Results of Safety Assessment Tests (Stress Tests) for HTGR

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Technical Meeting on the Safety of High Temperature Gas Cooled Reactors in the Light of the Fukushima Daiichi Accident
April 8 – 11, 2014, Vienna, Austria

Beyond-Design Basis Accidents Scenarios for Safety Analysis

For safety analysis of the MHR-HTE reactor plant in beyond-design-basis accidents (BDBA), the following accidents initiated by seismic impact are selected:

A)loss of power supply sources; scram actuated and heat removed by the RCCS:

B)loss of power supply sources, non-actuation of the reactor scram and heat removed by the RCCS

C)total blackout, with a loss of power supply sources and RCCS failure

D) loss of power supply sources, depressurization of the primary circuit and heat removed by the RCCS

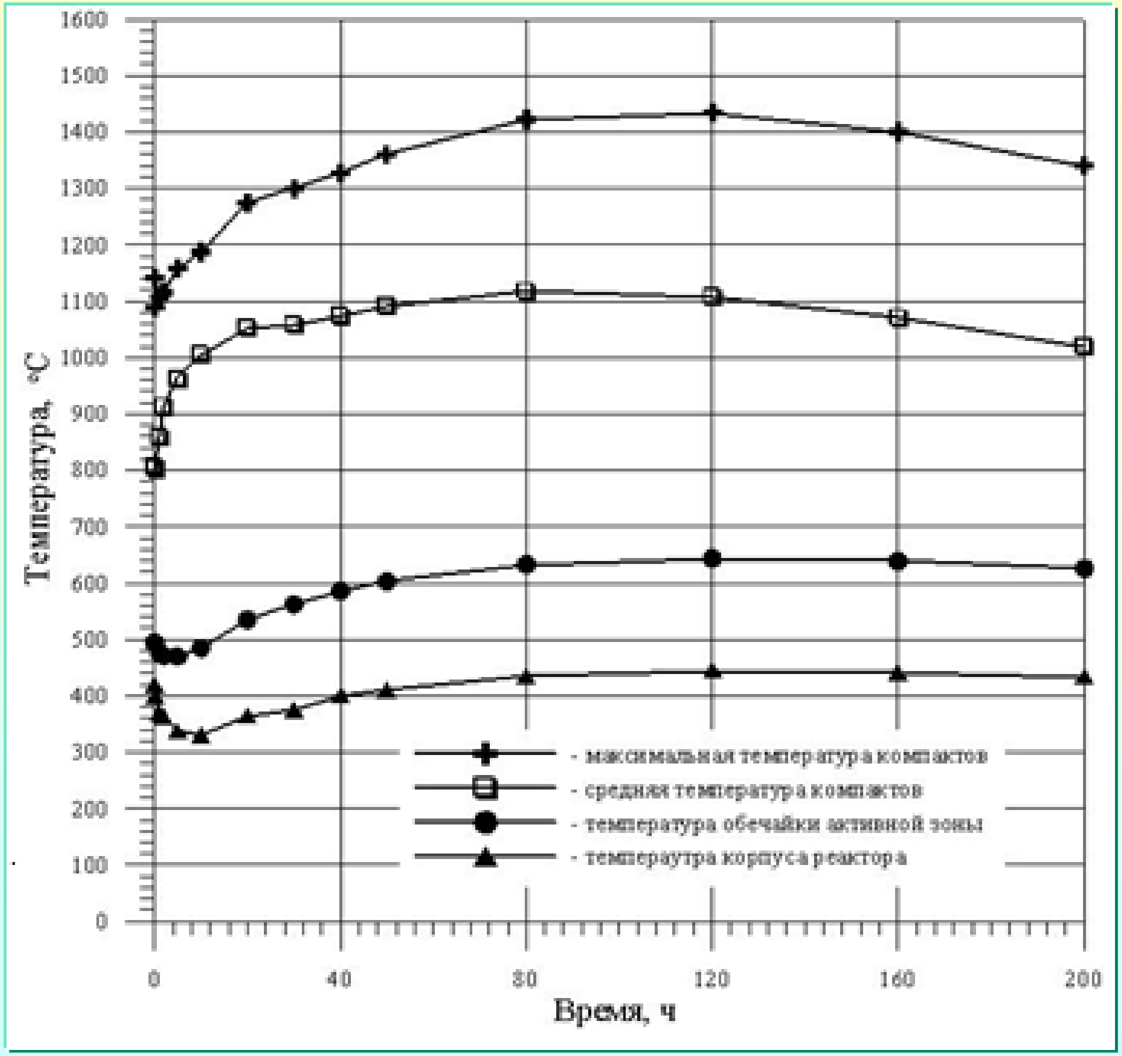
E) loss of power supply sources, inter-circuit leak in the steam generator and heat removed by the RCCS

