NUREG/IA-0202

International Agreement Report

Analyses of KS Test Data on the Heated Rod Bundle Temperature Behavior in RBMK-1500 Core Model Under Stop and Recovery Flow Using RELAP5/MOD3.2 and RELAP5/MOD3.2.2 GAMMA

Prepared by
V.A. Vinogradov, A.Y. Balykin
Nuclear Reactor Institute, Russian Research Center
Kurchatov Institute
Kurchatov Square 1
123182, Moscow Russia

Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

April 2001

Prepared as part of
The Agreement on Research Participation and Technical Exchange
under the International Code Application and Maintenance Program (CAMP)

Published by
U.S. Nuclear Regulatory Commission

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ABSTRACT

This report has been prepared as a part of the Agreement on Research Participation and Technical Exchange under the International Code Application and Maintenance Program.

KS experimental data on the behavior of the heated rod bundle temperature in the RBMK-1500 core model under stop and recovery flow conditions were simulated with RELAP5/MOD3.2 and RELAP5/MOD3.2.2GAMMA to assess the codes suitability. Especially calculations were performed to estimate differences in the code version predictions for processes/phenomena, which could occur under specific conditions of RBMK type reactor during LOCA with MCP's pressure header rupture and subsequent ECCS water injection.

This problem addresses phenomena of high importance to RBMK-1500 safety including water discharge, critical heat flux, post dryout heat transfer, reflood and propagation of rewetting front in the fuel channel during an accident.

The test have been carried out at KS semi-integral test facility (Russian Research Center Kurchatov Institute) represented RBMK primary circuit. The main purpose of the experiment was investigation of temperature conditions in the fuel assembly under high power value, inlet flow rate being decreased drastically up to complete stop of the flow followed by pressure header rupture. A subsequent flow rate resumption was also assumed, the fuel assembly power high level being unchanged.

First a study of the effect of the hydraulic nodalization to the code calculations was performed using different number of hydraulic volumes for the fuel channel model. After the choice of proper nodalization and maximum user-specified time step, base case calculations were done for the test.

Sensitivity studies were carried out to investigate the effects of modeling on the behavior of the rod simulator temperatures along the height of the fuel assembly model.

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EXECUTIVE SUMMARY

Analyses of KS test with stop and recovery flow in the RBMK-1500 core model are presented in the Report. The objective of the analyses is to assess the RELAP5/MOD3.2 and RELAP5/MOD3.2.2 GAMMA codes for covering thermal and hydrodynamic processes in RBMK type reactor under MCP's pressure header large break conditions. Especially calculations were performed to estimate differences in the code version predictions for phenomena/processes, which could occur during LOCA. This problem addresses phenomena of high importance to RBMK-1500 safety including water discharge, critical heat flux, post dryout heat transfer, reflood and propagation of rewetting front in the fuel channel during an accident.

The test have been carried out at the KS semi-integral test facility (RRC KI) represented RBMK primary circuit. The main purpose of the experiment was investigation of temperature conditions in the fuel assembly under high power value, inlet flow rate being decreased drastically up to complete stop of the flow followed pressure header rupture. A subsequent flow rate resumption was also assumed, the FA power high level being unchanged.

Full scale model of one fuel channel with RBMK-1500 fuel assembly was used in the test. An abrupt flow rate termination with a high FA power level conserving attributed to the emergency under consideration was modeled by the FC inlet valve closure. The flow rate was recovered as the heated rod temperature reached the limit value. To do this the FC inlet valve was opened. It was the way to simulate the ECCS water supply into the fuel channel. FA model power, FA inlet pressure, FC inlet flow rate and coolant temperature, pressure drop across the FC section with heated rod bundle, heated rod temperatures along the FA model were recorded during the test.

The models of RELAP5/MOD3.2 and RELAP5/MOD3.2.2 GAMMA codes were investigated. Special emphases were given to the codes performance for the following processes/phenomena:

* Pressure drop and water release from the fuel channel model and rod bundle surface drying.

* Dryout under sharp flow deceleration at the inlet of the RBMK-1500 fuel assembly model.

* Post dryout heat transfer and heated rod's wall temperature behavior in the fuel assembly model under channel drying.

* Propagation of the reflood and quench fronts in the fuel assembly model under water flow resumption at the channel inlet.

First a study of the effect of the hydraulic nodalization to the code results was performed using different number of hydraulic volumes for the fuel channel model. After the choice of proper

nodalization with 40 nodes for the FA channel and maximum user-specified time step dtmax=0.01 s, the base case calculations were done for the test.

Sensitivity studies were carried out to investigate the effects of modeling on the behaviors of the rod simulator temperatures along the heated bundle height using motor valve component or Time Dependent Junction in LWC. Use of TDJ to accurate code simulation of the real flow rate behavior at the channel inlet gives more realistic code results for the initial and boundary conditions in the fuel channel. In this case the code predicted time interval Δt_d from the moment t(G0) of complete stop flow to the beginning t_d of the rod's wall temperature Tw1(t) increase at the core outlet exceeds the experimental value Δt_d by about ~ 0.2 s. This indicates a reasonable adequacy of the code simulation of dryout initiation at rapid decrease of the coolant flow right down to its total termination. Also, sensitivity studies were performed with estimating what was the influence of various models applied in these codes on calculation accuracy.

Code results are presented as time–dependent curves: - pressure Pin (t) in the lower part of the heated rod bundle, coolant temperature Tin (t) and mass flow rate G (t) at the FC model inlet, total pressure drop DP16-4 (t) across the heated bundle height, heated rod temperatures Tw1 (t), Tw2 (t), Tw3 (t), Tw4 (t) along the FA model height.

The curves serve for comparison of the calculation results with test data to appreciate codes suitability.

- Comparison of RELAP5/MOD3.2 results allow to draw a conclusion on reasonable agreements of general pictures of simulated processes/phenomena with test data on the stage with the decrease and complete stop of flow.

At the same time, it was intimated that there is a need to modify RELAP5/MOD3.2 models used for interphase friction and critical heat flux in the channel with the RBMK-1500 fuel assembly under initial steady conditions with forced circulation.

- When simulating the recovery stage of water supply into the channel there were essential distinctions between RELAP5/MOD3.2 code results and test data on the behaviors of the rod wall temperatures along the FA height. The code does not give qualitative agreement between the curves for the rod temperatures along the FA height at the quenching in the test. The code gives insufficient agreements with test data concerning the time characteristics and conditions of the rod surface quenching in the upper and middle parts of the FA. The analysis results allow the code suitability being assessed as insufficient. This stems from the fact that RELAP5/MOD3.2 reflood model has not been adequately worked through and the developers do not recommend it to use. Shown is a necessity and importance of a special reflood model to be used for suitable description of the reflood stage of the transient. At assessment of the advanced code version RELAP5/MOD3.2.2 GAMMA and its reflood model, it is necessary to achieve a suitable simulation of the initial conditions for the recovery stage of water supply into the channel during the transient.

- Comparison RELAP5/MOD3.2.2 GAMMA results allow to draw a conclusion on a reasonable agreement of general pictures for simulated processes/phenomena with test data on the stage of the decrease and complete stop of flow.

RELAP5/MOD3.2.2 GAMMA results obtained when simulating reflood and quench fronts in the fuel cannel allow the code adequacy being assessed as reasonable for the upper part of RBMK-1500 fuel assembly and as insufficient for the lower part of the FA model.

- Shown is a necessity for formulation special Standard Problem "Propagation of the reflood and quench fronts in the lower and upper parts of the RBMK-1500 fuel assembly under flow resumption at the channel inlet" and its analysis using RELAP5/MOD3.2.2 GAMMA.

NOMENCLATURE

N - electrical power of the FA model, kW;

G - water flow rate at the fuel channel inlet, kg/s;

Pin - pressure in the sampling point 15 of the fuel channel model, MPa, bar;

DP16-4 - actual pressure drop between the pressure taps 16 and 4, Pa;

Tin - water temperature at the fuel channel inlet, K;

Tw1 – Tw4 - rod fuel simulator wall temperature, K;

RRC KI - Russian Research Centre ``Kurchatov Institute"

LWC - lower water communication lines;

SWC – steam-vapor water pipelines;

GDH - group distribution header;

ICV - isolating-control valve;

MFCC- multiple forced circulation circuit;

MCP - main circulation pump;

DS - drum-separator;

DM - differential manometer;

ECCS - emergency core cooling system;

PH - pressure header;

FE – fuel element;

FA - fuel assembly;

FC - fuel channel;

TDJ - Time Dependent Junction;

exp – experimental value;

calc – calculated value.

1. INTRODUCTION

1.1. Objectives

The main goals of this work are:

- Analyses of the KS experimental data on the behavior of the heated rod temperatures in the RBMK-1500 core model under stop and recovery flow conditions using RELAP5/MOD3.2 and RELAP5/MOD3.2.2 GAMMA;

- Assessment of the codes suitability for description of thermal and hydraulic processes, which could occur under specific conditions of RBMK-1500 type reactor during an accident with MCP's pressure header rupture and subsequent ECCS water injection.

Especially calculations were performed to estimate differences in the code version predictions for phenomena/processes, which could occur during LOCA. This problem addresses phenomena of high importance to RBMK-1500 safety including water discharge, critical heat flux, post dryout heat transfer, reflood and propagation of rewetting front in the fuel channel during an accident.

1.2. Background

To help ensure RELAP5 code can be used with confidence, Russian Research Centre ``Kurchatov Institute" has agreed to perform and document independent assessment of the code for a wide range of applications. These exercises are necessary to help identify and quantify any code shortcoming, in particular for the Russian types of reactors VVER and RBMK. This report has been prepared as a part of the Agreement on Research Participation and Technical Exchange under the International Code Application and Maintenance Program. Analyses of KS Test 5 with RBMK-1500 core model under stop and recovery flow conditions were performed using the latest versions of the codes RELAP5/MOD3.2 and RELAP5/MOD3.2.2 GAMMA.

1.3. Study Description

MCP's pressure header break is one of the design basis accidents in RBMK type reactor. KS RBMK MFCC model is semi-integral model of RBMK primary system for investigations hydrodynamics and heat transfer under normal and accident conditions of a reactor. In this facility series of the tests with RBMK-1500 core model under stop and recovery flow conditions were performed at Russian Research Centre "Kurchatov Institute" during 1977 year [1].

The aim of the chosen KS RBMK-1500 Test 5 was to investigate temperature mode of the fuel assembly under sharp decrease in coolant flow rate right down to its total termination and its recovery at constant high FA power generation. A similar situation can take place in the FC of the reference RBMK when MCP's pressure header breaking. In this case all the group distribution headers connected to the pressure header are cut off by the check valves, which are installed at the inlet to these group headers. Water ceases to be delivered into the fuel channels. There begins steam filling in the channels. To prevent FA overheating, ECCS water is supplied into the core.

Phenomena of hydrodynamics and heat transfer in RBMK-1500 core under MCP's pressure header break conditions are specific. So, it is necessary to estimate adequacy of the models of the code versions for modeling of these phenomena, because there are specific features in design of the core and fuel assembly of RBMK-1500. These specific features are FA rod location, geometry of rod and FA elements, hydraulic diameters of rod bundle cells and number of space grids, which are equipped with heat exchange intensifiers in the FA upper part. The behaviors of the core pressure drop and temperatures of the rods directly depends on these factors during LOCA.

The code simulation results are presented as curves. Pressure at the inlet of the FC model with FA, coolant temperature and mass flow rate at the FC model inlet, total pressure drop across the FA height and rod simulator temperature along FA have been plotted as time-dependent parameters for the experiment. The curves serve for comparisons of calculation results with experimental data to appreciate code suitability. The differences between RELAP5/MOD3.2 and RELAP5/MOD3.2.2 GAMMA predictions for the behaviors of the rod simulator temperatures along the height of the FA model and test data are described and analyzed.

Sensitivity studies were performed to investigate the influence of various process/phenomenon models applied in the code on calculation accuracy as well as nodalization and integration time step.

1.4. Report Organization

The following sections present and describe the steps that were taken to facilitate the codes assessments. In Section 2 the RBMK MFCC model at the KS Test Facility is described, and KS RBMK-1500 Test 5 is described in Section 3. Descriptions of RELAP5 model and base case input decks for the test modeling are given in Section 4. The base case results of the codes simulations for the test, comparisons of the calculated and measured values and conclusions are presented in Section 5. Sensitivity studies results are presented in Section 6, and run statistics are given in Section 7. In Section 8 summary of conclusions is presented. In the Appendix E one finds the base case RELAP5/MOD3.2 input deck listing for KS RBMK-1500 Test 5.

2. DESCRIPTION OF RBMK LOOP MODEL ON KS TEST FACILITY

The KS test facility simulates the main forced circulation loop of RBMK primary circuit.

KS RBMK MFCC model (Fig. 2.1) includes models of all the main elements of RBMK multiple forced circulation circuit: - (1) pressure header (PH), (2) group distribution header (DH), (3) lower water communication lines (LWC), (4) an isolating control valve (ICV), (5) a full-size fuel channel (FC) with (6) an electrically heated fuel assembly (FA), (7) the lifting path with (8) assembly suspension, and (9) steam water communication lines (SWC). The SWC horizontal section has a slope of 0.7 °. The upper horizontal header (10) and three vertical separators (11) do not model real drum separators (DS) but provide boundary conditions in the circuit outlet.

The model of RBMK-1500 fuel assembly (Fig. 2.2) includes 18 fuel element simulators made of stainless steel tubes of 13.5 mm OD and a central unheated rod (OD 15 mm) of the same steel. The radial power peaking in the fuel assembly is provided due to differences in wall thickness of the heated tubes: wall thickness of 12 tubes in the peripheral row is 4 mm and that of 6 tubes in the inner row is 3 mm. The FE power in the peripheral row is higher than that in the inner row being proportional to the ratio of cross section arias of FE simulator tube walls (~ 1.21), and it correlates as 1.061 to 0.878, if 1 is the average FE's power. The fuel assembly model is heated by the direct current passing through the fuel element simulators with uniform power density distribution along the FA height. Cable thermocouples of 1.5 mm OD are sealed in the fuel element simulator walls (Fig. 2.3).

Eleven RBMK-1500 reactor spacing grids-intensifiers with the full number of cells with pitch of 360 mm were installed in the upper part of the heated section along 3600 mm length. 20 grids-intensifiers of RBMK-1500 reactor were placed between them with 120 mm pitch, which served as spacers only for 6 fuel elements of the inner row. Nine authorized standard grids with 360 mm pitch were mounted in the lower part of the FA model.

The RBMK-1500 channel design differs from that of RBMK-1000 by spacer grids, which are equipped with heat exchange intensifiers in the FA upper part. Availability of these intensifiers in the upper part of the FA allows increasing in channel heat power.

The lower halves of RBMK-1500 and RBMK-1000 fuel assemblies are identical. Therefore some experimental results obtained in this experiment concerning the lower assembly half are applicable for RBMK-1000 (for instance, dryout onset, post dryout heat transfer...).

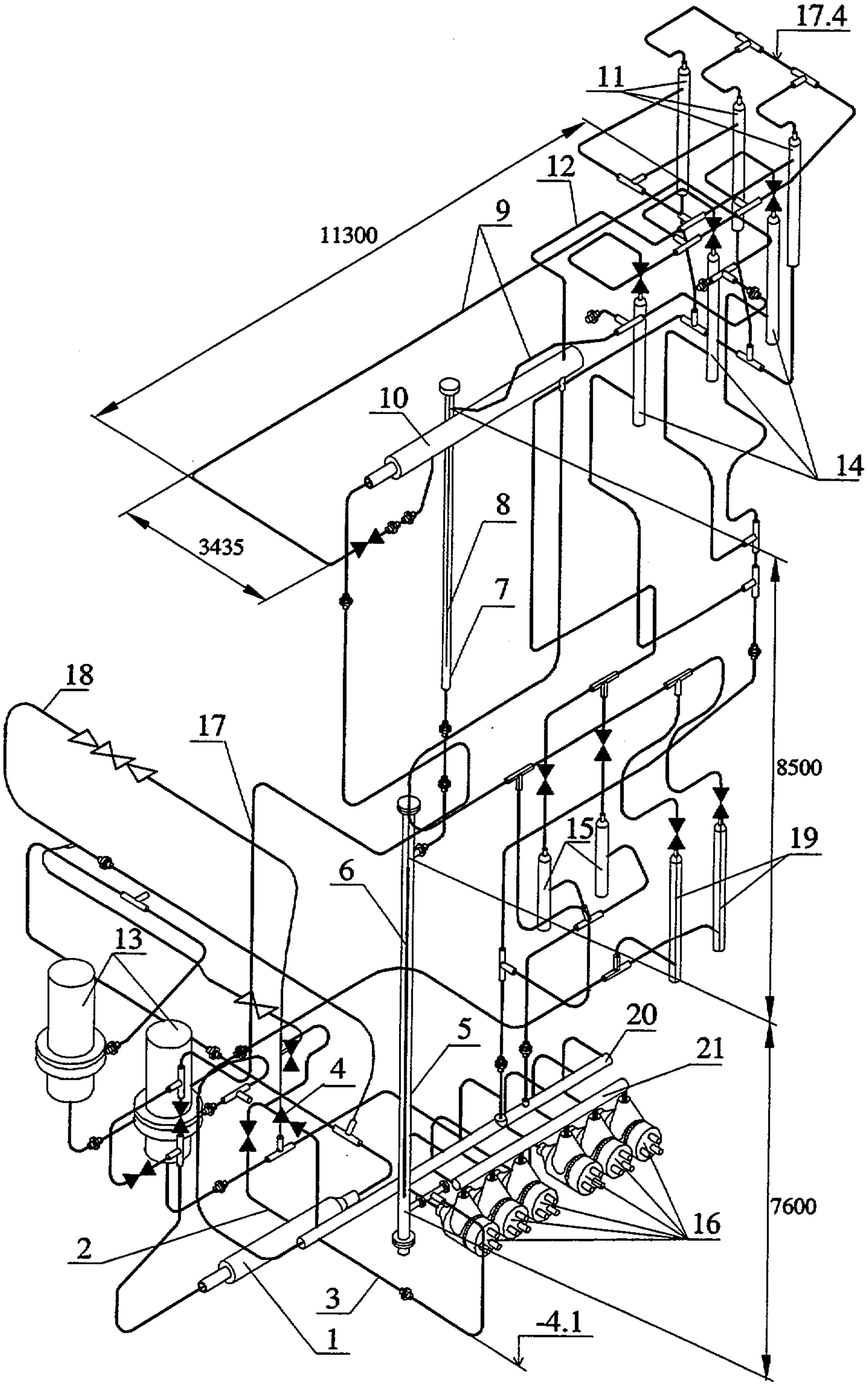

Fig. 2.1. KS RBMK MFCC model.

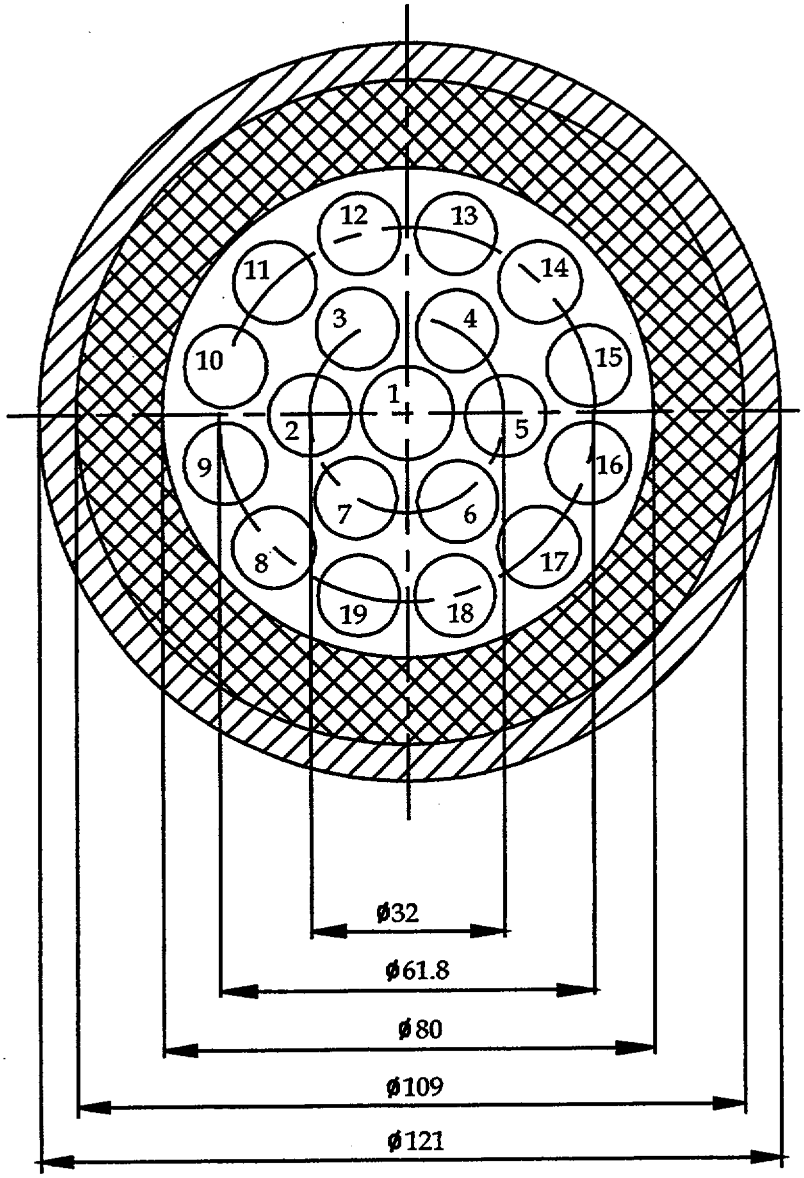

Fig. 2.2. Fuel channel model cross section.

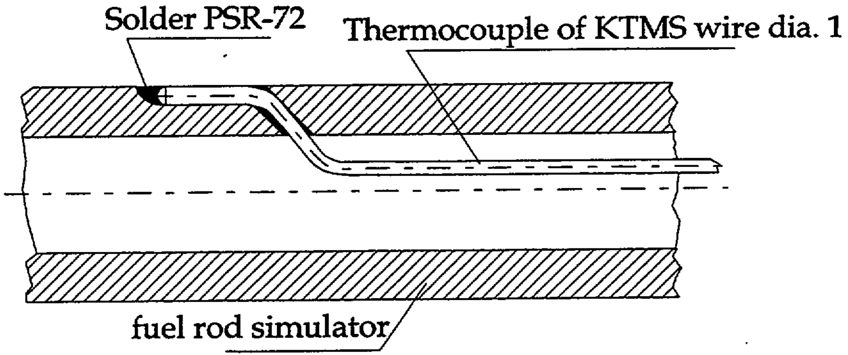

Fig. 2.3. Cable thermocouple placement into the wall of the fuel rod simulator.

There is also equipment that simulates operation of reactor drum separators (DS), steam condensers, downcomers and main circulation pumps of the RBMK primary circuit. However, this equipment do not model the appropriate RBMK MFCC components. For this reason the RBMK primary circuit model at the KS test facility is considered as semi-integral one.

Processes in the parallel fuel channels are under consideration during this experiment. One of the channels is considered as a full-size model of RBMK fuel channel. Impact of the rest parallel channels is simulated with the FC bypass (18). A great flow rate through the FC bypass provides practically constant pressure drop between the upper and lower headers in the course of the experiment.

The pressurization system used in the experiment includes 6 pressurizers of 0.52 m^3 in total volume connected to the 1-st collecting header. Nitrogen was used by way of gas medium.

More detailed description of RBMK MFCC model at the KS test facility is in [2].

3. DESCRIPTION OF THE TEST

The mode parameters in the course of the series of the tests were varied in the following ranges:

- FA model power: 1691 - 4566 kW;
- FA model inlet pressure: 7.68 - 8.74 MPa;
- FC model inlet temperature: 516 - 533 K;
- FC model inlet flow rate 3.9 – 6.27 kg/s.

Before the beginning chosen Test 5, the initial steady state with coolant forced circulation was set at given initial parameters outlined in Table 3.1.

Table 3.1. Parameters of the initial steady state for KS RBMK-1500 Test 5.

Designation of experiment	N kW	G Kg/s	Pin MPa	Tin K	DP16-4 MPa
KS RBMK-1500 Test 5	2486	4.70	8.40	527.4	0.2616

Given value of flow rate through the FC model was provided with an isolating control valve (see 4 in Fig.2.1). At given head-flow rate characteristic of the pumps a required total water flow rate through the FC model and FC bypass is provided with valve situated on the pump bypass.

Required flow rate distribution between MFCC and pump bypass is provided with matching local hydraulic resistance of the valve situated on the pump bypass at computer simulating of the test.

The FC model conditions during the experiment are nearly close to those when breaking the MCP's pressure header in the RBMK reactor and cutting off fuel channels with check valves.

When limiting temperature (this temperature mustn't be more than 870 K) is reached on the fuel rod simulator surface there is a resumption of flow rate through the fuel channel. Thus coolant circulation recovery on account of ECCS operation was simulated. The test is carried out at constant electrical power of the FA model.

Coolant been supplied from the pumps (13) went up through the riser of the fuel channel model (6, 7) and also through the FC bypass (17) up to the upper header (10) and then descended through four downcomers of RBMK MFCC model down to the suction side of the pumps.

Upon achieving a steady state, parameter recording began and an isolating control valve (4) at the inlet to the FC model closed completely and rapidly (during 3 s) causing the decrease in coolant flow rate down to zero. At achieving predetermined limit temperature of the rod simulators, an isolating control valve quickly opened and coolant flow rate recovered. In this case, temperature of the fuel element simulators decreased down to that close to saturation one.

States of the rest valve on the FC bypass and also the valves on the four downcomers and on the pump bypass were unchangeable during the transient.

During transient, a flow rate through the FC bypass remained practically constant (about 33.3 kg/s within the limits of experimental error). In the course of the experiment pressure in the upper header and separation columns was not maintained constant. The measurements scheme is shown in Fig.3.1.

The following parameters, outlined in Table 3.2, were measured and registered in the course of the experiment.

Table 3.2. List of measured parameters and measurement errors.

Parameter	Absolute measurement error
FA model electrical power N	± 60 kW
Water mass flow rate G at the FC inlet	± 0.14 kg/s
Pressure Pin at the FA model lower part	± 0.15 MPa
Pressure drop DP16-4 on the FA model height	± 0.1 KPa
Water temperature Tin at the FA model inlet	± 6 K
FE simulator wall temperatures Tw1 – Tw4 along the height of the FA model	± 16.5 K

The range of non-sensibility of the differential pressure gage is 0 - 120 KPa, because the device for measuring the pressure drop DP16-4 reached its lower measurement limit equal to 120 KPa.

According to special tests, response time of the thermocouples was 0.3 s.

