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Implementation of the Control Rod Movement Option by means of Control Variables in RELAP5/PARCS v2.7 Coupled Code

Prepared by:
R. Miró[1], P. Ana[1], T. Barrachina[1], J. C. Martínez-Murillo[2], C. Pereira[3], G. Verdú

[1]Institute for Industrial, Radiophysical and Environmental Safety (ISIRYM)
Universitat Politècnica de València
Camí de Vera, s/n
46022 Valencia, SPAIN

[2]Almaraz-Trillo AIE
Av Manoteras 46Bis
28050 Madrid, SPAIN

[3]Departamento de Engenharia Nuclear
Unversidade Federal de Mina Gerais
Av. Antonio Carlos, 6627
31270-901 Belo Horizonte, BRAZIL

K. Tien, NRC Project Manager

Division of Systems Analysis
Office of Nuclear Regulatory Research
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ABSTRACT

The objective of this work is to introduce an improvement in best estimate coupled neutronic-thermalhydraulic 3D codes simulations, by adding a model for the control rod movement in the coupled code RELAP5/PARCS v2.7, by means of control variables, with the aim of being able to dynamically analyze asymmetric transient accidents, as the reactivity insertion accidents (RIA) in a nuclear reactor, reproducing all the reactors control systems.

The modification developed in this work permits the automatic movement of the control rods, activated by the RELAP5 code control system, and also they can depend on signals related to the reactor reactivity, like pressure, fuel temperature or moderator temperature, etc., improving the realism of the calculation and increasing the simulation capabilities.

This report was prepared by the Nuclear Engineering Group belonging to the Institute for Industrial, Radiophysical and Environmental Safety (ISIRYM) at the Universitat Politècnica de València (UPV), which collaborates in the simulation area with the Spanish company Centrales Nucleares Almaraz-Trillo (CNAT). The Asociación Española de la Industria Eléctrica (UNESA, Electric Industry Association of Spain), equivalent to the American EPRI sponsored this work.

FOREWORD

This report represents one of the assessment or application calculations submitted to fulfill the bilateral agreement for cooperation in thermal-hydraulic activities between the Consejo de Seguridad Nuclear (CSN) and the U.S. Nuclear Regulatory Commission (NRC) in the form of a Spanish contribution to the NRC's Code Assessment and Management Program (CAMP), the main purpose of which is to validate the TRAC/RELAP Advanced Computational Engine (TRACE) code.

CSN and the Asociación Española de la Industria Eléctrica (UNESA, Electric Industry Association of Spain), together with some relevant universities, have established a coordinated framework (CAMP-Spain) with two main objectives: to fulfill the formal CAMP requirements and to improve the quality of the technical support groups that provide services to the Spanish utilities, CSN, research centers, and engineering companies.

The AP-28 Project Coordination Committee has reviewed this report: the contribution of one of the Spanish utilities to the above-mentioned CAMP-Spain program, for submission to CSN.

UNESA

June 2010

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EXECUTIVE SUMMARY

The objective of this project is to introduce an improvement in simulations with coupled neutronic-thermalhydraulic 3D best estimate system codes, by adding a model for control rod movement in coupled code RELAP5/PARCS v2.7, by means of control variables, with the aim of being able to analyze asymmetric transient accidents, like the reactivity insertion accidents (RIA) in a nuclear reactor, reproducing all the reactors control systems.

In the neutronic simulation codes developed up to now, the control rods have not much movement versatility during a simulation. The commands for their movements are simply instructions which have to be introduced before the beginning of the calculation, and they are not related to the core characteristics and the control systems at any time of the simulation. Figure 1 shows an example of the conditions that are used until now:

```
   Scram          F    1000.0  0.0  1048.0
   move_bank  14     2.   0.   2.1  335.625
! The above values need checking
!!!!   theta       0.5    0.5    0.5
```

Figure 1 Fragment of PARCS v2.7 input file

Figure 1 shows the order for the movement of control rod bank number 14: the movement begins in second 2.0, so that in 0.1 seconds that bank moves from totally inserted position to 335.625, position that means totally withdrawn in this example (*move_bank* command).

In this work many changes are introduced in RELAP5/PARCS v2.7 codes in order to achieve that control rods become a more dynamic component in these kind of simulators.

With the modification developed in this work, control rods can be moved automatically, activated by the RELAP5 code control system, and they can also depend on signals related to the reactor activity, like pressure, fuel temperature or moderator temperature, etc., improving the realism of the calculation and widening the simulation possibilities.

The environment of work chosen have been the graphic programming environment Compaq Visual Fortran 6.6A (CVF 6.6A). The fundamental reasons have been, on one hand the facility of programming and versatility of the debugger of this environment, and on the other hand the fact that PARCS v2.7 source code already came prepared for this environment. RELAP5 distribution did not come prepared for this programming environment, its compilation used to be made with *shell script* files for UNIX or CYGWIN operating systems, being all the process hidden for the user. Therefore, it was necessary to adapt the RELAP5 source code to the CVF 6.6A.

ABBREVIATIONS

BWR	Boiling Water Reactor
CAMP	Code Assessment and Management Program
CSN	Consejo de Seguridad Nuclear (Spanish Nuclear Regulatory Commission)
ID	Identification Number
NRC	U.S. Nuclear Regulatory Commission
PARCS	Purdue Advance Reactor Core Simulator
PVM	Parallel Virtual Machine
PWR	Pressurized Water Reactor
SCRAM	Safety Control Rod Axe Man (Emergency Reactor Shutdown)
SNAP	Symbolic Nuclear Analysis Package
VVER	Voda-Vodyanoi Energetichesky Reaktor (Russian Pressurized Water Reactor)

1. INTRODUCTION

The coupled code RELAP5/PARCS v2.7 is a neutronic-thermalhydraulic code that can be used to simulate transient accidents considering neutronic phenomena in 3D geometry and thermalhydraulic processes in 1D multiple channels geometry.

As thermalhydraulic module, it uses the optimal estimation code RELAP5, which implements a two fluid and six-equations model to simulate the thermalhydraulic phenomena. This computer code has models for normal components of regular Light Water Reactors (LWR), like valves, pumps, heat sources, etc.

The fuel elements in the reactor core are modeled with multiple channel components. For modeling the heat transfer in the fuel, an axial-radial heat transfer equation is used. The thermalhydraulic processes are solved with six equations: mass balance, moment and energy for the both liquid phase and steam.

As a neutronic module, it uses the nodal core simulator PARCS v2.7, which simulates the dynamic response of the reactor to reactivity disturbances solving the neutron diffusion equation in steady and transient states. This code is applicable to PWR, BWR and VVER, with rectangular or hexagonal fuel elements. PARCS v2.7 solves the neutron diffusion equation with the two energy groups approach for rectangular geometries and with any number of energy groups for hexagonal geometries. With this code it is possible to obtain the 3D space distribution of neutron flux and power, as well as its time evolution.

RELAP5 and PARCS v2.7 can be executed in a stand-alone way as well as coupled.

Coupled code RELAP5/PARCS v2.7 uses an internal integration scheme in which the thermalhydraulic solution is obtained from RELAP5 and the kinetic space solution is obtained from PARCS v2.7. PARCS uses the data from the thermalhydraulic solution (moderator temperature and density and fuel temperature) calculated by RELAP5 to incorporate the effects of the feedback through the cross sections. RELAP5 also solves the heat conduction in the heat structures of the core using the power distribution calculated by PARCS.

The temporal coupling of both codes is explicit. Essentially, the advance of time steps begins with RELAP5, which obtains the solution of the hydrodynamics field equations using the power of the previous time step. Later, the power in the time step in process is calculated by PARCS with the data provided by RELAP5.

The coupling between these two codes is obtained through a communication protocol between both processes (Parallel Virtual Machine - PVM). Both processes are executed in parallel and PARCS transfers the data of nodal power to RELAP5. After that, RELAP5 gives back the information of temperature (of fuel and moderator) and the moderator density to PARCS.

The coupling is made in an external form via PVM (Parallel Virtual Machine) (see Appendix B). Daemon *pvm3d* has to be working prior in all the machines that are going to share their computing resources with the virtual parallel machine, that is, it connects the execution of our programs with PVM: the administration of communication mechanisms between machines, the automatic conversion of data and the hiding of the network to the programmer.

The neutron nodal structure is generally different from the nodal structure of the thermalhydraulic model. This difference is solved with a nodal mapping written in a file called MAPTAB, where the fractions of the different thermalhydraulic nodes associated with each neutron node are specified.

The MAPTAB file allows the neutron and thermalhydraulic nodes association and also allows the definition of the reflector properties and the election of the calculation method for the Doppler temperature.

2. ACTION CRITERIA FOR THE CODE MODIFICATION

The adopted criteria to approach the implementation the modifications in the codes are the following:

- RELAP5 Control Variables will be used to move the control rod banks of the reactor core.
- The variables have to be introduced in the MAPTAB file, using the card %CRSIG.
- The Control Variables' identification numbers will be introduced by order, so that the first will move control rod bank number 1, and so on. If a position is left with a "0" value, this will indicate that the corresponding control bank will not be moved, and therefore it will maintain its initial position during the whole transient.

```
*   MAPTAB FILE FOR TRILLO_15
*
%DOPL
*
LINC  0.15
*
*
%TRIP
700
*
*
%CRSIG
521  0  522  523
*
*
%REFLPROP
```

Figure 2 Data entry in MAPTAB file

- Each control rod bank will be controlled only by one control variable. For each time step, the position of the control rod bank will be equal to the value of the corresponding RELAP5 Control Variable in that time step.
- User can opt for moving the control rods with the original method or using this new option, though this new option dominates over the previous one. Thus, if user implements the card %CRSIG in the MAPTAB file, control rods will be moved using the new option, although in the PARCS input deck the standard movement commands were also implemented (as in the normal case up to now).
- It is recommendable that the initial positions of the control rods in RELAP5 correspond with the initial positions indicated in the PARCS input file, but again, the initial values introduced in RELAP5 will dominate the situation.

3. DEVELOPMENT OF THE INTRODUCED MODIFICATIONS

Subsequently, the modifications carried out in RELAP5 and PARCS v2.7 codes are detailed in order to obtain the goal of the work. The modifications are explained step by step, in the same order in which they were introduced in the programs.

The behavior of both programs in a coupled calculation is explained step by step, for a given time step. That is, during a coupled calculation, the program will execute repeatedly the actions that are going to be described, once for each time step, until the end of the calculation is reached.

3.1 First time step: ID’s reading from MAPTAB and the sending to RELAP5

The first goal to reach is the acceptance from RELAP5 of the Control Variables identification numbers (ID’s) introduced in the MAPTAB file. This modification can only be achieved introducing changes in the source codes of both programs. Otherwise, there would be more information than the needed in the MAPTAB file and the program would not be able to function correctly or simply do not to carry out the calculation on having errors detected during this file processing.

In order to achieve that, PARCS v2.7 source code has been modified first, specifically, routines **pdmr_varM.f** and **pdmr_mapM.f**, that take charge of the following:

- **pdmr_varM.f**: It collects the statement of PARCS v2.7variables, that is, this file contains the declaration of the most important variables of PARCS v2.7. New variables ***var_leidas(1000)*** and ***n_var*** have been introduced here. The former serves to store the read data, to a maximum of 1000 numbers, while the latter, is only used to know how many data have been stored in total (see the following figure).

```
! Miscellaneous Calculational Control Variables:
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!  Pablo Ana  /  rmiro - UPV
      INTEGER(4)   ::  var_leidas(1000), n_var, mov_cr_relap
      real(8)      ::  var_cntrl(1000)
      integer(4)   ::  contador
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
      INTEGER(4)      ::  itrip, idopl
      INTEGER(4)      ::  ncrcntl
      REAL(8)         ::  wdopl
      REAL(8)         ::  tppm, ppmratio, corepow
      LOGICAL         ::  crcntl
      LOGICAL         ::  automap, lis3d, lisVsslByp, lisWaterRod
      CHARACTER(6),   ALLOCATABLE  ::  hsdscr(:)
      INTEGER(4),     ALLOCATABLE  ::  isgv(:), sgvbank(:)
      REAL(8),        ALLOCATABLE  ::  newcrp(:), initcrp(:)
```

Figure 3 Declaration of variables in PARCS v2.7 subroutine pdmr_varM.f

- **pdmr_mapM.f:** this routine processes the MAPTAB file. Specifically, subroutine **pdmr_map_readmat(icode)** has been modified. A new loop has been introduced that takes care of reading the information introduced in the card *%CRSIG* in the MAPTAB file. If the code is being executed coupled with RELAP5, the program processes the MAPTAB file, and upon detecting the card *%CRSIG*, reads the information introduced in next line. The read data are stored in the new variable ***var_leidas***, and the total number of read data is also stored, in the variable ***n_var***, declared also in PARCS v2.7 (see figure 4).

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!  Pablo Ana  /  rmiro - UPV
! Read control rod position control variables for RELAP.

        ELSEIF (table(1:5) .EQ. 'CRSIG' .AND. icode .EQ. RELAP5) THEN
          IF (iread .EQ. 2) THEN
              READ(line,*,err=900,end=900)
              n_var=nfields(line)
              READ(line,*,err=900,end=900) (var_leidas(i),i=1,n_var)
          ENDIF
          mov_cr_relap=1

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
! Read control rod position signal variable for TRAC-M.
```

Figure 4 Data reading and storage in PARCS v2.7 routine pdmr_mapM.f

The PARCS function **nfields** has been used in this loop. This function is capable of identifying the different data introduced in the line that has been read by the code, to determine the amount of data to be processed.

Before storing the data in the variable, it should be initialized before the previous loop (see figure 5).

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!  Pablo Ana  /  rmiro - UPV
      DO i=1,1000
        var_leidas(i)= -10000
      END DO
!!!!
      mov_cr_relap=0.0
!!!!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

Figure 5 Initialization of *var_leídas()* in PARCS v2.7 routine pdmr_mapM.f

Once the information introduced by the user have been stored, the following step is “the sending” of these variables ID’s read from MAPTAB file to the RELAP5 code. This information will permit the thermalhydraulic code to identify the Control Variables that will move the control rod banks, since it can be Control Variables that deal with other functions inside the program.

To carry out this information transfer, two new orders have been added in subroutine **gi_comm_sendbuf(iproc)** in **gi_commM.f** file (see the following figure). This addition has been made using the variable ***pneut%i4buf*** of the ***pneut*** Fortran structure as a reference. This variable is multidimensional and is used, among others things, for storing and transfer to RELAP5 the ID's of the RELAP5 *TRIP* that activates the PARCS SCRAM option.

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!  Pablo Ana  /  rmiro - UPV
          CALL pvmfpack( INTEGER4, var_leidas, 1000, istride, info)
          CALL pvmfpack( INTEGER4, n_var, 1, istride, info)
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
           IF (info .LT. 0) CALL gi_error_chkpvm(fpack,sendbuf,info)
           IF (errpvm_gi) GOTO 999
          CALL pvmfpack( REAL4, pneut%r4buf, dimbuf_neut(5), istride
     &,                 info)
           IF (info .LT. 0) CALL gi_error_chkpvm(fpack,sendbuf,info)
           IF (errpvm_gi) GOTO 999
          CALL pvmfpack( REAL8, pneut%r8buf, dimbuf_neut(6), istride
     &,                    info)
           IF (info .LT. 0) CALL gi_error_chkpvm(fpack,sendbuf,info)
           IF (errpvm_gi) GOTO 999
```

Figure 6 Data transfer to RELAP5, routine gi_commM.f

To achieve that changes previously introduced work correctly, it should be made a series of additional modifications in both PARCS v2.7 and RELAP5 codes.

For the neutronic code PARCS v2.7, a new declaration should be added in the routine **gi_commM.f** (see the following figure), otherwise, inside this routine, the program would not recognize the variables that it intends to send. It can be said, that it is a new declaration of variables ***var_leidas*** and ***n_var*** (the same had also to be done for variable ***contador*** and ***var_cntrl***, just as it will be explained further on).

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!  Pablo Ana  /  rmiro - UPV
     USE pdmr_commM, Only:var_leidas, n_var,
     & contador, var_cntrl
!!!!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

Figure 7 Variables declaration in PARCS v2.7 routine gi_commM.f

In the thermalhydraulic code RELAP5, it is necessary to introduce changes to correctly receive these variables from PARCS v2.7, without causing errors neither any problem on the program run. Some modifications have been made in the following routines:

- **r-var.f:** This routine contains the declaration of the most important variables of RELAP5. Here, two new variables have been declared, one to store the values of the Control Variables ID's and other to store the total number of transmitted ID's. These two variables store the information that comes from PARCS v2.7, for that it has been determined to call them in the same way they were declared in the neutronic code: ***var_leidas*** and ***n_var*** (see the following figure). Variables ***var_cntrl(1000)***, ***guardar_cntrlv(1000)*** and ***contador*** have been also declared here, but its function will be explained further on.

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!  Pablo Ana  /  rmiro - UPV
      integer(4)                   :: var_leidas(1000)
      real(8)                      :: var_cntrl(1000), guardar_cntrlv(1000)
      integer(4)                   :: contador
      integer(4)                   :: n_var
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

Figure 8 Variables declaration in RELAP5 subroutine r-var.f

- Subroutine **RDMR_Recv_PARCS_Buf()**, from file **r-commu.f**: This subroutine is responsible for receiving the information from PARCS. The information sent by PARCS with variable ***pneut%i4buf*** is received with a different name, ***i4bufn***, though the value of these variables is the same (figure 9).

```
#ifdef INT16
      call pvmfunpack( INTEGER2, i2bufn, dimbuf(3), istride, info)
#else
c SUN F90 Compiler V.1.2 maps integer*2 to integer*4.
      call pvmfunpack( INTEGER4, i2bufn, dimbuf(3), istride, info)
#endif
        if (info .lt. 0) then
          errcode = 6
          goto 999
        endif
      call pvmfunpack( INTEGER4, i4bufn, dimbuf(4), istride, info)
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!  Pablo Ana  /  rmiro - UPV
      call pvmfunpack( INTEGER4, var_leidas, 1000, istride, info)
      call pvmfunpack( INTEGER4, n_var, 1, istride, info)
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
        if (info .lt. 0) then
          errcode = 6
          goto 999
        endif
```

Figure 9 Data reception in RELAP5 routine r-commu.f

Once here, RELAP5 knows the value of variables ***var_leidas*** and ***n_var***, which will facilitate the following step.

3.2 Second step: Storage of the Control Variables' ID's in RELAP5 and transfer of the variables' values in each time step to PARCS v2.7

Once the information has been received from PARCS v2.7, it can be passed to the following step, which consists of the storage of the Control Variables values for each time step. We now remark that, the ID's of the control variables which will move the control rods in PARCS v2.7 from RELAP5, are stored in variable ***var_leidas***.

These ID numbers should be introduced according to the order explained previously, that is, the variable whose ID is written first, will be the responsible for controlling control rod bank number 1, the second variable will control bank number 2, and so on. If it the user wants to act on the banks 1 and 3, for example, then among the ID of variables 1, 3 and 4, a “0” should be written. This can be understood better with the example shown in the following figure:

```
*   MAPTAB FILE FOR TRILLO_15
*
%DOPL
*
LINC  0.15
*
*
%TRIP
700
*
*
%CRSIG
521  0  522  523
*
*
%REFLPROP
```

Figure 10 Fragment of MAPTAB file

In this example, the ID of control variables 521, 522 and 523 have been introduced. Variable 521 will control to the number rod bank 1, the bank number 2 will not suffer perturbations and will conserve its initial position, while variables 522 and 523 will move banks number 3 and number 4. The remainder control rod banks will conserve their initial position during all the calculation.

The following step consists of locating and storing the value of the RELAP5 Control Variables involved, for each time step. The locating is carried out by means of a simple search, using the CVF 6.6A *debugger* for going line by line during the debugging of the program process and locating the important variables.

Once realized the follow-up of the variables, the following modifications were implemented:

- Changes in the routine **r-var.f**: This routine gathers the declaration of the RELAP5 variables, reason why a new variable has been declared here, ***var_cntrl()*** that takes charge of storing, for each time step, the values of the Control Variables that move the control rod banks (see the following figure). As in the previous cases, in this figure more introduced variables appear, which will be explained later.

```
#ifdef WIN32
      INTEGER(4), ALLOCATABLE    ::   c2ibufn(:)
#endif
      logical, allocatable       ::   lbufn(:)
      integer(2), allocatable    ::   i2bufn(:)
      integer(4), allocatable    ::   i4bufn(:)
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!  Pablo Ana  /  rmiro - UPV
      integer(4)                 :: var_leidas(1000)
      real(8)                    :: var_cntrl(1000), guardar_cntrlv(1000)
      integer(4)                 :: contador
      integer(4)                 :: n_var
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
      real(4), allocatable       ::   r4bufn(:)
      real(8), allocatable       ::   r8bufn(:)
      real(8), allocatable       ::   vecnp(:)
      integer(4)                 ::   nvecnp
```

Figure 11 Declaration of the variable var_cntrl(1000) in RELAP5 routine r-var.f

- Changes in the subroutine **convar.f**: More auxiliary variables have to be declared (see the following figure) before loop in figure 13 can to be introduced. Specifically, the variable ***z*** has been declared, that is an auxiliary variable that will take the values for every step of calculation of the in figure 13, between 1 and the number of variables that are introduced in MAPTAB (***n_var***). This way, if ***n_var*** = 2, ***z*** will be equal to 1 for the first step of calculation of the loop and 2 for the second step of calculation.

```
       real*8 hold,var(4)
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!   Pablo Ana  /  rmiro - UPV
       integer i,ii,ir,ityp,j,l,m,z
!!!!   integer i,ii,ir,ityp,j,l,m
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
       logical tfail
```

Figure 12 Declaration of the variable *z*

<u>Working of Control Variables position storing loop in figure 13:</u>
The program performs a sweep along all the Control Variables introduced in RELAP5 input, so that for each of these variables, the corresponding instructions of the subroutine **convar.f** are processed.

The sweep is done by means of a loop, which maximum value is the total number of Control Variables. Thanks to the follow-up realized with the *debugger*, it can be known that variable ***cnvpnm(1,i)*** stores the ID of the Control Variable that is being processed for each value of ***i***, and the variable ***cnvarn (i)*** stores the value of the variable ***i*** for the time step in which we are.

With all this information, the implemented loop realizes a comparison between the above mentioned variable and ***var_leidas***, in this way it is possible to separate the variables entrusted to move the control rods of those that have some another function, and in this way the efforts are centered on these variables.

This way, for each value of ***i***, the loop will compare the values stored in ***var_leidas***, using the counter ***z***. If the value coincides, then the value of the control variable "ith" is stored in the position "zth" (that corresponds to the control bank number that moves the variable "ith"), of the variable ***var_cntrl(z)***.

