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Thermal-hydraulic conceptual design of the new multipurpose research reactor succeeding to JRR-3

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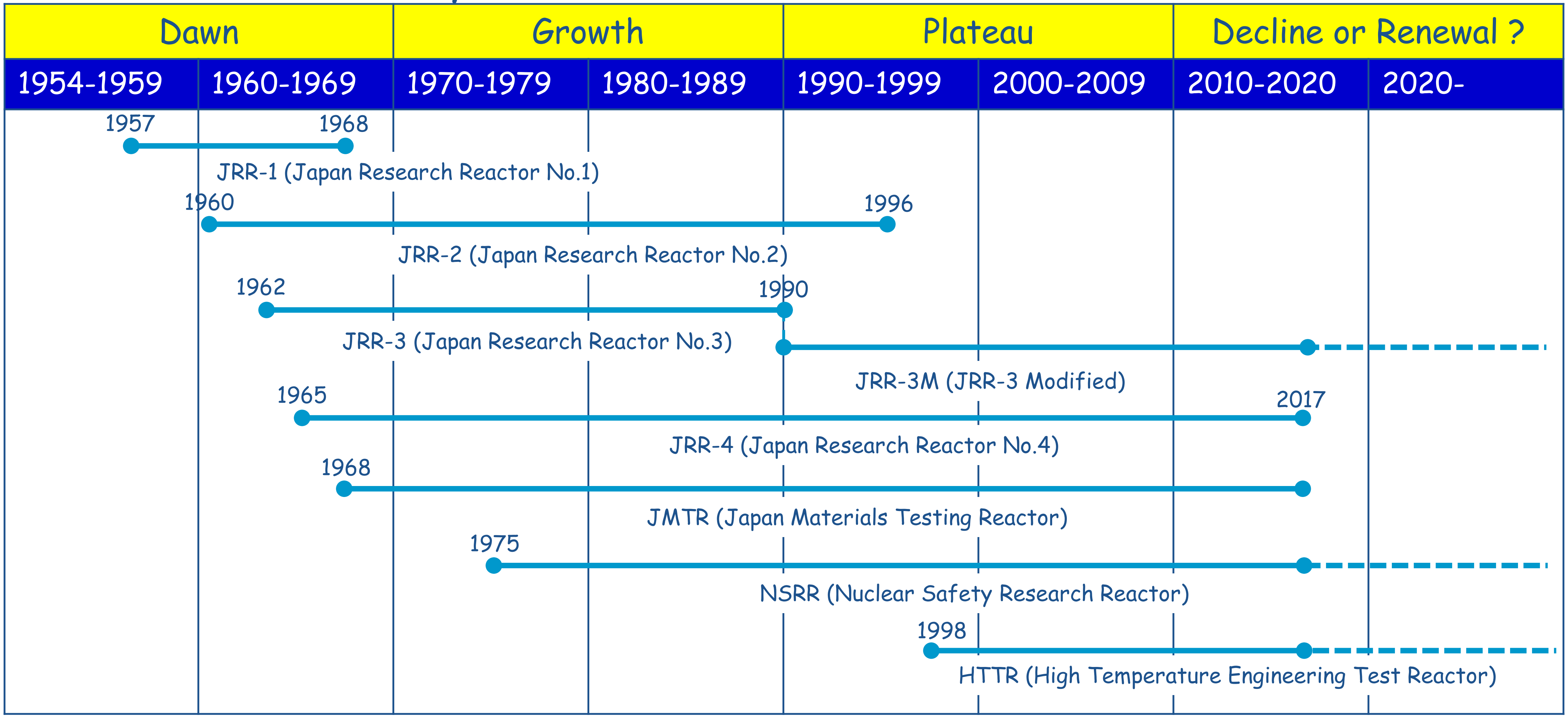
OUTLINE

1. Background and Purpose
2. Calculation Conditions
3. Results and Discussion
4. Conclusions

1.1 background

History of main research reactor in JAEA



1.2 New reactor concept

Our working group has started to look into basic concepts of the new research reactor that can be accepted as a successor of JRR-3.