Loss of power supply sources; scram actuated and heat removed by the RCCS

Peak temperatures of core components , metal structures and internals of the reactor vessel are reached after 80-120 h after the onset of the initial event and are as follows:

- fuel blocks, including fuel compacts – 1435°C ;
- core shell - 635 °C ;
- baseplates - 340 °C ;
- reactor vessel - 420 °C .

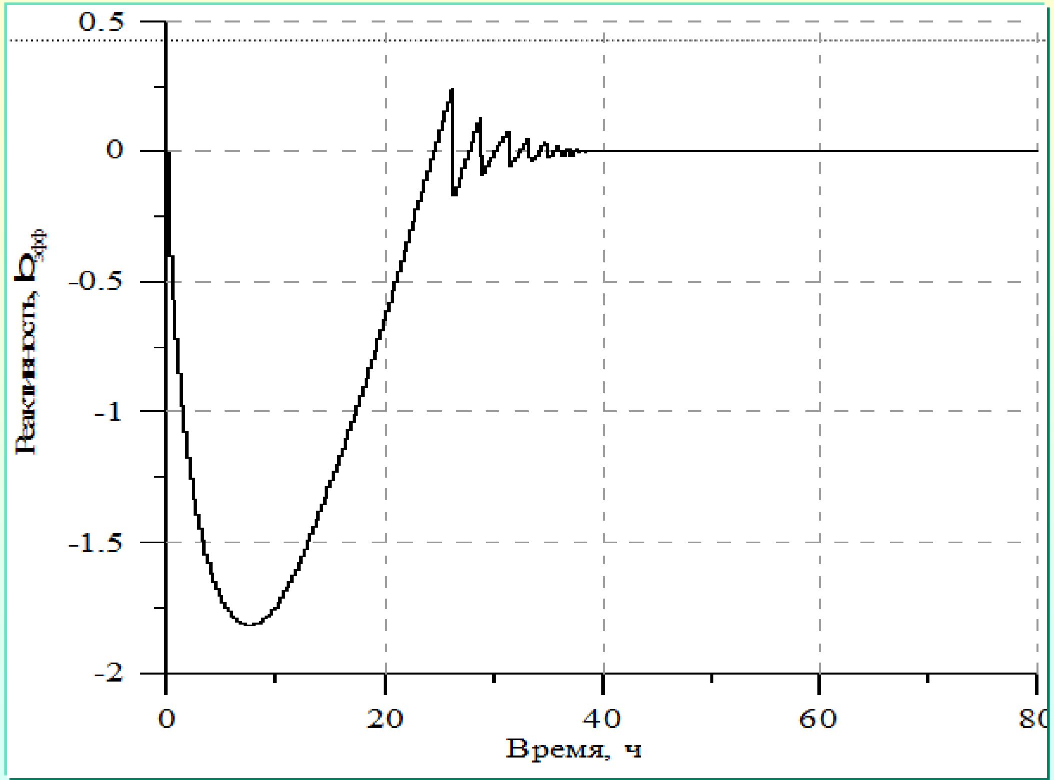
These values do not exceed the design limits of safe operation



Loss of power supply sources, non-actuation of the reactor scram and heat removed by the RCCS

In this situation, the reactor is in the correlated changes in key parameters : temperature , reactivity , power .