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!  Pablo Ana  /  rmiro - UPV
        do z=1, n_var
          if (cnvpnm(1,i)==var_leidas(z)) then
             var_cntrl(z) = cnvarn(i)
          endif
        enddo
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

Figure 13 Storage loop for the control variables values in convar.f

The following scheme explains this process:

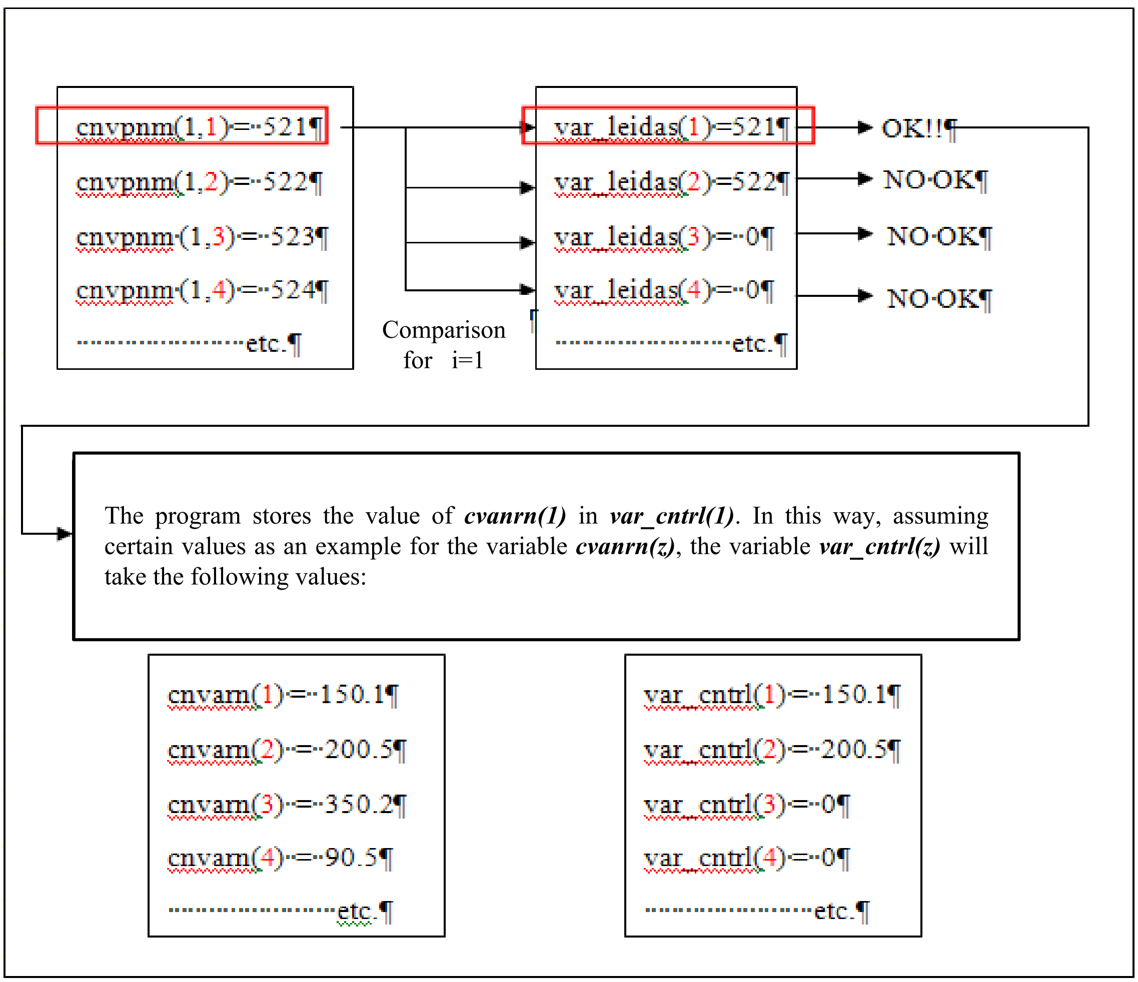

Figure 14 Working diagram of the loop shown in figure 13

Once here, all the information has to be sent to the neutronic code, which will be the one who finally uses these instructions to move the control rod banks.

In order to transfer of the information from RELAP5 to PARCS v2.7, the same steps have been followed that in the transfer of information from PARCS v2.7 to RELAP5 (that was explained previously). Studying a SCRAM activated by a RELAP *TRIP*, we found variable ***lbufth*** of RELAP5 and variable ***pth%lbuf*** of PARCS v2.7. These variables take charge of storing the same information, but each one do it in the corresponding program only.

These variables are those that use each code "to be informed" about if it is necessary or not to activate the SCRAM. The thermalhydraulic code is the one which decides if the *trip* is activated or not, depending on the calculation and the characteristics of the *trip*. If the *trip* is activated, then it will change its condition from "DEACTIVATED" to "ACTIVATED", i.e. from "0" to "1". The variable ***lbufth*** takes this logical value and then it is sent to PARCS v2.7.

The signal is then received by the neutron kinetics code by means of variable ***pth%lbuf,*** and activates or not the SCRAM depending on the value that has received from RELAP5. The knowledge of how this process works, has been of great help for the development of this work, since this variables have been used as a "guide" to transfer the new commands to the program. It is an easy form to assure that the information is sent in the correct calculation moment.

The commands to transfer the variable under study, ***var_cntrl***, which contains the positions that must have the control rod banks in every time step, were implemented just before the transfer of the variable ***lbufth***. In this way, the reception remains determined in PARCS v2.7 just before the reception of the above mentioned variable.

The following figure presents the fragments of the source code where these transfer and reception information commands have been implemented. Here, it can be remembered that it is important the rules of the programming language are accomplished in order that everything works correctly, that is, the information has to be of the same nature (real, integer), the dimension must be the same, etc., this is specified in the same command that transfers the information. In this figure, it can be also seen a loop that will be commented later on.

```
      endif
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!  Pablo Ana  /  rmiro - UPV
      if (contador==0) then
         do contador2=1,1000
         var_cntrl(contador2)=0
         end do
      contador2=1
         do contador2=1,n_var
                  if (var_leidas(contador2).gt.0) then
          var_cntrl(contador2)=guardar_cntrlv(var_leidas(contador2))
                  end if
      end do
      endif
       contador=contador+1
      call pvmfpack(real8, var_cntrl, 1000, istride, info)
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
      call pvmfpack( INTEGER4, lbufth, dimbuf(2), istride, info)
```

Figure 15 Fragment of modified RELAP5 routine r-commu.F

In the following figure, the implemented commands in PARCS v2.7's routine **gi_commM.f** for the reception of the information are shown. The above mentioned information reception command must respect also the rules of the programming language.

```
      IF (info .LT. 0) CALL gi_error_chkpvm(funpack,recvbuf,info)
      IF (errpvm_gi) GOTO 999
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!  Pablo Ana  /  rmiro - UPV
     CALL pvmfunpack( real8, var_cntrl, 1000, istride, info)
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
     CALL pvmfunpack( INTEGER4, pth%lbuf, dimbuf_th(2), istride
&,                    info)
```

Figure 16 Fragment of modified PARCS v2.7 routine gi_commM.f

3.3 Third step: control rod movement in PARCS v2.7 according to RELAP5 instructions

The last step consists of moving the control rod banks inside PARCS v2.7, following the directions received from RELAP5 for each time step.

The first thing that it is necessary to do, as in previous steps, is to perform a step by step tracking of PARCS v2.7 behavior using the debugger tool, to find the routine and variables that take care of the control rod movement.

This way, subroutine **perturb.f** was found. This subroutine processes all the control rod positions during the transient. Inside this subroutine, it is located the loop responsible for performing the control rods movement (figure 17):

```
      endif
! determine current crbank positions
      if (.not. scram) then
        do ib=1,npbanks
           id=idpbank(ib,1)
           nptb=idpbank(ib,2)
           do i=1,nptb
              if(tsgl.lt.tbank(i,1,id)) go to 200
           enddo
  200      iptbp1=i
           iptb=i-1
           if(iptb.lt.nptb) then
              crbpos(id)=fintp(tsgl,tbank(iptb,1,id),tbank(iptb,2,id))
           else
              crbpos(id)=tbank(iptb,2,id)
           endif
           if(crbpos(id).lt.0) crbpos(id)=0
        enddo
      else
```

Figure 17 Original loop for the control rod movement in PARCS v2.7 subroutine perturb.f

PARCS v2.7 carries out a loop over all the control rod banks, placing each of them in the correct position in each time step, according to the predefined movements included in the input file. If the time step in the calculation do not coincide with the predefined times in the input deck, then an interpolation scheme is used to calculate the intermediate position of the corresponding bank in each moment.

In this loop, the variable ***crbpos(id)*** stores the position for bank "***id***" in time step ***tsgl*** (variable that stores the calculation time). Variable ***tbank(i,1,d)*** is the responsible for storing the control rod positions that the user indicated in the PARCS v2.7 input file for each control rod bank.

For the implementation of the new loop, several calculation options must be taken into account, doing possible that the user executes any of them. The three calculation options are:

- <u>WITHOUT MODIFICATIONS.</u> Those cases in which the control rods do not move, or they move using the original way, that is, using the commands from PARCS v2.7 input file to define the positions of the rods in each moment.
- <u>WITH MODIFICATIONS.</u> In this case the rods will be moved receiving instructions from RELAP5; this option is the aim of this work.
- <u>SCRAM WITH TRIP.</u> This option can be used with any of the two previous ones, but with one more condition. In this case the transient is executed normally but can be SCRAMed by activating a trip from RELAP5.

To choose between these options, a new variable was introduced: ***mov_cr_relap***. The following figures present the declaration of variable in **pdmr_varM.f**, and the needed modifications for using this variable in the subroutine **perturb.f**:

```
! Miscellaneous Calculational Control Variables:
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!  Pablo Ana  /  rmiro - UPV
      INTEGER(4)   ::  var_leidas(1000), n_var, mov_cr_relap
      real(8)      ::  var_cntrl(1000)
      integer(4)   ::  contador
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
      INTEGER(4)      ::  itrip, idopl
      INTEGER(4)      ::  ncrcntl
      REAL(8)         ::  wdopl
```

Figure 18 Declaration of the variable *mov_cr_relap* in pdmr_varM.f

```
      subroutine perturb

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!  Pablo Ana  /  rmiro - UPV
      USE pdmr_commM, Only:var_leidas, n_var,
     & contador, var_cntrl, mov_cr_relap
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

Figure 19 Modifications introduced in perturb.f

The function of the variable ***mov_cr_relap*** is simple. The possible values of ***mov_cr_relap*** will be "0" or "1", depending on if the user has implemented (1) or not (0) card *%CRSIG* in the MAPTAB file. This control on the introduced information is obtained by setting the condition of the following figure in the subroutine **pdmr_mapM.f**.

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!  Pablo Ana  /  rmiro - UPV
! Read control rod position control variables for RELAP.

        ELSEIF (table(1:5) .EQ. 'CRSIG' .AND. icode .EQ. RELAP5) THEN
          IF (iread .EQ. 2) THEN
              READ(line,*,err=900,end=900)
              n_var=nfields(line)
              READ(line,*,err=900,end=900) (var_leidas(i),i=1,n_var)
          ENDIF
          mov_cr_relap=1

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
! Read control rod position signal variable for TRAC-M.
```

Figure 20 Condition for calculation mode selection in PARCS v2.7subroutine pdmr_mapM.f

If during the processing of the MAPTAB file, card *%CRSIG* is detected, the value of variable ***mov_cr_relap*** will change to "1". This information will be also used for selecting the execution option inside subroutine **perturb.f**.

If the value of this variable is "0", the program executes the original control rod movement PARCS v2.7 loop, without taking into account all the modifications implemented in the code, as can be seen in the following figure.

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!  Pablo Ana  /  rmiro - UPV
!!!!  Original control rod movement
      IF (MOV_CR_RELAP==0) THEN                                          !MOV_CF
!!!!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

      if (.not. scram) then                                              !scram
             do ib=1,npbanks
             id=idpbank(ib,1)
             nptb=idpbank(ib,2)
             do i=1,nptb
                if(tsgl.lt.tbank(i,1,id)) go to 200
             enddo
200         iptbp1=i
            iptb=i-1
             if(iptb.lt.nptb) then
               crbpos(id)=fintp(tsgl,tbank(iptb,1,id),tbank(iptb,2,id))
             else
               crbpos(id)=tbank(iptb,2,id)
             endif
             if(crbpos(id).lt.0) crbpos(id)=0
         enddo
      else                                                               !scram
        if (tscrmbeg .eq. 0.0) then                                      !scram
          tscrmbeg = time - delt                                         !scram
          print *                                                        !scram
          print *,"             ******************************"          !scram
          print *,"             *** Scram Signal Received ***"           !scram
          print *,"             ******************************"          !scram
          print *                                                        !scram
          write(ioutp,*)                                                 !scram
          write(ioutp,*)"             ******************************"    !scram
          write(ioutp,*)"             *** Scram Signal Received ***"     !scram
          write(ioutp,*)"             ******************************"    !scram
          write(ioutp,*)                                                 !scram
          do id=1,ncrb                                                   !scram
            pscrmbeg(id) = crbpos(id)                                    !scram
          enddo                                                          !scram
          pscrmend = 0.0                                                 !scram
        endif                                                            !scram
```

```
      do id=1,ncrb                                                        !scram
        tsum=0.0                                                          !scram
        do k=1,nz                                                         !scram
          tsum=tsum+hz(k)                                                 !scram
        enddo                                                             !scram
        if(isvel) then
! tony's test for pbtt
! use scramdelt as a cr insertion velocity
           crbpos(id) = pscrmbeg(id) - scramvel*(time-tscrmbeg)           !scram
        else
           scramstep = ((tsum-crbpos0)/crbstep)*delt/scramdelt            !scram
           tscrmend = tscrmbeg+scramdelt                                  !scram
           crbpos(id) = crbpos(id) - scramstep                            !scram
        endif

        if (crbpos(id).lt.0) crbpos(id)=0.0                               !scram
      enddo                                                               !scram
    endif

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!  Pablo Ana  /  rmiro - UPV
      END IF                                                              !MOV_CR
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

Figure 21 Condition for loop selection in PARCS v2.7 subroutine perturb.f

If the value of the variable ***mov_cr_relap*** is "1", this means that the user has introduced the card *%CRSIG* in MAPTAB file, and therefore the loop that moves the rods will be the new one implemented in PARCS v2.7 (figure 22).

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!  Pablo Ana  /  rmiro - UPV
!!!!
      IF (MOV_CR_RELAP==1) THEN
!
      if (.not. scram) then                                                !scram
         do i_mov_cb=1,n_var
            if (var_leidas(i_mov_cb) .ne. 0) then
               crbpos(i_mov_cb)=var_cntrl(i_mov_cb)
            endif
            if(crbpos(i_mov_cb).lt.0) crbpos(i_mov_cb)=0
         enddo
!
      else
!                                                                          !scram
        if (tscrmbeg .eq. 0.0) then                                        !scram
          tscrmbeg = time - delt                                           !scram
          print *                                                          !scram
          print *,"             ******************************"            !scram
          print *,"             *** Scram Signal Received ***"             !scram
          print *,"             ******************************"            !scram
          print *                                                          !scram
          write(ioutp,*)                                                   !scram
          write(ioutp,*)"             ******************************"      !scram
          write(ioutp,*)"             *** Scram Signal Received ***"       !scram
          write(ioutp,*)"             ******************************"      !scram
          write(ioutp,*)                                                   !scram
          do id=1,ncrb                                                     !scram
            pscrmbeg(id) = crbpos(id)                                      !scram
          enddo                                                            !scram
          pscrmend = 0.0                                                   !scram
        endif                                                              !scram
        do id=1,ncrb                                                       !scram
          tsum=0.0                                                         !scram
          do k=1,nz                                                        !scram
            tsum=tsum+hz(k)                                                !scram
          enddo                                                            !scram
          if(isvel) then
! tony's test for pbtt
! use scramdelt as a cr insertion velocity
             crbpos(id) = pscrmbeg(id) - scramvel*(time-tscrmbeg)          !scram
          else
             scramstep = ((tsum-crbpos0)/crbstep)*delt/scramdelt           !scram
             tscrmend = tscrmbeg+scramdelt                                 !scram
             crbpos(id) = crbpos(id) - scramstep                           !scram
          endif

          if (crbpos(id).lt.0) crbpos(id)=0.0                              !scram
        enddo                                                              !scram
      endif
!
      END IF                                                               !MOV_C
!!!!
!!!!  end Pablo Ana  /  rmiro - UPV
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

Figure 22 New loop for the control rod movement in PARCS v2.7 subroutine perturb.f

The third calculation mode is the PARCS v2.7 original option. This option allows the activation of a SCRAM controlled by a RELAP5 *trip*. This option continues available for the user, that is, it is possible to move the rods using Control Variables, and at the same time a SCRAM is allowed when the corresponding RELAP5 *trip* indicates it.

To use this option it is necessary to proceed like PARCS v2.7 manual indicates. In MAPTAB file, it can be implemented a *%TRIP* card with the *trip* ID of RELAP5 that activates the SCRAM. The calculation will continue its normal course until this *trip* activates a total SCRAM.

4. RESOLUTION OF THE CONTROL ROD INITIAL POSITION PROBLEM

Once finished the previous steps, it was detected some mistakes in the implemented procedure. The first error was related to the control rod bank initial position.

The value that Control Variables take for each time step, and therefore the position that control rods must have, is obtained from the RELAP5 routine **convar.f**. The problem found was that this routine is processed since the first time step, so it is not possible to load the Control Variables initial values.

To obtain these initial values, routine **iconvr.f** was modified. This routine processes the Control Variables initial values. Variable ***cnvarn (i)*** was used for that purpose, it stores the initial values of all the Control Variables introduced in RELAP5. This information is passed to another variable, ***guardar_cntrlv()***, that can be manipulated with more freedom without concerning to normal behavior of the code (see figure 23).

```
   31    cnvarn(i) = max(min(cnvarn(i),cnvmax(i)),cnvmin(i))
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!  Pablo Ana  /  rmiro - UPV
   29    guardar_cntrlv(cnvpnm(1,i))=cnvarn(i)
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!   29     i = i + cnvlen(1,i)
      i = i + cnvlen(1,i)
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
   30  continue
c  Restore cnvpck values.
       i = filndx(27)
```

Figure 23 Initial values storing instructions in iconvr.f

The variable that stores these values is ***guardar_cntrlv()***, declared in the general variables declaration routine **r-var.f**, see the following figure, close to other variables that have been explained previously. The values are stored using the indexes in ***cnvpnm(1, i)***. This variable makes a sweep over all of the control variables introduced in RELAP5 input deck, depending on the values of ***i***. Variable ***guardar_cntrlv(1000)*** has also been declared here.

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!  Pablo Ana  /  rmiro - UPV
      integer(4)                   ::  var_leidas(1000)
      real(8)                      ::  var_cntrl(1000), guardar_cntrlv(1000)
      integer(4)                   ::  contador
      integer(4)                   ::  n_var
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
      real(4), allocatable         ::   r4bufn(:)
      real(8), allocatable         ::   r8bufn(:)
      real(8), allocatable         ::   vecnp(:)
      integer(4)                   ::   nvecnp
```

Figure 24 Declaration of the variable *guardar_cntrlv(1000)* in the RELAP5 subroutine r-var.f

In this way, the initial values of all the introduced Control Variables will be stored, up to a maximum of 1000, arranged according to the ID control variable number. For instance, the initial value of the Control Variable 521, let's suppose that it is *300.625*, will be in position “521” of the information storage variable, keeping ***guardar_cntrlv(521)*** = 300.625.

To be able to use the declared variable (***guardar_cntrlv()***) in routine **iconvr.f**, one more line of code had to be added, see the following figure, since the declared variable is not a global variable which can be recognized in all the routines of the program in a predefined form.

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!  Pablo Ana  /  rmiro - UPV
      use RDMR_Var_Decl
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
       implicit none
      include 'cmpdat.h'
      include 'comctl.h'
      include 'contrl.h'
      include 'convarc.h'
      include 'fast.h'
      include 'gentblc.h'
      include 'machas.h'
      include 'machss.h'
      include 'pumpblk.h'
      include 'trpblk.h'
      include 'turbin.h'
      include 'ufiles.h'
```

Figure 25 Fragment of the subroutine iconvr.f

Once the values of the Control Variables have been stored, a new loop has been programmed. This loop is entrusted to transfer the information from the new variable ***guardar_cntrlv()*** to the variable that will be sent to PARCS v2.7 with the position of each control rod bank: ***var_cntrl()***, which declaration can also be seen in the figure 24.

With all these variables and the implemented modifications the new loop has been coded.

Two new variables ***contador*** and ***contador2*** have been also declared at the beginning of subroutine **r-commu.f**.

```
#ifdef WIN32
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!  Pablo Ana  /  rmiro - UPV
        integer(4):: l, i, j, m, n, contador, contador2
!!!!!!!!integer(4):: l, i, j
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
#endif
```

Figure 26 Declaration of variable *contador* in RELAP5 routine r-commu.f

Contador has the mission to assure that loop on figure 27 is only processed once, that is, the first time step of the run. During the following time steps the assignment of values will be realized in the routine **convar.f**.

Variable ***contador*** takes by default an initial value of “0”, so, when it arrives to the position of the outer loop in figure 27, it fulfills the initial condition and the loop is processed. At the end of the loop variable ***contador*** is incremented one unit, so in the following time step the initial condition will not be fulfilled, and the loop will not be processed again.

The loop commands are simple: first, variable ***var_cntrl()*** is set to “0”. The following step consists of assigning to this variable the initial values of each Control Variable. For that, the code performs a sweep over all the positions in variable ***var_leidas()***, that stores the ID’s of the Control Variables introduced in the MAPTAB file that will move the control rods groups.

Afterwards, it will make a comparison and, for those positions which their values are not zero, will assign the Control Variable initial value. Here it is possible to figure out why the zeros in the file MAPTAB have to be introduced.

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!  Pablo Ana  /  rmiro - UPV
      if (contador==0) then
         do contador2=1,1000
         var_cntrl(contador2)=0
         end do
      contador2=1
         do contador2=1,n_var
                if  (var_leidas(contador2).gt.0) then
          var_cntrl(contador2)=guardar_cntrlv(var_leidas(contador2))
                end if
      end do
      endif
       contador=contador+1
      call pvmfpack(real8, var_cntrl, 1000, istride, info)
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

Figure 27 Loop in r-commu.f

The process is explained graphically in figure 28’s scheme, where it is summarized a simple case in which two control variables ID’s have been used in MAPTAB file.

Values read from MAPTAB file

var_leidas(1) = 521
var_leidas(2) = 0
var_leidas(3) = 522
var_leidas(4) = 0

The positions 1, 2, etc. are the values of the variable ***contador2***. The value represents one of the control variables of RELAP5. In this example, the bank No. 1 will be moved by the control variable 521 and the bank No. 3 will be moved by the control variable 522.

Initial values of the control variables introduced in MAPTAB file

guardar_cntrlv(1) = 0.0
guardar_cntrlv(2) = 0.0
.
.
.
guardar_cntrlv(521) = 300.625
guardar_cntrlv(522) = 300.625
.
.
.
guardar_cntrlv(998) = 0.0
guardar_cntrlv(999) = 0.0

The variable ***guardar_cntrlv*** will store, in this case, the initial values of the variables 521 and 522.

var_cntrl(1) = guardar_cntrlv(var_leidas(1)) = 300.625

var_cntrl (2) = 0*

var_cntrl (3) = 300.625

var_cntrl (4) = 0*

*The control rod banks which are not modified with the control variables will keep their initial position defined in the PARCS input file.

Figure 28 Working sequence of the initial values loop

5. RESOLUTION OF THE TIME SHIFT PROBLEM

With all these introduced changes it was realized that the program moves correctly the control rods, following the instructions indicated by user, but with a shift in the time step. The position of the control rods was always set one time step after the desired step.

To correct this behavior, the program was analyzed with the *debugger*. It was enough to put the calling to subroutine **convar** before the calling to **rdmr** in subroutine **tran.f**, to solve the problem. With the new configuration, the values of the Control Variables are updated before sending the information to PARCS v2.7, for what the lag between the programs disappears, see the following figure:

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!  Pablo Ana  /  rmiro - UPV
c  Call control system advancement.                                    1
        if (filid(27) .ne. 0.0d0) call convar
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

c  Advance reactor kinetics.
cww
*if def,parcs
        if (.not. fail .and. chngno(88)) then                          2
           call rdmr(.false.)
        else
*endif
          if (filid(21) .ne. 0.0d0) call rkin
*if def,parcs
        endif
*endif
c  Call post-hydro scdap routines.
*if def,selap
*       if (scntrl(1)) call scdpsh
*endif
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!  Pablo Ana  /  rmiro - UPV
!!!!c  Call control system advancement.                                 3
!!!!    if (filid(27) .ne. 0.0d0) call convar
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

Figure 29 Fragment of the subroutine tran.f

In the original source code the line No. 3 was in use and was processed by the program. In line No. 2, a call to the routine **rdmr** transfers the information between both codes using the *pvm* library. Due to the former calling sequence the transfer of information was done first, i.e., line No. 2 was processed before the calling to **convar** (line No. 3).

Line No. 3 has been changed to position No. 1, obtaining thus the update of the Control Variables values before its transfer to PARCS v2.7. With this simple modification, and after the necessary checking to assure that these changes were not concerning the results of the original programs, the final aim of this work was achieved.

