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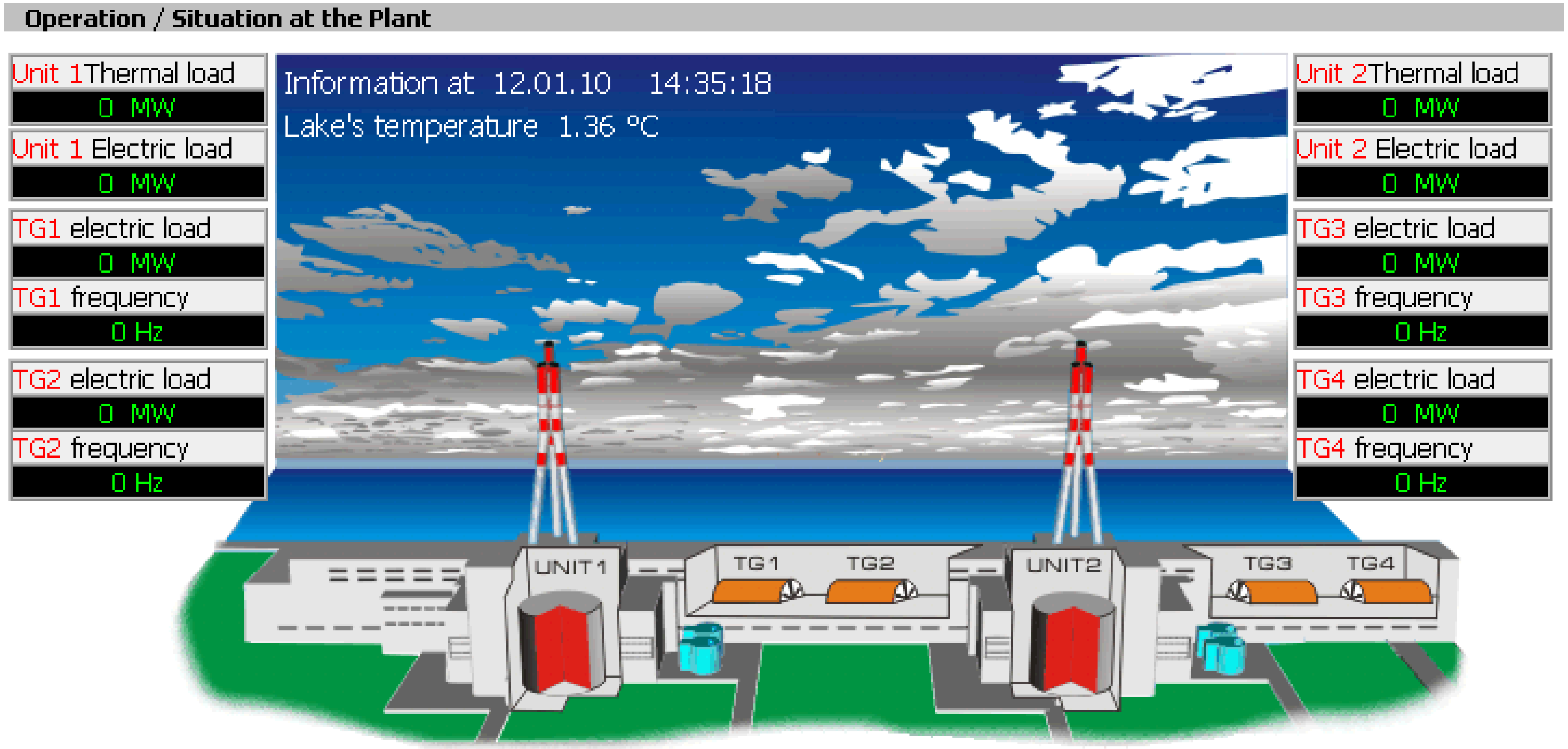
Safety Assessment of Shutdown Reactors at the Ignalina NPP