Vision

Maintain national neutron source for neutron beam experiment, material irradiation, RI production and training.

Purpose

Develop a new research reactor to stably supply the specified neutron flux and neutron spectra that satisfies the needs of stakeholders.

Requirements of stakeholders

- Advanced core of high reliability and safety
- Constant neutron source over 10^{14} n/cm^2/sec in a wide range of energy
- Wide experiment space and good accessibility.

→

The new reactor concept

- Open pool type reactor
  → Not having pressurizing mechanism
- Neutrons of various energy can be utilized
  → For neutron beam : cold, thermal (<1eV)
  → For irradiation : Fast (>10keV)
- High neutron flux intensity
  → Flux being over 1.5 times higher than JRR-3
- Lifetime extension of fuel
  → Adopting high density Uranium fuel

1.3 Reactor TYPE and Core shape arrangements

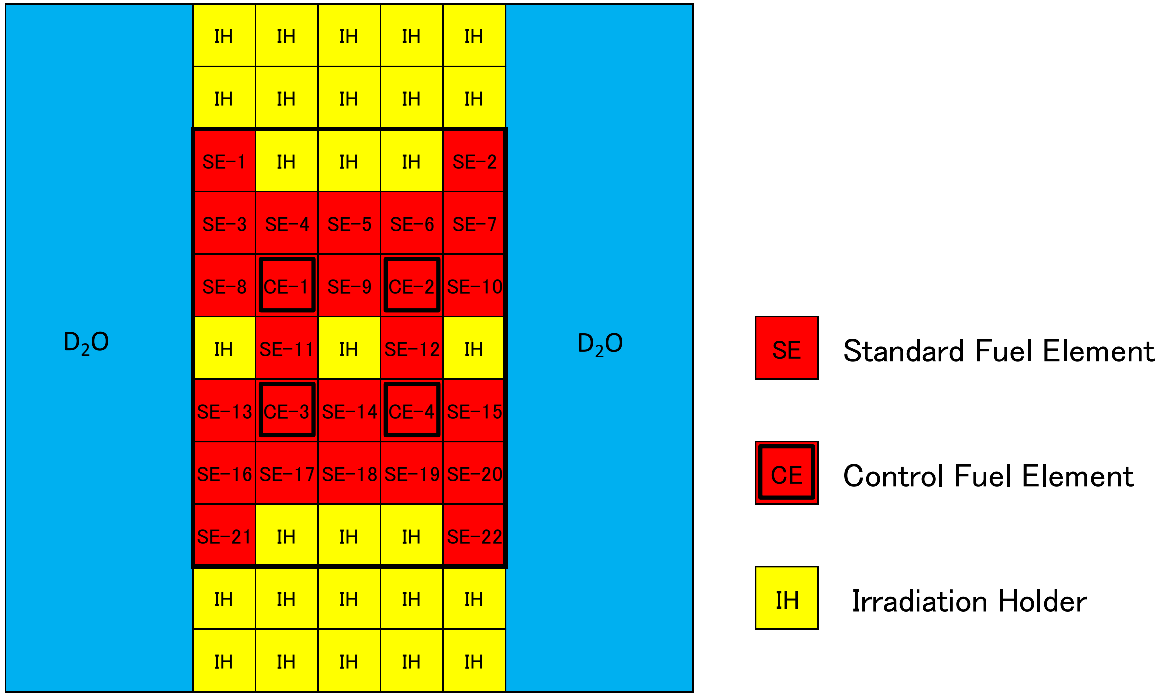
First step in design study of the new RR

- Thermal power,
- Basic shape of the reactor core,
- Fuel element design,
- Moderator component,

were proposed to gain high neutron flux and satisfy the safety levels.
(RRFM/IGORR 2016, Berlin, 13-17 Mar. 2016)

Thermal power [MW]	30
Reactor type	Pool type
U235 enrichment [wt%]	20
Number of fuel	26
Coolant	Light water
Moderator	Light water Heavy water

(Core layout)



1.4 PURPOSE

(Thermal-hydraulic characteristics and safety margins for the beginning of cycle core)

Two major design criteria were set up for the core thermal-hydraulic design of new RR so that fuel plates may have enough safety margins for the conditions of normal operation.