6. QUALIFICATION OF THE MODIFICATIONS INTRODUCED

In order to test that the modifications have been introduced properly, a Rod Ejection Accident (REA) transient to test the control rod movement modifications.

The Rod Ejection Accident (REA) belongs to the RIA category of accidents and it is part of the licensing basis accident analyses required for pressurized water reactors (PWR). The REA at hot zero power (HZP) is characterized by a single rod ejection from a core position with a very low power level. The evolution consists of a continuous reactivity insertion. The main feature limiting the consequences of the accident in a PWR is the Doppler Effect.

The reactor core studied is composed of 177 fuel elements, being the number of fuel rods per fuel element equal to 236 with 20 guide tubes. The neutronic model represents the whole core: the nodal discretization consists of 177 x 32 active nodes, considering 20 different fuel elements with 611 neutronic compositions. The cross-sections tables are generated with the SIMTAB methodology from CASMO4-SIMULATE3 code, developed at Universitat Politècnica de València, together with Iberdrola.

The model uses two prompt neutron groups and six delayed neutron groups, while the boundary condition for the neutron diffusion equation is zero-flux at the outer reflector surface.

Radially, the core is divided in 23 cm x 23 cm cells, each corresponding to one fuel assembly, plus a radial reflector. There are 177 fuel assemblies and 64 reflector assemblies.

Axially, the core is divided into 34 layers (32 fuel layers plus top and bottom reflector) with 10.625 cm height each one, with a total active core height of 340 cm.

The Doppler temperature (T_f) calculated by PARCS v2.7 code is found from the fuel temperature at the fuel rod center T_{fc} and at the fuel rod surface T_{fs} by the relation:

$$T_f = (1-\alpha)\cdot T_{fc} + \alpha \cdot T_{fs}$$

where α is taken as equal to 0.7.

The thermalhydraulic model has been performed using RELAP5-MOD3.3 code. The reactor core has been modeled with 10 thermalhydraulic channels connected with a multiple junction (MTPLJUN) and the by-pass has been modeled as an independent channel (figures 30 and 31). Each one of the channels has 34 axial nodes. The axial nodes 1 and 34 represent the non-active core region. A time dependent volume (TMDPVOL) and a time dependent junction (TMDPJUN) simulate the boundary conditions at the entrance and exit of the reactor core. Each thermalhydraulic channel representing the core is connected to a heat structure.

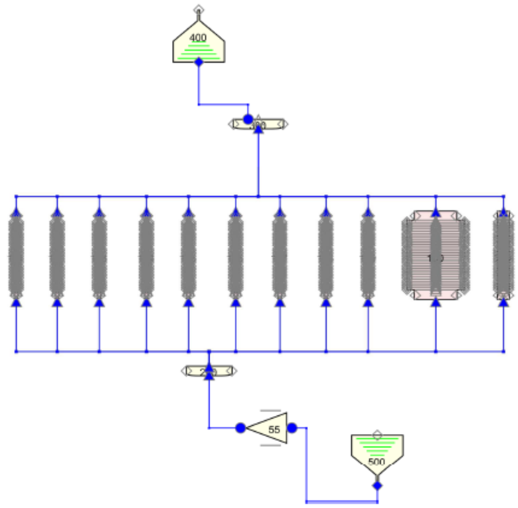

Figure 30: SNAP representation of the thermalhydraulic model

Q	P	O	Ñ	M	L	K	J	I	H	G	F	E	D	C	B	A	
					0	0	0	0	0	0	0						1
			0	0	0	100	100	100	100	100	0	0	0				2
		0	0	100	100	100	100	100	100	100	100	100	0	0			3
	0	0	100	100	100	100	100	100	100	100	100	100	100	0	0		4
	0	100	100	100	100	100	100	100	100	100	100	100	100	100	0		5
0	0	100	100	100	100	100	100	100	100	100	100	100	100	100	0	0	6
0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0	7
0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0	8
0	100	100	100	100	100	100	100	100	100	100	100	102	103	104	100	0	9
0	100	100	100	100	100	100	100	100	100	100	100	105	101	106	100	0	10
0	100	100	100	100	100	100	100	100	100	100	100	107	108	109	100	0	11
0	0	100	100	100	100	100	100	100	100	100	100	100	100	100	0	0	12
	0	100	100	100	100	100	100	100	100	100	100	100	100	100	0		13
	0	0	100	100	100	100	100	100	100	100	100	100	100	0	0		14
		0	0	100	100	100	100	100	100	100	100	100	0	0			15
			0	0	0	100	100	100	100	100	0	0	0				16
					0	0	0	0	0	0	0						17

Figure 31: Thermalhydraulic channels

Previous analysis determined that the control rod with the maximum worth belongs to the bank number 6 and it is located at position D-10. The thermalhydraulic channels surrounding the ejected control rod have been modeled as independent channels, while the others have been grouped in a unique channel (figure 31).

Control rods are grouped in 13 banks: initially banks 1, 5 and 6 are totally inserted and the other ones are out of the core. Figure 32 shows the control rods banks and the ejected rod D-10 is highlighted in red.

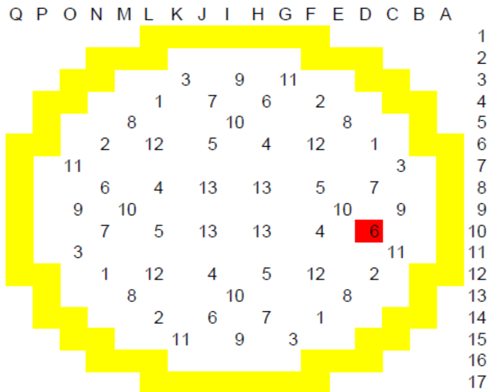

Figure 32: Control rods banks

RELAP5 and PARCS v2.7 input decks are provided in the annex for running this example, for both the original option and the new capability.

To compare the results using the older and the new option for the control rod movement, two parameters has been chosen: power and enthalpy. The results obtained are shown in Figures 33 and 34.

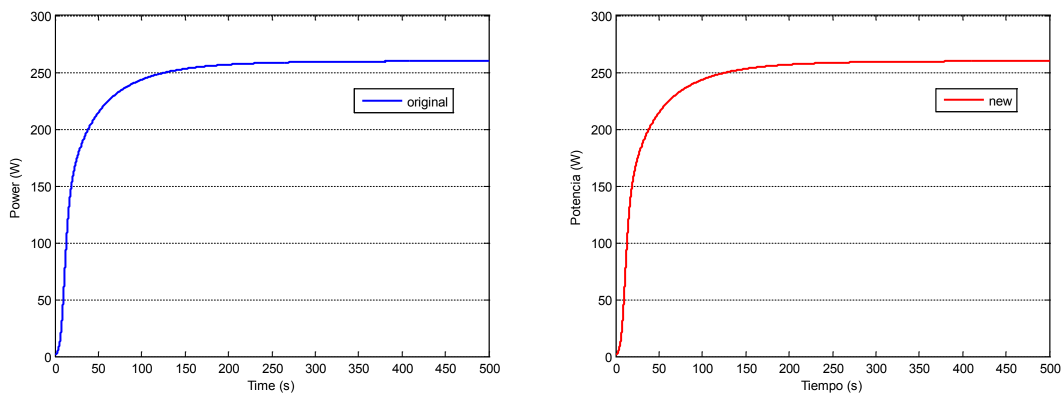

Figure 33: Comparison of the power evolution

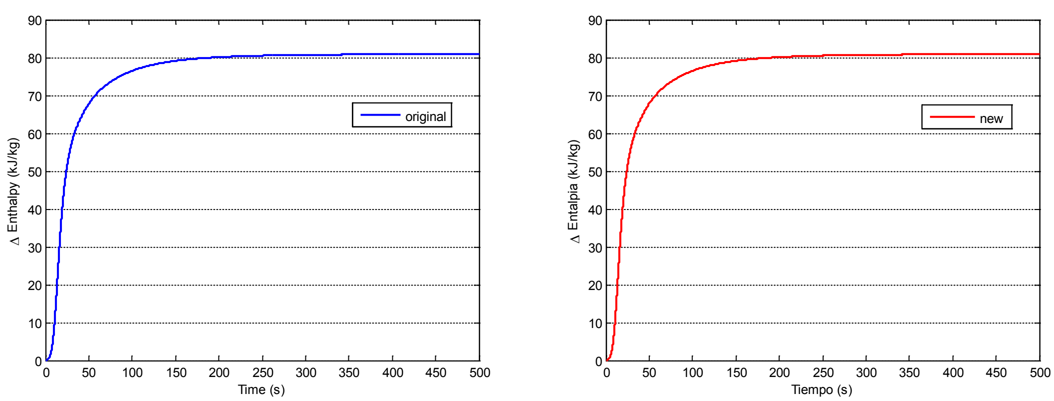

Figure 34: Comparison of the enthalpy evolution

This figures show that there is no difference between the two options, as can be seen also in the numerical results of the output files supplied in the annex. The obtained results show that the introduced modifications work properly, as the results obtained with the new methodology are identical to the ones obtained with the original.

7. CONCLUSIONS

The variables that have been introduced in the changes performed to the subroutines are summarized in the following table:

Table 1 Summary of the declared new variables in PARCS v2.7 and RELAP5 codes

Variable	Meaning	Code	File
n_var	Total stored data: total number of RELAP5 Control Variables that will move PARCS control rod banks	PARCS v2.7	**pdmr_varM.f**
var_leidas(1000)	It stores the read data, that is, the ID's for the RELAP5 Control Variables which will move the control rod banks in PARCS v2.7.	PARCS v2.7	**pdmr_varM.f**
mov_cr_relap	It is used to choose between one type of calculation option and another, i.e., between the former CR movement option and the new one.	PARCS v2.7	**pdmr_varM.f**
var_cntrl(1000)	It takes charge of storing, in each time step, the value of the Control Variables which will move the control rod banks.	RELAP5	**r-var.f**
guardar_cntrlv(1000)	It stores the initial values of the Control Variables which will move the control rod banks.	RELAP5	**r-var.f**
contador	It assures that the loop used to read the initial values of the control rod position is done only once.	RELAP5	**r-commu.f**
contador2	Auxiliary variable.	RELAP5	**r-commu.f**

The table 2 shows a summary of PARCS v2.7 and RELAP5 modified routines:

Table 2 Summary of the modified subroutines in PARCS V2.7 and RELAP5 codes

File	Function	Changes	Code
pdmr_varM.f	Declaration of PARCS v2.7 variables.	Declaration of the new variables: ***var_leidas***, ***n_var***, ***mov_cr_relap***	PARCS v2.7
pdmr_mapM.f	It processes the MAPTAB file.	New loop for reading the information from the *%CRSIG* card	PARCS v2.7
gi_commM.f	Sending and reception of the data from and to RELAP5 code.	Sending of the variables ***var_leidas*** and ***n_var*** and reception of the variable ***var_cntrl*** through the PVM	PARCS v2.7
perturb.f	Processes the perturbations that occur during the transient.	With variable ***mov_cr_relap*** the control rod banks are moved following the orders from RELAP5	PARCS v2.7
r-var.f	Declaration of RELAP5 variables.	Declaration of the new variables: ***var_leidas***, ***n_var***, ***guardar_cntrlv****,* ***var_cntrl***	RELAP5
r-commu.f	Sending and reception of the data from and to PARCS v2.7 code.	Sending of the variable ***var_cntrl*** and reception of the variables: ***var_leidas***, ***n_var***, through the PVM	RELAP5
iconvr.f	Processes the Control Variables initial values.	It stores the initial values in the variable ***guardar_cntrlv***	RELAP5
tran.f	It controls the advancement of the transient simulations: for each time step, it calls to the processing subroutine of the	It updates first the values by calling to the subroutine ***convar*** and after that it sends them to the subroutine ***rdmr****.*	RELAP5

File	Function	Changes	Code
	hydraulic components, heat structures and reactor kinetics (0D or PARCS).		

The main conclusions of this work are the following:

- In this project a new capability has added to RELAP5/PARCS v2.7 that converts it to a more real 3D simulator.
- Previous input files of both RELAP5 and PARCS v2.7 does not need to be modified, and they continue working without any modification.
- RELAP5 manual do not need to be modified.
- PARCS v2.7 manual only needs to incorporate the explanation of the new capability.
- Integration with the graphical environment SNAP.
- It permits the interactivity, both from SNAP and without graphical environment.

8. REFERENCES

1. Compaq Visual Fortran. Programmer's Guide. Compaq Computer Corporation, Houston, Texas, August, 2001.

2. RELAP5/MOD3.3 Code Manual Volume VIII: Programmers Manual. Information Systems Laboratories, Inc., Rockville, Maryland, NUREG/CR-5535/Rev 1-Vol VIII, December, 2001.

3. PARCS v2.7 US NRC Core Neutronics Simulator. T. Downar, Y. Xu, T. Kozlowski, D. Carlson, School of Nuclear Engineering, Purdue University, W. Lafayette, Indiana, 2006.

4. PVM: Parallel Virtual Machine. A Users' Guide and Tutorial for Networked Parallel Computing. MIT Press Scientific and Engineering Computation, Janusz Kowalik, Editor, Massachusetts Institute of Technology, 1994.

5. O. Roselló, Desarrollo de una metodología de generación de secciones eficaces para la simplificación del núcleo de reactores de agua ligera y aplicación en códigos acoplados neutrónicos termohidráulicos. PhD Thesis. UPV, Valencia, Spain (2004).

ANNEX 1: INPUT DECKS FOR RELAP5 AND PARCS V2.7 CODES

In order to test that the modifications have been introduced properly, input decks for RELAP5 and PARCS v2.7 codes are provided. The transient simulated is a Rod Ejection Accident (REA), and the control rod movement is implemented in both codes.

For PARCS v2.7 code, *GEOM_LWR* file is needed. This file contains the reactor geometry data, and the control rod bank position. The file is provided in this annex.

For coupled simulation, *MAPTAB_RP* file is also needed. This file contains the correspondence between neutronic and thermalhydraulic nodes, and is the file where the card %CRSIG is implemented. This file is also provided in this annex.

Cards and comments referring to the control rod movement capability are shaded in grey.

