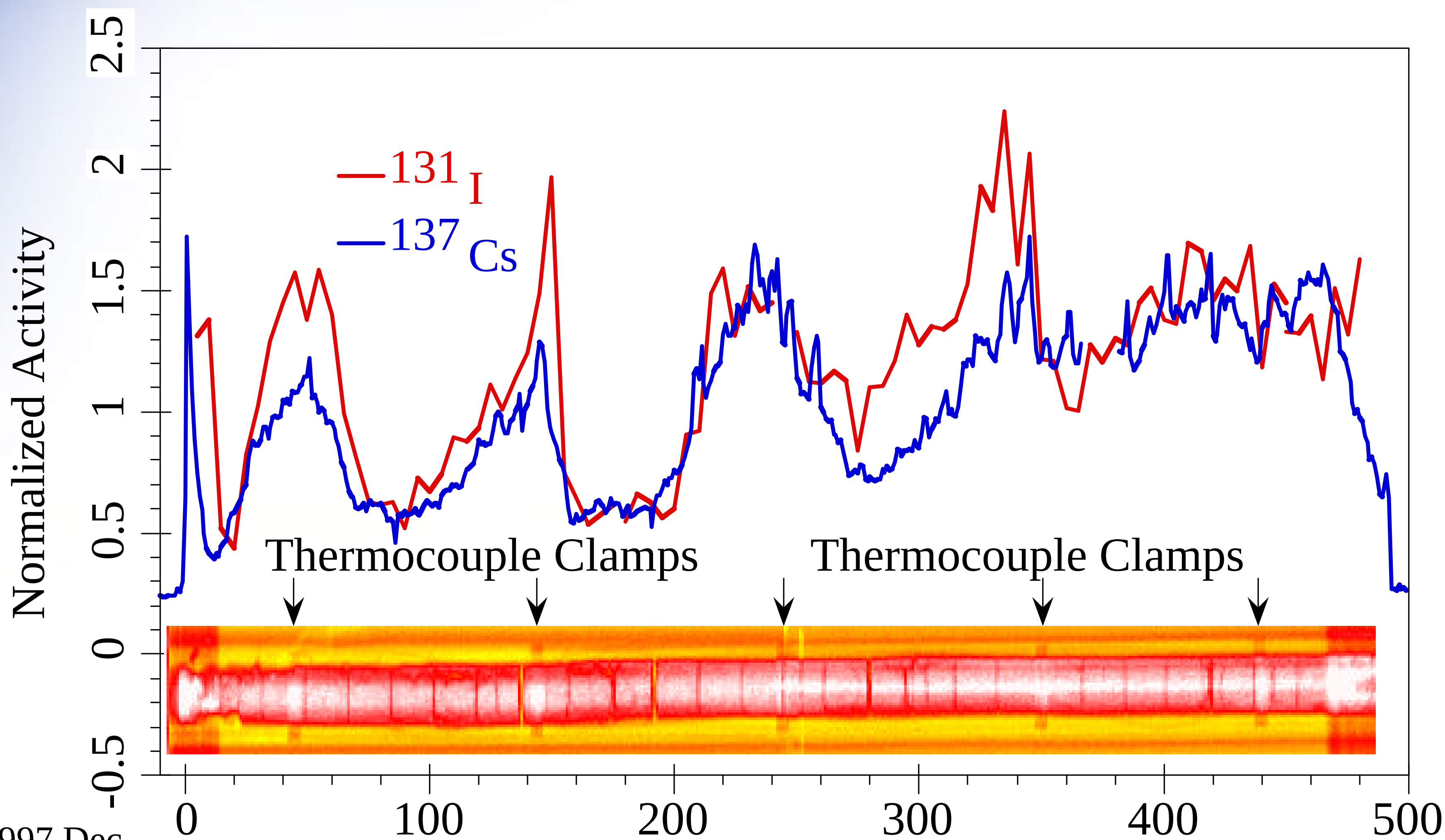
10 mm

BTF-105B Test Profile



