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JASMINE-PRO: A COMPUTER CODE FOR THE ANALYSIS OF PROPAGATION PROCESS IN STEAM EXPLOSIONS — USER'S MANUAL

December 2000

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A steam explosion is a phenomenon where a high temperature liquid gives its internal energy very rapidly to another low temperature volatile liquid, causing very strong pressure build up due to rapid vaporization of the latter. In the field of light water reactor safety research, steam explosions caused by the contact of molten core and coolant has been recognized as a potential threat which could cause failure of the pressure vessel or the containment vessel during a severe accident.

A numerical simulation code JASMINE was developed at Japan Atomic Energy Research Institute (JAERI) to evaluate the impact of steam explosions on the integrity of reactor boundaries. JASMINE code consists of two parts, JASMINE-pre and -pro, which handle the premixing and propagation phases in steam explosions, respectively.

JASMINE-pro code simulates the thermo-hydrodynamics in the propagation phase of a steam explosion on the basis of the multi-fluid model for multiphase flow.

This report, "User's Manual", gives the usage of JASMINE-pro code as well as the information on the code structures which should be useful for users to understand how the code works.

Keywords: Steam Explosion, Propagation, Numerical Simulation, JASMINE

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水蒸気爆発伝播過程解析コード JASMINE-pro
― ユーザーズ・マニュアル ―

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(2000年9月12日 受理)

蒸気爆発とは、高温液体が低温の揮発性液体にその内部エネルギーを与え、低温液が急速に蒸発して高圧を発生する現象である。軽水炉の安全研究の分野では、シビアアクシデント時に圧力容器や格納容器の健全性を損なう恐れのある現象のひとつとして、溶融炉心と冷却材の接触による蒸気爆発がとりあげられ、研究されてきた。

日本原子力研究所 (原研) では、このような蒸気爆発が原子炉のバウンダリに及ぼす影響を評価するため、蒸気爆発解析コード JASMINE を開発した。JASMINE コードは、蒸気爆発の「粗混合」および「伝播」過程を扱う JASMINE-pre および-pro の 2 つの部分から成るが、このうち JASMINE-pro は、蒸気爆発伝播過程における伝熱流動現象を混相流の多流体モデルに基づいて解析するものである。

本報告書は、JASMINE-pro コードの使用法および、ユーザーがコードの動作を理解する上で必要な情報を提供するユーザーズ・マニュアルである。

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1 Introduction

Steam explosion is a phenomenon that occurs due to the contact of a high-temperature melt material with a low-temperature liquid coolant. When the high-temperature melt is poured into a pool of the water or when the water is poured into a pool of melt, the water will be vaporized at a very high rate. The process produces a very strong pressure buildup in the system. In a certain condition, the vaporization can become very acute and form a propagating shock wave. This is called the steam explosion. The steam explosion is assumed to possibly occur under the severe accident condition such as the core damage accident in a nuclear reactor.

Thus, in the field of the nuclear safety, a lot of effort has been spent in order to study this phenomenon.

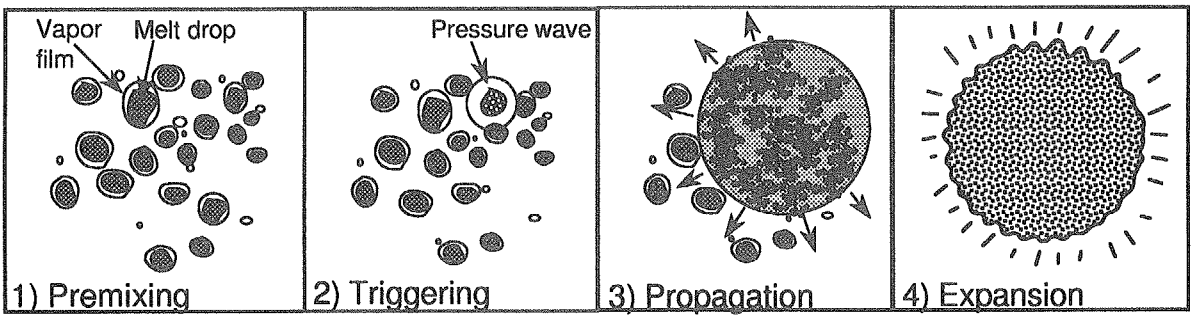

Figure 1.1: Four stages of steam explosions

The steam explosion is phenomenologically understood as four stages as shown in Figure 1.1. The phenomena involved in each stage can be described briefly as follows.

- Premixing: high temperature melt coarsely breaks up into droplets during thermally insulated from the liquid coolant with a vapor film; time scale 0.1 $\sim$ several seconds
- Triggering: distabilization of the vapor film and onset of rapid vaporization and fragmentation of the melt droplets
- Propagation: fine fragmentation of the melt droplets and rapid heat transfer associated with a propagating shock wave; time scale a few milliseconds
- Expansion: vaporization and expansion of the mixture potentially causing damages on the surroundings

To analyze and simulate the mechanism that is involved in the process, a thermal hydraulic code, JASMINE (JAeri Simulator for Multiphase INteraction and Explosion) was developed by JAERI (Japan Atomic Energy Research Institute) since 1995. JASMINE consists of two separate modules; JASMINE-pre and JAMSINE-pro, for the premixing stage and the propagation stage, respectively, of the steam explosion.

Since the time scales of these two major stages of the steam explosion, i.e. premixing and propagation, are quite different and that the different mechanisms are involved, two separate computer codes have been developed independently. In this manual, however, only the second, JAMSINE-pro, which was designed for the propagation stage is introduced.

JASMINE-pro code is, basically, a multi-component multi-field thermal hydraulic computer code. It was specifically designed to be used for the analysis of the phenomena in the propagation process in steam explosions. The numerical scheme used for the discretization of the governing equations is the finite difference method. The main part of the code is written in FORTRAN 90.

This manual provides the users the instruction and the reference information on using the JASMINE-pro code, as well as a brief description of the models employed in the code to describe the physical phenomena in question.

How to use this manual:

Readers who actually use the code should first read Chapter 4 to obtain information necessary to use it, and Chapter 5 which gives the detail to prepare the input files and interpret the outputs. Also, Chapter 6 provides the usage of the postprocess tool to extract the data for plotting.

Chapters 2–3 gives a brief description of the physical models and some cases of verification calculations.

In the appendix, some tables are attached to give the information about the source codes.

Version of the code:

This manual describes the code at the version 1.01. Most of the contents will be valid for version 1.xx. If any difference in the usage arises in the course of further development, the version-specific information will be given in electronic documents (README and HISTORY) attached to the source code.

2 Model Description

2.1 Fields of Fluids

In a typical premixing condition just before the triggering of the propagation phase of the steam explosion, the melt is coarsely broken up into particles whose sizes are in the range of millimeters. Those melt droplets are at a very high temperature so that they are wrapped by vapor film in a so called film boiling condition. At least 3 phases, or fields of fluid, i.e. water, vapor and melt droplets, are necessary to handle this premixing geometry.

After the triggering, the coarse droplets are fragmented into extremely fine particles with the diameter of 10 through 100 micro meters. These fine particles gives its heat to the coolant in the vicinity very quickly and causes rapid vaporization and pressure buildup. To model this phenomenon, two more phases were added: melt fragment and interaction-coolant. The interaction-coolant means a part of the coolant which resides close to the melt fragments, and receives heat from the fragments in a very short period – several milliseconds. In other words, the interaction coolant is a small part of the coolant which actually interacts with the melt fragments.

Therefore, `JASMINE-pro` code has 5 phases as listed below.

- water (outer-liquid)
- vapor (outer-vapor)
- melt droplets
- melt fragments
- interaction-coolant (inner-liquid/vapor)

In this multiphase framework, the term "phase" does not mean actual phase of a uniform material any more, but means a component of the system which has its own velocity and temperature. In this sense, "phase" can be called "component", "flow field" or "fluid field".

Each component has its own mass, energy and momentum equations. All interactions between components are included in the source terms of the associated equations.

In the following chapters, the "water" and "vapor" are sometimes referred to as "outer-liquid" and "outer-vapor", respectively, in the sense they are outside of the "interaction zone" where actual heat exchange is taking place between the coolant and fragments. In the same sense, the liquid and vapor, and properties relevant to the interaction-coolant are sometimes referred to as "inner-XXXX".

Table 2.1 summarizes the indices used in the equations in this manual and in the source code for each fluid components.

2.2 Basic Equations

The basic conservation equations for phase k are expressed as follows. Suffixes i and j are used to indicate the direction (coordinate). The suffix j is used specifically for the Einstein's suffix rule.