At - 25 hours the reactor reaches the secondary criticality with subsequent increase of its power and , accordingly, the fuel temperature, until the steady poisoning with compensation due to the negative temperature coefficient of reactivity (40 – 50 h since an accident) .



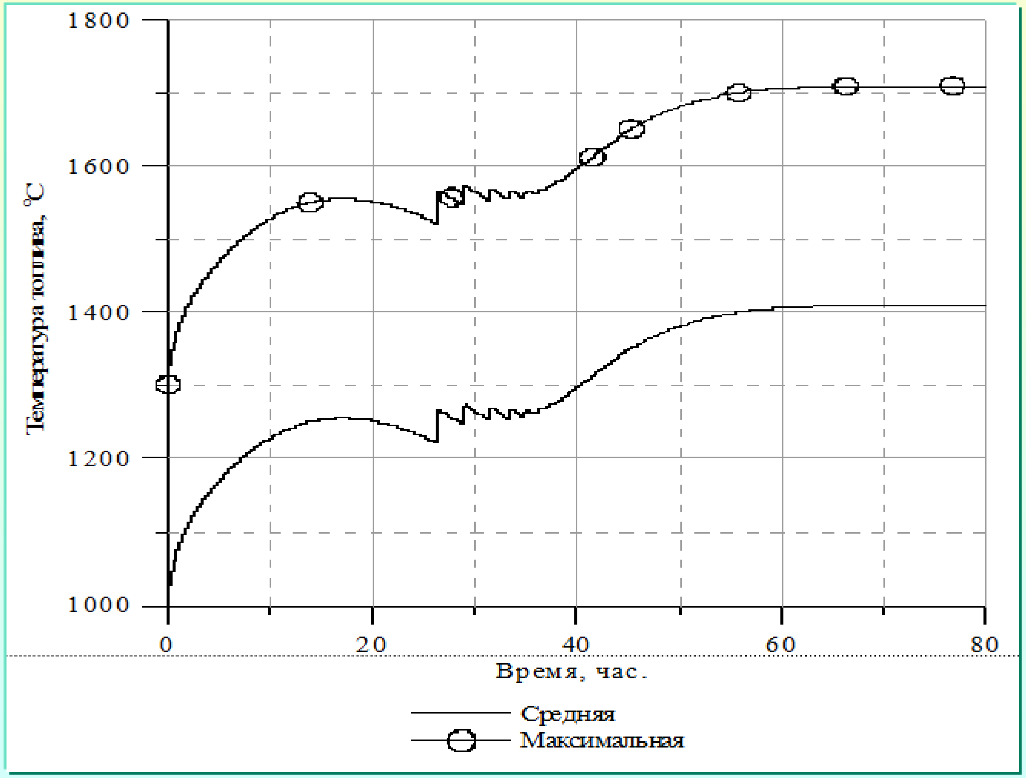
Loss of power supply sources, non-actuation of the reactor scram and heat removed by the RCCS

The average fuel temperature stabilizes at 1400ºC, and the maximum at 1700ºC.

Grace period for accident management measures with the purpose to ensure design basis accidents limits for the fuel temperature in the core (1600ºC) is at least 40 h.

These measures are to initiate actuation of control rod drive or RSS remotely by using available tools for these purposes in the control room.

Unless steps are taken to manage the accident, the reactor will be in the stationary self-oscillation power mode, characterized by a maximum temperature level of the fuel at 1710ºC for a long time.

