



Analysis of Water Hammer Phenomena in RBMK-1500 Reactor Main Circulation Circuit

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ABSTRACT

Water hammer can occur in any thermal-hydraulic systems. Water hammer can reach pressure levels far exceeding the pressure range of a pipe given by the manufacturer, and it can lead to the failure of the pipeline integrity. In the past three decades, since a large number of water hammer events occurred in the light-water- reactor power plants, a number of comprehensive studies on the phenomena associated with water hammer events have been performed. There are three basic types of severe water hammer occurring at power plants that can result in significant plant damage.

- rapid valve operation events;
- void-induced water hammer;
- condensation-induced water hammer.

Correct prediction of water hammer transients, is therefore of paramount importance for the safe operation of the plant. Therefore verifying of computer codes capability to simulate water hammer type transients is very important issue at performing of safety analyses for nuclear power plants. Verification of RELAP5/MOD3.3 code capability to simulate water hammer type transients employing the experimental investigations is presented. Experience gained from benchmarking analyses has been used at development of the detail RELAP5 code RBMK-1500 model for simulation of water hammer effects in reactor main circulation circuit.

Analysis of reactor cooling system shows, that water hammers can occur in main circulation circuit of RBMK-1500 reactor in cases of:

- (1) Guillotine break of the inlet piping upstream of the Group Distribution Header and
- (2) Guillotine break of the pressure piping upstream the Main Circulation Pump check valve.

Analysis of above mentioned accident scenarios is presented in this paper. First scenario of the accident potentially is more dangerous, because the pressure pulses influence not only the reactor cooling circuit, but also the piping of safety related system (Emergency Core Cooling System pipeline) connected to affected Group Distribution Header. The performed analysis using RELAP5 code has shown, that in general the maximum values of the pressure pulses, generated by the check valve closure, does not exceed the permissible loads on the pipelines.

1 INTRODUCTION. WATER HAMMER PROCESSES IN REACTOR COOLING SYSTEM

Water hammer is a pressure or momentum transient in a closed system caused by a rapid change in fluid velocity. It is classified according to the cause of the velocity change.

Generally water hammer can occur in any thermal-hydraulic systems and it is extremely dangerous for the thermal-hydraulic system since, if the pressure induced exceeds the pressure range of a pipe given by the manufacturer, it can lead to the failure of the pipeline integrity.

In the past three decades, since a large number of water hammer events occurred in the light-water- reactor power plants, a number of comprehensive studies on the phenomena associated with water hammer events have been performed. There are three basic types of severe water hammer occurring at power plants that can result in significant plant damage:

- rapid valve operation events;
- void-induced water hammer;
- condensation-induced water hammer.

There are several scenarios where water hammers can take place in the reactor cooling system of nuclear power plants. During normal operation, it may be caused by standard actions such as start-up or shut-down of systems and components, switch-over from one component (e.g. pump, heat exchanger) to another. There are also reports about water hammers during the execution of equipment test procedures requiring the activation of safety or auxiliary systems (e.g. by opening of valves). During transients, water hammer may occur as a consequence of the activation of emergency core cooling systems or auxiliary feed water systems. Finally, breaks of high energy pipes possibly followed by rapid isolation valve closure may cause severe water hammers [1]. These transients belong to the first type of water hammer.

Another one specific mechanism, which can lead to severe water hammer in the reactor cooling system, is interaction mechanism of sub-cooled water with condensing steam in a pipeline ("cold" steam present at the closed end of the pipe). The pressure difference between the tank and the closed end, and condensation of steam in evacuation area, accelerates water in the pipe, and the water hammer appears when the water column is abruptly stopped by the closed end of the pipe. This phenomenon belongs to the second type of water hammer.

In existing Nuclear Power Plants water hammers can occur in case of an inflow of sub-cooled water into pipes or other parts of the equipment, which are filled with steam or steam-water mixture [2]. Pressure pulses in the presence of liquid and vapour can lead to rapid condensation of the vapour, leading to so called condensation-induced water hammer [3, 4]. This type of transients is still not very well understood and so far no codes are available to accurately simulate this type of pressure pulses.

To understand specificity of water hammer phenomenon the experimental investigations performed at different test facilities which differ from each other by range of pressures, temperatures and geometries, as well as by mechanisms of water hammers they can produce, should be investigated first of all. Analysis of such experimental results allows to understand processes occurring at water hammer transients, to gain experience for developing of the mathematical models of these experimental facilities and furthermore to adopt it for analyses of water hammer type transients in nuclear power plants.

In this paper it is presented how the experience gained during the modelling of water hammer transient in UMSICHT test facility has allowed to develop detailed model for simulation of water hammer effects in RBMK-1500 reactor main circulation circuit.

2 EXPERIENCE OF WATER HAMMER MODELING GAINED FROM BENCHMARKING ANALYSES

As it has already been mentioned the phenomena of water hammer are investigated for many years. Special test facilities to characterize water hammers, shock waves and the resulting loads in relevant piping configurations were designed. It should be mentioned test

facilities at Fraunhofer Institute for Environmental, Safety and Energy Technology (UMSICHT) [5] and Forschungszentrum Rossendorf (CWHTF) [6]. Mathematical modelling of water hammer phenomena is carried out also together with the experimental investigations.