1. To avoid nucleate boiling of coolant anywhere in the core.

- The surface temperature of the fuel plate should be below ONB (onset of nucleate boiling) temperature at the hottest spot in the core.
  ($T_{ONB} - T_{PLATE} > 0$)

2. To give enough margins against the burnout itself of the fuel plate.

- The DNBR (departure from nucleate boiling ratio) must be not less than 1.5.
  ($DNBR = Q_{DNB}/Q_{CLAD} > 1.5$)

2.1 Calculation code

The thermal-hydraulic calculations and analysis were carried out using the COOLOD-N2 code.

This code is applicable for research reactors in which plate-type fuel is adopted.
Thermal-hydraulic analysis of JRR-2, JRR-3, JRR-4 and JMTR have been performed.

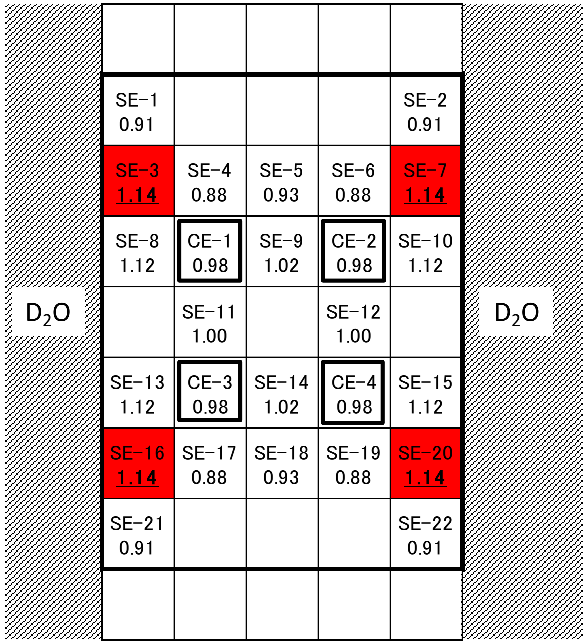
The COOLOD-N2 code calculates following values at every distance from the inlet of fuel element.

- Local temperature and velocities of coolant,
- Pressure drops and local pressures,
- Fuel plate surface heat flux,
- ONB temperature and DNB heat flux.

