LOCA TESTING AT HALDEN

TRIAL RUNS IN IFA-650

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LOSS OF COOLANT STUDIES

The move to high burnup and the introduction of new cladding materials have generated a need to re-examine the safety criteria for loss-of-coolant accidents and to verify their continued validity. The integral in-pile tests in the Halden reactor will address LOCA issues using ex-LWR high burnup fuel segments. The Halden experiment will focus on effects that are different from those obtained in out-of-reactor tests.

SOME HALDEN INVESTIGATIONS IN THE AREAS THERMAL-HYDRAULICS, CRITICAL HEAT TRANSFER AND LOCA

1963-68	Experiments on natural convection flow instabilities and dry-out limit
1965-72	Dry-out experiments in natural convection flow channels
1979-83	Safety-related tests. Blow-down, heatup & quench behaviour of nuclear rods and electric simulators.
511	Thermal response studies
1982-85	Safety-related tests. Blow-down, heatup & quench behaviour of nuclear rods and electric simulators.
54x	Ballooning and rod-to-rod interaction studies
1996-98	Short-term dry-out test series

LOSS OF COOLANT ACCIDENT

- **3 Phases:**
  - Blowdown (fuel/core uncovered), de-pressurisation
  - Refill (ECCS systems start)
  - Reflood (water level above core top)
- **Timing:** uncovery, quenching, long-term cooling
- Fuel temp. rises - - > cladding oxidation and hydriding: embrittlement (melting) of cladding - - > fragmentation

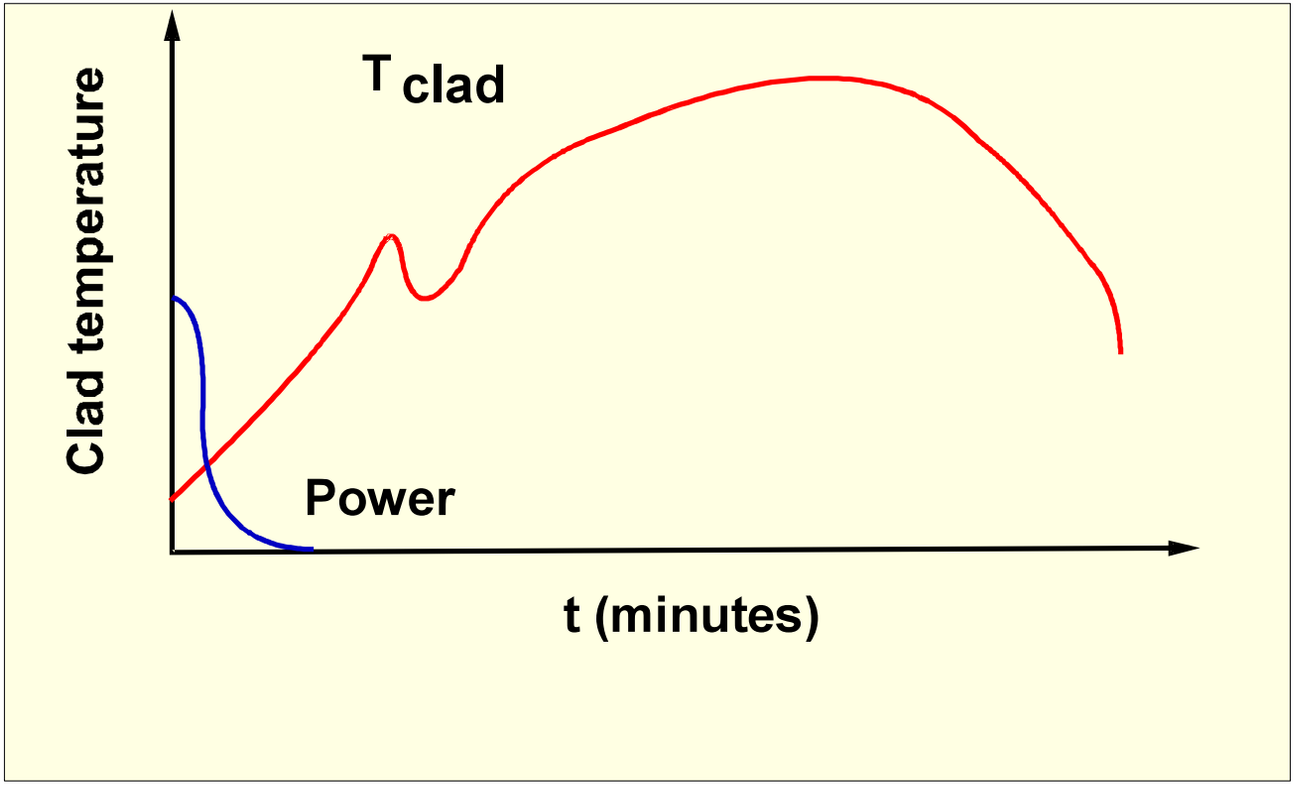
→**Safety criteria:**

- Peak Clad Temp. (PCT) not to exceed 2200 F (1204 C)
- Oxidation of cladding not to exceed 17% of total clad thickness