Several computer codes like RELAP5, ATHLET, CATHARE, TRAC were developed to perform the safety analyses of nuclear reactors. All these codes are based on one-dimensional two-fluid six-equation models of two-phase flow. Despite the fact that these codes are not verified for water hammer fast transients, they are often the only available tools for two-phase water hammer simulations. Therefore verifying of computer codes capability to simulate water hammer type transients is very important issue at performing of safety analyses for nuclear power plants. The capability of different state-of-the-art thermal-hydraulic codes to simulate different water hammer phenomena employing the experimental investigations performed at two above-mentioned facilities was validated and presented in papers [6, 7, 8, 9].

Lithuanian Energy Institute employs RELAP5 code for justification of Ignalina Nuclear Power Plant safety from 1992. Taking into account that there is the wide experience in use of this program tool in the institute the water hammer phenomena investigations employing RELAP5 code were performed. The capability of RELAP5 code to simulate different water hammer phenomena (rapid valve closure experiment performed at UMSICHT and cold water hammer experiment performed at CWHTF) was investigated in Lithuanian Energy Institute [10, 11, 12, 13]. The UMSICHT facility is being modified in order to simulate a piping system and associated supports that are typical for a nuclear power plant including RBMK reactor main circulation circuit (e. g. similar length of pipeline) also. Therefore transient initiated by the rapid closure of a valve performed in this test facility has been selected for benchmarking analysis using best estimate thermal hydraulic RELAP5 code. Uncertainty and sensitivity analysis of the water hammer test performed at Fraunhofer Institute for Environmental, Safety and Energy Technology (UMSICHT) was carried out and presented in [14] also. The carried out investigations have shown, that both the parameters of thermal-hydraulic system condition (pressure, water temperature, initial fluid velocity, valve closure time) and parameters of modelling (calculation time step, scheme nodalization) may impact results of water hammer analysis.

Magnitude of a pressure change due to an instantaneous valve closure is expressed by Joukowsky's law [15], which shows that the pressure change depends on the density of the fluid, the sound velocity, and the change of the fluid velocity. When sudden changes in flow occur, the energy associated with the flowing water is transformed into pressure at that location. This excess pressure is known as water hammer pressure and is greater with large changes in velocity.

As it is seen from Joukowsky's formula [15] one of the factors that determine water hammer is system fluid velocity. Water hammer tests performed at Fraunhofer Institute for Environmental, Safety and Energy Technology (UMSICHT) have shown, that fast closure of the valve at steady state water velocity from 2 to 4 m/s leads to strong pressure pulses. Also these experiments have shown strong dependence of steady state fluid velocity in the pipeline to the maximum pressure peaks downstream the valve after rapid valve closing. It is shown in Fig. 1 that the higher steady state fluid velocity corresponds to stronger pressure peaks downstream the closed valve. System fluid velocity is dependant on several factors. The most important of these factors are the roughness of the pipe wall and flow energy loss coefficient. The pressure peaks resulting from water hammer will be higher if these two parameters will have greater values. It confirms the fact, that these parameters were the most contributing uncertain parameters with respect to the maximum pressure values at carrying out of the uncertainty and sensitivity analysis [14]. Thus, at modelling it is necessary properly to select initial conditions (pressure, temperature) also to check up values of the roughness of the pipe

wall and flow energy loss coefficients in modelled pipelines to obtain correct initial fluid velocity in system.

