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CORE PERFORMANCE OF NEW CONCEPT PASSIVE-SAFETY REACTOR "KAMADO" - SAFETY, BURN-UP AND URANIUM RESOURCE PROBLEM -

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Objectives

- Showing ability of a new concept passive-safety reactor "KAMADO ;
  – Safety: negligible possibility of core melting without engineered safety systems
  – Economy: flexibility of total reactor power with sufficiently low construction cost
- Discussing neutronic and thermal-hydraulics evaluation of a fuel element. Technical R&D subjects were clarified in these evaluations.

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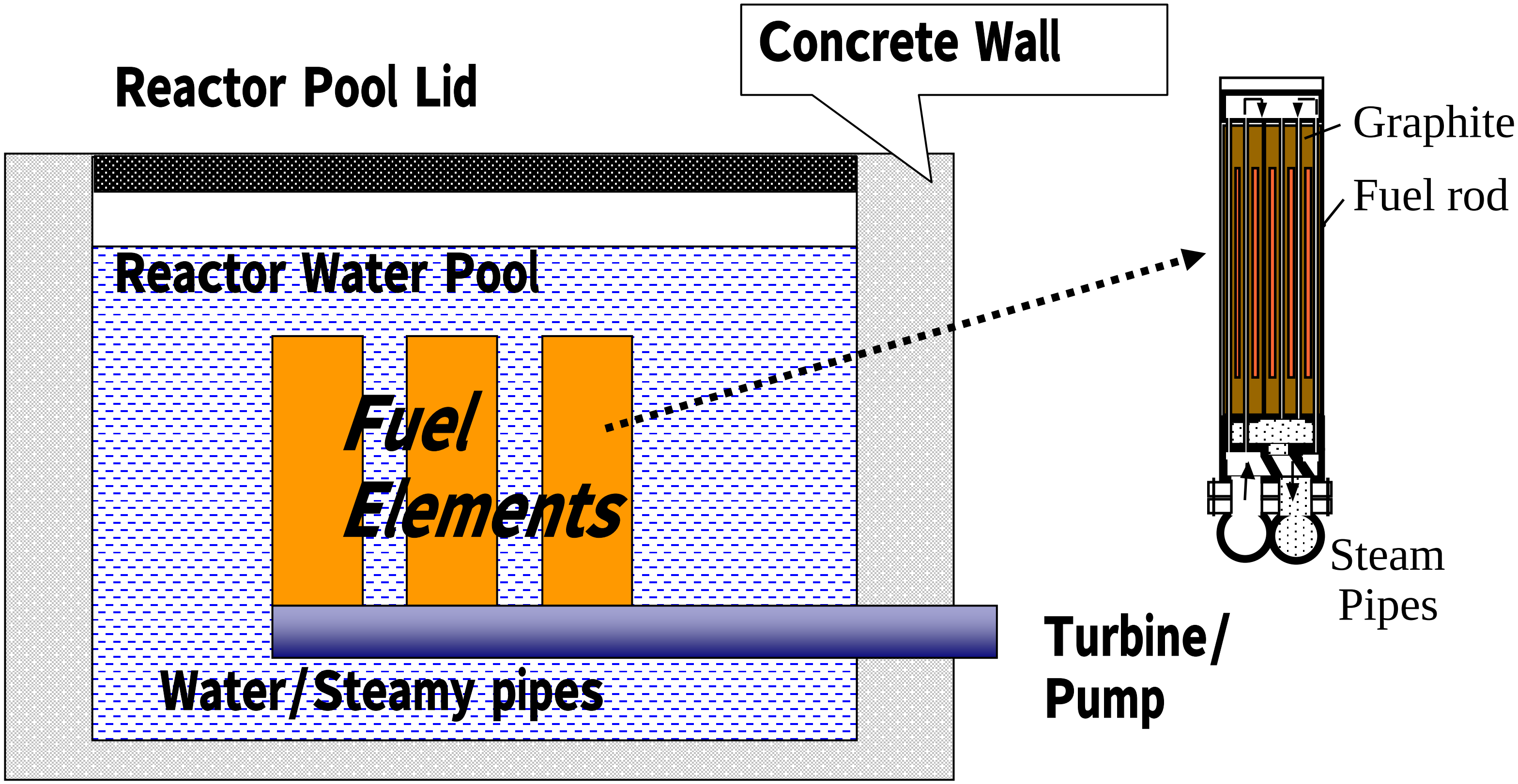
Overview of "KAMADO"



"KAMADO" core consists of fuel elements of graphite blocks, in which **UO_2 fuel rods** and **cooling water pipes** are contained. **Fuel elements** are located in a **reactor water pool** of atmospheric pressure (1 atm.) and low temperature (< 60 ^{0}C).

