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IJS Procedure for Converting Input Deck from RELAP5 to TRACE

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ABSTRACT

Much of efforts have been done in the past to develop the RELAP5 input decks. The purpose of this study is to present the RELAP5 to TRACE conversion procedure, developed at Institut "Jožef Stefan" (IJS). For demonstrating the conversion procedure the ACHILLES and BETHSY input decks (IJS legacy) were used using SNAP. The RELAP5 input decks of ACHILLES rig and BETHSY facility were developed in the frame of participation to international standard problem no. 25 (ISP-25) and international standard problem no. 27 (ISP-27). These RELAP5 legacy input decks were used for demonstration of the developed IJS conversion methodology, consisting of eleven steps. Besides demonstration of the methodology also the comparison between RELAP5 and TRACE has been done. It can be concluded that calculated results obtained by TRACE are as good as the results by RELAP5, thus suggesting that IJS conversion procedure may be used for conversion of separate and integral effect test legacy RELAP5 input decks to TRACE input decks.

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EXECUTIVE SUMMARY

Much of efforts have been done in the past to develop the RELAP5 input decks. In this study the RELAP5 to TRACE conversion procedure, developed at Institut “Jožef Stefan” (IJS), is presented. The conversion procedure consists of eleven steps and is based on the use of SNAP. For demonstrating the conversion procedure the ACHILLES and BETHSY input decks (IJS legacy) were used. One separate effect test and two integral effect tests were simulated by both RELAP5 and TRACE computer codes. The best estimate ACHILLES natural reflood experiment was the basis for the International Standard Problem no. 25 (ISP-25). The BETHSY 9.1.b test is a scaled 5.08 cm cold leg break without high pressure safety injection (HPSI) and with delayed operator action for secondary system depressurization and was selected for ISP-27. BETHSY 6.2TC test is a 15.24 cm (6 inch) cold leg break in the loop one without available high pressure and low pressure safety injection system and is counterpart test. Each of the eleven steps was demonstrated for ACHILLES and BETHSY RELAP5 input model conversion to TRACE input model. Before legacy RELAP5 input deck in ASCII format is converted, it had to be adapted to the RELAP5/MOD3.3 input deck, which can be imported by SNAP. After creating RELAP5 model in SNAP by importing ASCII legacy input deck, the SNAP is used for creating and arranging the views, creating model notebooks, performing RELAP5 calculation, conversion from RELAP5 to TRACE, checking for and resolving errors, and creating animation model.

Besides demonstration of the conversion methodology also the comparison between RELAP and TRACE has been done. It can be concluded that calculated results obtained by TRACE are as good as the results by RELAP5, thus suggesting that IJS conversion methodology may be used for separate and integral effect test legacy RELAP5 input deck conversions to TRACE input decks.

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ABBREVIATIONS

ASCII	American Standard Code for Information Interchange
CAMP	Code Applications and Maintenance Program
EM	evaluation model
HPSI	high pressure safety injection
IJS	Institut "Jožef Stefan" (in Slovene; in English called Jožef Stefan Institute)
ISP	international standard problem
LSTF	large scale test facility
RELAP5	Reactor Excursion and Leak Analysis Program
SB LOCA	small-break loss-of-coolant-accident
SI	safety injection
SNAP	Symbolic Nuclear Analysis Package
TRACE	TRAC/RELAP Advanced Computational Engine
U.S.	United States
U.S. NRC	U. S. Nuclear Regulatory Commission

1. INTRODUCTION

The TRAC/RELAP Advanced Computational Engine (TRACE) is the latest in a series of advanced, best-estimate reactor systems codes developed by the U.S. Nuclear Regulatory Commission (Ref. 1). The advanced TRACE comes with a graphical user interface called SNAP (Symbolic Nuclear Analysis Package) (Ref. 2), which is intended for pre- and post-processing, running the codes, RELAP5 to TRACE input deck conversion, input deck database generation etc. The TRACE code is still under development and it will have all capabilities of RELAP5. The TRACE has superior capabilities and accuracy for most applications compared to RELAP5. Although the TRACE is the future of U.S Nuclear Regulatory Commission (U.S. NRC), its use in countries members of Code Applications and Maintenance Program (CAMP) it is still not dominant against the RELAP5 computer code. However, TRACE it is now more and more used by the RELAP5 code users, in a great deal also because of better RELAP5 to TRACE conversion capability. The typical RELAP5 users start with legacy RELAP5 input decks, which are first automatically converted to TRACE input decks using SNAP and then manual corrections are done. Namely, much of efforts were done in the past to develop the RELAP5 input decks. The purpose of this report is to present the RELAP5 to TRACE conversion procedure (methodology), developed at Institut "Jožef Stefan" (IJS). For demonstrating the conversion methodology the ACHILLES and BETHSY input decks (IJS legacy input decks), were used. The ACHILLES and BETHSY RELAP5 input decks were developed in the frame of participation to international standard problem no. 25 (ISP-25) and international standard problem no. 27 (ISP-27). The ISP-25 reflood experiment was performed on ACHILLES separate effects test facility and the input deck was developed for RELAP5/MOD2 ver. 36.05 computer code (Ref. 3). The RELAP5/MOD2 input model used for pre- and post-test calculation of ISP-27, which was small-break loss-of-coolant-accident (SB LOCA), was later upgraded to RELAP5/MOD3, RELAP5/MOD3.1 and RELAP5/MOD3.2 code versions. The legacy RELAP5/MOD3.2 input model (Ref. 4) was the starting point for conversion to TRACE input model.

Although much work has been done to date on TRACE assessment, important part is also independent assessment performed by wide community. Therefore in the present study also the accuracy of the TRACE calculation of ACHILLES natural reflood experiment Run A1B105, BETHSY 9.1b and BETHSY 6.2TC tests using the converted and adapted RELAP5 nodalizations, which were developed in the past for international standard problem no. 25 (ISP-25) and ISP-27 at Jožef Stefan Institute (Ref. 4). The RELAP5 legacy input deck of BETHSY facility has different origin than the one, which has been used for conversion to TRACE in the original TRACE code assessment study (Ref. 5). When comparing the TRACE calculation to the RELAP5 calculation and to TRACE calculation described in the code assessment manual (Ref. 1), one can more easily see the peculiarities of the TRACE code. Finally, both RELAP5 and TRACE calculations were compared to the experimental data.

In Section 2 the IJS conversion procedure is described. In Sections 3 and 4 the facilities, scenarios and legacy RELAP5 input decks are described. In Sections 5 and 6 examples of conversion for ACHILLES and BETHSY are given. Besides, the calculations were performed by both RELAP5 and TRACE computers codes and compared to experimental data. Finally, in Section 7 conclusions are given.

2. IJS CONVERSION PROCEDURE DESCRIPTION

The IJS conversion procedure from RELAP5 to TRACE is based on the SNAP (Symbolic Nuclear Analysis Package) (Ref. 2) and the experience gained in the past. Not much open literature was available in this area. An exception is the work done for Almaraz nuclear power plant (Refs. 6 and 7). The IJS RELAP5 to TRACE conversion procedure is shown in Figure 1. The procedure consists of 11 steps. The starting point is legacy RELAP5 input model in ASCII form and the final result is TRACE model in SNAP. The steps of IJS conversion procedure are the following:

<u>Step 1</u>: Adapt legacy RELAP5 input deck to RELAP5/MOD3.3 input deck
The first requirement is the existing legacy RELAP5 input deck in ASCII form to adapt for use by RELAP5/MOD3.3 computer code. Namely, when input decks of older RELAP5 code versions are imported, errors are reported for RELAP5 input deck. It is helpful, if this is done with the analyst, familiar with previous code versions of RELAP5 and ASCII editing of input model. The modifications in the input model are needed mainly because of new options included in higher versions of RELAP5 code. Once having running input deck for RELAP5/MOD3.3, the second step may be performed.

<u>Step 2</u>: Import adapted RELAP5/MOD3.3 ASCII input model into SNAP
In the SNAP Model Editor the command Import, RELAP5 ASCII is used. The RELAP5 model is generated by SNAP in Model Editor, including optional Hydraulic Components View and Control Systems View. You may select also Job Streams View, however old legacy input decks does not have such information. When checking RELAP5 model, there should be no errors in principle.

<u>Step 3</u>: Manually arrange Hydraulic Components View
When automatically generating Hydraulic Components View, the layout may not be good enough for the user. Therefore it is highly recommended to help with the drawing of original nodalization representing legacy RELAP5 input model in ASCII and to manually rearrange the layout of components, add labels etc. This step is very important to be done before conversion, because during RELAP5 to TRACE conversion also Hydraulic Components View is converted and there is no need to repeat the work done for RELAP5 view. Good hydraulic components view helps to locate TRACE components, being at the same location as corresponding RELAP5 components. In addition, from Hydraulic Components View the basic animation model is also created.

<u>Step 4</u>: Export RELAP5 Model Notebook
RELAP5 Model Notebook is useful, because information about RELAP5 input deck is presented in well-organized way. Model Options, Hydraulic Components, Control Systems, Heat Structure and Materials are described. For example, for General Tables, which are parts of Control Systems, the table data are presented also graphically and this helps among other things also the users not too familiar with RELAP5 legacy input deck. The RELAP5 Model Notebook is also used for verification of converted TRACE model.

<u>Step 5</u>: Perform RELAP5 calculation
Running the RELAP5 is important, because in this way the calculated data may be checked against old calculations (performed by ASCII legacy RELAP5 input decks) and may be used as source data for animation model. Moreover, from the output file the data on hydraulic diameter

may be extracted. These data are needed for checking hydraulic diameters in converted TRACE models.

Step 6: Create animation model for RELAP5 (optional)
This step is optional. It turned out to be very useful for old legacy input decks not having much documentation available. The animation model helps to understand the RELAP5 calculated results, what is very useful for later TRACE calculation. The basic animation model consists of RELAP5 model Views copied to animation model. The components are already connected to source data (no need to specify channels). It should also be noted that this basic RELAP5 animation model cannot be converted to TRACE basic animation model, but there is no need for this, because it can be created after conversion of RELAP5 model to TRACE model (again just Copy Paste is needed). On the other hand, several additional animation masks may be created. These are the candidates to be copied to TRACE animation model. Namely, not much effort is needed for converting the RELAP5 animation masks to TRACE animation masks. In principle, the channels with source data need to be adjusted to TRACE and the possible geometry changes.

Step 7: Convert RELAP5 model to TRACE model
In this step the Convert to TRACE command is used in RELAP5 Analysis Code plugin. Besides RELAP5 input model also SNAP Model editor Views are converted, including Hydraulic Components View. The Views can be further adapted in TRACE model.

Step 8: Check for and resolve TRACE model errors
After converting RELAP5 model to TRACE model, checking a TRACE model for errors is done using model editor Check Model menu command. Usually, the converted TRACE model is not error free. First all errors identified by SNAP are manually corrected. Once corrected, the first TRACE run can be done.

Step 9: Export TRACE Model Notebook
Before running the error free TRACE input model, the converted TRACE input model need to be compared to RELAP5 input model. Consistency checks may be done for geometry data, control systems etc.

Step 10: Perform TRACE calculation
In this step, the first calculation is performed to check for errors by TRACE computer code. The errors, not identified by SNAP Check Model button need to be corrected and this may be quite time consuming. The information about errors is obtained directly from the TRACE output file for specific calculation. As it is difficult to eliminate all errors at once, the work is iterative (repeating Steps 9 and 10). Once all errors are eliminating and TRACE is running, the calculated results present Source Data for animation model.

Step 11: Create TRACE animation model (optional)
It is recommended to develop TRACE animation model. The simplest model is created by copying TRACE Hydraulic View to Animation model. For the purpose of this report it is called basic animation model. Such Copy Paste is very efficient, because hydraulic components are already connected to Source Data. More advanced animation masks may be created later by importing drawings of facilities and use them as template to put SNAP Display Beans over. In this respect Polygon is very useful.

The first calculation will probably not satisfy the analyst, therefore manual work may be needed to further modify the model or add additional components. The above procedure was described for the whole model only. However, the RELAP5 transient input model is typically in the separate ASCII restart file and steady-state is calculated first. The difficulty is that restart input models cannot be imported as full plant model. Therefore TRACE transient input model has to be built manually. For example, the RELAP5 ASCII restart input model may be appended to steady-state input model and after conversion to TRACE the components needed for transient calculation may be copied into TRACE transient model. The TRACE calculation is then performed and the results can be compared to experimental, plant or other data and RELAP5 calculations. The RELAP5 calculated results provide several variables, for which no measured data exists.

Important is also to mention that when steady state is achieved by RELAP5 and such model is converted, the TRACE model does not require steady-state controllers. The converted TRACE model can be used directly for transient calculation.

The IJS procedure for converting input deck from RELAP5 to TRACE will be demonstrated on IJS legacy RELAP5 input models for ACHILLES rig and BETHSY facility.

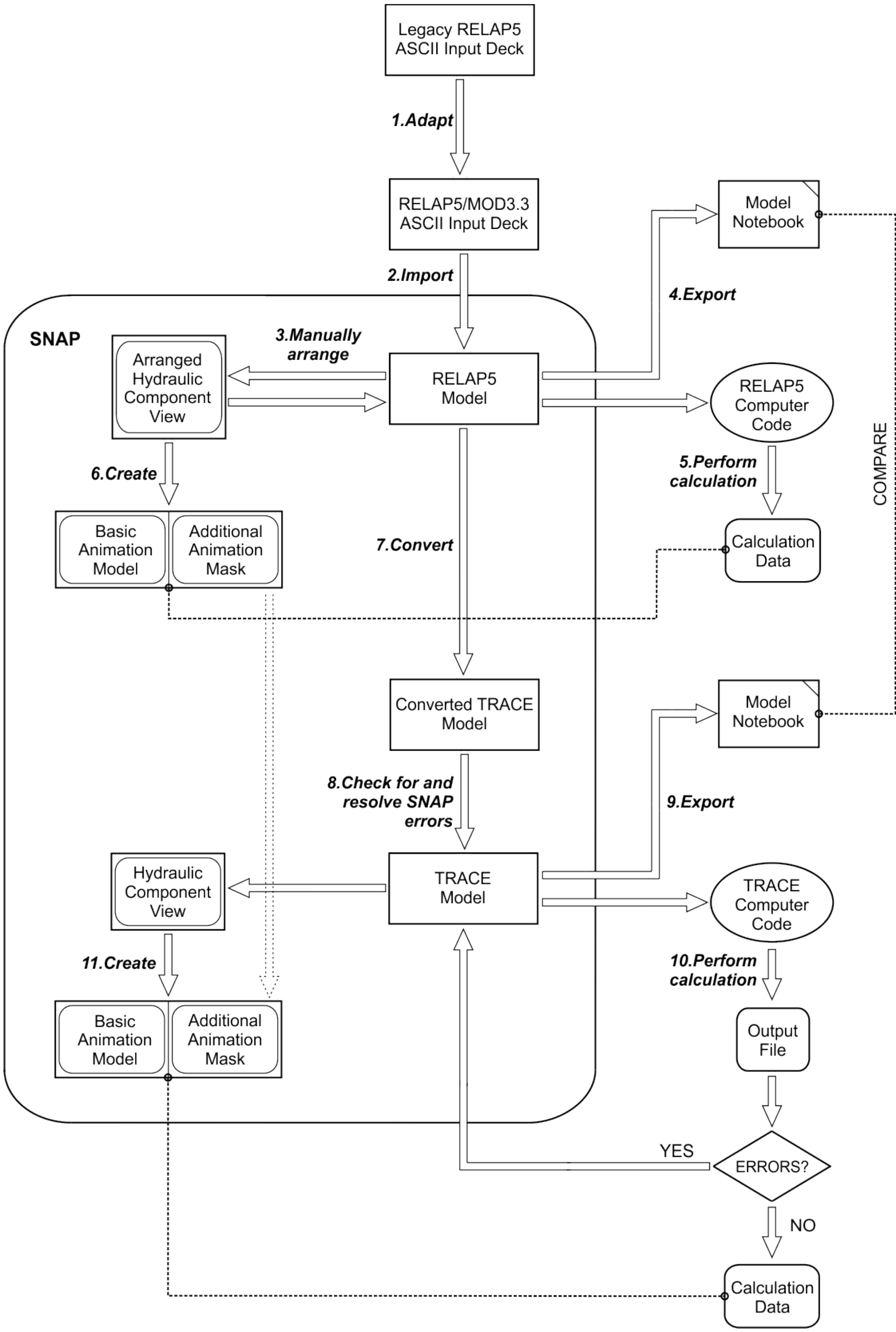

Figure 1 IJS conversion procedure from RELAP5 model to TRACE model

3. ACHILLES RIG, TEST AND RELAP5 INPUT MODEL DESCRIPTION

Before conversion of legacy RELAP5 input deck for ACHILLES, the ACHILLES rig is described first. Then scenario of the test is described and finally the legacy RELAP5 input model. This information is very useful to analyst before conversion is done.

3.1 Achilles rig

The Achilles test experiment was an experimental study performed at AEA Winfrith Technology Center, Dorchester, UK in 1991. This experiment investigated the end phase of the accumulator injection in the primary system of a Pressurized Water Reactor and the heat transfer in the core during the reflood phase of a postulated large break loss of coolant accident (LOCA). The best estimate ACHILLES natural reflood experiment was also the basis for the ISP-25 (Ref. 8). A simplified schematic of the test facility configuration for best estimate natural reflood test series is presented in Figure 2.

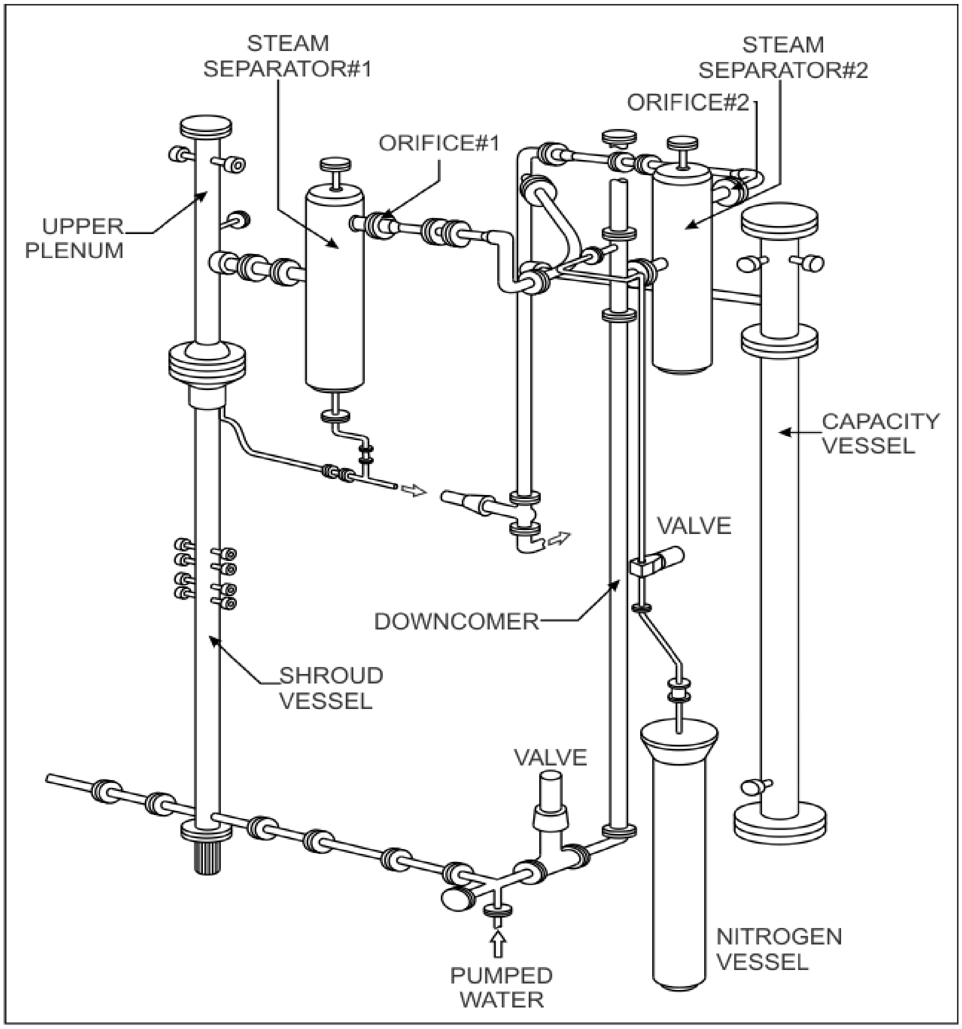

Figure 2 Schematic of Achilles test facility

The simulated core or the test section comprised of 69 rods corresponding to Westinghouse 17x17 geometry, electrically heated over a length of 3.66 m. Aside from these nuclear fuel rods simulators, the test section is also housing the heat shroud and temperature and pressure measurement instrumentation. A centrifugal steam separator located at the top of the test section discharges the test section output liquid flow. Furthermore, a separator located downstream, ensures the separation and collection of the liquid phase flowing out of the upper plenum, and outputs the single phase steam flow through an orifice, designed to simulate the hot leg associated losses. Thus, the liquid is separated from the flow out the upper part of the downcomer by means of another separator and outputs the gas through a second orifice that simulates the cold leg associated losses.

3.2 ACHILLES Run A1B105

The natural reflood experiment Run A1B105 was selected for ISP-25 (Ref. 8). The experimental procedure is started with the downcomer full with water and with no water in the simulated core. The rig is heated and circulated with steam until saturation temperature and pressure is reached and the rods and shroud have reached the required temperatures. When all initial conditions are reached, the valve between the downcomer and the shroud vessel is opened. Under the effect of both gravity head and nitrogen pressure, the water in the downcomer enters the core. After the flow oscillations that are occurring at this point in the transient decay, the reflooding of the core continues by means of pumped water injection, until all the test section rods have been quenched.