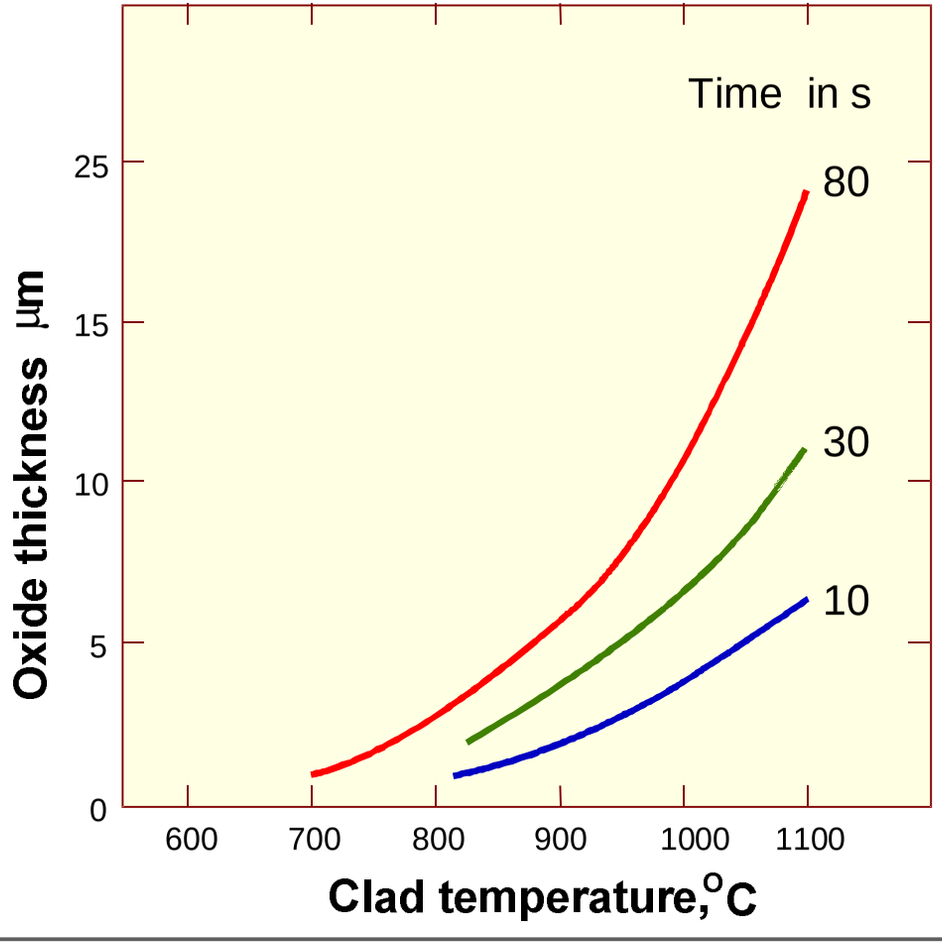
- Rod swelling/ballooning may endanger core geometry/coolability