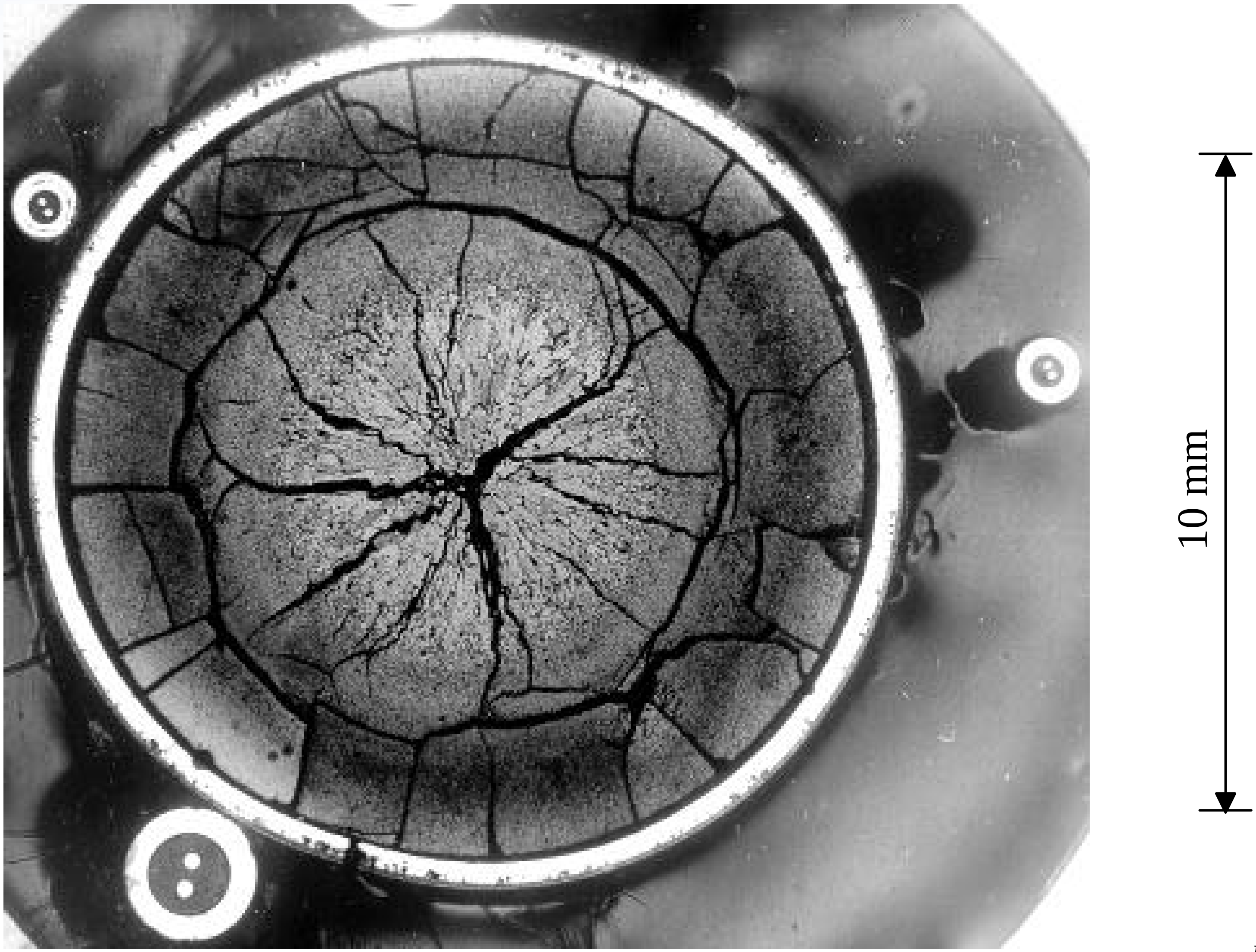
1997 Nov. 17
21h00

^{131}I, ^{137}Cs Along BTF-105B Fuel Element