- Mass conservation

Table 2.1: Fluid Components in JASMINE-pro

Sign in Equation	Sign in Code	Default Index	Name	Description
l	pl	1	bulk liquid	coolant liquid
v	pg	2	bulk vapor	gas and vapor
m	pm	3	melt-droplet	melt droplets
f	pf	4	melt-fragment	fine melt particles produced by fragmentation
i	pi	5	interaction-coolant(I.C.)	coolant inside the interaction zone
ig	xx[ig]		I.C.-vapor	vapor inside the interaction coolant
il	xx[il]		I.C.-liquid	liquid inside the interaction coolant

$$\frac{\partial \alpha_k \rho_k}{\partial t} + \frac{\partial}{\partial x_j}(\alpha_k \rho_k v_{k,j}) = \sum_{k'} \Gamma_{k'k} \tag{2.1}$$

• Energy conservation

$$\frac{\partial \alpha_k \rho_k e_k}{\partial t} + \frac{\partial}{\partial x_j}(\alpha_k \rho_k e_k v_{k,j}) = \frac{\partial}{\partial x_j}(k_k \alpha_k \frac{\partial T_k}{\partial x_j}) \tag{2.2}$$

$$- \alpha_k p \frac{\partial v_{k,j}}{\partial x_j} - \alpha_k \rho_k g_j v_{k,j} + E_k \tag{2.3}$$

$$\tag{2.4}$$

where

$$E_k = \sum_{k'} f_{kk',eng}(e_{k'} - e_k) + \sum_{k'} \Gamma_{k' \to k} e_{k'}$$

• Momentum conservation for i direction

$$\frac{\partial \alpha_k \rho_k v_{k,i}}{\partial t} + \frac{\partial}{\partial x_j}(\alpha_k \rho_k v_{k,i} v_{k,j}) = \frac{\partial}{\partial x_j}(\mu_k \alpha_k \frac{\partial v_{k,i}}{\partial x_j}) \tag{2.5}$$

$$+ \frac{\partial \tau_{arti.vis}}{\partial x_j} - \alpha_k \frac{\partial p}{\partial x_i} - \alpha_k \rho_k g_i + F_k \tag{2.6}$$

$$\tag{2.7}$$

where

$$F_k = \sum_{k'} f_{kk',mom}(v_{k',i} - v_{k,i}) + \sum_{k'} \Gamma_{k' \to k} v_{k',i}$$

• Equation of state

$$\rho_k = f(p, T_k), \quad e_k = f(p, T_k) \tag{2.8}$$

and

• Constraint on the volume fractions

$$\sum_k \alpha_k = 1. \tag{2.9}$$

The basic conservation equations are discretized by the semi-implicit scheme, where the convection terms are treated explicitly.

The interactions between components are modeled by constitutive equations. Convection, radiation and transient heat transfer between components are considered for the heat transfer. Evaporation, condensation, melt fragmentation and the entrainment of the interaction-coolant from the water (outer-liquid) are considered for the mass exchange. The major constitutive equations and models are stated in the following section.

2.3 Constitutive Models

2.3.1 Momentum Exchange

The general form of the momentum exchange between any two components, k and k', is written as

$$F_{k'k} = f_{k'k,mom}(v_{k'} - v_k) \tag{2.10}$$

The drag force correlation for a particle moving in a continuum fluid is used to give the momentum transfer coefficient $f_{k'k,mom}$.

$$f_{k'k,mom} = \frac{1}{2} C_d \rho_{k'k} |v_k - v_{k'}| A_{k'k}, \tag{2.11}$$

where $A_{k'k}$ is the interfacial area between a pair of components k and k' per unit volume, and $\rho_{k'k}$ is the density of the continuum fluid in the pair. $A_{k'k}$ is obtained from an interpolation of areas in the assumption that both the components are in the shape of particles, as

$$A_{k'k} = \omega_k \alpha_k^{k'k} A_k + (1 - \omega_k) \alpha_{k'}^{kk'} A_{k'} \tag{2.12}$$

where $A_k = 3\alpha_k / 2d_k$ is the particle-based surface area, $\alpha_k^{k'k}$ represents the relative contact fraction given by

$$\alpha_k^{k'k} = \frac{\alpha_{k'}}{\sum_{q \neq k} \alpha_q}. \tag{2.13}$$

Here, component q includes all the components which contact with component k, and ω_k represents the relative flow pattern defined by

$$\omega_k^{k'k}(\alpha_\alpha, \alpha_\beta) = \frac{(\alpha_k^{k'k}, \alpha_\beta)_{max} - (\alpha_k^{k'k}, \alpha_\alpha)_{max}}{(\alpha_\beta - \alpha_\alpha)}. \tag{2.14}$$

In the same way, $\rho_{k'k}$ is obtained from

$$\rho_{k'k} = \omega_k \rho_{k'} + (1 - \omega_k) \rho_k. \tag{2.15}$$

2.3.2 Heat Transfer

The general form of the energy transfer interaction between any two components, k and k', is written by

$$E_{k'k} = f_{k'k,eng}(e_{k'} - e_k) \tag{2.16}$$

where the rate $f_{k'k,eng}$ is written in terms of heat transfer coefficient and temperature difference, as

$$f_{k'k,eng} = \frac{h_{k'k}(T_{k'} - T_k) A_{k'k}}{e_{k'} - e_k}. \tag{2.17}$$

Several channels of heat transfer have been taken into account, including heat conduction, convection, radiation, etc.

- Heat Conduction and Convection

The correlation for particles flowing within a continuum fluid is used for the heat transfer in the side of any coolant component,

$$h_{sk',k}^{cnvd} = \frac{\lambda_k}{d_{k'k}}(2 + 0.6Re_{k'k}^{0.5}Pr_k^{0.33}). \tag{2.18}$$

The first term on the right hand side represents the conduction effect and the second represents the convection effect. The characteristic size takes the same form as in Eq.2.15. It should be noted that, for the continuity of the correlations under all pressure conditions, i.e. sub- and super-critical, liquid and vapor are treated in the same way.

• Radiation

The radiation between the high-temperature melt components with the surrounding liquid is considered by

$$(h_{k'k}A_{k'k})^{rad} = \varepsilon_h\sigma\frac{T_h^4 - T_c^4}{T_h - T_c}A_{k'k}^{rad} \tag{2.19}$$

where the subscripts c and h represent the "cold" and "hot" components, respectively. Under the sub-critical pressure condition, the vapor is assumed to be transparent for the radiation. In the supercritical case, it is assumed the radiation heats all the coolant. A linear interpolation for the vapor is done in the range from 95% to 105% of the critical pressure. The surface area in the radiation correlation $A_{k'k}^{rad}$, is the area of two components facing each other.

• Rapid heat transfer from the fragments

Since the heat transfer between the fragments and the interaction-coolant is a very rapid transient, it is very difficult to be modeled. Therefore, a constant coefficient, h_{fi}, is given. The value 10^5 might be adequate considering the development of thermal boundary layer inside a fragment particle.

2.3.3 Mass Exchange

• Fragmentation model

The hydrodynamic fragmentation model used in CULDESAC code by Fletcher [1] is adopted.

$$\Gamma_{m\to f} = C_{frag}|v_m - v_i|\alpha_m\sqrt{\rho_m\rho_i}/d_m \tag{2.20}$$

The empirical constant C_{frag} takes a value of approximately 1.0.

• Entrainment rate of interaction-coolant

JASMINE-pro model considers the entrainment rate, from the outer-liquid to the interaction-coolant, in view of the local energy and real void fraction of the interaction-coolant. First, two limits for the entrainment rate can be obtained from the energy conservation and the intrinsic nature of the interaction-coolant.

Limit 1: The energy of the interaction-coolant should not decrease due to the entrainment of the outer-liquid. From the energy conservation of the interaction-coolant, the entrainment rate limit is

$$\Gamma_I < \frac{\sum_k Q_{\to i}}{e_i - e_l} = \Gamma_{i-max}. \tag{2.21}$$

Limit 2: The void fraction of the interaction-coolant should not reach 1.0 when the outer-liquid exists. This limit depends on the definition of the inner void. Using a relative factor, ϵ_i, to indicate the ratio of the possible supper-heated vapor energy, which can be reached in the interaction-coolant, to the saturated vapor enthalpy, the second limit for the entrainment rate can be obtained from the energy conservation equation

$$\Gamma_I > \frac{\sum_k Q_{k\to i}}{\epsilon_i e_{gs} - e_l} = \Gamma_{i-min}. \tag{2.22}$$

If $\epsilon_i = 1$ is used, this means the thermal equilibrium condition to give the inner void fraction. Thus $\epsilon_i > 1$ is necessary.

A combination of the two limits are adopted in the present JASMINE-pro model, which is defined by

$$\Gamma_i = \omega_i \Gamma_{i-max} + (1 - \omega_i)\Gamma_{i-min} \tag{2.23}$$

where ω_i is an empirical constants in the range of $0 \leq \omega_i \leq 1$.

• Evaporation and condensation

The evaporation and condensation are considered only under the sub-critical pressure condition. The heat deposition due to the difference in the heat fluxes at the liquid-vapor interface is taken to make phase change.

$$\Gamma_{lv} = \frac{\sum_k Q_{k \to l} - Q_{s \to l}}{h_{fg}} \tag{2.24}$$

Here, h_{fg} is the latent heat.