→ **Safety requirement:** calculated geometry changes still warrant core cooling

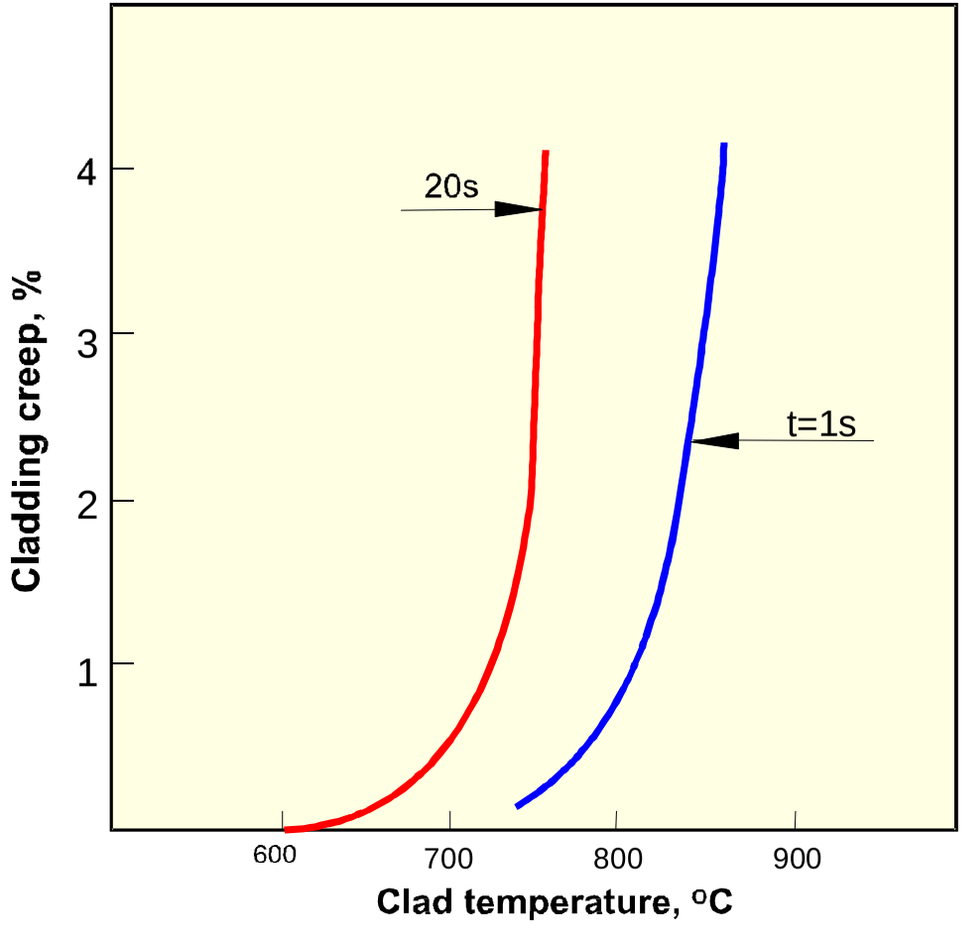
LOSS OF COOLANT ACCIDENT



HIGH TEMPERATURE OXIDATION OF ZIRCALOY



HIGH TEMPERATURE CREEP OF ZIRCALOY

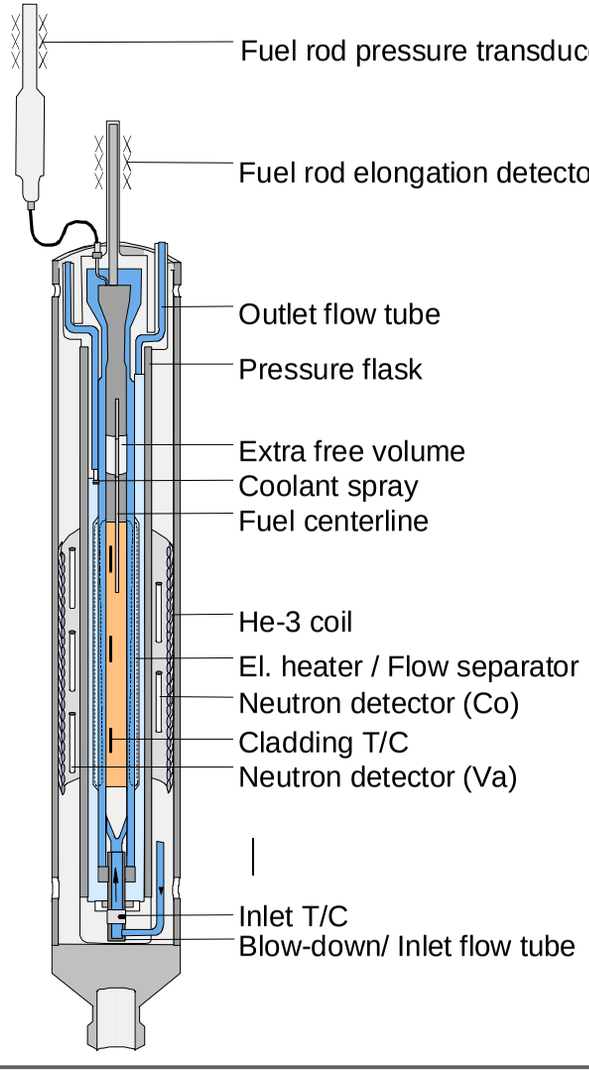


HALDEN LOCA EXPERIMENT (IFA-650)
(USNRC/EPRI/IRSN/EDF/FRAMATOM-ANP/GNF)