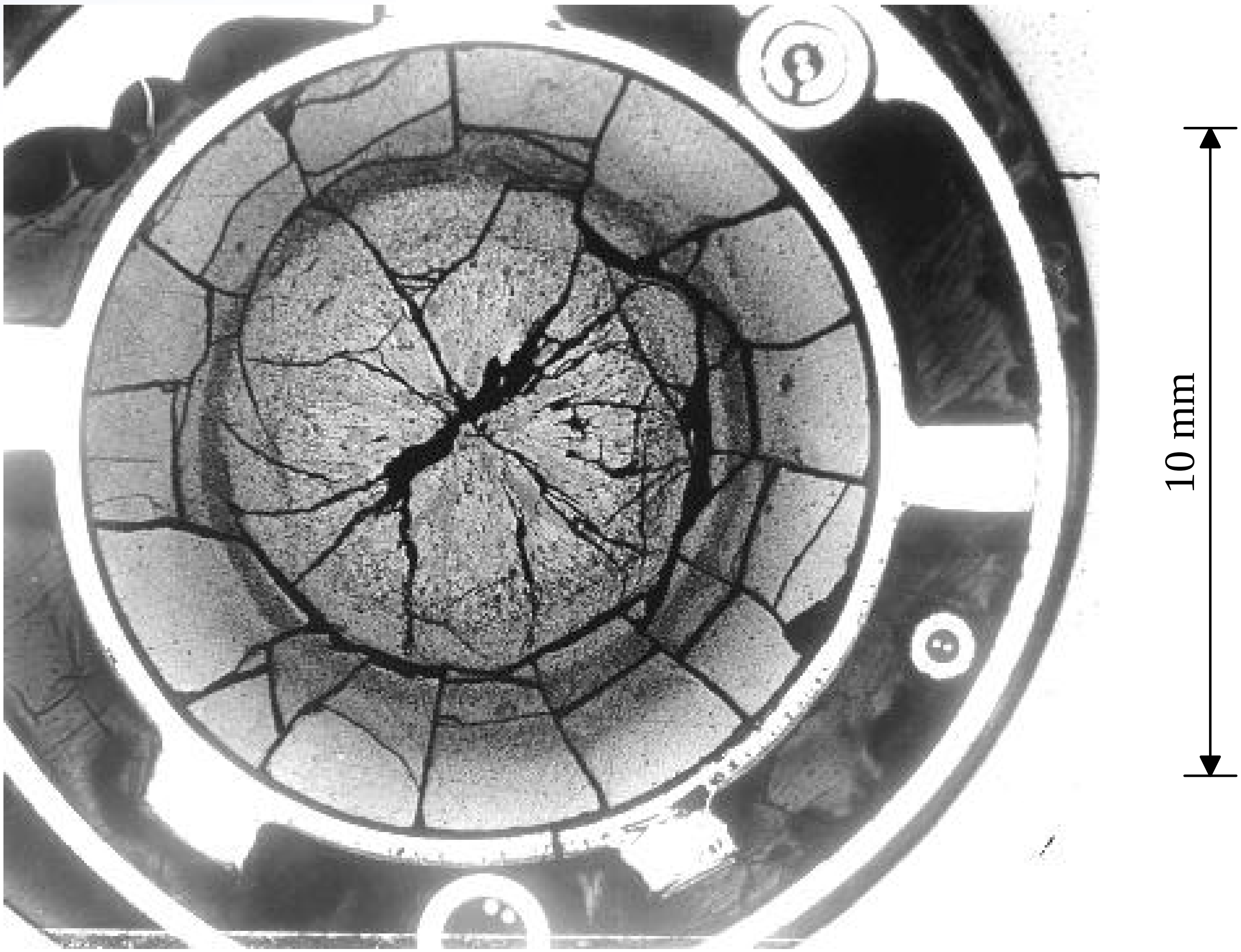


1997 Dec.,
1998 Jul. 10

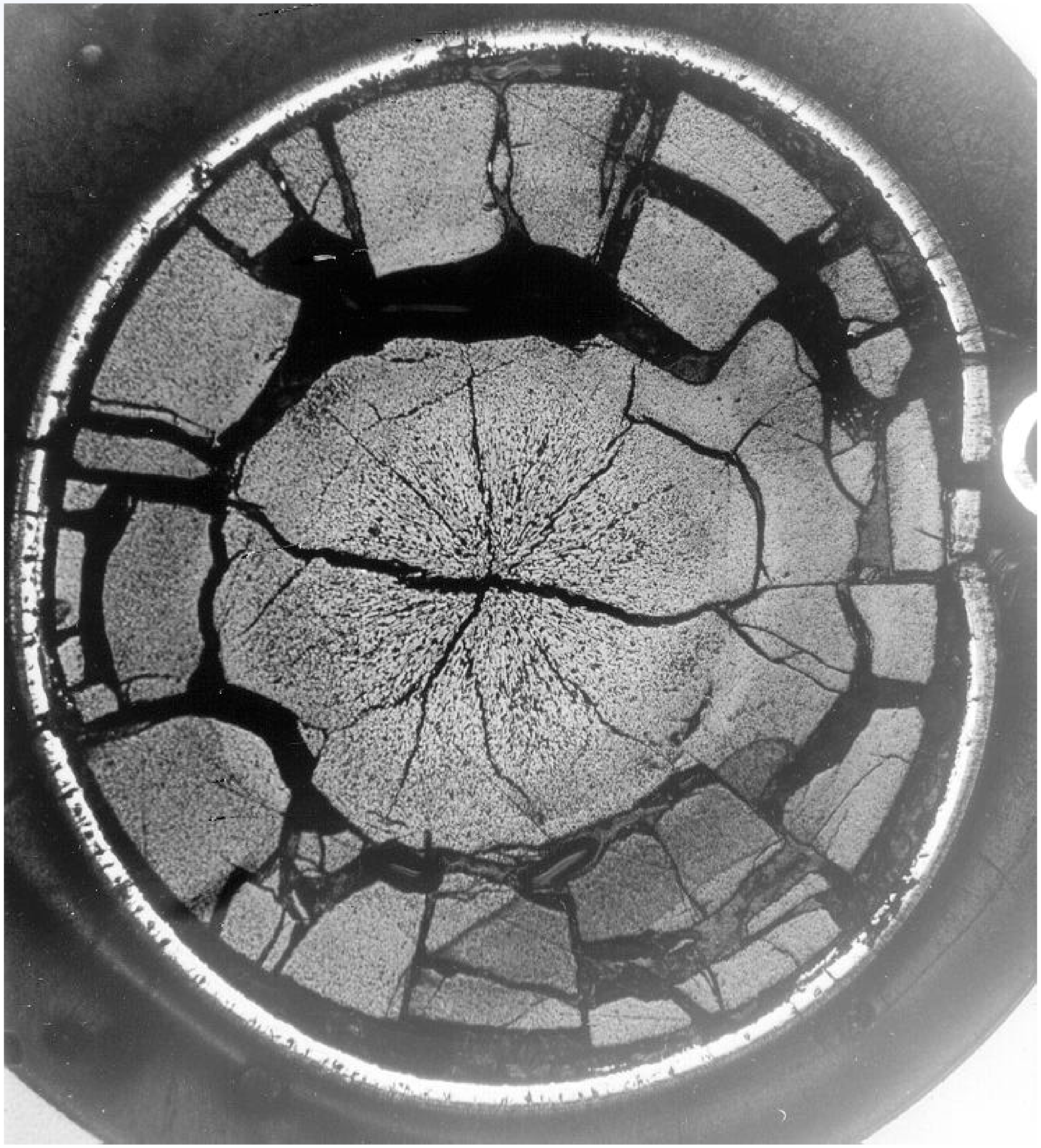