The nature of the ISP-25 transient is such that it was divided into two periods (Ref. 8). The first period lasted around 20 seconds (when the nitrogen vessel discharged into the top of the downcomer) was characterized by a highly oscillatory flow between the downcomer and core. The high flooding rates during this early period quenched the bottom of the rod bundle. In the second period a steady rate of reflood was established by the pumped injection and conditions in the rod bundle are then similar to a conservative evaluation model (EM) transient of the type prescribed by the appendix K rules of 10CFR.50. The main difference between the latter part of the ISP-25 experiment and an appendix K type of EM transient is that the lower elevations of the rod bundle quench during the initial surge of water from the downcomer. This combined with rewetting of the grids during the initial surge lead to an overall improvement in heat transfer from the surface of the fuel rods.

3.3 RELAP5 Input Model of ACHILLES

The RELAP5/MOD3.3 input model originated from a RELAP5/MOD2 input model, created at IJS, during the participation to the ISP-25. The original RELAP5/MOD2 nodalization consists of 50 volumes, 50 junctions and 13 heat slabs and is shown in Figure 3. The nitrogen vessel is modeled by an accumulator component. For this component it is assumed that it is not initially in injection mode. For that reason the valve was placed in between the accumulator and top of the downcomer. The accumulator was filled with nitrogen only. The separators were modeled by RELAP5 branch components to avoid calculation problems. In the RELAP5/MOD3.3 input model only some slight changes were needed. For heat structure some additional left and right boundary data were added and separators were modeled by RELAP5 “separatr” component. The rest of the model was unchanged. So prepared, the RELAP5/MOD3.3 input model served for calculation and RELAP5 to TRACE conversion.

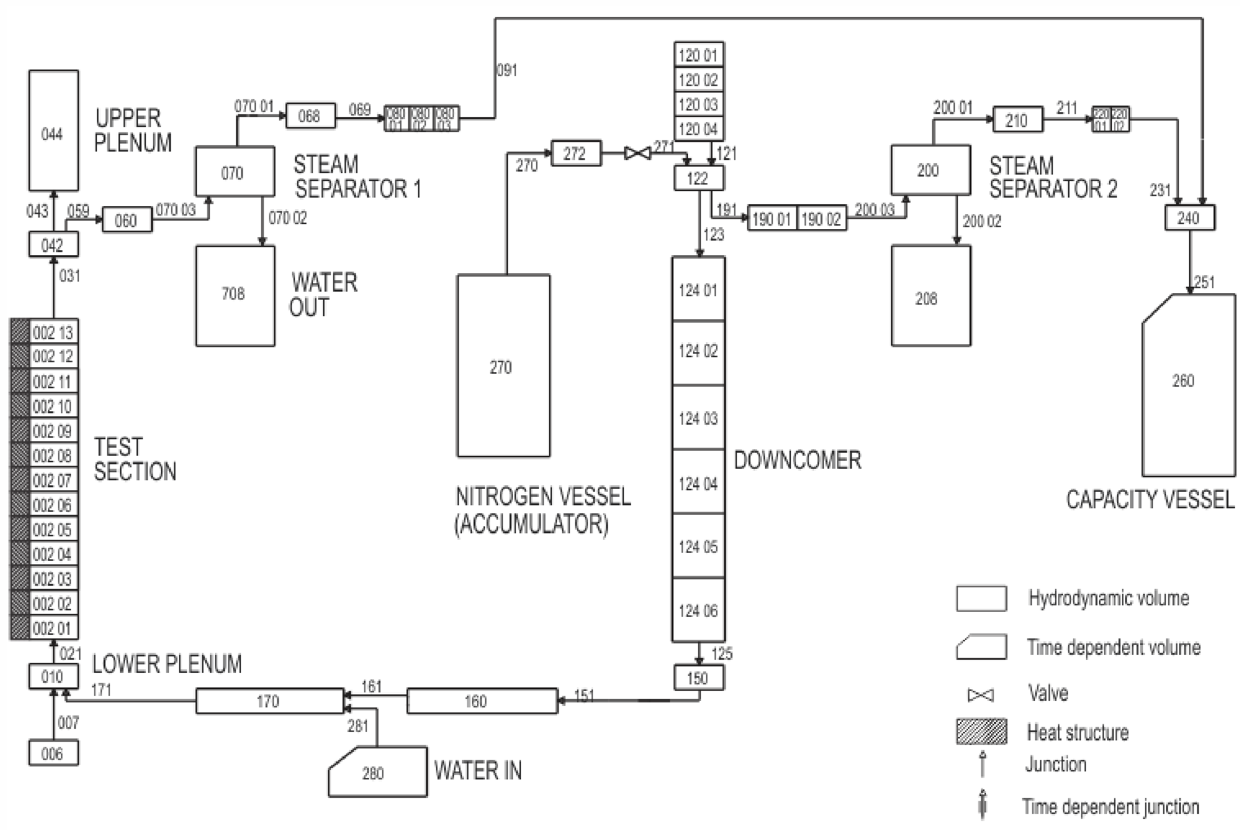

Figure 3 Achilles facility RELAP5 nodalization (Ref. 9)

4. BETHSY FACILTY, TESTS AND RELAP5 INPUT MODEL DESCRIPTION

Before conversion of legacy RELAP5 input deck for BETHSY, the BETHSY facility is described first. Then scenario is described and finally the legacy RELAP5 input model. This information is very useful to the analyst before conversion is done.

4.1 BETHSY Facility

BETHSY is an integral test facility, which was designed to simulate most pressurized water reactor accidents of interest, to study accident management procedures and to validate the computer codes. BETHSY facility was located at Centre D'Etudes Nucleaires de Grenoble, France (Ref. 10). It was a scaled down model of three loop Framatome nuclear power plant with the thermal power 2775 MW. Six important choices have been made which characterize indeed the general design of the BETHSY facility. They concern: the number of loops, the rated pressure of both the primary and the secondary side, the maximum core power level, the maximum flow rate of primary pumps, the general scaling factors and the connected circuits and systems. Volume, mass flow and power were scaled to 1:96.9, while the elevations and the pressure of the primary and secondary system were preserved. The design pressure on the primary side was 17.2 MPa and on the secondary side 8 MPa. The power was limited to the decay heat level; therefore the transient without reactor trip could not be simulated. The facility was equipped with all important systems and measurement system, needed for performance and observing the analyzed transients. The facility consisted of pressure vessel, reactor coolant pumps and piping, heat tracing system, the system for break simulation, instrumentation and the control systems. The core power was 3 MW, what is 10% of the reference power considering scaling. The break system enabled simulation of the break in different locations, i.e. in the cold leg, the lower plenum, the pressurizer, the steam generator U tubes and the feedwater pipe. The instrumentation data system measured all data needed for the transient analysis. The control system could simulate the plant control systems and operator actions.

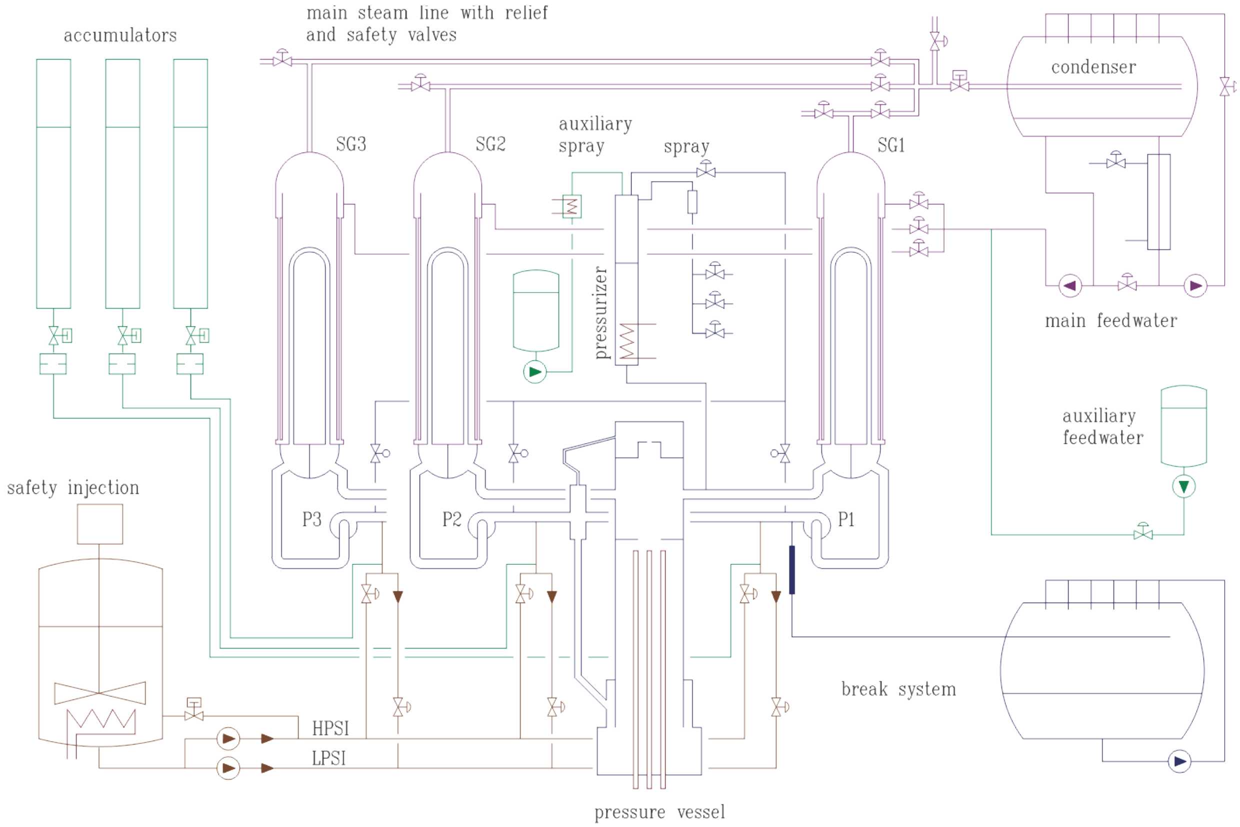

Figure 4 BETHSY facility

4.2 <u>BETHSY Test 9.1b</u>

The BETHSY 9.1.b test is a scaled 5.08 cm cold leg break without high pressure safety injection (HPSI) and with delayed operator action for secondary system depressurization (Ref. 11). This transient leads to a large core uncovery and fuel heat-up, requiring the implementation of an ultimate procedure. The scenario of the test started at 10% nominal power. At time 0 s the break was opened (initiation of the transient). The scram signal was obtained when pressurizer pressure dropped below 13.1 MPa and was delayed 17 s. The safety injection (SI) signal is triggered at 11.9 MPa. However, high pressure safety injection, turbine bypass and main feedwater were assumed to be off. Thirty seconds after SI signal the auxiliary feedwater started. Three hundred seconds after SI the reactor coolant pump started to coast down. When the maximum core cladding temperature reaches 723 K, the ultimate procedure was started, i.e. full opening of three steam dumps to atmosphere. Accumulators were available in the intact loops only. They started to inject when pressurizer pressure dropped below 4.2 MPa and were isolated at pressurizer pressure 1.5 MPa. The low pressure safety injection system started at pressurizer pressure 0.91 MPa and injected in the two intact loops. When stable residual heat removal system operating condition prevail (core outlet fluid temperature < 450 K, primary pressure < 2.5 MPa, saturation margin > 20 K), the transient was terminated.

4.3 BETHSY Test 6.2TC

BETHSY 6.2TC test was a 15.24 cm (6 inch) cold leg break in the loop one without available high pressure and low pressure safety injection system (Ref. 12). Accumulators were available in the intact loops. The main aims of this test were to compare the counterpart test data from BETHSY and LSTF facilities and qualification of CATHARE 2 computer code. The experiment scenario was the following: opening of the valve simulating the break in the cold leg no. 1, accumulator injection in the intact loops when a primary circuit pressure was lower than 4.2 MPa and end of transient, when the primary circuit pressure was below 0.7 MPa.

4.4 RELAP5 Input Model of BETHSY

The RELAP5/MOD2 input model was developed, when participating to ISP-27. It was initialized according to the specified data for each test. Each of the three coolant loops were represented explicitly without taking into account the small asymmetry between the loops. The base RELAP5/MOD2 model of Bethsy facility for pre-test calculations contained 196 volumes, 207 junctions and 191 heat structures (see Ref. 4). This base RELAP5/MOD2 input model was further upgraded to RELAP5/MOD3.1, which is shown in Figure 5 (Ref. 4). The base RELAP5/MOD2 input model was renodalized, increasing the number of nodes in reactor coolant system piping (from 9 to 45 nodes), reactor coolant pumps (2 nodes more not shown in Figure 5), core bypass section (from 1 to 12 nodes), reactor vessel (two more in the head) and downcomer (from 5 to 14 nodes). The elevations of parallel volumes of the reactor downcomer, in bypass, reactor core, hot leg and cold leg were preserved. Nodalization of the reactor core, pressurizer, reactor head, upper plenum and lower plenum remained the same. This RELAP5 input model of BETHSY facility, called middle input model and shown in Figure 5, contains 332 volumes, 343 junctions and 330 heat structures. This RELAP5 model was further refined, increasing the number of nodes in the steam generator. The U-tubes were modeled with 20 nodes instead of 10, and the downcomer and riser region of steam generator were modeled with 11 nodes instead of five, what gives 22 more nodes per steam generator and 66 more nodes in total. The common input model for RELAP5/MOD3.2 has increased number of nodes in the upper head and consisted of 398 volumes, 408 junctions and 402 heat structures (Ref. 4). With the exception of the number of nodes, the layout is the same as for middle RELAP5/MOD3.1 input model shown in Figure 5. The RELAP5/MOD3.2 input model was adapted for the use with RELAP5/MOD3.3, with no changes to the geometry and the number of hydrodynamic components and heat structures.

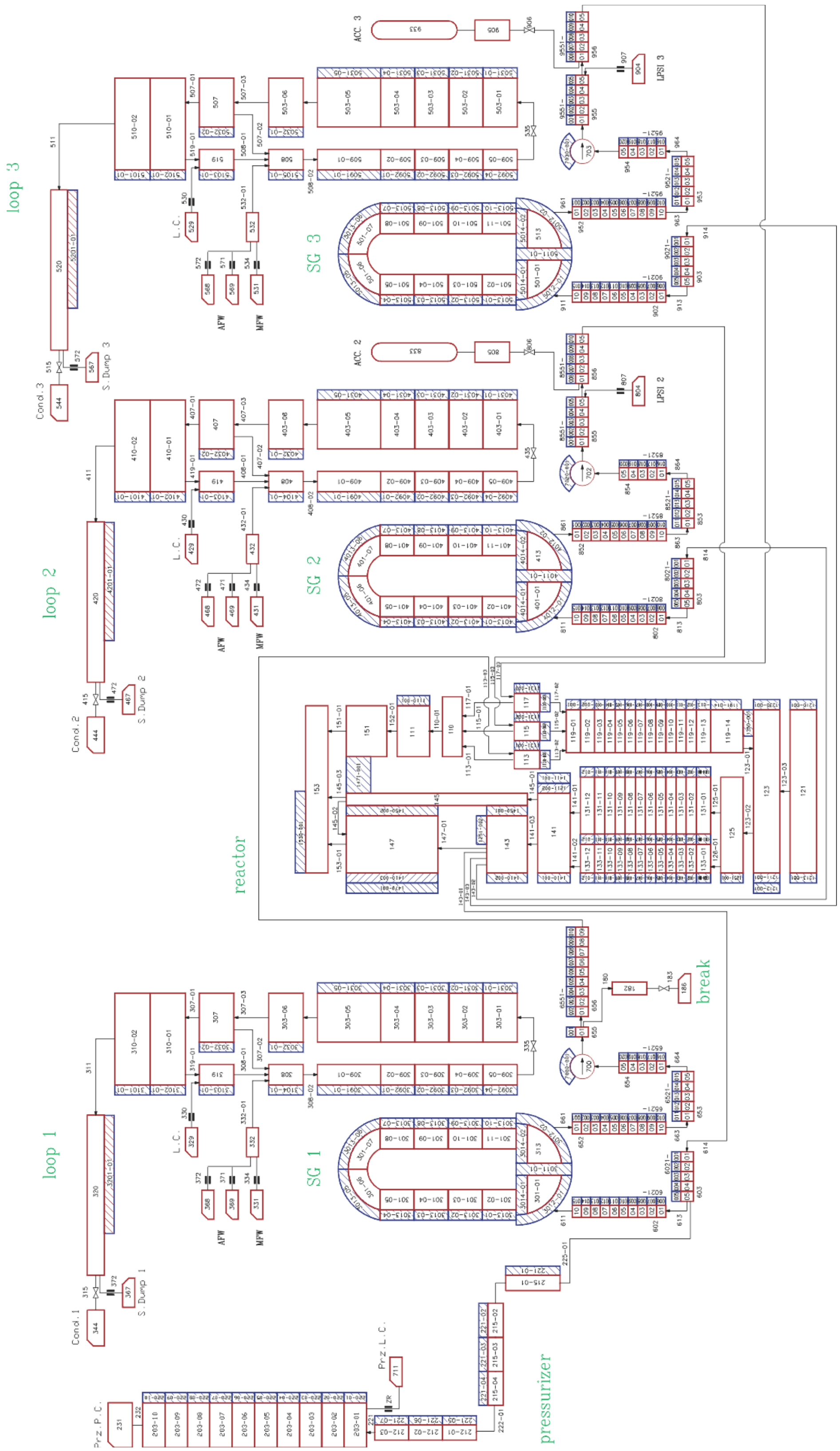

Figure 5 RELAP5/MOD3.1 input model of BETHSY facility.

5. ACHILLES EXAMPLE OF CONVERSION

The IJS conversion procedure, described in Section 2, is first demonstrated step by step on the RELAP5 input model of ACHILLES separate effects test rig.

5.1 Adaptation of legacy RELAP5 input model to RELAP5/MOD3.3 (Step 1)

The RELAP5/MOD2 input model was first adapted to RELAP5/MOD3.3. First the model was changed to lower case. When running lower case RELAP5/MOD2 input model by RELAP5/MOD3.3 Patch 3, several errors were reported because of heat structure component, as shown in Table 1. All these error were first manually corrected.

Table 1 Errors reported by RELAP5/MOD3.3 for ACHILLES input model

```
0******** word  5 on card  10020801 should be in floating point format
 ******** Default values being entered.
0******** word  5 on card  10020901 should be in floating point format
 ******** Default values being entered.
0********   Right boundary of heat structure   20001 does not have chf-heat transfer correlation data entered.
0********   Right boundary of heat structure   20002 does not have chf-heat transfer correlation data entered.
0********   Right boundary of heat structure   20003 does not have chf-heat transfer correlation data entered.
0********   Right boundary of heat structure   20004 does not have chf-heat transfer correlation data entered.
0********   Right boundary of heat structure   20005 does not have chf-heat transfer correlation data entered.
0********   Right boundary of heat structure   20006 does not have chf-heat transfer correlation data entered.
0********   Right boundary of heat structure   20007 does not have chf-heat transfer correlation data entered.
0********   Right boundary of heat structure   20008 does not have chf-heat transfer correlation data entered.
0********   Right boundary of heat structure   20009 does not have chf-heat transfer correlation data entered.
0********   Right boundary of heat structure   20010 does not have chf-heat transfer correlation data entered.
0********   Right boundary of heat structure   20011 does not have chf-heat transfer correlation data entered.
0********   Right boundary of heat structure   20012 does not have chf-heat transfer correlation data entered.
0********   Right boundary of heat structure   20013 does not have chf-heat transfer correlation data entered.
0******** Alphanumeric part,   ztrwt   , of variable request ,  20800001, is not in table of legal variables.
0******** Errors detected during input processing.
```

5.2 Importation of ASCII input model into SNAP (Step 2)

Once Import RELAP5 ASCII is done, the RELAP5 model is created in SNAP. The Model Editor screen (see Figure 6) shows Message Window, which displays a running list of error, warning, alert, and notice messages. The Navigator on the left shows the RELAP5 model content.

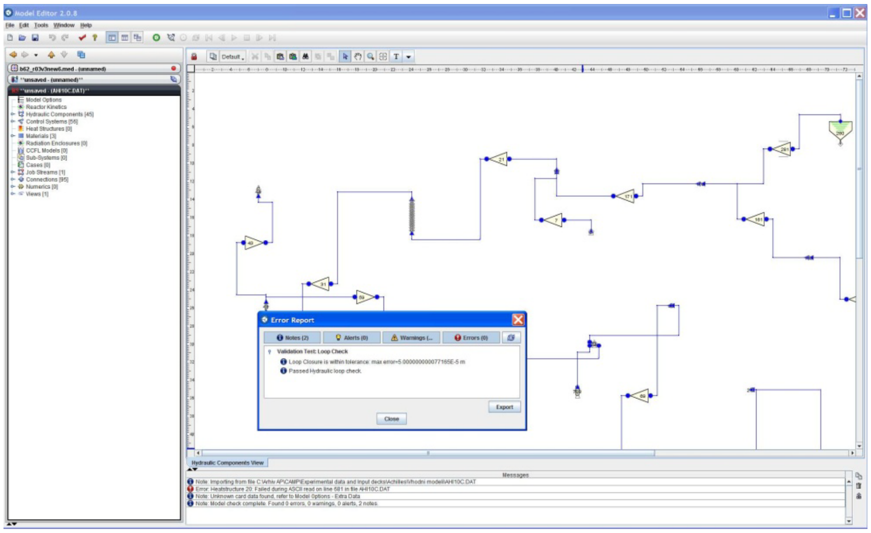

Figure 6 Model Editor screen after importing ASCII input file

5.3 Manually arrange Hydraulic Components View (Step 3)

Figure 6 shows also a part of Hydraulic Components View (whole model is visible Figure 7). It may be seen that the view can be significantly improved when comparing to nodalization shown in Figure 3. After manually arranging components, mostly by moving and scaling components and adding labels, the Hydraulic Components View shown in Figure 8 was obtained.