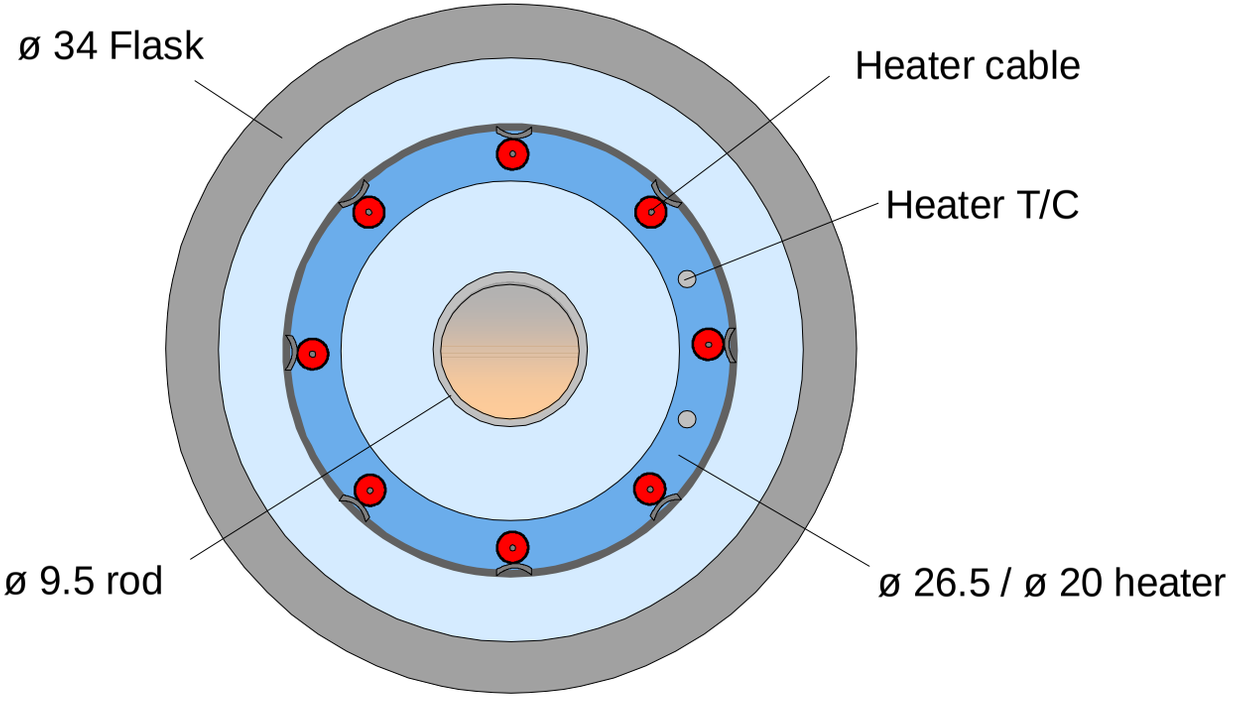
Primary objectives

- Measure the extent of fuel (fragment) relocation into the ballooned region and evaluate its possible effect on cladding temperature and oxidation
- Investigate the extent (if any) of – ”secondary transient hydriding”- on the inner side of the cladding above and below the burst region

SCHEMATIC OF LOCA TEST RIG



CROSS SECTION GEOMETRY OF THE FUEL PIN, FLOW SEPARATOR AND PRESSURE TUBE



LOCA TRIAL RUNS - IFA-650.1

Test rod / instrumentation

Rod (Zr-4)

Length:	500 mm
O.D / I.D:	9.50/8.36 mm
Gap size:	0.70 mm
Enrichment:	4 w/o U-235
Fill pressure:	2 bar He