Outline

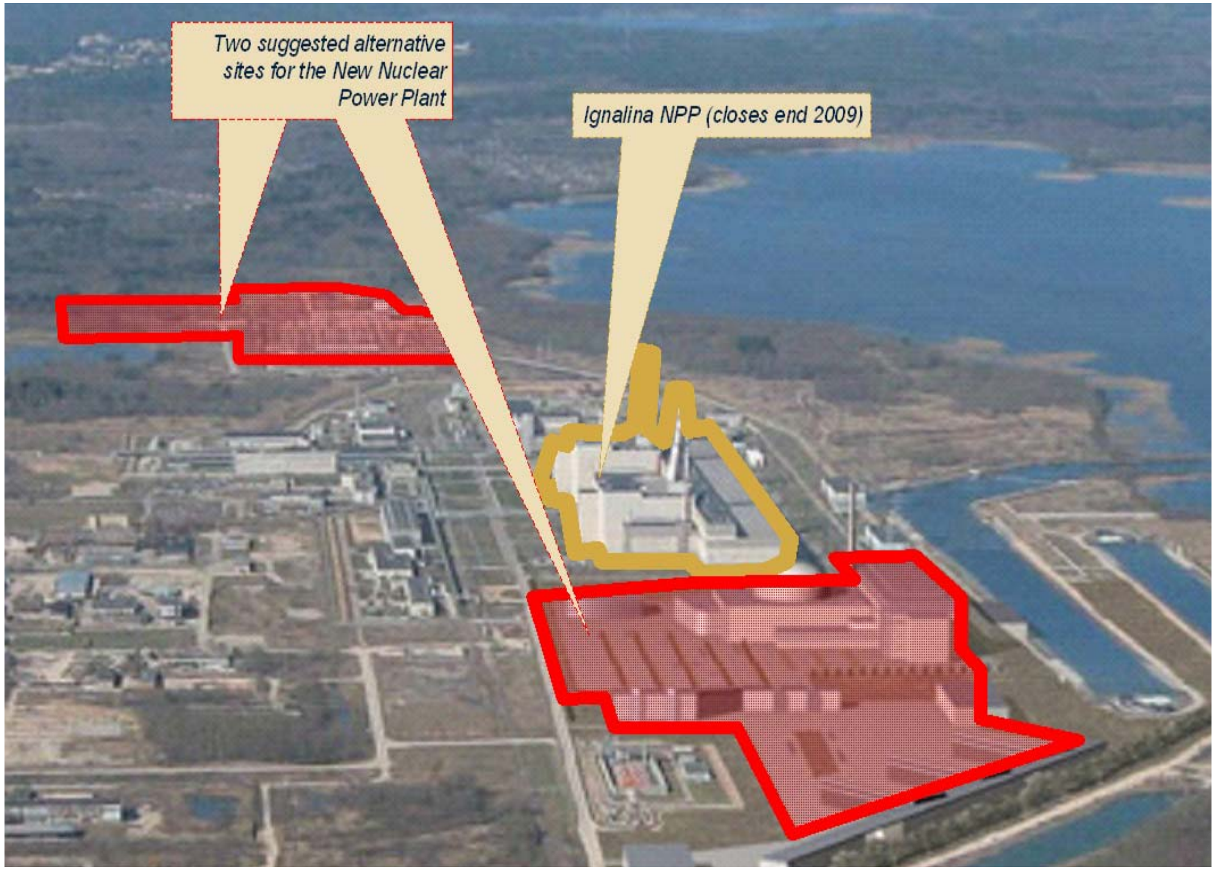
- Introduction
- Specific of heat removal from shutdown RBMK-type reactor
- RELAP5-3D model of shutdown and cooled RBMK-1500 reactor of Ignalina NPP
- Analysis of loss of heat removal in finally shutdown reactor of unit 2 of Ignalina NPP
  - Analysis of station blackout case at shutdown reactor
  - Analysis of water flow rate blockage through FC at shutdown reactor
- Analysis of heat removal from shutdown reactor of unit 1 of Ignalina NPP when circulation circuit is filled by air
- Conclusions

INTRODUCTION (1)



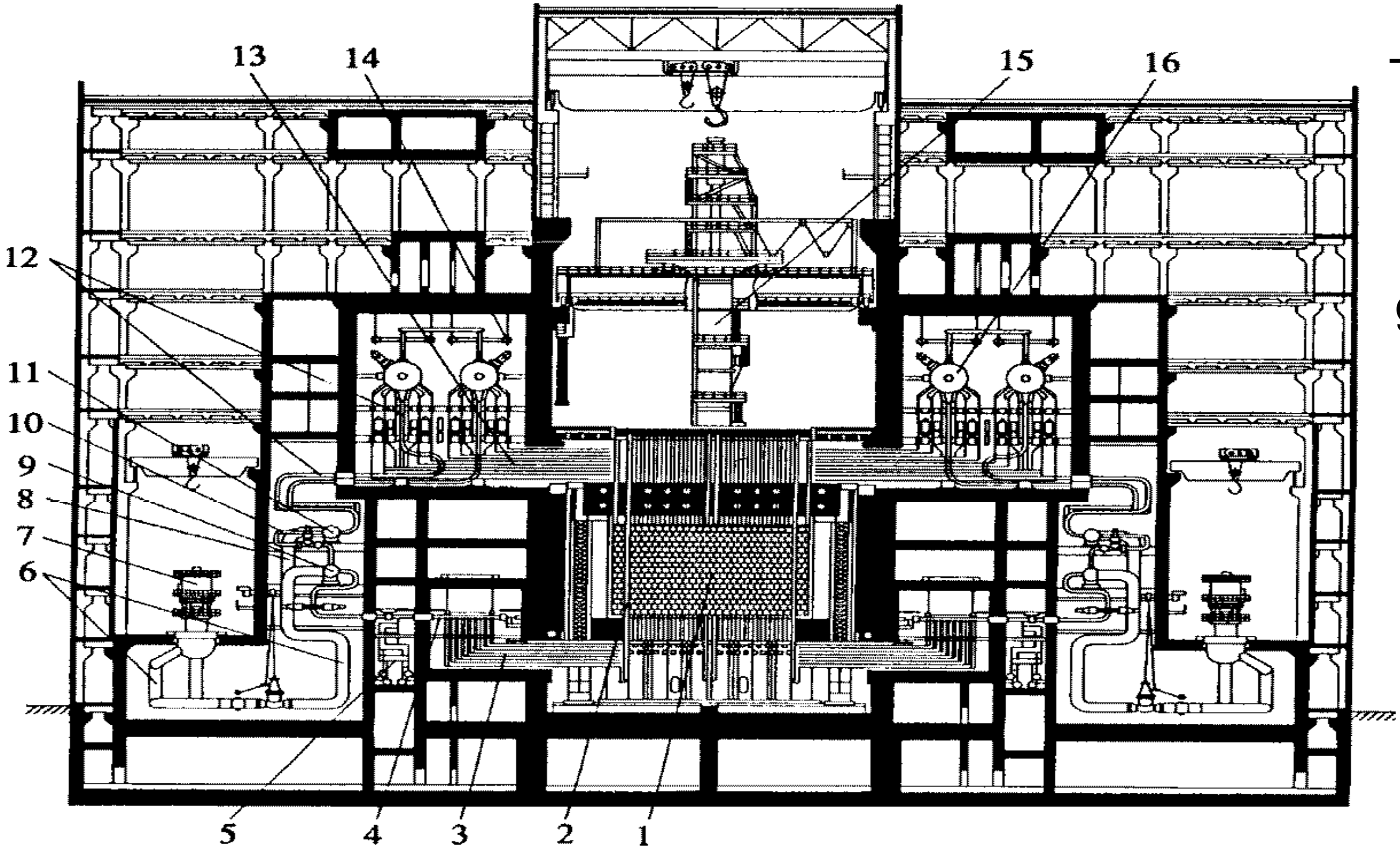
- Ignalina NPP – two units of RBMK-1500, commissioned in 1983 and 1987, shutdown for decommissioning at the end of 2004 and 2009.
- In time period 1984 – 2009 Ignalina NPP produced up to 82% of electric energy for Lithuania.

