Modeling RD-14M Header Conditions: Coupling of STAR-CCM+ and CATHENA

MODELING RD-14M HEADER CONDITIONS: COUPLING OF STAR-CCM+ AND CATHENA

BY

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A THESIS
SUBMITTED TO THE DEPARTMENT OF ENGINEERING PHYSICS
AND THE SCHOOL OF GRADUATE STUDIES
OF MCMASTER UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF APPLIED SCIENCE

Master of Applied Science (2013)	McMaster University
(Engineering Physics)	Hamilton, Ontario, Canada

TITLE:	Modeling RD-14M Header Conditions: Coupling of STAR-CCM+ and CATHENA
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NUMBER OF PAGES:	xx, 498

Dedicated to my parents

Abstract

The nuclear safety industry makes extensive use of thermalhydraulics system analysis and computational fluid dynamics codes for validation and predictive purposes. These codes take different approaches to provide the user with reasonable estimates of system and component behaviors. With each displaying its own strengths, it is only logical to pursue coupled systems of these codes to create increasingly accurate, versatile, and more computationally efficient safety analysis tools.

This work presents results of the attempted coupling of CD-ADAPCO's STAR-CCM+, a computational fluid dynamics (CFD) code, to Atomic Energy of Canada's CATHENA thermalhydraulics (TH) code. This coupled system is used in the simulation of the conditions within an inlet header of the RD-14M experimental facility under single phase conditions in the initial phase of selected test. This inlet header is removed from a modified CATHENA test B9401 deck and instead modelled in STAR-CCM+. Custom applications were written to allow information exchange at the newly created boundaries to provide an attempt at a coupled system.

Results are provided through multiple stages of development of the coupled system, from the unmodified B9401 test case of CATHENA into a coupled system with header behavior predicted by STAR-CCM+. Though successful information transfer between codes was established at each desired time step and interval, the current

technique was found to be insufficient for establishing an acceptable steady-state conditions for the commencement of more complex (transient and two-phase) conditions.

Acknowledgements

There are many people without which this thesis would not exist. I would like to thank Dr. David Novog, my supervisor, as well as Dr. Duane Baker, Dr. Thomas Beuthe, Dr. Aleksandar Vasic, and all the others at AECL Deep River who provided invaluable guidance and support.

I would also like to thank my family, friends, and fellow graduate students for their help, guidance, and for keeping me motivated.

Thanks to everyone who helped bring this report to light.

Abbreviations

AECL	Atomic Energy of Canada Limited
ASTM	American Society for Testing and Materials
ATHENA	Advanced Thermal Hydraulic Energy Network Analyzer
ATHLET	Analysis of THermal-hydraulics of LEaks and Transients
CANDU	CANada Deuterium Uranium
CAE	Computer Aided Engineering
CATHENA	Canadian Algorithm for THErmalhydraulic Network Analysis
CFD	Computational Fluid Dynamics
CWIT	Cold Water Injection Test
DNB	Departure from Nucleate Boiling
ECC	Emergency Core Cooling
ECI	Emergency Coolant Injection
FES	Fuel Element Simulator
FINCH	Fully Instrumented Channels
GENHTP	Generalized Heat Transfer Package
GUI	Graphical User Interface
HLWP	Heavy and Light Water Properties
HTS	Heat Transport System

IAEA	International Atomic Energy Agency
LASH	LArge Scale Header
LBLOCA	Large Break Loss of Coolant Accident
LOCA	Loss of Coolant
LOF	Loss of Flow
NEA	Nuclear Energy Agency
OECD	Organization for Economic Co-Operation and Development
PHTS	Primary Heat Transport System
PHWR	Pressurized Heavy Water Reactor
PVM	Parallel Virtual Machine
PWR	Pressurized Water Reactor
RANS	Reynolds-Averaged Navier-Stokes
RIH	Reactor Inlet Header
RNG	Re-Normalization Group
ROH	Reactor Outlet Header
ROSA	Rig of Safety Assessment
RTD	Resistance Temperature Detector
SBLOCA	Small Break Loss of Coolant Accident
TH	ThermalHydraulics
TUF	Two Unequal Fluids

Contents

List of Tables

List of Figures

Chapter 1

INTRODUCTION

The objective of this thesis is to explore the potential for improved fidelity in thermal-hydraulic simulations of a CANDU Pressurized Heavy Water Reactor. Specifically this work examines the coupling of state-of the-art three-dimensional (3D) Computational Fluid Dynamics (CFD) codes to the main one-dimensional (1D) average safety analysis system thermalhydraulics code. The resulting tool suite is then used to simulate a large scale CANDU experimental facility in order to demonstrate its potential.

1.1 The CANDU Reactor

The Canadian CANDU^{TM} (*CAN*ada *D*euterium *U*ranium) reactor is a heavy water cooled and moderated reactor developed by Atomic Energy of Canada (AECL). The CANDU has a versatile design which allows for configurations for various powers and fuel designs, however, traditional CANDU designs hold the following characteristics in common:

- A large, low energy density core (compared to a similar power PWR), consisting of several hundred parallel pressurized fuel channels within a low pressure calandria vessel
- Use of heavy water (D_2O) moderator and coolant
- Online refueling
- Ability to use non-enriched fuel
- Two fully capable and independent fast shutdown systems

CANDU reactors have an excellent service history with 29 reactors in operation around the world, as of December 31, 2012 (IAEA, 2013).

A CANDU reactor typically contains two separate figure-of-eight thermalhydraulic loops which provide coolant to each of the fuel channels. Four large pumps provide flow to distribution headers (Reactor Inlet Headers - RIH) which divide the flow into separate feeder pipes, which are in turn connected to the fuel channels. After removing heat from the fuel the coolant is then passed through outlet feeder pipes which connect to large outlet headers (Reactor Outlet Headers - ROH). Large bore piping then connects these outlet headers to the steam generators which in turn are connected to the circulation pumps. A diagram of the coolant loop is shown in figure 1.2.

Pressure is controlled by a pressurizer consisting of a tank of water, heaters and sprays, which can be actively controlled to ensure pressure regulation. Feed and bleed systems are also used to control fluid inventory and to provide adequate coolant chemistry and composition control.

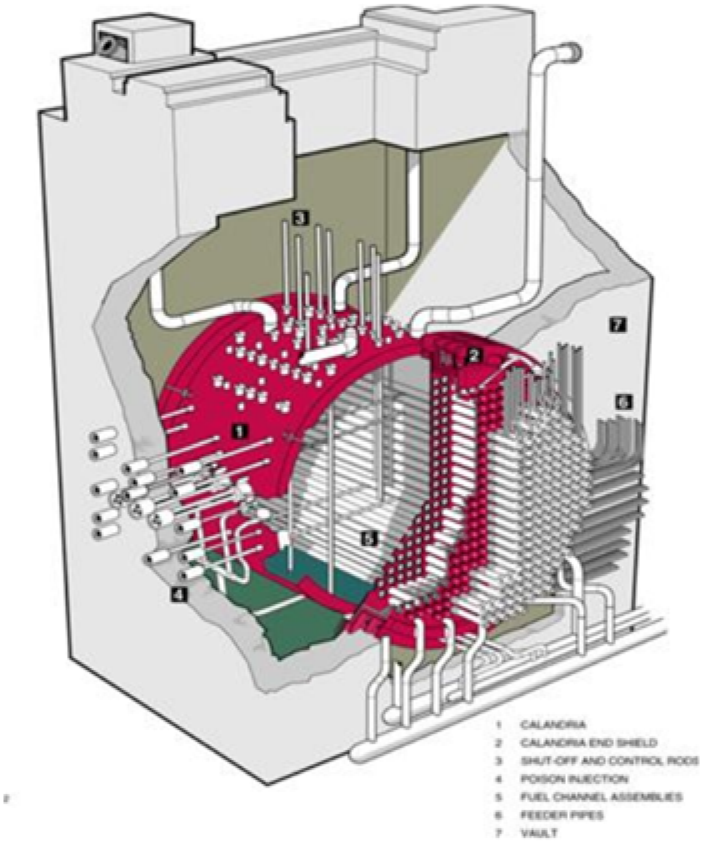


Figure 1.1: A Typical Representation of a CANDU Reactor (IAEA, 2011)

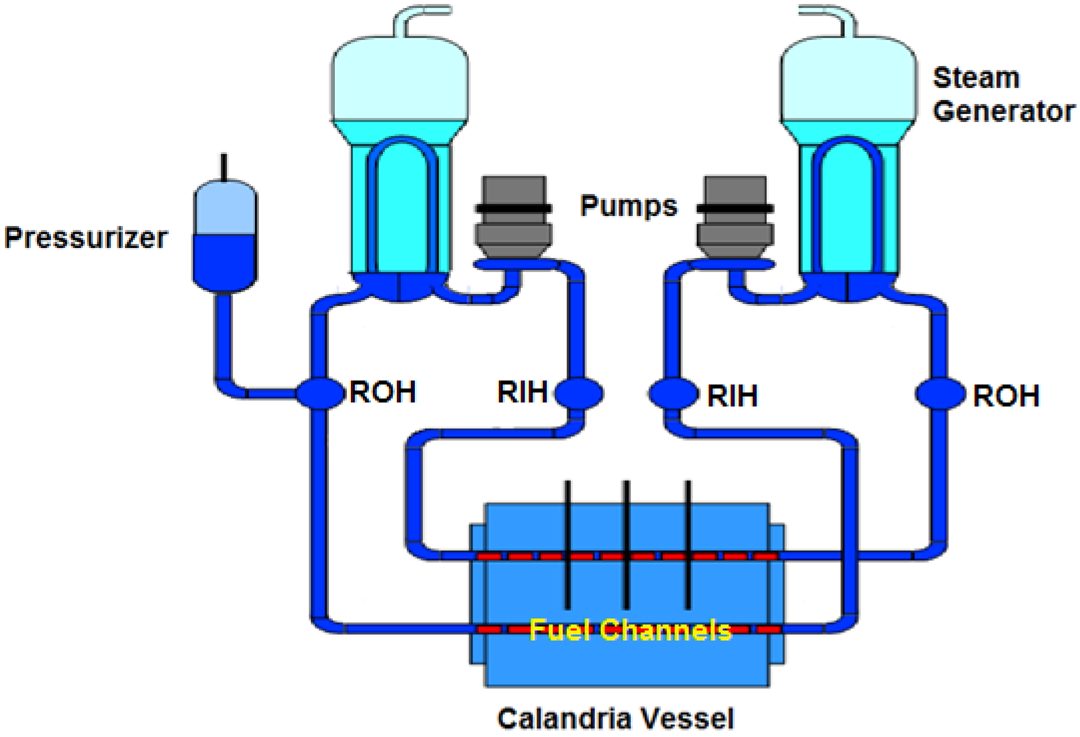


Figure 1.2: A CANDU Primary Heat Transport System (Snell, 2001)

Given the design of the piping network, the parallel flow paths, and the potential for two-phase flow in some parts of the system, computational tools are used to predict the steady and transient flows, temperatures and pressures in the heat transport system. For safety analyses the majority of tools use 1D finite volume solutions to determine the flow in each reactor component. Here the 1D approximation (i.e., volume averaging) is necessary since a complete 3D solution for the entire heat transport solution is impracticable. These computational tools undergo vigorous validation to ensure their accuracy and robustness. A key experimental facility is the RD-14 experiment described in the following section.

Of particular importance to this thesis is the flow and pressure distribution inside the headers which distribute the flow to the inlet feeder pipes. Since these headers are large 3D structures with two-discrete inlets and up to 120 feeder outlets, there is complex flow and pressure behaviour within this volume. While some attempts have been made to model the flow pressure and temperature behaviour within this volume (i.e., to improve the predictions relative to a volume average of the entire header), little work has been performed using CFD tools for these components coupled to the system codes for the remainder of the heat transport system solution.

While volume averaging of the header modules (and subsequent attempts to subdivide each header into interconnected 1D elements) has had some success in modelling CANDU transients, the effect of 3D flow in the headers has not been analyzed fully in open literature. In particular, since volume averaged conditions provide a mean pressure and temperature for the flow into each feeder pipe, there may be some feeders that experience larger (or smaller) pressures and temperatures as compared to this volume average. Hence, more accurate solutions must include some of the 3D

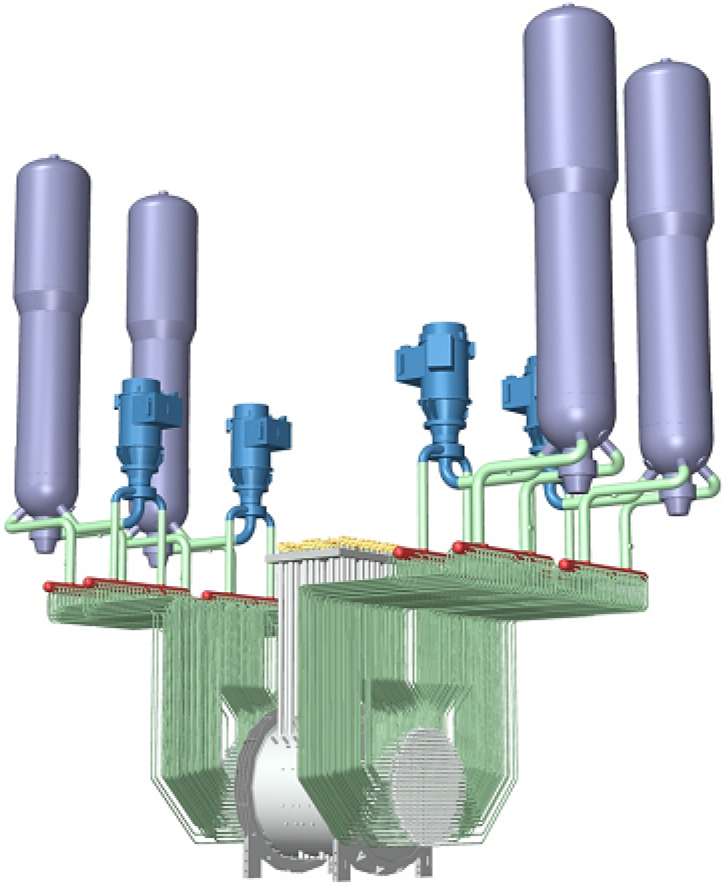


Figure 1.3: A PHWR Header and Feeder System (IAEA, 2012)

behaviour inside the headers.

1.2 The RD-14M Experimental Facility

The RD-14M experimental facility was constructed during the 1980's at AECL's Whiteshell Nuclear Research Establishment (Whiteshell Laboratories). The RD-14M facility is a pressurized water loop with many characteristics similar to those found in a CANDU reactor, including a figure of eight primary heat transport system (PHTS), as well as electrically heated fuel channels. The RD-14M facility is richly instrumented for detailed measurement of various thermal-hydraulic parameters during testing. The well documented behavior of this system is the reason why data involving this facility has, in the past, provided a benchmark for code inter-comparison and validation exercises. (AECL, 1997).

A more detailed description of the RD-14M facility and its CATHENA model may be found in section 4.1.

1.3 Validation of Thermal-Hydraulics System Codes

It is necessary to ensure that the output given by thermal-hydraulic system codes provides a reasonable estimate of behaviour found in a physical system. For this reason, codes must be validated against measured thermal-hydraulic data obtained from facilities such as RD-14M. These comparisons often take the form of code intercomparison and validation exercises, in which various similar code outputs are compared to benchmark data, as well as to each other. Such is often the case for data obtained by the RD-14M facility, as demonstrated by IAEA TECDOC-1395 (IAEA, 2004). A greater description of this document and its contents may be found in section 2.3.

1.4 The CATHENA Code

CATHENA is the *C*anadian *A*lgorithm for *THE*rmalhydraulic *N*etwork *A*nalysis. It is a one dimensional, two fluid system thermalhydraulics code whose primary focus of development has been on the analysis of events related to loss of coolant accidents (LOCA's) in CANDU reactors. CATHENA has also been used for safety analysis of WOLSONG-II, SLOWPOKE, MAPLE, and test facility analysis such as RD-14M, CWIT, and others. Further details of the CATHENA code system can be found in chapter 3.1. (AECL, 1998)

The CATHENA code utilizes an input data file structure which specifies:

- Geometries and properties of each volume average component
- How volume components are linked together
- Heat addition (if necessary in a given volume)
- Correlations for friction and heat transfer within each volume (as well as the selection of a large number of other supporting correlations that form the closure of the hydraulics equations).
- Boundary conditions
- Solution and time step control

With its primary focus being the simulation of CANDU type pressure tube reactors, CATHENA is an excellent choice for simulating a thermalhydraulic coupled system with a CFD component for simulating the complex flow behaviours found within a header or manifold. Already containing capabilities such as reactor kinetic models and real-time controller capability, a logical expansion of this safety analysis tool would be the integration of CFD capability.

1.5 The STAR-CCM+ Code

STAR-CCM+ provides a suite of utilities for simulating a wide range of potential modelling requirements. Boasting an integrated heat transfer and fluid flow solver, 3D-CAD modelling and meshing utilities, physics modelling, turbulence modelling, post processing, and computer aided engineering (CAE) integration, STAR-CCM+ holds much promise for safety analysis in the field of nuclear engineering (CD-ADAPCO, 2012). STAR-CCM+ solves the 3D Navier-Stokes Equations including the effects of turbulence, the conservation of mass, and the conservation of energy to provide the fine structure of flow, pressure and temperature within complex geometries. A wide variety of turbulence modelling options are available with STAR and are selected based on the nature of the flow and the intended applications. The major steps in the CFD code analyses include: (NEA, 2007)

- Geometry description
- Mesh generation
- Wall modelling selection
- Turbulence model selection
- Boundary condition selection

In addition to its many simulation capabilities, STAR-CCM+ provides an object oriented architecture. The solver and server are written in C++ while a JAVA shell allows for a versatile user interface. This shell provides an ideal opportunity for preliminary coupling attempts, since essentially any action taken by the user through the GUI interface may also be performed through a JAVA script. (CD-ADAPCO, 2012)

1.6 Summary and Objectives

As the availability of computing resources continues to increase, simulation of more complex geometries and transients for the purpose of safety analysis becomes increasingly viable and desirable. CAE tools, including CFD, have been used extensively in other industries to improve designs and efficiency, and would provide valuable insights into the complex phenomena occurring during postulated accident scenarios such as loss of coolant accidents. However, simulating a full reactor system in a CFD environment is still prohibitively costly, and also unnecessary, as much of the reactor system can be adequately modelled using existing one dimensional thermalhydraulic codes. The ideal solution, therefore, would be a coupled modelling environment where components of complex geometry and phenomena may be simulated in a CFD modeller, while the remaining system is managed by a more computing cost effective thermalhydraulic code.

The challenges for such a coupled solution are:

- Information transfer from 3D solutions to 1D codes
- Ensuring the problem does not become over or under constrained as a result of

data transfer

- Time step and solution control
- Convergence monitoring and criteria
- Ensuring uniqueness of solution
- Solution stability

The methodology adopted for this work uses the transfer of boundary conditions from each code within a time step to ensure that that 3D effects are captured in the final solution. This thesis attempts solutions to these challenges and demonstrates their acceptability by performing coupled analyses of a RD-14M experiment.

While the ultimate goal would be a coupled simulation of a complete reactor system, work must begin with a much simpler problem. For this reason, AECL's thermalhydraulic system code CATHENA is to be coupled to CD-ADAPCO's CFD environment STAR-CCM+ to model the RD-14M thermalhydraulic testing facility. To work towards the ultimate goal, the objectives of this study are as follow:

- Gain familiarity with CATHENA to produce a model of the RD-14M facility
- Gain familiarity with STAR-CCM+ to produce a CFD model of an inlet header
- Produce some sort of coupling interface to allow for transfer of information between codes
- Complete a coupled simulation of the RD-14M in steady state under single phase flow conditions

The remainder of this report is organized as follows. Chapter 2 of this report will provide a background into the current state of 1D to 3D coupling in the field of nuclear safety analysis as well as an overview of desired applications. Chapter 3 will provide a brief description of the models employed by CATHENA and STAR-CCM+ for modelling physical phenomena. Chapter 4 will provide background into the RD-14M facility, the motivations for choosing the B9401 blowdown experiment as a starting point, as well as steps taken to produce a coupled system. Chapter 5 will detail the results obtained in the pursuit of this coupled system. Chapter 6 will provide conclusions based on the results of chapter 5, and provide recommendations for future work.

Chapter 2

BACKGROUND AND LITERATURE REVIEW

This chapter provides a literature review relevant to coupling system thermalhydraulics codes to CFD tools. It includes a general review of system thermalhydraulics principles, CFD computational tools, and the technology related to code coupling.

2.1 Themalhydraulics System Codes

Modern thermalhydraulic system codes employed by the nuclear industry address numerous phenomena associated with heat transfer and fluid flow. Table 2.1 of the IAEA document *Thermalhydraulic relationships for advanced water cooled reactors* (IAEA, 2001) gives a comprehensive list of phenomena that should be considered for current generation reactors. This includes, but is not limited to: natural and forced convection, critical flow, pressure drops, wall to fluid friction, and phase separation. Current generation one-dimensional thermalhydraulic system codes provide predictions of system behaviour, usually through use of six field equations ensuring conservation of mass, momentum, and energy for each of two fluid phases (liquid and vapour), as well as the interphase transfer of these quantities.

The volume averaged conservation equations for each phase, along with the interfacial transfer equations, are in the form of non-linear partial differential equations with derivatives with respect to time and one spatial variable. These equations make use of the unknown quantities such as pressure, mass flow rate and enthalpy, and dependent variables such as the density, viscosity and specific heat. In addition variables related to fluid properties and wall or interfacial transfer mechanisms appear in the equations. First the equations are discretized in space and time to form a system of algebraic equations from each volume in the heat transport system. These equations are linked through the physical connections between each volume in the heat transport system. Closure of these equations requires additional information to either:

1. compute dependent variables such as the density, viscosity and specific heat in terms of the independent variables: pressure (P), enthalpy (h)
2. compute the wall and interfacial transfer terms through constitutive relationships involving a combination of the dependent and independent variables.

Suitable boundary conditions are then determined and the non-linear features of these equations are then treated through standard numerical iterative routines and a final solution is determined. Since the solution is determined based on a discretized and iterative method, complex numerical techniques are applied.

This section provides an overview of the most notable aspects of computer models used in thermalhydraulic safety analysis. Due to the relevance to this thesis, discussed modelling procedures will be focused around those found within CATHENA (AECL, 1998). Detailed descriptions of essential models implemented in CATHENA may be found in Section 3: Theory.

2.1.1 Thermalhydraulic Studies of CANDU Headers

Gulshani (Gulshani, 1988) presents a two phase flow study in which he demonstrated how two phase inlet injection impacts the flow pattern in a CANDU header. The method developed to predict the water level as a result of two phase fluid injection is called MISSFINCH (Models for Injection and Steady Stratified Flow IN CANDU Header). Gulshani demonstrates the MISSFINCH models predict hydraulic jump of the collapsed water level with both single and dual inlet injection, and as a result, provides agreement with the water level distribution measured in LArge Scale Header (LASH) tests.

Kowalski and Hanna (Kowalski and Hanna, 1988) provide a study of cold water injection under near zero header to header pressure drop conditions. Through comparison to LASH data, Kowalski and Hanna demonstrate water injection flow rates and header preheat temperatures have the greatest influence on header refill times, while break size and location have less influence, but may influence injection flow rate. It was also determined that CATHENA provided good agreement with experimental results.

Holiday et al (Holliday *et al.*, 2007) employs the Two Unequal Fluids (TUF) code to simulate the behavior of the heat transport system under postulated accident scenarios. Due to the rotation of pumps to provide flow to each of the four RIH of a CANDU PHTS, leads to differences in pressure and flow distribution within each

RIH, and as a result, differences in flow to each fuel channel. The TUF model was compared to flow measurements from Fully INstrumented CHannels (FINCH) before and after pump configuration changes as a way of validating the model. By separating each RIH into a number of different regions and assigning a frictional loss coefficient between each region and adjusting it to match station data, the pressure gradient within each header was simulated. It was demonstrated that this approach provides a reasonably accurate prediction of flow changes for a variety of pump configurations.

2.2 CFD

Computational fluid dynamics codes predict the local 3-dimensional flow and heat transfer phenomena. In general, CFD codes make use of discretized versions of mass, momentum, and energy conservation equations. Using a finite volume approach, as common in CFD, these equations are applied over a domain of control volumes corresponding to cells of a computational grid, usually in three dimensions. This approach provides much greater detail than a one-dimensional code, but is also much more expensive in terms of computing cost and still requires assumptions and models related to turbulence as well as wall interactions. Furthermore, CFD applications for two-phase conditions are still in their infancy with most safety applications being limited to single-phase predictions. IAEA TECDOC 1379 provides a number of examples where CFD analysis is being pursued including in-vessel boron mixing in pressurized water reactors (PWR) and hydrogen combustion modelling (IAEA, 2002). At the time this TECDOC document was written, CFD codes being used for analysis included FLUENT, CFX, and STAR-CD; STAR-CD being a precursor to CD-ADAPCOs newer STAR-CCM+ platform. Detailed descriptions of essential models implemented in STAR-CCM+ may be found in Chapter 3.

2.2.1 Modeling Manifolds in CFD

The simulation of single-phase manifold or header flows is an ideal problem for application for CFD analysis. The complex flow behaviour present in these types of problems poses a unique challenge in various fields including injection moulding and nuclear safety analysis. Rather than using empirically derived correlations for safety analysis, use of CFD modelling provides a first principles prediction of physical behaviour. Validation of CFD models against experimental data provides justification for use of CFD in prediction of flow behaviour for design or safety purposes. Muhana investigated the use of computational fluid dynamic tools for single-phase flow distribution in CANDU headers (Muhana, 2009).

Muhana made use of FLUENT version 6.3.26 for simulation of three header geometries to be compared to experimental results. The first geometry was based on experiments by Horiki, consisting of a horizontal rectangular header with four rising cylindrical outlet pipes (Horiki *et al.*, 2004). The second and third header geometries consisted of a cylindrical header with five vertical and five horizontal outlet headers. The difference between these two test configurations depended on the choice of inlet piping. Two evenly spaced, vertical inlet pipes feeding the top of the tank were used for the second configuration, while two horizontal feeders on either side of the tank are used for the third configuration.

Use of the first configuration yielded a FLUENT model which closely matched mass flow rates between CFD and experimental results. Low flow rates were avoided as it was determined that error became significant as the effect of exit conditions and

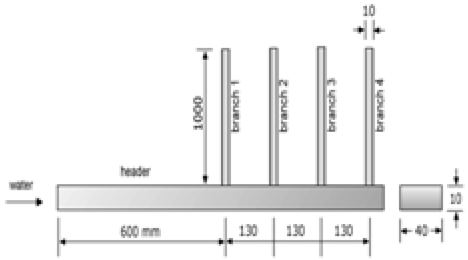


Figure 2.1: Header Configuration 1 (Muhana, 2009)

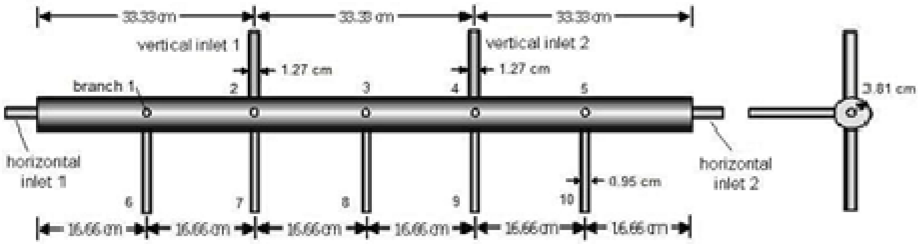


Figure 2.2: Header Configuration 2 (Muhana, 2009)

difficulty of accurate flow measurement became more problematic. A 6x 10^6 node header model with a standard k- ε turbulence model with enhanced wall treatment provided results with closest fit to experiment. Configuration two displayed optimal results, also closely matching experiment, with a 2.5x 10^6 node grid density and RNG (Re-Normalization Group) k- ε turbulence model with enhanced wall treatment. Configuration three also provided good agreement to experiment with 2.5x 10^6 nodes and the RNG k- ε turbulence model with enhanced wall treatment.

The work done by Muhana demonstrates the method by which CFD programs are shown to provide accurate prediction of flow behaviour in complex geometries. While the simulated system may be a highly simplified model compared to a CANDU header, it provided a valuable proof of concept for possible application to simulation of a full size flow model or a TH to CFD coupled approach to safety analysis.

2.2.2 CFD Studies Relevant to CANDU Headers

Gulshani (Gulshani, 2006) outlines a FLUENT simulation of an RD-14M outlet header under two-phase flow conditions with natural circulation. The study concentrates on phase separation in the header with reverse flow and vapor entrainment into heated section pipe 8 at low flow rates. Unexpected and complex bubble trajectories were of note.

Moffett et al (Moffett *et al.*, 1996) provide a comparison between a one and a three dimensional model of a CANDU-6 reactor inlet header, with focus on pressure and flow distributions. Comparison of results from NUCIRC (1-D TH code) and CFDS-FLOW3D (3D CFD code) showed that three dimensional effects influence the pressure distribution and were most pronounced near the junction of the pump discharge pipe and the header.

Teclemariam et al (Teclemariam *et al.*, 2003) investigate two-phase flow in an 8.5:1 scale down of a CANDU header with 2 inlets and 30 outlets. A total of 16 test configurations demonstrate significant variation in water and air flow rates in both axial and circumferential directions with strong dependence on inlet flow conditions.

2.3 Modelling RD-14M

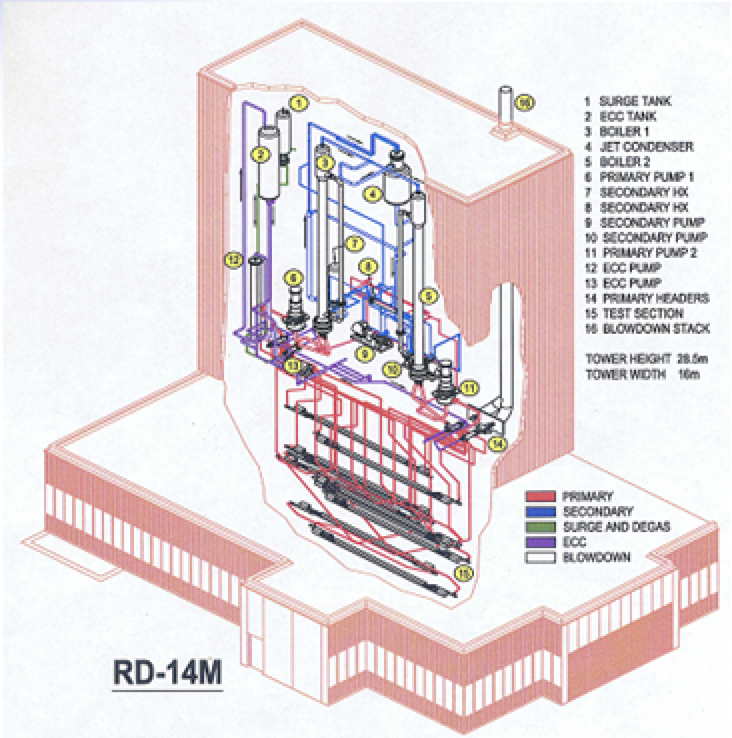


Figure 2.3: The RD-14M Facility (Buell *et al.*, 2003)

The RD-14M facility is a scaled experiment designed to mimic the CANDU reactor primary heat transport system, and as a result, exhibits much of the same behaviour in terms of fluid mass flux, transit time, pressure, and enthalpy. As in a CANDU, a figure-of-eight geometry is employed with exact scale vertical elevations to ensure pressure drops and buoyancy effects reflect actual CANDU conditions. Unlike the CANDU, RD-14M has total of ten fuel channels which contain electrically powered fuel element simulators (FES). The FES are designed to mimic CANDU fuel bundle characteristics to ensure similar power density, heat flux, and heat capacities (IAEA, 2004). An Emergency Core Coolant (ECC) system is present for investigation of postulated LOCA scenarios. LOCAs are artificially induced using a fast-acting ball valve at either the inlet or outlet headers. The size of the break is adjusted using selectively sized orifice plates before the discharge valve. The experimental facility has been used to examine LBLOCA, SBLOCA and LOF events in CANDU reactors for the last 25 years.

Test B9401 involves a 30-mm diameter inlet header break with high pressure emergency coolant injection (ECI). Desired system conditions were 10.0 MPa outlet header pressure, 4.0MW per pass nominal input power, 186°C feed water temperature, and forced ECI injection at 30°C. At ten seconds after initiation of data sampling, a blowdown valve at header one of the inlet headers is opened to simulate the break. Two seconds after break initiation, FES power was decreased to reflect decay power levels. Loss of class IV power (loss of connection to off-site power grid) is then simulated by a primary pump rundown. ECC isolation valves are opened at 20.6 seconds and the Pressurizer is isolated at 22.8 seconds. High pressure ECC is transitioned to low pressure ECC at 116.2 seconds. Primary pumps are disengaged at 213.2 seconds and low pressure ECC is terminated at 350.7 seconds. The test is ended after a sufficient period at decay power levels.

IAEA TECDOC-1395 (IAEA, 2004) provides a benchmark study of RD-14M.

Six countries, Argentina, Canada, India, Italy, the Republic of Korea, and Romania participated in an intercomparison and validation study of four different computer codes: CATHENA, Firebird, and RELAP5/MOD3.2, and RELAP5/CANDU. The experimental results to which code outputs are compared come from the RD14-M test B9401, a large LOCA test. The B9401 LOCA experiment involved the measurement of over 558 channels of data which were available for use in the benchmark exercise. 43 Variables were chosen for final comparison of code outputs.

It was determined that all four codes were able to provide a consistent steady state result with minimal deviation from experimental data. Transient phenomena such as break discharge, system depressurization, temperature excursion, and heated section rewet were satisfactorily captured. Deviations in void fraction were attributed to geometrical complexities that could not be sufficiently modeled using a 1-D system, but were not significant enough to affect prediction of overall system performance. While large header gradients may not occur in the RD-14M facility in the headers due to its smaller physical size, the experiment provides data which can be used to validate the coupled models proposed in this work. Once validated, the CFD tool can be used to assess the geometrical factors and scaling of the RD-14M, and in particular the 3D header gradients as compared to those predicted for a larger CANDU header. The next section summarizes some of the more relevant coupling publications in the area of thermalhydraulics.

2.4 Use of Code Coupling in Nuclear Safety

There are a large number of examples in literature of thermalhydraulic to reactor physics coupling as demonstrated by the following subsection and also some attempts at multi-scale thermalhydraulic coupling (CFD to system or CFD to subchannel) codes. Within thermalhydraulics multi-scale coupling, the most common technique involves explicit information exchange between the codes, while some employ semi-implicit methods. As time progresses, and computing resource costs continue to drop, many more types of coupling systems are being investigated due to the interrelated nature of nuclear power generation processes. Two of the more relevant recent coupling schemes are reviewed in the following subsections.

2.4.1 ATHLET to CFX

Papukchiev et al (Papukchiev *et al.*, 2009) attempted to expand the simulation capability of the thermalhydraulics code ATHLET to allow for multidimensional thermalhydraulic representation of primary circuit geometries. This was done through coupling to the CFD package, ANSYS-CFX. A description of coupling methodology as well as discussion of results was given.

The coupling strategy, developed by teams from ANSYS Germany and Gesellschaft fur Anlagen- und Reaktorsicherheit (GRS), relies on an explicit coupling scheme in which CFX is the master and ATHLET is the slave. In particular the CFD and system code would pass information at specifically defined boundaries and hence the outlet predictions from one code become the inlet boundary conditions for the other (and vise versa). The ATHLET code was modified to allow it to be run as a subroutine from another program and included two options for data transfer from CFD code. These options deal with the transfer of information at the interface and the way in which ATHLET interprets information it receives from CFX. A slightly modified version of CFX was used, whose main deviation from standard was the inclusion of extended command language definitions to allow for the use of symmetry for the CFD model, as well as definitions which allow ATHLET execution.

The coupling procedure followed an explicit scheme in which CFX was the driving code. The geometry, mesh, turbulence modelling and other features for the CFX modelled component were predetermined as well as the appropriate inputs for ATHLET. Simulation began with a time step of CFX with predefined boundary conditions at either end of the geometry being modelled by CFX (either pressure, flow and/or temperature). Once converged for this time step the results were then translated into suitable boundary conditions for ATHLET. ATHLET would use these boundary conditions to run up to the same time step as CFX, sometimes breaking this time interval into multiple steps to increase stability. The resultant flow, pressure and temperatures were then processed to form new boundary conditions for the CFX code and the next time step would begin.

Boundary conditions within CFX were set to *inlet* where flow was expected to be within the simulation domain and *outlet* where flows were expected to be leaving the domain. During transfers from ATHLET to CFX, ATHLET would provide mass flow and enthalpy to the CFX inlet. During CFX to ATHLET transfers CFX would determine the pressure and temperature and pass these to ATHLET. The reverse procedure was taken at the outlet. This method demonstrated good results but was updated to have ATHLET provide fluid velocity to a CFX inlet condition of *opening*, so as to allow for the consideration of reverse flows. Use of constant temperature was attempted before the introduction of full thermal coupling. This was done after a comparison between water property tables for the two codes to ensure consistency.

The model consisted of a 5.0 m long pipe, modelled by CFX, between two pipes of the same geometry which were modelled by ATHLET. A second configuration housed the same CFX pipe model within a closed loop consisting of two 20 m long pipes attached to a pressure control volume, with a pump midway between one of these pipes to drive flow through the CFD domain.

Figure 2.4: Open Loop Configuration (Papukchiev *et al.*, 2009)

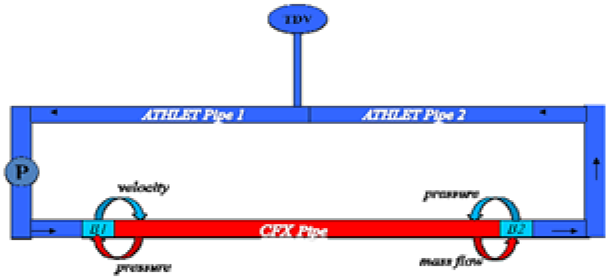


Figure 2.5: Closed Loop Configuration (Papukchiev *et al.*, 2009)

It was concluded that results from these models provided adequate solutions, in that flow reversal was successfully modelled, thermal characteristics were successfully transferred across boundaries, and sufficient mass conservation was demonstrated within the closed loop to maintain stability. Mass flow rate and pressure for the closed loop were also compared to results to an analogous uncoupled ATHLET geometry and were shown to have excellent agreement.

Steps to increase simulation stability included refinement of the velocity inlet boundary transfer to use a correlation due to the different discretization methods the two codes employ in the treatment of cross sectional pipe area. For example, in the ATHLET input only a single velocity is needed, while for CFX the velocity inlet must follow a well-defined profile. This greatly improved observed mass conservation. Description of future work focused on the development of a semi-implicit coupling scheme and experimental validation of the simulation results.

A more recent body of work by Papukchiev et al (Papukchiev *et al.*, 2011) provides an update on these coupling initiatives. An ATHLET to ANSYS CFX simulation of a pressurized thermal shock experiment of the Japanese Large Scale Test Facility (LSTF) was created to validate the applied coupling methodology. As part of an Organization for Economic Co-operation Development (OECD) Nuclear Energy Agency (NEA) Rig of Safety Assessment (ROSA) project, the transient being studied involves flow mixing and temperature stratification of flows during ECI and natural circulation conditions of the primary HTS of a PWR. Very good agreement was demonstrated between coupled and uncoupled codes demonstrating the validity of the coupling approach. An example of this agreement is shown in figure 2.6.

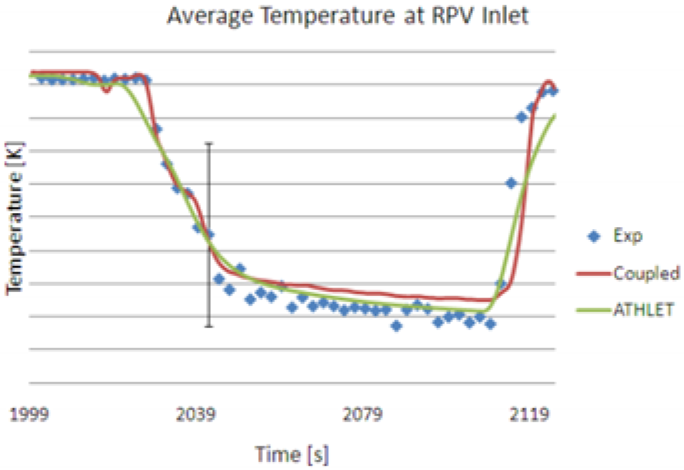


Figure 2.6: Reactor Pressure Vessel Inlet Temperature(Papukchiev *et al.*, 2011)

2.4.2 Relap5-3D Coupling to CFD

Aumiller et al (Aumiller *et al.*, 2000) details the development of an explicit coupling scheme of RELAP5 to RELAP5 (to test data transfer), as well as RELAP5-3D to CFD for simulation of a two phase flow condition. The CFD code used for this purpose was based on CFDS-FLOW3D, which is now CFX. Difficulties in ensuring mass, momentum, and energy conservation include determination of frequency of information transfer, point of information transfer, simulation domains assigned to each code, definition of variables transferred between codes, as well as a method of time step control. Explicit coupling procedure was chosen as proof of concept before a more difficult semi-implicit approach was attempted.

An outline of the relevant simulation models was given in addition to a standalone RELAP5-3D model of the same problem. Transferred quantities between codes were also detailed. These quantities were chosen according to the independent variables used by either code (CFD vs. TH) such as specific internal energy versus enthalpy. This was done to ensure each code received information that was in a usable format. This raised concerns of water property consistency between codes, as well as accurate interfacial heat transfer. Due to the possibility of differing water property tables, phasic densities were passed to the CFD code to ensure accuracy of convection terms.

A rigid time step control was implemented where both codes performed with fixed uniform timesteps to ensure synchronization. For this method, the greatest adverse contribution to code performance was lack of proper conservation of momentum. Aumiller et al indicate both the CFD and TH code do not both have all of the required information to correctly calculate the VV term at pressure boundary locations.

RELAP5-3D code modifications included PVM software alterations as well as the capability to specify the phasic mass flow rate in time dependent junctions. The CFD package used a one-dimensional, two-field configuration, without implementation of a turbulence model rather than a full three-dimensional, four field model that the code is capable of. The standard CFX USRBCS subroutine was used to update boundary condition data.

The problem modelled by these codes was an Edwards-O'Brien depressurization study of a 4.096 m long straight pipe of 0.0073 m inside diameter, full of water, with initial conditions of 7.00 MPa and 513.7K. RELAP5/RELAP5 results were found to closely match the full RELAP5-3D model. Some observed deviation was attributed to the nature of the explicit coupling scheme. To ensure the CFD code could properly simulate the chosen problem, a full CFD simulation of the model was performed as well. Despite limitations in chosen modelling scheme and numerics, Aumiller et al concluded the standalone CFD code was capable of calculating the rapidly changing conditions in the problem. Since these previous two methods proved successful, the RELAP5/CFD calculation was performed. It was found that the fluid within the CFD domain flashes at a slower rate than within the RELAP5-3D domain leading to a deviance in solution from the near identical RELAP5-3D and RELAP/RELAP coupled models. The successful simulation of this problem demonstrated the feasibility of this approach for coupled modelling and justified the pursuit of further coupling method refinement.

Rodriguez (Rodriguez, 2012) discusses the coupling of RELAP5-3D to STAR-CCM+. Rodriguez employed a beta version of STAR-CCM+ 6.0.4, which is the first version of the code designed with specific modules to allow for direct coupling to RELAP5. Working with support from CD-ADAPCO, Rodriguez attempted to apply coupling in modeling a facility at Texas A& M University, designed to simulate the conditions in a Reactor Cavity Cooling System (RCCS) of a Very High Temperature Reactor (VHTR). Through transfer of information through the use of sockets, two coupling structures are available for use between these codes; thermal coupling, and flow coupling. Thermal coupling couples a single side of a RELAP5-3D heat structure to the wall surface of STAR-CCM+, while flow coupling collects RELAP5-3D pressure-temperature data from time dependent volumes and mass flux values at time dependent junctions, and exchanges this information with STAR-CCM+. Results using only thermal coupling appeared promising, while obtaining flow results from a flow coupled system remained problematic. Additional limitations were identified as follows:

- Both simulations must be transient
- Coupling using compressible fluids (like air) is stable, but with incompressible

fluids is unstable

- Flow coupling does not function in a closed loop system

Volpenhein (Volpenhein, 2013), who was involved in the work of Rodriguez, provides a brief overview of the coupling method between STAR-CCM+ and RELAP5-3D. An example of the implementation of this type of system is given in modeling a natural convection test facility for the VTHR RCCS design concept. The results provided demonstrate a successful simulation of a thermal coupled system. The work done by Rodriguez and Volpenhein occured during the time the work for this thesis was being performed.

2.4.3 Other Examples of Code Coupling Applications in Nuclear Safety

Most coupling methods in the nuclear industry have thus far been focused on neutron kinetics coupling to 1-D thermal hydraulics codes or in some cases, 3D CFD codes. The remainder of this section provides a cursory glance at the types of coupling being developed to improve the accuracy of nuclear safety codes.

Sasakawa et al (Sasakawa *et al.*, 2011) demonstrate the benefit in coupling a subchannel analysis code to a CFD code. By coupling the VIPRE-01 code to a custom CFD code, the authors are able to improve predictability of departure from nucleate boiling (DNB) as compared to the uncoupled model, using a set of Freon DNB test data as a basis for comparison.

Hoffman et al (Hoffmann *et al.*, 2011) simulate a boiling water reactor (BWR)

LOCA using a coupled system comprised of the thermahydraulic system code ATHLET and the containment code COCOSYS. Through comparison to stand-alone ATHLET simulation results, it is shown that events resolved by the containment code may be beneficial for predicting certain quantities during accident transients, such as collapsed water level of the reactor pressure vessel.

Fanning and Thomas (Fanning and Thomas, 2011) describe the results of their coupled SAS4A/SASSYS-1 to STAR-CD simulation of plenum thermal stratification in a sodium cooled fast reactor during a protected loss of flow transient. The authors demonstrate that thermal stratification resolved in CFD has a significant effect on core temperature as determined by the TH system analysis code.

Jeltsov et al (Jeltsov *et al.*, 2011) discuss the development of validation procedure for coupled TH to CFD codes. Topics covered included the adaptation of the TALL-3D for validation of coupled systems, steady state STAR-CCM+ calculations in support of the design, geometry considerations, potential validation scenarios, and instrumentation requirements.

Betzler et al (Betzler *et al.*, 2011) describe the results of their coupled RELAP5 to MCNP5 thermal feedback effect study. RELAP5 calculates axial temperature distribution while MCNP5 (a Monte-Carlo N-Particle Transport Code System) calculates power fraction. It was shown that the coupled system performed well in predicting behavior of this complementary system through comparison to a benchmark TH simulation.

Judd and Grandi (Judd and Grandi, 2011) provide an investigation into the coupling of the reactor core kinetics code SIMULATE-3K to a number of thermalhydraulics codes. Using a generic coupling interface, coupled results using TRACE, RELAP5-3D, and RELAP5-Mod3.3 are compared to data in order to demonstrate the viability of using such a coupled system for use in best estimate safety analysis.

Nikitin et al (Nikitin *et al.*, 2011) provide a coupling study of the system code TRACE to the SIMULATE-3K reactor kinetics code. Results of this coupled system were compared to OECD/NEA Main Steam Line Break PWR benchmark data. The coupled system was satisfactory in its ability to predict transient parameters.

Lapins et al (Lapins *et al.*, 2011) have studied the coupling of TH system code ATTICA 3D to the neutron transport code TORT-TD. The OECD/NEA/NSC PBMR-400 benchmark is used for validation of results. While simulation results of events such as total control rod withdrawal or ejection were not optimal, the study demonstrates the promise of this type of coupled system for use in safety analysis of high temperature gas cooled reactors.

Zerkak et al (Zerkak *et al.*, 2011) provide an overview of the difficulties associated with code coupling in nuclear analysis, particularly issues dealing related to time stepping and iteration with regard to TH system code to neutronics code coupling . Preliminary results of proposed coupling optimization strategies are given for a reactivity insertion transient simulated by the NURESIM LWR simulation platform.

Abarca et al (Abarca *et al.*, 2011) have employed a RELAP5-MOD3.3 to PARCS v2.7 (neutron diffusion code) coupled system for simulation of power oscillations for comparison to the NEA Ringhals 1 BWR Stability Benchmark. The authors demonstrate that the coupled system is able to achieve good agreement to benchmark results, through results are highly dependent on the type and amplitude of the event which initiates the power oscillation.

Monferrer et al (Monferrer *et al.*, 2011) present results of their coupled neutron diffusion code PARCS v2.7 with the CFD code Ansys CFX 12.1. Through comparison to results of a RELAP5/PARCS coupled system, it is shown that coupling a CFD code to a neutronics code is a viable and attractive tool to pursue for improved accuracy and simulation fidelity of reactor core behaviour.

Yan et al (Yan *et al.*, 2011) describe the coupling of the method of characteristics neutronics code DeCART to STAR-CCM+. A model of a 3x3 fuel pin with spacer grid was employed to demonstrate that the coupled system holds promise to provide a more truthful model with improved prediction of physical effects such as fission energy and heat convection, and as a result, clad temperature and departure from nucleate boiling.

Ammirabile and Walker (Ammirabile and Walker, 2011) provide a MATARE study which demonstrates successful simulation of fuel assembly deformation under reflood conditions. The MATARE code is a coupled system consisting of the single-pin thermal-mechanics code MABEL and RELAP, done through the dynamic coupling code TALINK.

These authors demonstrate that the use of coupling is being pursued in multiple avenues to improve the accuracy of the predictive tools of nuclear safety.

Chapter 3

THEORY

CATHENA is one of a number of thermal-hydraulics system codes found in the field of nuclear safety analysis. These codes are often used in best-estimate safety and accident analyses to model the behaviour of a nuclear power plant's heat transport systems. STAR-CCM+ is a software package which incorporates an extensive computational fluid dynamics solver. While it is beyond the scope of this thesis to present all theory on 1D system codes and CFD, a brief overview of the key features is presented in this chapter.

3.1 CATHENA Mathematical Model

3.1.1 One-Dimensional, Two-Fluid, Non-equilibrium Representation of Two-Phase Flow

The core functionality of a modern thermalhydraulics system code is based on a series of differential fluid equations which describe the behaviour of mass, momentum, and

A	Conduit cross sectional area
α_k	Phase fraction
ρ_k	Phase density
v_k	Phase velocity
P_k	Phase pressure
h_k	Phase specific enthalpy
P_i	Interface pressure
v_{ki}	Interface velocity
m_{ki}	Interface mass transfer rate per unit volume
$_{kw}$	Wall shear per unit length acting on phase k
τ_{ki}	Interphase shear per unit length
q_{kw}	Heat input to phase k per unit volume
q_{ki}	Heat transfer to the interface per unit volume
h_{ki}	Phase specific enthalpy at the interface
g_z	Gravitational acceleration due to gravity (z direction)
ρ_{AP}	Apparent mass density
$v*$	Velocity associated with AP
Γ_{zk}	Net phase removal rate per unit volume of the zirconium-steam reaction

Table 3.1: CATHENA Variable Definitions (AECL, 1998)

energy, in a continuum. The one-dimensional, two-phase flow equations are derived as a macroscopic time and area average of local, instantaneous conservation equations. CATHENA employs six conservation equations to describe its flow field, three equations per phase, with each phase having an equation to describe the behaviour of its mass, momentum, and energy. A number of closure equations are also necessary to create a closed system with a unique solution. Table 3.1 provides a list of variables used in the conservation equations. (AECL, 1998)

The first pair of equations are the mass conservation equations. They may be written as found in equation 3.1 for phase k (k=l for a liquid, and k=g for a gas). Angular brackets indicate cross section averaged quantities.

$$\frac{\partial}{\partial t}\left\langle \alpha_k \rho_k \right\rangle + \frac{1}{A}\frac{\partial}{\partial z}\left(A\left\langle \alpha_k \rho_k v_k \right\rangle\right) = m_{ki} - \Gamma_{zk} \tag{3.1}$$

The momentum equations in CATHENA may be found in equation 3.2, with the relationship provided in equation 3.3.

$$\begin{gathered}\frac{\partial}{\partial t}\langle \alpha_k \rho_k v_k\rangle + \frac{1}{A}\frac{\partial}{\partial z}\left(A\langle \alpha_k \rho_k v_k^2\rangle\right) + \frac{1}{A}\frac{\partial}{\partial z}\left(A\langle \alpha_k P_k\rangle\right) = \\ \langle P_i \frac{1}{A}\frac{\partial}{\partial z}\left(A\alpha_k\right)\rangle + \tau_{kw} + \tau_{ki} + m_{ki}v_{ki} + P'_{ki} - \langle \alpha_k \rho_k\rangle g_z\end{gathered} \tag{3.2}$$

Where

$$P'_{ki} = \left(-1\right)^k \rho_{AP}\left[\frac{\partial}{\partial t}\left(v_g - v_f\right) + v^* \frac{\partial}{\partial z}(v_g - v_f)\right] \tag{3.3}$$

In equation 3.3, $(-1)^k$ is +1 for a liquid and -1 for a gas.

The energy equations may be found in equation 3.4.

$$\begin{gathered}\frac{\partial}{\partial t}\langle \alpha_k \rho_k \left(h_k + \frac{v_k^2}{2}\right)\rangle + \frac{1}{A}\frac{\partial}{\partial z}\left[A\left\langle \alpha_k \rho_k v_k \left(h_k + \frac{v_k^2}{2}\right)\right\rangle\right] - \frac{\partial}{\partial t}\left\langle \alpha_k P_k\right\rangle = \\ -\left\langle P_i \frac{\partial \alpha_k}{\partial t}\right\rangle + q_{kw} + q_{ki} + \tau_{ki}v_{ki} + v_{ki}P'_{ki} + \left\langle m_{ki}\left(h_{ki} + \frac{v_{ki}^2}{2}\right)\right\rangle - \left\langle \alpha_k \rho_k v_k\right\rangle g_z\end{gathered} \tag{3.4}$$

Under single phase conditions, this system of equations simplifies significantly. Under single phase conditions expected without a gaseous phase, α_g=0, and α_l=1, leading to the elimination of many of these terms. In CATHENA, void fraction may be specified for many components, and changes to void fraction may also be limited through options in time step controls.

3.1.2 Numerical Discretization

For successful evaluation of the flow field equations, discretization in both time and space is necessary. In the case of CATHENA, spatial discretization is achieved through the use of a series of finite volumes to construct discrete cells or nodes. Within each of these volumes, mass, momentum, and energy are conserved in the form of thermalhydraulic finite-difference equations. Mass, energy, and void fractions are stored as volume averages within a cell. Momentum values (in the form of phase velocities) are stored as "Links" between cells, yielding a staggered mesh approach as shown in figure 3.1.2. Flow equations within CATHENA area integrated semi-implicitly in time.

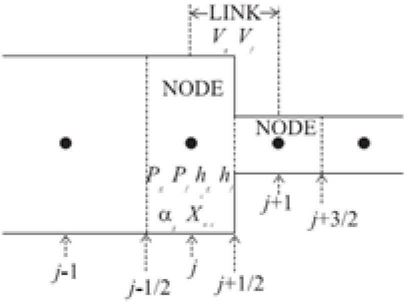


Figure 3.1: Staggered Mesh Approach Employed by CATHENA (AECL, 1998)

3.1.3 Boundary Conditions

Additional relationships that must be defined in order to close the set of six fluid equations include boundary conditions. CATHENA employs an upwind, first-order, semi-implicit, finite-difference method numerical approach. This has an impact on the type of boundary conditions which must be considered. For example, consideration of phase density at external boundaries is only truly necessary only if the flow condition has an inflow component. Regardless of these types of these considerations, CATHENA typically employs two types of boundary condition: reservoir and flow boundary. (AECL, 1998)

The reservoir boundary condition in CATHENA requires user specification of pressures, phase enthalpies, void fraction, and non-condensable mass fractions. These values would be necessary in the event that there is no longer an n+1 node to be found in the node chain (i.e. a boundary). As mentioned, the phase velocity directions have an effect on which of these quantities are eventually used in the system of equations. All values are necessary for inflowing phases, while only pressure would be necessary in an outflow condition to close the system of equations.

The flow boundary condition allows for specification of values applied at a link between nodes due to the staggered mesh approach. These conditions are applied at a link between a reservoir and a pipe node. Specification of velocity boundary conditions must be treated with special consideration. The momentum equations at this boundary link are replaced by the phase velocities. The mass flow rate of each phase is specified by the user where it is converted into a velocity using upwind phase densities and phase fractions.

3.1.4 Fluid Properties

A reliable method of predicting fluid properties is essential for proper operation of thermalhydraulics codes. These codes rely on fluid properties such as density and viscosity to close the set of conservation equations upon which these systems are built. The most widespread database of water properties is published by the International Association for the Properties of Water and Steam (IAPWS, 2011). Examples of codes built using this water properties package include TRACE and RELAP5-3D (RELAP5-3D code includes ATHENA features and models). CATHENA makes use of a FORTRAN-77 subroutine library called HLWP (Heavy and Light Water Properties), in which the generating function by Hill et al (Hill *et al.*, 1998) is used to calculate heavy water properties.

3.1.5 Pressure Drops

Pressure losses within the CATHENA may be attributed to a variety of phenomena including wall friction, form losses, interface friction, or density changes in the fluid. This section will give a brief description of some approaches CATHENA takes for calculation of pressure loss in a single-phase fluid system.(AECL, 1998)

3.1.5.1 Frictional Losses

In any thermalhydraulic analysis, it is essential to consider the momentum transfer resulting from the interaction between fluid and the conduit surface. In cases of single phase, incompressible, and steady flows, an analytical approach, such as use of the modified Bernoulli equation along with friction factor information, is often sufficient for prediction of pressure loss in a pipe arising from frictional losses. Frictional pressure losses are typically expressed as a function of fluid velocity, fluid density, equivalent hydraulic diameter, and a friction factor which is representative of the fluid shear stresses near the fluid-wall interface. In the case of laminar flows (low Reynolds number), this friction factor is usually satisfactorily expressed as 64/Re.

With more complex or turbulent flows, more sophisticated approaches are necessary.

For turbulent flows on rough surfaces, in order to determine its Rough Pipe Friction Factor (for pipe surfaces that have a nonzero surface roughness ε, with pipe hydraulic diameter D_e), CATHENA calculates the friction factor (f) by solving the Colebrook-White formula (AECL, 1998):

$$\frac{1}{\sqrt{f}} + 2\log(\frac{\varepsilon}{D_e}) = 1.14 - 2\log(1 + 9.35\frac{D_e/\varepsilon}{Re\sqrt{f}}) \tag{3.5}$$

Due to this expression being transcendental with regard to the friction factor, an explicit version of this expression is usually preferred. CATHENA employs an explicit nonlinear curve fit by Rajan (AECL, 1998) as an initial estimate which is then iteratively refined with Colebrook-White to convergence.

3.1.5.2 Form Losses

Additional factors which must be considered, even in single phase flow, are form losses. Such losses occur where the flow field encounters an element which causes disruption. Common examples include elbows and sudden contractions/expansions (see figure 3.1.5.2). It is common for these form losses to be treated as seen in equation 3.6, where K is a form loss coefficient that is determined empirically for the type of form loss being considered. CATHENA provides a number of methods for calculating these form losses, with special consideration for two-phase flows.

$$\Delta P_{JNK} = K_{eff}\rho_m\frac{v_m^2}{2} \tag{3.6}$$

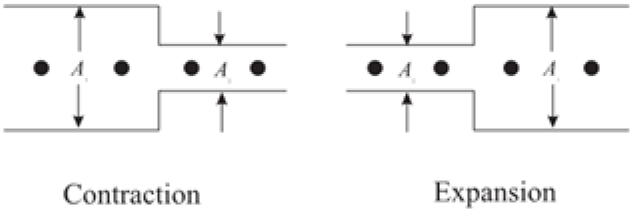


Figure 3.2: Sudden Contraction or Expansion (AECL, 1998)

3.1.6 Wall to Fluid Heat Transfer

CATHENA makes use of a Generalized Heat Transfer Package (GENHTP) for treatment of heat transfer phenomena. This section outlines some of the methods employed by this package for heat transfer calculations

CATHENA treats the heat transfer across the wall to fluid interface as seen in equation 3.7. q is the heat transferred from the wall to the fluid for phase k, and node n. This is integrated over the length of the thermalhydraulic cell (tc). h represents the heat transfer coefficient and a represents the contact area. T represents temperature, and w indicates the wall. (AECL, 1998)

$$q_k^{(n)} = \int_{tc} h_k^{(n)} a_k^{(n)} \left(T_w^{(n)} - T_k \right) dA \tag{3.7}$$

The method of integration employed by CATHENA is dependent upon the temperature distribution over the piping segments being considered.

For calculating wall-to-fluid heat transfer, CATHENA provides a number of correlations for determining the heat transfer coefficient. In single phase turbulent flow, the default correlation is that of Dittus-Boelter(AECL, 1998).

3.2 STAR-CCM+ Mathematical Model

This section provides an outline of the three dimensional header mathematical model, a brief description of the STAR-CCM+ simulation code and the method of solution employed by the CFD solver.

3.2.1 Conservation Equations

The CFD models employed by STAR-CCM+ rely on finite volume methods making use of the conservation equations described in the upcoming subsections.

3.2.1.1 Mass Conservation Equation

The vector notation for an unsteady, three-dimensional mass conservation equation for a compressible fluid may be seen in equation 3.8 (CD-ADAPCO, 2012). Otherwise known as the continuity equation, this equation provides a consideration of the rate of change of density with time as well as consideration of the gradient of mass change. The scope of this project is limited to steady state conditions as well as the assumption of an incompressible fluid.

$$\frac{\partial}{\partial t} + \bigtriangledown \cdot (\rho \overrightarrow{v}) = 0 \tag{3.8}$$

A more refined form of the continuity equation is employed by STAR-CCM+ to allow for simulation of porous media and use of moving grids. It is provided as equation 3.9. (CD-ADAPCO, 2012)

$$\frac{\partial}{\partial t} \int\limits_{V} \rho \chi dV + \oint\limits_{A} \rho (v - v_g) \cdot da = \int\limits_{V} S_u dV \tag{3.9}$$

This becomes equation 3.10 in discrete form.(CD-ADAPCO, 2012)

$$\sum_f \dot{m}_f = \sum_f (\dot{m}_f^* + \dot{m}'_f) = 0 \tag{3.10}$$

The terms m_f* is the uncorrected face mass flow rate which is calculated after the discrete momentum equations have been solved. m_f is the mass flow pressure correction term require to satisfy continuity. STAR-CCM+ employs separate methods for calculating the uncorrected mass flow rate at interior faces and at boundaries.

3.2.1.2 Momentum Conservation Equations

The continuous form of the momentum equation in STAR-CCM+ may be seen in equation 3.11 (CD-ADAPCO, 2012). A list of variables may be found in table 3.2. Of particular note are the fluid stresses which must be modeled (through turbulence modeling) to close the equations.

$$\begin{aligned} \frac{d}{dt}\int_V \rho\chi v dV + \oint \rho v \otimes (v - v_g) \cdot da = \\ -\oint_A p\mathbf{I} \cdot da + \oint_A T \cdot da + \int_V (f_r + f_g + f_p + f_u + f_\omega) dV \end{aligned} \tag{3.11}$$

In discrete form around cell 0, this becomes equation 3.12 (CD-ADAPCO, 2012).

$$\frac{d}{dt}(\rho\chi v V)_0 + \sum_f \left[v\rho(v - v_g \cdot a\right]_f = -\sum_f (pI \cdot a)_f + \sum_f T \cdot a \tag{3.12}$$

χ	porosity
v	Fluid velocity
ρ	Phase density
v_g	Grid velocity
p	Pressure
I	Identity matrix
T	Stress tensor
f_r	Body force due to rotation
f_g	Body force due to gravity
f_p	Porous media force
f_u	User defined body force
f_ω	Vorticity confinement force
f	Face quantity
V	Cell volume
a	Linear coefficient

Table 3.2: List of Variables for the STAR-CCM+ Momentum Equation

3.2.1.3 Energy Conservation Equations

The energy equation in STAR-CCM+ may be seen in equation 3.13 (CD-ADAPCO, 2012). Table 3.3 provides a list of variables.

$$\frac{d}{dt}\int_V \rho E dV + \oint_A [\rho H(v - v_g) + v_g p]\cdot da = -\oint_A \dot{q}'' \cdot da + \oint_A T \cdot v da + \int_V f \cdot c dV + \int_V s_u dV \tag{3.13}$$

In discrete form, this becomes

$$\frac{d}{dt}(\rho E V_0) + \sum_f \{[\rho H(v - v_g) + \dot{q}'' \cdot a - (T \cdot v)] \cdot a\}_f = (f \cdot v + s)V_0 \tag{3.14}$$

ρ	Density
E	Total energy
V	Cell volume
H	Total enthalpy
v	Velocity
v_g	Grid velocity
p	Pressure
a	Face area vector
q”	Heat flux
T	Viscous stress tensor
f	Body force vector
s_u	User specified energy source term

Table 3.3: List of Variables for the STAR-CCM+ Energy Equation

3.2.2 Turbulence Modeling

A turbulence model is required in order to close the Reynolds-Averaged Navier-Stokes equations. In practical terms, much information is lost as instantaneous pressure and velocity fields are averaged out into mean values for practical application of the RANS equations. To approximately account for these effects, a turbulence model is employed. The k-ϵ turbulence model has proven to be suitable choice for header geometries, as demonstrated by Muhana (Muhana, 2009). The k-ϵ turbulence model is a two equation model, providing two extra transport equations for turbulent kinetic energy (k) and its turbulent dissipation rate(ϵ). These extra transport equations help account for effects such as convection and diffusion of turbulent energy.

3.2.3 Time Stepping

An implicit unsteady time stepping approach is chosen due to the time-varying nature of the boundary conditions. This approach performs some number of inner iterations at a given instant in time before stepping to the next time increment. The physical time step size, Courant number, and number of inner iterations are specified for each time step.

3.2.4 Method of Solution

The SIMPLE algorithm is employed to control progression of the solution. The steps taken by STAR-CCM+ in its use of this algorithm are as follow (CD-ADAPCO, 2012):

1. Set the boundary conditions
2. Compute the reconstruction gradients of velocity and pressure
3. Compute the velocity and pressure gradients
4. Solve the discretized momentum equation to create the intermediate velocity field: v^*
5. Compute the uncorrected mass fluxes at faces: m_f^*
6. Solve the pressure correction equation to produce cell values of the pressure correction p
7. Update the pressure field: $p^{n+1} = p^n + \omega$ p (where ω is the under-relaxation for pressure)
8. Update the boundary pressure corrections p_b
9. Correct the face mass fluxes: $m_f^{n+1} = m_f^* + m_f$

10. Correct the cell velocities: $v^{n+1} =$ v* - V $\bigtriangledown p/a_p^v$
11. Update density due to pressure changes
12. Free all temporary storage

Chapter 4

METHODOLOGY

This section provides a detailed description of the RD-14M facility, an overview of experimental conditions for test B9401, the modifications to the standard B9401 CATHENA test deck, as well as a description of STAR-CCM+ header modelling approach. Finally, the coupling procedures explored in this thesis are highlighted.

4.1 RD-14M Facility Description

The RD-14M experimental facility is designed to exhibit many of the same thermal hydraulic behaviors of a CANDU reactor. This is a result of the design which consists of full scale component elevation, figure of eight fuel channel configuration with five channels per pass, and electrically heated fuel simulators for accurate simulation of reactor behavior. This facility is used for simulation of many safety scenarios including various LOCA scenarios, analysis of natural convection behavior, and reactor shutdown transients. Extensive instrumentation provides data for computer code validation and allows for analysis of thermal hydraulic phenomena.

Figure 4.1 shows the significant components of the RD14M facility including the primary, secondary, and ECC systems. The ten horizontal channels each contain seven electrical heaters which function as fuel element simulators. The test sections are connected to full-length feeders through the use of end fitting simulators. Two inlet headers provide water to the feeders with flow driven by two bottom-suction centrifugal pumps. The two outlet headers direct flow into two full-height U-tube steam generators. A jet condenser is used to condense steam from the steam generators so as to be recycled back into the boilers by the feed water pumps. The pressure of the PHTS is controlled by an electrically heated pressurizer tank. An emergency coolant injection (ECI) system is present to provide coolant injection into the primary circuit. Figure 4.3 provides a comparison of system characteristics between RD-14M and a typical CANDU.

4.1.1 Primary Heat Transport System

This section provides a description of the RD-14M primary heat transport system. These components include the primary system piping (including feeders and piping connections), test sections, headers, steam generators, and primary system pumps. Component characteristics such as form losses have been evaluated from experimental data for their use in computer models of the facility. These facility characteristics may be found in McGee et al and would be too long to include in this report (McGee *et al.*, 1985).