Free volume: 15 cc

Dished pellets

Instrumentation

3 Clad TCs

1 Clad extensometer

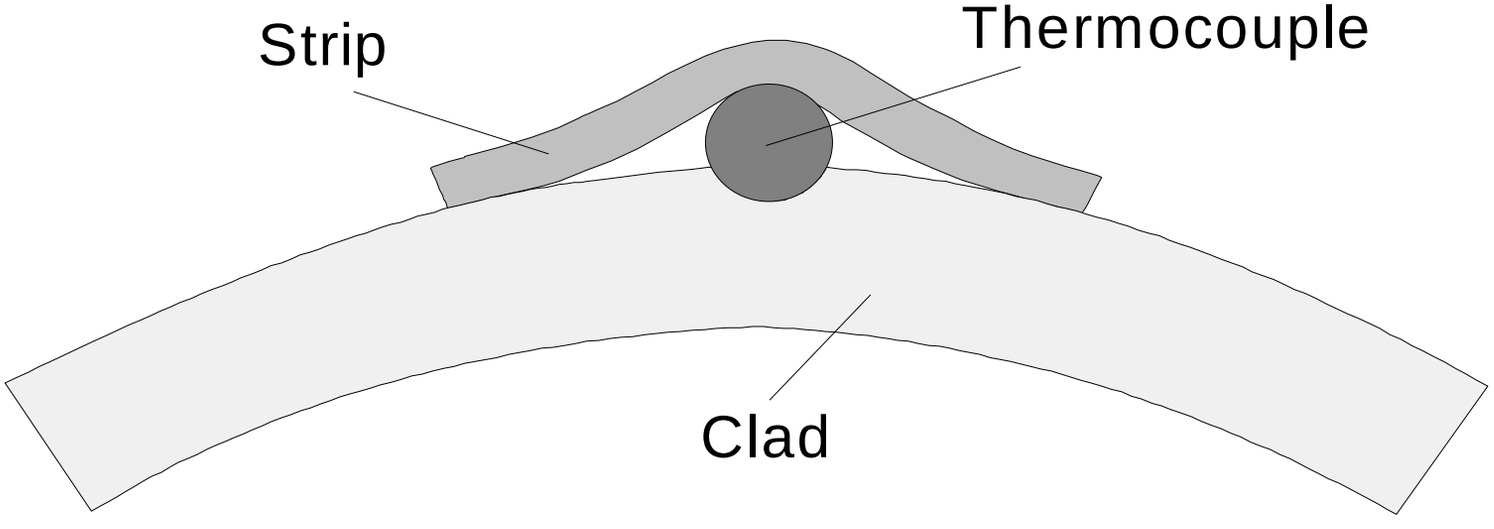
1 Fuel thermocouple

1 Rod pressure sensor

2 Heater thermocouples

LOCA TESTS-IFA-650.1 & IFA-650.2

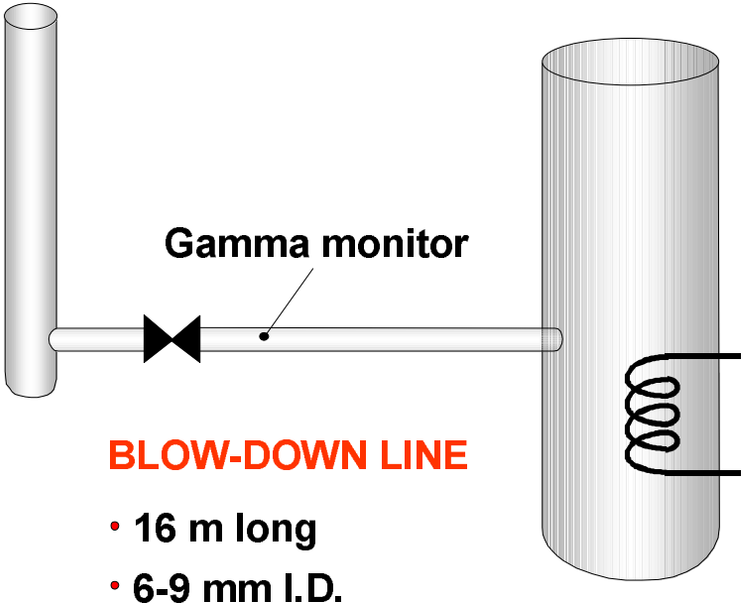
Attachment of clad O.D. thermocouples



LOCA TRIAL RUNS – IFA-650.1

IN-PILE RIG

1 liter
70 bar
Natural
circulation D_2O
(15-30 w/cm)



DUMP TANK

- Shielded tank
- Cooled
- Slight over-pressure (2-3 bar)
- Level gauge

BLOW-DOWN LINE

- 16 m long
- 6-9 mm I.D.
- Gamma monitor
- Blow-down rate control

LOCA TRIALS RUNS - IFA - 650.1

Pre-test code calculations

- TRAC-BF1 code (PSI)
- FRAPTRAN – GENFLOW (VTT)
- SCTEMP and ALGOR (Halden)

LOCA TRIALS RUNS - IFA - 650.1

- Blow-down tests at zero power
- Power calibrations (~18 MW)
- Trial runs (5-6 MW)

800^{O}C (2 runs)

- 14 W/cm (rod) + 6 W/cm (heater) (~ 830^{O}C)
- 14 W/cm + 6 W/cm (~ 830^{O}C)

1100^{O}C (4 runs)

- 14 W/cm + 12 W/cm (~ 900^{O}C)
- 25 W/cm + 6 W/cm (~ 930^{O}C)
- 25 W/cm + 18 W/cm (~1030^{O}C)
- 30 W/cm + 20 W/cm (~1120^{O}C)