3 Verification Calculation

Verification on the fundamental abilities of JASMINE-pro code was performed with two basic benchmark problems, one-dimensional two-phase problems of shock tube and a nozzle flow. Those test problems were taken from the reference [2] to examine the code on the ability to handle phenomena with pressure propagation and phase change. In the specification of these problems, the interface exchange terms and the fluid properties are given so that the basic equation set and the numerical solution procedure in the code can be tested.

Another test calculation was done on one dimensional steam explosion, i.e. KROTOS experiments [3] performed in Italy. In this calculation, all the constitutive models related to the steam explosion were tested.

3.1 Shock Tube

The arrangement is shown schematically in Fig.3.1, which also gives geometrical and initial condition information. A straight closed duct of uniform cross-section is divided into two parts of identical volume by a diaphragm. The left hand side of the diaphragm is filled with compressed air, the other side is filled with atmospheric-pressure air mixed with finely divided water.

The equations of state for the two fluids are given as follows.

$$\begin{array}{lll} \text{Fluid 1 (air)} & & p = (\gamma - 1)\rho e \\ & \text{with} & \gamma = 1.4 \\ \text{Fluid 2 (water)} & & p = C_o^2(\rho - \rho_o) + (\gamma - 1)\rho e \\ & \text{with} & C_o^2 = 2 \times 10^6 \\ & & \gamma = 1.4 \;\; \rho_o = 1000 \text{ kg/m}^3 \end{array} \tag{3.1}$$

A simple quadratic interphase-friction law was used.

$$f_1 = -f_2 = C_f \rho_1 \alpha_1 \alpha_2 |u_1 - u_2| \tag{3.2}$$

Three values should be used for the constant C_f: (a) $C_f = 10^{20}$, giving negligible velocity separation; (b) $C_f = 3 \times 10^5$, giving some velocity separation (c) $C_f = 10^4$, giving a large velocity separation.

All calculation results show that JASMINE-pro can provide very good agreement with results obtained by other codes, such as PHOENICS, DLY and MINCS. The result for $C_f = 3 \times 10^5$ is shown in Fig.3.2.

3.2 Nozzle Flow

The objective of this problem is to check the ability to calculate pressure, volume fraction and velocity distribution under various steady-state conditions.

The arrangement is shown schematically in Fig.3.3. Two fluids flow through a convergent-divergent nozzle. The lighter one is a compressible gas; the second one, which is in much smaller

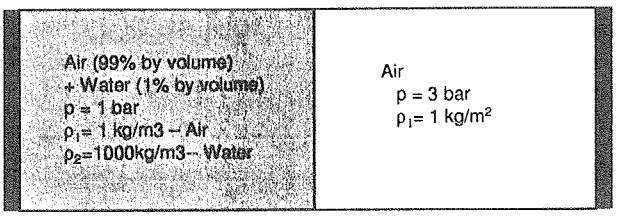

Figure 3.1: Initial and geometric conditions of shock tube problem

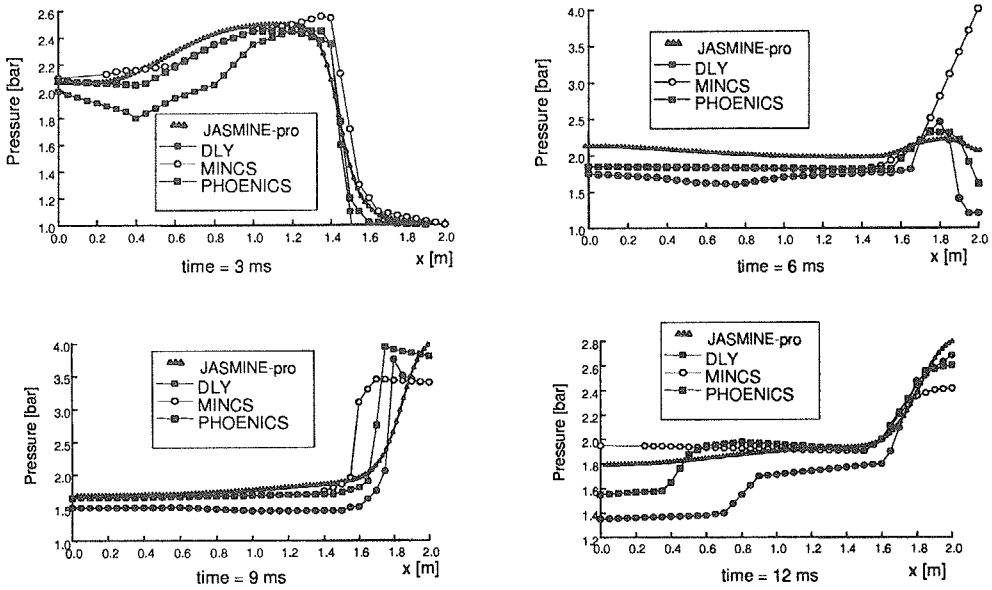

Figure 3.2: Calculation result for the shock tube problem ($C_f = 3 \times 10^5$)

volumetric concentration, is incompressible. The density ratio is such that the pressure gradients which accelerate the gas have less effect upon the motion of the heavier fluid; but the latter is nevertheless also accelerated by the drag exerted upon it by the gas.

The light phase density is given by

$$\rho_1 = p^{5/7}. \tag{3.3}$$

The heavier phase density has the following values. (a) for case 1,2,3,5,6,7,8: $\rho_2 = 10$; (b) for case 9: $\rho_2 = 1$; (c) for case 10: $\rho_2 = 100$; (d) for case 4 and 11: $\rho_2 = 1000$.

Inter-phase friction is supposed to obey the law,

$$f_{12} = C_f \rho_1 \alpha_2 \alpha_1 (u_2 - u_1), \tag{3.4}$$

where f_{12} is the force per unit volume of the space exerted by phase 2 on phase 1.

The results from all the calculations showed good agreements with the results by other codes. The result of case 4, where $\rho_2 = 1000$, $p_{exit} = 0.5$ and $C_f = 0$ is shown in Fig.3.4.

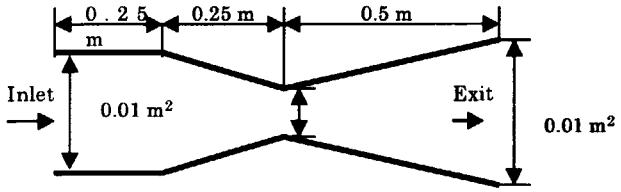

Figure 3.3: Geometric conditions of the nozzle flow problem

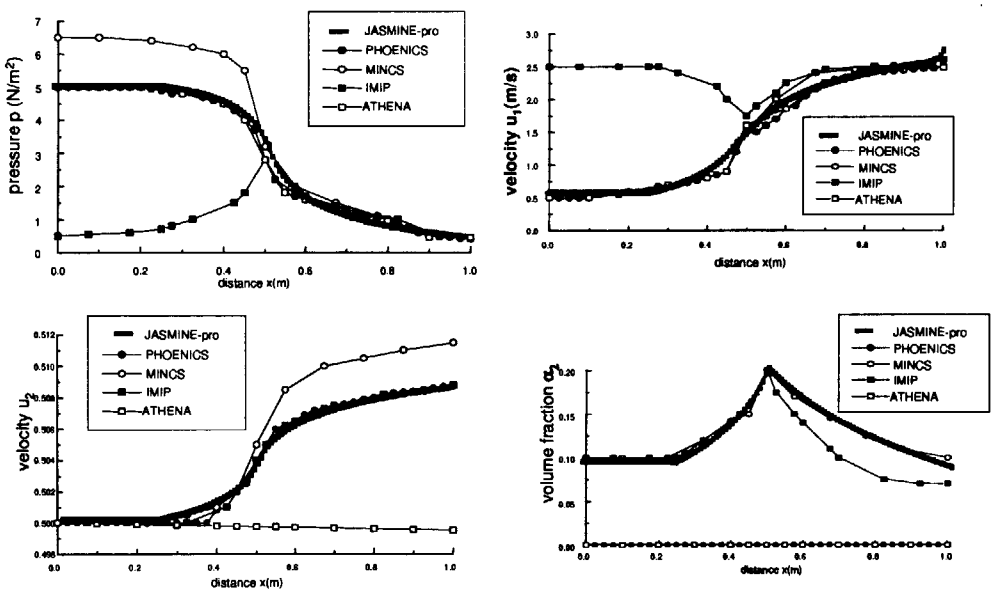

Figure 3.4: Calculation result for nozzle flow problem (Case 4: $C_f = 0$, $\rho_2 = 1000$, $p_{exit} = 0.5$)

3.3 One Dimensional Steam Explosion Calculation

One dimensional propagation calculations were performed based on the geometric conditions of KROTOS one dimensional steam explosion facility [3].

Three cases, an ideal condition, KROTOS-26 and KROTOS-28 initial conditions were used.

A vertical rigid steel tube of length 1.0 m and diameter 0.095 m is initially filled with water at a prescribed temperature under the atmospheric pressure. The water subcool is 40 K for the case KROTOS-26 and 10 K for KROTOS-28. An external "triggering" is given by compressed gas released at the bottom of the tube. The triggering gas chamber initially contains 15 cm^3 of compressed gas at 65 bar.