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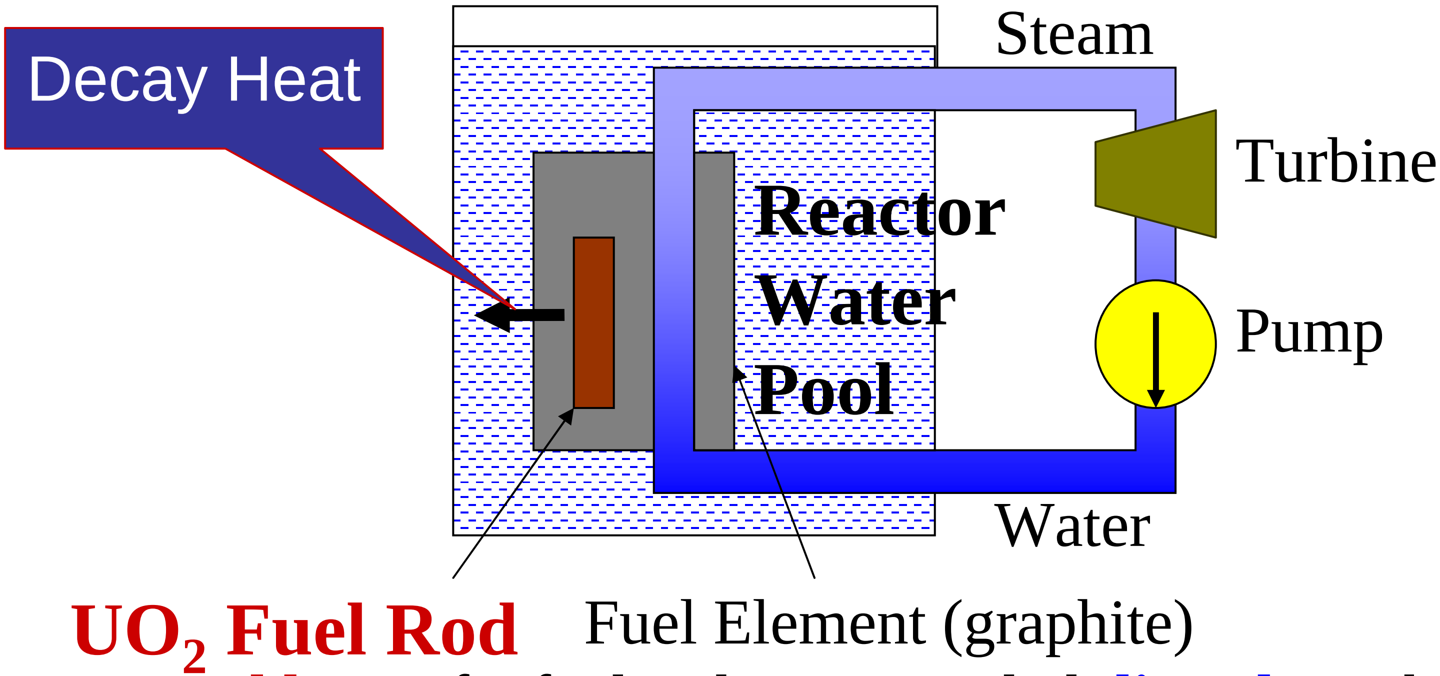
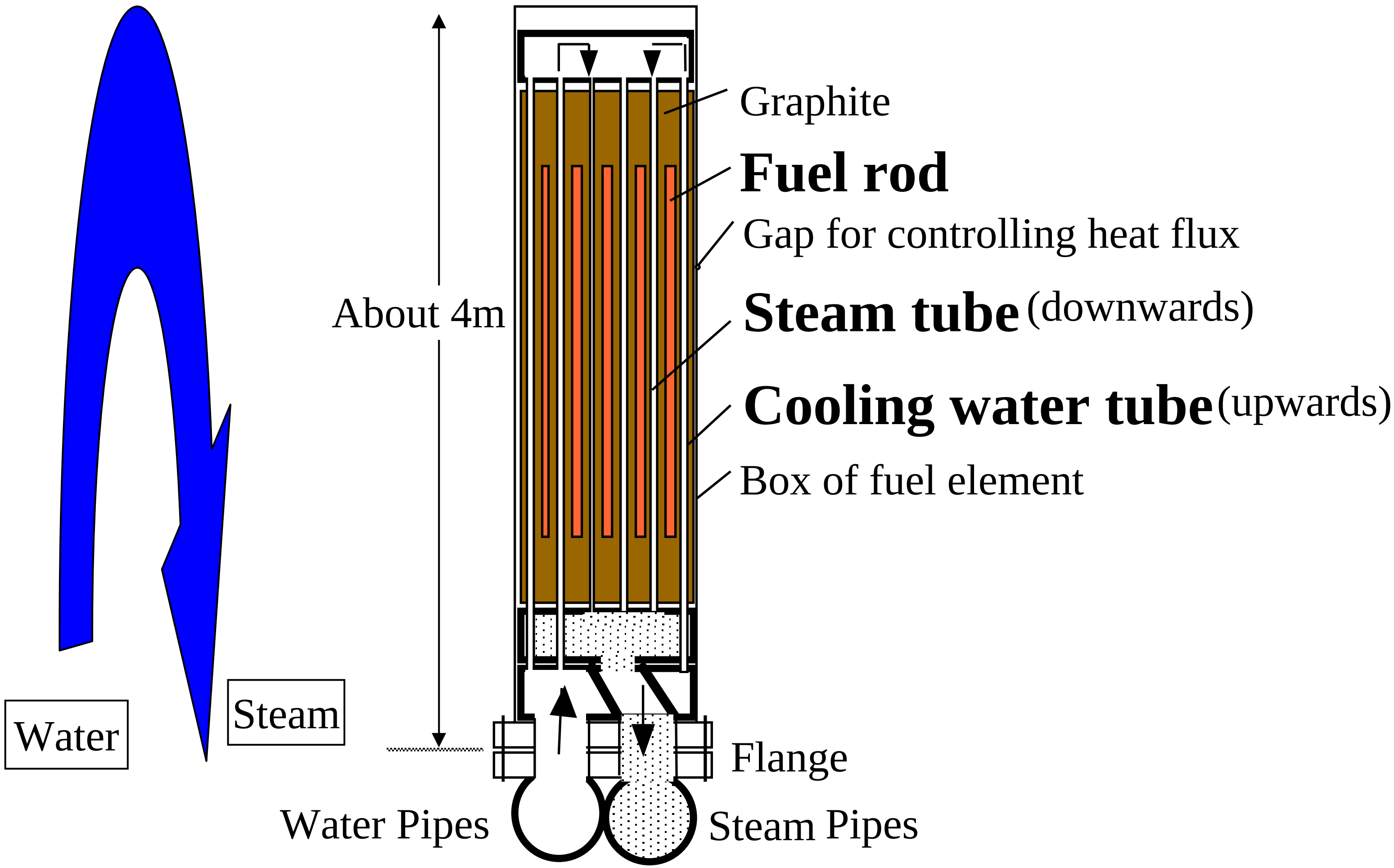
Basic concept of “KAMADO”