INTRODUCTION (2)



- A decree endorsed by Lithuanian Parliament in June, 2007 about construction of a new NPP in Lithuania in cooperation with Latvia, Estonia and Poland.

INTRODUCTION (3)



The Ignalina Nuclear Power Plant is a twin-unit with two RBMK-1500, graphite moderated, boiling water, multichannel reactors.

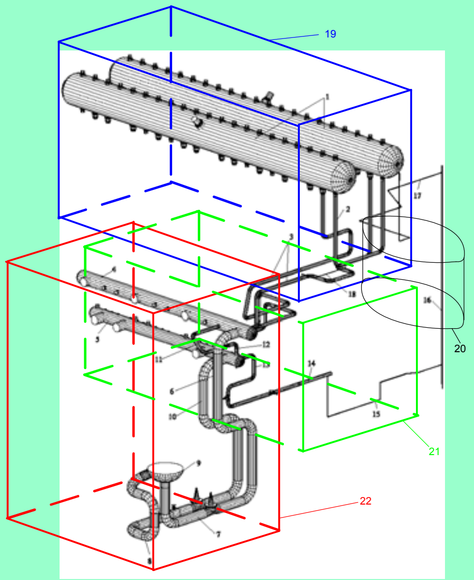
P_{nom} = 7 MPa.
Design thermal power 4800 MW.
Electrical power 1500 MW.

INTRODUCTION (4)

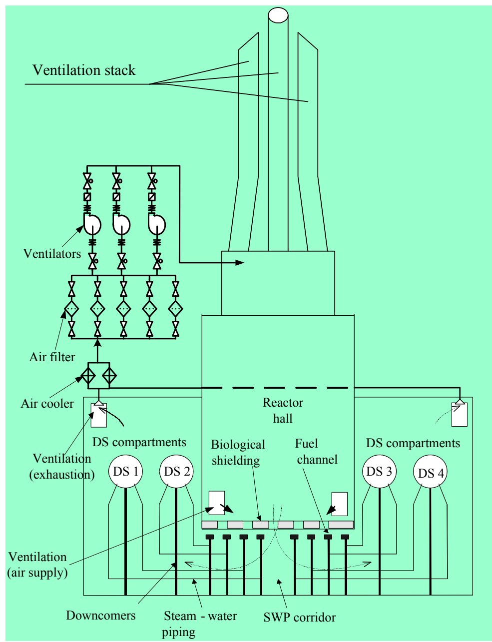
Acceptance criteria for accident analysis in shutdown reactor

Parameter	Acceptance criterion
Subcriticality	Not less 0.02
Fuel channel power, MW	Below 4.25
Fuel linear power, W/cm	Below 485
Calculated temperature of the graphite stack, ^{o}C	not more than 760 ^{o}C (when the reactor space is pressurized by nitrogen and helium) no more than 350 ^{o}C (when the reactor space is pressurized by air)
Maximal fuel cladding temperature, ^{o}C	Below 700
Maximal fuel channel pressure tube temperature, ^{o}C	Below 650
Maximal Excess pressure in the RCS, MPa	Below 10.4
Heat-up rate of reactor and RCS, $^{o}C/h$	Below 30
Cooldown rate of the reactor and the RCS, $^{o}C/h$	Below 30
The annual effective dose to the population, mSv	Less than 1