2.2 Input data

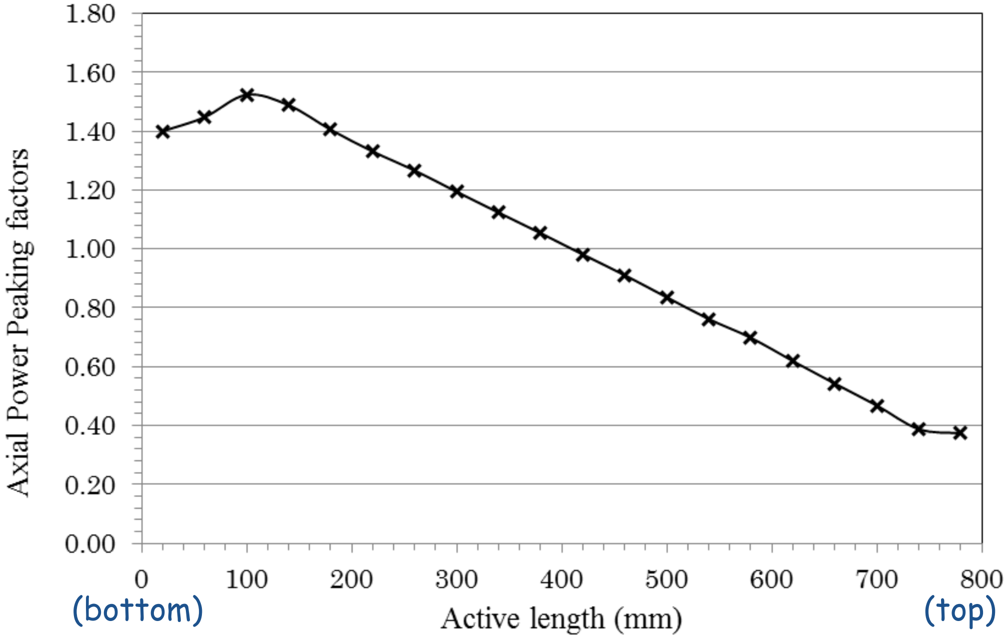
- Thermal power of core : 30 MW
- Core inlet water temperature : 35 ° C
- Core inlet pressures : 1.49 kg/cm^2, 1.69 kg/cm^2, 1.88 kg/cm^2
- Primary cooling water flow rate: Select form 400 kg/s to 1100 kg/s