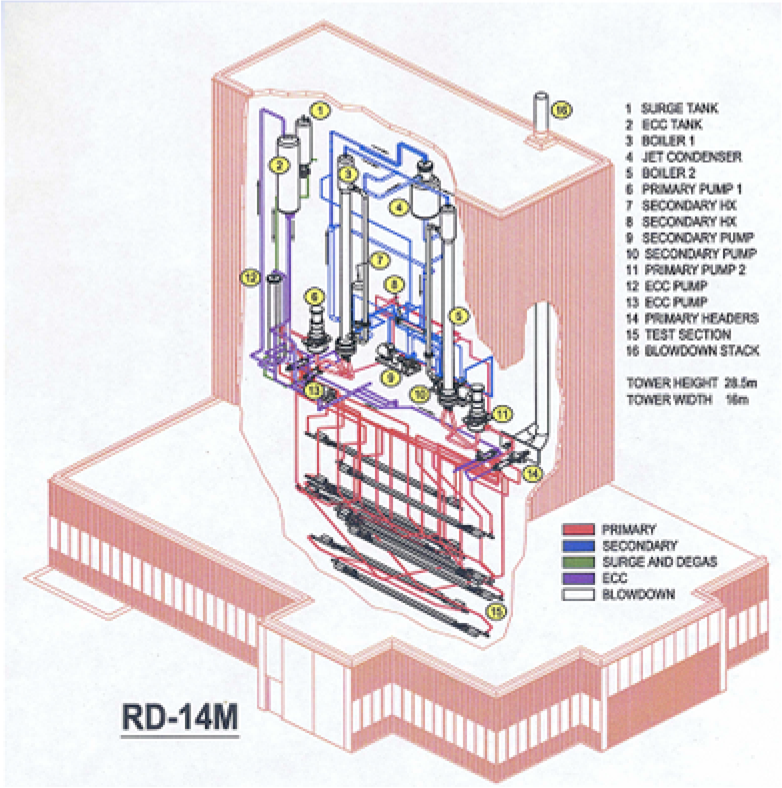


Figure 4.1: The RD-14M Facility (Buell *et al.*, 2003)

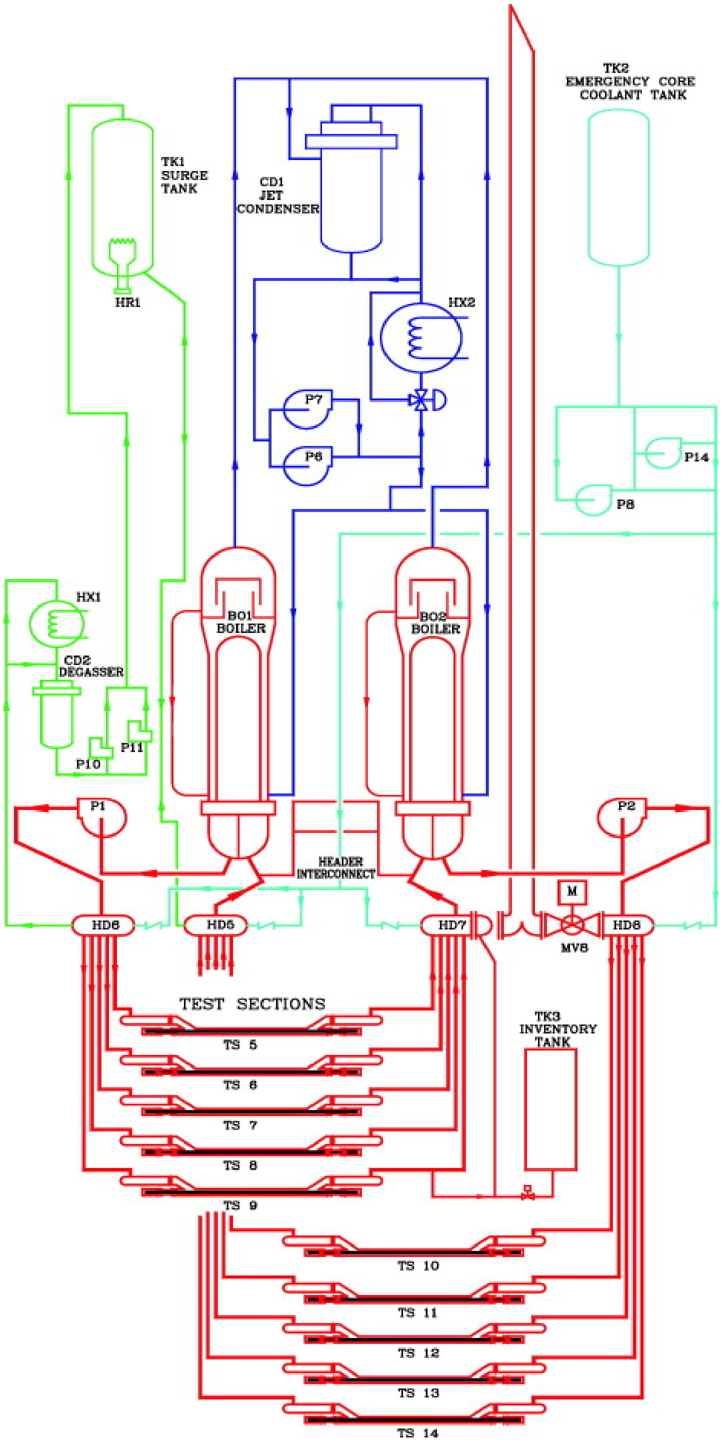
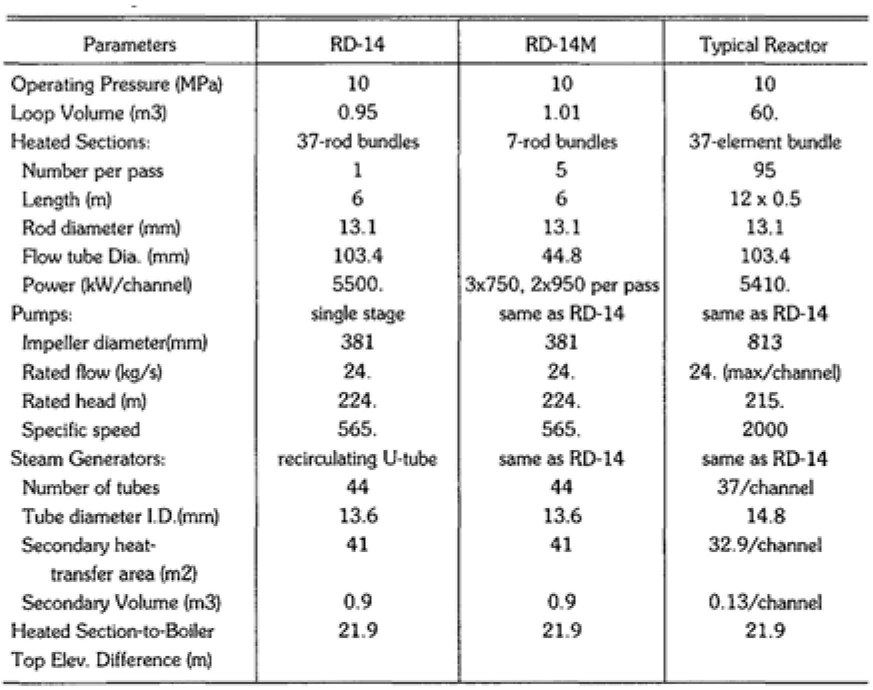


Figure 4.2: RD-14M Facility Schematic(Kim *et al.*, 2011)



Parameters	RD-14	RD-14M	Typical Reactor
Operating Pressure (MPa)	10	10	10
Loop Volume (m3)	0.95	1.01	60.
Heated Sections:	37-rod bundles	7-rod bundles	37-element bundle
Number per pass	1	5	95
Length (m)	6	6	12 x 0.5
Rod diameter (mm)	13.1	13.1	13.1
Flow tube Dia. (mm)	103.4	44.8	103.4
Power (kW/channel)	5500.	3x750, 2x950 per pass	5410.
Pumps:	single stage	same as RD-14	same as RD-14
Impeller diameter(mm)	381	381	813
Rated flow (kg/s)	24.	24.	24. (max/channel)
Rated head (m)	224.	224.	215.
Specific speed	565.	565.	2000
Steam Generators:	recirculating U-tube	same as RD-14	same as RD-14
Number of tubes	44	44	37/channel
Tube diameter I.D.(mm)	13.6	13.6	14.8
Secondary heat-transfer area (m2)	41	41	32.9/channel
Secondary Volume (m3)	0.9	0.9	0.13/channel
Heated Section-to-Boiler Top Elev. Difference (m)	21.9	21.9	21.9

Figure 4.3: Comparison of CANDU to RD-14M (Cho and Jeun, 2003)

4.1.1.1 Primary System Piping

Primary system piping is composed of ASTM A106 Grade B carbon steel. The carbon steel feeder piping joins the test sections to the headers and the rest of the PHTS. The feeders maintain the same vertical elevation as that found in a full-scale CANDU with a pipe roughness of 4.5E-5 m. This is done to ensure hydrostatic pressure effects reflect those found within a CANDU. Flow limiting orifices are employed to ensure equal flow distribution between channels within the same pass. Feeder orifice sizes are usually 15.2, 15.7, or 23.5 mm in diameter.

4.1.1.2 Test Sections and End Fitting Simulators

The ten test sections or heated channels found in the RD-14M facility are essentially pressure tubes which contain the fuel element simulators, capped with end fitting simulators. A strongback provides additional structural support. The test section pressure tubes are 6.3 m long, with a 57.2mm outer diameter, 44.8mm inner diameter, and are made of stainless steel.

End fitting simulators are located on the ends of the test sections, primarily to allow for electrical power connections to the fuel element simulators. The end fitting simulators contain a dead volume, around which flow is directed, as seen in figure 4.5. The end fitting simulators are designed to simulate CANDU reactor end fittings which allow for online refuelling. The end fittings are designed to exhibit similar pressure drops, scaled thermal mass, and fluid volumes to that of a CANDU. (Buell *et al.*, 2003)

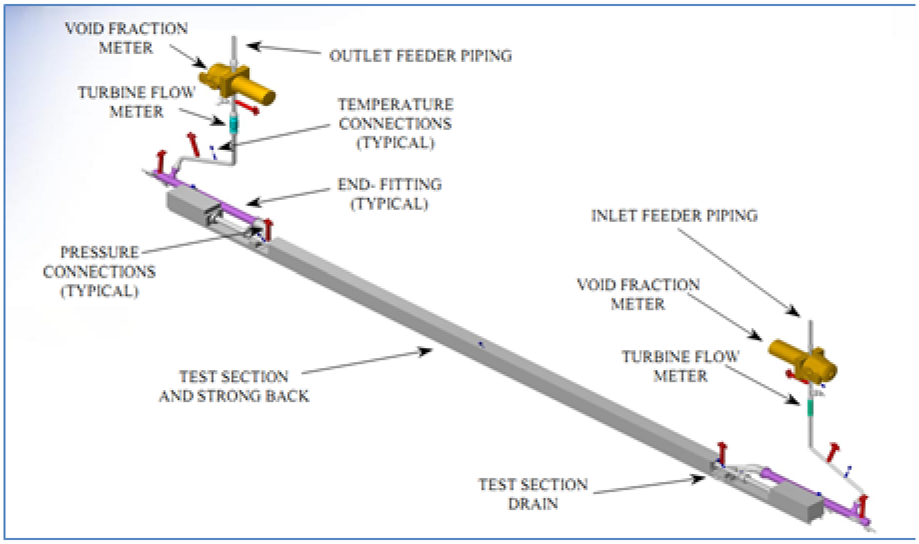


Figure 4.4: RD-14M Test Section Diagram (Buell *et al.*, 2003)

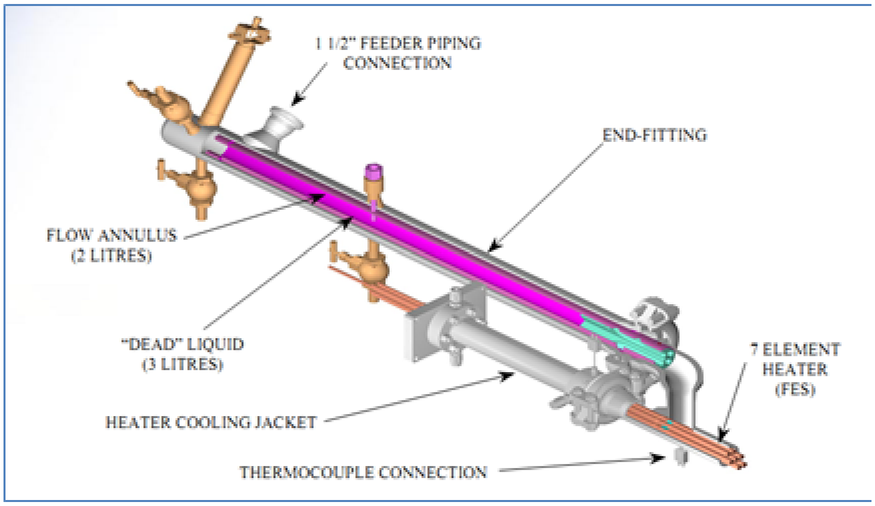


Figure 4.5: RD-14M End Fitting Simulator (Buell *et al.*, 2003)

4.1.1.3 The RD-14M Header

The RD-14M headers are made from ASTM A106 grade B carbon steel, similar to the rest of the PHTS. The dimensions of the headers are approximately 1 meter long with a 203mm outer diameter and 193.7mm inner diameter. An inlet header is shown in figure 4.6, while an outlet header may be found in figure 4.7.

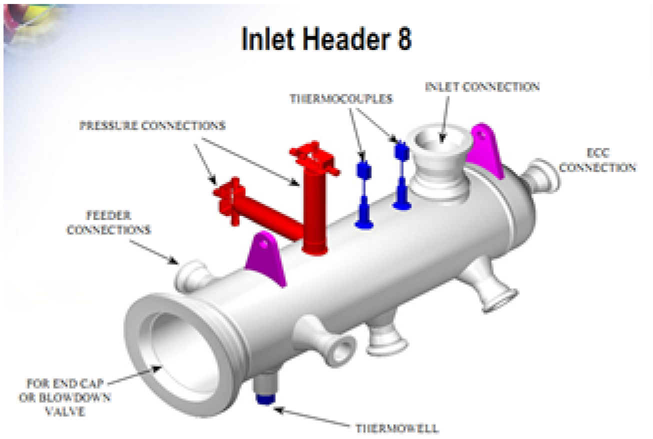


Figure 4.6: Inlet Header 8 (Buell *et al.*, 2003)

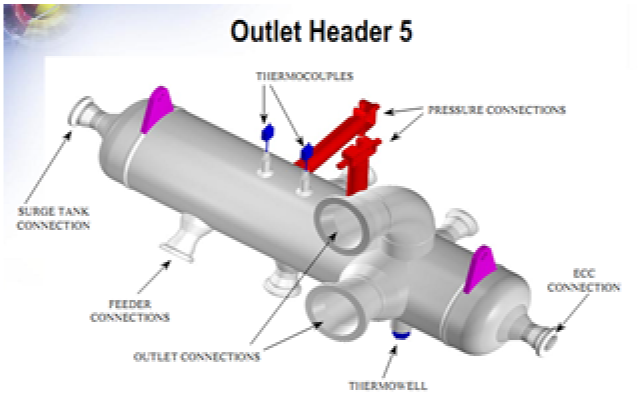


Figure 4.7: Outlet Header 5 (Buell *et al.*, 2003)

4.1.1.4 Fuel Element Simulators

The fuel element simulators are constructed of a magnesium oxide core surrounded by a 7.62 mm outer diameter Inconel tube. This Inconel tube is in turn surrounded by boron nitride layer surrounded by a 13.18 outer diameter stainless steel cladding. Figures 4.8 and 4.9 provide a more in depth view of the FES. (Buell *et al.*, 2003) To better approximate the behaviour expected from a 37 element CANDU, the total core flow and power in each of the five channel passes is set to equal the average flow of a CANDU channel (28.5 kg/s nominal). Pin power in outer elements is elevated relative to inner pins to more closely resemble the power profile of the represented nuclear fuel bundle.

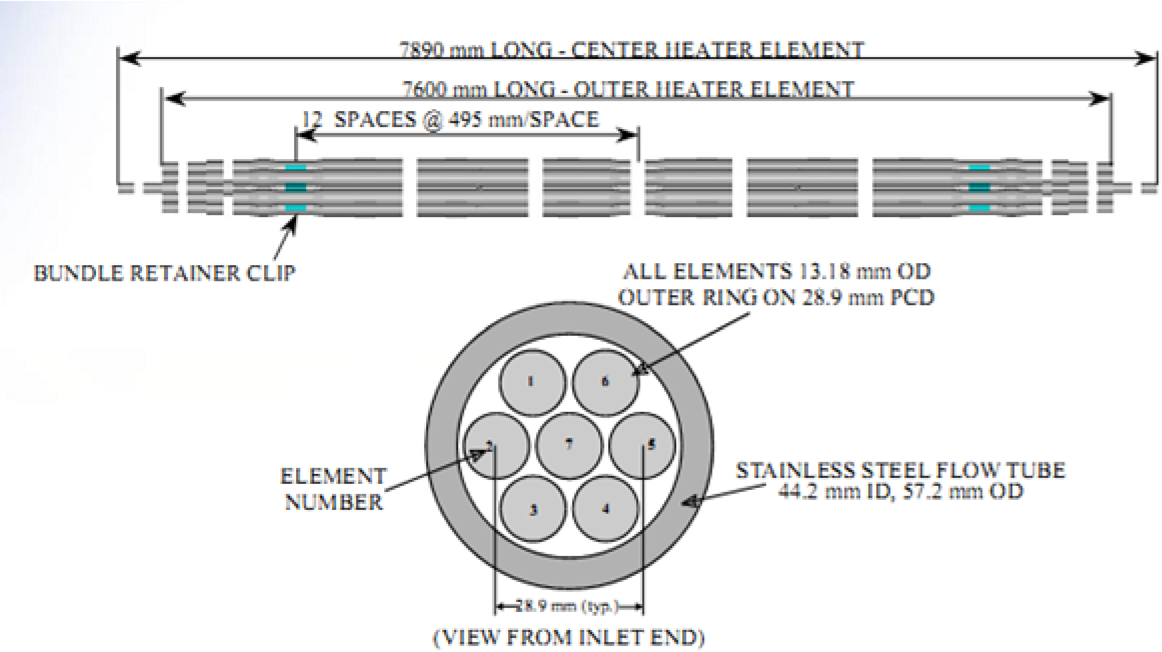


Figure 4.8: Fuel Element Simulator Bundle Diagram (Buell *et al.*, 2003)

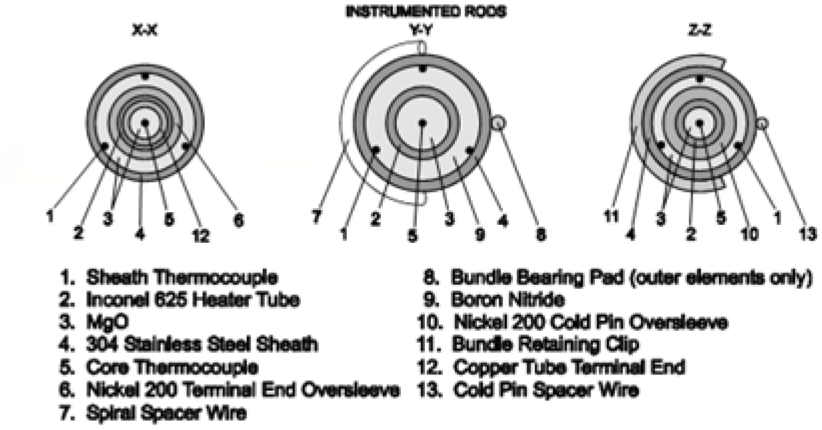


Figure 4.9: Fuel Element Simulator Cross Section (Buell *et al.*, 2003)

4.1.1.5 Pressurizer

The pressurizer (or surge tank) system provides control of the coolant pressure in the reactor coolant loop. This allows for compensations in pressure in case of fluid phase changes or more general changes in density. A 100 kW immersion heater provides a means of raising or maintaining pressure within the tank. The volume of the pressurizer is 550 L. The pressurizer inlet sits 11.6 m above the header 1 inlet. A diagram of the pressurizer may be seen in figure 4.10.

4.1.1.6 Steam Generators

The steam generators used in the construction of RD-14M are recirculating U-type and are scaled approximately 1:1 with regards to a typical CANDU steam generator (in terms of vertical height, tube diameter, mass flux, and heat flux) (Buell *et al.*, 2003). The tube side of the steam generator is considered part of the PHTS, while the shell side is considered part of the secondary heat transport system. Figure 4.11 provides a comparison between an RD-14M steam generator and that of a typical

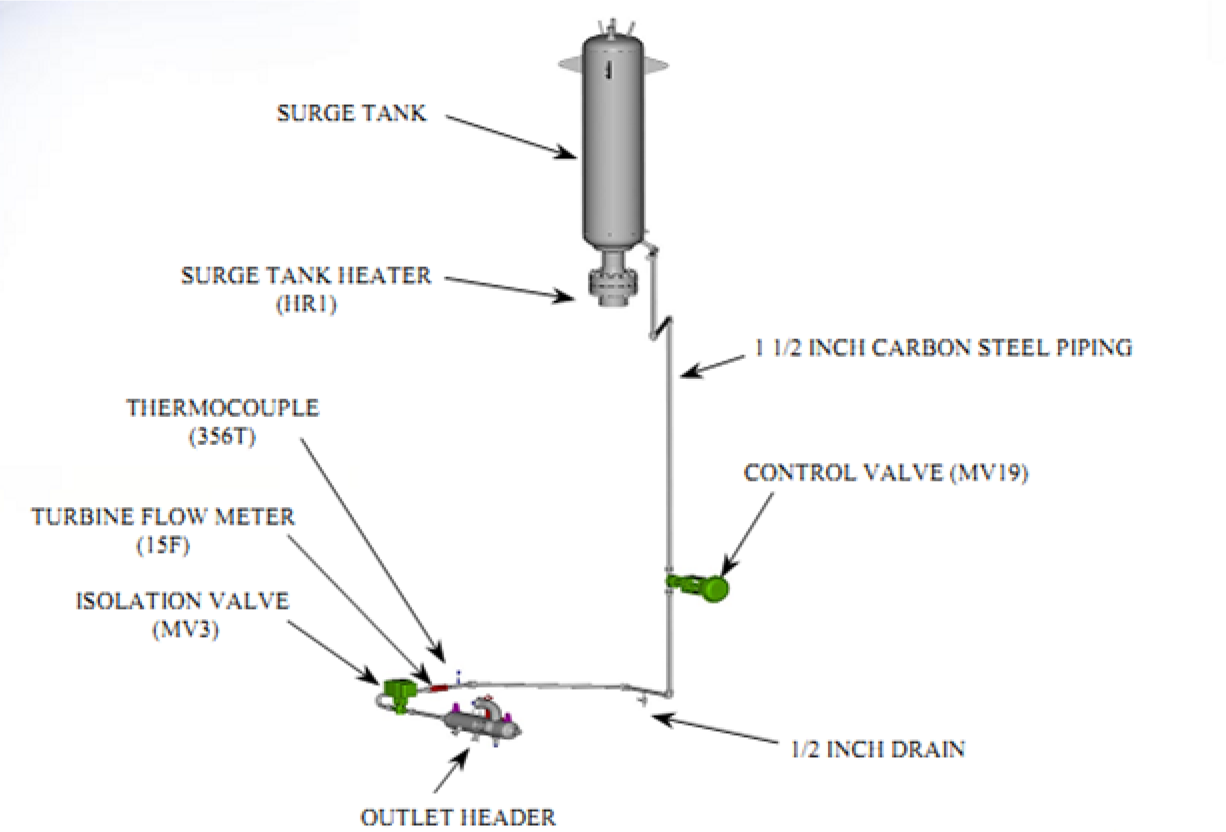
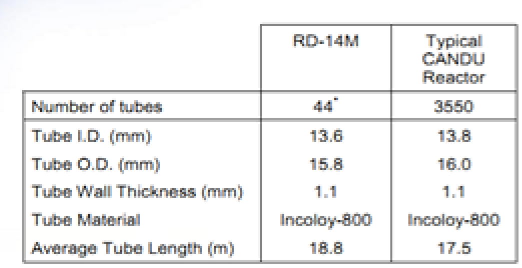


Figure 4.10: Pressurizer (or Surge Tank) Diagram (Buell *et al.*, 2003)

CANDU. A schematic of the steam generator is shown in figure 4.12.



	RD-14M	Typical CANDU Reactor
Number of tubes	44*	3550
Tube I.D. (mm)	13.6	13.8
Tube O.D. (mm)	15.8	16.0
Tube Wall Thickness (mm)	1.1	1.1
Tube Material	Incoloy-800	Incoloy-800
Average Tube Length (m)	18.8	17.5

Figure 4.11: Steam Generator Comparison (Buell *et al.*, 2003)

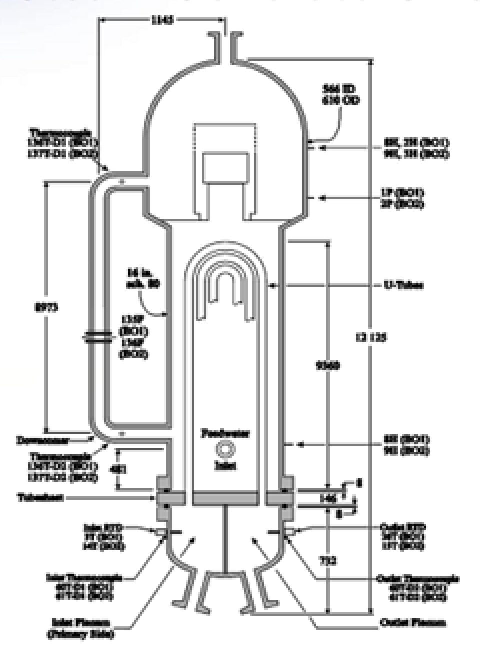


Figure 4.12: Steam Generator Diagram (Buell *et al.*, 2003)

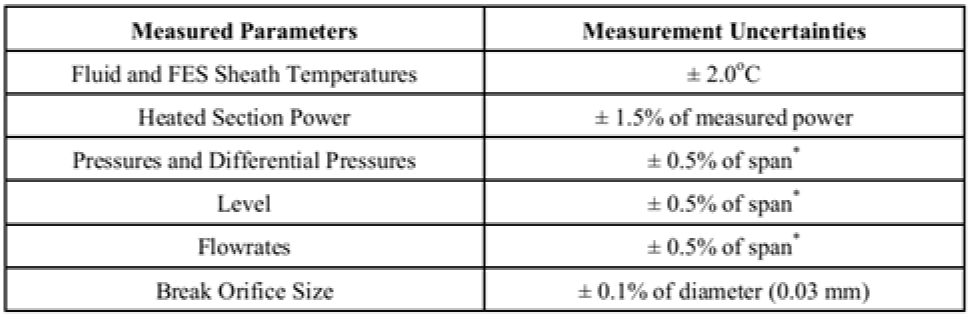
4.1.1.7 Instrumentation and Data Acquisition

Extensive instrumentation is present throughout the RD-14M facility. Measured quantities include pressures, flows, void fraction, and temperatures. Approximately

60 pressure drop measurements are taken throughout the PHTS, secondary side and the ECC system to ensure measurements are taken across all potential flow paths.

Extensive flow measurements are available for the pump, channels, feedwater, ECC, and steam leaving the steam generator. Pressure measurements were generated through the use of rosemount pressure transducers. Flow rate measurements including those taken at test section inlets and outlets, pump discharge locations, and feedwater flows to boilers were taken using turbine flow meters.(IAEA, 2004) (Buell *et al.*, 2003)

Thermocouples are located for temperature measurement throughout the facility. Fuel element simulators, steam generator tubes, and secondary side components are all monitored through the use of K-type thermocouples or RTDs at over 400 locations.(IAEA, 2004) (Buell *et al.*, 2003)

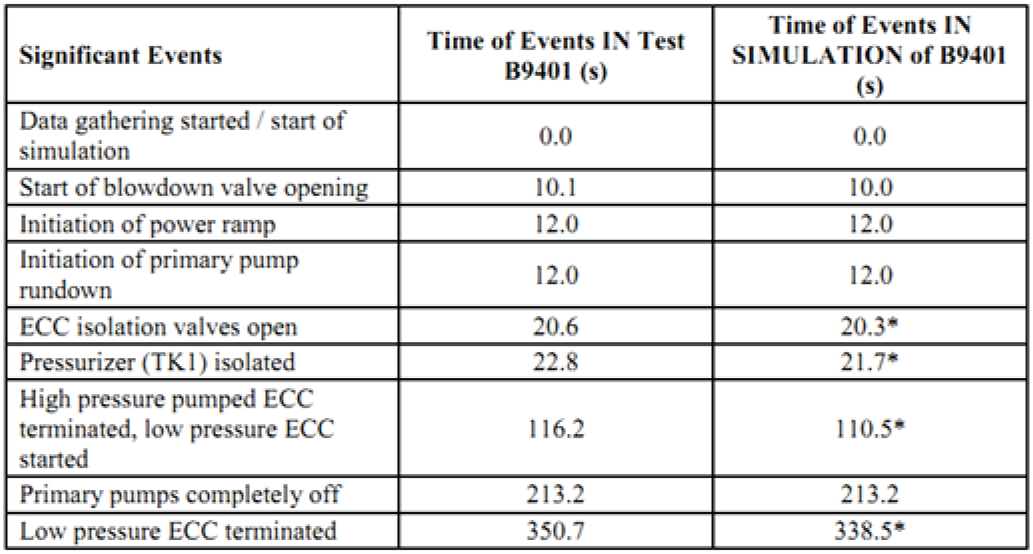


Measured Parameters	**Measurement Uncertainties**
Fluid and FES Sheath Temperatures	± 2.0°C
Heated Section Power	± 1.5% of measured power
Pressures and Differential Pressures	± 0.5% of span*
Level	± 0.5% of span*
Flowrates	± 0.5% of span*
Break Orifice Size	± 0.1% of diameter (0.03 mm)

Figure 4.13: Experimental Measurement Uncertainties (IAEA, 2004)

4.1.2 Test B9401 Description

Test B9401 was a 30 mm diameter inlet header break test with ECC injection. Characterized as a critical break test, worst case flow degradation conditions are present downstream of the break, resulting in high cladding temperatures . Figure 4.14 shows the progression of events as measured during the actual test, as well as the progression timetable of events in the CATHENA input file described in the next section. (AECL, 2004) (Swartz, 2000)



Significant Events	Time of Events IN Test B9401 (s)	Time of Events IN SIMULATION of B9401 (s)
Data gathering started / start of simulation	0.0	0.0
Start of blowdown valve opening	10.1	10.0
Initiation of power ramp	12.0	12.0
Initiation of primary pump rundown	12.0	12.0
ECC isolation valves open	20.6	20.3*
Pressurizer (TK1) isolated	22.8	21.7*
High pressure pumped ECC terminated, low pressure ECC started	116.2	110.5*
Primary pumps completely off	213.2	213.2
Low pressure ECC terminated	350.7	338.5*

Figure 4.14: Event Progression (AECL, 2004)

4.1.3 CATHENA Model of the RD-14M Facility

The RD-14M model used CATHENA version 3.5.4.4. An existing validation input file for test B9401 provided by AECL was modified for the goals of this project. The model includes the primary heat transport system, secondary side cooling, and ECC systems. The CATHENA idealization of test B9401 consisted of 530 thermalhydraulic nodes, 546 links, and 179 wall heat transfer models (Buell *et al.*, 2003). The CATHENA input file may be modified with any standard text editor such as Programmers Notepad.

This section will provide a description of the RD-14M model used in this thesis as well as changes made to the original input file to create a trial steady state case for coupling to STAR-CCM+. A copy of a modified CATHENA input file may be found in the appendix.

4.1.3.1 Primary Heat Transport System

The primary heat transport system, as modelled in CATHENA, consists of the headers, all piping forming a flow loop between headers, test sections, steam generators, pumps, and the pressurizer (Buell *et al.*, 2003). Figures 4.15 and 4.16 show a visualization of the PHTS as constructed in the CATHENA input file.

4.1.3.2 Primary System Piping

The primary objective in the establishment of a nodalized PHTS is to preserve, as much as possible, all system characteristics and behaviours such as elevation, fluid volumes and hydraulic resistances. This is important since deviation in quantities such as elevation may have a significant effect on calculated quantities such as hydrostatic pressures. Combination of vertical and horizontal piping sections was generally avoided due to the different treatment of flow regime in each case. The total volume of the primary side idealization varies by less than 1”%” from the actual facility volume (Buell *et al.*, 2003). Table 4.1 provides a summary of important characteristics.

Operating Pressure	10 MPa
Header to Header Pressure Drop	1.5 MPa
Flow Channel Temperature Change	262 Inlet to 298 Outlet
Rated Pump Flow	24 kg/s
Nominal FES Input Power	4.0 MW per Pass

Table 4.1: PHTS Characteristics (AECL, 2004)

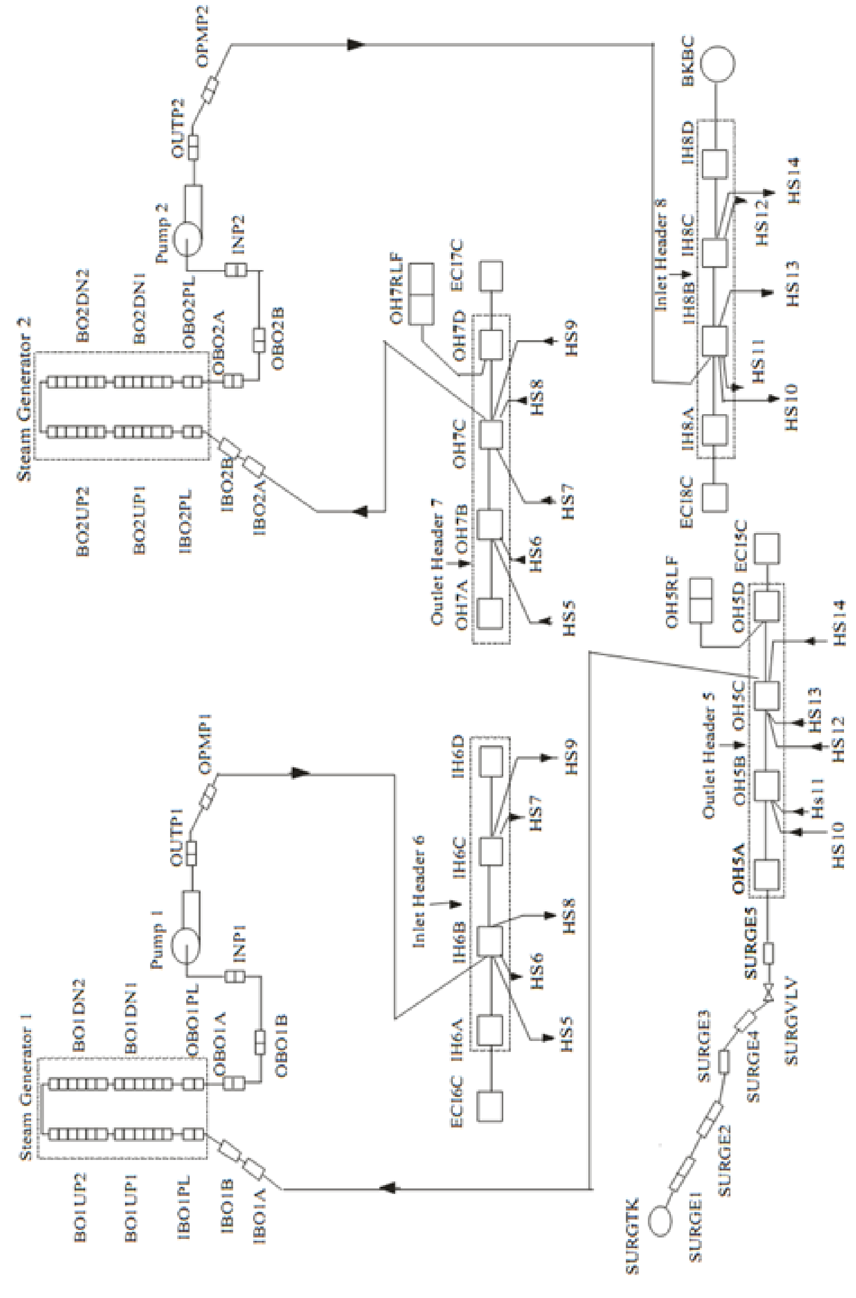


Figure 4.15: Above Header Nodalization (AECL, 2004)

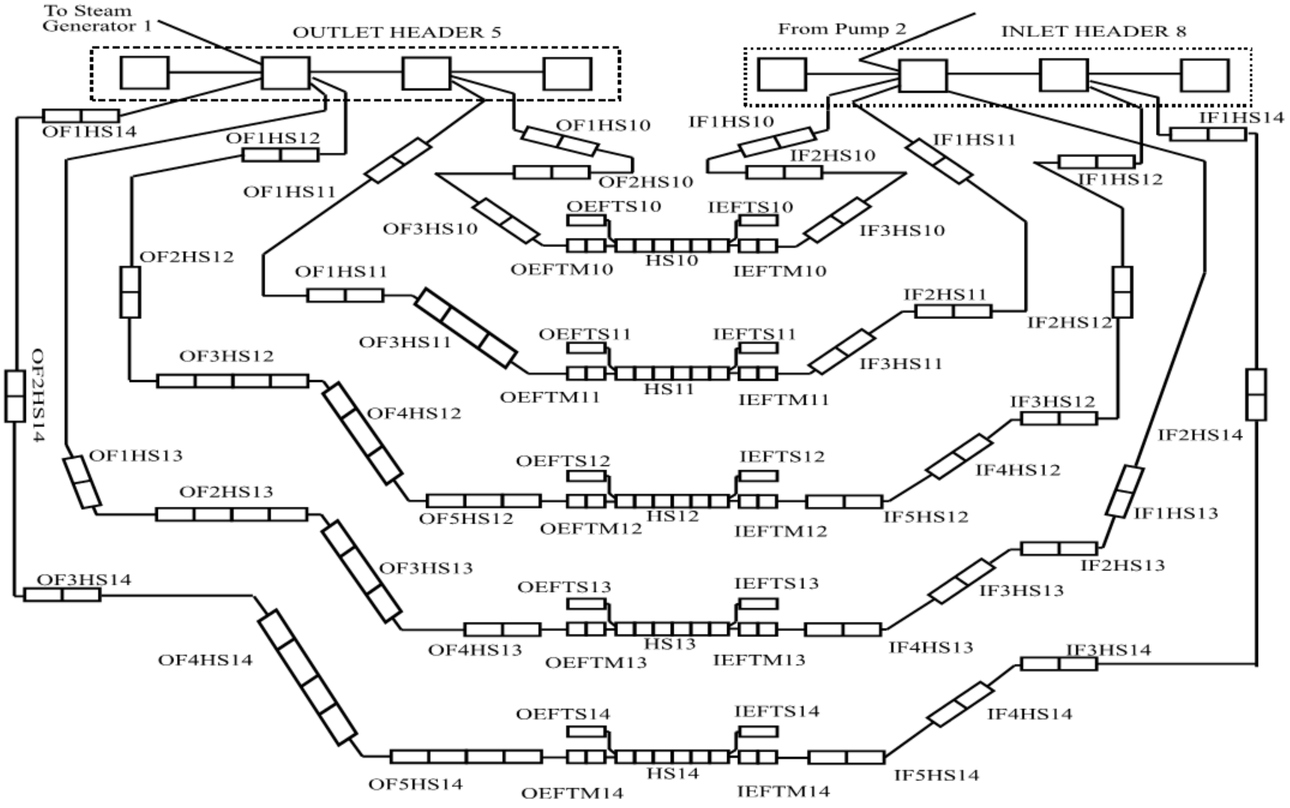


Figure 4.16: Below Header Nodalization (AECL, 2004)

4.1.3.3 Secondary Side Model

The secondary side idealization consists of the steam generators up to the steam nozzle, as well as the feedwater line from feedwater temperature thermocouple to the steam generator feedwater inlets. Boundary conditions were used for representation of feedwater lines upstream of this location. These boundary conditions may be seen as SEC10BC (outlet) and SECI1BC (Inlet) in Figure 4.17. For transient scenarios, experimental results were used for setting the boundary flow conditions.

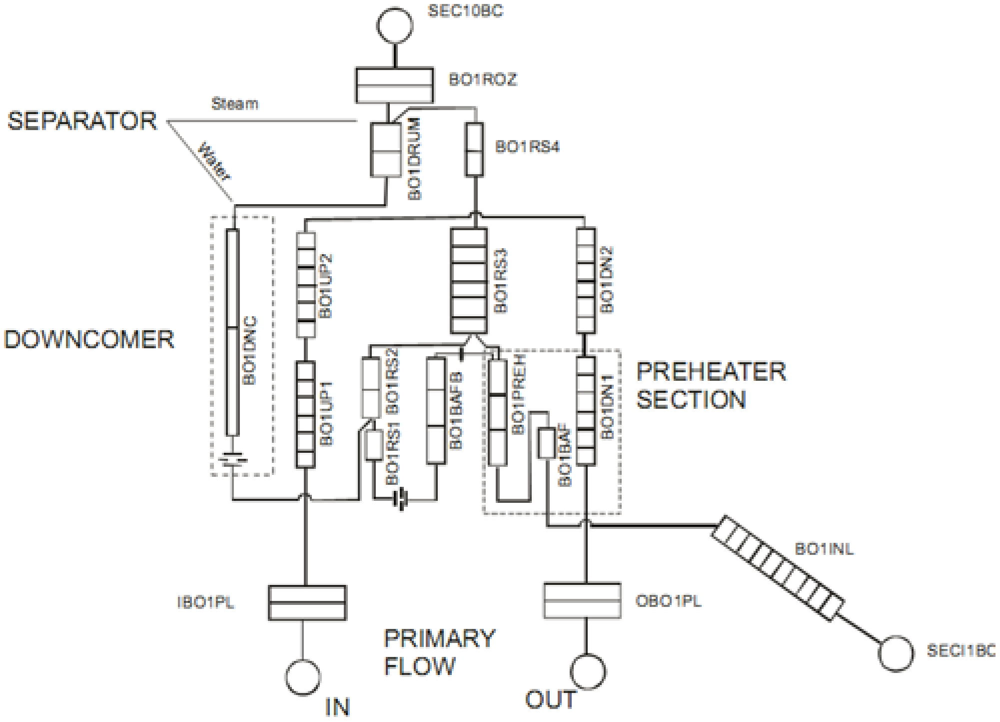


Figure 4.17: Secondary Side Nodalization (AECL, 2004)

4.1.3.4 Emergency Coolant Injection System

The CATHENA idealization of the ECI system as configured for test B9401 may be found in figure 4.18. Both high pressure and low pressure ECI phases were considered and normally made use of in test B9401. However, since the input file is modified to steady state for the purposes of testing code coupling, ECI trips are avoided and not of concern for the purposes of this report.

4.1.4 Modifications to the CATHENA B9401 Input Deck

Significant modification was made to the original test B9401 CATHENA file for preparation as a coupling test file. This primarily consisted of removal of the header components as well as modifications to the control triggers to create a steady state. Figure 4.19 shows the chosen header to be removed. Inlet header 6 was chosen over inlet header 8 for the sake of simplicity, due to the presence of the blowdown components in header 8.

The components of header 6 were removed and new reservoir components were created so as to create boundary conditions for the newly severed pipes. The inlet feeder pipe and outlet flow pipes were then shortened by the appropriate length and height, according to the length of each to be simulated by the CFD side of the coupled system. This was also done for the heat structures in the heat transfer package. ECI connections to this header were also severed.

Significant effort was expended to troubleshoot the boundary conditions required for the new coupled analyses. In particular the overall system pressure boundary condition was complicated by the presence of the new CFD-CATHENA boundary conditions. In particular if an absolute boundary condition was set in the pressurizer

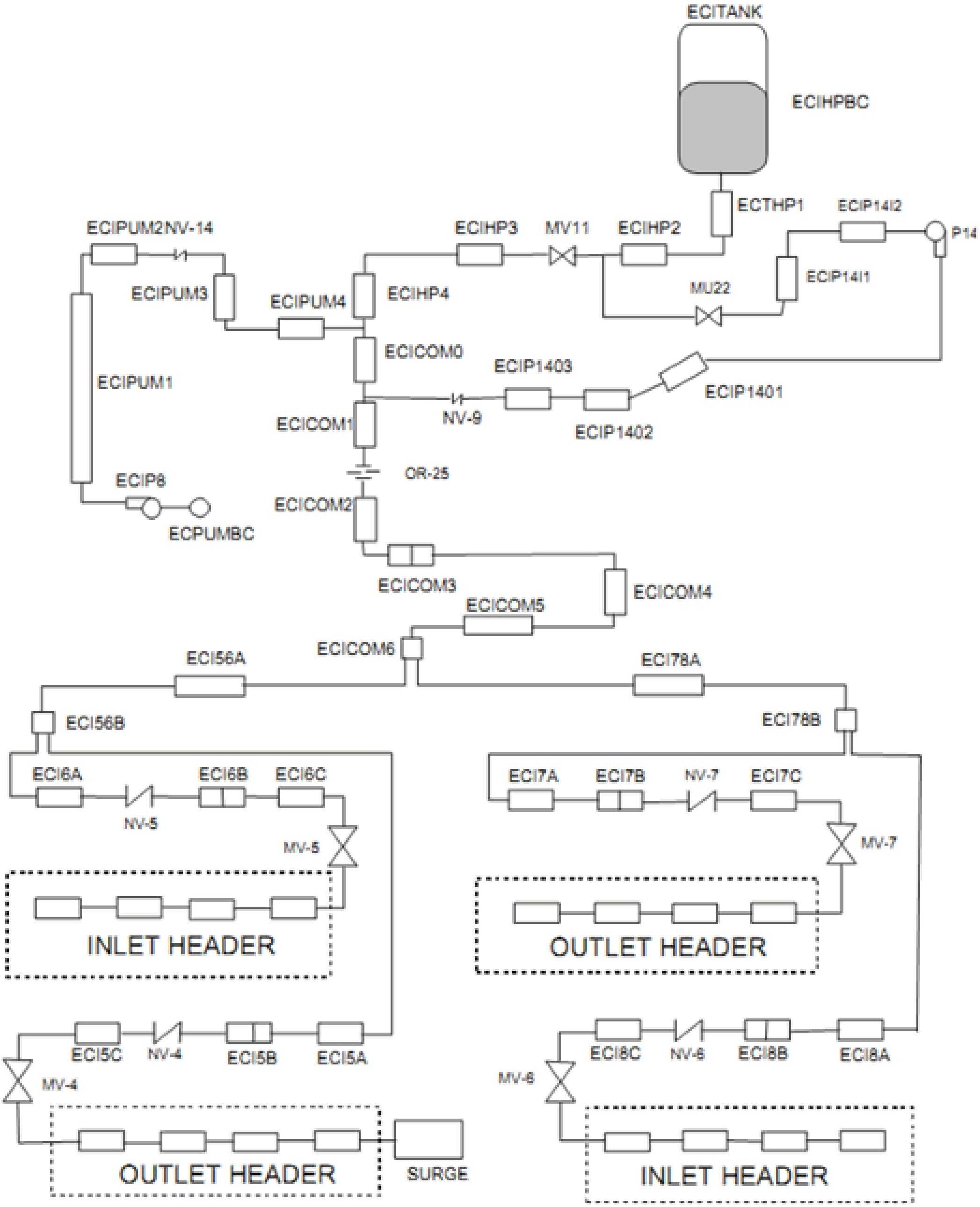


Figure 4.18: CATHENA Nodalization of the ECI (AECL, 2004)

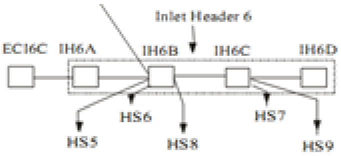


Figure 4.19: Removed Section (AECL, 2004)

and an absolute pressure boundary condition was set at the CFD interface, instabilities could develop due to the over prescription of the pressure boundary within the CATHENA simulation. In fact this was observed in many instances during the development of this work. It was necessary to remove the boundary condition found within the surge tank (SURGETNK), as the presence of a boundary condition caused instabilities in the coupled code system. Further work could be attempted in order to resolve this issue in a different manner. In particular, the relationship between the pressurizer boundary condition, pressure, and the newly created boundary conditions in the coupled model could be overcome using a relative pressure specificiation. It may be worthwhile to attempt other methods of creating a system with a consistent solution other than direct removal of the pressurizer, such as the addition of a controller to adjust the pressurizer pressure based on pressures received by STAR-CCM+.

System control modules were then modified to prevent any transient behaviour, such as the initiation of the blowdown event, change in channel power, or pump run down. Secondary side transient triggers were also addressed.

The final change was the addition of the PVM system control models to allow for import and export of desired system variables. A copy of the CATHENA input file may be found in the appendix. The changes to this input file are provided as comments. Modified values are noted next to their changes and removed sections are relocated to the comment area at the end of the file. The individual modifications would be too numerous to list here, but as explained, involve the removal of the header and its heat models, introduction of boundary conditions to severance points, addition of remote process models for coupling, and value monitors to observe desired values.

4.1.5 STAR-CCM+ Header Model

The CAD model of the header may be seen in figure 4.20. This is a modified design of a geometry used in an AECL Fluent study, Fluid Simulations of Flow Distribution in an RD-14M CCF Inlet Header (AECL, 2006)(AECL, 2007). Table 4.2 provides the main header model dimensions.

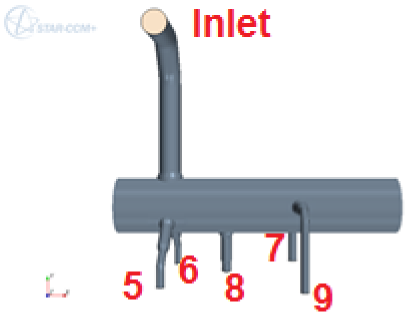


Figure 4.20: STAR-CCM+ Header Profile

4.1.5.1 Meshing

Figure 4.22 displays the chosen mesh consisting of 86485 cells, 233746 faces, and 80604 vertices. Care was taken to ensure greater cell density around pipe junction points, to ensure accurate capture of flow phenomena around these points of interest.

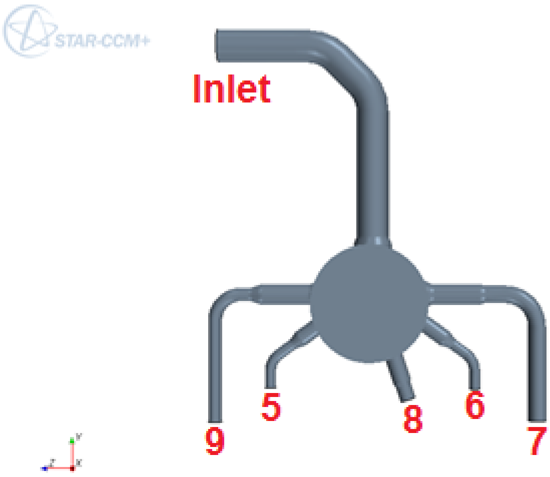


Figure 4.21: STAR-CCM+ Header Profile

Component	Pipe Diameter at Boundary (m)	Axial Distance from ECI End (m)	Radial Orientation
Inlet	0.078	0.315	0°
Outlet 5	0.0266	0.315	126°
Outlet 6	0.0266	0.315	234°
Outlet 7	0.0351	0.775	270°
Outlet 8	0.0351	0.515	198°
Outlet 9	0.0266	0.775	90°

Table 4.2: Header Model Main Dimensions

Two additional meshes were considered, of approximately 160000 and 320000 cells, however no significant changes in the flow results were obtained. Hence, for the sake of computing cost, only the lowest mesh density case was used.

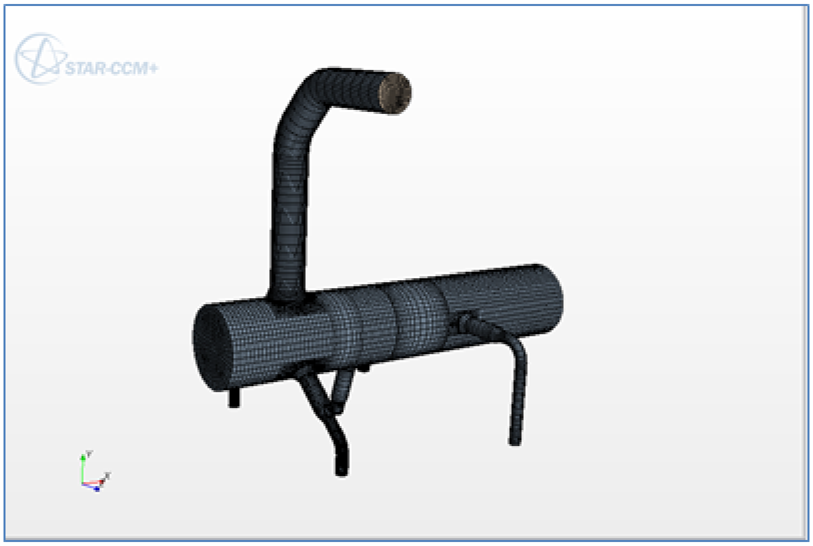


Figure 4.22: Full Model Mesh

4.1.5.2 Physics Conditions

Star-CCM+ offers a variety of physics models to choose from. A more thorough description of these models may be found in the Theory section of this report. The physics models employed in the fluid domain may be found in Figure 4.24.

A three dimensional physics domain is chosen as the main purpose of this exercise is to simulate the behaviour of the fluid within the header in three dimensions, using boundary conditions from the one dimensional system code. A user defined density is chosen since the steady state conditions of the problem will should not cause any significant changes in density. This is supported by supported the fluid density given by CATHENA over the course of a simulation, which typically remains between 787.7

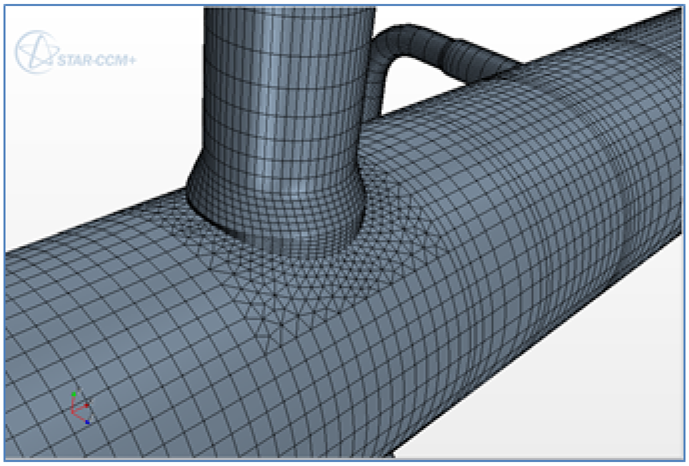
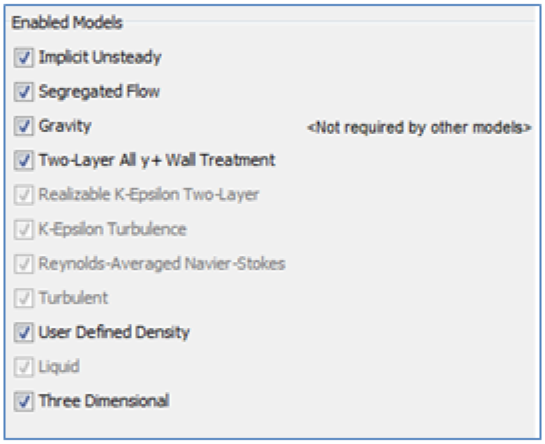


Figure 4.23: Increased Cell Density around Component Junctions



Enabled Models

☑ Implicit Unsteady

☑ Segregated Flow

☑ Gravity <Not required by other models>

☑ Two-Layer All y+ Wall Treatment

☑ Realizable K-Epsilon Two-Layer

☑ K-Epsilon Turbulence

☑ Reynolds-Averaged Navier-Stokes

☑ Turbulent

☑ User Defined Density

☑ Liquid

☑ Three Dimensional

Figure 4.24: Selection of Physics Models

and 787.8 kg/M^3. The temperature of the fluid is set to 262°C to match the CATHENA fluid temperature. For a steady state simulation, this should be sufficient, however, in a transient with significant temperature change, this fluid density should be included as an updated value in the information transfer between codes. Failing to do so could result in additional instability. The standard k-ϵ turbulence model was chosen for its robustness and applicability over a range of conditions, a decision supported by the header modeling work done by Muhana (Muhana, 2009).

4.1.5.3 Initial Conditions

Initial conditions are set according to the steady state simulation portion of the unmodified B9401 deck from monitor values applied at the cut positions where boundaries are located. Reference pressure is subtracted from total values due to numeric considerations. The STAR-CCM+ governing script adds and subtracts the reference pressure as needed when communicating with CATHENA.

Inlet Flow	21.779 kg/s
Outlet 5 Pressure	140500.0 Pa
Outlet 6 Pressure	143738.0 Pa
Outlet 7 Pressure	156659.0 Pa
Outlet 8 Pressure	157616.0 Pa
Outlet 9 Pressure	146930.0 Pa
Time Step Interval	0.1 Seconds
Reference Pressure	11500000 Pa

Table 4.3: Initial Conditions

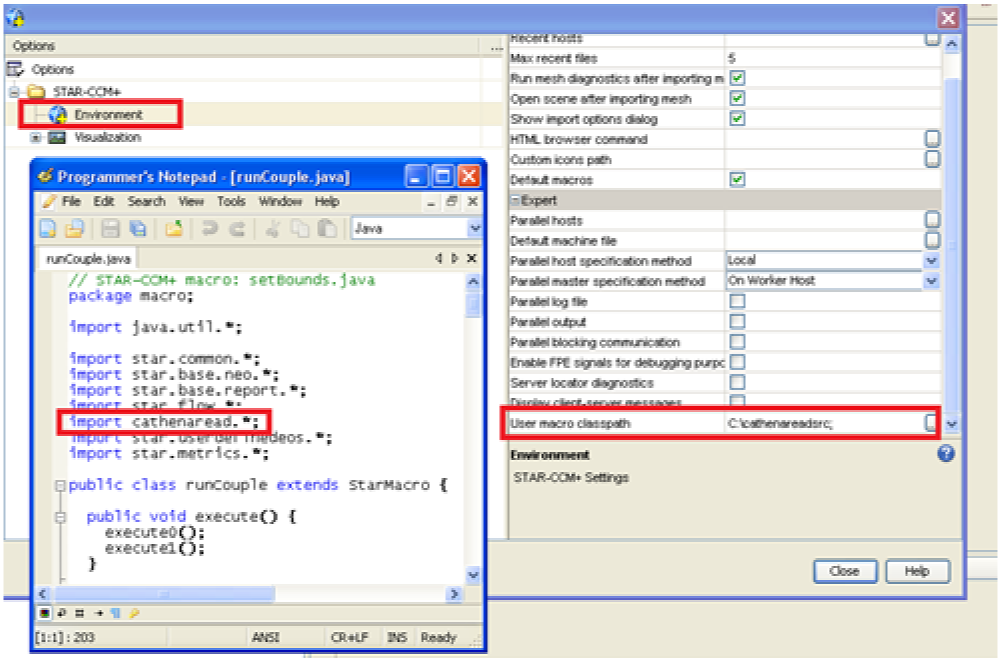
4.1.6 Coupling Method

Recent versions of STAR-CCM+ have been increasing their support for 1D coupling applications. It is interesting to note that one of the recent additions to the list of supported programs is RELAP, a one dimensional thermalhydraulics code similar in purpose to CATHENA. At the time of commencement of this project, however, it appeared that a custom solution was necessary in order to allow CATHENA and STAR-CCM+ to work in tandem. Two custom programs were written to allow for exchange of information between codes.

4.1.6.1 Programming STAR-CCM+ Interface

A beneficial characteristic of STAR-CCM+ is its reliance on a JAVA shell for execution of scripting commands. This is exploited to allow transfer of information with external programs. The NetBeans integrated development environment was used to program a routine called CathenaRead. This program contains two subroutines which may be called to write and read values when called from a script in STAR-CCM+. Two text files are employed to exchange this information. The first stores data that is written from STAR-CCM+, and the second stores values that are written from CATHENA. Two additional text files are used as flags to ensure each program completes its required operations before reading in new information. A copy of this program code may be found within the appendix in addition to an example STAR-CCM+ Java script.

By utilizing the extensive scripting capabilities of the STAR-CCM+ Java shell, it is then possible to use newly imported information to update nearly any desired value, in our case providing updated boundary condition values.



```
// STAR-CCM+ macro: setBounds.java
package macro;

import java.util.*;

import star.common.*;
import star.base.neo.*;
import star.base.report.*;
import star.flow.*;
import cathenaread.*;
import star.userDefinedeos.*;
import star.metrics.*;

public class runCouple extends StarMacro {

  public void execute() {
    execute0();
    execute1();
  }
```

Recent hosts
Max recent files 5
Run mesh diagnostics after importing m ☑
Open scene after importing mesh ☑
Show import options dialog ☑
HTML browser command
Custom icons path
Default macros ☑
Expert
Parallel hosts
Default machine file
Parallel host specification method Local
Parallel master specification method On Worker Host
Parallel log file ☐
Parallel output ☐
Parallel blocking communication ☐
Enable FPE signals for debugging purpc ☐
Server locator diagnostics ☐
Display client-server messages ☐
User macro classpath C:\cathenareadsrc;

Environment
STAR-CCM+ Settings

Figure 4.25: Including Custom Routines into STAR-CCM+

4.1.6.2 The CathenaRead Function

As stated previously, the core purpose of the CathenaRead function is to contain the write and read subroutines that read data in and out from text files used to communicate between codes. In addition, the CathenaRead may itself be run to test the function of the contained subroutines according to figure 4.26.

Calling the JCathena subroutine must be done with either a read or a write command in order to indicate the desired operation. The basic function of this subroutine found in figure 4.27 while code for readCat and writeCat may be found in appendices 1b and 1c, respectively. Should one wish to modify or increase the number of output values that writeCat outputs, care should be taken to ensure output formatting is set as desired (e.g. decimal notation to 3 significant digits).

When called to read, the JCathena subroutine populates the valyus array with the

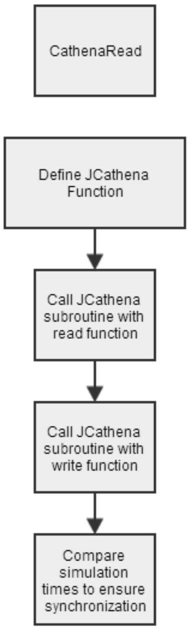


Figure 4.26: CathenaRead Function Process

values written to a text file from CATHENA. This is only done once a flag file appears which is created upon successful output of CATHENA boundary conditions. Once catDoneFlag.txt is created, the values in CAT_OUT.txt are read into the valyous array and passed up to the function which called the subroutine. The CAT_DONE_FLAG is then deleted to indicate that STAR-CCM+ is finished reading values, and that it is clear to write the next set of values into the CATHENA output file. Similarly, once STAR-CCM+ has completed its half of the simulation, the write function of JCathena is called, and the write function performs a similar operation. The function writeCat is called to write the boundary conditions to a text file to be read by the PVM routine in CATHENA. A STAR_DONE_FLAG file is created to indicate that the STAR-CCM+ portion of the simulation has successfully output its solution into the text file to be read by CATHENA.

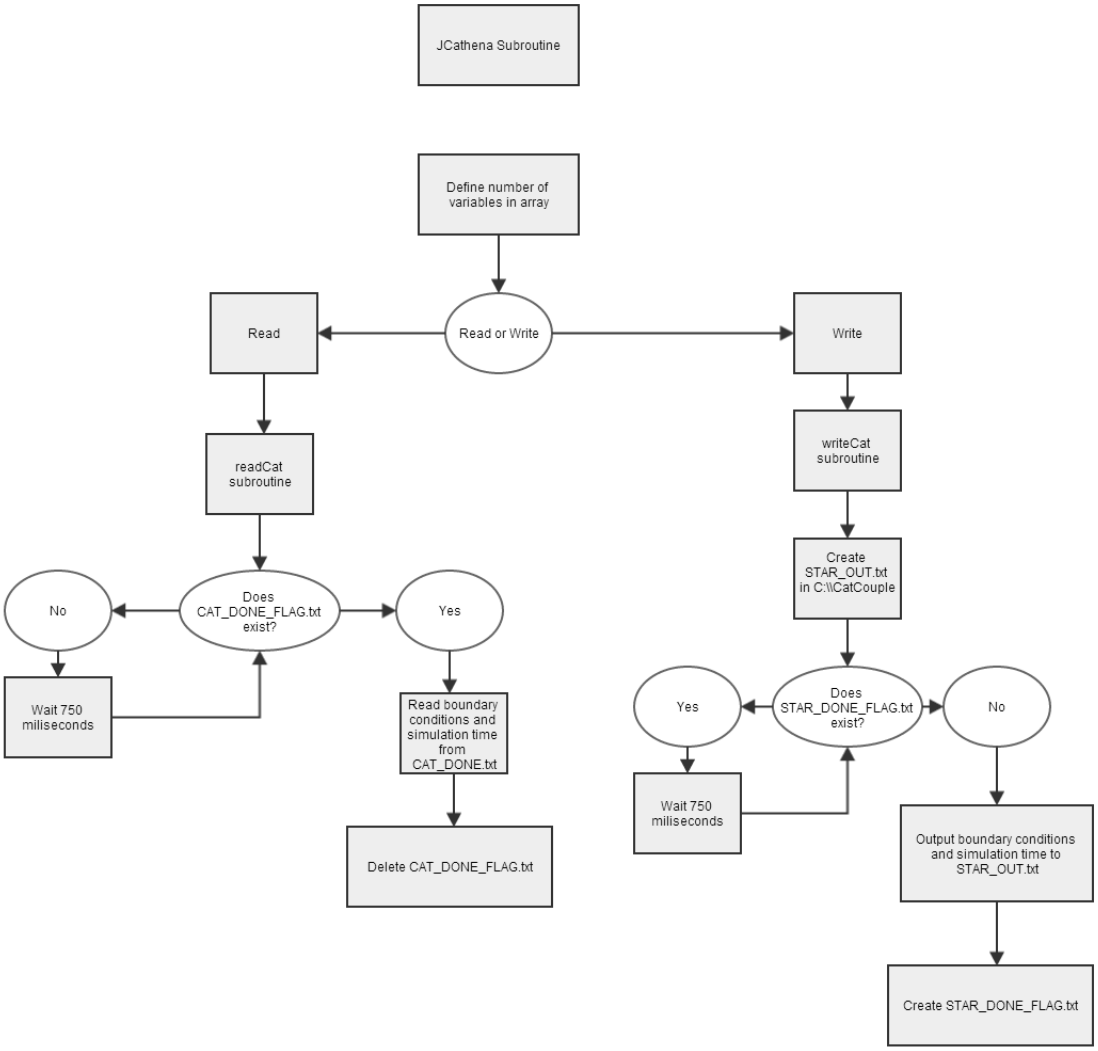


Figure 4.27: The JCathena Subroutine

4.1.6.3 Creating the STAR-CCM+ Run Script

The script used to execute STAR-CCM+ operations in a coupled configuration was also written from scratch. This script contains all necessary commands for the program to load a simulation file, apply necessary modifications, and run to completion, without the need for user input. This script is meant to load a STAR-CCM+ simulation that has already been run to steady state before initiation of coupling. It is essential to verify that boundaries and monitors are correctly defined after execution of the script so that boundary condition values are correctly read and transferred to their correct positions in the storage matrix. A copy of this script may be found in the appendix.

Through examination of figure 4.27 and 4.28, it is apparent that this side of the coupled system is able to delete the CAT_DONE_FLAG file, yet not create it, and also create the STAR_DONE_FLAG, but not delete it. These two files create the situation by which the STAR-CCM+ side of the simulation is dependent upon outside input, if only in the form of the removal of these two flags. To create a troubleshooting situation, for instance, one may create a simple batch file which creates the CAT_DONE_FLAG and deletes the STAR_DONE_FLAG, in order to create a situation in which STAR-CCM+ repeatedly reads in the same values from a CAT_OUT.txt file, which should lead to a steady state solution. Use of complementary programs on the CATHENA side of the simulation should now result in a coupled system.

4.1.7 Programming the CATHENA Interface

CATHENA makes use of a parallel virtual machine (PVM) software package to communicate with external programs. This is exploited with another custom program, a

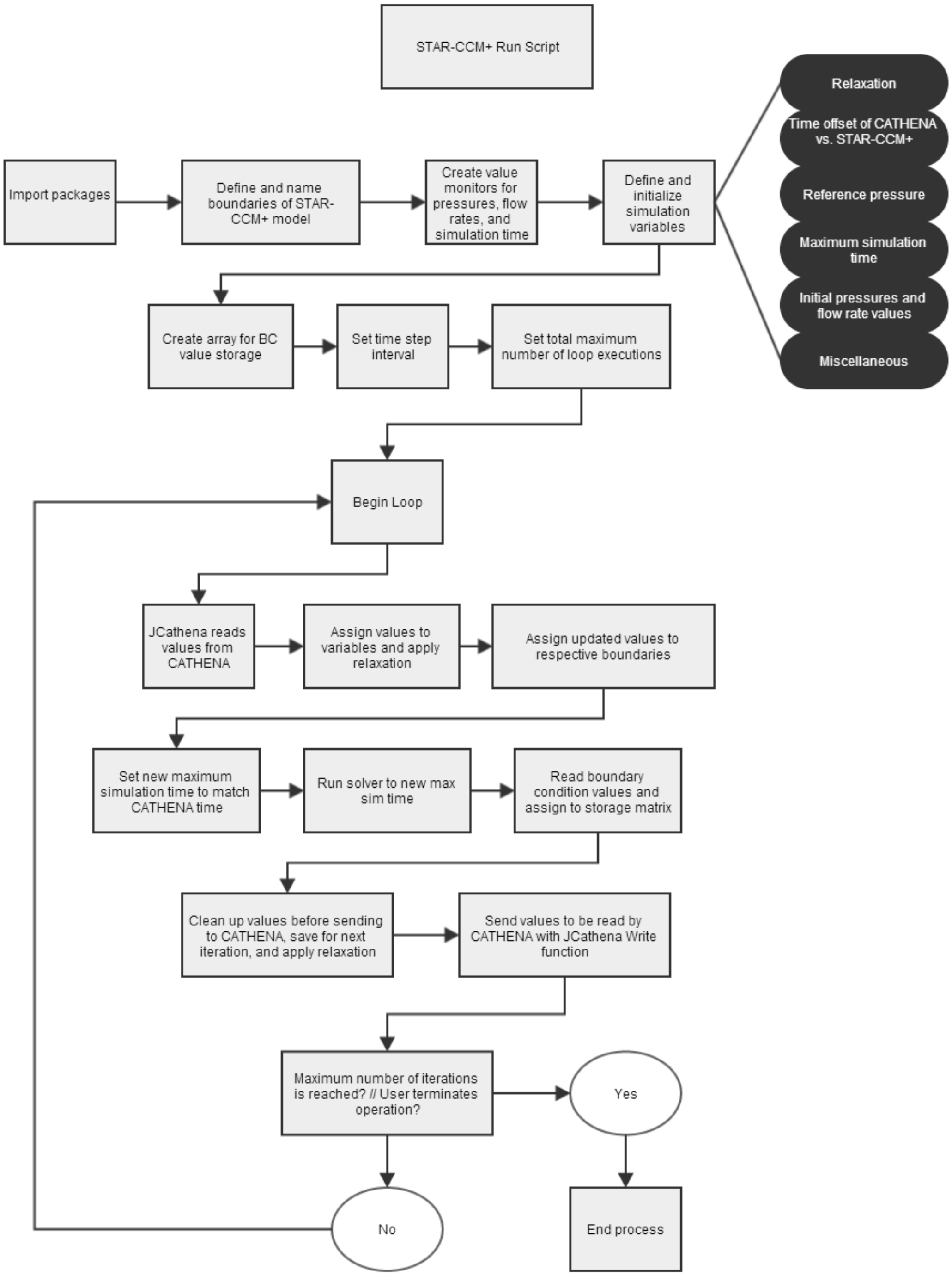


Figure 4.28: STAR-CCM+ Execution Script

modified version of a TROL-BB program, originally used as an interface to a Bruce Power controller. Compaq Visual Fortran 6.6c is used to program an executable in FORTRAN which performs a similar function to the JCathena subroutines called by the STAR-CCM+ script. This routine receives values sent over the PVM interface from CATHENA, writes them to a text file , reads values from the text file written by the JCathena subroutines, and sends them back over PVM to CATHENA. The program also manipulates the two flag files when necessary. A copy of this custom FORTRAN code may be found in appendix A.

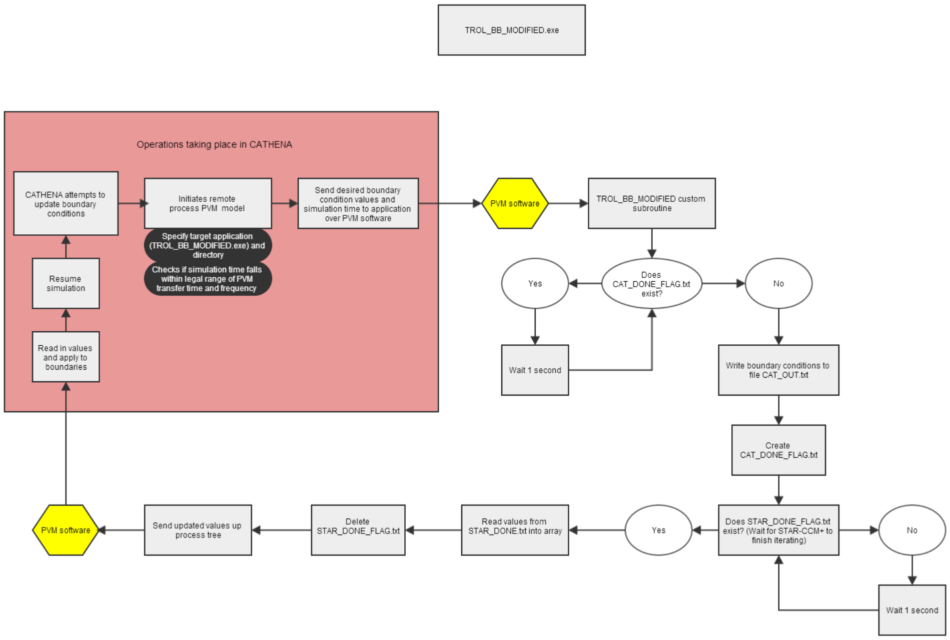


Figure 4.29: CATHENA Side Custom Application

4.1.7.1 Running the Coupled System

An explicit coupling scheme is employed to advance the simulation through time. A STAR-CCM+ simulation is brought to steady state in advance in order to act as a starting point for the coupled simulation. This is saved as a .sim file for later access. With the PVM program running in the background, CATHENA is then executed. Once it has reached steady state and the desired initiation time is met (usually around t=0s), information exchange with PVM commences. To allow transients to begin at t=0s, CATHENA is able to run forward in time from some specified negative time in order to allow the simulation to reach steady state without having to modify any existing event triggers. To allow for more time for CATHENA to reach steady state, a greater negative simulation start time may be specified. The modified TROL-BB program writes these values to a text file and awaits action by STAR-CCM+. A flag file is created indicating that CATHENA has completed its operation. The steady state .sim file is loaded by STAR-CCM+ at this point, and the JAVA macro is initiated . When executed in the script, JCathena performs a check to see if the CATHENA complete flag file exists before reading the values in the CATHENA output file. If the file is not present, JCathena waits for a small time period before performing another check. This ensures only updated CATHENA values are used.