SPECIFIC OF HEAT REMOVAL FROM SHUTDOWN RBMK-TYPE REACTOR



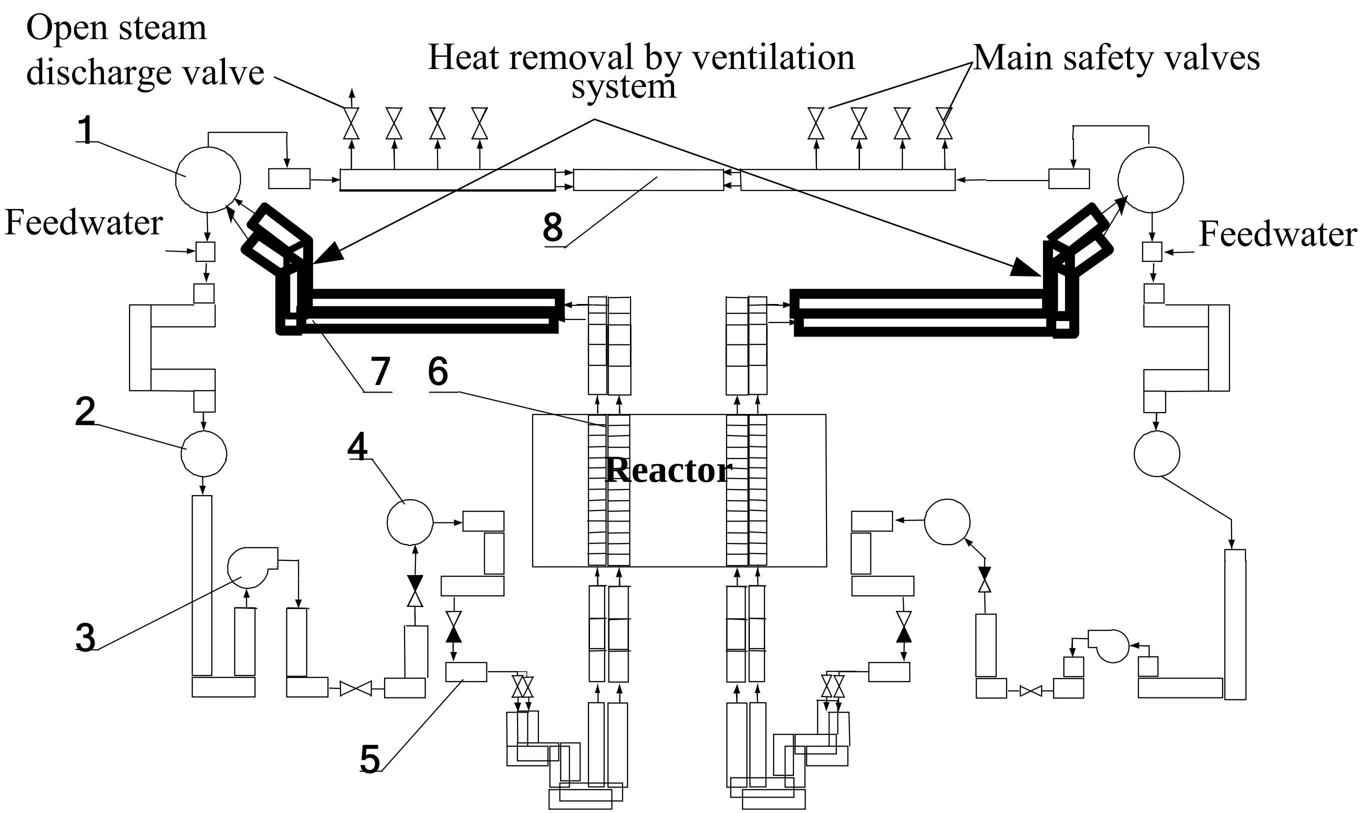
Tree-dimensional diagram of one loop of reactor cooling system, with schematic of compartments, covering main equipment



Schematic of air ventilation in reactor hall and DS compartments

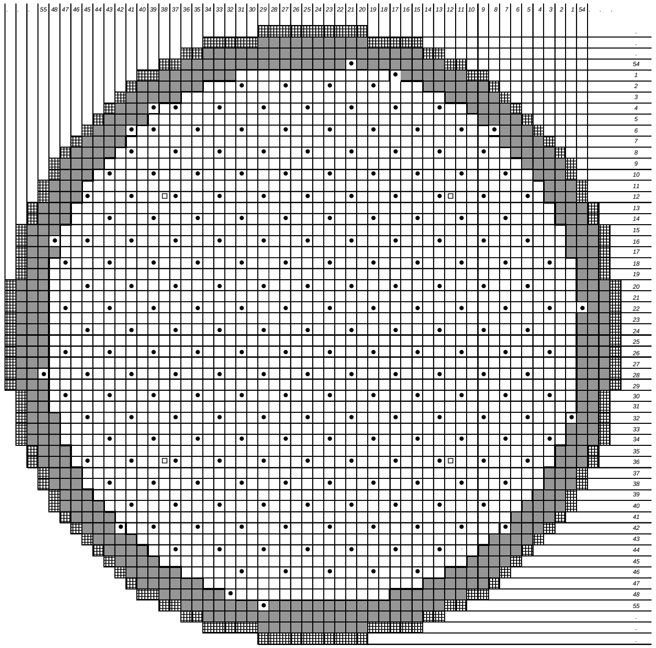
- Initial stage:
- temperature of water in FCs is 110 – 115 °C and temperature of graphite stack is 120 °C (~ 1 day after reactor shutdown).
- the constant decay heat level (13.99 kW in one fuel channel) was assumed.

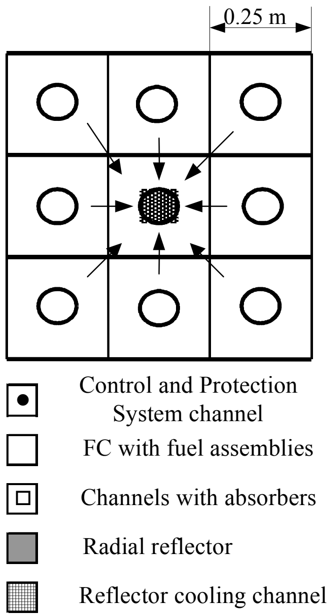
ANALYSIS OF LOSS OF HEAT REMOVAL IN FINALLY SHUTDOWN REACTOR OF UNIT 2 OF IGNALINA NPP (1)

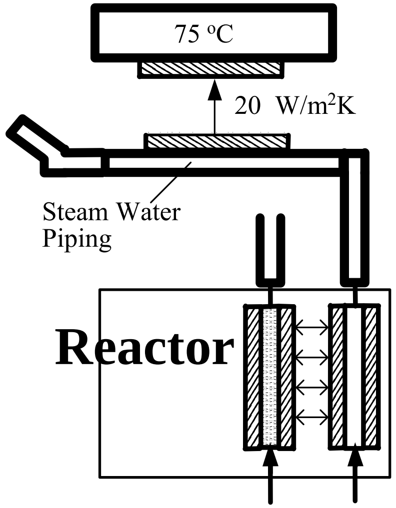


RELAP5-3D Nodalization scheme of shutdown and cooled RBMK-1500 reactor of Ignalina NPP

ANALYSIS OF LOSS OF HEAT REMOVAL IN FINALLY SHUTDOWN REACTOR OF UNIT 2 OF IGNALINA NPP (2)







RELAP5-3D Nodalization scheme for modelling of heat removal from SWP

Two most likely initiating events were analysed:

- station blackout case;
- blockage of water flow rate in the group of fuel channels.