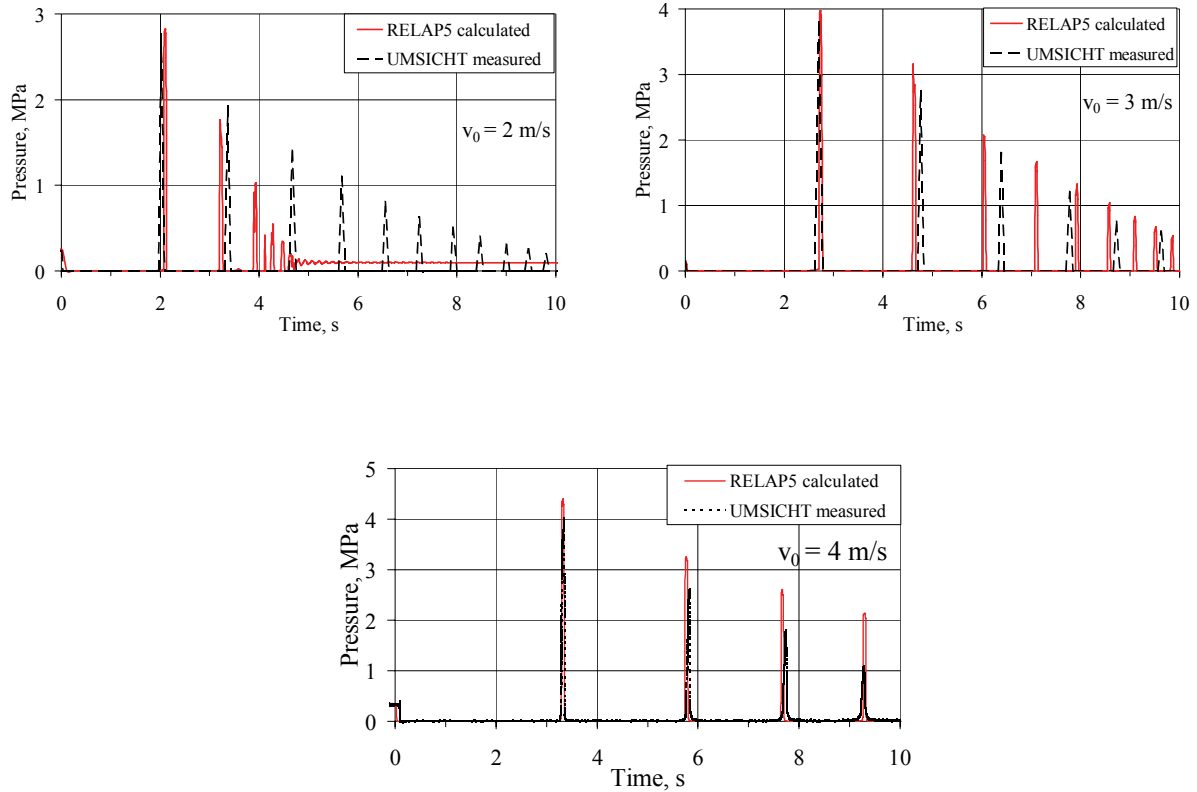


Figure 1: Pressure history downstream the closed valve at steady state velocities 2, 3 and 4 m/s

During the closing of a valve, kinetic energy of the moving fluid is converted into potential energy (the energy of a wave, which bounces back and forth). If the valve is closed slowly, the loss of kinetic energy is gradual. If it is closed quickly, the loss of kinetic energy is very rapid. In other words, if the valve closes where the valve closing time is equal to or less than the time for the pressure wave travel back and forth in the pipe, the maximum water hammer will be applied and if the valve closing time is greater than the time for the pressure wave to travel back and forth in the pipe, the water hammer will be reduced. Therefore another important factor that determine water hammer is closing time of valve. Fig. 2 shows that valve with smaller closing time produce stronger pressure peaks and on the contrary, greater closing time corresponds to reduced pressure peaks. For greater closing time, the reflected pressure wave returns to the valve, which is still partially opened, what produces reduction on the maximum valve in the valve. Therefore is very important correctly to simulate the valve, to obtain proper time of it closing.

Using RELAP5 model for water hammer event analysis, close attention must be paid to the calculation time step. Use of an explicit integration scheme leads to sometimes large numerical errors during rapid fluid transients unless a time step is selected much smaller than the maximum allowed by the Courant condition [16] as shown in Eq. (1) below:

$$\delta t_{\max} = \frac{\delta x}{a_w} \quad (1)$$

where: δx node length;
 a_w sonic velocity in the fluid.

Typically, the actual time step would have to be an order of magnitude smaller than δt_{\max} . On the basis of modelling of water hammer phenomenon (rapid valve closure experiment performed at UMSICHT) the example of the selection of a suitable calculational time step is presented below. Taking into account, that the length of piping control volume size has been accepted equal 0.5 m, and sonic velocity in the fluid is about 1440 m/s, the maximum allowed time step by the Courant condition was reached about 3×10^{-4} seconds.

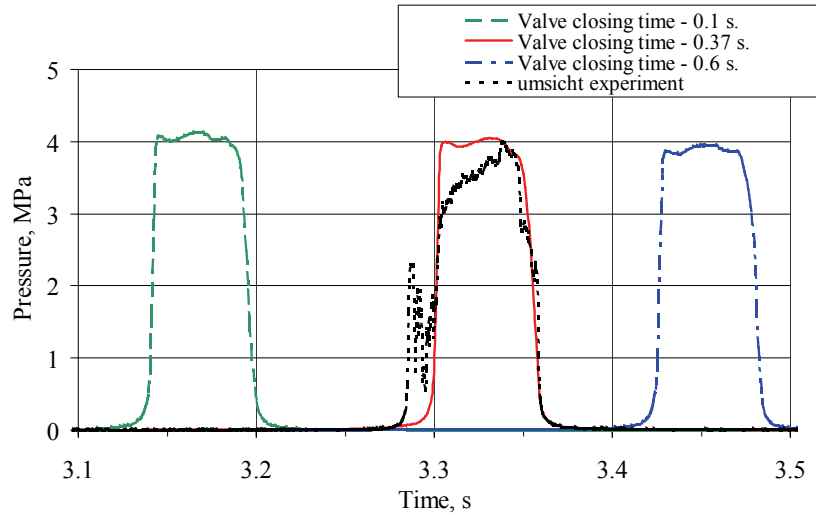


Figure 2: Maximum pressure peaks for different valve closing times

For the selection of a suitable calculational time step, the analysis for different ratio from 1 to 0.05 of current time step (dt) and current Courant time step ($dtrnt$) is assumed. It is shown in Fig. 3 that calculated pressure oscillations due to check valve closing are the least and most attenuated when current time step is equal to the current Courant time step ($dt/dtrnt=1.0$). When this ratio is decreased, the amplitude of pressure oscillations increases.

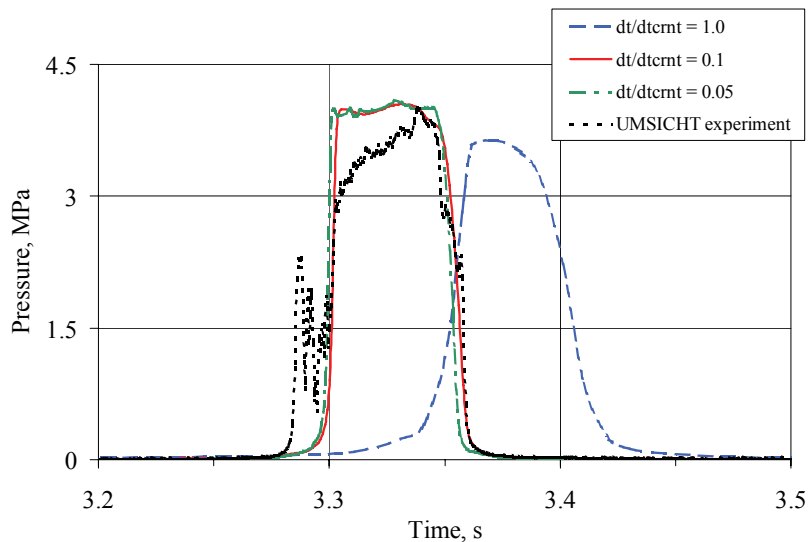


Figure 3: Influence of calculation time step for first pressure pulse calculated by employing RELAP5