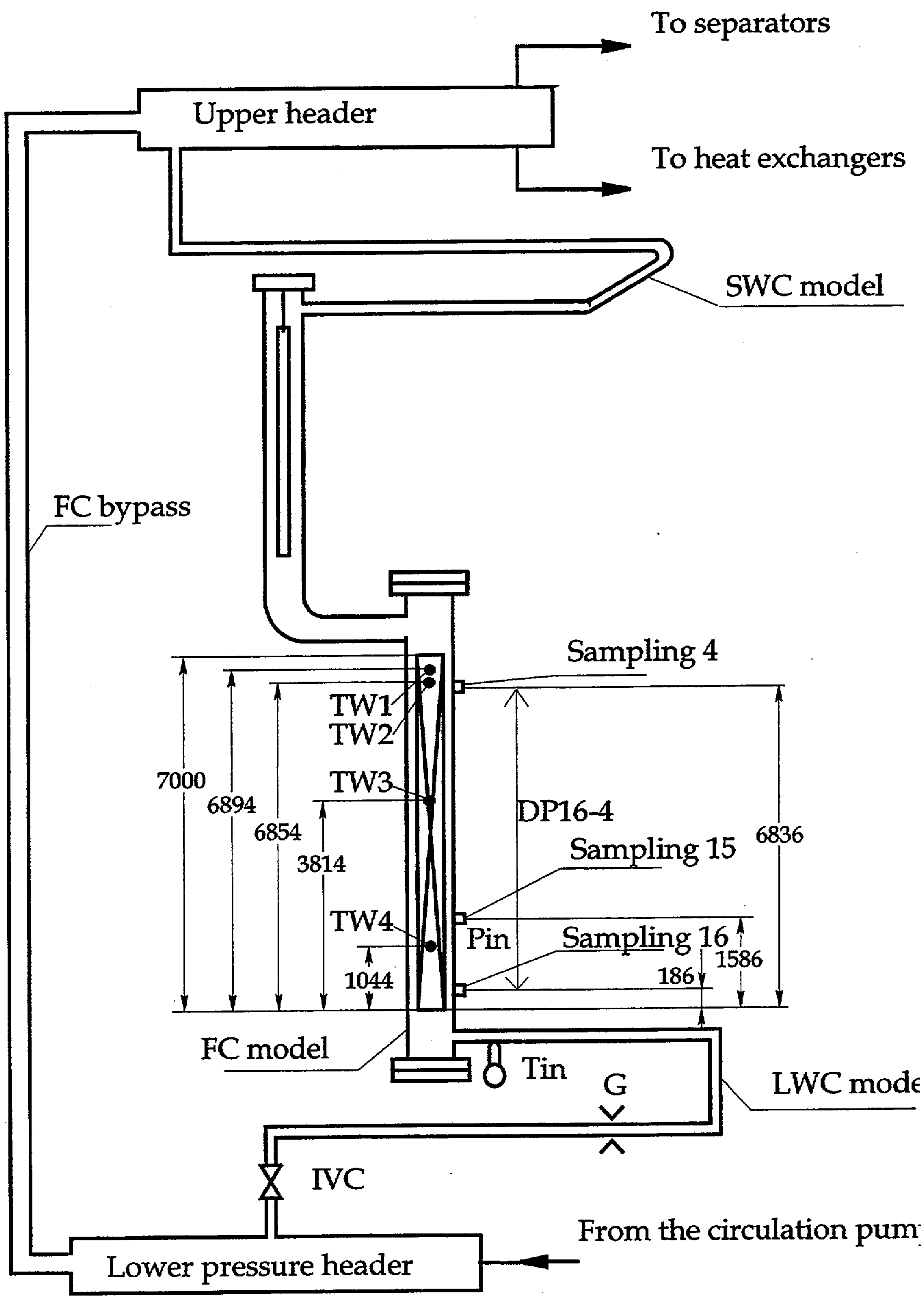

Fig. 3.1. Measurements scheme.

4. DESCRIPTIONS OF RELAP5 MODELS AND BASE CASE INPUT DECKS FOR THE TEST

4.1. RELAP5/MOD3.2 model and assumptions

4.1.1. Main allowances for simulation of the test

When calculating and assessing suitability of RELAP5/MOD3.2 and its modeling units for description of separate phenomena and complex processes, it is conventional in the first stage of the code simulation to use the options recommended by the code developers for actuating the code models under analogous conditions. The general modeling approaches recommended in the RELAP5 manuals [3, 4] should continue to be used.

The following assumptions were made:

- Volume Vertical Stratification, Water Packing, Abrupt Area Change, Branching, Noncondesables, Umbrella Model were process models activated for the corresponding circuit components;
- Process models such as an additional model of countercurrent flow limitation (CCFL Model), model of critical mass flow rate (Choked Model), and Reflood Model were not to be used in the corresponding circuit components.

To describe interphase friction in the coolant in the FC model with the FA, an option designating to rod bundle (with flag b=1) is applied. Semi-implicit scheme of numerical integration specified with the tt=3 option is used to calculate conjugate hydrodynamics and heat transfer/conduction processes.

4.1.2. KS RBMK MFCC model nodalization and input data description

RELAP5/MOD3.2 model simulates RBMK MFCC model at the KS test facility. This model includes a riser being investigated that contains two branches with models of the MFCC components, and auxiliary downcomer of four branches including components that ensure initial and boundary conditions in the MFCC part under consideration and also the test facility operation as a whole. Nodalization scheme for RBMK MFCC model at the KS test facility (in terms of RELAP5) is presented in Fig. 4.1. This nodalization scheme and input decks were developed with regard to the main assumptions when carrying out computer analysis of the test.

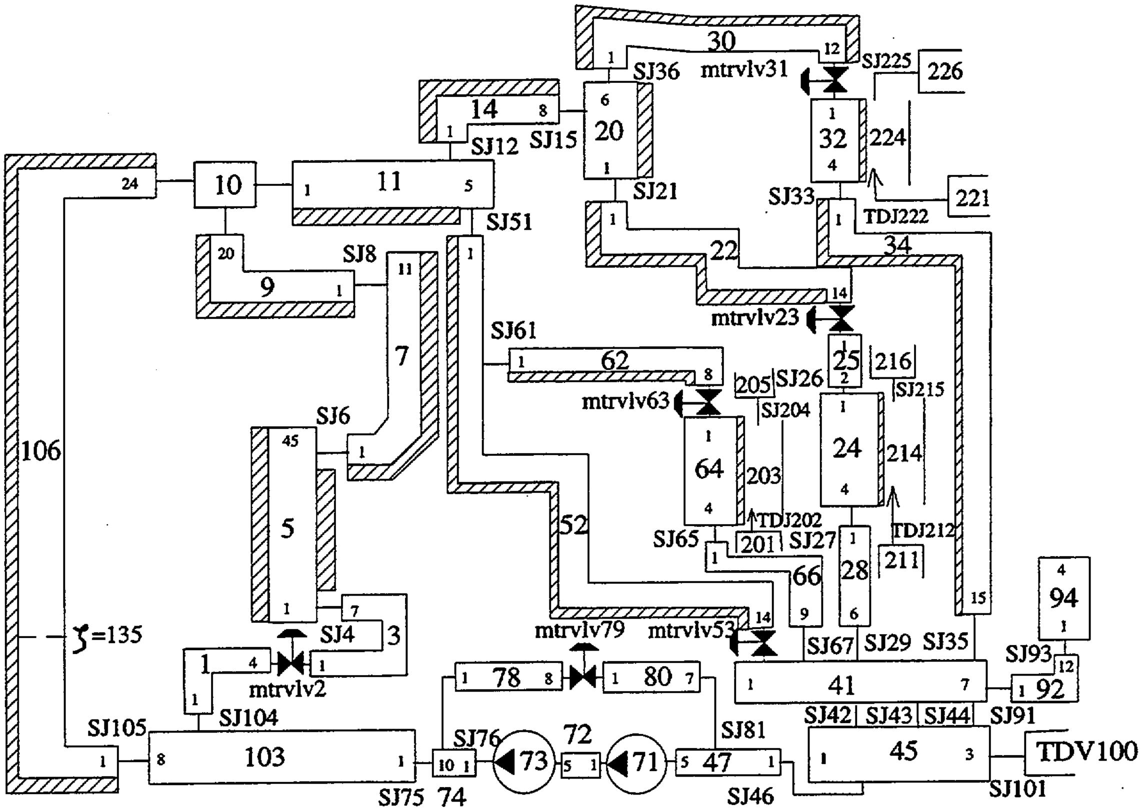

Fig. 4.1. Nodalization scheme of the RBMK MFCC model at the KS test facility.

To simulate operation of each pump when them activated simultaneously it was necessary to use conjectural homological head and torque curves for 8 single-phase modes of TsEN-146 pumps.

During the experiments the pumps operated continuously in single-phase flow at the wheel velocity of 3000 rpm.

At given head/flow characteristics of TsEN-146 pumps for normal operating conditions, required total water flow rate through the FC model and channel bypass is provided with the valve in the pumps bypass. This valve is modeled with component mtrvlv79. Given distribution of flow rates between MFCC model and pumps bypass is provided with choosing local hydraulic resistance of the valve component (mtrvlv79) during computer modeling of the experiment. Positions of the valve on the FC bypass (in Fig. 4.1 an orifice of constant local hydraulic resistance ξ=135 is shown instead of the FC bypass valve) and the valve on the pumps bypass were not changed during the transient under investigation.

Taking into account a great quantity of components in the primary and secondary circuits of the KS test facility, it was used only one equivalent component when modeling each appropriate group of the typical components located in four branches of the downcomer. In particular, only one component vol. 20 is used to simulate three separators (11). Three condensers (14) are modeled with one component vol. 32. When developing these equivalent models, particular attention was given to parity between real volumes and lengths of the inlet and outlet pipelines and those of corresponding hydrodynamic components as well as between surface areas of heat transfer toward water in the second circuit. These conditions are necessary to bring about representation of experimental conditions of heat exchange between primary and secondary circuits and to ensure simulation of coolant pressure behavior in the primary circuit at transient under investigation. To do this the modeling of circuit volume sections with two-phase mixture and gas must be obviously suitable.

Coolant flow termination to the FC model inlet with successive flow resumption are simulated with closing and next opening of ICV that uses a component like "motor valve 2". To control valve "close" and "open" procedures at given time moments Trip Input Data are used.

When modeling the section of the fuel channel with the FA model it was chosen a fine nodalization for hydrodynamic components and heat structures along the channel height that was connected to the pitches between spacer grids and grid-intensifiers (see Fig. 4.2).

The alignment of the nodalization in the fuel channel with the grid spacers is presented in Table 4.1. However, this resulting grid does not align well with some of the temperature and pressure measuring positions. This adds an uncertainty (< 1%) when comparing calculated and experimental values.

Table 4.1. The alignment of the nodalization in the fuel channel with the grid spacers.

Measurement	Experimental Height [m]	Closest Component in RELAP Model		
		Component Input Deck	Node Center Height [m]	Node Span Height [m]
DP16-4 bottom	0.186	vol. 5, node 3	0.340	0.160 – 0.520
PIN	1.586	vol. 5, node 6	1.420	1.240 – 1.600
DP16-4 top	6.836	vol. 5, node 40	6.820	6.760 – 6.880
TW4	1.044	ht. st. 51, node 4	1.060	0.880 – 1.240
TW3	3.814	ht. st. 51, node 14	3.820	3.760 – 3.880
TW2	6.854	ht. st. 51, node 39	6.820	6.760 – 6.880
TW1	6.894	ht. st. 51, node 40	6.940	6.880 – 7.000

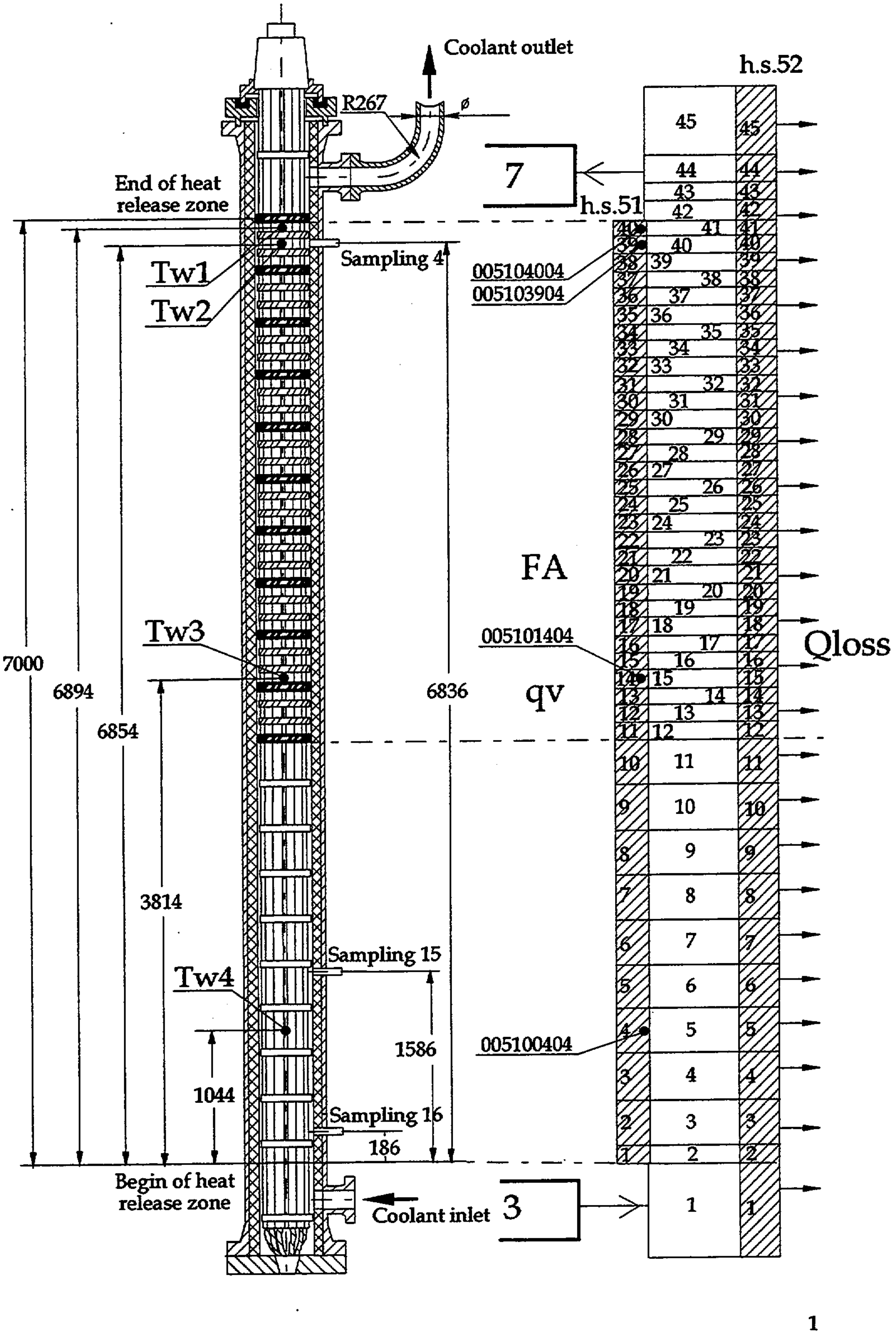

Fig. 4.2. Nodalization scheme of the RBMK-1500 Fuel channel model.

Rod simulator walls were modeled with "heat structure" components with internal heat sources. Boundary conditions on the rod's outer surfaces were set with Right Boundary Condition Cards with boundary condition type W3 (I)=110 ("Vertical bundle without cross flow" with P/D = 16.5/13.5= 1.222 on 901-940 cards). Heat transfer hydraulic diameter (i.e., heated equivalent diameter) De=11.92 mm is used for fuel channel with the 19-rods bundle (with 18 heated rods).

To account the heat exchange processes to be impact by the grids, it were used "Additional Right Boundary Cards". Local hydraulic resistance ξ=0.55 are to simulate 9 spacer grids arranged with the pitch of 360 mm in the lower part of the heated region. For 11 grid intensifiers situated with the pitch of 360 mm in the upper part of the heated region, local hydraulic resistance are defined to be ξ=0.91. As for 20 grid intensifiers, which are in the upper part of the heated region having the pitch of 120 mm, their local hydraulic resistance are equal to ξ=0.28.

In the "base case" calculations, power density distribution in the fuel rod simulators over the FA cross section was non-uniform. Power of 12 rods in the peripheral row was higher than rod power in the inner row of the bundle, because of the real radial power peaking factor of the FA model was 1.061.

The rod simulator wall is portioned in thickness into 4 layers so that the external layer thickness is 0.75 mm corresponding to the deepness at which the thermocouple's hot junction is positioned in the wall. This enables a direct comparison of RELAP5/MOD3.2 calculation results for wall temperature at this depth with the test data on temperatures Tw1, Tw2, Tw3 and Tw4.

Channel walls of the riser and descending circuit sections to the points of the condenser, heat exchanger and aftercooler were also modeled with "heat structure" components in order to simulate heat accumulation in the metal and external heat losses.

External heat losses from the primary circuit are modeled with setting up the heat transfer coefficient to be K=10 W/[m^2 K]. This value is constant in the region from the external surface of the heat structure which models the channel wall to the points of time-independent temperature of 295 K.

4.1.3. Methods of computer modeling of the experiment

This computer model makes it possible to simulate directly the experiment. When computer modeling the experiment the problem is setting up adequate thermal hydraulic characteristics of the components in the primary and secondary circuits (in the auxiliary section).

Using valve mtrvlv2, it is especially difficult to ensure experimental time-dependency of the coolant flow rate at the FC inlet obtained in the test. Because of it there was special computer simulation method and an Input Deck developed for the test.

When modeling the initial steady state with forced circulation, a balance between the FA power and heat removal in the condenser, heat exchanger and aftercooler was achieved with setting distribution of primary circuit coolant flows between descending branches and choosing water temperature in the secondary circuit. In this case, circuit pressure Pin, coolant temperature Tin and flow rate G through the FA model were stabilized after reaching the values equal to corresponding initial parameters obtained in the test at the moment texp=0 within the measurement error. Mass inventory in the primary circuit of MFCC was also stabilized. Water flow rate about 33.3 kg/s within the limits of experimental error through the bypass was set at a constant local hydraulic resistance ξ=135 of the valve on the FC bypass. Given flow rate at the FC inlet was ensured with the valve mtrvlv2, which local hydraulic resistance ξ=770 was chosen in the course of computer modeling for the test.

Calculations of this preset regime were run during tcalc=1000 seconds for stabilizing coolant parameters and heat structure temperatures in the primary circuit. Before this took place, the volume TDV100 containing subcooling water was connected to the primary circuit model. The water temperature equal to required value Tin at the FC inlet and also the pressure for supporting required pressure Pin in the channel at the moment texp=0 were set in this volume.

Vary small or close to zero values of water flow rates in the conjunctions SJ93 and SJ101 and, consequently, stabilization of mass inventory in the primary circuit were also demonstrations of stabilization of the processes in the primary and secondary circuits.

After achieving the steady state in the primary circuit at required coolant mode parameters at the FC inlet, the volume TDV100 was disconnected from the primary circuit of MFCC model and a closed primary circulation circuit including the pressurizer was formed. In so doing, only the pressurizer with subcooled water was connected to the primary circuit model. In the pressurizer, liquid level was preset to be in the middle of its vessel, as for liquid temperature its value was equal to Tin i.e.

the initial magnitude required at the FC inlet. Gas (nitrogen) pressure was specified to ensure a given FC pressure Pin at the moment texp=0 s. Stabilization of the calculated pressures P(t)calc and volume equilibrium qualities Xe(t)calc at the inlet and outlet of the FA model were also demonstrations of stabilization of the processes in the primary and secondary circuits during the time interval from tcalc=1000 s to tcalc=1400 s.

Simulation of the curve of sharp decrease in water flow rate down to zero at the FC model inlet with valve mtrvlv2 was performed by choosing its close rate and a related value of its initial position as well as moments to begin its opening and closing. The FA power was unchanged during the test.

When the rod simulator temperature preset limit was reached (it should not be above 870 K) valve 2r was quickly opened with coolant flow being recovered. In this case, the rod simulator temperatures were decreased down those closed to saturation temperature. Simulation of the curve of sharp increase in water flow rate at the FC model inlet up to a given value with valve mtrvlv2 was performed by choosing its opening rate as well as moments to begin its opening and closing. This flow rate was smaller than the initial one at the moment texp= 0 s.

When modeling transient in the fuel channel with the FA model, it was chosen a maximum time step dtmax =0.01 s. This value is in agreement with the recommendations [3, 4] for calculating such processes.

4.2. RELAP5/MOD3.2.2 GAMMA model and assumptions

When calculating and assessing suitability of RELAP5/MOD3.2.2 GAMMA and its modeling units for description of separate phenomena and complex processes, it is conventional to use the options recommended by the code developers for actuating the code models under analogous conditions.

The following assumptions were made:

- Volume Vertical Stratification, Water Packing, Abrupt Area Change, Branching, Noncondesables, Umbrella Model and Reflood Model were process models activated for the corresponding circuit components;
- Process models such as an additional model of countercurrent flow limitation (CCFL Model), model of critical mass flow rate (Choked Model) were not to be used in the corresponding circuit components.

When modeling transient in the fuel channel with the FA model, it was chosen a maximum time step dtmax =0.01 s.

5. RESULTS OF THE CODES ASSESSMENT

5.1. RELAP5/MOD3.2 base case results, comparisons to KS test data and conclusions

Calculation of presetting mode with TDV100 been connected was performed during first 1000 s and then, after disconnecting TDV100, was continued up to 1400 s for achieving a steady state in the primary circuit. When calculating both preset mode and transient under investigation, option TRANSNT was used. To justify the basic nodalization scheme, methods for modeling of the test and corresponding input deck, preliminary calculations of the experiment were performed.

Calculation results and test data for the main mode parameters Gin, Tin, and Pin at the FC inlet under steady conditions with forced circulation are presented in Figures 1, 2 and 3, respectively, in Appendix B and in Table 5.1 to be compared. In these figures and in the table, one can see the calculated values of mentioned parameters at the steady state are close to the experimental ones or they lie within the range of measurement accuracy. During the test the steady state is considered a mode to be in the interval of time from texp=0 s to the moment when water flow rate begins to decrease.

To estimate suitability of computer modeling of complex thermal hydraulic processes in the FC with FA model at the steady state the base case calculation results of the total pressure drop DP16-4 and rod's wall temperatures Tw1, Tw2, Tw3, Tw4 across the FA model height were used. These base case results are presented in Figures 4 - 8 in Appendix B and in Table 5.1 to be compared with test data, too.

As an integral criterion for the suitability assessment of simulation of thermal hydraulic processes in the channel with the RBMK-1500 fuel assembly, it was used the value of relative mismatching of total pressure drop DP16-4 along the FA model height which is determined as follows:

$$\Delta \equiv \frac{DPcalc - DP\exp}{DP\exp} \bullet 100\%$$

For comparison, Table 5.1 lists calculation results and data for DP16-4 obtained during the test.

In the preliminary case with FC wall roughness 4·10-6 m the code gives – 9.7 % underestimation in pressure drop DP16-4 relating to the measured value in the steady state. This discrepancy for total pressure drop DP16-4 may be resulted from inaccurate code description of the local losses of pressure on the spacer grids and grid-intensifiers as well as wall and interphase frictions in the two-phase flow in the heated rod bundle. There needs to be some effort to address this error via parametric changes in the input. Therefore, sensitivity study was performed with different FC wall roughness for the test.

In the base case calculation with FC wall roughness 4·10-5 m the code gives + 5.4 % overestimation in pressure drop DP16-4 relating to the measured value in the steady state. The increasing of the FC wall roughness in 10 times results in code over prediction for DP16-4 pressure drop, however the base case calculated value of pressure drop DP16-4 is in a satisfactory agreement with the measured one.

The calculated values of the rod temperatures Tw1, Tw2, Tw3, Tw4 along the FA height are in satisfactory agreements with the test data, too. In steady state the code describes with a reasonable suitability a heat transfer in two-phase flow in the channel with the RBMK-1500 fuel assembly.

Table 5.1. Comparison of the base case calculated, sensitivity studied and experimental values of the main mode parameters at the steady state.

Steady state parameters	N kW	Gin Kg/s	Pin MPa	Tin K	G_{bypass} Kg/s	Total pressure drop DP16-4, Pa	Mismatching ± Δ (DP16-4), %
5 (experiment)	2486	4.70	8.40	527.4	33.3	261600	
5 (calculation with roughness 4·10-6 m)	2486	4.73	8.38	526.5	30.8	236290	– 9.7
5 (base case calculation with roughness 4·10-5 m)	2486	4.62	8.42	526.5	30.8	275820	+ 5.4

RELAP5/MOD3.2 describes with a reasonable suitability the complex processes at the stage of the transient in the test when the coolant flow rate decreases and completely terminates.

In particular, the pictures of the experimental and calculated pressures P (t) are in a qualitative agreement, although at certain stages the calculated one is higher or lower than measured value in the transient. At the same time, the rates of the increase or decrease in pressures dP/dt as well as finally achieved pressure values are essentially different from those obtained experimentally (see Fig. B-3). Predicted pattern of the behavior of total pressure drop DP16-4 (t) is in a qualitative agreement with experimental data. The reasons for these discrepancies when describing the 1-st stage of the transient may be a non-adequate code description of dynamic processes of steam generation in the FC with FA as well as steam condensation in the components of the closed circuit as a whole and, consequently, non-adequate description of the pressure behavior in the primary circuit and in the fuel channel.

RELAP5/MOD3.2 code reasonably describes the character and rate of the thermal and hydrodynamic processes and the behaviors of the parameters concerned in the first stage of the transient. To assess integrally an accuracy of the code simulation of the complex processes, the time interval Δt_d (from the moment of full stop of flow to the beginning of increase in wall temperature Tw1 (t) at the FA outlet) was used. The value of the time interval $\Delta t_d = t_d - t(G0)$ been predicted for the test exceeds the experimental value Δt_d by about ~1.0 s. This indicates a reasonable suitability of the code simulation of the dryout initiation and its propagation along the FA height during the 1-st stage of the transient. The results would be still closer to the test data when simulating the flow rate behavior at the FC inlet as in a reality. Use of Time Dependent Junction to accurate code simulation of a real flow rate behavior at the channel inlet gives more realistic code results for the initial and boundary conditions for the fuel channel during the test.

The comparisons of the behaviors of rod's wall temperatures Tw1 (t), Tw2 (t), Tw3 (t), and Tw4 (t) been measured and also those of calculated wall temperatures during the transient in the experiment are presented in Figures B-5, B-6, B-7 and B-8, respectively.

When simulating the test, the dryout primarily happens at the FA outlet leading to an increase in temperatures Tw1 (t) and Tw2 (t), as evident from Fig. B-5, B-6. Then the dryout propagates with time from top to bottom along the FA height. This predicted picture of the dryout initiation and its propagation from the top down along the FA height is in a qualitative agreement with test data.

This indicates a reasonable suitability of the code simulation of the dryout initiation and its propagation along the FA height during the 1-st stage of the transient at FA power been constant.

It should be specially noticed that the maximum values Tw $(t)_{max}$calc of the calculated wall temperatures exceed the maximum experimental magnitudes $Tw(t)_{max}$ exp. It means that the code would be likely to overestimate the maximum cladding temperature, which would be a conservative result from a safety perspective.

The reflood model does not behave in RELAP5/MOD3.2, therefore the second stage of the investigated transient in the test was simulated under conditions when a special reflood model is not in usage. This allowed to make more exact the conditions for modeling the thermal and hydrodynamic processes as well as to estimate a necessity and importance of a special code model to be used for analyzing of reflood during the second stage of the transient.

The adequate code simulation of the complex processes at the first stage of the transient allow exactly modeling the initial conditions for the second stage of the transient.

The code gives an insufficient agreement with test data concerning the time characteristics and conditions of the rod surface quenching in the upper part of the FA model. The code gives only a qualitative agreement demonstrating a presence of rod surface quenching in the lower FA part in the cross-section where thermocouple Tw4 is installed (see Fig. B-8). At the same time, the rest of the cross-sections been positioned above (see thermocouples Tw1 (t), Tw2 (t), Tw3 (t) in Figures B-5, B-6, B-7) do not quench during the 2-nd stage when calculating the experiment during 40 seconds. Shown is that the calculated velocity of quench front propagation is less than that in the test at constant power N=2486 kW.

The analysis results obtained when modeling the reflooding of FC with RBMK-1500 fuel assembly allow RELAP5/MOD3.2 code suitability being assessed as insufficient. Shown is a necessity and importance of a special Reflood Model to be used for suitable description of the second stage of the transient. At validation of the advanced code version RELAP5/MOD3.2.2 GAMMA and assessment of its reflood model, it will be necessary to achieve a suitable simulation of the initial conditions for the second stage of the transient.

The results of RELAP5/MOD3.2 code assessment are presented in Table 5.2.

Table 5.2. The results of RELAP5/MOD3.2 code assessment (code performance for process/phenomenon).