BTF-105B PIE, Elevation 373 mm

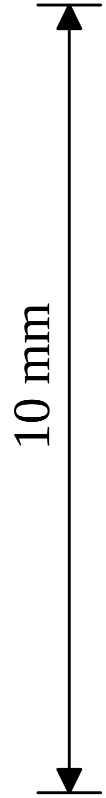


BTF-105B PIE, Elevation 247 mm

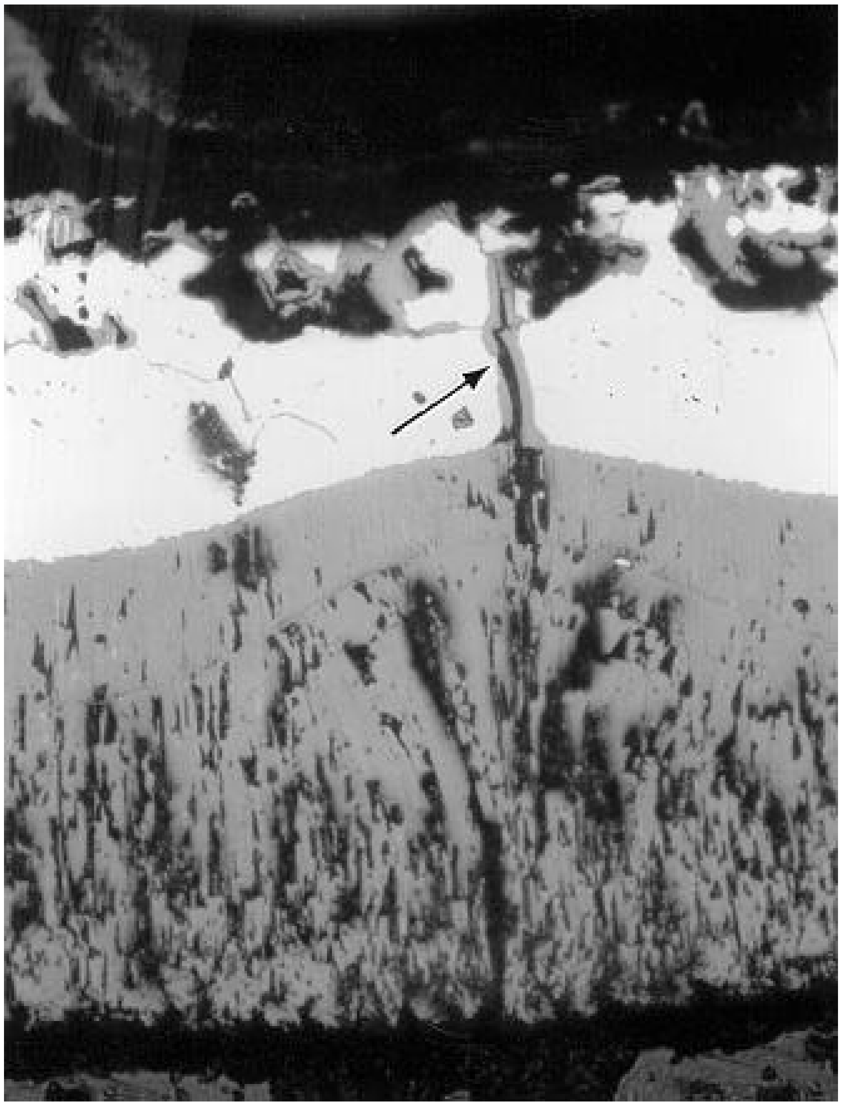


BTF-105B PIE, Elevation 