However, the decrease of the current time step more than ten times compared to the current Courant time step is impractical. Influence of the ratio $dt/dtrnt < 0.1$ to the pressure

oscillations is insignificant. Hence, the ratio of current time step (dt) and current Courant time step ($dtrnt$) should not exceed 0.1 at modelling of water hammer transients using RELAP5.

Employing RELAP5 code for water hammer analysis, a very close attention must be paid to the cell (control volume) size. As it has been mentioned in previous subsection, the acoustic wave Courant limit is the time required for a wave travelling at the sonic velocity to pass through any given model cell. Since the sonic velocity can be quite high, the time step usually has to be reduced to a rather small number. Also, if the pressure wave is expected to have a very rapid rate of increase, then the cell nodalization scheme must be implemented to give a small length dimension [17, 18, 19].

A number of RELAP5 calculations with different control volume sizes for the UMSICHT test facility model pipe elements were carried out to obtain the pressure peaks without high rate of change at steady state water velocity. Graphs in Fig. 4 shows performed analysis to estimate the influence of control volume sizes in the pipe components. As it is seen from figure the values of pressure peaks and the frequencies of cavitation pressure peaks are different in these investigated cases.

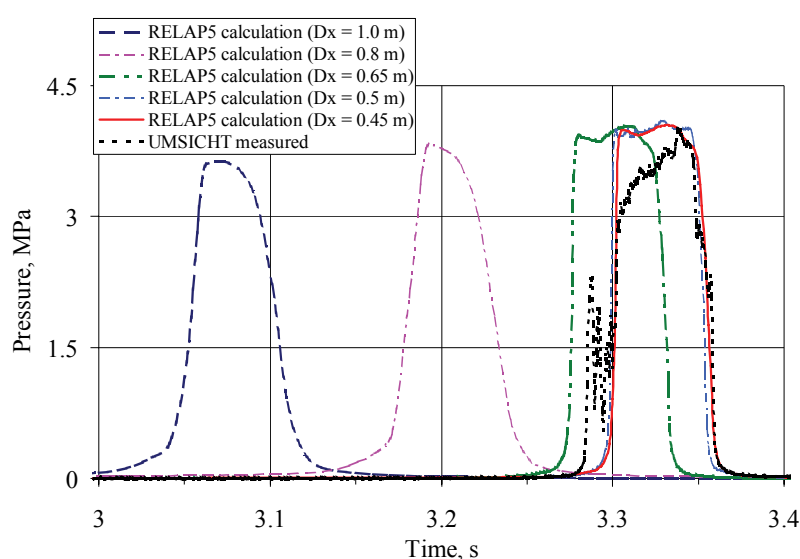


Figure 4: RELAP5 calculations using different control volume sizes in the pipeline

The model cell length was decreased to 0.5 m to obtain the pressure peaks without high rate of change. However, finer nodalization does not affect first pressure peak (Fig. 4). Thus, the length of one computational volume D_x should not exceed 0.5 m in the modelled pipelines where water hammer is expected.

3 RELAP5 MODEL OF IGNALINA NPP RBMK – 1500 REACTOR FOR WATER HAMMER ANALYSIS

Ignalina Nuclear Power Plant is Lithuania's only nuclear power plant with boiling water graphite-moderated RBMK-1500 reactor. The detailed description of Ignalina RBMK-1500 NPP is presented in [20].

Very complex hydraulic system (with long pipelines of different diameter having a plenty of the valves) distinguishes Ignalina NPP with RBMK-1500 reactor from other types of reactors. Breaks of some pipelines may cause rapid closing of the check valves. Such fast closure of the check valve can lead to severe water hammers. Therefore the rapid valve operation induced events are most important at investigation of water hammer occurrence in

the circulation circuit of the RBMK-1500 reactor from all types of water hammer discussed in section 1. Steamlines in RBMK-1500 main circulation circuit are connected to the drum separators. The steam-water mixture arrives at the drum separators from the reactor core and direct supply of subcooled water into steamlines is impossible. Therefore, condensation-induced water hammer type transients are not relevant to the accidents in RBMK-type reactors.

Lithuanian Energy Institute employs RELAP5 code for justification of Ignalina Nuclear Power Plant safety from 1992. Nodalization scheme of the RELAP5 MCC model is presented in Fig. 5. The description of the model, which was used as the basic, is submitted in a paper [21]. Main circulation pumps system is modelled with three equivalent pumps and one core pass represents one GDH for the right MCC loop in this model. Breaks of MCC pipelines are simulated by using special valve models and “time – dependent volume” elements.