1. Process/Phenomenon in the steady state in Test 5	***Results of RELAP5/MOD3.2 assessment***
1.1. Total pressure drop along the height of the channel with RBMK-1500 fuel assembly	Reasonable adequacy
1.2. Heat transfer in the two-phase flow in the channel with the RBMK-1500 fuel assembly	Reasonable adequacy
2. Process/Phenomenon on the stage of decrease and full stop of flow in Test 5	***Results of RELAP5/MOD3.2 assessment***
2.1. Total pressure drop and water release from the fuel channel model and heated rod surface dryout	Reasonable adequacy
2.2. Dryout under sharp flow deceleration at the inlet of the RBMK-1500 fuel assembly	Reasonable adequacy
2.4. Post dryout heat transfer and heated rod bundle temperature behavior in the lower and upper parts of RBMK-1500 fuel assembly under stop of flow and channel drying conditions	Reasonable adequacy
3. Process/Phenomenon on the recovery stage of water supply into the fuel channel model	***Results of RELAP5/MOD3.2 assessment***
3.1. Propagation of the reflood and quench fronts in the RBMK-1500 fuel assembly under flow resumption at the channel inlet	Insufficient adequacy

5.2. RELAP5/MOD3.2.2 GAMMA base case results, comparisons to KS test data and conclusions

Calculation of presetting mode with TDV100 been connected was performed during first 1000 s and then, after disconnecting TDV100, was continued up to 1400 s for achieving a steady state in the primary circuit.

RELAP5/MOD3.2.2 GAMMA ***results and test data for the main mode parameters Gin and Pin at the FC inlet under steady conditions with forced circulation*** are presented in Figures C-1 and C-2, respectively, in Appendix C to be compared. In these figures one can see the calculated values of mentioned parameters at the steady state are close to the experimental ones.

The base case results for total pressure drop DP16-4 and rod's wall temperatures Tw1, Tw2, Tw3, Tw4 across the FA model height are presented in Figures C-2, C-3, C-4 in Appendix C to be compared with test data. The code gives + 5.4 % overestimation in pressure drop DP16-4 relating to the measured value in the steady state. The calculated values of the rod's wall temperatures along the FA height are in satisfactory agreements with test data, too. In steady state the code describes with a reasonable suitability a heat transfer in two-phase flow in the channel with the RBMK-1500 fuel assembly.

RELAP5/MOD3.2.2 GAMMA describes with a reasonable suitability the complex processes at the first stage of the transient with stop of flow.

The pictures of the experimental and calculated pressures P (t) are in a qualitative agreement, although at certain stages the calculated pressure is higher or lower than measured one in the transient (see Fig. C-2). Predicted pattern of the behavior of total pressure drop DP16-4 (t) is in a qualitative agreement with test data. The reasons for these discrepancies when describing the 1-st stage of the transient may be a non-adequate code description of dynamic processes of steam generation in the fuel channel as well as steam condensation in the components of the closed circuit as a whole and, consequently, non-adequate description of pressure behavior in the primary circuit and in the fuel channel.

RELAP5/MOD3.2.2 GAMMA code reasonably describes the character and rate of the thermal and hydrodynamic processes and the behaviors of the parameters concerned in the 1-st stage of the transient. Comparisons between test data and RELAP5/MOD3.2 and RELAP5/MOD3.2.2 GAMMA predictions for the behaviors of the considered parameters in the base case with "motor valve 2r" are presented in Appendix C. The comparisons of the behaviors of rod's wall temperatures Tw1 (t), Tw2 (t), Tw3 (t), and Tw4 (t) been measured and also those of calculated temperatures during the transient are presented in Figures C-3, C-4 and C-5. These indicate a reasonable suitability of the code simulation of the dryout initiation and its propagation along the FA height during the 1-st stage of the transient at FA power been constant. The maximum values Tw $(t)_{max}$calc of the calculated wall temperatures exceed the maximum experimental magnitudes $Tw(t)_{max}$ exp. It means that RELAP5/MOD3.2.2 GAMMA code would be likely to overestimate the maximum cladding temperature, which would be a conservative result from a safety perspective.

The reflood model behaves in RELAP5/MOD3.2.2 GAMMA code, therefore the transient in the test was simulated using a special reflood model. This allowed to assess adequacy of a special model for analyzing of reflood during the second stage of the transient.

The adequate code simulation of the complex processes at the first stage of the transient allow exactly modeling the initial conditions for the second stage of the transient with FC reflood.

The code gives reasonable agreements with test data concerning the time characteristics and conditions of the rod surface quenching in the upper part of the FA model (see thermocouples Tw1 (t) and Tw2 (t) at the elevations 6.94 m and 6.82 m, respectively, in Figure C-3). The code gives only a qualitative agreement demonstrating a presence of rod surface quenching in the middle FA part (see thermocouple Tw3 (t) at the elevation 3.82 m in Figure C-4).

At the same time, the cross-section been positioned below does not quench during the 2-nd stage when calculating the experiment during 40 or 350 seconds (see temperatures Tw (tcalc) at the elevation 1.04 m in Figures C-4 and C-5). Shown is an insufficient code adequacy for the lower FA model part

RELAP5/MOD3.2.2 GAMMA results obtained when simulating reflood and quench fronts in the fuel cannel model allow the code adequacy being assessed as a reasonable adequacy for the upper part of RBMK-1500 fuel assembly model and an insufficient adequacy for its lower part.

Shown is a necessity for formulation special Standard Problem “Propagation of the reflood and quench fronts in the lower and upper parts of RBMK-1500 fuel assembly model under flow resumption at the channel inlet” and its analysis using RELAP5/MOD3.2.2 GAMMA

The results of RELAP5/MOD3.2.2 GAMMA code assessment are presented in Table 5.3.

Table 5.3. The results of RELAP5/MOD3.2.2 GAMMA code assessment (code performance for process/phenomenon)

1. Process/Phenomenon in the steady state in Test 5	*Results of RELAP5/MOD3.2.2 GAMMA assessment*
1.1. Total pressure drop along the height of the channel with RBMK-1500 fuel assembly model	Reasonable adequacy
1.2. Heat transfer in the two-phase flow in the channel with the RBMK-1500 fuel assembly model	Reasonable adequacy
2. Process/Phenomenon on the stage of decrease and full stop of flow in Test 5	*Results of RELAP5/MOD3.2.2 GAMMA assessment*
2.1. Total pressure drop and water release from the fuel channel model and heated rod surface dryout	Reasonable adequacy
2.2. Dryout under sharp flow deceleration at the inlet of the RBMK-1500 fuel assembly model	Reasonable adequacy
2.4. Post dryout heat transfer and heated rod bundle temperature behavior in the lower and upper parts of RBMK-1500 fuel assembly model under stop of flow and channel drying conditions	Reasonable adequacy
3. Process/Phenomenon on the recovery stage of water supply into the fuel channel model	*Results of RELAP5/MOD3.2.2 GAMMA assessment*
3.1. Propagation of the reflood and quench fronts in the lower and upper parts of RBMK-1500 fuel assembly model under flow resumption at the channel inlet	Reasonable adequacy for the upper FA model part Insufficient adequacy for the lower FA model part

6. SENSITIVITY STUDY

Sensitivity studies were performed with different FC wall roughness $4 \cdot 10^{-6}$ m and $4 \cdot 10^{-5}$ m in the FC model to estimate its influence on code simulation of complex thermal hydraulic processes in the FC. In steady conditions the increasing in FC wall roughness leads to a better agreement between experimental and calculated values of pressure drop DP16-4 across the FA model height with achieving good coincidence within the measurement accuracy for test 5 at FA power of 2486 kW.

The increased FC wall roughness weakly influences on the behavior of pressure drop DP16-4 (t), and also of the wall temperatures Tw1 (t), Tw2 (t), Tw3 (t), and Tw4 (t)) during the 1-st and 2-nd stages of the transient.

Also, sensitivity study was carried out to investigate the effects of modeling on the behaviors of the rod simulator temperatures along the heated bundle height using motor valve component or Time Dependent Junction in LWC.

Comparisons between test data and RELAP5/MOD3.2.2 GAMMA predictions for the behaviors of the considered parameters G (t), Pin (t) and DP16-4 (t) in the base case with "motor valve 2r" and in the sensitivity study case with TDJ in LWC are presented in Figures D-1 and D-2 in Appendix D.

The comparisons of the behaviors of rod's wall temperatures Tw1 (t), Tw2 (t), Tw3 (t), and Tw4 (t) been measured and also those of calculated temperatures during the transient are presented in Figures D-3 and D-4. These indicate a reasonable suitability of the code simulation of the dryout initiation and its propagation along the FA height during the 1-st stage of the transient at FA power been constant.

Using two lumped rod simulators (Kr=1.061) and TDJ to accurate code simulation of the real flow rate behavior at the channel inlet gives more realistic code results for the initial and boundary conditions in the fuel channel. In this case the code predicted time interval Δt_d from the moment t(G0) of complete stop flow to the beginning t_d of the rod's wall temperature Tw1(t) increase at the core outlet exceeds the experimental value Δt_d by about ~ 0.2 s. The excess of calculated value Δt_d over that obtained experimentally decreases from ~ 1.0 s to ~ 0.2 s and the pictures of the dryout initiation and its propagation along the FA height become more resembling in this case.

7. RUN STATISTICS

The simulation model for KS Test 5 includes:

307 volumes, 311 junctions, 282 heat structures with 729 nodes.

There were the following resources been used for the calculation:

Run time – CPU = 855.13 s;

Step number – DT = 3751;

Volume number – C = 307.

Calculation results of **grind time** (program efficiency factor)

$$\textbf{\textit{Grind time}} = \frac{CPU \cdot 10^3}{C \cdot DT} = \textbf{\textit{0.74259}}$$

For the calculations, it was used a computer IBM PC AT with processor INTEL Pentium-166MMX. Windows-95 was used as an operating system. CPU-time as well as the integration step variations are presented in Fig. 7.1 and 7.2, respectively.

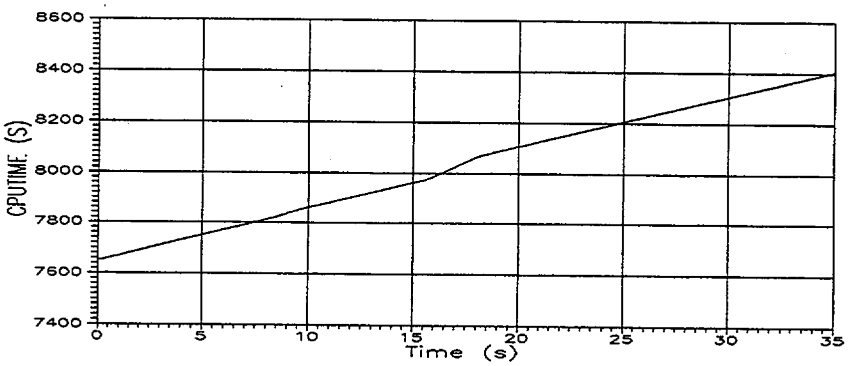

Fig. 7.1. Execution time (CPU TIME) of the main variant computation for the experiment.

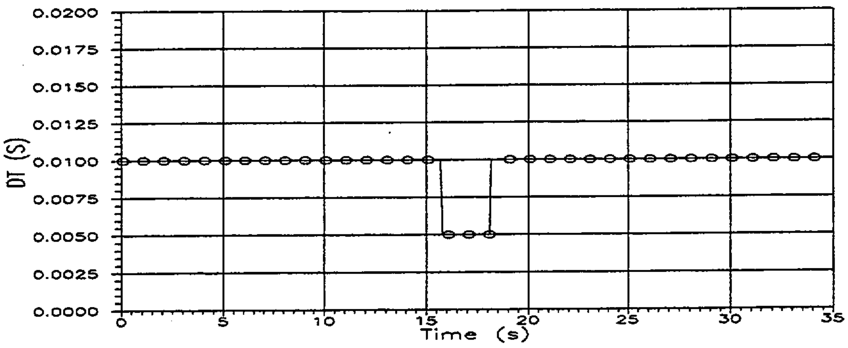

Fig. 7.2. Integration step (dt) variations at the main variant computation for the experiment.

8. SUMMARY OF CONCLUSIONS

KS test data on the behavior of the heated rod bundle temperature in the RBMK-1500 core model under stop and recovery flow conditions were simulated with RELAP5/MOD3.2 and RELAP5/MOD3.2.2GAMMA to assess these codes suitability. Especially calculations were performed to estimate differences in the code version predictions for processes/phenomena, which could occur under specific conditions of RBMK type reactor during LOCA with MCP's pressure header rupture and subsequent ECCS water injection. This problem addresses phenomena of high importance to RBMK-1500 safety including water discharge, critical heat flux, post dryout heat transfer, reflood and propagation of rewetting front in the fuel channel during an accident.

In this work some deficiencies of RELAP5/MOD3.2 and RELAP5/MOD3.2.2GAMMA in analyses of KS Test 5 could be identified, and the following conclusions can be drawn:

- RELAP5/MOD3.2 gives reasonable agreements of general pictures of simulated processes/phenomena with test data on the stage with the decrease and complete stop of flow at the FC inlet. At the same time, it was intimated that there is a need to modify RELAP5/MOD3.2 models used for interphase friction and critical heat flux in the channel with the RBMK-1500 fuel assembly under initial steady conditions with forced circulation.

- When simulating the recovery stage of water supply into the channel there were essential distinctions between RELAP5/MOD3.2 code results and test data on the behaviors of the rod's wall temperatures along the FA height. The code does not give qualitative agreements between the curves for the rod temperatures along the FA height at the quenching in the test. The code gives insufficient agreement with test data concerning the time characteristics and conditions of the rod surface quenching in the upper and middle parts of the FA. The analysis results allow RELAP5/MOD3.2 code suitability being assessed as insufficient. Shown is a necessity and importance of a special reflood model to be used for suitable description of the reflood stage of the transient.

- RELAP5/MOD3.2.2 GAMMA gives reasonable agreements of general pictures of simulated processes/phenomena with test data on the transient stage with the decrease and complete stop of flow. Sensitivity study was carried out to investigate the effects of modeling on the behaviors of the rod simulator temperatures along the heated bundle height using motor valve component or Time Dependent Junction in LWC. Use of TDJ to accurate code simulation of the real flow rate behavior at the channel inlet gives more realistic code results for the initial and boundary conditions in the fuel channel. In this case the code predicted time interval Δt_d from the moment t(G0) of complete stop flow to the beginning t_d of the rod's wall temperature Tw1(t) increase at the core outlet exceeds the experimental value Δt_d by about ~ 0.2 s. This indicates a reasonable adequacy of the code simulation of dryout initiation at rapid decrease of the flow right down to its total termination.

- RELAP5/MOD3.2.2 GAMMA results obtained when simulating reflood and quench fronts in the fuel cannel allow the code adequacy being assessed as reasonable only for the upper part of RBMK-1500 fuel assembly and as insufficient for the lower part of the FA model.

Shown is a necessity for formulation special Standard Problem "Propagation of the reflood and quench fronts in the lower and upper parts of RBMK-1500 fuel assembly under flow resumption at the channel inlet" and its analysis using RELAP5/MOD3.2.2 GAMMA.

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APPENDIX-A

Original Data Plots From KS RBMK-1500 Test 5

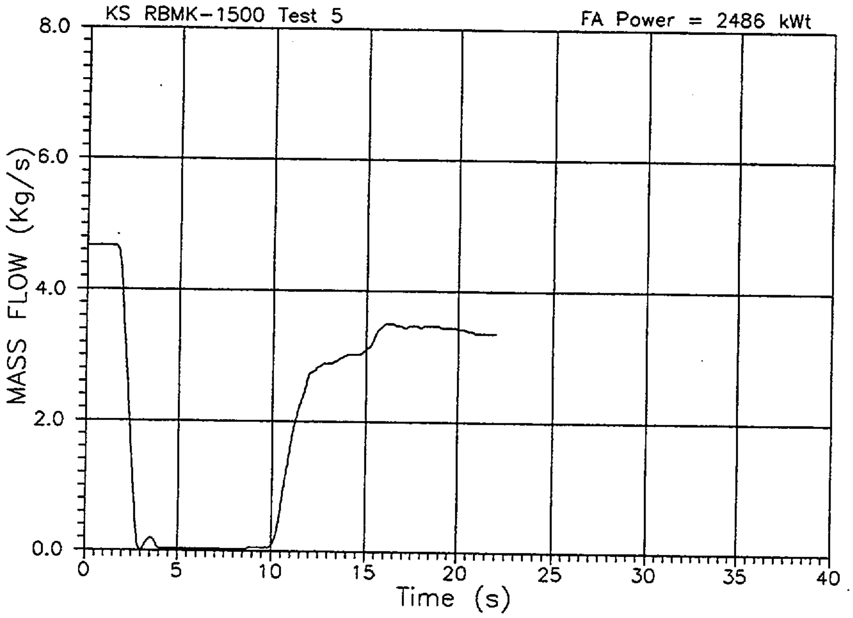


Fig. A-1. Mass flow rate G history at the FC model inlet in experiment 5.

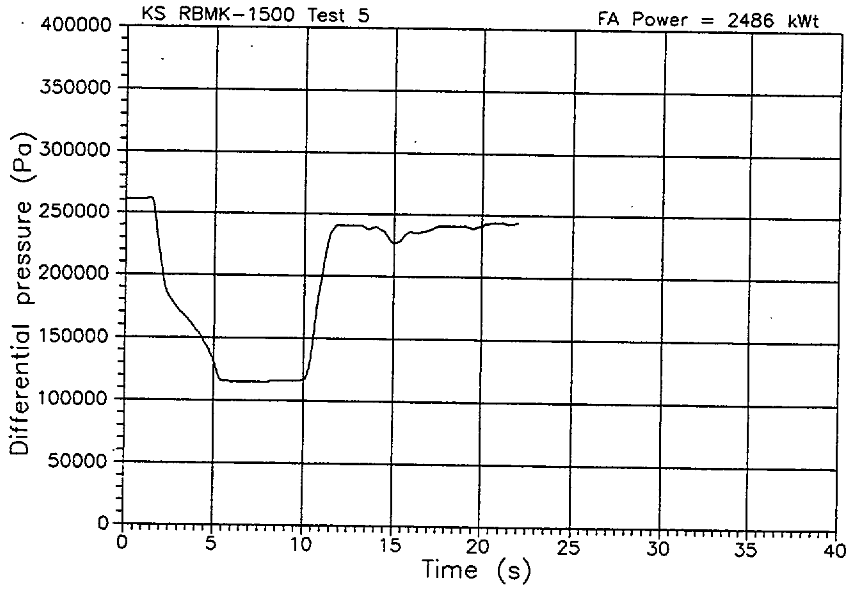


Fig.A-2. Pressure drop P16-4 history along the FA model in experiment 5.

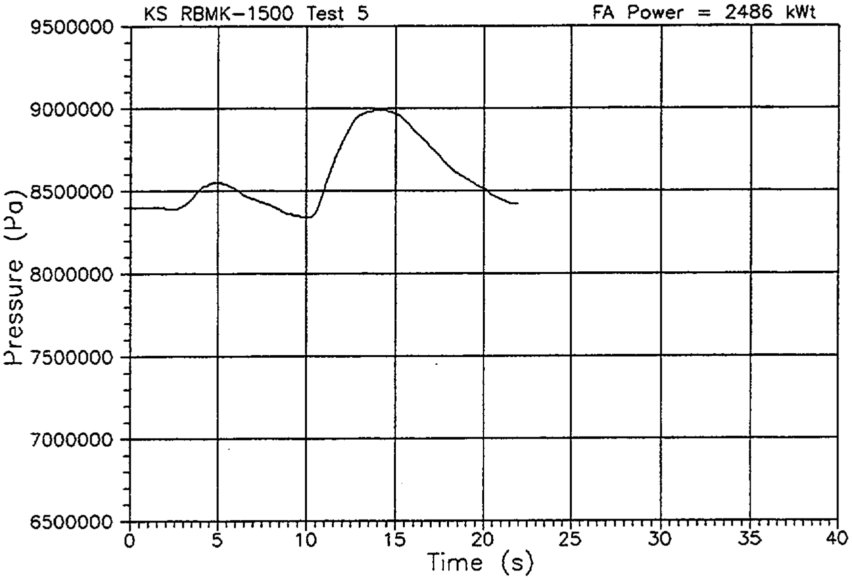


Fig. A-3. Pressure Pin history in the lower part of the FA model in experiment 5.

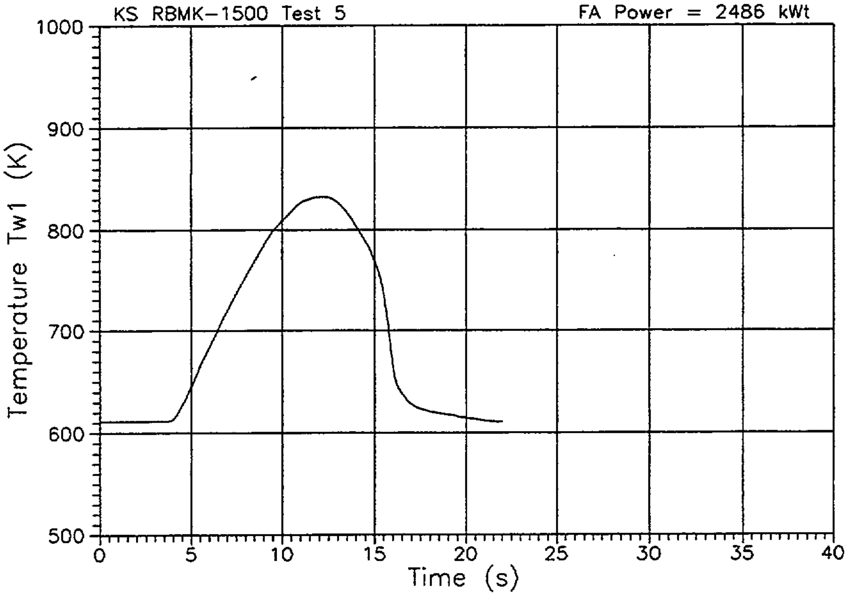


Fig. A-4. Fuel rod simulator temperature Tw1 (z=6.894 m) history in experiment 5.

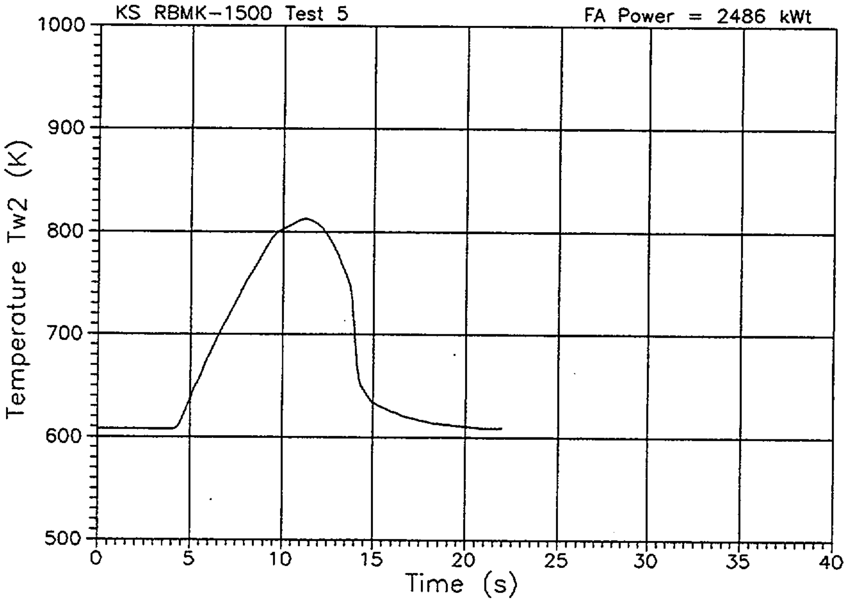


Fig. A-5. Fuel rod simulator temperature Tw2 (z=6.854 m) history in experiment 5.

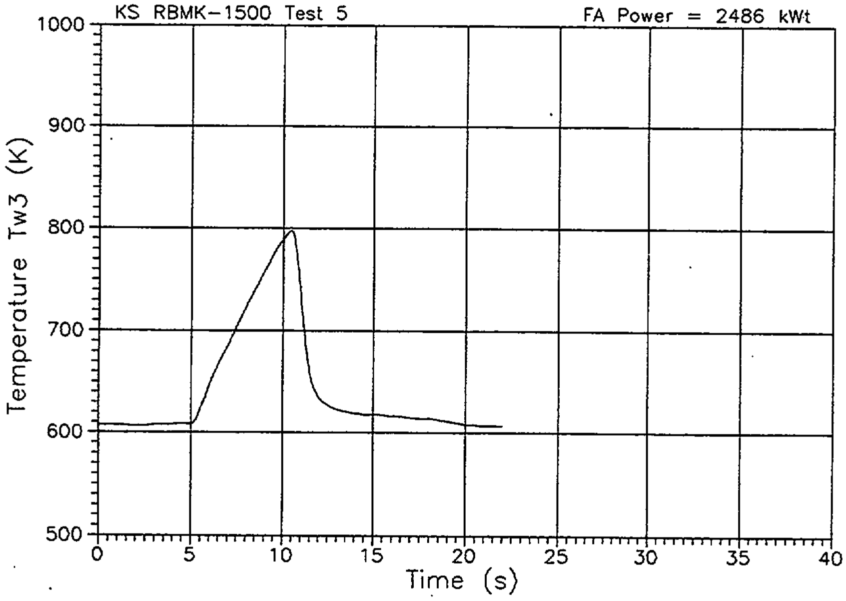


Fig. A-6. Fuel rod simulator temperature Tw3 (z=3.814 m) history in experiment 5.

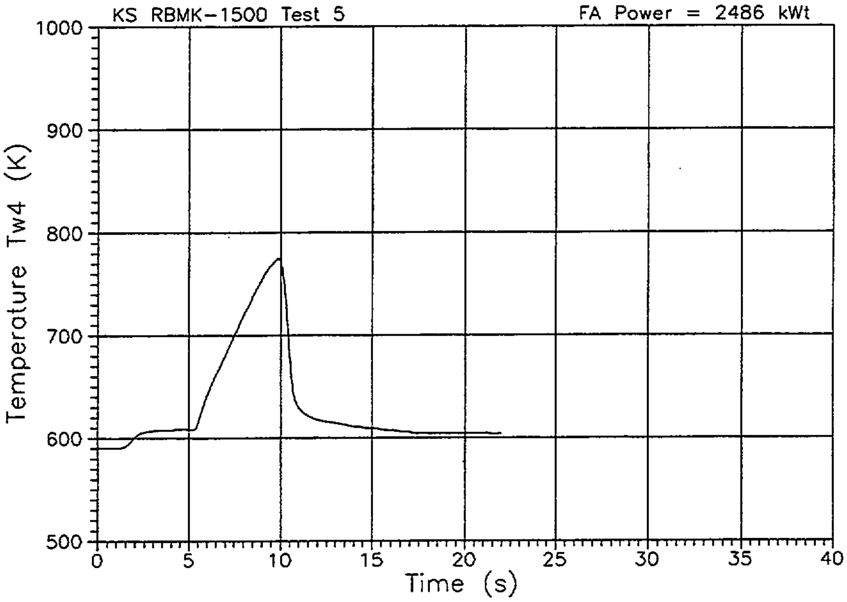


Fig. A-7. Fuel rod simulator temperature Tw4 (z=1.044 m) history in experiment 5.

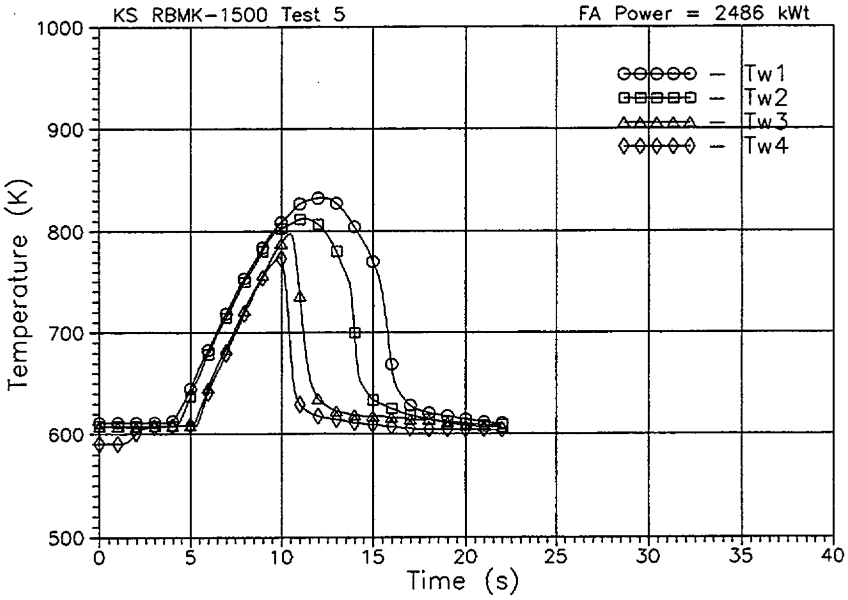


Fig. A-8. Behavior of measured wall temperatures Tw1, Tw2, Tw3 and Tw4 in experiment 5.