ANALYSIS OF LOSS OF HEAT REMOVAL IN FINALLY SHUTDOWN REACTOR OF UNIT 2 OF IGNALINA NPP (3)

Station blackout during reactor cooling by coolant natural circulation mode

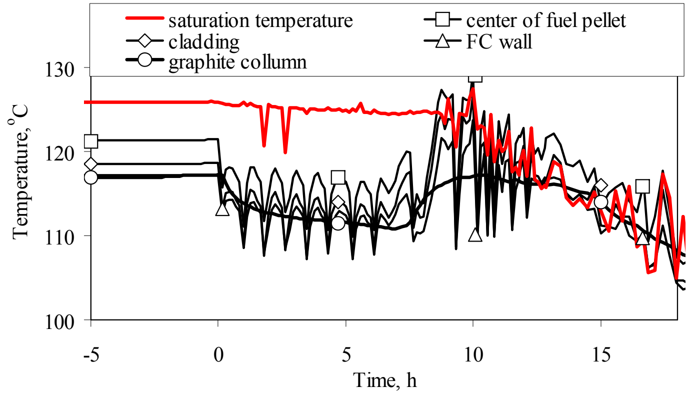


Fig. 1. Behaviour of temperature of the core components

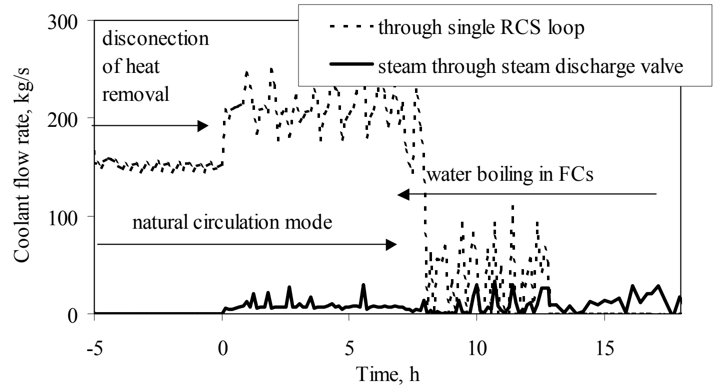


Fig. 2. Behaviour of coolant flow rate through FCs of one RCS loop

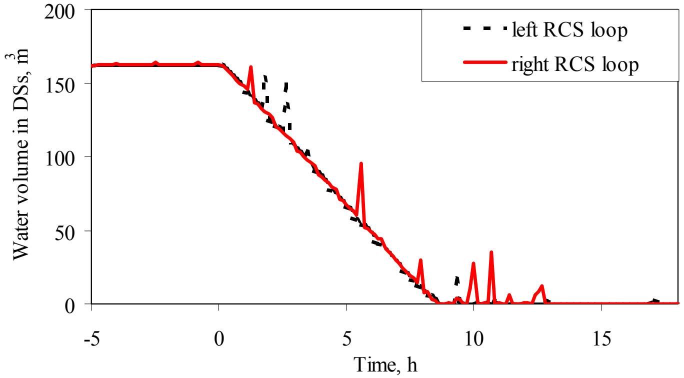


Fig. 3. Behaviour of water volume in both DS of one RCS loop

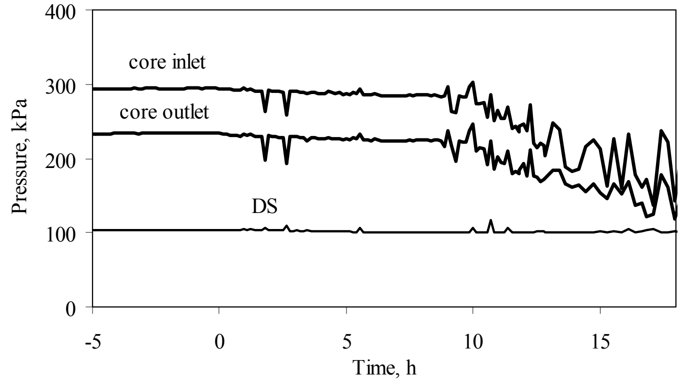


Fig. 4. Behaviour of pressure in RCS

ANALYSIS OF LOSS OF HEAT REMOVAL IN FINALLY SHUTDOWN REACTOR OF UNIT 2 OF IGNALINA NPP (4)