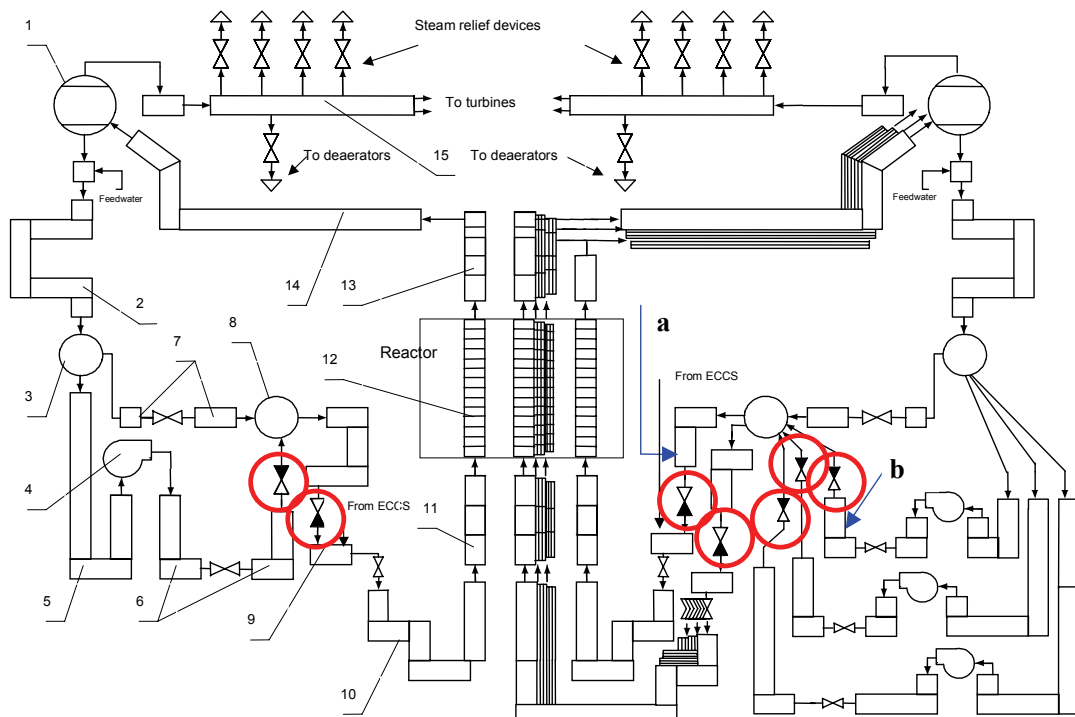


Figure 5: Ignalina NPP RELAP5 thermalhydraulic model nodalization diagram: 1 - DS, 2 - downcomers, 3 - MCP Suction Header, 4 - MCPs, 5 - MCP suction piping, 6 - MCP pressure piping, 7 - bypass line, 8 - MCP Pressure Header, 9 - GDHs, 10 - LWC, 11 - reactor core inlet piping, 12 - reactor core piping, 13 - reactor core outlet piping, 14 - Steam-Water Communication line, 15 - steam line, **a**, **b** – location of the break

As was mentioned above, employing the RELAP5 code for water hammer event analysis, a very close attention must be paid to the cell (control volume) size. A number of RELAP5 calculations with different control volume sizes for Group Distribution Header inlet piping (outside diameter is 325 mm and the length is ~13 m), Low Water Communications (outside diameter is 57 mm and the length is ~27 m), Fuel Channels (outside diameter is 57 mm and the length is 7 m) and Emergency Core Cooling System piping into GDH (outside diameter is 108 mm and the length is ~19 m) were carried out. The control volume size was decreased so that there were a number of cells over the region of the pressure wave that has a high rate of change. After such investigations, these pipelines were modelled with different number of control volumes, however the length of one computational volume D_x did not exceed 0.5 m. It was assumed that guillotine rupture occurs in the GDH inlet pipe. This pipe

connects MCP pressure header and GDH. In one end of the GDH inlet pipe (at the location where MCP pressure header is connected) the flow-limiting device with diameter of 0.1515 m is fixed. Flow-limiting device (bushing) reduces the loss of coolant in the case of GDH rupture. In other end of GDH inlet pipe (at the location where GDH is connected) the check valve is fixed. A location of guillotine rupture is defined in meter upstream GDH check valve. Guillotine break is simulated by using valve model, which cross section is equal double area of cross section area of GDH. The ALS compartments are simulated by “time – dependent volume” element of constant pressure. The time of guillotine rupture opening is assumed 0.01 second.

The same approach was used at development of nodalization scheme of piping connections between Main Circulation Pump and Pressure Header. A number of RELAP5 calculations with different control volume sizes for MCP – PH connecting pipelines (outside diameter is 828 mm and the length is ~41 m) were carried out to obtain the pressure peaks without a high rate of change. The control volumes size in these connecting pipes was decreased in comparison with basic model and vary from 0.5 m to 0.55 m. Guillotine break of the pressure piping upstream the MCP check valve is simulated similar as in case of break of the piping upstream GDH.

Fast deceleration of the coolant flow rate in MCC is possible only in case of break of pipelines with following closure of the check valve. As was mentioned above the rapid valve operation induced water hammer are most probable in the circulation circuit of the RBMK-1500 reactor. Circles in Fig. 5 designate check valves in the main circulation circuit, which fast closing can lead to water hammer. The bypass lines (7, in Fig. 5) are also the place in MCC where the check valves are located. These junctions between the pump suction header (3, in Fig. 5) and the pump pressure header (8, in Fig. 5) are modelled, but manual valves are closed as was mentioned above. There is no flow rate of the coolant in this pipeline and water hammer followed by rapid check valve closure is impossible. Therefore this case was not investigated.