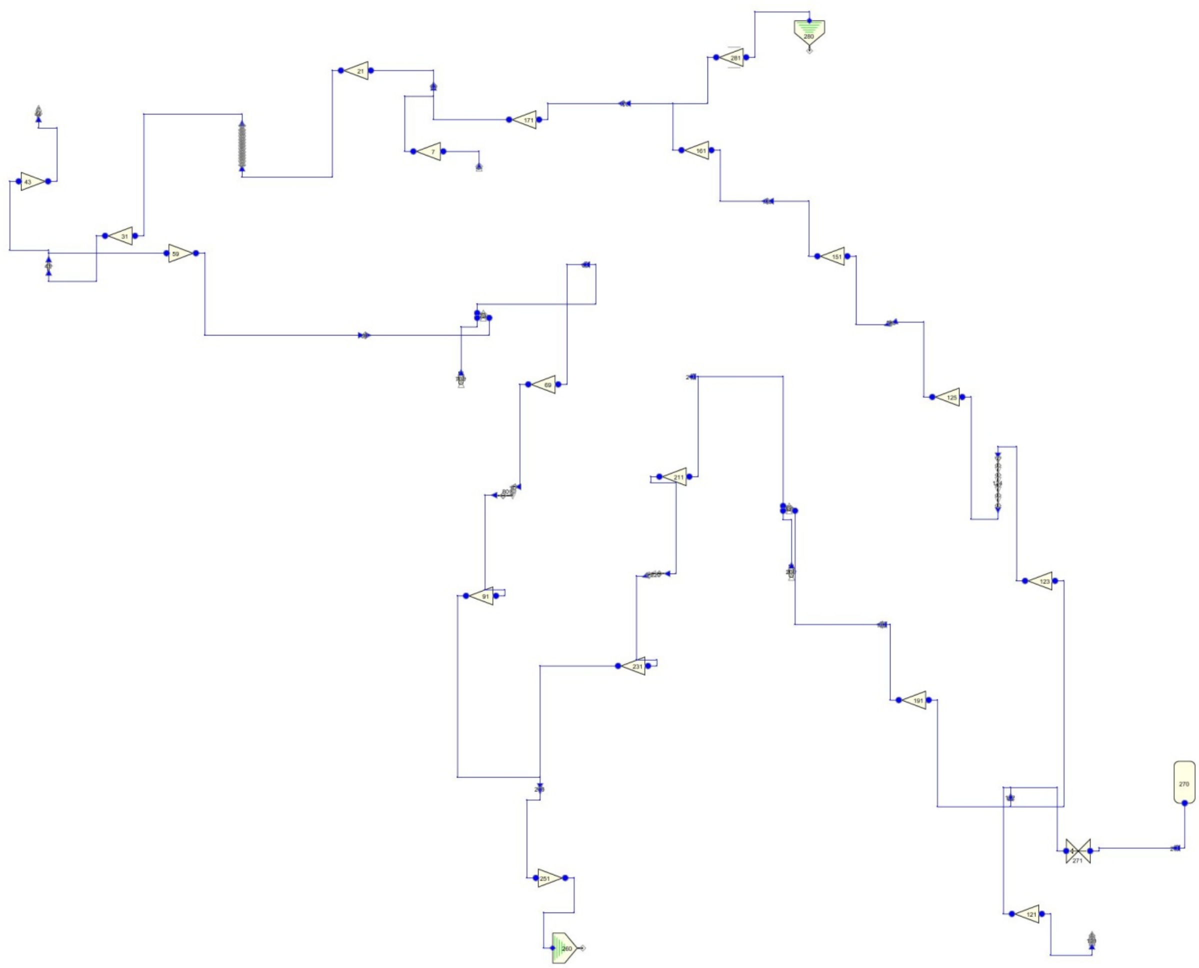

Figure 7 SNAP hydrodynamic component view for RELAP5 input model of ACHILLES rig - original

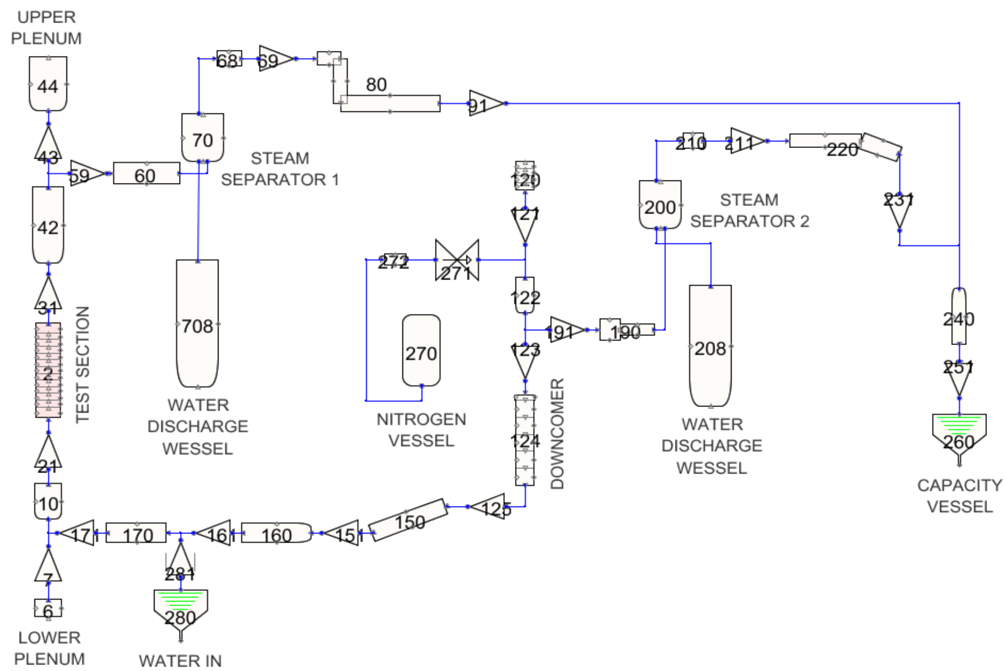

Figure 8 SNAP hydrodynamic components view for RELAP5 input model of ACHILLES rig – arranged

5.4 Export RELAP5 Model Notebook (Step 4)

The RELAP5 plug-in allows generating model-wide reports as a single annotated document, called a model notebook. Information such as calculations, export data, model status, attribute descriptions, etc. are all included. Table 2 shows, which components are included in the RELAP5 model for ACHILLES.

Table 2 RELAP5 model report table for ACHILLES

Component		Count
Hydraulic	Accumulators	1
	Branches	10
	Pipes	6
	Single Junctions	17
	Single Volumes	7
	Time Dependent Volumes	2
	Time Dependent Junctions	1
	Valves	1
	Total:	45
Control System	Variable Trips	3
	Control Blocks	14
	General Tables	1
	Total:	18
Heat Structures	Materials	3
	Total:	3

5.5 Perform RELAP5 calculation (Step 5)

The calculation may be performed from Model Editor or directly by the computer used. In this way the data needed are obtained, especially RELAP5 junction areas, from which hydraulic diameters can be calculated.

5.6 Create animation model for RELAP5 (Step 6)

Having Hydraulic Component View of RELAP5 model for ACHILLES, the basic animation model was created using Copy Paste (in animation model) technique as shown in Figure 9. The void fraction color map was selected.

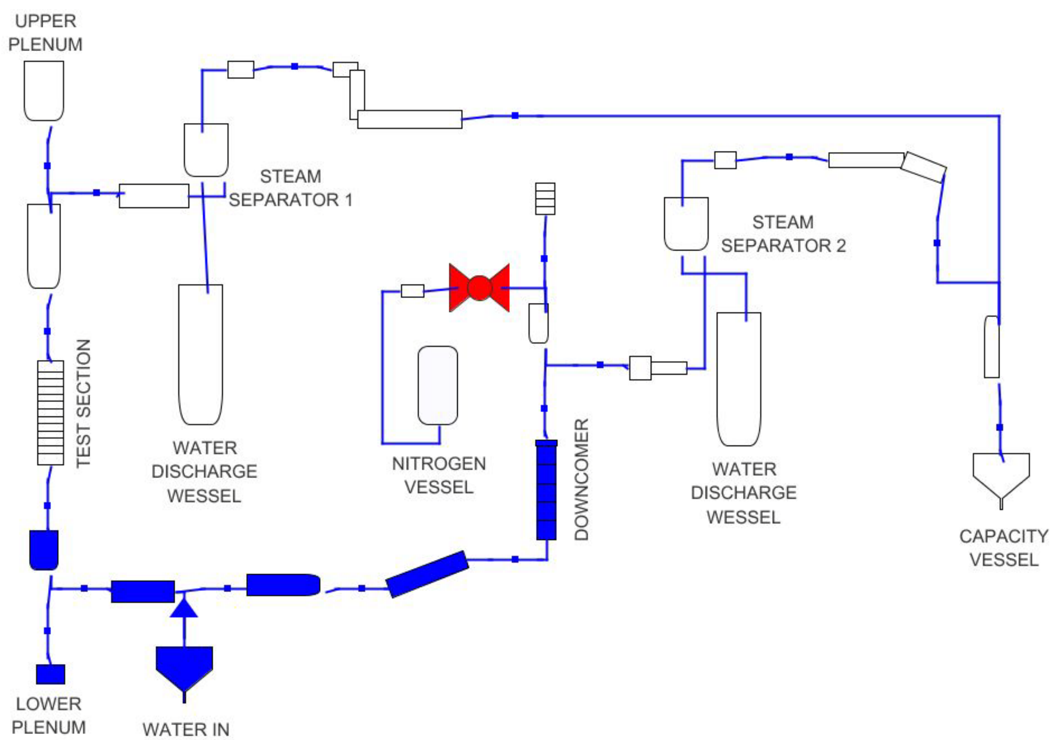

Figure 9 Basic animation model for RELAP5 model of ACHILLES rig

5.7 Convert RELAP5 model to TRACE model (Step 7)

After conversion the TRACE model was obtained. The Hydrodynamic Components View of TRACE model is shown in Figure 10. The only modification was down scaling the junction components (converted from RELAP5 Branch component). The Achilles facility TRACE Hydrodynamic Components View is presented in Figure 10 and it comprises of 37 hydraulic components with a core test section nodalization divided in 13 cells, and a downcomer nodalization geometry of 11 cells. When comparing TRACE Hydrodynamic Components View (Figure 10) to RELAP5 Hydrodynamic Components View (Figure 8), it may be seen that component numbering was mostly preserved.

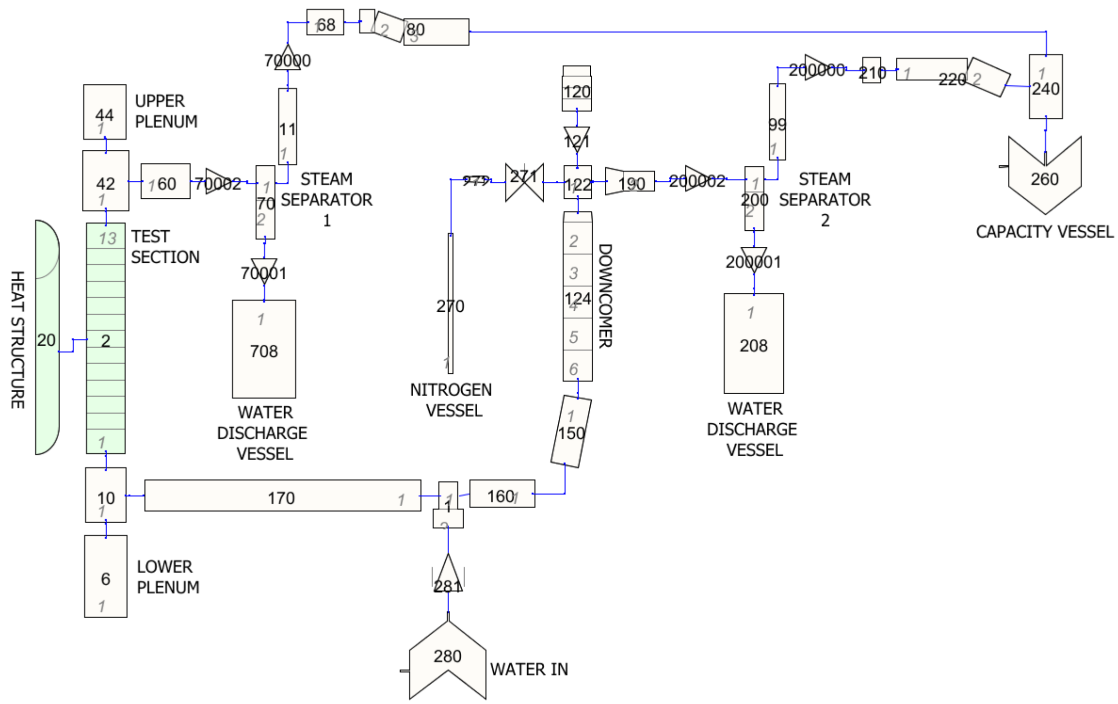

Figure 10 SNAP hydrodynamic components view for TRACE input model of ACHILLES rig

5.8 Check for and resolve TRACE model errors (Step 8)

Once the model is imported, check for errors is done. The errors are shown in Error Report, which is shown in Figure 11. All these error need to be resolved, before TRACE can be run. SNAP helps a lot to locate the error.

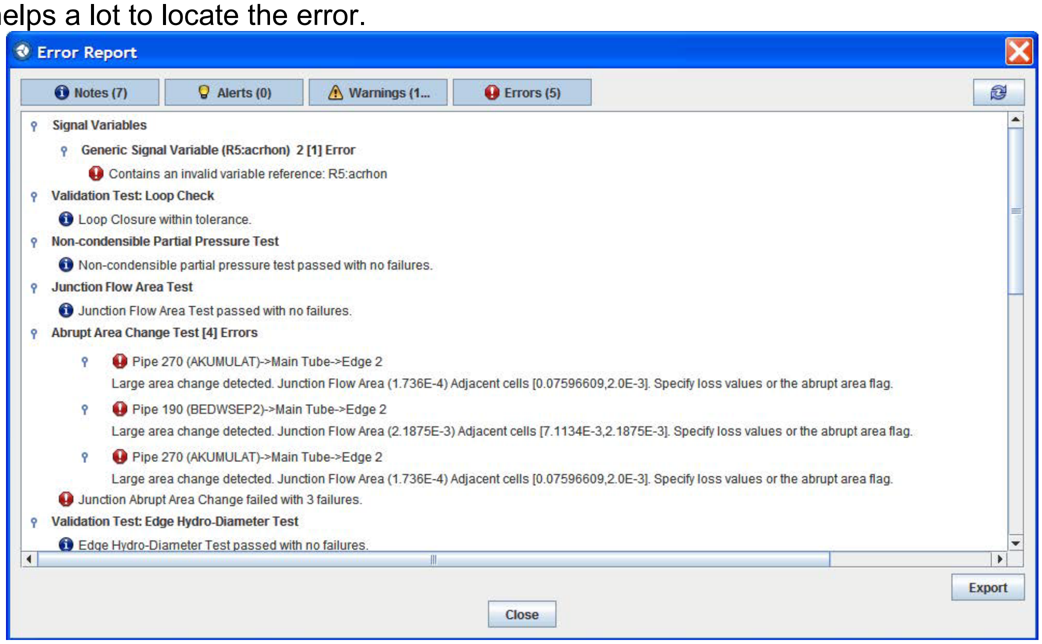

Figure 11 Error report for TRACE model of ACHILLES rig

5.9 Export TRACE Model Notebook (Step 9)

The TRACE plug-in also allows generating a model notebook. Table 3 shows, which components are included in the TRACE model for ACHILLES.

Table 3 TRACE model report table for ACHILLES

Component		Count
Hydraulic Components	Breaks	1
	Fills	1
	Pipes	23
	Pumps	1
	Separators	2
	Single Junctions	7
	Tees	1
	Valves	1
	Total:	37
Control Systems	Trips	3
	Control Blocks	16
	Signal Variables	64
	General Tables	1
	Total:	84
Thermal	User Defined Materials	3
	All Heatstructures	1
	Total:	4
Power Components	Powers	1
	Total:	1

After having both RELAP5 and TRACE Model Notebooks the comparison is performed. For example, in the case of ACHILLES wall-roughness for some hydraulic components was not converted and the nitrogen non-condensable gas option was not included. The nitrogen vessel represented by an Accumulator component in the RELAP5 input model was automatically converted to Pipe component - Liquid separator type instead of Accumulator type. It was manually changed to Accumulator type of pipe (Ref. 14). Hydraulic diameters can be obtained from RELAP5 output file and then comparison with TRACE values is performed.

5.10 Perform TRACE calculation (Step 10)

This step helps to identify any other possible errors remaining in the TRACE model. In the example of ACHILLES (using SNAP 2.0.8) the TRACE code start to run (this was not the case with SNAP 1.2.6). This does not mean that the model perform the same as RELAP5. To check the correctness, the first calculation is performed and the results needed for plotting the graphs and animation model are generated.

5.11 <u>Create TRACE animation model (Step 11)</u>

Similarly as for RELAP5 the TRACE basic animation model can be created from Hydrodynamic Components View using Copy Paste. It is shown in Figure 12. In the basic animation mask the fluid condition color map is shown. Additional Animation Mask was also created as shown in Figure 13.