The ideal case was set up to do a sensitivity study on the initial conditions and constitutive parameters. For the simulations of experiments KROTOS-26 and 28, the initial conditions were set referring the results of the premixing calculations by PM-ALPHA code presented in the paper [4]. The major parameters used in the calculations are listed in Table 3.1.

The calculation results strongly depended on the assumptions for the heat transfer coefficient between fragments and interaction-coolant, i.e. h_{fi}, and the entrainment rate, Γ_i. Fig.3.5 and 3.6 shows the pressure developments in the two calculation results for KROTOS-26 and KROTOS-28, respectively, at the locations of six pressure transducers, K0 – K5, which are

Table 3.1: Parameters used in the propagation calculations

Parameter	Value	Unit
time step	5×10^{-6}	s
space step	0.04	m
initial pressure	1	bar
initial subcooling	40 in KROTOS-26	K
	10 in KROTOS-28	
initial void fraction	0.001 in KROTOS-26	
	0.05 – 0.2 in KROTOS-28	
initial melt fraction	0.0 – 0.2 in KROTOS-26	
	0.03 – 0.05 in KROTOS-28	
trigger pressure	85	bar
trigger volume	3	cm^3
initial melt temper.	2573 in KROTOS-26	K
	2673 in KROTOS-28	
initial size of melt drops	6	m
initial size of fragments	0.5	mm
surface absorbency of radiation by coolant	0.6	%
coefficient of h_{fi}	10^5	W/m^2K

arranged along the tube from bottom to a location near the water surface with intervals about 200 mm. $h_{fi} = 10^5$ is used in the calculations. In the figures, results by JASMINE-pro is compared with the experimental results and also another calculation results by ESPROSE.m code (Yuen et al. [4]). These two calculations agreed well with the experimental results in the shock propagation velocity. However, the values of the pressure in the supercritical regime were overestimated.

Since the results were obtained by adjusting the constant in the entrainment rate correlation, we still need improvements to give an adequate value based on a certain mechanistic reason.

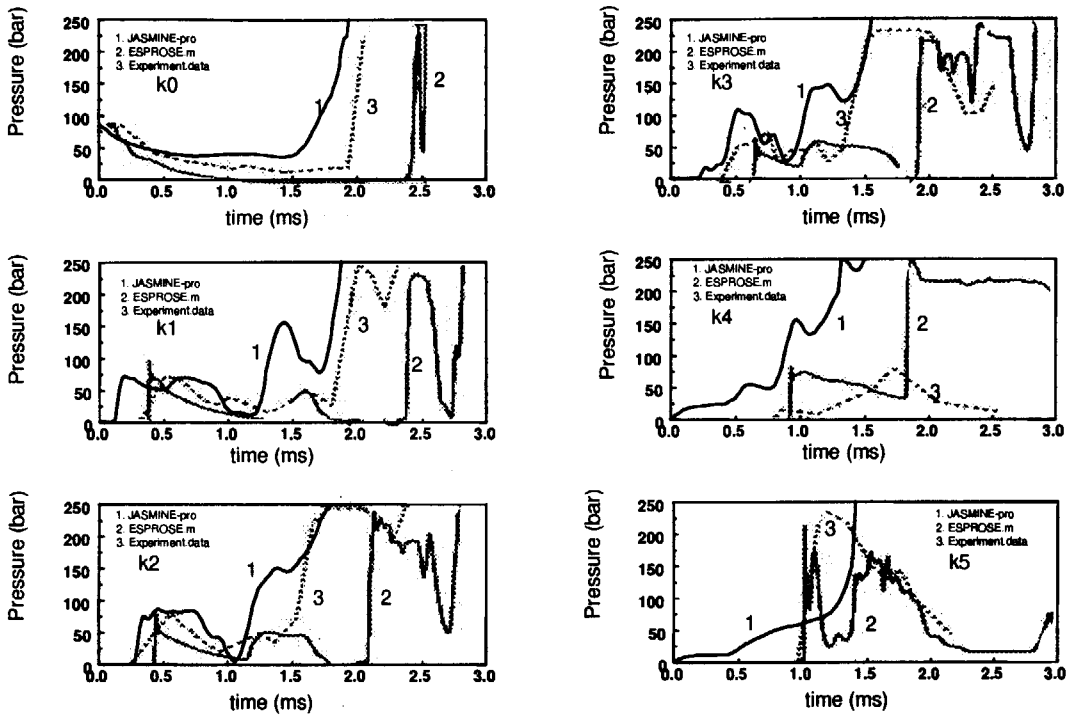

Figure 3.5: Calculation result for KROTOS-26

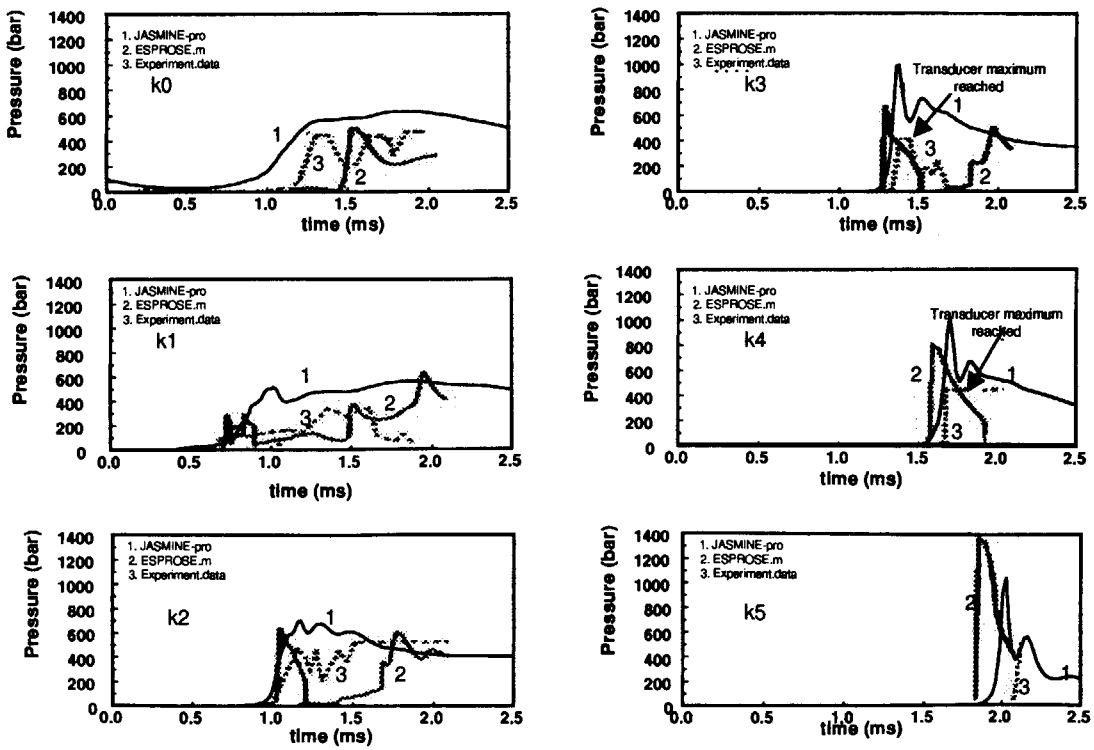

Figure 3.6: Calculation result for KROTOS-28

4 Quick Usage

This chapter provides how to install and compile the JASMINE-pro code on a UNIX-like environment, and perform a calculation and post processing. Detail information about the setup of input files for JASMINE-pro and the post processor script will be given in the following chapters.

4.1 Installation and Directory Setup

A specific version of JASMINE-pro distribution package is provided as a compressed archive file (*.tar.gz format) which includes source files, scripts, manual documents and a sample of calculation directory.

```
jsmpro-1.xx.tgz     (version 1.xx archive)
```

After extracting the archive file, a directory for jsmpro and some subdirectories are created. (Figure 4.1)

```
 jsmpro-1.xx --+-- README    : document to be read first
 -----------   |
Top directory  +-- HISTORY   : document on the development history
              |
              +-- bin       : execution binary and scripts
              |
              +-- calc-skel : sample calculation directory
              |
            (  +-- calc      : an example calculation directory )
            (  |               to be made by users              )
               |
               +-- doc       : manual document
               |
               +-- source    : source files
```

Figure 4.1: A directory tree created after extracting the distribution archive of JASMINE-pro

The name of the top directory of this tree jsmpro-1.xx can be changed in any manner. This directory is called "JASMINE-pro top directory".

Compilation of the load module for JASMINE-pro and related tools can be done by doing

```
make
make graph
```

in the source directory. Detail instructions for the specific version are given in the README document.

Users are supposed to make a copy of the sample calculation directory calc-skel. Any name can be put to the actual calculation directory. However the position should be kept at the level just below the JASMINE-pro top directory (same as calc-skel), in order to make use of the scripts under bin directory. An example is given in Fig. 4.1 as calc. Execution of JASMINE-pro code and the postprocess tools are supposed to be done in the calculation directory.

After running a calculation by JASMINE-pro and doing the postprocess (extraction of data for plots), more directories will be created under the calculation directory as listed in Table 4.1.