➢ Radial peaking factor : 1.14



Radial peaking factors distribution at BOC core configuration

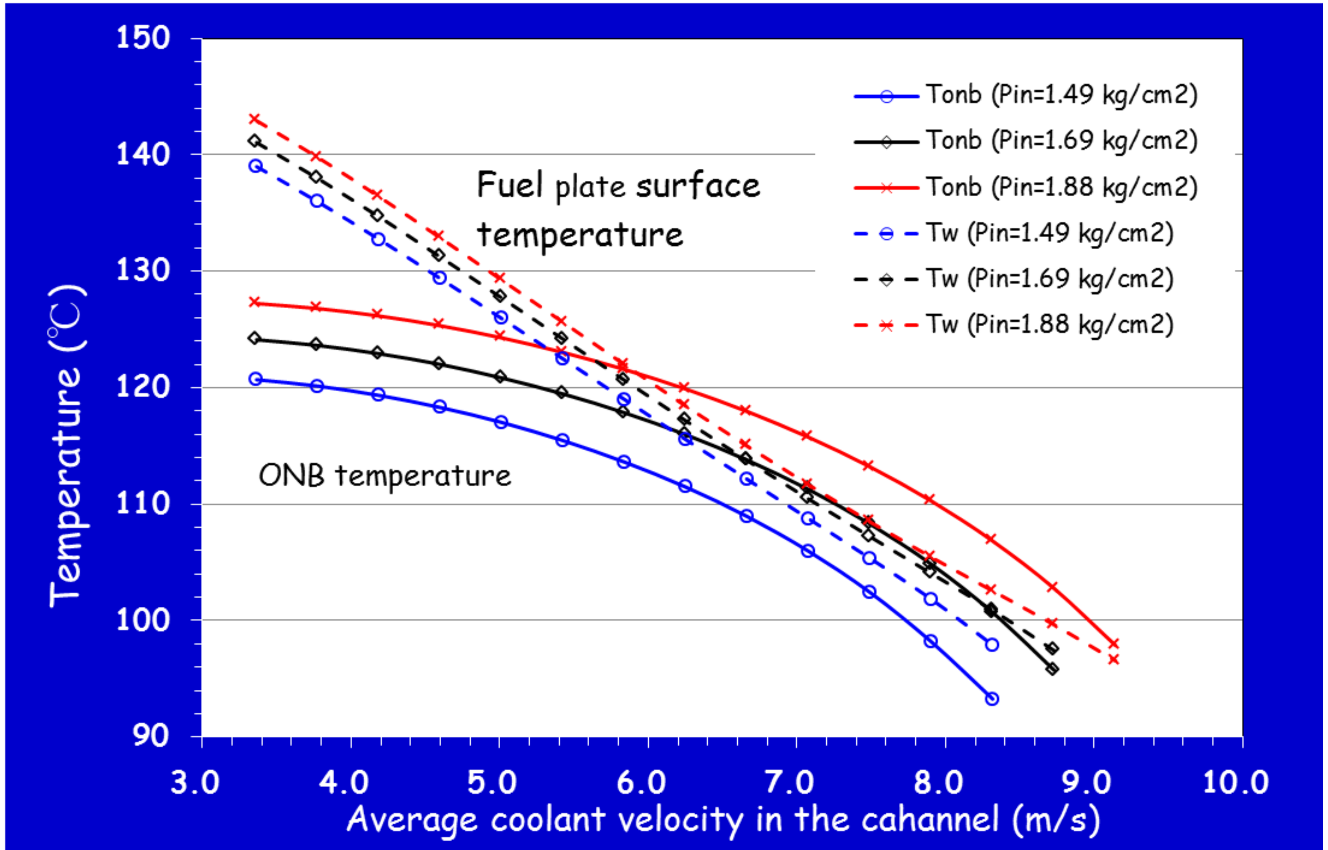
➢ Axial peaking factors



Axial peaking factors distribution used in the thermal-hydraulic calculation

3.1 Results of ONB temperature

- T_{ONB} decrease with an increase of the coolant velocity because an increase in the coolant velocity gives lower local pressure according to the increase of pressure loss.



ONB temperature and fuel plate surface temperature vs coolant velocity

Range of coolant velocities without boiling occurs in the hot channel.

Core inlet pressure (kg/cm^2 abs)	Range of coolant velocities (m/s)
1.49	-
1.69	6.6 to 8.2
1.88	6.0 to 9.3