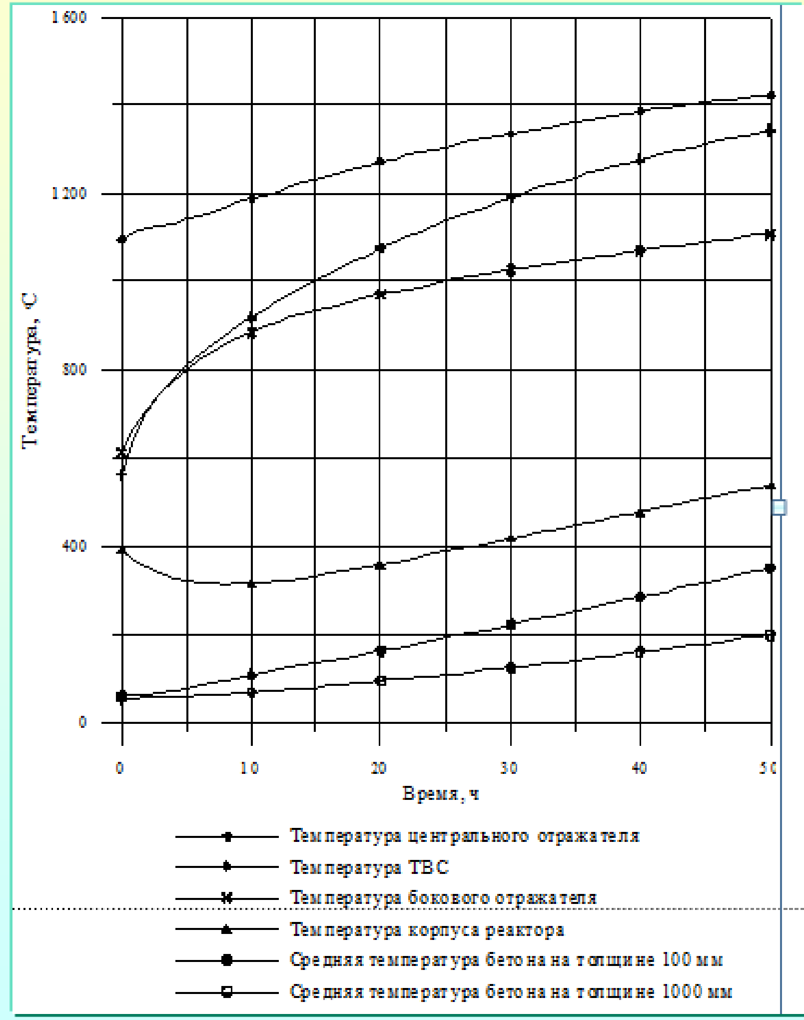


Total blackout, with a loss of power supply sources, reactor scram and RCCS failure

-Within about 50 hours after the beginning of the accident temperatures of the fuel, reactor vessel and concrete shaft do not exceed the maximum permissible values: fuel temperature is 1420°C, reactor vessel temperature is 525°C, by ~ 100°C higher in comparison with situation of normal RCCS operation. This level of temperature does not exceed the maximum permissible value from viewpoint of integrity of the reactor vessel.

-The average temperature of the 150 mm thick concrete layer is 340°C, while the average temperature of the concrete layer with 1000 mm thickness is 190°C. At these temperatures the loss of bearing capacity of building structures of the reactor cavity is excluded

- However, the process characterized by a fairly rapid growth of temperature of metal internals and reactor cavity that determines the need for timely action on accident management.