Generated heat of a fuel rod is **not** cooled **directly** with **cooling water** but cooled via graphite blocks of a fuel element.

In case of **LOCA**, **decay heats** of fuel rods are **naturally transferred** to the reactor pool after the **reactor stops passively**.

Concept of a fuel element



Cooling water is fed from the bottom of the fuel element. Heated steam is also discharged from the bottom of the fuel element.

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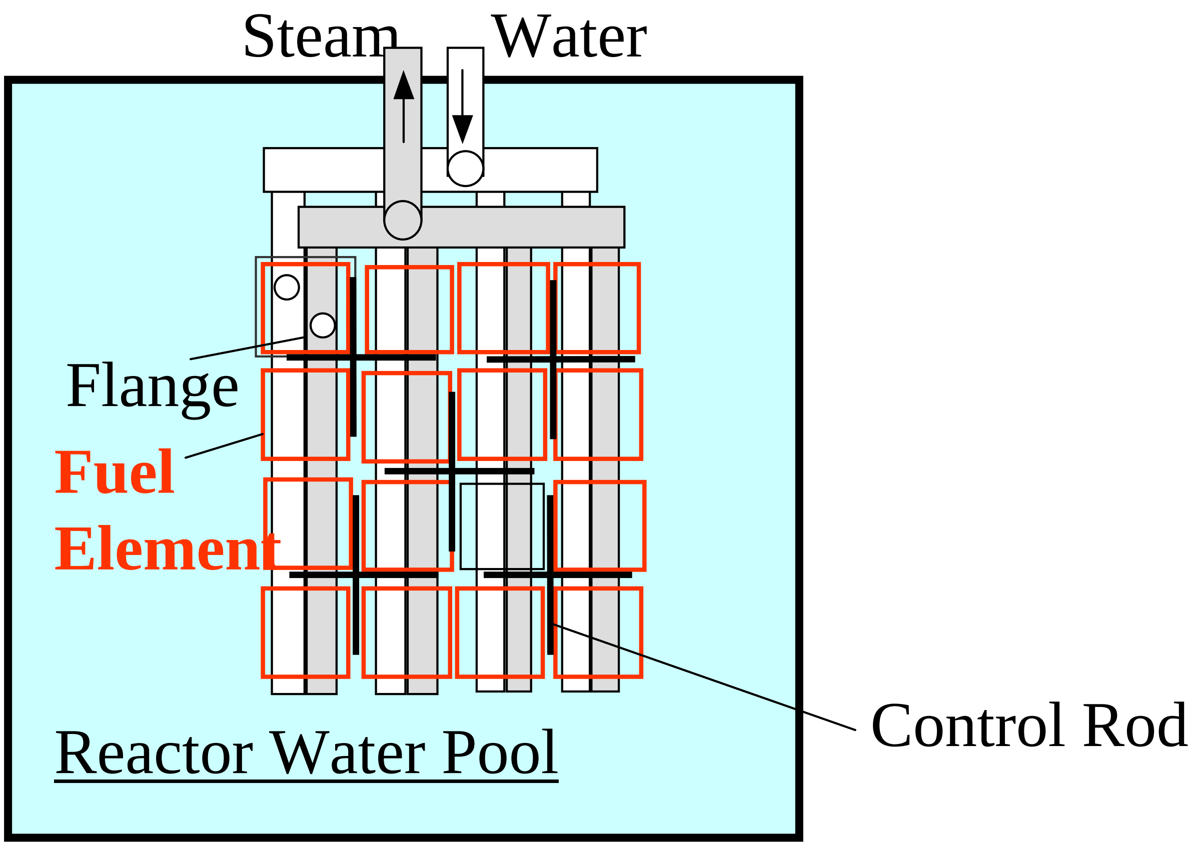
Fuel elements in the reactor water pool



The core consists of two or more **fuel elements**, **control rods**, etc. within the **reactor water pool**.