Table 4.1: The directories created under the calculation directory after running JASMINE-pro and postprocess tools

Directory	Description
calc	The calculation directory
JSMPRO.PLOT	Sub-directory for the extracted data for plotting
data	Sub-directory for the temporary files
data_x1	Sub-directory for the temporary files
data_x2	Sub-directory for the temporary files
data_node	Sub-directory for the extracted data, arranged by nodes
data_2dx1	Sub-directory for the extracted data, arranged along x-axis
data_2dx2	Sub-directory for the extracted data, arranged along y-axis
data_3d	Sub-directory for the extracted data, arranged in two dimensions

4.2 Managing Many Runs

It is totally up to users to manage the calculation data etc., but it might be smart to keep the input files and results for one calculation case in one directory, not to make confusion between cases. This is easily done by the following procedure.

1. create a calculation directory: e.g. "calc.1"
2. prepare (create or copy) an input file in the calculation directory
3. run the calculation
4. run the postprocess
5. move the calculation directory to somewhere else, and create another calculation directory for the next case: e.g. "calc.2" ...

4.3 Performing Calculation

The below is an example command line to run a calculation with the sample input.

```
./JSMPRO JSMPRO.SAMPLE.input JSMPRO.SAMPLE.output JSMPRO.SAMPLE.conf
```

JASMINE-pro needs two input files to run a calculation. The most essential is the one that describes the system to be calculated (called "input" file). The other one is used to monitor the calculation process ("second input" or "configuration" file). In most cases, the file JSMPRO.conf supplied with JASMINE-pro works fine with the calculation. Therefore, this second file is not essential to the calculation and may be omitted.

The detailed information regarding both input files are postponed to the following chapter and the procedure how to perform the calculation is to be described.

In performing the calculation, a script called JSMPRO is to be used. The user can call JSMPRO with up to 3 arguments as in the example above. An explanation on these arguments is given in the followings.

- 1st argument
  This is the name of the input file that describes the system to be calculated. If the user want to let JSMPRO use the default input file JSMPRO.input, a wild card character * can be used instead. However, due to the way UNIX parses the character, an * cannot be entered directly. To get around this problem, * or '*' must be used.
- 2nd argument
  This is the base name which is put to the output files. If a wild card is used, the base name of the output files is the same as the input file name given by the first argument, and a suffix .output is attached.
- 3rd argument
  This is the name of the file that gives the configuration used to monitor the calculation. If a wild card is used or if it is omitted, the default JSMPRO.conf is then applied.

It should be noted that JSMPRO always replaces the default input files with the given input files. As a result, if one calculation of JSMPRO is done with the specific input files and then another calculation is immediately performed with the default arguments, the second calculation is actually done with the input files that have exactly the same contents as the first one.

In other words, according to the way the binary part of JASMINE-pro works, only the filenames JSMPRO.input, JSMPRO.output and JSMPRO.conf are read or created by the execution binary. Therefore, JSMPRO script copies the given input files onto those names before the calculation, and rename the output file to the given output file name after the calculation.

4.4 The Results

The calculation of JASMINE-pro results in five different output files. Assuming that XXXX is the base name for the output files, these outputs are

- XXXX
  This is the diagnostic file. It contains the initial data of the system and the monitoring parameters.
- XXXX.list
  This is the main output file. All the data for further analysis are to be extracted from this file.
- XXXX.mess
  This is the message file. Together with the diagnostic file, they can be used to trace the problem during the calculation.
- XXXX.recd
  This is the output for extra information. Currently it contains the history profiles of the total kinetic energy and the upward momentum of the coolant.
- XXXX.rest
  This is the data for restarting the calculation. Since JASMINE-pro dumps its internal data to a file at a regular interval, it is possible to restart a calculation at a specific time step.

4.5 Postprocess to Extract the Data for Plots

In order to extract the data, a shell script called `JSMPROplot` is to be used. To run this script, another input file is required. The name of the input for `JSMPROplot` should have a name `XXXX.dat` where `XXXX` is the base name of the `JASMINE-pro` output files. The detail about the input preparation and the output files are given in Chapter 6.

The below is an example command line to run the postprocess tools for the "SAMPLE" case.

```
./JSMPROplot JSMPRO.SAMPLE.output
```

In this example, an input file `JSMPRO.SAMPLE.output.dat` is required.

Users can extract the data in a different fashion up to their preference.

4.6 Restarting the Calculation

The procedure for restarting the calculation is exactly the same as that of a normal calculation. The extra process is to copy the restart file generated from the previous calculation to a file named `jsm.rin`. `JASMINE-pro` reads it for the initial condition to continue the calculation. The user also will have to change some parameters in the initial data file so that `JASMINE-pro` can restart the calculation at the specific time step instead of from the beginning. The input file must contain the following information:

- In "Initial" block, the parameter "Type" must be set to "restart", i.e.,

  ```
  Type = Restart
  ```

- In "Time" block, the point at which the calculation is to be restarted must be specified. This is done by setting "Restart-Step" to the number according to the desired point at which the restart is to be executed. For example, if the calculation is to be restarted at the second restarting point, the following setting must be used;

  ```
  Restart-Step = 2
  ```

  The number of the available restarting points and the time at each point are specified in the original input file by the parameter "step" and "dtime" in "Restart-File" block. If you cannot find the original input, try setting "Restart-Step" to a very large number. Once the number exceeds the available restarting points, the code will not run but will give you the number of the available starting points.

While it is possible to specify the name of the restart file directly in the input file, the usage of such options is not clearly defined. If you choose to directly specify the restart file, the parameter "file" in "Restart-File" may be set.

4.7 Example Command Lines

Some examples for the usage of JSMPRO are given in the followings.

```
#  JSMPRO
#    The above command runs JSMPRO with all the default files.  That is
#    JSMPRO will run with "JSMPRO.input" as its input, "JSMPRO.input.output"
#    as its output and with "JSMPRO.conf" as its configuration file.
```

```
#
#  JSMPRO JSMPRO.SAMPLE.input
#    The above command runs JSMPRO with "JSMPRO.SAMPLE.input" as its input
#    file.  However, the default files are used for the output and the
#    configuration files.  Therefore, the output is written to
#    "JSMPRO.SAMPLE.input.output" with "JSMPRO.conf" as it configuration
#    file.
#
#  JSMPRO JSMPRO.SAMPLE.input JSMPRO.SAMPLE.output
#    The above command runs JSMPRO with "JSMPRO.SAMPLE.input" as its input
#    and "JSMPRO.SAMPLE.output" as its output.  The default configuration
#    file "JSMPRO.conf" is also used.
#
#  JSMPRO \* JSMPRO.output
#    This command runs JSMPRO with the default input file "JSMPRO.input"
#    but "JSMPRO.output" is used for its output.  The default
#    configuration file "JSMPRO.conf" is also used.
#
#  JSMPRO \* JSMPRO.output JSMPRO.SAMPLE.conf
#    This command runs JSMPRO with the default input file "JSMPRO.input"
#    but "JSMPRO.output" and "JSMPRO.SAMPLE.conf" are used for its output
#    and its configuration files.
#
#  JSMPRO \* \* JSMPRO.SAMPLE.conf
#    This command runs JSMPRO with "JSMPRO.input" and "JSMPRO.input.output"
#    as its input and output files.  However, "JSMPRO.SAMPLE.conf" is
#    used as the configuration file.
#
#  JSMPRO \* \* \*
#    This command is simply the same as issuing JSMPRO alone.
```

4.8 Notes on Properties and Usage of JASMINE-pro

The main features of JASMINE-pro code and the information on the numerical solution scheme which is considered important for the users are summarized in this section.

- **Programming languages for source codes**
  The source codes for the calculation were written in FORTRAN 90. For post processing of the output data, computer codes were written in C. The scripts for operating a calculation and for controlling the data processing were written in Perl and in Unix shell script. The graphical presentation of the obtained results can be performed on any kind of computer with softwares for data plotting that is preferred by the user.
- **Spatial dimension and geometry**
  JAMSINE-pro was initially designed as a three-dimensional code. However, presently only one and two-dimensional models have been successfully developed. The geometry of the system can be modeled rectangularly in the Cartesian coordinate or as a cylinder in the cylindrical coordinate. The size of the cells are presumed to be uniform. However, a certain deformation can be specified with the parameters "x-ratio" and/or "y-ratio". By default, the x-axis lies in the direction of the major flow in which the point of origin is set at the top.

The y-axis is in the radial direction for the cylindrical coordinate or in the direction normal to the x-axis in the Cartesian coordinate. For the system in one-dimension, only the x-axis is presumed and used. Even though a user may always defines the alternate axes for x and y, they are modified during the pre-processing by the code such that their arrangement may conform to the condition as preferred by the code.