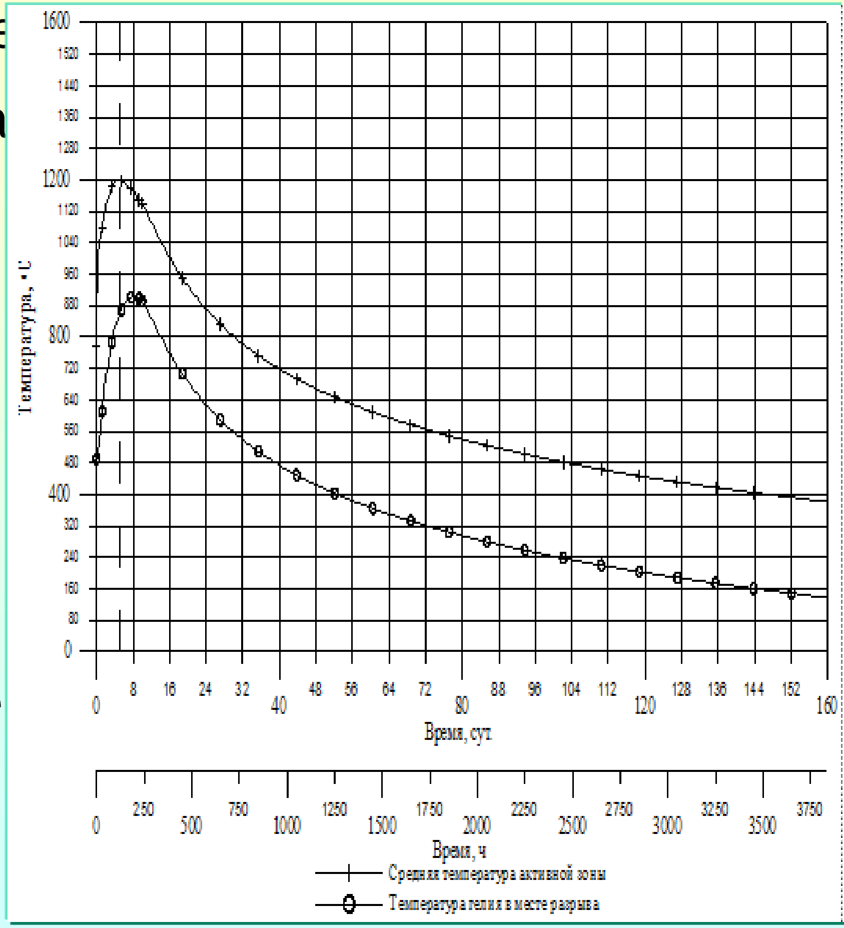
Loss of power supply sources, depressurization of the primary circuit and heat removed by the RCCS

-In the analysis of the accident it was assumed that all the air present in the shaft reactor is fed into the reactor oxidizing the heated core graphite

-In the development of the accident takes place a slow cooldown of the reactor by RCCS in the presence of mass transfer between the atmosphere, containment, reactor and core .

- According to calculations, core graphite temperature decreases during cooldown to 400 °C (the temperature at which practically stops the oxidation of graphite) for about 140 days.

- The depth of the graphite oxidation zone does not exceed 2.93 mm when the thickness of the graphite layer between the surface of the channe for the coolant and the external surface of compact is 4.65 mm. Consequently, in this accident oxidation of compacts is excluded



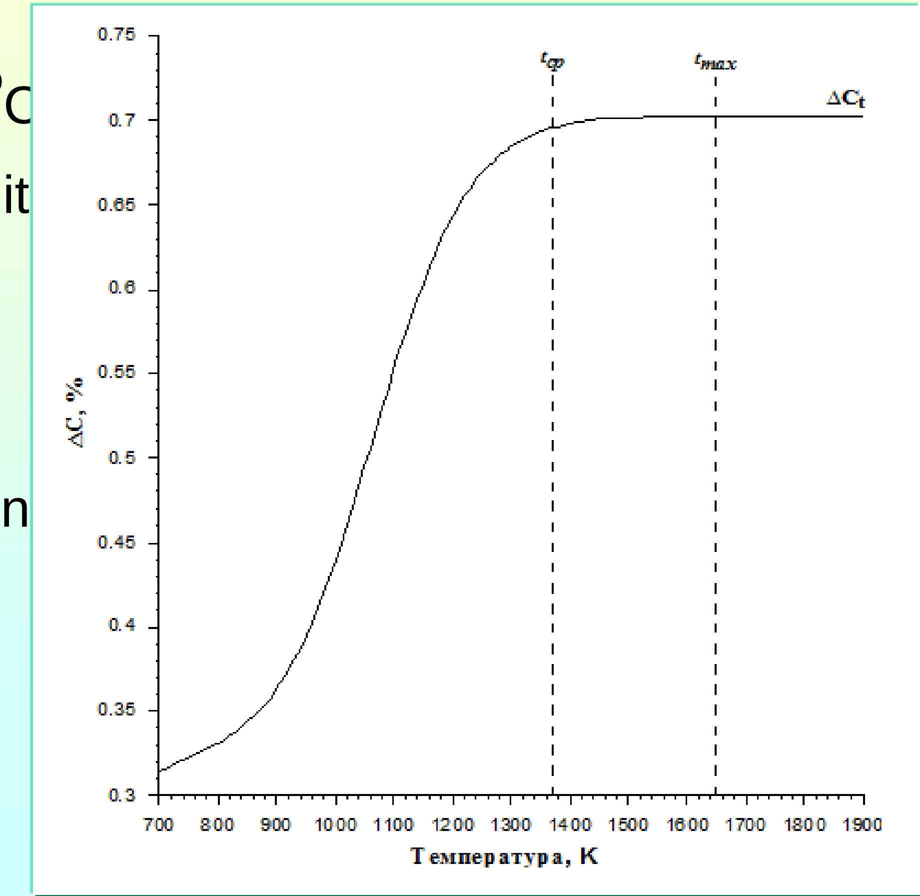
Loss of power supply sources, inter-circuit leak in the steam generator and heat removed by the RCCS