INPUT DECK FOR RELAP5 STAND ALONE SIMULATION:

```
=PWR R5M3.3 beta  (INPUT FOR RIA TEST)
* PWR REACTOR RELAP5 INPUT FILE0
*
*-----------------------------------------------------------------
*   Problem Options
*-----------------------------------------------------------------
*
*****************************************************************
100 new      stdy-st
101 run
102 si  si
* remaining  cpu  time
105   5.   6.
*                              Min   mj    re
201   100.0  .1e-05  0.10  07003     5  4000  4000
202   500.0  .1e-05  0.10  07003   100  5000  5000
*
*-----------------------------------------------------------------
*  T/H Volumes
*-----------------------------------------------------------------
*-----------------------------------------------------------------
* Core Inlet Boundary Conditions
*-----------------------------------------------------------------
5000000  inlet  tmdpvol
5000101  100.0  .1e+9    0.  0.  0.  0.  0.  0.  00
5000200  113
5000201    0.0   0.1552e+08  567.922  0.131e-02
5000202  .1e+07   0.1552e+08  567.922  0.131e-02
*
*  tmdpjun   feedwater
*
0550000  feedwate  tmdpjun
0550101   500010000  200000000   3.048
0550200  1
550201    0.0  16000.0000  0.0  0.0
550202  .1e+07  16000.0000  0.0  0.0
*
*  lower plenum part 0
*
2000000  lwpt0      branch
2000001  4          1
2000101  3.0000  0.5  0.0  0.0  90.0  0.5  0  0.013083    0000000
2000200  113   0.1552e+08  567.922  0.131e-02
2001101  200010000  201000000  0.20  0.0  0.0  0000000
2002101  200010000  202000000  2.70  0.0  0.0  0000000
2003101  200010000  203000000  0.10  0.0  0.0  0000000
2004101  200010000  204000000  0.05  0.0  0.0  0000000
2001201    420.0  0.0  0.0
2002201  15000.0  0.0  0.0
2003201    500.0  0.0  0.0
2004201    260.0  0.0  0.0
*
*
```

```
*lower plenum
*
2010000  lw201    branch
2010001  1        1
2010101  0.20  0.5  0.0  0.0  90.0  0.5  0  0.013083    0000000
2010200  113   0.1552e+08  567.922  0.131e-02
2011101  201010000  250000000  0.20  0.0  0.0  0000000
2011201    420.0  0.0  0.0
*
*
*lower plenum
*
2020000  lw202    branch
2020001  1        1
2020101  2.5  0.5  0.0  0.0  90.0  0.5  0  0.013083    0000000
2020200  113   0.1552e+08  567.922  0.131e-02
2021101  202010000  100000000  2.70  0.0  0.0  0000000
2021201  15000.0  0.0  0.0
*
*lower plenum
*
2030000  lw203    branch
2030001  6        1
2030101  0.1  0.5  0.0  0.0  90.0  0.5  0  0.013083    0000000
2030200  113   0.1552e+08  560.0  0.131e-02
2031101  203010000  101000000  0.0150  0.0  0.0  0000000
2032101  203010000  102000000  0.0150  0.0  0.0  0000000
2033101  203010000  103000000  0.0150  0.0  0.0  0000000
2034101  203010000  104000000  0.0150  0.0  0.0  0000000
2035101  203010000  105000000  0.0150  0.0  0.0  0000000
2036101  203010000  106000000  0.0150  0.0  0.0  0000000
2031201     90.0      0.0  0.0
2032201     90.0      0.0  0.0
2033201     90.0      0.0  0.0
2034201     90.0      0.0  0.0
2035201     90.0      0.0  0.0
2036201     90.0      0.0  0.0
*
*lower plenum
*
2040000  lw204    branch
2040001  3        1
2040101  0.05  0.5  0.0  0.0  90.0  0.5  0  0.013083    0000000
2040200  113   0.1552e+08  567.922  0.131e-02
2041101  204010000  107000000  0.0150  0.0  0.0  0000000
2042101  204010000  108000000  0.0150  0.0  0.0  0000000
2043101  204010000  109000000  0.0150  0.0  0.0  0000000
2041201     90.0      0.0  0.0
2042201     90.0      0.0  0.0
2043201     90.0      0.0  0.0
*
*
*
********Internal Bundles*******
*
```

```
* Channel 100
*
1000000   inb100   pipe
1000001            34
1000101  2.70           1
1000102  4.85           33
1000103  2.60           34
1000301  0.4670         1
1000302  0.1067         33
1000303  0.4540         34
1000601  90.0           34
1000701  0.4670         1
1000702  0.1067         33
1000703  0.4540         34
1000801  .60e-05  0.013083 34
1000901  1.4  1.4       1
1000902  0.0  0.0       4
1000903  1.8  1.8       5
1000904  0.0  0.0       10
1000905  1.8  1.8       11
1000906  0.0  0.0       15
1000907  1.8  1.8       16
1000908  0.0  0.0       21
1000909  1.8  1.8       22
1000910  0.0  0.0       26
1000911  1.8  1.8       27
1000912  0.0  0.0       32
1000913  0.70  0.70     33
1001001  0000100        34
1001101  00001000       33
1001201  113  0.1552e+08  567.874  0.0  0.0  0.0  1
1001202  113  0.1552e+08  567.874  0.0  0.0  0.0  2
1001203  113  0.1552e+08  567.874  0.0  0.0  0.0  3
1001204  113  0.1552e+08  567.874  0.0  0.0  0.0  4
1001205  113  0.1552e+08  567.874  0.0  0.0  0.0  5
1001206  113  0.1552e+08  567.874  0.0  0.0  0.0  6
1001207  113  0.1552e+08  567.874  0.0  0.0  0.0  7
1001208  113  0.1552e+08  567.874  0.0  0.0  0.0  8
1001209  113  0.1552e+08  567.874  0.0  0.0  0.0  9
1001210  113  0.1552e+08  567.874  0.0  0.0  0.0  10
1001211  113  0.1552e+08  567.874  0.0  0.0  0.0  11
1001212  113  0.1552e+08  567.874  0.0  0.0  0.0  12
1001213  113  0.1552e+08  567.874  0.0  0.0  0.0  13
1001214  113  0.1552e+08  567.874  0.0  0.0  0.0  14
1001215  113  0.1552e+08  567.874  0.0  0.0  0.0  15
1001216  113  0.1552e+08  567.874  0.0  0.0  0.0  16
1001217  113  0.1552e+08  567.874  0.0  0.0  0.0  17
1001218  113  0.1552e+08  567.874  0.0  0.0  0.0  18
1001219  113  0.1552e+08  567.874  0.0  0.0  0.0  19
1001220  113  0.1552e+08  567.874  0.0  0.0  0.0  20
1001221  113  0.1552e+08  567.874  0.0  0.0  0.0  21
1001222  113  0.1552e+08  567.874  0.0  0.0  0.0  22
1001223  113  0.1552e+08  567.874  0.0  0.0  0.0  23
1001224  113  0.1552e+08  567.874  0.0  0.0  0.0  24
1001225  113  0.1552e+08  567.874  0.0  0.0  0.0  25
```

```
1001226  113   0.1552e+08  567.874  0.0  0.0  0.0  26
1001227  113   0.1552e+08  567.874  0.0  0.0  0.0  27
1001228  113   0.1552e+08  567.874  0.0  0.0  0.0  28
1001229  113   0.1552e+08  567.874  0.0  0.0  0.0  29
1001230  113   0.1552e+08  567.874  0.0  0.0  0.0  30
1001231  113   0.1552e+08  567.874  0.0  0.0  0.0  31
1001232  113   0.1552e+08  567.874  0.0  0.0  0.0  32
1001233  113   0.1552e+08  567.874  0.0  0.0  0.0  33
1001234  113   0.1552e+08  567.874  0.0  0.0  0.0  34
1002001  .1308e-02        34
1001300  1
1001301  15000.0  0.0  0.0                    33
*
* Channel 101
*
1010000    inb101   pipe
1010001                 34
1010101  0.0150           1
1010102  0.0290          33
1010103  0.0150          34
1010301  0.4670           1
1010302  0.1067          33
1010303  0.4540          34
1010601  90.0            34
1010701  0.4670           1
1010702  0.1067          33
1010703  0.4540          34
1010801  .60e-05  0.013083 34
1010901  1.4  1.4         1
1010902  0.0  0.0         4
1010903  1.8  1.8         5
1010904  0.0  0.0        10
1010905  1.8  1.8        11
1010906  0.0  0.0        15
1010907  1.8  1.8        16
1010908  0.0  0.0        21
1010909  1.8  1.8        22
1010910  0.0  0.0        26
1010911  1.8  1.8        27
1010912  0.0  0.0        32
1010913  0.70  0.70        33
1011001  0000100          34
1011101  00001000          33
1011201  113   0.1552e+08  567.874  0.0  0.0  0.0   1
1011202  113   0.1552e+08  567.874  0.0  0.0  0.0   2
1011203  113   0.1552e+08  567.874  0.0  0.0  0.0   3
1011204  113   0.1552e+08  567.874  0.0  0.0  0.0   4
1011205  113   0.1552e+08  567.874  0.0  0.0  0.0   5
1011206  113   0.1552e+08  567.874  0.0  0.0  0.0   6
1011207  113   0.1552e+08  567.874  0.0  0.0  0.0   7
1011208  113   0.1552e+08  567.874  0.0  0.0  0.0   8
1011209  113   0.1552e+08  567.874  0.0  0.0  0.0   9
1011210  113   0.1552e+08  567.874  0.0  0.0  0.0  10
1011211  113   0.1552e+08  567.874  0.0  0.0  0.0  11
1011212  113   0.1552e+08  567.874  0.0  0.0  0.0  12
```

```
1011213  113   0.1552e+08  567.874  0.0  0.0  0.0  13
1011214  113   0.1552e+08  567.874  0.0  0.0  0.0  14
1011215  113   0.1552e+08  567.874  0.0  0.0  0.0  15
1011216  113   0.1552e+08  567.874  0.0  0.0  0.0  16
1011217  113   0.1552e+08  567.874  0.0  0.0  0.0  17
1011218  113   0.1552e+08  567.874  0.0  0.0  0.0  18
1011219  113   0.1552e+08  567.874  0.0  0.0  0.0  19
1011220  113   0.1552e+08  567.874  0.0  0.0  0.0  20
1011221  113   0.1552e+08  567.874  0.0  0.0  0.0  21
1011222  113   0.1552e+08  567.874  0.0  0.0  0.0  22
1011223  113   0.1552e+08  567.874  0.0  0.0  0.0  23
1011224  113   0.1552e+08  567.874  0.0  0.0  0.0  24
1011225  113   0.1552e+08  567.874  0.0  0.0  0.0  25
1011226  113   0.1552e+08  567.874  0.0  0.0  0.0  26
1011227  113   0.1552e+08  567.874  0.0  0.0  0.0  27
1011228  113   0.1552e+08  567.874  0.0  0.0  0.0  28
1011229  113   0.1552e+08  567.874  0.0  0.0  0.0  29
1011230  113   0.1552e+08  567.874  0.0  0.0  0.0  30
1011231  113   0.1552e+08  567.874  0.0  0.0  0.0  31
1011232  113   0.1552e+08  567.874  0.0  0.0  0.0  32
1011233  113   0.1552e+08  567.874  0.0  0.0  0.0  33
1011234  113   0.1552e+08  567.874  0.0  0.0  0.0  34
1012001  .1308e-02        34
1011300  1
1011301    90.0      0.0  0.0                    33
*
* Channel 102
*
1020000    inb102   pipe
1020001                34
1020101  0.0150           1
1020102  0.0290          33
1020103  0.0150          34
1020301  0.4670           1
1020302  0.1067          33
1020303  0.4540          34
1020601  90.0            34
1020701  0.4670           1
1020702  0.1067          33
1020703  0.4540          34
1020801  .60e-05  0.013083 34
1020901  1.4  1.4         1
1020902  0.0  0.0         4
1020903  1.8  1.8         5
1020904  0.0  0.0        10
1020905  1.8  1.8        11
1020906  0.0  0.0        15
1020907  1.8  1.8        16
1020908  0.0  0.0        21
1020909  1.8  1.8        22
1020910  0.0  0.0        26
1020911  1.8  1.8        27
1020912  0.0  0.0        32
1020913  0.70  0.70       33
1021001  0000100          34
```

```
1021101  00001000         33
1021201  113   0.1552e+08  567.874  0.0  0.0  0.0   1
1021202  113   0.1552e+08  567.874  0.0  0.0  0.0   2
1021203  113   0.1552e+08  567.874  0.0  0.0  0.0   3
1021204  113   0.1552e+08  567.874  0.0  0.0  0.0   4
1021205  113   0.1552e+08  567.874  0.0  0.0  0.0   5
1021206  113   0.1552e+08  567.874  0.0  0.0  0.0   6
1021207  113   0.1552e+08  567.874  0.0  0.0  0.0   7
1021208  113   0.1552e+08  567.874  0.0  0.0  0.0   8
1021209  113   0.1552e+08  567.874  0.0  0.0  0.0   9
1021210  113   0.1552e+08  567.874  0.0  0.0  0.0  10
1021211  113   0.1552e+08  567.874  0.0  0.0  0.0  11
1021212  113   0.1552e+08  567.874  0.0  0.0  0.0  12
1021213  113   0.1552e+08  567.874  0.0  0.0  0.0  13
1021214  113   0.1552e+08  567.874  0.0  0.0  0.0  14
1021215  113   0.1552e+08  567.874  0.0  0.0  0.0  15
1021216  113   0.1552e+08  567.874  0.0  0.0  0.0  16
1021217  113   0.1552e+08  567.874  0.0  0.0  0.0  17
1021218  113   0.1552e+08  567.874  0.0  0.0  0.0  18
1021219  113   0.1552e+08  567.874  0.0  0.0  0.0  19
1021220  113   0.1552e+08  567.874  0.0  0.0  0.0  20
1021221  113   0.1552e+08  567.874  0.0  0.0  0.0  21
1021222  113   0.1552e+08  567.874  0.0  0.0  0.0  22
1021223  113   0.1552e+08  567.874  0.0  0.0  0.0  23
1021224  113   0.1552e+08  567.874  0.0  0.0  0.0  24
1021225  113   0.1552e+08  567.874  0.0  0.0  0.0  25
1021226  113   0.1552e+08  567.874  0.0  0.0  0.0  26
1021227  113   0.1552e+08  567.874  0.0  0.0  0.0  27
1021228  113   0.1552e+08  567.874  0.0  0.0  0.0  28
1021229  113   0.1552e+08  567.874  0.0  0.0  0.0  29
1021230  113   0.1552e+08  567.874  0.0  0.0  0.0  30
1021231  113   0.1552e+08  567.874  0.0  0.0  0.0  31
1021232  113   0.1552e+08  567.874  0.0  0.0  0.0  32
1021233  113   0.1552e+08  567.874  0.0  0.0  0.0  33
1021234  113   0.1552e+08  567.874  0.0  0.0  0.0  34
1022001  .1308e-02        34
1021300  1
1021301     90.0      0.0  0.0                    33
*
* Channel 103
*
1030000    inb103   pipe
1030001                  34
1030101  0.0150            1
1030102  0.0290           33
1030103  0.0150           34
1030301  0.4670            1
1030302  0.1067           33
1030303  0.4540           34
1030601  90.0            34
1030701  0.4670            1
1030702  0.1067           33
1030703  0.4540           34
1030801  .60e-05  0.013083 34
1030901  1.4  1.4          1
```

```
1030902  0.0  0.0          4
1030903  1.8  1.8          5
1030904  0.0  0.0         10
1030905  1.8  1.8         11
1030906  0.0  0.0         15
1030907  1.8  1.8         16
1030908  0.0  0.0         21
1030909  1.8  1.8         22
1030910  0.0  0.0         26
1030911  1.8  1.8         27
1030912  0.0  0.0         32
1030913  0.70  0.70        33
1031001  0000100           34
1031101  00001000          33
1031201  113   0.1552e+08  567.874  0.0  0.0  0.0   1
1031202  113   0.1552e+08  567.874  0.0  0.0  0.0   2
1031203  113   0.1552e+08  567.874  0.0  0.0  0.0   3
1031204  113   0.1552e+08  567.874  0.0  0.0  0.0   4
1031205  113   0.1552e+08  567.874  0.0  0.0  0.0   5
1031206  113   0.1552e+08  567.874  0.0  0.0  0.0   6
1031207  113   0.1552e+08  567.874  0.0  0.0  0.0   7
1031208  113   0.1552e+08  567.874  0.0  0.0  0.0   8
1031209  113   0.1552e+08  567.874  0.0  0.0  0.0   9
1031210  113   0.1552e+08  567.874  0.0  0.0  0.0  10
1031211  113   0.1552e+08  567.874  0.0  0.0  0.0  11
1031212  113   0.1552e+08  567.874  0.0  0.0  0.0  12
1031213  113   0.1552e+08  567.874  0.0  0.0  0.0  13
1031214  113   0.1552e+08  567.874  0.0  0.0  0.0  14
1031215  113   0.1552e+08  567.874  0.0  0.0  0.0  15
1031216  113   0.1552e+08  567.874  0.0  0.0  0.0  16
1031217  113   0.1552e+08  567.874  0.0  0.0  0.0  17
1031218  113   0.1552e+08  567.874  0.0  0.0  0.0  18
1031219  113   0.1552e+08  567.874  0.0  0.0  0.0  19
1031220  113   0.1552e+08  567.874  0.0  0.0  0.0  20
1031221  113   0.1552e+08  567.874  0.0  0.0  0.0  21
1031222  113   0.1552e+08  567.874  0.0  0.0  0.0  22
1031223  113   0.1552e+08  567.874  0.0  0.0  0.0  23
1031224  113   0.1552e+08  567.874  0.0  0.0  0.0  24
1031225  113   0.1552e+08  567.874  0.0  0.0  0.0  25
1031226  113   0.1552e+08  567.874  0.0  0.0  0.0  26
1031227  113   0.1552e+08  567.874  0.0  0.0  0.0  27
1031228  113   0.1552e+08  567.874  0.0  0.0  0.0  28
1031229  113   0.1552e+08  567.874  0.0  0.0  0.0  29
1031230  113   0.1552e+08  567.874  0.0  0.0  0.0  30
1031231  113   0.1552e+08  567.874  0.0  0.0  0.0  31
1031232  113   0.1552e+08  567.874  0.0  0.0  0.0  32
1031233  113   0.1552e+08  567.874  0.0  0.0  0.0  33
1031234  113   0.1552e+08  567.874  0.0  0.0  0.0  34
1032001  .1308e-02         34
1031300  1
1031301    90.0      0.0  0.0                 33
*
* Channel 104
*
1040000    inb104   pipe
```

```
1040001                34
1040101  0.0150           1
1040102  0.0290          33
1040103  0.0150          34
1040301  0.4670           1
1040302  0.1067          33
1040303  0.4540          34
1040601  90.0            34
1040701  0.4670           1
1040702  0.1067          33
1040703  0.4540          34
1040801  .60e-05  0.013083 34
1040901  1.4  1.4         1
1040902  0.0  0.0         4
1040903  1.8  1.8         5
1040904  0.0  0.0        10
1040905  1.8  1.8        11
1040906  0.0  0.0        15
1040907  1.8  1.8        16
1040908  0.0  0.0        21
1040909  1.8  1.8        22
1040910  0.0  0.0        26
1040911  1.8  1.8        27
1040912  0.0  0.0        32
1040913  0.70  0.70        33
1041001  0000100           34
1041101  00001000          33
1041201  113   0.1552e+08  567.874  0.0  0.0  0.0   1
1041202  113   0.1552e+08  567.874  0.0  0.0  0.0   2
1041203  113   0.1552e+08  567.874  0.0  0.0  0.0   3
1041204  113   0.1552e+08  567.874  0.0  0.0  0.0   4
1041205  113   0.1552e+08  567.874  0.0  0.0  0.0   5
1041206  113   0.1552e+08  567.874  0.0  0.0  0.0   6
1041207  113   0.1552e+08  567.874  0.0  0.0  0.0   7
1041208  113   0.1552e+08  567.874  0.0  0.0  0.0   8
1041209  113   0.1552e+08  567.874  0.0  0.0  0.0   9
1041210  113   0.1552e+08  567.874  0.0  0.0  0.0  10
1041211  113   0.1552e+08  567.874  0.0  0.0  0.0  11
1041212  113   0.1552e+08  567.874  0.0  0.0  0.0  12
1041213  113   0.1552e+08  567.874  0.0  0.0  0.0  13
1041214  113   0.1552e+08  567.874  0.0  0.0  0.0  14
1041215  113   0.1552e+08  567.874  0.0  0.0  0.0  15
1041216  113   0.1552e+08  567.874  0.0  0.0  0.0  16
1041217  113   0.1552e+08  567.874  0.0  0.0  0.0  17
1041218  113   0.1552e+08  567.874  0.0  0.0  0.0  18
1041219  113   0.1552e+08  567.874  0.0  0.0  0.0  19
1041220  113   0.1552e+08  567.874  0.0  0.0  0.0  20
1041221  113   0.1552e+08  567.874  0.0  0.0  0.0  21
1041222  113   0.1552e+08  567.874  0.0  0.0  0.0  22
1041223  113   0.1552e+08  567.874  0.0  0.0  0.0  23
1041224  113   0.1552e+08  567.874  0.0  0.0  0.0  24
1041225  113   0.1552e+08  567.874  0.0  0.0  0.0  25
1041226  113   0.1552e+08  567.874  0.0  0.0  0.0  26
1041227  113   0.1552e+08  567.874  0.0  0.0  0.0  27
1041228  113   0.1552e+08  567.874  0.0  0.0  0.0  28
```