Appendix B

Comparisons between Test Data and RELAP5/MOD3.2 Base Case Results

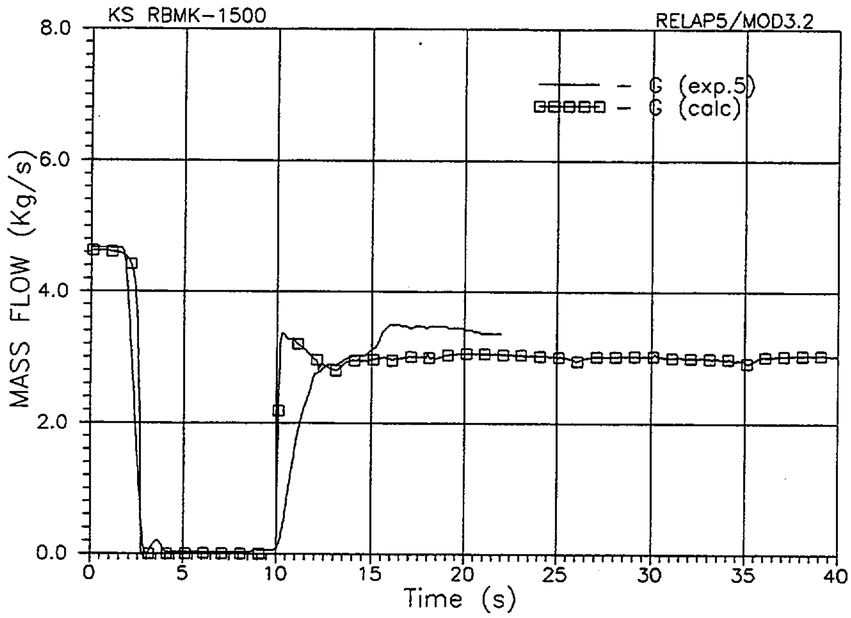


Fig. B-1. Mass flow rate G (t) history at the FC model inlet.

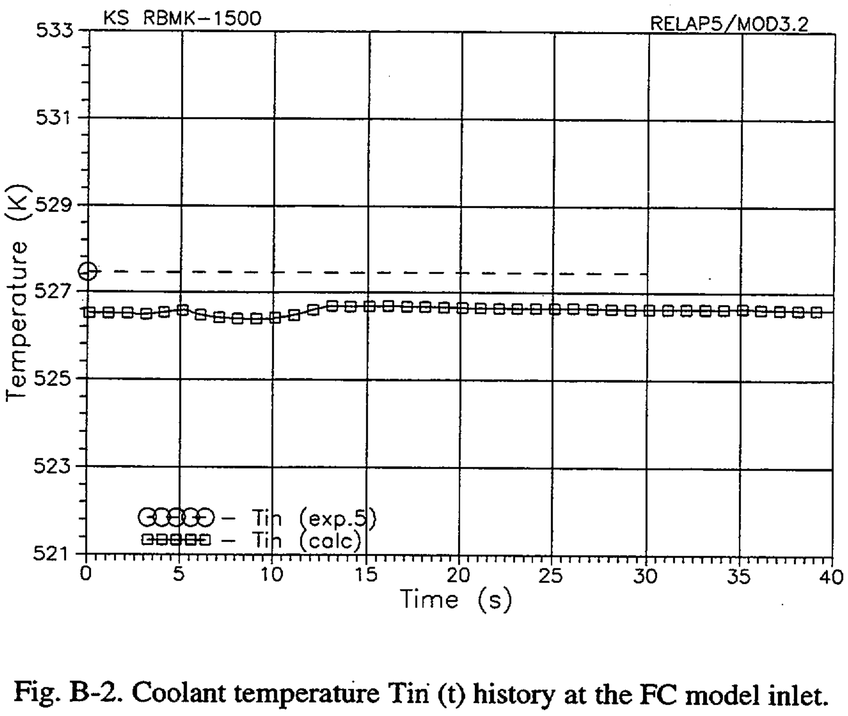


Fig. B-2. Coolant temperature Tin (t) history at the FC model inlet.

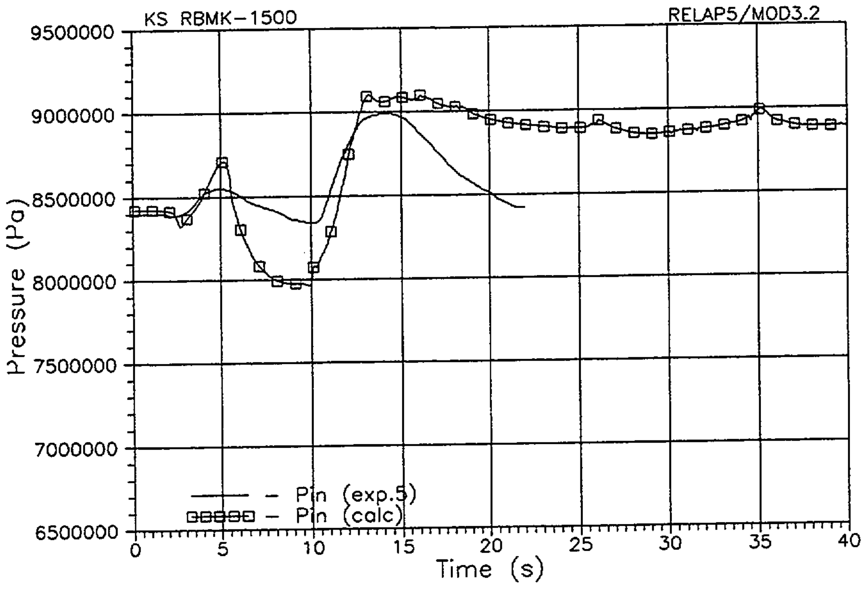


Fig. B-3. Pressure P (t) history in the lower part of the FA model.

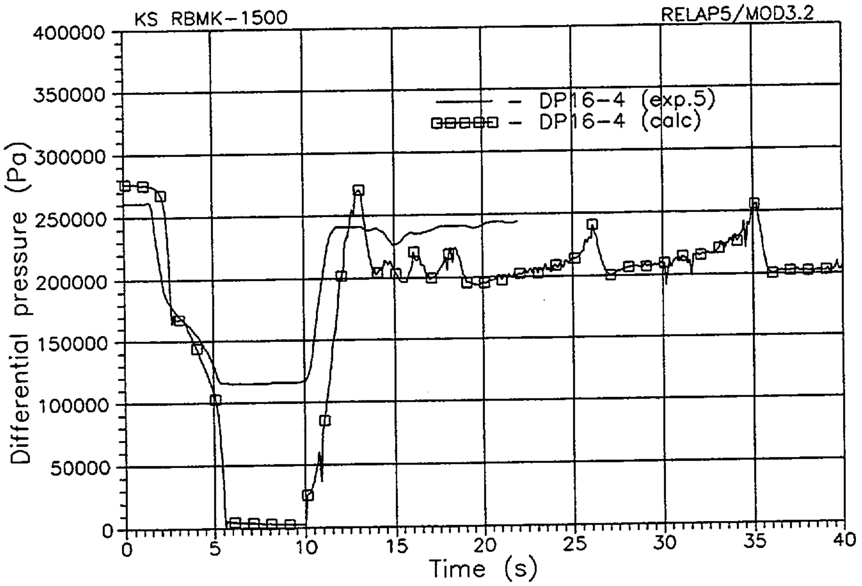


Fig. B-4. Pressure drop DP16-4 (t) history along the FA model.

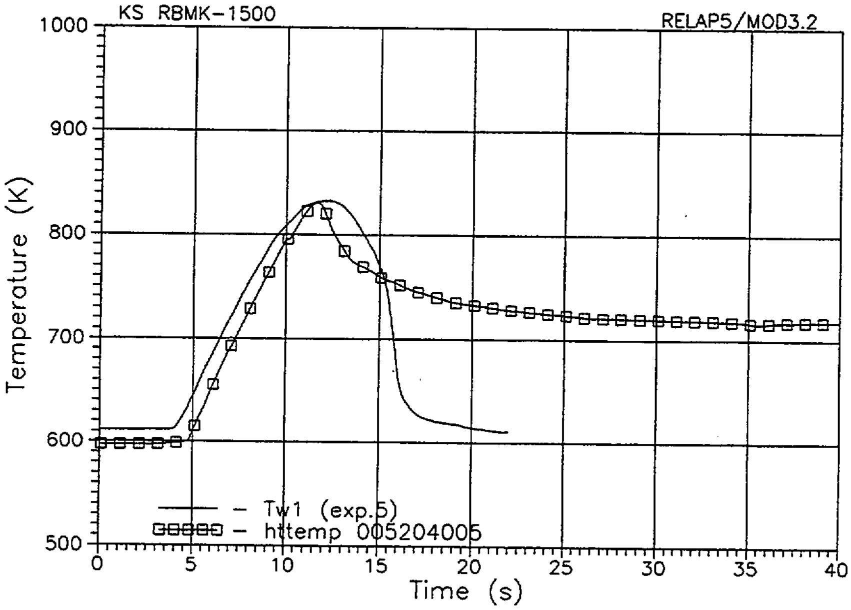


Fig. B-5. Fuel rod simulator temperature Tw1 (t) history.

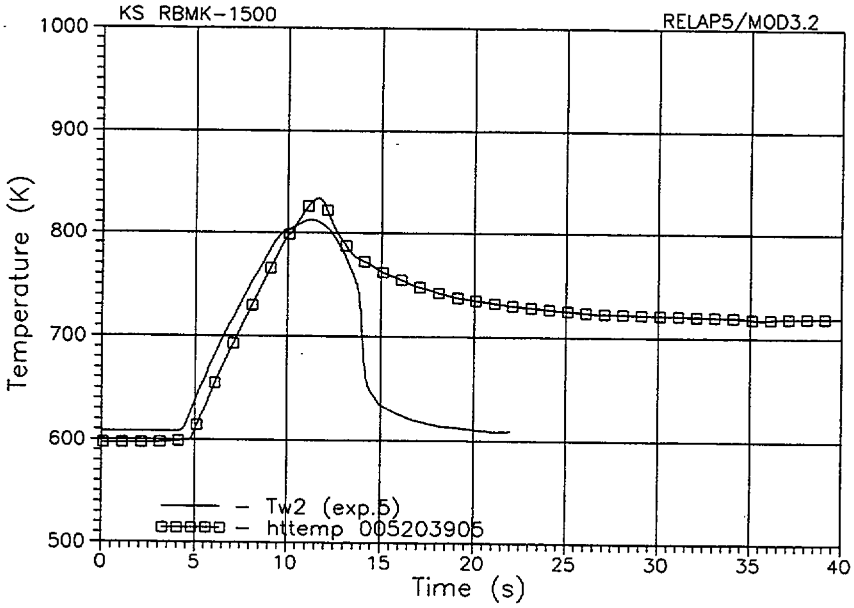


Fig. B-6. Fuel rod simulator temperature Tw2 (t) history.

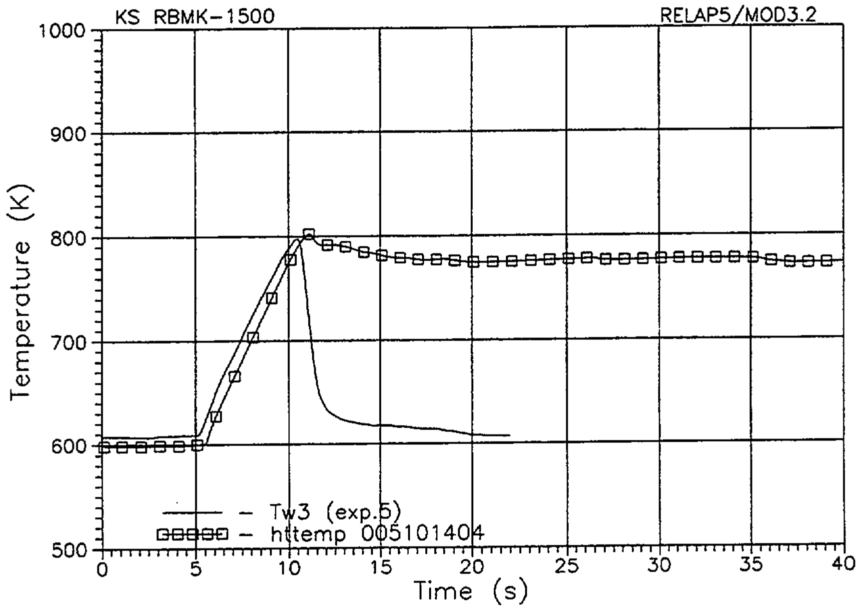


Fig. B-7. Fuel rod simulator temperature Tw3 (t) history.

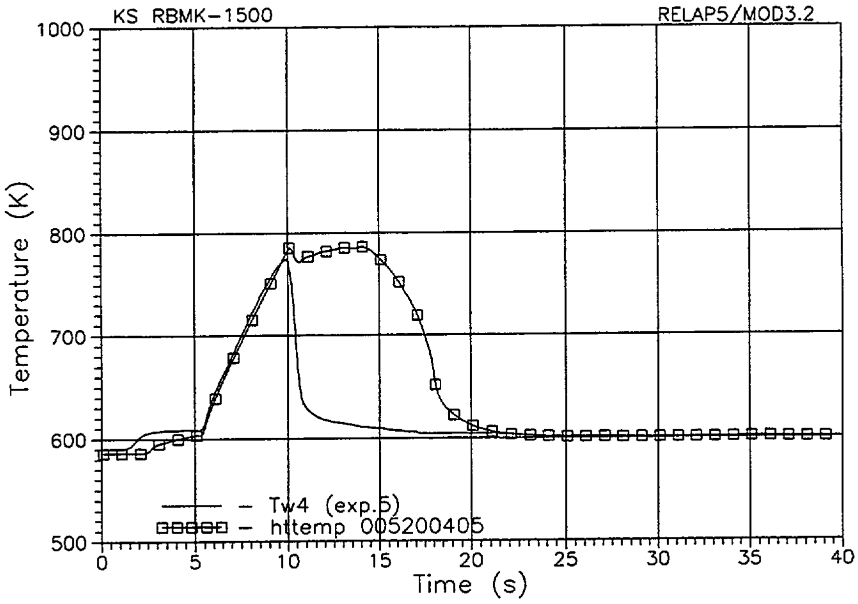
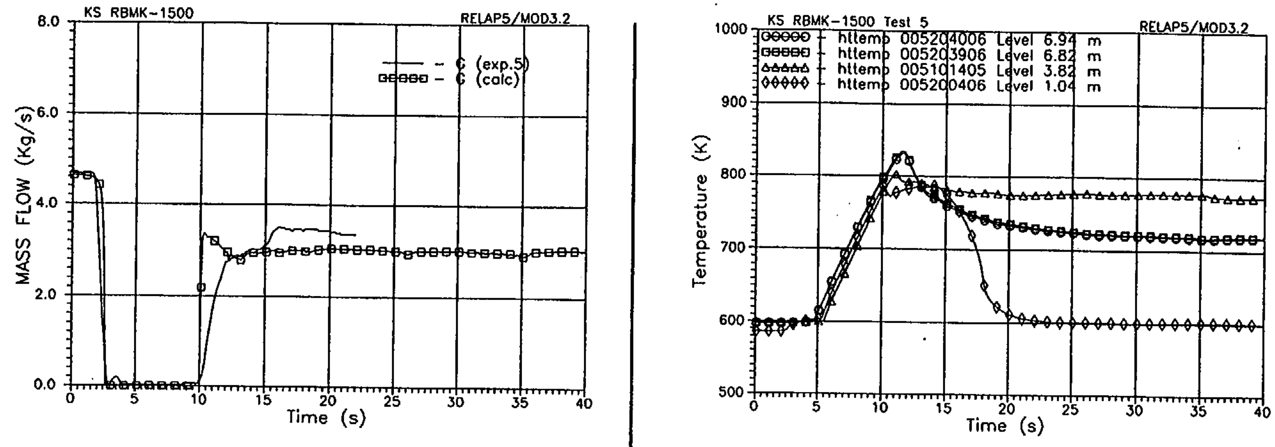


Fig. B-8. Fuel rod simulator temperature Tw4 (t) history.

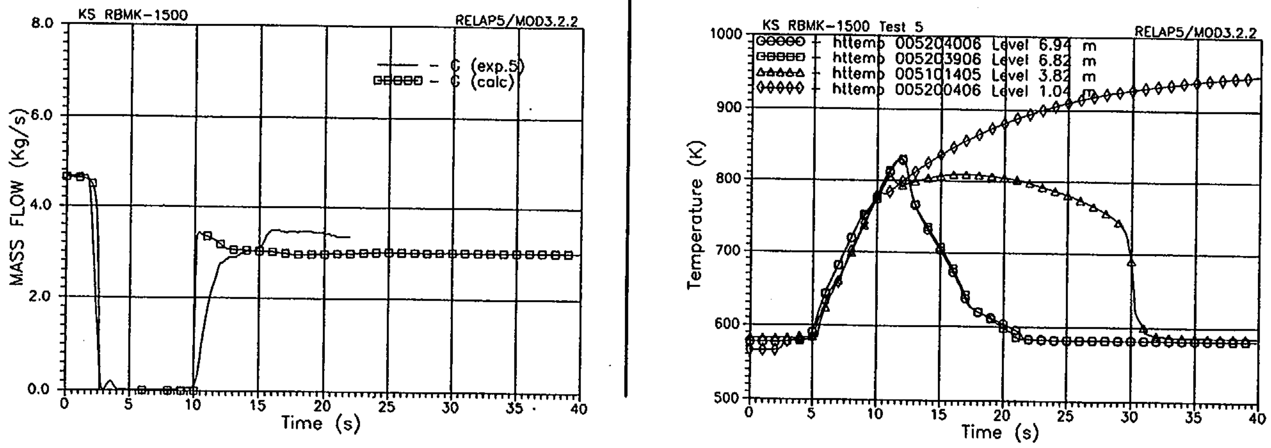
Appendix C

Comparisons between Test Data and RELAP5/MOD3.2 and RELAP5/MOD3.2.2GAMMA Base Case Results



Mass flow rate at the FC inlet

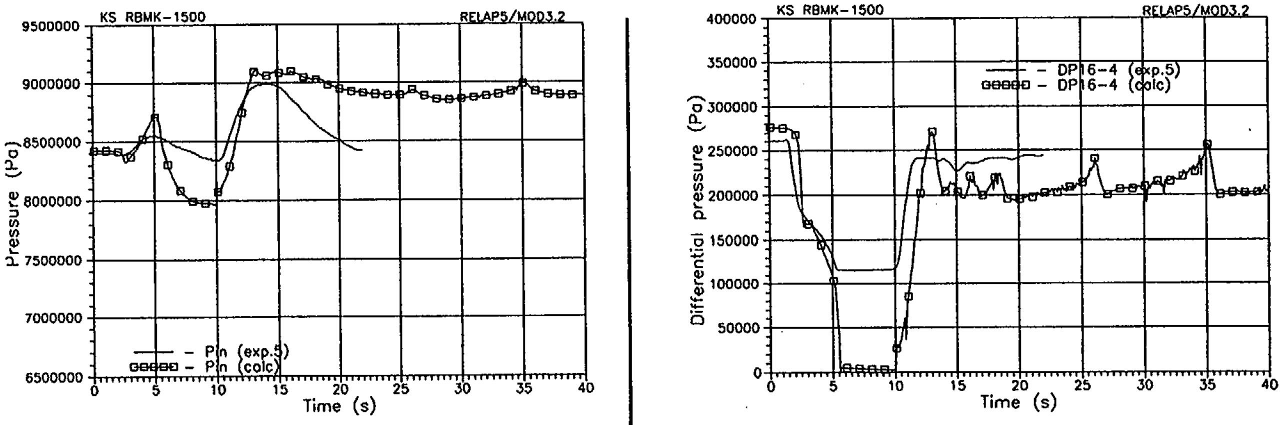
FA rod's wall temperatures Tw1-Tw4



Mass flow rate at the FC inlet

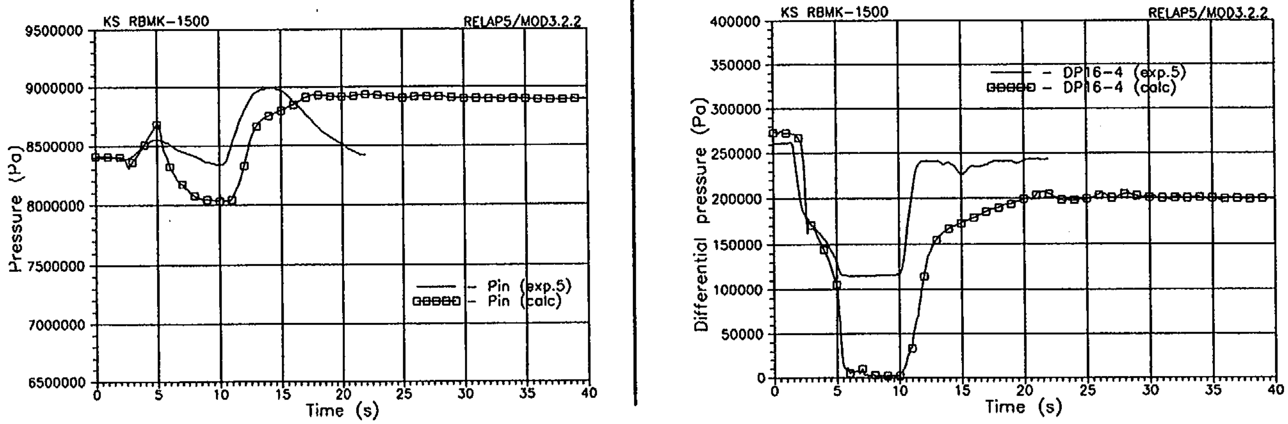
FA rod's wall temperatures Tw1-Tw4

Fig. C-1. Comparisons between test data and RELAP5/MOD3.2 and RELAP5/MOD3.2.2GAMMA predictions for the behaviors of the considered parameter G and rod's wall temperatures Tw1-Tw4 in the base case with "motor valve 2r".



Pressure P in the lower part of FA

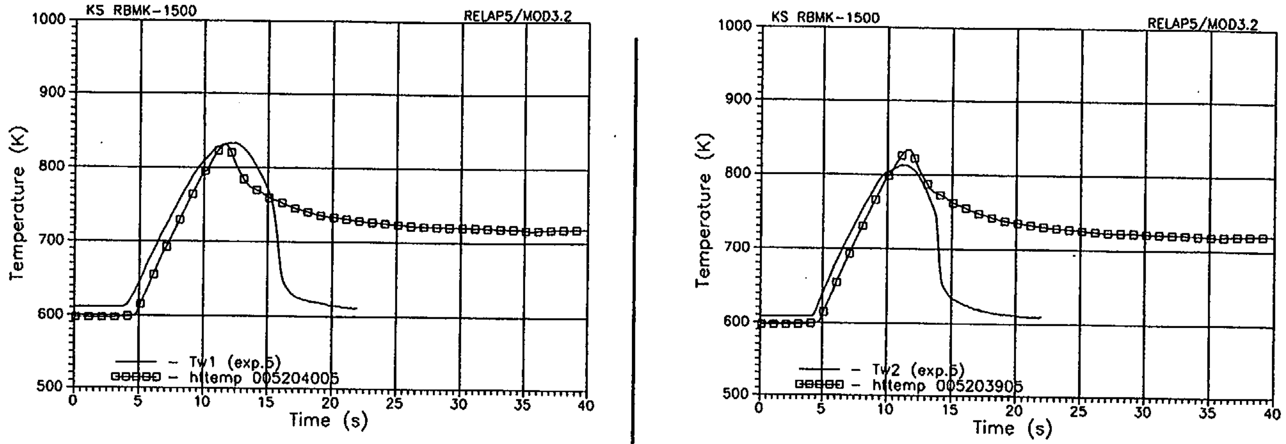
Pressure drop DP16-4 along FA



Pressure P in the lower part of FA

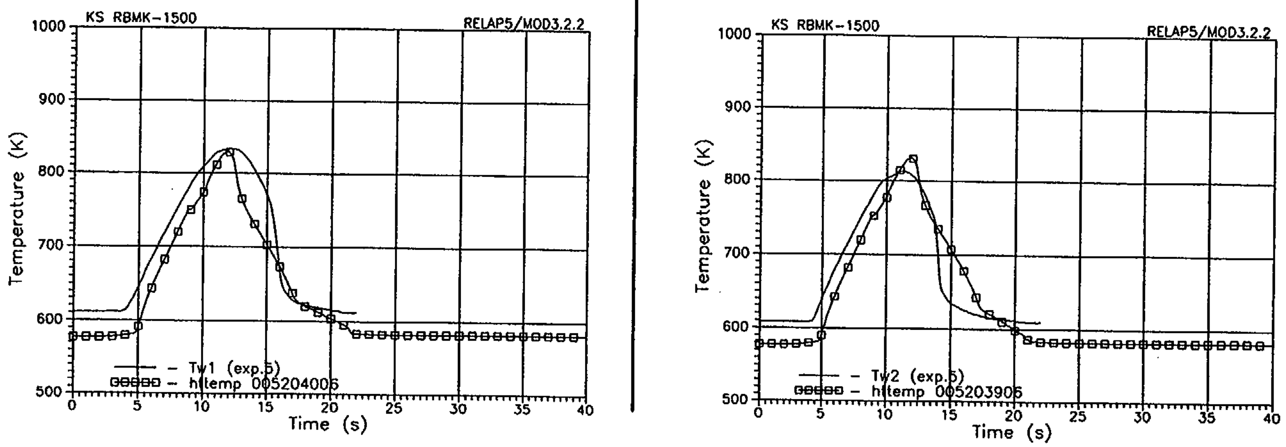
Pressure drop P16-4 along FA

Fig. C-2. Comparisons between test data and RELAP5/MOD3.2 and RELAP5/MOD3.2.2GAMMA predictions for the behaviors of the considered parameters P and DP16-4 in the base case with “motor valve 2r”.