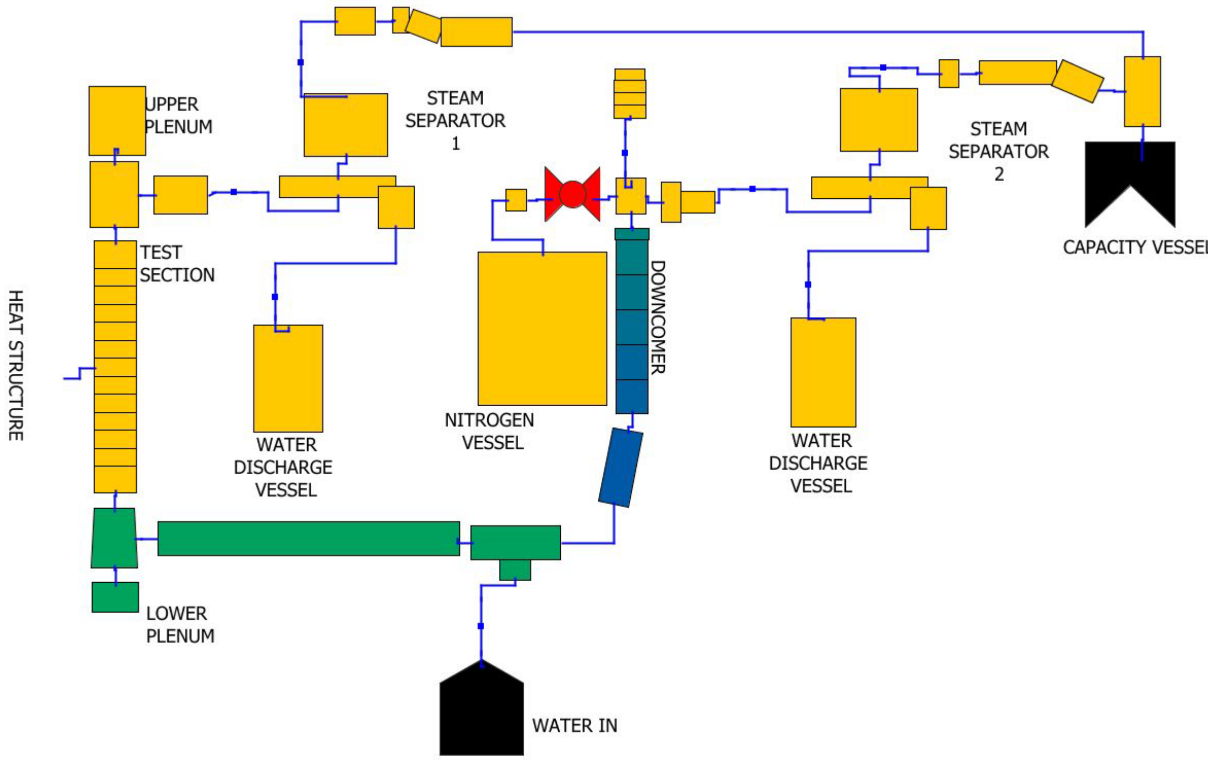

Figure 12 Basic animation model for RELAP5 model of ACHILLES rig

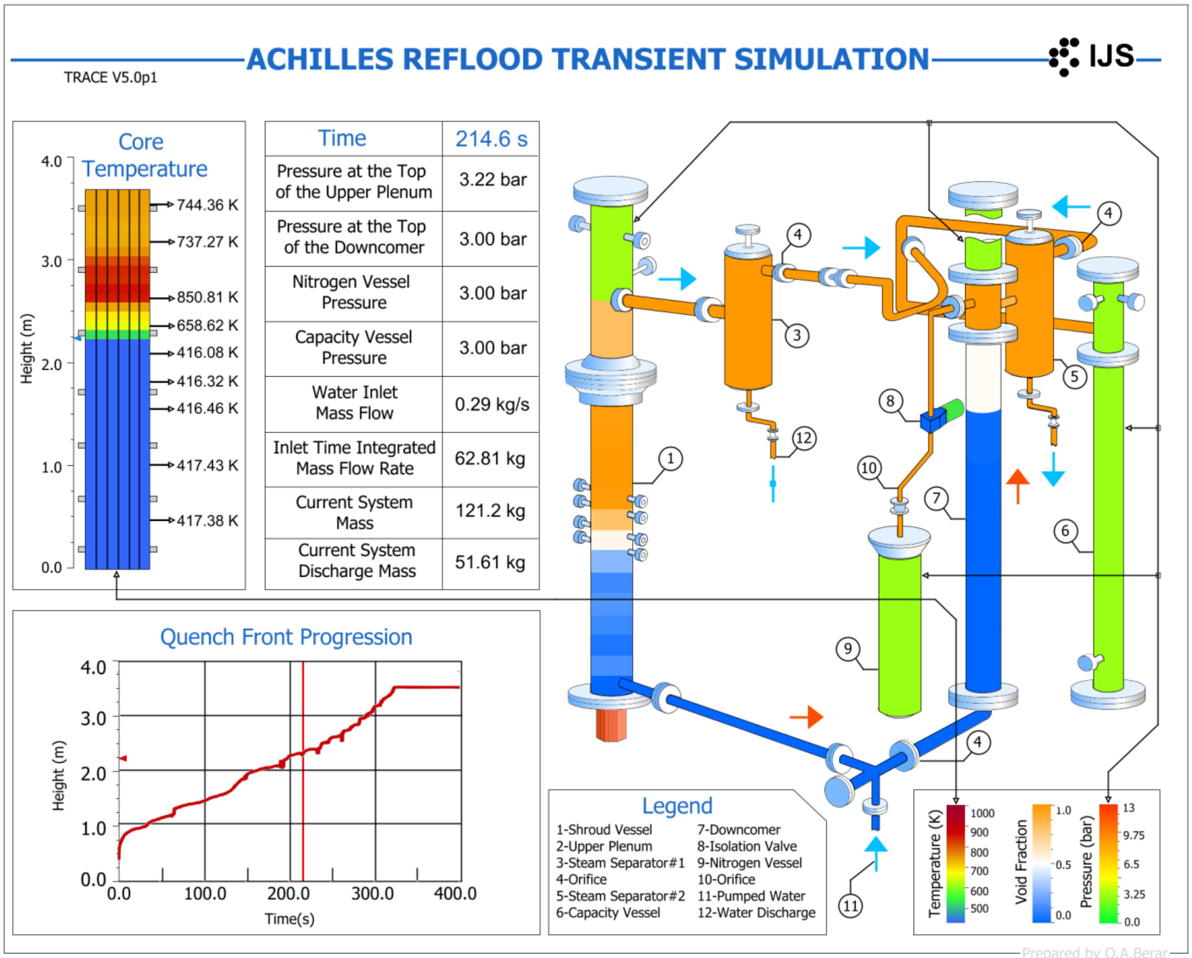

Figure 13 SNAP additional animation mask for the Achilles TRACE model

5.12 Results for ACHILLES natural reflood test

Once having running the TRACE model, the basic conversion process from RELAP5 to TRACE is completed. Now the analysis using TRACE can be started. The analysis reveals the need for several other modification and improvements of the TRACE model. This is not described here, as this is not part of IJS conversion procedure. Nevertheless, based on the converted TRACE model the 1D and 3D models of ACHILLES rig were created and calculations were performed. These two TRACE calculations were compared against the experimental data and the RELAP5/MOD3.3 calculation data obtained in Step 5 of IJS conversion procedure. The TRACE calculation has a tendency to under predict the quench front time for the test sections, Figure 14, although, compared to RELAP5/MOD3.3, the TRACE overall quench front progression, is closer to the experimental results, as shown in Figure 15. The under prediction of quench front time is in an agreement with the TRACE assessment report conclusions where it is stated that TRACE has a tendency to under predict quench times for low flow, low power cases (Ref. 5). The test section peak cladding temperatures predicted by the codes are in agreement with the experimental data although TRACE has a tendency to over predict the peak cladding temperatures in higher elevations, but this is also part of the TRACE assessment report conclusions (Ref. 5). The peak cladding temperatures code predictions, for the highest temperature test section are presented in Figure 14. The closest result to the experimental value is provided by the TRACE 1D model, followed closely by the TRACE 3D model result. The results for static pressure at various elevations in the core show an oscillatory behaviour for TRACE, and RELAP5/MOD3.3 calculations, manifesting particularly during the early stages of the transient. Nevertheless, the TRACE prediction for the pressure at the top of the upper plenum is in good agreement with the experimental data, and RELAP5/Mod3.3 calculation data, although the initial pressure peak is under predicted and an oscillatory behaviour is observable, Figure 16.

The downcomer collapsed liquid level transient proved difficult to be predicted by both codes, Figure 8, but the core collapsed liquid level predicted by RELAP5/MOD3.3 and TRACE is in good agreement to the experimental results, although some oscillations are present, as shown in Figure 17.

It is important to mention that the results of both the TRACE 1D model calculations and TRACE calculation with 3D test section model are in close agreement.

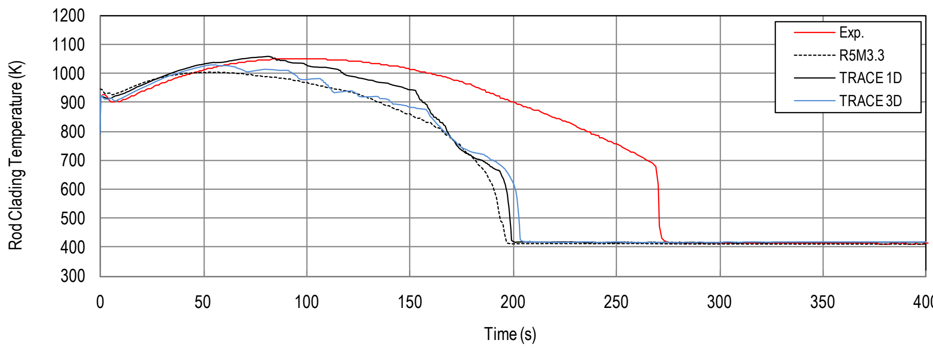

Figure 14 Peak cladding temperature at 2.13 m elevation

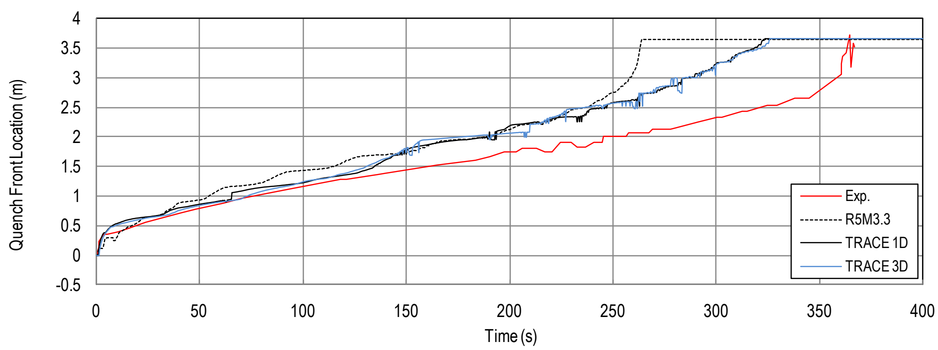

Figure 15 Quench front progression

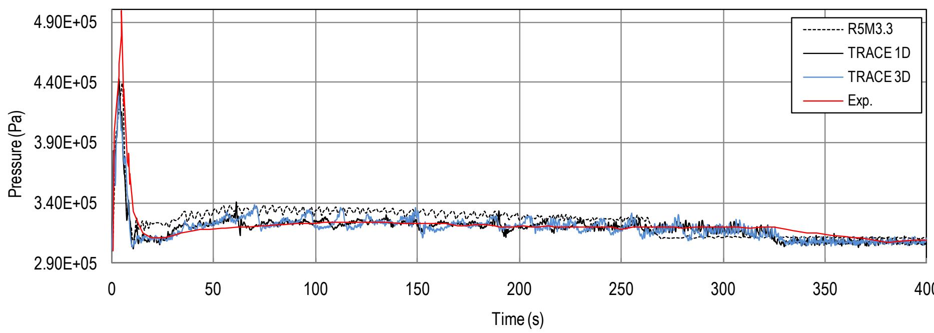

Figure 16 Pressure at the top of the upper plenum

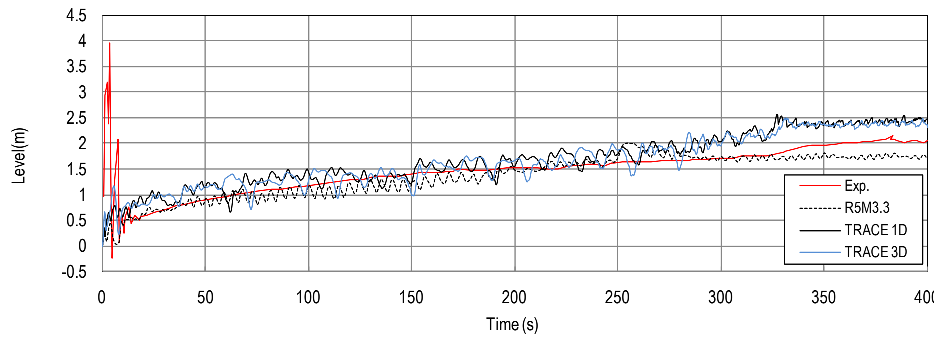

Figure 17 Core collapsed liquid level

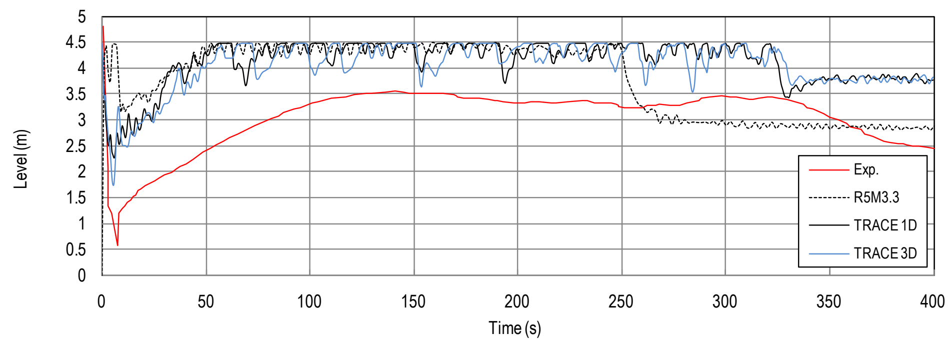

Figure 18 Downcommer collapsed liquid level

A SNAP animation model for the Achilles TRACE model with 3D VESSEL component was also developed, for the purpose of graphically displaying the evolution of different phenomena during the 400 seconds transient. In addition it is important to mention that this model is using both the TRACE nodalization (basic animation model) as well as the Achilles facility simplified schematic as a layout for the various hydraulic components (additional animation mask). A screen capture of the animation model at 214.7 seconds in the transient is presented in Figure 13.

Finally, it should be noted, that for demonstration of APTPlot capabilities Figures 14 through 18 were created by APTPlot.

6. BETHSY EXAMPLE OF CONVERSION

6.1 Adaptation of legacy RELAP5 input model to RELAP5/MOD3.3 (Step 1)

The RELAP5/MOD3.2 input model was first adapted to RELAP5/MOD3.3. When running RELAP5/MOD3.2 computer code, several errors were reported because of junction options (v-flag), as shown in Table 4.

Table 4 Errors reported by RELAP5/MOD3.3 for BETHSY input model

```
0******** Junction 125010000: Neither the FROM volume 125010002 or the TO volume 131010001 are horizontal
0******** Junction 221000000: Neither the FROM volume 212030002 or the TO volume 203010001 are horizontal
0******** Junction 308010000: Neither the FROM volume 319010001 or the TO volume 308010001 are horizontal
0******** Junction 308020000: Neither the FROM volume 308010002 or the TO volume 309010001 are horizontal
0******** Junction 313010000: Neither the FROM volume 301210002 or the TO volume 313010001 are horizontal
0******** Junction 319010000: Neither the FROM volume 310010001 or the TO volume 319010002 are horizontal
0******** Junction 408010000: Neither the FROM volume 419010001 or the TO volume 408010001 are horizontal
0******** Junction 408020000: Neither the FROM volume 408010002 or the TO volume 409010001 are horizontal
0******** Junction 413010000: Neither the FROM volume 401210002 or the TO volume 413010001 are horizontal
0******** Junction 419010000: Neither the FROM volume 410010001 or the TO volume 419010002 are horizontal
0******** Junction 508010000: Neither the FROM volume 519010001 or the TO volume 508010001 are horizontal
0******** Junction 508020000: Neither the FROM volume 508010002 or the TO volume 509010001 are horizontal
0******** Junction 513010000: Neither the FROM volume 501210002 or the TO volume 513010001 are horizontal
0******** Junction 519010000: Neither the FROM volume 510010001 or the TO volume 519010002 are horizontal
0******** Junction 535000000: Neither the FROM volume 509110002 or the TO volume 503010001 are horizontal
0******** Junction 663000000: is not connected to face 5 of horizontal stratification volume 653010000
It is connected from face 1 (Requirement for junction v-flag = 2)
0******** Junction 863000000: is not connected to face 5 of horizontal stratification volume 853010000
It is connected from face 1 (Requirement for junction v-flag = 2)
0******** Junction 963000000: is not connected to face 5 of horizontal stratification volume 953010000
It is connected from face 1 (Requirement for junction v-flag = 2)
```

6.2 Importation of ASCII input model into SNAP (Step 2)

The hydrodynamic components view was generated by SNAP from RELAP5 ASCII input model as shown in Figure 19 and then arranged manually using Model Editor of SNAP (see Figure 20).

Figure 19 SNAP hydrodynamic components view for RELAP5 input model of BETHSY facility - original

The RELAP5/MOD3.3 input model in terms of SNAP consists of 141 hydrodynamic components and 72 heat structures. The difference comparing to RELAP5 output file information on volumes is that pipes consist of several volumes; however they are considered as one component by SNAP. Similar is the case with the heat structures.

6.3 Manually arrange Hydraulic Components View (Step 3)

Figure 20 shows Hydraulic Components View for arranged model. It may be seen that the view can be significantly improved when comparing to nodalization shown in Figure 19. After manually arranging components, mostly by moving and scaling components and adding labels, the Hydraulic Components View shown in Figure 20 was obtained.

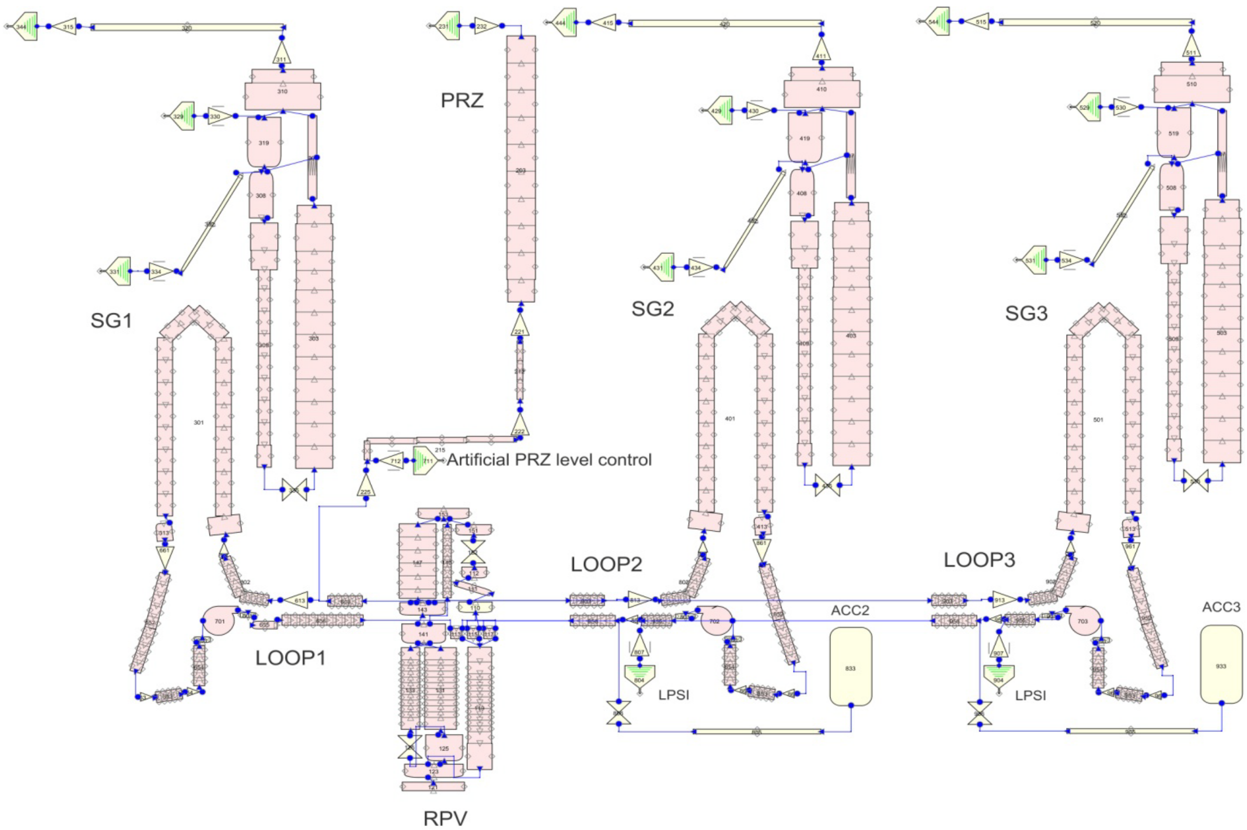

Figure 20 SNAP hydrodynamic component view for RELAP5 input model of BETHSY facility – arranged

6.4 Export RELAP5 Model Notebook (Step 4)

The RELAP5 plug-in allows generating model-wide reports as a single annotated document, called a model notebook. Information such as calculations, export data, model status, attribute descriptions, etc. are all included. Table **5** shows, which components are included in the RELAP5 model for BETHSY.

Table 5 RELAP5 model report table for BETHSY

Component		Count
Hydraulic	Accumulators	2
	Branches	31
	Pipes	40
	Pumps	3
	Single Junctions	27
	Single Volumes	6
	Separators	3
	Time Dependent Volumes	13
	Time Dependent Junctions	9
	Valves	7
	Total:	141
Control System	Logical Trips	3
	Variable Trips	5
	Control Blocks	38
	General Tables	16
	Total:	62
Heat Structures	Materials	3
	Heat Structures	72
	Total:	75

6.5 Perform RELAP5 calculation (Step 5)

The RELAP5 calculations were performed for BETHSY 9.1b and 6.2TC tests. The results are presented in Section 5.12 where comparison between RELAP5 and TRACE computer code calculations is shown.

6.6 Create animation model for RELAP5 (Step 6)

Animation model for RELAP5 was created, consisting from basic animation model and additional animation masks. In Figure 21 the additional animation mask is shown, representing the facility view, the loops arrangement and core part. The results used are RELAP5 calculations performed in Step 5 for BETHSY 9.1b test.

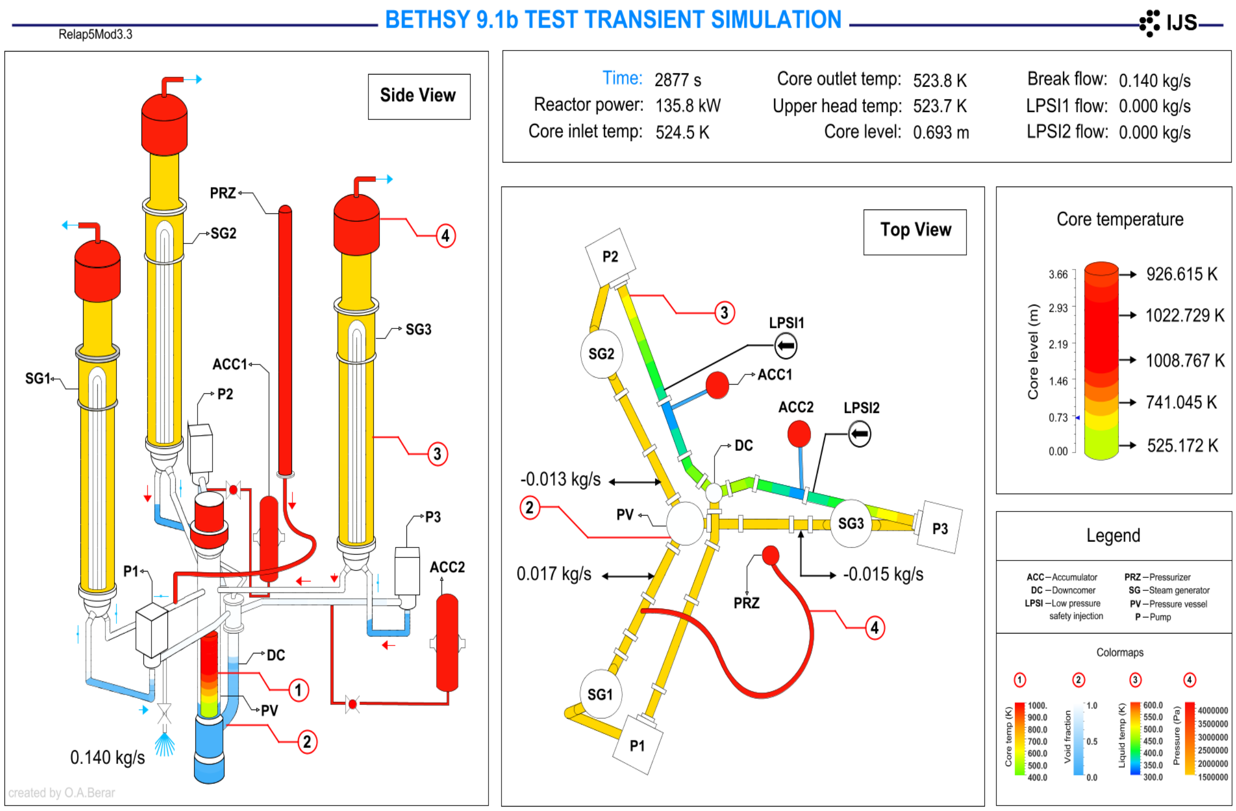

Figure 21 SNAP animation model for RELAP5 model of BETHSY facility

6.7 <u>Convert RELAP5 model to TRACE model (Step 7)</u>

After conversion from RELAP5 model the TRACE model was obtained. This model was then further adapted (reactor vessel model was moved to left, break was added etc.). The final Hydrodynamic Components View of TRACE model for BETHSY 6.2TC test is shown in Figure 22. When comparing TRACE Hydrodynamic Components View (Figure 22) to RELAP5 Hydrodynamic Components View (Figure 20), it may be seen that component numbering was mostly preserved.