What is "KAMADO"

KAMADO is a Japanese traditional kitchen range with firewood.

Tentative design parameters of the fuel element and reactor core

Items	Values
Fuel rod/cooling tube pitch	13.1 mm (d=3 mm)
Fuel element size	223 mm x 223 mm
Number of fuel rods in a fuel element	60
Liner heat rate of a fuel rod	20 kW/m
Height of a fuel rod	3 m
Thermal output of a fuel element	3.6 MW
Thermal output of core	1000 MW (~300 MWe)
Number of fuel elements in a reactor core	278
core size	4.5 m x 4.5 m

"d": Distance between the outer surfaces of a fuel rod and a cooling tube.

Neutronic characteristics of reactor core

- Void coefficient :

  -15 % $\delta k/k$ at 40% void, BOL

- Temperature coefficient of graphite :

  -2.3E-4 % dk/k/^{0}C

  enough negative void coefficients

Continuous energy Monte Carlo code MVP calculations

- Possibility of high burn-up (more than 55 MWd/kgU) with 5% enriched UO_2 fuels.

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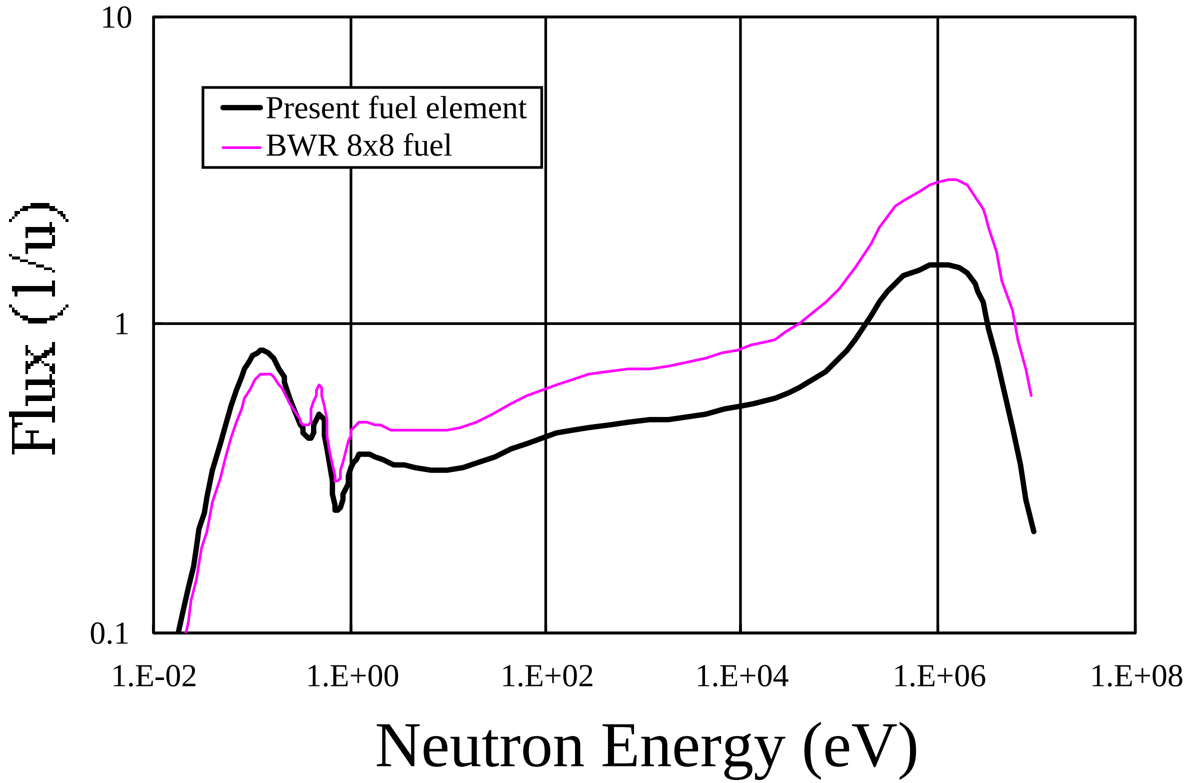
Neutron Energy Spectrum



Neutron energy spectrum of the fuel element is a little softer than that of BWR 8x8 type of fuel, because of neutron moderation effect of graphite.