When JCathena detects the flag indicating CATHENA has completed its operations, the values written by CATHENA are read into the program and boundary conditions are updated (under a pre-set level of relaxation). A number of relaxation factors were tested, and after some time a relaxation of close to 90% was found to be appropriately conservative (10% of new solution used). The CATHENA completion flag file is also deleted. STAR-CCM+ then runs for a set maximum time (usually at some fraction of the time advanced in CATHENA), and the JCathena subroutines outputs the updated (and relaxed) values to be written into the text file which stores these values. A STAR complete flag file is created to indicate when this process is complete.

The modified TROL-BB program performs a similar check for a flag file as the CathenaRead program to ensure STAR-CCM+ has completed its operations. The values in the STAR output file are read, and the boundary conditions within CATHENA are updated, and the simulation continues. A simplified diagram of this entire process may be seen in figure 4.30.

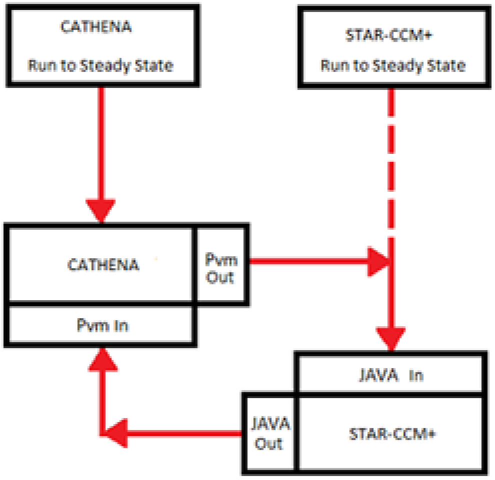


Figure 4.30: Simplified Coupling Diagram

4.1.7.2 Choice of Coupled Boundary Conditions

A number of boundary condition choices were investigated over the course of this project. It was decided that the only meaningful results are obtained when boundary conditions are set according to figure 25. This figure demonstrates the type of boundary condition used in the specified program. For CATHENA, the boundary condition at the inlet of the absent header is set to a pressure boundary condition, while the five outlets are set to mass flow boundary conditions. The inverse case is chosen for STAR-CCM+ in that the boundary conditions are pressure at the 5 header outlets and it is mass flow at the inlet. With this scheme, the split in mass flow is calculated by the CFD program according to the difference in pressure at the various outlets, which would be the main goal of using a CFD program for simulation of header type geometry. It should be noted that significant care must be taken in the use of mass flow boundary conditions in CATHENA, since all calculations are performed using pressures. This means a pressure is calculated and enforced just after the mass flow boundary which further complicated the absolute pressure specification issues discussed previously.

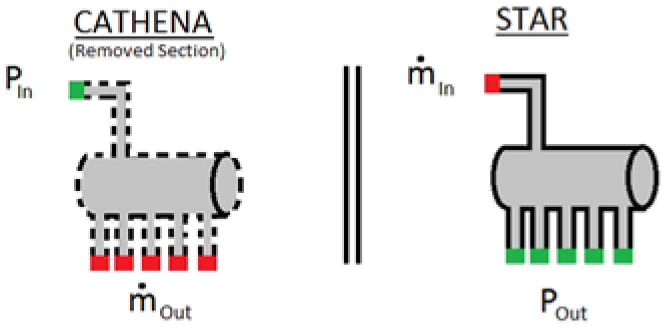


Figure 4.31: Choice of Boundary Conditions

4.1.7.3 Initial Conditions

All initial boundary condition values are taken from the steady state solution of CATHENA in a configuration where the header has not been removed. Mass flow rates and pressures are monitored and recorded at the header cut points, to obtain a reasonable expectation of their steady state value. These values are used in the modified CATHENA deck, with header removed, and set as initial conditions for

	Mass Flow Rate (kg/s)	Pressure(kPa)
Inlet	21.779	11666
Feeder 5	4.08	11624
Feeder 6	4.01	11625
Feeder 7	4.90	11640
Feeder 8	4.89	11643
Feeder 9	3.89	11621

Table 4.4: Initial Boundary Conditions

boundaries in both CATHENA and STAR-CCM+.

Chapter 5

RESULTS

This section presents the progress made in converting a standalone CATHENA input file into a coupled simulation. Results will progress from outputs given by the reference case, test B9401, to outputs given by a steady state simulation of CATHENA coupled to STAR-CCM+. Explanations of results as well as relevance to project goals are outlined. For reference, table 5.1 provides a description of labels used for figures in this section.

OH5B	TH node B in outlet header 5
OH5C	TH node C in outlet header 5
IH6B	TH node B in inlet header 6
IH6C	TH node C in inlet header 6
OH7B	TH node B in outlet header 7
OH7C	TH node C in outlet header 7
IH8B	TH node B in outlet header 8
IH8C	TH node C in outlet header 8
OF3HS5	TH node OF3 in heated section 5
OF3HS6	TH node OF3 in heated section 6
OF5HS7	TH node OF3 in heated section 7
OF4HS8	TH node OF4 in heated section 8
OF5HS9	TH node OF5 in heated section 9
OF3HS10	TH node OF3 in heated section 10
OF3HS11	TH node OF3 in heated section 11
OF5HS12	TH node OF5 in heated section 12
OF4HS13	TH node OF4 in heated section 13
OF5HS14	TH node OF5 in heated section 14
INT_VOID:OH5A(1)>OH5D(99)	Integrated void fraction from outlet header 5, nodes A though D
INT_VOID:OH7A(1)>OH7D(99)	Integrated void fraction from outlet header 7, nodes A though D
INT_VOID:IH6A(1)>OH6D(99)	Integrated void fraction from outlet header 6, nodes A though D
INT_ VOID:IH8A(1)>OH8D(99)	Integrated void fraction from outlet header 8, nodes A though D
VOID: IB01B(1.421)	Void fraction in section leading up to the steam generator 1, at a position 1.421 m down the pipe
VOID: IB02B(1.421)	Void fraction in section leading up to the steam generator 2 inlet, at a position 1.421 m down the pipe
VOID: OB01A(0.41)	Void fraction in section after steam generator 1 outlet, at a position 0.41 m down the pipe
VOID: OB02B(0.41)	Void fraction in section after steam generator 2 outlet, at a position 0.41 m down the pipe
OH5	Outlet header 5
OH7	Outlet header 7

Table 5.1: Reference Definitions

IH8	Inlet header 8
IBO1B	TH node preceding steam generator 1 inlet
IBO2B	TH node preceding steam generator 2 inlet
OBO1A	TH node following steam generator 1 outlet
OBO2A	TH node following steam generator 2 outlet

Table 5.2: Reference Definitions Continued

5.1 CATHENA Model and Predictions before Coupling

This section provides a description of the CATHENA test B9401 input deck as it relates to the overall goal of this thesis. The most relevant data outputs are given and explained as well as a description of the initial steps taken to modify this test case to a steady state simulation.

5.1.1 CATHENA Model and Predictions for RD-14M Test B9401

The main goal of this work is to demonstrate a converged steady-state coupled CFD-CATHENA simulation. As a test we examined the pre-break, steady-state conditions from RD-14M test B9401. However, to ensure the CATHENA simulations performed adequately, the transients were first simulated using only CATHENA. Test B9401 contains several events which had to be modified or removed in order to produce a steady state case for use in coupling procedures. Prior to developing a new steady state file, we first examine the entire transient prediction of CATHENA. Without modification, the test involves a 30 mm diameter inlet header break (in header number

8) with 10.0 MPa outlet header pressure at 4.0 MW per pass of nominal power input. Feedwater is at 186°C and ECI injection fluid temperature is set to 30°C. As can be seen in figures 5.1 and 5.2, once the break trigger is activated, system pressures and flow rates rapidly drop from the established steady state. Figure 5.3 shows void generation as a result of the inlet break for the same simulation.

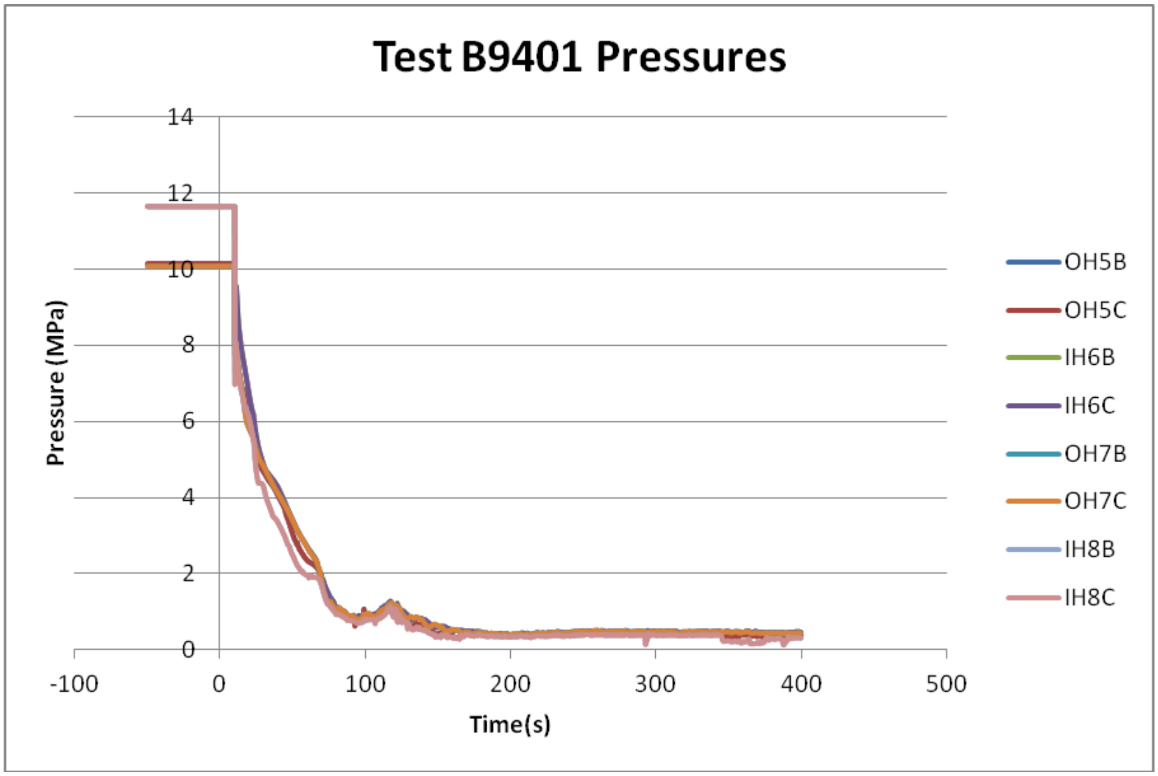


Figure 5.1: Test B9401 Pressures as Predicted by CATHENA

Figure 5.1 presents the test B9401 system pressure predicted by CATHENA. The pressures are given at inlet headers 6 and 8 (as numerically designated by the CATHENA input file) at the thermalhydraulic (TH) nodes to which the idealized flow channels are connected. IH6B would therefore represent the pressure in inlet header 6 in the TH node to which flow channels HS5, HS6, and HS8 are connected. The pressure difference between IH6B and OH7B would, therefore, be a representation of the pressure difference between inlet and outlet headers. During the steady state lead up to the transient, seen as the flat lines leading up to the 10 second point, the inlet to outlet header pressure differences are approximately 1.5 MPa. Once the break valve is opened at the 10 second point, the pressure differential rapidly drops to below 1 MPa with a jump at 110 seconds due to initiation of low pressure ECC, and a drop at 338 seconds due to termination of low pressure ECC.

The pressure transient naturally has an effect on the coolant flow rates through the flow channels. Figure 5.2 provides the mass flow rates predicted by CATHENA for this same test. The flow rate in each of the ten channels is plotted at the indicated node for channels HS5 to HS14 (see figure 4.15 of chapter 4 for the nodalization diagram). Figure 5.2 demonstrates what would be expected in a large break LOCA. A steady state flow up to the triggering event at 10 seconds, to a rapid reduction in flow as pressure and fluid inventory is lost. The large oscillations are due to steam generation resulting from flow stagnation in the channels, as can be seen in figure 5.3.

Figure 5.3 provides the void fraction within each header and in locations in close proximity to the steam generators. This provides a visual representation of the fraction of fluid inventory within the header that is liquid phase (0 is representative of all fluid being liquid phase) and the fraction that is vapor phase (1 represents all fluid is vapour phase).For example, INT_VOID: IH6A(1)→IH6D(99) gives the integrated void fraction from nodes A to D of inlet header 6. IBO1B and IBO2B give the void fraction at nodes just before steam generators 1 and 2, while OBO1A and OBO2A give the void fraction at nodes just after the steam generators (relative to flow during normal operation). The CATHENA predictions shown by figure 5.3,

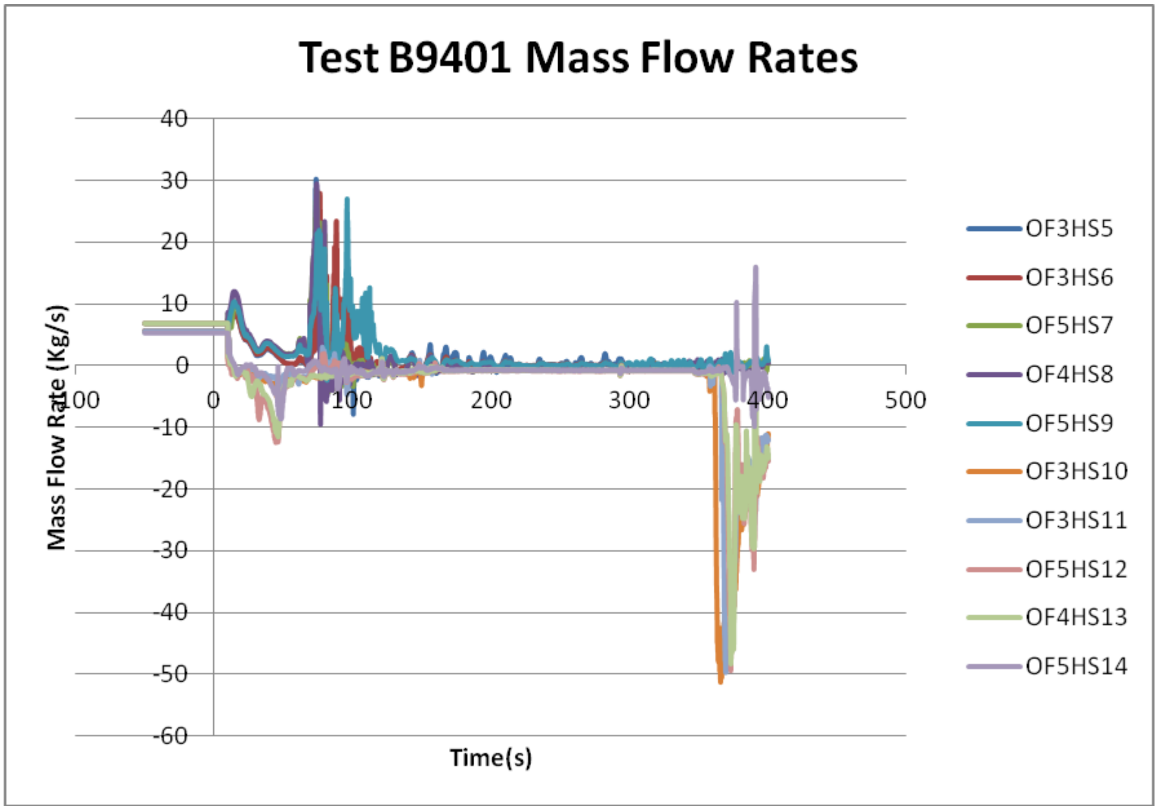


Figure 5.2: Test B9401 Mass Flow Rates

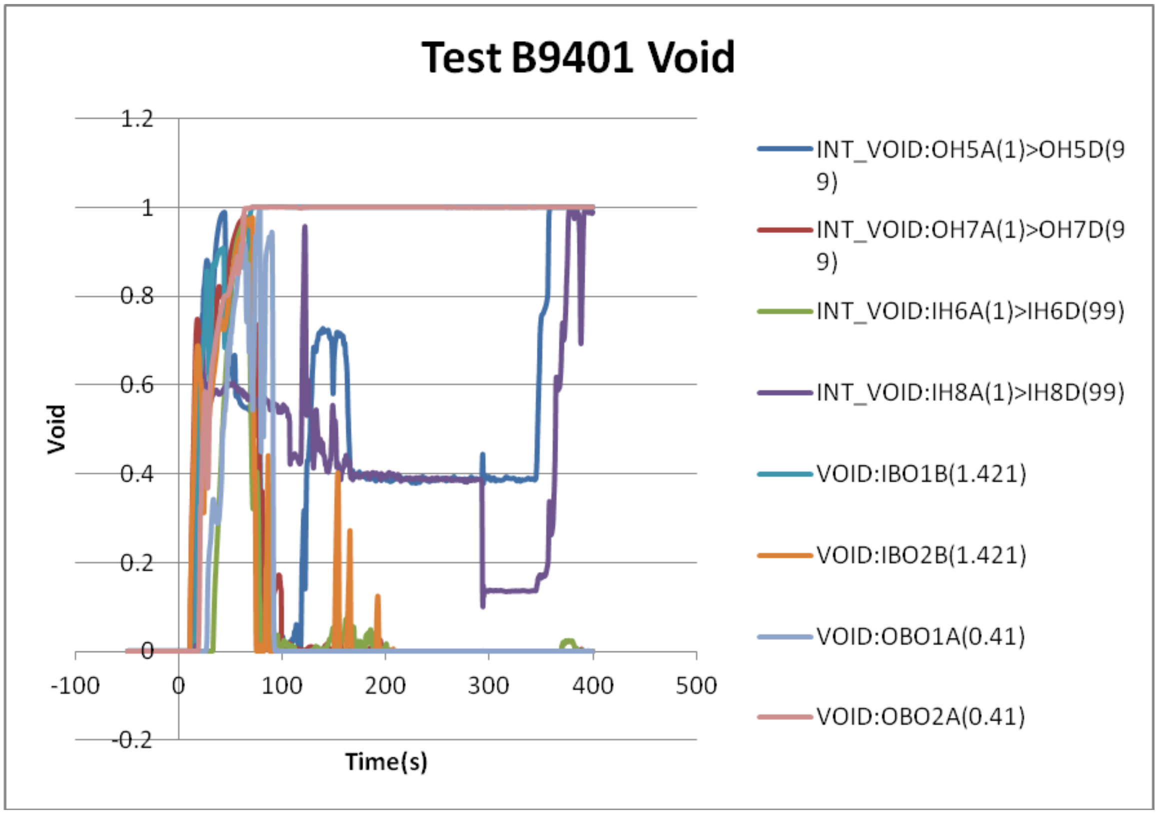


Figure 5.3: Test B9401 Void Fractions

therefore, demonstrates rapid vapour generation just after the break event at the ten second mark, followed by a reduction in void due to high pressure ECC injection at 20 seconds. A sudden spike, then reduction in void in outlet header 5 as well as inlet header 8 occurs (where the break occurs) due to initiation of low pressure ECC at 110 seconds. Void again shows a rapid increase as low pressure ECC is terminated at 338 seconds. Steam quality also rapidly reaches 100 percent at OBO2A after the break event, due to its position between the steam generator and the header at which the break condition is applied. Other positions show some void generation, which is collapsed over time due to ECC injection.

The events described by these three figures demonstrate the motivation for introducing a CFD element into the simulation of a thermalhydraulics loop. Events in one section of the loop affect the rest of the system, so by attempting to provide TH feedback to conditions determined by a CFD solver, it is hoped that our understanding of system behaviour may be improved. The two phase conditions within inlet header 8 during this transient would be of particular interest, for instance. A more simple starting point is desirable, however, which is why inlet header 6 was chosen as the section to be simulated under the first attempt of code coupling. This header is not part of the loop with the break condition and would therefore not be subject to as drastic phase change and flow phenomena. Before the CFD model of the header can be interfaced, it was necessary to modify this CATHENA input deck into a simpler test for initial attempts at creating a coupled simulation.

5.1.2 Steady State CATHENA Model Development

In order to prime the CATHENA input deck for coupling, a number of changes were made to the B9401 input files. A number of elements were removed from the CATHENA input file in order to transform the dataset for the coupling procedures. These removed items included:

- Auxiliary files used for sensitivity analysis
- Pipe break at 10 second mark removed
- Power ramp down of heated sections removed
- Pump rundowns removed
- Surge tank pressure drop removed
- Isolation event of surge tank removed
- Secondary side feedwater temperature drop removed
- Secondary side drum pressure transient removed
- Feedwater Flow transients removed
- Boiler level transients removed and logic set to steady state
- ECI trip removed
- ECI pressure transient removed
- High pressure ECI isolation events removed
- Low pressure ECI transients removed

- Additional variable monitors added where needed

The desired outcome from removal of these triggers was a steady state simulation, similar to what would be expected in figures 5.1, 5.2, and 5.3, before the ten second mark of the simulation. Additional monitors were added at desired points in the TH loop, at the inlet and outlets of header 6 where the connections would later modified to allow for CFD coupling, for later comparison. The simulation was also extended farther back into negative time in order to give more time for a coupled simulation to reach convergence before the 0 time mark. Beginning the simulation in negative time allows the simulation to run for a greater number of time steps before executing any transient events, without forcing the user to change the initiating time of all event triggers. The simulation end time was set at an arbitrary value found to be sufficient to demonstrate steady state behaviour. The result of these changes is a steady state CATHENA simulation with constant flow rates and pressures with no void generation at any point. This is shown by figures 5.4, 5.5, and 5.6, which present these variables at the added monitor points in header 6. Figure 5.6 demonstrates that there is no void generation throughout the course of the simulation.

Table 5.3 lists the final converged monitor values which are to be used as reference values at boundary conditions where the CATHENA model is to be replaced with the STAR-CCM+ model. These values were then used as initial conditions at all boundaries for the CFD simulation.

The reference values in this table closely match those plotted in figures 5.1 and 5.2 before transient events are initiated. The boundaries all exhibit different pressures and flow rates due to their varying positions on the header. Additionally, the piping for flow channels 7 and 8 is of a larger diameter, resulting in a greater flow rate. The

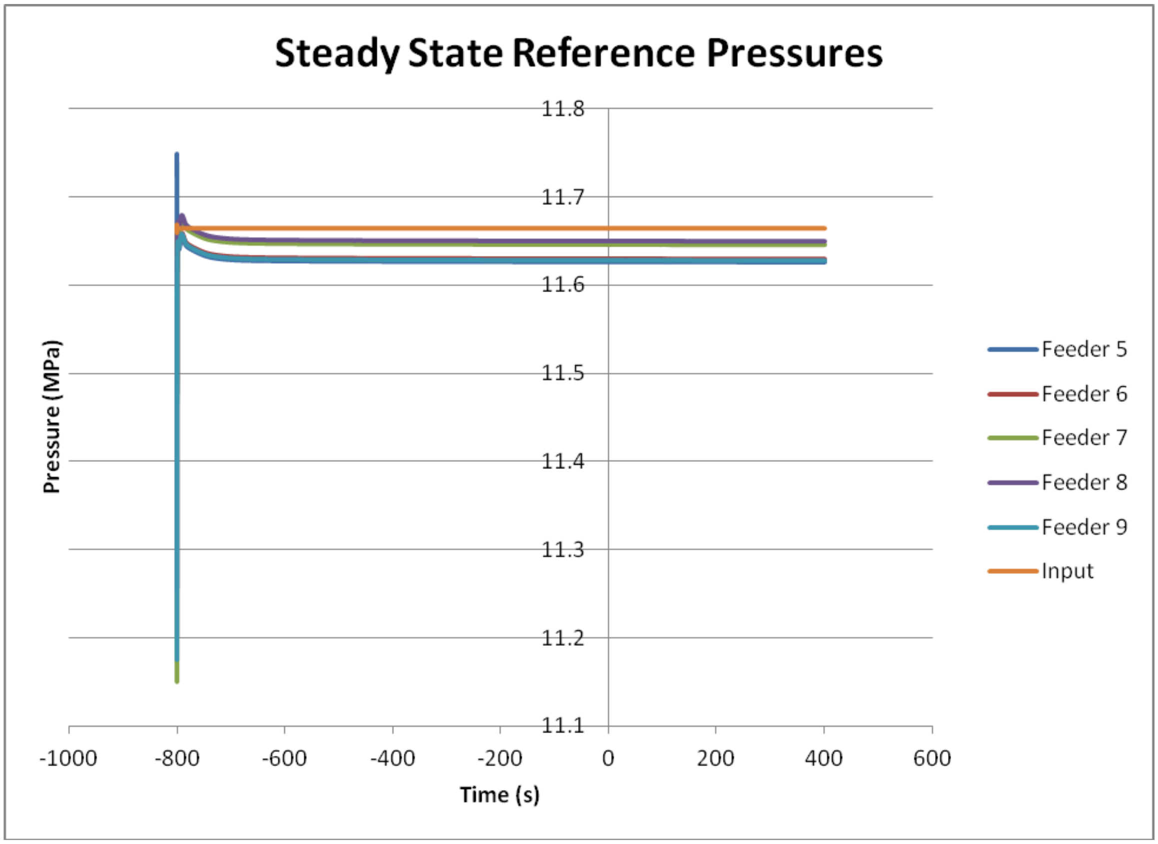


Figure 5.4: Pressures Predicted with the Steady State CATHENA Model at Monitor Points in Header 6

	Mass Flow Rate (kg/s)	Pressure(kPa)
Inlet	21.78	11666
Feeder 5	4.08	11624
Feeder 6	4.01	11624
Feeder 7	4.90	11640
Feeder 8	4.89	11642
Feeder 9	3.89	11621

Table 5.3: Reference Conditions for Coupled Simulations

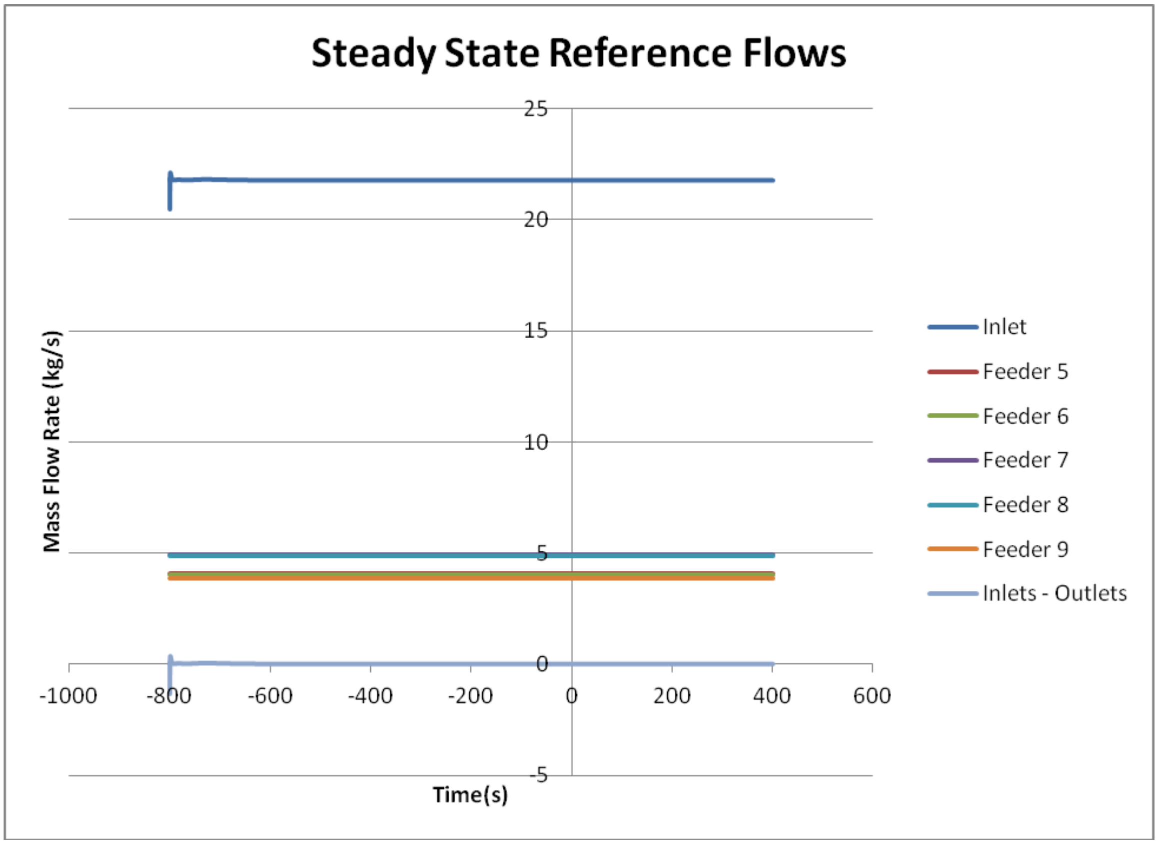


Figure 5.5: Flow Rates Predicted with the Steady State CATHENA Model at Monitor Points in Header 6

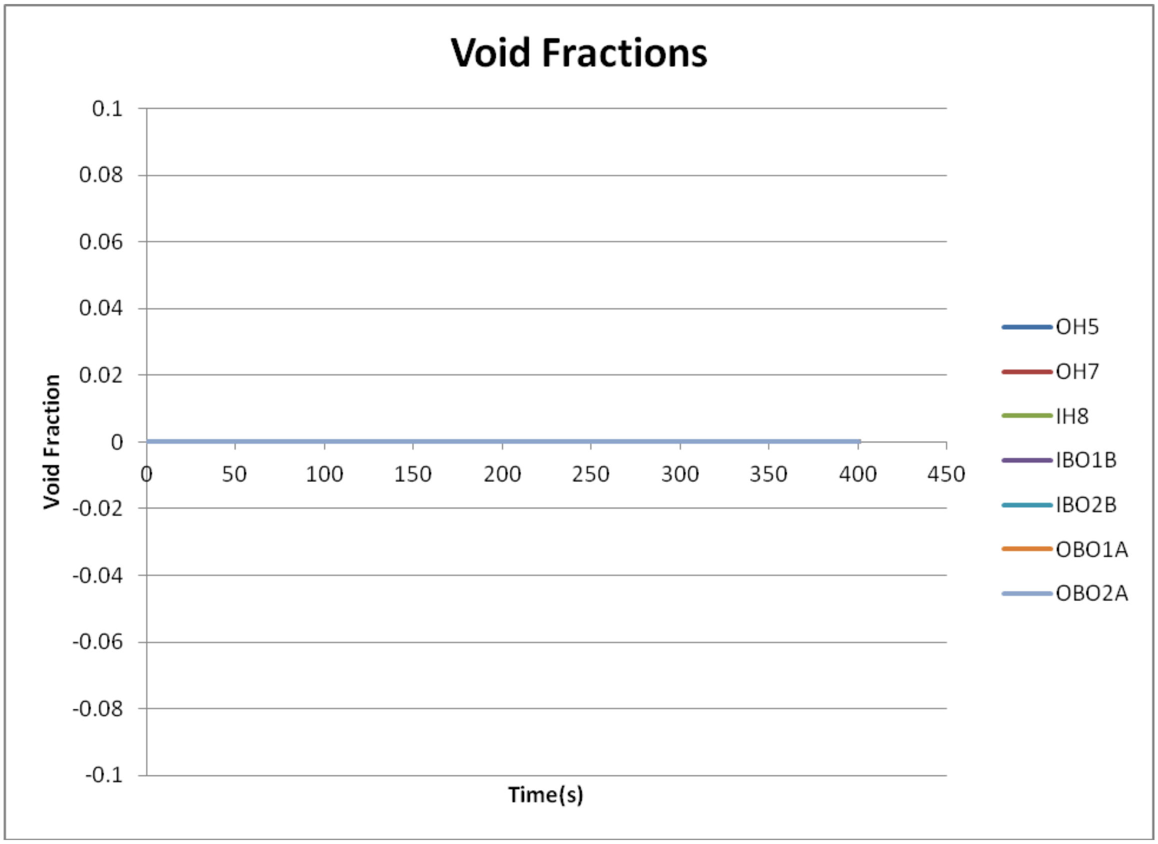


Figure 5.6: Void Predicted with the Steady State CATHENA Model at Monitor Points in Header 6

mass conservation remained very good, and remained at levels of mass loss (inlet-outlet flow) of 10^{-3} kg/s or less.

5.1.3 Modifying the CATHENA Geometry Model for Coupling with STAR-CCM+

A number of changes were made to the CATHENA steady-state model presented in the previous section to allow coupling to STAR-CCM+. A section of the CATHENA system was removed which was to be simulated by STAR-CCM+. The changes included:

- Removal of the pipe components representing header 6
- Addition of boundary conditions to close the new system
- The shortening of inlet and outlet pipes of header 6 to accurately reflect the missing section
- Removal of ECI piping and components involving header 6
- Boundary conditions (pressure, temperature, etc.) were set according to values taken from their corresponding locations in the unmodified B9401 case during steady state
- GENHTP heat structures corresponding to removed sections modified to reflect new system configuration
- Additional variable modifiers added where required

All changes made to the CATHENA input files have been extensively commented within their input files. CATHENA was then run for a duration sufficient for convergence, with the new boundary conditions and with no CFD coupling.

Figures 5.7 and 5.8 show the results of the simulation. Void is no longer shown as it is demonstrated to remain at zero in the previous section.

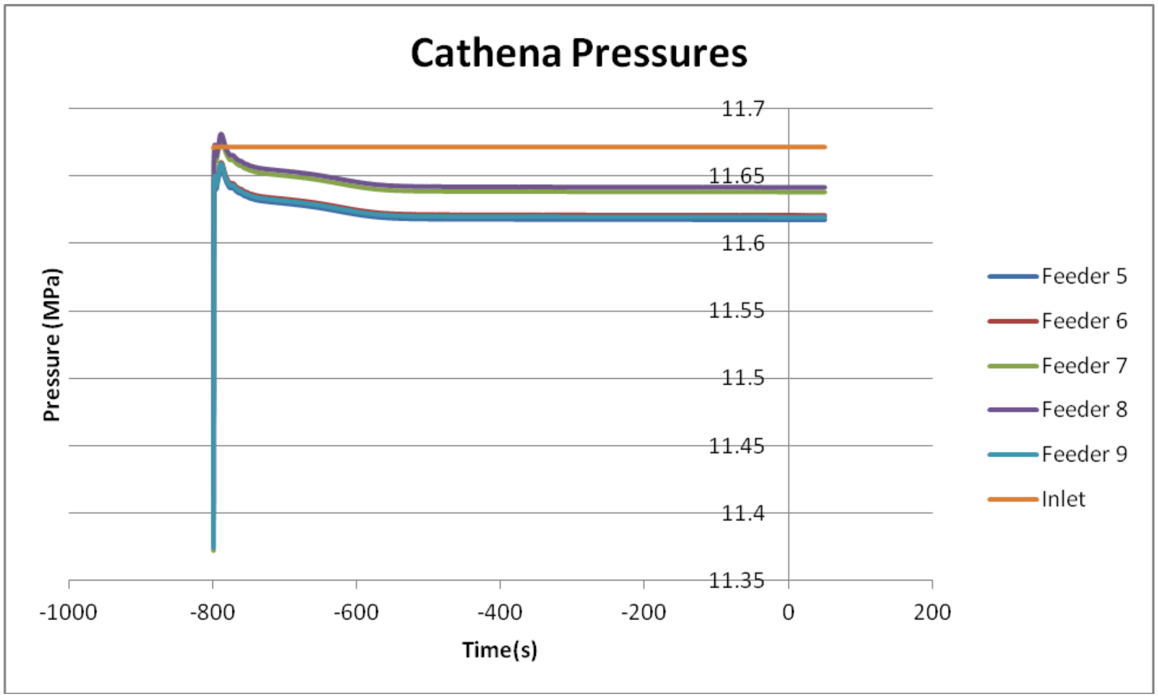


Figure 5.7: Coupling Prepared Pressures

Figure 5.7 appears very similar to the reference case in figure 5.4, with some increased initial inlet variation in flow as well as a small imbalance in inflow and outflow of approximately 0.3 kg/s. This will be addressed further in a later section.

The pressures shown in figure 5.8 match those in the reference case of figure 5.5 after a longer initial time to convergence. The greater number of boundary conditions was the likely cause of this delay to convergence.

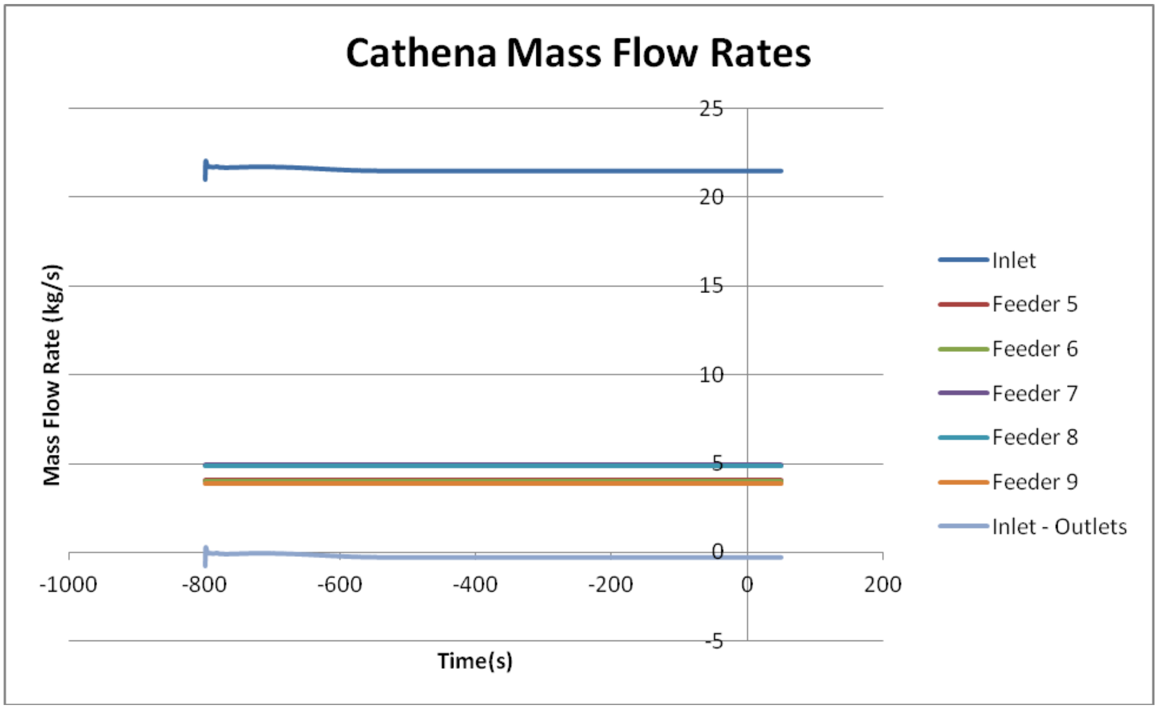


Figure 5.8: Coupling Prepared Mass Flow Rates

	Mass Flow Rate (kg/s)	Pressure(kPa)
Inlet	21.48	11671
Feeder 5	4.08	11617
Feeder 6	4.01	11621
Feeder 7	4.90	11638
Feeder 8	4.90	11641
Feeder 9	3.89	11619

Table 5.4: Simulation Results

5.2 Preliminary and Failed Coupling Algorithms

This section provides details of the preliminary work performed in pursuit of a functioning coupled system as well as configurations that were deemed not to provide any meaningful results.

5.2.1 Exploratory modeling

The first step in creating a coupled code system would of course be to create models in each respective code. After running a few basic simulations of simple geometries and preliminary test cases, a comparative simulation was performed in order to determine if similar simulation results could be expected under the same conditions in both the CATHENA and STAR-CCM+ case. This subsection presents a comparison of CATHENA and STAR-CCM+ simulations for an isolated header.

A heavily simplified CATHENA model of a header was produced in order to be compared to the STAR-CCM+ simulation of our CFD model under the same conditions. The CATHENA model was a simple system of components to provide a very rough comparison to the CFD model and may be seen in figure 5.9. Component lengths are provided by table 5.5. Pipe diameters match those of the STAR-CCM+ model as given by table 4.1.5.

The results and initial conditions for this comparison may be seen in tables 5.6 and 5.7 for a steady state case.

The goal of this exercise was to demonstrate that the flow split between channels for independent CATHENA and STAR-CCM+ simulations is within a few percentage points, and it should therefore be possible to pursue a more sophisticated system.

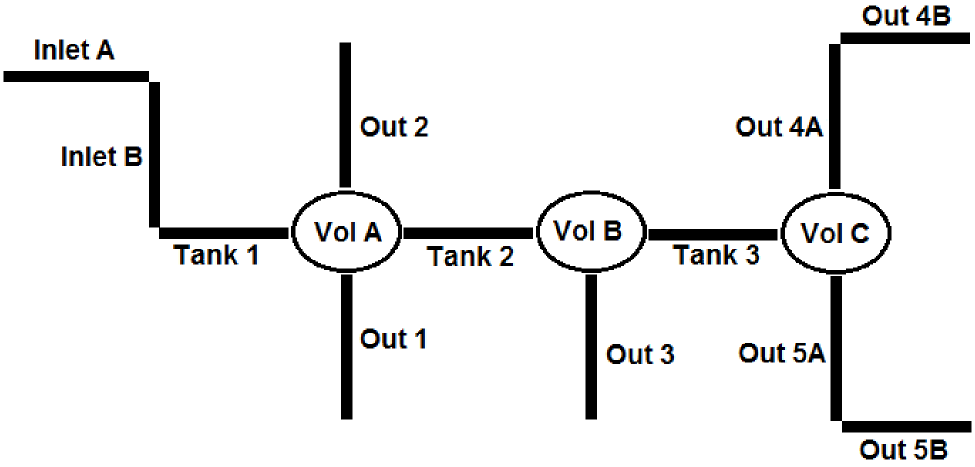


Figure 5.9: The Simplified CATHENA Model

Pipe Section	Length (m)	Elevation Change (m)
Inlet A	0.375	0
Inlet B	0.581	-0.581
Tank 1	0.187	0
Tank 2	0.200	0
Tank 3	0.200	0
Out 1	0.425	-0.250
Out 2	0.425	-0.250
Out 3	0.263	-0.250
Out 4A	0.330	0
Out 4B	0.250	-0.250
Out 5A	0.330	0
Out 5B	0.250	-0.250

Table 5.5: Component Lengths and Elevation Changes

	Flow Rate (kg/s)	% of Total Flow
Inlet A	40.73	100
Out 1	6.67	16.37
Out 2	6.67	16.37
Out 3	10.98	26.96
Out 4	6.01	14.75
Out 5	10.40	25.54
Initial Conditions: Inlet Pressure: 100 kPa Outlet Pressures: 0 kPa Reference Pressure 0 kPa Reference Density 997 kg/m^3 kPa		

Table 5.6: STAR-CCM+ Simulation Results

	Flow Rate (kg/s)	% of Total Flow
Inlet A	42.00	100
Out 1	6.66	15.86
Out 2	6.66	15.86
Out 3	13.32	31.71
Out 4	5.34	12.71
Out 5	10.02	23.86
Initial Conditions: Inlet Pressure: 200 kPa Outlet Pressures: 100 kPa		

Table 5.7: CATHENA Simulation Results

5.2.2 Mass Loss in the CATHENA Model

There were numerous hurdles preventing initiation of coupling trials. One such readily apparent cause for concern was the negative differential pressure result between the inlet and outlets demonstrated by CATHENA after removal of the header components that are simulated by STAR-CCM+. This may be seen in figure 5.10. The negative differential pressure between the header inlet and header outlet would, of course, cause difficulty in obtaining a correct flow field in the CFD simulation. To determine if the type of boundary condition was having an effect on simulation results, all CATHENA boundaries were changed to pressure boundaries, and all initial conditions were set to an appropriate and constant value.

Upon inspection of the flow rates, it was determined that there was an inequality in mass flow rates between the inlet and the outlets. This may be seen in table 5.8. CATHENA, however reported a mass loss of -0.9599507E-03 kg/s over the whole loop (vs. -1.194 kg/s for the header alone), strongly indicating inventory entering the system at some other point in the system.

	Final Mass Flow Rates (kg/s)
Inlet	20.318
Feeder 5	3.640
Feeder 6	3.570
Feeder 7	4.307
Feeder 8	4.149
Feeder 9	3.459
Feeder Sum	19.124
Inlet - Feeder Sum	1.194

Table 5.8: System Inventory Loss

This increase of fluid inventory was a clear indication of a problem with the model.

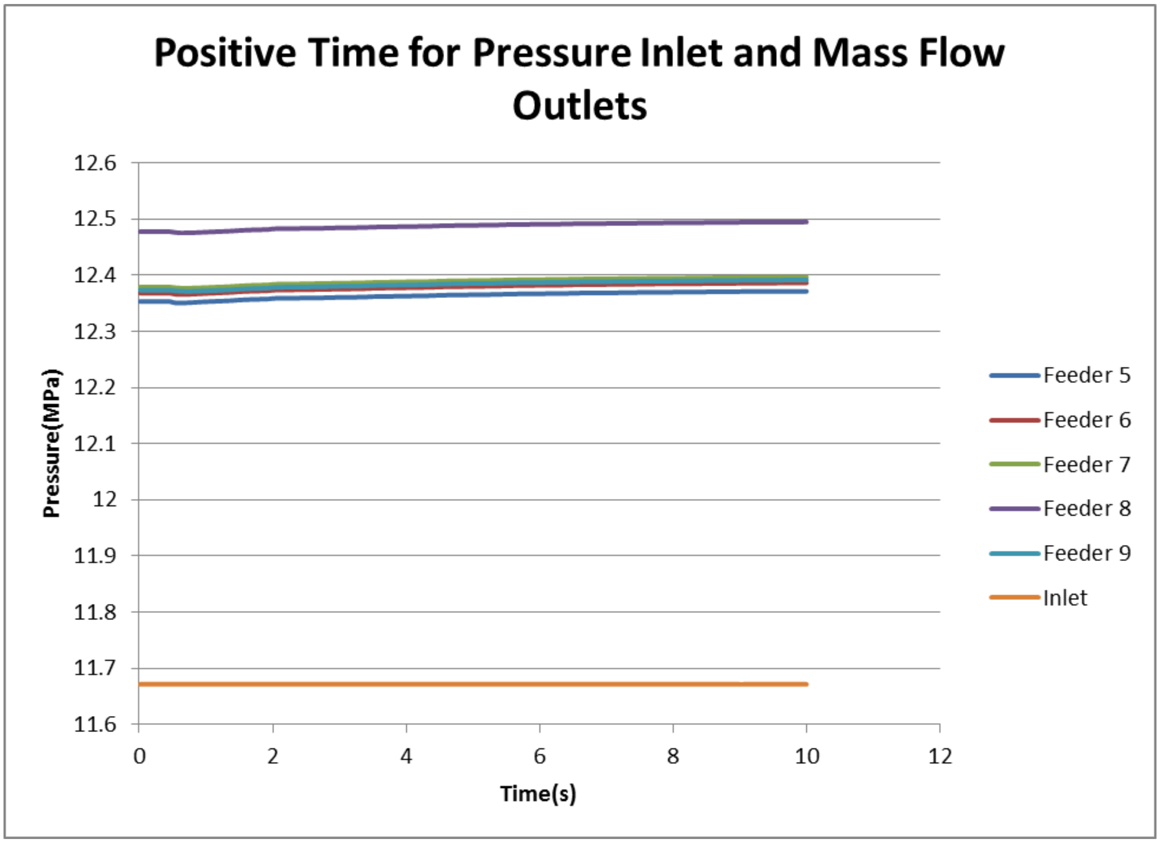


Figure 5.10: CATHENA Differential Pressures

Since mass was not conserved, the simulation became unstable. The test was rerun with flow outlet boundary conditions. There was little effect on the outcome of the simulation.

5.2.3 Surge Tank Modelling (Pressurizer)

As a continuation to the investigation in the previous section, it was speculated that the surge tank was influencing the flow into the system. To determine if this was the case, an arbitrarily large K factor was set (10 million or so) at its junction to essentially block off flow. This seemed to stabilize the system back to a more reasonable output, as seen in figures 5.11 and 5.12. This change dropped the flow from the surge tank from 1.121 kg/s to 0.001 kg/s, and dropped the flow difference from the inlet to outlets to the same value. The matter was not fully resolved, as will be addressed in a later section with regards to removing the pressurizer boundary condition.

5.2.4 Bringing Coupling Online

Early coupling trials demonstrated considerable instability at initial stages. Initial values may be found in table 5.9. These values were less accurate than those used later, since it was discovered at some point that they were taken at a slightly different location than appropriate from the reference model. It was hoped at this time that a roughly close initial guess would be sufficient to reach convergence. Steady state was achieved by both codes before transfer of values exchanged every 0.2 seconds. Relaxation of 98 % was used (98 % of old solution maintained) for testing purposes[1].

The simulation would come to an end due to a STAR-CCM+ internal error at

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[1] This is clearly unacceptable for a real scenario

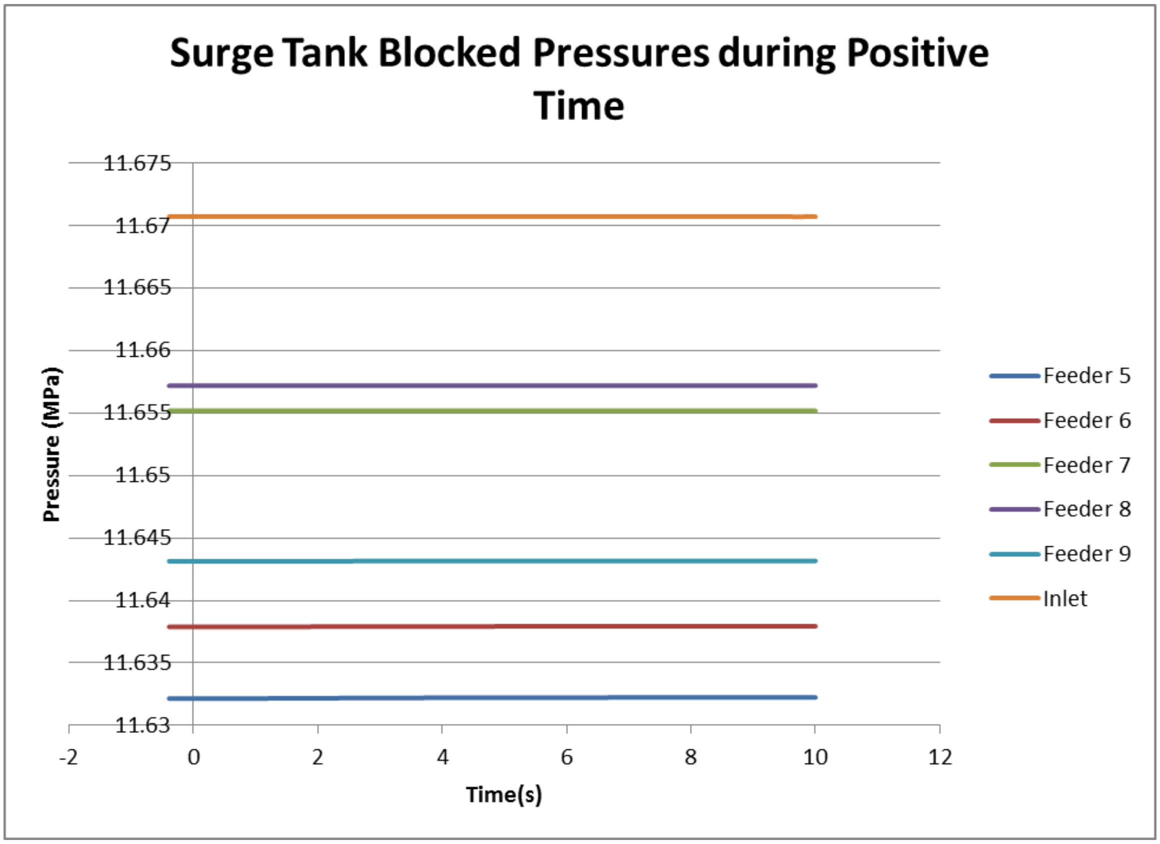

Figure 5.11: CATHENA Pressures after Blocking the Surge Tank

	Final Mass Flow Rates (kg/s)	Pressure (kPa)
Inlet	21.78	11673
Feeder 5	4.08	11641
Feeder 6	4.01	11644
Feeder 7	4.90	11657
Feeder 8	4.89	11658
Feeder 9	3.89	11647

Table 5.9: Initial Conditions

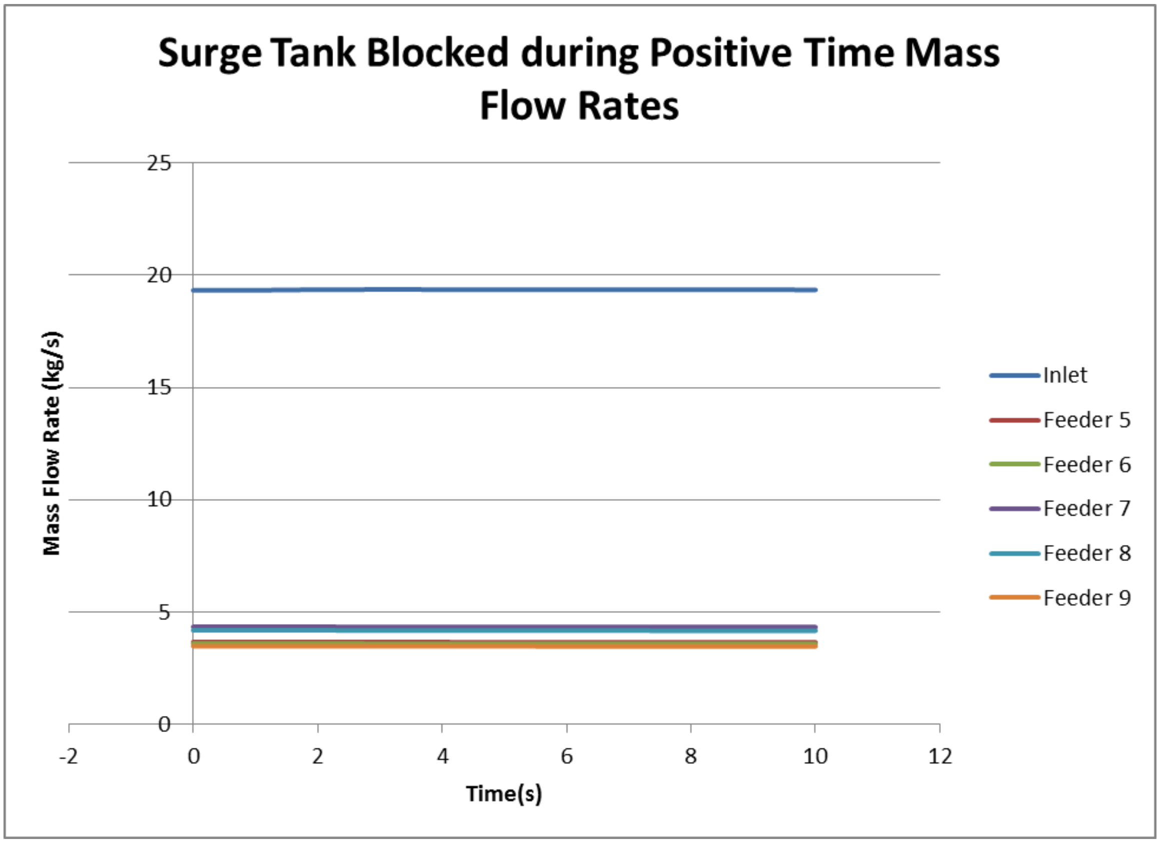

Figure 5.12: CATHENA Flow Rates after Blocking the Surge Tank

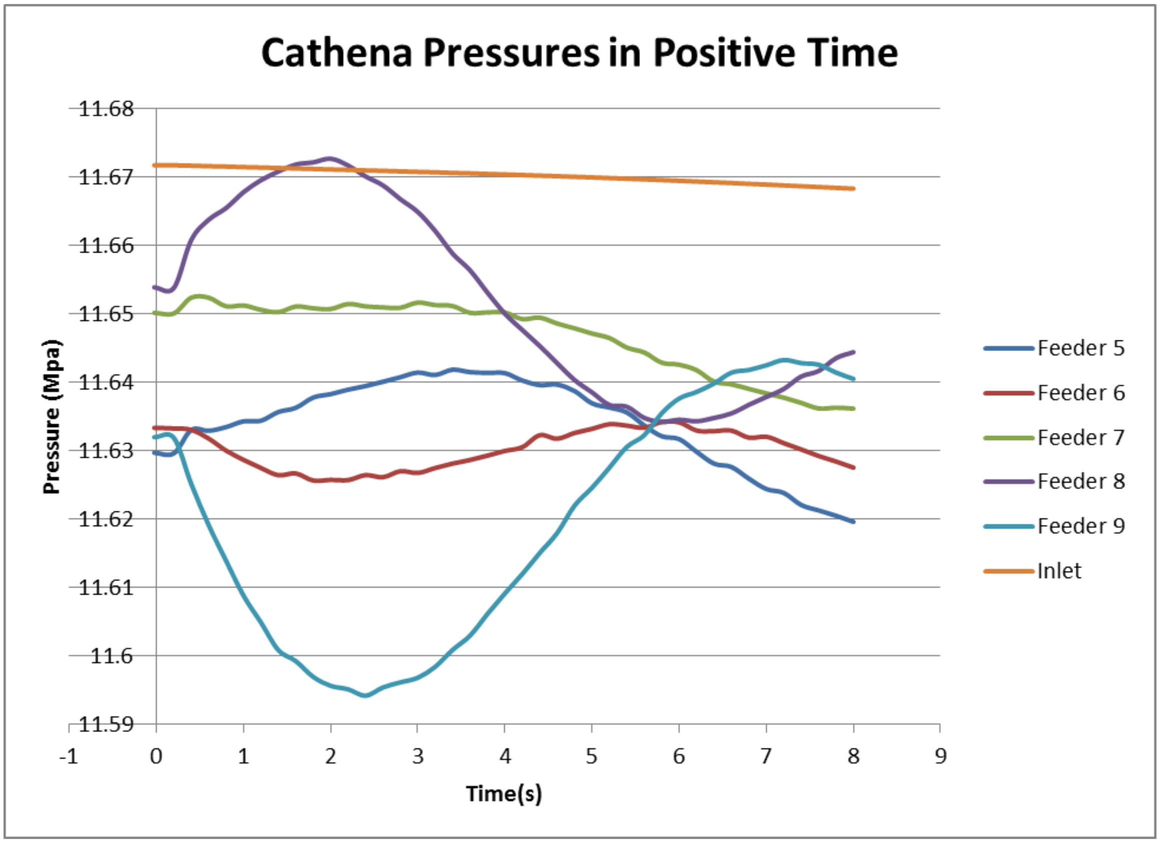

Figure 5.13: CATHENA Pressures

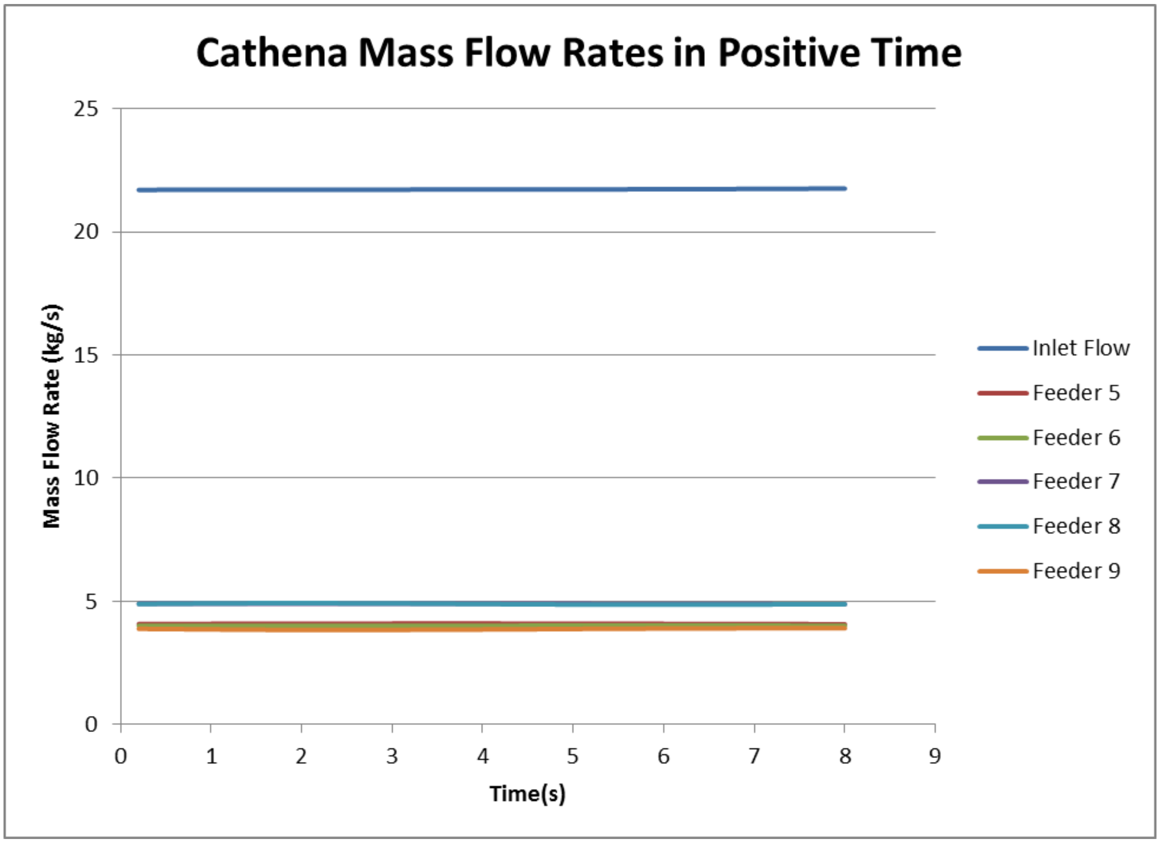

Figure 5.14: CATHENA Mass Flow Rates

8 seconds. This was later resolved by updating to a newer version of the CFD software. Despite stable mass flow rates, the pressures continued to show concerning behaviour. At this point, it was hoped that the solution would converge given a lengthier simulation time. This became a more distant hope upon inspection of the STAR-CCM+ solution. Figure 5.15 shows the STAR-CCM+ inlet pressure. The differential pressure between inlet and the outlets remained constant. The boundary condition update points are readily apparent. The gradual decline of pressure along with the mass flow oscillations provided a clear indication that continued refinement of the system was necessary.

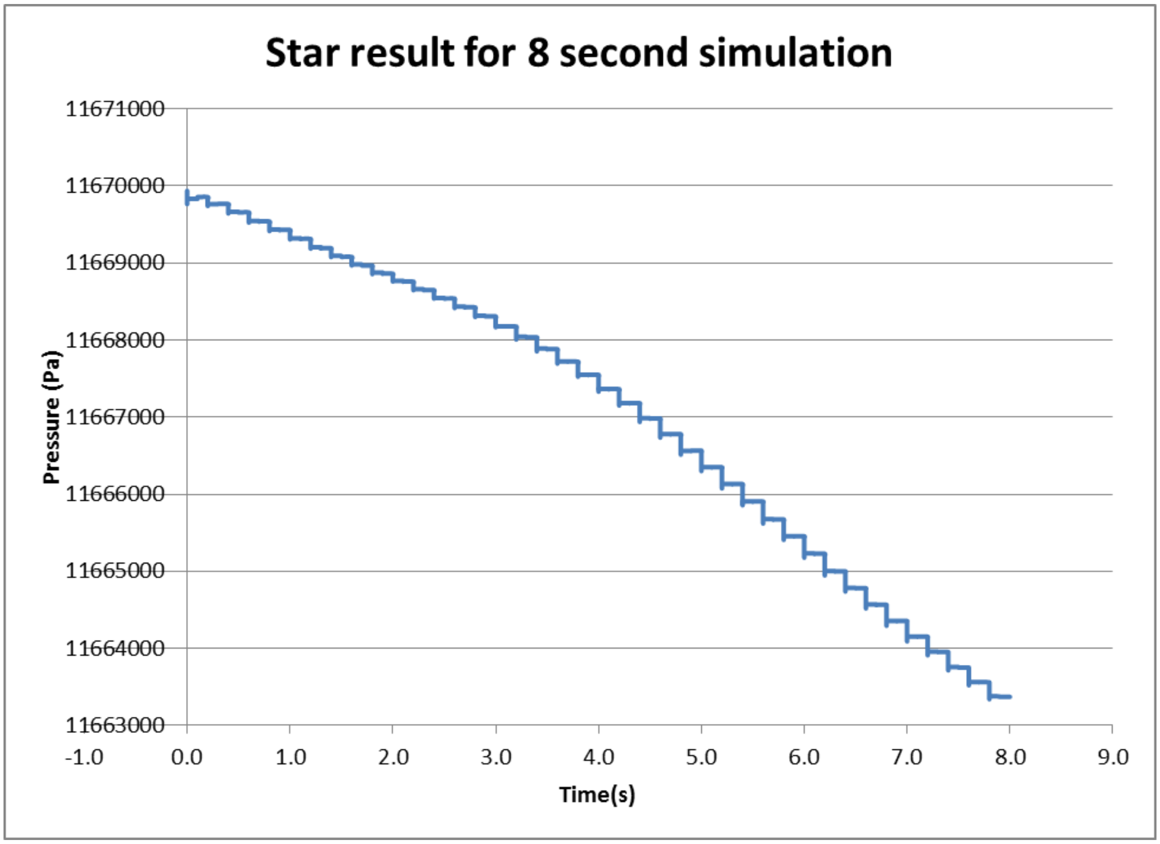

Figure 5.15: STAR-CCM+ Pressure Result

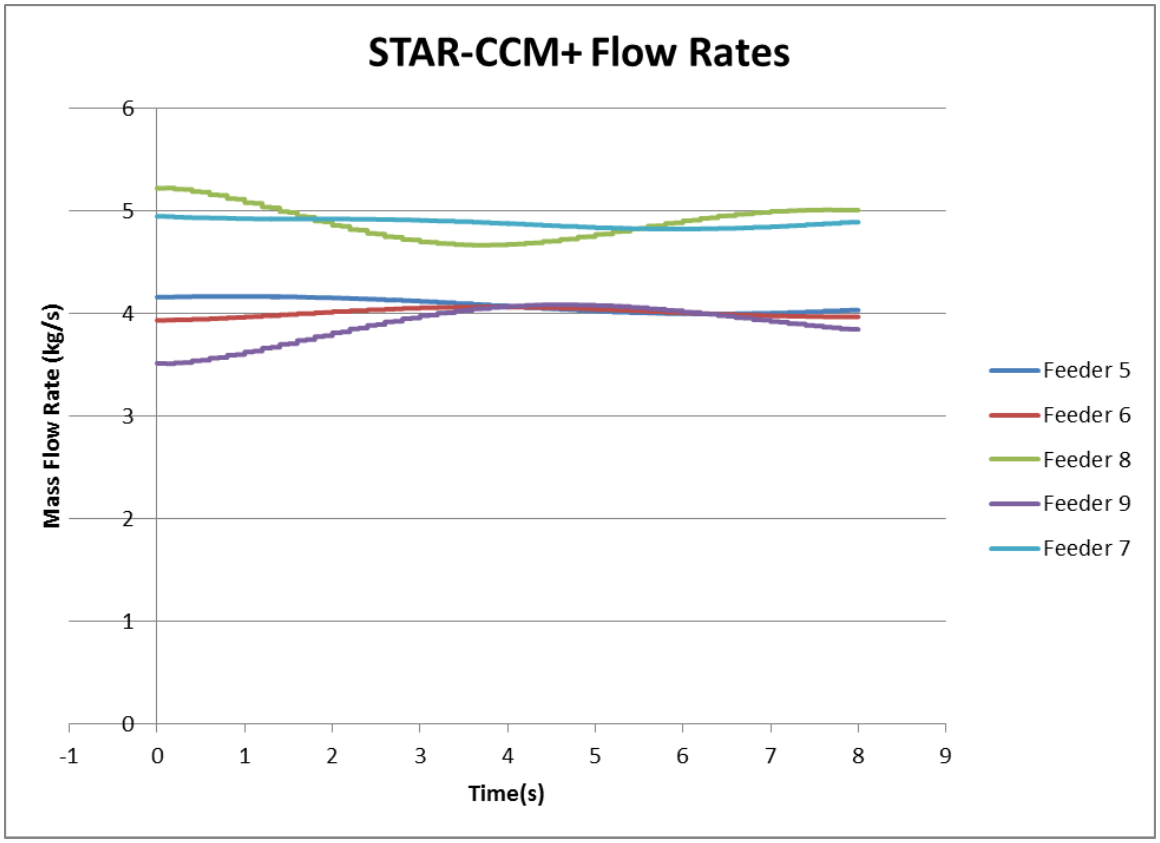

Figure 5.16: STAR-CCM+ Mass Flow Rates

5.2.5 Finite Time Stepping

In order to gain an insight into the continued instabilities observed in the coupled system, simulations were run using only a single boundary condition transfer between codes. This was later expanded to multiple exchanges, with significant delays between transfers. One such simulation may be seen in figures 5.16 and 5.17. 90 % relaxation was used for this case.