- Analysis assumes that at the SG depressurization the entire volume of water contained in it is thrown in the reactor (1200 kg).

- Estimation of amount of oxidized graphite was conducted in a conservative assumption of its maximum constant temperature achieved during the reactor cooldown by SCCR to 700°C

- In accordance with this, the fraction of graphit reacted with water is ~ 0.7 %, which corresponds to ~ 800 kg of oxidized core graphite core.

- In this case, as in accident with the depressurization of the primary circuit, the oxidation of microfuel with damage of its coatin is excluded



Analysis of the radiological consequences of accidents

- Total blackout with reactor scram failure and with heat removal by SCCS that is characterized by the highest level of fuel temperature in the process of accident

The maximum effective dose to the population in the worst weather conditions at the site boundary (500 m from the reactor building) for the first year after the accident due to direct exposure pathways (cloud , inhalation, contamination of the surface of the earth) will be 4.4 mSv. The maximum radiation dose due to the consumption of locally produced food for the first year after the accident could reach 10 mSv .

Analysis of the radiological consequences of accidents

- Total blackout with depressurization of the primary circuit and with the heat removal by RCCS characterized by increased release of radioactivity from the reactor due to loss of its integrity

The maximum effective dose to the critical group of the population in the worst weather conditions at the site boundary (500 m from the reactor building) for the first year after the accident due to direct exposure pathways (cloud , inhalation, contamination of the surface of the earth) will be about 25 mSv. The maximum radiation dose due to the consumption of locally produced food for the first year after the accident, may be about 50 mSv.

At this level of exposure, in accordance with the criteria established in the Russian regulation, the need for evacuation or relocation of the population is eliminated. Measures to protect the population are reduced mainly to limit the consumption of locally produced food

Conclusions

In accidents with a total unit blackout but with maintaining of operation of the reactor cavity cooling system (SCCR) compliance is provided with the established limits for the design basis accident temperatures for fuel, reactor vessel internals and metalwork.

At adding to the original event of failure of either SCCR or all means of reactor shutdown, time to transition to the stage of a severe accident is not less than 40 hours.

Temperature state of the core during accidents with depressurization of the primary circuit and interloop steam leak is close to the case with total blackout of the unit and its cooldown by SCCR. Under the conditions of these accidents oxidation of microfuel with damage of its coatings is excluded.

For all considered accidents, in accordance with the criteria established in the Russian regulation, the need for evacuation or relocation of the population is eliminated. Measures to protect the population are reduced mainly to limit the consumption of locally produced food

Beyond-Design Basis Accidents for the Safety Analysis

For a safety analysis of the MHR-HTE reactor plant in beyond-design-basis accidents (BDBA), the following accidents are selected:

A)seismic impact with a loss of power supply sources and heat removed by the RCCS:

B)seismic impact with a loss of power supply sources, non-actuation of the reactor scram and heat removed by the RCCS

C)seismic impact with a total blackout, with a loss of power supply sources and RCCS failure

D) seismic impact with a loss of power supply sources, depressurization of the primary circuit and heat removed by the RCCS

E) seismic impact with a loss of power supply sources, inter-circuit leak in the steam generator and heat removed by the RCCS