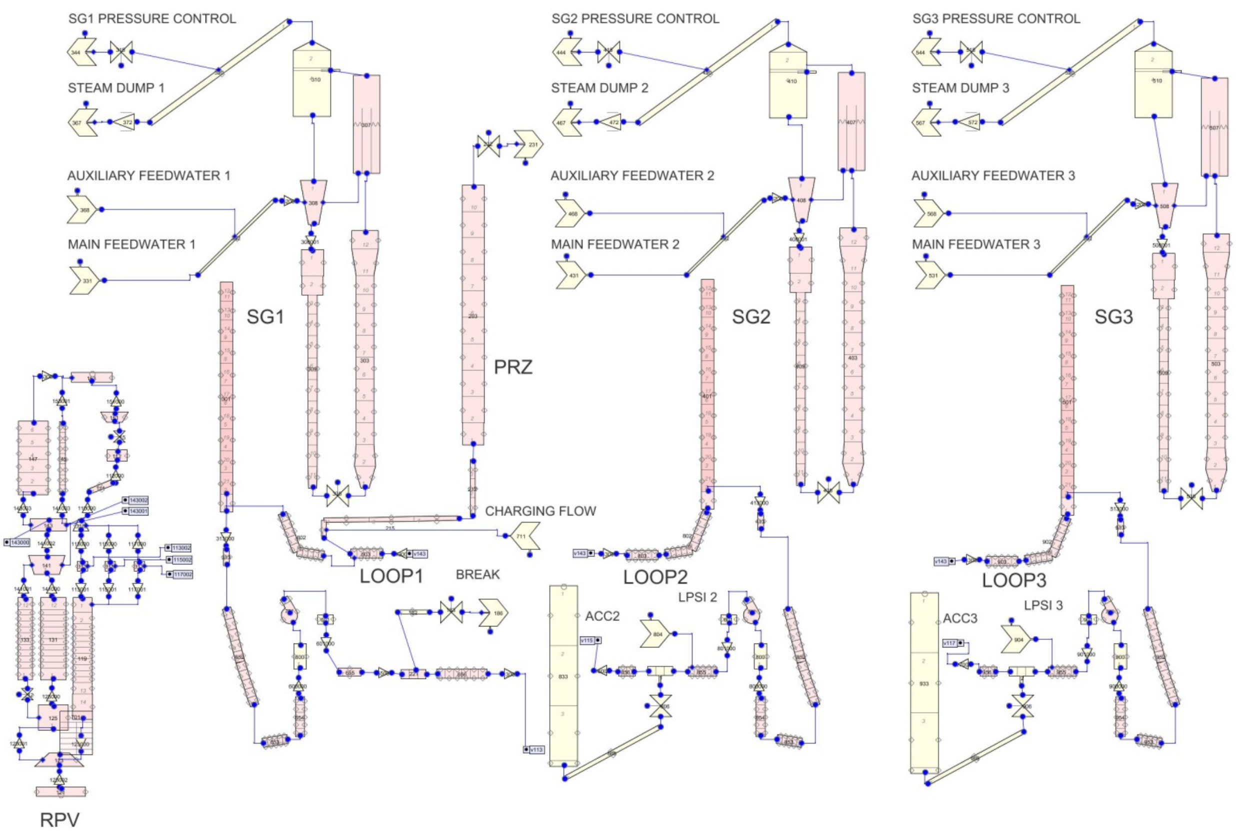

Figure 22 SNAP hydrodynamic component view for converted (and adapted) TRACE input model of BETHSY facility

6.8 Check for and resolve TRACE model errors (Step 8)

Once the model is imported, check for errors is done. The errors are shown in Error Report, which is shown in Figure 23. All these error need to be resolved, before TRACE can be run. SNAP helps a lot to locate the error.

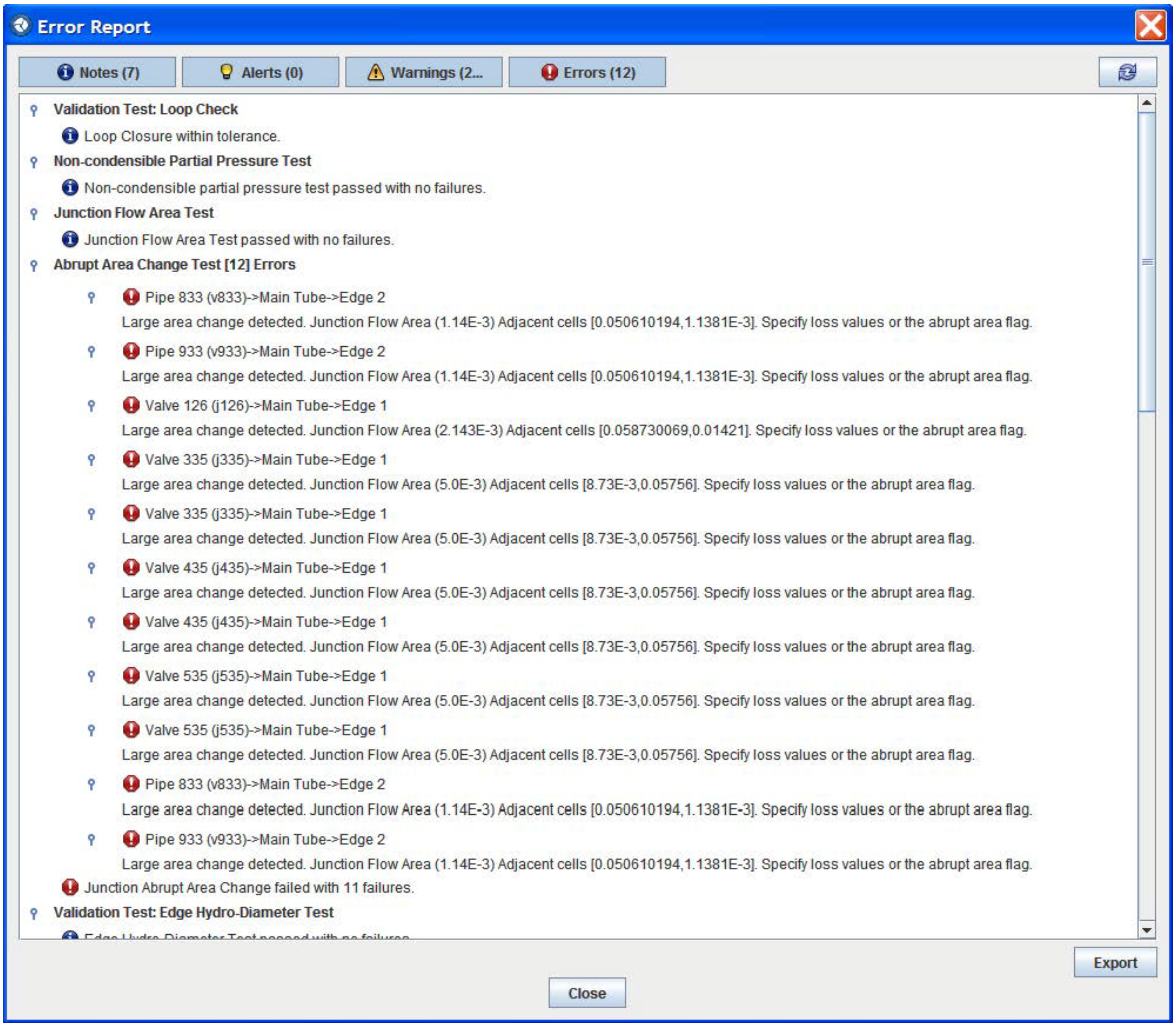

Figure 23 Error report for TRACE model of BETHSY facility

6.9 Export TRACE Model Notebook (Step 9)

In Table 6 a model notebook generated by TRACE plug-in shown. When comparing to RELAP5 model report table shown in Table 5, it may be seen that the number of hydraulic components are similar and that some hydraulic components are specific for codes. From Table 6 can also be seen that after conversion there are many more Control Systems components in TRACE model than in RELAP5 model.

Table 6 TRACE model report table for BETHSY

Component		Count
Hydraulic Components	Breaks	19
	Pipes	74
	Pumps	18
	Separators	3
	Single Junctions	42
	Tees	6
	Valves	11
	Total:	173
Control Systems	Trips	13
	Control Blocks	236
	Signal Variables	318
	General Tables	20
	Total:	587
Thermal	User Defined Materials	3
	All Heatstructures	71
	Total:	74
Power Components	Powers	1
	Total:	1
Global	CCFL Models	1

6.10 Perform TRACE calculation (Step 10)

This step helps to identify any other possible errors remaining in TRACE model. To check the correctness, the first calculation is performed and the results needed for plotting the graphs and animation model are generated. The results of final calculations are shown in Section 6.12.

6.11 Create TRACE animation model (Step 11)

Similarly as for RELAP5 the basic animation model for TRACE can be creating from Hydrodynamic Components View (see Figure 22) using Copy command in Model Editor, then opening Animation Model and pasting the copied content, which results in basic animation mask. Each view has to be copied separately and in this way the basic animation model is obtained. Once the basic animation model is connected to TRACE calculated source data, the animation model may be run. In Figure 24 the fluid condition color map is used to animate the calculated results.

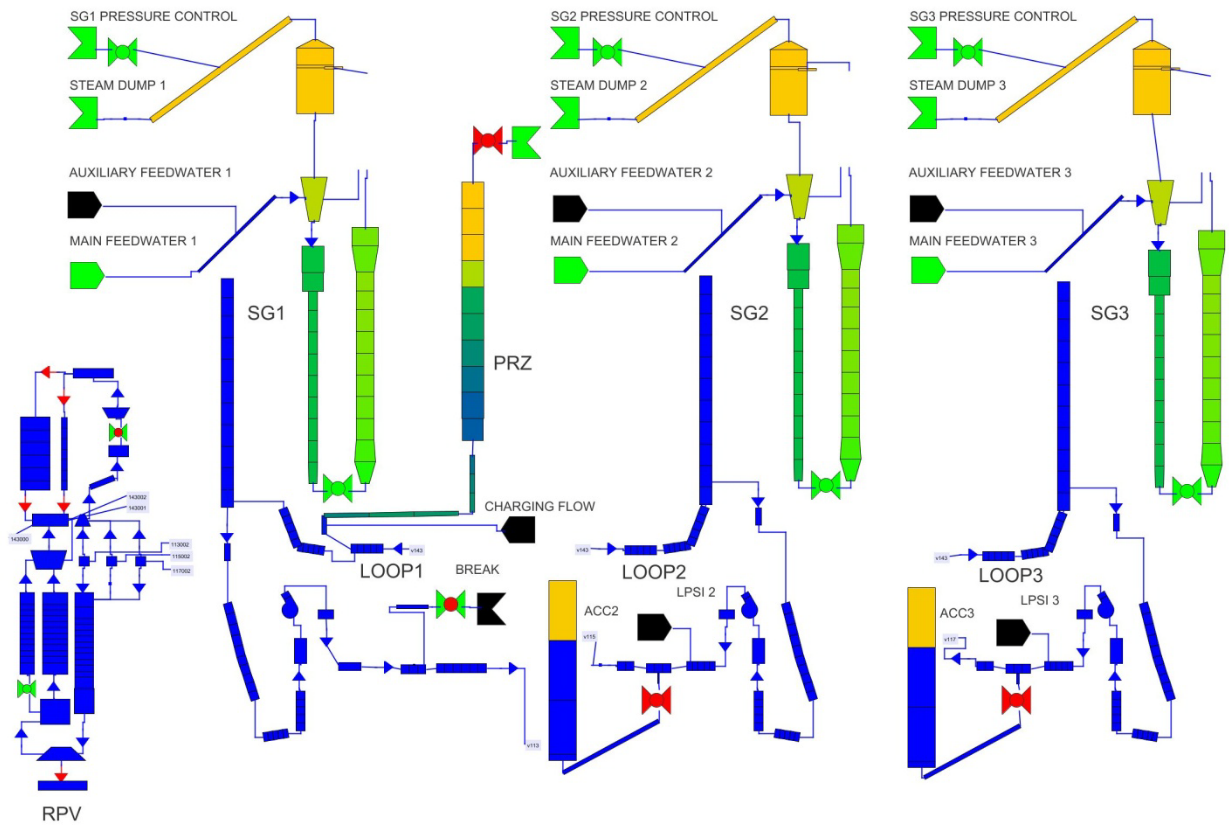

Figure 24 SNAP basic animation model for TRACE model of BETHSY facility

6.12 Results for BETHSY tests

The results are shown for two BETHSY tests, 9.1b and 6.2TC. Subsection 6.12.1 shows the results for BETHSY 9.1b test and Subsection 6.12.2 shows the results for BETHSY 6.2TC test.

6.12.1 RELAP5 and TRACE calculations of BETHSY 9.1b test

The TRACE V5.0 Patch 1 and RELAP5/MOD3.3 Patch 3 were used for calculations of BETHSY 9.1b test. Only transient calculation was performed.

Table 7 shows initial and boundary conditions for BETHSY 9.1b test. The initial conditions for TRACE come from converted model and are practically the same as for RELAP5. No steady-state calculation was therefore performed. The RELAP5 model was originally initialized to cold leg temperature; therefore the secondary pressure is not exactly matched. The steam generator levels and masses were matched to average measured values. The pressurizer pressure and level were also matched to average measured values. The core power was input value. In the experiment the electrical trace heating system was installed of the power of 107.5 kW and was operating till ultimate procedure start. In the calculations the heat losses were modeled only after the electrical heat system was off. Before ultimate procedure start there were no heat losses, what is equal to experiment which compensates the heat losses by electrical heat system.

Table 7 Comparison of initial conditions for BETHSY 9.1b test

Parameter	Measured	RELAP5	TRACE
core thermal power	2864 ± 30 kW	2864 kW	2864 kW
cold leg temperature (per loop)	559.9 ± 0.5 K	559.9 K (core inlet)	559.4 K (core inlet)
downcomer mass flow rate	150.0 ± 5.0 kg/s	155.2 kg/s	155.2 kg/s
reactor coolant pump speed (per loop)	2940 ± 30 rpm	2940 rpm	2970 rpm
pressurizer pressure	15.51 ± 0.09 MPa	15.51 MPa	15.51 MPa
pressurizer level	4.08 ± 0.1 m	4.08 m	4.08 m
reactor coolant system mass	1960 kg	1948 kg	1948 kg
secondary side pressure (per SG)	6.91 ± 0.04 MPa	6.77 MPa	6.77 MPa
steam generator level (per SG)	13.45 ± 0.05 m	13.41 m	13.18 m
feedwater temperature	491.1 ± 2.0 K	491.0 K	491.0 K
secondary coolant mass (per SG)	820 ± 30 kg	820 kg	804 kg
RCS trace heating	107.5 kW	no heat losses considering the trace heating system on	no heat losses considering the trace heating system on

The TRACE transient calculation was performed with already verified restart input model after conversion. The main sequence of events is shown in Table 8. As can be seen the RELAP5 calculation using standard BETHSY input model is in a good agreement with the experiment in the initial phase, while in later phase the TRACE calculation using converted model has better agreement. The reason is the break flow. For RELAP5 original Ransom-Trapp break flow model the values of 0.8, 1.0 and 1.1 were used for subcooled, two phase and superheated discharge coefficients, respectively. For TRACE break model the values of 1.0 and 1.1 were used for subcooled and two phase discharge coefficients, respectively. The values for TRACE were selected after some sensitivity studies and the aim was to use the values as close as possible to the default vales. Decreasing of discharge coefficients delays the ultimate procedure initiation. To match the initial period the TRACE subcooled discharge coefficient should be around 0.85, but this would require larger value of two phase coefficient. This also explains why the timing of RELAP5 calculation was better in the initial phase. Our goal was to as closely as possible to match the start of ultimate heat procedure. In Figures 25 and 26 are shown the break flow and integrated break mass flow, respectively. There are periods with some disagreements. In general the agreement is satisfactory. TRACE and RELAP5 are practically the same until accumulator injection. During accumulator injection TRACE is better, while during low pressure injection the slightly higher secondary pressure calculated by TRACE causes lower injection flow and therefore also lower break flow. The pressurizer pressure is shown in Figure 27. Due to selected break discharge coefficients the timing of pressure drop is better in TRACE, while after ultimate procedure initiation pressure drop is slightly slower in TRACE calculation than in experiment, what causes lower low pressure injection system flow. As can be seen from Figure 28, the secondary pressure is better predicted by TRACE. In the period before ultimate procedure initiation the pressure in both calculations is constant, because in the experiment the pressure was controlled to be constant at 6.91 MPa.

Table 8 Main sequence of events – BETHSY 9.1b

Events	Time (s)		
	Experiment	RELAP5	TRACE
Break opening	0	0	0
Scram signal (13.1 MPa)	41	31	21
Safety injection signal (11.9 MPa)	50	54	35
Main feedwater off, turbine bypass	54	58	39
Core power decay start (17 s after scram)	58	48	38
Auxiliary feedwater on (30 s after SI signal)	82	84	65
Pump coastdown start (300 s after SI signal)	356	354	335
End of pump coastdown	971	969	950
Start of the first core level depletion	1830	2020	1820
Start of second core uncovery	2180	2130	2183
Ultimate procedure initiation	2562	2508	2573
Accumulator injection starts (4.2 MPa)	2962	2880	2930
Primary mass inventory is minimum	2970	2880	2932
Maximum core clad heatup	3053	3009	3002
Accumulator isolation (1.5 MPa)	3831	3865	3957
Low pressure injection system start (0.91 MPa)	5177	5235	5330
End of test/calculation	8200 to 8330	8330	8500

The maximum heater rod temperature is shown in Figure 29. The heater rods start to heatup when core uncovers, as it is shown in Figure 30. TRACE calculation has very good timing, while the peak cladding temperature is slightly underpredicted. The core level (see Figure 30) shows that the core level depression occurred twice and the core level recovered respectively at about 1940 seconds and 3020 seconds in RELAP5 calculation, concurring with the first and second loop seal reformation. The TRACE calculation also predicts the core level depression twice with about the same minimum collapsed liquid levels as in the test. In the TRACE calculation, the core level recovers respectively at about 1820 seconds and 2990 seconds, corresponding with the times of the first and second loop sealing clearings. Both in the test and the calculation, there is an instantaneous core level recovery at the moment the loop seal clearing occurs (see Figure 31). TRACE calculation of core level is better than RELAP5 calculation. For quenching the rod the primary depressurization was needed to enable accumulator injection. Figure 32 shows the accumulator pressure drop due to discharging. TRACE calculation is in better agreement. During accumulator injection the core recovers. After accumulator injection the primary mass start to decrease again until the low pressure injections start as shown in Figure 33. Due to the slightly higher primary pressure prediction in TRACE the injection started a bit later and the injected flow is also lower. Finally, in Figure 34 the primary system mass is shown. The agreement is good both for RELAP5 and TRACE until accumulator injection start. Initially is slightly better RELAP5 because of the selected subcooled discharge coefficient, however later TRACE is superior.