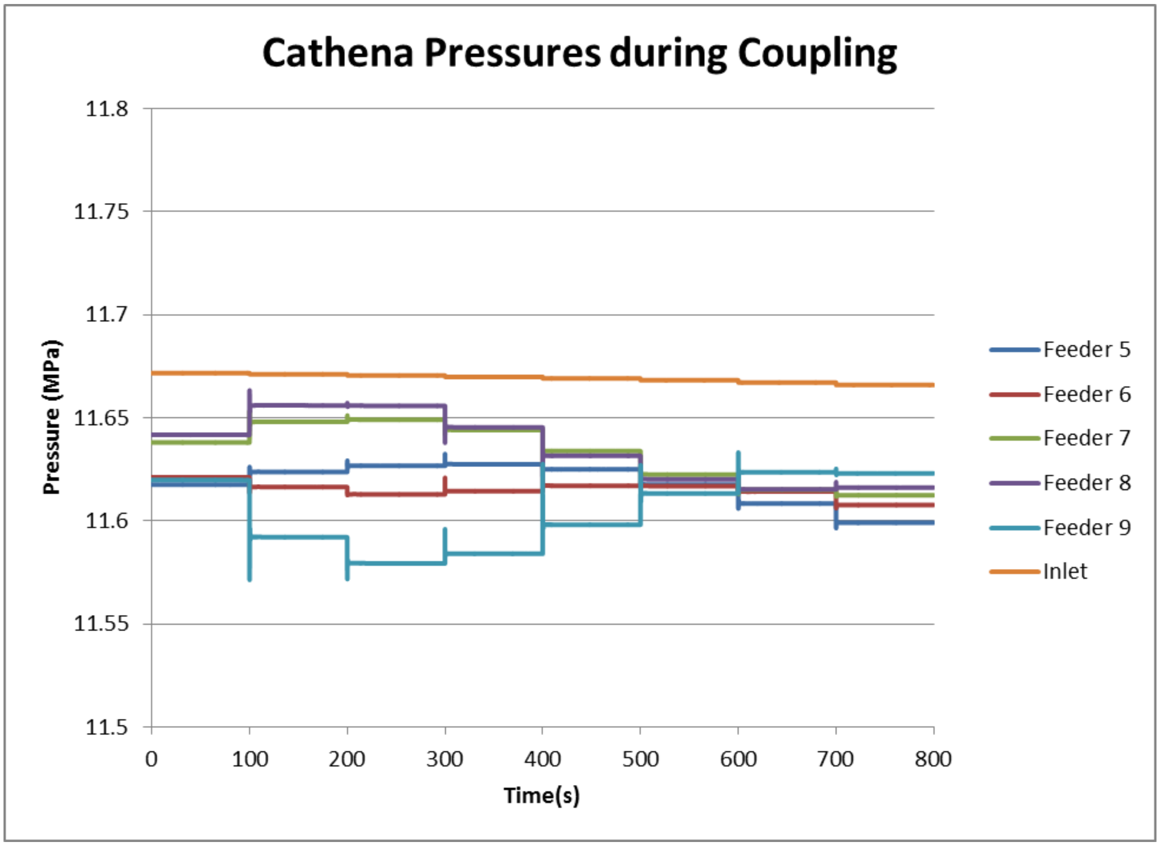

Figure 5.17: Slow BC Transfer over a Long Simulation

This practice allowed for a more detailed look at the value trends and ensured ample simulation time for convergence in both codes. These simulations allowed for

Solution Interval	Inlet Flow (kg/s)	Feeder 5 Flow (kg/s)	Feeder 6 Flow (kg/s)	Feeder 7 Flow (kg/s)	Feeder 8 Flow (kg/s)	Feeder 9 Flow (kg/s)	Inlet-Outlets
0	21.482	4.08	4.013	4.902	4.895	3.889	-0.297
1	21.490	4.088	4.006	4.918	4.918	3.852	-0.292
2	21.498	4.094	4.003	4.922	4.920	3.837	-0.278
3	21.507	4.097	4.007	4.916	4.905	3.845	-0.263
4	21.517	4.096	4.013	4.902	4.885	3.866	-0.245
5	21.528	4.089	4.013	4.887	4.870	3.889	-0.223
6	21.544	4.079	4.015	4.878	4.865	3.905	-0.198
7	21.563	4.069	4.009	4.877	4.98	3.907	-0.169

Table 5.10: CATHENA Values at Each Time Step

generation of tables such as the one found in table 5.10, which once again demonstrated a mass flow balance discrepancy in CATHENA.

The mass flow discrepancy appeared to be decreasing, however, so it was hoped that a longer total simulation time would sufficient. This was not the case. Figure 5.18 demonstrates the system behaviour over a much longer overall simulation time. This was several days worth of computation.

This system is clearly demonstrating divergent behaviour along with significant mass loss in CATHENA.

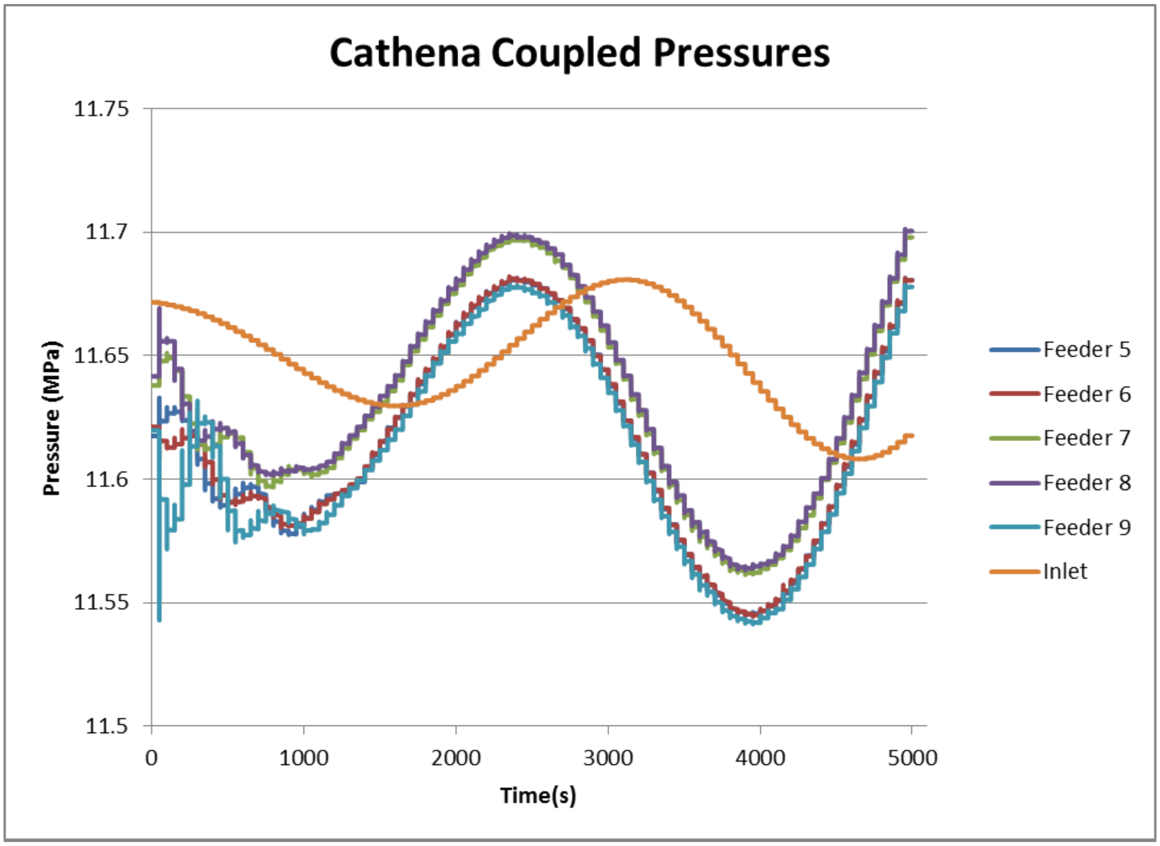

Figure 5.18: CATHENA Pressure Result

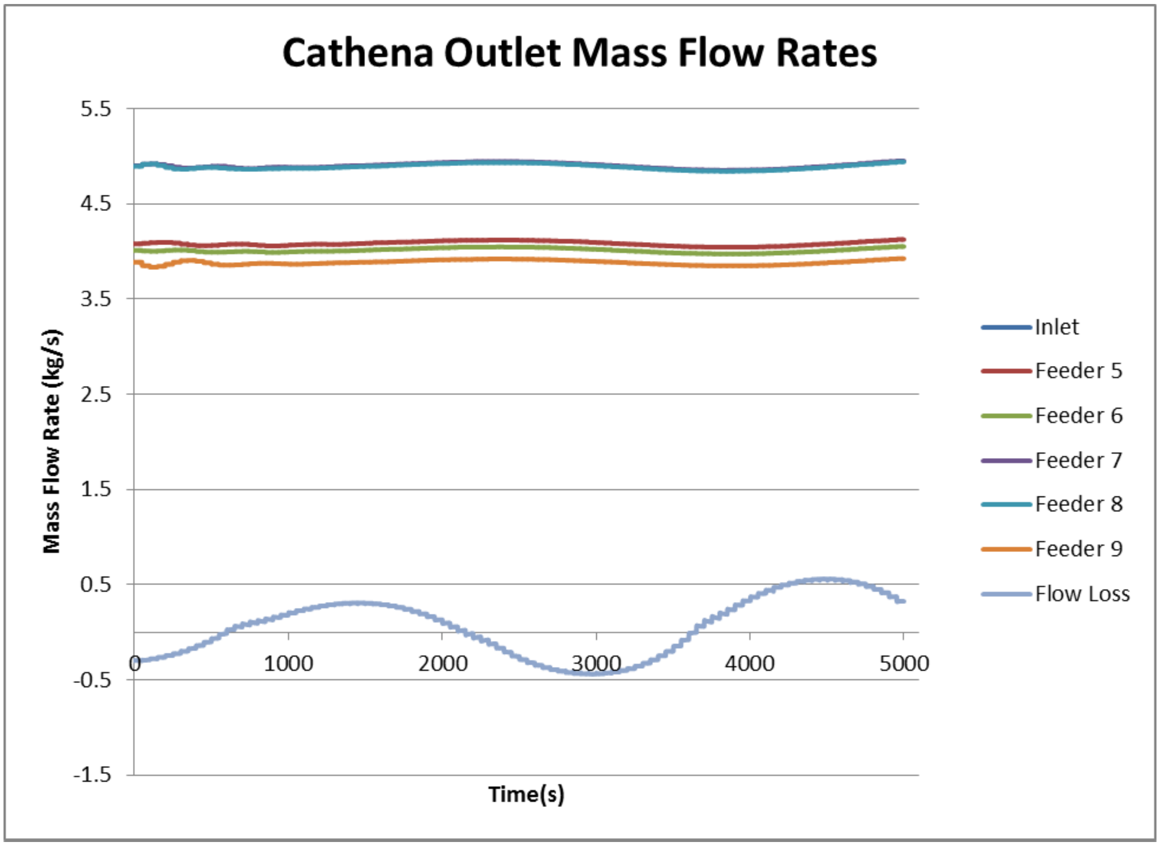

Figure 5.19: CATHENA Mass Flow Rates

Relaxation between transfers	90 %
Time step duration in CATHENA	1 second maximum
Time step duration in STAR-CCM+	0.1 seconds
Exchange Frequency	1 Second of simulation time

Table 5.11: Additional Simulation Parameters

5.2.6 Complete Removal of the Pressurizer Boundary Condition

It was decided that blocking off the surge tank with an arbitrarily large resistance to flow may be insufficient to provide simulation stability. The boundary condition maintaining pressure inside of the pressurizer model in CATHENA was therefore removed to reduce the number of boundary conditions in the system. As can be seen in figures 5.20 and 5.21, the simulation becomes relatively stable.

The pressures present in figure 5.20 are an improvement over those seen in previously, but do not exhibit the desired steady state behaviour. The simulation was terminated after a lengthy duration once it became apparent that the boundary values would not return to a range close to those of the reference case in any reasonable time frame. While the stability of the simulation seemed to be significantly improved, it was unclear whether the trend was part of a longer period oscillation or if it was stabilizing at a converged value. However, since the overall duration of the simulation increased by a factor of 20 without any apparent instability, removal of the pressurizer boundary condition appeared to have a beneficial result.

The mass flow rates in figure 5.21 appear much more stable than those in figure 5.19, with minor change as may be seen in table 5.12.

While the percentage difference in expected and final solutions remains quite small,

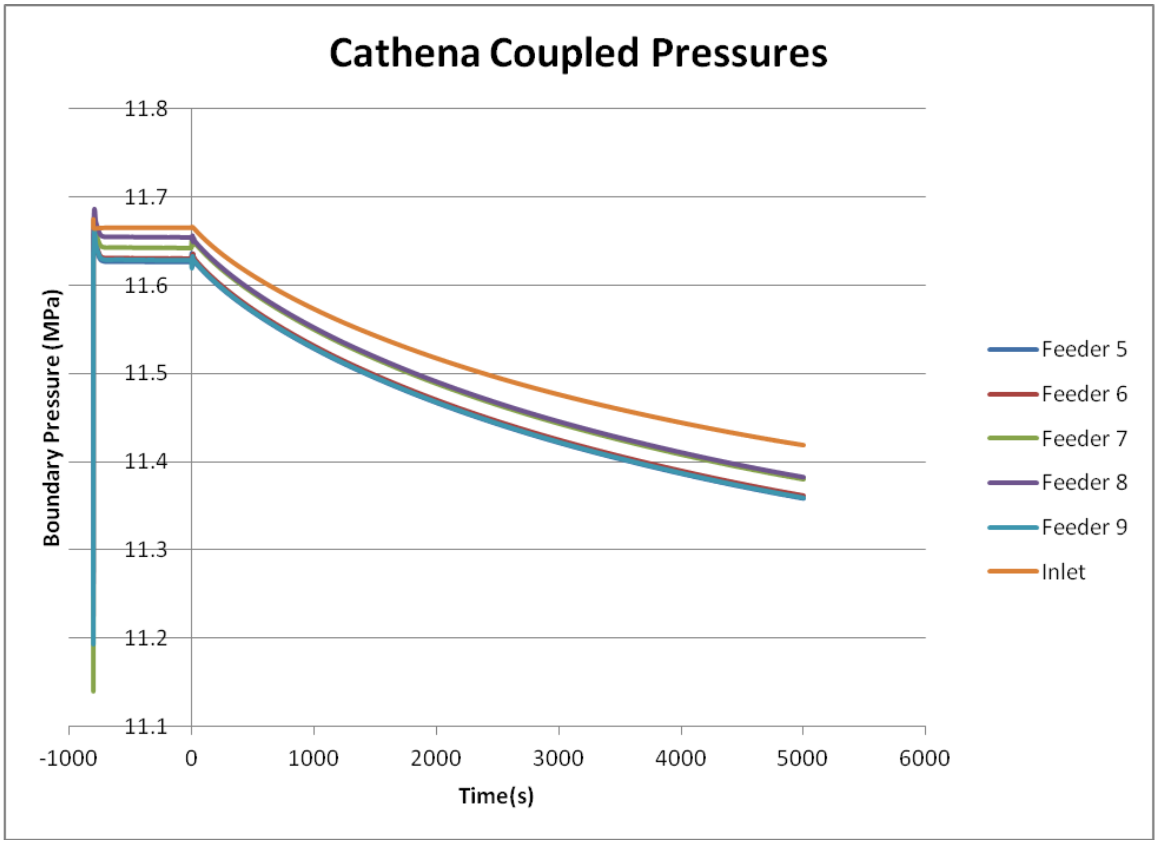

Figure 5.20: Coupled Pressures after Removal of the Pressurizer Boundary Condition

Boundary	Initial (Reference) (kPa)	Final Values (kPa)	% Change
Inlet	11666	11418	-2.120
Feeder 5	11624	11358	-2.282
Feeder 6	11624	11361	-2.262
Feeder 7	11640	11380	-2.235
Feeder 8	11642	11382	-2.234
Feeder 9	11621	11359	-2.251

Table 5.12: Coupled Pressure Results

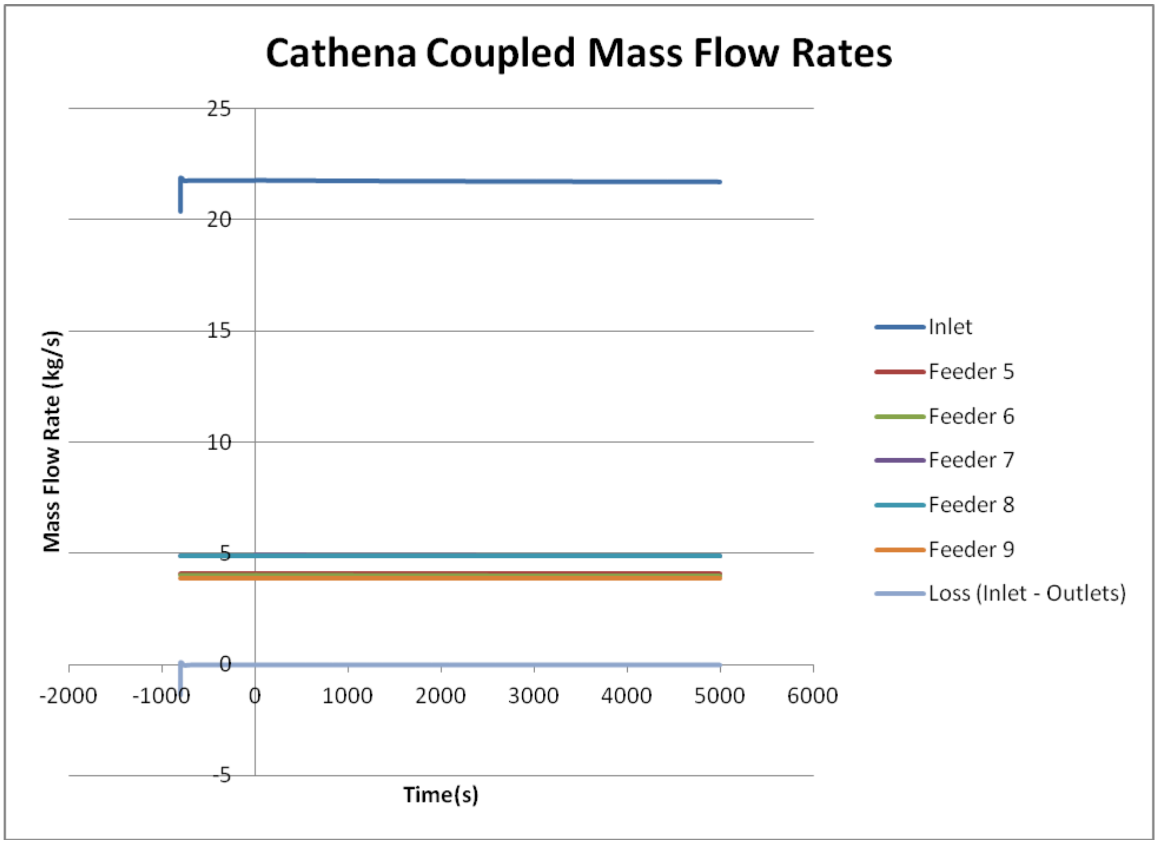

Figure 5.21: Coupled Mass Flow Rates after Removal of the Pressurizer Boundary Condition

Boundary	Initial (Reference) (kPa)	Final Values (kPa)	% Change
Inlet	21.779	21.714	-0.298
Feeder 5	4.080	4.068	-0.294
Feeder 6	4.010	4.000	-0.249
Feeder 7	4.900	4.890	-0.204
Feeder 8	4.890	4.880	-0.204
Feeder 9	3.890	3.876	-0.360

Table 5.13: Coupled Mass Flow Results

it is still large enough to indicate that there are still some sources of error present in the algorithm. However, the instabilities seen in the previous sections have been resolved, appearing to indicate that they were the result of overspecification of boundary conditions within the coupled code system.

The gradual pressure decline as seen over the long time scale may indicate that there is still a loss of energy somewhere within the system. This is likely due to the imperfect transfer of information between coupled stages as is currently implemented. This is a very gradual loss as indicated by the long time scale, but is nonetheless significant. This loss of energy will be addressed in section 5.2.8.

5.2.7 Alternate Boundary Condition Configurations

Due to the inability to achieve a successful coupled system in the previous section, alternate boundary condition configurations for coupling were explored.

5.2.7.1 Configuration 1: Modified Boundaries

The first alternate configuration attempted was that of a pressure inlet and 5 pressure outlets for CATHENA, a pressure inlet and single combined mass flow outlet boundary for STAR-CCM+, along with removal of the surge tank boundary condition. 90% relaxation was used for this simulation. The CATHENA results of this simulation may be seen in figures 5.22-5.24.

It was observed that pressure elsewhere in the system was continuing to drop, as seen in figure 5.27 demonstrating pressurizer pressure (which, without the internal boundary condition, acts more as a tank), a special condition was added that would add 10% of the difference between the nominal (reference) pressurizer pressure and its

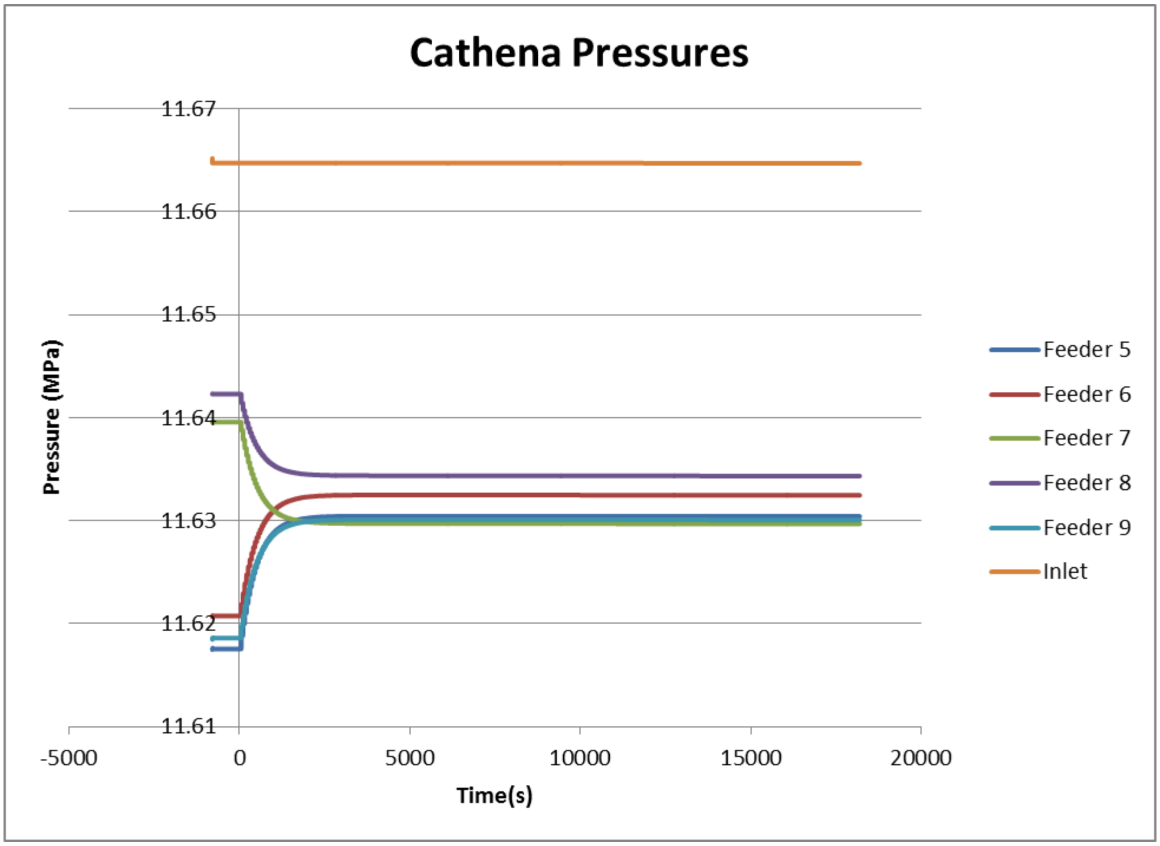

Figure 5.22: CATHENA Pressures

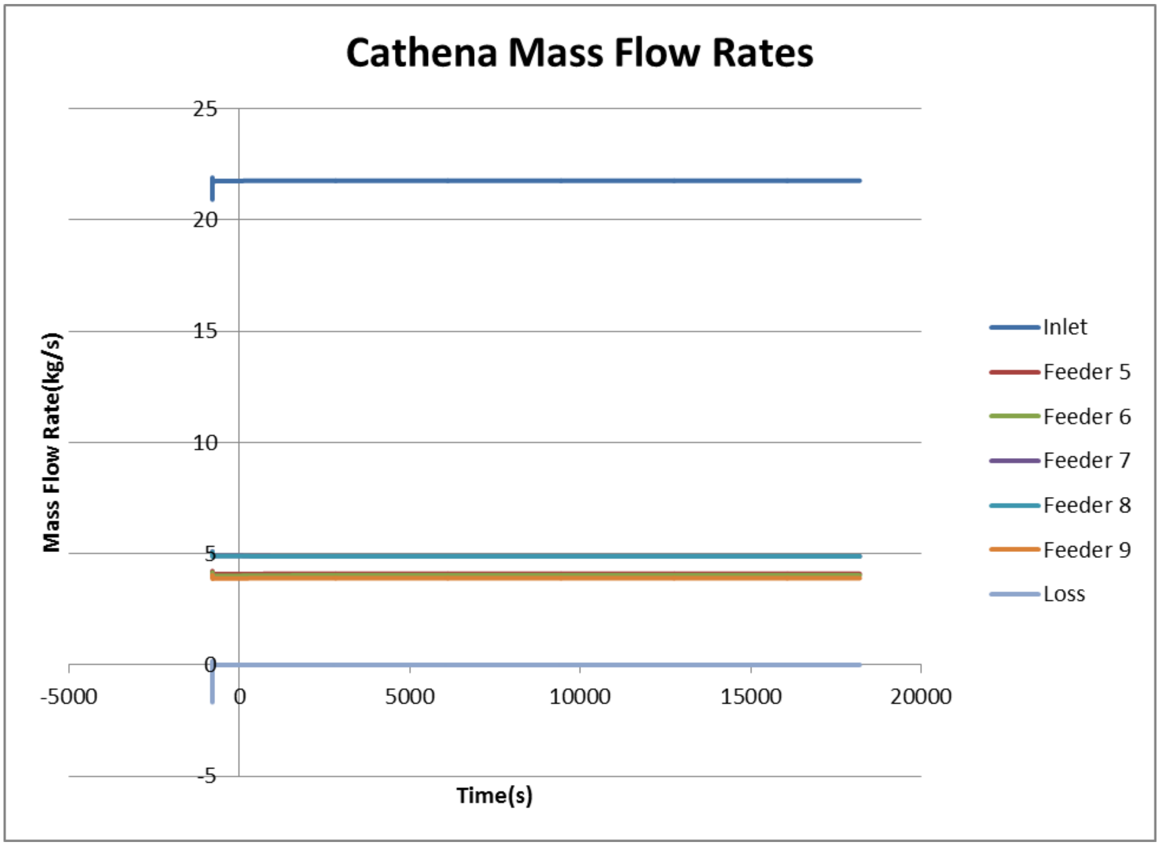

Figure 5.23: CATHENA Mass Flow Rates

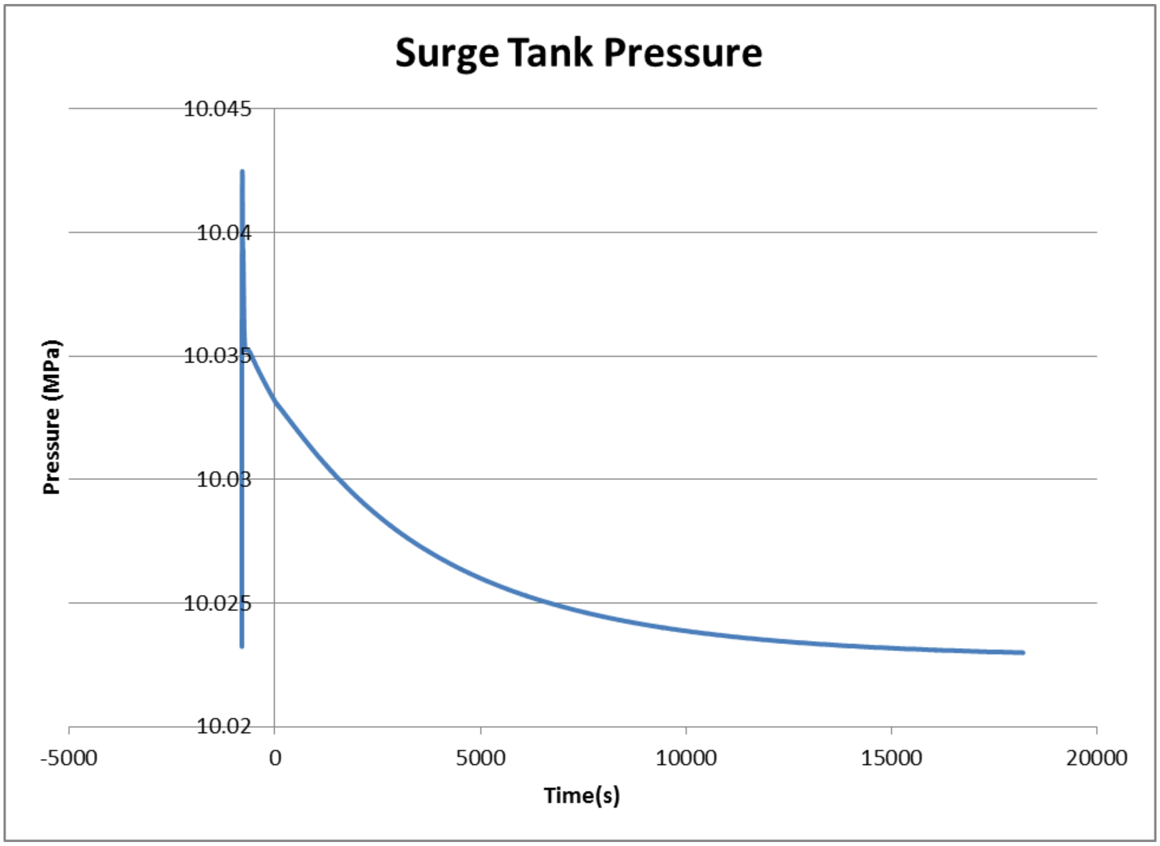

Figure 5.24: CATHENA Surge Tank Pressure

actual value to the inlet pressure of the CATHENA model upon boundary condition update. The result of this may be seen in figures 5.25 through 5.27.

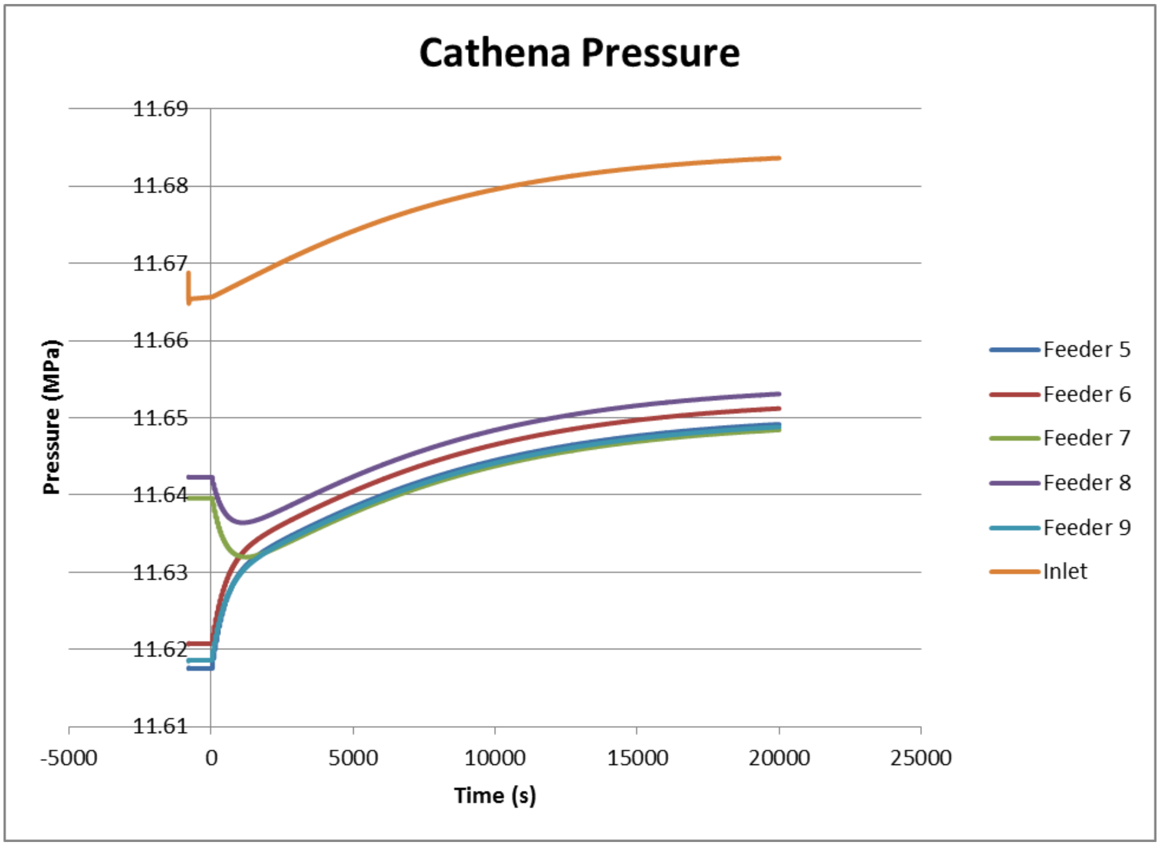

Figure 5.25: CATHENA Pressure

While the CATHENA results appear encouraging, the STAR-CCM+ results are less so. While the outputted pressures also appear as if a solution is converging, the mass flow rates demonstrate the draw back to this boundary condition configuration. As seen in figure 5.29, with a single mass flow outlet condition, the CFD code no longer provides individualized flows for each header. Instead, the two large diameter feeders obtain one value, while the three remaining feeders demonstrate a second value. It should be expected, that with a complicated geometry such as a flow header, each

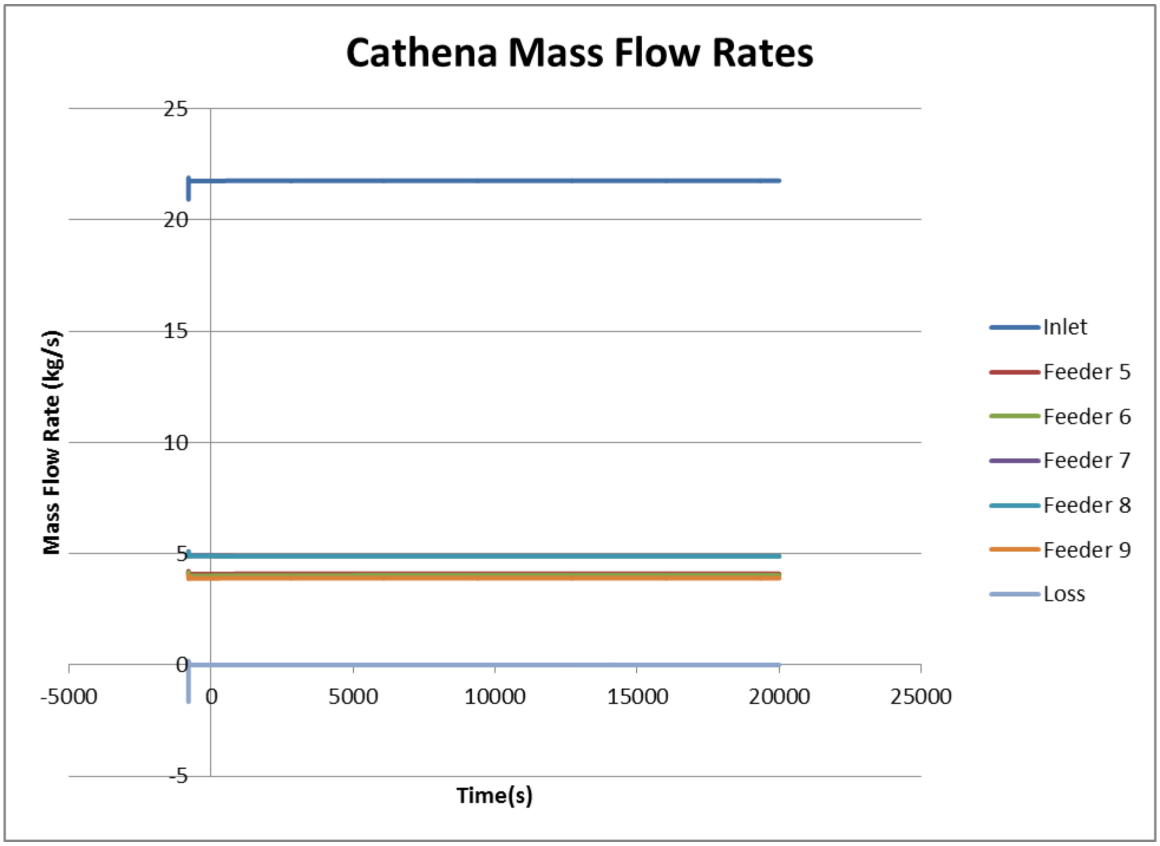

Figure 5.26: CATHENA Mass Flow Rate

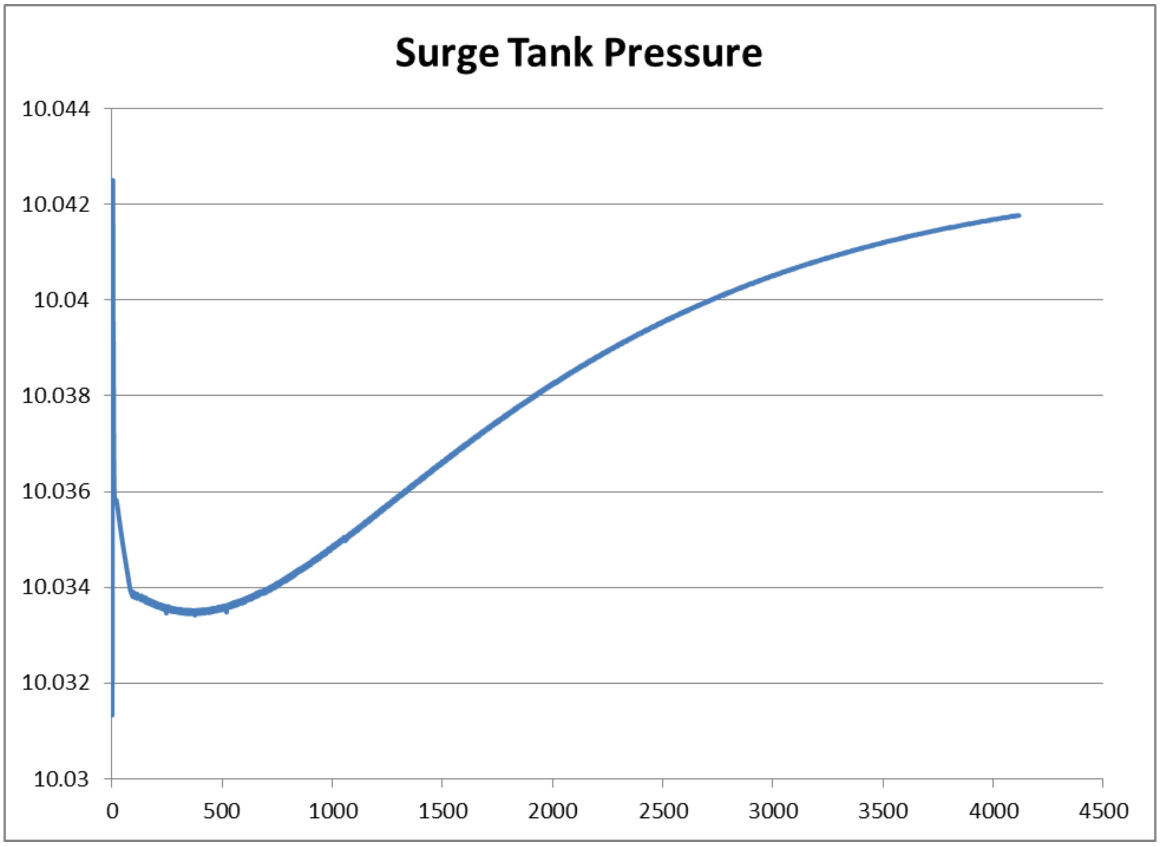

Figure 5.27: CATHENA Surge Tank Pressure

flow channel should demonstrate its own unique solution.

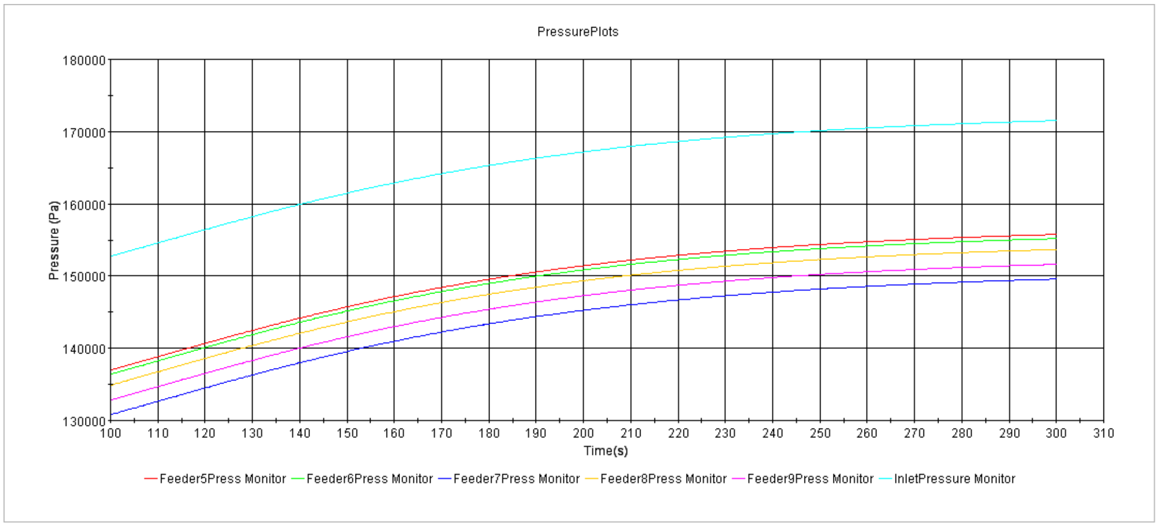

Figure 5.28: STAR-CCM+ Pressure Plot

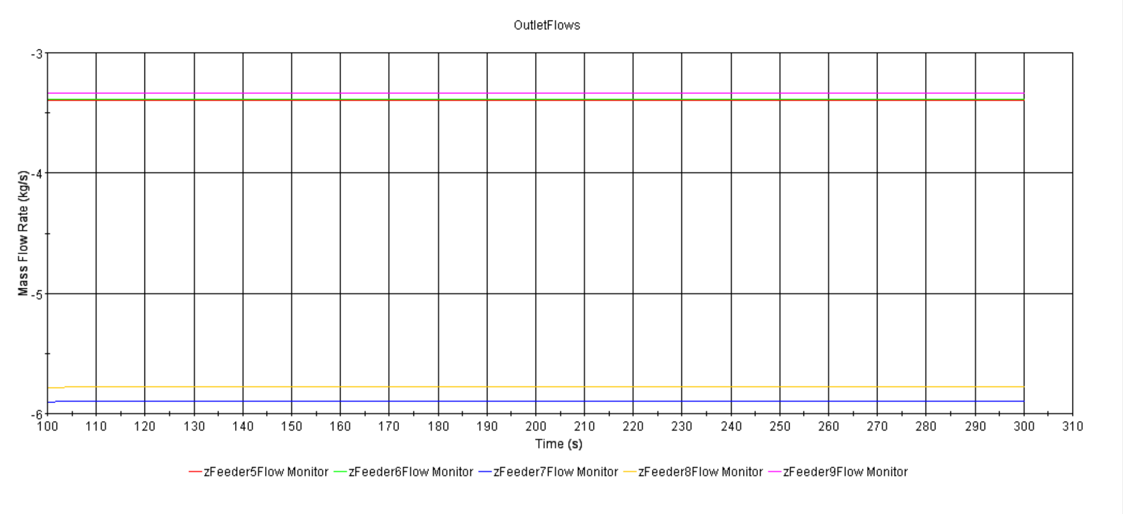

Figure 5.29: STAR-CCM+ Outlet Flows

5.2.7.2 Configuration 2: Inverted Boundaries

The second alternate configuration attempted was that of a mass flow inlet, 5 pressure outlets for CATHENA, and a single pressure inlet, 5 mass flow outlets for STAR-CCM+. These results may be seen in figures 5.30 to 5.32. While appearing quite stable, the results provided by this configuration did not provide the data output that is desired from the system. In this configuration, the flow split is no longer calculated by the CFD code. This is the primary piece of information desired from the use of a 3D code, since the fluid flow rate has such a large effect on the rest of the system and such 3D calculations are better performed by CFD, not by 1D, two-fluid codes.

After reviewing these alternate possibilities for boundary condition configurations, it was determined that the original boundary condition set up was the proper configuration to pursue. This is, once again, a single pressure inlet with 5 mass flow outlets in CATHENA, and a single mass flow inlet with 5 pressure outlets for STAR-CCM+. However, a successful steady state configuration is still to be found.

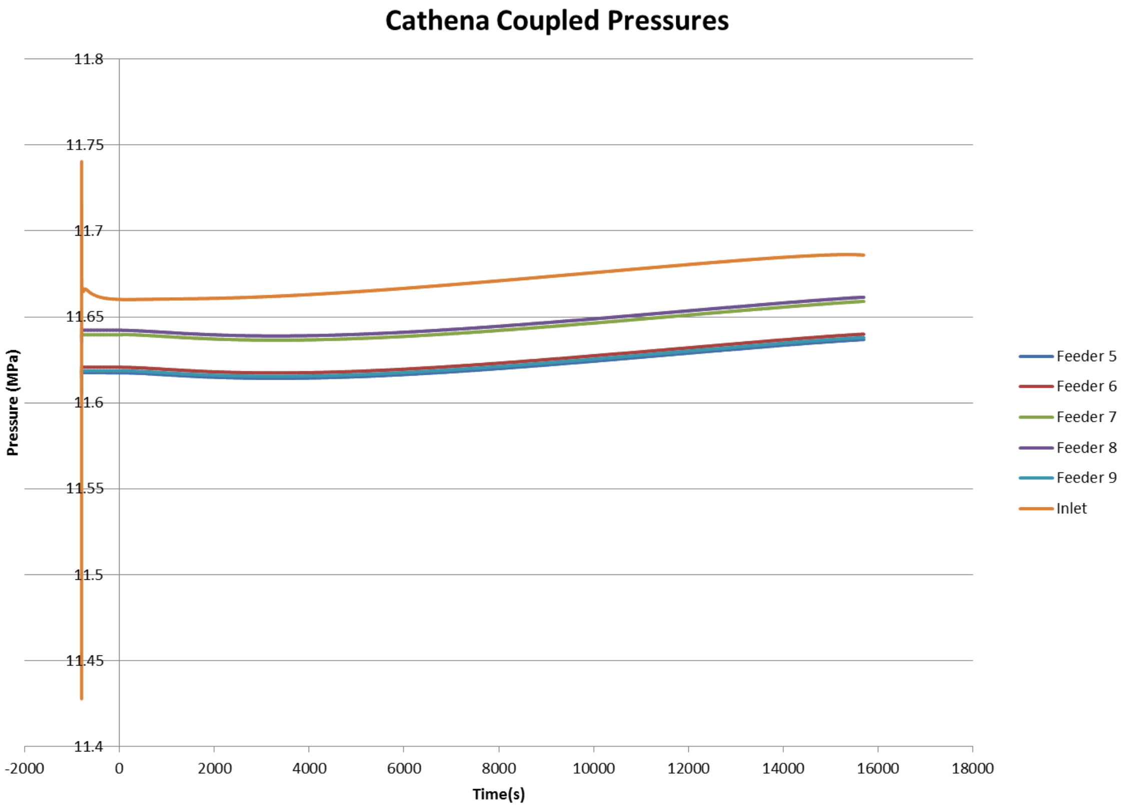

Figure 5.30: CATHENA Coupled Pressures

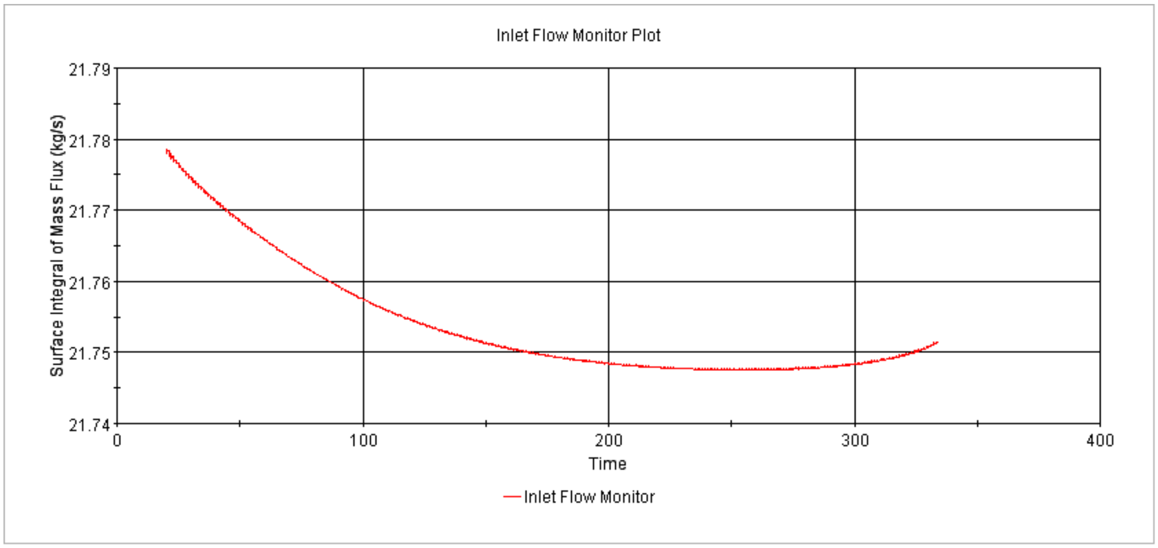

Figure 5.31: STAR-CCM+ Header Inflow

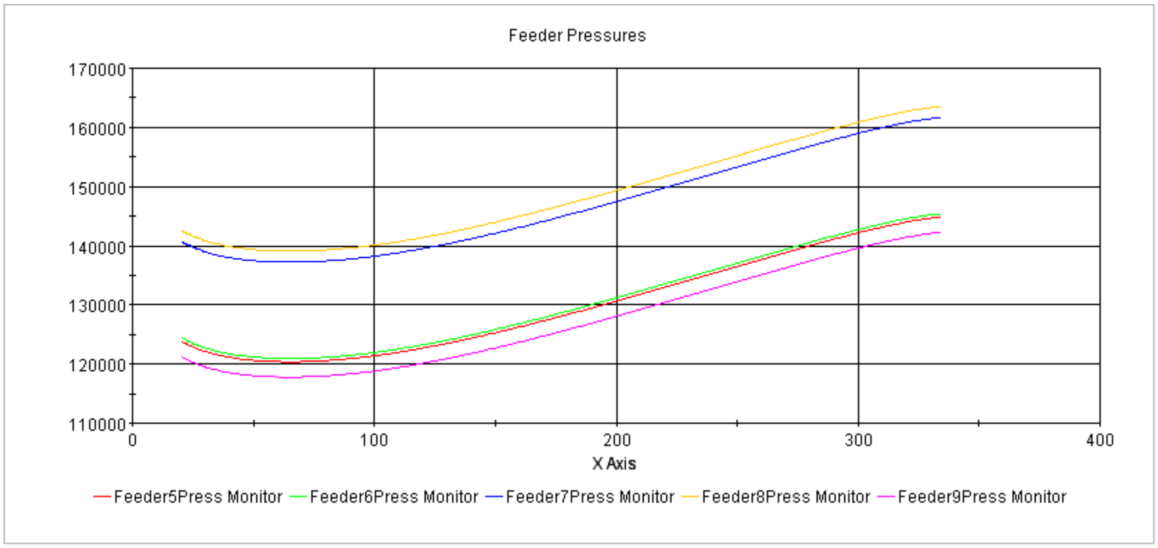

Figure 5.32: STAR-CCM+ Feeder Pressures

After reviewing these alternate possibilities for boundary condition configurations, it was determined that the original boundary condition set up was the proper configuration to pursue. This is, once again, a single pressure inlet with 5 mass flow outlets in CATHENA, and a single mass flow inlet with 5 pressure outlets for STAR-CCM+. However, a successful steady state configuration is still to be found.

5.2.8 Possible Loss of Energy in Code Coupling

The working hypothesis for explaining the lack of convergence of the coupled codes and the pressure deficit seen in figure 5.20 is that the non-uniform velocity profile produced by STAR-CCM+ carries different momentum and energy fluxes than the uniform velocity distribution implicit in the one-dimensional CATHENA case (assuming the mass fluxes are the same). This can be shown using the following form of the Bernoulli equation with losses for a fictitious pipe crossing the interface plane between STAR-CCM+ and CATHENA as a cross section. The general form of the Bernoulli equation with losses may be seen in the equation below, with variable definitions in table 5.14 (Blevins, 1992).

$$\frac{\rho\alpha_1 V_1^2}{2} + p_1 + \rho g z_1 - (\frac{\rho\alpha_2 V_2^2}{2} + p_2 + \rho g z_2) = \rho(u_1 - u_2) \tag{5.1}$$

α is the kinetic energy correction coefficient defined by equation 5.2 (Bobok, 1993).

$$\alpha \equiv \frac{E_{k,real}}{E_{k,uniform}} = \frac{\int_A v^3 dA}{V^3 A_T} \tag{5.2}$$

Typical values for α are shown in table 5.15.

A	Pipe Cross Sectional Area
A_T	Total Cross Sectional Area (Integral of dA over A)
α	Kinetic Energy Correction Coefficient
g	Acceleration due to Gravity
p	Static Pressure
ρ	Fluid Density
u	Specific Internal Energy
V	Cross Section Averaged Fluid Velocity
v	Local Velocity
z	Height

Table 5.14: Variable Definitions (Blevins, 1992)

Flow Profile	α Value
Uniform Velocity over Cross Section	1
Fully Developed Laminar Flow in a Circular Pipe	4/3
Fully Developed Turbulent Flow in a Circular Pipe	1.01 to 1.05

Table 5.15: Typical α Values (Blevins, 1992)

Applying this to the imagined pipe crossing between STAR-CCM+ and CATHENA in figure 5.33, equation 5.3 becomes appropriate. The indices 1 and 2 are changed to S, for STAR-CCM+ and C, for CATHENA.

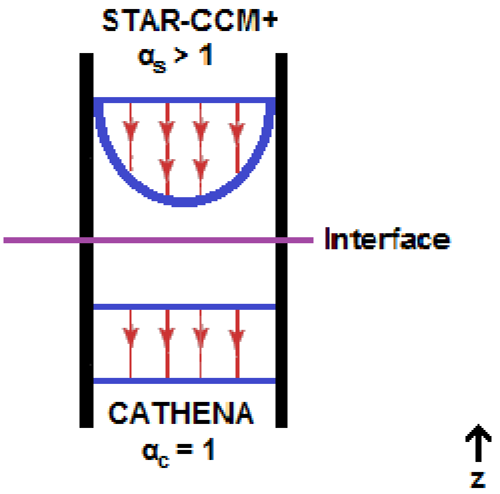

Figure 5.33: Idealized Interface

$$\frac{\rho\alpha_S V_S^2}{2} + p_S = \frac{\rho\alpha_C V_C^2}{2} + p_C + \rho(u_S - u_C) + \rho g(z_C - z_S) \tag{5.3}$$

From the continuity equation,

$$V_S = V_C = \frac{\dot{m}}{\rho A_T} = V \tag{5.4}$$

As the distance between the cross sections at which the STAR-CCM+ and CATHENA values approaches zero, the last two terms in equation 5.3 vanish. This leads to equation 5.5.

$$P_C = P_S + \frac{(\alpha_S - 1)\rho V^2}{2} \tag{5.5}$$

Since α_S is greater than 1 (for any non-uniform STAR-CCM+ flow profile), if P_C is set to P_S in the coupling procedure, then energy is lost in transition from STAR-CCM+ to CATHENA. To correct for this, the interface pressure in CATHENA should be increased by the last term on the right hand side. This would require, at every boundary condition update from STAR-CCM+ to CATHENA, calculation of α_S from STAR-CCM+ outlet profiles. To perform this correction would likely require access to the source code for CATHENA, which is not possible at this time.

In order to determine if this mismatch in boundary flow profile is the cause of the gradual decline in predicted pressure, selection of alternate boundary break points could be useful. By setting the coupling positions closer to areas in the CFD model where the flow profile becomes as uniform as possible, such as the position where the inlet pipe meets the header tank, the observed pressure loss should be less pronounced over coupling exchanges. If this hypothesis proves correct, then it would be a strong indication that the described mismatch in carried momentum and kinetic energy is the cause of the observed pressure decline.

In the more general case of non-isothermal flow, which may be addressed in the future, the introduction of a similar coefficient for enthalpy may be necessary to establish a stable interface between codes. This coefficient would compensate for energy lost through the difference in interface velocity and enthalpy distributions between the coupled codes.

Chapter 6

CONCLUSIONS and EXTENSIONS

6.1 Conclusions

Updating and expanding modeling resources is an essential component of nuclear safety analysis. Combining an information rich CFD component with a computationally conservative thermalhydraulic component is a logical next step for use in many nuclear systems. A coupled CFD/thermalhydraulic system was thus developed to demonstrate the feasibility of coupling the two chosen codes. This study represents the initial steps in attempts to integrate a CFD capability into a CATHENA thermalhydraulic system analysis.

6.2 The Coupled System

After preliminary tests and familiarization with the required programs, a coupling program was written in FORTRAN to exploit the CATHENA PVM function, and a JAVA program was written to interface with the JAVA scripting available in STAR-CCM+. A number of boundary configurations were attempted and it was determined that use of a single pressure inlet and five mass flow outlets in CATHENA, matched to a single mass flow inlet with five pressure outlets in STAR-CCM+ provided most meaningful results. It was also determined that care must be taken with use of boundary conditions to avoid overspecification of the problem, as demonstrated by the instabilities introduced into CATHENA through the addition of boundary conditions to those already present in the unmodified case (in the form of the pressurizer boundary condition). Unfortunately, the coupled system was unable to match the steady state results predicted by CATHENA, and is, therefore, not yet ready for problems of increased complexity, such as transient or two-phase flow.

6.3 Recommendations for Future Work

Through the coupling attempt outlined in this paper, an understanding of the goals and difficulties involving code coupling has been obtained. Throughout the course of this project, several avenues for progressing this research have become clear.

6.3.1 Improve Coupling Code Functionality

The most obvious progression of the work outlined in this report would be the modification of existing code to provide a stable steady state solution. While every effort was made to create a functional code interface, a new approach might be necessary to provide a viable coupled system for accurate boundary condition exchange. The recommended next step is to include, in the coupling code, the correction coefficients outlined in section 5.2.8. Should this prove to be insufficient, it may be necessary to fundamentally alter the approach to coupling implementation.

Recent additions to STAR-CCM+ include a coupling component to RELAP5 (refer to section 2.4.2). This would provide a much more streamlined study as elaborate workarounds, such as those attempted throughout the course of this work, would no longer be necessary for a functional system.

6.3.2 Reevaluate CFD Modeled Component

An alternative selection of the CFD component used in the coupled system is worth consideration. Introduction of a full pass simulation in CFD could provide a much more flexible structure to be coupled to CATHENA. In this case, only two new boundary conditions would be created, one inlet, and one outlet, and the entire complexity of flows would be handled by the CFD code. If it is undesirable to simulate all of the flow channels, a porous media model could be employed to reduce the complexity of the model. This approach would reduce the number of boundary conditions present in CATHENA, and also allow the CFD model to more accurately model downstream effects that can have an effect on header flow conditions. Increasing the complexity of the CFD portion of the simulation would likely cause a significant increase in computational cost.

6.3.3 One-Directional Coupling

One possibility for extracting information relevant to TH system flow from the CFD would be to use the flow solution from STAR-CCM+ to enforce a flow solution on CATHENA, through the use of valve or junction resistance components. By using a control program to adjust valve opening fraction or junction resistance levels, header flows in CATHENA could be adjusted to match the results provided by STAR-CCM+.

6.3.4 Recommendation for CATHENA

If the use of a pressure correction factor presented in section 5.2.8 is insufficient to resolve the boundary condition mismatch, an alternate method would involve modification of CATHENA itself. It may be insufficient to specify only mass or momentum at the boundary, since specification of one would cause improper 3D to 1D translation of the other. This boundary mismatch could be resolved through the addition of an option to specify both mass and momentum fluxes at a boundary. Extending the boundary condition options in this way would allow for the passing of cross-section averaged momentum from the CFD code in the following form:

$$\frac{\int \nu\rho\nu dA}{A} \tag{6.1}$$

Specification of momentum and mass fluxes at CATHENA boundaries would ensure conservation of both mass and momentum by accurately averaging three dimensional values into one dimension.

6.3.5 Applicability to Transient Cases

The next logical step after a stable coupled system is established, would be a simulation attempt of a more complex problem, namely a transient simulation of single phase flow within the CFD modeled header. This would necessitate transfer and parsing of additional values, such as enthalpy and fluid density, in order to maintain system congruence.

The primary purpose of simulating components of the thermalhydraulic system in CFD is to obtain greater detail of complex phenomena occurring mainly during postulated accident scenarios, such as a LOCA. Therefore, should the simulation of a single-phase transient be successful, the final goal of modeling two-phase transient conditions within a header, including feedback from the rest of the thermalhydraulic system, would be within reach. Achieving this goal would demonstrate the feasibility of applying this modeling technique to a full CANDU thermalhydraulic loop, and allow for CFD analysis of various components in a manner which is much more reflective of the actual real world conditions.

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Appendix A

The CATHENA Side Custom Code

```

$STRICT
      SUBROUTINE TROL_BB_Con ( PvmOld, Pvm, Old, Now )
!
C   DECLARATIONS AND INITIALIZATIONS
C ---- Reference modules.
      USE TROL_BB_Pvm_def  ! TRAOL_BB_Pvm type definition.
      USE TROL_BB_All_def  ! TROL_BB_All type definition.
!
!  All variables must be explicitly declared.
      IMPLICIT  NONE
CHB=TROL_BB_Con
!
!       SYNOPSIS
```

```
!         This subroutine is the main subroutine of plant controller
!         that assigns values to all parameters that should be
!         transfered to thermalhydraulics code.
!
CHE
!
!       DECLARATIONS AND INITIALIZATIONS
!  Declare subroutine arguments.
CPB=TROL_BB_Con
CP>INPUT
CP<OUTPUT
        TYPE (TROL_BB_Pvm), INTENT(INOUT) ::
     &  PvmOld,   ! PVM-related variables from previous step
     &  Pvm       ! PVM-related variables for this step
!
        TYPE (TROL_BB_All), INTENT(INOUT) ::
     &  Old,   ! TROL-BB arguments from previous step.
     &  Now    ! TROL-BB arguments for this step.
CPE
CP<OUTPUT
!
CPE
!  Declare local variables.
```

```
CDB=TROL_BB_Con
        INTEGER ::
       &I,
       &J, !loop counter
       &CATOUT=57, !cathena output text file index
       &STAROUT=58, !STAR output text file index
       &CATFLAG=59, !cathena done flag index
       &STARFLAG=56, !star done flag index
       &IERROR=0, !error flag
       &NOUT=6, !temporary test number of variables from cathena
       &WAITTIME=1 !Delay between file exist checks
!
        LOGICAL:: CATDONE=.TRUE. !is star still reading?
        LOGICAL:: STARDONE=.FALSE. !star done writing?
!
!
CDE
!         MODIFICATION HISTORY
CNB=TROL_BB_Con
!         Created
!           2005-04-11 by Aleksandar Vasic' (TB, AECL)
!         Modified 2011-02-21 by Paul Szymanski for STARCCM+ communication
```

```
CNE
!         open ( UNIT=PvmLgU, FILE=Pvm%LgName, STATUS='UNKNOWN',
!       &  POSITION='APPEND')
!            write (PvmLgU,*) 'TROL_BB_Con: Pvm%VIn(1..NIn)',
!       &       (Pvm%VIn(I), I=1,Pvm%NIn)
!
!
!Write cathena values to a file
!
!ENSURE STAR IS NOT READING FROM FILE

        WRITE(99,*) 'Check␣if␣cathena␣flag␣gone'

          PRINT *, '␣Checking␣if␣CATHENA_FLAG␣is␣gone␣(star␣done␣reading?)
␣␣␣␣␣&...'
        CATDONE=.TRUE.
        DO WHILE(CATDONE)
          INQUIRE ( FILE='C:\CatCouple\CAT_DONE_FLAG.txt', EXIST=CATDONE)
          CALL SLEEP(WAITTIME)
         ! added wait in case of too many requests
        END DO  ! wait for star to finish writing
        WRITE(99,*) 'Open␣␣CAT_OUT'
```

```

      OPEN (UNIT = CATOUT, STATUS='UNKNOWN', FILE =
     &  'C:\CatCouple\CAT_OUT.txt', ACTION='WRITE'  )
!
      WRITE(99,*)  'write to CAT_OUT'
!
      WRITE (CATOUT,168) Pvm%VIn(1)
      WRITE (CATOUT,169) Pvm%VIn(2)
      DO J=3 , Pvm%NIn
        WRITE (CATOUT,168) Pvm%VIn(J)
        PRINT *, Pvm%VOut(J)
      END DO
  168 FORMAT(F12.5)
  169 FORMAT(F12.0)
      WRITE(99,*)  'Close CAT_OUT'
      CLOSE (UNIT=CATOUT)
!
!     CREATE FLAG FILE FOR JAVA CODE
      WRITE(99,*)  'Create CAT_DONE_FLAG'
      OPEN (UNIT=CATFLAG, STATUS='NEW',FILE=
     &  'C:\CatCouple\CAT_DONE_FLAG.txt', ACTION='WRITE'  )
      CLOSE (CATFLAG)

```

```
!OPEN THE STAR output file and read from it when it is finished being  written to
        WRITE(99,*)  'Check␣if␣star␣is␣done'
           PRINT *,  '␣Checking␣if␣STAR␣is␣done...'
        STARDONE=.FALSE.
        DO WHILE(.NOT. STARDONE)
          INQUIRE ( FILE='C:\CatCouple\STAR_DONE_FLAG.txt', EXIST=STARDONE)
          CALL SLEEP(WAITTIME)
         ! add some sort of wait? too many requests?
        END DO  ! wait for star to finish writing
        WRITE(99,*)  'Open␣STAR_OUT'
!
        OPEN (UNIT = STAROUT, STATUS='OLD', FILE =
     &   'C:\CatCouple\STAR_OUT.txt', ACTION='READ', IOSTAT=IERROR)
!
        WRITE(99,*)  'Read␣from␣STAR_OUT'
        DO J=1  , Pvm%NOut
          READ (STAROUT,*) Pvm%VOut(J)
          PRINT *, Pvm%VOut(J)
        END DO
        WRITE(99,*)  'Close␣STAR_OUT'
        CLOSE (UNIT=STAROUT)
```

```
            WRITE(99,*) 'Create STAR_DONE_FLAG'
            OPEN (UNIT=STARFLAG, STATUS='OLD',FILE=
     & 'C:\CatCouple\STAR_DONE_FLAG.txt', ACTION='READ' )
      CLOSE(UNIT=STARFLAG, STATUS='DELETE')
!
!
!
!
!
!        DO J = 1, Pvm%NOut
!          The following line was written for testing only!!
!           Now%CPar(J) = Old%CPar(J) + Pvm%VIn(J) + Pvm%VIn(J+5)
!
!          Assignment of the outgoing variables from TROL-BB defined array.
!           Pvm%VOut(J) = Now%CPar(J)
!        END DO
!
!       write (PvmLgU,*) 'TROL_BB_Con: Pvm%VOut(1..NOut)',
!   &      (Pvm%VOut(I), I=1,Pvm%NOut)
!     close ( PvmLgU )
!
! Return to TROL_BB_Int.
```

```
        RETURN
!
        END SUBROUTINE TROL_BB_Con
```

Appendix B

STAR-CCM+ Side Custom Code

B.1 The cathenaread Function

```
package cathenaread;
 /** * * @author Szymanski */
  public class Main{ /** * @param args the command line arguments */
   public static void main(String[] args){
double catSimTime=0;
double starSimTime=0;
JCathena puppetMaster=new JCathena();
double[] valyus={10000,100000,100000,100000,100000,100000,0};
puppetMaster.catTalk(valyus,'r');
catSimTime=valyus[0];
puppetMaster.catTalk(valyus,'w');
```

```
starSimTime=valyus[0];
System.out.println("Time DIfference: "+(catSimTime-starSimTime));
}}
```

B.2 The JCathena Function

```

package cathenaread;
import java.io.*;
import java.util.logging.Level;
import java.util.logging.Logger;
 /** * * @author Szymanski */
public class JCathena{//Determines the read or write action
public double[] catTalk(double[] valyus, char action){
int numVar=7;//Number of variables in array
if(action=='r'){
 valyus=readCat(valyus,numVar);
System.out.println("CAT in values:");
System.out.println("Inlet: "+valyus[1]);
System.out.println("Out1: "+valyus[2]);
System.out.println("Out2: "+valyus[3]);
System.out.println("Out3: "+valyus[4]);
System.out.println("Out4: "+valyus[5]);
System.out.println("Out5: "+valyus[6]);
```

```
 System.out.println("Cat␣Time:␣"+valyus[0]);
}//end if action == 'r'
elseif(action=='w'){
 writeCat(valyus,numVar);
System.out.println("STAR␣Out:");
System.out.println("Inlet:␣"+valyus[1]);
 System.out.println("Out1:␣"+valyus[2]);
System.out.println("Out2:␣"+valyus[3]);
System.out.println("Out3:␣"+valyus[4]);
 System.out.println("Out4:␣"+valyus[5]);
 System.out.println("Out5:␣"+valyus[6]);
 System.out.println("Star␣Time:␣"+valyus[0]);
}
return valyus; }
```

B.3 The readCat Function

```


private static double[] readCat(double[] valyous,int numVar){
BufferedReader readinator=null;
String dirName="C:\\CatCouple";//directory
File catDir=new File(dirName);
if(!catDir.exists()){// If directory doesnt exist
catDir.mkdir();// Make it }
```

```
elseif(!catDir.isDirectory()){
System.err.println(catDir+”␣does␣not␣exist”);
 returnvalyous; }

FilecatOutput=newFile(catDir,”CAT_OUT.txt”);
FileReader fzile;
 try{ fzile=new FileReader(catOutput);
readinator=new BufferedReader(fzile);
 }catch(FileNotFoundExceptionex){ Logger.getLogger(Main.class
     .getName()).log(Level.SEVERE, null, ex); }
// Create flag file which indicates star has finished writing
     to file
 File catDoneFlag=new File(catDir,”CAT_DONE_FLAG.txt”);
//wait for cathena to write if necessary
while(!catDoneFlag.exists()){//wait until cathena finishes
    writing

try{ System.out.println(”’Waiting␣/’”);
Thread.sleep(750);// do nothing for 750 milisecond

}catch(InterruptedException e) { e.printStackTrace(); } }

//read from text file StringtempString=null;
try{
```

```
for(inti=0;i<numVar;i++){
 tempString=readinator.readLine(); valyous[i]=Double.valueOf(tempString.trim()).doubleValue();
 }
readinator.close();
}catch(IOException ex){ Logger.getLogger(Main.class.getName()).log(Level.SEVERE,null,ex); }
//return into mainline
catDoneFlag.delete();
return valyous;
} }
```

B.4 The writeCat Function

```


private static void writeCat(double[] valyus,int numVar){
StringdirName=”C:\\CatCouple”;//directory
 FilecatDir=newFile(dirName); // Create flag file which indicates star has finished writing to file
 File starDoneFlag=new File(catDir,”STAR_DONE_FLAG.txt”);
if(!catDir.exists()){// If directory doesnt exist
catDir.mkdir();// Make it
}
elseif(!catDir.isDirectory()){
```

```
System.err.println(catDir+" does not exist");
return; }

File starOutput=newFile(catDir,"STAR_OUT.txt");
//wait for cathena to write if necessary
while(starDoneFlag.exists()){//Make sure cathena has finished reading
try { Thread.sleep(750);// do nothing for 750 miliseconds System.out.println("'Waiting /'");
} catch(InterruptedExceptione) { e.printStackTrace(); } }

 //Create output stream

PrintWriter writinator=null;
try{ writinator=new PrintWriter(new BufferedWriter(new FileWriter( starOutput)));
}catch(IOException ex){ Logger.getLogger(Main.class.getName()).log(Level.SEVERE,null,ex); }
writinator.format("%.0f",valyus[0]);//output pressure in decimal format
writinator.println();
 for(int i=1;i<numVar;i++){
writinator.format("%.3f",valyus[i]);//output mass flow rates to 3 decimal places
```

```
writinator.println(valyus[i]);
} writinator.close();
// Create flag file which indicates star has finished writing to file
try{ starDoneFlag.createNewFile(); }
catch(IOExceptionex){ Logger.getLogger(Main.class.getName()).log(Level.SEVERE, null, ex); }}
```