The water hammers can occur in main circulation circuit of RBMK-1500 reactor in cases of:

- (1) Guillotine break of the inlet piping upstream of the Group Distribution Header (location of the break is designated by arrow **a** in Fig. 5) and
- (2). Guillotine break of the pressure piping upstream the Main Circulation Pump check valve (location of the break is designated by arrow **b** in Fig. 5)

First scenario of the accident potentially is dangerous, because the pressure pulses influence the piping of safety related system (Emergency Core Cooling System pipeline) connected to affected Group Distribution Header. Thus, function of ECCS operation can be failed.

3.1 Group Distribution Header and Main Circulation Pump check valve model

Benchmarking, uncertainty and sensitivity analyses have confirmed that the valve closure time is very important specificity at simulation of water hammer phenomenon. Therefore is very important correctly to set time of valve closure that is impossible using RELAP5 “check valve” component. Standard practice of modelling of check valves in reactor unit models with RELAP5 code assumes use of “check valve” component. In thermal-hydraulic model of the Ignalina NPP power unit at the analysis of water hammer phenomena in RBMK-1500 reactor main circulation circuit the given approach appeared unacceptable at modelling of GDH and MCP check valves, because the time of closing of RBMK check valve at water hammer transients is not known. Therefore in this case it is necessary to model the check valve in details as it is possible. The mathematical model of RELAP5 “check valve”

component does not take into account parameters of the valve design, the mass moment of inertia and closing rate of the valve flapper. The RELAP5 code gives possibility to model the check valve in details by means of “inertial valve” component, however RELAP5/MOD3.3 code user’s guidelines warns, that there has been only limited user experience applying the inertial valve component [22].

This valve models the motion of the valve flapper assembly as an inertial-type check valve. The abrupt area change model is used to calculate kinetic form losses, assuming that the area between the flapper and the valve seat behaves as an orifice whose area changes in time as a function of the inertial valve geometry. For this valve model the energy loss coefficient is assumed to increase from zero at the full opening up to 0.5 for complete closure [22]. For RELAP5 inertial valve model the motion of the flapper about the shaft is given by Newton’s second law, taking into account flapper mass, gravity vector, moment of inertia, distance from the hinge pin to the center of mass, flapper area, pressure difference across the valve, etc. Minimum and maximum flapper angular positions are taken into account also in model. Schematic representation of the check valve also diagram of RELAP5 inertial valve component are presented in Fig. 6.

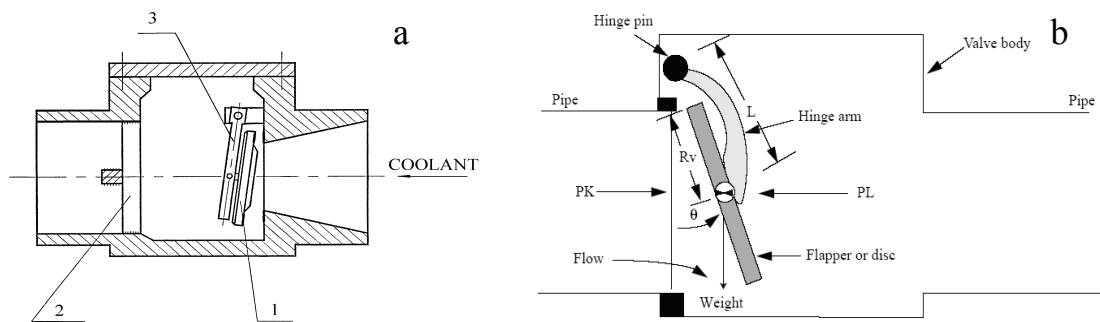


Figure 6: Schematic representation of the MCP pressure piping check valve and GDH check valve (a): 1 - disc, 2 - protective cross, 3 – hinge arm; diagram of RELAP5 inertial valve model (b)

Check valves for Ignalina NPP are manufactured by MOSTRO a. s., Czech Republic. Applicability of such type of valves is to prevent reverse flow of the fluid. The design drawing of the RBMK-1500 GDH check valve is shown in Fig. 7. At Ignalina NPP the check valves in MCP pressure piping have the same design as GDH check valves only overall dimensions differ.

The selection of parameters for a RELAP5 inertial valve component was carried out employing the design documentation and drawing of the RBMK-1500 check valves [23].

4 ANALYSES OF POTENTIAL WATER HAMMERS IN IGNALINA NPP RBMK – 1500 MAIN CIRCULATION CIRCUIT

The guillotine break of the pipe upstream the MCP check valve can lead to break away of the pipeline segment downstream the MCP check valve up to the pressure header and to loss of the coolant. However in this case connection of ECCS to the pipeline will not be damaged. Protection of the RBMK-1500 reactor core, in case of piping or header rupture, is provided by the ECCS. The ECCS brings water to the core via the GDHs.

The circulation circuit of the RBMK-1500 reactor has a series of check valves in the GDHs that serve the coolant distribution in the fuel channels. However, to prevent the

parts filled with water. Steam generated in the fuel channels attenuates the coolant flow oscillations very effectively, thus, at the core outlet they are not observed.