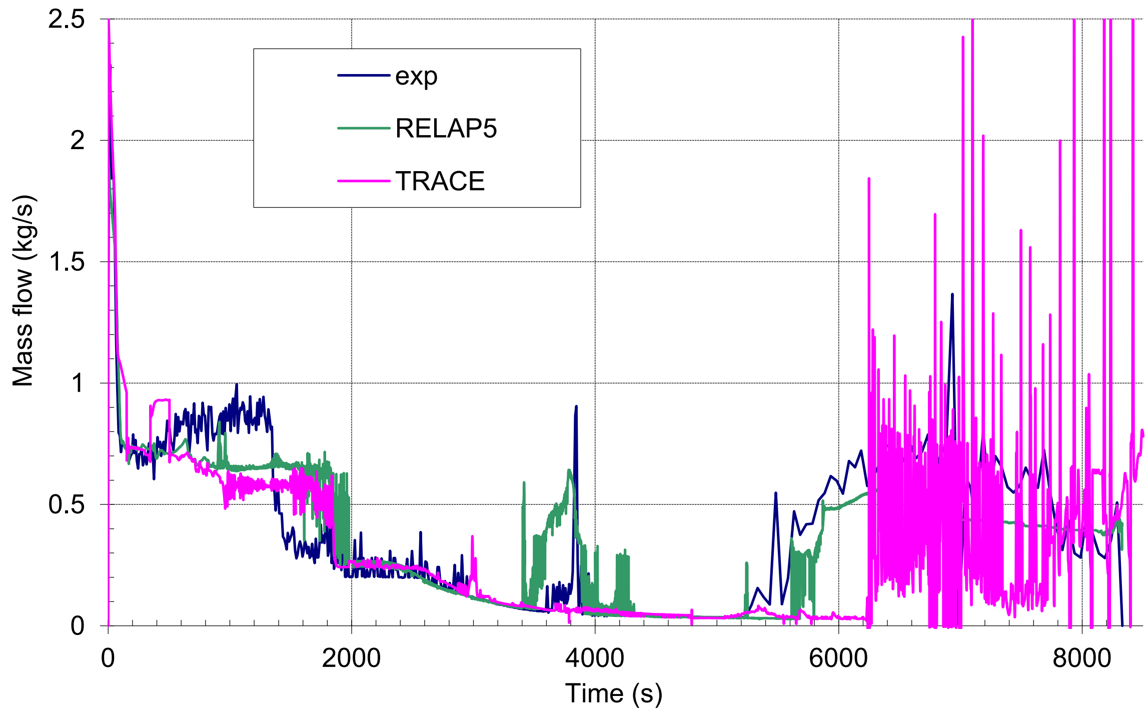

Figure 25 Break mass flow – BETHSY 9.1b

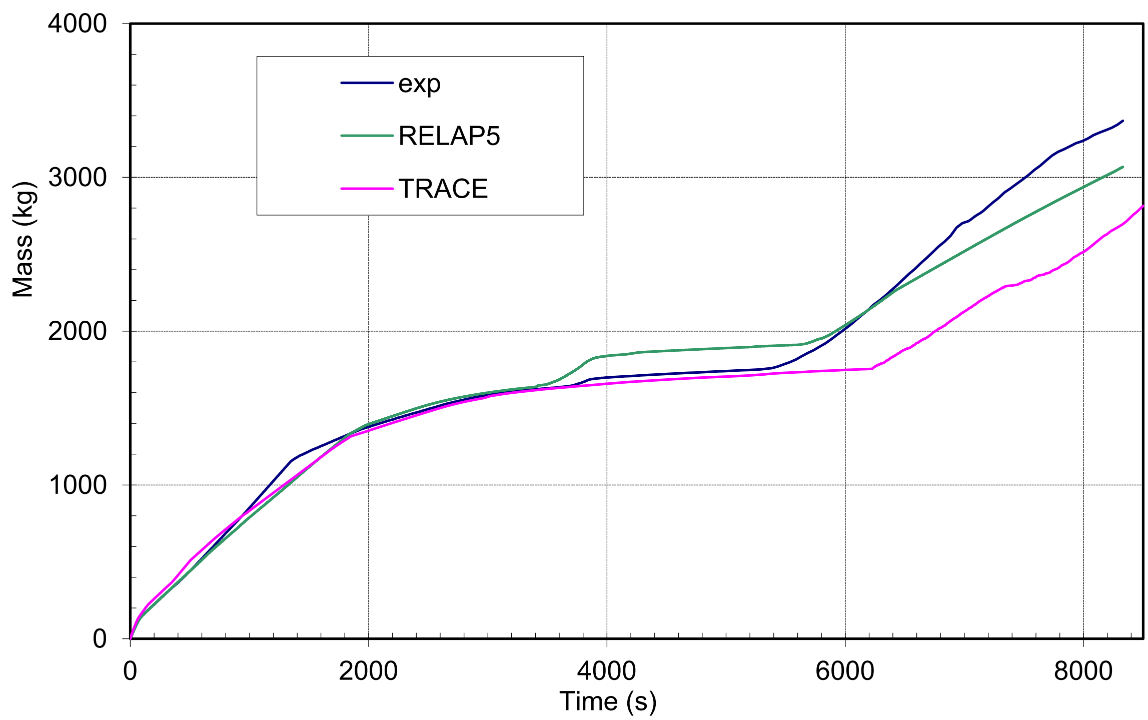

Figure 26 Integrated break mass flow – BETHSY 9.1b

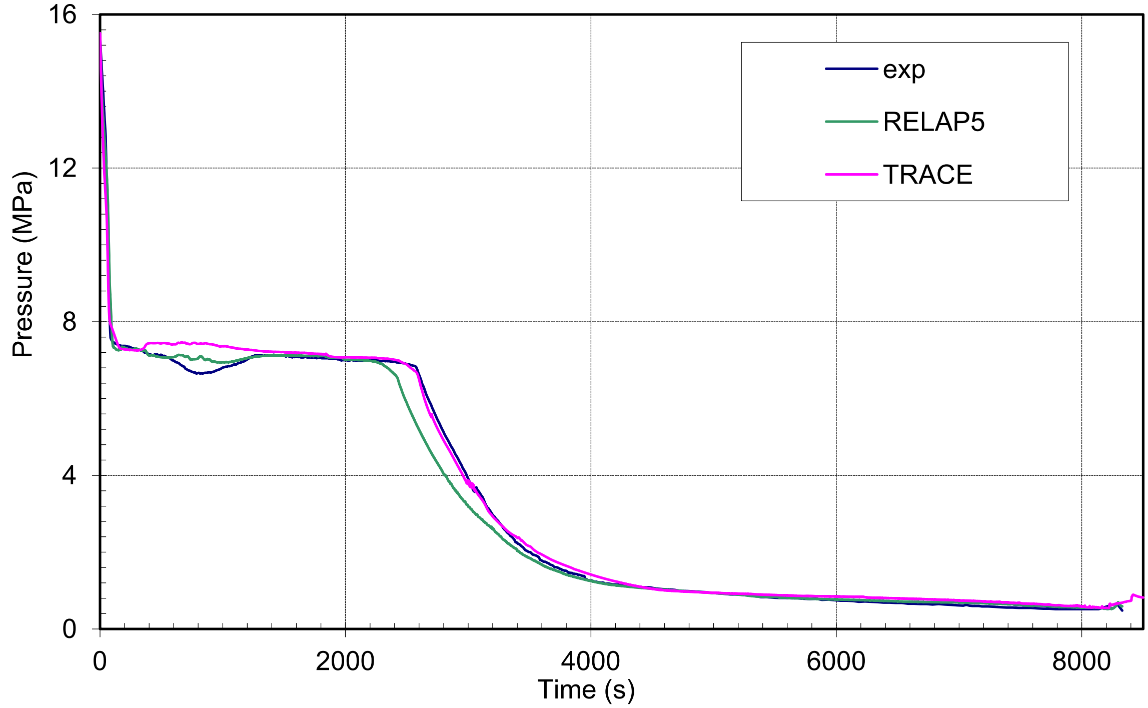

Figure 27 Pressurizer pressure – BETHSY 9.1b

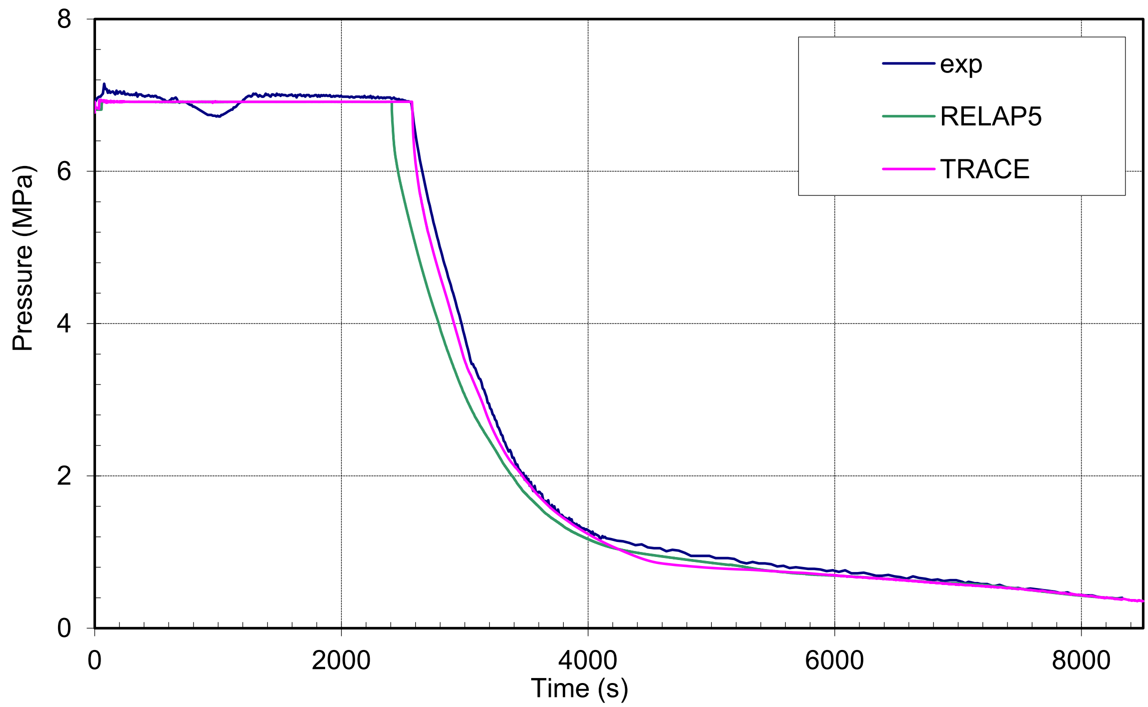

Figure 28 Steam generator 1 pressure – BETHSY 9.1b

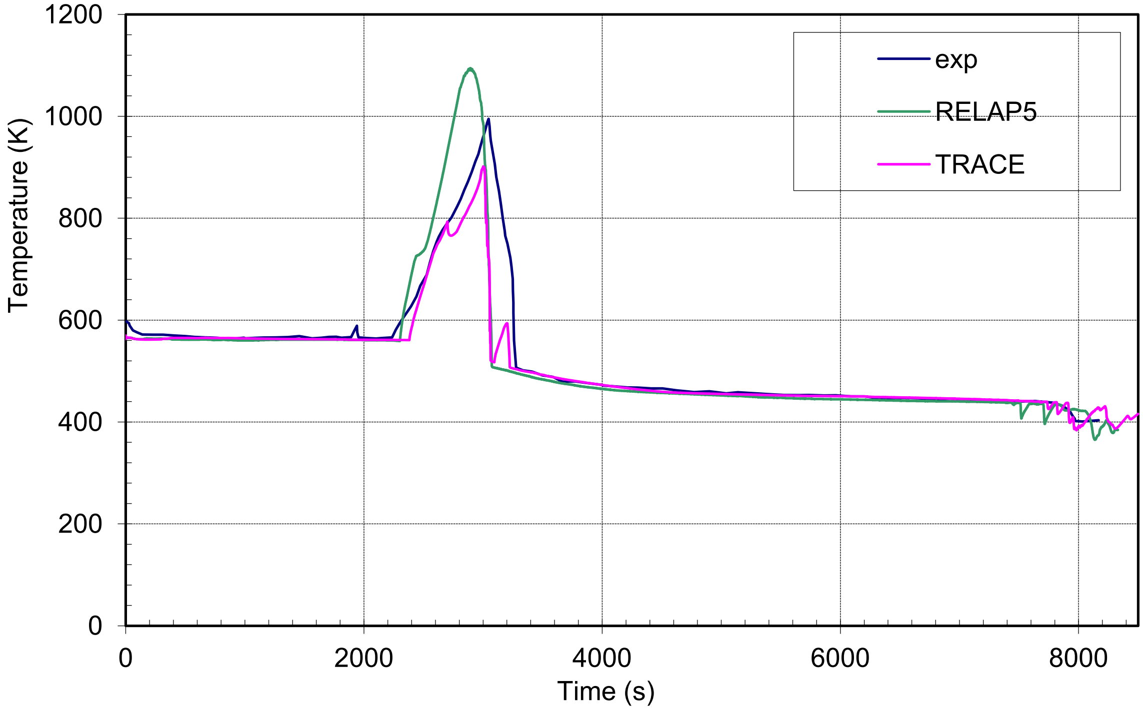

Figure 29 Maximum heater rod surface temperature – BETHSY 9.1b

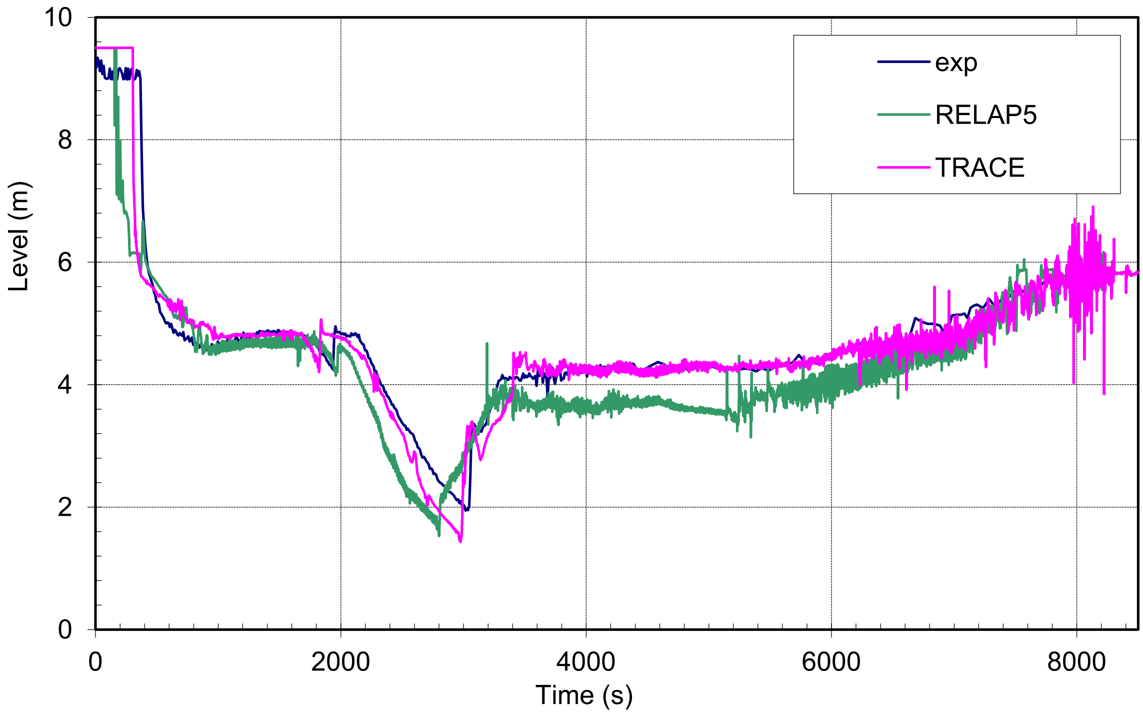

Figure 30 Core level – BETHSY 9.1b

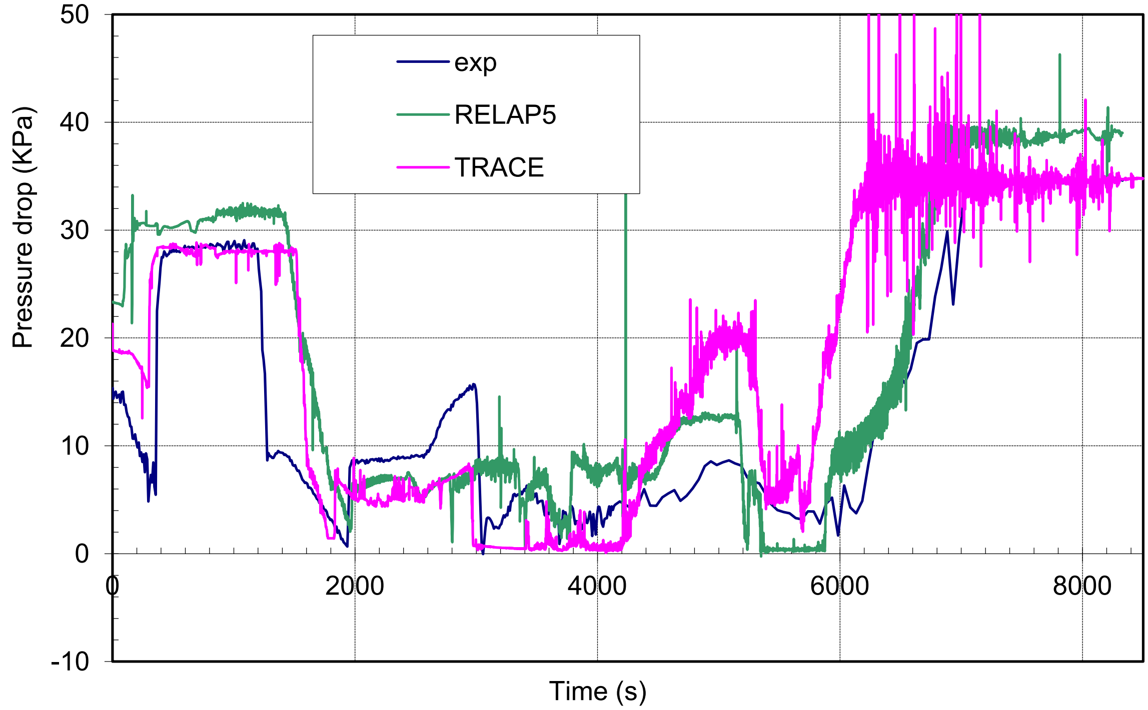

Figure 31 Loop 1 Seal Downflow Side Differential Pressure

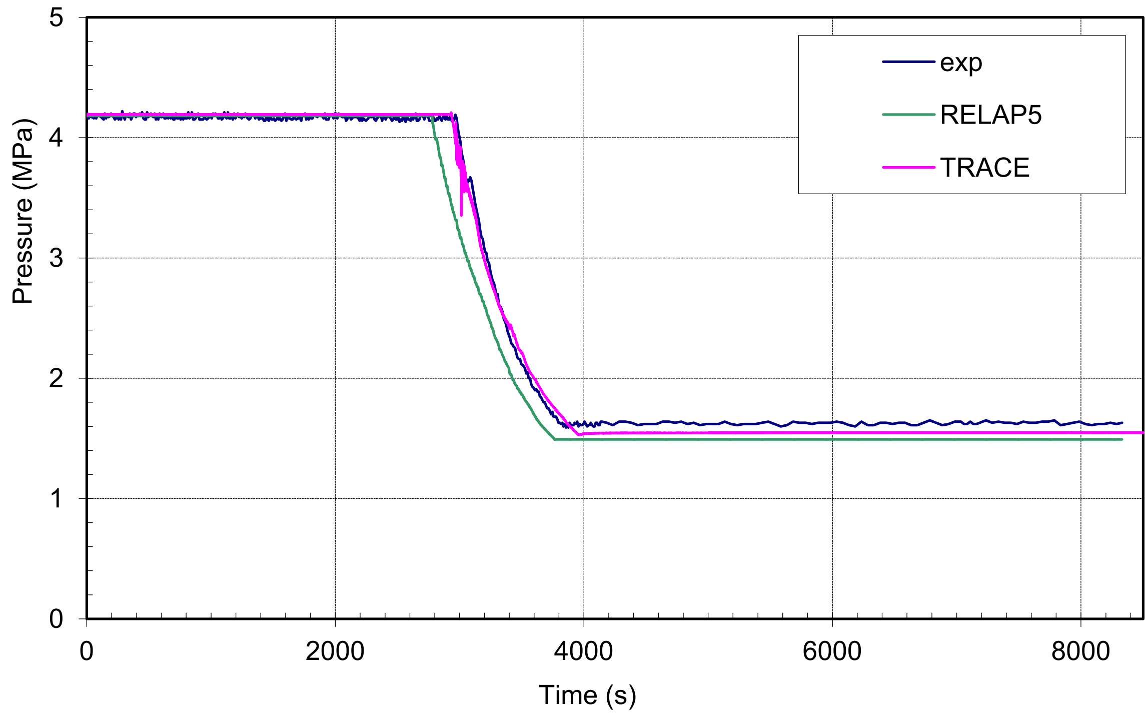

Figure 32 Accumulator pressure – BETHSY 9.1b

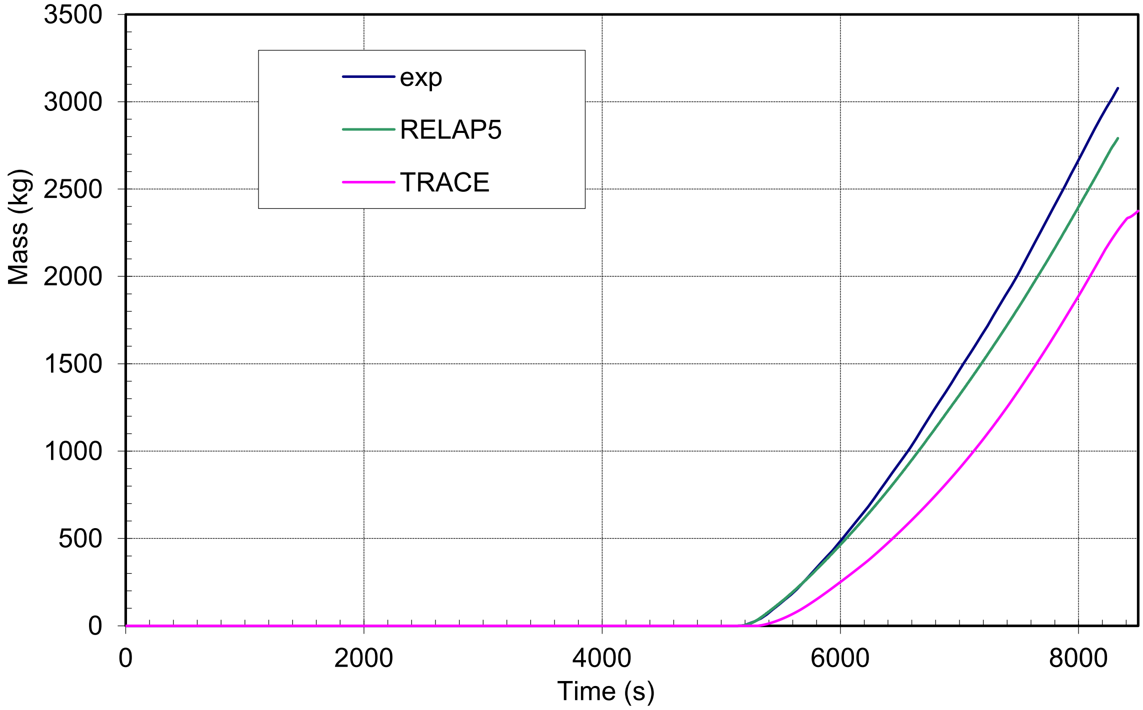

Figure 33 Integrated low pressure injection system mass – BETHSY 9.1b

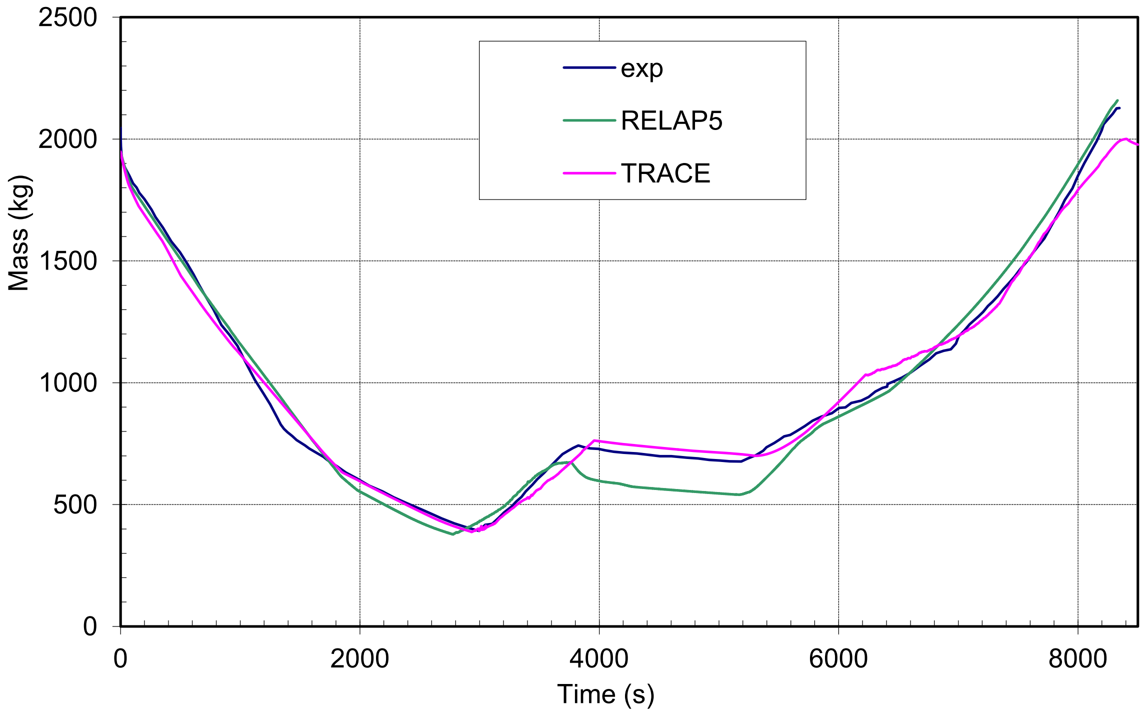

Figure 34 Primary coolant mass – BETHSY 9.1b

6.12.2 RELAP5 and TRACE calculations of BETHSY 6.2TC test

Table 9 shows the initial and boundary conditions for BETHSY 6.2TC test. The RELAP5 and TRACE input model were initialized to the cold leg temperature. This is different from 9.1b test where no stead-state calculation was performed. In the case of TRACE the secondary pressure is not exactly matched. The difference comes from the geometry and the code models. In the TRACE assessment report (Ref. 5) the cold leg temperature was not matched for the sake of matching secondary pressure. The steam generator levels and masses were matched to average measured values both for RELAP5 and TRACE. The pressurizer pressure and level were also matched to average measured values. The core power was boundary condition. In the experiment the electrical trace heating system was installed of the power of 54.82 kW and was operating till the transient start. Therefore in the calculations the heat losses were modeled after the electrical heat system was off.

Table 9 Comparison of initial conditions for BETHSY 6.2TC test

Parameter	Measured	RELAP5	TRACE
core thermal power (kW)	2863 ± 30	2864	2863
pressurizer pressure (MPa)	15.38 ± 0.15	15.38	15.38
pressurizer level (m)	7.45 ± 0.2	7.45	7.45
total flow (kg/s)	16.81 (calculated from core power)	16.84	16.61
core inlet temperature (K)	557.2 ± 0.4	557.2	557.2
core outlet temperature (K)	588.2 ± 0.4	588.1	588.8
reactor coolant system mass (kg)	1984 ± 50	1948	1948
secondary side pressure - per SG (MPa)	6.84 ± 0.07	6.83	6.69
steam generator level - per SG (m)	11.1 ± 0.05	11.1	11.1
feedwater temperature (K)	523.2 ± 4	523.2	523.2
heat loss (kW)	54.82	N.A.	N.A.
downcomer to upper head flow (kg/s)	0.047	0. 47	0.047

The main sequence of events for BETHSY 6.2TC test is shown in Table 10. The graphical comparison between the experiment, RELAP5 and TRACE for main variables is shown in Figures 35 through 46. The calculation results showed that occurrences and trends of key transient phenomena are reasonably predicted by both computer codes.

As shown in Table 10 most of times were reasonably captured. The times of reactor trip and safety injection signals are similar for both RELAP5 and TRACE calculation. As the pressure drop in TRACE calculation is slower, the primary to secondary pressure reversal is delayed in case of TRACE. The main reason is probably the secondary side behavior. Namely, the mass released through atmospheric relief valves in the initial period greatly influenced the primary pressure drop. Higher secondary pressure indicated that in first 100 s the atmospheric relief valves were open few tens of seconds. The overall accumulator time performance is better by TRACE than by RELAP5.

Table 10 Main sequence of events – BETHSY 6.2TC

Events	Time (s)		
	Experiment	RELAP5	TRACE