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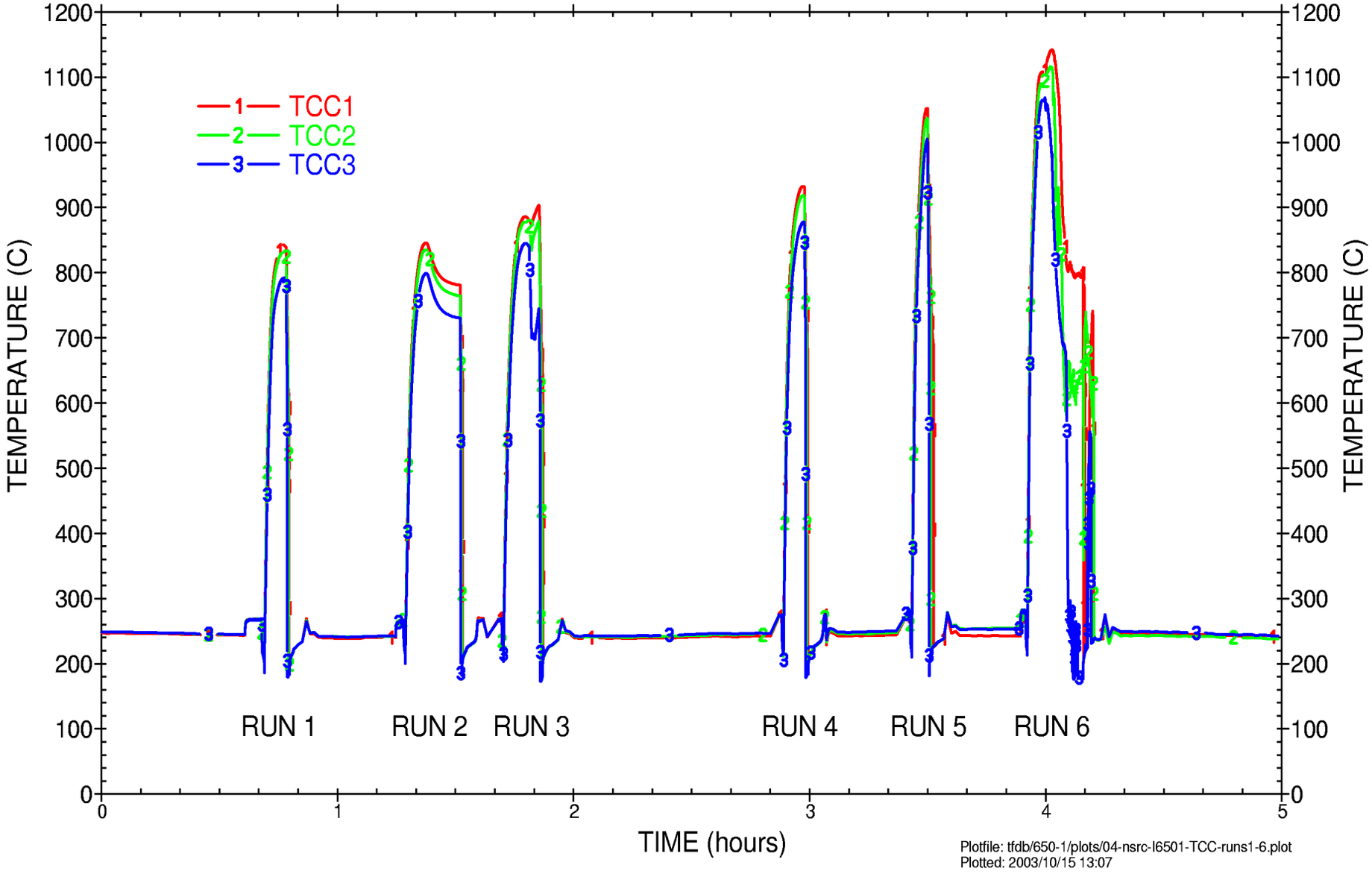
IFA-650.1 CLAD TEMPERATURES

From: 2003/05/23 19:00
To : 2003/05/23 23:59



Plotfile: tfdb/650-1/plots/04-nsrc-I6501-TCC-runs1-6.plot
Plotted: 2003/10/15 13:07