Appendix C

The STAR-CCM+ Run Script

```java
// STAR-CCM+ macro: FinalRunScript2.java
package macro;

import java.util.*;
import star.common.*;
import star.base.neo.*;
import star.base.report.*;
import star.flow.*;
import cathenaread.*;
import star.userdefinedeos.*;
import star.metrics.*;

public class FinalRunScript2 extends StarMacro {

```

```
public void execute() {
execute0();
  }

private void execute0() {

Simulation simulation_0 = getActiveSimulation();

Region region_0 =
 simulation_0.getRegionManager().getRegion(”fluid”);

Boundary boundary_0 =
 region_0.getBoundaryManager().getBoundary(”inlet”);

MassFlowRateProfile massFlowRateProfile_0 = boundary_0.
    getValues().get(MassFlowRateProfile.class);

Boundary boundary_1 =
 region_0.getBoundaryManager().getBoundary(”Feeder5”);

StaticPressureProfile staticPressureProfile_0 =
boundary_1.getValues().get(StaticPressureProfile.class);

Boundary boundary_2 =
```

```
 region_0.getBoundaryManager().getBoundary("Feeder6");

StaticPressureProfile staticPressureProfile_1 =
 boundary_2.getValues().get(StaticPressureProfile.class);

Boundary boundary_3 =
 region_0.getBoundaryManager().getBoundary("Feeder7");

StaticPressureProfile staticPressureProfile_2 =
 boundary_3.getValues().get(StaticPressureProfile.class);

Boundary boundary_4 =
 region_0.getBoundaryManager().getBoundary("Feeder8");

StaticPressureProfile staticPressureProfile_3 =
 boundary_4.getValues().get(StaticPressureProfile.class);

Boundary boundary_5 =
 region_0.getBoundaryManager().getBoundary("Feeder9");

StaticPressureProfile staticPressureProfile_4 =
 boundary_5.getValues().get(StaticPressureProfile.class);


```

```
PhysicalTimeStoppingCriterion physicalTimeStoppingCriterion_0 =
((PhysicalTimeStoppingCriterion)simulation_0.getSolverStoppingCriterionManager().getSolverStoppingCriterion(”Maximum␣Physical␣Time”));

ReportMonitor reportMonitor_0 =
((ReportMonitor) simulation_0.getMonitorManager().getMonitor(”simTime␣Monitor”));

ReportMonitor reportMonitor_1 =
 ((ReportMonitor) simulation_0.getMonitorManager().getMonitor(”InletPressure␣Monitor”));

ReportMonitor reportMonitor_2 =
 ((ReportMonitor) simulation_0.getMonitorManager().getMonitor(”Feeder5␣Flow␣Monitor”));

ReportMonitor reportMonitor_3 =
 ((ReportMonitor) simulation_0.getMonitorManager().getMonitor(”Feeder6␣Flow␣Monitor”));

ReportMonitor reportMonitor_4 =
```

```
 ((ReportMonitor) simulation_0.getMonitorManager().getMonitor("Feeder7␣Flow␣Monitor"));

ReportMonitor reportMonitor_5 =
 ((ReportMonitor) simulation_0.getMonitorManager().getMonitor("Feeder8␣Flow␣Monitor"));

ReportMonitor reportMonitor_6 =
 ((ReportMonitor) simulation_0.getMonitorManager().getMonitor("Feeder9␣Flow␣Monitor"));


//PVM Communication begins here
double catSimTime=0;
double starStepTime=0;
double setStarStep=0;
double starSimTime=0;
double inputRelax=0.1;//set relaxation constant currently 10% of new value
double timeRef=21.0;  //     offset compared to cathena initiating time
double maxTime=400;
double refPress=11500000;//simulation reference pressure
```

```
double timeFactor=1; //time simulated per time step compared
    to cathena time simulated

//initialize relaxation parameters
double StarInFlo=21.786;
double StarOut5=140500.0;
double StarOut6=143738.0;
double StarOut7=156659.0;
double StarOut8=157616.0;
double StarOut9=146930.0;

double catInletP=11666000;
double catOutlet5=4.081;
double catOutlet6=4.014;
double catOutlet7=4.903;
double catOutlet8=4.896;
double catOutlet9=3.890;

 JCathena puppetMaster = new JCathena();
double[] valyus={2,10000,100000,100000,100000,100000,100000};

ImplicitUnsteadySolver implicitUnsteadySolver_0 =
   ((ImplicitUnsteadySolver)simulation_0.getSolverManager().
      getSolver(ImplicitUnsteadySolver.class));
```

```

implicitUnsteadySolver_0.getTimeStep().setValue(0.1);//set
    timestep interval

int totalRuns=5000;
for (int Banana=0; Banana<totalRuns; Banana++){

puppetMaster.catTalk(valyus, 'r');

StarInFlo=(inputRelax*(valyus[1])+(1-inputRelax)*StarInFlo);
StarOut5=(inputRelax*(valyus[2]-refPress)+(1-inputRelax)*
    StarOut5);
StarOut6=(inputRelax*(valyus[3]-refPress)+(1-inputRelax)*
    StarOut6);
StarOut7=(inputRelax*(valyus[4]-refPress)+(1-inputRelax)*
    StarOut7);
StarOut8=(inputRelax*(valyus[5]-refPress)+(1-inputRelax)*
    StarOut8);
StarOut9=(inputRelax*(valyus[6]-refPress)+(1-inputRelax)*
    StarOut9);



```

```
massFlowRateProfile_0.getMethod(ConstantScalarProfileMethod.class).getQuantity().setValue(StarInFlo);

staticPressureProfile_0.getMethod(ConstantScalarProfileMethod.class).getQuantity().setValue(StarOut5);

staticPressureProfile_1.getMethod(ConstantScalarProfileMethod.class).getQuantity().setValue(StarOut6);

staticPressureProfile_2.getMethod(ConstantScalarProfileMethod.class).getQuantity().setValue(StarOut7);

staticPressureProfile_3.getMethod(ConstantScalarProfileMethod.class).getQuantity().setValue(StarOut8);

staticPressureProfile_4.getMethod(ConstantScalarProfileMethod.class).getQuantity().setValue(StarOut9);


starStepTime=valyus[0]-catSimTime;

catSimTime=valyus[0];

```

```
implicitUnsteadySolver_0.getTimeStep().setValue(starStepTime);//Time Step Control

                    physicalTimeStoppingCriterion_0.getMaximumTime().setValue(timeRef+(timeFactor*valyus[0]));//Max time step control for explicit solution

 starSimTime=valyus[0];

simulation_0.getSimulationIterator().run();

Simulation mySim = getActiveSimulation();

Collection<Report> reportCollection =
mySim.getReportManager().getObjects();

int reportNumber=0;

for (Report thisReport : reportCollection){ //Acquire values to send to cathena

if (reportNumber==1){  //Only write wanted reports for cathena
```

```

valyus[1]=thisReport.getReportMonitorValue();//Pressure and Mass flows
reportNumber++;
}else if(reportNumber==2){

valyus[2]=thisReport.getReportMonitorValue();//Pressure and Mass flows
reportNumber++;
}else if(reportNumber==3){

valyus[3]=thisReport.getReportMonitorValue();//Pressure and Mass flows
reportNumber++;
}else if(reportNumber==4){

valyus[4]=thisReport.getReportMonitorValue();//Pressure and Mass flows
reportNumber++;
}else if(reportNumber==5){

valyus[5]=thisReport.getReportMonitorValue();//Pressure and Mass flows
reportNumber++;
```

```
}else if(reportNumber==6){

valyus[6]=thisReport.getReportMonitorValue();//Pressure and
    Mass flows
reportNumber++;
}else if(reportNumber==0){

valyus[0]=thisReport.getReportMonitorValue();//Pressure and
    Mass flows
reportNumber++;
                        }
                        }

// remove negatives which indicate outflow and add reference
    pressure to working pressure

valyus[0]=(-timeRef)+valyus[0];//time
valyus[1]=(valyus[1]+refPress);//inflow
valyus[2]=(-valyus[2]);//feed5+ Pressure
valyus[3]=(-valyus[3]);
valyus[4]=(-valyus[4]);
valyus[5]=(-valyus[5]);
valyus[6]=(-valyus[6]);

```

```

//save old values for next loop and relax
catInletP=(inputRelax*valyus[1])+(1-inputRelax)*catInletP;
catOutlet5=(inputRelax*valyus[2])+(1-inputRelax)*catOutlet5;
catOutlet6=(inputRelax*valyus[3])+(1-inputRelax)*catOutlet6;
catOutlet7=(inputRelax*valyus[4])+(1-inputRelax)*catOutlet7;
catOutlet8=(inputRelax*valyus[5])+(1-inputRelax)*catOutlet8;
catOutlet9=(inputRelax*valyus[6])+(1-inputRelax)*catOutlet9;




//save values to be sent over PVM
valyus[1]=catInletP;
valyus[2]=catOutlet5;
valyus[3]=catOutlet6;
valyus[4]=catOutlet7;
valyus[5]=catOutlet8;
valyus[6]=catOutlet9;


puppetMaster.catTalk(valyus, 'w');

```

```
System.out.println("Time DIfference: " +(catSimTime-
    starSimTime));


//if (catSimTime>maxTime) break;
}
}
}
```

Appendix D

The Modified CATHENA Input File

```

'PROTECTED-SENSITIVE, RD-14M REFERENCE IDEALIZATION (2.01) 2008-11-24 ',
'Test B9401: 30mm RIH Break, High-P & Pimped ECI, Power Decay & Pump Ramp'/

'CONTROL PARAMETERS'/

'*** RD-14M FACILITY IDEALIZATION FOR TEST: B9401                              '/
'*** STEADY-STATE/TRANSIENT SIMULATION                                          '/
```

```
'*** 2008-11-24; BY S. LIU                                                 '/
'*** 2011-01-01- Modified by Paul Szymanski to be coupled to STAR CCM+     '/
'***              Removed transient triggers                               '/
'*** THE LOOP SETUP:                                                       '/
'***     PPRIMARY CIRCUIT:                        5 CHANNELS PER PASS      '/
'***     SECONDARY CIRCUIT:                       HIGH POWER MODE          '/
'***     ECI SYSTEM:                              DARLINGTON ECI           '/
'***     PRESSURIZER SYSTEM:                      ON/OFF                   '/
'***     OUTLET-HEADER INTERCONNECT:              NO                       '/
'***                                                                       '/
'***     BOILERS TUBE # (BO1/BO2):                39/41                    '/
```

```
'***      HEAT ELEMENT DISCONNECTED:                   HS7 E#5/HS12 E
   #7               '/
'***      TRACE HEATING:                               OFF
                               '/
'***      NEUTRON SCATTEROMETER:                       NOT INSTALLED
                    '/
'***      ECI LINE ORIFICE OR25 DIAMETER:              35.5 MM
                          '/
'***      ECI P14 INLET LINE:                          Before 1998
   MARCH              '/
'***      ECI ISOLATION VALVES:                        CLOSED/OPEN
                      '/
'***      SURGE TANK LINE ISOLATION VALVE:             OPENED
                           '/
'***      INTERCONNECT ORIFICE SIZE:                   N/A
                               '/
'***      BREAK SIZE AND LOCATION:                     30-mm IH
                         '/
'***


   '/
'*** OPERATION PARAMETERS
                                                     '/
```

```
'***      INPUT POWER:                                   4 MW -> 160 kW
    /Pass            '/
'***      PARIMARY PUMPS:                                3290 RPM/
    RAMPDOWN              '/
'***      PRIMARY-SIDE PRESSURE (AT SURGE TANK):         10.0 MPa
                          '/
'***      TRACE HEATING POWER (INLET/OUTLET):            0.0/0.0
                           '/
'***      SECONDARY-SIDE PRESSURE:                       4.4 MPa
                           '/
'***      BOILER LEVEL (BO1/BO2):                        55.3% /54.6%
                       '/
'***      FEEDWATER TEMPERATURE:                         186 deg C
                         '/
'***      HIGH-PRESSURE ECI START AT PRESSURE :          5.5 MPa
                           '/
'***      LOW PRESSURE ECI START AT PRESSURE :           1.5 MPa
                           '/
'***


    '/
'*** IDEALIZATION
                                                        '/
```

```
'***      SECONDARY OUTLET B.C.:  WITH STEAM LINES
                            '/
'***      SURGE TANK:  RESERVOIR
                                               '/
'***      ECI TANK:    RESERVOIR
                                               '/
'***

   '/
'**********************************************************************

'* Last Updated: 24/11/2008
                                                 '/
'*

   '/



'SOLUTION CONTROL'/
-800.0,10000.0,,0.1,0.001,1,,0.5/

'PRINT CONTROL'/
500.0,500.0,500.0,,,,.TRUE./
```

```

'RESTART CONTROL'/
'','B9401.rst',500.0,,,,,/

'PROCESSING OPTION'/
'RUN'/'GENDECK','RD14M_B9401_new.inp'/

'NUMERIC OPTIONS'/
'#-TSTM-NE-TNC(-1)','#-PRESS-LOW(-9999)','#-HG-LOW(-9999)','#-HF-LOW(-9999)',
'#-PRESS-HIGH(-9999)','#-HG-HIGH(-9999)','#-HF-HIGH(-9999)',
'#-VEL-HIGH(-9999)','#GENHTP-CLIP(-9999)'/

'END'/



'COMPONENTS'/

'HDRIN' /NEW Reservoirs TO CUT PIPE
'HDROT5'/Header Outlets
'HDROT6'/
'HDROT7'/
'HDROT8'/
```

```
'HDROT9'/



'IF1HS5'  1.1979 -1.1131 5.5739E-4 .02664 4.5E-5 0.000 'CIRC' 2,,,9.8531E-4/ subtract 0.4253 from L and -0.25 from H
'IF2HS5'  2.0700  0.0000 5.5739E-4 .02664 4.5E-5 0.000 'CIRC' 3/
'IF3HS5'  3.5000 -2.7800 5.5739E-4 .02664 4.5E-5 0.000 'CIRC' 3,,,2.0141E-3/
'IEFTM5'  1.5033  0.0000 1.8354E-3 .02520 4.5E-5 0.000 'CIRC'/
2*0.5565,0.3903/
'IEFTS5'  1.1130  0.0000 2.3569E-3 .05478 4.5E-5 0.000 'CIRC' 3,,,2.9865E-3/
'HS5'     5.9400  0.0000 6.3573E-4 .00594 0.0000 11.23 '7ELMT' 12,,,,'FRICTION=FR_CREPT'/
'OEFTS5'  1.1130  0.0000 2.3569E-3 .05478 4.5E-5 0.000 'CIRC' 3,,,2.9865E-3/
'OEFTM5'  1.5033  0.0000 1.8354E-3 .02520 4.5E-5 0.000 'CIRC'/
0.3903,2*0.5565/
'OF3HS5'  3.5900  2.7800 9.6487E-4 .03505 4.5E-5 0.682 'CIRC' 3/
```

```
'OF2HS5'  3.8500  0.0000 9.6487E-4 .03505 4.5E-5 0.732 'CIRC'
     3/
'OF1HS5'  1.6232  1.3631 9.6487E-4 .03505 4.5E-5 0.308 'CIRC'
     2,,,1.6033E-3/

'IF1HS6'  0.7369 -0.6531 5.5739E-4 .02664 4.5E-5 0.000 'CIRC'
     2,,,7.2883E-4/subtract 0.4253 from L and -0.25 from H
'IF2HS6'  1.8600  0.0000 5.5739E-4 .02664 4.5E-5 0.000 'CIRC'
     3/
'IF3HS6'  7.1900 -5.7900 5.5739E-4 .02664 4.5E-5 0.000 'CIRC'
     6,,,4.0715E-3/
'IEFTM6'  1.5033  0.0000 1.8354E-3 .02520 4.5E-5 0.000 'CIRC
    '/
2*0.5565,0.3903/
'IEFTS6'  1.1130  0.0000 2.3569E-3 .05478 4.5E-5 0.000 'CIRC'
     3,,,2.9865E-3/
'HS6'     5.9400  0.0000 6.3573E-4 .00594 0.0000 10.81 '7ELMT
    ' 12,,,,'FRICTION=FR_CREPT'/
'OEFTS6'  1.1130  0.0000 2.3569E-3 .05478 4.5E-5 0.000 'CIRC'
     3,,,2.9865E-3/
'OEFTM6'  1.5033  0.0000 1.8354E-3 .02520 4.5E-5 0.000 'CIRC
    '/
0.3903,2*0.5565/
```

```
'OF3HS6'  7.2600   5.7900 9.6487E-4 .03505 4.5E-5 1.158 'CIRC' 6,,,7.0120E-3/
'OF2HS6'  3.6700   0.0000 9.6487E-4 .03505 4.5E-5 0.587 'CIRC' 3/
'OF1HS6'  1.1632   0.9031 9.6487E-4 .03505 4.5E-5 0.186 'CIRC' 2,,,1.1594E-3/

'IF1HS7'  0.3832   0.0000 9.6487E-4 .03505 4.5E-5 0.164 'CIRC' 3,,,7.2519E-4/subtract 0.33 from L
'IF2HS7'  0.5700  -0.5700 9.6487E-4 .03505 4.5E-5 0.189 'CIRC' 2/subtract 0.25 from L and -0.25 from H
'IF3HS7'  3.0800   0.0000 9.6487E-4 .03505 4.5E-5 0.708 'CIRC' 3/
'IF4HS7'  6.6400  -6.2300 9.6487E-4 .03505 4.5E-5 1.527 'CIRC' 5/
'IF5HS7'  4.5500   0.0000 9.6487E-4 .03505 4.5E-5 1.046 'CIRC' 4,,,4.4276E-3/
'IEFTM7'  1.5033   0.0000 1.8354E-3 .02520 4.5E-5 0.000 'CIRC'/
2*0.5565,0.3903/
'IEFTS7'  1.1130   0.0000 2.3569E-3 .05478 4.5E-5 0.000 'CIRC' 3,,,2.9865E-3/
'HS7'     5.9400   0.0000 6.3573E-4 .00594 0.0000 10.69 '7ELMT' 12,,,,'FRICTION=FR_CREPT'/
```

```
'OEFTS7'  1.1130  0.0000 2.3569E-3 .05478 4.5E-5 0.000 'CIRC'
     3,,,2.9865E-3/
'OEFTM7'  1.5033  0.0000 1.8354E-3 .02520 4.5E-5 0.000 'CIRC
    '/
0.3903,2*0.5565/
'OF5HS7'  4.9500  0.0000 9.6487E-4 .03505 4.5E-5 1.386 'CIRC'
     4,,,4.8136E-3/
'OF4HS7'  6.6300  6.3400 1.3134E-3 .04089 4.5E-5 1.856 'CIRC'
     5,,,8.5234E-3/
'OF3HS7'  5.9700  0.0000 1.3134E-3 .04089 4.5E-5 1.672 'CIRC'
     4/
'OF2HS7'  0.7100  0.7100 1.3134E-3 .04089 4.5E-5 0.199 'CIRC'
     2/
'OF1HS7'  0.7132  0.0000 1.3134E-3 .04089 4.5E-5 0.172 'CIRC'
     3,,,9.3672E-4/

'IF1HS8'  0.9403 -0.9240 9.6487E-4 .03505 4.5E-5 0.000 'CIRC'
     2,,,1.1980E-3/subtract 0.2629 from L and -0.25 from H
'IF2HS8'  3.3300  0.0000 9.6487E-4 .03505 4.5E-5 0.000 'CIRC'
     3/
'IF3HS8'  7.0900 -6.3300 9.6487E-4 .03505 4.5E-5 0.000 'CIRC'
     5/
'IF4HS8'  2.3300  0.0000 9.6487E-4 .03505 4.5E-5 0.000 'CIRC'
     3,,,2.2854E-3/
```

```
'IEFTM8'  1.5033  0.0000 1.8354E-3 .02520 4.5E-5 0.000 'CIRC
    '/
2*0.5565,0.3903/
'IEFTS8'  1.1130  0.0000 2.3569E-3 .05478 4.5E-5 0.000 'CIRC'
     3,,,2.9865E-3/
'HS8'     5.9400  0.0000 6.3573E-4 .00594 0.0000 10.28 '7ELMT
    ' 12,,,,'FRICTION=FR_CREPT'/
'OEFTS8'  1.1130  0.0000 2.3569E-3 .05478 4.5E-5 0.000 'CIRC'
     3,,,2.9865E-3/
'OEFTM8'  1.5033  0.0000 1.8354E-3 .02520 4.5E-5 0.000 'CIRC
    '/
0.3903,2*0.5565/
'OF4HS8'  2.5100  0.0000 9.6487E-4 .03505 4.5E-5 0.552 'CIRC'
     3/
'OF3HS8'  7.0700  6.3300 1.3134E-3 .04089 4.5E-5 1.555 'CIRC'
     5,,,9.1013E-3/
'OF2HS8'  6.1700  0.0000 1.3134E-3 .04089 4.5E-5 1.357 'CIRC'
     5/
'OF1HS8'  1.2032  1.1740 1.3134E-3 .04089 4.5E-5 0.265 'CIRC'
     2/

'IF1HS9'  0.3832  0.0000 5.5739E-4 .02664 4.5E-5 0.200 'CIRC'
     3,,,4.7792E-4/subtract 0.33 from L
```

```
'IF2HS9'   0.5600  -0.5600 5.5739E-4 .02664 4.5E-5 0.227 'CIRC'
        2/subtract 0.25 from L and -0.25 from H
'IF3HS9'   0.9700   0.0000 5.5739E-4 .02664 4.5E-5 0.272 'CIRC'
        3/
'IF4HS9'  11.7000  -9.4200 5.5739E-4 .02664 4.5E-5 3.304 'CIRC'
        8/
'IF5HS9'   4.8400   0.0000 5.5739E-4 .02664 4.5E-5 1.355 'CIRC'
        4,,,2.7789E-3/
'IEFTM9'   1.5033   0.0000 1.8354E-3 .02520 4.5E-5 0.000 'CIRC
       '/
2*0.5565,0.3903/
'IEFTS9'   1.1130   0.0000 2.3569E-3 .05478 4.5E-5 0.000 'CIRC'
        3,,,2.9865E-3/
'HS9'      5.9400   0.0000 6.3573E-4 .00594 0.0000 10.93 '7ELMT
       ' 12,,,,'FRICTION=FR_CREPT'/
'OEFTS9'   1.1130   0.0000 2.3569E-3 .05478 4.5E-5 0.000 'CIRC'
        3,,,2.9865E-3/
'OEFTM9'   1.5033   0.0000 1.8354E-3 .02520 4.5E-5 0.000 'CIRC
       '/
0.3903,2*0.5565/
'OF5HS9'   5.2400   0.0000 9.6487E-4 .03505 4.5E-5 0.299 'CIRC'
        4/
'OF4HS9'  11.6500   9.5200 9.6487E-4 .03505 4.5E-5 0.664 'CIRC'
        8/
```

```
'OF3HS9'  1.8700  0.0000 9.6487E-4 .03505 4.5E-5 0.107 'CIRC' 3/
'OF2HS9'  0.7100  0.7100 9.6487E-4 .03505 4.5E-5 0.041 'CIRC' 2/
'OF1HS9'  0.7132  0.0000 9.6487E-4 .03505 4.5E-5 0.041 'CIRC' 3,,,7.2519E-4/

'OH7A'    0.34233  0.000 0.02946 0.193675 4.5E-5 0.000 'CIRC' 1,,,,'FIX-MIXED'/ L=0.160, V=4.71E-3 *** FOR OUTLET-HEADER BLOWDOWN
'OH7B'    0.20000  0.000 0.02946 0.193675 4.5E-5 0.000 'CIRC' 1,,,,'FIX-MIXED'/
'OH7C'    0.26000  0.000 0.02946 0.193675 4.5E-5 0.000 'CIRC' 1,,,,'FIX-MIXED'/
'OH7D'    0.15896  0.000 0.02946 0.193675 4.5E-5 0.000 'CIRC' 1,,,4.82255E-3,'FIX-MIXED'/
'OH7RLF'  1.64320  0.290 1.905E-3 0.04925 4.5E-5 0.000 'CIRC' ,,,,4.69300E-3/
0.2,1.4432/

'IBO2A'   1.9532   0.6332 7.4173E-3 .09718 4.5E-5 0.000 'CIRC' 2/
'IBO2B'   1.91298  1.3230 7.4173E-3 .09718 4.5E-5 0.000 'CIRC' 2/
```

```
'IBO2PL'  0.67820  0.6782 3.9364E-2 .13608 4.5E-5 0.000 'CIRC' 2/
'BO2UP1'  3.25210  3.2521 1.4570E-4 .01362 3.8E-6 0.000 'CIRC',,,41,,'STM-GEN-COND'/!!! CHECK THE PIPE NUMBER
2*0.31315,4*0.65645/
'BO2UP2'  6.1071  6.04857 1.4570E-4 .01362 3.8E-6 0.000 'CIRC',10,,41,,'STM-GEN-COND'/!!! CHECK THE PIPE NUMBER
'BO2DN2'  6.1071 -6.04857 1.4570E-4 .01362 3.8E-6 0.000 'CIRC',10,,41,,'STM-GEN-COND'/!!! CHECK THE PIPE NUMBER
'BO2DN1'  3.2521 -3.25210 1.4570E-4 .01362 3.8E-6 0.000 'CIRC',,,41,,'STM-GEN-COND'/!!! CHECK THE PIPE NUMBER
4*0.65645,2*0.31315/
'OBO2PL'  0.6782 -0.6782 3.9364E-2 .13608 4.5E-5 0.000 'CIRC' 2/
'OBO2A'   1.4330 -1.3560 7.4173E-3 .09718 4.5E-5 0.000 'CIRC' 2/
'OBO2B'   2.1400  0.0000 7.4173E-3 .09718 4.5E-5 0.000 'CIRC' 3/
'INP2'    1.2430  1.2430 7.4173E-3 .09718 4.5E-5 0.000 'CIRC' 2,,,1.4930E-2,'FIX-MIXED'/
'OUTP2 '  1.4100  0.0000 3.4889E-3 .06665 4.5E-5 0.000 'CIRC' 3,,,1.0813E-2,'FIX-MIXED'/
'OUTP2A'  0.7900  0.0000 4.6816E-3 .07721 4.5E-5 0.000 'CIRC' 3,,,/
```

```
'OPMP2'    2.1732  -1.8432  4.7694E-3  .07793  4.5E-5  0.000  'CIRC' 2/

'IH8A'     0.15896  0.000  0.02946  0.193675  4.5E-5  0.000  'CIRC' 1,,,4.8226E-3,'FIX-MIXED'/
'IH8B'     0.20000  0.000  0.02946  0.193675  4.5E-5  0.000  'CIRC' 1,,,,'FIX-MIXED'/
'IH8C'     0.26000  0.000  0.02946  0.193675  4.5E-5  0.000  'CIRC' 1,,,,'FIX-MIXED'/
'IH8D'     0.23000  0.000  0.02946  0.193675  4.5E-5  0.000  'CIRC' 1,,,6.78E-3,'FIX-MIXED'/ L=0.23000, V=6.78E-3 *** FOR BLOWDOWN TEST
'BKBC'/

'IF1HS10'  1.6232  -1.3631  5.5739E-4  .02664  4.5E-5  0.000  'CIRC' 2,,,9.8531E-4/
'IF2HS10'  2.0700   0.0000  5.5739E-4  .02664  4.5E-5  0.000  'CIRC' 3/
'IF3HS10'  3.5000  -2.7800  5.5739E-4  .02664  4.5E-5  0.000  'CIRC' 3,,,2.0141E-3/
'IEFTM10'  1.5033   0.0000  1.8354E-3  .02520  4.5E-5  0.000  'CIRC'/
2*0.5565,0.3903/
```

```
'IEFTS10'  1.1130  0.0000 2.3569E-3 .05478 4.5E-5 0.000 'CIRC' 3,,,2.9865E-3/
'HS10'     5.9400  0.0000 6.3573E-4 .00594 0.0000 11.05 '7 ELMT' 12,,,,'FRICTION=FR_CREPT'/
'OEFTS10'  1.1130  0.0000 2.3569E-3 .05478 4.5E-5 0.000 'CIRC' 3,,,2.9865E-3/
'OEFTM10'  1.5033  0.0000 1.8354E-3 .02520 4.5E-5 0.000 'CIRC'/
0.3903,2*0.5565/
'OF3HS10'  3.5900  2.7800 9.6487E-4 .03505 4.5E-5 0.682 'CIRC' 3/
'OF2HS10'  3.8500  0.0000 9.6487E-4 .03505 4.5E-5 0.732 'CIRC' 3/
'OF1HS10'  1.6232  1.3631 9.6487E-4 .03505 4.5E-5 0.308 'CIRC' 2,,,1.6033E-3/

'IF1HS11'  1.1632 -0.9031 5.5739E-4 .02664 4.5E-5 0.000 'CIRC' 2,,,7.2883E-4/
'IF2HS11'  1.8600  0.0000 5.5739E-4 .02664 4.5E-5 0.000 'CIRC' 3/
'IF3HS11'  7.1900 -5.7900 5.5739E-4 .02664 4.5E-5 0.000 'CIRC' 6,,,4.0715E-3/
'IEFTM11'  1.5033  0.0000 1.8354E-3 .02520 4.5E-5 0.000 'CIRC'/
```

```
2*0.5565,0.3903/
'IEFTS11'   1.1130   0.0000  2.3569E-3 .05478  4.5E-5 0.000  'CIRC' 3,,,2.9865E-3/
'HS11'      5.9400   0.0000  6.3573E-4 .00594  0.0000 10.99  '7 ELMT' 12,,,,'FRICTION=FR_CREPT'/
'OEFTS11'   1.1130   0.0000  2.3569E-3 .05478  4.5E-5 0.000  'CIRC' 3,,,2.9865E-3/
'OEFTM11'   1.5033   0.0000  1.8354E-3 .02520  4.5E-5 0.000  'CIRC'/
0.3903,2*0.5565/
'OF3HS11'   7.2600   5.7900  9.6487E-4 .03505  4.5E-5 1.158  'CIRC' 6,,,7.0120E-3/
'OF2HS11'   3.6700   0.0000  9.6487E-4 .03505  4.5E-5 0.587  'CIRC' 3/
'OF1HS11'   1.1632   0.9031  9.6487E-4 .03505  4.5E-5 0.186  'CIRC' 2,,,1.1594E-3/

'IF1HS12'   0.7132   0.0000  9.6487E-4 .03505  4.5E-5 0.164  'CIRC' 3,,,7.2519E-4/
'IF2HS12'   0.8200  -0.8200  9.6487E-4 .03505  4.5E-5 0.189  'CIRC' 2/
'IF3HS12'   3.0800   0.0000  9.6487E-4 .03505  4.5E-5 0.708  'CIRC' 3/
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'IF4HS12'   6.6400  -6.2300  9.6487E-4  .03505  4.5E-5  1.527  'CIRC
    ' 5/
'IF5HS12'   4.5500   0.0000  9.6487E-4  .03505  4.5E-5  1.046  'CIRC
    ' 4,,,4.4276E-3/
'IEFTM12'   1.5033   0.0000  1.8354E-3  .02520  4.5E-5  0.000  'CIRC
    '/
2*0.5565,0.3903/
'IEFTS12'   1.1130   0.0000  2.3569E-3  .05478  4.5E-5  0.000  'CIRC
    ' 3,,,2.9865E-3/
'HS12'      5.9400   0.0000  6.3573E-4  .00594  0.0000  8.078  '7
    ELMT' 12,,,,'FRICTION=FR_CREPT'/
'OEFTS12'   1.1130   0.0000  2.3569E-3  .05478  4.5E-5  0.000  'CIRC
    ' 3,,,2.9865E-3/
'OEFTM12'   1.5033   0.0000  1.8354E-3  .02520  4.5E-5  0.000  'CIRC
    '/
0.3903,2*0.5565/
'OF5HS12'   4.9500   0.0000  9.6487E-4  .03505  4.5E-5  1.386  'CIRC
    ' 4,,,4.8136E-3/
'OF4HS12'   6.6300   6.3400  1.3134E-3  .04089  4.5E-5  1.856  'CIRC
    ' 5,,,8.5234E-3/
'OF3HS12'   5.9700   0.0000  1.3134E-3  .04089  4.5E-5  1.672  'CIRC
    ' 4/
'OF2HS12'   0.7100   0.7100  1.3134E-3  .04089  4.5E-5  0.199  'CIRC
    ' 2/
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'OF1HS12'  0.7132  0.0000 1.3134E-3 .04089 4.5E-5 0.172 'CIRC ' 3,,,9.3672E-4/

'IF1HS13'  1.2032 -1.1740 9.6487E-4 .03505 4.5E-5 0.000 'CIRC ' 2,,,1.1980E-3/
'IF2HS13'  3.3300  0.0000 9.6487E-4 .03505 4.5E-5 0.000 'CIRC ' 3/
'IF3HS13'  7.0900 -6.3300 9.6487E-4 .03505 4.5E-5 0.000 'CIRC ' 5/
'IF4HS13'  2.3300  0.0000 9.6487E-4 .03505 4.5E-5 0.000 'CIRC ' 3,,,2.2854E-3/
'IEFTM13'  1.5033  0.0000 1.8354E-3 .02520 4.5E-5 0.000 'CIRC '/
2*0.5565,0.3903/
'IEFTS13'  1.1130  0.0000 2.3569E-3 .05478 4.5E-5 0.000 'CIRC ' 3,,,2.9865E-3/
'HS13'     5.9400  0.0000 6.3573E-4 .00594 0.0000 9.975 '7 ELMT' 12,,,,'FRICTION=FR_CREPT'/
'OEFTS13'  1.1130  0.0000 2.3569E-3 .05478 4.5E-5 0.000 'CIRC ' 3,,,2.9865E-3/
'OEFTM13'  1.5033  0.0000 1.8354E-3 .02520 4.5E-5 0.000 'CIRC '/
0.3903,2*0.5565/
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'OF4HS13'  2.5100  0.0000 9.6487E-4 .03505 4.5E-5 0.552 'CIRC
    ' 3/
'OF3HS13'  7.0700  6.3300 1.3134E-3 .04089 4.5E-5 1.555 'CIRC
    ' 5,,,9.1013E-3/
'OF2HS13'  6.1700  0.0000 1.3134E-3 .04089 4.5E-5 1.357 'CIRC
    ' 5/
'OF1HS13'  1.2032  1.1740 1.3134E-3 .04089 4.5E-5 0.265 'CIRC
    ' 2/

'IF1HS14'  0.7132  0.0000 5.5739E-4 .02664 4.5E-5 0.200 'CIRC
    ' 3,,,4.7792E-4/
'IF2HS14'  0.8100 -0.8100 5.5739E-4 .02664 4.5E-5 0.227 'CIRC
    ' 2/
'IF3HS14'  0.9700  0.0000 5.5739E-4 .02664 4.5E-5 0.272 'CIRC
    ' 3/
'IF4HS14' 11.7000 -9.4200 5.5739E-4 .02664 4.5E-5 3.304 'CIRC
    ' 8/
'IF5HS14'  4.8400  0.0000 5.5739E-4 .02664 4.5E-5 1.355 'CIRC
    ' 4,,,2.7789E-3/ L=5.24, V=3.0019E-3 *** WITH
    SCATTEROMETER
'IEFTM14'  1.5033  0.0000 1.8354E-3 .02520 4.5E-5 0.000 'CIRC
    '/
2*0.5565,0.3903/
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'IEFTS14'   1.1130   0.0000 2.3569E-3 .05478 4.5E-5 0.000 'CIRC' 3,,,2.9865E-3/
'HS14'      5.9400   0.0000 6.3573E-4 .00594 0.0000 10.40 '7 ELMT' 12,,,,'FRICTION=FR_CREPT'/
'OEFTS14'   1.1130   0.0000 2.3569E-3 .05478 4.5E-5 0.000 'CIRC' 3,,,2.9865E-3/
'OEFTM14'   1.5033   0.0000 1.8354E-3 .02520 4.5E-5 0.000 'CIRC'/
0.3903,2*0.5565/
'OF5HS14'   5.2400   0.0000 9.6487E-4 .03505 4.5E-5 0.299 'CIRC' 4/ L=5.66 *** WITH SCATTEROMETER
'OF4HS14'  11.6500   9.5200 9.6487E-4 .03505 4.5E-5 0.664 'CIRC' 8/
'OF3HS14'   1.8700   0.0000 9.6487E-4 .03505 4.5E-5 0.107 'CIRC' 3/
'OF2HS14'   0.7100   0.7100 9.6487E-4 .03505 4.5E-5 0.041 'CIRC' 2/
'OF1HS14'   0.7132   0.0000 9.6487E-4 .03505 4.5E-5 0.041 'CIRC' 3,,,7.2519E-4/

'OH5A'      0.24786  0.0000 0.02946 0.193675 4.5E-5 0.000 'CIRC' 1,,,,'FIX-MIXED'/
'OH5B'      0.20000  0.0000 0.02946 0.193675 4.5E-5 0.000 'CIRC' 1,,,,'FIX-MIXED'/
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'OH5C'     0.26000  0.0000 0.02946 0.193675 4.5E-5 0.000 'CIRC' 1,,,,'FIX-MIXED'/
'OH5D'     0.24786  0.0000 0.02946 0.193675 4.5E-5 0.000 'CIRC' 1,,,7.44147E-3,'FIX-MIXED'/
'OH5RLF'   1.64320  0.2900 1.905E-3 0.04925 4.5E-5 0.000 'CIRC' ,,,,4.69300E-3/
0.2,1.4432/

'IBO1A'    1.9532   0.6332 7.4173E-3 .09718 4.5E-5 0.000 'CIRC' 2/
'IBO1B'    1.91298  1.3230 7.4173E-3 .09718 4.5E-5 0.000 'CIRC' 2/
'IBO1PL'   0.67820  0.6782 3.9364E-2 .13608 4.5E-5 0.000 'CIRC' 2/
'BO1UP1'   3.25210  3.2521 1.4570E-4 .01362 3.8E-6 0.000 'CIRC',,,39,,'STM-GEN-COND'/!!! CHECK THE PIPE NUMBER
2*0.31315,4*0.65645/
'BO1UP2'   6.1071  6.04857 1.4570E-4 .01362 3.8E-6 0.000 'CIRC',10,,39,,'STM-GEN-COND'/!!! CHECK THE PIPE NUMBER
'BO1DN2'   6.1071 -6.04857 1.4570E-4 .01362 3.8E-6 0.000 'CIRC',10,,39,,'STM-GEN-COND'/!!! CHECK THE PIPE NUMBER
'BO1DN1'   3.2521 -3.25210 1.4570E-4 .01362 3.8E-6 0.000 'CIRC',,,39,,'STM-GEN-COND'/!!! CHECK THE PIPE NUMBER
4*0.65645,2*0.31315/
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'OBO1PL'  0.6782 -0.6782  3.9364E-2 .13608 4.5E-5 0.000 'CIRC' 2/
'OBO1A'   1.4330 -1.3560  7.4173E-3 .09718 4.5E-5 0.000 'CIRC' 2/
'OBO1B'   2.1400  0.0000 7.4173E-3 .09718 4.5E-5 0.000 'CIRC' 3/
'INP1'    1.2430  1.2430 7.4173E-3 .09718 4.5E-5 0.000 'CIRC' 2,,,1.4930E-2,'FIX-MIXED'/
'OUTP1'   1.4100  0.0000 3.4889E-3 .06665 4.5E-5 0.000 'CIRC' 3,,,1.0813E-2,'FIX-MIXED'/
'OUTP1A'  0.4150  0.0000 4.6816E-3 .07721 4.5E-5 0.000 'CIRC' 3,,,/subtract 0.375 for length
'OPMP1'   1.5922 -1.2622 4.7694E-3 .07793 4.5E-5 0.000 'CIRC' 2/subtracted 0.581 for length, 0.581 for height

'SURGE5'  0.7850  0.0000 0.001238 0.0397  4.5E-5  0.0  'CIRC' 3/
'SURGE4'  0.5650 -.12000 0.001278 0.04034 4.5E-5  1.2  'CIRC' 1/
'SURGE3'  1.4800  0.0000 0.000333 0.0206  4.5E-5  0.3  'CIRC' 3/
'SURGE2'  4.8800 -3.5000 0.001140 0.0381  4.5E-5  1.42 'CIRC' 2/
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'SURGE1'  9.6100 -9.3300 0.001140 0.0381  4.5E-5 21.4  'CIRC' 5/

'*X*'/'SURGETK', 2.517, 2.517, 0.2181,,,,'TANK',,'H2O',, 0.549/*** TANK MODEL
'*X*'/1.0, 2.0, 3000.0/ Bubble rise and droplet velocities, HTC

'SEC1IBC'/ *** SECONDARY SIDE INLET
'BO2INL'  12.460  0.3500 .0013776 .04188 3.82E-6 0.0000 'CIRC' 10/ !!! HIGH POWER: FROM RTD 37T
'*X*'/'BO2INL'  6.3750 -2.3400 .0001489 .01377 3.82E-6 0.0000 'CIRC' 5/  !!! LOW POWER: FROM 331T-D1
'BO2BAF'  0.6263 -0.6263 .0038608 .05080 3.82E-6 0.0000 'CIRC' 2/
'BO2PREH' 3.2521  3.2521 .0058900 .02650 3.82E-6 27.709 'CIRC',,,,.0816,'FIX-MIXED,NO-SLUG'/
2*0.31315, 4*0.65645/
'BO2RS1'  0.6263  0.6263 .026190  .03160 3.82E-6 0.0000 'CIRC',2,,,,'FIX-MIXED,NO-SLUG'/
'BO2RS2'  2.6258  2.6258 .026190  .03160 3.82E-6 5.2516 'CIRC',4,,,,'FIX-MIXED,NO-SLUG'/
'BO2BAFB' 3.2521 -3.2521 .025460  .12390 3.82E-6 0.0000 'CIRC',,,,,'FIX-MIXED,NO-SLUG'/
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4*0.65645, 2*0.31315/
'BO2RS3'  6.1071  6.1071 .060000  .0316 3.82E-6 12.2928 'CIRC',10,,,.36878,'FIX-MIXED,NO-SLUG'/
'BO2RS4'  1.1271  1.1271 .020870  .1630 3.82E-6  0.0000 'CIRC',,,,,'FIX-MIXED,NO-SLUG'/
0.0448,1.0823/
'BO2DRUM' 1.1271 -1.1271 .225400  .17070 3.82E-6 0.0000 'CIRC'/
1.0823,0.0448/
'BO2NOZ'  0.6363  0.6363 .247600  .25240 3.82E-6 0.0000 'CIRC' 2/
'BO2DNC' 10.6018 -8.7329 .0168200 .1463 3.82E-6  0.2532 'CIRC',2/
'BO2STM1' 0.5800  0.5800 .004261  .07366 4.50E-5 0.4000 'CIRC' 1/
'BO2STM2' 2.8700  0.0000 .004261  .07366 4.50E-5 0.4000 'CIRC' 3/
'*X*'/'SEC2OBC'/*** SECONDARY SIDE OUTLET, USE IT ONLY IF BO2 DRUM PRESSURE IS DIFFERENT FROM BO1

'BO1INL'  12.460  0.3500 .0013776 .04188 3.82E-6 0.0000 'CIRC' 10/ !!! HIGH POWER: FROM RTD 37T
'*X*'/'BO1INL'  6.3750 -2.3400 .0001489 .01377 3.82E-6 0.0000 'CIRC' 5/  !!! LOW POWER: FROM 331T-D1
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'BO1BAF'  0.6263  -0.6263 .0038608 .05080 3.82E-6 0.0000 'CIRC
    ' 2/
'BO1PREH' 3.2521   3.2521 .0058900 .02650 3.82E-6 27.709 'CIRC
    ',,,,.0816,'FIX-MIXED,NO-SLUG'/
2*0.31315, 4*0.65645/
'BO1RS1'  0.6263   0.6263 .0261900 .03160 3.82E-6 0.0000 'CIRC
    ',2,,,,'FIX-MIXED,NO-SLUG'/
'BO1RS2'  2.6258   2.6258 .0261900 .03160 3.82E-6 5.2516 'CIRC
    ',4,,,,'FIX-MIXED,NO-SLUG'/
'BO1BAFB' 3.2521  -3.2521 .0254600 .12390 3.82E-6 0.0000 'CIRC
    ',,,,,'FIX-MIXED,NO-SLUG'/
4*0.65645, 2*0.31315/
'BO1RS3'  6.1071   6.1071 .0600000 .0316 3.82E-6 12.2928 'CIRC
    ',10,,,.36878,'FIX-MIXED,NO-SLUG'/
'BO1RS4'  1.1271   1.1271 .0208700 .1630 3.82E-6  0.0000 'CIRC
    ',,,,,'FIX-MIXED,NO-SLUG'/
0.0448,1.0823/
'BO1DRUM' 1.1271  -1.1271 .2254000 .1707 3.82E-6  0.0000 'CIRC
    '/
1.0823,0.0448/
'BO1NOZ'  0.6363   0.6363 .2476000 .2524 3.82E-6  0.0000 'CIRC
    ',2/
'BO1DNC' 10.6018  -8.7329 .0168200 .1463 3.82E-6  0.2532 'CIRC
    ',2/
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'BO1STM1' 0.5800  0.5800 .0042610 .07366 4.5E-5  0.4000 'CIRC
    ' 1/
'BO1STM2' 2.8700  0.0000 .0042610 .07366 4.5E-5  0.4000 'CIRC
    ' 3/
'SEC1OBC'/ *** SECONDARY SIDE OUTLET

'ECPUMBC'/
'ECIPUM1'  1.6800  1.6800 0.001905 0.04925 4.5E-5 0.3000 '
   CIRC' 1/
'ECIPUM2'  1.0100  0.0000 0.001905 0.04925 4.5E-5 10.300 '
   CIRC' 3/
'ECIPUM3'  0.3600 -0.3600 0.001905 0.04925 4.5E-5 0.6000 '
   CIRC' 1/
'ECIPUM4'  0.9400  0.0000 0.001905 0.04925 4.5E-5 1.4000 '
   CIRC' 3/

'ECIHPBC'/'ECITANK'  4.2931  4.2931 0.656118,,,,'TANK',,'H2O
    ',,2.81676/ *** Tank model
'ECIHP1'   6.6600 -6.6600 0.004261 0.07366 4.5E-5 0.8000 '
   CIRC' 2/
'ECIHP2'   0.8000  0.0000 0.004261 0.07366 4.5E-5 0.4000 '
   CIRC' 3/
'ECIHP3'   0.4500  0.0000 0.004261 0.07366 4.5E-5 1.4000 '
   CIRC' 3/
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'ECIHP4'   1.2600 -1.2600 0.001905 0.04925 4.5E-5 0.4000 'CIRC' 1/

'ECICOM0'  0.3000 -0.3000 0.001905 0.04925 4.5E-5 0.5000 'CIRC' 1/
'ECICOM1'  0.8000 -0.8000 0.001905 0.04925 4.5E-5 0.0000 'CIRC' 1/
'ECICOM2'  0.5000 -0.5000 0.001905 0.04925 4.5E-5 0.3000 'CIRC' 1/
'ECICOM3'  2.5200  0.0000 0.001905 0.04925 4.5E-5 0.9000 'CIRC' 3/
'ECICOM4'  0.8000 -0.8000 0.001905 0.04925 4.5E-5 0.3000 'CIRC' 1/
'ECICOM5'  4.7300  0.0000 0.001905 0.04925 4.5E-5 1.9000 'CIRC' 3/
'ECICOM6'  0.1100 -0.1100 0.001905 0.04925 4.5E-5 1.0000 'CIRC' 1/

'*X*'/'ECIP14I1' 9.3400 -9.2500 0.016817 0.14633 4.5E-5 0.0000 'CIRC' 2/ !!! the Geometry After 1998 March
'*X*'/'ECIP14I2' 0.4600  0.0000 0.016817 0.14633 4.5E-5 0.0000 'CIRC' 3/ !!! the Geometry After 1998 March
'ECIP14I1' 2.5900 -2.5900 0.004261 0.07366 4.5E-5 0.0000 'CIRC' 2/ !!! the Geometry Before 1998 March
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'ECIP14I2' 1.6000  0.0000 0.004261 0.07366 4.5E-5 0.0000 'CIRC' 3/ !!! the Geometry Before 1998 March
'ECIP14O1' 5.7300  5.1300 0.004261 0.07366 4.5E-5 0.0000 'CIRC' 2/ * INCULDED PUMP LENGTH
'ECIP14O2' 4.1000 -4.1000 0.004261 0.07366 4.5E-5 0.0000 'CIRC' 2/
'ECIP14O3' 1.5600  0.0000 0.001905 0.04925 4.5E-5 0.0000 'CIRC' 3/

'ECI56A'   5.6700  0.0000 0.001905 0.04925 4.5E-5 0.7000 'CIRC' 3/
'ECI78A'   5.7800  0.0000 0.001905 0.04925 4.5E-5 0.7000 'CIRC' 3/
'ECI56B'   0.1500 -0.1500 0.001905 0.04925 4.5E-5 1.2000 'CIRC' 1/
'ECI78B'   0.1500 -0.1500 0.001905 0.04925 4.5E-5 1.2000 'CIRC' 1/

'ECI5A'    0.2700  0.0000 0.001905   0.04925 4.5E-5 0.40 'CIRC' 3/
'ECI5B'    1.7700  0.0000 1.1401E-03 0.03810 4.5E-5 4.20 'CIRC' 3/
'ECI5C'    1.7700 -0.3300 1.1401E-03 0.03810 4.5E-5 1.30 'CIRC' 3/
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'ECI7A'     0.2700   0.0000  0.001905    0.04925  4.5E-5  0.40  '
    CIRC'  3/
'ECI7B'     1.7700   0.0000  1.1401E-03  0.03810  4.5E-5  4.20  '
    CIRC'  3/
'ECI7C'     2.1100  -0.3300  1.1401E-03  0.03810  4.5E-5  1.30  '
    CIRC'  3/

'ECI8A'     0.2700   0.0000  0.001905    0.04925  4.5E-5  0.40  '
    CIRC'  3/
'ECI8B'     1.7700   0.0000  1.1401E-03  0.03810  4.5E-5  0.90  '
    CIRC'  3/
'ECI8C'     2.0000  -0.3300  1.1401E-03  0.03810  4.5E-5  1.30  '
    CIRC'  3/

'END'/



'CONNECTIONS'/

'R-OPMP1'          ,'HDRIN'/  COUPLING INTERFACES
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'HDROT5'            ,'L–IF1HS5'/
'HDROT6'            ,'L–IF1HS6'/
'HDROT7'            ,'L–IF1HS7'/
'HDROT8'            ,'L–IF1HS8'/
'HDROT9'            ,'L–IF1HS9'/



'R–IF1HS5'          ,'L–IF2HS5'/
'R–IF2HS5'          ,'L–IF3HS5'/
'R–IF3HS5'          ,'L–IEFTM5'/
'R–IEFTM5'          ,'L–HS5'/
'L–IEFTS5'/
'R–IEFTS5'          ,'L–HS5'         ,'FIX–MIXED'/
'R–HS5'             ,'L–OEFTS5'      ,'FIX–MIXED'/
'R–OEFTS5'/
'R–HS5'             ,'L–OEFTM5'/
'R–OEFTM5'          ,'L–OF3HS5'/
'R–OF3HS5'          ,'L–OF2HS5'/
'R–OF2HS5'          ,'L–OF1HS5'/

'R–IF1HS6'          ,'L–IF2HS6'/
'R–IF2HS6'          ,'L–IF3HS6'/
'R–IF3HS6'          ,'L–IEFTM6'/
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'R–IEFTM6'      ,'L–HS6'/
'L–IEFTS6'/
'R–IEFTS6'      ,'L–HS6'       ,'FIX–MIXED'/
'R–HS6'         ,'L–OEFTS6'    ,'FIX–MIXED'/
'R–OEFTS6'/
'R–HS6'         ,'L–OEFTM6'/
'R–OEFTM6'      ,'L–OF3HS6'/
'R–OF3HS6'      ,'L–OF2HS6'/
'R–OF2HS6'      ,'L–OF1HS6'/

'R–IF1HS7'      ,'L–IF2HS7'/
'R–IF2HS7'      ,'L–IF3HS7'/
'R–IF3HS7'      ,'L–IF4HS7'/
'R–IF4HS7'      ,'L–IF5HS7'/
'R–IF5HS7'      ,'L–IEFTM7'/
'R–IEFTM7'      ,'L–HS7'/
'L–IEFTS7'/
'R–IEFTS7'      ,'L–HS7'       ,'FIX–MIXED'/
'R–HS7'         ,'L–OEFTS7'    ,'FIX–MIXED'/
'R–OEFTS7'/
'R–HS7'         ,'L–OEFTM7'/
'R–OEFTM7'      ,'L–OF5HS7'/
'R–OF5HS7'      ,'L–OF4HS7'/
'R–OF4HS7'      ,'L–OF3HS7'/
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'R–OF3HS7'      ,'L–OF2HS7'/
'R–OF2HS7'      ,'L–OF1HS7'/

'R–IF1HS8'      ,'L–IF2HS8'/
'R–IF2HS8'      ,'L–IF3HS8'/
'R–IF3HS8'      ,'L–IF4HS8'/
'R–IF4HS8'      ,'L–IEFTM8'/
'R–IEFTM8'      ,'L–HS8'/
'L–IEFTS8'/
'R–IEFTS8'      ,'L–HS8'      ,'FIX–MIXED'/
'R–HS8'         ,'L–OEFTS8'   ,'FIX–MIXED'/
'R–OEFTS8'/
'R–HS8'         ,'L–OEFTM8'/
'R–OEFTM8'      ,'L–OF4HS8'/
'R–OF4HS8'      ,'L–OF3HS8'/
'R–OF3HS8'      ,'L–OF2HS8'/
'R–OF2HS8'      ,'L–OF1HS8'/

'R–IF1HS9'      ,'L–IF2HS9'/
'R–IF2HS9'      ,'L–IF3HS9'/
'R–IF3HS9'      ,'L–IF4HS9'/
'R–IF4HS9'      ,'L–IF5HS9'/
'R–IF5HS9'      ,'L–IEFTM9'/
'R–IEFTM9'      ,'L–HS9'/
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'L–IEFTS9'/
'R–IEFTS9'          ,'L–HS9'        ,'FIX–MIXED'/
'R–HS9'             ,'L–OEFTS9'     ,'FIX–MIXED'/
'R–OEFTS9'/
'R–HS9'             ,'L–OEFTM9'/
'R–OEFTM9'          ,'L–OF5HS9'/
'R–OF5HS9'          ,'L–OF4HS9'/
'R–OF4HS9'          ,'L–OF3HS9'/
'R–OF3HS9'          ,'L–OF2HS9'/
'R–OF2HS9'          ,'L–OF1HS9'/

'L–OH7A'/
'R–OH7A'            ,'L–OH7B'       ,'ADJ–NODE–MIXING(+50),FIX–MIXED'/
'L–OH7B'            ,'R–OF1HS5'     ,'FIX–MIXED'/
'L–OH7B'            ,'R–OF1HS6'     ,'FIX–MIXED'/
'R–OH7B'            ,'L–OH7C'       ,'FIX–MIXED'/
'L–OH7C'            ,'R–OF1HS7'     ,'FIX–MIXED'/
'L–OH7C'            ,'R–OF1HS8'     ,'FIX–MIXED'/
'R–OH7C'            ,'R–OF1HS9'     ,'FIX–MIXED'/
'R–OH7C'            ,'L–IBO2A'      ,'FIX–MIXED'/
'R–OH7C'            ,'L–OH7D'       ,'ADJ–NODE–MIXING(+50),FIX–MIXED'/
'L–OH7RLF'/
'L–OH7D'            ,'R–OH7RLF'     ,'FIX–MIXED'/
'R–OH7D'            ,'R–ECI7C'      ,'FIX–MIXED'/ 'R–OH7D'/
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'R–IBO2A'          ,'L–IBO2B'/
'R–IBO2B'          ,'L–IBO2PL'/
'R–IBO2PL'         ,'L–BO2UP1'/
'R–BO2UP1'         ,'L–BO2UP2'/
'R–BO2UP2'         ,'L–BO2DN2'/
'R–BO2DN2'         ,'L–BO2DN1'/
'R–BO2DN1'         ,'L–OBO2PL'/
'R–OBO2PL'         ,'L–OBO2A'/
'R–OBO2A'          ,'L–OBO2B'/
'R–OBO2B'          ,'L–INP2'/
'R–INP2'           ,'L–OUTP2'     ,'FIX–MIXED'/
'R–OUTP2'          ,'L–OUTP2A'/
'R–OUTP2A'          ,'L–OPMP2'/

'L–IH8A'           ,'R–ECI8C'     ,'FIX–MIXED'/'L–IH8A'/
'R–IH8A'           ,'L–IH8B'      ,'ADJ–NODE–MIXING(+50),FIX–MIXED'/
'L–IH8B'           ,'R–OPMP2'     ,'FIX–MIXED'/
'L–IH8B'           ,'L–IF1HS10'   ,'FIX–MIXED'/
'L–IH8B'           ,'L–IF1HS11'   ,'FIX–MIXED'/
'R–IH8B'           ,'L–IH8C'      ,'FIX–MIXED'/
'R–IH8B'           ,'L–IF1HS13'   ,'FIX–MIXED'/
'R–IH8C'           ,'L–IF1HS12'   ,'FIX–MIXED'/
'R–IH8C'           ,'L–IF1HS14'   ,'FIX–MIXED'/
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'R–IH8C'          ,'L–IH8D'      ,'ADJ–NODE–MIXING(+50),FIX–MIXED'/
'R–IH8D'          ,'BKBC'        ,'FIX–MIXED'/ *** FOR INLET–HEADER BLOWDOWN/'R–IH8D'/

'R–IF1HS10'       ,'L–IF2HS10'/
'R–IF2HS10'       ,'L–IF3HS10'/
'R–IF3HS10'       ,'L–IEFTM10'/
'R–IEFTM10'       ,'L–HS10'/
'L–IEFTS10'/
'R–IEFTS10'       ,'L–HS10'      ,'FIX–MIXED'/
'R–HS10'          ,'L–OEFTS10'   ,'FIX–MIXED'/
'R–OEFTS10'/
'R–HS10'          ,'L–OEFTM10'/
'R–OEFTM10'       ,'L–OF3HS10'/
'R–OF3HS10'       ,'L–OF2HS10'/
'R–OF2HS10'       ,'L–OF1HS10'/

'R–IF1HS11'       ,'L–IF2HS11'/
'R–IF2HS11'       ,'L–IF3HS11'/
'R–IF3HS11'       ,'L–IEFTM11'/
'R–IEFTM11'       ,'L–HS11'/
'L–IEFTS11'/
'R–IEFTS11'       ,'L–HS11'      ,'FIX–MIXED'/
'R–HS11'          ,'L–OEFTS11'   ,'FIX–MIXED'/
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'R–OEFTS11'/
'R–HS11'           ,'L–OEFTM11'/
'R–OEFTM11'        ,'L–OF3HS11'/
'R–OF3HS11'        ,'L–OF2HS11'/
'R–OF2HS11'        ,'L–OF1HS11'/

'R–IF1HS12'        ,'L–IF2HS12'/
'R–IF2HS12'        ,'L–IF3HS12'/
'R–IF3HS12'        ,'L–IF4HS12'/
'R–IF4HS12'        ,'L–IF5HS12'/
'R–IF5HS12'        ,'L–IEFTM12'/
'R–IEFTM12'        ,'L–HS12'/
'L–IEFTS12'/
'R–IEFTS12'        ,'L–HS12'      ,'FIX–MIXED'/
'R–HS12'           ,'L–OEFTS12' ,'FIX–MIXED'/
'R–OEFTS12'/
'R–HS12'           ,'L–OEFTM12'/
'R–OEFTM12'        ,'L–OF5HS12'/
'R–OF5HS12'        ,'L–OF4HS12'/
'R–OF4HS12'        ,'L–OF3HS12'/
'R–OF3HS12'        ,'L–OF2HS12'/
'R–OF2HS12'        ,'L–OF1HS12'/

'R–IF1HS13'        ,'L–IF2HS13'/
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'R–IF2HS13'     ,'L–IF3HS13'/
'R–IF3HS13'     ,'L–IF4HS13'/
'R–IF4HS13'     ,'L–IEFTM13'/
'R–IEFTM13'     ,'L–HS13'/
'L–IEFTS13'/
'R–IEFTS13'     ,'L–HS13'     ,'FIX–MIXED'/
'R–HS13'        ,'L–OEFTS13'  ,'FIX–MIXED'/
'R–OEFTS13'/
'R–HS13'        ,'L–OEFTM13'/
'R–OEFTM13'     ,'L–OF4HS13'/
'R–OF4HS13'     ,'L–OF3HS13'/
'R–OF3HS13'     ,'L–OF2HS13'/
'R–OF2HS13'     ,'L–OF1HS13'/

'R–IF1HS14'     ,'L–IF2HS14'/
'R–IF2HS14'     ,'L–IF3HS14'/
'R–IF3HS14'     ,'L–IF4HS14'/
'R–IF4HS14'     ,'L–IF5HS14'/
'R–IF5HS14'     ,'L–IEFTM14'/
'R–IEFTM14'     ,'L–HS14'/
'L–IEFTS14'/
'R–IEFTS14'     ,'L–HS14'     ,'FIX–MIXED'/
'R–HS14'        ,'L–OEFTS14'  ,'FIX–MIXED'/
'R–OEFTS14'/
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'R–HS14'          ,'L–OEFTM14'/
'R–OEFTM14'       ,'L–OF5HS14'/
'R–OF5HS14'       ,'L–OF4HS14'/
'R–OF4HS14'       ,'L–OF3HS14'/
'R–OF3HS14'       ,'L–OF2HS14'/
'R–OF2HS14'       ,'L–OF1HS14'/

'R–SURGE5'        ,'L–OH5A'      ,'ADJ–NODE–MIXING(+50),FIX–MIXED'/
'R–OH5A'          ,'L–OH5B'      ,'ADJ–NODE–MIXING(+50),FIX–MIXED'/
'L–OH5B'          ,'R–OF1HS10'   ,'FIX–MIXED'/
'L–OH5B'          ,'R–OF1HS11'   ,'FIX–MIXED'/
'R–OH5B'          ,'L–OH5C'      ,'FIX–MIXED'/
'L–OH5C'          ,'R–OF1HS12'   ,'FIX–MIXED'/
'L–OH5C'          ,'R–OF1HS13'   ,'FIX–MIXED'/
'R–OH5C'          ,'R–OF1HS14'   ,'FIX–MIXED'/
'R–OH5C'          ,'L–IBO1A'     ,'FIX–MIXED'/
'R–OH5C'          ,'L–OH5D'      ,'ADJ–NODE–MIXING(+50),FIX–MIXED'/
'L–OH5RLF'/
'L–OH5D'          ,'R–OH5RLF'    ,'FIX–MIXED'/
'R–OH5D'          ,'R–ECI5C'     ,'FIX–MIXED'/'R–OH5D'/

'R–IBO1A'         ,'L–IBO1B'/
'R–IBO1B'         ,'L–IBO1PL'/
'R–IBO1PL'        ,'L–BO1UP1'/
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’R–BO1UP1’        , ’L–BO1UP2’ /
’R–BO1UP2’        , ’L–BO1DN2’ /
’R–BO1DN2’        , ’L–BO1DN1’ /
’R–BO1DN1’        , ’L–OBO1PL’ /
’R–OBO1PL’        , ’L–OBO1A’ /
’R–OBO1A’         , ’L–OBO1B’ /
’R–OBO1B’         , ’L–INP1 ’ /
’R–INP1 ’         , ’L–OUTP1’     , ’FIX–MIXED’ /
’R–OUTP1’         , ’L–OUTP1A’ /
’R–OUTP1A’          , ’L–OPMP1’ /

’SEC1IBC ’        , ’L–BO2INL ’ /
’R–BO2INL ’       , ’L–BO2BAF’ /
’R–BO2BAF’        , ’L–BO2PREH’ /
’R–BO2PREH’       , ’L–BO2BAFB’ , ’FIX–MIXED’ /
’R–BO2BAFB’       , ’L–BO2RS1 ’   , ’FIX–MIXED’ /
’R–BO2RS1 ’       , ’L–BO2RS2 ’   , ’FIX–MIXED’ /
’R–BO2RS2 ’       , ’L–BO2RS3 ’   , ’FIX–MIXED’ /
’R–BO2PREH’       , ’L–BO2RS3 ’   , ’FIX–MIXED’ /
’R–BO2RS3 ’       , ’L–BO2RS4 ’   , ’FIX–MIXED’ /
’R–BO2RS4 ’       , ’L–BO2DRUM’ , ’FIX–MIXED’ /
’R–BO2DRUM’       , ’L–BO2DNC’ /
’R–BO2DNC’        , ’L–BO2RS2 ’ /
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'L–BO2DRUM'    ,'L–BO2NOZ'/  'R–BO2NOZ'       ,'SEC2OBC'/  ***
    Drum Pressure as BC
'R–BO2NOZ'     ,'L–BO2STM1'/
'R–BO2STM1'    ,'L–BO2STM2'/
'R–BO2STM2'    ,'SEC1OBC'/

'SEC1IBC'      ,'L–BO1INL'/
'R–BO1INL'     ,'L–BO1BAF'/
'R–BO1BAF'     ,'L–BO1PREH'/
'R–BO1PREH'    ,'L–BO1BAFB','FIX–MIXED'/
'R–BO1BAFB'    ,'L–BO1RS1' ,'FIX–MIXED'/
'R–BO1RS1'     ,'L–BO1RS2' ,'FIX–MIXED'/
'R–BO1RS2'     ,'L–BO1RS3' ,'FIX–MIXED'/
'R–BO1PREH'    ,'L–BO1RS3' ,'FIX–MIXED'/
'R–BO1RS3'     ,'L–BO1RS4' ,'FIX–MIXED'/
'R–BO1RS4'     ,'L–BO1DRUM','FIX–MIXED'/
'R–BO1DRUM'    ,'L–BO1DNC'/
'R–BO1DNC'     ,'L–BO1RS2'/
'L–BO1DRUM'    ,'L–BO1NOZ'/
'R–BO1NOZ'     ,'L–BO1STM1'/'R–BO1NOZ'       ,'SEC1OBC'/  ***
    Drum Pressure as BC
'R–BO1STM1'    ,'L–BO1STM2'/
'R–BO1STM2'    ,'SEC1OBC'/

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'L–SURGE1'/
'R–SURGE1'          ,'L–SURGE2'/
'R–SURGE2'          ,'L–SURGE3'/
'R–SURGE3'          ,'L–SURGE4'/
'R–SURGE4'          ,'L–SURGE5'/

'ECIHPBC'            ,'L–ECIHP1'/  'ECITANK'           ,'L–ECIHP1', 0.0, 0.0/ *** TANK MODEL CONNECTION
'R–ECIHP1'           ,'L–ECIHP2'/
'R–ECIHP2'           ,'L–ECIHP3'/ VALVE MV−11 ISOLATES HI−PRESS ECI
'R–ECIHP3'           ,'L–ECIHP4'/
'R–ECIHP4'           ,'L–ECICOM0'/

'ECPUMBC'            ,'L–ECIPUM1'/
'R–ECIPUM1'          ,'L–ECIPUM2'/
'R–ECIPUM2'          ,'L–ECIPUM3'/ CHECK VALVE NV−14
'R–ECIPUM3'          ,'L–ECIPUM4'/
'R–ECIPUM4'          ,'L–ECICOM0'/

'R–ECICOM0'          ,'L–ECICOM1'/
'R–ECICOM1'          ,'L–ECICOM2'/
'R–ECICOM2'          ,'L–ECICOM3'/
'R–ECICOM3'          ,'L–ECICOM4'/
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’R–ECICOM4’        ,’L–ECICOM5’/
’R–ECICOM5’        ,’L–ECICOM6’/
’R–ECICOM6’        ,’L–ECI56A’/
’R–ECICOM6’        ,’L–ECI78A’/

’R–ECIHP2’         ,’L–ECIP14I1’/  !!! For the Geometry Before 1998 March /’ECIHPBC’        ,’L–ECIP14I1’/!!! For the Geometry after 1998 March
’R–ECIP14I1’       ,’L–ECIP14I2’/
’R–ECIP14I2’       ,’L–ECIP14O1’/

’R–ECIP14O1’       ,’L–ECIP14O2’/
’R–ECIP14O2’       ,’L–ECIP14O3’/
’R–ECIP14O3’       ,’L–ECICOM1’/  Check valve NV–9

’R–ECI56A’         ,’L–ECI56B’/
’R–ECI56B’         ,’L–ECI5A’/

’R–ECI5A’          ,’L–ECI5B’/
’R–ECI5B’          ,’L–ECI5C’/



’R–ECI78A’         ,’L–ECI78B’/
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'R-ECI78B'          ,'L-ECI7A'/
'R-ECI78B'          ,'L-ECI8A'/
'R-ECI7A'           ,'L-ECI7B'/
'R-ECI7B'           ,'L-ECI7C'/
'R-ECI8A'           ,'L-ECI8B'/
'R-ECI8B'           ,'L-ECI8C'/

'END'/



'BOUNDARY CONDITIONS'/  !!! Test Boundary Conditions



'RESERVOIR B.C.','INLBC'/
'HDRIN'/
11.666E6,,263.0,0.0,'HG-BY-SAT','HF-BY-TEMP'/



'RESERVOIR B.C.','OUTBC5'/
'HDROT5'/
11.624001E6,,263.0,0.0,'HG-BY-SAT','HF-BY-TEMP'/
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'RESERVOIR B.C.','OUTBC6'/
'HDROT6'/
11.624609E6,,263.0,0.0,'HG-BY-SAT','HF-BY-TEMP'/

'RESERVOIR B.C.','OUTBC7'/
'HDROT7'/
11.640669E6,,263.0,0.0,'HG-BY-SAT','HF-BY-TEMP'/

'RESERVOIR B.C.','OUTBC8'/
'HDROT8'/
11.642813E6,,263.0,0.0,'HG-BY-SAT','HF-BY-TEMP'/

'RESERVOIR B.C.','OUTBC9'/
'HDROT9'/
11.621314E6,,263.0,0.0,'HG-BY-SAT','HF-BY-TEMP'/

 'FLOW B.C.','FLOBC5'/
'HDROT5',  'L-IF1HS5'/
4.08/

'FLOW B.C.','FLOBC6'/
'HDROT6',  'L-IF1HS6'/
4.013/
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'FLOW B.C.','FLOBC8'/
'HDROT8', 'L-IF1HS8'/
4.895/

'FLOW B.C.','FLOBC7'/
'HDROT7', 'L-IF1HS7'/
4.902/

'FLOW B.C.','FLOBC9'/
'HDROT9', 'L-IF1HS9'/
3.889/



'RESERVOIR B.C.','SEC1IN'/ *** Inlet B.C. for both Boiler 1 and 2
'SEC1IBC'/
4.70E6,,188.05,0.0,'HG-BY-SAT','HF-BY-TEMP'/ Channel 188 for Temp.

'FLOW B.C.','FSEC1IN'/
'SEC1IBC','L-BO1INL'/
1.8946/ *** FSEC1IN Flow Kg/s, Channel 170
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'FLOW B.C.','FSEC2IN'/
'SEC1IBC','L-BO2INL'/
1.9844/ *** FSEC2IN Flow Kg/s, Channel 174

'RESERVOIR B.C.','SEC1OUT'/
'SEC1OBC'/
4.5084E6,,,0.999,'HG-BY-SAT','HF-BY-SAT'/ CHANNEL 102 (31P-D1) FOR PRESSURE or Channel 105

'*X*'/'RESERVOIR B.C.','SEC2OUT'/
'*X*'/'SEC2OBC'/
'*X*'/4.50E6,,,1.0,'HG-BY-SAT','HF-BY-SAT'/ Channel 104

'RESERVOIR B.C.','HPECIBC'/ Pressure & temp (27P & 48T-D1)
'ECIHPBC'/
0.11845E6,,30.0,0.0,'HG-BY-SAT','HF-BY-TEMP'/

'RESERVOIR B.C.','LPECIBC'/
'ECPUMBC'/
0.114234E6,,25.0,0.0,'HG-BY-SAT','HF-BY-TEMP'/ Pressure & temp

'RESERVOIR B.C.','ATMOS'/
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'BKBC'/
0.1E6,,25.0,1.0,'HG-BY-SAT','HF-BY-TEMP'/

'END'/



'SYSTEM MODELS'/

'CREPT_PT','CR_HS5'/
'HS5', 0.0448, 0.01308, 0.0289, 0.00136,,2,.TRUE./
1, 0.01308, 0.0/
6, 0.01308, 0.0289/
'BY-DIST'/
2/
0.0  , 0.0/
5.94, 0.0/
/
'ECCENTRICITY'/


'CREPT_PT','CR_HS6'/
'HS6', 0.0448, 0.01308, 0.0289, 0.00136,,2,.TRUE./
1, 0.01308, 0.0/
```

```
6, 0.01308, 0.0289/
'BY-DIST'/
2/
0.0  , 0.0/
5.94, 0.0/
/
'ECCENTRICITY'/


'CREPT_PT','CR_HS7'/
'HS7', 0.0448, 0.01308, 0.0289, 0.00136,,2,.TRUE./
1, 0.01308, 0.0/
6, 0.01308, 0.0289/
'BY-DIST'/
2/
0.0  , 0.0/
5.94, 0.0/
/
'ECCENTRICITY'/


'CREPT_PT','CR_HS8'/
'HS8', 0.0448, 0.01308, 0.0289, 0.00136,,2,.TRUE./
1, 0.01308, 0.0/
```

```
6, 0.01308, 0.0289/
'BY-DIST'/
2/
0.0  , 0.0/
5.94, 0.0/
/
'ECCENTRICITY'/


'CREPT_PT','CR_HS9'/
'HS9', 0.0448, 0.01308, 0.0289, 0.00136,,2,.TRUE./
1, 0.01308, 0.0/
6, 0.01308, 0.0289/
'BY-DIST'/
2/
0.0  , 0.0/
5.94, 0.0/
/
'ECCENTRICITY'/


'CREPT_PT','CR_HS10'/
'HS10', 0.0448, 0.01308, 0.0289, 0.00136,,2,.TRUE./
1, 0.01308, 0.0/
```

```
6, 0.01308, 0.0289/
'BY–DIST'/
2/
0.0 , 0.0/
5.94, 0.0/
/
'ECCENTRICITY'/


'CREPT_PT','CR_HS11'/
'HS11', 0.0448, 0.01308, 0.0289, 0.00136,,2,.TRUE./
1, 0.01308, 0.0/
6, 0.01308, 0.0289/
'BY–DIST'/
2/
0.0 , 0.0/
5.94, 0.0/
/
'ECCENTRICITY'/


'CREPT_PT','CR_HS12'/
'HS12', 0.0448, 0.01308, 0.0289, 0.00136,,2,.TRUE./
1, 0.01308, 0.0/
```

```
6, 0.01308, 0.0289/
'BY–DIST'/
2/
0.0 , 0.0/
5.94, 0.0/
/
'ECCENTRICITY'/


'CREPT_PT','CR_HS13'/
'HS13', 0.0448, 0.01308, 0.0289, 0.00136,,2,.TRUE./
1, 0.01308, 0.0/
6, 0.01308, 0.0289/
'BY–DIST'/
2/
0.0 , 0.0/
5.94, 0.0/
/
'ECCENTRICITY'/


'CREPT_PT','CR_HS14'/
'HS14', 0.0448, 0.01308, 0.0289, 0.00136,,2,.TRUE./
1, 0.01308, 0.0/
```

```
6, 0.01308, 0.0289/
'BY-DIST'/
2/
0.0  ,  0.0/
5.94, 0.0/
/
'ECCENTRICITY'/

'JUNCTION RESISTANCE','RIBO1'/   *** MAIN PRIMARY LOOP RESISTANCES ***
'R-IBO1PL','L-BO1UP1'/
1.7,1.7/


 'JUNCTION RESISTANCE','PAUL1'/
 'R-OUTP1A','L-OPMP1'/Remove inlet elbow resistance
 0.0,0.0/


'JUNCTION RESISTANCE','ROBO1'/
'R-BO1DN1','L-OBO1PL'/
1.7,1.7/

'JUNCTION RESISTANCE','RINP1'/
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'R-OBO1B' , 'L-INP1'/
0.75,0.75/

'JUNCTION RESISTANCE' , 'ROUTP1'/
'R-OUTP1' , 'L-OUTP1A'/
0.0,0.0/

'JUNCTION RESISTANCE' , 'RIBO2'/
'R-IBO2PL' , 'L-BO2UP1'/
1.85,1.85/

'JUNCTION RESISTANCE' , 'ROBO2'/
'R-BO2DN1' , 'L-OBO2PL'/
1.85,1.85/

'JUNCTION RESISTANCE' , 'RINP2'/
'R-OBO2B' , 'L-INP2'/
0.75,0.75/

'JUNCTION RESISTANCE' , 'ROUTP2'/
'R-OUTP2' , 'L-OUTP2A'/
0.0,0.0/

'JUNCTION RESISTANCE' , 'RANIHS5'/
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'R-IF3HS5' , 'L-IEFTM5'/
0.85,0.61/

'JUNCTION RESISTANCE' , 'RSPIHS5'/
'R-IEFTM5' , 'L-HS5'/
1.11,0.80/

'JUNCTION RESISTANCE' , 'RSPOHS5'/
'R-HS5' , 'L-OEFTM5'/
0.86,1.26/

'JUNCTION RESISTANCE' , 'RANOHS5'/
'R-OEFTM5' , 'L-OF3HS5'/
1.98,2.88/

'JUNCTION RESISTANCE' , 'RANIHS6'/
'R-IF3HS6' , 'L-IEFTM6'/
0.72,0.52/

'JUNCTION RESISTANCE' , 'RSPIHS6'/
'R-IEFTM6' , 'L-HS6'/
0.94,0.68/

'JUNCTION RESISTANCE' , 'RSPOHS6'/
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```
'R–HS6','L–OEFTM6'/
0.91,1.26/

'JUNCTION RESISTANCE','RANOHS6'/
'R–OEFTM6','L–OF3HS6'/
2.09,2.88/

'JUNCTION RESISTANCE','RANIHS7'/
'R–IF5HS7','L–IEFTM7'/
2.84,1.95/

'JUNCTION RESISTANCE','RSPIHS7'/
'R–IEFTM7','L–HS7'/
1.23,0.85/

'JUNCTION RESISTANCE','RSPOHS7'/
'R–HS7','L–OEFTM7'/
0.85,1.23/

'JUNCTION RESISTANCE','RANOHS7'/
'R–OEFTM7','L–OF5HS7'/
1.95,2.84/

'JUNCTION RESISTANCE','RANIHS8'/
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'R–IF4HS8' , 'L–IEFTM8'/
2.73,2.19/

'JUNCTION RESISTANCE' , 'RSPIHS8'/
'R–IEFTM8' , 'L–HS8'/
1.18,0.95/

'JUNCTION RESISTANCE' , 'RSPOHS8'/
'R–HS8' , 'L–OEFTM8'/
0.95,1.18/

'JUNCTION RESISTANCE' , 'RANOHS8'/
'R–OEFTM8' , 'L–OF4HS8'/
2.19,2.73/

'JUNCTION RESISTANCE' , 'RANIHS9'/
'R–IF5HS9' , 'L–IEFTM9'/
0.69,0.60/

'JUNCTION RESISTANCE' , 'RSPIHS9'/
'R–IEFTM9' , 'L–HS9'/
0.89,0.78/

'JUNCTION RESISTANCE' , 'RSPOHS9'/
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'R–HS9' , 'L–OEFTM9'/
0.77,1.06/

'JUNCTION RESISTANCE' , 'RANOHS9'/
'R–OEFTM9' , 'L–OF5HS9'/
1.77,2.44/

'JUNCTION RESISTANCE' , 'RANIHS10'/
'R–IF3HS10' , 'L–IEFTM10'/
0.72,0.61/

'JUNCTION RESISTANCE' , 'RSPIHS10'/
'R–IEFTM10' , 'L–HS10'/
0.94,0.80/

'JUNCTION RESISTANCE' , 'RSPOHS10'/
'R–HS10' , 'L–OEFTM10'/
0.91,1.26/

'JUNCTION RESISTANCE' , 'RANOHS10'/
'R–OEFTM10' , 'L–OF3HS10'/
2.09,2.88/

'JUNCTION RESISTANCE' , 'RANIHS11'/
```

```
'R–IF3HS11' , 'L–IEFTM11'/
0.72,0.52/

'JUNCTION RESISTANCE' , 'RSPIHS11'/
'R–IEFTM11' , 'L–HS11'/
0.94,0.68/

'JUNCTION RESISTANCE' , 'RSPOHS11'/
'R–HS11' , 'L–OEFTM11'/
1.05,1.45/

'JUNCTION RESISTANCE' , 'RANOHS11'/
'R–OEFTM11' , 'L–OF3HS11'/
2.52,3.48/

'JUNCTION RESISTANCE' , 'RANIHS12'/
'R–IF5HS12' , 'L–IEFTM12'/
2.58,1.66/

'JUNCTION RESISTANCE' , 'RSPIHS12'/
'R–IEFTM12' , 'L–HS12'/
1.12,0.71/

'JUNCTION RESISTANCE' , 'RSPOHS12'/
```

```
'R–HS12' , 'L–OEFTM12'/
0.71,1.12/

'JUNCTION RESISTANCE' , 'RANOHS12'/
'R–OEFTM12' , 'L–OF5HS12'/
1.66,2.58/

'JUNCTION RESISTANCE' , 'RANIHS13'/
'R–IF4HS13' , 'L–IEFTM13'/
2.73,2.19/

'JUNCTION RESISTANCE' , 'RSPIHS13'/
'R–IEFTM13' , 'L–HS13'/
1.18,0.95/

'JUNCTION RESISTANCE' , 'RSPOHS13'/
'R–HS13' , 'L–OEFTM13'/
0.95,1.18/

'JUNCTION RESISTANCE' , 'RANOHS13'/
'R–OEFTM13' , 'L–OF4HS13'/
2.19,2.73/

'JUNCTION RESISTANCE' , 'RANIHS14'/
```

```
'R-IF5HS14','L-IEFTM14'/
0.76,0.60/

'JUNCTION RESISTANCE','RSPIHS14'/
'R-IEFTM14','L-HS14'/
0.99,0.78/

'JUNCTION RESISTANCE','RSPOHS14'/
'R-HS14','L-OEFTM14'/
0.77,1.06/

'JUNCTION RESISTANCE','RANOHS14'/
'R-OEFTM14','L-OF5HS14'/
1.77,2.44/

'PUMP','PMP1'/   *** PRIMARY PUMPS ***
'R-INP1','L-OUTP1'/
'RD-14',1,224.5,0.03104,778.,3560.0,3600.0,200/  !!! CHECK CHANNEL 197 FOR P1 OPERATING SPEED

'PUMP','PMP2'/
'R-INP2','L-OUTP2'/
'RD-14',1,224.5,0.03104,778.,3560.0,3600.0,200/  !!! CHECK CHANNEL 200 FOR P2 OPERATING SPEED
```

```

'JUNCTION RESISTANCE','HS5_ORF'/ *** INLET FEEDER ORIFICES ***
'R-IF2HS5','L-IF3HS5'/
12.29,6.145/ 15.2 mm w9.12

'JUNCTION RESISTANCE','HS6_ORF'/
'R-IF2HS6','L-IF3HS6'/
11.06,5.53/ 15.7 mm w6.68

'JUNCTION RESISTANCE','HS8_ORF'/
'R-IF2HS8','L-IF3HS8'/
8.01,4.005/ 23.5 mm w3.81

'JUNCTION RESISTANCE','HS10_ORF'/
'R-IF2HS10','L-IF3HS10'/
12.10,6.05/ 15.2 mm w8.93

'JUNCTION RESISTANCE','HS11_ORF'/
'R-IF2HS11','L-IF3HS11'/
9.56,4.78/ 15.7 mm w6.18

'JUNCTION RESISTANCE','HS13_ORF'/
'R-IF2HS13','L-IF3HS13'/
```

```
6.08,3.04/  23.5 mm w2.88

'VALVE','IHS5FTG'/   *** VALVE MODS – NARROW ANNULUS TO ENDFTG DEAD VOLS ***
'R–IEFTS5','L–HS5'/
0.000068361,0.61,1.0,'  '/

'VALVE','OHS5FTG'/
'R–HS5','L–OEFTS5'/
0.000068361,0.61,1.0,'  '/

'VALVE','IHS6FTG'/
'R–IEFTS6','L–HS6'/
0.000068361,0.61,1.0,'  '/

'VALVE','OHS6FTG'/
'R–HS6','L–OEFTS6'/
0.000068361,0.61,1.0,'  '/

'VALVE','IHS7FTG'/
'R–IEFTS7','L–HS7'/
0.000068361,0.61,1.0,'  '/

'VALVE','OHS7FTG'/
```

```
'R–HS7' , 'L–OEFTS7'/
0.000068361,0.61,1.0,' '/

'VALVE' , 'IHS8FTG'/
'R–IEFTS8' , 'L–HS8'/
0.000068361,0.61,1.0,' '/

'VALVE' , 'OHS8FTG'/
'R–HS8' , 'L–OEFTS8'/
0.000068361,0.61,1.0,' '/

'VALVE' , 'IHS9FTG'/
'R–IEFTS9' , 'L–HS9'/
0.000068361,0.61,1.0,' '/

'VALVE' , 'OHS9FTG'/
'R–HS9' , 'L–OEFTS9'/
0.000068361,0.61,1.0,' '/

'VALVE' , 'IHS10FTG'/
'R–IEFTS10' , 'L–HS10'/
0.000068361,0.61,1.0,' '/

'VALVE' , 'OHS10FTG'/
```

```
'R–HS10' , 'L–OEFTS10'/
0.000068361,0.61,1.0,'  '/

'VALVE' , 'IHS11FTG'/
'R–IEFTS11' , 'L–HS11'/
0.000068361,0.61,1.0,'  '/

'VALVE' , 'OHS11FTG'/
'R–HS11' , 'L–OEFTS11'/
0.000068361,0.61,1.0,'  '/

'VALVE' , 'IHS12FTG'/
'R–IEFTS12' , 'L–HS12'/
0.000068361,0.61,1.0,'  '/

'VALVE' , 'OHS12FTG'/
'R–HS12' , 'L–OEFTS12'/
0.000068361,0.61,1.0,'  '/

'VALVE' , 'IHS13FTG'/
'R–IEFTS13' , 'L–HS13'/
0.000068361,0.61,1.0,'  '/

'VALVE' , 'OHS13FTG'/
```

```
'R-HS13','L-OEFTS13'/
0.000068361,0.61,1.0,' '/

'VALVE','IHS14FTG'/
'R-IEFTS14','L-HS14'/
0.000068361,0.61,1.0,' '/

'VALVE','OHS14FTG'/
'R-HS14','L-OEFTS14'/
0.000068361,0.61,1.0,' '/

'JUNCTION RESISTANCE','RBO2SEP'/   *** BOILERS SECONDARY SIDE ***
'R-BO2RS4','L-BO2DRUM'/
3.4,340.0/

'JUNCTION RESISTANCE','RBO2RS34'/
'R-BO2RS3','L-BO2RS4'/
0.2,1.0/

'JUNCTION RESISTANCE','RBO2XS'/
'R-BO2DRUM','L-BO2DNC'/
0.42,0.42/