Break opening	0	0	0
Scram signal (13.1 MPa)	8	2	3
Safety injection signal (11.9 MPa)	11	8	9
First core uncovery	92	90	136
Loop seal clearing	134	155	173
Primary/secondary pressure reversal	172	175	203
Second core uncovery	334	280	253
Accumulator injection starts (4.2 MPa)	363	365	329
Accumulator isolation (1.5 MPa)	895	1125	801
Pressurizer pressure < 0.7 MPa	2065	2230	2167

The timing of the transient very much depends on the break mass flow. For RELAP5 original Ransom-Trapp break flow model the values of 0.85, 1.25 and 0.75 were used for subcooled, two phase and superheated discharge coefficients, respectively. For TRACE break model the values of 0.8 and 0.9 were used for subcooled and two phase discharge coefficients, respectively. The values for TRACE were selected after some sensitivity studies. In Figure 35 and Figure 36 are shown the break flow and the integrated break mass flow. It can be seen that the calculated break flows are quite well matched, in the range of 10% uncertainty. The integrated break flow better agree for the TRACE calculation. Primary pressure is shown in Figure 37. In spite of larger RELAP5 break flow than TRACE break flow the pressure drop is faster in the case of TRACE calculation. Secondary pressure is shown in Figure 38. The experimental values indicated that atmospheric relief valves were open a few tens of seconds. Later, the agreement between experiment and calculation is better for TRACE than for RELAP5. This is due to better heat losses modeling in the case of TRACE. However, in general after initial period the secondary side has small influence on the primary side and by this on the overall calculation. Figure 39 and Figure 40 show the heater rod surface temperatures in the middle and at the top of the core, respectively. The core heatup corresponds by the minimum core collapsed liquid level shown in Figure 41. Both calculations predicted with delay the first peak of heater rod surface temperature at the middle of the core. The second rod heatup was better calculated by TRACE. In the case of heater rod surface temperature at the top of the core the timing of heatup prediction was better in the case of TRACE, while heatup rate was better in the case of RELAP5. The primary mass is shown in Figure 42. In spite of correct TRACE calculated mass discharged through the break the TRACE calculated primary mass is smaller than the experimental. Similar is the situation in the case of RELAP5 calculation. The information on the loop seal clearing can be obtained from Figure 43 and Figure 44, showing the differential pressures on the steam generator and pump side, respectively. It may be seen that some further adjustment is needed for TRACE pressure drop on the pump side. Finally, the accumulator behavior is shown in Figure 45 showing the accumulator pressure and Figure 46 shown the integrated accumulator injected mass. Again the accumulator injected mass was very close to measurement value in the case of TRACE. The trend for RELAP5 is very good with exception that approximately 10% more mass was discharged. The difference in the calculated masses originates partly from a bit smaller initial primary mass, while the rest of difference may be attributed to the measurement uncertainty.

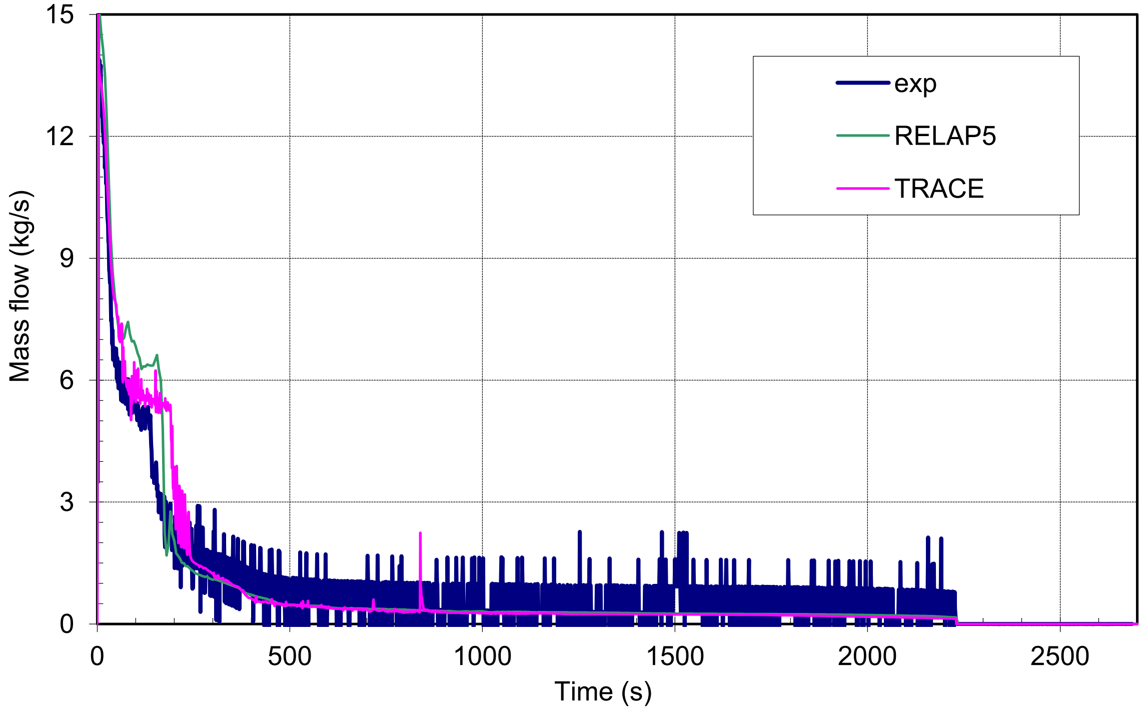

Figure 35 Break mass flow – BETHSY 6.2TC

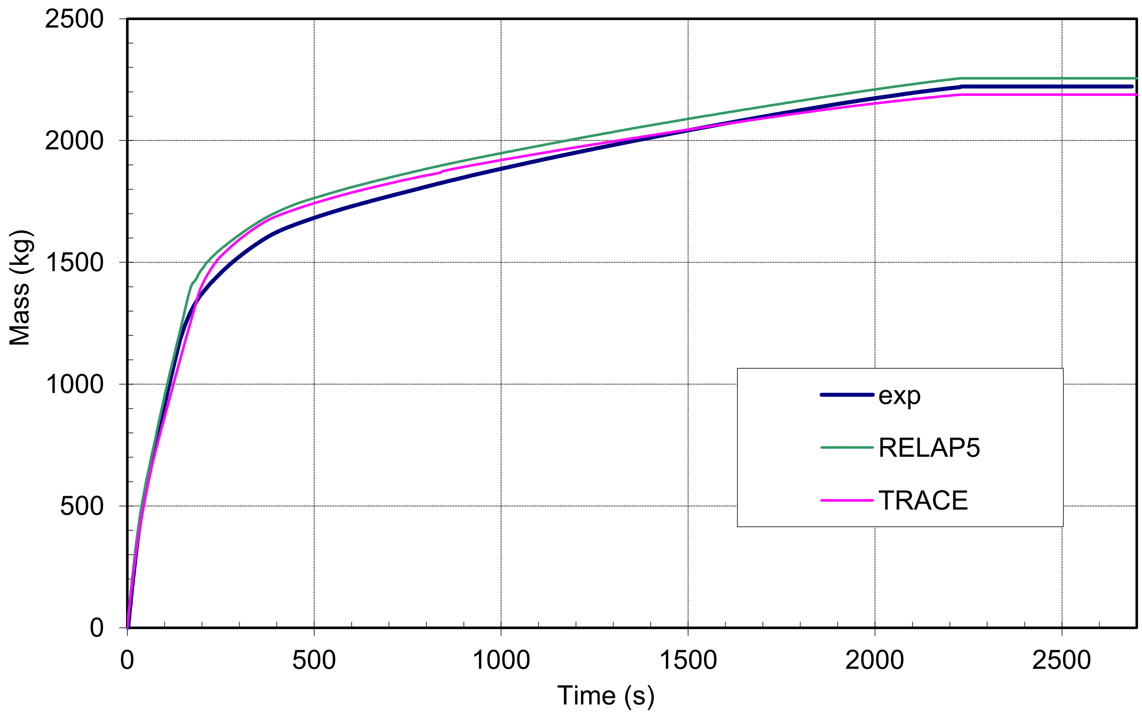

Figure 36 Integrated break mass flow – BETHSY 6.2TC

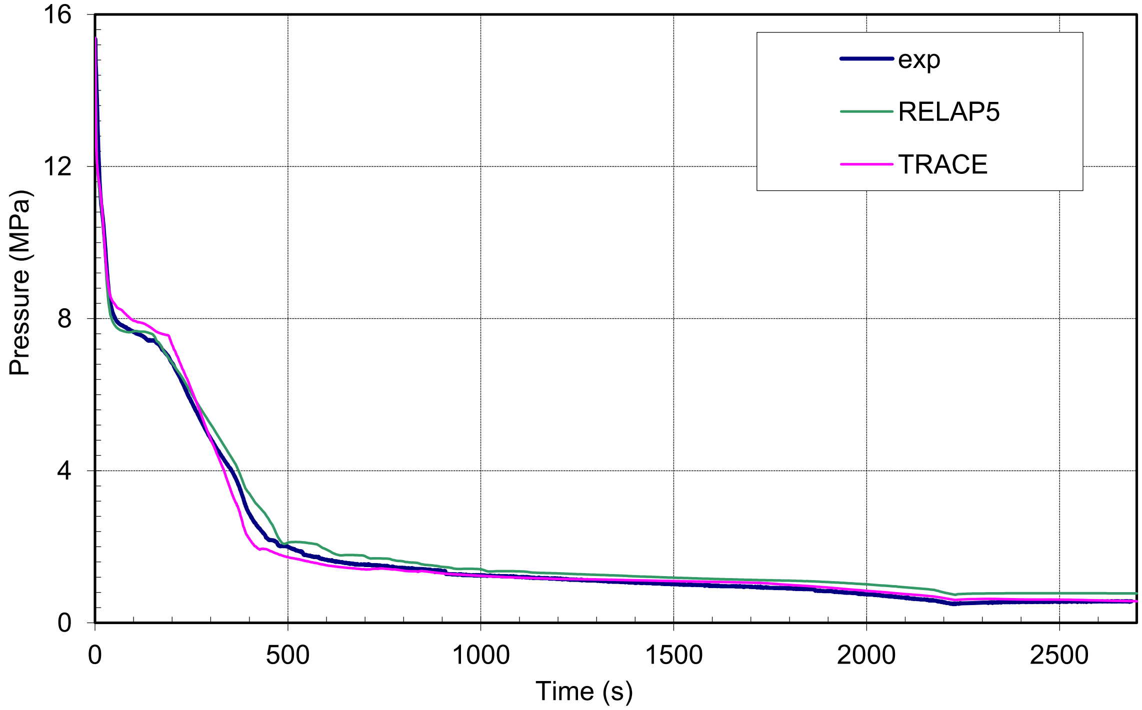

Figure 37 Pressurizer pressure – BETHSY 6.2TC

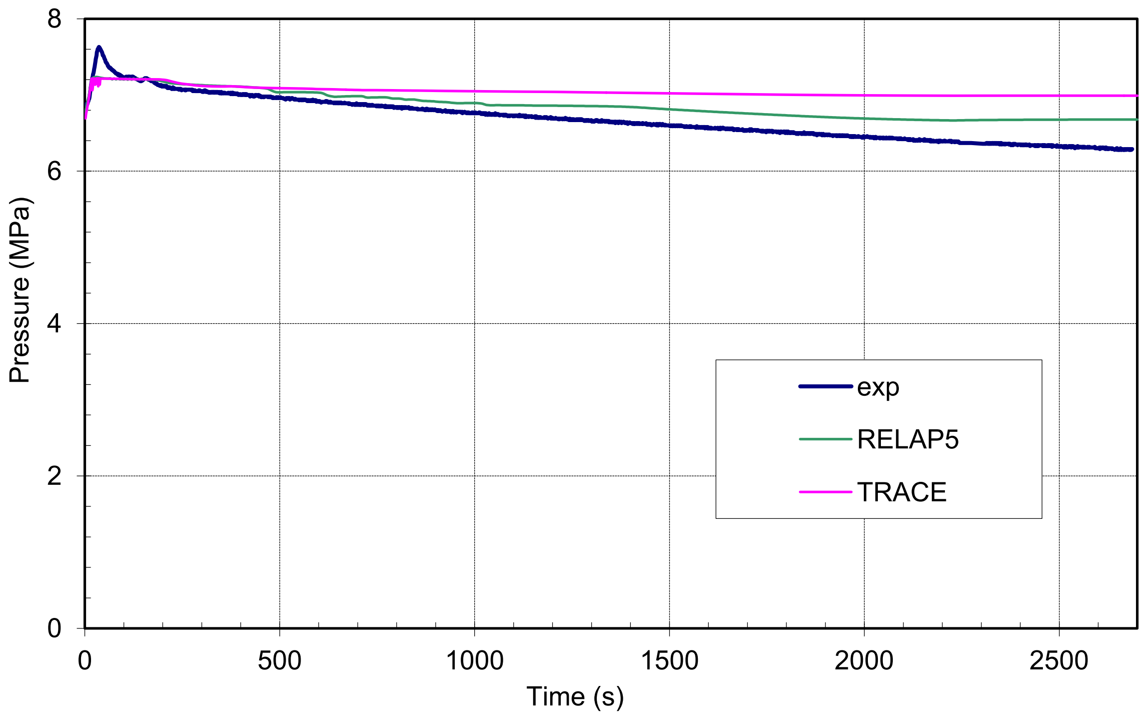

Figure 38 Steam generator 1 pressure – BETHSY 6.2TC

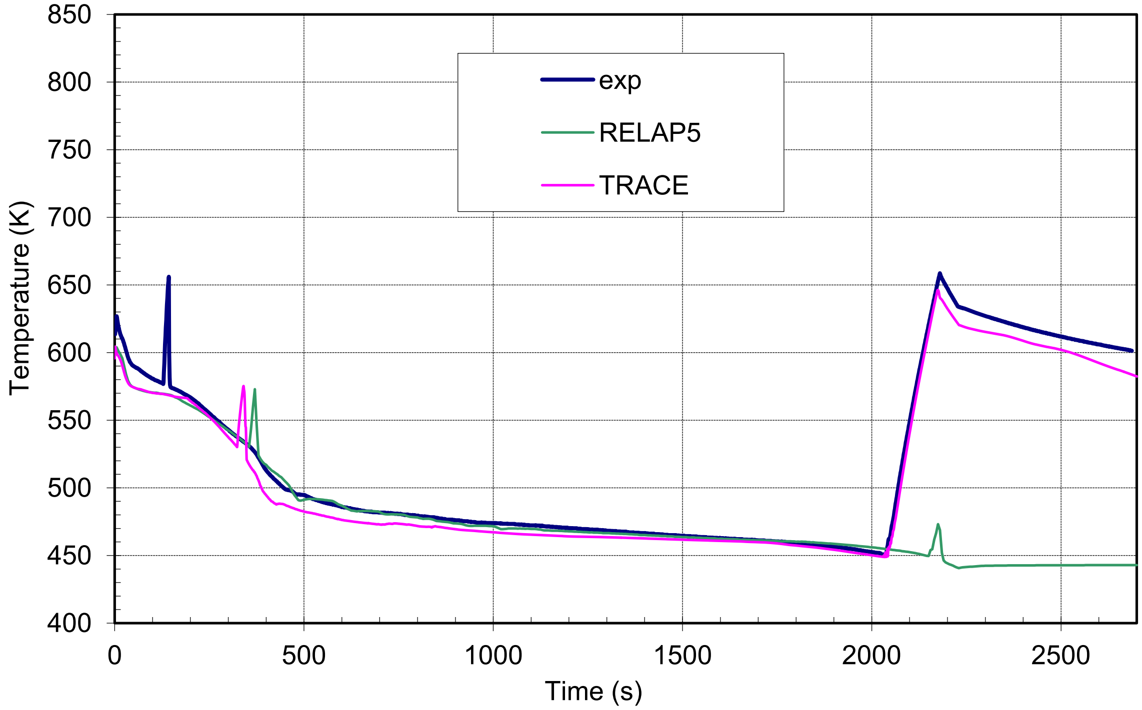

Figure 39 Heater rod surface temperature at the middle of the core – BETHSY 6.2TC