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1041229  113   0.1552e+08  567.874  0.0  0.0  0.0  29
1041230  113   0.1552e+08  567.874  0.0  0.0  0.0  30
1041231  113   0.1552e+08  567.874  0.0  0.0  0.0  31
1041232  113   0.1552e+08  567.874  0.0  0.0  0.0  32
1041233  113   0.1552e+08  567.874  0.0  0.0  0.0  33
1041234  113   0.1552e+08  567.874  0.0  0.0  0.0  34
1042001  .1308e-02        34
1041300  1
1041301     90.0      0.0  0.0                    33
*
* Channel 105
*
1050000    inb105   pipe
1050001                  34
1050101  0.0150           1
1050102  0.0290          33
1050103  0.0150          34
1050301  0.4670           1
1050302  0.1067          33
1050303  0.4540          34
1050601  90.0            34
1050701  0.4670           1
1050702  0.1067          33
1050703  0.4540          34
1050801  .60e-05  0.013083 34
1050901  1.4  1.4         1
1050902  0.0  0.0         4
1050903  1.8  1.8         5
1050904  0.0  0.0        10
1050905  1.8  1.8        11
1050906  0.0  0.0        15
1050907  1.8  1.8        16
1050908  0.0  0.0        21
1050909  1.8  1.8        22
1050910  0.0  0.0        26
1050911  1.8  1.8        27
1050912  0.0  0.0        32
1050913  0.70  0.70       33
1051001  0000100          34
1051101  00001000         33
1051201  113   0.1552e+08  567.874  0.0  0.0  0.0   1
1051202  113   0.1552e+08  567.874  0.0  0.0  0.0   2
1051203  113   0.1552e+08  567.874  0.0  0.0  0.0   3
1051204  113   0.1552e+08  567.874  0.0  0.0  0.0   4
1051205  113   0.1552e+08  567.874  0.0  0.0  0.0   5
1051206  113   0.1552e+08  567.874  0.0  0.0  0.0   6
1051207  113   0.1552e+08  567.874  0.0  0.0  0.0   7
1051208  113   0.1552e+08  567.874  0.0  0.0  0.0   8
1051209  113   0.1552e+08  567.874  0.0  0.0  0.0   9
1051210  113   0.1552e+08  567.874  0.0  0.0  0.0  10
1051211  113   0.1552e+08  567.874  0.0  0.0  0.0  11
1051212  113   0.1552e+08  567.874  0.0  0.0  0.0  12
1051213  113   0.1552e+08  567.874  0.0  0.0  0.0  13
1051214  113   0.1552e+08  567.874  0.0  0.0  0.0  14
1051215  113   0.1552e+08  567.874  0.0  0.0  0.0  15
```

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1051216  113   0.1552e+08  567.874  0.0  0.0  0.0  16
1051217  113   0.1552e+08  567.874  0.0  0.0  0.0  17
1051218  113   0.1552e+08  567.874  0.0  0.0  0.0  18
1051219  113   0.1552e+08  567.874  0.0  0.0  0.0  19
1051220  113   0.1552e+08  567.874  0.0  0.0  0.0  20
1051221  113   0.1552e+08  567.874  0.0  0.0  0.0  21
1051222  113   0.1552e+08  567.874  0.0  0.0  0.0  22
1051223  113   0.1552e+08  567.874  0.0  0.0  0.0  23
1051224  113   0.1552e+08  567.874  0.0  0.0  0.0  24
1051225  113   0.1552e+08  567.874  0.0  0.0  0.0  25
1051226  113   0.1552e+08  567.874  0.0  0.0  0.0  26
1051227  113   0.1552e+08  567.874  0.0  0.0  0.0  27
1051228  113   0.1552e+08  567.874  0.0  0.0  0.0  28
1051229  113   0.1552e+08  567.874  0.0  0.0  0.0  29
1051230  113   0.1552e+08  567.874  0.0  0.0  0.0  30
1051231  113   0.1552e+08  567.874  0.0  0.0  0.0  31
1051232  113   0.1552e+08  567.874  0.0  0.0  0.0  32
1051233  113   0.1552e+08  567.874  0.0  0.0  0.0  33
1051234  113   0.1552e+08  567.874  0.0  0.0  0.0  34
1052001  .1308e-02         34
1051300  1
1051301     90.0      0.0  0.0                    33
*
* Channel 106
*
1060000    inb106   pipe
1060001                  34
1060101  0.0150           1
1060102  0.0290          33
1060103  0.0150          34
1060301  0.4670           1
1060302  0.1067          33
1060303  0.4540          34
1060601  90.0            34
1060701  0.4670           1
1060702  0.1067          33
1060703  0.4540          34
1060801  .60e-05  0.013083 34
1060901  1.4  1.4         1
1060902  0.0  0.0         4
1060903  1.8  1.8         5
1060904  0.0  0.0        10
1060905  1.8  1.8        11
1060906  0.0  0.0        15
1060907  1.8  1.8        16
1060908  0.0  0.0        21
1060909  1.8  1.8        22
1060910  0.0  0.0        26
1060911  1.8  1.8        27
1060912  0.0  0.0        32
1060913  0.70  0.70       33
1061001  0000100          34
1061101  00001000         33
1061201  113   0.1552e+08  567.874  0.0  0.0  0.0   1
1061202  113   0.1552e+08  567.874  0.0  0.0  0.0   2
```

```
1061203  113   0.1552e+08  567.874  0.0  0.0  0.0   3
1061204  113   0.1552e+08  567.874  0.0  0.0  0.0   4
1061205  113   0.1552e+08  567.874  0.0  0.0  0.0   5
1061206  113   0.1552e+08  567.874  0.0  0.0  0.0   6
1061207  113   0.1552e+08  567.874  0.0  0.0  0.0   7
1061208  113   0.1552e+08  567.874  0.0  0.0  0.0   8
1061209  113   0.1552e+08  567.874  0.0  0.0  0.0   9
1061210  113   0.1552e+08  567.874  0.0  0.0  0.0  10
1061211  113   0.1552e+08  567.874  0.0  0.0  0.0  11
1061212  113   0.1552e+08  567.874  0.0  0.0  0.0  12
1061213  113   0.1552e+08  567.874  0.0  0.0  0.0  13
1061214  113   0.1552e+08  567.874  0.0  0.0  0.0  14
1061215  113   0.1552e+08  567.874  0.0  0.0  0.0  15
1061216  113   0.1552e+08  567.874  0.0  0.0  0.0  16
1061217  113   0.1552e+08  567.874  0.0  0.0  0.0  17
1061218  113   0.1552e+08  567.874  0.0  0.0  0.0  18
1061219  113   0.1552e+08  567.874  0.0  0.0  0.0  19
1061220  113   0.1552e+08  567.874  0.0  0.0  0.0  20
1061221  113   0.1552e+08  567.874  0.0  0.0  0.0  21
1061222  113   0.1552e+08  567.874  0.0  0.0  0.0  22
1061223  113   0.1552e+08  567.874  0.0  0.0  0.0  23
1061224  113   0.1552e+08  567.874  0.0  0.0  0.0  24
1061225  113   0.1552e+08  567.874  0.0  0.0  0.0  25
1061226  113   0.1552e+08  567.874  0.0  0.0  0.0  26
1061227  113   0.1552e+08  567.874  0.0  0.0  0.0  27
1061228  113   0.1552e+08  567.874  0.0  0.0  0.0  28
1061229  113   0.1552e+08  567.874  0.0  0.0  0.0  29
1061230  113   0.1552e+08  567.874  0.0  0.0  0.0  30
1061231  113   0.1552e+08  567.874  0.0  0.0  0.0  31
1061232  113   0.1552e+08  567.874  0.0  0.0  0.0  32
1061233  113   0.1552e+08  567.874  0.0  0.0  0.0  33
1061234  113   0.1552e+08  567.874  0.0  0.0  0.0  34
1062001  .1308e-02         34
1061300  1
1061301     90.0      0.0  0.0                     33
*
* Channel 107
*
1070000    inb107   pipe
1070001                  34
1070101  0.0150           1
1070102  0.0290          33
1070103  0.0150          34
1070301  0.4670           1
1070302  0.1067          33
1070303  0.4540          34
1070601  90.0           34
1070701  0.4670           1
1070702  0.1067          33
1070703  0.4540          34
1070801  .60e-05  0.013083 34
1070901  1.4  1.4          1
1070902  0.0  0.0          4
1070903  1.8  1.8          5
1070904  0.0  0.0         10
```

```
1070905  1.8  1.8        11
1070906  0.0  0.0        15
1070907  1.8  1.8        16
1070908  0.0  0.0        21
1070909  1.8  1.8        22
1070910  0.0  0.0        26
1070911  1.8  1.8        27
1070912  0.0  0.0        32
1070913  0.70  0.70       33
1071001  0000100          34
1071101  00001000         33
1071201  113   0.1552e+08  567.874  0.0  0.0  0.0   1
1071202  113   0.1552e+08  567.874  0.0  0.0  0.0   2
1071203  113   0.1552e+08  567.874  0.0  0.0  0.0   3
1071204  113   0.1552e+08  567.874  0.0  0.0  0.0   4
1071205  113   0.1552e+08  567.874  0.0  0.0  0.0   5
1071206  113   0.1552e+08  567.874  0.0  0.0  0.0   6
1071207  113   0.1552e+08  567.874  0.0  0.0  0.0   7
1071208  113   0.1552e+08  567.874  0.0  0.0  0.0   8
1071209  113   0.1552e+08  567.874  0.0  0.0  0.0   9
1071210  113   0.1552e+08  567.874  0.0  0.0  0.0  10
1071211  113   0.1552e+08  567.874  0.0  0.0  0.0  11
1071212  113   0.1552e+08  567.874  0.0  0.0  0.0  12
1071213  113   0.1552e+08  567.874  0.0  0.0  0.0  13
1071214  113   0.1552e+08  567.874  0.0  0.0  0.0  14
1071215  113   0.1552e+08  567.874  0.0  0.0  0.0  15
1071216  113   0.1552e+08  567.874  0.0  0.0  0.0  16
1071217  113   0.1552e+08  567.874  0.0  0.0  0.0  17
1071218  113   0.1552e+08  567.874  0.0  0.0  0.0  18
1071219  113   0.1552e+08  567.874  0.0  0.0  0.0  19
1071220  113   0.1552e+08  567.874  0.0  0.0  0.0  20
1071221  113   0.1552e+08  567.874  0.0  0.0  0.0  21
1071222  113   0.1552e+08  567.874  0.0  0.0  0.0  22
1071223  113   0.1552e+08  567.874  0.0  0.0  0.0  23
1071224  113   0.1552e+08  567.874  0.0  0.0  0.0  24
1071225  113   0.1552e+08  567.874  0.0  0.0  0.0  25
1071226  113   0.1552e+08  567.874  0.0  0.0  0.0  26
1071227  113   0.1552e+08  567.874  0.0  0.0  0.0  27
1071228  113   0.1552e+08  567.874  0.0  0.0  0.0  28
1071229  113   0.1552e+08  567.874  0.0  0.0  0.0  29
1071230  113   0.1552e+08  567.874  0.0  0.0  0.0  30
1071231  113   0.1552e+08  567.874  0.0  0.0  0.0  31
1071232  113   0.1552e+08  567.874  0.0  0.0  0.0  32
1071233  113   0.1552e+08  567.874  0.0  0.0  0.0  33
1071234  113   0.1552e+08  567.874  0.0  0.0  0.0  34
1072001  .1308e-02        34
1071300  1
1071301     90.0      0.0  0.0                  33
*
* Channel 108
*
1080000    inb108   pipe
1080001               34
1080101  0.0150          1
1080102  0.0290         33
```

```
1080103  0.0150          34
1080301  0.4670           1
1080302  0.1067          33
1080303  0.4540          34
1080601  90.0            34
1080701  0.4670           1
1080702  0.1067          33
1080703  0.4540          34
1080801  .60e-05  0.013083 34
1080901  1.4  1.4         1
1080902  0.0  0.0         4
1080903  1.8  1.8         5
1080904  0.0  0.0        10
1080905  1.8  1.8        11
1080906  0.0  0.0        15
1080907  1.8  1.8        16
1080908  0.0  0.0        21
1080909  1.8  1.8        22
1080910  0.0  0.0        26
1080911  1.8  1.8        27
1080912  0.0  0.0        32
1080913  0.70  0.70       33
1081001  0000100          34
1081101  00001000          33
1081201  113   0.1552e+08  567.874  0.0  0.0  0.0   1
1081202  113   0.1552e+08  567.874  0.0  0.0  0.0   2
1081203  113   0.1552e+08  567.874  0.0  0.0  0.0   3
1081204  113   0.1552e+08  567.874  0.0  0.0  0.0   4
1081205  113   0.1552e+08  567.874  0.0  0.0  0.0   5
1081206  113   0.1552e+08  567.874  0.0  0.0  0.0   6
1081207  113   0.1552e+08  567.874  0.0  0.0  0.0   7
1081208  113   0.1552e+08  567.874  0.0  0.0  0.0   8
1081209  113   0.1552e+08  567.874  0.0  0.0  0.0   9
1081210  113   0.1552e+08  567.874  0.0  0.0  0.0  10
1081211  113   0.1552e+08  567.874  0.0  0.0  0.0  11
1081212  113   0.1552e+08  567.874  0.0  0.0  0.0  12
1081213  113   0.1552e+08  567.874  0.0  0.0  0.0  13
1081214  113   0.1552e+08  567.874  0.0  0.0  0.0  14
1081215  113   0.1552e+08  567.874  0.0  0.0  0.0  15
1081216  113   0.1552e+08  567.874  0.0  0.0  0.0  16
1081217  113   0.1552e+08  567.874  0.0  0.0  0.0  17
1081218  113   0.1552e+08  567.874  0.0  0.0  0.0  18
1081219  113   0.1552e+08  567.874  0.0  0.0  0.0  19
1081220  113   0.1552e+08  567.874  0.0  0.0  0.0  20
1081221  113   0.1552e+08  567.874  0.0  0.0  0.0  21
1081222  113   0.1552e+08  567.874  0.0  0.0  0.0  22
1081223  113   0.1552e+08  567.874  0.0  0.0  0.0  23
1081224  113   0.1552e+08  567.874  0.0  0.0  0.0  24
1081225  113   0.1552e+08  567.874  0.0  0.0  0.0  25
1081226  113   0.1552e+08  567.874  0.0  0.0  0.0  26
1081227  113   0.1552e+08  567.874  0.0  0.0  0.0  27
1081228  113   0.1552e+08  567.874  0.0  0.0  0.0  28
1081229  113   0.1552e+08  567.874  0.0  0.0  0.0  29
1081230  113   0.1552e+08  567.874  0.0  0.0  0.0  30
1081231  113   0.1552e+08  567.874  0.0  0.0  0.0  31
```

```
1081232  113   0.1552e+08  567.874  0.0  0.0  0.0  32
1081233  113   0.1552e+08  567.874  0.0  0.0  0.0  33
1081234  113   0.1552e+08  567.874  0.0  0.0  0.0  34
1082001  .1308e-02        34
1081300  1
1081301    90.0      0.0  0.0                   33
*
* Channel 109
*
1090000    inb109   pipe
1090001                  34
1090101  0.0150           1
1090102  0.0290          33
1090103  0.0150          34
1090301  0.4670           1
1090302  0.1067          33
1090303  0.4540          34
1090601  90.0            34
1090701  0.4670           1
1090702  0.1067          33
1090703  0.4540          34
1090801  .60e-05  0.013083 34
1090901  1.4  1.4         1
1090902  0.0  0.0         4
1090903  1.8  1.8         5
1090904  0.0  0.0        10
1090905  1.8  1.8        11
1090906  0.0  0.0        15
1090907  1.8  1.8        16
1090908  0.0  0.0        21
1090909  1.8  1.8        22
1090910  0.0  0.0        26
1090911  1.8  1.8        27
1090912  0.0  0.0        32
1090913  0.70  0.70       33
1091001  0000100          34
1091101  00001000         33
1091201  113   0.1552e+08  567.874  0.0  0.0  0.0   1
1091202  113   0.1552e+08  567.874  0.0  0.0  0.0   2
1091203  113   0.1552e+08  567.874  0.0  0.0  0.0   3
1091204  113   0.1552e+08  567.874  0.0  0.0  0.0   4
1091205  113   0.1552e+08  567.874  0.0  0.0  0.0   5
1091206  113   0.1552e+08  567.874  0.0  0.0  0.0   6
1091207  113   0.1552e+08  567.874  0.0  0.0  0.0   7
1091208  113   0.1552e+08  567.874  0.0  0.0  0.0   8
1091209  113   0.1552e+08  567.874  0.0  0.0  0.0   9
1091210  113   0.1552e+08  567.874  0.0  0.0  0.0  10
1091211  113   0.1552e+08  567.874  0.0  0.0  0.0  11
1091212  113   0.1552e+08  567.874  0.0  0.0  0.0  12
1091213  113   0.1552e+08  567.874  0.0  0.0  0.0  13
1091214  113   0.1552e+08  567.874  0.0  0.0  0.0  14
1091215  113   0.1552e+08  567.874  0.0  0.0  0.0  15
1091216  113   0.1552e+08  567.874  0.0  0.0  0.0  16
1091217  113   0.1552e+08  567.874  0.0  0.0  0.0  17
1091218  113   0.1552e+08  567.874  0.0  0.0  0.0  18
```

```
1091219  113   0.1552e+08  567.874  0.0  0.0  0.0  19
1091220  113   0.1552e+08  567.874  0.0  0.0  0.0  20
1091221  113   0.1552e+08  567.874  0.0  0.0  0.0  21
1091222  113   0.1552e+08  567.874  0.0  0.0  0.0  22
1091223  113   0.1552e+08  567.874  0.0  0.0  0.0  23
1091224  113   0.1552e+08  567.874  0.0  0.0  0.0  24
1091225  113   0.1552e+08  567.874  0.0  0.0  0.0  25
1091226  113   0.1552e+08  567.874  0.0  0.0  0.0  26
1091227  113   0.1552e+08  567.874  0.0  0.0  0.0  27
1091228  113   0.1552e+08  567.874  0.0  0.0  0.0  28
1091229  113   0.1552e+08  567.874  0.0  0.0  0.0  29
1091230  113   0.1552e+08  567.874  0.0  0.0  0.0  30
1091231  113   0.1552e+08  567.874  0.0  0.0  0.0  31
1091232  113   0.1552e+08  567.874  0.0  0.0  0.0  32
1091233  113   0.1552e+08  567.874  0.0  0.0  0.0  33
1091234  113   0.1552e+08  567.874  0.0  0.0  0.0  34
1092001  .1308e-02        34
1091300  1
1091301     90.0      0.0  0.0                    33
*
* Bypass
*
 2500000    bypa    pipe
2500001                  34
2500101  0.20            34
2500301  0.4670            1
2500302  0.1067           33
2500303  0.4540           34
2500601  90.0             34
2500701  0.4670            1
2500702  0.1067           33
2500703  0.4540           34
2500801  .60e-05  0.000000 34
2500901  2.8  2.8          1
2500902  0.0  0.0          4
2500903  2.8  2.8          5
2500904  0.0  0.0         10
2500905  2.8  2.8         11
2500906  0.0  0.0         15
2500907  2.8  2.8         16
2500908  0.0  0.0         21
2500909  2.8  2.8         22
2500910  0.0  0.0         26
2500911  2.8  2.8         27
2500912  0.0  0.0         32
2500913  2.8  2.8         33
2501001  0000100          34
2501101  00001000         33
2501201  113   0.1552e+08  567.874  0.0  0.0  0.0   1
2501202  113   0.1552e+08  567.874  0.0  0.0  0.0   2
2501203  113   0.1552e+08  567.874  0.0  0.0  0.0   3
2501204  113   0.1552e+08  567.874  0.0  0.0  0.0   4
2501205  113   0.1552e+08  567.874  0.0  0.0  0.0   5
2501206  113   0.1552e+08  567.874  0.0  0.0  0.0   6
2501207  113   0.1552e+08  567.874  0.0  0.0  0.0   7
```

```
2501208  113   0.1552e+08  567.874  0.0  0.0  0.0   8
2501209  113   0.1552e+08  567.874  0.0  0.0  0.0   9
2501210  113   0.1552e+08  567.874  0.0  0.0  0.0  10
2501211  113   0.1552e+08  567.874  0.0  0.0  0.0  11
2501212  113   0.1552e+08  567.874  0.0  0.0  0.0  12
2501213  113   0.1552e+08  567.874  0.0  0.0  0.0  13
2501214  113   0.1552e+08  567.874  0.0  0.0  0.0  14
2501215  113   0.1552e+08  567.874  0.0  0.0  0.0  15
2501216  113   0.1552e+08  567.874  0.0  0.0  0.0  16
2501217  113   0.1552e+08  567.874  0.0  0.0  0.0  17
2501218  113   0.1552e+08  567.874  0.0  0.0  0.0  18
2501219  113   0.1552e+08  567.874  0.0  0.0  0.0  19
2501220  113   0.1552e+08  567.874  0.0  0.0  0.0  20
2501221  113   0.1552e+08  567.874  0.0  0.0  0.0  21
2501222  113   0.1552e+08  567.874  0.0  0.0  0.0  22
2501223  113   0.1552e+08  567.874  0.0  0.0  0.0  23
2501224  113   0.1552e+08  567.874  0.0  0.0  0.0  24
2501225  113   0.1552e+08  567.874  0.0  0.0  0.0  25
2501226  113   0.1552e+08  567.874  0.0  0.0  0.0  26
2501227  113   0.1552e+08  567.874  0.0  0.0  0.0  27
2501228  113   0.1552e+08  567.874  0.0  0.0  0.0  28
2501229  113   0.1552e+08  567.874  0.0  0.0  0.0  29
2501230  113   0.1552e+08  567.874  0.0  0.0  0.0  30
2501231  113   0.1552e+08  567.874  0.0  0.0  0.0  31
2501232  113   0.1552e+08  567.874  0.0  0.0  0.0  32
2501233  113   0.1552e+08  567.874  0.0  0.0  0.0  33
2501234  113   0.1552e+08  567.874  0.0  0.0  0.0  34
2502001  .1308e-02        34
2501300  1
2501301    415.04513  0.0  0.0                    33
*
*
*  upper plenum part 0
*
3000000  uppt0      branch
3000001  5         1
3000101  3.7387  0.450  0.0  0.0  90.0  0.450  0  0.013083    0000000
3000200  113   0.1552e+08  602.291  0.131e-02
3001101  300000000  301010000  0.20  0.0  0.0  0000000
3002101  300000000  302010000  2.70  0.0  0.0  0000000
3003101  300000000  303010000  0.10  0.0  0.0  0000000
3004101  300000000  304010000  0.05  0.0  0.0  0000000
3005101  300010000  400000000  0.6903  0.0  0.0  0000000
3001201    420.0  0.0  0.0
3002201  15000.0  0.0  0.0
3003201    530.0  0.0  0.0
3004201    260.0  0.0  0.0
3005201  16000.00000  0.0  0.0
*
*
*upper plenum
*
3010000  up301    branch
3010001  1         1
3010101  0.20  0.450  0.0  0.0  90.0  0.450  0  0.013083    0000000
```

```
3010200  113   0.1552e+08  602.291  0.131e-02
3011101  301000000  250010000  0.20  0.0  0.0  0000000
3011201    420.0  0.0  0.0
*
*
*upper plenum
*
3020000  up302    branch
3020001  1         1
3020101  2.70  0.450  0.0  0.0  90.0  0.450  0  0.013083    0000000
3020200  113   0.1552e+08  602.291  0.131e-02
3021101  302000000  100010000  2.60    0.0  0.0  0000000
3021201  15000.0  0.0  0.0
*
*upper plenum
*
3030000  up303    branch
3030001  6         1
3030101  0.10  0.450  0.0  0.0  90.0  0.450  0  0.013083    0000000
3030200  113   0.1552e+08  602.291  0.131e-02
3031101  303000000  101010000  0.0150  0.0  0.0  0000000
3032101  303000000  102010000  0.0150  0.0  0.0  0000000
3033101  303000000  103010000  0.0150  0.0  0.0  0000000
3034101  303000000  104010000  0.0150  0.0  0.0  0000000
3035101  303000000  105010000  0.0150  0.0  0.0  0000000
3036101  303000000  106010000  0.0150  0.0  0.0  0000000
3031201     90.0      0.0  0.0
3032201     90.0      0.0  0.0
3033201     90.0      0.0  0.0
3034201     90.0      0.0  0.0
3035201     90.0      0.0  0.0
3036201     90.0      0.0  0.0
*
*upper plenum
*
3040000  up304    branch
3040001  3         1
3040101  0.05  0.450  0.0  0.0  90.0  0.450  0  0.013083    0000000
3040200  113   0.1552e+08  602.291  0.131e-02
3041101  304000000  107010000  0.0150  0.0  0.0  0000000
3042101  304000000  108010000  0.0150  0.0  0.0  0000000
3043101  304000000  109010000  0.0150  0.0  0.0  0000000
3041201     90.0      0.0  0.0
3042201     90.0      0.0  0.0
3043201     90.0      0.0  0.0
*
*
*-----------------------------------------------------------------
*Core Outlet Boundary Conditions
*-----------------------------------------------------------------
4000000  outle  tmdpvol
4000101  100.0  .1e+9    0.  0.  0.  0.  0.  0.  00
4000200  113
4000201    0.0   0.1552e+08  602.291  0.131e-02
4000202  .1e+07   0.1552e+08  602.291  0.131e-02
```

```
*
********************************************************************
*
********************************************************************
*
********Heat Structures********
*
* Heat Structure Channel 100
*
11000000  34    6    2    1    0.0  0  34
11000100  0    1
11000101  3    .458e-02    1    .466e-02    1    .539e-02
11000201   1     3     2     4     3     5
11000301  0.3131  1  0.3207  2  0.3592  3  0.0000  4  0.0070  5
11000400   -1
11000401   729.222   683.440   637.627   591.844   589.627   567.874
11000402   729.222   683.440   637.627   591.844   589.627   567.874
11000403   729.222   683.440   637.627   591.844   589.627   567.874
11000404   729.222   683.440   637.627   591.844   589.627   567.874
11000405   729.222   683.440   637.627   591.844   589.627   567.874
11000406   729.222   683.440   637.627   591.844   589.627   567.874
11000407   729.222   683.440   637.627   591.844   589.627   567.874
11000408   729.222   683.440   637.627   591.844   589.627   567.874
11000409   729.222   683.440   637.627   591.844   589.627   567.874
11000410   729.222   683.440   637.627   591.844   589.627   567.874
11000411   729.222   683.440   637.627   591.844   589.627   567.874
11000412   729.222   683.440   637.627   591.844   589.627   567.874
11000413   729.222   683.440   637.627   591.844   589.627   567.874
11000414   729.222   683.440   637.627   591.844   589.627   567.874
11000415   729.222   683.440   637.627   591.844   589.627   567.874
11000416   729.222   683.440   637.627   591.844   589.627   567.874
11000417   729.222   683.440   637.627   591.844   589.627   567.874
11000418   729.222   683.440   637.627   591.844   589.627   567.874
11000419   729.222   683.440   637.627   591.844   589.627   567.874
11000420   729.222   683.440   637.627   591.844   589.627   567.874
11000421   729.222   683.440   637.627   591.844   589.627   567.874
11000422   729.222   683.440   637.627   591.844   589.627   567.874
11000423   729.222   683.440   637.627   591.844   589.627   567.874
11000424   729.222   683.440   637.627   591.844   589.627   567.874
11000425   729.222   683.440   637.627   591.844   589.627   567.874
11000426   729.222   683.440   637.627   591.844   589.627   567.874
11000427   729.222   683.440   637.627   591.844   589.627   567.874
11000428   729.222   683.440   637.627   591.844   589.627   567.874
11000429   729.222   683.440   637.627   591.844   589.627   567.874
11000430   729.222   683.440   637.627   591.844   589.627   567.874
11000431   729.222   683.440   637.627   591.844   589.627   567.874
11000432   729.222   683.440   637.627   591.844   589.627   567.874
11000433   729.222   683.440   637.627   591.844   589.627   567.874
11000434   729.222   683.440   637.627   591.844   589.627   567.874
11000501  0     0      0  1   18515.6160   1
11000502  0     0      0  1    4230.4416  33
11000503  0     0      0  1   18000.1920  34
11000601  100010000      0      1  1   18515.6160   1
11000602  100020000  10000      1  1    4230.4416  33
11000603  100340000      0      1  1   18000.1920  34
```

```
11000701  0000  0.0  0.0  0.0   1
11000702  1000  0.031394791  0.0  0.000592853   2
11000703  1000  0.030188161  0.0  0.000570067   3
11000704  1000  0.029432508  0.0  0.000555797   4
11000705  1000  0.029017072  0.0  0.000547952   5
11000706  1000  0.028751731  0.0  0.000542942   6
11000707  1000  0.028641488  0.0  0.000540860   7
11000708  1000  0.028589559  0.0  0.000539879   8
11000709  1000  0.028598875  0.0  0.000540055   9
11000710  1000  0.028608191  0.0  0.000540231  10
11000711  1000  0.028564198  0.0  0.000539400  11
11000712  1000  0.028575757  0.0  0.000539619  12
11000713  1000  0.028584038  0.0  0.000539775  13
11000714  1000  0.028628894  0.0  0.000540622  14
11000715  1000  0.028663226  0.0  0.000541270  15
11000716  1000  0.028630619  0.0  0.000540655  16
11000717  1000  0.028650459  0.0  0.000541029  17
11000718  1000  0.028609399  0.0  0.000540254  18
11000719  1000  0.028595942  0.0  0.000540000  19
11000720  1000  0.028639763  0.0  0.000540827  20
11000721  1000  0.028610434  0.0  0.000540273  21
11000722  1000  0.028634932  0.0  0.000540736  22
11000723  1000  0.028658913  0.0  0.000541189  23
11000724  1000  0.028709808  0.0  0.000542150  24
11000725  1000  0.028770881  0.0  0.000543303  25
11000726  1000  0.028764498  0.0  0.000543183  26
11000727  1000  0.028831092  0.0  0.000544440  27
11000728  1000  0.029034088  0.0  0.000546385  28
11000729  1000  0.029118171  0.0  0.000549861  29
11000730  1000  0.029420432  0.0  0.000555569  30
11000731  1000  0.029822067  0.0  0.000563154  31
11000732  1000  0.030596179  0.0  0.000577772  32
11000733  1000  0.031653058  0.0  0.000597730  33
11000734  0000  0.0  0.0  0.0  34
11000901  0.13083e-01  10.0  10.0  0.0  0.0  0.0  0.0  1.0  34
*
* Heat Structure Channel 101
*
11010000  34    6    2    1    0.0  0  34
11010100  0    1
11010101  3    .458e-02    1    .466e-02    1    .539e-02
11010201   1     3     2     4     3     5
11010301  0.3131  1  0.3207  2  0.3592  3  0.0000  4  0.0070  5
11010400    -1
11010401  729.222   683.440   637.627   591.844   589.627   567.874
11010402  729.222   683.440   637.627   591.844   589.627   567.874
11010403  729.222   683.440   637.627   591.844   589.627   567.874
11010404  729.222   683.440   637.627   591.844   589.627   567.874
11010405  729.222   683.440   637.627   591.844   589.627   567.874
11010406  729.222   683.440   637.627   591.844   589.627   567.874
11010407  729.222   683.440   637.627   591.844   589.627   567.874
11010408  729.222   683.440   637.627   591.844   589.627   567.874
11010409  729.222   683.440   637.627   591.844   589.627   567.874
11010410  729.222   683.440   637.627   591.844   589.627   567.874
11010411  729.222   683.440   637.627   591.844   589.627   567.874
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11010412 729.222 683.440 637.627 591.844 589.627 567.874
11010413 729.222 683.440 637.627 591.844 589.627 567.874
11010414 729.222 683.440 637.627 591.844 589.627 567.874
11010415 729.222 683.440 637.627 591.844 589.627 567.874
11010416 729.222 683.440 637.627 591.844 589.627 567.874
11010417 729.222 683.440 637.627 591.844 589.627 567.874
11010418 729.222 683.440 637.627 591.844 589.627 567.874
11010419 729.222 683.440 637.627 591.844 589.627 567.874
11010420 729.222 683.440 637.627 591.844 589.627 567.874
11010421 729.222 683.440 637.627 591.844 589.627 567.874
11010422 729.222 683.440 637.627 591.844 589.627 567.874
11010423 729.222 683.440 637.627 591.844 589.627 567.874
11010424 729.222 683.440 637.627 591.844 589.627 567.874
11010425 729.222 683.440 637.627 591.844 589.627 567.874
11010426 729.222 683.440 637.627 591.844 589.627 567.874
11010427 729.222 683.440 637.627 591.844 589.627 567.874
11010428 729.222 683.440 637.627 591.844 589.627 567.874
11010429 729.222 683.440 637.627 591.844 589.627 567.874
11010430 729.222 683.440 637.627 591.844 589.627 567.874
11010431 729.222 683.440 637.627 591.844 589.627 567.874
11010432 729.222 683.440 637.627 591.844 589.627 567.874
11010433 729.222 683.440 637.627 591.844 589.627 567.874
11010434 729.222 683.440 637.627 591.844 589.627 567.874
11010501 0 0 0 1 110.2120 1
11010502 0 0 0 1 25.1812 33
11010503 0 0 0 1 107.1440 34
11010601 101010000 0 1 1 110.2120 1
11010602 101020000 10000 1 1 25.1812 33
11010603 101340000 0 1 1 107.1440 34
11010701 0000 0.0 0.0 0.0 1
11010702 1000 0.000192536 0.0 0.000003636 2
11010703 1000 0.000186153 0.0 0.000003515 3
11010704 1000 0.000182012 0.0 0.000003437 4
11010705 1000 0.000179597 0.0 0.000003391 5
11010706 1000 0.000177872 0.0 0.000003359 6
11010707 1000 0.000177182 0.0 0.000003346 7
11010708 1000 0.000176664 0.0 0.000003336 8
11010709 1000 0.000176837 0.0 0.000003339 9
11010710 1000 0.000176837 0.0 0.000003339 10
11010711 1000 0.000176492 0.0 0.000003333 11
11010712 1000 0.000176492 0.0 0.000003333 12
11010713 1000 0.000176664 0.0 0.000003336 13
11010714 1000 0.000177009 0.0 0.000003343 14
11010715 1000 0.000177182 0.0 0.000003346 15
11010716 1000 0.000177009 0.0 0.000003343 16
11010717 1000 0.000177182 0.0 0.000003346 17
11010718 1000 0.000156479 0.0 0.000002955 18
11010719 1000 0.000136984 0.0 0.000002587 19
11010720 1000 0.000137156 0.0 0.000002590 20
11010721 1000 0.000136984 0.0 0.000002587 21
11010722 1000 0.000137156 0.0 0.000002590 22
11010723 1000 0.000137156 0.0 0.000002590 23
11010724 1000 0.000137501 0.0 0.000002597 24
11010725 1000 0.000137674 0.0 0.000002600 25
11010726 1000 0.000137674 0.0 0.000002600 26
```