```

```
'VALVE','OBO2BP'/ MODELLED AS AN ORIFICE
'R-BO2PREH','L-BO2BAFB'/
1.140091D-3,0.5,/ 1-1.5 INCH HOLE (SQUARE EDGE)

'VALVE','OBO2BH'/  MODELLED AS AN ORIFICE
'R-BO2BAFB','L-BO2RS1'/
2.234508D-3,0.5,/ 1-1.5 INCH HOLE AND 2- 1.5X0.5 INCH SLOTS

'VALVE','OBO2DCOR'/
'R-BO2DNC','L-BO2RS2'/   3.7 INCH ORIFICE PLATE
6.936825D-3,0.61,/

'SEPARATOR',  'SBO2SEP1'/
'R-BO2DRUM','L-BO2DNC'/
0.797, .927, 1.0, 'RBO2XS'/

'SEPARATOR',  'SBO2SEP2'/
'L-BO2DRUM','L-BO2NOZ'/
0.0, 0.01, 1.0/

'JUNCTION RESISTANCE','RBO1SEP'/
'R-BO1RS4','L-BO1DRUM'/
3.4,340.0/

```

```
'JUNCTION RESISTANCE','RBO1RS34'/
'R-BO1RS3','L-BO1RS4'/
0.2,1.0/

'JUNCTION RESISTANCE','RBO1XS'/
'R-BO1DRUM','L-BO1DNC'/
0.42,0.42/

'VALVE','OBO1BP'/ MODELLED AS AN ORIFICE
'R-BO1PREH','L-BO1BAFB'/
1.140091D-3,0.5,/ 1-1.5 INCH HOLE (SQUARE EDGE)

'VALVE','OBO1BH'/  MODELLED AS AN ORIFICE
'R-BO1BAFB','L-BO1RS1'/
2.234508D-3,0.5,/ 1-1.5 INCH HOLE AND 2- 1.5X0.5 INCH SLOTS

'VALVE','OBO1DCOR'/
'R-BO1DNC','L-BO1RS2'/ 3.7 INCH ORIFICE PLATE
6.936825D-3,0.61,/

'SEPARATOR', 'SBO1SEP1'/
'R-BO1DRUM','L-BO1DNC'/
0.797, .927, 1.0, 'RBO1XS'/

```

```
'SEPARATOR', 'SBO1SEP2'/
'L-BO1DRUM','L-BO1NOZ'/
0.0, 0.01, 1.0/

'VALVE','B2STMORF'/ *** STEAM LINE ORIFICES AND VALVES ***
'R-BO2STM1','L-BO2STM2'/
2.96285E-3,0.61,1.0,' '/ 61.42 mm

'VALVE','B1STMORF'/
'R-BO1STM1','L-BO1STM2'/
2.96285E-3,0.61,1.0,' '/ 61.42 mm

'VALVE','SURGVLV'/    *** SURGE LINE ISOLATION VALVE MV3 ***
'R-SURGE4','L-SURGE5'/
0.001238,0.61,1.0,' '/

'PUMP','ECHPUMP'/  ***  HI PRESSURE ECI PUMP-14 ***
'R-ECIP14I2','L-ECIP14O1'/
'USER-1P',1,475.6,0.01125,995.,3600.,3600.,10./ H'=475.6,Q'=0.01125 *** for ECI CONFIGURATION BEFORE 1998 MARCH/ H'=560.86,Q'=0.0213, *** for ECI CONFIGURATION AFTER 1998 MARCH
'HPUMTAB'/

```

```
'PUMP','ECPUMP'/   *** LO PRESSURE ECI PUMP-8 ***
'ECPUMBC','L-ECIPUM1'/
'USER-1P',1,102.88,0.00900,997.,3600,3600,10./
'PUMCHAR'/

'VALVE','ECTKISO'/ *** HI-PRESSURE ECI ISOLATION VALVE MV-11 ***
'R-ECIHP2','L-ECIHP3'/ MV-11
0.001445,1.0,,/ 42.9 mm

'VALVE','ECIHPISO'/ *** VALVE # MV-22  !!! Configuration before 1998 March
'R-ECIHP2','L-ECIP14I1'/
0.004261,1.0/ 73.66 mm

'VALVE','ECIHPISB'/
'R-ECIP14I1','L-ECIP14I2'/ *** Fictitious VALVE for HP Pumped ECI isolation
0.01681,1.0/

'VALVE','ECPUMISO'/ *** Fictitious VALVE for LP PUMPED ECI ISOLATION ***
'R-ECIPUM3','L-ECIPUM4'/
0.001905,1.0 /
```

```

'VALVE','ECPUCHK'/ **** CHECK VALVE NV-14 ****
'R-ECIPUM1','L-ECIPUM2'/
7.91730E-4,0.61,,'CVF',2*0.05/ 1.25”

'VALVE','ECHPCHK'/ **** CHECK VALVE NV-9 ****
'R-ECIP14O3','L-ECICOM1'/
7.91730E-4,0.61,,'CVF',2*0.05/ 1.25”

'VALVE','ECIMORF'/ ORIFICE # OR-25  *** ECI VALVES AND ORIFICES ***
'R-ECICOM1','L-ECICOM2'/
9.898E-04,0.61,,/ OR-25 35.5 mm for Darlington /!!! 3.530E-04,0.61,,/ 21.2 mm for CANDU 6 /!!! 1.767E-04,0.61,,/ 15.0 mm for Darlington

'VALVE','ECI5ISO'/
'R-OH5D','R-ECI5C'/ VALVE # MV-4
0.001445,1.0/ 42.9 mm



'VALVE','ECI7ISO'/
'R-OH7D','R-ECI7C'/ VALVE # MV-7
```

```
0.001445,1.0/ 42.9 mm

'VALVE','ECI8ISO'/
'L-IH8A','R-ECI8C'/ VALVE # MV-6
0.001445,1.0/ 42.9 mm

'*** MODELS FOR ECI SYSTEM Darlington CONFIGURATION *** '/

'VALVE','ECI5CHK'/          NV-4
'R-ECI5B','L-ECI5C'/
7.91730E-4,0.61,,'CVF',2*0.05/ 1.25"



'VALVE','ECI7CHK'/          NV-7
'R-ECI7B','L-ECI7C'/
7.91730E-4,0.61,,'CVF',2*0.05/ 1.25"

'VALVE','ECI8CHK'/          NV-6
'R-ECI8B','L-ECI8C'/
7.91730E-4,0.61,,'CVF',2*0.05/ 1.25"

'DISCHARGE','BREAKIH8'/    ********** BREAK MODEL CONTROL ***********
```

```
'R-IH8D','BKBC'/
7.0686E-4,0.61,'HENFK-ORIF'/ 30 mm dia break IH8

'END'/



'SYSTEM CONTROL'/



'***'/ -------------------- Controls for simulation parameters ------------------





'INPUT TABLE','OPENB'/
1,1,,.TRUE.,/
  'TIME',          'BFRACT'/
     0.0,              0.0/


```

```
'TIME VAR.', 'BOPEN'/
'OPENB', 'BFRACT'/
/9.9E9
          'BREAKIH8', 'AREABRK', .TRUE./
          /


'INPUT TABLE', 'PWRRD1'/ ********* HEATED SECTION 5, 6 & 9 POWER ************
1,1,,.FALSE./
    'TIME',         'PS1'/
     .0000        1.0000 / Channel 82


'INPUT TABLE', 'PWRRD2'/ ********* HEATED SECTION 7 & 8 POWER ************
1,1,,.FALSE./
    'TIME',         'PS2'/
     .0000        1.0000 / Channel 83


'INPUT TABLE', 'PWRRD3'/ ********* HEATED SECTION 10, 11 & 14 POWER ************
1,1,,.FALSE./
```

```
     'TIME',          'PS3'/
      .0000         1.0000 / Channel 84


'INPUT TABLE','PWRRD4'/ ********* HEATED SECTION 12 & 13 POWER ************
1,1,,.FALSE./
     'TIME',          'PS4'/
      .0000         1.0000 / Channel 85



'TIME VAR.','P1LP'/
'PWRRD1','PS1'/
/9.9E9
             '*GENHTP','PWR',.TRUE./
             /

'TIME VAR.','P1HP'/
'PWRRD2','PS2'/
/9.9E9
             '*GENHTP','PWR',.TRUE./
             /

```

```
'TIME VAR.','P2LP'/
'PWRRD3','PS3'/
/9.9E9
            '*GENHTP','PWR',.TRUE./
            /

'TIME VAR.','P2HP'/
'PWRRD4','PS4'/
/9.9E9
            '*GENHTP','PWR',.TRUE./
            /


'INPUT TABLE','PMP1RD'/   ******** PUMP RUNDOWN ***************
1,1,,.TRUE.,/
'TIME',  'SFRAC'/
   0.000        1.00000/  for PUMP 1 & 2


'*X*'/'INPUT TABLE','PMP2RD'/   ******** PUMP RUNDOWN ***************
'*X*'/1,2,,.FALSE./
'*X*'/'TIME',  'SFRAC'/
```

```
'*X*'/     0.0000          3560.0    / Channel 200
'*X*'/     9.9E9           3560.0/

'TIME VAR.','PMPTRP1'/  *** PUMP RUNDOWN
'PMP1RD','SFRAC'/
/9.9E9
             'PMP1','OPPRPM',.TRUE./
             /

'TIME VAR.','PMPTRP2'/  *** PUMP RUNDOWN
'PMP1RD','SFRAC'/PMP2RD
/9.9E9
             'PMP2','OPPRPM',.TRUE./
             /

'INPUT TABLE','SRGTPRES'/********SURGE TANK PRESSURE **********
1,1,,.FALSE.,/
 'TIME',  'SPRESS'/
    0.0     10.02E6/




```

```
'INPUT TABLE','SURGTAB'/ *** SURGE TANK ISOLATION ***
1,1,,.TRUE.,/
'TIME',  'SGVLARE'/
 0.0,          1.0/



'TIME VAR.','SGVLAR'/
'SURGTAB','SGVLARE'/
/9.9E9
            'SURGVLV','OPENFR',.TRUE./
            /

'*** SECONDARY CIRCUIT CONTROL MODELS'/

'INPUT TABLE','SBCINT'/ Use Channel 188, T/C or Channel 67, RTD
1,1,,.TRUE./
'TIME','INLETT'/
    0.0000        188.05/  Using Channel 188, T/C


'TIME VAR.','SBCTEM'/ Secondary Side inlet feed water temp
'SBCINT','INLETT'/
```

```
/9.9E9
            'SEC1IN','HF',.FALSE./
            /

'INPUT TABLE','DRUMP1'/
1,1,,.TRUE.,/
'TIME','DPRESS'/
    0.0000        .45084E+07/    (Using CD1 DATA, Channel 102, Absolute Press)


'TIME VAR.','SSPRESS1'/
'DRUMP1','DPRESS'/
/9.9E9
            'SEC1OUT','PRESS',.FALSE./
            /

'INPUT TABLE','DRUMP2'/
1,2,,.FALSE./
'TIME','DPRESS'/
    0.0000        .450E+07/  Using BO2 DRUM Pressure, Channel 104
    9.99E9        .450E+07/

```

```
'TIME VAR.','SSPRESS2'/
'DRUMP2','DPRESS'/
9.9E9/   'SEC2OUT','PRESS',.FALSE./
/

'*** FEEDWATER FLOW CONTROL ***'/ <<<<<<<<<<<<<<<<<<<<<<<<<

'INPUT TABLE','FWFCNT1'/
1,1,,.TRUE./ Used channel 168 (l/s) and T/C 188 @ P6/P7 for this table
 'TIME',   'FLOSG1'/ Also tried RTD channel 67 instead of 188 (nearly identical)
   0.0000       1.8946/ Adjusted to match Drum Steam flo S.S initially


'TIME VAR.','FWFBO1'/
'FWFCNT1','FLOSG1'/
/9.9E9
/

'INPUT TABLE','FWFCNT2'/
1,1,,.TRUE./ Used channel 173 (l/s) and T/C 188 @ P6/P7 for this table
```

```
 'TIME',   'FLOSG2'/ Also tried RTD channel 67 instead of 188 (nearly identical)
   0.0000       1.9844/ Adjusted to match Drum Steam flo S.S initially


'TIME VAR.','FWFBO2'/
'FWFCNT2','FLOSG2'/
/9.9E9
/

'*** BOILER LEVEL CONTROL LOGIC'/ <<<<<<<<<<<<<<<<<<<<<<<<

'INPUT TABLE','BLCMOD'/
1,1,,.FALSE./
 'TIME',   'BLCID'/ *Auto Boiler Level Control use 1.0 (recommonded in s-s runs)
 -9.9E9      1.0/   *Imposed Exper. Flow Data use -1.0 (recommonded in trans. runs)


'TIME VAR.','BLC'/
'BLCMOD','BLCID'/
```

```
/9.9E9
/

'CALCULATION','BO1LEV'/ UNIT MM
'ENTER'/
        'VOID:BO1DRUM(1)',-1082.3,,,,0.3/
        'VOID:BO1DRUM(2)',-44.8,,,,0.3/
        'CONSTANT(1052.2)'/
        /
'STORE'/
/

'CALCULATION','EFW1'/
'ENTER'/
        'BO1LEV',-1.0E-3/
        'CONSTANT(0.8497)'/ !!! Using BO1 Drum Level, Channel 169
        /
'STORE'/
/

'CONTROL DEVICE','SFWA1'/
'PD',5.0,,1.0,1.0/
0.0,3.0,0.3/
```

```
           'EFW1'/
           /
/

'CALCULATION','SFW1'/
'ENTER'/
           'SFWA1'/
           /
'MULTIPLY'/
           'MFLO:L-BO1DRUM->L-BO1NOZ',0.0,3.0,0.0,3.0,0.3/
           /
'STORE'/
/

'IF','FWF1'/
/
'IF BLC .GT. 0 THEN'/
           'SFW1'/
           /
'ELSE'/
           'FWFBO1'/
           /
'ENDIF'/
           'FSEC1IN','MFLO',.FALSE./
```

```
/

'CALCULATION','BO2LEV'/ UNIT MM
'ENTER'/
          'VOID:BO2DRUM(1)',-1082.3,,,,0.3/
          'VOID:BO2DRUM(2)',-44.8,,,,0.3/
          'CONSTANT(1052.2)'/
          /
'STORE'/
/

'CALCULATION','EFW2'/
'ENTER'/
          'BO2LEV',-1.0E-3/
          'CONSTANT(0.8344)'/ !!! Using BO2 Drum Level, Channel 172
          /
'STORE'/
/

'CONTROL DEVICE','SFWA2'/
'PD',5.0,,1.0,1.0/
0.0,3.0,0.3/
          'EFW2'/
```

```
        /
/

'CALCULATION' , 'SFW2'/
'ENTER'/
        'SFWA2'/
        /
'MULTIPLY'/
        'MFLO:L–BO2DRUM▷L–BO2NOZ' ,0.0 ,3.0 ,0.0 ,3.0 ,0.3/
        /
'STORE'/
/

'IF' , 'FWF2'/
/
'IF BLC .GT. 0 THEN'/
        'SFW2'/
        /
'ELSE'/
        'FWFBO2'/
        /
'ENDIF'/
        'FSEC2IN' , 'MFLO' , .FALSE./
/
```

```

'*** ECI SYSTEM CONTROL MODELS ***'/<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<

'INPUT TABLE','HPUMTAB'/ ******** HI PRESS ECI PUMP CHARACTERISTIC *********
1,18,,.TRUE.,/
  'QFLOW',      'HPRESS'/  Pump 14 (HI PRES ECI) Pump Characteristic
   .0921     1.27416 / Flow Ratio vs Head Ratio (Absolute) derived at 77P
   .1060     1.22965 / Qrated=11.25 l/s, Hrated=475.6 m.
   .1941     1.18514/  *** FOR CONFIGRATION BEFORE 1998 MARCH
   .3008     1.14804/
   .4697     1.10786/
   .7134     1.05885/
   .9512     1.01614/
  1.1469     .964831/
  1.3154     .918657/
  1.5059     .843614/
  1.6815     .752366/
  1.8186     .668314/
  1.8661     .633490/
  1.9185     .553353/
```

```
  1.9549     .444131/
  1.9774     .351440/
  1.9931     .276053/
  2.0000    0.000000/

'*x*'/'INPUT TABLE','HPUMTAB'/ ******** HI PRESS ECI PUMP CHARACTERISTIC *********
'*x*'/1,4,,.TRUE.,/
'*x*'/   'QFLOW',  'HPRESS'/  Pump 14 (HI PRES ECI) Pump Characteristic (146 mm inlet line, 35.5mm OR25)
'*x*'/     1.08     1.0000/ Flow Ratio vs Head Ratio (Absolute) derived at 77P
'*x*'/     1.14     0.9677/ Qrated=21.30 l/s, Hrated=560.86 m.
'*x*'/     1.20     0.9333/
'*x*'/     1.38     0.8213/

'INPUT POLYNOMIAL','PUMCHAR'/
4/
0.131025E+01,+0.230212E-01,-0.278399E+00,-0.476007E-01/

'INPUT TABLE','ECITAB'/ *** ECI SYSTEM ISOLATION VALVES ***
1,1,,.TRUE.,/
'TIME',  'ECIVLV'/
  0.0,      0.00/
```

```


'TIME VAR.','ECIOP'/
'ECITAB','ECIVLV'/
/9.9E9
'ECI5ISO','OPENFR',.TRUE./

'ECI7ISO','OPENFR',.TRUE./
'ECI8ISO','OPENFR',.TRUE./
/

'*X*'/'TRIP','ECI_OPER',/
'*X*'/'COMPARE'/
'*X*'/          'PRESS:IH8C(1)'/
'*X*'/          /
'*X*'/'LT'/
'*X*'/          'CONSTANT(5.5E06)'/
'*X*'/          /
'*X*'//
'*X*'/'ECIOP'/
'*X*'//

'INPUT TABLE','ECIPTAB'/ *** TK2 pressure boundary
1,1,,.TRUE.,/
```

```
'TIME',  'ECIPP'/
    0.0000        119.03E3/ Absolute pressures, Channel 103


'TIME VAR.','ECIPBC'/
'ECIPTAB','ECIPP'/
/9.9E9
'HPECIBC','PRESS',.FALSE./
/

'INPUT TABLE','ECTKTAB'/ ******** MV−11 HI−PRESS ECI ISOLATION ***************
1,2,,.TRUE.,/
'TIME',  'FRMV11'/
0.000,      0.0/
9.9E9,      0.0/

'TIME VAR.','ECTKOP'/
'ECTKTAB','FRMV11'/
/
'ECTKISO','OPENFR',.TRUE./ *** Hi Pressure ECI isolation MV−11
/

```

```
'INPUT TABLE','ECIHPTAB'/ *** HP Pumped ECI Isolation
1,1,,.TRUE.,/
'TIME', 'FRHPIS'/
  0.00  0.0/


'TIME VAR.','ECHPOP'/
'ECIHPTAB','FRHPIS'/
/9.9E9
'ECHPUMP','OPPRPM',.TRUE./ *** Turn on HP ECI Pump-14 /
'ECIHPISO','OPENFR',.TRUE./*** CONTROL MV-22 used only for ECI Configuration before 1998 March
/

'INPUT TABLE','ECIMV22B'/
1,1,,.TRUE.,/
'TIME', 'FRMV22B'/
  0.00  1.0/


'TIME VAR.','ECHPOFF'/
'ECIMV22B','FRMV22B'/
/
'ECIHPISB','OPENFR',.TRUE./*** CONTROL MV-22B - P14 ISOLATION
```

```
/

'INPUT TABLE','ECILPTAB'/  ******** START LP PUMPED ECI ***************
1,1,,.TRUE.,/
'TIME',  'P8ON'/
0.0,          0.0/



'TIME VAR.','ECPUMOP'/
'ECILPTAB','P8ON'/
/
'ECPUMP','OPPRPM',.TRUE./ *** Start low pressure ECI pump
/

'INPUT TABLE','ECLPISO'/  ******** CONTROL LP PUMPED ECI ***************
1,1,,.TRUE.,/
'TIME',  'FRLPISO'/
0.0,          1.0/


'TIME VAR.','ECPUMOFF'/
```

```
'ECLPISO','FRLPISO'/
/
'ECPUMISO','OPENFR',.TRUE./ Tune off LP ECI pump
/

'INPUT TABLE','ECLPTMP'/ *** LO PRESS ECI PUMP TEMP ***
1,1,,.TRUE.,/
'TIME',  'LPTEMP'/
 0.0,        25.0/


'TIME VAR.','ECLPTBC'/
'ECLPTMP','LPTEMP'/
/
'LPECIBC','HF',.FALSE./ *** Low pressure PUMP-8 Temperature of flow
/

'*** Calculation for ECI Tank TK2 water lever *** '/

'DEFINE','ECIVOLD'/
0.0/

'CALCULATE','ECIVOL'/
```

```
'ENTER'/
        'MFLO:R–ECIHP1>L–ECIHP2'/ !!! For the Geometry Before 1998 March/'MFLO:R–ECIP14I1>L–ECIP14I2'/!!! After 1998 March
/
'DIVIDE'/
        'RHOF:ECIHP1(1)'/ !!! For the Geometry Before 1998 March/'RHOF:ECIP14I1(1)'/!!! After 1998 March
/
'MULTIPLY'/
        'TIMESTEP:'/
/
'STORE'/
/

'CALCULATE','ECIVOLD'/
'ENTER'/
        'ECIVOLD'/
        'ECIVOL'/
/
'STORE'/
/

'CALCULATE','LEVELD'/
```

```
'ENTER'/
            'ECIVOLD'/
/
'DIVIDE'/
            'CONSTANT(0.656118)'/ *** Inside cross-section area of the ECI tank
/
'STORE'/
/

'CALCULATE','ECILEVEL'/
'ENTER'/
            'LEVELD',-1.0/
            'CONSTANT(2.900)'/
/
'STORE'/
/

'TRIP','VLV_OPER',/  ***  if TK2 water level lower than 10%, MV-11 off, LP PUMPED ECI start
'COMPARE'/
            'ECILEVEL'/
            /
'LT'/
```

```
          'CONSTANT(0.270)'/
          /
          /NO TIME DELAY
'ECTKOP'/ MV-11 off
'ECHPOFF'/ HI PRESS PUMPED ECI OFF
'ECPUMOP'/ Low Pressure Pumped ECI on
'ECPUMOFF'/ Low Pressure Pumped ECI off
'ECLPTBC'/
/


 'PARAMETER','STARTIME'/PVM CONTROL MODULES
0.0/

'PARAMETER','STARTI'/
0.0/

'PARAMETER','PVMINP'/
11.666E6/

'PARAMETER','PVMIN1'/
4.08/

'PARAMETER','PVMIN2'/
```

```
4.013/

'PARAMETER','PVMIN3'/
4.895/

'PARAMETER','PVMIN4'/
4.902/

'PARAMETER','PVMIN5'/
3.889/





'REMOTE PROCESS','TOSTAR'/
'PVM',7,7/
0.0,1.0,10000000/Coupling initiaion time, Exchange Frequency, End time
'pc-novog-model3','TROL_BB_MODIFIED.exe'/Network Node, Target executable
'C:\RD14MCouple4_SS\trol-bb','ss_bpcon.inp'/
'SIMTIME:'/   #0:
'MFLO:R-OPMP1>HDRIN'/   #1:
```

```
'PRESS:IF1HS5(0.01)'/   #2:
'PRESS:IF1HS6(0.01)'/   #3:
'PRESS:IF1HS7(0.01)'/   #4:
'PRESS:IF1HS8(0.01)'/   #5:
'PRESS:IF1HS9(0.01)'/   #6:


'STARTI','VALUE_P'/   #0
'PVMINP','VALUE_P'/   #1:
'PVMIN1','VALUE_P'/   #2:
'PVMIN2','VALUE_P'/   #3:
'PVMIN3','VALUE_P'/   #4:
'PVMIN4','VALUE_P'/   #5:
'PVMIN5','VALUE_P'/   #6:


'CALCULATE','OUT_T'/
'PROGRAM'/
        OUT_T = "STARTI"
        END
'STARTIME'   ,'VALUE_P'/
/

'CALCULATE','OUT_P_0'/
```

```
'PROGRAM'/
          OUT_P_0 = "PVMINP" + 0.1* (10.0427E6 - "PRESS:SURGE1(2)")
          END
'INLBC'  ,'PRESS'/
/

'CALCULATE','OUT_P_1'/
'PROGRAM'/
          OUT_P_1 = "PVMIN1"
          END
'FLOBC5'  ,'MFLO'/
/

'CALCULATE','OUT_P_2'/
'PROGRAM'/
          OUT_P_2 = "PVMIN2"
          END
'FLOBC6'  ,'MFLO'/
/

'CALCULATE','OUT_P_3'/
'PROGRAM'/
          OUT_P_3 = "PVMIN3"
```

```
            END
'FLOBC7'   ,'MFLO'/
/

'CALCULATE' , 'OUT_P_4'/
'PROGRAM'/
            OUT_P_4 = "PVMIN4"
            END
'FLOBC8'   ,'MFLO'/
/

'CALCULATE' , 'OUT_P_5'/
'PROGRAM'/
            OUT_P_5 = "PVMIN5"
            END
'FLOBC9'   ,'MFLO'/
/




'*** OUTPUT MODELS ***'/
'INCLUDE OUTPUT.INP'/
'INCLUDE outb9401_NM.inp'/
```

```





 'OUTPUT','FLOW1'/  OPMP flow rate
6,'feederFlow.out','(1X,F9.3,8(1X,F9.3))',10,,.TRUE.,.TRUE.,'GNUPLOT'/
'MFLO:R-OPMP1>HDRIN'/
/
'MFLO:HDROT5>L-IF1HS5'/
/
'MFLO:HDROT6>L-IF1HS6'/
/
'MFLO:HDROT7>L-IF1HS7'/
/
'MFLO:HDROT8>L-IF1HS8'/
/
'MFLO:HDROT9>L-IF1HS9'/
/


'OUTPUT','CHPRES'/  OPMP flow rate
```

```
7,'Press.out','(1X,F9.3,8(1X,F9.5))',10,,.TRUE.,.TRUE.,'GNUPLOT'/
'PRESS:IF1HS5(1)', 1.0E-6/
/
'PRESS:IF1HS6(1)', 1.0E-6/
/
'PRESS:IF1HS7(1)', 1.0E-6/
/
'PRESS:IF1HS8(1)', 1.0E-6/
/
'PRESS:IF1HS9(1)', 1.0E-6/
/
'PRESS:OPMP1(2)', 1.0E-6/
/
'PRESS:SURGE1(2)', 1.0E-6/
/


'OUTPUT','CHDENS'/  OPMP flow rate
6,'Density.out','(1X,F9.3,8(1X,F9.5))',10,,.TRUE.,.TRUE.,'GNUPLOT'/
'RHOF:IF1HS5(1)'/
/
'RHOF:IF1HS6(1)'/
```

```
/
'RHOF:IF1HS7(1)'/
/
'RHOF:IF1HS8(1)'/
/
'ROMIX:IF1HS9(1)'/
/
'RHOF:OPMP1(2)'/
/

  'OUTPUT','STRTME'/  OPMP flow rate
1,'starTime.out','(1X,F9.3,8(1X,F9.3))',10,,.TRUE.,.TRUE.,'GNUPLOT'/
'STARTIME'/
/




'END'/

'HEAT TRANSFER PACKAGE'/


```

```

'MODEL:(WIFHS5)'/
'RADIAL:(2,0.013322,4,0.0157,2,0.0167)','AXIAL:(7.1932,8)-USER-LENGTH'/
2*0.8116,3*0.69,3*1.16667/
'BOUNDARY CONDITIONS:(3,1)'/
'INSIDE HYDRAULIC:(IF1HS5)','BRANCH POSITION:(0.,1.1979)',
'MODEL POSITION:(0.,1.1979)'/changed 1.6232 to 1.1979
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF2HS5)','BRANCH POSITION:(0.,2.07)',
'MODEL POSITION:(1.6232,3.6932)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF3HS5)','BRANCH POSITION:(0.,3.50)',
'MODEL POSITION:(3.6932,7.1932)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
'CARBON STEEL'/
/
/HQ:(983.)/ *** Trace Heating Power
```

```
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WIEFT5A)'/
'RADIAL:(1,0.04343,4,0.050445)','AXIAL:(1.113,2)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IEFTM5)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(0.,1.113)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WIEFT5E)'/
'RADIAL:(1,0.025276,4,0.032514)','AXIAL:(0.3903,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IEFTM5)','BRANCH POSITION:(1.113,1.5033)',
'MODEL POSITION:(0.,0.3903)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
```

```
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WHS5PT)'/
'RADIAL:(1,0.0224,4,0.028916)','AXIAL:(5.94,12)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(HS5)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(35.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-1D-AXI'/
 266.0, 269.0, 272.0, 275.0, 277.0, 280.0, 283.0, 286.0, 289.0, 292.0, 294.0, 297.0/
'PRINT:(00105)'/

'MODEL:(WHS5PIN)'/
```

```
'RADIAL:(4,0.0,4,0.0037975,3,0.0040895,4,0.0059175,4,0.00654)',
'AXIAL:(5.94,12)',,'CYLINDER:(3,2,3,2)'/
'BOUNDARY CONDITIONS:(0,1)'/
'OUTSIDE HYDRAULIC:(HS5)'/
'7-ROD-3','HT-CRIT-DEFAULT',HT-CORR-DEFAULT,,'CONSTANT-TEMPERATURE-OVER-EACH-SEGMENT',
'WALL-INTERFACE-HEAT-TRANSFER:(6*9,1)',,,,,,,/
'MPF-TEMP:(9)'/MgO TEMP DEPENDENT
 200., 8.5, 3.014E6,
 300., 7.1, 3.170E6,
 400., 5.9, 3.352E6,
 500., 4.8, 3.404E6,
 600., 3.9, 3.421E6,
 700., 3.2, 3.441E6,
 800., 2.4, 3.478E6,
 900., 1.9, 3.519E6,
1000., 1.5, 3.571E6/
'INCONEL'/
'MPF-TEMP:(10)'/BN TEMP DEPENDENT
 100., 15.4, 2.1359E6,
 200., 14.5, 2.5618E6,
 300., 13.5, 2.8662E6,
 400., 12.3, 3.1378E6,
```

```
 500., 11.3, 3.3934E6,
 600., 10.3, 3.6140E6,
 700.,  9.3, 3.8115E6,
 800.,  8.3, 4.0291E6,
 900.,  7.4, 4.2286E6,
1000.,  6.6, 4.3709E6/
'STAINLESS STEEL'/
'HQ-NIL'/
'HQ-TIME:(772.0E3,P1LP)'/
/
'HQ-NIL'/
'HQ-NIL'/
'TEMP-1D-RAD'/
 376.0, 376.0, 376.0, 376.0, 374.0, 370.0, 339.0, 312.0,
    289.0, 283.0, 278.0, 273.0/
'PRINT:(06220)'/

'MODEL:(WOEFT5E)'/
'RADIAL:(1,0.025276,4,0.032514)','AXIAL:(0.3903,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OEFTM5)','BRANCH POSITION:(0.,0.3903)',
'MODEL POSITION:(0.,0.3903)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
```

```
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-0D:(297.0)'/
'PRINT:(00105)'/

'MODEL:(WOEFT5A)'/
'RADIAL:(1,0.04343,4,0.050445)','AXIAL:(1.113,2)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OEFTM5)','BRANCH POSITION:(0.3903,1.5033)',
'MODEL POSITION:(0.,1.113)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(297.0)'/
'PRINT:(00105)'/

'MODEL:(WOFHS5)'/
```

```
'RADIAL:(2,0.017526,4,0.020082,2,0.021082)','AXIAL:(9.0632,8)-USER-LENGTH'/
3*1.19667,3*1.28333,2*0.8116/
'BOUNDARY CONDITIONS:(3,1)'/
'INSIDE HYDRAULIC:(OF3HS5)','BRANCH POSITION:(0.,3.59)',
'MODEL POSITION:(0.,3.59)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OF2HS5)','BRANCH POSITION:(0.,3.85)',
'MODEL POSITION:(3.59,7.44)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OF1HS5)','BRANCH POSITION:(0.,1.6232)',
'MODEL POSITION:(7.44,9.0632)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
'CARBON STEEL'/
/
/HQ:(1451.)/ *** Trace Heating Power
'TEMP-0D:(297.0)'/
'PRINT:(00105)'/
```

```

'MODEL:(WIFHS6)'/
'RADIAL:(2,0.013322,4,0.0157,2,0.0167)','AXIAL:(10.2132,11)-USER-LENGTH'/
2*0.5816,3*0.62,6*1.198333/
'BOUNDARY CONDITIONS:(3,1)'/
'INSIDE HYDRAULIC:(IF1HS6)','BRANCH POSITION:(0.,0.7369)',
'MODEL POSITION:(0.,0.7369)'/replaced 1.1632 with 0.7369
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF2HS6)','BRANCH POSITION:(0.,1.86)',
'MODEL POSITION:(1.1632,3.0232)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF3HS6)','BRANCH POSITION:(0.,7.19)',
'MODEL POSITION:(3.0232,10.2132)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
'CARBON STEEL'/
/
/HQ:(1351.)/ *** Trace Heating Power
```

```
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WIEFT6A)'/
'RADIAL:(1,0.04343,4,0.050445)','AXIAL:(1.113,2)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IEFTM6)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(0.,1.113)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WIEFT6E)'/
'RADIAL:(1,0.025276,4,0.032514)','AXIAL:(0.3903,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IEFTM6)','BRANCH POSITION:(1.113,1.5033)',
'MODEL POSITION:(0.,0.3903)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
```

```
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WHS6PT)'/
'RADIAL:(1,0.0224,4,0.028916)','AXIAL:(5.94,12)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(HS6)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(35.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-1D-AXI'/
 266.0, 269.0, 272.0, 275.0, 278.0, 281.0, 284.0, 287.0,
     289.0, 292.0, 295.0, 299.0/
'PRINT:(00105)'/

'MODEL:(WHS6PIN)'/
```

```
'RADIAL:(4,0.0,4,0.0037975,3,0.0040895,4,0.0059175,4,0.00654)',
'AXIAL:(5.94,12)',,'CYLINDER:(3,2,3,2)'/
'BOUNDARY CONDITIONS:(0,1)'/
'OUTSIDE HYDRAULIC:(HS6)'/
'7-ROD-3','HT-CRIT-DEFAULT',HT-CORR-DEFAULT,,'CONSTANT-TEMPERATURE-OVER-EACH-SEGMENT',
'WALL-INTERFACE-HEAT-TRANSFER:(6*9,1)',,,,,,,/
'MPF-TEMP:(9)'/MgO TEMP DEPENDENT
 200., 8.5, 3.014E6,
 300., 7.1, 3.170E6,
 400., 5.9, 3.352E6,
 500., 4.8, 3.404E6,
 600., 3.9, 3.421E6,
 700., 3.2, 3.441E6,
 800., 2.4, 3.478E6,
 900., 1.9, 3.519E6,
1000., 1.5, 3.571E6/
'INCONEL'/
'MPF-TEMP:(10)'/BN TEMP DEPENDENT
 100., 15.4, 2.1359E6,
 200., 14.5, 2.5618E6,
 300., 13.5, 2.8662E6,
 400., 12.3, 3.1378E6,
```

```
 500.,  11.3, 3.3934E6,
 600.,  10.3, 3.6140E6,
 700.,   9.3, 3.8115E6,
 800.,   8.3, 4.0291E6,
 900.,   7.4, 4.2286E6,
1000.,   6.6, 4.3709E6/
'STAINLESS STEEL'/
'HQ-NIL'/
'HQ-TIME:(775.0E3,P1LP)'/
/
'HQ-NIL'/
'HQ-NIL'/
'TEMP-1D-RAD'/
 376.0, 376.0, 376.0, 376.0, 374.0, 370.0, 339.0, 312.0, 289.0, 283.0, 278.0, 273.0/
'PRINT:(06220)'/

'MODEL:(WOEFT6E)'/
'RADIAL:(1,0.025276,4,0.032514)','AXIAL:(0.3903,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OEFTM6)','BRANCH POSITION:(0.,0.3903)',
'MODEL POSITION:(0.,0.3903)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
```

```
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-0D:(297.5)'/
'PRINT:(00105)'/

'MODEL:(WOEFT6A)'/
'RADIAL:(1,0.04343,4,0.050445)','AXIAL:(1.113,2)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OEFTM6)','BRANCH POSITION:(0.3903,1.5033)',
'MODEL POSITION:(0.,1.113)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(297.5)'/
'PRINT:(00105)'/

'MODEL:(WOFHS6)'/
```

```
'RADIAL:(2,0.017526,4,0.020082,2,0.021082)','AXIAL:(12.0932,11)-USER-LENGTH'/
6*1.21,3*1.223333,2*0.5816/
'BOUNDARY CONDITIONS:(3,1)'/
'INSIDE HYDRAULIC:(OF3HS6)','BRANCH POSITION:(0.,7.26)',
'MODEL POSITION:(0.,7.26)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OF2HS6)','BRANCH POSITION:(0.,3.67)',
'MODEL POSITION:(7.26,10.93)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OF1HS6)','BRANCH POSITION:(0.,1.1632)',
'MODEL POSITION:(10.93,12.0932)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
'CARBON STEEL'/
/
/HQ:(1677.)/ *** Trace Heating Power
'TEMP-0D:(297.5)'/
'PRINT:(00105)'/
```

```

'MODEL:(WIFHS7)'/
'RADIAL:(2,0.017526,4,0.020082,2,0.021082)','AXIAL:(15.8032,17)-USER-LENGTH'/
3*0.23773,2*0.41,3*1.026667,5*1.328,4*1.1375/
'BOUNDARY CONDITIONS:(5,1)'/
'INSIDE HYDRAULIC:(IF1HS7)','BRANCH POSITION:(0.,0.3832)',
'MODEL POSITION:(0.,0.3832)'/replaced 0.7132 with 0.3832
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF2HS7)','BRANCH POSITION:(0.,0.57)',
'MODEL POSITION:(0.7132,1.2832)'/replaced 0.82 with 0.57, 1.5332 with 1.2832
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF3HS7)','BRANCH POSITION:(0.,3.08)',
'MODEL POSITION:(1.5332,4.6132)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF4HS7)','BRANCH POSITION:(0.,6.64)',
'MODEL POSITION:(4.6132,11.2532)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF5HS7)','BRANCH POSITION:(0.,4.55)',
```

```
'MODEL POSITION:(11.2532,15.8032)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
'CARBON STEEL'/
/
/HQ:(2402.)/ *** Trace Heating Power
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WIEFT7A)'/
'RADIAL:(1,0.04343,4,0.050445)','AXIAL:(1.113,2)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IEFTM7)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(0.,1.113)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(262.0)'/
```

```
'PRINT:(00105)'/

'MODEL:(WIEFT7E)'/
'RADIAL:(1,0.025276,4,0.032514)','AXIAL:(0.3903,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IEFTM7)','BRANCH POSITION:(1.113,1.5033)',
'MODEL POSITION:(0.,0.3903)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WHS7PT)'/
'RADIAL:(1,0.0224,4,0.028916)','AXIAL:(5.94,12)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(HS7)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(35.00,20.)'/
```

```
'STAINLESS STEEL'/
/
'TEMP-1D-AXI'/
 266.0, 269.0, 272.0, 275.0, 278.0, 281.0, 284.0, 287.0, 289.0, 292.0, 295.0, 299.0/
'PRINT:(00105)'/

'MODEL:(WHS7PIN)'/
'RADIAL:(4,0.0,4,0.0037975,3,0.0040895,4,0.0059175,4,0.00654)',
'AXIAL:(5.94,12)',,'CYLINDER:(4,2,1,2,2)'/
'BOUNDARY CONDITIONS:(0,1)'/
'OUTSIDE HYDRAULIC:(HS7)'/
'USER-ALPHA','HT-CRIT-DEFAULT',HT-CORR-DEFAULT,,'CONSTANT-TEMPERATURE-OVER-EACH-SEGMENT',
'WALL-INTERFACE-HEAT-TRANSFER:(6*9,1)',,,,,,,/
0.0840,0.3692,0.3692,0.6078/
0.3922,0.6308,0.6308,0.9160/
'MPF-TEMP:(9)'/MgO TEMP DEPENDENT
 200., 8.5, 3.014E6,
 300., 7.1, 3.170E6,
 400., 5.9, 3.352E6,
 500., 4.8, 3.404E6,
 600., 3.9, 3.421E6,
```

```
 700., 3.2, 3.441E6,
 800., 2.4, 3.478E6,
 900., 1.9, 3.519E6,
1000., 1.5, 3.571E6/
'INCONEL'/
'MPF-TEMP:(10)'/BN TEMP DEPENDENT
 100., 15.4, 2.1359E6,
 200., 14.5, 2.5618E6,
 300., 13.5, 2.8662E6,
 400., 12.3, 3.1378E6,
 500., 11.3, 3.3934E6,
 600., 10.3, 3.6140E6,
 700.,  9.3, 3.8115E6,
 800.,  8.3, 4.0291E6,
 900.,  7.4, 4.2286E6,
1000.,  6.6, 4.3709E6/
'STAINLESS STEEL'/
'HQ-NIL'/
'HQ-TIME:(819.0E3,P1HP)'/
,,,'C-USER:(0.3333,0.0,0.3334,0.3333)'/
'HQ-NIL'/
'HQ-NIL'/
'TEMP-1D-RAD'/
```

```
 382.0, 382.0, 382.0, 382.0, 380.0, 375.0, 342.0, 314.0, 289.0, 283.0, 277.0, 272.0/
'PRINT:(06220)'/

'MODEL:(WOEFT7E)'/
'RADIAL:(1,0.025276,4,0.032514)','AXIAL:(0.3903,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OEFTM7)','BRANCH POSITION:(0.,0.3903)',
'MODEL POSITION:(0.,0.3903)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-0D:(297.5)'/
'PRINT:(00105)'/

'MODEL:(WOEFT7A)'/
'RADIAL:(1,0.04343,4,0.050445)','AXIAL:(1.113,2)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OEFTM7)','BRANCH POSITION:(0.3903,1.5033)',
'MODEL POSITION:(0.,1.113)'/
```

```
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(297.5)'/
'PRINT:(00105)'/

'MODEL:(WOFHS7A)'/
'RADIAL:(2,0.017526,4,0.020082,2,0.021082)','AXIAL:(4.95,4)-USER-LENGTH'/
4*1.2375/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OF5HS7)','BRANCH POSITION:(0.,4.95)',
'MODEL POSITION:(0.,4.95)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
'CARBON STEEL'/
/
/HQ:(774.8)/ *** Trace Heating Power
```

```
'TEMP-0D:(297.5)'/
'PRINT:(00105)'/

'MODEL:(WOFHS7B)'/
'RADIAL:(2,0.020447,4,0.02313,2,0.02413)','AXIAL:(14.0232,14)
    -USER-LENGTH'/
5*1.326,4*1.4925,2*0.355,3*0.237733/
'BOUNDARY CONDITIONS:(4,1)'/
'INSIDE HYDRAULIC:(OF4HS7)','BRANCH POSITION:(0.,6.63)',
'MODEL POSITION:(0.,6.63)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OF3HS7)','BRANCH POSITION:(0.,5.97)',
'MODEL POSITION:(6.63,12.60)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OF2HS7)','BRANCH POSITION:(0.,0.71)',
'MODEL POSITION:(12.60,13.31)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OF1HS7)','BRANCH POSITION:(0.,0.7132)',
'MODEL POSITION:(13.31,14.0232)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
```

```
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
'CARBON STEEL'/
/
/HQ:(2179.2)/ *** Trace Heating Power
'TEMP-0D:(297.5)'/
'PRINT:(00105)'/

'MODEL:(WIFHS8)'/
'RADIAL:(2,0.017526,4,0.020082,2,0.021082)','AXIAL:(13.9532,13)-USER-LENGTH'/
2*0.6016,3*1.11,5*1.418,3*0.77667/
'BOUNDARY CONDITIONS:(4,1)'/
'INSIDE HYDRAULIC:(IF1HS8)','BRANCH POSITION:(0.,0.9403)',
'MODEL POSITION:(0.,0.9403)'/replaced 1.2032 with 0.9403
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF2HS8)','BRANCH POSITION:(0.,3.33)',
'MODEL POSITION:(1.2032,4.5332)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF3HS8)','BRANCH POSITION:(0.,7.09)',
'MODEL POSITION:(4.5332,11.6232)'/
```

```
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF4HS8)','BRANCH POSITION:(0.,2.33)',
'MODEL POSITION:(11.6232,13.9532)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
'CARBON STEEL'/
/
/HQ:(2402.)/ *** Trace Heating Power
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WIEFT8A)'/
'RADIAL:(1,0.04343,4,0.050445)','AXIAL:(1.113,2)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IEFTM8)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(0.,1.113)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
```

```
'CARBON STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WIEFT8E)'/
'RADIAL:(1,0.025276,4,0.032514)','AXIAL:(0.3903,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IEFTM8)','BRANCH POSITION:(1.113,1.5033)',
'MODEL POSITION:(0.,0.3903)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WHS8PT)'/
'RADIAL:(1,0.0224,4,0.028916)','AXIAL:(5.94,12)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(HS8)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
```

```
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(35.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-1D-AXI'/
 266.0, 269.0, 272.0, 275.0, 278.0, 281.0, 284.0, 287.0, 290.0, 293.0, 296.0, 300.0/
'PRINT:(00105)'/

'MODEL:(WHS8PIN)'/
'RADIAL:(4,0.0,4,0.0037975,3,0.0040895,4,0.0059175,4,0.00654)',
'AXIAL:(5.94,12)',,'CYLINDER:(3,2,3,2)'/
'BOUNDARY CONDITIONS:(0,1)'/
'OUTSIDE HYDRAULIC:(HS8)'/
'7-ROD-3','HT-CRIT-DEFAULT',HT-CORR-DEFAULT,,'CONSTANT-TEMPERATURE-OVER-EACH-SEGMENT',
'WALL-INTERFACE-HEAT-TRANSFER:(6*9,1)',,,,,,,/
'MPF-TEMP:(9)'/MgO TEMP DEPENDENT
 200., 8.5, 3.014E6,
 300., 7.1, 3.170E6,
 400., 5.9, 3.352E6,
 500., 4.8, 3.404E6,
```

```
 600., 3.9, 3.421E6,
 700., 3.2, 3.441E6,
 800., 2.4, 3.478E6,
 900., 1.9, 3.519E6,
1000., 1.5, 3.571E6/
'INCONEL'/
'MPF-TEMP:(10)'/BN TEMP DEPENDENT
 100., 15.4, 2.1359E6,
 200., 14.5, 2.5618E6,
 300., 13.5, 2.8662E6,
 400., 12.3, 3.1378E6,
 500., 11.3, 3.3934E6,
 600., 10.3, 3.6140E6,
 700.,  9.3, 3.8115E6,
 800.,  8.3, 4.0291E6,
 900.,  7.4, 4.2286E6,
1000.,  6.6, 4.3709E6/
'STAINLESS STEEL'/
'HQ-NIL'/
'HQ-TIME:(954.0E3,P1HP)'/
/
'HQ-NIL'/
'HQ-NIL'/
'TEMP-1D-RAD'/
```

```
 405.0, 405.0, 405.0, 405.0, 403.0, 397.0, 357.0, 323.0, 294.0, 287.0, 280.0, 273./
'PRINT:(06220)'/

'MODEL:(WOEFT8E)'/
'RADIAL:(1,0.025276,4,0.032514)','AXIAL:(0.3903,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OEFTM8)','BRANCH POSITION:(0.,0.3903)',
'MODEL POSITION:(0.,0.3903)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-0D:(299.0)'/
/'PRINT:(00105)'/

'MODEL:(WOEFT8A)'/
'RADIAL:(1,0.04343,4,0.050445)','AXIAL:(1.113,2)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OEFTM8)','BRANCH POSITION:(0.3903,1.5033)',
'MODEL POSITION:(0.,1.113)'/
```

```
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(299.0)'/
'PRINT:(00105)'/

'MODEL:(WOFHS8A)'/
'RADIAL:(2,0.017526,4,0.020082,2,0.021082)','AXIAL:(2.51,3)-USER-LENGTH'/
3*0.83667/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OF4HS8)','BRANCH POSITION:(0.,2.51)',
'MODEL POSITION:(0.,2.51)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
'CARBON STEEL'/
/
/HQ:(370.4)/ *** Trace Heating Power
```

```
'TEMP-0D:(299.0)'/
'PRINT:(00105)'/

'MODEL:(WOFHS8B)'/
'RADIAL:(2,0.020447,4,0.02313,2,0.02413)','AXIAL:(14.4432,12)
    -USER-LENGTH'/
5*1.414,5*1.234,2*0.6016/
'BOUNDARY CONDITIONS:(3,1)'/
'INSIDE HYDRAULIC:(OF3HS8)','BRANCH POSITION:(0.,7.07)',
'MODEL POSITION:(0.,7.07)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OF2HS8)','BRANCH POSITION:(0.,6.17)',
'MODEL POSITION:(7.07,13.24)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OF1HS8)','BRANCH POSITION:(0.,1.2032)',
'MODEL POSITION:(13.24,14.4432)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
'CARBON STEEL'/
```

```
/
/HQ:(2131.6)/ *** Trace Heating Power
'TEMP-0D:(299.0)'/
'PRINT:(00105)'/

'MODEL:(WIFHS9)'/
'RADIAL:(2,0.013322,4,0.0157,2,0.0167)','AXIAL:(19.0332,20)-USER-LENGTH'/
3*0.237733,2*0.405,3*0.323333,8*1.4625,4*1.21/
'BOUNDARY CONDITIONS:(5,1)'/
'INSIDE HYDRAULIC:(IF1HS9)','BRANCH POSITION:(0.,0.3832)',
'MODEL POSITION:(0.,0.3832)'/replaced 0.7132 with 0.3832
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF2HS9)','BRANCH POSITION:(0.,0.56)',
'MODEL POSITION:(0.7132,1.2732)'/replaced 0.81 with 0.56, 1.5232 with 1.2732
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF3HS9)','BRANCH POSITION:(0.,0.97)',
'MODEL POSITION:(1.5232,2.4932)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF4HS9)','BRANCH POSITION:(0.,11.70)',
```

```
'MODEL POSITION:(2.4932,14.1933)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF5HS9)','BRANCH POSITION:(0.,4.84)',
'MODEL POSITION:(14.1932,19.0332)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
'CARBON STEEL'/
/
/HQ:(2502.)/ *** Trace Heating Power
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WIEFT9A)'/
'RADIAL:(1,0.04343,4,0.050445)','AXIAL:(1.113,2)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IEFTM9)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(0.,1.113)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
```

```
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WIEFT9E)'/
'RADIAL:(1,0.025276,4,0.032514)','AXIAL:(0.3903,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IEFTM9)','BRANCH POSITION:(1.113,1.5033)',
'MODEL POSITION:(0.,0.3903)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WHS9PT)'/
'RADIAL:(1,0.0224,4,0.028916)','AXIAL:(5.94,12)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(HS9)'/
```

```
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(35.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-1D-AXI'/
 265.57, 268.76, 271.92, 275.04, 278.13, 281.19, 284.21, 287.20, 290.14, 293.09, 295.76, 299.74/
'PRINT:(00105)'/

'MODEL:(WHS9PIN)'/
'RADIAL:(4,0.0,4,0.0037975,3,0.0040895,4,0.0059175,4,0.00654)',
'AXIAL:(5.94,12)',,'CYLINDER:(3,2,3,2)'/
'BOUNDARY CONDITIONS:(0,1)'/
'OUTSIDE HYDRAULIC:(HS9)'/
'7-ROD-3','HT-CRIT-DEFAULT',HT-CORR-DEFAULT,,'CONSTANT-TEMPERATURE-OVER-EACH-SEGMENT',
'WALL-INTERFACE-HEAT-TRANSFER:(6*9,1)',,,,,,,/
'MPF-TEMP:(9)'/MgO TEMP DEPENDENT
 200., 8.5, 3.014E6,
 300., 7.1, 3.170E6,
 400., 5.9, 3.352E6,
```

```
 500., 4.8, 3.404E6,
 600., 3.9, 3.421E6,
 700., 3.2, 3.441E6,
 800., 2.4, 3.478E6,
 900., 1.9, 3.519E6,
1000., 1.5, 3.571E6/
'INCONEL'/
'MPF-TEMP:(10)'/BN TEMP DEPENDENT
 100., 15.4, 2.1359E6,
 200., 14.5, 2.5618E6,
 300., 13.5, 2.8662E6,
 400., 12.3, 3.1378E6,
 500., 11.3, 3.3934E6,
 600., 10.3, 3.6140E6,
 700.,  9.3, 3.8115E6,
 800.,  8.3, 4.0291E6,
 900.,  7.4, 4.2286E6,
1000.,  6.6, 4.3709E6/
'STAINLESS STEEL'/
'HQ-NIL'/
'HQ-TIME:(786.0E3,P1LP)'/
/
'HQ-NIL'/
'HQ-NIL'/
```

```
'TEMP-1D-RAD'/
 376.0, 376.0, 376.0, 376.0, 374.0, 370.0, 339.0, 312.0, 289.0, 284.0, 278.0, 273.0/
'PRINT:(06220)'/

'MODEL:(WOEFT9E)'/
'RADIAL:(1,0.025276,4,0.032514)','AXIAL:(0.3903,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OEFTM9)','BRANCH POSITION:(0.,0.3903)',
'MODEL POSITION:(0.,0.3903)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-0D:(299.0)'/
'PRINT:(00105)'/

'MODEL:(WOEFT9A)'/
'RADIAL:(1,0.04343,4,0.050445)','AXIAL:(1.113,2)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OEFTM9)','BRANCH POSITION:(0.3903,1.5033)',
```

```
'MODEL POSITION:(0.,1.113)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(299.0)'/
'PRINT:(00105)'/

'MODEL:(WOFHS9)'/
'RADIAL:(2,0.017526,4,0.020082,2,0.021082)','AXIAL:(20.1832,20)-USER-LENGTH'/
4*1.31,8*1.45625,3*0.623333,2*0.355,3*0.237733/
'BOUNDARY CONDITIONS:(5,1)'/
'INSIDE HYDRAULIC:(OF5HS9)','BRANCH POSITION:(0.,5.24)',
'MODEL POSITION:(0.,5.24)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OF4HS9)','BRANCH POSITION:(0.,11.65)',
'MODEL POSITION:(5.24,16.89)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OF3HS9)','BRANCH POSITION:(0.,1.87)',
```

```
'MODEL POSITION:(16.89,18.76)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OF2HS9)','BRANCH POSITION:(0.,0.71)',
'MODEL POSITION:(18.76,19.47)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OF1HS9)','BRANCH POSITION:(0.,0.7132)',
'MODEL POSITION:(19.47,20.1832)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
'CARBON STEEL'/
/
/HQ:(2954.)/ *** Trace Heating Power
'TEMP-0D:(299.0)'/
'PRINT:(00105)'/

'MODEL:(WOH7A)'/
'RADIAL:(1,0.110534,4,0.123234)','AXIAL:(0.34233,1)'/  *** FOR OUTLET HEADER BREAK, LENGTH=0.16 M
'BOUNDARY CONDITIONS:(1,1)'/
```

```
'INSIDE HYDRAULIC:(OH7A)','BRANCH POSITION:(0.,0.34233)',
'MODEL POSITION:(0.,0.34233)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(296.5)'/
'PRINT:(00105)'/

'MODEL:(WOH7B)'/
'RADIAL:(1,0.096837,4,0.109537)','AXIAL:(0.20,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OH7B)','BRANCH POSITION:(0.,0.20)',
'MODEL POSITION:(0.,0.20)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(296.5)'/
'PRINT:(00105)'/
```

```

'MODEL:(WOH7C)'/
'RADIAL:(1,0.096837,4,0.109537)','AXIAL:(0.26,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OH7C)','BRANCH POSITION:(0.,0.26)',
'MODEL POSITION:(0.,0.26)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(296.5)'/
'PRINT:(00105)'/

'MODEL:(WOH7D)'/
'RADIAL:(1,0.135436,4,0.148184)','AXIAL:(0.15896,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OH7D)','BRANCH POSITION:(0.,0.15896)',
'MODEL POSITION:(0.,0.15896)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
```

```
'CARBON STEEL'/
/
'TEMP-0D:(296.5)'/
'PRINT:(00105)'/

'MODEL:(WOH7RLF)'/
'RADIAL:(1,0.02972,4,0.036)','AXIAL:(1.6432,2)-USER-LENGTH'/
0.2,1.4432/
'BOUNDARY CONDITIONS:(1,0)'/
'INSIDE HYDRAULIC:(OH7RLF)','BRANCH POSITION:(0.,1.6432)',
'MODEL POSITION:(0.,1.6432)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'CARBON STEEL'/
/
'TEMP-0D:(296.5)'/
'PRINT:(00105)'/

'MODEL:(WIBO2)'/
'RADIAL:(1,0.04859,4,0.05715)','AXIAL:(3.86619,4)-USER-LENGTH'/
2*0.9766,2*0.95649/
'BOUNDARY CONDITIONS:(2,1)'/
'INSIDE HYDRAULIC:(IBO2A)','BRANCH NODE:(1,2)',
```

```
'MODEL NODE:(1,2)'/
'TUBE–CIR',,'HT–CORR–DEFAULT',,,
'WALL–INTERFACE–HEAT–TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IBO2B)','BRANCH NODE:(1,2)',
'MODEL NODE:(3,4)'/
'TUBE–CIR',,'HT–CORR–DEFAULT',,,
'WALL–INTERFACE–HEAT–TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF–HC,TF:(10.00,20.)'/
'CARBON STEEL'/
/
'TEMP–0D:(296.5)'/
'PRINT:(00105)'/

'MODEL:(WIBO2PL)'/
'RADIAL:(1,0.148027,4,0.226253)','AXIAL:(0.6782,2)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IBO2PL)'/
'TUBE–CIR',,'HT–CORR–DEFAULT',,,
'WALL–INTERFACE–HEAT–TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF–HC,TF:(10.00,20.)'/
'CARBON STEEL'/
/
```

```
'TEMP-0D:(296.0)'/
'PRINT:(00105)'/

'MODEL:(WBO2PDV)',/
'RADIAL:(1,100.0,6,100.0127)','AXIAL:(0.5266,2)',
'SECTOR:(1,1,5.861994D-4)',/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IBO2PL)','BRANCH POSITION:(0.0,0.5266)',/
'ALPHA:(0.95,1.0)',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE HYDRAULIC:(OBO2PL)','BRANCH POSITION:(0.1516,0.6782)',/
'ALPHA:(0.95,1.0)',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'CARBON STEEL'/
/
'TEMP-0D:(288.0)'/
'PRINT:(00307)'/

'MODEL:(WOBO2PL)'/
'RADIAL:(1,0.148027,4,0.226253)','AXIAL:(0.6782,2)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OBO2PL)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
```

```
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(10.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WOBO2)'/
'RADIAL:(1,0.04859,4,0.05715)','AXIAL:(3.573,5)-USER-LENGTH'/
2*0.7165,3*0.71333/
'BOUNDARY CONDITIONS:(2,1)'/
'INSIDE HYDRAULIC:(OBO2A)','BRANCH NODE:(1,2)',
'MODEL NODE:(1,2)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OBO2B)','BRANCH NODE:(1,3)',
'MODEL NODE:(3,5)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(12.00,20.)'/
'CARBON STEEL'/
/
```

```
'TEMP–0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WINP2)'/
'RADIAL:(1,0.059555,4,0.173625)','AXIAL:(1.243,2)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(INP2)'/
'TUBE–CIR',,'HT–CORR–DEFAULT',,,
'WALL–INTERFACE–HEAT–TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF–HC,TF:(17.0,20.)'/
'CARBON STEEL'/
/
'TEMP–0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WOUTP2)'/
'RADIAL:(1,0.045871,4,0.156187)','AXIAL:(1.41,3)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OUTP2)'/
'TUBE–CIR',,'HT–CORR–DEFAULT',,,
'WALL–INTERFACE–HEAT–TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF–HC,TF:(30.0,20.)'/
```

```
'CARBON STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WOUTP2A)'/
'RADIAL:(1,0.03896,4,0.04445)','AXIAL:(0.79,3)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OUTP2A)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(12.0,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WOPMP2)'/
'RADIAL:(1,0.038964,4,0.04445)','AXIAL:(2.1732,2)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OPMP2)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
```

```
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF–HC,TF:(12.0,20.)'/
'CARBON STEEL'/
/
'TEMP–0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WIH8A)'/
'RADIAL:(1,0.135436,4,0.148184)','AXIAL:(0.15896,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IH8A)','BRANCH POSITION:(0.,0.15896)',
'MODEL POSITION:(0.,0.15896)'/
'TUBE–CIR',,'HT–CORR–DEFAULT',,,
'WALL–INTERFACE–HEAT–TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF–HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP–0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WIH8B)'/
'RADIAL:(1,0.096837,4,0.109537)','AXIAL:(0.20,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
```

```
'INSIDE HYDRAULIC:(IH8B)','BRANCH POSITION:(0.,0.20)',
'MODEL POSITION:(0.,0.20)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WIH8C)'/
'RADIAL:(1,0.096837,4,0.109537)','AXIAL:(0.26,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IH8C)','BRANCH POSITION:(0.,0.26)',
'MODEL POSITION:(0.,0.26)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/
```

```

'MODEL:(WIH8D)'/
'RADIAL:(1,0.108432,4,0.12113)','AXIAL:(0.23,1)'/ *** FOR INLET HEADER BREAK, LENGTH=0.23 M
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IH8D)','BRANCH POSITION:(0.,0.23)',
'MODEL POSITION:(0.,0.23)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WIFHS10)'/
'RADIAL:(2,0.013322,4,0.0157,2,0.0167)','AXIAL:(7.1932,8)-USER-LENGTH'/
2*0.8116,3*0.69,3*1.16667/
'BOUNDARY CONDITIONS:(3,1)'/
'INSIDE HYDRAULIC:(IF1HS10)','BRANCH POSITION:(0.,1.6232)',
'MODEL POSITION:(0.,1.6232)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
```

```
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF2HS10)','BRANCH POSITION:(0.,2.07)',
'MODEL POSITION:(1.6232,3.6932)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF3HS10)','BRANCH POSITION:(0.,3.50)',
'MODEL POSITION:(3.6932,7.1932)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
'CARBON STEEL'/
/
/HQ:(983.)/ *** Trace Heating Power
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WIEFT10A)'/
'RADIAL:(1,0.04343,4,0.050445)','AXIAL:(1.113,2)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IEFTM10)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(0.,1.113)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
```

```
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WIEFT10E)'/
'RADIAL:(1,0.025276,4,0.032514)','AXIAL:(0.3903,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IEFTM10)','BRANCH POSITION:(1.113,1.5033)',
'MODEL POSITION:(0.,0.3903)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WHS10PT)'/
```

```
'RADIAL:(1,0.0224,4,0.028916)','AXIAL:(5.94,12)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(HS10)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(35.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-1D-AXI'/
 266.0, 269.0, 272.0, 275.0, 278.0, 281.0, 284.0, 286.0, 289.0, 292.0, 295.0, 299.0/
'PRINT:(00105)'/

'MODEL:(WHS10PIN)'/
'RADIAL:(4,0.0,4,0.0037975,3,0.0040895,4,0.0059175,4,0.00654)',
'AXIAL:(5.94,12)',,'CYLINDER:(3,2,3,2)'/
'BOUNDARY CONDITIONS:(0,1)'/
'OUTSIDE HYDRAULIC:(HS10)'/
'7-ROD-3','HT-CRIT-DEFAULT',HT-CORR-DEFAULT,,'CONSTANT-TEMPERATURE-OVER-EACH-SEGMENT',
'WALL-INTERFACE-HEAT-TRANSFER:(6*9,1)',,,,,,,,/
'MPF-TEMP:(9)'/MgO TEMP DEPENDENT
```

```
 200., 8.5, 3.014E6,
 300., 7.1, 3.170E6,
 400., 5.9, 3.352E6,
 500., 4.8, 3.404E6,
 600., 3.9, 3.421E6,
 700., 3.2, 3.441E6,
 800., 2.4, 3.478E6,
 900., 1.9, 3.519E6,
1000., 1.5, 3.571E6/
'INCONEL'/
'MPF-TEMP:(10)'/BN TEMP DEPENDENT
 100., 15.4, 2.1359E6,
 200., 14.5, 2.5618E6,
 300., 13.5, 2.8662E6,
 400., 12.3, 3.1378E6,
 500., 11.3, 3.3934E6,
 600., 10.3, 3.6140E6,
 700.,  9.3, 3.8115E6,
 800.,  8.3, 4.0291E6,
 900.,  7.4, 4.2286E6,
1000.,  6.6, 4.3709E6/
'STAINLESS STEEL'/
'HQ-NIL'/
'HQ-TIME:(761.0E3,P2LP)'/
```

```
/
'HQ-NIL'/
'HQ-NIL'/
'TEMP-1D-RAD'/
 375.76, 375.76, 375.76, 375.76, 374.21, 369.67, 338.69,
     312.19, 289.10, 283.48, 278.03, 272.74/
'PRINT:(06220)'/

'MODEL:(WOEFT10E)'/
'RADIAL:(1,0.025276,4,0.032514)','AXIAL:(0.3903,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OEFTM10)','BRANCH POSITION:(0.,0.3903)',
'MODEL POSITION:(0.,0.3903)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-0D:(297.5)'/
'PRINT:(00105)'/

'MODEL:(WOEFT10A)'/
'RADIAL:(1,0.04343,4,0.050445)','AXIAL:(1.113,2)'/
```

```
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OEFTM10)','BRANCH POSITION:(0.3903,1.5033)',
'MODEL POSITION:(0.,1.113)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(297.5)'/
'PRINT:(00105)'/

'MODEL:(WOFHS10)'/
'RADIAL:(2,0.017526,4,0.020082,2,0.021082)','AXIAL:(9.0632,8)-USER-LENGTH'/
3*1.19667,3*1.28333,2*0.8116/
'BOUNDARY CONDITIONS:(3,1)'/
'INSIDE HYDRAULIC:(OF3HS10)','BRANCH POSITION:(0.,3.59)',
'MODEL POSITION:(0.,3.59)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OF2HS10)','BRANCH POSITION:(0.,3.85)',
'MODEL POSITION:(3.59,7.44)'/
```

```
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OF1HS10)','BRANCH POSITION:(0.,1.6232)',
'MODEL POSITION:(7.44,9.0632)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
'CARBON STEEL'/
/
/HQ:(1451.)/ *** Trace Heating Power
'TEMP-0D:(297.5)'/
'PRINT:(00105)'/

'MODEL:(WIFHS11)'/
'RADIAL:(2,0.013322,4,0.0157,2,0.0167)','AXIAL:(10.2132,11)-USER-LENGTH'/
2*0.5816,3*0.62,6*1.198333/
'BOUNDARY CONDITIONS:(3,1)'/
'INSIDE HYDRAULIC:(IF1HS11)','BRANCH POSITION:(0.,1.1632)',
'MODEL POSITION:(0.,1.1632)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
```

```
'INSIDE HYDRAULIC:(IF2HS11)','BRANCH POSITION:(0.,1.86)',
'MODEL POSITION:(1.1632,3.0232)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF3HS11)','BRANCH POSITION:(0.,7.19)',
'MODEL POSITION:(3.0232,10.2132)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
'CARBON STEEL'/
/
/HQ:(1351.)/ *** Trace Heating Power
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WIEFT11A)'/
'RADIAL:(1,0.04343,4,0.050445)','AXIAL:(1.113,2)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IEFTM11)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(0.,1.113)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
```

```
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WIEFT11E)'/
'RADIAL:(1,0.025276,4,0.032514)','AXIAL:(0.3903,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IEFTM11)','BRANCH POSITION:(1.113,1.5033)',
'MODEL POSITION:(0.,0.3903)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WHS11PT)'/
'RADIAL:(1,0.0224,4,0.028916)','AXIAL:(5.94,12)'/
```

```
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(HS11)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(35.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-1D-AXI'/
 266.0, 269.0, 272.0, 275.0, 278.0, 281.0, 284.0, 287.0, 290.0, 292.0, 295.0, 299.0/
'PRINT:(00105)'/

'MODEL:(WHS11PIN)'/
'RADIAL:(4,0.0,4,0.0037975,3,0.0040895,4,0.0059175,4,0.00654)',
'AXIAL:(5.94,12)',,'CYLINDER:(3,2,3,2)'/
'BOUNDARY CONDITIONS:(0,1)'/
'OUTSIDE HYDRAULIC:(HS11)'/
'7-ROD-3','HT-CRIT-DEFAULT',HT-CORR-DEFAULT,,'CONSTANT-TEMPERATURE-OVER-EACH-SEGMENT',
'WALL-INTERFACE-HEAT-TRANSFER:(6*9,1)',,,,,,,/
'MPF-TEMP:(9)'/MgO TEMP DEPENDENT
 200., 8.5, 3.014E6,
```

```
 300., 7.1, 3.170E6,
 400., 5.9, 3.352E6,
 500., 4.8, 3.404E6,
 600., 3.9, 3.421E6,
 700., 3.2, 3.441E6,
 800., 2.4, 3.478E6,
 900., 1.9, 3.519E6,
1000., 1.5, 3.571E6/
'INCONEL'/
'MPF-TEMP:(10)'/BN TEMP DEPENDENT
 100., 15.4, 2.1359E6,
 200., 14.5, 2.5618E6,
 300., 13.5, 2.8662E6,
 400., 12.3, 3.1378E6,
 500., 11.3, 3.3934E6,
 600., 10.3, 3.6140E6,
 700.,  9.3, 3.8115E6,
 800.,  8.3, 4.0291E6,
 900.,  7.4, 4.2286E6,
1000.,  6.6, 4.3709E6/
'STAINLESS STEEL'/
'HQ-NIL'/
'HQ-TIME:(765.0E3,P2LP)'/
/
```

```
'HQ-NIL'/
'HQ-NIL'/
'TEMP-1D-RAD'/
 376.0, 376.0, 376.0, 376.0, 374.0, 370.0, 339.0, 312.0, 289.0, 283.0, 278.0, 273.0/
'PRINT:(06220)'/

'MODEL:(WOEFT11E)'/
'RADIAL:(1,0.025276,4,0.032514)','AXIAL:(0.3903,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OEFTM11)','BRANCH POSITION:(0.,0.3903)',
'MODEL POSITION:(0.,0.3903)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-0D:(298.0)'/
'PRINT:(00105)'/

'MODEL:(WOEFT11A)'/
'RADIAL:(1,0.04343,4,0.050445)','AXIAL:(1.113,2)'/
'BOUNDARY CONDITIONS:(1,1)'/
```

```
'INSIDE HYDRAULIC:(OEFTM11)','BRANCH POSITION:(0.3903,1.5033)',
'MODEL POSITION:(0.,1.113)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(298.0)'/
'PRINT:(00105)'/

'MODEL:(WOFHS11)'/
'RADIAL:(2,0.017526,4,0.020082,2,0.021082)','AXIAL:(12.0932,11)-USER-LENGTH'/
6*1.21,3*1.223333,2*0.5816/
'BOUNDARY CONDITIONS:(3,1)'/
'INSIDE HYDRAULIC:(OF3HS11)','BRANCH POSITION:(0.,7.26)',
'MODEL POSITION:(0.,7.26)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OF2HS11)','BRANCH POSITION:(0.,3.67)',
'MODEL POSITION:(7.26,10.93)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
```

```
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OF1HS11)','BRANCH POSITION:(0.,1.1632)',
'MODEL POSITION:(10.93,12.0932)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
'CARBON STEEL'/
/
/HQ:(1677.)/ *** Trace Heating Power
'TEMP-0D:(298.0)'/
'PRINT:(00105)'/

'MODEL:(WIFHS12)'/
'RADIAL:(2,0.017526,4,0.020082,2,0.021082)','AXIAL:(15.8032,17)-USER-LENGTH'/
3*0.23773,2*0.41,3*1.02667,5*1.328,4*1.1375/
'BOUNDARY CONDITIONS:(5,1)'/
'INSIDE HYDRAULIC:(IF1HS12)','BRANCH POSITION:(0.,0.7132)',
'MODEL POSITION:(0.,0.7132)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF2HS12)','BRANCH POSITION:(0.,0.82)',
```

```
'MODEL POSITION:(0.7132,1.5332)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF3HS12)','BRANCH POSITION:(0.,3.08)',
'MODEL POSITION:(1.5332,4.6132)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF4HS12)','BRANCH POSITION:(0.,6.64)',
'MODEL POSITION:(4.6132,11.2532)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF5HS12)','BRANCH POSITION:(0.,4.55)',
'MODEL POSITION:(11.2532,15.8032)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
'CARBON STEEL'/
/
/HQ:(2402.)/ *** Trace Heating Power
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