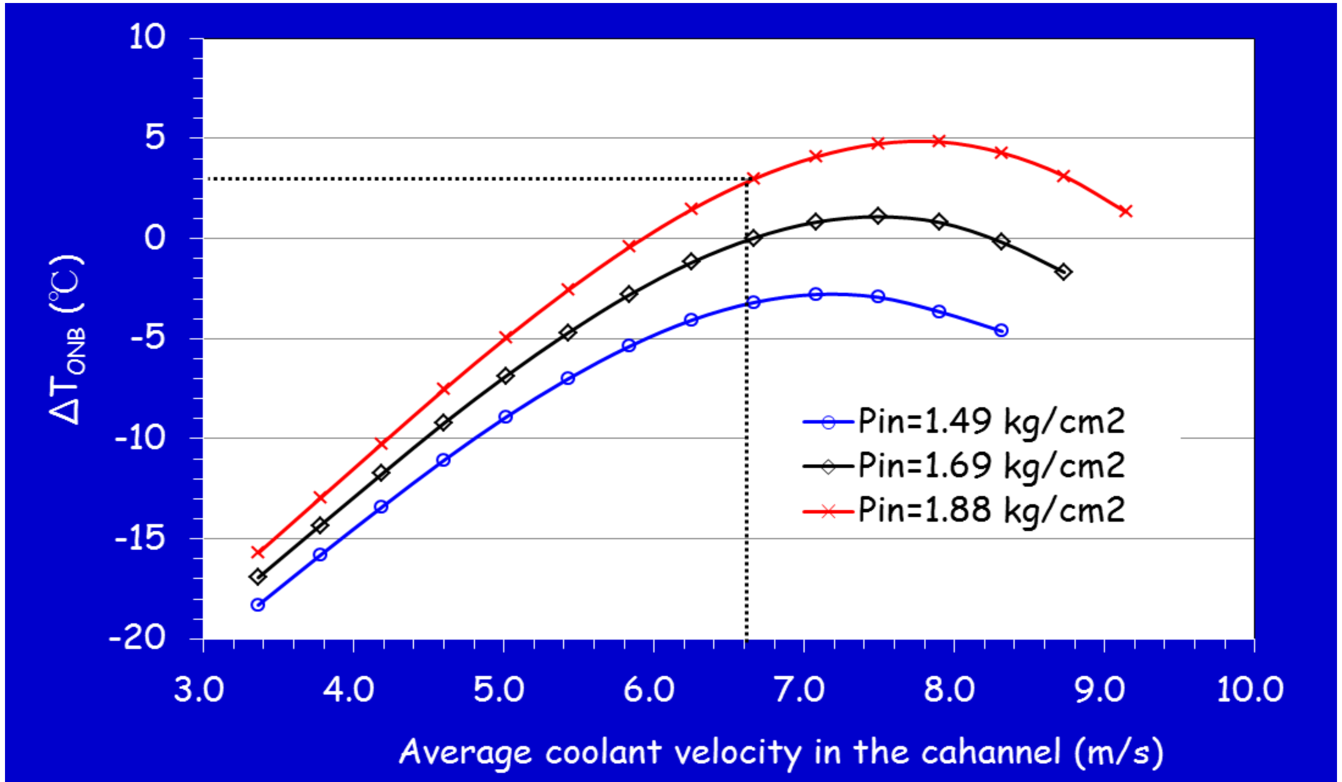
3.2 Discussion of ONB temperature

The coolant velocity of 6.6 m/s is proposed as conceptual design velocity for the fuel elements.

The coolant velocity of 6.6 m/s corresponds to a primary coolant flow rate of 780 kg/s (2800 m^3/h).

The coolant velocity of 6.6 m/s is the maximum in the linear part.

- Coolant velocity : Under 6.6 m/s
  ΔT_{ONB} increases linearly.
- Coolant velocity : Over 6.6 m/s
  ΔT_{ONB} increase ratio is decreases by pressure drop.