Coolant flow blockage in group of fuel channels of one RCS loop

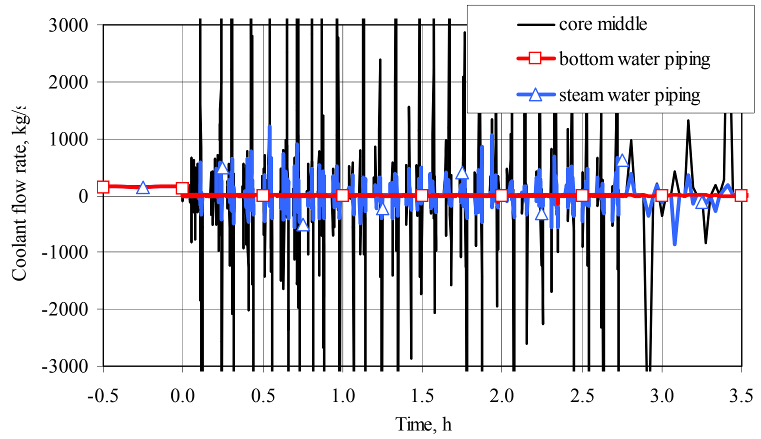


Fig. 1. Coolant flow rate through fuel channel

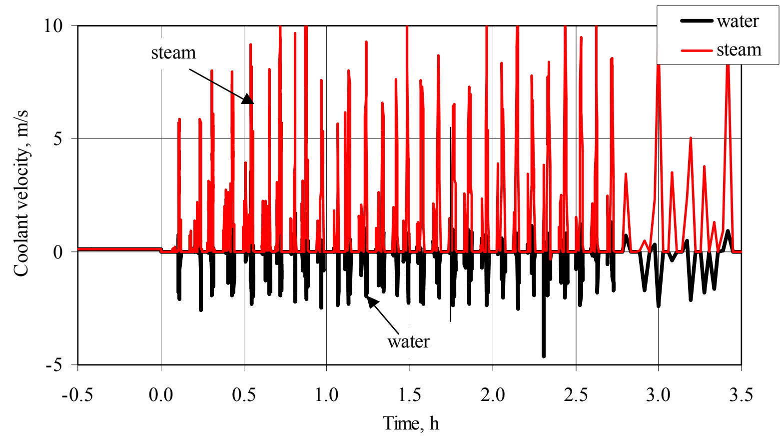


Fig. 2. Change of rate of separate coolant phases in FC

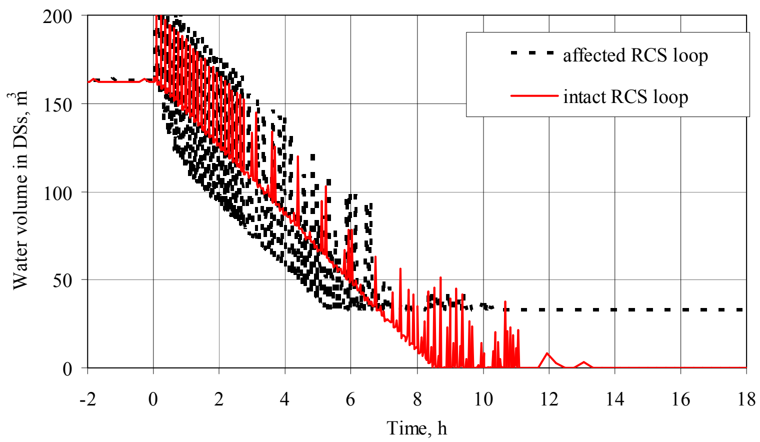


Fig. 3. Change of water volume in DSs

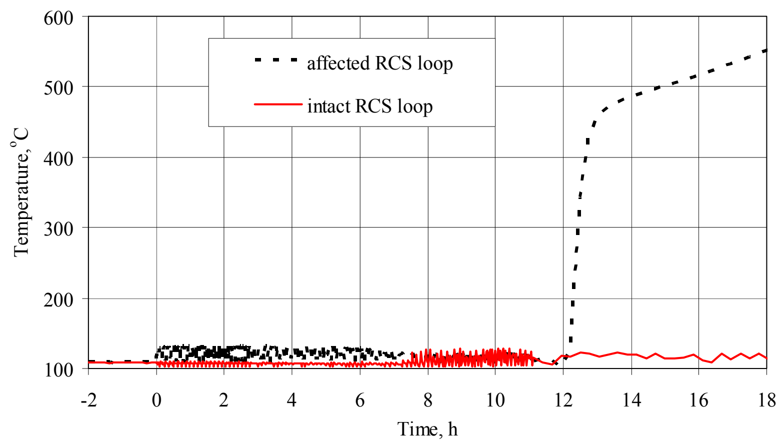
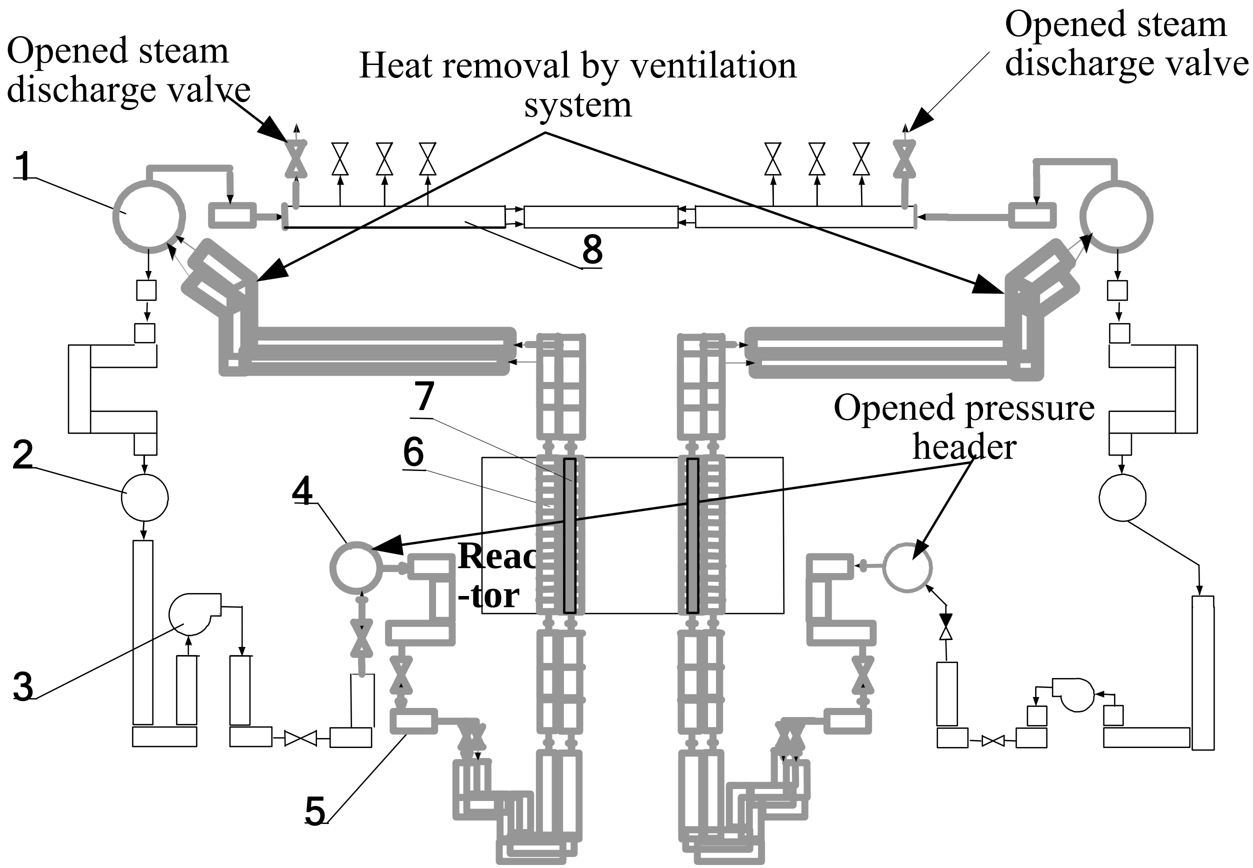