```

```
'MODEL:(WIEFT12A)'/
'RADIAL:(1,0.04343,4,0.050445)','AXIAL:(1.113,2)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IEFTM12)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(0.,1.113)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WIEFT12E)'/
'RADIAL:(1,0.025276,4,0.032514)','AXIAL:(0.3903,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IEFTM12)','BRANCH POSITION:(1.113,1.5033)',
'MODEL POSITION:(0.,0.3903)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
```

```
'STAINLESS STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WHS12PT)'/
'RADIAL:(1,0.0224,4,0.028916)','AXIAL:(5.94,12)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(HS12)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(35.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-1D-AXI'/
 266.0, 269.0, 272.0, 275.0, 278.0, 281.0, 284.0, 287.0,
    290.0, 292.0, 295.0, 299.0/
'PRINT:(00105)'/

'MODEL:(WHS12PIN)'/
'RADIAL:(4,0.0,4,0.0037975,3,0.0040895,4,0.0059175,4,0.00654)',
'AXIAL:(5.94,12)',,'CYLINDER:(4,2,2,1,2)'/
```

```
'BOUNDARY CONDITIONS:(0,1)'/
'OUTSIDE HYDRAULIC:(HS12)'/
'USER-ALPHA','HT-CRIT-DEFAULT',HT-CORR-DEFAULT,,'CONSTANT-TEMPERATURE-OVER-EACH-SEGMENT',
'WALL-INTERFACE-HEAT-TRANSFER:(6*9,1)',,,,,,,/
0.0840,0.3692,0.3692,0.6078/
0.3922,0.6308,0.6308,0.9160/
'MPF-TEMP:(9)'/MgO TEMP DEPENDENT
 200., 8.5, 3.014E6,
 300., 7.1, 3.170E6,
 400., 5.9, 3.352E6,
 500., 4.8, 3.404E6,
 600., 3.9, 3.421E6,
 700., 3.2, 3.441E6,
 800., 2.4, 3.478E6,
 900., 1.9, 3.519E6,
1000., 1.5, 3.571E6/
'INCONEL'/
'MPF-TEMP:(10)'/BN TEMP DEPENDENT
 100., 15.4, 2.1359E6,
 200., 14.5, 2.5618E6,
 300., 13.5, 2.8662E6,
 400., 12.3, 3.1378E6,
 500., 11.3, 3.3934E6,
```

```
 600., 10.3, 3.6140E6,
 700.,  9.3, 3.8115E6,
 800.,  8.3, 4.0291E6,
 900.,  7.4, 4.2286E6,
1000.,  6.6, 4.3709E6/
'STAINLESS STEEL'/
'HQ-NIL'/
'HQ-TIME:(797.0E3,P2HP)'/
,,,'C-USER:(0.3333,0.3334,0.0,0.3333)'/
'HQ-NIL'/
'HQ-NIL'/
'TEMP-1D-RAD'/
 376.0, 376.0, 376.0, 376.0, 374.0, 370.0, 339.0, 312.0,
    289.0, 283.0, 278.0, 273.0/
'PRINT:(06220)'/

'MODEL:(WOEFT12E)'/
'RADIAL:(1,0.025276,4,0.032514)','AXIAL:(0.3903,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OEFTM12)','BRANCH POSITION:(0.,0.3903)',
'MODEL POSITION:(0.,0.3903)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
```

```
'SURF-HC,TF:(5.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-0D:(298.0)'/
'PRINT:(00105)'/

'MODEL:(WOEFT12A)'/
'RADIAL:(1,0.04343,4,0.050445)','AXIAL:(1.113,2)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OEFTM12)','BRANCH POSITION:(0.3903,1.5033)',
'MODEL POSITION:(0.,1.113)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(298.0)'/
'PRINT:(00105)'/

'MODEL:(WOFHS12A)'/
'RADIAL:(2,0.017526,4,0.020082,2,0.021082)','AXIAL:(4.95,4)-USER-LENGTH'/
```

```
4*1.2375/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OF5HS12)','BRANCH POSITION:(0.,4.95)',
'MODEL POSITION:(0.,4.95)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
'CARBON STEEL'/
/
/HQ:(774.8)/ *** Trace Heating Power
'TEMP-0D:(298.0)'/
'PRINT:(00105)'/

'MODEL:(WOFHS12B)'/
'RADIAL:(2,0.020447,4,0.02313,2,0.02413)','AXIAL:(14.0232,14)-USER-LENGTH'/
5*1.326,4*1.4925,2*0.355,3*0.237733/
'BOUNDARY CONDITIONS:(4,1)'/
'INSIDE HYDRAULIC:(OF4HS12)','BRANCH POSITION:(0.,6.63)',
'MODEL POSITION:(0.,6.63)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
```

```
'INSIDE HYDRAULIC:(OF3HS12)','BRANCH POSITION:(0.,5.97)',
'MODEL POSITION:(6.63,12.60)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OF2HS12)','BRANCH POSITION:(0.,0.71)',
'MODEL POSITION:(12.60,13.31)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OF1HS12)','BRANCH POSITION:(0.,0.7132)',
'MODEL POSITION:(13.31,14.0232)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
'CARBON STEEL'/
/
/HQ:(2179.2)/ *** Trace Heating Power
'TEMP-0D:(298.0)'/
'PRINT:(00105)'/

'MODEL:(WIFHS13)'/
'RADIAL:(2,0.017526,4,0.020082,2,0.021082)','AXIAL:(13.9532,13)-USER-LENGTH'/
```

```
2*0.6016,3*1.11,5*1.418,3*0.77667/
'BOUNDARY CONDITIONS:(4,1)'/
'INSIDE HYDRAULIC:(IF1HS13)','BRANCH POSITION:(0.,1.2032)',
'MODEL POSITION:(0.,1.2032)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF2HS13)','BRANCH POSITION:(0.,3.33)',
'MODEL POSITION:(1.2032,4.5332)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF3HS13)','BRANCH POSITION:(0.,7.09)',
'MODEL POSITION:(4.5332,11.6232)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF4HS13)','BRANCH POSITION:(0.,2.33)',
'MODEL POSITION:(11.6232,13.9532)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
'CARBON STEEL'/
/
/HQ:(2402.)/ *** Trace Heating Power
```

```
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WIEFT13A)'/
'RADIAL:(1,0.04343,4,0.050445)','AXIAL:(1.113,2)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IEFTM13)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(0.,1.113)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WIEFT13E)'/
'RADIAL:(1,0.025276,4,0.032514)','AXIAL:(0.3903,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IEFTM13)','BRANCH POSITION:(1.113,1.5033)',
'MODEL POSITION:(0.,0.3903)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
```

```
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WHS13PT)'/
'RADIAL:(1,0.0224,4,0.028916)','AXIAL:(5.94,12)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(HS13)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(35.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-1D-AXI'/
 265.69, 268.90, 272.06, 275.19, 278.30, 281.36, 284.40,
     287.39, 290.34, 293.29, 295.96, 299.95/
'PRINT:(00105)'/

'MODEL:(WHS13PIN)'/
```

```
'RADIAL:(4,0.0,4,0.0037975,3,0.0040895,4,0.0059175,4,0.00654)',
'AXIAL:(5.94,12)',,'CYLINDER:(3,2,3,2)'/
'BOUNDARY CONDITIONS:(0,1)'/
'OUTSIDE HYDRAULIC:(HS13)'/
'7-ROD-3','HT-CRIT-DEFAULT',HT-CORR-DEFAULT,,'CONSTANT-TEMPERATURE-OVER-EACH-SEGMENT',
'WALL-INTERFACE-HEAT-TRANSFER:(6*9,1)',,,,,,,/
'MPF-TEMP:(9)'/MgO TEMP DEPENDENT
 200., 8.5, 3.014E6,
 300., 7.1, 3.170E6,
 400., 5.9, 3.352E6,
 500., 4.8, 3.404E6,
 600., 3.9, 3.421E6,
 700., 3.2, 3.441E6,
 800., 2.4, 3.478E6,
 900., 1.9, 3.519E6,
1000., 1.5, 3.571E6/
'INCONEL'/
'MPF-TEMP:(10)'/BN TEMP DEPENDENT
 100., 15.4, 2.1359E6,
 200., 14.5, 2.5618E6,
 300., 13.5, 2.8662E6,
 400., 12.3, 3.1378E6,
```

```
 500., 11.3, 3.3934E6,
 600., 10.3, 3.6140E6,
 700.,  9.3, 3.8115E6,
 800.,  8.3, 4.0291E6,
 900.,  7.4, 4.2286E6,
1000.,  6.6, 4.3709E6/
'STAINLESS STEEL'/
'HQ-NIL'/
'HQ-TIME:(940.0E3,P2HP)'/
/
'HQ-NIL'/
'HQ-NIL'/
'TEMP-1D-RAD'/
 405.0, 405.0, 405.0, 405.0, 403.0, 397.0, 357.0, 323.0,
    294.0, 287.0, 280.0, 273.0/
'PRINT:(06220)'/

'MODEL:(WOEFT13E)'/
'RADIAL:(1,0.025276,4,0.032514)','AXIAL:(0.3903,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OEFTM13)','BRANCH POSITION:(0.,0.3903)',
'MODEL POSITION:(0.,0.3903)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
```

```
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-0D:(299.0)'/
'PRINT:(00105)'/

'MODEL:(WOEFT13A)'/
'RADIAL:(1,0.04343,4,0.050445)','AXIAL:(1.113,2)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OEFTM13)','BRANCH POSITION:(0.3903,1.5033)',
'MODEL POSITION:(0.,1.113)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(299.0)'/
'PRINT:(00105)'/

'MODEL:(WOFHS13A)'/
```

```
'RADIAL:(2,0.017526,4,0.020082,2,0.021082)','AXIAL:(2.51,3)-USER-LENGTH'/
3*0.83667/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OF4HS13)','BRANCH POSITION:(0.,2.51)',
'MODEL POSITION:(0.,2.51)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
'CARBON STEEL'/
/
/HQ:(370.4)/ *** Trace Heating Power
'TEMP-0D:(299.0)'/
'PRINT:(00105)'/

'MODEL:(WOFHS13B)'/
'RADIAL:(2,0.020447,4,0.02313,2,0.02413)','AXIAL:(14.4432,12)-USER-LENGTH'/
5*1.414,5*1.234,2*0.6016/
'BOUNDARY CONDITIONS:(3,1)'/
'INSIDE HYDRAULIC:(OF3HS13)','BRANCH POSITION:(0.,7.07)',
'MODEL POSITION:(0.,7.07)'/
```

```
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OF2HS13)','BRANCH POSITION:(0.,6.17)',
'MODEL POSITION:(7.07,13.24)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OF1HS13)','BRANCH POSITION:(0.,1.2032)',
'MODEL POSITION:(13.24,14.4432)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
'CARBON STEEL'/
/
/HQ:(2131.6)/ *** Trace Heating Power
'TEMP-0D:(299.0)'/
'PRINT:(00105)'/

'MODEL:(WIFHS14)'/
'RADIAL:(2,0.013322,4,0.0157,2,0.0167)','AXIAL:(19.0332,20)-USER-LENGTH'/ !!! L=19.4332 *** WITH SCATTEROMETER
3*0.237733,2*0.405,3*0.323333,8*1.4625,4*1.21/ !!! 4*1.31 *** WITH SCATTEROMETER
```

```
'BOUNDARY CONDITIONS:(5,1)'/
'INSIDE HYDRAULIC:(IF1HS14)','BRANCH POSITION:(0.,0.7132)',
'MODEL POSITION:(0.,0.7132)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF2HS14)','BRANCH POSITION:(0.,0.81)',
'MODEL POSITION:(0.7132,1.5232)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF3HS14)','BRANCH POSITION:(0.,0.97)',
'MODEL POSITION:(1.5232,2.4932)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF4HS14)','BRANCH POSITION:(0.,11.70)',
'MODEL POSITION:(2.4932,14.1933)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IF5HS14)','BRANCH POSITION:(0.,4.84)',
'MODEL POSITION:(14.1932,19.0332)'/!!! L=5.24 *** WITH SCATTEROMETER
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
```

```
'CARBON STEEL'/
'CARBON STEEL'/
/
/HQ:(2502.)/ *** Trace Heating Power
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WIEFT14A)'/
'RADIAL:(1,0.04343,4,0.050445)','AXIAL:(1.113,2)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IEFTM14)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(0.,1.113)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WIEFT14E)'/
'RADIAL:(1,0.025276,4,0.032514)','AXIAL:(0.3903,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
```

```
'INSIDE HYDRAULIC:(IEFTM14)','BRANCH POSITION:(1.113,1.5033)',
'MODEL POSITION:(0.,0.3903)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WHS14PT)'/
'RADIAL:(1,0.0224,4,0.028916)','AXIAL:(5.94,12)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(HS14)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(35.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-1D-AXI'/
```

```
 266.0, 269.0, 272.0, 275.0, 278.0, 281.0, 285.0, 288.0, 291.0, 294.0, 296.0, 300.0/
'PRINT:(00105)'/

'MODEL:(WHS14PIN)'/
'RADIAL:(4,0.0,4,0.0037975,3,0.0040895,4,0.0059175,4,0.00654)',
'AXIAL:(5.94,12)',,'CYLINDER:(3,2,3,2)'/
'BOUNDARY CONDITIONS:(0,1)'/
'OUTSIDE HYDRAULIC:(HS14)'/
'7-ROD-3','HT-CRIT-DEFAULT',HT-CORR-DEFAULT,,'CONSTANT-TEMPERATURE-OVER-EACH-SEGMENT',
'WALL-INTERFACE-HEAT-TRANSFER:(6*9,1)',,,,,,,/
'MPF-TEMP:(9)'/MgO TEMP DEPENDENT
 200., 8.5, 3.014E6,
 300., 7.1, 3.170E6,
 400., 5.9, 3.352E6,
 500., 4.8, 3.404E6,
 600., 3.9, 3.421E6,
 700., 3.2, 3.441E6,
 800., 2.4, 3.478E6,
 900., 1.9, 3.519E6,
1000., 1.5, 3.571E6/
'INCONEL'/
```

```
'MPF-TEMP:(10)'/BN TEMP DEPENDENT
 100., 15.4, 2.1359E6,
 200., 14.5, 2.5618E6,
 300., 13.5, 2.8662E6,
 400., 12.3, 3.1378E6,
 500., 11.3, 3.3934E6,
 600., 10.3, 3.6140E6,
 700.,  9.3, 3.8115E6,
 800.,  8.3, 4.0291E6,
 900.,  7.4, 4.2286E6,
1000.,  6.6, 4.3709E6/
'STAINLESS STEEL'/
'HQ-NIL'/
'HQ-TIME:(771.0E3,P2LP)'/
/
'HQ-NIL'/
'HQ-NIL'/
'TEMP-1D-RAD'/
 376.0, 376.0, 376.0, 376.0, 375.0, 370.0, 339.0, 313.0,
    289.0, 284.0, 278.0, 273.0/
'PRINT:(06220)'/

'MODEL:(WOEFT14E)'/
'RADIAL:(1,0.025276,4,0.032514)','AXIAL:(0.3903,1)'/
```

```
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OEFTM14)','BRANCH POSITION:(0.,0.3903)',
'MODEL POSITION:(0.,0.3903)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'STAINLESS STEEL'/
/
'TEMP-0D:(299.0)'/
'PRINT:(00105)'/

'MODEL:(WOEFT14A)'/
'RADIAL:(1,0.04343,4,0.050445)','AXIAL:(1.113,2)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OEFTM14)','BRANCH POSITION:(0.3903,1.5033)',
'MODEL POSITION:(0.,1.113)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
```

```
'TEMP-0D:(299.0)'/
'PRINT:(00105)'/

'MODEL:(WOFHS14)'/
'RADIAL:(2,0.017526,4,0.020082,2,0.021082)','AXIAL :(20.1832,20)-USER-LENGTH'/!!! L=20.6032 *** WITH SCATTEROMETER
4*1.31,8*1.45625,3*0.623333,2*0.355,3*0.237733/!!! 4*1.415 *** WITH SCATTEROMETER
'BOUNDARY CONDITIONS:(5,1)'/
'INSIDE HYDRAULIC:(OF5HS14)','BRANCH POSITION:(0.,5.24)',
'MODEL POSITION:(0.,5.24)'/!!! L=5.66 *** WITH SCATTEROMETER
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OF4HS14)','BRANCH POSITION:(0.,11.65)',
'MODEL POSITION:(5.24,16.89)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OF3HS14)','BRANCH POSITION:(0.,1.87)',
'MODEL POSITION:(16.89,18.76)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OF2HS14)','BRANCH POSITION:(0.,0.71)',
'MODEL POSITION:(18.76,19.47)'/
```

```
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OF1HS14)','BRANCH POSITION:(0.,0.7132)',
'MODEL POSITION:(19.47,20.1832)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
'CARBON STEEL'/
/
/HQ:(2954.0)/ *** Trace Heating Power
'TEMP-0D:(299.0)'/
'PRINT:(00105)'/

'MODEL:(WOH5A)'/
'RADIAL:(1,0.12335,4,0.136096)','AXIAL:(0.24786,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OH5A)','BRANCH POSITION:(0.,0.24786)',
'MODEL POSITION:(0.,0.24786)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
```

```
'CARBON STEEL'/
/
'TEMP-0D:(297.0)'/
'PRINT:(00105)'/

'MODEL:(WOH5B)'/
'RADIAL:(1,0.096837,4,0.109537)','AXIAL:(0.20,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OH5B)','BRANCH POSITION:(0.,0.20)',
'MODEL POSITION:(0.,0.20)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(297.0)'/
'PRINT:(00105)'/

'MODEL:(WOH5C)'/
'RADIAL:(1,0.096837,4,0.109537)','AXIAL:(0.26,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OH5C)','BRANCH POSITION:(0.,0.26)',
'MODEL POSITION:(0.,0.26)'/
```

```
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(297.0)'/
'PRINT:(00105)'/

'MODEL:(WOH5D)'/
'RADIAL:(1,0.12335,4,0.136096)','AXIAL:(0.24786,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OH5D)','BRANCH POSITION:(0.,0.24786)',
'MODEL POSITION:(0.,0.24786)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(297.0)'/
'PRINT:(00105)'/

'MODEL:(WOH5RLF)'/
```

```
'RADIAL:(1,0.02972,4,0.036)','AXIAL:(1.6432,2)-USER-LENGTH'/
0.2,1.4432/
'BOUNDARY CONDITIONS:(1,0)'/
'INSIDE HYDRAULIC:(OH5RLF)','BRANCH POSITION:(0.,1.6432)',
'MODEL POSITION:(0.,1.6432)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'CARBON STEEL'/
/
'TEMP-0D:(297.0)'/
'PRINT:(00105)'/

'MODEL:(WIBO1)'/
'RADIAL:(1,0.04859,4,0.05715)','AXIAL:(3.86619,4)-USER-LENGTH'/
2*0.9766,2*0.95649/
'BOUNDARY CONDITIONS:(2,1)'/
'INSIDE HYDRAULIC:(IBO1A)','BRANCH NODE:(1,2)',
'MODEL NODE:(1,2)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IBO1B)','BRANCH NODE:(1,2)',
'MODEL NODE:(3,4)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
```

```
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(10.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(297.0)'/
'PRINT:(00105)'/

'MODEL:(WIBO1PL)'/
'RADIAL:(1,0.148027,4,0.226253)','AXIAL:(0.6782,2)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IBO1PL)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(10.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(297.0)'/
'PRINT:(00105)'/

'MODEL:(WBO1PDV)',/
'RADIAL:(1,100.0,6,100.0127)','AXIAL:(0.5266,2)',
'SECTOR:(1,1,5.861994D-4)',/
```

```
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IBO1PL)','BRANCH POSITION:(0.0,0.5266)',/
'ALPHA:(0.95,1.0)',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE HYDRAULIC:(OBO1PL)','BRANCH POSITION:(0.1516,0.6782)',/
'ALPHA:(0.95,1.0)',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'CARBON STEEL'/
/
'TEMP-0D:(288.0)'/
'PRINT:(00307)'/

'MODEL:(WOBO1PL)'/
'RADIAL:(1,0.148027,4,0.226253)','AXIAL:(0.6782,2)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OBO1PL)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(10.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(262.0)'/
```

```
'PRINT:(00105)'/

'MODEL:(WOBO1)'/
'RADIAL:(1,0.04859,4,0.05715)','AXIAL:(3.573,5)-USER-LENGTH'/
2*0.7165,3*0.71333/
'BOUNDARY CONDITIONS:(2,1)'/
'INSIDE HYDRAULIC:(OBO1A)','BRANCH NODE:(1,2)',
'MODEL NODE:(1,2)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OBO1B)','BRANCH NODE:(1,3)',
'MODEL NODE:(3,5)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(12.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WINP1)'/
'RADIAL:(1,0.059555,4,0.173625)','AXIAL:(1.243,2)'/
'BOUNDARY CONDITIONS:(1,1)'/
```

```
'INSIDE HYDRAULIC:(INP1)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(17.0,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WOUTP1)'/
'RADIAL:(1,0.045871,4,0.156187)','AXIAL:(1.41,3)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OUTP1)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(30.0,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WOUTP1A)'/
```

```
'RADIAL:(1,0.03896,4,0.04445)','AXIAL:(0.415,3)'/ replace 0.79 with 0.415
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OUTP1A)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(12.0,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WOPMP1)'/
'RADIAL:(1,0.038964,4,0.04445)','AXIAL:(1.5922,2)'/replaced 2.1732 with 1.5922
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(OPMP1)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(12.0,20.)'/
'CARBON STEEL'/
/
```

```
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WIEFTCAP)'/
'RADIAL:(1,0.042,4,0.04885)','AXIAL:(1.86,10)'/
'BOUNDARY CONDITIONS:(10,1)'/
'INSIDE HYDRAULIC:(IEFTS5)','BRANCH POSITION:(0.,0.186)',
'MODEL POSITION:(0.,0.186)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IEFTS6)','BRANCH POSITION:(0.,0.186)',
'MODEL POSITION:(0.186,0.372)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IEFTS7)','BRANCH POSITION:(0.,0.186)',
'MODEL POSITION:(0.372,0.558)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IEFTS8)','BRANCH POSITION:(0.,0.186)',
'MODEL POSITION:(0.558,0.744)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IEFTS9)','BRANCH POSITION:(0.,0.186)',
'MODEL POSITION:(0.744,0.930)'/
```

```
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IEFTS10)','BRANCH POSITION:(0.,0.186)',
'MODEL POSITION:(0.930,1.116)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IEFTS11)','BRANCH POSITION:(0.,0.186)',
'MODEL POSITION:(1.116,1.302)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IEFTS12)','BRANCH POSITION:(0.,0.186)',
'MODEL POSITION:(1.302,1.488)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IEFTS13)','BRANCH POSITION:(0.,0.186)',
'MODEL POSITION:(1.488,1.674)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IEFTS14)','BRANCH POSITION:(0.,0.186)',
'MODEL POSITION:(1.674,1.860)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
```

```
'CARBON STEEL'/
/
'TEMP-0D:(259.0)'/
'PRINT:(00105)'/

'MODEL:(WIEFTLIN)'/
'RADIAL:(1,0.028727,4,0.031447)','AXIAL:(11.13,10)'/
'BOUNDARY CONDITIONS:(10,10)'/
'INSIDE HYDRAULIC:(IEFTS5)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(0.,1.113)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE HYDRAULIC:(IEFTM5)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(0.,1.113)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IEFTS6)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(1.113,2.226)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE HYDRAULIC:(IEFTM6)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(1.113,2.226)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
```

```
'INSIDE HYDRAULIC:(IEFTS7)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(2.226,3.339)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE HYDRAULIC:(IEFTM7)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(2.226,3.339)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IEFTS8)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(3.339,4.452)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE HYDRAULIC:(IEFTM8)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(3.339,4.452)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IEFTS9)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(4.452,5.565)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE HYDRAULIC:(IEFTM9)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(4.452,5.565)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
```

```
'INSIDE HYDRAULIC:(IEFTS10)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(5.565,6.678)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE HYDRAULIC:(IEFTM10)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(5.565,6.678)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IEFTS11)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(6.678,7.791)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE HYDRAULIC:(IEFTM11)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(6.678,7.791)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IEFTS12)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(7.791,8.904)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE HYDRAULIC:(IEFTM12)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(7.791,8.904)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
```

```
'INSIDE HYDRAULIC:(IEFTS13)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(8.904,10.017)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE HYDRAULIC:(IEFTM13)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(8.904,10.017)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(IEFTS14)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(10.017,11.130)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE HYDRAULIC:(IEFTM14)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(10.017,11.130)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'STAINLESS STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WOEFTCAP)'/
'RADIAL:(1,0.042,4,0.04885)','AXIAL:(1.86,10)'/
'BOUNDARY CONDITIONS:(10,1)'/
```

```
'INSIDE HYDRAULIC:(OEFTS5)','BRANCH POSITION:(0.927,1.113)',
'MODEL POSITION:(0.,0.186)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OEFTS6)','BRANCH POSITION:(0.927,1.113)',
'MODEL POSITION:(0.186,0.372)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OEFTS7)','BRANCH POSITION:(0.927,1.113)',
'MODEL POSITION:(0.372,0.558)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OEFTS8)','BRANCH POSITION:(0.927,1.113)',
'MODEL POSITION:(0.558,0.744)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OEFTS9)','BRANCH POSITION:(0.927,1.113)',
'MODEL POSITION:(0.744,0.930)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OEFTS10)','BRANCH POSITION:(0.927,1.113)',
'MODEL POSITION:(0.930,1.116)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
```

```
'INSIDE HYDRAULIC:(OEFTS11)','BRANCH POSITION:(0.927,1.113)',
'MODEL POSITION:(1.116,1.302)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OEFTS12)','BRANCH POSITION:(0.927,1.113)',
'MODEL POSITION:(1.302,1.488)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OEFTS13)','BRANCH POSITION:(0.927,1.113)',
'MODEL POSITION:(1.488,1.674)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OEFTS14)','BRANCH POSITION:(0.927,1.113)',
'MODEL POSITION:(1.674,1.860)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(295.0)'/
'PRINT:(00105)'/

'MODEL:(WOEFTLIN)'/
```

```
'RADIAL:(1,0.028727,4,0.031447)','AXIAL:(11.13,10)'/
'BOUNDARY CONDITIONS:(10,10)'/
'INSIDE HYDRAULIC:(OEFTS5)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(0.,1.113)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE HYDRAULIC:(OEFTM5)','BRANCH POSITION:(0.3903,1.5033)',
'MODEL POSITION:(0.,1.113)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OEFTS6)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(1.113,2.226)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE HYDRAULIC:(OEFTM6)','BRANCH POSITION:(0.3903,1.5033)',
'MODEL POSITION:(1.113,2.226)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OEFTS7)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(2.226,3.339)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
```

```
'OUTSIDE HYDRAULIC:(OEFTM7)','BRANCH POSITION:(0.3903,1.5033)',
'MODEL POSITION:(2.226,3.339)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OEFTS8)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(3.339,4.452)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE HYDRAULIC:(OEFTM8)','BRANCH POSITION:(0.3903,1.5033)',
'MODEL POSITION:(3.339,4.452)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OEFTS9)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(4.452,5.565)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE HYDRAULIC:(OEFTM9)','BRANCH POSITION:(0.3903,1.5033)',
'MODEL POSITION:(4.452,5.565)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OEFTS10)','BRANCH POSITION:(0.,1.113)',
```

```
'MODEL POSITION:(5.565,6.678)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE HYDRAULIC:(OEFTM10)','BRANCH POSITION
    :(0.3903,1.5033)',
'MODEL POSITION:(5.565,6.678)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OEFTS11)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(6.678,7.791)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE HYDRAULIC:(OEFTM11)','BRANCH POSITION
    :(0.3903,1.5033)',
'MODEL POSITION:(6.678,7.791)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OEFTS12)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(7.791,8.904)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE HYDRAULIC:(OEFTM12)','BRANCH POSITION
    :(0.3903,1.5033)',
'MODEL POSITION:(7.791,8.904)'/
```

```
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OEFTS13)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(8.904,10.017)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE HYDRAULIC:(OEFTM13)','BRANCH POSITION:(0.3903,1.5033)',
'MODEL POSITION:(8.904,10.017)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(OEFTS14)','BRANCH POSITION:(0.,1.113)',
'MODEL POSITION:(10.017,11.130)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE HYDRAULIC:(OEFTM14)','BRANCH POSITION:(0.3903,1.5033)',
'MODEL POSITION:(10.017,11.130)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'STAINLESS STEEL'/
/
'TEMP-0D:(298.0)'/
'PRINT:(00105)'/
```

```

'MODEL:(WBO2INL)'/
'RADIAL:(1,0.01905,5,0.02413)','AXIAL:(12.46,10)'/'RADIAL:(1,0.00352,5,0.00635)','AXIAL:(6.375,5)'/ !!! FOR LOW POWER
'BOUNDARY CONDITIONS:(1,0)'/
'INSIDE HYDRAULIC:(BO2INL)'/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(200.0)'/
'PRINT:(00105)'/

'MODEL:(WBO2BAFW)'/
'RADIAL:(1,1.0,5,1.0095)','AXIAL:(0.6263,2)'/
'BOUNDARY CONDITIONS:(1,0)'/
'INSIDE HYDRAULIC:(BO2BAF)'/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(200.0)'/
'PRINT:(00105)'/

'MODEL:(WBO2BAFH)'/
```

```
'RADIAL:(1,1.0,5,1.0095)','AXIAL:(0.6263,2)','SECTOR:(1,1,0.02018084)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(BO2BAF)',,,,,,'FLOW ENTRY POINT:(0.0)'/
'ALPHA:(0.95,1.0)',,,,/
'OUTSIDE HYDRAULIC:(BO2RS1)',,,,,,'FLOW ENTRY POINT:(0.0)'/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP–0D:(210.0)'/
'PRINT:(00307)'/

'MODEL:(WBO2BAFC)'/
'RADIAL:(1,1.0,5,1.0095)','AXIAL:(0.6263,2)','SECTOR:(1,1,0.00808507)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(BO2BAF)',,,,,,'FLOW ENTRY POINT:(0.0)'/
'ALPHA:(0.95,1.0)',,,,/
'OUTSIDE HYDRAULIC:(BO2PREH)','BRANCH NODE:(1,2)'/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP–0D:(202.0)'/
'PRINT:(00307)'/
```

```

'MODEL:(WBO2PSL1)'/
'RADIAL:(1,0.18175,5,0.3057)','AXIAL:(0.6263,2)','SECTOR:(1,1,0.50)'/
'BOUNDARY CONDITIONS:(1,0)'/
'INSIDE HYDRAULIC:(BO2PREH)','BRANCH NODE:(1,2)'/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(213.0)'/
'PRINT:(00105)'/

'MODEL:(WBO2PSL2)'/
'RADIAL:(1,0.18175,5,0.2032)','AXIAL:(2.6258,4)','SECTOR:(1,1,0.50)'/
'BOUNDARY CONDITIONS:(1,0)'/
'INSIDE HYDRAULIC:(BO2PREH)','BRANCH NODE:(3,6)'/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(240.0)'/
'PRINT:(00105)'/

'MODEL:(WBO2HTLG)',/
```

```
'RADIAL:(1,0.00681,6,0.00794)','AXIAL:(9.3592,16)-USER-LENGTH',
,'CYLINDER:(1,41)'/ !!! CHECK PIPE NUMBER
2*0.31315,4*0.65645,10*0.61071/
'BOUNDARY CONDITIONS:(2,3)'/
'INSIDE HYDRAULIC:(BO2UP1)','BRANCH POSITION:(0.0,3.2521)','MODEL NODE:(1,6)'/
'ALPHA:(0.95,1.0)',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)',
'CORRECTION FACTOR:(0.8)'/
'INSIDE HYDRAULIC:(BO2UP2)','BRANCH POSITION:(0.0,6.1071)','MODEL NODE:(7,16)'/
'ALPHA:(0.95,1.0)',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)',
'CORRECTION FACTOR:(0.8)'/
'OUTSIDE HYDRAULIC:(BO2RS1)','BRANCH POSITION:(0.0,0.6263)','MODEL NODE:(1,2)'/
'ALPHA:(0.95,1.0)',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)',
'CORRECTION FACTOR:(0.8)'/
'OUTSIDE HYDRAULIC:(BO2RS2)','BRANCH POSITION:(0.0,2.6258)','MODEL NODE:(3,6)'/
'ALPHA:(0.95,1.0)',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)',
```

```
'CORRECTION FACTOR:(0.8)'/
'OUTSIDE HYDRAULIC:(BO2RS3)','BRANCH POSITION:(0.0,6.1071)','
    MODEL NODE:(7,16)'/
'ALPHA:(0.95,1.0)',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)',
'CORRECTION FACTOR:(0.8)'/
'INCONEL'/
/
'TEMP-0D:(275.0)'/
'PRINT:(00337)'/

'MODEL:(WBO2CDLG)',/
'RADIAL:(1,0.00681,6,0.00794)','AXIAL:(9.3592,16)-USER-LENGTH
    ',
,'CYLINDER:(1,41)'/ !!! CHECK PIPE NUMBER
10*0.61071,4*0.65645,2*0.31315/
'BOUNDARY CONDITIONS:(2,2)'/
'INSIDE HYDRAULIC:(BO2DN2)','BRANCH POSITION:(0.0,6.1071)','
    MODEL NODE:(1,10)'/
'ALPHA:(0.95,1.0)',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)',
'CORRECTION FACTOR:(0.8)'/
'INSIDE HYDRAULIC:(BO2DN1)','BRANCH POSITION:(0.0,3.2521)','
    MODEL NODE:(11,16)'/
```

```
'ALPHA:(0.95,1.0)',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)',
'CORRECTION FACTOR:(0.8)'/
'OUTSIDE HYDRAULIC:(BO2RS3)','BRANCH POSITION:(6.1071,0.0)','MODEL NODE:(1,10)'/
'ALPHA:(0.95,1.0)',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)',
'CORRECTION FACTOR:(0.8)'/
'OUTSIDE HYDRAULIC:(BO2PREH)','BRANCH POSITION:(3.2521,0.0)',
'MODEL NODE:(11,16)'/
'ALPHA:(0.95,1.0)',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)',
'CORRECTION FACTOR:(0.8)'/
'INCONEL'/
/
'TEMP-0D:(260.0)'/
'PRINT:(00337)'/

'MODEL:(WBO2HTBF)',/
'RADIAL:(1,0.13085,5,0.1409)','AXIAL:(3.2521,6)-USER-LENGTH',
'SECTOR:(1,1,0.50)'/
2*0.31315,4*0.65645/
'BOUNDARY CONDITIONS:(1,2)'/
'INSIDE HYDRAULIC:(BO2BAFB)','BRANCH POSITION:(3.2521,0.0)',/
```

```
'ALPHA:(0.95,1.0)',,,,/
'OUTSIDE HYDRAULIC:(BO2RS1)',,'MODEL NODE:(1,2)'/
'ALPHA:(0.95,1.0)',,,,/
'OUTSIDE HYDRAULIC:(BO2RS2)',,'MODEL NODE:(3,6)'/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(255.0)'/
'PRINT:(00307)'/


'MODEL:(WBO2CDBF)',/
'RADIAL:(1,0.13085,5,0.1409)','AXIAL:(3.2521,6)-USER-LENGTH',
'SECTOR:(1,1,0.6203)'/
2*0.31315,4*0.65645/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(BO2BAFB)','BRANCH POSITION:(3.2521,0.0)'/
'ALPHA:(0.95,1.0)',,,,/
'OUTSIDE HYDRAULIC:(BO2PREH)','BRANCH NODE:(1,6)'/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(240.0)'/
'PRINT:(00307)'/
```

```

'MODEL:(WBO2UPBF)',/
'RADIAL:(1,100.0,5,100.0031738)','AXIAL:(6.1071,10)','SECTOR:(1,4,1.157E-3)'/
'BOUNDARY CONDITIONS:(0,1)'/
'OUTSIDE HYDRAULIC:(BO2RS3)','BRANCH NODE:(1,10)'/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(258.0)'/
'PRINT:(00206)'/

'MODEL:(WBO2RS1L)',/
'RADIAL:(1,0.18175,5,0.3057)','AXIAL:(0.6263,2)','SECTOR:(1,1,0.5)'/
'BOUNDARY CONDITIONS:(1,0)'/
'INSIDE HYDRAULIC:(BO2RS1)'/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(257.0)'/
'PRINT:(00105)'/

'MODEL:(WBO2RS2L)',/
```

```
'RADIAL:(1,0.18175,5,0.2032)','AXIAL:(2.6258,4)','SECTOR:(1,1,0.5)'/
'BOUNDARY CONDITIONS:(1,0)'/
'INSIDE HYDRAULIC:(BO2RS2)',/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(259.0)'/
'PRINT:(00105)'/

'MODEL:(WBO2RS3L)',/
'RADIAL:(1,0.18175,5,0.2032)','AXIAL:(6.1071,10)'/
'BOUNDARY CONDITIONS:(1,0)'/
'INSIDE HYDRAULIC:(BO2RS3)'/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(258.0)'/
'PRINT:(00105)'/

'MODEL:(WBO2RS4L)',/
'RADIAL:(1,0.1683,6,0.17084)','AXIAL:(1.1271,2)-USER-LENGTH',/
0.0448,1.0823/
```

```
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(BO2RS4)',/
'ALPHA:(0.95,1.0)',,,,/
'OUTSIDE HYDRAULIC:(BO2DRUM)','BRANCH NODE:(2,1)',/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(258.0)'/
'PRINT:(00307)'/

'MODEL:(WBO2SEPT)',/
'RADIAL:(1,100.0,2,100.0127)',  'AXIAL:(0.0448,1)',
'SECTOR:(1,1,8.372E-3)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(BO2RS3)','BRANCH POSITION:(6.0623,6.1071)'/
'ALPHA:(0.5,1.0)',,,,/
'OUTSIDE HYDRAULIC:(BO2DRUM)','BRANCH NODE:(2,2)'/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(258.0)'/
'PRINT:(00307)'/

```

```
'MODEL:(WBO2DRML)',/
'RADIAL:(1,0.2826,5,0.3048)', 'AXIAL:(1.1271,2)-USER-LENGTH',/
1.0823,0.0448/
'BOUNDARY CONDITIONS:(1,0)'/
'INSIDE HYDRAULIC:(BO2DRUM)','BRANCH POSITION:(0.0,1.1271)'/
'ALPHA:(0.5,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(258.0)'/
'PRINT:(00105)'/

'MODEL:(WBO2DRMD)',/
'RADIAL:(1,0.7214,5,0.7229)', 'AXIAL:(1.1271,2)-USER-LENGTH',/
1.0823,0.0448/
'BOUNDARY CONDITIONS:(1,0)'/
'INSIDE HYDRAULIC:(BO2DRUM)','BRANCH POSITION:(0.0,1.1271)'/
'ALPHA:(0.5,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(258.0)'/
'PRINT:(00105)'/

```

```
'MODEL:(WBO2NOZL)',/
'RADIAL:(1,0.2826,5,0.3048)', 'AXIAL:(0.6363,2)'/
'BOUNDARY CONDITIONS:(1,0)'/
'INSIDE HYDRAULIC:(BO2NOZ)','BRANCH POSITION:(0.0,0.6363)'/
'ALPHA:(0.5,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(258.0)'/
'PRINT:(00105)'/

'MODEL:(WBO2DNC)',/
'RADIAL:(1,0.09684,5,0.10954)', 'AXIAL:(10.6018,2)'/
'BOUNDARY CONDITIONS:(1,0)'/
'INSIDE HYDRAULIC:(BO2DNC)','BRANCH NODE:(1,2)'/
'ALPHA:(0.5,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(258.0)'/
'PRINT:(00105)'/

'MODEL:(WBO2STM)',/
'RADIAL:(1,0.03683,5,0.041275)', 'AXIAL:(3.45,4)-USER-LENGTH'/
0.58,3*0.95667/
```

```
'BOUNDARY CONDITIONS:(2,0)'/
'INSIDE HYDRAULIC:(BO2STM1)','BRANCH POSITION:(0.0,0.58)','MODEL NODE:(1,1)'/
'ALPHA:(0.5,1.0)',,,,/
'INSIDE HYDRAULIC:(BO2STM2)','BRANCH POSITION:(0.0,2.87)','MODEL NODE:(2,4)'/
'ALPHA:(0.5,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(258.0)'/
'PRINT:(00105)'/

'MODEL:(WBO1INL)'/
'RADIAL:(1,0.01905,5,0.02413)','AXIAL:(12.46,10)'/'RADIAL:(1,0.00352,5,0.00635)','AXIAL:(6.375,5)'/ !!! FOR LOW POWER
'BOUNDARY CONDITIONS:(1,0)'/
'INSIDE HYDRAULIC:(BO1INL)'/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(200.0)'/
'PRINT:(00105)'/

```

```
'MODEL:(WBO1BAFW)'/
'RADIAL:(1,1.0,5,1.0095)','AXIAL:(0.6263,2)'/
'BOUNDARY CONDITIONS:(1,0)'/
'INSIDE HYDRAULIC:(BO1BAF)'/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(200.0)'/
'PRINT:(00105)'/

'MODEL:(WBO1BAFH)'/
'RADIAL:(1,1.0,5,1.0095)','AXIAL:(0.6263,2)','SECTOR:(1,1,0.02018084)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(BO1BAF)',,,,,,'FLOW ENTRY POINT:(0.0)'/
'ALPHA:(0.95,1.0)',,,,/
'OUTSIDE HYDRAULIC:(BO1RS1)',,,,,,'FLOW ENTRY POINT:(0.0)'/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(220.0)'/
'PRINT:(00307)'/

'MODEL:(WBO1BAFC)'/
```

```
'RADIAL:(1,1.0,5,1.0095)','AXIAL:(0.6263,2)','SECTOR:(1,1,0.00808507)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(BO1BAF)',,,,,,'FLOW ENTRY POINT:(0.0)'/
'ALPHA:(0.95,1.0)',,,,/
'OUTSIDE HYDRAULIC:(BO1PREH)','BRANCH NODE:(1,2)'/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(205.0)'/
'PRINT:(00307)'/

'MODEL:(WBO1PSL1)'/
'RADIAL:(1,0.18175,5,0.3057)','AXIAL:(0.6263,2)','SECTOR:(1,1,0.50)'/
'BOUNDARY CONDITIONS:(1,0)'/
'INSIDE HYDRAULIC:(BO1PREH)','BRANCH NODE:(1,2)'/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(215.0)'/
'PRINT:(00105)'/

'MODEL:(WBO1PSL2)'/
```

```
'RADIAL:(1,0.18175,5,0.2032)','AXIAL:(2.6258,4)','SECTOR:(1,1,0.50)'/
'BOUNDARY CONDITIONS:(1,0)'/
'INSIDE HYDRAULIC:(BO1PREH)','BRANCH NODE:(3,6)'/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(240.0)'/
'PRINT:(00105)'/

'MODEL:(WBO1HTLG)',/
'RADIAL:(1,0.00681,6,0.00794)','AXIAL:(9.3592,16)-USER-LENGTH',
,'CYLINDER:(1,39)'/ !!! CHECK PIPE NUMBER
2*0.31315,4*0.65645,10*0.61071/
'BOUNDARY CONDITIONS:(2,3)'/
'INSIDE HYDRAULIC:(BO1UP1)','BRANCH POSITION:(0.0,3.2521)','MODEL NODE:(1,6)'/
'ALPHA:(0.95,1.0)',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)',
'CORRECTION FACTOR:(0.8)'/
'INSIDE HYDRAULIC:(BO1UP2)','BRANCH POSITION:(0.0,6.1071)','MODEL NODE:(7,16)'/
'ALPHA:(0.95,1.0)',,'HT-CORR-DEFAULT',,,
```

```
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)',
'CORRECTION FACTOR:(0.8)'/
'OUTSIDE HYDRAULIC:(BO1RS1)','BRANCH POSITION:(0.0,0.6263)','
   MODEL NODE:(1,2)'/
'ALPHA:(0.95,1.0)',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)',
'CORRECTION FACTOR:(0.8)'/
'OUTSIDE HYDRAULIC:(BO1RS2)','BRANCH POSITION:(0.0,2.6258)','
   MODEL NODE:(3,6)'/
'ALPHA:(0.95,1.0)',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)',
'CORRECTION FACTOR:(0.8)'/
'OUTSIDE HYDRAULIC:(BO1RS3)','BRANCH POSITION:(0.0,6.1071)','
   MODEL NODE:(7,16)'/
'ALPHA:(0.95,1.0)',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)',
'CORRECTION FACTOR:(0.8)'/
'INCONEL'/
/
'TEMP-0D:(275.0)'/
'PRINT:(00337)'/

'MODEL:(WBO1CDLG)',/
```

```
'RADIAL:(1,0.00681,6,0.00794)','AXIAL:(9.3592,16)-USER-LENGTH',
,'CYLINDER:(1,39)'/ !!! CHECK PIPE NUMBER
10*0.61071,4*0.65645,2*0.31315/
'BOUNDARY CONDITIONS:(2,2)'/
'INSIDE HYDRAULIC:(BO1DN2)','BRANCH POSITION:(0.0,6.1071)','MODEL NODE:(1,10)'/
'ALPHA:(0.95,1.0)',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)',
'CORRECTION FACTOR:(0.8)'/
'INSIDE HYDRAULIC:(BO1DN1)','BRANCH POSITION:(0.0,3.2521)','MODEL NODE:(11,16)'/
'ALPHA:(0.95,1.0)',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)',
'CORRECTION FACTOR:(0.8)'/
'OUTSIDE HYDRAULIC:(BO1RS3)','BRANCH POSITION:(6.1071,0.0)','MODEL NODE:(1,10)'/
'ALPHA:(0.95,1.0)',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)',
'CORRECTION FACTOR:(0.8)'/
'OUTSIDE HYDRAULIC:(BO1PREH)','BRANCH POSITION:(3.2521,0.0)',
'MODEL NODE:(11,16)'/
'ALPHA:(0.95,1.0)',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)',
```

```
'CORRECTION FACTOR:(0.8)'/
'INCONEL'/
/
'TEMP-0D:(260.0)'/
'PRINT:(00337)'/

'MODEL:(WBO1HTBF)',/
'RADIAL:(1,0.13085,5,0.1409)','AXIAL:(3.2521,6)-USER-LENGTH',
'SECTOR:(1,1,0.50)'/
2*0.31315,4*0.65645/
'BOUNDARY CONDITIONS:(1,2)'/
'INSIDE HYDRAULIC:(BO1BAFB)','BRANCH POSITION:(3.2521,0.0)',/
'ALPHA:(0.95,1.0)',,,,/
'OUTSIDE HYDRAULIC:(BO1RS1)',,'MODEL NODE:(1,2)'/
'ALPHA:(0.95,1.0)',,,,/
'OUTSIDE HYDRAULIC:(BO1RS2)',,'MODEL NODE:(3,6)'/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(255.0)'/
'PRINT:(00307)'/

'MODEL:(WBO1CDBF)',/
'RADIAL:(1,0.13085,5,0.1409)','AXIAL:(3.2521,6)-USER-LENGTH',
```

```
'SECTOR:(1,1,0.6203)'/
2*0.31315,4*0.65645/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(BO1BAFB)','BRANCH POSITION:(3.2521,0.0)',/
'ALPHA:(0.95,1.0)',,,,/
'OUTSIDE HYDRAULIC:(BO1PREH)','BRANCH NODE:(1,6)'/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(240.0)'/
'PRINT:(00307)'/

'MODEL:(WBO1UPBF)',/
'RADIAL:(1,100.0,5,100.0031738)','AXIAL:(6.1071,10)','SECTOR:(1,4,1.157E-3)'/
'BOUNDARY CONDITIONS:(0,1)'/
'OUTSIDE HYDRAULIC:(BO1RS3)','BRANCH NODE:(1,10)'/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(258.0)'/
'PRINT:(00206)'/

'MODEL:(WBO1RS1L)',/
```

```
'RADIAL:(1,0.18175,5,0.3057)','AXIAL:(0.6263,2)','SECTOR
    :(1,1,0.5)'/
'BOUNDARY CONDITIONS:(1,0)'/
'INSIDE HYDRAULIC:(BO1RS1)'/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(257.0)'/
'PRINT:(00105)'/

'MODEL:(WBO1RS2L)',/
'RADIAL:(1,0.18175,5,0.2032)','AXIAL:(2.6258,4)','SECTOR
    :(1,1,0.5)'/
'BOUNDARY CONDITIONS:(1,0)'/
'INSIDE HYDRAULIC:(BO1RS2)',/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(258.50)'/
'PRINT:(00105)'/

'MODEL:(WBO1RS3L)',/
'RADIAL:(1,0.18175,5,0.2032)','AXIAL:(6.1071,10)'/
'BOUNDARY CONDITIONS:(1,0)'/
```

```
'INSIDE HYDRAULIC:(BO1RS3)'/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(258.0)'/
'PRINT:(00105)'/

'MODEL:(WBO1RS4L)',/
'RADIAL:(1,0.1683,6,0.17084)','AXIAL:(1.1271,2)-USER-LENGTH',/
0.0448,1.0823/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(BO1RS4)',/
'ALPHA:(0.95,1.0)',,,,/
'OUTSIDE HYDRAULIC:(BO1DRUM)','BRANCH NODE:(2,1)',/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(258.0)'/
'PRINT:(00307)'/

'MODEL:(WBO1SEPT)',/
'RADIAL:(1,100.0,2,100.0127)', 'AXIAL:(0.0448,1)',
'SECTOR:(1,1,8.372E-3)'/
```

```
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(BO1RS3)','BRANCH POSITION:(6.0623,6.1071)'/
'ALPHA:(0.5,1.0)',,,,/
'OUTSIDE HYDRAULIC:(BO1DRUM)','BRANCH NODE:(2,2)'/
'ALPHA:(0.95,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(258.0)'/
'PRINT:(00307)'/

'MODEL:(WBO1DRML)',/
'RADIAL:(1,0.2826,5,0.3048)', 'AXIAL:(1.1271,2)-USER-LENGTH',/
1.0823,0.0448/
'BOUNDARY CONDITIONS:(1,0)'/
'INSIDE HYDRAULIC:(BO1DRUM)','BRANCH POSITION:(0.0,1.1271)'/
'ALPHA:(0.5,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(258.0)'/
'PRINT:(00105)'/

'MODEL:(WBO1DRMD)',/
```

```
'RADIAL:(1,0.7214,5,0.7229)', 'AXIAL:(1.1271,2)-USER-LENGTH',/
1.0823,0.0448/
'BOUNDARY CONDITIONS:(1,0)'/
'INSIDE HYDRAULIC:(BO1DRUM)','BRANCH POSITION:(0.0,1.1271)'/
'ALPHA:(0.5,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(258.0)'/
'PRINT:(00105)'/

'MODEL:(WBO1NOZL)',/
'RADIAL:(1,0.2826,5,0.3048)', 'AXIAL:(0.6363,2)'/
'BOUNDARY CONDITIONS:(1,0)'/
'INSIDE HYDRAULIC:(BO1NOZ)','BRANCH POSITION:(0.0,0.6363)'/
'ALPHA:(0.5,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(258.0)'/
'PRINT:(00105)'/

'MODEL:(WBO1DNC)',/
'RADIAL:(1,0.09684,5,0.10954)', 'AXIAL:(10.6018,2)'/
'BOUNDARY CONDITIONS:(1,0)'/
```

```
'INSIDE HYDRAULIC:(BO1DNC)','BRANCH NODE:(1,2)'/
'ALPHA:(0.5,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(258.0)'/
'PRINT:(00105)'/

'MODEL:(WBO1STM)',/
'RADIAL:(1,0.03683,5,0.041275)', 'AXIAL:(3.45,4)-USER-LENGTH'/
0.58,3*0.95667/
'BOUNDARY CONDITIONS:(2,0)'/
'INSIDE HYDRAULIC:(BO1STM1)','BRANCH POSITION:(0.0,0.58)','MODEL NODE:(1,1)'/
'ALPHA:(0.5,1.0)',,,,/
'INSIDE HYDRAULIC:(BO1STM2)','BRANCH POSITION:(0.0,2.87)','MODEL NODE:(2,4)'/
'ALPHA:(0.5,1.0)',,,,/
'CARBON STEEL'/
/
'TEMP-0D:(258.0)'/
'PRINT:(00105)'/

'MODEL:(WSURGE5)'/
```

```
'RADIAL:(1,0.01985,4,0.02920)','AXIAL:(0.785,3)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(SURGE5)','BRANCH POSITION:(0.0,0.785)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(8.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(250.0)'/
'PRINT:(00105)'/

'MODEL:(WSURGE4)'/
'RADIAL:(1,0.020133,4,0.030239)','AXIAL:(0.565,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(SURGE4)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(8.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(236.0)'/
'PRINT:(00105)'/
```

```

'MODEL:(WSURGE3)'/
'RADIAL:(1,0.0103,4,0.01823)','AXIAL:(1.48,3)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(SURGE3)','BRANCH POSITION:(0.0,1.48)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(8.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(220.0)'/
'PRINT:(00105)'/

'MODEL:(WSURGE2)'/
'RADIAL:(1,0.01905,4,0.02413)','AXIAL:(4.88,2)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(SURGE2)','BRANCH POSITION:(0.0,4.88)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(8.00,20.)'/
'CARBON STEEL'/
/
```

```
'TEMP–0D:(190.0)'/
'PRINT:(00105)'/

'MODEL:(WSURGE1)'/
'RADIAL:(1,0.01905,4,0.02413)','AXIAL:(9.61,5)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(SURGE1)','BRANCH POSITION:(0.0,9.61)'/
'TUBE–CIR',,'HT–CORR–DEFAULT',,,
'WALL–INTERFACE–HEAT–TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF–HC,TF:(8.00,20.)'/
'CARBON STEEL'/
/
'TEMP–1D–AXI'/
 247.0, 218.0, 202.0, 191.0, 186.0/
'PRINT:(00105)'/

'MODEL:(WECI56A)'/
'RADIAL:(1,0.02463,4,0.03015)','AXIAL:(5.67,3)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(ECI56A)','BRANCH POSITION:(0.,5.670)',
'MODEL POSITION:(0.,5.670)'/
'TUBE–CIR',,'HT–CORR–DEFAULT',,,
'WALL–INTERFACE–HEAT–TRANSFER:(6*5,1)'/
```

```
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(8.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(21.0)'/
'PRINT:(00105)'/

'MODEL:(WECI78A)'/
'RADIAL:(1,0.02463,4,0.03015)','AXIAL:(5.78,3)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(ECI78A)','BRANCH POSITION:(0.,5.780)',
'MODEL POSITION:(0.,5.780)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(8.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(21.0)'/
'PRINT:(00105)'/

'MODEL:(WECI5A)'/
'RADIAL:(1,0.02463,4,0.03015)','AXIAL:(0.27,3)'/
'BOUNDARY CONDITIONS:(1,1)'/
```

```
'INSIDE HYDRAULIC:(ECI5A)','BRANCH POSITION:(0.,0.270)',
'MODEL POSITION:(0.,0.270)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(8.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(21.0)'/
'PRINT:(00105)'/



'MODEL:(WECI7A)'/
'RADIAL:(1,0.02463,4,0.03015)','AXIAL:(0.27,3)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(ECI7A)','BRANCH POSITION:(0.,0.270)',
'MODEL POSITION:(0.,0.270)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(8.00,20.)'/
'CARBON STEEL'/
/
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'TEMP-0D:(21.0)'/
'PRINT:(00105)'/

'MODEL:(WECI8A)'/
'RADIAL:(1,0.02463,4,0.03015)','AXIAL:(0.27,3)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(ECI8A)','BRANCH POSITION:(0.,0.270)',
'MODEL POSITION:(0.,0.270)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(8.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(21.0)'/
'PRINT:(00105)'/

'MODEL:(WECI5BC)'/
'RADIAL:(1,0.01905,4,0.02413)','AXIAL:(3.54,6)-USER-LENGTH'/
3*0.59,3*0.59/
'BOUNDARY CONDITIONS:(2,1)'/
'INSIDE HYDRAULIC:(ECI5B)','BRANCH POSITION:(0.,1.770)',
'MODEL POSITION:(0.,1.770)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
```