105 mm





Zr-4 Cladding at 105 mm



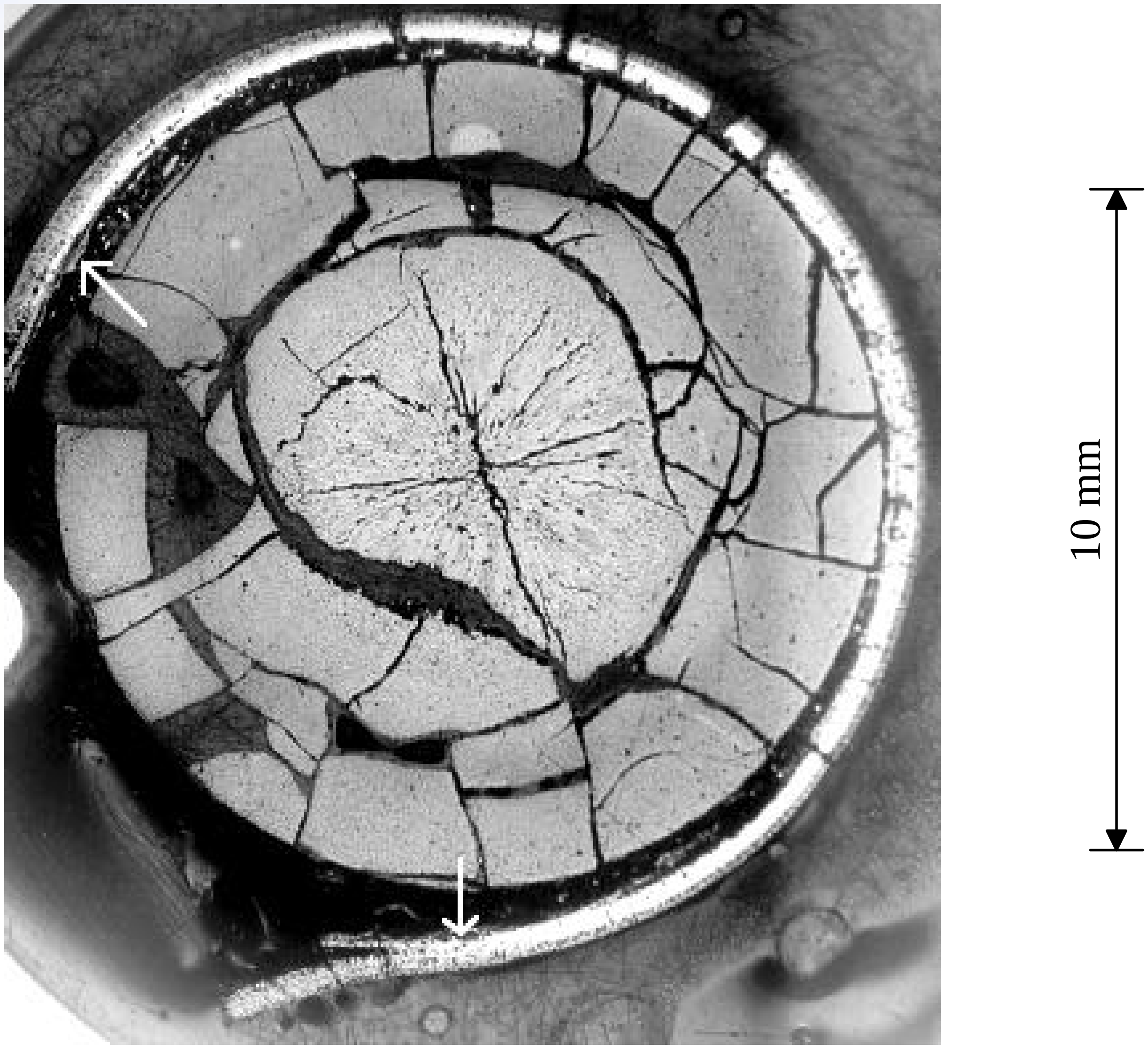
I.D.