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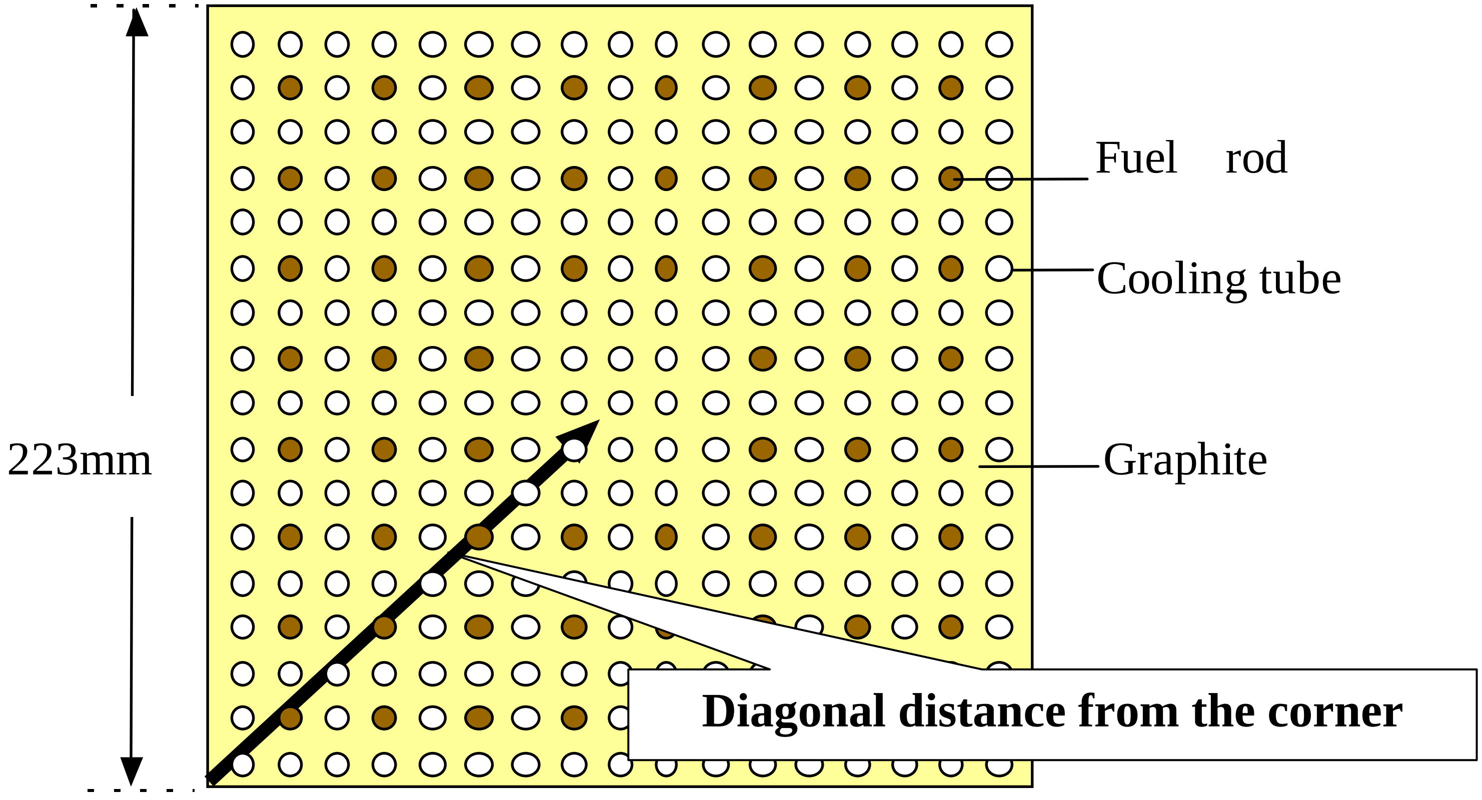
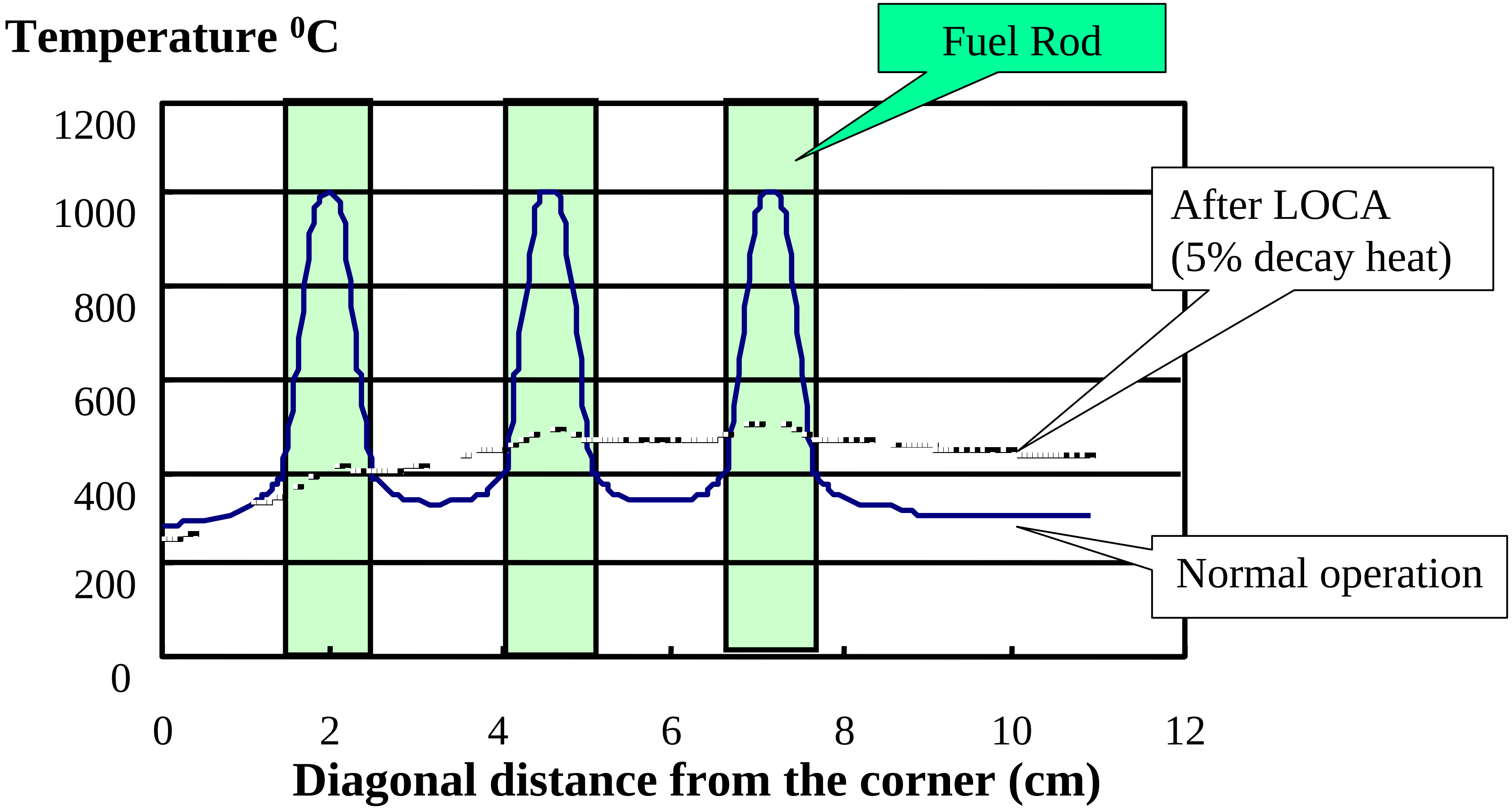
Fuel rods arrangement within a fuel element