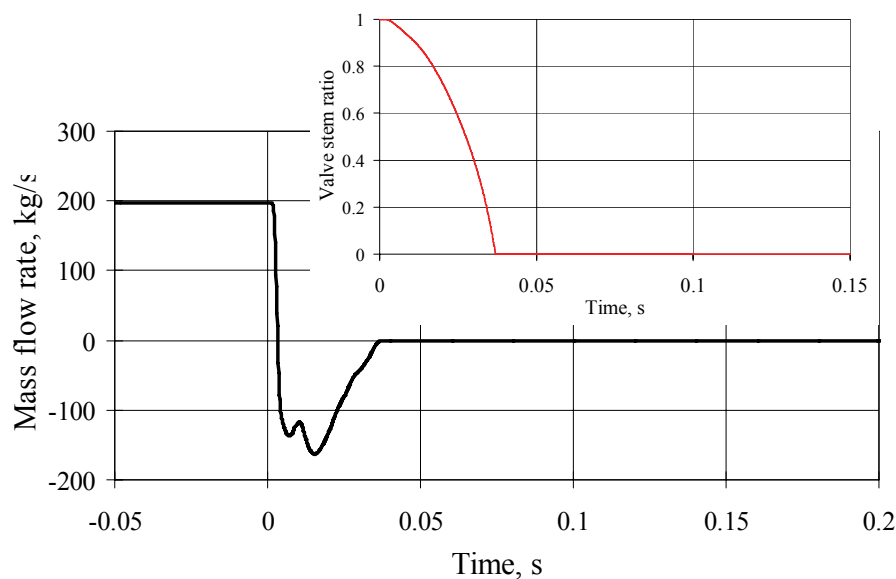


Figure 8: GDH check valve closing rate and the coolant flow rate through this valve

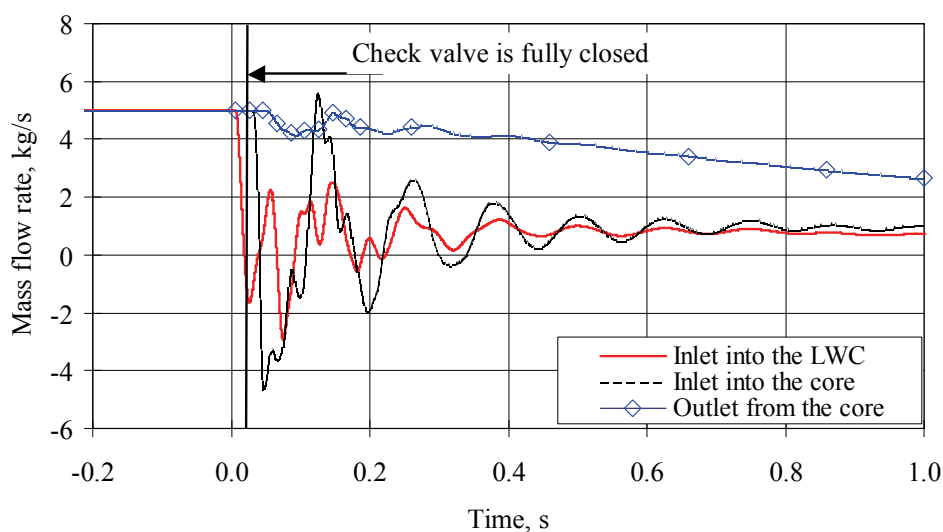


Figure 9: Coolant flow rate in the LWC and fuel channels, connected to the affected GDH

Rapid change of the coolant flow direction and following rapid deceleration of the coolant flow rate due closure of the check valve leads to pressure pulses (water hammer) in the GDH, which is shown in Fig. 10. As it is shown in Fig. 8, the check valve is closed in 0.04 s after the rupture. Because of rupture, the pressure in the piping at the initial moment of the accident (while check valve is still open) decreases down to 4 MPa. As the rate of a check valve closure increases very strongly at the last few degrees before the disk angle reaches the closed position, the reverse water flow of approximately 160 kg/s (Fig. 8) is stopped in a very short time.

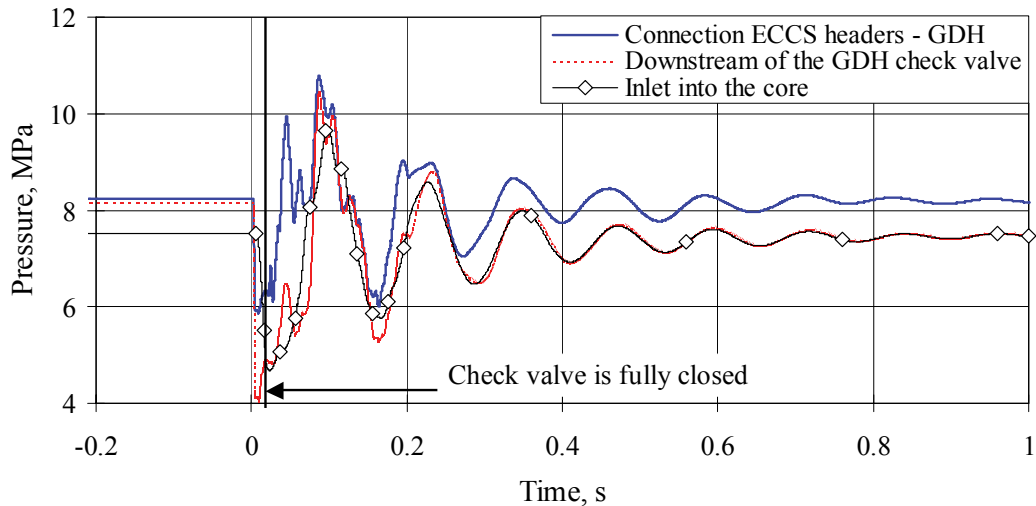


Figure 10: Pressure pulses in the GDH, at the core inlet and the GDH-ECCS connecting piping

After check valve closing the pressure pulses occurred and maximum pressure in the GDH of about 10.3 MPa is observed at a time of about 0.1 s after the initial rupture. Pressure pulses oscillate with decreasing period and cease in about 1 s. Pressure pulses in the adjusted GDH-ECCS piping (up to the ECCS check valves) follow pressure pulses in the GDH. Pressure pulses from the GDH are also transmitted to the LWC and fuel channels, as displayed in Fig. 10.