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11010727  1000  0.000138019  0.0  0.000002606  27
11010728  1000  0.000138364  0.0  0.000002613  28
11010729  1000  0.000139226  0.0  0.000002629  29
11010730  1000  0.000140607  0.0  0.000002655  30
11010731  1000  0.000142159  0.0  0.000002685  31
11010732  1000  0.000145092  0.0  0.000002740  32
11010733  1000  0.000148888  0.0  0.000002812  33
11010734  0000  0.0  0.0  0.0  34
11010901  0.13083e-01  10.0  10.0  0.0  0.0  0.0  0.0  1.0  34
*
* Heat Structure Channel 102
*
11020000  34     6     2     1     0.0  0  34
11020100  0     1
11020101  3     .458e-02     1     .466e-02     1     .539e-02
11020201   1      3      2      4      3      5
11020301  0.3131  1  0.3207  2  0.3592  3  0.0000  4  0.0070  5
11020400    -1
11020401   729.222   683.440   637.627   591.844   589.627   567.874
11020402   729.222   683.440   637.627   591.844   589.627   567.874
11020403   729.222   683.440   637.627   591.844   589.627   567.874
11020404   729.222   683.440   637.627   591.844   589.627   567.874
11020405   729.222   683.440   637.627   591.844   589.627   567.874
11020406   729.222   683.440   637.627   591.844   589.627   567.874
11020407   729.222   683.440   637.627   591.844   589.627   567.874
11020408   729.222   683.440   637.627   591.844   589.627   567.874
11020409   729.222   683.440   637.627   591.844   589.627   567.874
11020410   729.222   683.440   637.627   591.844   589.627   567.874
11020411   729.222   683.440   637.627   591.844   589.627   567.874
11020412   729.222   683.440   637.627   591.844   589.627   567.874
11020413   729.222   683.440   637.627   591.844   589.627   567.874
11020414   729.222   683.440   637.627   591.844   589.627   567.874
11020415   729.222   683.440   637.627   591.844   589.627   567.874
11020416   729.222   683.440   637.627   591.844   589.627   567.874
11020417   729.222   683.440   637.627   591.844   589.627   567.874
11020418   729.222   683.440   637.627   591.844   589.627   567.874
11020419   729.222   683.440   637.627   591.844   589.627   567.874
11020420   729.222   683.440   637.627   591.844   589.627   567.874
11020421   729.222   683.440   637.627   591.844   589.627   567.874
11020422   729.222   683.440   637.627   591.844   589.627   567.874
11020423   729.222   683.440   637.627   591.844   589.627   567.874
11020424   729.222   683.440   637.627   591.844   589.627   567.874
11020425   729.222   683.440   637.627   591.844   589.627   567.874
11020426   729.222   683.440   637.627   591.844   589.627   567.874
11020427   729.222   683.440   637.627   591.844   589.627   567.874
11020428   729.222   683.440   637.627   591.844   589.627   567.874
11020429   729.222   683.440   637.627   591.844   589.627   567.874
11020430   729.222   683.440   637.627   591.844   589.627   567.874
11020431   729.222   683.440   637.627   591.844   589.627   567.874
11020432   729.222   683.440   637.627   591.844   589.627   567.874
11020433   729.222   683.440   637.627   591.844   589.627   567.874
11020434   729.222   683.440   637.627   591.844   589.627   567.874
11020501  0      0      0  1     110.2120   1
11020502  0      0      0  1      25.1812  33
11020503  0      0      0  1     107.1440  34
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11020601  102010000     0      1  1     110.2120   1
11020602  102020000  10000      1  1      25.1812  33
11020603  102340000     0      1  1     107.1440  34
11020701  0000  0.0  0.0  0.0   1
11020702  1000  0.000192364  0.0  0.000003633   2
11020703  1000  0.000185980  0.0  0.000003512   3
11020704  1000  0.000181840  0.0  0.000003434   4
11020705  1000  0.000179424  0.0  0.000003388   5
11020706  1000  0.000177699  0.0  0.000003356   6
11020707  1000  0.000177009  0.0  0.000003343   7
11020708  1000  0.000176664  0.0  0.000003336   8
11020709  1000  0.000176664  0.0  0.000003336   9
11020710  1000  0.000176664  0.0  0.000003336  10
11020711  1000  0.000176492  0.0  0.000003333  11
11020712  1000  0.000176492  0.0  0.000003333  12
11020713  1000  0.000176492  0.0  0.000003333  13
11020714  1000  0.000176837  0.0  0.000003339  14
11020715  1000  0.000177009  0.0  0.000003343  15
11020716  1000  0.000176837  0.0  0.000003339  16
11020717  1000  0.000177009  0.0  0.000003343  17
11020718  1000  0.000177182  0.0  0.000003346  18
11020719  1000  0.000177354  0.0  0.000003349  19
11020720  1000  0.000177699  0.0  0.000003356  20
11020721  1000  0.000177527  0.0  0.000003352  21
11020722  1000  0.000177699  0.0  0.000003356  22
11020723  1000  0.000177872  0.0  0.000003359  23
11020724  1000  0.000178044  0.0  0.000003362  24
11020725  1000  0.000178562  0.0  0.000003372  25
11020726  1000  0.000178389  0.0  0.000003369  26
11020727  1000  0.000178907  0.0  0.000003378  27
11020728  1000  0.000179424  0.0  0.000003388  28
11020729  1000  0.000180632  0.0  0.000003411  29
11020730  1000  0.000182357  0.0  0.000003444  30
11020731  1000  0.000184600  0.0  0.000003486  31
11020732  1000  0.000188741  0.0  0.000003564  32
11020733  1000  0.000194261  0.0  0.000003668  33
11020734  0000  0.0  0.0  0.0  34
11020901  0.13083e-01  10.0  10.0  0.0  0.0  0.0  0.0  1.0  34
*
* Heat Structure Channel 103
*
11030000  34    6    2    1    0.0  0  34
11030100  0    1
11030101  3    .458e-02    1    .466e-02    1    .539e-02
11030201   1     3     2     4     3     5
11030301  0.3131  1  0.3207  2  0.3592  3  0.0000  4  0.0070  5
11030400    -1
11030401   729.222   683.440   637.627   591.844   589.627   567.874
11030402   729.222   683.440   637.627   591.844   589.627   567.874
11030403   729.222   683.440   637.627   591.844   589.627   567.874
11030404   729.222   683.440   637.627   591.844   589.627   567.874
11030405   729.222   683.440   637.627   591.844   589.627   567.874
11030406   729.222   683.440   637.627   591.844   589.627   567.874
11030407   729.222   683.440   637.627   591.844   589.627   567.874
11030408   729.222   683.440   637.627   591.844   589.627   567.874
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11030409   729.222   683.440   637.627   591.844   589.627   567.874
11030410   729.222   683.440   637.627   591.844   589.627   567.874
11030411   729.222   683.440   637.627   591.844   589.627   567.874
11030412   729.222   683.440   637.627   591.844   589.627   567.874
11030413   729.222   683.440   637.627   591.844   589.627   567.874
11030414   729.222   683.440   637.627   591.844   589.627   567.874
11030415   729.222   683.440   637.627   591.844   589.627   567.874
11030416   729.222   683.440   637.627   591.844   589.627   567.874
11030417   729.222   683.440   637.627   591.844   589.627   567.874
11030418   729.222   683.440   637.627   591.844   589.627   567.874
11030419   729.222   683.440   637.627   591.844   589.627   567.874
11030420   729.222   683.440   637.627   591.844   589.627   567.874
11030421   729.222   683.440   637.627   591.844   589.627   567.874
11030422   729.222   683.440   637.627   591.844   589.627   567.874
11030423   729.222   683.440   637.627   591.844   589.627   567.874
11030424   729.222   683.440   637.627   591.844   589.627   567.874
11030425   729.222   683.440   637.627   591.844   589.627   567.874
11030426   729.222   683.440   637.627   591.844   589.627   567.874
11030427   729.222   683.440   637.627   591.844   589.627   567.874
11030428   729.222   683.440   637.627   591.844   589.627   567.874
11030429   729.222   683.440   637.627   591.844   589.627   567.874
11030430   729.222   683.440   637.627   591.844   589.627   567.874
11030431   729.222   683.440   637.627   591.844   589.627   567.874
11030432   729.222   683.440   637.627   591.844   589.627   567.874
11030433   729.222   683.440   637.627   591.844   589.627   567.874
11030434   729.222   683.440   637.627   591.844   589.627   567.874
11030501  0      0      0  1     110.2120   1
11030502  0      0      0  1      25.1812  33
11030503  0      0      0  1     107.1440  34
11030601  103010000      0       1  1     110.2120   1
11030602  103020000  10000       1  1      25.1812  33
11030603  103340000      0       1  1     107.1440  34
11030701  0000  0.0  0.0  0.0   1
11030702  1000  0.000194089  0.0  0.000003665   2
11030703  1000  0.000188223  0.0  0.000003554   3
11030704  1000  0.000184255  0.0  0.000003479   4
11030705  1000  0.000181840  0.0  0.000003434   5
11030706  1000  0.000180287  0.0  0.000003405   6
11030707  1000  0.000179597  0.0  0.000003391   7
11030708  1000  0.000179252  0.0  0.000003385   8
11030709  1000  0.000179252  0.0  0.000003385   9
11030710  1000  0.000179252  0.0  0.000003385  10
11030711  1000  0.000178907  0.0  0.000003378  11
11030712  1000  0.000178907  0.0  0.000003378  12
11030713  1000  0.000179079  0.0  0.000003382  13
11030714  1000  0.000179252  0.0  0.000003385  14
11030715  1000  0.000179424  0.0  0.000003388  15
11030716  1000  0.000179252  0.0  0.000003385  16
11030717  1000  0.000179424  0.0  0.000003388  17
11030718  1000  0.000179597  0.0  0.000003391  18
11030719  1000  0.000179942  0.0  0.000003398  19
11030720  1000  0.000180287  0.0  0.000003405  20
11030721  1000  0.000180115  0.0  0.000003401  21
11030722  1000  0.000180115  0.0  0.000003401  22
11030723  1000  0.000180287  0.0  0.000003405  23
```

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11030724  1000  0.000180632  0.0  0.000003411  24
11030725  1000  0.000180977  0.0  0.000003418  25
11030726  1000  0.000180977  0.0  0.000003418  26
11030727  1000  0.000181322  0.0  0.000003424  27
11030728  1000  0.000181840  0.0  0.000003434  28
11030729  1000  0.000183047  0.0  0.000003457  29
11030730  1000  0.000184600  0.0  0.000003486  30
11030731  1000  0.000186843  0.0  0.000003528  31
11030732  1000  0.000190811  0.0  0.000003603  32
11030733  1000  0.000195987  0.0  0.000003701  33
11030734  0000  0.0  0.0  0.0  34
11030901  0.13083e-01  10.0  10.0  0.0  0.0  0.0  0.0  1.0  34
*
* Heat Structure Channel 104
*
11040000  34     6     2     1     0.0  0  34
11040100  0     1
11040101  3    .458e-02    1    .466e-02    1    .539e-02
11040201   1     3     2     4     3     5
11040301  0.3131  1  0.3207  2  0.3592  3  0.0000  4  0.0070  5
11040400    -1
11040401   729.222   683.440   637.627   591.844   589.627   567.874
11040402   729.222   683.440   637.627   591.844   589.627   567.874
11040403   729.222   683.440   637.627   591.844   589.627   567.874
11040404   729.222   683.440   637.627   591.844   589.627   567.874
11040405   729.222   683.440   637.627   591.844   589.627   567.874
11040406   729.222   683.440   637.627   591.844   589.627   567.874
11040407   729.222   683.440   637.627   591.844   589.627   567.874
11040408   729.222   683.440   637.627   591.844   589.627   567.874
11040409   729.222   683.440   637.627   591.844   589.627   567.874
11040410   729.222   683.440   637.627   591.844   589.627   567.874
11040411   729.222   683.440   637.627   591.844   589.627   567.874
11040412   729.222   683.440   637.627   591.844   589.627   567.874
11040413   729.222   683.440   637.627   591.844   589.627   567.874
11040414   729.222   683.440   637.627   591.844   589.627   567.874
11040415   729.222   683.440   637.627   591.844   589.627   567.874
11040416   729.222   683.440   637.627   591.844   589.627   567.874
11040417   729.222   683.440   637.627   591.844   589.627   567.874
11040418   729.222   683.440   637.627   591.844   589.627   567.874
11040419   729.222   683.440   637.627   591.844   589.627   567.874
11040420   729.222   683.440   637.627   591.844   589.627   567.874
11040421   729.222   683.440   637.627   591.844   589.627   567.874
11040422   729.222   683.440   637.627   591.844   589.627   567.874
11040423   729.222   683.440   637.627   591.844   589.627   567.874
11040424   729.222   683.440   637.627   591.844   589.627   567.874
11040425   729.222   683.440   637.627   591.844   589.627   567.874
11040426   729.222   683.440   637.627   591.844   589.627   567.874
11040427   729.222   683.440   637.627   591.844   589.627   567.874
11040428   729.222   683.440   637.627   591.844   589.627   567.874
11040429   729.222   683.440   637.627   591.844   589.627   567.874
11040430   729.222   683.440   637.627   591.844   589.627   567.874
11040431   729.222   683.440   637.627   591.844   589.627   567.874
11040432   729.222   683.440   637.627   591.844   589.627   567.874
11040433   729.222   683.440   637.627   591.844   589.627   567.874
11040434   729.222   683.440   637.627   591.844   589.627   567.874
```

```
11040501  0      0       0  1     110.2120   1
11040502  0      0       0  1      25.1812  33
11040503  0      0       0  1     107.1440  34
11040601  104010000      0       1  1     110.2120   1
11040602  104020000  10000       1  1      25.1812  33
11040603  104340000      0       1  1     107.1440  34
11040701  0000  0.0  0.0  0.0   1
11040702  1000  0.000178044  0.0  0.000003362   2
11040703  1000  0.000168555  0.0  0.000003183   3
11040704  1000  0.000162690  0.0  0.000003072   4
11040705  1000  0.000159412  0.0  0.000003010   5
11040706  1000  0.000157341  0.0  0.000002971   6
11040707  1000  0.000156651  0.0  0.000002958   7
11040708  1000  0.000156306  0.0  0.000002952   8
11040709  1000  0.000156479  0.0  0.000002955   9
11040710  1000  0.000156651  0.0  0.000002958  10
11040711  1000  0.000156306  0.0  0.000002952  11
11040712  1000  0.000156479  0.0  0.000002955  12
11040713  1000  0.000156479  0.0  0.000002955  13
11040714  1000  0.000156996  0.0  0.000002965  14
11040715  1000  0.000157341  0.0  0.000002971  15
11040716  1000  0.000156996  0.0  0.000002965  16
11040717  1000  0.000157169  0.0  0.000002968  17
11040718  1000  0.000157341  0.0  0.000002971  18
11040719  1000  0.000157859  0.0  0.000002981  19
11040720  1000  0.000158204  0.0  0.000002987  20
11040721  1000  0.000158032  0.0  0.000002984  21
11040722  1000  0.000158204  0.0  0.000002987  22
11040723  1000  0.000158377  0.0  0.000002991  23
11040724  1000  0.000158894  0.0  0.000003001  24
11040725  1000  0.000159239  0.0  0.000003007  25
11040726  1000  0.000159239  0.0  0.000003007  26
11040727  1000  0.000159757  0.0  0.000003017  27
11040728  1000  0.000160447  0.0  0.000003030  28
11040729  1000  0.000162000  0.0  0.000003059  29
11040730  1000  0.000164242  0.0  0.000003102  30
11040731  1000  0.000167348  0.0  0.000003160  31
11040732  1000  0.000173386  0.0  0.000003274  32
11040733  1000  0.000181495  0.0  0.000003427  33
11040734  0000  0.0  0.0  0.0  34
11040901  0.13083e-01  10.0  10.0  0.0  0.0  0.0  0.0  1.0  34
*
* Heat Structure Channel 105
*
11050000  34     6     2     1     0.0  0  34
11050100  0     1
11050101  3     .458e-02     1     .466e-02     1     .539e-02
11050201   1      3      2      4      3      5
11050301  0.3131  1  0.3207  2  0.3592  3  0.0000  4  0.0070  5
11050400    -1
11050401   729.222   683.440   637.627   591.844   589.627   567.874
11050402   729.222   683.440   637.627   591.844   589.627   567.874
11050403   729.222   683.440   637.627   591.844   589.627   567.874
11050404   729.222   683.440   637.627   591.844   589.627   567.874
11050405   729.222   683.440   637.627   591.844   589.627   567.874
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11050406  729.222  683.440  637.627  591.844  589.627  567.874
11050407  729.222  683.440  637.627  591.844  589.627  567.874
11050408  729.222  683.440  637.627  591.844  589.627  567.874
11050409  729.222  683.440  637.627  591.844  589.627  567.874
11050410  729.222  683.440  637.627  591.844  589.627  567.874
11050411  729.222  683.440  637.627  591.844  589.627  567.874
11050412  729.222  683.440  637.627  591.844  589.627  567.874
11050413  729.222  683.440  637.627  591.844  589.627  567.874
11050414  729.222  683.440  637.627  591.844  589.627  567.874
11050415  729.222  683.440  637.627  591.844  589.627  567.874
11050416  729.222  683.440  637.627  591.844  589.627  567.874
11050417  729.222  683.440  637.627  591.844  589.627  567.874
11050418  729.222  683.440  637.627  591.844  589.627  567.874
11050419  729.222  683.440  637.627  591.844  589.627  567.874
11050420  729.222  683.440  637.627  591.844  589.627  567.874
11050421  729.222  683.440  637.627  591.844  589.627  567.874
11050422  729.222  683.440  637.627  591.844  589.627  567.874
11050423  729.222  683.440  637.627  591.844  589.627  567.874
11050424  729.222  683.440  637.627  591.844  589.627  567.874
11050425  729.222  683.440  637.627  591.844  589.627  567.874
11050426  729.222  683.440  637.627  591.844  589.627  567.874
11050427  729.222  683.440  637.627  591.844  589.627  567.874
11050428  729.222  683.440  637.627  591.844  589.627  567.874
11050429  729.222  683.440  637.627  591.844  589.627  567.874
11050430  729.222  683.440  637.627  591.844  589.627  567.874
11050431  729.222  683.440  637.627  591.844  589.627  567.874
11050432  729.222  683.440  637.627  591.844  589.627  567.874
11050433  729.222  683.440  637.627  591.844  589.627  567.874
11050434  729.222  683.440  637.627  591.844  589.627  567.874
11050501 0     0     0  1    110.2120   1
11050502 0     0     0  1     25.1812  33
11050503 0     0     0  1    107.1440  34
11050601  105010000     0      1  1     110.2120   1
11050602  105020000  10000      1  1     25.1812  33
11050603  105340000     0      1  1     107.1440  34
11050701  0000  0.0  0.0  0.0   1
11050702  1000  0.000179424  0.0  0.000003388   2
11050703  1000  0.000170453  0.0  0.000003219   3
11050704  1000  0.000164760  0.0  0.000003111   4
11050705  1000  0.000161655  0.0  0.000003053   5
11050706  1000  0.000159757  0.0  0.000003017   6
11050707  1000  0.000158894  0.0  0.000003001   7
11050708  1000  0.000158549  0.0  0.000002994   8
11050709  1000  0.000158722  0.0  0.000002997   9
11050710  1000  0.000158722  0.0  0.000002997  10
11050711  1000  0.000158377  0.0  0.000002991  11
11050712  1000  0.000158549  0.0  0.000002994  12
11050713  1000  0.000158549  0.0  0.000002994  13
11050714  1000  0.000158894  0.0  0.000003001  14
11050715  1000  0.000159239  0.0  0.000003007  15
11050716  1000  0.000158894  0.0  0.000003001  16
11050717  1000  0.000159239  0.0  0.000003007  17
11050718  1000  0.000159412  0.0  0.000003010  18
11050719  1000  0.000159757  0.0  0.000003017  19
11050720  1000  0.000160102  0.0  0.000003023  20
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11050721  1000  0.000159757  0.0  0.000003017  21
11050722  1000  0.000159929  0.0  0.000003020  22
11050723  1000  0.000160102  0.0  0.000003023  23
11050724  1000  0.000160447  0.0  0.000003030  24
11050725  1000  0.000160964  0.0  0.000003040  25
11050726  1000  0.000160792  0.0  0.000003036  26
11050727  1000  0.000161309  0.0  0.000003046  27
11050728  1000  0.000162000  0.0  0.000003059  28
11050729  1000  0.000163380  0.0  0.000003085  29
11050730  1000  0.000165623  0.0  0.000003128  30
11050731  1000  0.000168555  0.0  0.000003183  31
11050732  1000  0.000174249  0.0  0.000003290  32
11050733  1000  0.000182185  0.0  0.000003440  33
11050734  0000  0.0  0.0  0.0  34
11050901  0.13083e-01  10.0  10.0  0.0  0.0  0.0  0.0  1.0  34
*
* Heat Structure Channel 106
*
11060000  34    6    2    1    0.0  0  34
11060100  0    1
11060101  3    .458e-02    1    .466e-02    1    .539e-02
11060201  1    3    2    4    3    5
11060301  0.3131  1  0.3207  2  0.3592  3  0.0000  4  0.0070  5
11060400   -1
11060401   729.222   683.440   637.627   591.844   589.627   567.874
11060402   729.222   683.440   637.627   591.844   589.627   567.874
11060403   729.222   683.440   637.627   591.844   589.627   567.874
11060404   729.222   683.440   637.627   591.844   589.627   567.874
11060405   729.222   683.440   637.627   591.844   589.627   567.874
11060406   729.222   683.440   637.627   591.844   589.627   567.874
11060407   729.222   683.440   637.627   591.844   589.627   567.874
11060408   729.222   683.440   637.627   591.844   589.627   567.874
11060409   729.222   683.440   637.627   591.844   589.627   567.874
11060410   729.222   683.440   637.627   591.844   589.627   567.874
11060411   729.222   683.440   637.627   591.844   589.627   567.874
11060412   729.222   683.440   637.627   591.844   589.627   567.874
11060413   729.222   683.440   637.627   591.844   589.627   567.874
11060414   729.222   683.440   637.627   591.844   589.627   567.874
11060415   729.222   683.440   637.627   591.844   589.627   567.874
11060416   729.222   683.440   637.627   591.844   589.627   567.874
11060417   729.222   683.440   637.627   591.844   589.627   567.874
11060418   729.222   683.440   637.627   591.844   589.627   567.874
11060419   729.222   683.440   637.627   591.844   589.627   567.874
11060420   729.222   683.440   637.627   591.844   589.627   567.874
11060421   729.222   683.440   637.627   591.844   589.627   567.874
11060422   729.222   683.440   637.627   591.844   589.627   567.874
11060423   729.222   683.440   637.627   591.844   589.627   567.874
11060424   729.222   683.440   637.627   591.844   589.627   567.874
11060425   729.222   683.440   637.627   591.844   589.627   567.874
11060426   729.222   683.440   637.627   591.844   589.627   567.874
11060427   729.222   683.440   637.627   591.844   589.627   567.874
11060428   729.222   683.440   637.627   591.844   589.627   567.874
11060429   729.222   683.440   637.627   591.844   589.627   567.874
11060430   729.222   683.440   637.627   591.844   589.627   567.874
11060431   729.222   683.440   637.627   591.844   589.627   567.874
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11060432  729.222  683.440  637.627  591.844  589.627  567.874
11060433  729.222  683.440  637.627  591.844  589.627  567.874
11060434  729.222  683.440  637.627  591.844  589.627  567.874
11060501 0     0     0  1    110.2120   1
11060502 0     0     0  1     25.1812  33
11060503 0     0     0  1    107.1440  34
11060601  106010000     0      1  1     110.2120   1
11060602  106020000  10000      1  1     25.1812  33
11060603  106340000     0      1  1     107.1440  34
11060701  0000  0.0  0.0  0.0   1
11060702  1000  0.000208581  0.0  0.000003939   2
11060703  1000  0.000206856  0.0  0.000003906   3
11060704  1000  0.000205993  0.0  0.000003890   4
11060705  1000  0.000205303  0.0  0.000003877   5
11060706  1000  0.000204785  0.0  0.000003867   6
11060707  1000  0.000204613  0.0  0.000003864   7
11060708  1000  0.000204440  0.0  0.000003861   8
11060709  1000  0.000204268  0.0  0.000003857   9
11060710  1000  0.000204095  0.0  0.000003854  10
11060711  1000  0.000204095  0.0  0.000003854  11
11060712  1000  0.000203923  0.0  0.000003851  12
11060713  1000  0.000203923  0.0  0.000003851  13
11060714  1000  0.000203923  0.0  0.000003851  14
11060715  1000  0.000203923  0.0  0.000003851  15
11060716  1000  0.000204095  0.0  0.000003854  16
11060717  1000  0.000204095  0.0  0.000003854  17
11060718  1000  0.000204268  0.0  0.000003857  18
11060719  1000  0.000204440  0.0  0.000003861  19
11060720  1000  0.000204613  0.0  0.000003864  20
11060721  1000  0.000204613  0.0  0.000003864  21
11060722  1000  0.000204785  0.0  0.000003867  22
11060723  1000  0.000204785  0.0  0.000003867  23
11060724  1000  0.000204958  0.0  0.000003870  24
11060725  1000  0.000204958  0.0  0.000003870  25
11060726  1000  0.000205130  0.0  0.000003874  26
11060727  1000  0.000205303  0.0  0.000003877  27
11060728  1000  0.000205475  0.0  0.000003880  28
11060729  1000  0.000205648  0.0  0.000003883  29
11060730  1000  0.000205993  0.0  0.000003890  30
11060731  1000  0.000206683  0.0  0.000003903  31
11060732  1000  0.000207546  0.0  0.000003919  32
11060733  1000  0.000208753  0.0  0.000003942  33
11060734  0000  0.0  0.0  0.0  34
11060901  0.13083e-01  10.0  10.0  0.0  0.0  0.0  0.0  1.0  34
*
* Heat Structure Channel 107
*
11070000  34    6    2    1    0.0  0  34
11070100  0    1
11070101  3    .458e-02    1    .466e-02    1    .539e-02
11070201   1     3     2     4     3     5
11070301  0.3131  1  0.3207  2  0.3592  3  0.0000  4  0.0070  5
11070400    -1
11070401   729.222   683.440   637.627   591.844   589.627   567.874
11070402   729.222   683.440   637.627   591.844   589.627   567.874
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11070403   729.222   683.440   637.627   591.844   589.627   567.874
11070404   729.222   683.440   637.627   591.844   589.627   567.874
11070405   729.222   683.440   637.627   591.844   589.627   567.874
11070406   729.222   683.440   637.627   591.844   589.627   567.874
11070407   729.222   683.440   637.627   591.844   589.627   567.874
11070408   729.222   683.440   637.627   591.844   589.627   567.874
11070409   729.222   683.440   637.627   591.844   589.627   567.874
11070410   729.222   683.440   637.627   591.844   589.627   567.874
11070411   729.222   683.440   637.627   591.844   589.627   567.874
11070412   729.222   683.440   637.627   591.844   589.627   567.874
11070413   729.222   683.440   637.627   591.844   589.627   567.874
11070414   729.222   683.440   637.627   591.844   589.627   567.874
11070415   729.222   683.440   637.627   591.844   589.627   567.874
11070416   729.222   683.440   637.627   591.844   589.627   567.874
11070417   729.222   683.440   637.627   591.844   589.627   567.874
11070418   729.222   683.440   637.627   591.844   589.627   567.874
11070419   729.222   683.440   637.627   591.844   589.627   567.874
11070420   729.222   683.440   637.627   591.844   589.627   567.874
11070421   729.222   683.440   637.627   591.844   589.627   567.874
11070422   729.222   683.440   637.627   591.844   589.627   567.874
11070423   729.222   683.440   637.627   591.844   589.627   567.874
11070424   729.222   683.440   637.627   591.844   589.627   567.874
11070425   729.222   683.440   637.627   591.844   589.627   567.874
11070426   729.222   683.440   637.627   591.844   589.627   567.874
11070427   729.222   683.440   637.627   591.844   589.627   567.874
11070428   729.222   683.440   637.627   591.844   589.627   567.874
11070429   729.222   683.440   637.627   591.844   589.627   567.874
11070430   729.222   683.440   637.627   591.844   589.627   567.874
11070431   729.222   683.440   637.627   591.844   589.627   567.874
11070432   729.222   683.440   637.627   591.844   589.627   567.874
11070433   729.222   683.440   637.627   591.844   589.627   567.874
11070434   729.222   683.440   637.627   591.844   589.627   567.874
11070501  0      0      0  1     110.2120   1
11070502  0      0      0  1      25.1812  33
11070503  0      0      0  1     107.1440  34
11070601  107010000      0       1  1     110.2120   1
11070602  107020000  10000       1  1      25.1812  33
11070603  107340000      0       1  1     107.1440  34
11070701  0000  0.0  0.0  0.0   1
11070702  1000  0.000179424  0.0  0.000003388   2
11070703  1000  0.000170453  0.0  0.000003219   3
11070704  1000  0.000164760  0.0  0.000003111   4
11070705  1000  0.000161655  0.0  0.000003053   5
11070706  1000  0.000159757  0.0  0.000003017   6
11070707  1000  0.000158894  0.0  0.000003001   7
11070708  1000  0.000158549  0.0  0.000002994   8
11070709  1000  0.000158722  0.0  0.000002997   9
11070710  1000  0.000158722  0.0  0.000002997  10
11070711  1000  0.000158377  0.0  0.000002991  11
11070712  1000  0.000158549  0.0  0.000002994  12
11070713  1000  0.000158722  0.0  0.000002997  13
11070714  1000  0.000159067  0.0  0.000003004  14
11070715  1000  0.000159239  0.0  0.000003007  15
11070716  1000  0.000159067  0.0  0.000003004  16
11070717  1000  0.000159239  0.0  0.000003007  17
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11070718  1000  0.000159412  0.0  0.000003010  18
11070719  1000  0.000159757  0.0  0.000003017  19
11070720  1000  0.000160102  0.0  0.000003023  20
11070721  1000  0.000159757  0.0  0.000003017  21
11070722  1000  0.000159929  0.0  0.000003020  22
11070723  1000  0.000160102  0.0  0.000003023  23
11070724  1000  0.000160619  0.0  0.000003033  24
11070725  1000  0.000160964  0.0  0.000003040  25
11070726  1000  0.000160792  0.0  0.000003036  26
11070727  1000  0.000161309  0.0  0.000003046  27
11070728  1000  0.000162000  0.0  0.000003059  28
11070729  1000  0.000163380  0.0  0.000003085  29
11070730  1000  0.000165623  0.0  0.000003128  30
11070731  1000  0.000168728  0.0  0.000003186  31
11070732  1000  0.000174421  0.0  0.000003294  32
11070733  1000  0.000182357  0.0  0.000003444  33
11070734  0000  0.0  0.0  0.0  34
11070901  0.13083e-01  10.0  10.0  0.0  0.0  0.0  0.0  1.0  34
*
* Heat Structure Channel 108
*
11080000  34     6     2     1     0.0  0  34
11080100  0     1
11080101  3    .458e-02     1     .466e-02     1     .539e-02
11080201   1      3      2      4      3      5
11080301  0.3131  1  0.3207  2  0.3592  3  0.0000  4  0.0070  5
11080400    -1
11080401   729.222   683.440   637.627   591.844   589.627   567.874
11080402   729.222   683.440   637.627   591.844   589.627   567.874
11080403   729.222   683.440   637.627   591.844   589.627   567.874
11080404   729.222   683.440   637.627   591.844   589.627   567.874
11080405   729.222   683.440   637.627   591.844   589.627   567.874
11080406   729.222   683.440   637.627   591.844   589.627   567.874
11080407   729.222   683.440   637.627   591.844   589.627   567.874
11080408   729.222   683.440   637.627   591.844   589.627   567.874
11080409   729.222   683.440   637.627   591.844   589.627   567.874
11080410   729.222   683.440   637.627   591.844   589.627   567.874
11080411   729.222   683.440   637.627   591.844   589.627   567.874
11080412   729.222   683.440   637.627   591.844   589.627   567.874
11080413   729.222   683.440   637.627   591.844   589.627   567.874
11080414   729.222   683.440   637.627   591.844   589.627   567.874
11080415   729.222   683.440   637.627   591.844   589.627   567.874
11080416   729.222   683.440   637.627   591.844   589.627   567.874
11080417   729.222   683.440   637.627   591.844   589.627   567.874
11080418   729.222   683.440   637.627   591.844   589.627   567.874
11080419   729.222   683.440   637.627   591.844   589.627   567.874
11080420   729.222   683.440   637.627   591.844   589.627   567.874
11080421   729.222   683.440   637.627   591.844   589.627   567.874
11080422   729.222   683.440   637.627   591.844   589.627   567.874
11080423   729.222   683.440   637.627   591.844   589.627   567.874
11080424   729.222   683.440   637.627   591.844   589.627   567.874
11080425   729.222   683.440   637.627   591.844   589.627   567.874
11080426   729.222   683.440   637.627   591.844   589.627   567.874
11080427   729.222   683.440   637.627   591.844   589.627   567.874
11080428   729.222   683.440   637.627   591.844   589.627   567.874
```

```
11080429   729.222   683.440   637.627   591.844   589.627   567.874
11080430   729.222   683.440   637.627   591.844   589.627   567.874
11080431   729.222   683.440   637.627   591.844   589.627   567.874
11080432   729.222   683.440   637.627   591.844   589.627   567.874
11080433   729.222   683.440   637.627   591.844   589.627   567.874
11080434   729.222   683.440   637.627   591.844   589.627   567.874
11080501  0      0       0  1     110.2120   1
11080502  0      0       0  1      25.1812  33
11080503  0      0       0  1     107.1440  34
11080601  108010000      0       1  1     110.2120   1
11080602  108020000  10000       1  1      25.1812  33
11080603  108340000      0       1  1     107.1440  34
11080701  0000  0.0  0.0  0.0   1
11080702  1000  0.000191846  0.0  0.000003623   2
11080703  1000  0.000185290  0.0  0.000003499   3
11080704  1000  0.000181150  0.0  0.000003421   4
11080705  1000  0.000178734  0.0  0.000003375   5
11080706  1000  0.000177009  0.0  0.000003343   6
11080707  1000  0.000176319  0.0  0.000003330   7
11080708  1000  0.000175974  0.0  0.000003323   8
11080709  1000  0.000175974  0.0  0.000003323   9
11080710  1000  0.000175974  0.0  0.000003323  10
11080711  1000  0.000175629  0.0  0.000003317  11
11080712  1000  0.000175801  0.0  0.000003320  12
11080713  1000  0.000175801  0.0  0.000003320  13
11080714  1000  0.000176146  0.0  0.000003326  14
11080715  1000  0.000176319  0.0  0.000003330  15
11080716  1000  0.000176146  0.0  0.000003326  16
11080717  1000  0.000176319  0.0  0.000003330  17
11080718  1000  0.000176664  0.0  0.000003336  18
11080719  1000  0.000177009  0.0  0.000003343  19
11080720  1000  0.000177354  0.0  0.000003349  20
11080721  1000  0.000177182  0.0  0.000003346  21
11080722  1000  0.000177354  0.0  0.000003349  22
11080723  1000  0.000177527  0.0  0.000003352  23
11080724  1000  0.000177872  0.0  0.000003359  24
11080725  1000  0.000178217  0.0  0.000003365  25
11080726  1000  0.000178217  0.0  0.000003365  26
11080727  1000  0.000178562  0.0  0.000003372  27
11080728  1000  0.000179252  0.0  0.000003385  28
11080729  1000  0.000180287  0.0  0.000003405  29
11080730  1000  0.000182185  0.0  0.000003440  30
11080731  1000  0.000184428  0.0  0.000003483  31
11080732  1000  0.000189086  0.0  0.000003571  32
11080733  1000  0.000194952  0.0  0.000003681  33
11080734  0000  0.0  0.0  0.0  34
11080901  0.13083e-01  10.0  10.0  0.0  0.0  0.0  0.0  1.0  34
*
* Heat Structure Channel 109
*
11090000  34     6     2     1     0.0  0  34
11090100  0     1
11090101  3     .458e-02     1     .466e-02     1     .539e-02
11090201   1      3      2      4      3      5
11090301  0.3131  1  0.3207  2  0.3592  3  0.0000  4  0.0070  5
```

```
11090400    -1
11090401   729.222   683.440   637.627   591.844   589.627   567.874
11090402   729.222   683.440   637.627   591.844   589.627   567.874
11090403   729.222   683.440   637.627   591.844   589.627   567.874
11090404   729.222   683.440   637.627   591.844   589.627   567.874
11090405   729.222   683.440   637.627   591.844   589.627   567.874
11090406   729.222   683.440   637.627   591.844   589.627   567.874
11090407   729.222   683.440   637.627   591.844   589.627   567.874
11090408   729.222   683.440   637.627   591.844   589.627   567.874
11090409   729.222   683.440   637.627   591.844   589.627   567.874
11090410   729.222   683.440   637.627   591.844   589.627   567.874
11090411   729.222   683.440   637.627   591.844   589.627   567.874
11090412   729.222   683.440   637.627   591.844   589.627   567.874
11090413   729.222   683.440   637.627   591.844   589.627   567.874
11090414   729.222   683.440   637.627   591.844   589.627   567.874
11090415   729.222   683.440   637.627   591.844   589.627   567.874
11090416   729.222   683.440   637.627   591.844   589.627   567.874
11090417   729.222   683.440   637.627   591.844   589.627   567.874
11090418   729.222   683.440   637.627   591.844   589.627   567.874
11090419   729.222   683.440   637.627   591.844   589.627   567.874
11090420   729.222   683.440   637.627   591.844   589.627   567.874
11090421   729.222   683.440   637.627   591.844   589.627   567.874
11090422   729.222   683.440   637.627   591.844   589.627   567.874
11090423   729.222   683.440   637.627   591.844   589.627   567.874
11090424   729.222   683.440   637.627   591.844   589.627   567.874
11090425   729.222   683.440   637.627   591.844   589.627   567.874
11090426   729.222   683.440   637.627   591.844   589.627   567.874
11090427   729.222   683.440   637.627   591.844   589.627   567.874
11090428   729.222   683.440   637.627   591.844   589.627   567.874
11090429   729.222   683.440   637.627   591.844   589.627   567.874
11090430   729.222   683.440   637.627   591.844   589.627   567.874
11090431   729.222   683.440   637.627   591.844   589.627   567.874
11090432   729.222   683.440   637.627   591.844   589.627   567.874
11090433   729.222   683.440   637.627   591.844   589.627   567.874
11090434   729.222   683.440   637.627   591.844   589.627   567.874
11090501  0      0      0  1     110.2120   1
11090502  0      0      0  1      25.1812  33
11090503  0      0      0  1     107.1440  34
11090601  109010000      0       1  1     110.2120   1
11090602  109020000  10000       1  1      25.1812  33
11090603  109340000      0       1  1     107.1440  34
11090701  0000  0.0  0.0  0.0   1
11090702  1000  0.000208753  0.0  0.000003942   2
11090703  1000  0.000207201  0.0  0.000003913   3
11090704  1000  0.000206166  0.0  0.000003893   4
11090705  1000  0.000205648  0.0  0.000003883   5
11090706  1000  0.000205130  0.0  0.000003874   6
11090707  1000  0.000204958  0.0  0.000003870   7
11090708  1000  0.000204613  0.0  0.000003864   8
11090709  1000  0.000204440  0.0  0.000003861   9
11090710  1000  0.000204440  0.0  0.000003861  10
11090711  1000  0.000204268  0.0  0.000003857  11
11090712  1000  0.000204268  0.0  0.000003857  12
11090713  1000  0.000204268  0.0  0.000003857  13
11090714  1000  0.000204268  0.0  0.000003857  14
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11090715  1000  0.000204268  0.0  0.000003857  15
11090716  1000  0.000204268  0.0  0.000003857  16
11090717  1000  0.000204440  0.0  0.000003861  17
11090718  1000  0.000204440  0.0  0.000003861  18
11090719  1000  0.000204613  0.0  0.000003864  19
11090720  1000  0.000204785  0.0  0.000003867  20
11090721  1000  0.000204785  0.0  0.000003867  21
11090722  1000  0.000204958  0.0  0.000003870  22
11090723  1000  0.000204958  0.0  0.000003870  23
11090724  1000  0.000205130  0.0  0.000003874  24
11090725  1000  0.000205130  0.0  0.000003874  25
11090726  1000  0.000205303  0.0  0.000003877  26
11090727  1000  0.000205475  0.0  0.000003880  27
11090728  1000  0.000205648  0.0  0.000003883  28
11090729  1000  0.000205821  0.0  0.000003887  29
11090730  1000  0.000206338  0.0  0.000003896  30
11090731  1000  0.000206856  0.0  0.000003906  31
11090732  1000  0.000207718  0.0  0.000003923  32
11090733  1000  0.000209098  0.0  0.000003949  33
11090734  0000  0.0  0.0  0.0  34
11090901  0.13083e-01  10.0  10.0  0.0  0.0  0.0  0.0  1.0  34
*
* Heat Structure Bypass
*
12500000  34    6    2    1    0.0  0  34
12500100  0    1
12500101  3    .458e-02    1    .466e-02    1    .539e-02
12500201   1    3    2    4    3    5
12500301  0.3131  1  0.3207  2  0.3592  3  0.0000  4  0.0070  5
12500400   -1
12500401   567.874  567.874  567.874  567.874  567.874  567.874
12500402   567.874  567.874  567.874  567.874  567.874  567.874
12500403   567.874  567.874  567.874  567.874  567.874  567.874
12500404   567.874  567.874  567.874  567.874  567.874  567.874
12500405   567.874  567.874  567.874  567.874  567.874  567.874
12500406   567.874  567.874  567.874  567.874  567.874  567.874
12500407   567.874  567.874  567.874  567.874  567.874  567.874
12500408   567.874  567.874  567.874  567.874  567.874  567.874
12500409   567.874  567.874  567.874  567.874  567.874  567.874
12500410   567.874  567.874  567.874  567.874  567.874  567.874
12500411   567.874  567.874  567.874  567.874  567.874  567.874
12500412   567.874  567.874  567.874  567.874  567.874  567.874
12500413   567.874  567.874  567.874  567.874  567.874  567.874
12500414   567.874  567.874  567.874  567.874  567.874  567.874
12500415   567.874  567.874  567.874  567.874  567.874  567.874
12500416   567.874  567.874  567.874  567.874  567.874  567.874
12500417   567.874  567.874  567.874  567.874  567.874  567.874
12500418   567.874  567.874  567.874  567.874  567.874  567.874
12500419   567.874  567.874  567.874  567.874  567.874  567.874
12500420   567.874  567.874  567.874  567.874  567.874  567.874
12500421   567.874  567.874  567.874  567.874  567.874  567.874
12500422   567.874  567.874  567.874  567.874  567.874  567.874
12500423   567.874  567.874  567.874  567.874  567.874  567.874
12500424   567.874  567.874  567.874  567.874  567.874  567.874
12500425   567.874  567.874  567.874  567.874  567.874  567.874
```