Fig. 4. Change of peak fuel cladding temperature in FCs

ANALYSIS OF LOSS OF HEAT REMOVAL IN FINALLY SHUTDOWN REACTOR OF UNIT 2 OF IGNALINA NPP (5)

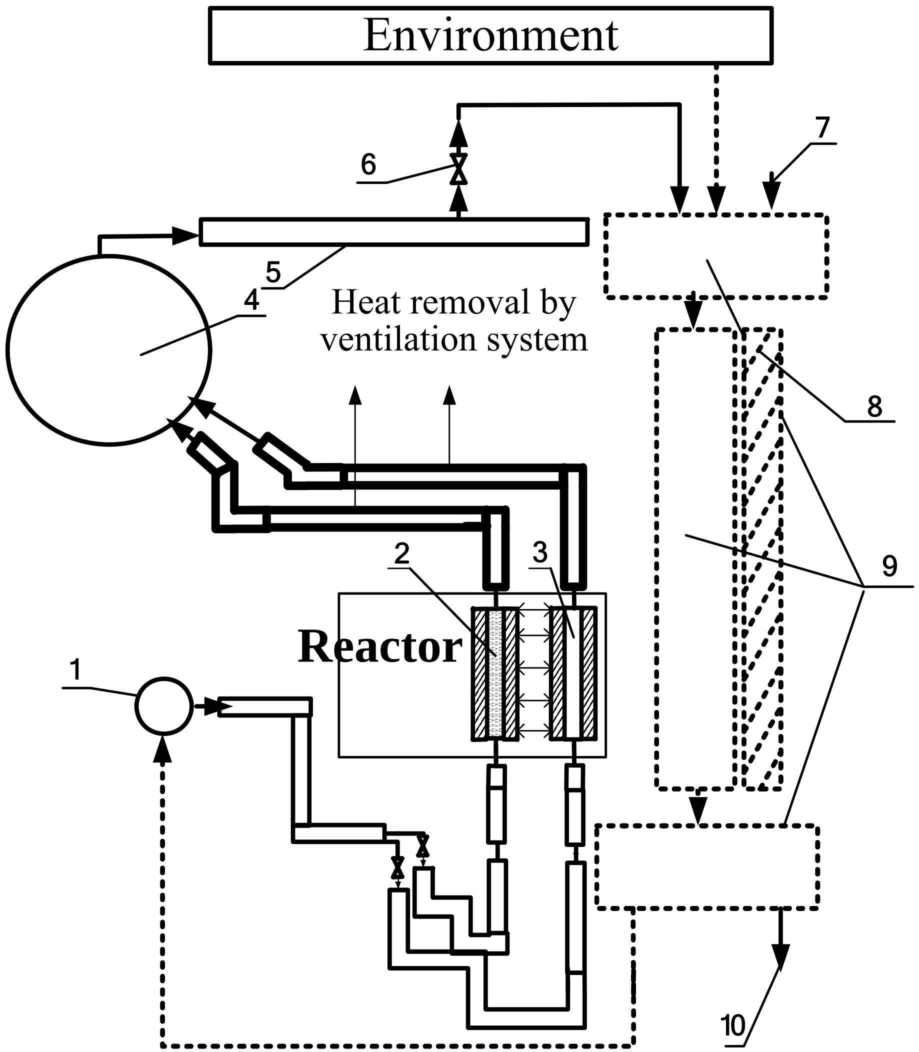
- The process of reactor core heat-up at shutdown reactor is very slow.
- The increase of temperature of fuel claddings starts not earlier as 12 – 18 hours after the beginning of accident.
- In both beyond design basis cases (station blackout case and blockage of water flow rate in the group of fuel channels) the operators have enough time to find the possibilities to provide make-up of RCS by water, using non-regular, non-designed water sources.
- Before mentioned time moment (12 – 18 hours after the beginning of accident) none of acceptance criteria are exceeded.