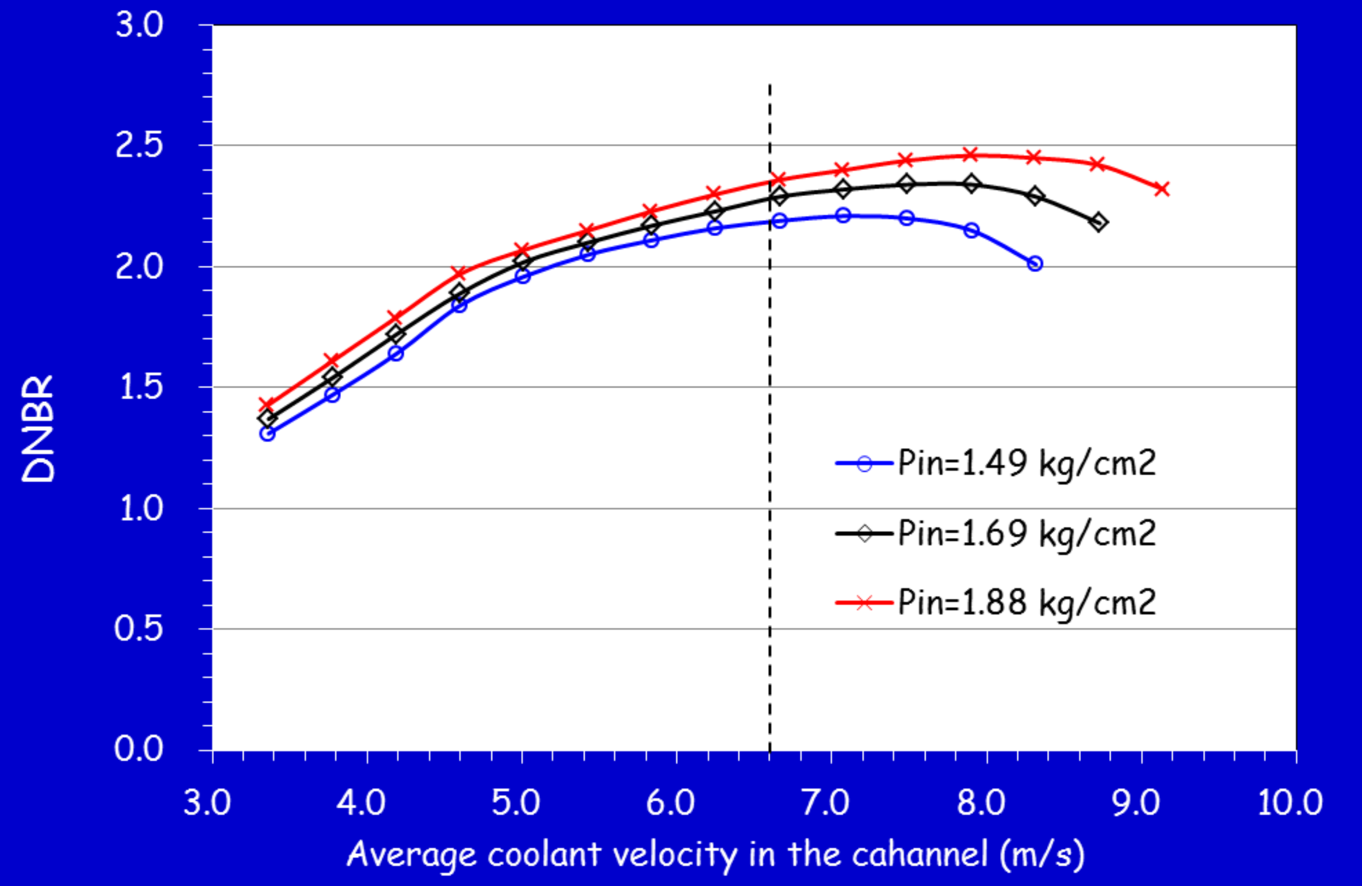
Temperature margin against the ONB temperature vs coolant velocity

Coolant velocity of 6.6 m/s
Core inlet pressure of 1.88 kg/cm^2
ΔT_{ONB} = 3.0 ° C.

3.3 Results and discussion of DNBR

Enough safety margins against DNB were obtained.