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12500426  567.874  567.874  567.874  567.874  567.874  567.874
12500427  567.874  567.874  567.874  567.874  567.874  567.874
12500428  567.874  567.874  567.874  567.874  567.874  567.874
12500429  567.874  567.874  567.874  567.874  567.874  567.874
12500430  567.874  567.874  567.874  567.874  567.874  567.874
12500431  567.874  567.874  567.874  567.874  567.874  567.874
12500432  567.874  567.874  567.874  567.874  567.874  567.874
12500433  567.874  567.874  567.874  567.874  567.874  567.874
12500434  567.874  567.874  567.874  567.874  567.874  567.874
12500501 0     0      0  1   19507.5240   1
12500502 0     0      0  1    4457.0724  33
12500503 0     0      0  1   18964.4880  34
12500601  250010000  10000     1  1   19507.5240   1
12500602  250020000  10000     1  1    4457.0724  33
12500603  250340000  10000     1  1   18964.4880  34
12500701  1000  0.0  0.0  0.0   1
12500702  1000  0.0  0.0  0.000016037   2
12500703  1000  0.0  0.0  0.000015425   3
12500704  1000  0.0  0.0  0.000015042   4
12500705  1000  0.0  0.0  0.000014831   5
12500706  1000  0.0  0.0  0.000014696   6
12500707  1000  0.0  0.0  0.000014640   7
12500708  1000  0.0  0.0  0.000014613   8
12500709  1000  0.0  0.0  0.000014618   9
12500710  1000  0.0  0.0  0.000014623  10
12500711  1000  0.0  0.0  0.000014600  11
12500712  1000  0.0  0.0  0.000014606  12
12500713  1000  0.0  0.0  0.000014610  13
12500714  1000  0.0  0.0  0.000014633  14
12500715  1000  0.0  0.0  0.000014651  15
12500716  1000  0.0  0.0  0.000014634  16
12500717  1000  0.0  0.0  0.000014644  17
12500718  1000  0.0  0.0  0.000014615  18
12500719  1000  0.0  0.0  0.000014600  19
12500720  1000  0.0  0.0  0.000014623  20
12500721  1000  0.0  0.0  0.000014608  21
12500722  1000  0.0  0.0  0.000014620  22
12500723  1000  0.0  0.0  0.000014633  23
12500724  1000  0.0  0.0  0.000014659  24
12500725  1000  0.0  0.0  0.000014689  25
12500726  1000  0.0  0.0  0.000014686  26
12500727  1000  0.0  0.0  0.000014720  27
12500728  1000  0.0  0.0  0.000014772  28
12500729  1000  0.0  0.0  0.000014866  29
12500730  1000  0.0  0.0  0.000015019  30
12500731  1000  0.0  0.0  0.000015222  31
12500732  1000  0.0  0.0  0.000015614  32
12500733  1000  0.0  0.0  0.000016149  33
12500734  1000  0.0  0.0  0.0  34
12500901  0.13083e-01  10.0  10.0  0.0  0.0  0.0  0.0  1.0  34
*------------------------------------------------------------------
*********************************************************************
*  modelo de cinetica
 *********************************************************************
*          tipo cin       realim
```

```
30000000     point       separabl
 *          pr.fis        potencia   reac   n.ret    cte     cte
30000001    gamma-ac      .101000000e+01     0.    .2467e+03  1.    1.
*           dec prod fis (ans73,ans79-1,ans79-3
30000002    ans79-3    200.   0.531    0.078    0.391
30000101  0.030221  0.012800
30000102  0.205212  0.031500
30000103  0.184944  0.124700
30000104  0.389432  0.328200
30000105  0.151466  1.405200
30000106  0.038726  3.844700
*
***************************************************************
*     h e a t   s t r u c t u r e s   p r o p e r t i e s  *
***************************************************************
*
20100100  tbl/fctn  1        1      * uo-2
20100200  tbl/fctn  1        1      * gap-normalstab
20100300  tbl/fctn  1        1      * zircaloy
20100400  tbl/fctn  1        1      * s-steel extrapolado
20100500  tbl/fctn  1        1      * inconel
20100600  tbl/fctn  1        1      * ferrit
20100700  tbl/fctn  1        1      * austenit aprox. 7800 kg/m3
20100800  tbl/fctn  1        1      * spalt heisstab
20100900  tbl/fctn  1        1      * aislante r213/e41/81, re-l 2668 ea
20101000  tbl/fctn  1        1      * aire
20101100  tbl/fctn  1        1      * cobre
*
************************************************************
*         thermal  conductivity
************************************************************
*
*       fuel     uo-2     ( wie bethy eingabe )
*
*        temp(k)   lambda(w/m-k)   temp(k)   lambda(w/m-k)
*
20100101   273.15     7.8736       373.15     7.874
20100102   473.15     6.675        573.15     5.733
20100103   673.14     5.107        773.15     4.599
20100104   873.15     4.178        973.15     3.833
20100105  1073.15     3.53        1173.15     3.282
20100106  1273.15     3.066        1373.15     2.872
20100107  1473.15     2.731        1573.15     2.613
20100108  1673.15     2.516        1773.15     2.462
20100109  1873.15     2.418        1973.15     2.429
20100110  2073.15     2.429        2173.15     2.429
20100111  2273.15     2.451        2373.15     2.505
20100112  2473.15     2.591        2573.15     2.688
20100113  2673.15     2.807        2773.15     2.969
20100114  2873.15     3.142        2973.15     3.336
20100115  3073.15     3.561        3173.15     3.828
20100116  3573.15     5.224        4873.15    14.959
*
*--------------
*        gap        gas   normalstab
```