Rod wall temperature Tw1 (z=6.94 m)

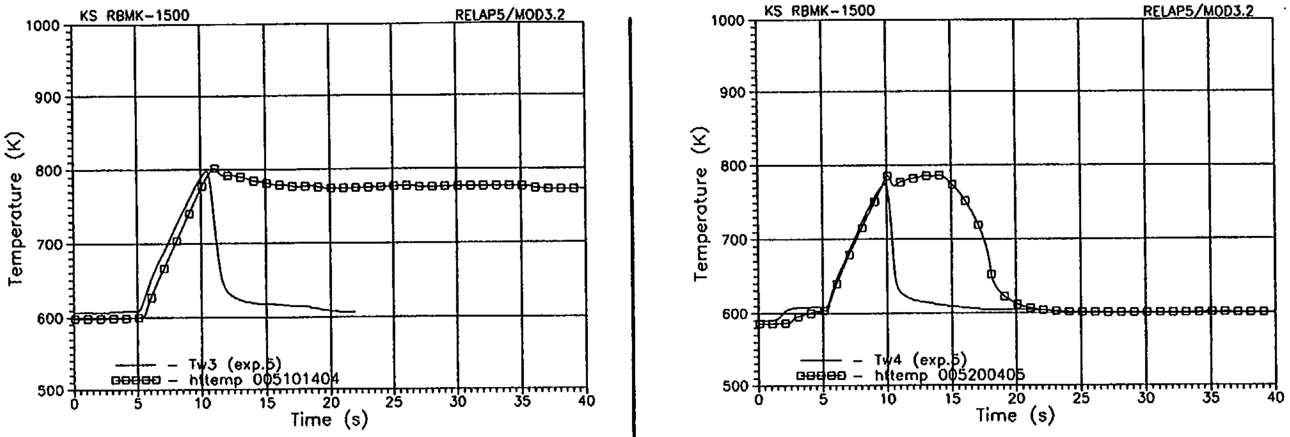
Rod wall temperature Tw2 (z=6.82 m)



Rod wall temperature Tw1(z=6.94 m)

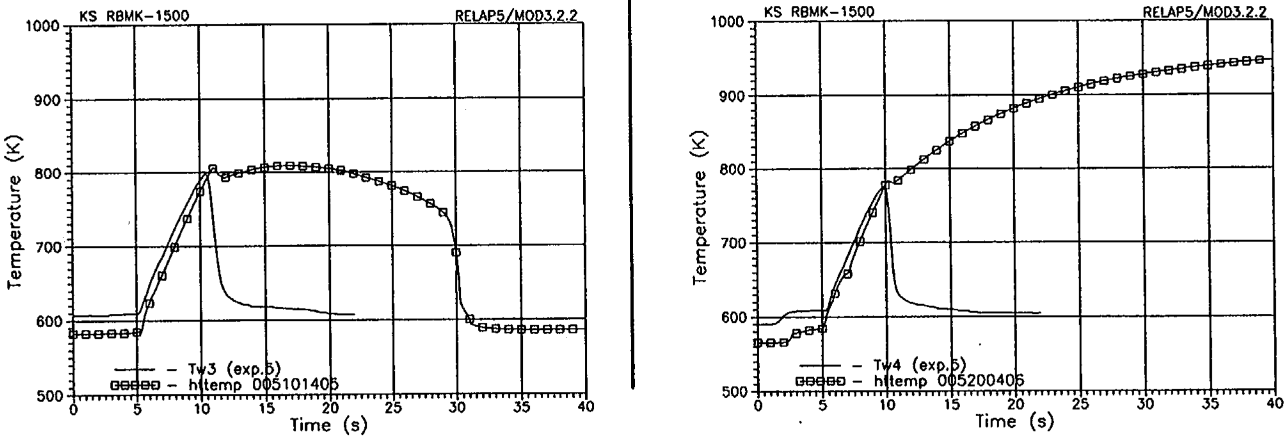
Rod wall temperature Tw2 (z=6.82 m)

Fig. C-3. Comparisons between test data and RELAP5/MOD3.2 and RELAP5/MOD3.2.2GAMMA predictions for the behaviors of the the rod's wall temperatures Tw1 and Tw2 in the base case with "motor valve 2r".



Rod wall temperature Tw3 (z=3.82 m)

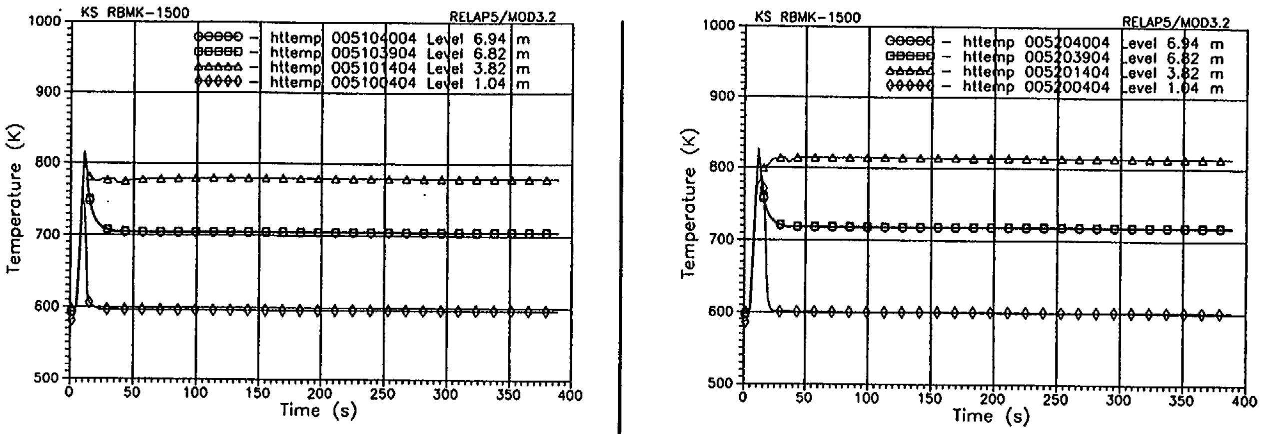
Rod wall temperature Tw4 (z=1.04 m)



Rod wall temperature Tw3 (z=3.82 m)

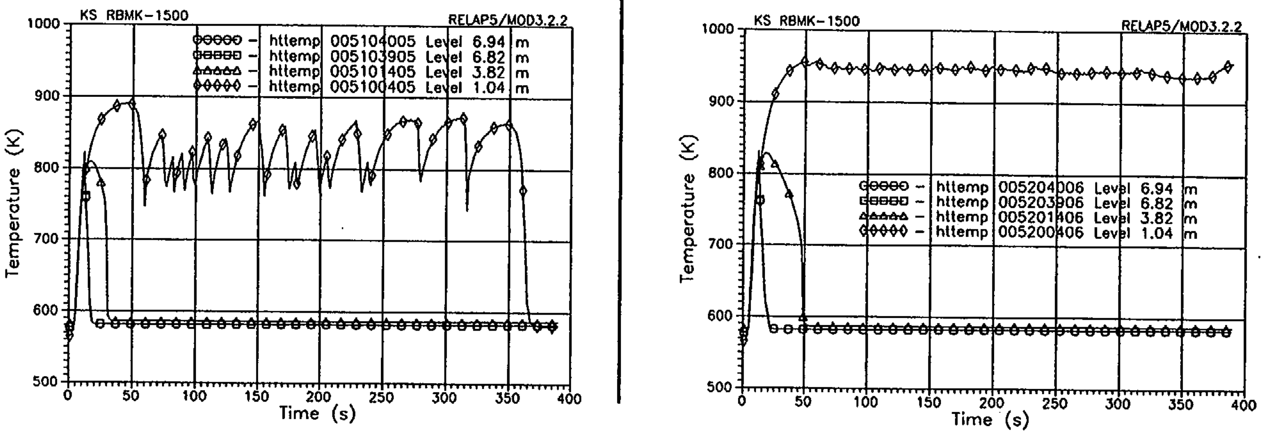
Rod wall temperature Tw4 (z=1.04 m)

Fig. C-4. Comparisons between test data and RELAP5/MOD3.2 and RELAP5/MOD3.2.2GAMMA predictions for the behaviors of the the rod's wall temperatures Tw3 and Tw4 in the base case with "motor valve 2r".



Inner row rod's wall temperatures Tw1-Tw4

Outer row rod's wall temperatures Tw1-Tw4



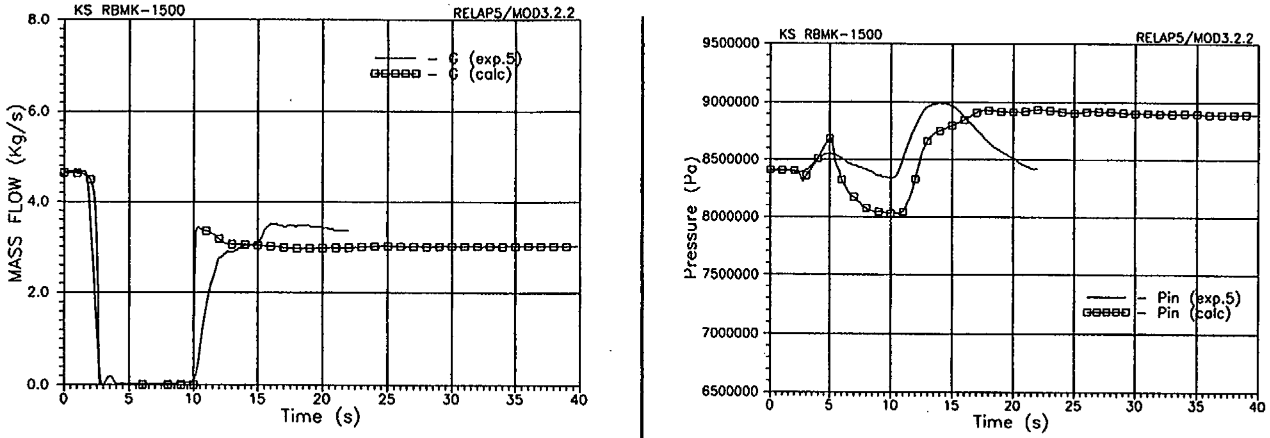
Inner row rod's wall temperatures Tw1-Tw4

Outer row rod's wall temperatures Tw1-Tw4

Fig. C-5. Comparisons between RELAP5/MOD3.2 and RELAP5/MOD3.2.2GAMMA predictions for the behaviors of the rod's wall temperatures Tw1-Tw4 in the base case with "motor valve 2r".

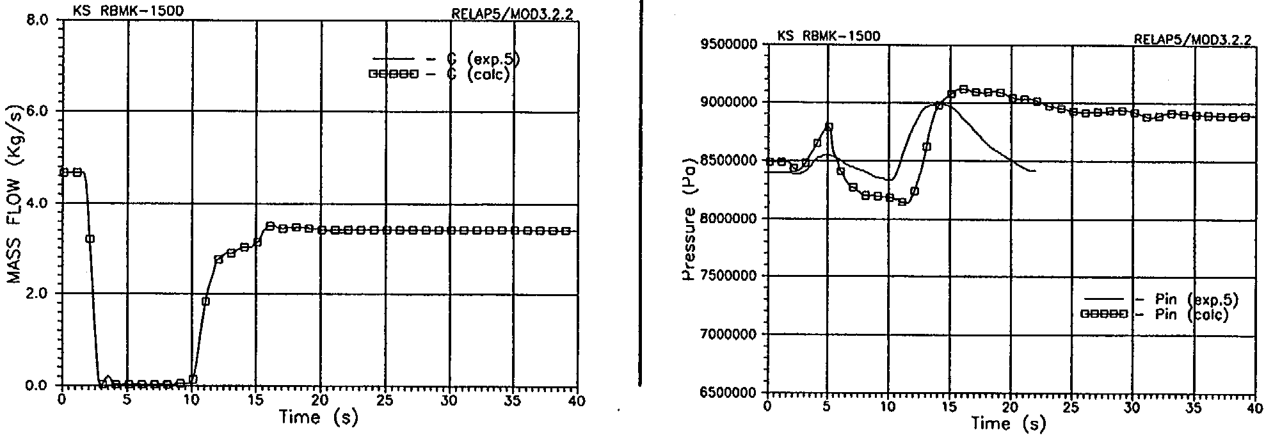
Appendix D

Comparisons between Test Data and RELAP5/MOD3.2.2GAMMA Sensitivity Study Results



Mass flow rate G at the FC inlet (motor valve 2r)

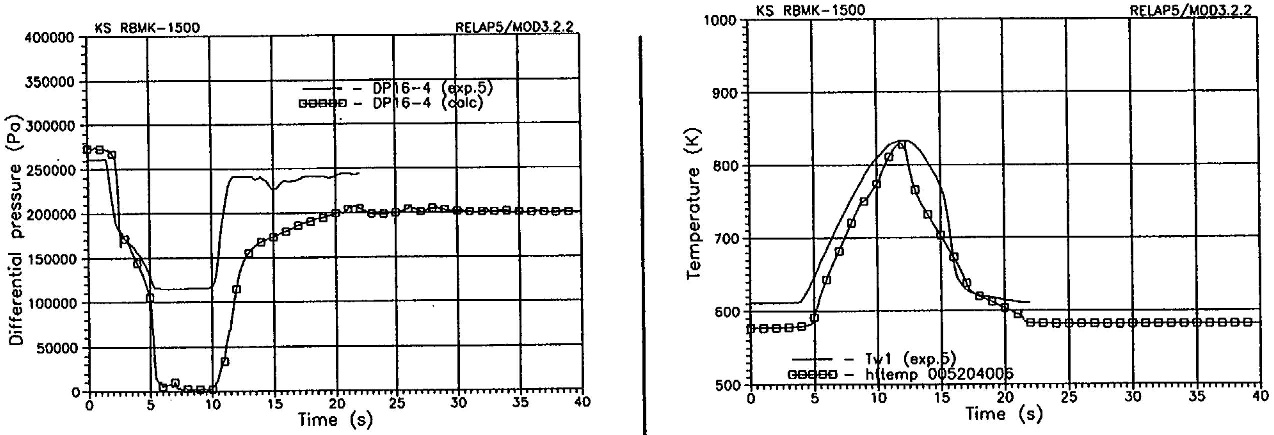
Pressure P in the lower part of FA(motor valve 2r)



Mass flow rate G at the FC inlet (TDJ)

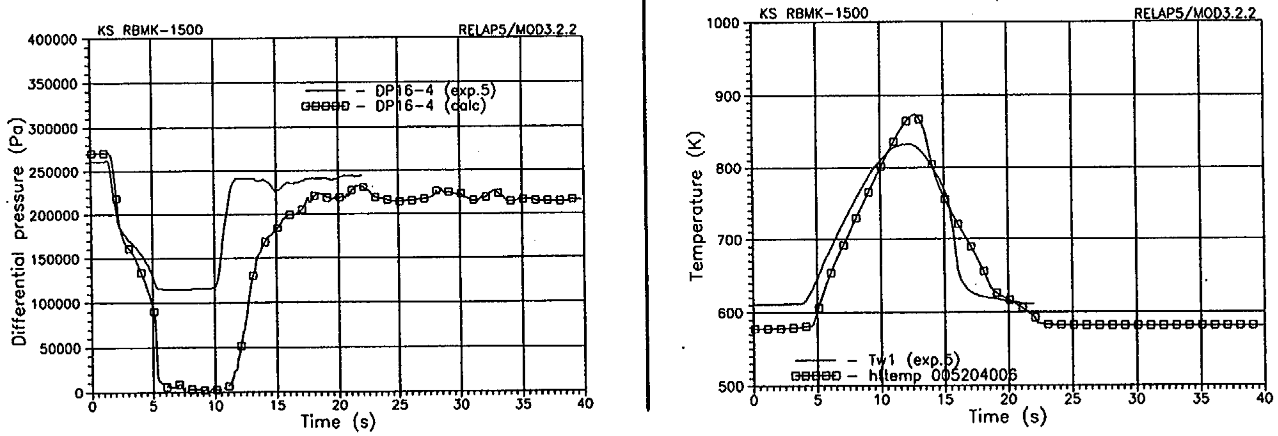
Pressure P in the lower part of FA (TDJ)

Fig. D-1. Comparisons between test data and RELAP5/MOD3.2.2GAMMA predictions for the behaviors of the considered parameters G and P in the cases with "motor valve 2r" and Time Dependent Junction in LWC



Pressure drop DP16-4 along FA (motor valve 2r)

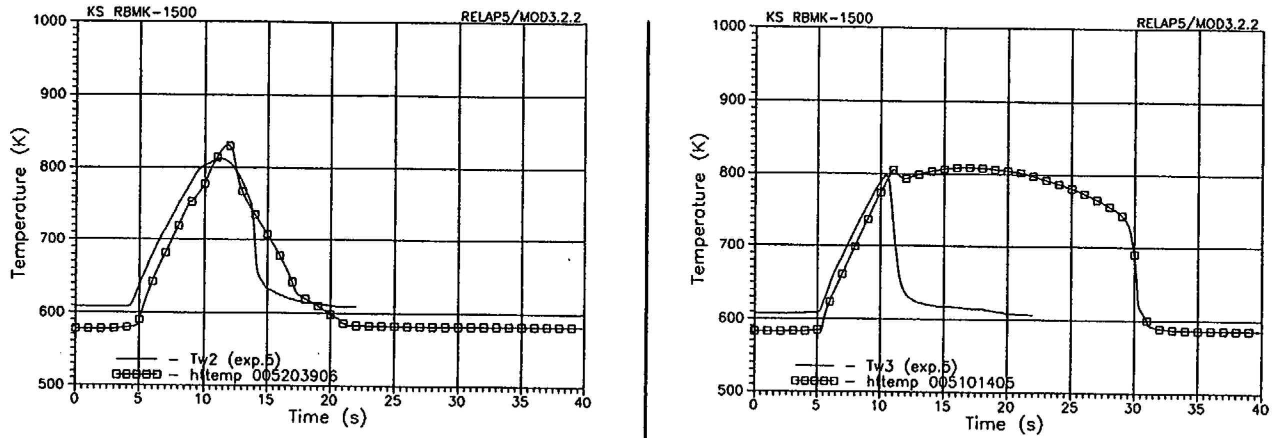
Rod wall temperature Tw1, z=6.94 m (motor valve 2r)



Pressure drop DP16-4 along FA (TDJ)

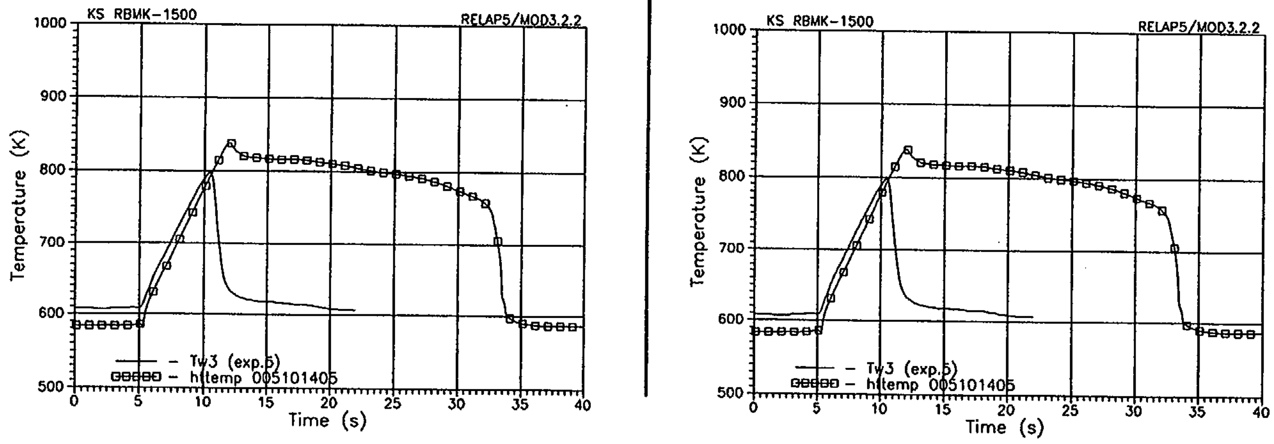
Rod wall temperature Tw1, z=6.94 m (TDJ)

Fig. D-2. Comparisons between test data and RELAP5/MOD3.2.2GAMMA predictions for the behaviors of the considered parameters DP16-4 and Tw1 in the cases with “motor valve 2r” and Time Dependent Junction in LWC.



Rod wall temperature Tw2, z=6.82 m (motor valve 2r)

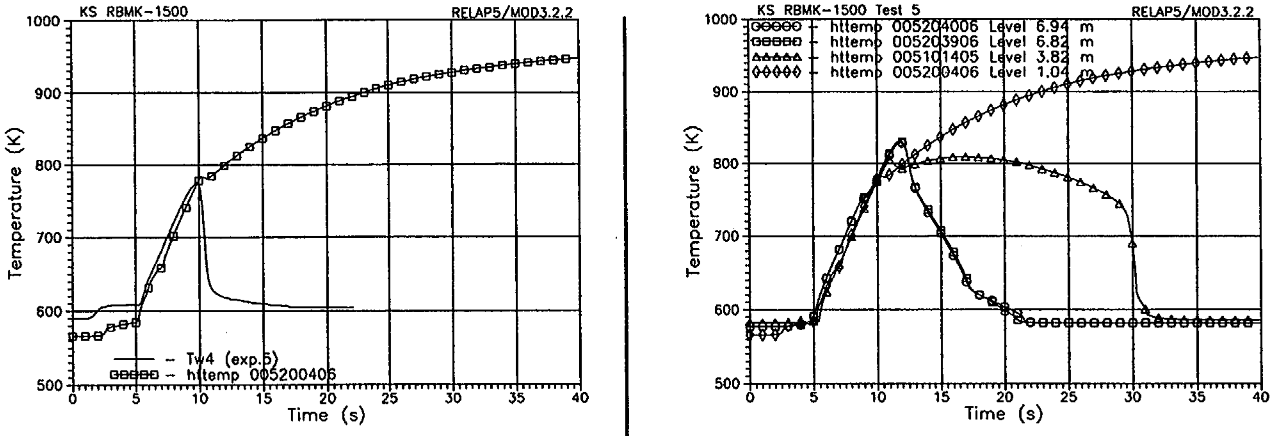
Rod wall temperature Tw3, z=3.82 m (motor valve 2r)



Rod wall temperature Tw2 , z=6.82 m (TDJ)

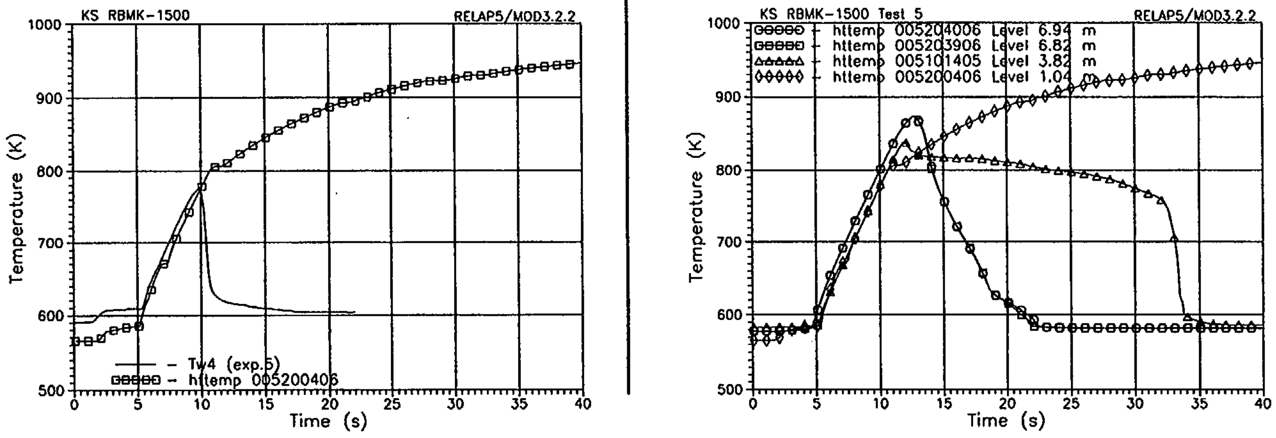
Rod wall temperature Tw3, z=3.82 m (TDJ)

Fig. D-3. Comparisons between test data and RELAP5/MOD3.2.2GAMMA predictions for the behaviors of the rod's wall temperatures Tw2 and Tw3 in the cases with "motor valve 2r" and Time Dependent Junction in LWC.



Rod wall temperature Tw4, z=1.04 m (motor valve 2r)

FA rod's wall temperatures Tw1-Tw4 (motor valve 2r)



Rod wall temperature Tw4, z=1.04 m (TDJ)

FA rod's wall temperatures Tw1-Tw4 (TDJ)

Fig. D-4. Comparisons between test data and RELAP5/MOD3.2.2GAMMA predictions for the behaviors of the rod's wall temperatures Tw4 and Tw1-Tw4 in the cases with "motor valve 2r" and Time Dependent Junction in LWC.