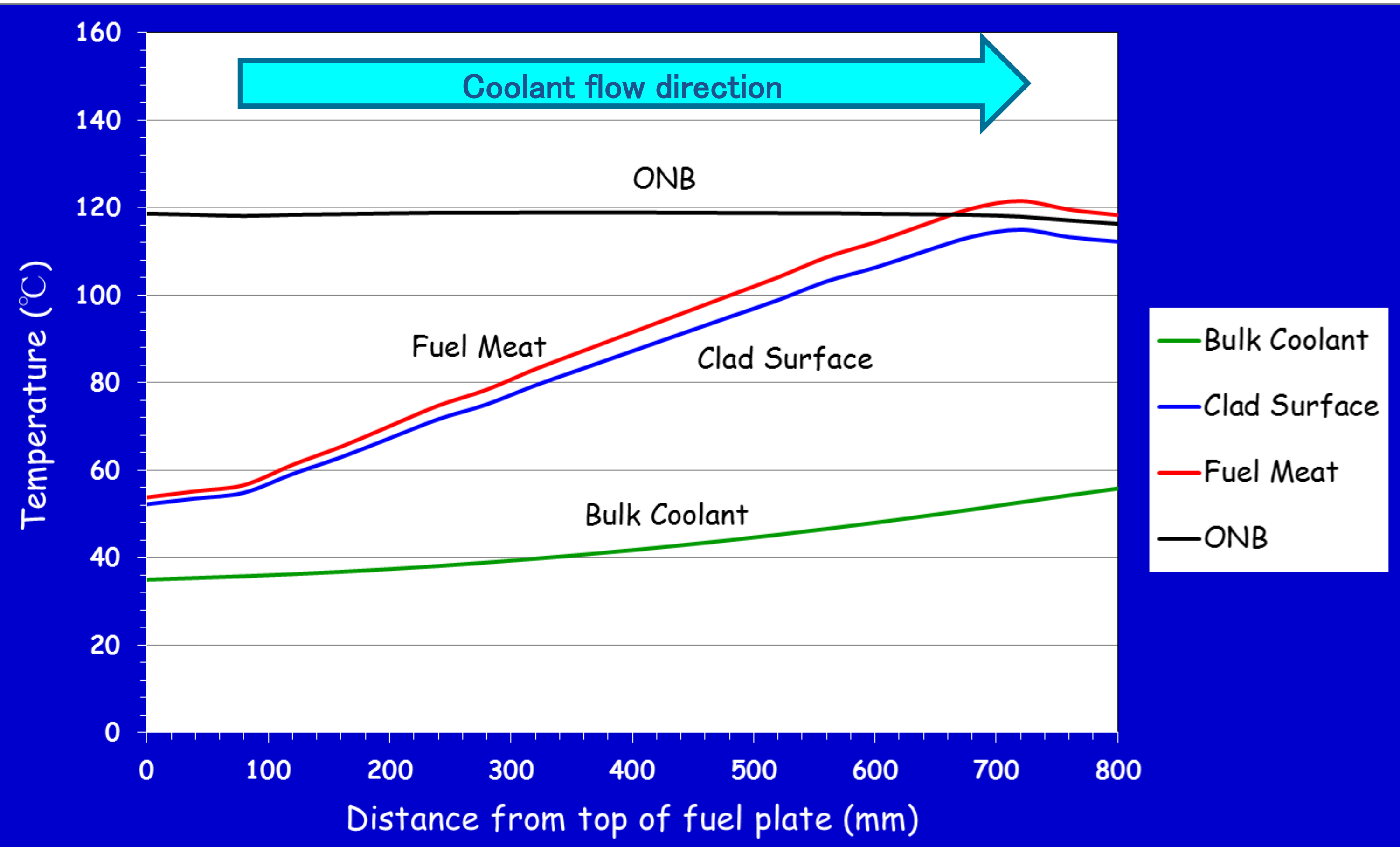
- An increase of the coolant velocity gives higher safety margins of DNBR.
- DNBRs are larger than 1.5 with each three different core inlet pressures.



DNBR and the OFIR as a function of coolant velocity

3.4 Temperature distributions

The major thermal hydraulic analysis results calculated for the standard fuel elements under the proposed the core inlet pressures of 1.88 kg/cm^2 and the core flow rate of 780 kg/s.



Temperature distributions for the hot channel

Core inlet temperature: 35 ° C

Core outlet temperature: 55 ° C

Maximum clad surface temperature: 115 ° C

Maximum fuel meat temperature: 121 ° C

4. Conclusions

The core thermal-hydraulic conceptual design of the multipurpose research reactor succeeding to JRR-3 was performed for forced convection cooling mode at a thermal power 30 MW.

(Results)

- A coolant velocity of 6.6 m/s was proposed as a conceptual design velocity for the fuel elements. This coolant velocity in a channel corresponds to a primary coolant flow rate of 780 kg/s (2800 m^3/h).
- A core inlet pressure of 1.88 kg/cm^2 abs. was proposed as a conceptual design core inlet pressure. With this pressure, the top of core will be locates at about 9m below the surface of the water of the reactor pool.
- In the above condition, temperature margin against ONB (3.0 °C > 0°C) and enough safety margin against DNB (2.36 > 1.5) were obtained.

The results obtained in this work established the preliminary technical specifications for the core thermal-hydraulic design of the new research reactor.

Thank you for your attention!

ご清聴、ありがとうございました。