Zr - 4 Clad
Remaining

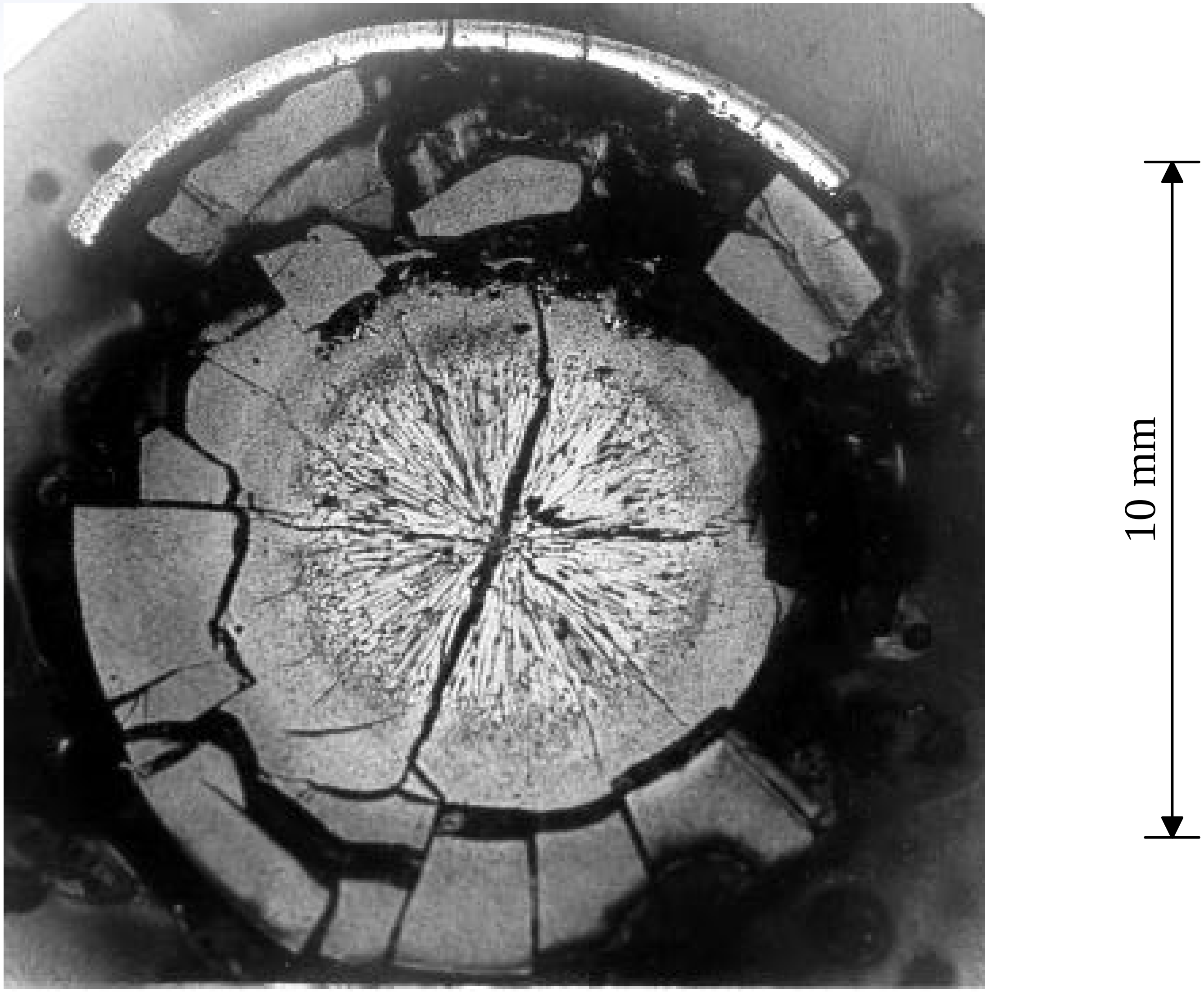
ZrO_2

O.D.

BTF-105B PIE, Elevation 69 mm



BTF-105B PIE, Elevation 20 mm



Grain Size and Oxide Thickness

I.D. (mm)	Avg. Grain Size (µm) Periphery	Mid	Centre	Oxide Thickness (µm)
MET 3 (373)	5.5 (1%)	20 (135%)	91 (20%)	80 - 150
MET 5 (247)	5.7 (10%)	19 (40%)	95 (5%)	20 - 240
MET 6 (105)	5.3	13	60	130 - full
MET 7 (69)	5.1 (-5%)	17 (62%)	80 (8%)	135 - full
MET 1 (44)	4.8	11	69	60 - 370
MET 1 (22)	4.5 (-8%)**	12 (106%)	120 (48%)	220 - 375
MET 2 (0-22)	4.8	5.2	11	94 - 300