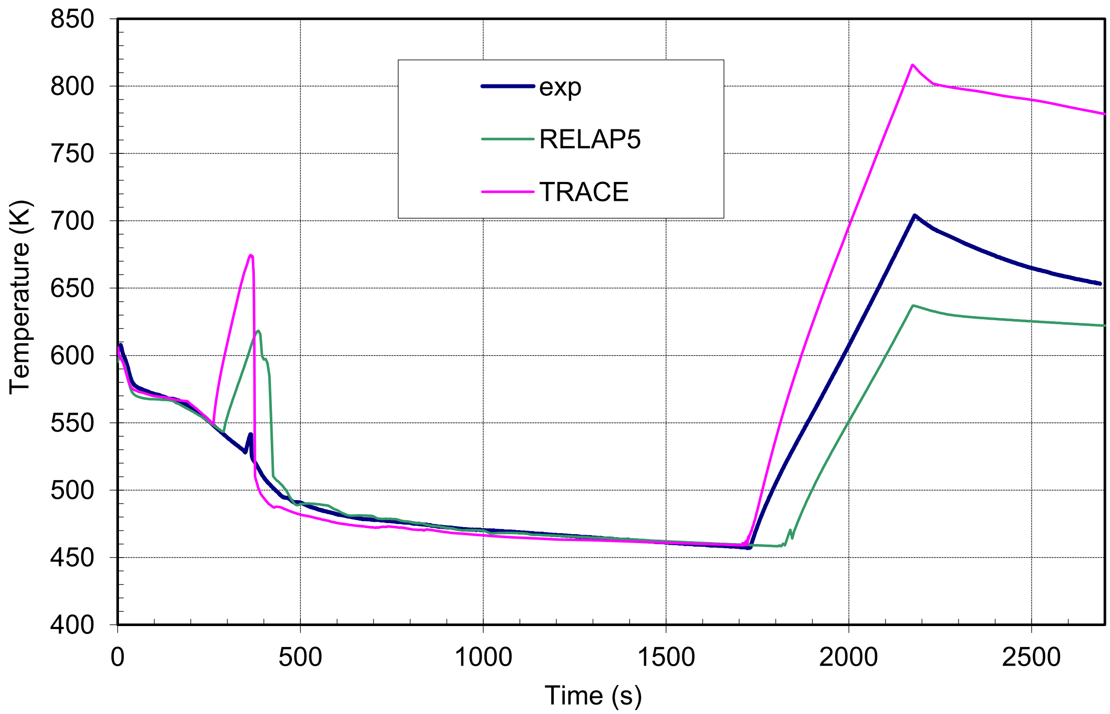

Figure 40 Heater rod surface temperature at the top of the core – BETHSY 6.2TC

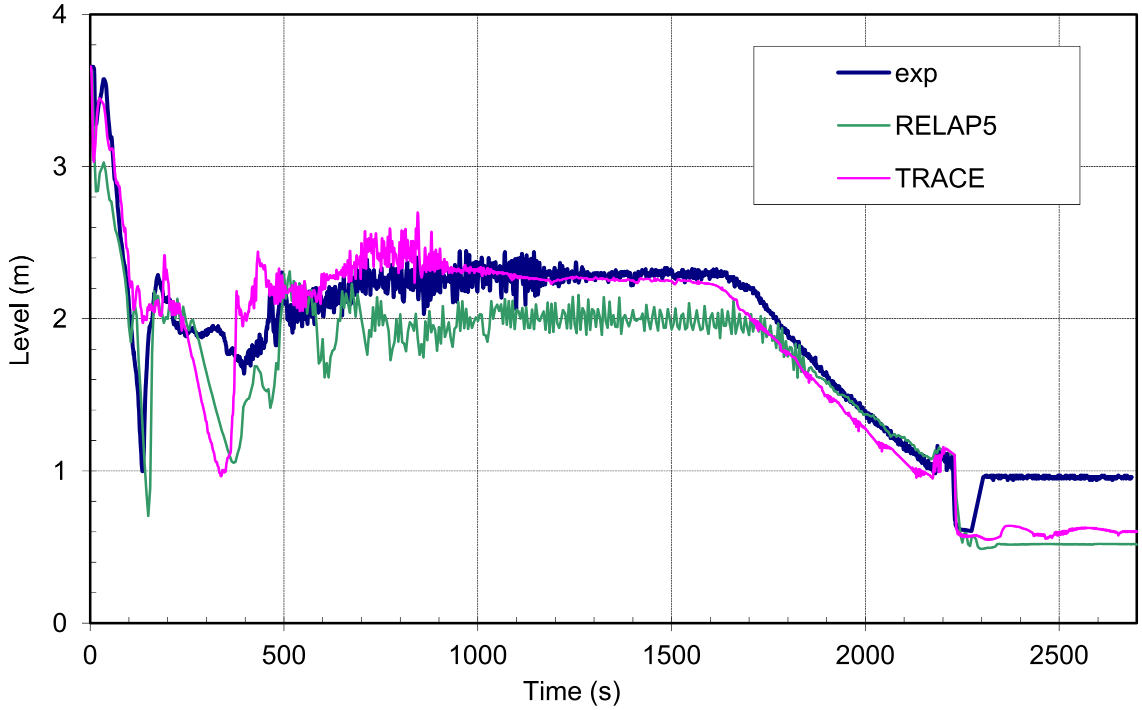

Figure 41 Core collapsed liquid level – BETHSY 6.2TC

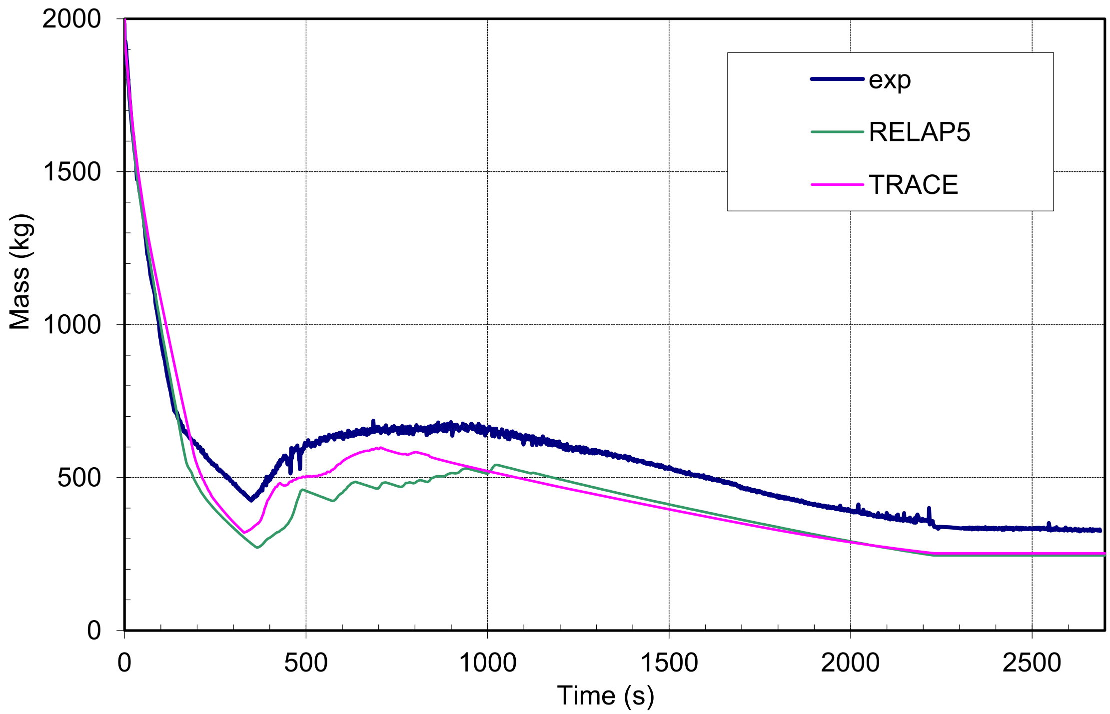

Figure 42 Total primary mass – BETHSY 6.2TC

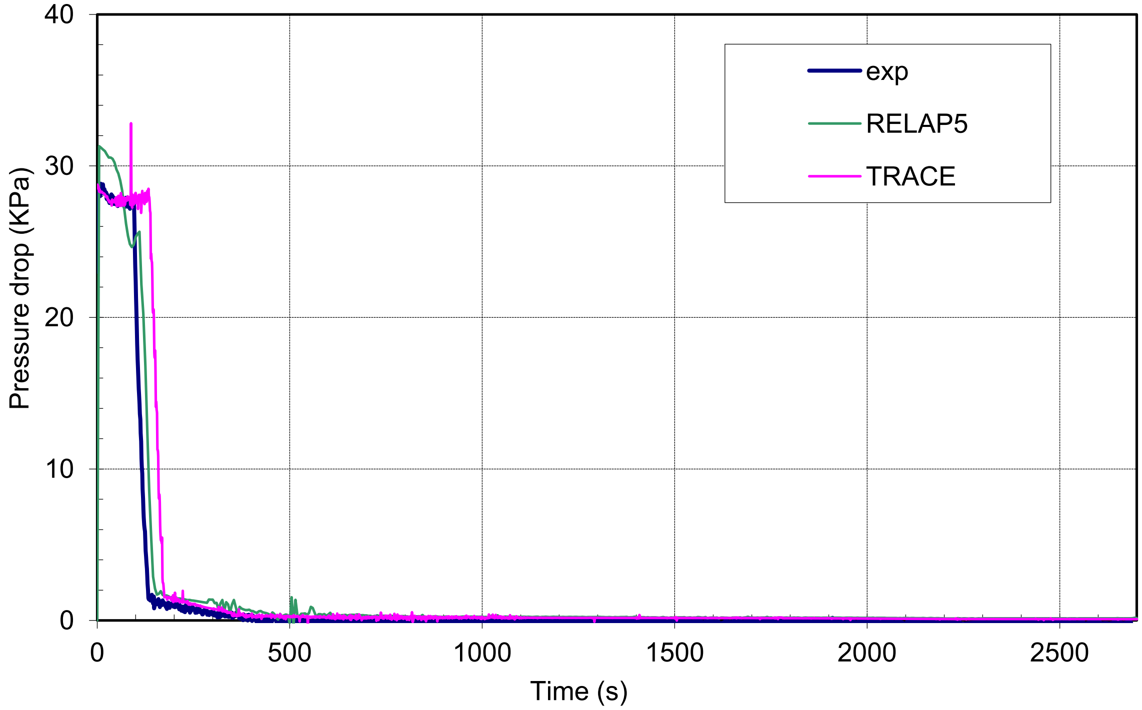

Figure 43 Intermediate leg 1 DP (SG side) – BETHSY 6.2TC

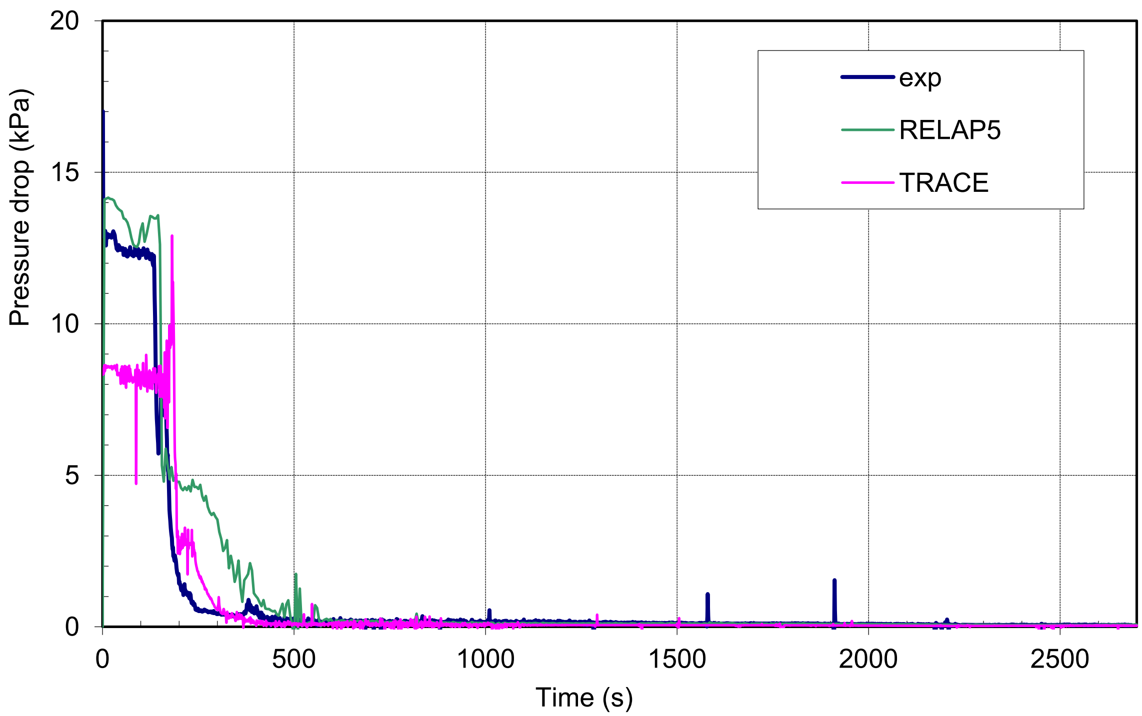

Figure 44 Intermediate leg 1 DP (pump side) – BETHSY 6.2TC

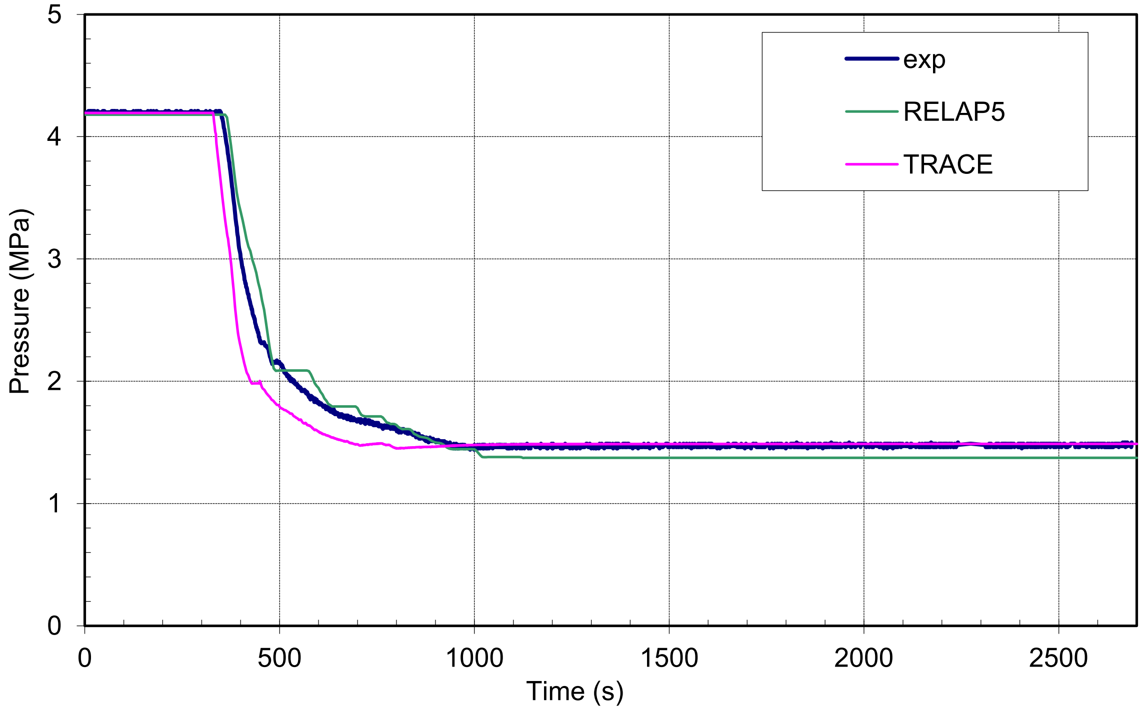

Figure 45 Accumulator no. 2 pressure – BETHSY 6.2TC

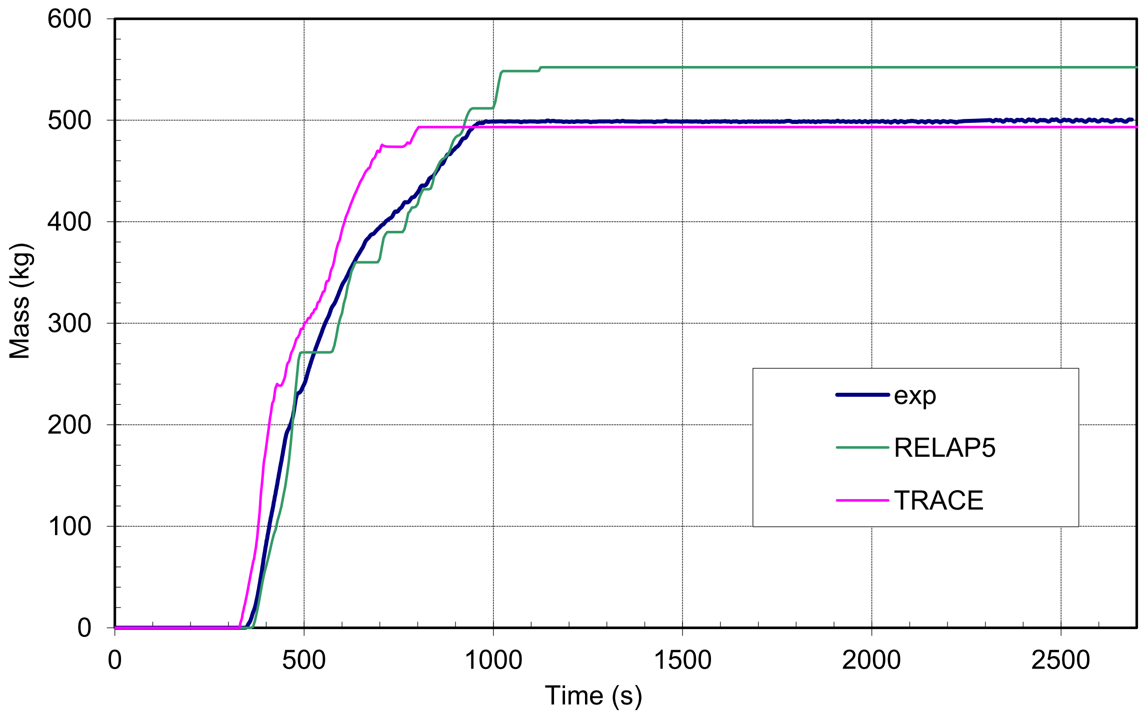

Figure 46 Integrated accumulators injected mass – BETHSY 6.2TC

7. CONCLUSIONS

In the report the IJS procedure for converting input deck from RELAP5 to TRACE is described. Besides, examples of conversion are given for separate effects test ACHILLES rig and integral effects test BETHSY facility. The conversion methodology consists of eleven steps and is based on SNAP. The ACHILLES and BETHSY legacy RELAP5 input decks were developed at IJS in the frame of participation to international standard problem no. 25 and international standard problem no. 27. These legacy input decks were successfully converted from RELAP5 to TRACE. Besides demonstration of the conversion methodology also the comparison between RELAP and TRACE has been done. It can be concluded that calculated results obtained by TRACE are as good as the results by RELAP5, thus suggesting that IJS conversion methodology may be used for separate and integral effect test legacy RELAP5 input deck conversions to TRACE input decks.

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10. SUPPLEMENTARY NOTES
A. Calvo, NRC Project Manager

11. ABSTRACT *(200 words or less)*

Much of efforts have been done in the past to develop the RELAP5 input decks. The purpose of this study is to present the RELAP5 to TRACE conversion procedure, developed at Institut “Jožef Stefan” (IJS). For demonstrating the conversion procedure the ACHILLES and BETHSY input decks (IJS legacy) were used using SNAP. The RELAP5 input decks of ACHILLES rig and BETHSY facility were developed in the frame of participation to international standard problem no. 25 (ISP-25) and international standard problem no. 27 (ISP-27). These RELAP5 legacy input decks were used for demonstration of the developed IJS conversion methodology, consisting of eleven steps. Besides demonstration of the methodology also the comparison between RELAP5 and TRACE has been done. It can be concluded that calculated results obtained by TRACE are as good as the results by RELAP5, thus suggesting that IJS conversion procedure may be used for conversion of separate and integral effect test legacy RELAP5 input decks to TRACE input decks.

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

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RELAP5 input model
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