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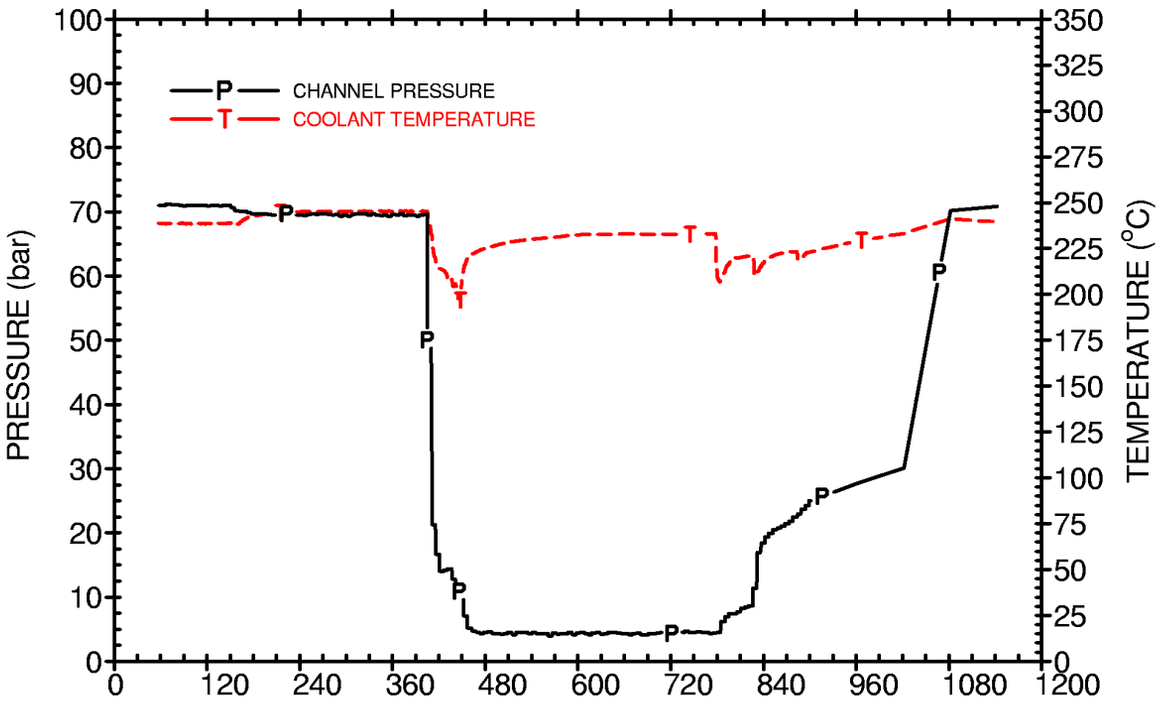
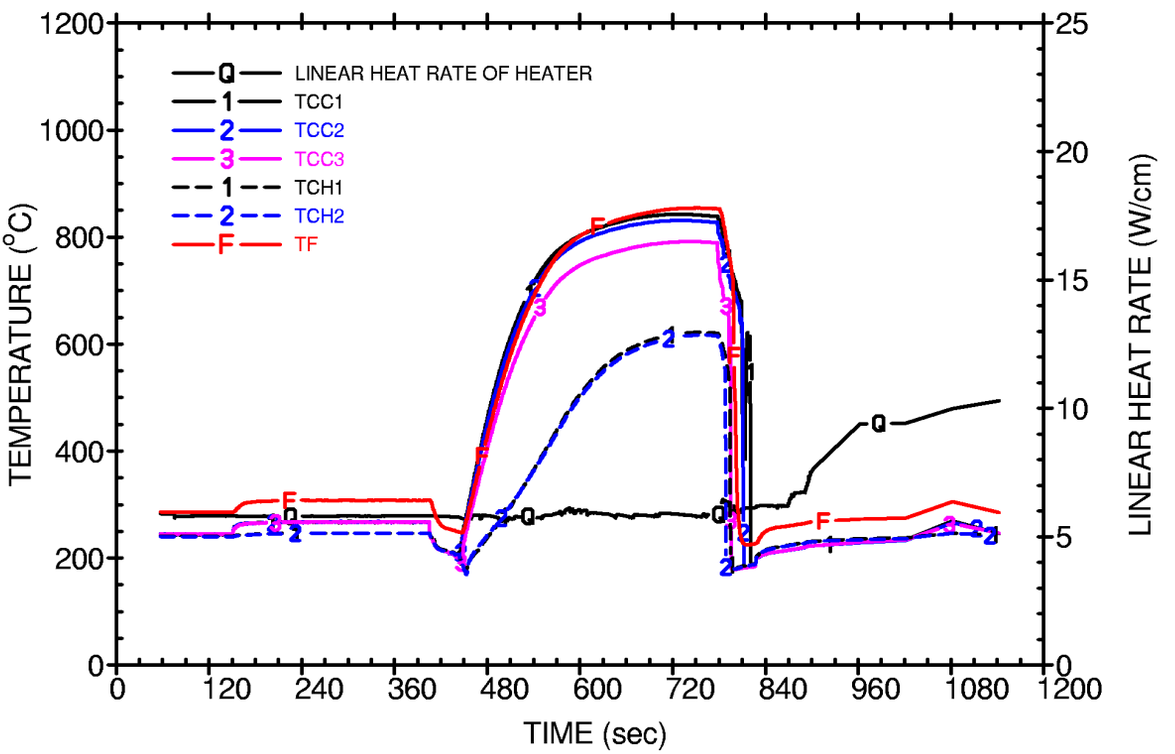
LOCA Trial Runs, IFA-650.1