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'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(ECI5C)','BRANCH POSITION:(0.,1.770)',
'MODEL POSITION:(1.770,3.540)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(8.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(21.0)'/
'PRINT:(00105)'/



'MODEL:(WECI7BC)'/
'RADIAL:(1,0.01905,4,0.02413)','AXIAL:(3.88,6)-USER-LENGTH'/
3*0.59,3*0.70333/
'BOUNDARY CONDITIONS:(2,1)'/
'INSIDE HYDRAULIC:(ECI7B)','BRANCH POSITION:(0.,1.770)',
'MODEL POSITION:(0.,1.770)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(ECI7C)','BRANCH POSITION:(0.,2.11)',
'MODEL POSITION:(1.770,3.880)'/
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'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(8.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(21.0)'/
'PRINT:(00105)'/

'MODEL:(WECI8BC)'/
'RADIAL:(1,0.01905,4,0.02413)','AXIAL:(3.77,6)-USER-LENGTH'/
3*0.59,3*0.66667/
'BOUNDARY CONDITIONS:(2,1)'/
'INSIDE HYDRAULIC:(ECI8B)','BRANCH POSITION:(0.,1.770)',
'MODEL POSITION:(0.,1.770)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(ECI8C)','BRANCH POSITION:(0.,2.00)',
'MODEL POSITION:(1.770,3.770)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(8.00,20.)'/
'CARBON STEEL'/
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/
'TEMP-0D:(21.0)'/
'PRINT:(00105)'/

'END'/

'INITIAL CONDITIONS'/




'IF1HS5','BY-NODE','HG-BY-SAT','HF-BY-TEMP'/
0.11607E+08,,262.0,0.00000E+00,0.40E+01/
0.11589E+08,,262.0,0.00000E+00,0.40E+01/

'IF2HS5','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.11569E+08,,262.0,0.00000E+00,0.40E+01/
0.11530E+08,,262.0,0.00000E+00,0.40E+01/

'IF3HS5','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.11086E+08,,262.0,0.00000E+00,0.40E+01/
0.11033E+08,,262.0,0.00000E+00,0.40E+01/

'IEFTM5','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
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```
0.10989E+08,,262.0,0.00000E+00,0.40E+01/
0.10986E+08,,262.0,0.00000E+00,0.40E+01/

'IEFTS5','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.10929E+08,,262.0,0.00000E+00,0.00000E+00/
0.10929E+08,,262.0,0.00000E+00,0.00000E+00/

'HS5','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.10929E+08,,266.0,0.00000E+00,0.40E+01/
0.10289E+08,,297.0,0.00000E+00,0.40E+01/

'OEFTS5','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.10289E+08,,297.0,0.00000E+00,0.00000E+00/
0.10289E+08,,297.0,0.00000E+00,0.00000E+00/

'OEFTM5','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.10234E+08,,297.0,0.00000E+00,0.40E+01/
0.10230E+08,,297.0,0.00000E+00,0.40E+01/

'OF3HS5','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.10196E+08,,297.0,0.00000E+00,0.40E+01/
0.10159E+08,,297.0,0.00000E+00,0.40E+01/

'OF2HS5','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
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0.10143E+08,,297.0,0.00000E+00,0.40E+01/
0.10118E+08,,297.0,0.00000E+00,0.40E+01/

'OF1HS5','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.10105E+08,,297.0,0.00000E+00,0.40E+01/
0.10093E+08,,297.0,0.00000E+00,0.40E+01/

'IF1HS6','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.11610E+08,,262.0,0.00000E+00,0.40E+01/
0.11597E+08,,262.0,0.00000E+00,0.40E+01/

'IF2HS6','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.11582E+08,,262.0,0.00000E+00,0.40E+01/
0.11548E+08,,262.0,0.00000E+00,0.40E+01/

'IF3HS6','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.11160E+08,,262.0,0.00000E+00,0.40E+01/
0.11029E+08,,262.0,0.00000E+00,0.40E+01/

'IEFTM6','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.10992E+08,,262.0,0.00000E+00,0.40E+01/
0.10989E+08,,262.0,0.00000E+00,0.40E+01/

'IEFTS6','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
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0.10938E+08,,262.0,0.00000E+00,0.00000E+00/
0.10938E+08,,262.0,0.00000E+00,0.00000E+00/

'HS6', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
0.10938E+08,,266.0,0.00000E+00,0.40E+01/
0.10328E+08,,299.0,0.00000E+00,0.40E+01/

'OEFTS6', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
0.10328E+08,,297.5,0.00000E+00,0.00000E+00/
0.10328E+08,,297.5,0.00000E+00,0.00000E+00/

'OEFTM6', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
0.10273E+08,,297.5,0.00000E+00,0.40E+01/
0.10270E+08,,297.5,0.00000E+00,0.40E+01/

'OF3HS6', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
0.10235E+08,,297.5,0.00000E+00,0.40E+01/
0.10145E+08,,297.5,0.00000E+00,0.40E+01/

'OF2HS6', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
0.10131E+08,,297.5,0.00000E+00,0.40E+01/
0.10108E+08,,297.5,0.00000E+00,0.40E+01/

'OF1HS6', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
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0.10099E+08,,297.5,0.00000E+00,0.40E+01/
0.10090E+08,,297.5,0.00000E+00,0.40E+01/

'IF1HS7','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.11623E+08,,262.0,0.00000E+00,0.50E+01/
0.11616E+08,,262.0,0.00000E+00,0.50E+01/

'IF2HS7','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.11614E+08,,262.0,0.00000E+00,0.50E+01/
0.11611E+08,,262.0,0.00000E+00,0.50E+01/

'IF3HS7','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.11603E+08,,262.0,0.00000E+00,0.50E+01/
0.11575E+08,,262.0,0.00000E+00,0.50E+01/

'IF4HS7','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.11563E+08,,262.0,0.00000E+00,0.50E+01/
0.11528E+08,,262.0,0.00000E+00,0.50E+01/

'IF5HS7','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.11516E+08,,262.0,0.00000E+00,0.50E+01/
0.11469E+08,,262.0,0.00000E+00,0.50E+01/

'IEFTM7','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
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0.11413E+08,,262.0,0.00000E+00,0.50E+01/
0.11409E+08,,262.0,0.00000E+00,0.50E+01/

'IEFTS7','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.11322E+08,,262.0,0.00000E+00,0.00000E+00/
0.11322E+08,,262.0,0.00000E+00,0.00000E+00/

'HS7','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.11322E+08,,266.0,0.00000E+00,0.50E+01/
0.10436E+08,,299.0,0.00000E+00,0.50E+01/

'OEFTS7','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.10436E+08,,297.5,0.00000E+00,0.00000E+00/
0.10436E+08,,297.5,0.00000E+00,0.00000E+00/

'OEFTM7','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.10358E+08,,297.5,0.00000E+00,0.50E+01/
0.10353E+08,,297.5,0.00000E+00,0.50E+01/

'OF5HS7','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.10308E+08,,297.5,0.00000E+00,0.50E+01/
0.10249E+08,,297.5,0.00000E+00,0.50E+01/

'OF4HS7','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
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0.10229E+08,,297.5,0.00000E+00,0.50E+01/
0.10152E+08,,297.5,0.00000E+00,0.50E+01/

'OF3HS7', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
0.10137E+08,,297.5,0.00000E+00,0.50E+01/
0.10104E+08,,297.5,0.00000E+00,0.50E+01/

'OF2HS7', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
0.10096E+08,,297.5,0.00000E+00,0.50E+01/
0.10090E+08,,297.5,0.00000E+00,0.50E+01/

'OF1HS7', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
0.10087E+08,,297.5,0.00000E+00,0.50E+01/
0.10084E+08,,297.5,0.00000E+00,0.50E+01/

'IF1HS8', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
0.11624E+08,,262.0,0.00000E+00,0.49E+01/
0.11622E+08,,262.0,0.00000E+00,0.49E+01/

'IF2HS8', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
0.11616E+08,,262.0,0.00000E+00,0.49E+01/
0.11594E+08,,262.0,0.00000E+00,0.49E+01/

'IF3HS8', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
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0.11454E+08,,262.0,0.00000E+00,0.49E+01/
0.11437E+08,,262.0,0.00000E+00,0.49E+01/

'IF4HS8','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.11431E+08,,262.0,0.00000E+00,0.49E+01/
0.11416E+08,,262.0,0.00000E+00,00.49E+01/

'IEFTM8','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.11366E+08,,262.0,0.00000E+00,0.49E+01/
0.11361E+08,,262.0,0.00000E+00,0.49E+01/

'IEFTS8','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.11277E+08,,262.0,0.00000E+00,0.00000E+00/
0.11277E+08,,262.0,0.00000E+00,0.00000E+00/

'HS8','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.11277E+08,,266.0,0.00000E+00,0.49E+01/
0.10403E+08,,300.0,0.00000E+00,0.49E+01/

'OEFTS8','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.10403E+08,,299.0,0.00000E+00,0.00000E+00/
0.10403E+08,,299.0,0.00000E+00,0.00000E+00/

'OEFTM8','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
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0.10322E+08,,299.0,0.00000E+00,0.49E+01/
0.10317E+08,,299.0,0.00000E+00,0.49E+01/

'OF4HS8' , 'BY–ENDS' , 'HG–BY–SAT' , 'HF–BY–TEMP'/
0.10270E+08,,299.0,0.00000E+00,0.49E+01/
0.10245E+08,,299.0,0.00000E+00,0.49E+01/

'OF3HS8' , 'BY–ENDS' , 'HG–BY–SAT' , 'HF–BY–TEMP'/
0.10228E+08,,299.0,0.00000E+00,0.49E+01/
0.10153E+08,,299.0,0.00000E+00,0.49E+01/

'OF2HS8' , 'BY–ENDS' , 'HG–BY–SAT' , 'HF–BY–TEMP'/
0.10139E+08,,299.0,0.00000E+00,0.49E+01/
0.10104E+08,,299.0,0.00000E+00,0.49E+01/

'OF1HS8' , 'BY–ENDS' , 'HG–BY–SAT' , 'HF–BY–TEMP'/
0.10096E+08,,299.0,0.00000E+00,0.49E+01/
0.10088E+08,,299.0,0.00000E+00,0.49E+01/

'IF1HS9' , 'BY–ENDS' , 'HG–BY–SAT' , 'HF–BY–TEMP'/
0.11613E+08,,262.0,0.00000E+00,0.39E+01/
0.11597E+08,,262.0,0.00000E+00,0.39E+01/

'IF2HS9' , 'BY–ENDS' , 'HG–BY–SAT' , 'HF–BY–TEMP'/
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0.11587E+08,,262.0,0.00000E+00,0.39E+01/
0.11576E+08,,262.0,0.00000E+00,0.39E+01/

'IF3HS9', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
0.11565E+08,,262.0,0.00000E+00,0.39E+01/
0.11542E+08,,262.0,0.00000E+00,0.39E+01/

'IF4HS9', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
0.11515E+08,,262.0,0.00000E+00,0.39E+01/
0.11219E+08,,262.0,0.00000E+00,0.39E+01/

'IF5HS9', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
0.11176E+08,,262.0,0.00000E+00,0.39E+01/
0.11050E+08,,262.0,0.00000E+00,0.39E+01/

'IEFTM9', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
0.11006E+08,,262.0,0.00000E+00,0.39E+01/
0.11004E+08,,262.0,0.00000E+00,0.39E+01/

'IEFTS9', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
0.10957E+08,,262.0,0.00000E+00,0.00000E+00/
0.10957E+08,,262.0,0.00000E+00,0.00000E+00/

'HS9', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
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0.10957E+08,,266.0,0.00000E+00,0.39E+01/
0.10380E+08,,300.0,0.00000E+00,0.39E+01/

'OEFTS9','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.10380E+08,,299.0,0.00000E+00,0.00000E+00/
0.10380E+08,,299.0,0.00000E+00,0.00000E+00/

'OEFTM9','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.10332E+08,,299.0,0.00000E+00,0.39E+01/
0.10329E+08,,299.0,0.00000E+00,0.39E+01/

'OF5HS9','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.10303E+08,,299.0,0.00000E+00,0.39E+01/
0.10274E+08,,299.0,0.00000E+00,0.39E+01/

'OF4HS9','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.10259E+08,,299.0,0.00000E+00,0.39E+01/
0.10124E+08,,299.0,0.00000E+00,0.39E+01/

'OF3HS9','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.10112E+08,,299.0,0.00000E+00,0.39E+01/
0.10103E+08,,299.0,0.00000E+00,0.39E+01/

'OF2HS9','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
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0.10098E+08,,299.0,0.00000E+00,0.39E+01/
0.10093E+08,,299.0,0.00000E+00,0.39E+01/

'OF1HS9','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10090E+08,,299.0,0.00000E+00,0.39E+01/
0.10086E+08,,299.0,0.00000E+00,0.39E+01/

'OH7A','BY-NODE','HG-BY-SAT','HF-BY-TEMP'/
0.10098E+08,,297,0.00000E+00,0.00000E+00/

'OH7B','BY-NODE','HG-BY-SAT','HF-BY-TEMP'/
0.10098E+08,,297,0.00000E+00,0.80E+01/

'OH7C','BY-NODE','HG-BY-SAT','HF-BY-TEMP'/
0.10098E+08,,297,0.00000E+00,-.218E+02/

'OH7D','BY-NODE','HG-BY-SAT','HF-BY-TEMP'/
0.10098E+08,,297,0.00000E+00,0.00000E+00/

'OH7RLF','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10098E+08,,297,0.00000E+00,0.00000E+00/
0.10098E+08,,297,0.00000E+00,0.00000E+00/

'IBO2A','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
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0.10070E+08,,297,0.00000E+00,0.218E+02/
0.10067E+08,,297,0.00000E+00,0.218E+02/

'IBO2B','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10062E+08,,297,0.00000E+00,0.218E+02/
0.10056E+08,,297,0.00000E+00,0.218E+02/

'IBO2PL','BY-NODES','HG-BY-SAT','HF-BY-TEMP'/
0.10048E+08,,296.0,0.00000E+00,0.218E+02/
0.10046E+08,,296.0,0.00000E+00,0.218E+02/

'BO2UP1','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10027E+08,,293.0,0.00000E+00,0.218E+02/
0.99814E+07,,286.0,0.00000E+00,0.218E+02/

'BO2UP2','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.99710E+07,,285.0,0.00000E+00,0.218E+02/
0.98806E+07,,274.0,0.00000E+00,0.218E+02/

'BO2DN2','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.98751E+07,,273.0,0.00000E+00,00.218E+02/
0.98674E+07,,267.0,0.00000E+00,0.218E+02/

'BO2DN1','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
```

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0.98665E+07,,266.5,0.00000E+00,0.218E+02/
0.98633E+07,,262.5,0.00000E+00,0.218E+02/

'OBO2PL' , 'BY–ENDS' , 'HG–BY–SAT' , 'HF–BY–TEMP'/
0.98507E+07,,262.0,0.00000E+00,0.218E+02/
0.98533E+07,,262.0,0.00000E+00,0.218E+02/

'OBO2A' , 'BY–ENDS' , 'HG–BY–SAT' , 'HF–BY–TEMP'/
0.98545E+07,,262.0,0.00000E+00,0.218E+02/
0.98589E+07,,262.0,0.00000E+00,0.218E+02/

'OBO2B' , 'BY–ENDS' , 'HG–BY–SAT' , 'HF–BY–TEMP'/
0.98607E+07,,262.0,0.00000E+00,0.218E+02/
0.98594E+07,,262.0,0.00000E+00,0.218E+02/

'INP2' , 'BY–ENDS' , 'HG–BY–SAT' , 'HF–BY–TEMP'/
0.98523E+07,,262.0,0.00000E+00,0.218E+02/
0.98470E+07,,262.0,0.00000E+00,0.218E+02/

'OUTP2' , 'BY–ENDS' , 'HG–BY–SAT' , 'HF–BY–TEMP'/
0.11620E+08,,262.0,0.00000E+00,0.218E+02/
0.11610E+08,,262.0,0.00000E+00,0.218E+02/

'OUTP2A' , 'BY–ENDS' , 'HG–BY–SAT' , 'HF–BY–TEMP'/
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0.11620E+08,,262.0,0.00000E+00,0.218E+02/
0.11610E+08,,262.0,0.00000E+00,0.218E+02/

'OPMP2','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.11609E+08,,262.0,0.00000E+00,0.218E+02/
0.11613E+08,,262.0,0.00000E+00,0.218E+02/

'IH8A','BY–NODE','HG–BY–SAT','HF–BY–TEMP'/
0.11606E+08,,262.0,0.00000E+00,0.00000E+00/

'IH8B','BY–NODE','HG–BY–SAT','HF–BY–TEMP'/
0.11606E+08,,262.0,0.00000E+00,0.218E+02/

'IH8C','BY–NODE','HG–BY–SAT','HF–BY–TEMP'/
0.11606E+08,,262.0,0.00000E+00,0.890E+01/

'IH8D','BY–NODE','HG–BY–SAT','HF–BY–TEMP'/
0.11606E+08,,262.0,0.00000E+00,0.00000E+00/

'IF1HS10','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.11581E+08,,262.0,0.00000E+00,0.40E+01/
0.11563E+08,,262.0,0.00000E+00,0.40E+01/

'IF2HS10','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
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0.11545E+08,,262.0,0.00000E+00,0.40E+01/
0.11506E+08,,262.0,0.00000E+00,0.40E+01/

'IF3HS10','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.11078E+08,,262.0,0.00000E+00,0.40E+01/
0.11026E+08,,262.0,0.00000E+00,0.40E+01/

'IEFTM10','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10989E+08,,262.0,0.00000E+00,0.40E+01/
0.10986E+08,,262.0,0.00000E+00,0.40E+01/

'IEFTS10','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10934E+08,,262.0,0.00000E+00,0.00000E+00/
0.10934E+08,,262.0,0.00000E+00,0.00000E+00/

'HS10','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10934E+08,,266.0,0.00000E+00,0.40E+01/
0.10311E+08,,299.0,0.00000E+00,0.40E+01/

'OEFTS10','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10311E+08,,297.5,0.00000E+00,0.00000E+00/
0.10311E+08,,297.5,0.00000E+00,0.00000E+00/

'OEFTM10','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
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0.10256E+08,,297.5,0.00000E+00,0.40E+01/
0.10253E+08,,297.5,0.00000E+00,0.40E+01/

'OF3HS10','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10217E+08,,297.5,0.00000E+00,0.40E+01/
0.10181E+08,,297.5,0.00000E+00,0.40E+01/

'OF2HS10','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10166E+08,,297.5,0.00000E+00,0.40E+01/
0.10141E+08,,297.5,0.00000E+00,0.40E+01/

'OF1HS10','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10129E+08,,297.5,0.00000E+00,0.40E+01/
0.10116E+08,,297.5,0.00000E+00,0.40E+01/

'IF1HS11','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.11584E+08,,262.0,0.00000E+00,0.40E+01/
0.11571E+08,,262.0,0.00000E+00,0.40E+01/

'IF2HS11','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.11556E+08,,262.0,0.00000E+00,0.40E+01/
0.11522E+08,,262.0,0.00000E+00,0.40E+01/

'IF3HS11','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
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0.11187E+08,,262.0,0.00000E+00,0.40E+01/
0.11059E+08,,262.0,0.00000E+00,0.40E+01/

'IEFTM11', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
0.11021E+08,,262.0,0.00000E+00,0.40E+01/
0.11019E+08,,262.0,0.00000E+00,0.40E+01/

'IEFTS11', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
0.10968E+08,,262.0,0.00000E+00,0.00000E+00/
0.10968E+08,,262.0,0.00000E+00,0.00000E+00/

'HS11', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
0.10968E+08,,266.0,0.00000E+00,0.40E+01/
0.10359E+08,,299.0,0.00000E+00,0.40E+01/

'OEFTS11', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
0.10359E+08,,298.0,0.00000E+00,0.00000E+00/
0.10359E+08,,298.0,0.00000E+00,0.00000E+00/

'OEFTM11', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
0.10301E+08,,298.0,0.00000E+00,0.40E+01/
0.10297E+08,,298.0,0.00000E+00,0.40E+01/

'OF3HS11', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
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0.10258E+08,,298.0,0.00000E+00,0.40E+01/
0.10169E+08,,298.0,0.00000E+00,0.40E+01/

'OF2HS11','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10154E+08,,298.0,0.00000E+00,0.40E+01/
0.10132E+08,,298.0,0.00000E+00,0.40E+01/

'OF1HS11','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10122E+08,,298.0,0.00000E+00,0.40E+01/
0.10114E+08,,298.0,0.00000E+00,0.40E+01/

'IF1HS12','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.11596E+08,,262.0,0.00000E+00,0.50E+01/
0.11589E+08,,262.0,0.00000E+00,0.50E+01/

'IF2HS12','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.11586E+08,,262.0,0.00000E+00,0.50E+01/
0.11583E+08,,262.0,0.00000E+00,0.50E+01/

'IF3HS12','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.11575E+08,,262.0,0.00000E+00,0.50E+01/
0.11545E+08,,262.0,0.00000E+00,0.50E+01/

'IF4HS12','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
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0.11532E+08,,262.0,0.00000E+00,0.50E+01/
0.11494E+08,,262.0,0.00000E+00,0.50E+01/

'IF5HS12','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.11481E+08,,262.0,0.00000E+00,0.50E+01/
0.11431E+08,,262.0,0.00000E+00,0.50E+01/

'IEFTM12','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.11377E+08,,262.0,0.00000E+00,0.50E+01/
0.11372E+08,,262.0,0.00000E+00,0.50E+01/

'IEFTS12','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.11290E+08,,262.0,0.00000E+00,0.00000E+00/
0.11290E+08,,262.0,0.00000E+00,0.00000E+00/

'HS12','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.11290E+08,,266.0,0.00000E+00,0.50E+01/
0.10459E+08,,299.0,0.00000E+00,0.50E+01/

'OEFTS12','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10459E+08,,298.0,0.00000E+00,0.00000E+00/
0.10459E+08,,298.0,0.00000E+00,0.00000E+00/

'OEFTM12','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
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0.10388E+08,,298.0,0.00000E+00,0.50E+01/
0.10383E+08,,298.0,0.00000E+00,0.50E+01/

'OF5HS12','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.10341E+08,,298.0,0.00000E+00,0.50E+01/
0.10279E+08,,298.0,0.00000E+00,0.50E+01/

'OF4HS12','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.10258E+08,,298.0,0.00000E+00,0.50E+01/
0.10180E+08,,298.0,0.00000E+00,0.50E+01/

'OF3HS12','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.10164E+08,,293.0,0.00000E+00,0.50E+01/
0.10129E+08,,293.0,0.00000E+00,0.50E+01/

'OF2HS12','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.10120E+08,,298.0,0.00000E+00,0.50E+01/
0.10115E+08,,298.0,0.00000E+00,0.50E+01/

'OF1HS12','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.10111E+08,,298.0,0.00000E+00,0.50E+01/
0.10108E+08,,298.0,0.00000E+00,0.50E+01/

'IF1HS13','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
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0.11598E+08,,262.0,0.00000E+00,0.49E+01/
0.11596E+08,,262.0,0.00000E+00,0.49E+01/

'IF2HS13','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.11590E+08,,262.0,0.00000E+00,0.49E+01/
0.11568E+08,,262.0,0.00000E+00,0.49E+01/

'IF3HS13','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.11461E+08,,262.0,0.00000E+00,0.49E+01/
0.11444E+08,,262.0,0.00000E+00,0.49E+01/

'IF4HS13','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.11438E+08,,262.0,0.00000E+00,0.49E+01/
0.11422E+08,,262.0,0.00000E+00,0.49E+01/

'IEFTM13','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.11372E+08,,262.0,0.00000E+00,0.49E+01/
0.11368E+08,,262.0,0.00000E+00,0.49E+01/

'IEFTS13','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.11285E+08,,262.0,0.00000E+00,0.00000E+00/
0.11285E+08,,262.0,0.00000E+00,0.00000E+00/

'HS13','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
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0.11285E+08,,266.0,0.00000E+00,0.49E+01/
0.10426E+08,,300.0,0.00000E+00,0.49E+01/

'OEFTS13','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10426E+08,,299.0,0.00000E+00,0.00000E+00/
0.10426E+08,,299.0,0.00000E+00,0.00000E+00/

'OEFTM13','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10345E+08,,299.0,0.00000E+00,0.49E+01/
0.10340E+08,,299.0,0.00000E+00,0.49E+01/

'OF4HS13','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10293E+08,,299.0,0.00000E+00,0.49E+01/
0.10268E+08,,299.0,0.00000E+00,0.49E+01/

'OF3HS13','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10251E+08,,299.0,0.00000E+00,0.49E+01/
0.10176E+08,,299.0,0.00000E+00,0.49E+01/

'OF2HS13','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10163E+08,,299.0,0.00000E+00,0.49E+01/
0.10128E+08,,299.0,0.00000E+00,0.49E+01/

'OF1HS13','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
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0.10120E+08,,299.0,0.00000E+00,0.49E+01/
0.10111E+08,,299.0,0.00000E+00,0.49E+01/

'IF1HS14','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.11588E+08,,262.0,0.00000E+00,0.39E+01/
0.11571E+08,,262.0,0.00000E+00,0.39E+01/

'IF2HS14','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.11562E+08,,262.0,0.00000E+00,0.39E+01/
0.11551E+08,,262.0,0.00000E+00,0.39E+01/

'IF3HS14','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.11541E+08,,262.0,0.00000E+00,0.39E+01/
0.11519E+08,,262.0,0.00000E+00,0.39E+01/

'IF4HS14','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.11493E+08,,262.0,0.00000E+00,0.39E+01/
0.11206E+08,,262.0,0.00000E+00,0.39E+01/

'IF5HS14','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.11165E+08,,262.0,0.00000E+00,0.39E+01/
0.11042E+08,,262.0,0.00000E+00,0.39E+01/

'IEFTM14','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
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0.10997E+08,,262.0,0.00000E+00,0.39E+01/
0.10995E+08,,262.0,0.00000E+00,0.39E+01/

'IEFTS14','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10947E+08,,262.0,0.00000E+00,0.00000E+00/
0.10947E+08,,262.0,0.00000E+00,0.00000E+00/

'HS14','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10947E+08,,266.0,0.00000E+00,0.39E+01/
0.10397E+08,,300.0,0.00000E+00,0.39E+01/

'OEFTS14','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10397E+08,,299.0,0.00000E+00,0.00000E+00/
0.10397E+08,,299.0,0.00000E+00,0.00000E+00/

'OEFTM14','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10350E+08,,299.0,0.00000E+00,0.39E+01/
0.10348E+08,,299.0,0.00000E+00,0.39E+01/

'OF5HS14','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10323E+08,,299.0,0.00000E+00,0.39E+01/
0.10294E+08,,299.0,0.00000E+00,0.39E+01/

'OF4HS14','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
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0.10280E+08,,299.0,0.00000E+00,0.39E+01/
0.10147E+08,,299.0,0.00000E+00,0.39E+01/

'OF3HS14','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10135E+08,,299.0,0.00000E+00,0.39E+01/
0.10126E+08,,299.0,0.00000E+00,0.39E+01/

'OF2HS14','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10121E+08,,299.0,0.00000E+00,0.39E+01/
0.10116E+08,,299.0,0.00000E+00,0.39E+01/

'OF1HS14','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10113E+08,,299.0,0.00000E+00,0.39E+01/
0.10109E+08,,299.0,0.00000E+00,0.39E+01/

'OH5A','BY-NODE','HG-BY-SAT','HF-BY-TEMP'/
0.10098E+08,,297.0,0.00000E+00,0.00000E+00/

'OH5B','BY-NODE','HG-BY-SAT','HF-BY-TEMP'/
0.10098E+08,,297.0,0.00000E+00,0.80E+01/

'OH5C','BY-NODE','HG-BY-SAT','HF-BY-TEMP'/
0.10098E+08,,297.0,0.00000E+00,-0.218E+02/

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'OH5D','BY-NODE','HG-BY-SAT','HF-BY-TEMP'/
0.10098E+08,,297.0,0.00000E+00,0.00000E+00/

'OH5RLF','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10100E+08,,297.0,0.00000E+00,0.00000E+00/
0.10099E+08,,297.0,0.00000E+00,0.00000E+00/

'IBO1A','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10094E+08,,297.0,0.00000E+00,0.218E+02/
0.10090E+08,,297.0,0.00000E+00,0.218E+02/

'IBO1B','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10086E+08,,297.0,0.00000E+00,0.218E+02/
0.10080E+08,,297.0,0.00000E+00,0.218E+02/

'IBO1PL','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10072E+08,,296.0,0.00000E+00,0.218E+02/
0.10070E+08,,296.0,0.00000E+00,0.218E+02/

'BO1UP1','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10052E+08,,293.0,0.00000E+00,0.218E+02/
0.10006E+08,,286.0,0.00000E+00,0.218E+02/

'BO1UP2','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
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0.99960E+07,,285.0,0.00000E+00,0.218E+02/
0.99056E+07,,274.0,0.00000E+00,0.218E+02/

'BO1DN2' , 'BY–ENDS' , 'HG–BY–SAT' , 'HF–BY–TEMP'/
0.99001E+07,,273.0,0.00000E+00,0.218E+02/
0.98924E+07,,267.0,0.00000E+00,0.218E+02/

'BO1DN1' , 'BY–ENDS' , 'HG–BY–SAT' , 'HF–BY–TEMP'/
0.98915E+07,,266.5,0.00000E+00,0.218E+02/
0.98883E+07,,262.5,0.00000E+00,0.218E+02/

'OBO1PL' , 'BY–ENDS' , 'HG–BY–SAT' , 'HF–BY–TEMP'/
0.98768E+07,,262.0,0.00000E+00,0.218E+02/
0.98794E+07,,262.0,0.00000E+00,0.218E+02/

'OBO1A' , 'BY–ENDS' , 'HG–BY–SAT' , 'HF–BY–TEMP'/
0.98806E+07,,262.0,0.00000E+00,0.218E+02/
0.98850E+07,,262.0,0.00000E+00,0.218E+02/

'OBO1B' , 'BY–ENDS' , 'HG–BY–SAT' , 'HF–BY–TEMP'/
0.98869E+07,,262.0,0.00000E+00,0.218E+02/
0.98855E+07,,262.0,0.00000E+00,0.218E+02/

'INP1' , 'BY–ENDS' , 'HG–BY–SAT' , 'HF–BY–TEMP'/
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0.98784E+07,,262.0,0.00000E+00,0.218E+02/
0.98731E+07,,262.0,0.00000E+00,0.218E+02/

'OUTP1', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
0.11646E+08,,262.0,0.00000E+00,0.218E+02/
0.11636E+08,,262.0,0.00000E+00,0.218E+02/

'OUTP1A', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
0.11646E+08,,262.0,0.00000E+00,0.218E+02/
0.11636E+08,,262.0,0.00000E+00,0.218E+02/

'OPMP1', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
0.11636E+08,,262.0,0.00000E+00,0.218E+02/
0.11640E+08,,262.0,0.00000E+00,0.218E+02/

'SURGE5', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
0.10098E+08,,250.0,0.00000E+00,0.00000E+00/
0.10098E+08,,250.0,0.00000E+00,0.00000E+00/

'SURGE4', 'BY–NODE', 'HG–BY–SAT', 'HF–BY–TEMP'/
0.10098E+08,,236.0,0.00000E+00,0.00000E+00/

'SURGE3', 'BY–ENDS', 'HG–BY–SAT', 'HF–BY–TEMP'/
0.10097E+08,,220.0,0.00000E+00,0.00000E+00/
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0.10097E+08,,220.0,0.00000E+00,0.00000E+00/

'SURGE2','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10075E+08,,190.0,0.00000E+00,0.00000E+00/
0.10090E+08,,190.0,0.00000E+00,0.00000E+00/

'SURGE1','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.10006E+08,,247.0,0.00000E+00,0.00000E+00/
0.10060E+08,,186.0,0.00000E+00,0.00000E+00/

'BO2INL','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.46042E+07,,200.0,0.00000E+00,0.20E+01/
0.45969E+07,,200.0,0.00000E+00,0.20E+01/

'BO2BAF','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.45973E+07,,200.0,0.00000E+00,0.20E+01/
0.45999E+07,,210.0,0.00000E+00,0.20E+01/

'BO2PREH','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.45998E+07,,211.0,0.00000E+00,0.20E+01/
0.45759E+07,,258.2,0.20535E-01,0.20E+01/

'BO2RS1','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.45932E+07,,256.5,0.27379E+00,0.20E+01/
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0.45917E+07,,258.2,0.50448E+00,0.20E+01/

'BO2RS2','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.45891E+07,,258.7,0.23988E+00,0.20E+01/
0.45758E+07,,258.6,0.44068E+00,0.20E+01/

'BO2BAFB','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.45721E+07,,259.0,0.82338E-03,0.20E+01/
0.45936E+07,,259.0,0.00000E+00,0.20E+01/

'BO2RS3','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.45721E+07,,258.5,0.45631E+00,0.20E+01/
0.45494E+07,,258.2,0.76476E+00,0.20E+01/

'BO2RS4','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.45479E+07,,258.1,0.65644E+00,0.20E+01/
0.45464E+07,,258.1,0.80227E+00,0.20E+01/

'BO2DRUM','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.45297E+07,,258.0,0.19608E+00,0.20E+01/
0.45336E+07,,258.0,0.77598E-05,0.20E+01/

'BO2NOZ','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.45252E+07,,258.0,0.12518E+00,0.20E+01/
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0.45241E+07,,258.0,0.10000E+01,0.20E+01/

'BO2DNC' , 'BY-ENDS' , 'HG-BY-SAT' , 'HF-BY-TEMP'/
0.45502E+07,,258.0,0.00000E+00,0.20E+01/
0.45835E+07,,258.0,0.00000E+00,0.20E+01/

'BO2STM1' , 'BY-NODE' , 'HG-BY-SAT' , 'HF-BY-TEMP'/
0.45204E+07,,258.0,0.10000E+01,0.20E+01/

'BO2STM2' , 'BY-ENDS' , 'HG-BY-SAT' , 'HF-BY-TEMP'/
0.45044E+07,,258.0,0.10000E+01,0.20E+01/
0.45009E+07,,258.0,0.10000E+01,0.20E+01/

'BO1INL' , 'BY-ENDS' , 'HG-BY-SAT' , 'HF-BY-TEMP'/
0.46022E+07,,200.0,0.00000E+00,0.20E+01/
0.45949E+07,,200.0,0.00000E+00,0.20E+01/

'BO1BAF' , 'BY-ENDS' , 'HG-BY-SAT' , 'HF-BY-TEMP'/
0.45953E+07,,200.0,0.00000E+00,0.20E+01/
0.45979E+07,,210.0,0.00000E+00,0.20E+01/

'BO1PREH' , 'BY-ENDS' , 'HG-BY-SAT' , 'HF-BY-TEMP'/
0.45978E+07,,211.0,0.00000E+00,0.20E+01/
0.45739E+07,,258.2,0.20518E-01,0.20E+01/
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'BO1RS1','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.45911E+07,,256.5,0.27429E+00,0.20E+01/
0.45896E+07,,258.2,0.50515E+00,0.20E+01/

'BO1RS2','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.45871E+07,,258.7,0.24053E+00,0.20E+01/
0.45738E+07,,258.6,0.44147E+00,0.20E+01/

'BO1BAFB','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.45701E+07,,259.0,0.82469E-03,0.20E+01/
0.45916E+07,,259.0,0.00000E+00,0.20E+01/

'BO1RS3','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.45701E+07,,258.5,0.45711E+00,0.20E+01/
0.45474E+07,,258.2,0.76529E+00,0.20E+01/

'BO1RS4','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.45459E+07,,258.1,0.65691E+00,0.20E+01/
0.45444E+07,,258.1,0.80282E+00,0.20E+01/

'BO1DRUM','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.45276E+07,,258.0,0.19239E+00,0.20E+01/
0.45316E+07,,258.0,0.78086E-05,0.20E+01/
```

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'BO1NOZ','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.45242E+07,,258.0,0.10000E+01,0.20E+01/
0.45242E+07,,258.0,0.10000E+01,0.20E+01/

'BO1DNC','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.45481E+07,,258.0,0.00000E+00,0.20E+01/
0.45814E+07,,258.0,0.00000E+00,0.20E+01/

'BO1STM1','BY-NODE','HG-BY-SAT','HF-BY-TEMP'/
0.45204E+07,,258.0,0.10000E+01,0.20E+01/

'BO1STM2','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.45044E+07,,258.0,0.10000E+01,0.20E+01/
0.45009E+07,,258.0,0.10000E+01,0.20E+01/

'ECIPUM1','BY-NODE','HG-BY-SAT','HF-BY-TEMP'/
0.11179E+06,,21.0,0.00000E+00,0.00000E+00/

'ECIPUM2','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.20961E+06,,21.0,0.00000E+00,0.00000E+00/
0.20961E+06,,21.0,0.00000E+00,0.00000E+00/

'ECIPUM3','BY-NODE','HG-BY-SAT','HF-BY-TEMP'/
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0.21137E+06,,21.0,0.00000E+00,0.00000E+00/

'ECIPUM4','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.18412E+06,,21.0,0.00000E+00,0.00000E+00/
0.18412E+06,,21.0,0.00000E+00,0.00000E+00/

'ECIHP1','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.13628E+06,,21.0,0.00000E+00,0.00000E+00/
0.16884E+06,,21.0,0.00000E+00,0.00000E+00/

'ECIHP2','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.18512E+06,,21.0,0.00000E+00,0.00000E+00/
0.18512E+06,,21.0,0.00000E+00,0.00000E+00/

'ECIHP3','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.17168E+06,,21.0,0.00000E+00,0.00000E+00/
0.17168E+06,,21.0,0.00000E+00,0.00000E+00/

'ECIHP4','BY-NODE','HG-BY-SAT','HF-BY-TEMP'/
0.17796E+06,,21.0,0.00000E+00,0.00000E+00/

'ECICOM0','BY-NODE','HG-BY-SAT','HF-BY-TEMP'/
0.18558E+06,,21.0,0.00000E+00,0.00000E+00/

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'ECICOM1', 'BY-NODE', 'HG-BY-SAT', 'HF-BY-TEMP'/
0.19096E+06,,21.0,0.00000E+00,0.00000E+00/

'ECICOM2', 'BY-NODE', 'HG-BY-SAT', 'HF-BY-TEMP'/
0.19732E+06,,21.0,0.00000E+00,0.00000E+00/

'ECICOM3', 'BY-ENDS', 'HG-BY-SAT', 'HF-BY-TEMP'/
0.19976E+06,,21.0,0.00000E+00,0.00000E+00/
0.19976E+06,,21.0,0.00000E+00,0.00000E+00/

'ECICOM4', 'BY-NODE', 'HG-BY-SAT', 'HF-BY-TEMP'/
0.20367E+06,,21.0,0.00000E+00,0.00000E+00/

'ECICOM5', 'BY-ENDS', 'HG-BY-SAT', 'HF-BY-TEMP'/
0.20758E+06,,21.0,0.00000E+00,0.00000E+00/
0.20758E+06,,21.0,0.00000E+00,0.00000E+00/

'ECICOM6', 'BY-NODE', 'HG-BY-SAT', 'HF-BY-TEMP'/
0.20812E+06,,21.0,0.00000E+00,0.00000E+00/

'ECIP14I1', 'BY-ENDS', 'HG-BY-SAT', 'HF-BY-TEMP'/
0.14261E+06,,21.0,0.00000E+00,0.00000E+00/
0.18783E+06,,21.0,0.00000E+00,0.00000E+00/

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'ECIP14I2','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.21045E+06,,21.0,0.00000E+00,0.00000E+00/
0.21045E+06,,21.0,0.00000E+00,0.00000E+00/

'ECIP14O1','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.19791E+06,,21.0,0.00000E+00,0.00000E+00/
0.17282E+06,,21.0,0.00000E+00,0.00000E+00/

'ECIP14O2','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.17031E+06,,21.0,0.00000E+00,0.00000E+00/
0.19035E+06,,21.0,0.00000E+00,0.00000E+00/

'ECIP14O3','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.20037E+06,,21.0,0.00000E+00,0.00000E+00/
0.20037E+06,,21.0,0.00000E+00,0.00000E+00/

'ECI56A','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.20866E+06,,21.0,0.00000E+00,0.00000E+00/
0.20866E+06,,21.0,0.00000E+00,0.00000E+00/

'ECI78A','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.20866E+06,,21.0,0.00000E+00,0.00000E+00/
0.20866E+06,,21.0,0.00000E+00,0.00000E+00/

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'ECI56B','BY-NODE','HG-BY-SAT','HF-BY-TEMP'/
0.20939E+06,,21.0,0.00000E+00,0.00000E+00/

'ECI78B','BY-NODE','HG-BY-SAT','HF-BY-TEMP'/
0.20939E+06,,21.0,0.00000E+00,0.00000E+00/

'ECI5A','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.21013E+06,,21.0,0.00000E+00,0.00000E+00/
0.21013E+06,,21.0,0.00000E+00,0.00000E+00/

'ECI5B','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.21013E+06,,21.0,0.00000E+00,0.00000E+00/
0.21013E+06,,21.0,0.00000E+00,0.00000E+00/

'ECI5C','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.19982E+06,,21.0,0.00000E+00,0.00000E+00/
0.20197E+06,,21.0,0.00000E+00,0.00000E+00/



'ECI7A','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.21013E+06,,21.0,0.00000E+00,0.00000E+00/
0.21013E+06,,21.0,0.00000E+00,0.00000E+00/

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'ECI7B','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.21013E+06,,21.0,0.00000E+00,0.00000E+00/
0.21013E+06,,21.0,0.00000E+00,0.00000E+00/

'ECI7C','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.20475E+06,,21.0,0.00000E+00,0.00000E+00/
0.20690E+06,,21.0,0.00000E+00,0.00000E+00/

'ECI8A','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.21013E+06,,21.0,0.00000E+00,0.00000E+00/
0.21013E+06,,21.0,0.00000E+00,0.00000E+00/

'ECI8B','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.21013E+06,,21.0,0.00000E+00,0.00000E+00/
0.21013E+06,,21.0,0.00000E+00,0.00000E+00/

'ECI8C','BY-ENDS','HG-BY-SAT','HF-BY-TEMP'/
0.20408E+06,,21.0,0.00000E+00,0.00000E+00/
0.20623E+06,,21.0,0.00000E+00,0.00000E+00/


'R-OPMP1','HDRIN'/
0.218E+02/

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```
'HDROT5' , 'L–IF1HS5'/
0.40E+01/

'HDROT6' , 'L–IF1HS6'/
0.40E+01/


'HDROT8' , 'L–IF1HS8'/
0.49E+01/

'HDROT7' , 'L–IF1HS7'/
0.50E+01/

'HDROT9' , 'L–IF1HS9'/
0.39E+01/


'R–IF1HS5' , 'L–IF2HS5'/
0.40E+01/

'R–IF2HS5' , 'L–IF3HS5'/
0.40E+01/

'R–IF3HS5' , 'L–IEFTM5'/
```

```
0.40E+01/

'R–IEFTM5' , 'L–HS5'/
0.40E+01/

'R–IEFTS5' , 'L–HS5'/
0.00000E+00/

'R–HS5' , 'L–OEFTS5'/
0.00000E+00/

'R–HS5' , 'L–OEFTM5'/
0.40E+01/

'R–OEFTM5' , 'L–OF3HS5'/
0.40E+01/

'R–OF3HS5' , 'L–OF2HS5'/
0.40E+01/

'R–OF2HS5' , 'L–OF1HS5'/
0.40E+01/

'R–IF1HS6' , 'L–IF2HS6'/
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```
0.40E+01/

'R–IF2HS6' , 'L–IF3HS6'/
0.40E+01/

'R–IF3HS6' , 'L–IEFTM6'/
0.40E+01/

'R–IEFTM6' , 'L–HS6'/
0.40E+01/

'R–IEFTS6' , 'L–HS6'/
0.00000E+00/

'R–HS6' , 'L–OEFTS6'/
0.00000E+00/

'R–HS6' , 'L–OEFTM6'/
0.40E+01/

'R–OEFTM6' , 'L–OF3HS6'/
0.40E+01/

'R–OF3HS6' , 'L–OF2HS6'/
```

```
0.40E+01/

'R–OF2HS6', 'L–OF1HS6'/
0.40E+01/

'R–IF1HS7', 'L–IF2HS7'/
0.50E+01/

'R–IF2HS7', 'L–IF3HS7'/
0.50E+01/

'R–IF3HS7', 'L–IF4HS7'/
0.50E+01/

'R–IF4HS7', 'L–IF5HS7'/
0.50E+01/

'R–IF5HS7', 'L–IEFTM7'/
0.50E+01/

'R–IEFTM7', 'L–HS7'/
0.50E+01/

'R–IEFTS7', 'L–HS7'/
```

```
0.00000E+00/

'R–HS7' , 'L–OEFTS7'/
0.00000E+00/

'R–HS7' , 'L–OEFTM7'/
0.50E+01/

'R–OEFTM7' , 'L–OF5HS7'/
0.50E+01/

'R–OF5HS7' , 'L–OF4HS7'/
0.50E+01/

'R–OF4HS7' , 'L–OF3HS7'/
0.50E+01/

'R–OF3HS7' , 'L–OF2HS7'/
0.50E+01/

'R–OF2HS7' , 'L–OF1HS7'/
0.50E+01/

'R–IF1HS8' , 'L–IF2HS8'/
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```
0.49E+01/

'R–IF2HS8' , 'L–IF3HS8'/
0.49E+01/

'R–IF3HS8' , 'L–IF4HS8'/
0.49E+01/

'R–IF4HS8' , 'L–IEFTM8'/
0.49E+01/

'R–IEFTM8' , 'L–HS8'/
0.49E+01/

'R–IEFTS8' , 'L–HS8'/
0.00000E+00/

'R–HS8' , 'L–OEFTS8'/
0.00000E+00/

'R–HS8' , 'L–OEFTM8'/
0.49E+01/

'R–OEFTM8' , 'L–OF4HS8'/
```

```
0.49E+01/

'R–OF4HS8','L–OF3HS8'/
0.49E+01/

'R–OF3HS8','L–OF2HS8'/
0.49E+01/

'R–OF2HS8','L–OF1HS8'/
0.49E+01/

'R–IF1HS9','L–IF2HS9'/
0.39E+01/

'R–IF2HS9','L–IF3HS9'/
0.39E+01/

'R–IF3HS9','L–IF4HS9'/
0.39E+01/

'R–IF4HS9','L–IF5HS9'/
0.39E+01/

'R–IF5HS9','L–IEFTM9'/
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```
0.39E+01/

'R–IEFTM9' , 'L–HS9'/
0.39E+01/

'R–IEFTS9' , 'L–HS9'/
0.00000E+00/

'R–HS9' , 'L–OEFTS9'/
0.00000E+00/

'R–HS9' , 'L–OEFTM9'/
0.39E+01/

'R–OEFTM9' , 'L–OF5HS9'/
0.39E+01/

'R–OF5HS9' , 'L–OF4HS9'/
0.39E+01/

'R–OF4HS9' , 'L–OF3HS9'/
0.39E+01/

'R–OF3HS9' , 'L–OF2HS9'/
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```
0.39E+01/

’R–OF2HS9’ , ’L–OF1HS9’/
0.39E+01/

’R–OH7A’ , ’L–OH7B’/
0.00000E+00/

’L–OH7B’ , ’R–OF1HS5’/
−0.40E+01/

’L–OH7B’ , ’R–OF1HS6’/
−0.40E+01/

’R–OH7B’ , ’L–OH7C’/
0.80E+01/

’L–OH7C’ , ’R–OF1HS7’/
−0.50E+01/

’L–OH7C’ , ’R–OF1HS8’/
−0.49E+01/

’R–OH7C’ , ’R–OF1HS9’/
```

```
-0.39E+01/

'R-OH7C' , 'L-IBO2A'/
0.21800E+02/

'R-OH7C' , 'L-OH7D'/
0.00000E+00/

'L-OH7D' , 'R-OH7RLF'/
0.00000E+00/

'R-OH7D' , 'R-ECI7C'/
0.00000E+00/

'R-IBO2A' , 'L-IBO2B'/
0.21800E+02/

'R-IBO2B' , 'L-IBO2PL'/
0.21800E+02/

'R-IBO2PL' , 'L-BO2UP1'/
0.21800E+02/

'R-BO2UP1' , 'L-BO2UP2'/
```

```
0.21800E+02/

'R–BO2UP2', 'L–BO2DN2'/
0.21800E+02/

'R–BO2DN2', 'L–BO2DN1'/
0.21800E+02/

'R–BO2DN1', 'L–OBO2PL'/
0.21800E+02/

'R–OBO2PL', 'L–OBO2A'/
0.21800E+02/

'R–OBO2A', 'L–OBO2B'/
0.21800E+02/

'R–OBO2B', 'L–INP2'/
0.21800E+02/

'R–INP2', 'L–OUTP2'/
0.21800E+02/

'R–OUTP2', 'L–OUTP2A'/
```

```
0.21800E+02/

’R–OUTP2A’ , ’L–OPMP2’/
0.21800E+02/

’L–IH8A’ , ’R–ECI8C’/
0.00000E+00/

’R–IH8A’ , ’L–IH8B’/
0.00000E+00/

’L–IH8B’ , ’R–OPMP2’/
−0.21800E+02/

’L–IH8B’ , ’L–IF1HS10’/
0.40E+01/

’L–IH8B’ , ’L–IF1HS11’/
0.40E+01/

’R–IH8B’ , ’L–IH8C’/
0.89E+01/

’R–IH8B’ , ’L–IF1HS13’/
```

```
0.49E+01/

'R–IH8C' , 'L–IF1HS12'/
0.50E+01/

'R–IH8C' , 'L–IF1HS14'/
0.39E+01/

'R–IH8C' , 'L–IH8D'/
0.00000E+00/

'R–IH8D' , 'BKBC'/
0.00000E+00/

'R–IF1HS10' , 'L–IF2HS10'/
0.40E+01/

'R–IF2HS10' , 'L–IF3HS10'/
0.40E+01/

'R–IF3HS10' , 'L–IEFTM10'/
0.40E+01/

'R–IEFTM10' , 'L–HS10'/
```

```
0.40E+01/

'R–IEFTS10' , 'L–HS10'/
0.00000E+00/

'R–HS10' , 'L–OEFTS10'/
0.00000E+00/

'R–HS10' , 'L–OEFTM10'/
0.40E+01/

'R–OEFTM10' , 'L–OF3HS10'/
0.40E+01/

'R–OF3HS10' , 'L–OF2HS10'/
0.40E+01/

'R–OF2HS10' , 'L–OF1HS10'/
0.40E+01/

'R–IF1HS11' , 'L–IF2HS11'/
0.40E+01/

'R–IF2HS11' , 'L–IF3HS11'/
```

```
0.40E+01/

'R–IF3HS11', 'L–IEFTM11'/
0.40E+01/

'R–IEFTM11', 'L–HS11'/
0.40E+01/

'R–IEFTS11', 'L–HS11'/
0.00000E+00/

'R–HS11', 'L–OEFTS11'/
0.00000E+00/

'R–HS11', 'L–OEFTM11'/
0.40E+01/

'R–OEFTM11', 'L–OF3HS11'/
0.40E+01/

'R–OF3HS11', 'L–OF2HS11'/
0.40E+01/

'R–OF2HS11', 'L–OF1HS11'/
```

```
0.40E+01/

'R–IF1HS12' , 'L–IF2HS12'/
0.50E+01/

'R–IF2HS12' , 'L–IF3HS12'/
0.50E+01/

'R–IF3HS12' , 'L–IF4HS12'/
0.50E+01/

'R–IF4HS12' , 'L–IF5HS12'/
0.50E+01/

'R–IF5HS12' , 'L–IEFTM12'/
0.50E+01/

'R–IEFTM12' , 'L–HS12'/
0.50E+01/

'R–IEFTS12' , 'L–HS12'/
0.00000E+00/

'R–HS12' , 'L–OEFTS12'/
```

```
0.00000E+00/

'R–HS12', 'L–OEFTM12'/
0.50E+01/

'R–OEFTM12', 'L–OF5HS12'/
0.50E+01/

'R–OF5HS12', 'L–OF4HS12'/
0.50E+01/

'R–OF4HS12', 'L–OF3HS12'/
0.50E+01/

'R–OF3HS12', 'L–OF2HS12'/
0.50E+01/

'R–OF2HS12', 'L–OF1HS12'/
0.50E+01/

'R–IF1HS13', 'L–IF2HS13'/
0.49E+01/

'R–IF2HS13', 'L–IF3HS13'/
```

```
0.49E+01/

'R–IF3HS13' , 'L–IF4HS13'/
0.49E+01/

'R–IF4HS13' , 'L–IEFTM13'/
0.49E+01/

'R–IEFTM13' , 'L–HS13'/
0.49E+01/

'R–IEFTS13' , 'L–HS13'/
0.00000E+00/

'R–HS13' , 'L–OEFTS13'/
0.00000E+00/

'R–HS13' , 'L–OEFTM13'/
0.49E+01/

'R–OEFTM13' , 'L–OF4HS13'/
0.49E+01/

'R–OF4HS13' , 'L–OF3HS13'/
```

```
0.49E+01/

’R–OF3HS13’ , ’L–OF2HS13’/
0.49E+01/

’R–OF2HS13’ , ’L–OF1HS13’/
0.49E+01/

’R–IF1HS14’ , ’L–IF2HS14’/
0.39E+01/

’R–IF2HS14’ , ’L–IF3HS14’/
0.39E+01/

’R–IF3HS14’ , ’L–IF4HS14’/
0.39E+01/

’R–IF4HS14’ , ’L–IF5HS14’/
0.39E+01/

’R–IF5HS14’ , ’L–IEFTM14’/
0.39E+01/

’R–IEFTM14’ , ’L–HS14’/
```

```
0.39E+01/

'R–IEFTS14','L–HS14'/
0.00000E+00/

'R–HS14','L–OEFTS14'/
0.00000E+00/

'R–HS14','L–OEFTM14'/
0.39E+01/

'R–OEFTM14','L–OF5HS14'/
0.39E+01/

'R–OF5HS14','L–OF4HS14'/
0.39E+01/

'R–OF4HS14','L–OF3HS14'/
0.39E+01/

'R–OF3HS14','L–OF2HS14'/
0.39E+01/

'R–OF2HS14','L–OF1HS14'/
```

```
0.39E+01/

'R–OH5A' , 'L–OH5B'/
0.00000E+00/

'L–OH5B' , 'R–OF1HS10'/
−0.40E+01/

'L–OH5B' , 'R–OF1HS11'/
−0.40E+01/

'R–OH5B' , 'L–OH5C'/
0.80E+01/

'L–OH5C' , 'R–OF1HS12'/
−0.50E+01/

'L–OH5C' , 'R–OF1HS13'/
−0.49E+01/

'R–OH5C' , 'R–OF1HS14'/
−0.39E+01/

'R–OH5C' , 'L–IBO1A'/
```

```
0.21800E+02/

'R–OH5C' , 'L–OH5D'/
0.00000E+00/

'L–OH5D' , 'R–OH5RLF'/
0.00000E+00/

'R–OH5D' , 'R–ECI5C'/
0.00000E+00/

'R–IBO1A' , 'L–IBO1B'/
0.21800E+02/

'R–IBO1B' , 'L–IBO1PL'/
0.21800E+02/

'R–IBO1PL' , 'L–BO1UP1'/
0.21800E+02/

'R–BO1UP1' , 'L–BO1UP2'/
0.21800E+02/

'R–BO1UP2' , 'L–BO1DN2'/
```

```
0.21800E+02/

'R–BO1DN2' , 'L–BO1DN1'/
0.21800E+02/

'R–BO1DN1' , 'L–OBO1PL'/
0.21800E+02/

'R–OBO1PL' , 'L–OBO1A'/
0.21800E+02/

'R–OBO1A' , 'L–OBO1B'/
0.21800E+02/

'R–OBO1B' , 'L–INP1 '/
0.21800E+02/

'R–INP1 ' , 'L–OUTP1'/
0.21800E+02/

'R–OUTP1' , 'L–OUTP1A'/
0.21800E+02/

'R–OUTP1A' , 'L–OPMP1'/
```

```
0.21800E+02/

'R–SURGE5','L–OH5A'/
0.00000E+00/

'R–SURGE4','L–SURGE5'/
0.00000E+00/

'R–SURGE3','L–SURGE4'/
0.00000E+00/

'R–SURGE2','L–SURGE3'/
0.00000E+00/

'R–SURGE1','L–SURGE2'/
0.00000E+00/



'SEC1IBC','L–BO2INL'/
0.20000E+01/

'SEC1IBC','L–BO1INL'/
0.20000E+01/
```

```

'R–BO2INL' , 'L–BO2BAF'/
0.20000E+01/

'R–BO2BAF' , 'L–BO2PREH'/
0.20000E+01/

'R–BO2PREH' , 'L–BO2BAFB'/
0.20000E+01/

'R–BO2PREH' , 'L–BO2RS3'/
0.20000E+01/

'R–BO2RS1' , 'L–BO2RS2'/
0.20000E+01/

'R–BO2RS2' , 'L–BO2RS3'/
0.20000E+01/

'R–BO2BAFB' , 'L–BO2RS1'/
0.20000E+01/

'R–BO2RS3' , 'L–BO2RS4'/
0.20000E+01/
```

```

'R-BO2RS4','L-BO2DRUM'/
0.20000E+01/

'L-BO2DRUM','L-BO2NOZ'/
0.20000E+01/

'R-BO2DRUM','L-BO2DNC'/
0.20000E+01/

'R-BO2NOZ','L-BO2STM1'/
0.20000E+01/

'R-BO2DNC','L-BO2RS2'/
0.20000E+01/

'R-BO2STM1','L-BO2STM2'/
0.20000E+01/

'R-BO2STM2','SEC1OBC'/
0.20000E+01/

'R-BO1INL','L-BO1BAF'/
0.20000E+01/
```

```

'R-BO1BAF' , 'L-BO1PREH'/
0.20000E+01/

'R-BO1PREH' , 'L-BO1BAFB'/
0.20000E+01/

'R-BO1PREH' , 'L-BO1RS3'/
0.20000E+01/

'R-BO1RS1' , 'L-BO1RS2'/
0.20000E+01/

'R-BO1RS2' , 'L-BO1RS3'/
0.20000E+01/

'R-BO1BAFB' , 'L-BO1RS1'/
0.20000E+01/

'R-BO1RS3' , 'L-BO1RS4'/
0.20000E+01/

'R-BO1RS4' , 'L-BO1DRUM'/
0.20000E+01/
```

```

'L–BO1DRUM' , 'L–BO1NOZ'/
0.20000E+01/

'R–BO1DRUM' , 'L–BO1DNC'/
0.20000E+01/

'R–BO1NOZ' , 'L–BO1STM1'/
0.20000E+01/

'R–BO1DNC' , 'L–BO1RS2'/
0.20000E+01/

'R–BO1STM1' , 'L–BO1STM2'/
0.20000E+01/

'R–BO1STM2' , 'SEC1OBC'/
0.20000E+01/

'ECPUMBC' , 'L–ECIPUM1'/
0.00000E+00/

'R–ECIPUM1' , 'L–ECIPUM2'/
0.00000E+00/
```

```

'R–ECIPUM2' , 'L–ECIPUM3'/
0.00000E+00/

'R–ECIPUM3' , 'L–ECIPUM4'/
0.00000E+00/

'R–ECIPUM4' , 'L–ECICOM0'/
0.00000E+00/

'ECIHPBC' , 'L–ECIHP1'/
0.00000E+00/

'R–ECIHP1' , 'L–ECIHP2'/
0.00000E+00/

'R–ECIHP2' , 'L–ECIHP3'/
0.00000E+00/

'R–ECIHP2' , 'L–ECIP14I1'/
0.00000E+00/

'R–ECIHP3' , 'L–ECIHP4'/
0.00000E+00/
```

```

’R–ECIHP4 ’ , ’L–ECICOM0’/
0.00000E+00/

’R–ECICOM0’ , ’L–ECICOM1’/
0.00000E+00/

’R–ECICOM1’ , ’L–ECICOM2’/
0.00000E+00/

’R–ECICOM2’ , ’L–ECICOM3’/
0.00000E+00/

’R–ECICOM3’ , ’L–ECICOM4’/
0.00000E+00/

’R–ECICOM4’ , ’L–ECICOM5’/
0.00000E+00/

’R–ECICOM5’ , ’L–ECICOM6’/
0.00000E+00/

’R–ECICOM6’ , ’L–ECI56A ’/
0.00000E+00/
```

```

'R–ECICOM6','L–ECI78A'/
0.00000E+00/

'R–ECIP14I1','L–ECIP14I2'/
0.00000E+00/

'R–ECIP14I2','L–ECIP14O1'/
0.00000E+00/

'R–ECIP14O1','L–ECIP14O2'/
0.00000E+00/

'R–ECIP14O2','L–ECIP14O3'/
0.00000E+00/

'R–ECIP14O3','L–ECICOM1'/
0.00000E+00/

'R–ECI56A','L–ECI56B'/
0.00000E+00/

'R–ECI78A','L–ECI78B'/
0.00000E+00/
```

```

'R–ECI56B','L–ECI5A'/
0.00000E+00/



'R–ECI78B','L–ECI7A'/
0.00000E+00/

'R–ECI78B','L–ECI8A'/
0.00000E+00/

'R–ECI5A','L–ECI5B'/
0.00000E+00/

'R–ECI5B','L–ECI5C'/
0.00000E+00/



'R–ECI7A','L–ECI7B'/
0.00000E+00/

'R–ECI7B','L–ECI7C'/
```

```
0.00000E+00/

'R-ECI8A','L-ECI8B'/
0.00000E+00/

'R-ECI8B','L-ECI8C'/
0.00000E+00/

'END'/ END INITIAL CONDITION



Components removed:
'IH6A'     0.28696  0.000  0.02946  0.193675  4.5E-5  0.000  'CIRC'
      1,,,8.5935E-3,'FIX-MIXED'/
'IH6B'     0.20000  0.000  0.02946  0.193675  4.5E-5  0.000  'CIRC'
      1,,,,'FIX-MIXED'/
'IH6C'     0.26000  0.000  0.02946  0.193675  4.5E-5  0.000  'CIRC'
      1,,,,'FIX-MIXED'/
'IH6D'     0.28696  0.000  0.02946  0.193675  4.5E-5  0.000  'CIRC'
      1,,,1.0036E-2,'FIX-MIXED'/

'ECI6A'     0.2700  0.0000  0.001905   0.04925  4.5E-5  0.40  '
    CIRC' 3/
```

```
'ECI6B'      1.7700   0.0000 1.1401E-03 0.03810 4.5E-5 4.20 'CIRC' 3/
'ECI6C'      1.6700  -0.3300 1.1401E-03 0.03810 4.5E-5 1.30 'CIRC' 3/

Connections removed:
'L-IH6A'             ,'R-ECI6C'  ,'FIX-MIXED'/'L-IH6A'/
'R-IH6A'             ,'L-IH6B'   ,'ADJ-NODE-MIXING(+50),FIX-MIXED'/
'L-IH6B'             ,'R-OPMP1'  ,'FIX-MIXED'/
'L-IH6B'             ,'L-IF1HS5','FIX-MIXED'/
'L-IH6B'             ,'L-IF1HS6','FIX-MIXED'/
'R-IH6B'             ,'L-IH6C'   ,'FIX-MIXED'/
'R-IH6B'             ,'L-IF1HS8','FIX-MIXED'/
'R-IH6C'             ,'L-IF1HS7','FIX-MIXED'/
'R-IH6C'             ,'L-IF1HS9','FIX-MIXED'/
'R-IH6C'             ,'L-IH6D'   ,'ADJ-NODE-MIXING(+50),FIX-MIXED'/
'R-IH6D'/

'R-ECI56B'           ,'L-ECI6A'/
'R-ECI6A'            ,'L-ECI6B'/
'R-ECI6B'            ,'L-ECI6C'/

System models removed:

```

```
'VALVE','ECI6ISO'/
'L-IH6A','R-ECI6C'/ VALVE # MV-5
0.001445,1.0/ 42.9 mm

'VALVE','ECI6CHK'/              NV-5
'R-ECI6B','L-ECI6C'/
7.91730E-4,0.61,,'CVF',2*0.05/ 1.25”

'ECI6ISO','OPENFR',.TRUE./


OUTPUT MODELS REMOVED (from INP file):

'PRESS:IH6B(1)', 1.0E-6/    in MPa
/
'PRESS:IH6C(1)', 1.0E-6/    in MPa  Channel 180, Druck Channel 323, Rosemont
/

'TEMPF:IH6B(1)'/
/
'TEMPF:IH6C(1)'/ Channel 74, RTD Channel 135, TC
/

```

```

'PRESS:IH6B(1)',1.0E-03/
'PRESS:OH7B(1)',-1.0E-03/
/
'PRESS:IH6C(1)',1.0E-03/
'PRESS:OH7C(1)',-1.0E-03/
/
'PRESS:OH5B(1)',1.0E-03/
'PRESS:IH6B(1)',-1.0E-03/ Channel 198
/

'INT_VOID:IH6A(1)>IH6D(99)'/
/

'VFLO:ECI6A(1.08)',1.0e3/ flow L/s at TFM (232F-D1)
/

OUTPUT MODELS REMOVED (from B901_NM INP file):

'TEMPF:ECI6C(0.86)'/  112T-D1
/

HEAT TRANSFER PACKAGE REMOVED:

```

```
'MODEL:(WIH6A)'/
'RADIAL:(1,0.118353,4,0.131086)','AXIAL:(0.28696,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IH6A)','BRANCH POSITION:(0.,0.28696)',
'MODEL POSITION:(0.,0.28696)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WIH6B)'/
'RADIAL:(1,0.096837,4,0.109537)','AXIAL:(0.20,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IH6B)','BRANCH POSITION:(0.,0.20)',
'MODEL POSITION:(0.,0.20)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
```

```
/
'TEMP—0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WIH6C)'/
'RADIAL:(1,0.096837,4,0.109537)','AXIAL:(0.26,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IH6C)','BRANCH POSITION:(0.,0.26)',
'MODEL POSITION:(0.,0.26)'/
'TUBE—CIR',,'HT—CORR—DEFAULT',,,
'WALL—INTERFACE—HEAT—TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF—HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP—0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WIH6D)'/
'RADIAL:(1,0.118353,4,0.131086)','AXIAL:(0.28696,1)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(IH6D)','BRANCH POSITION:(0.,0.28696)',
'MODEL POSITION:(0.,0.28696)'/
'TUBE—CIR',,'HT—CORR—DEFAULT',,,
```

```
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(5.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(262.0)'/
'PRINT:(00105)'/

'MODEL:(WECI6A)'/
'RADIAL:(1,0.02463,4,0.03015)','AXIAL:(0.27,3)'/
'BOUNDARY CONDITIONS:(1,1)'/
'INSIDE HYDRAULIC:(ECI6A)','BRANCH POSITION:(0.,0.270)',
'MODEL POSITION:(0.,0.270)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(8.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(21.0)'/
'PRINT:(00105)'/

'MODEL:(WECI6BC)'/
'RADIAL:(1,0.01905,4,0.02413)','AXIAL:(3.44,6)-USER-LENGTH'/
```

```
3*0.59,3*0.55667/
'BOUNDARY CONDITIONS:(2,1)'/
'INSIDE HYDRAULIC:(ECI6B)','BRANCH POSITION:(0.,1.770)',
'MODEL POSITION:(0.,1.770)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'INSIDE HYDRAULIC:(ECI6C)','BRANCH POSITION:(0.,1.670)',
'MODEL POSITION:(1.770,3.440)'/
'TUBE-CIR',,'HT-CORR-DEFAULT',,,
'WALL-INTERFACE-HEAT-TRANSFER:(6*5,1)'/
'OUTSIDE PRESCRIBED:(ENVIRON)',,,,,'SURFACE OPTION:(1)'/
'SURF-HC,TF:(8.00,20.)'/
'CARBON STEEL'/
/
'TEMP-0D:(21.0)'/
'PRINT:(00105)'/


INITIAL CONDITIONS REMOVED:

'IH6A','BY-NODE','HG-BY-SAT','HF-BY-TEMP'/
0.11606E+08,,262.0,0.00000E+00,0.00000E+00/

'IH6B','BY-NODE','HG-BY-SAT','HF-BY-TEMP'/
```

```
0.11606E+08,,262.0,0.00000E+00,0.218E+02/

'IH6C','BY–NODE','HG–BY–SAT','HF–BY–TEMP'/
0.11606E+08,,262.0,0.00000E+00,0.89E+01/

'IH6D','BY–NODE','HG–BY–SAT','HF–BY–TEMP'/
0.11606E+08,,262.0,0.00000E+00,0.00000E+00/

'ECI6A','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.21013E+06,,21.0,0.00000E+00,0.00000E+00/
0.21013E+06,,21.0,0.00000E+00,0.00000E+00/

'ECI6B','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.21013E+06,,21.0,0.00000E+00,0.00000E+00/
0.21013E+06,,21.0,0.00000E+00,0.00000E+00/

'ECI6C','BY–ENDS','HG–BY–SAT','HF–BY–TEMP'/
0.20296E+06,,21.0,0.00000E+00,0.00000E+00/
0.20511E+06,,21.0,0.00000E+00,0.00000E+00/

'L–IH6A','R–ECI6C'/
0.00000E+00/

'R–IH6A','L–IH6B'/
```

```
0.00000E+00/
 'R-IH6B', 'L-IH6C'/
0.89E+01/
 'R-IH6C', 'L-IH6D'/
0.00000E+00/

 'R-ECI56B', 'L-ECI6A'/
0.00000E+00/

'R-ECI6A', 'L-ECI6B'/
0.00000E+00/

'R-ECI6B', 'L-ECI6C'/
0.00000E+00/

'FLOW B.C.', 'INFLBC'/
'R-OPMP1',  'HDRIN'/
21.779/




'INPUT TABLE', 'TMINDT'/ *** Minimum time step control
1,2,,.FALSE.,/
```

```
'TIME','MINSTEP'/
0.000,  0.001/
9.9E9,  0.001/

'TIME VAR.','MINDTCTL'/
'TMINDT','MINSTEP'/
/9.9E9
           '*CONTROL','DTMIN'/
           /

'INPUT TABLE','TMAXDT'/ *** Maximum time step control
1,2,,.FALSE.,/
'TIME','MAXSTEP'/
0.000,  0.100/
9.9E9,  0.100/

'TIME VAR.','MAXDTCTL'/
'TMAXDT','MAXSTEP'/
/9.9E9
           '*CONTROL','DTMAX'/
           /


'SURGETK'/ surge tank as a RESERVOIR
```

```

'SURGETK'           ,'L–SURGE1'/'SURGETK'           ,'L–SURGE1',  ,0.0,
    0.0/ *** Surge line connected to bottom of tank

'RESERVOIR B.C.','SURGTNK'/
'SURGETK'/
9.978E6,,309.0,0.0,'HG–BY–SAT','HF–BY–TEMP'/  Channel 177,
    Channel 70

'SURGETK','L–SURGE1'/
0.00000E+00/

'TIME VAR.','SRGPRESS'/
'SRGTPRES','SPRESS'/
/9.9E9
            'SURGTNK','PRESS',.FALSE./ SURGE TANK PRESSURE
                CONTROL
/
```