- **Material components and fields**

  JASMINE-pro uses a five component model. These components are the water, the vapor, the melt-droplets, the (melt-)fragments and the interaction-coolant. The fragments are the particles produced by the fragmentation of the melt-droplets. For the interaction-coolant, it is a mixture of the water and the vapor that thermally interact with the fragments. Optionally, the stage of thermal non-equilibrium can be assumed for the liquid and the vapor inside the interaction-coolant. The melt components are assumed to be particle-like while the coolant water and vapor can be treated as the particles or as the continuous fluid according to their volume fractions. The number of the components can be increased. Additional constitutive correlations for the new components must be added in the code if new components are introduced.

- **Iteration schemes**

  The schemes for the overall iteration and for the treatment of the source and the convection terms in the governing equations can be optionally selected in the input file. The options include the explicit, the semi-implicit and the implicit scheme for the calculation. However, since the explicit scheme does not always converge, it is recommended that the other two options are used. A typical selection which had yielded the satisfactory results is to use the explicit-source terms together with the semi-implicit convection terms for the calculation.

- **Relaxation factors**

  All major variables have their own relaxation factors. In general, low values are recommended in order to obtain a stability. Usually, the factors for the pressure-correction (ω_p) and for the mass-conservation terms in the pressure-correction equation (ω_b), as well as that for the density (ω_d) are recommended to be set less than 0.1.

- **Iteration times and accuracy**

  There are several selections that can be used to adjust the converging rate and the accuracy of the results. One is the criteria for the convergence of the total pressure-correction (less than a given value). One is for the convergence of the mass term in the pressure-correction equation. Another is to check the convergence of both parameters. However, these criteria are overridden by the maximum number of iterations. Even if the convergence of the calculation is not enough within a given number of the iterations, the calculation is forced to be finished and proceeded to the next time step. This treatment prevents too frequent fail of calculation caused by numerical instability.

5 Input/Output Files

As described in the previous chapter, JASMINE-pro requires two kinds of input files and creates several output files. In this chapter, the detail of the input file (section 5.1), output files and the variable names written in them (section 5.2), option keys and debug options which should be defined in the configuration file (section 5.3) are given.

5.1 Input File

Currently, two input files are needed for the calculation, one containing the data for the calculation itself and the other containing the configurations for monitoring the calculation. In this section, the first input file, the format of the data to describe the calculation conditions are given.

The input file consists of "blocks", a set of data to be used for a specific purpose. Table 5.1 through 5.18 are the descriptions of each input block and the variables to be given in it.

Table 5.1: BOUNDARY block (in ibndcd.f)

Meaning: Boundary condition.

No	Variable Name	Selection	Var. in code	Description	Value
1	area		ioubc2(noutbc,1)	Boundary area name	
2	dens-l-value		roubc2(noutbc,3)	Liquid density (kg/m^3)	
3	heat-flux		roubc2(noutbc,1)	Heat-flux from wall	
4	heat-ht		roubc2(noutbc,1)	Heat transfer coefficient at wall	
5	p-table		ioubc2(noutbc,4)	Index of pressure in table (N/m^2)	
6	p-value		roubc2(noutbc,2)	Pressure (N/m^2)	
7	t-g-table		ioubc1(noutbc,pg,4)	Index of temperature of vapor in table (K)	
8	t-g-value		roubc1(noutbc,pg,4)	Temperature of vapor (K)	
9	t-l-table		ioubc1(noutbc,pl,4)	Index of temperature of liquid in table (K)	
10	t-l-value		roubc1(noutbc,pl,4)	Temperature of liquid (K)	
11	t-m-table		ioubc1(noutbc,pm,4)	Index of temperature of melt-droplets in table (K)	
12	t-m-value		roubc1(noutbc,pm,4)	Temperature of melt-droplets (K)	

Table 5.1: BOUNDARY block (in ibndcd.f) (continued)

No	Variable Name	Selection	Var. in code	Description	Value
13	total-m-mass		totmms	Total melt mass in pool (pouring-inlet condition only) (kg)	
14	type		ioubc2(noutbc,2)	Option of the boundary type:	
15		free-outlet		Free outlet condition	0
		pres-fixed-outlet		Fixed outlet pressure	1
		wall-pres		Pressure condition on wall	2
		wall		Wall condition	3
		velo-fixed-inlet		Constant inlet velocity	4
		pouring-inlet		Inlet for melt poured to pool	5
16	u-g-table		ioubc1(noutbc,pg,1)	X-velocity of vapor index	
17	u-g-value		roubc1(noutbc,pg,1)	X-velocity of vapor (m/s)	
18	u-l-table		ioubc1(noutbc,pl,1)	X-velocity of liquid index	
19	u-l-value		roubc1(noutbc,pl,1)	X-velocity of liquid (m/s)	
20	u-m-table		ioubc1(noutbc,pm,1)	X-velocity of melt-droplets index	
21	u-m-value		roubc1(noutbc,pm,1)	X-velocity of melt-droplets (m/s)	
22	v-g-table		ioubc1(noutbc,pg,2)	Y-velocity of vapor index	
23	v-g-value		roubc1(noutbc,pg,2)	Y-velocity of vapor (m/s)	
24	v-l-table		ioubc1(noutbc,pl,2)	Y-velocity of liquid index	
25	v-l-value		roubc1(noutbc,pl,2)	Y-velocity of liquid (m/s)	
26	v-m-table		ioubc1(noutbc,pm,2)	Y-velocity of melt-droplets index	
27	v-m-value		roubc1(noutbc,pm,2)	Y-velocity of melt droplets (m/s)	
28	vol-g-table		ioubc1(noutbc,pg,5)	Volume fraction of vapor index	
29	vol-g-value		roubc1(noutbc,pg,5)	Volume fraction of vapor	
30	vol-l-table		ioubc1(noutbc,pl,5)	Volume fraction of liquid index	
31	vol-l-value		roubc1(noutbc,pl,5)	Volume fraction of liquid	
32	w-g-table		ioubc1(noutbc,pg,3)	Z-velocity of vapor index	
33	w-g-value		roubc1(noutbc,pg,3)	Z-velocity of vapor (m/s)	
34	w-l-table		ioubc1(noutbc,pl,3)	Z-velocity of liquid index	
35	w-l-value		roubc1(noutbc,pl,3)	Z-velocity of liquid (m/s)	
36	w-m-table		ioubc1(noutbc,pm,3)	Z-velocity of melt-droplets index	
37	w-m-value		roubc1(noutbc,pm,3)	Z-velocity of melt droplets (m/s)	
38	wall-heat		ioubc2(noutbc,3)	Heat conditions at wall boundary:	
39		adiabatic		Adiabatic wall	0
		flux		Known heat flux	1
		heat-transfer		Known heat transfer coeff.	2
		temperature		Known temperature	3

Table 5.2: BOUNDARY-AREA block (in ibndar.f)

Meaning: Boundary area name, location.

No	Variable Name	Selection	Var. in code	Description	Value
1	direction		ibarea(nbarea,1)	Direction of the boundary surface	
2	i-end		ibarea(nbarea,4)	End grid number in i-axis	
3	i-start		ibarea(nbarea,1)	Start grid number in i-axis	
4	j-end		ibarea(nbarea,5)	End grid number in j-axis	
5	j-start		ibarea(nbarea,2)	Start grid number in j-axis	
6	k-end		ibarea(nbarea,6)	End grid number in k-axis	
7	k-start		ibarea(nbarea,3)	Start grid number in k-axis	
8	name		cbarea(nbarea)	Boundary area name	

Table 5.3: CONSTITUTIVE block (in icnseq.f)

Meaning: Options and coefficient values for constitutive relationships.

No	Variable Name	Selection	Var. in code	Description	value
1	cd		cdrg	Drag coefficient	
2	cd-wall		cd_wall	Friction coefficient at wall	
3	ch		cheat	Heat transfer coefficient	
4	ch-gs		ch(pg,pl)	Heat transfer coefficient at gl surface ,g side under subcritical pressure	
5	ch-lli		ch(pl,pl)	Heat transfer coefficient at $il-l$ surface	
6	ch-ls		ch(pl,pg)	Heat transfer coefficient at lg surface, l side under subcritical pressure	
7	ctrs-rad		epstrs	Transparent ratio of the liquid for the radiative heat	
8	f-rad		crad	Radiative heat fraction absorbed by liquid surface	
9	type-drag		keydrg	Option for drag calculation:	
10		no-drag		No drag calculation	0
		drag		Perform drag calculation	1

Table 5.3: CONSTITUTIVE block (in icnseq.f) (continued)

No	Variable Name	Selection	Var. in code	Description	value
11	type-heat		keyhtc	Option for heat transfer calculation:	
12		no-heat		No heat calculation	0
		heat		Perform heat calculation	1
		no-melt-heat		No calculation for melt	2
		no-meli-heat		No calculation for melt, interaction-coolant	3

Table 5.4: COORDINATE block (in icord.f)

Meaning: System coordinate and components included.