```
*
20100201   273.15      0.366725381  3000.00      0.366725381
*
*---------------
*       cladding     zircaloy
*        temp(k)   lamda(w/m-k)   temp(k)   lamda(w/m-k)
*
20100301   273.15      13.6         373.15      14.1
20100302   473.15      14.8         573.15      15.8
20100303   673.15      16.9         773.15      18.1
20100304   873.15      19.5         973.15      21.1
20100305  1073.15      22.8        1173.15      24.6
20100306  1273.15      26.8        1373.15      29.2
20100307  1473.15      31.7        1573.15      34.4
20100308  1673.15      37.3        1773.15      40.4
*
*---------------
*       s-steel
*  internally stored thermal property,   s-steel
*    temperature    thermal conduct.  temperature   thermal conduct.
*      (k)          (watt/m-k)           (k)         (watt/m-k)
*
20100401  2.731500e+02 1.298051e+01    1.199817e+03  2.510604e+01
*
*---------------
***   inconel   ***
20100501  293.0  17.612
20100502  533.0  21.777
20100503  833.0  27.132
*
*---------------
*        ferrit
*
*        temp(k)   lambda(w/m-k)   temp(k)   lambda(w/m-k)
*
* se extrapola a 273.15 para locas
20100601   273.15       44.         373.15     44.
20100602   473.15       43.         573.15     42.
20100603   673.15       40.         773.15     39.
20100604   873.15       39.         973.15     39.
20100605   1073.15      39.        1173.15     39.
*
*
*---------------
*        austenit
*
*        temp(k)   lamda(w/m-k)   temp(k)   lamda(w/m-k)
*
* se extrapola a 273.15 para locas
20100701   273.15     13.83    413.15     16.7
20100702   523.15     18.6     683.15     18.6
20100703   773.15     20.9     873.15     20.9
20100704   973.15     20.9    2000.       20.9
*
*---------------
```

```
*        gap         gas   heisstab
*
20100801   273.15      0.731969044 3000.00      0.731969044
*---------------
*     aislante
*        temp(k)   lamda(w/m-k)   temp(k)   lamda(w/m-k)
20100901   273.15      0.1         3000.00      0.1   * dato r213 /e41/81
*
*---------------
*     aire
*        temp(k)   lamda(w/m-k)   temp(k)   lamda(w/m-k)
20101001   277.75      0.0247       361.15     0.027
20101002   555.54      0.045        833.15     0.064
20101003  1333.15      0.09
*
*---------------
*     cobre
*        temp(k)   lamda(w/m-k)   temp(k)   lamda(w/m-k)
20101101   250.        406.         300.       401.
20101102   350.        396.         400.       393.
20101103   500.        386.         600.       379.
20101104   800.        366.        1000.       352.
20101105  1200.        339.
*
**************************************************************
*                                                *
*       volumetric heat capacity                        *
*                                                *
**************************************************************
*
*        fuel   uo-2
*
*         temp(k)   cp(j/m3-k)     temp(k)   cp(j/m3-k)
*
20100151   273.150    2.427e6       400.       2.754e6
20100152   500.       2.927e6       600.       3.043e6
20100153   700.       3.139e6       800.       3.178e6
20100154   900.       3.236e6       1000.      3.274e6
20100155   1100.      3.313e6       1200.      3.351e6
20100156   1300.      3.378e6       1400.      3.428e6
20100157   1500.      3.459e6       1600.      3.502e6
20100158   1700.      3.582e6       1800.      3.660e6
20100159   1900.      3.775e6       2000.      3.992e6
20100160   2100.      4.169e6       2200.      4.366e6
20100161   2300.      4.622e6       2400.      4.897e6
20100162   2500.      5.212e6       2600.      5.585e6
20100163   3000.      7.395e6
*
*---------------
*         gap         gas   normalstab
*         temp(k)   cp(j/m3-k)     temp(k)   cp(j/m3-k)
*
20100251   273.15     5.4          3273.15    5.4
*
*---------------
```

```
*    cladding     zircaloy
*        temp(k)   cp(j/m3-k)     temp(k)   cp(j/m3-k)
*
20100351   273.15     1.881e6      573.15     2.079e6
20100352   773.15     2.211e6      903.15     2.290e6
20100353   923.15     2.376e6      1083.15    2.376e6
20100354   1103.15    3.630e6      1123.15    4.455e6
20100355   1143.15    4.950e6      1163.15    5.115e6
20100356   1183.15    4.950e6      1203.15    4.455e6
20100357   1213.15    3.360e6      1243.15    2.376e6
20100358   2073.15    2.376e6
*
*---------------
*       s-steel   (extrapolado a 273c)
*  internally stored thermal property,   s-steel
*   temperature    heat capacity     temperature    heat capacity
*    (k)           (j/m3-k)           (k)          (j/m3-k)
20100451  2.7315e+2   3.604613e+06
20100452 3.664833e+02 3.830413e+06   4.220389e+02     3.964814e+06
20100453 4.775944e+02 4.099214e+06   5.331500e+02     4.233615e+06
20100454 5.887056e+02 4.334415e+06   6.442611e+02     4.435081e+06
20100455 6.998167e+02 4.502416e+06   8.109278e+02     4.636816e+06
20100456 1.366483e+03 5.376019e+06
*
*---------------
*      inconel
*
*      temp(k)   cp(j/m3-k)      temp(k)     cp(j/m3-k)
*
20100551  273.     3.988e6        293.0       3.916e6
20100552  373.     4.169e6        473.0       4.418e6
20100553  573.     4.703e6        673.0       5.095e6
20100554  773.     5.593e6        873.0       6.307e6
20100555  973.     7.482e6       1000.0       7.482e6
*
*---------------
*         ferrit
*
*         temp(k)   cp(j/m3-k)     temp(k)   cp(j/mf-k)
*
* se extrapola a 273.15 para locas
*20100651    293.15    3.611e6  373.15   3.847e6
20100651    273.15    3.552e6   373.15   3.847e6
20100652    473.15    4.082e6   573.15   4.396e6
20100653    673.15    4.788e6   773.15   5.338e6
20100654   2000.      5.338e6
*
*---------------
*         austenit
*
*         temp(k)   cp(j/m3-k)     temp(k)   cp(j/m3-k)
*
* se extrapola a 273.15 para locas
20100751    273.15    3.5012e6   368.      3.837e6
20100752    478.15    4.102e6   588.15    4.333e6
```

```
20100753    698.15    4.465e6   813.15    4.597e6
20100754    873.15    4.465e6  2000.      4.465e6
*
*---------------
*        gap          gas   heisstab
*        temp(k)   cp(j/m3-k)     temp(k)   cp(j/m3-k)
*
20100851   200.       5.4          3273.15    5.4
*
*---------------
*   aislante
*        temp(k)   cp(j/m3-k)     temp(k)   cp(j/m3-k)
20100951   200.      130.e3        1200.    130.e3   *
*
*---------------
*   aire
*        temp(k)   cp(j/m3-k)     temp(k)   cp(j/m3-k)
20101051   200.       400.         1200.      478.
*
*---------------
*   cobre (8960 kg/m3) (25C)
*        temp(k)   cp(j/m3-k)     temp(k)   cp(j/m3-k)
20101151   200.      3.5e6       1200.      3.5e6
*
*****************************************************************************
.    *  end
```

INPUT DECK FOR RELAP5 COUPLED STEADY-STATE SIMULATION:

```
=PWR R5M3.3 beta  (INPUT FOR STEADY-STATE FROM RESTART)
* PWR REACTOR RELAP5 INPUT FILE0
****************restart file input*********************************
*
1  88
*
*------------------------------------------------------------------
*   Problem Options
*------------------------------------------------------------------
*
100 restart  stdy-st *1
101 run
102 si si
103  -1
* remaining  cpu  time
105   5.   6.
*
*                                  Min      mj      re
201   600.0    0.00002  0.05  07003    1      1    5000
202   500.0    0.00002  0.05  07003    1      1    5000
*
.
```

INPUT DECK FOR PARCS V2.7 COUPLED STEADY-STATE SIMULATION:

```
!*****************************************************************************
CASEID PARCS_CSS              GENERAL DATA FOR A PWR
!*****************************************************************************
CNTL  !table 5
    core_type  PWR
    core_power 0.1  !
    ppm        0.0
!
!!!    Control Rod Banks position in steps withdrawn: (14 cont. rod banks)
!!!            Totally withdrawn=   340.0
!!!            Totally inserted=     15.0 (corresponds to the minimum insertion lenght)
!
!                   bk1  bk2  bk3   bk4   bk5   bk6   bk7   bk8   bk9  bk10  bk11  bk12  bk13  bk14
    bank_pos   15.0  340.  340.  340.  15.0  15.0  340.  340.  340.  340.  340.  340.  340.  15.0
    th_fdbk    F  T
    xe_sm      3 0
!            0 : no xe, 1 : eq. xe   2 : tr. xe  3 : given xe
    decay_heat F
    rot_adf       T
!   for LPRM
    DETECTOR   F   5848.
    pin_power  F
    ext_th     T    MAPTAB_RP         RELAP   1    1
    transient  F
    restart    F   PARCS_SS.rst  1
!               input  iteration    planar                adj
!                edit      table     power       pin      reac
    print_opt          T         F         T         F         T
!                fdbk       flux     planar
!                 rho    precurs      flux       Xe       T/H
    print_opt          T         F         F         F         F
!
!                oneD       PKRE     Radial     Radial      assy
!               const      Data      Shape      Shape      const
    print_opt          F         F         F         F         F
    oned_kin   F   SA1D
!
!                     END OF CONTROL CARD
!
!*****************************************************************************
PARAM !table 6
    n_iters    5      500
    conv_ss    1.0e-6  1.e-5  1.e-5  0.001 !keff,globfs,locfs,tempf
    wielandt   0.04   0.1    1.0
    nodal_kern HYBRID
    nlupd_ss   2 3 1
    eps_anm    0.005
    eps_erf    0.005
    decusp     0
    init_guess 0
!*****************************************************************************
XSEC  !tabl 7
```

```
    func_type  13
    dnp_ngrp   6
    kin_comp   1  1 -867
! PWR specs
  dnp_beta   0.000158    0.001100    0.000977    0.002046    0.000789    0.000195
  dnp_lambda 0.012812    0.031456    0.124555    0.328429    1.410936    3.818017
!******************************************************************************
GEOM  !table 8
    file      GEOM_LWR
!******************************************************************************
TH    !table 9
    UNIF_TH    0.2    1200.00    650.0
!******************************************************************************
PFF  !table 10, power form function
 npin_side 16
 pff_comp  1  1 -867
 pff_unrodd  1  !group 1 of set 1
1. 1. 1. 1. 1. 1. 1. 1.
1. 1. 1. 1. 1. 1. 1. 1.
1. 1. 0. 1. 1. 0. 1. 1.
1. 1. 1. 1. 1. 1. 1. 1.
1. 1. 1. 1. 1. 1. 0. 1.
1. 1. 0. 1. 1. 1. 1. 1.
1. 1. 1. 1. 0. 1. 1. 1.
1. 1. 1. 1. 1. 1. 1. 1.
 pff_unrodd  2  !group 2 of set 1
1. 1. 1. 1. 1. 1. 1. 1.
1. 1. 1. 1. 1. 1. 1. 1.
1. 1. 0. 1. 1. 0. 1. 1.
1. 1. 1. 1. 1. 1. 1. 1.
1. 1. 1. 1. 1. 1. 0. 1.
1. 1. 0. 1. 1. 1. 1. 1.
1. 1. 1. 1. 0. 1. 1. 1.
1. 1. 1. 1. 1. 1. 1. 1.
 pff_rodded  1  !group 1 of set 1
1. 1. 1. 1. 1. 1. 1. 1.
1. 1. 1. 1. 1. 1. 1. 1.
1. 1. 0. 1. 1. 0. 1. 1.
1. 1. 1. 1. 1. 1. 1. 1.
1. 1. 1. 1. 1. 1. 0. 1.
1. 1. 0. 1. 1. 1. 1. 1.
1. 1. 1. 1. 0. 1. 1. 1.
1. 1. 1. 1. 1. 1. 1. 1.
 pff_rodded  2  !group 2 of set 1
1. 1. 1. 1. 1. 1. 1. 1.
1. 1. 1. 1. 1. 1. 1. 1.
1. 1. 0. 1. 1. 0. 1. 1.
1. 1. 1. 1. 1. 1. 1. 1.
1. 1. 1. 1. 1. 1. 0. 1.
1. 1. 0. 1. 1. 1. 1. 1.
1. 1. 1. 1. 0. 1. 1. 1.
1. 1. 1. 1. 1. 1. 1. 1.
!!******************************************************************************
TRAN  !table 11
  time_step  1000.  1.e-4  200.  1.
```

```
!  time_step  600.0 0.05   !TIME STEP N.B.
   expo_opt   F     F
   Scram      F 1000.0 0.0  1048.
!
!!!   move_bank provides the control rod bank movement.
!!!       The first parameter is the number of the control rod bank
!!!       The following parameters are: time and position (for each step)
!
!   move_bank  14  0.0  15.0  2.0  15.0  2.1  340.0
!
! The above values need checking
   theta      0.5   0.5   0.5
   conv_tr    0.001
   nlupd_tr   5 1 5 10
   eps_xsec   0.01
.
```

GEOM_LWR FILE TAIL FOR PARCS V2.7 SIMULATION:

```
.
.
.
PR_Assign  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
27 28 29 30 31 32 33 34
!
!
!fix: assume 340 steps: 1
 CR_axinfo  14.0  1.       !fully withdrawn position and step size
!
!!!     Control rod banks radial configuration
!!!     (14 control rod banks defined)
!!!     (0 means no bank defined)
!
 bank_conf
                 0  0  0  0  0  0  0
           0  0  0  0  0  0  0  0  0  0  0
        0  0  0  0  3  0  9  0 11  0  0  0  0
     0  0  0  0  1  0  7  0  6  0  2  0  0  0  0
     0  0  0  8  0  0  0 10  0  0  0  8  0  0  0
  0  0  0  2  0 12  0  5  0  4  0 12  0  1  0  0  0
  0  0 11  0  0  0  0  0  0  0  0  0  0  0  3  0  0
  0  0  0  6  0  4  0 13  0 13  0  5  0  7  0  0  0
  0  0  9  0 10  0  0  0  0  0  0  0 10  0  9  0  0
  0  0  0  7  0  5  0 13  0 13  0  4  0 14  0  0  0
  0  0  3  0  0  0  0  0  0  0  0  0  0  0 11  0  0
  0  0  0  1  0 12  0  4  0  5  0 12  0  2  0  0  0
     0  0  0  8  0  0  0 10  0  0  0  8  0  0  0
     0  0  0  0  2  0  6  0  7  0  1  0  0  0  0
        0  0  0  0 11  0  9  0  3  0  0  0  0
           0  0  0  0  0  0  0  0  0  0  0
                 0  0  0  0  0  0  0
```

MAPTAB_RP FILE HEAD FOR COUPLED STEADY-STATE AND TRANSIENT SIMULATION:

```
*
*   MAPTAB FILE FOR LWR - RELAP/PARCS COUPLING
*
%DOPL
*
LINC  0.70
*
***
*** %CRSIG - Control variables identification for
***     Control Rod Banks movement
***   - Control variables have to be introduced by order
***     (1 for each control rod bank).
***   - 0 means that the control rod bank is not moved.
***   - If %CRSIG is enabled, control rod bank movement is
***     drived by RELAP input, no matter what PARCS input says.
***
*
%CRSIG
0  0  0  0  0  0  0  0  0  0  0  0  0  521
*
*
%REFLPROP
*
 569.55   569.55   724.00  0.0  0.0
* tcoolrefl(K) tfuelrefl(K)  rhomixrefl  alparefl  ppmrefl
*
*
* VOLUME TO NODE TABLE
*
%TABLE1
250010000       1   1.00000
250010000       2   1.00000
.
.
.
```

INPUT DECK FOR RELAP5 COUPLED TRANSIENT SIMULATION:

```
=PWR R5M3.3 beta  (INPUT FOR TRANSIENT FROM RESTART)
* PWR REACTOR RELAP5 INPUT FILE0
****************restart file input*********************************
*
1  88
*
*-------------------------------------------------------------
*   Problem Options
*-------------------------------------------------------------
*
100 restart  transnt *1
101 run
102 si si
103  -1
* remaining  cpu  time
105   5.   6.
*                                Min     mj     re
201      2.0    0.00002    0.1      07003    10      10    5000
202      4.0    0.00002    0.001  07003    10      10    5000
203    15.0    0.00002    1.000  07003    10      10    5000
204  500.0    0.00002    1.0      07003    10      10    5000
*
* control expandido 205cccc0 (0001 < cccc < 9999)
20500000   9999
*
*  trips expandidos 206cccc0 (0001 < cccc < 0999)
*  trips logicos    206cccc0 (1000 < cccc < 2000)
20600000   expanded
*
**************************
*Variables de control
*
***   Control variable for Control Rod Bank movement
***    - Initial position of the CRB is indicated
***    - Movement table is identified
*
*         name/type/scaling factor/initial value/initial flag/limiter control/minimum/maximum
20505210   bar_pos   function   1.  15.0  0  3   0.   340.
***        name of variable on 'function'/integer name of variable/table number
20505211   time   0    521
*
***   Control Rod Bank movement table
***    - 202TTT00 where TTT is the table number
***    - react-t for reactivity versus time quantities; 0 means no trip used
***    - linear interpolation is used between argument values:
***                   time   position (in notches)
20252100   reac-t   0
20252101             0.0       15.0
20252102             2.0       15.0
20252103             2.1      340.0
*
.
```

INPUT DECK FOR PARCS V2.7 COUPLED TRANSIENT SIMULATION:

```
!****************************************************************************
CASEID PARCS_TR               GENERAL DATA FOR A PWR
!****************************************************************************
CNTL  !table 5
    core_type  PWR
    core_power 0.1  !
    ppm       0.0
!
!!!   Control Rod Banks position in steps withdrawn: (14 cont. rod banks)
!!!          Totally withdrawn=   340.0
!!!          Totally inserted=     15.0 (corresponds to the minimum insertion lenght)
!
!                 bk1  bk2  bk3  bk4  bk5  bk6   bk7  bk8  bk9  bk10  bk11  bk12  bk13  bk14
    bank_pos   15.0  340. 340.  340.  15.0  15.0  340.  340.  340.  340.  340.  340.  340.  15.0
    th_fdbk    F  T
    xe_sm      3 0
!           0 : no xe, 1 : eq. xe   2 : tr. xe  3 : given xe
    decay_heat F
    rot_adf       T
!   for LPRM
    DETECTOR   F   5848.
    pin_power  F
    ext_th     T    MAPTAB_RP        RELAP   1    1
    transient  T
    restart    T   PARCS_CSS.rst  1
!              input  iteration    planar              adj
!               edit     table     power      pin      reac
    print_opt        T        F        T        F        T
!               fdbk      flux    planar
!                rho    precurs      flux       Xe       T/H
    print_opt        T        F        F        F        F
!
!               oneD      PKRE     Radial     Radial      assy
!              const      Data      Shape      Shape      const
    print_opt        F        F        F        F        F
    oned_kin   F   SA1D
!
!                     END OF CONTROL CARD
!
!****************************************************************************
PARAM !table 6
    n_iters    5      500
    conv_ss    1.0e-6  1.e-5  1.e-5  0.001 !keff,globfs,locfs,tempf
    wielandt   0.04   0.1    1.0
    nodal_kern HYBRID
    nlupd_ss   2 3 1
    eps_anm    0.005
    eps_erf    0.005
    decusp     0
    init_guess 0
!****************************************************************************
XSEC  !tabl 7
```

```
     func_type  13
     dnp_ngrp   6
     kin_comp   1  1 -867
! PWR specs
  dnp_beta   0.000158    0.001100    0.000977    0.002046    0.000789    0.000195
  dnp_lambda 0.012812    0.031456    0.124555    0.328429    1.410936    3.818017
!*******************************************************************************
GEOM  !table 8
     file      GEOM_LWR
!*******************************************************************************
TH    !table 9
!fix assume all assemblies are 16x16 with 20 guide/instumentation tubes
!     N_PINGT    236 20                     !npin,ngt(n guide tubes)
!fix by ldj: 3010/177=17.005
!     FA_POWPIT  17. 10.625            !assembly power(Mw) and pitch(cm)
!
!     gamma_frac 0.                !direct heating fraction
!             Dm_u      Tf_u     Tm_u
     UNIF_TH    0.2    1200.00    650.0
!*******************************************************************************
PFF  !table 10, power form function
 npin_side 16
 pff_comp  1  1 -867
 pff_unrodd  1  !group 1 of set 1
1. 1. 1. 1. 1. 1. 1. 1.
1. 1. 1. 1. 1. 1. 1. 1.
1. 1. 0. 1. 1. 0. 1. 1.
1. 1. 1. 1. 1. 1. 1. 1.
1. 1. 1. 1. 1. 1. 0. 1.
1. 1. 0. 1. 1. 1. 1. 1.
1. 1. 1. 1. 0. 1. 1. 1.
1. 1. 1. 1. 1. 1. 1. 1.
 pff_unrodd  2  !group 2 of set 1
1. 1. 1. 1. 1. 1. 1. 1.
1. 1. 1. 1. 1. 1. 1. 1.
1. 1. 0. 1. 1. 0. 1. 1.
1. 1. 1. 1. 1. 1. 1. 1.
1. 1. 1. 1. 1. 1. 0. 1.
1. 1. 0. 1. 1. 1. 1. 1.
1. 1. 1. 1. 0. 1. 1. 1.
1. 1. 1. 1. 1. 1. 1. 1.
 pff_rodded  1  !group 1 of set 1
1. 1. 1. 1. 1. 1. 1. 1.
1. 1. 1. 1. 1. 1. 1. 1.
1. 1. 0. 1. 1. 0. 1. 1.
1. 1. 1. 1. 1. 1. 1. 1.
1. 1. 1. 1. 1. 1. 0. 1.
1. 1. 0. 1. 1. 1. 1. 1.
1. 1. 1. 1. 0. 1. 1. 1.
1. 1. 1. 1. 1. 1. 1. 1.
 pff_rodded  2  !group 2 of set 1
1. 1. 1. 1. 1. 1. 1. 1.
1. 1. 1. 1. 1. 1. 1. 1.
1. 1. 0. 1. 1. 0. 1. 1.
1. 1. 1. 1. 1. 1. 1. 1.
```

```
1. 1. 1. 1. 1. 1. 0. 1.
1. 1. 0. 1. 1. 1. 1. 1.
1. 1. 1. 1. 0. 1. 1. 1.
1. 1. 1. 1. 1. 1. 1. 1.
!!*******************************************************************************
TRAN  !table 11
  time_step  1000.  1.e-4  200.  1.
!  time_step  600.0 0.05   !TIME STEP N.B.
  expo_opt   F     F
  Scram      F 1000.0 0.0  1048.
!
!!!   move_bank provides the control rod bank movement.
!!!       The first parameter is the number of the control rod bank
!!!       The following parameters are: time and position (for each step)
!
!   move_bank  14  0.0  15.0  2.0  15.0  2.1  340.0
!
! The above values need checking
  theta      0.5   0.5   0.5
  conv_tr    0.001
  nlupd_tr   5 1 5 10
  eps_xsec   0.01
.
```

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ISIRYM
Universitat Politècnica de València
Camí de Vera, s/n
46022 Valencia, SPAIN

Almaraz-Trillo AIE
Av Manoteras 46Bis
28050 Madrid, SPAIN

Departamento de Engenharia Nuclear
Universidade Federal de Minas Gerais
Av. Antonio Carlos, 6627
31270-901 Belo Horizonte, BRAZIL

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Division of Systems Analysis
Office of Nuclear Regulatory Research
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10. SUPPLEMENTARY NOTES

K.Tien, NRC Project Manager

11. ABSTRACT (200 words or less)

The objective of this work is to introduce an improvement in best estimate coupled neutronic-thermalhydraulic 3D codes simulations, by adding a model for the control rod movement in the coupled code RELAP5/PARCS v2.7, by means of control variables, with the aim of being able to dynamically analyze asymmetric transient accidents, as the reactivity insertion accidents (RIA) in a nuclear reactor, reproducing all the reactors control systems.

The modification developed in this work permits the automatic movement of the control rods, activated by the RELAP5 code control system, and also they can depend on signals related to the reactor reactivity, like pressure, fuel temperature or moderator temperature, etc., improving the realism of the calculation and increasing the simulation capabilities.

This report was prepared by the Nuclear Engineering Group belonging to the Institute for Industrial, Radiophysical and Environmental Safety (ISIRYM) at the Universitat Politècnica de València (UPV), which collaborates in the simulation area with the Spanish company Centrales Nucleares Almaraz-Trillo (CNAT). The Asociación Española de la Industria Eléctrica (UNESA, Electric Industry Association of Spain), equivalent to the American EPRI sponsored this work.

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