ANALYSIS OF HEAT REMOVAL FROM SHUTDOWN REACTOR OF UNIT 1 WHEN RCS IS FILLED BY AIR (1)



Schematic representation of RCS of RBMK-1500 with scheme of reactor core cooling by air natural circulation (the air path is marked in grey)

ANALYSIS OF HEAT REMOVAL FROM SHUTDOWN REACTOR OF UNIT 1 WHEN RCS IS FILLED BY AIR (2)



RELAP5-3D
Nodalization scheme

ANALYSIS OF HEAT REMOVAL FROM SHUTDOWN REACTOR OF UNIT 1 WHEN RCS IS FILLED BY AIR (3)

Analysis of heat removal from the shutdown reactor when circulation circuit is filled by air

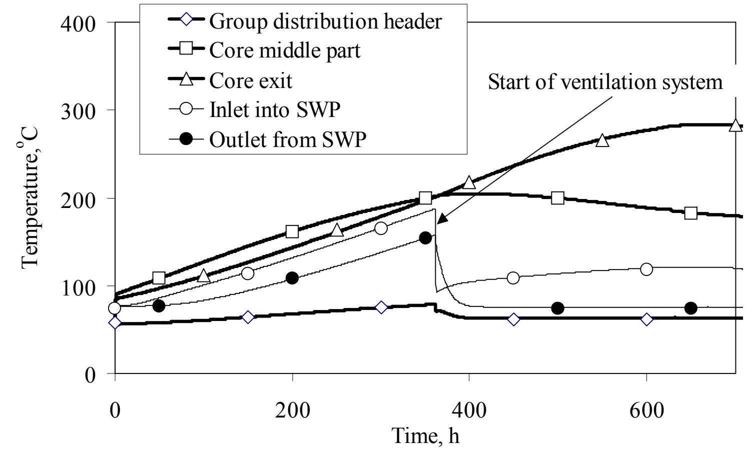


Fig. 1.Behaviour of air temperature in RCS

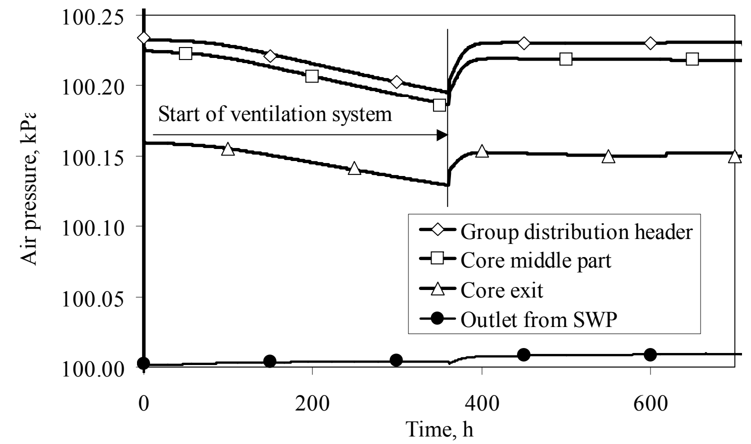


Fig. 2. Behaviour of air pressure in RCS

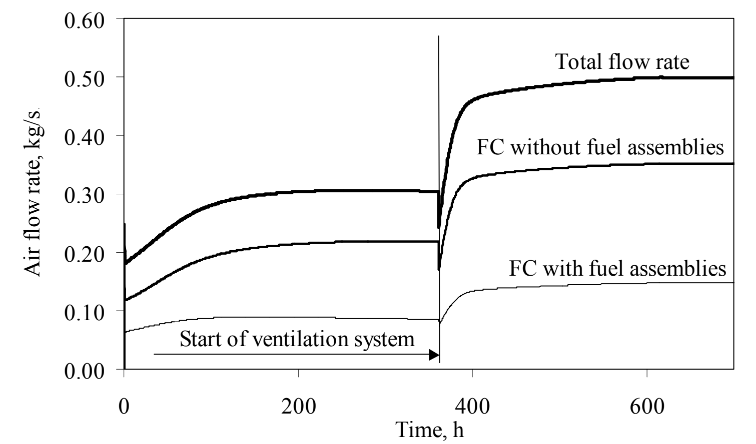


Fig. 3. Air flow rate through FC with and without fuel assemblies

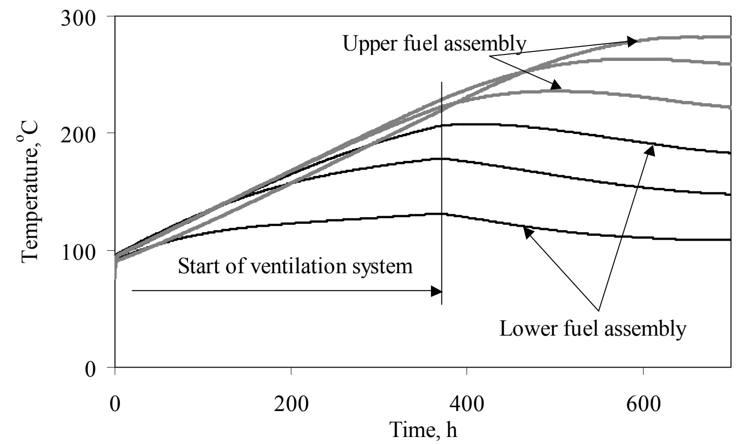


Fig. 4. Behaviour of fuel temperature in lower and upper fuel bundles

ANALYSIS OF HEAT REMOVAL FROM SHUTDOWN REACTOR OF UNIT 1 WHEN RCS IS FILLED BY AIR (4)

- The results of performed analysis demonstrate, that if the conditions for natural air circulation will be fulfilled and ventilation system in drum separator compartments will be available, the reactor core will be cooled by natural circulation of air.
- The maximum reached fuel temperature is 282 ^{o}C – such temperature of fuel is during normal reactor operation, thus the fuel claddings remain intact during this accident.
- The contamination of surrounding area is minimal, none of acceptance criteria are exceeded.

CONCLUSIONS

- The performed analysis using RELAP5-3D code shows that the RBMK-1500 reactor after shutdown can be cooled by natural circulation of water or air.
- Two bounding events were analysed for cooling of core by water after reactor shutdown: station blackout and coolant flow blockage in the fuel channels of one RCS loop.
- The increase of temperature of fuel claddings starts not earlier as 12 – 18 hours after the beginning of accident.
- The performed analysis demonstrated, that partially reloaded reactor, in long term after shutdown can by cooled by natural circulation of air.

Thank you for your attention

Questions?