No	Variable Name	Selection	Var. in code	Description	value
1	dimension		gravx	Dimension index list	
2		x		1D in x direction	1
		y		1D in y direction	
		z		[explain]	
		xy		2D in xy surface	
		xz		[to be defined]	
		yz		[to be defined]	
		yx		[to be defined]	
		zx		[to be defined]	
		zy		[to be defined]	
		xyz		[to be defined]	3
		xzy		[to be defined]	
		yxz		[to be defined]	
		yzx		[to be defined]	
		zxy		[to be defined]	
		zyx		[to be defined]	
3	gx		gravx	Gravity in x-axis	
4	gy		gravy	Gravity in y-axis	
5	gz		gravz	[to be defined]	
6	phase		s	Component name index list	
7		lgmfi		Component name index	
		lgm		[to be defined]	
		lg		[to be defined]	
		l		[to be defined]	
		g		[to be defined]	
8	type		icylnd	Option for coordinate type:	
9		cartesian		Cartesian coordinate	0
		cylindric		Cylindrical coordinate	1

Table 5.5: DEBUG block (in idebg.f)

Meaning: Routine debug setting.

No	Variable Name	Selection	Var. in code	Description	value
1	dstep		idstep	Time step for debug print	
2	flag		iflag	Flag for specified subroutine	
3	ip-flag		ipflag	Flag for specified phase	
4	iteration		iditer(nditer)	Iter. step for debug print	
5	k-flag		kiflag	Flag for specified debug level	
6	node-flag		infrag	Specified node number for debug	
7	step		idtime(ndtime)	Time step for debug print	
8	time		s	Time list for debug print (s)	

Table 5.6: FRAGMENTATION block (in ifrgmt.f)

Meaning: Options and coefficient values for fragmentation and interaction-coolant models.

No	Variable Name	Selection	Var. in code	Description	value
1	c-frag		cfrag	Fragmentation rate coefficient	
2	c-inte		cinte	Interaction-coolant entrainment rate coefficient	
3	delta-il		delta_il	Heat transfer thickness for outer-coolant and inner-coolant (m)	
4	frag-model		model_frag	Option of the fragmentation models:	
5		carachalios		Carahalios model [5, 1]	0
		esprose		ESPROSE model [6]	1
		mc3d		MC3D model [7]	2
6	inter-model		model_inte	Interaction coolant model	
7		jsmpro		JASMINE-pro model	0
		esprose		ESPROSE model [4]	1
		user-defined		User-defined model	2
8	tau-1		tau_1	Transient heat transfer time constant at fragments surface	
9	tau-2		tau_2	Transient heat transfer time constant at micro iteration-coolant zone surface	
10	type-frag		keyfrg	Option if fragmentation calculation is to be performed:	
11		frag		Fragmentation calculated	1
		no-frag		No fragmentation	0

Table 5.6: FRAGMENTATION block (in ifrgmt.f) (continued)

Meaning: Options and coefficient values for fragmentation and interaction-coolant models.

No	Variable Name	Selection	Var. in code	Description	value
12	type-inte		keyint	Option of interaction calculation method:	
13		homogeneous model		Homogeneous model	1
				JASMINE-pro's model	0
		equation		Ind. inner phase equation	2
14	type-tf		keytf	Option of the fragment energy calculation method:	
15		non-equilibrium		Non-equilibrium model	0
		equilibrium		Equilibrium model	1
16	vr-max		vrmax	Maximum velocity difference in fragmentation model	
17	vr-min		vrmin	Minimum velocity difference in fragmentation model	

Table 5.7: FUEL-PROPERTY block (in ifuel.f)

Meaning: Fuel material selection.

No	Variable Name	Selection	Var. in code	Description	value
1	conduct-f		rcondf1(kidnpf)	Conductivity of fragments	
2	conduct-m		rcondm1(kidnpm)	Conductivity of melt droplets	
3	cv-f		rcvf1(kidnpf)	Special heat capability of fragment	
4	cv-m		rcvm1(kidnpm)	Special heat capability melt droplets	
5	kind		rrhom1(kindpm)	Option of melt species kind:	
6		alumina		Alumina melt	1
		alumina-mixture		Alumina mixture	3
		corium		Corium melt	2
		corium-mixture		Corium mixture	
7	rho-f		rrhof1(kidnpf)	Density of fragments	
8	rho-m		rrhom1(kindpm)	Density of melt-droplet	
9	type		ipropm	Option of the melt property definition form:	
10		constant		Constant	0
		function		Calculated by function	1
11	visc-f		rviscf1(kidnpf)	Viscosity of fragments	
12	visc-m		rviscm1(kidnpm)	Viscosity of melt-droplet	

Table 5.8: HISTORY-FILE block (in ihist.f)

Meaning: Requirements for history file output.

No	Variable Name	Selection	Var. in code	Description	value
1	ascii-file		hafile	Output ascii file name	
2	binary-file		hbfile	Output binary-file name	
3	i		s	Output cell i number	
4	j		ihcell(nhcell,2)	Output cell j number	
5	k		ihcell(nhcell,3)	Output cell k number	
6	phs-value		ihphys(nhphys)	Output physical name list	
7	step-end		ihend	Time step for record end	
8	step-interval		ihint	Time step interval	
9	step-start		ihstrt	Time step for record start	
10	time-end		rhend	Time for record is end	
11	time-interval		rhint	Time interval	
12	time-start		rhstrt	Time for record start	
13	type		lhouta	Output file data :	
14		ascii		Ascii	1
		binary		Binary	0
		both		Both	1

Table 5.9: INITIAL block (in iintl.f)

Meaning: Initial distribution (invalidated in restart calculation).

No	Variable Name	Selection	Var. in code	Description	value
1	area		minit(ninit)	Initial area name	
2	base-coord		ipoten	Base line for calculating gravity potential head	
3	file		rifile	Input restart file name	
4	main-region		mmain	Set a main-region for initial condition as same as the trigger region	NINIT
5	p		pres0(ninit)	Initial pressure (N/m^2)	
6	potential		lpoten	Potential based node	
7		yes		Is the case	1
		no		Not the case	0
8	pressure-trigger		itrg(ninit)	Trigger region	
9		yes		Is the case	1
		no		Not the case	0
10	type		keyrst	Option of calculation start form:	
11		constant		From beginning	0
		restart		Restart from JASMINE-pro	1
		function		User defined	
		res-mixing		Restart JASMINE-pre	2

Table 5.10: INNER-AREA block (in iinar.f)

Meaning: Area division for initial distribution in inner region.

No	Variable Name	Selection	Var. in code	Description	value
1	i-end		iiarea(niarea,4)	End grid number in i-axis	
2	i-start		iiarea(niarea,1)	Start grid number in i-axis	
3	j-end		iiarea(niarea,5)	End grid number in j-axis	
4	j-start		iiarea(niarea,2)	Start grid number in j-axis	
5	k-end		iiarea(niarea,6)	End grid number in k-axis	
6	k-start		iiarea(niarea,3)	Start grid number in k-axis	
7	name		s	Inner area name	

Table 5.11: ITERATION block (in iiter.f)

Meaning: Iteration relaxation and scheme selection.

No	Variable Name	Selection	Var. in code	Description	value
1	allowance		epsalw	Maximum allowable error factor for convergence check	
2	artificial-viscosity		epsvis	Artificial viscosity coefficient	
3	converge		itromi	Option for convergence judgement.	
4		max-bmass		Max. mass error (pressure eq.)	0
		total-bmass		Tot sum of mass error	1
		pressure		Max. value (pressure eq.)	2
		all		All	4
		max-or-pressure		Mass error and pressure	
5	dpplus		dpplus	Estimated value of pressure increase fraction every time step	
6	ener-difference		keydif_e	Option for energy equation difference scheme.	
7		non-conservative		Non-conservative	1
		conservative		Conservative	0
8	ener-iteration		kenitr	Option for the iteration scheme of energy equation solution:	
9		explicit		Explicit	0
		implicit		Implicit	2
		semi-implicit		Semi-implicit	1
10	epsilon-nw-p		epsnwp	Allowable pressure cosrrection error when convergence	
11	epsilon-nw-s		epsnws	Allowable maximum mass error in pressure equation when convergence	
12	epsilon-nw-t		epsnwt	Allowable total mass error in pressure equation when convergence	
13	epsilon-sor		epssor	Allowable relative error in solving matrix equation	
14	equation-solve		keysor	Option for solving linear matrix equation.	
15		sor		SOR method	1
		tdma		TDMA method	0

Table 5.11: ITERATION block (in iiter.f) (continued)

No	Variable Name	Selection	Var. in code	Description	value
16	fraction-calc		keyvol	Option for applying the volume fraction unity equation.	
17		pg-main		Vapor phase only	0
		largest-main		Phase with largest vol.fraction	1
		average		All	2
		average-but-hot		All but hot one	3
18	iteration-form		keyitr	Option for the iteration scheme of momentum equation:	
19		explicit		Explicit	0
		semi-implicit		Semi-implicit	1
		implicit		Implicit	2
20	mass-iteration		kmsitr	Option for the iteration scheme of mass equation solution.	
21		explicit		Explicit	0
		implicit		Implicit	2
		semi-implicit		Semi-implicit	1
22	max-inner-iter		itrimx	Maximum inner iteration times	
23	max-outer-iter		itromx	Maximum outlet iteration times	
24	min-outer-iter		itromi	Minimum outlet iteration times	
25	mom-difference		keydif_x	Option for momentum difference scheme.	
26		non-conservative		Non-conservative	1
		conservative		Conservative	0
27	omega-all		omega0	Default relaxation value	
28	omega-e		omegae	Relaxation value (energy)	
29	omega-m		omegam	Relaxation value (mass)	
30	omega-p		omegap	Relaxation value (pressure)	
31	omega-u		omegau	Relaxation value (x-momentum)	
32	omega-v		omegav	Relaxation value (y-momentu)	
33	omega-w		omegaw	Relaxation value (z-momentum)	