The tentative design of the fuel element has 60 fuel rods and 229 cooling water/steamy tubes.

Temperature distribution of the fuel element



After **LOCA** (5% decay heat, decay heat at 13 seconds after reactor stop), maximum temperature of graphite is < 500 ^{0}C **without** heat removal of cooling water tubes.

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Passive-Safety Feature

- **Reactor Stop**

  by negative void reactivity coefficients

- **Decay Heat Removal**

  by natural heat transfer to the reactor pool

- **Isolation of “hot” material**

  by no-interface between fuel and coolant, and multiple barricades

⇨ **<u>3 days away safety of operators</u>**

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Advantages of A Reactor Concept of "KAMADO"

- Passive-safety, which has negligible possibility of core melting.
- Flexibility of total reactor power from small scale (order of MW) to large scale (order of GW) with module composition of a reactor core.
- Sufficiently low construction cost comparing with conventional large scale LWRs by simple plant system design without a reactor pressure vessel, ECCS, re-circulation systems (of BWR) and others.
- Easy development and demonstration, because LWR technology (including fuel rods) can be used for development of the present concept and irradiation test of fuel element can be carried out in existing test reactors.
- Small amount of radioactive waste and simple and easy maintenance because of small radiation area.

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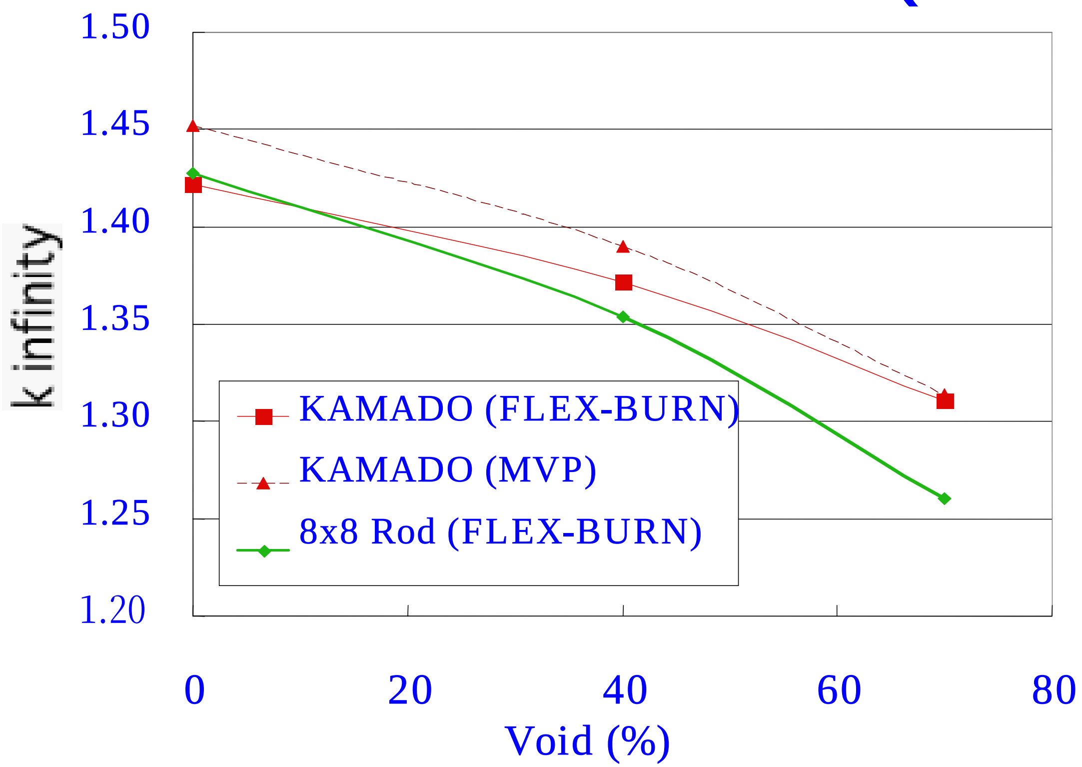
Preliminary Neutronic and Thermal-Hydraulics Evaluation of a Fuel Element.

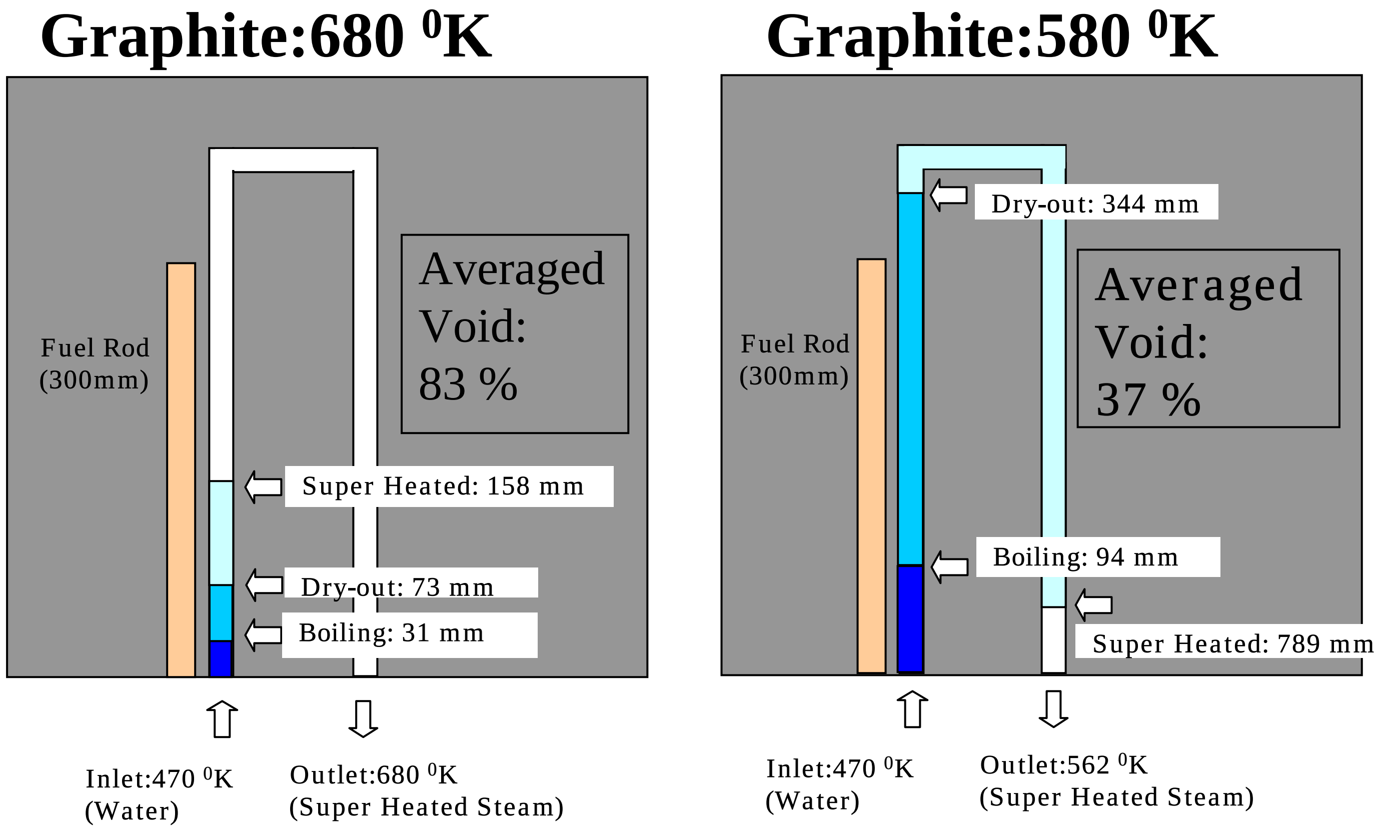
- Void coefficient is calculated with Multi-grouped transport code FLUX-BURN and continuous energy Monte Carlo code MVP
- Two phase flow of a fuel element is evaluated considering dry-out and super-heat