** Change w.r.t. reference element
MET 1 cross-section compared to ref. longitudinal-section

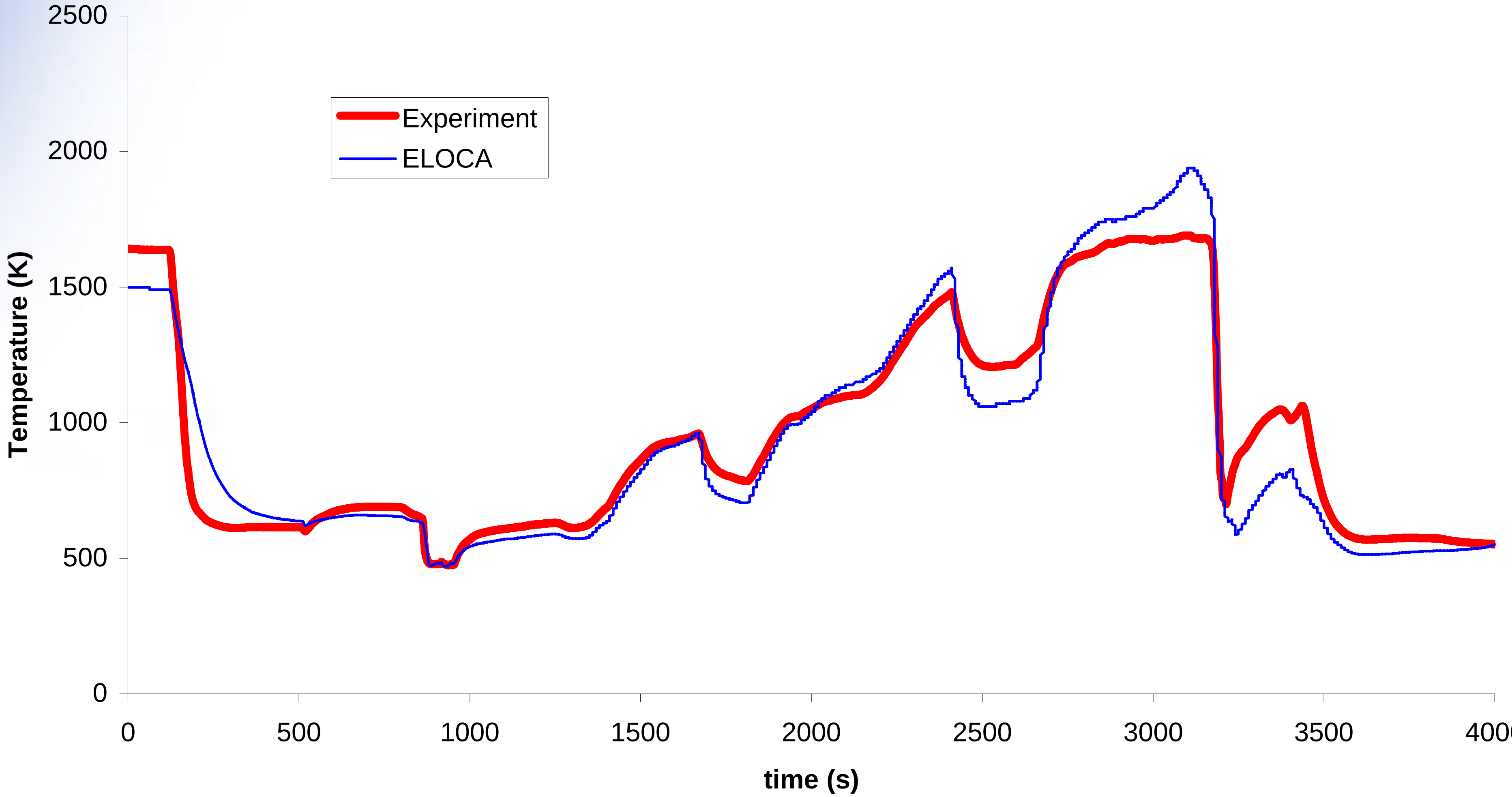
Integral % FPR in the BTF Experiments

Isotope	BTF-107	BTF-104	BTF-105A	BTF-105B
^{85m}Kr	37 ± 3	10 ± 4	2 ± 1	25 ± 6
^{85}Kr	-	47 ± 6	-	24 ± 7
^{88}Kr	37 ± 2	7 ± 2	3 ± 2	11 ± 3
^{131}I	56 ± 2	33 ± 5	< 2.0	21 ± 7
^{133}I	68 ± 34	20 ± 5	< 2.0	21 ± 8
^{137}Cs	56 ± 3	59 ± 5	-	34 ± 7
^{132}Te	20.8 ± 1.3	2.5 ± 0.7	-	1.1 ± 0.3

ELOCA-IST 2.1

- ELOCA-IST models the thermo-mechanical behavior of the fuel and fuel cladding under the transient conditions of an accident
- The model was first developed in the mid 1970s and has undergone continuous development since that time
- The model was chosen as part of the Canadian Industry Standard Tool Set (IST) in 1998
- The current version, ELOCA-IST 2.1, completed validation in 2001 and was released for use in 2002

BTF-105A Fuel Centerline Temperature



BTF Program Conclusions

- Data obtained for validation of CANDU fuel behavior codes under severe-fuel-damage accident conditions
- Post-test simulations performed using CANDU safety analysis computer codes (CATHENA, ELOCA, SOURCE and SOPHAEROS)
- No new phenomena or phenomena interactions identified

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