Appendix E

Base Case RELAP5/MOD3.2 input deck listing

```
=ks2 05 test
**********************************************************
*RBMK-1500 Stop Flow Experiment at KS-2 Test Facility
*Base case input deck listing of KS2-05 test
**********************************************************
*       Assesment of RELAP5/MOD3.2 against KS2-05 test
*       Initial conditions
*       FA power  = 2486.0 kWt
*       FA inlet pressure  = 8.40 MPa
*       FA inlet mass flow = 4.70 kg/s
*       FA inlet water temperature = 527.45 K
**********************************************************
100  new transnt
*0000101  inp-chk
0000102  si si
0000110  nitrogen
**********************************************************
*       TIME STEPS CONTROL CARDS
**********************************************************
*crdno    time   min_dt max_dt ssdtt  minor major restart
0000201   1000.0 1.0-6  0.01   15003  500   10000 50000
*0000202   1400.  1.0-6  0.01   15003  200   40000 4000000
*0000203   1450.  1.0-6  0.01   15003  10    40000 4000000
*0000204   1600.  1.0-6  0.01   15003  100   40000 4000000
**********************************************************
*       HIDRODYNAMIC COMPONENTS
**********************************************************
*       PUMP 1 AND PUMP 2 PERFORMANCE DATA
*
*    Volume = 0.0587 m*m*m
*    rated pump velocity = 314 rad/s
*    rated flow = 0.158 m*m*m/s
*    rated head = 105.4 m
*    rated torque = 782.0 N*m
*    rated density 854.9 kg/m*m*m
*    moment of inertia = 11.2 kg*m*m
*    actual pump velocity = 314 rad/s
*_______________________________________
*           PUMP 1, component 71
*
0710000  pump1 pump
*      flow area length volume  az   inc  dz   tlpvbfe
0710101 0.0214   0.0   0.0587  0.0  0.0  0.0  0000000
*      from      area  floss  rloss  efvcahs
0710108 047050002 0.0  0.1    0.1    0001120
*      to        area  floss  rloss  efvcahs
0710109 072010001 0.0  0.1    0.1    0001120
0710200  103 7.8+6 527.45
0710201  1   0.00  0.0  0.0
0710202  1   0.00  0.0  0.0
0710301  0  -1    -3   0   0   0   0
*      rad/s veloc rflow rhead rtorq inert rdens rmtorq
0710302  314.0  1.0  0.158 105.4 445.0 11.2  854.9 782.0  0.0 0.0 0.0 0.0
0716001  0.0   0.0
0716002  314.0 1.0
0716100  0 time
0716101  0.0   314.0
0716102  500.  314.0
0716103  4000. 314.0
*
*___________________________________________
*        SINGL PHASE HEAD AND TORQUE CURVES
*
*          head curve no 1  han
*
*crdno      curve type     curve regime
0711100         1              1
*         flow/rflow     head/rhead
0711101      0.0          1.0700
0711102      0.3515         1.0721
0711103      0.5272         1.0816
0711104      0.7030         1.0721
0711105      0.8787         1.0436
0711106      1.0000         1.0000
*
*          torque curve no 1  ban
*
*crdno      curve type     curve regime
0711200         2              1
*         flow/rflow     torque/rtorque
0711201      0.0          0.98
0711202      0.3515         0.693
0711203      0.5272         0.845
0711204      0.7030         0.955
0711205      0.8787         0.994
0711206      1.0000         1.000
*
* Head curve no 2  HVN
*crdno   type  regime
0711300  1     2
*       gnom/g   (h/hnom)/(g/gnom)**2
0711301  0.0       -1.584
0711302  0.221      -1.056
0711303  0.442      -0.528
0711304  0.663       0.0587
0711305  0.884       0.704
0711306  1.0        1.00
*
*        Torque  curve no 2  HVN
*crdno   type  regime
0711400  2     2
*        gnom/g    (m/mnom)/(g/gnom)**2
0711401   0.0       -1.148
0711402   0.221      -0.549
0711403   0.442      -0.075
0711404   0.663       0.349
0711405   0.884       0.749
0711406   1.000       1.000
*
* Head curve no 3  HAD
*crdno   type  regime
0711500  1     3
*       g/gnom    h/hnom
0711501  -1.0       5.5
0711502  -0.452     3.276
0711503  -0.362     2.928
0711504  -0.271     2.658
0711505  -0.181     2.430
0711506  -0.0905    2.244
0711507   0.000     2.058
*
* Torque  curve no 3  HAD
*crdno   type  regime
0711600  2     3
*       gnom/g    (m/mnom)
0711601   -1.0       3.64
0711602   -0.995     3.612
0711603   -0.905     3.326
0711604   -0.814     2.96
0711605   -0.724     2.653
0711606   -0.633     2.388
0711607   -0.543     2.133
0711608   -0.452     1.888
0711609   -0.362     1.653
0711610   -0.271     1.449
0711611   -0.181     1.265
0711612   -0.0905    1.020
0711613    0.000     0.980
*
* Head curve no 4  HVD
*crdno   type  regime
0711700  1     4
*      gnom/g   (h/hnom)/(g/gnom)**2
0711701  -1.0       5.5
0711702  -0.884     4.869
0711703  -0.663     3.755
0711704  -0.442     2.992
0711705  -0.221     2.464
0711707   0.000     2.024
*
* Torque  curve no 4  HVD
*crdno   type  regime
0711800  2     4
*      gnom/g   (m/mnom)/(g/gnom)**2
```

```
0711801 -1.0      3.64
0711802 -0.884    3.343
0711803 -0.663    2.644
0711804 -0.442    2.095
0711805 -0.221    1.746
0711813  0.000    1.547
*
* Head curve no 5  HAT
*crdno  type  regime
0711900  1    5
*      gnom/g  (h/hnom)
0711901 0.0      0.42
0711902 0.0452   0.426
0711903 0.0905   0.420
0711904 0.181    0.444
0711905 0.271    0.480
0711906 0.362    0.504
0711907 0.452    0.552
0711908 0.543    0.600
0711909 0.633    0.696
0711910 0.724    0.828
0711911 0.814    0.984
0711912 0.905    1.188
0711913 1.000    1.360
*
* Torque curve no 5  HAT
*crdno  type  regime
0712000  2    5
*      gnom/g  (m/mnom)/(g/gnom)**2
0712001 0.0      -0.704
0712002 0.0452   -0.684
0712003 0.136    -0.684
0712004 0.181    -0.612
0712005 0.271    -0.449
0712006 0.362    -0.255
0712007 0.452    -0.122
0712008 0.543    -0.0306
0712009 0.633     0.0816
0712010 0.724     0.224
0712011 0.814     0.388
0712012 0.905     0.592
0712013 0.995     0.776
0712014 1.000     0.790
*
* Head curve no 6  HVT
*crdno  type  regime
0712100  1    6
*      gnom/g  (h/hnom)/(g/gnom)**2
0712101  0.0      2.024
0712102  0.221    1.731
0712103  0.442    1.525
0712104  0.663    1.408
0712105  0.884    1.379
0712106  1.0      1.36
*
* Torque curve no 6  HVT
*crdno  type  regime
0712200  2    6
*      gnom/g  (m/mnom)/(g/gnom)**2
0712201  0.0      1.547
0712202  0.221    1.397
0712203  0.442    1.197
0712204  0.663    1.048
0712205  0.884    0.848
0712206  1.000    0.790
*
* Head curve no 7  HAR
*crdno  type  regime
0712300  1    7
*      g/gnom    h/hnom
0712301 -1.0     -3.12
0712302 -0.814   -2.016
0712303 -0.724   -1.608
0712304 -0.633   -1.296
0712305 -0.543   -0.996
0712306 -0.452   -0.672
0712307 -0.362   -0.360
0712308 -0.271   -0.072
0712309 -0.181    0.216
```

```
0712310 -0.0905   0.360
0712311 -0.0452   0.408
0712312  0.000    0.420
*
* Torque  curve no 7  HAR
*crdno  type  regime
0712400  2    7
*      gnom/g  (m/mnom)
0712401 -1.0     -4.34
0712402 -0.814   -3.142
0712403 -0.724   -2.724
0712404 -0.543   -2.286
0712405 -0.452   -1.939
0712406 -0.362   -1.592
0712407 -0.271   -1.286
0712408 -0.181   -1.000
0712409 -0.0905  -0.796
0712410  0.000   -0.704
*
* Head curve no 8  HVR
*crdno  type  regime
0712500  1    8
*      gnom/g  (h/hnom)/(g/gnom)**2
0712501 -1.0     -3.12
0712502 -0.884   -2.992
0712503 -0.663   -2.757
0712504 -0.442   -2.435
0712505 -0.221   -2.053
0712507  0.000   -1.584
*
* Torque  curve no 8  HVR
*crdno  type  regime
0712600  2    8
*      gnom/g  (m/mnom)/(g/gnom)**2
0712601 -1.0     -4.34
0712602 -0.884   -3.941
0712603 -0.663   -3.218
0712604 -0.442   -2.495
0712605 -0.221   -1.821
0712613  0.000   -1.148
*
*-------------------------------------------------------*
*       PUMP 1 DISCHARGE PIPELINE, component v.72
*
0720000 disch2 pipe
0720001 5
0720101 28.65-3 5
0720301 1.15 2, 1.85 4, 2.2 5
0720601 0.0 5
0720801 40.0-6 0.191 5
*
0720901 0.0 0.0 1, 0.10 0.10 2
0720902 0.0 0.0 3, 0.10 0.10 4
*
*crdno   tlpvbfe
0721001   0000000 5
*crdno   efvcahs
0721101   0001000 4
*
0721201 103 7.8+6 527.45 0.0 0.0 0.0 5
0721300 1
0721301 0.0 0.0 0.0 4
*
*-------------------------------------------------------
*           PUMP 2, component 73
*
0730000  pump2 pump
*      flow area length volume  az   inc  dz   tlpvbfe
0730101  0.0214    0.0    0.0587  0.0  0.0  0.0  0000000
*      from      area  floss  rloss  efvcahs
0730108  072050002 0.0   0.1    0.1    0001120
*      to        area  floss  rloss  efvcahs
0730109  074010001 0.0   0.1    0.1    0001120
0730200  103 8.5+6 527.45
0730201  1   0.00  0.0  0.0
0730202  1   0.00  0.0  0.0
0730301 0 -1    -3  0  0  0  0
*      rad/s veloc rflow rhead rtorq inert rdens
0730302  314.0  1.0  0.158 105.4 445.0 11.2  854.9 782.0 0.0 0.0 0.0 0.0
```

```
0736001 0.0  0.0
0736002 314.0 1.0
0736100 0 time
0736101 0.0   314.0
0736102 500.  314.0
0736103 4000. 314.0
*
*-----------------------------------------------------------
*          SINGL PHASE HEAD AND TORQUE CURVES
*
*           head curve no 1  han
*
*crdno      curve type     curve regime
0731100          1              1
*          flow/rflow     head/rhead
0731101      0.3515         1.0721
0731102      0.5272         1.0816
0731103      0.7030         1.0721
0731104      0.8787         1.0436
0731105      1.0000         1.0000
*
*           torque curve no 1  ban
*
*crdno      curve type     curve regime
0731200          2              1
*          flow/rflow     torque/rtorque
0731201      0.0            0.693
0731202      0.3515          0.693
0731203      0.5272          0.845
0731204      0.7030          0.955
0731205      0.8787          0.994
0731206      1.0000          1.000
*
* Head curve no 2  HVN
*crdno  type  regime
0731300  1    2
*      gnom/g   (h/hnom)/(g/gnom)**2
0731301  0.0       -1.584
0731302  0.221      -1.056
0731303  0.442      -0.528
0731304  0.663       0.0587
0731305  0.884       0.704
0731306  1.0        1.00
*
*        Torque  curve no 2  HVN
*crdno  type  regime
0731400  2    2
*       gnom/g   (m/mnom)/(g/gnom)**2
0731401  0.0       -1.148
0731402  0.221      -0.549
0731403  0.442      -0.075
0731404  0.663       0.349
0731405  0.884       0.749
0731406  1.000       1.000
*
* Head curve no 3  HAD
*crdno  type  regime
0731500  1    3
*      g/gnom    h/hnom
0731501  -1.0       5.5
0731502  -0.452     3.276
0731503  -0.362     2.928
0731504  -0.271     2.658
0731505  -0.181     2.430
0731506  -0.0905    2.244
0731507   0.000     2.058
*
* Torque  curve no 3  HAD
*crdno  type  regime
0731600  2    3
*      gnom/g    (m/mnom)
0731601  -1.0      3.64
0731602  -0.995    3.612
0731603  -0.905    3.326
0731604  -0.814    2.96
0731605  -0.724    2.653
0731606  -0.633    2.388
0731607  -0.543    2.133
0731608  -0.452    1.888
```

```
0731609  -0.362    1.653
0731610  -0.271    1.449
0731611  -0.181    1.265
0731612  -0.0905   1.020
0731613   0.000    0.980
*
* Head curve no 4  HVD
*crdno  type  regime
0731700  1    4
*      gnom/g   (h/hnom)/(g/gnom)**2
0731701  -1.0      5.5
0731702  -0.884    4.869
0731703  -0.663    3.755
0731704  -0.442    2.992
0731705  -0.221    2.464
0731707   0.000    2.024
*
* Torque  curve no 4  HVD
*crdno  type  regime
0731800  2    4
*      gnom/g   (m/mnom)/(g/gnom)**2
0731801  -1.0     3.64
0731802  -0.884    3.343
0731803  -0.663    2.644
0731804  -0.442    2.095
0731805  -0.221    1.746
0731813  0.000     1.547
*
* Head  curve no 5  HAT
*crdno  type  regime
0731900  1    5
*     gnom/g   (h/hnom)
0731901  0.0      0.42
0731902  0.0452   0.426
0731903  0.0905   0.420
0731904  0.181    0.444
0731905  0.271    0.480
0731906  0.362    0.504
0731907  0.452    0.552
0731908  0.543    0.600
0731909  0.633    0.696
0731910  0.724    0.828
0731911  0.814    0.984
0731912  0.905    1.188
0731913  1.000    1.360
*
* Torque curve no 5  HAT
*crdno  type  regime
0732000  2    5
*      gnom/g   (m/mnom)/(g/gnom)**2
0732001  0.0     -0.704
0732002  0.0452   -0.684
0732003  0.136    -0.684
0732004  0.181    -0.612
0732005  0.271    -0.449
0732006  0.362    -0.255
0732007  0.452    -0.122
0732008  0.543    -0.0306
0732009  0.633     0.0816
0732010  0.724     0.224
0732011  0.814     0.388
0732012  0.905     0.592
0732013  0.995     0.776
0732014  1.000     0.790
*
* Head curve no 6  HVT
*crdno  type  regime
0732100  1    6
*      gnom/g   (h/hnom)/(g/gnom)**2
0732101  0.0      2.024
0732102  0.221     1.731
0732103  0.442     1.525
0732104  0.663     1.408
0732105  0.884     1.379
0732106  1.0      1.36
*
* Torque  curve no 6  HVT
*crdno  type  regime
0732200  2    6
```

```
*     gnom/g  (m/mnom)/(g/gnom)**2
0732201  0.0      1.547
0732202  0.221    1.397
0732203  0.442    1.197
0732204  0.663    1.048
0732205  0.884    0.848
0732206  1.000    0.790
*
* Head curve no 7  HAR
*crdno  type  regime
0732300  1     7
*      g/gnom    h/hnom
0732301  -1.0      -3.12
0732302  -0.814    -2.016
0732303  -0.724    -1.608
0732304  -0.633    -1.296
0732305  -0.543    -0.996
0732306  -0.452    -0.672
0732307  -0.362    -0.360
0732308  -0.271    -0.072
0732309  -0.181     0.216
0732310  -0.0905    0.360
0732311  -0.0452    0.408
0732312  0.000      0.420
*
* Torque  curve no 7  HAR
*crdno  type  regime
0732400  2     7
*      gnom/g    (m/mnom)
0732401  -1.0      -4.34
0732402  -0.814    -3.142
0732403  -0.724    -2.724
0732404  -0.543    -2.286
0732405  -0.452    -1.939
0732406  -0.362    -1.592
0732407  -0.271    -1.286
0732408  -0.181    -1.000
0732409  -0.0905   -0.796
0732410  0.000     -0.704
*
* Head curve no 8  HVR
*crdno  type  regime
0732500  1     8
*      gnom/g   (h/hnom)/(g/gnom)**2
0732501  -1.0     -3.12
0732502  -0.884   -2.992
0732503  -0.663   -2.757
0732504  -0.442   -2.435
0732505  -0.221   -2.053
0732507  0.000    -1.584
*
* Torque  curve no 8  HVR
*crdno  type  regime
0732600  2     8
*      gnom/g  (m/mnom)/(g/gnom)**2
0732601  -1.0    -4.34
0732602  -0.884  -3.941
0732603  -0.663  -3.218
0732604  -0.442  -2.495
0732605  -0.221  -1.821
0732613  0.000   -1.148
*
*-----------------------------------------------------
*      PUMP 2 DISCHARGE PIPELINE, component v.74
*
0740000 disch2 pipe
0740001 10
0740101 28.65-3 10
0740301 1.5 2, 2.4 4, 2.0 5, 2.25 9, 1.0 10
0740601 0.0 10
0740801 40.0-6 0.191 10
*
0740901 0.0 0.0 1, 0.10 0.10 2
0740902 0.0 0.0 3, 0.10 0.10 4
0740903 0.10 0.10 5, 0.0 0.0 8
0740904 0.10 0.10 9
*
*crdno   tlpvbfe
0741001   0000000 10
```

```
*crdno   efvcahs
0741101   0001000 9
*
0741201 103 8.5+6 527.45 0.0 0.0 0.0 10
0741300 1
0741301 0.0 0.0 0.0 9
*
*-----------------------------------------------
0750000   sj75 sngljun
*crdno   from      to       area floss rloss efvcahs
0750101   074010000 103000000 0.0  0.0   0.0   0001100
0750201   1 2.7 0.0 0.0
*-----------------------------------------------
0760000   sj76 sngljun
*crdno   from      to       area floss rloss efvcahs
0760101   074010000 078000000 0.0  0.5   0.5   0001100
0760201   1 5.47 0.0 0.0
*-----------------------------------------------
*  PUMPS BYPASS, components v.78, valve jun.79, v.80
*
0780000 pbypas1 pipe
0780001 8
0780101 28.65-3 8
0780301 1.56 1, 1.2 2, 2.9 5, 2.5 6, 1.325 8
0780601 0.0 8
0780801 40.0-6 0.191 8
*
0780901 0.10 0.10 2, 0.0 0.0 4
0780902 0.10 0.10 6, 0.10 0.10 7
*
*crdno   tlpvbfe
0781001   0000000 8
*crdno   efvcahs
0781101   0001000 7
*
0781201 103 8.5+6 527.45 0.0 0.0 0.0 8
0781300 1
0781301 5.47 0.0 0.0 7
*
*     pumps bypass motor valve 28
*
0790000   valv28 valve
*crdno   from      to       area     floss rloss efvcahs
0790101   078010000 080000000 28.65-3 262.0 262.0 0001100
0790201   1 0.0 0.0 0.0
0790300   mtrvlv
*      open close rate    initl  table
0790301   428  628   0.0005  1.0    0
*
438      time 0 ge null 0  500.0  n * close
538      time 0 ge null 0 1000.0  n * stop
628            438 and -538  n * close
428      time 0 ge null 0 9999.0  n * open
*
*
0800000 pbypas2 pipe
0800001 7
0800101 28.65-3 7
0800301 1.5125 4, 1.6167 7
0800601 0.0 7
0800801 40.0-6 0.191 7
*
0800901 0.0 0.0 3, 0.10 0.10 4
0800902 0.0 0.0 6
*
*crdno   tlpvbfe
0801001   0000000 7
*crdno   efvcahs
0801101   0001000 6
*
0801201 103 7.65+6 527.45 0.0 0.0 0.0 7
0801300 1
0801301 5.47 0.0 0.0 6
*
*-----------------------------------------------
0810000   sj81 sngljun
*crdno   from      to       area floss rloss efvcahs
0810101   080010000  47030002 0.0  0.5   0.5   0001100
0810201   1 5.47 0.0 0.0
```

```
*-----------------------------------------
*   GAS PRESSURIZER, components sj.91, v.92, sj.93, v.94
*
0910000   sj91 sngljun
*crdno    from      to        area floss rloss efvcahs
0910101   041010000 092000000 0.0  0.0   0.0   0001100
0910201   0 0.0 0.0 0.0
*
0920000   surge pipe
0920001   12
0920101   3.1416-4 12
0920301   1.0 12
0920601   0.0 12
0920801   6.0-6 0.020 12
0920901   0.0 0.0 11
*
*crdno    tlpvbfe
0921001   0000000 12
*crdno    efvcahs
0921101   0001000 11
*
0921201   103 7.65+6 527.45 0.0 0.0 0.0 12
0921300   1
0921301   0.0 0.0 0.0 11
*-----------------------------------------
0930000   sj93 sngljun
*crdno    from      to        area floss rloss efvcahs
0930101   092010000 094000000 0.0  0.0   0.0   0001100
0930201   0 0.0 0.0 0.0
*-----------------------------------------
0940000   gasprz pipe
0940001   4
0940101   1.7349-1 4
0940301   0.75 4
0940601   90.0 4
0940801   50.0-6 0.0 4
0940901   0.0 0.0 3
*
*crdno    tlpvbfe
0941001   0000000 4
*crdno    efvcahs
0941101   0001000 3
*
0941201   103 7.85+6 527.45 0.0 0.0 0.0 2
0941202   004 7.85+6 527.45 1.0 0.0 0.0 4
0941300   1
0941301   0.0 0.0 0.0 3
*
*-----------------------------------------
*      PRESSURE HEADER, coponents no v.103, sj105
*
1030000 pheader pipe
1030001 8
1030101 0.06835 8
1030301 0.3 8
1030601 0.0 8
1030801 50.0-6 0.295 8
1030901 0.0 0.0 7
*
*crdno   tlpvbfe
1031001  0000000 8
*crdno   efvcahs
1031101  0001000 7
*
1031201 103 9.2+6 527.45 0.0 0.0 0.0 8
1031300 1
1031301 3.33 0.0 0.0 7
*-----------------------------------------
1050000   sj105 sngljun
*crdno    from      to        area floss rloss efvcahs
1050101   103010000 106000000 0.0  0.0   0.0   0001100
1050201   1,33.33 0.0 0.0
*-----------------------------------------
*      BYPASS, component v.106
*
1060000 bypass pipe
1060001 24
1060101 8.171-3 24
*
```

```
1060301 1.0 2, 1.511 3, 1.3 4, 1.137445 6
1060302 1.55 7, 1.1425 11, 1.4 13, 1.7 14
1060303 1.3 15, 1.4 17, 1.7292 22, 0.6 24
*
1060601 0.0 2, 90.0 3, 23.0 4, 90.0 6
1060602 0.0 7, 90.0 11, 0.0 13, 0.0 14
1060603 90.0 15, 0.0 17, 90.0 22, 0.0 24
*
1060801 30.0-6 0.102 24
*
1060901 0.0 0.0 1
1060902 0.15 0.15 4
*      floss rloss constant for valve 5
1060903  135.0 135.0 5
1060904 0.15 0.15 7
1060905 0.0 0.0 10
1060906 0.15 0.15 11
1060907 0.0 0.0 12
1060908 0.15 0.15 14
1060909 0.0 0.0 15
1060910 0.15 0.15 16
1060911 0.0 0.0 21
1060912 0.15 0.15 22
1060914 0.0 0.0 23
*
*crdno  tlpvbfe
1061001 0000000 24
*crdno  efvcahs
1061101 0001000 23
*
1061201 103 8.4+6 527.45 0.0 0.0 0.0 24
1061300 1
1061301 33.33 0.0 0.0 23
*-----------------------------------------
1040000   sj104 sngljun
*crdno    from      to        area  floss rloss efvcahs
1040101   103050003 001010001 0.0   0.5   0.5   0001100
1040201   1 3.9 0.0 0.0
*-----------------------------------------
*      GROUP DISTRIBUTION HEADER AND LOWER WATER
*      COMMUNICATION, components v.1,valve jun.2, v.3
*
0010000   gdh pipe
0010001   4
0010101   3.32-3 4
0010301   0.5 1, 0.95 3, 0.80 4
0010601   0.0 1, 90.0 3, 0.0 4
0010801   20.0-6 0.065 4
0010901   0.5 0.5 1, 0.0 0.0 2, 0.5 0.5 3
*
*crdno    tlpvbfe
0011001   0000000 4
*crdno    efvcahs
0011101   0001000 3
*
0011201   103 9.2+6 527.45 0.0 0.0 0.0 4
0011300   1
0011301   3.9 0.0 0.0 3
*
*-----------------------------------------
*      isolating control valve 2r
0020000   valv2r valve
*crdno    from      to        area      floss rloss  efvcahs
0020101   001010000 003000000 3.3183-3 770.0 770.0  0001100
0020201   1 3.9 0.0 0.0
0020300   mtrvlv
*      open close rate  initl  table
0020301   702  602   0.25   1.0    0
*
412     time 0 ge null 0 1400.5  n * close
512     time 0 ge null 0 1406.0  n * stop
602              412 and -512  n * close
*
403     time 0 ge null 0 1410.00 n * open
503     time 0 ge null 0 1410.12 n * stop
702              403 and -503  n * open
*
*-----------------------------------------
*      lower water communication
```

```
0030000  lwc pipe
0030001  7
0030101  3.3183-3 7
0030301  0.8 1, 1.7 2, 1.775 4, 1.6 5,0.85 7
0030601  0.0 1, -90.0 2, 0.0 4, 90.0 5, 0.0 7
0030801  20.0-6 0.065 7
0030901  0.5 0.5 2, 0.0 0.0 3, 0.5 0.5 6
*
*crdno   tlpvbfe
0031001  0000000  7
*crdno   efvcahs
0031101  0001000 6
*
0031201  103 8.40+6 527.45 0.0 0.0 0.0 7
0031300  1
0031301  0.0 0.0 0.0 6
*----------------------------------------------
0040000  sj4 sngljun
*crdno   from     to       area  floss rloss efvcahs
0040101  003010000 005010003 0.0   0.5   0.5   0001100
0040201  1 3.9 0.0 0.0
*----------------------------------------------
*      FUEL CHANNEL WITH FUEL ASSEMBLY, component v.5
*
0050000  fuelchn pipe
0050001  45
0050101  0.002273 1, 0.002273 41, 0.002273 45
0050301  0.578 1, 0.16 2, 0.36 11, 0.12 41
0050302  0.131 43, 0.098 44, 0.1 45
0050601  90.0 45
0050801  4.0-5 8.563-3 45
*
0050901  0.0 0.0 1, 0.55 0.55 10
0050902  0.91 0.91 11,0.28 0.28 13
0050903  0.91 0.91 14,0.28 0.28 16
0050904  0.91 0.91 17,0.28 0.28 19
0050905  0.91 0.91 20,0.28 0.28 22
0050906  0.91 0.91 23,0.28 0.28 25
0050907  0.91 0.91 26,0.28 0.28 28
0050908  0.91 0.91 29,0.28 0.28 31
0050909  0.91 0.91 32,0.28 0.28 34
0050910  0.91 0.91 35,0.28 0.28 37
0050911  0.91 0.91 38,0.28 0.28 40
0050912  0.91 0.91 41,0.0 0.0 43, 0.55 0.55 44
*
*crdno   tlpvbfe
0051001  0000100  45
*crdno   efvcahs
0051101  0001000 44
*0051101  0101000 44
*
0051201  102 8.40+6 0.12 0.0 0.0 0.0 45
0051300  1
0051301  3.9 0.0 0.0 44
*----------------------------------------------
0060000  sj6 sngljun
*crdno   from     to       area floss rloss efvcahs
0060101  005440003 007000000 0.0  1.74  1.74  0001100
0060201  1 3.9 0.0 0.0
*----------------------------------------------
*      LIFTING PATH WITH FA SUSPENTION, component v.7
*
0070000  lftpath pipe
0070001  11
0070101  0.0041854 4
0070102  0.00721 7, 0.00488 8, 0.0076 11
*
0070301  0.38 1, 0.35 2, 0.7975 3, 0.795 4
0070302  1.635 7, 1.07 8, 0.68 9, 0.1 10, 0.24 11
*
0070601  0.0 1, 45.0 2, 90.0 11
*
0070801  25.0-6 0.073 4
0070802  20.0-6 0.067 7, 4.0-6 0.0299 8, 4.0-6 0.05288 11
*
0070901  0.07 0.07 2
0070902  0.00 0.00 3
0070903  0.50 0.20 4
0070904  0.00 0.00 6
0070905  0.16 0.24 7
0070906  0.24 0.16 8
0070907  0.0  0.0 10
*
*crdno   tlpvbfe
0071001   0000000 11
*crdno   efvcahs
0071101  0001000 10
*0071101  0101000 10
*
0071201  102 8.0+6 0.12 0.0 0.0 0.0 11
0071300  1
0071301  3.9 0.0 0.0 10
*----------------------------------------------
0080000  sj8 sngljun
*crdno   from     to       area floss rloss efvcahs
0080101  007100003 009000000 0.0  0.5   0.5   0001100
0080201  1 3.9 0.0 0.0
*----------------------------------------------
*      STEAM WATER COMMUNICATION, component v.9
*
0090000  swc pipe
0090001  20
0090101  3.3183-3 20
0090301  0.75 2, 0.6 3, 1.375 5, 0.8 6, 1.3 7
0090302  1.4 8, 0.8 9, 2.15 10, 2.26 15
0090303  1.7175 17, 2.3 18, 0.7 19, 0.5 20
0090601  0.72 19, 90.0 20
0090801  20.0-6 0.065 20
*
0090901  0.5  0.5 3
0090902  0.0  0.0  4
0090904  0.5  0.5 9
0090905  0.0  0.0  14
0090908  0.5  0.5 15
0090909  0.0  0.0  16
0090910  0.5  0.5 19
*
*crdno   tlpvbfe
0091001  0000000 20
*crdno   efvcahs
0091101  0001000 19
*0091101  0101000 19
*
0091201  102 8.0+6 0.11 0.0 0.0 0.0 20
0091300  1
0091301  3.9 0.0 0.0 19
*----------------------------------------------
*      UPPER HEADER, components branch 10, v.11
*
0100000  dcclil  branch
0100001  3       1
0100101  0.06835 0.7 0.0 0.0 0.0 0.0 4.0-5 0.295 0000000
0100200  003      8.0+6    527.45
0101101  010010003 009200002  0.0033183 0.0 0.0  0001000
0101201  0.0      0.0      0.0
0102101  010010002 011010001  0.0   0.0  0.0   0001000
0102201  0.0      0.0      0.0
0103101  106010000 010010001  0.0   0.0  0.0   0001000
0103201  0.0      0.0      0.0
*
0110000 upphdr pipe
0110001 5
0110101 68.35-3 5
0110301 0.7 4, 0.9 5
0110601 3.0 5
0110801 50.0-6 0.295 5
0110901 0.0 0.0 4
*
*crdno   tlpvbfe
0111001   0000000 5
*crdno   efvcahs
0111101   0001000 4
*
0111201 103 8.0+6 539.0  0.0 0.0 0.0 5
0111300 1
0111301 37.23 0.0 0.0 4
*----------------------------------------------
0120000 sj12 sngljun
```

```
*crdno  from      to        area floss rloss efvcahs
0120101 011050003 014010001 0.0  0.5   0.5   0001100
0120201 1 0.0 0.0 0.0
*-----------------------------------------
*       STEAM WATER PIPELINE, component v.14
*
0140000   swpline pipe
0140001   8
0140101   7.7-3 8
0140301   0.9 1,1.0 2, 1.3 3, 1.5 4, 0.8 5
0140302   1.0 6, 1.5 7, 0.5 8
0140601   90.0 1,0.0 8
0140801   30.0-6 0.099 8
0140901   0.15 0.15 7
*
*crdno    tlpvbfe
0141001   0000000 8
*crdno    efvcahs
0141101   0001000 7
*
0141201   102 8.0+6 0.05 0.0 0.0 0.0 8
0141300   1
0141301   0.0 0.0 0.0 7
*-----------------------------------------
0150000   sj15 sngljun
*crdno    from      to        area floss rloss efvcahs
0150101   014010000 020030003 0.0  0.0   0.0   0001100
0150201   0 0.0 0.0 0.0
*-----------------------------------------
*       SEPARATOR (1c,2c,3c), component v.20
*
0200000   seprt pipe
0200001   6
0200101   78.87-3 6
0200301   0.5 2, 0.7 3, 0.5 5, 0.4 6
0200601   90.0 6
0200801   50.0-6 0.317 6
*
*crdno    tlpvbfe
0201001   0000000 6
*crdno    efvcahs
0201101   0001000 5
*
0201201   102 8.0+6 0.03 0.0 0.0 0.0 6
0201300   1
0201301   0.0 0.0 0.0 5
*-----------------------------------------
0210000   sj21 sngljun
*crdno    from      to        area floss rloss efvcahs
0210101   020000000 022000000 0.0  0.0   0.0   0001100
0210201   0 0.0 0.0 0.0
*-----------------------------------------
*     AFTER SEPARATOR WATER DOWNCOMER, component v.22,
*     valve jun.23, v.25, sj.26
*
0220000   downcm22 pipe
0220001   14
0220101   8.171-3 14
0220301   1.15 2, 1.05 4, 1.425 6, 1.2 10, 1.325 12
0220302   1.3 13, 1.275 14
0220601   -90.0 2, 0.0 6, -90.0 10, 0.0 12
0220602   -90.0 14
0220801   30.0-6 0.102 14
*
0220901   0.0 0.0 1, 0.15 0.15 2
0220902   0.0 0.0 3, 0.15 0.15 4
0220903   0.0 0.0 5, 0.15 0.15 6
0220904   0.0 0.0 9, 0.15 0.15 10
0220905   0.0 0.0 11, 0.15 0.15 13
*
*crdno    tlpvbfe
0221001   0000000 14
*crdno    efvcahs
0221101   0001000 13
*
0221201   102 8.0+6 0.01 0.0 0.0 0.0 14
0221300   1
0221301   0.0 0.0 0.0 13
*
```

```
*     after separator water downcomer motor valve 22
0230000   valv22 valve
*crdno    from      to        area    floss rloss efvcahs
0230101   022010000 025000000 8.171-3 400.0 400.0 0001100
0230201   1 0.0 0.0 0.0
0230300   mtrvlv
*       open close rate  initl  table
0230301   422  622   0.001 1.0    0
*
432       time 0 ge null 0  500.0 n * close
532       time 0 ge null 0 1000.0 n * stop
622                432 and -532 n * close
422       time 0 ge null 0 9999.0 n * open
*
*
0250000   downcm25 pipe
0250001   2
0250101   8.171-3 2
0250301   0.6375 2
0250601   -90.0 2
0250801   30.0-6 0.099 2
*
0250901   0.0 0.0 1
*
*crdno    tlpvbfe
0251001   0000000 2
*crdno    efvcahs
0251101   0001000 1
*
0251201   102 8.0+6 0.01 0.0 0.0 0.0 2
0251300   1
0251301   0.0 0.0 0.0 1
*-----------------------------------------
0260000   sj26 sngljun
*crdno    from      to        area floss rloss efvcahs
0260101   025010000 024000000 0.0  0.0   0.0   0001100
0260201   0 0.0 0.0 0.0
*-----------------------------------------
*       AFTERCOOLER (7t,8t), component v.24
*
0240000   cooler pipe * 96 annulus (tube inside tube)
0240001   4
0240101   6.5563-3 4
0240301   0.275 4
0240601   -90.0 4
0240801   4.0-6 0.003 4
*
*crdno    tlpvbfe
0241001   0000000  4
*crdno    efvcahs
0241101   0001000 3
*
0241201   102 7.5+6 0.01 0.0 0.0 0.0 4
0241300   1
0241301   0.0 0.0 0.0 3
*-----------------------------------------
0270000   sj27 sngljun
*crdno    from      to        area floss rloss efvcahs
0270101   024010000 028000000 0.0  0.0   0.0   0001100
0270201   0 0.0 0.0 0.0
*-----------------------------------------
* AFTERCOOLER WATER DOWNCOMER, components v.28, sj.29
*
0280000   downcm28 pipe
0280001   6
0280101   8.171-3 6
0280301   0.95 2, 1.075 4, 1.215 6
0280601   -90.0 6
0280801   30.0-6 0.102 6
0280901   0.0 0.0 1,0.15 0.15 2, 0.0 0.0 5
*
*crdno    tlpvbfe
0281001   0000000  6
*crdno    efvcahs
0281101   0101000 5
*
0281201   103 7.3+6 527.45 0.0 0.0 0.0 6
0281300   1
0281301   0.0 0.0 0.0 5
```

```
*___________________________________
0290000  sj29 sngljun
*crdno   from     to      area floss rloss efvcahs
0290101  028010000 041050003 0.0  0.0   0:0   0001100
0290201  0 0.0 0.0 0.0
*___________________________________
* AFTER SEPARATOR STEAM PIPELINE, components sj.36, v.30,
*
0360000  sj36 sngljun
*crdno   from     to      area floss rloss efvcahs
0360101  020010000 030000000 0.0  0.0   0.0   0101100
0360201  0 0.0 0.0 0.0
*
0300000  steam pipe
0300001  12
0300101  8.171-3 12
0300301  0.6 1, 0.8 2, 0.7 3, 0.95 4
0300302  1.475 6, 1.4 7, 1.7 8, 0.75 9
0300303  0.65 10, 0.75 12
0300601  90.0 1, 0.0 6, -45.0 7, 0.0 10, -90.0 12
0300801  30.0-6 0.102 12
*
0300901  0.15 0.15 1, 0.0 0.0 4
0300902  0.0 0.0 5, 0.15 0.15 10, 0.0 0.0 11
*
*crdno   tlpvbfe
0301001  0000000 12
*crdno   efvcahs
0301101  0001000 11
*
0301201  102 8.0+6 0.03 0.0 0.0 0.0 12
0301300  1
0301301  0.0 0.0 0.0 11
*___________________________________
*  after separator steam downcomer motor valve 19
0310000  valv19 valve
*crdno   from     to      area    floss rloss efvcahs
0310101  030010000 032000000 8.171-3 400.0 400.0 0001100
0310201  1 0.0 0.0 0.0
0310300  mtrvlv
*     open close rate  initl  table
0310301  419  619  0.001 1.0  0
*
439      time 0 ge null 0  500.0 n * close
539      time 0 ge null 0 1000.0 n * stop
619               439 and -539 n * close
419      time 0 ge null 0 9999.0 n * open
*
*___________________________________
*     CONDENSER (1k,2k,3k), component v.32
*
0320000  condens pipe  * bundle of 72 U-tubes
0320001  4
0320101  81.804-3 4
0320301  0.60625 4
0320601  -90.0 4
0320801  4.0-6 46.73-3 4
*
*crdno   tlpvbfe
0321001  0000100 4
*0321001   0000000 4
*crdno   efvcahs
0321101  0001000 3
*
0321201  102 7.9+6 0.03 0.0 0.0 0.0 4
0321300  1
0321301  0.0 0.0 0.0 3
*
*___________________________________
0330000  sj33 sngljun
*crdno   from     to      area floss rloss efvcahs
0330101  032010000 034000000 0.0  0.5   0.5   0001100
0330201  0 0.0 0.0 0.0
*___________________________________
*   AFTER CONDENSER WATER DOWNCOMER, component v.34
*
0340000  downcm34 pipe
0340001  15
0340101  8.171-3 15
```

```
0340301  0.85 1, 1.7 2, 0.85 3, 2.0 4, 1.7 5
0340302  1.843 8, 2.4 9, 1.85 11,
0340303  2.26725 12, 2.11625 13, 1.85125 15
*
0340601  0.0 1, -90.0 2, 0.0 3, -90.0 4, 0.0 5
0340602  -90.0 8, 0.0 11, -90.0 15
0340801  30.0-6 0.102 15
*
0340901  0.15 0.15 6, 0.0 0.0 8
0340902  0.15 0.15  9, 0.0 0.0 10
0340903  0.15 0.15 11, 0.0 0.0 12
0340904  0.15 0.15 13, 0.0 0.0 14
*
*crdno   tlpvbfe
0341001  0000000 15
*crdno   efvcahs
0341101  0001000 14
*
0341201  103 7.9+6 527.45 0.0 0.0 0.0 15
0341300  1
0341301  0.0 0.0 0.0 14
*___________________________________
0350000  sj35 sngljun
*crdno   from     to      area floss rloss efvcahs
0350101  034010000 041040003 0.0  0.0   0.0   0001100
0350201  0 0.0 0.0 0.0
*___________________________________
*      FIRST INTAKE HEADER, component v.41
*
0410000 inthdr1 pipe
0410001 7
0410101 0.02865 7
0410301 0.5 1, 1.00 6, 0.5 7
0410601 0.0 7
0410701 0.0 7
0410801 40.0-6 0.191 7
0410901 0.0 0.0 6
*
*crdno   tlpvbfe
0411001  0000000  7
*crdno   efvcahs
0411101  0001000 6
*
0411201 103 7.9+6 527.45 0.0 0.0 0.0 7
0411300 1
0411301 0.0 0.0 0.0 6
*___________________________________
* MECHANICAL FILTERS, components sj.42, sj.43, sj.44
*
0420000  sj42 sngljun
*crdno   from     to      area    floss rloss efvcahs
0420101  041040004 045010003 6.6476-3 140.0 140.0 0001100
0420201  0 0.0 0.0 0.0
*
0430000  sj43 sngljun
*crdno   from     to      area    floss rloss  efvcahs
0430101  041050004 045020003 6.6476-3 140.0 140.0  0001100
0430201  0 0.0 0.0 0.0
*