1st Run, Q_{rod} = 12 W/cm, Q_{heater} = 6 W/cm, $T_{cladmax}$ = 843°C





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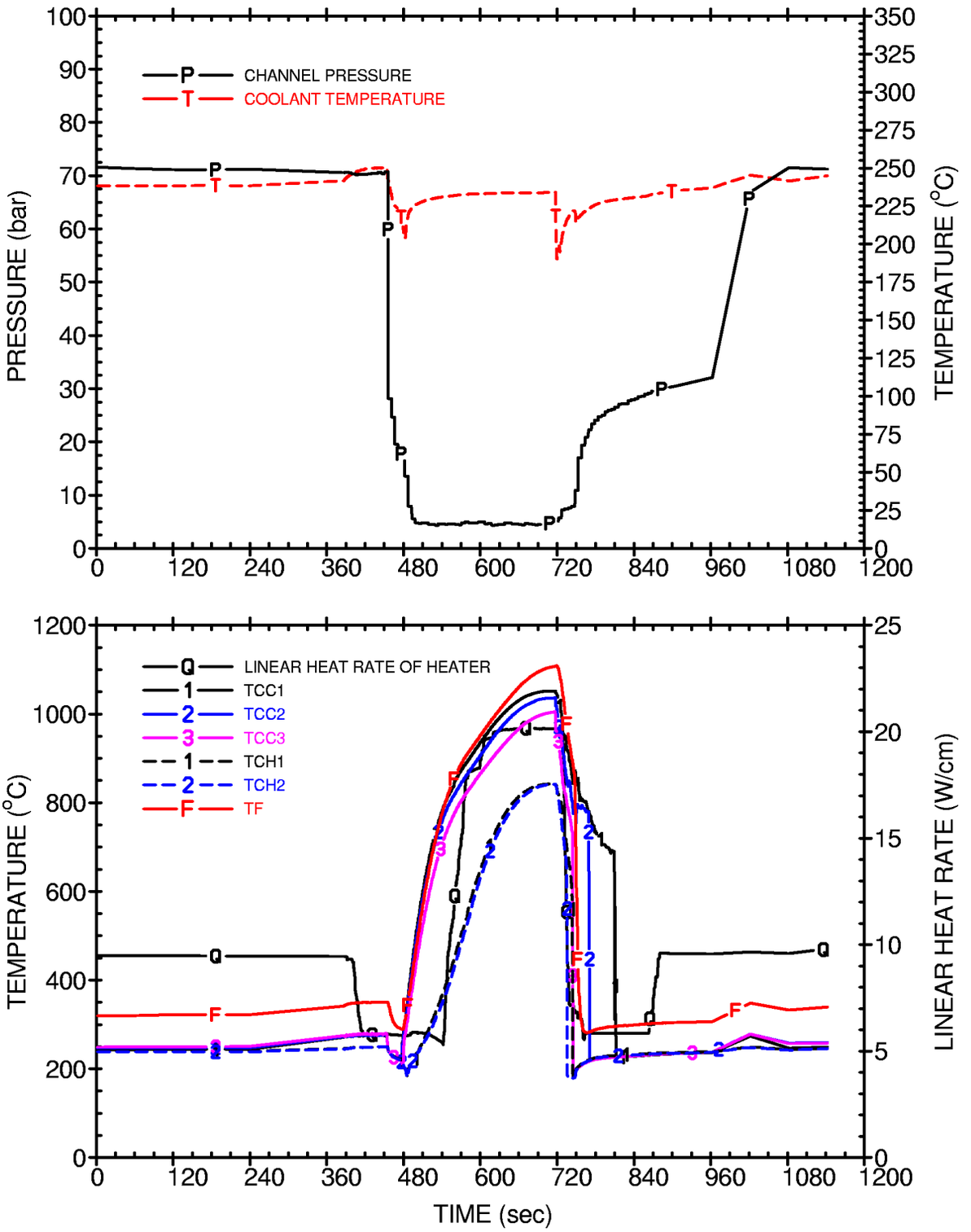
LOCA Trial Runs, IFA-650.1

5th Run, Q_{rod} = 23 W/cm, Q_{heater} = 18 W/cm, $T_{clad.max}$ = 1052°C



LOCA TRIALS RUNS - IFA - 650.1

Summary:

- Trial runs on May 23rd
  - 2 runs to PCT = 800^{O}C
  - 4 runs to PCT = 1100^{O}C
- Loop and rig worked well
- Rod instrumentation worked well
- PCT reached by adjusting
  - LHGR (15 – 30 W/cm)
  - Heater (6 – 20 W/cm)
- Blowdown times ~30 secs
- Quench by spray system
- Next test with pressurised, fresh PWR rod

TEST OBJECTS

- Pairs of rods (50 - 80 MWd/kg, 40-50 cm length) from commercial LWRs to be tested in PWR and BWR conditions, suitable to address possible effect of axial fuel fragment relocation
  - when does it occur (blow-down/heat-up, quenching)?
  - does bonding prevent the movement of fragments?
- Include medium burnup fuel (~40 MWd/kg, less or no bonding) to bridge the gap between low and high burnup
- VVER fuel envisaged for testing at a later stage