However, maximum pressure pulses generated following the guillotine break upstream of the GDH remain below the value of the hydraulic test pressure, which is equal 12.4 MPa.

Second probable case of water hammer occurring in RBMK-1500 reactor main circulation circuit is guillotine break of the pressure header piping upstream the MCP check valve. Maximum pressure pulse of about 10.8 MPa is observed downstream MCP check valve after fast closure (Fig. 11).

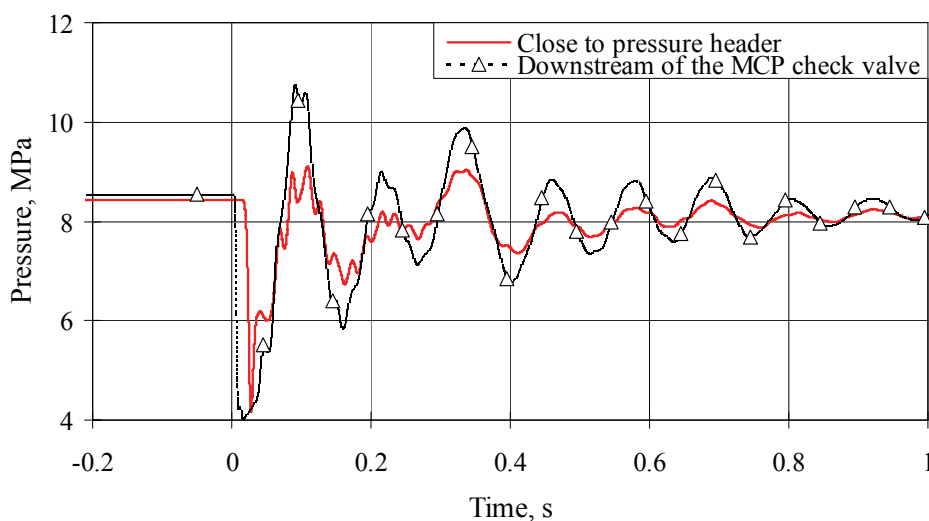


Figure 11: Pressure pulses in pressure header piping downstream MCP check valve and close to the pressure header in case of guillotine break of the pipe upstream the MCP check valve

However this value remains below the value of the hydraulic test pressure. Hence the integrity of pipelines should not be violated because of water hammer in RBMK-1500 reactor main circulation circuit.

5 CONCLUSIONS

Validation and verification of RELAP5 code capability to simulate water hammer types transients employing the experimental investigations performed at the test facilities has been performed.

Sufficiently close agreement between the calculation results using RELAP5 code and the measured values of peak pressure in test case performed at UMSICHT test facility, which piping system is typical for a nuclear power plant including RBMK reactor main circulation circuit, was found.

From benchmarking analysis has been determined, that the most contributing factors with respect to the maximum pressure values are:

- calculational time step (current time step to the current Courant time step ratio was selected ($dt/dt_{crnt} = 0.1$) to obtain the amplitude of pressure oscillations without high change of rate);
- nodalization (the length of one computational volume D_x should not exceed 0.5 m);
- valve closure time.

Gained experience from benchmarking water hammer calculations has allowed to develop model for thermal-hydraulic analysis of potential water hammer effects at the RBMK-1500 reactor main circulation circuit employing RELAP5/MOD3.3 code.

Two accident scenarios of water hammer occurrence in main circulation circuit of RBMK-1500 reactor: (1) the guillotine break upstream of the group distribution header and (2) guillotine break of the pipe upstream the MCP check valve have been determined and simulated employing RELAP5/MOD3.3 code.

RELAP5 code “inertial valve” component has been selected at modelling of potential water hammer transients in RBMK reactor because it gives possibility to model the check valve in details and thus it allows correctly to simulate the time of valve closure.

The scenario of guillotine break upstream of the group distribution header potentially is more dangerous, because the pressure pulses influence not only the reactor cooling circuit, but also the pipeline of safety related system (ECCS piping) in this case. However the results of the performed analysis demonstrated that in general the maximum values of the pressure pulses, generated by the check valve closure, following the hypothetical accidents, remain below the value of pressure of the hydraulic tests, which are performed at the NPP.

NOMENCLATURE

| | |
|-------|---------------------------------|
| ALS | Accident Localization System |
| CV | Check Valve |
| CWHTF | Cold Water Hammer Test Facility |
| ECCS | Emergency Core Cooling System |
| FC | Fuel Channel |
| GDH | Group Distribution Header |
| LWC | Lower Water Communications |
| MCC | Main Circulation Circuit |
| MCP | Main Circulation Pump |
| NPP | Nuclear Power Plant |

| | |
|---------|--|
| PH | Pressure Header |
| RBMK | Russian Acronym for "Channelised Large Power Reactor" |
| UMSICHT | Fraunhofer Institute for Environmental, Safety and Energy Technology |

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