0440000  sj44 sngljun
*crdno   from     to      area    floss rloss  efvcahs
0440101  041060004 045030003 6.6476-3 140.0 140.0  0001100
0440201  0 0.0 0.0 0.0
*___________________________________
*      SECOND INTAKE HEADER, component v.45
*
0450000 inthdr2 pipe
0450001 3
0450101 0.02865 3
0450301 1.00 2, 1.35 3
0450601 0.0 3
0450801 40.0-6 0.191 3
0450901 0.0 0.0 2
*
*crdno   tlpvbfe
0451001  0000000  3
*crdno   efvcahs
0451101  0001000 2
*
```

```
0451201 103 7.5+6 527.45 0.0 0.0 0.0 3
0451300 1
0451301 0.0 0.0 0.0 2
*-------------------------------------------
0460000   sj46 sngljun
*crdno   from      to        area floss rloss efvcahs
0460101   045010004 047000000 0.0  0.0   0.0   0001100
0460201   0 0.0 0.0 0.0
*-------------------------------------------
*
1000000   calclt tmdpvol
1000101   0.0 2.0 2.0 0.0 0.0 0.0 1.0-6 0.0 0
1000200   103
1000201   0.0 7.85+6 527.45
*
1010000   sj101 sngljun
*crdno   from      to        area floss rloss efvcahs
1010101   100000000 045000000 0.0  0.0   0.0   0001100
1010201   0 0.0 0.0 0.0
*-------------------------------------------
*
*1010000   inventor tmdpjun
*1010101   100000000 045000000 0.0
*1010200   1
*1010201      0.0 0.00 0.0 0.0
*
*-------------------------------------------
* PUMP 1 SUCTION PIPELINE, component v.47
*
0470000 suctn1 pipe
0470001 5
0470101 28.65-3 5
0470301 1.95 2, 2.1 4, 2.2 5  * check 2.2 height for subvol 5
0470601 0.0 5
0470801 40.0-6 0.191 5
*
0470901 0.0 0.0 1, 0.10 0.10 2
0470902 0.0 0.0 3, 0.10 0.10 4
*
*crdno   tlpvbfe
0471001   0000000  5
*crdno   efvcahs
0471101   0001000 4
*
0471201 103 7.5+6 527.45 0.0 0.0 0.0 5
0471300 1
0471301 0.0 0.0 0.0 4
*
*-------------------------------------------
* DOWNCOMER PAST SEPARATORS AND CONDENSERS,
* components sj.51, v.52
*
0510000   sj51 sngljun
*crdno   from      to        area floss rloss efvcahs
0510101   011050003 052010001 0.0  0.0   0.0   0001100
0510201   0 0.0 0.0 0.0
*-------------------------------------------
*
0520000   downcm52 pipe
0520001   14
0520101   16.06-3 14
0520301   1.663 3, 2.2 4, 1.9 5, 1.6 6, 1.5 8
0520302   1.9 9, 2.45 10, 1.5 11, 2.091 12, 2.275 14
0520601   -90.0 3, 0.0 4, -90.0 5, 0.0 6, -90.0 8
0520602   0.0 9, -90.0 10, 0.0 11, -90.0 14
0520801   35.0-6 0.143 14
*
0520901   0.0 0.0 2, 0.15 0.15 6
0520902   0.0 0.0 7, 0.15 0.15 10
0520903   0.15 0.15 11
0520904   0.0 0.0 13
*
*crdno   tlpvbfe
0521001   0000000 14
*crdno   efvcahs
0521101   0001000 13
*
0521201   103 8.0+6 538.0 0.0 0.0 0.0 14
0521300   1
0521301   0.0 0.0 0.0 13
*-------------------------------------------
*past separators and condensers downcomer motor valve 29
0530000   valv29 valve
*crdno   from      to        area   floss  rloss  efvcahs
0530101   052010000 041030003 16.06-3 1900.0 1900.0 0001100
0530201   1 0.0 0.0 0.0
0530300   mtrvlv
*       open close rate   initl  table
0530301   429  629   0.001   1.0    0
*
449      time 0 ge null 0  500.0 n * close
549      time 0 ge null 0 1000.0 n * stop
629               449 and -549 n * close
429      time 0 ge null 0 9999.  n * open
*
*-------------------------------------------
* DOWNCOMER FROM UPPER HEADER TO HEAT
EXCHANGERS (5t,6t),
* components sj.61, v.62
*
0610000   sj61 sngljun
*crdno   from      to        area floss rloss efvcahs
0610101   052060001 062000000 0.0  0.0   0.0   0001100
0610201   0 0.0 0.0 0.0
*
0620000   downcm62 pipe
0620001   8
0620101   16.06-3 8
0620301   1.72 3, 1.375 4, 1.35 5, 1.325 6, 1.2 7, 1.2 8
0620601   0.0 3, -90.0 4, 0.0 5, -90.0 6, 0.0 7, -90.0 8
0620801   35.0-6 0.143 8
0620901   0.0 0.0 2, 0.15 0.15 7
*
*crdno   tlpvbfe
0621001   0000000 8
*crdno   efvcahs
0621101   0001000 7
*
0621201   103 8.0+6 538.0 0.0 0.0 0.0 8
0621300   1
0621301   0.0 0.0 0.0 7
*
*-------------------------------------------
*       heat exchanger downcomer motor valve 14
0630000   valv14 valve
*crdno   from      to        area   floss  rloss  efvcahs
0630101   062010000 064000000 16.06-3 1550.0 1550.0 0001100
0630201   1 0.0 0.0 0.0
0630300   mtrvlv
*       open close rate  initl  table
0630301   414  614   0.001 1.0    0
*
424      time 0 ge null 0  500.0 n * close
524      time 0 ge null 0 1000.0 n * stop
614               424 and -524 n * close
414      time 0 ge null 0 9999.0  n * open
*
*-------------------------------------------
*       HEAT EXCHANGER (5t, 6t), component v.64
*
0640000   htexch pipe  * bundle of 48 U-tubes
0640001   4
0640101   54.536-3 4
0640301   0.60625 4
0640601  -90.0 4
0640801   4.0-6 45.09-3 4
*
*crdno   tlpvbfe
0641001   0000100 4
*crdno   efvcahs
0641101   0001000 3
*
0641201   103 7.5+6 538.0 0.0 0.0 0.0 4
0641300   1
0641301   0.0 0.0 0.0 3
*-------------------------------------------
0650000   sj65 sngljun
*crdno   from      to        area floss rloss efvcahs
```

```
0650101  064010000 066000000 0.0  0.0   0.0   0001100
0650201  0 0.0 0.0 0.0
*-----------------------------------------
*  AFTER HEAT EXCHANGERER DOWNCOMER, component v.66
*
0660000  downcm66 pipe
0660001  9
0660101  0.016060 9
0660301  1.642 3, 1.649 4, 2.725 5, 2.637 7, 2.0585 9
0660601  0.0 3, -90.0 4, 0.0 7, -90.0 9
0660801  35.0-6 0.143 9
0660901  0.0 0.0 2,0.15 0.15 4, 0.0 0.0 6, 0.15 0.15 8
*
*crdno   tlpvbfe
0661001  0000000 9
*crdno   efvcahs
0661101  0001000 8
*
0661201  103 7.5+6 527.45 0.0 0.0 0.0 9
0661300  1
0661301  0.0 0.0 0.0 8
*---------------------------------------
0670000  sj67 sngljun
*crdno   from     to       area floss rloss efvcahs
0670101  066010000 041000000 0.0  0.0   0.0   0001100
0670201  0 0.0 0.0 0.0
*
*===============================================================
*      SECOND CIRCUIT
*===============================================================
2010000  tdv201 tmdpvol
2010101  0.0 2.0 2.0 0.0 0.0 0.0 1.0-6 0.0 0
2010200  103
2010201  0.0 7.5+6 481.0
*
2020000  regul  tmdpjun
2020101  201000000 203000000 0.0
2020200  1
2020201    0.0   9.50 0.0 0.0
*
2030000  htexch pipe  * heat exchanger 5t,6t (bundle of 48 U-tubes)
2030001  8
2030101  3.768-3 8
2030301  0.60625 8
2030601  90.0 4, -90.0 8
2030801  2.0-6 0.01 8
2030901  0.0 0.0 7
*
*crdno   tlpvbfe
2031001  0000000  8
*crdno   efvcahs
2031101  0001000 7
*
2031201  103 7.0+6 485.0 0.0 0.0 0.0 8
2031300  1
2031301  0.0 0.0 0.0 7
*
2040000  sj204 sngljun
2040101  203010000 205000000 0.0 0.0  0.0  001100
2040201  0 0.0 0.0 0.0
*
2050000  tdv205 tmdpvol
2050101  0.0 2.0 2.0 0.0 0.0 0.0 1.0-6 0.0 0
2050200  103
2050201  0.0 7.0+6 500.0
*
10641000    8 2 2 0 0.005
10641100    0 1
10641101    1 0.0065
10641201    1 1
10641301    0. 1
10641401    507.0 2
10641501    203010000  10000   1   1 29.1 8
10641601    064040000 -10000 110  1 29.1 4
10641602    064010000  10000 110  1 29.1 8
10641701    0 0.0 0.0  0.0 8
10641801    0.0 20.0 20.0 0.0 0.0 0.0 0.0 1.0 8
10641901    0.0 20.0 20.0 0.0 0.0 0.0 0.0 1.0 8
*-------------------------------------
*
2110000  tdv211 tmdpvol
2110101  0.0 2.0 2.0 0.0 0.0 0.0 1.0-6 0.0 0
2110200  103
2110201  0.0 7.5+6 481.0
*
2120000  regul  tmdpjun
2120101  211000000 214000000 0.0
2120200  1
2120201    0.0   9.50 0.0 0.0
*
2140000  htexch pipe  * aftercooler 7t,8t (tube inside tube)
2140001  8
2140101  3.768-3 8
2140301  0.275 8
2140601  90.0 4, -90.0 8
2140801  2.0-6 0.01 8
2140901  0.0 0.0 7
*
*crdno   tlpvbfe
2141001  0000000  8
*crdno   efvcahs
2141101  0001000 7
*
2141201  103 7.0+6 485.0 0.0 0.0 0.0 8
2141300  1
2141301  0.0 0.0 0.0 7
*
2150000  sj215  sngljun
2150101  214010000 216000000 0.0 0.0  0.0  001100
2150201  0 0.0 0.0 0.0
*
2160000  tdv216  tmdpvol
2160101  0.0 2.0 2.0 0.0 0.0 0.0 1.0-6 0.0 0
2160200  103
2160201  0.0 7.0+6 500.0
*
10241000    8 2 2 0 0.005
10241100    0 1
10241101    1 0.0065
10241201    1 1
10241301    0. 1
10241401    507.0 2
10241501    214010000  10000   1  1 13.2 8
10241601    024040000 -10000 110 1 13.2 4
10241602    024010000  10000 110  1 13.2 8
10241701    0 0.0 0.0  0.0 8
10241801    0.0 20.0 20.0 0.0 0.0 0.0 0.0 1.0 8
10241901    0.0 20.0 20.0 0.0 0.0 0.0 0.0 1.0 8
*-------------------------------------
*
2210000  tdv221 tmdpvol
2210101  0.0 2.0 2.0 0.0 0.0 0.0 1.0-6 0.0 0
2210200  103
2210201  0.0 7.5+6 481.0
*
2220000  regul  tmdpjun
2220101  221000000 224000000 0.0
2220200  1
2220201    0.0 14.3  0.0 0.0
*
2240000  condens pipe * condenser 1k,2k,3k (bundle of 72 U-tubes)
2240001  8
2240101  5.652-3 8
2240301  0.0625 8
2240601  90.0 4, -90.0 8
2240801  2.0-6 0.01 8
2240901  0.0 0.0 7
*
*crdno   tlpvbfe
2241001  0000000 8
*crdno   efvcahs
2241101  0001000 7
*
2241201  103 7.0+6 485.0 0.0 0.0 0.0 8
2241300  1
2241301  0.0 0.0 0.0 7
*
2250000  sj225 sngljun
```

```
2250101   224010000 226000000 0.0 0.0  0.0  001100
2250201   0 0.0 0.0 0.0
*
2260000   tdv226 tmdpvol
2260101   0.0 2.0 2.0 0.0 0.0 0.0 1.0-6 0.0 0
2260200   103
2260201   0.0 7.0+6 500.0
*
10321000    8 2 2 0 0.005
10321100    0 1
10321101    1 0.0065
10321201    1 1
10321301    0. 1
10321401    507.0 2
10321501    224010000  10000   1  1 43.65 8
10321601    032040000 -10000 110  1 43.65 4
10321602    032010000  10000 110  1 43.65 8
10321701    0 0.0 0.0  0.0 8
10321801    0.0 20.0 20.0 0.0 0.0 0.0 0.0 1.0 8
10321901    0.0 20.0 20.0 0.0 0.0 0.0 0.0 1.0 8
*
*****************************************************
*          HEAT STRUCTURES
*****************************************************
20800001 httemp 005100104
20800002 httemp 005100204
20800003 httemp 005100304
20800004 httemp 005100404
20800005 httemp 005100504
20800006 httemp 005100604
20800007 httemp 005100704
20800008 httemp 005100804
20800009 httemp 005100904
20800010 httemp 005101004
20800011 httemp 005101104
20800012 httemp 005101204
20800013 httemp 005101304
20800014 httemp 005101404
20800015 httemp 005101504
20800016 httemp 005101604
20800017 httemp 005101704
20800818 httemp 005101804
20800919 httemp 005101904
20800020 httemp 005102004
20800021 httemp 005102104
20800022 httemp 005102204
20800023 httemp 005102304
20800024 httemp 005102404
20800025 httemp 005102504
20800026 httemp 005102604
20800027 httemp 005102704
20800028 httemp 005102804
20800029 httemp 005102904
20800030 httemp 005103004
20800031 httemp 005103104
20800032 httemp 005103204
20800033 httemp 005103304
20800034 httemp 005103404
20800035 httemp 005103504
20800036 httemp 005103604
20800037 httemp 005103704
20800038 httemp 005103804
20800039 httemp 005103904
20800040 httemp 005104004
*
20800041 httemp 005200104
20800042 httemp 005200204
20800043 httemp 005200304
20800044 httemp 005200404
20800045 httemp 005200504
20800046 httemp 005200604
20800047 httemp 005200704
20800048 httemp 005200804
20800049 httemp 005200904
20800050 httemp 005201004
20800051 httemp 005201104
20800052 httemp 005201204
20800053 httemp 005201304
20800054 httemp 005201404
20800055 httemp 005201504
20800056 httemp 005201604
20800057 httemp 005201704
20800858 httemp 005201804
20800959 httemp 005201904
20800060 httemp 005202004
20800061 httemp 005202104
20800062 httemp 005202204
20800063 httemp 005202304
20800064 httemp 005202404
20800065 httemp 005202504
20800066 httemp 005202604
20800067 httemp 005202704
20800068 httemp 005202804
20800069 httemp 005202904
20800070 httemp 005203004
20800071 httemp 005203104
20800072 httemp 005203204
20800073 httemp 005203304
20800074 httemp 005203404
20800075 httemp 005203504
20800076 httemp 005203604
20800077 httemp 005203704
20800078 httemp 005203804
20800079 httemp 005203904
20800080 httemp 005204004
*
20800081 vgjj 005410000
20800082 dt 0
20800083 cputime 0
20800084 dtcrnt 0
*
*         fuel channel
*
*10051000    40 13 2 0 0.00375
*10051100    0 1
*10051101    1 0.004  1 0.00425 1 0.0045 1 0.00475
*10051102    1 0.005  1 0.00525 1 0.0055 1 0.00575
*10051103    1 0.006  1 0.00625 1 0.0065 1 0.00675
*10051201    1 12
*10051301    1. 12
*10051401    527.3 13
10051000    40 5 2 0 0.00375
10051100    0 1
10051101    1 0.004  1 0.005
10051102    1 0.006  1 0.00675
10051201    1 4
10051301    1. 4
10051401    527.3 5
10051501    0 0 0 1 0.96 1
10051502    0 0 0 1 2.16 10
10051503    0 0 0 1 0.72 40
10051601    005020000 10000 110 1 0.96 1
10051602    005030000 10000 110 1 2.16 10
10051603    005120000 10000 110 1 0.72 40
10051701    001 0.006689523559 0.0  0.0  1
10051702    001 0.015051428446 0.0  0.0 10
10051703    001 0.005017142815 0.0  0.0 40
10051900    1
10051901    0.03576 0.08 5.92 0.08 0.08 0.55 0.55 1.0 0.16 1.222 1.0 1
10051902    0.03576 0.34 6.66 0.18 0.18 0.55 0.55 1.0 0.36 1.222 1.0 2
10051903    0.03576 0.70 6.30 0.18 0.18 0.55 0.55 1.0 0.36 1.222 1.0 3
10051904    0.03576 1.06 5.94 0.18 0.18 0.55 0.55 1.0 0.36 1.222 1.0 4
10051905    0.03576 1.42 5.58 0.18 0.18 0.55 0.55 1.0 0.36 1.222 1.0 5
10051906    0.03576 1.78 5.22 0.18 0.18 0.55 0.55 1.0 0.36 1.222 1.0 6
10051907    0.03576 2.14 4.86 0.18 0.18 0.55 0.55 1.0 0.36 1.222 1.0 7
10051908    0.03576 2.50 4.50 0.18 0.18 0.55 0.55 1.0 0.36 1.222 1.0 8
10051909    0.03576 2.86 4.14 0.18 0.18 0.55 0.55 1.0 0.36 1.222 1.0 9
10051910    0.03576 3.22 3.78 0.18 0.18 0.55 0.91 1.0 0.36 1.222 1.0 10
10051911    0.03576 3.46 3.54 0.06 0.06 0.91 0.28 1.0 0.12 1.222 1.0 11
10051912    0.03576 3.58 3.42 0.06 0.06 0.25 0.28 1.0 0.12 1.222 1.0 12
10051913    0.03576 3.70 3.30 0.06 0.06 0.28 0.91 1.0 0.12 1.222 1.0 13
10051914    0.03576 3.82 3.18 0.06 0.06 0.91 0.28 1.0 0.12 1.222 1.0 14
10051915    0.03576 3.94 3.06 0.06 0.06 0.28 0.28 1.0 0.12 1.222 1.0 15
10051916    0.03576 4.06 2.94 0.06 0.06 0.28 0.91 1.0 0.12 1.222 1.0 16
10051917    0.03576 4.18 2.82 0.06 0.06 0.91 0.28 1.0 0.12 1.222 1.0 17
10051918    0.03576 4.30 2.70 0.06 0.06 0.28 0.28 1.0 0.12 1.222 1.0 18
10051919    0.03576 4.42 2.58 0.06 0.06 0.28 0.91 1.0 0.12 1.222 1.0 19
10051920    0.03576 4.54 2.46 0.06 0.06 0.91 0.28 1.0 0.12 1.222 1.0 20
```

```
10051921    0.03576 4.66 2.34 0.06 0.06 0.28 0.28 1.0 0.12 1.222 1.0 21
10051922    0.03576 4.78 2.22 0.06 0.06 0.28 0.91 1.0 0.12 1.222 1.0 22
10051923    0.03576 4.90 2.10 0.06 0.06 0.91 0.28 1.0 0.12 1.222 1.0 23
10051924    0.03576 5.02 1.98 0.06 0.06 0.28 0.28 1.0 0.12 1.222 1.0 24
10051925    0.03576 5.14 1.86 0.06 0.06 0.28 0.91 1.0 0.12 1.222 1.0 25
10051926    0.03576 5.26 1.74 0.06 0.06 0.91 0.28 1.0 0.12 1.222 1.0 26
10051927    0.03576 5.38 1.62 0.06 0.06 0.28 0.28 1.0 0.12 1.222 1.0 27
10051928    0.03576 5.50 1.50 0.06 0.06 0.28 0.91 1.0 0.12 1.222 1.0 28
10051929    0.03576 5.62 1.38 0.06 0.06 0.91 0.28 1.0 0.12 1.222 1.0 29
10051930    0.03576 5.74 1.26 0.06 0.06 0.28 0.28 1.0 0.12 1.222 1.0 30
10051931    0.03576 5.86 1.14 0.06 0.06 0.28 0.91 1.0 0.12 1.222 1.0 31
10051932    0.03576 5.98 1.02 0.06 0.06 0.91 0.28 1.0 0.12 1.222 1.0 32
10051933    0.03576 6.10 0.90 0.06 0.06 0.28 0.28 1.0 0.12 1.222 1.0 33
10051934    0.03576 6.22 0.78 0.06 0.06 0.28 0.91 1.0 0.12 1.222 1.0 34
10051935    0.03576 6.34 0.66 0.06 0.06 0.91 0.28 1.0 0.12 1.222 1.0 35
10051936    0.03576 6.46 0.54 0.06 0.06 0.28 0.28 1.0 0.12 1.222 1.0 36
10051937    0.03576 6.58 0.42 0.06 0.06 0.28 0.91 1.0 0.12 1.222 1.0 37
10051938    0.03576 6.70 0.30 0.06 0.06 0.91 0.28 1.0 0.12 1.222 1.0 38
10051939    0.03576 6.82 0.18 0.06 0.18 0.28 0.28 1.0 0.12 1.222 1.0 39
10051940    0.03576 6.94 0.06 0.06 0.06 0.28 0.91 1.0 0.12 1.222 1.0 40
*
10052000    40 5 2 0 0.00275
10052100    0 1
10052101    1 0.004  1 0.005
10052102    1 0.006  1 0.00675
10052201    1 4
10052301    1. 4
10052401    527.3 5
*10052000    40 17 2 0 0.00275
*10052100    0 1
*10052101    1 0.003  1 0.00325 1 0.0035 1 0.00375
*10052102    1 0.004  1 0.00425 1 0.0045 1 0.00475
*10052103    1 0.005  1 0.00525 1 0.0055 1 0.00575
*10052104    1 0.006  1 0.00625 1 0.0065 1 0.00675
*10052201    1 16
*10052301    1. 16
*10052401    527.3 17
10052501    0 0 0 1 1.92 1
10052502    0 0 0 1 4.32 10
10052503    0 0 0 1 1.44 40
10052601    005020000 10000 110 1 1.92 1
10052602    005030000 10000 110 1 4.32 10
10052603    005120000 10000 110 1 1.44 40
10052701    001 0.016167618441 0.0  0.0  1
10052702    001 0.036377142554 0.0  0.0 10
10052703    001 0.012125714185 0.0  0.0 40
10052900    1
10052901    0.01788 0.08 5.92 0.08 0.08 0.55 0.55 1.0 0.16 1.222 1.0 1
10052902    0.01788 0.34 6.66 0.18 0.18 0.55 0.55 1.0 0.36 1.222 1.0 2
10052903    0.01788 0.70 6.30 0.18 0.18 0.55 0.55 1.0 0.36 1.222 1.0 3
10052904    0.01788 1.06 5.94 0.18 0.18 0.55 0.55 1.0 0.36 1.222 1.0 4
10052905    0.01788 1.42 5.58 0.18 0.18 0.55 0.55 1.0 0.36 1.222 1.0 5
10052906    0.01788 1.78 5.22 0.18 0.18 0.55 0.55 1.0 0.36 1.222 1.0 6
10052907    0.01788 2.14 4.86 0.18 0.18 0.55 0.55 1.0 0.36 1.222 1.0 7
10052908    0.01788 2.50 4.50 0.18 0.18 0.55 0.55 1.0 0.36 1.222 1.0 8
10052909    0.01788 2.86 4.14 0.18 0.18 0.55 0.55 1.0 0.36 1.222 1.0 9
10052910    0.01788 3.22 3.78 0.18 0.18 0.55 0.91 1.0 0.36 1.222 1.0 10
10052911    0.01788 3.46 3.54 0.06 0.06 0.91 0.28 1.0 0.12 1.222 1.0 11
10052912    0.01788 3.58 3.42 0.06 0.06 0.25 0.28 1.0 0.12 1.222 1.0 12
10052913    0.01788 3.70 3.30 0.06 0.06 0.28 0.91 1.0 0.12 1.222 1.0 13
10052914    0.01788 3.82 3.18 0.06 0.06 0.91 0.28 1.0 0.12 1.222 1.0 14
10052915    0.01788 3.94 3.06 0.06 0.06 0.28 0.28 1.0 0.12 1.222 1.0 15
10052916    0.01788 4.06 2.94 0.06 0.06 0.28 0.91 1.0 0.12 1.222 1.0 16
10052917    0.01788 4.18 2.82 0.06 0.06 0.91 0.28 1.0 0.12 1.222 1.0 17
10052918    0.01788 4.30 2.70 0.06 0.06 0.28 0.28 1.0 0.12 1.222 1.0 18
10052919    0.01788 4.42 2.58 0.06 0.06 0.28 0.91 1.0 0.12 1.222 1.0 19
10052920    0.01788 4.54 2.46 0.06 0.06 0.91 0.28 1.0 0.12 1.222 1.0 20
10052921    0.01788 4.66 2.34 0.06 0.06 0.28 0.28 1.0 0.12 1.222 1.0 21
10052922    0.01788 4.78 2.22 0.06 0.06 0.28 0.91 1.0 0.12 1.222 1.0 22
10052923    0.01788 4.90 2.10 0.06 0.06 0.91 0.28 1.0 0.12 1.222 1.0 23
10052924    0.01788 5.02 1.98 0.06 0.06 0.28 0.28 1.0 0.12 1.222 1.0 24
10052925    0.01788 5.14 1.86 0.06 0.06 0.28 0.91 1.0 0.12 1.222 1.0 25
10052926    0.01788 5.26 1.74 0.06 0.06 0.91 0.28 1.0 0.12 1.222 1.0 26
10052927    0.01788 5.38 1.62 0.06 0.06 0.28 0.28 1.0 0.12 1.222 1.0 27
10052928    0.01788 5.50 1.50 0.06 0.06 0.28 0.91 1.0 0.12 1.222 1.0 28
10052929    0.01788 5.62 1.38 0.06 0.06 0.91 0.28 1.0 0.12 1.222 1.0 29
10052930    0.01788 5.74 1.26 0.06 0.06 0.28 0.28 1.0 0.12 1.222 1.0 30
10052931    0.01788 5.86 1.14 0.06 0.06 0.28 0.91 1.0 0.12 1.222 1.0 31
10052932    0.01788 5.98 1.02 0.06 0.06 0.91 0.28 1.0 0.12 1.222 1.0 32
10052933    0.01788 6.10 0.90 0.06 0.06 0.28 0.28 1.0 0.12 1.222 1.0 33
10052934    0.01788 6.22 0.78 0.06 0.06 0.28 0.91 1.0 0.12 1.222 1.0 34
10052935    0.01788 6.34 0.66 0.06 0.06 0.91 0.28 1.0 0.12 1.222 1.0 35
10052936    0.01788 6.46 0.54 0.06 0.06 0.28 0.28 1.0 0.12 1.222 1.0 36
10052937    0.01788 6.58 0.42 0.06 0.06 0.28 0.91 1.0 0.12 1.222 1.0 37
10052938    0.01788 6.70 0.30 0.06 0.06 0.91 0.28 1.0 0.12 1.222 1.0 38
10052939    0.01788 6.82 0.18 0.06 0.18 0.28 0.28 1.0 0.12 1.222 1.0 39
10052940    0.01788 6.94 0.06 0.06 0.06 0.28 0.91 1.0 0.12 1.222 1.0 40
*
10053000    45 2 2 0 0.00
10053100    0 1
10053101    1 0.0075
10053201    1 1
10053301    0. 1
10053401    527.45 2
10053501    0 0-0 1 0.578 1
10053502    0 0 0 1 0.16  2
10053503    0 0 0 1 0.36  11
10053504    0 0 0 1 0.12  41
10053505    0 0 0 1 0.131 43
10053506    0 0 0 1 0.098 44
10053507    0 0 0 1 0.1   45
10053601    005010000 10000 110 1 0.578 1
10053602    005020000 10000 110 1 0.16  2
10053603    005030000 10000 110 1 0.36  11
10053604    005120000 10000 110 1 0.12  41
10053605    005420000 10000 110 1 0.131 43
10053606    005440000 10000 110 1 0.098 44
10053607    005450000 10000 110 1 0.1   45
10053701    0 0.0 0.0  0.0 45
10053901    0.0 15.0 15.0 0.0 0.0 0.0 0.0 1.0 45
*
10054000    45 3 2 0 0.04
10054100    0 1
10054101    1 0.055
10054102    1 0.0625
10054201    3 1 2 2
10054301    0.0 2
10054401    530.0 3
10054501    005010000 10000 110 1 0.578 1
10054502    005020000 10000 110 1 0.16  2
10054503    005030000 10000 110 1 0.36  11
10054504    005120000 10000 110 1 0.12  41
10054505    005420000 10000 110 1 0.131 43
10054506    005440000 10000 110 1 0.098 44
10054507    005450000 10000 110 1 0.1   45
10054601    -12 0 3011 1 0.578 1
10054602    -12 0 3011 1 0.16  2
10054603    -12 0 3011 1 0.36  11
10054604    -12 0 3011 1 0.12  41
10054605    -12 0 3011 1 0.131 43
10054606    -12 0 3011 1 0.098 44
10054607    -12 0 3011 1 0.1   45
10054701    0 0.0 0.0 0.0 45
10054801    0.0 15.0 15.0 0.0 0.0 0.0 0.0 1.0 45
*
*        lifting path tube
10071000    4 2 2 0 0.0365
10071100    0 1
10071101    1 0.0445
10071201    2 1
10071301    0.0 1
10071401    550.0 2
10071501    007010000 00000 1 1 0.38  1
10071502    007020000 00000 1 1 0.35  2
10071503    007030000 10000 1 1 0.7975 3
10071504    007040000 10000 1 1 0.795 4
10071601    -12 0 3011 1 0.38  1
10071602    -12 0 3011 1 0.35  2
10071603    -12 0 3011 1 0.7975 3
10071604    -12 0 3011 1 0.795 4
10071701    0 0.0 0.0 0.0 4
10071801    0.0 15.0 15.0 0.0 0.0 0.0 0.0 1.0 4
*
*        lifting path tube
10072000    7 2 2 0 0.051
10072100    0 1
10072101    1 0.057
10072201    2 1
```

```
10072301   0.0 1
10072401   550.0 2
10072501   007050000 10000 1 1 1.635  3
10072502   007080000 0 1 1 1.07 4
10072503   007090000 0 1 1 0.68 5
10072504   007100000 0 1 1 0.1  6
10072505   007110000 0 1 1 0.24 7
10072601   -12 0 3011 1 1.635   3
10072602   -12 0 3011 1 1.07    4
10072603   -12 0 3011 1 0.68    5
10072604   -12 0 3011 1 0.1     6
10072605   -12 0 3011 1 0.24    7
10072701   0 0.0 0.0 0.0 7
10072801   0.0 15.0 15.0 0.0 0.0 0.0 0.0 1.0 7
*
*        swc tube
10091000   20 2 2 0 0.0325
10091100   0 1
10091101   1 0.0375
10091201   2 1
10091301   0.0 1
10091401   550.0 2
10091501   009010000 10000 1 1 0.75   2
10091502   009030000 10000 1 1 0.6    3
10091503   009050000 10000 1 1 1.375  5
10091504   009060000 10000 1 1 0.8    6
10091505   009070000 10000 1 1 1.3    7
10091506   009080000 00000 1 1 1.4    8
10091507   009090000 00000 1 1 0.8    9
10091508   009100000 00000 1 1 2.15   10
10091509   009150000 00000 1 1 2.26   15
10091510   009170000 00000 1 1 1.7175 17
10091511   009180000 00000 1 1 2.3    18
10091512   009190000 00000 1 1 0.7    19
10091513   009200000 00000 1 1 0.5    20
10091601   -12 0 3011 1 0.75  2
10091602   -12 0 3011 1 0.6   3
10091603   -12 0 3011 1 1.375 5
10091604   -12 0 3011 1 0.8   6
10091605   -12 0 3011 1 1.3   7
10091606   -12 0 3011 1 1.4   8
10091607   -12 0 3011 1 0.8   9
10091608   -12 0 3011 1 2.15  10
10091609   -12 0 3011 1 2.26  15
10091610   -12 0 3011 1 1.7175 17
10091611   -12 0 3011 1 2.3   18
10091612   -12 0 3011 1 0.7   19
10091613   -12 0 3011 1 0.5   20
10091701   0 0.0 0.0 0.0 20
10091801   0.0 15.0 15.0 0.0 0.0 0.0 0.0 1.0 20
*
*        upper header tube
10111000   6 2 2 0 0.1475
10111100   0 1
10111101   1 0.1635
10111201   2 1
10111301   0.0 1
10111401   536.0 2
10111501   010010000 00000 1 1 0.7  1
10111502   011010000 10000 1 1 0.7  5
10111503   011050000 00000 1 1 0.9  6
10111601   -12 0 3011 1 0.7  1
10111602   -12 0 3011 1 0.7  5
10111603   -12 0 3011 1 0.9  6
10111701   0 0.0 0.0 0.0 6
10111801   0.0 15.0 15.0 0.0 0.0 0.0 0.0 1.0 6
*
*        swpline pipe
10141000   8 2 2 0 0.05
10141100   0 1
10141101   1 0.06
10141201   2 1
10141301   0.0 1
10141401   550.0 2
10141501   014010000 00000 1 1 0.9   1
10141502   014020000 10000 1 1 1.0   2
10141503   014030000 10000 1 1 1.3   3
10141504   014040000 10000 1 1 1.5   4
10141505   014050000 10000 1 1 0.8   5
10141506   014060000 10000 1 1 1.0   6
10141507   014070000 10000 1 1 1.5   7
10141508   014080000 10000 1 1 0.5   8
10141601   -12 0 3011 1  0.9  1
10141602   -12 0 3011 1  1.0  2
10141603   -12 0 3011 1  1.3  3
10141604   -12 0 3011 1  1.5  4
10141605   -12 0 3011 1  0.8  5
10141606   -12 0 3011 1  1.0  6
10141607   -12 0 3011 1  1.5  7
10141608   -12 0 3011 1  0.5  8
10141701   0 0.0 0.0 0.0 8
10141801   0.0 15.0 15.0 0.0 0.0 0.0 0.0 1.0 8
*
*        separator tube
10201000   8 2 2 0 0.091
10201100   0 1
10201101   1 0.111
10201201   2 1
10201301   0.0 1
10201401   536.0 2
10201501   020010000 10000 1 1 0.5 2
10201502   020020000 10000 1 1 0.7 3
10201503   020020000 10000 1 1 0.5 8
10201601   -12 0 3011 1 0.5 2
10201602   -12 0 3011 1 0.7 3
10201603   -12 0 3011 1 0.5 8
10201701   0 0.0 0.0 0.0 8
10201801   0.0 15.0 15.0 0.0 0.0 0.0 0.0 1.0 8
*
*        downcm22 pipe
10221000   14 2 2 0 0.051
10221100   0 1
10221101   1 0.057
10221201   2 1
10221301   0.0 1
10221401   536.0 2
10221501   022010000 10000 1 1 1.15   2
10221502   022030000 10000 1 1 1.05   4
10221503   022050000 10000 1 1 1.425  6
10221504   022070000 10000 1 1 1.2   10
10221505   022110000 10000 1 1 1.325 12
10221506   022130000 10000 1 1 1.3   13
10221507   022140000 10000 1 1 1.275 14
10221601   -12 0 3011 1 1.15   2
10221602   -12 0 3011 1 1.05   4
10221603   -12 0 3011 1 1.425  6
10221604   -12 0 3011 1 1.2   10
10221605   -12 0 3011 1 1.325 12
10221606   -12 0 3011 1 1.3   13
10221607   -12 0 3011 1 1.275 14
10221701   0 0.0 0.0 0.0 14
10221801   0.0 15.0 15.0 0.0 0.0 0.0 0.0 1.0 14
*
*        steam pipe
10301000   12 2 2 0 0.051
10301100   0 1
10301101   1 0.057
10301201   2 1
10301301   0.0 1
10301401   550.0 2
10301501   030010000 10000 1 1 0.6   1
10301502   030020000 10000 1 1 0.8   2
10301503   030030000 10000 1 1 0.7   3
10301504   030040000 10000 1 1 0.95  4
10301505   030050000 10000 1 1 1.475 6
10301506   030070000 10000 1 1 1.4   7
10301507   030080000 10000 1 1 1.7   8
10301508   030090000 10000 1 1 0.75  9
10301509   030100000 10000 1 1 0.65 10
10301510   030110000 10000 1 1 0.7  12
10301601   -12 0 3011 1 0.6   1
10301602   -12 0 3011 1 0.8   2
10301603   -12 0 3011 1 0.7   3
10301604   -12 0 3011 1 0.95  4
10301605   -12 0 3011 1 1.475 6
10301606   -12 0 3011 1 1.4   7
10301607   -12 0 3011 1 1.7   8
10301608   -12 0 3011 1 0.75  9
```

```
10301609    -12 0 3011 1 0.65 10
10301610    -12 0 3011 1 0.7  12
10301701    0 0.0 0.0 0.0 12
10301801    0.0 15.0 15.0 0.0 0.0 0.0 0.0 1.0 12
*
*       downcm34 pipe
10341000    15 2 2 0 0.051
10341100    0 1
10341101    1 0.057
10341201    2 1
10341301    0.0 1
10341401    527.45 2
10341501    034010000 10000 1 1 0.85  1
10341502    034020000 10000 1 1 1.7   2
10341503    034030000 10000 1 1 0.85  3
10341504    034040000 10000 1 1 2.0   4
10341505    034050000 10000 1 1 1.7   5
10341506    034060000 10000 1 1 1.843 8
10341507    034090000 10000 1 1 2.4   9
10341508    034100000 10000 1 1 1.85  11
10341509    034120000 10000 1 1 1.586 12
10341510    034130000 10000 1 1 1.435 13
10341511    034140000 10000 1 1 1.42  15
10341601    -12 0 3011 1 0.85  1
10341602    -12 0 3011 1 1.7   2
10341603    -12 0 3011 1 0.85  3
10341604    -12 0 3011 1 2.0   4
10341605    -12 0 3011 1 1.7   5
10341606    -12 0 3011 1 1.843 8
10341607    -12 0 3011 1 2.4   9
10341608    -12 0 3011 1 1.85  11
10341609    -12 0 3011 1 1.586 12
10341610    -12 0 3011 1 1.435 13
10341611    -12 0 3011 1 1.42  15
10341701    0 0.0 0.0 0.0 15
10341801    0.0 15.0 15.0 0.0 0.0 0.0 0.0 1.0 15
*
*       downcm52 pipe
10521000    14 2 2 0 0.0715
10521100    0 1
10521101    1 0.0795
10521201    2 1
10521301    0.0 1
10521401    536.0 2
10521501    052010000 10000 1 1 1.663  3
10521502    052040000 10000 1 1 2.2    4
10521503    052050000 10000 1 1 1.9    5
10521504    052060000 10000 1 1 1.6    6
10521505    052070000 10000 1 1 1.5    8
10521506    052090000 10000 1 1 1.9    9
10521507    052100000 10000 1 1 2.45  10
10521508    052110000 10000 1 1 1.5   11
10521509    052120000 10000 1 1 1.516 12
10521510    052130000 10000 1 1 1.45  14
10521601    -12 0 3011 1 1.663  3
10521602    -12 0 3011 1 2.2    4
10521603    -12 0 3011 1 1.9    5
10521604    -12 0 3011 1 1.6    6
10521605    -12 0 3011 1 1.5    8
10521606    -12 0 3011 1 1.9    9
10521607    -12 0 3011 1 2.45  10
10521608    -12 0 3011 1 1.5   11
10521609    -12 0 3011 1 1.516 12
10521610    -12 0 3011 1 1.45  14
10521701    0 0.0 0.0 0.0 14
10521801    0.0 15.0 15.0 0.0 0.0 0.0 0.0 1.0 14
*
*       downcm62 pipe
10621000    8 2 2 0 0.0715
10621100    0 1
10621101    1 0.0795
10621201    2 1
10621301    0.0 1
10621401    536.0 2
10621501    062010000 10000 1 1 1.72  3
10621502    062040000 10000 1 1 1.375 4
10621503    062050000 10000 1 1 1.35  5
10621504    062060000 10000 1 1 1.325 6
10621505    062070000 10000 1 1 1.2   7
10621506    062080000 10000 1 1 1.2   8
10621601    -12 0 3011 1 1.72  3
10621602    -12 0 3011 1 1.375 4
10621603    -12 0 3011 1 1.35  5
10621604    -12 0 3011 1 1.325 6
10621605    -12 0 3011 1 1.2   7
10621606    -12 0 3011 1 1.2   8
10621701    0 0.0 0.0 0.0 8
10621801    0.0 15.0 15.0 0.0 0.0 0.0 0.0 1.0 8
*
*       bypass pipe
11061000    24 2 2 0 0.051
11061100    0 1
11061101    1 0.057
11061201    2 1
11061301    0.0 1
11061401    527.45 2
11061501    106010000 10000 1 1 1.0   2
11061502    106030000 10000 1 1 1.511 3
11061503    106040000 10000 1 1 1.3   4
11061504    106050000 10000 1 1 1.137445 6
11061505    106070000 10000 1 1 1.55    7
11061506    106080000 10000 1 1 1.1425  11
11061507    106120000 10000 1 1 1.4     13
11061508    106140000 10000 1 1 1.7     14
11061509    106150000 10000 1 1 1.3     15
11061510    106160000 10000 1 1 1.4     17
11061511    106180000 10000 1 1 1.3842  22
11061512    106230000 10000 1 1 0.6     24
11061601    -12 0 3011 1 1.0   2
11061602    -12 0 3011 1 1.511 3
11061603    -12 0 3011 1 1.3   4
11061604    -12 0 3011 1 1.137445 6
11061605    -12 0 3011 1 1.55    7
11061606    -12 0 3011 1 1.1425  11
11061607    -12 0 3011 1 1.4     13
11061608    -12 0 3011 1 1.7     14
11061609    -12 0 3011 1 1.3     15
11061610    -12 0 3011 1 1.4     17
11061611    -12 0 3011 1 1.3842  22
11061612    -12 0 3011 1 0.6     24
11061701    0 0.0 0.0 0.0 24
11061801    0.0 15.0 15.0 0.0 0.0 0.0 0.0 1.0 24
**************************************************
*       GENERAL TABLES
**************************************************
*        MATEREAL
**************************************************
20100100    s-steel
20100200    s-steel
20100300    tbl/fctn 1 1
20100301    1.15
20100351    2.465+6
**************************************************
*       HEAT SOURCE
**************************************************
20200100    power 0 1. 1000.0
20200101    0.00  0000.0
20200102   10.00  2486.0
**************************************************
*       HEAT LOSS
**************************************************
20200200    htrnrate 0 1.0 1.0
20200201    0.0 2282.12
*
**heat
20200300    temp 0
20200301    0.00    560.0
*
20201100    htc-t 0
20201101    0.00    10.0
*
20201200    temp 0
20201201    0.00    295.0
.*end of data set

=
0000100 restart transnt
*0000101  inp-chk
```

```
0000102 si si
0000103 198474  cmpress
0000202   1350. 1.0-6  0.01  15003   500    40000 4000000
0000203   1400. 1.0-6  0.01  15003   100    40000 4000000
*0000204   1460. 1.0-6  0.01  15003   10     40000 4000000
*0000205   1600. 1.0-6  0.01  15003   500    40000 4000000
*
1000000   tdv100 delete
*
1010000   outleg delete
*
.end data set

=
0000100 restart transnt
*0000101  inp-chk
0000102 si  si
*0000103 198457  cmpress
0000103 278474  *1400 s
*0000103 297835  *1500 s
*0000202   1350. 1.0-6  0.01  15003   500    40000 4000000
0000203   1400. 1.0-6  0.01  15003   100    10000  10000
0000204   1800. 1.0-6  0.01  15003   10     10000  10000
*0000205   1500. 1.0-6  0.01  15003   500    40000 4000000
*
*1000000   tdv100 delete
*
*1010000   outleg delete
*
*       isolating control valve 2r
0020000   valv2r valve
*crdno    from      to        area     floss rloss  efvcahs
0020101   001010000 003000000 3.3183-3 775.0 775.0  0001100
0020201   1 3.9 0.0 0.0
0020300   mtrvlv
*         open close rate  initl  table
0020301   702  602   0.25   1.0    0
*
412      time 0 ge null 0 1408.7  n * close
512      time 0 ge null 0 1416.0  n * stop
602               412 and -512  n * close
*
403      time 0 ge null 0 1420.00 n * open
503      time 0 ge null 0 1420.17 n * stop
702               403 and -503  n * open
*
.end data set
```