K-infinity of a fuel element vs. void ratio (BOL)



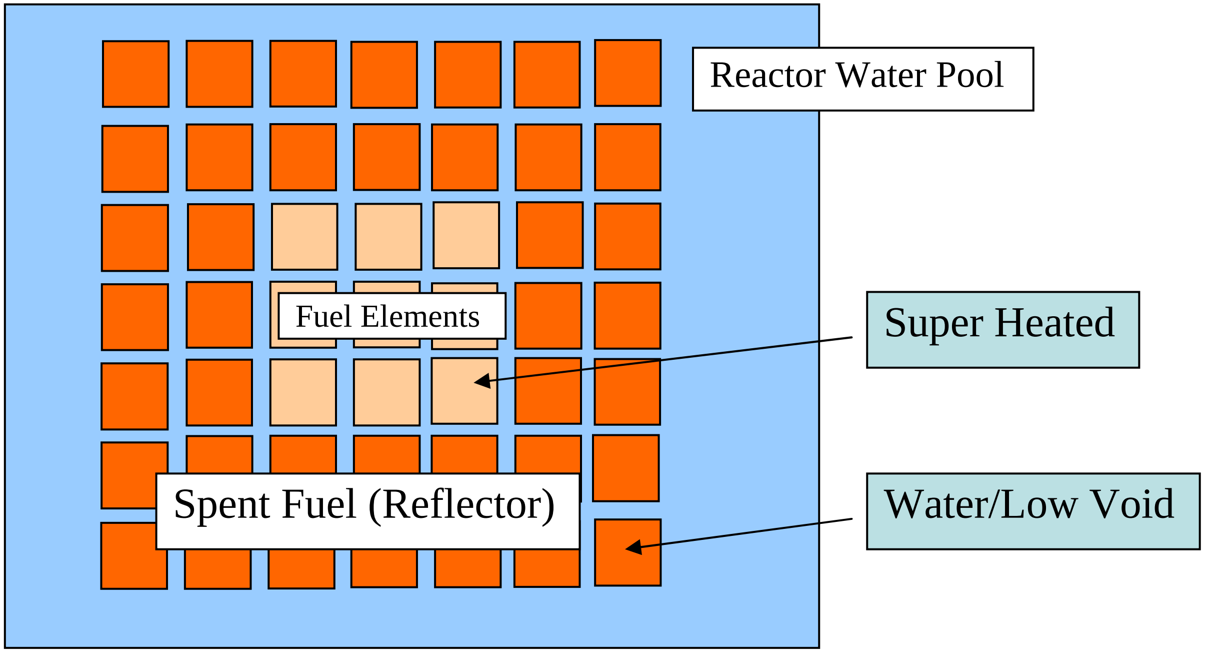
Difference between results of FLUX-BURN and MVP show complexity of resonance shielding on the fuel element consist of UO_2, graphite and H_2O.

Preliminary two phase flow evaluation of a fuel element



Since cooling water does not contact a fuel rod directly, considerations of **dry-out limitation** and **MCPR** are **not necessary**. Therefore **super-heated steam** is taken out from the fuel element.

Use of spent fuel elements in the reflector region



Spent fuel elements put on the **reflector region** of the nuclear reactor core, a certain amount of burn-up of nuclear fuel is expectable. If a spent fuel of 60 MWd/kg can be burned more 10 MWd/kg in the reflector region, it will become **effective use** of 17% of **uranium resources**.

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Summary

- **Ability of a new concept passive-safety reactor "KAMADO** ;
  - Safety: negligible possibility of core melting without engineered safety systems
  - Economy: flexibility of total reactor power with sufficiently low construction cost
- **Preliminary neutronic and thermal-hydraulics evaluation of a fuel element;**
  - Difference between results of FLUX-BURN and MVP show complexity of resonance shielding on the fuel element consist of UO_2, graphite and H_2O
  - Since cooling water does not contact a fuel rod directly, considerations of dry-out limitation and MCPR are not necessary. Therefore super-heated steam is taken out from the fuel element.
  - Importance of relation of thermal output and void feedback in a fuel element for the stability of the reactor core.
- **If spent fuel elements put on the reflector region, a certain amount of burn-up of nuclear fuel, and effective use of uranium resources is expectable.**