NRC FORM 335
(2-89)
NRCM 1102,
3201, 3202

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

(See instructions on the reverse)

1. REPORT NUMBER
(Assigned by NRC, Add Vol., Supp., Rev., and Addendum Numbers, if any.)

NUREG/IA-0202

2. TITLE AND SUBTITLE

Analyses of KS Test Data on the Heated Rod Bundle Temperature Behavior in RBMK-1500 Core Model Under Stop and Recovery Flow Using RELAP5/MOD3.2 and RELAP5/MOD3.2.2 GAMMA

3. DATE REPORT PUBLISHED

MONTH	YEAR
April	2001

4. FIN OR GRANT NUMBER

5. AUTHOR(S)

V.A. Vinogradov, A.Y. Balykin

6. TYPE OF REPORT

Technical

7. PERIOD COVERED *(Inclusive Dates)*

8. PERFORMING ORGANIZATION - NAME AND ADDRESS *(If NRC, provide Division, Office or Region, U.S. Nuclear Regulatory Commission, and mailing address; if contractor, provide name and mailing address.)*

Nuclear Reactor Institute, Russian Research Center
Kurchatov Institute
Kurchatov Square 1
123182, Moscow Russia

9. SPONSORING ORGANIZATION - NAME AND ADDRESS *(If NRC, type "Same as above"; if contractor, provide NRC Division, Office or Region, U.S. Nuclear Regulatory Commission, and mailing address.)*

Division of Systems Analysis and Regulatory Effectiveness
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

10. SUPPLEMENTARY NOTES

11. ABSTRACT *(200 words or less)*

This report has been prepared as a part of the Agreement on Research Participation and Technical Exchange under the International Code Application and Maintenance Program. KS experimental data on the behavior of the heated rod bundle temperature in the RBMK-1500 core model under stop and recovery flow conditions were simulated with RELAP5/MOD3.2 and RELAP5/MOD3.2.2 GAMMA to assess the codes suitability. Especially calculations were performed to estimate differences in the code version predictions for processes/phenomena, which could occur under specific conditions of RBMK type reactor during LOCA with MCP's pressure header rupture and subsequent ECCS water injection. This problem addresses phenomena of high importance to RBMK-1500 safety including water discharge, critical heat flux, post dryout heat transfer, reflood and propagation of rewetting front in the fuel channel during an accident. The tests has been carried out at KS semi-integral test facility (Russian Research Center Kurchatov Institute) represented RBMK primary circuit. The main purpose of the experiment was investigation of temperature conditions in the fuel assembly under high power value, inlet flow rate being decreased drastically up to complete stop of the flow followed by pressure header rupture. A subsequent flow rate resumption was also assumed, the fuel assembly power high level being unchanged. First, a study of the effect of the hydraulic nodalization to the code calculations was performed using different number of hydraulic volumes for the fuel channel model. After the choice of proper nodalization and maximum user-specified time step, base case calculations were done for the test. Sensitivity studies were carried out to investigate the effects of modeling on the behavior of the rod simulator temperatures along the height of the fuel assembly model.

12. KEY WORDS/DESCRIPTORS *(List words or phrases that will assist researchers in locating the report.)*

RELAP5
RBMK
LOCA

13. AVAILABILITY STATEMENT

unlimited

14. SECURITY CLASSIFICATION

(This Page)
unclassified

(This Report)
unclassified

15. NUMBER OF PAGES

16. PRICE

Printed
on recycled
paper

Federal Recycling Program

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, DC 20555-0001

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PENALTY FOR PRIVATE USE, $300