Table 5.11: ITERATION block (in iiter.f) (continued)

No	Variable Name	Selection	Var. in code	Description	value
34	p-equ-solve		keysrp	Option for solving linear matrix equation (Pressure equation only):	
35		sor		SOR	1
		tdma		TDMA	0
36	pres-iteration		kpritr	Option for the iteration scheme of pressure equation solution:	
37		explicit		Explicit	0
		implicit		Implicit	2
		semi-implicit		Semi-implicit	1
38	relax-a		relaxa	Relaxation value (volume fraction)	
39	relax-all		relax0	Default relaxation value	
40	relax-b		relaxb	Relaxation value for mass balance term in pressure correction equation	
41	relax-d		relaxd	Relaxation value (density)	
42	relax-gamma		relaxg	Relaxation value (mass exchange)	
43	relax-i		relaxi	Relaxation value for inner quality of interaction-coolant	
44	relax-p		relaxp	Relaxation value (pressure)	
45	relax-pr		relaxr	Relaxation value (pressure)	
46	relax-pr-g		relxrg	Relaxation value (vapor pressure)	
47	relax-t		relaxt	Relaxation value (enthalpy)	
48	relax-u		relaxu	Relaxation value (u-velocity)	
49	relax-ug		relaxug	Relaxation value (vapor u-velocity)	
50	relax-v		relaxv	Relaxation value (v-velocity)	
51	relax-w		relaxw	Relaxation value (w-velocity)	
52	solution-form		keysln	Option of the solution scheme form:	
53		simple		simple	1
		newton		Newton	0

Table 5.12: LIST-FILE block (in ilist.f)

Meaning: Requirements for list file output.

No	Variable Name	Selection	Var. in code	Description	value
1	dstep		idslist	Print every *dstep* time steps	
2	dtime		dtlist	Print every *dtime* time interval (s)	
3	file		lsfile	Output file (user defined)	
4	phs-value		ilphys(nlphys)	Output physical name list	
5	step		iltime(nltime)	Time step list at which print output	
6	time		s	Time list at which print output (s)	

Table 5.13: MASS-BALANCE block (in imsbal.f)

Meaning: Requirements for mass-balance file output.

No	Variable Name	Selection	Var. in code	Description	value
1	dtime		dtmspr	Recording step of time	
2	file		msfile	Output file name (user defined)	
3	step		imtime(nmtime)	Time step at which data record	
4	time		rmtime(nmtime)	Time at which data record	
5	type		keymsb	Mass balance check type	
6		each-iter		at each iteration step	1
		each-step		at each time step	2
		no		No check	0

Table 5.14: MESH block (in imesh.f)

Meaning: Geometric condition and grid discretisation.

No	Variable Name	Selection	Var. in code	Description	value
1	x-div		s	Number of the division in x-direction in the present geometric region	
2	x-end		xdiv(nxpart,2)	End of the present geometric region in x-direction (m) (center line direction in cylindrical coordinate condition)	
3	x-ratio		xr	Width change ration factor in x-direction	
4	x-start		xdiv(1,1)	Start of present geometric region in x-direction (m)	
5	x-tan		xtan	Tangent of the x-direction angle	
6	y-div		jdiv	Number of the division at y-direction in the present geometric region	
7	y-end		ydiv(nypart,2)	End of present geometric region in y-direction (radius in cylindrical coordinate condition) (m)	
8	y-ratio		yr	Width change ration factor in y-direction	
9	y-start		ydiv(1,1)	Start present geometric region in y-direction (m)	
10	y-tan		ytan	Tangent of the y-direction angle	
11	z-div		kdiv	Number of the division at z-direction in the present geometric region	
12	z-end		zdiv(nzpart,2)	End of present geometric region in z-direction (m)	
13	z-ratio		zr	Width change ration factor in z-direction	
14	z-start		zdiv(1,1)	Start present geometric region in z-direction (m)	
15	z-tan		ztan	Tangent of the z-direction angle	

Table 5.15: RESTART-FILE block (in irest.f)

Meaning: Record time for restart file.

No	Variable Name	Selection	Var. in code	Description	value
1	dtime		dtrest	Restart writing time step (s)	
2	file		rofile	Restart data output file name	
3	step		irtime(nrtime)	Irregular writing time steps	
4	time		rrtime(nrtime)	Irregular writing time (s)	

Table 5.16: TIME block (in itime.f)

Meaning: Time step and calculation time. (*: not implemented yet)

No	Variable Name	Selection	Var. in code	Description	value
1	courant-number		csafe	Courant number limit for time step*	
2	dt		dtime	Time step (s)	
3	dt-max		dtmax	Maximum time step*	
4	dt-min		dtmin	Minimum time step*	
5	dt-table		idttbl	Time step table*	
6	dt-type		lauto	Option of the time step control:	
7		constant		Fixed time step	0
		table		User defined table*	1
		auto		Self control time step*	2
8	max-step		maxstp	Allowance of the maximum step	
9	restart-step		irstp	Start point in restart file	
10	step-end		iend	Final time step at which calculation are to cease	
11	step-start		istart	Initial time step at which calculation are to begin	
12	time-end		rend	Final time at which calculation are to cease (s)	
13	time-start		rstart	Initial time at which calculation are to begin (s)	

Table 5.17: TITLE block (in ititl.f)

Meaning: Title of the job.

No	Variable Name	Selection	Var. in code	Description	value
1	case		s	Case name (select from default list)	
2	date		date	Date of the calculation day (user defined)	
3	job		jobnam	Job number (user defined)	
4	title		ctitle	Job name (user defined)	

Table 5.18: TRIGGER block (in itrigr.f)

Meaning: Initial trigger position, distribution and the trigger form.

No	Variable Name	Selection	Var. in code	Description	value
1	dpdtcr		dpdcri	Critical pressure increase rate (N/m^2s)	
2	dpdxcr		dpdcri	Critical pressure gradient (N/m^3)	
3	form		ltrig	Option of trigger condition:	
4		we		Critical Weber number	0
		we/dpdx		Critical Weber, P-gradient	1
		dpdx		P-gradient	2
		pres		Pressure	4
		dpdt		Pressurization rate	3
5	frag-time-delay		timdel	Time delay from a trigger arriving to fragmentation beginning (s)	
6	init-trig-type		initrt	Option of the Initial trigger type	
7		pressure		Pressure trigger	0
		velocity		Velocity difference trigger	1
8	init-trig-velocity		vtrg	X-velocity at the initial trigger location	
9	pres-cri		prescr	Fragmentation critical pressure value (N/m^2)	
10	trig-area		mtrig	Initial trigger location area name	
11	trig-init		trgini	Initial trigger start time instant	
12	trig-time-last		trgtme	Initial trigger added time last	
13	type		vtrg	Option of the fragmentation determination method:	
14		no-conditional-trigger		Always	
		conditional-check		Predefined condition	1
		constant		Always, after trigger	2
15	we-cri		wecri	Fragmentation critical Weber number	

5.2 Output Files

Several files of the output data for various purposes are designed in JASMINE-pro. Table 5.19 is the list of the output files and their brief descriptions.

Table 5.19: List of the output files
([XXXX] is the base name of the output from JASMINE-pro.)

File Name	Data Format	Description
[XXXX]	ACSII	running messages: constants, initial condition and debugging message, used for user keeping watch on the calculation development on-line
[XXXX].list	ACSII	distribution of the variable values on xy-surface, at specified time steps, to be used for plotting later
[XXXX].mess	ACSII	basic initial messages and constants about the calculation, providing the information about the job after the calculation
[XXXX].hist	ACSII	histories of variables at specified nodes (NOT used in the current version)
[XXXX].recd	ACSII	histories of total mass and energy for each component
[XXXX].rest	binary	record of variables necessary for restarting, a record at any time step of which can be taken as the initial condition in the following restart calculation

5.2.1 Output Variable Names

Table 5.20 is the list of variables written in the output files and the actual variable name in the source code.

5.2.2 Recording for Restart

Calculation can be stopped at any time step and also can be continued from the previous calculation at some step where the data have been recorded in the restart file. Table 5.21 is the list of variables which are necessary to setup the initial condition for restarting a calculation.

Table 5.20: List of output variables

No	Name	Variable
1	PRES	pres(n)
2	ALPHA-L	alpha(n, kl)
3	ALPHA-G	alpha(n, kg)
4	ALPHA-M	alpha(n, km)
5	ALPHA-F	alpha(n, kf)
6	ALPHA-I	alpha(n, ki)
7	TEMP-L	temp(n, kl)
8	TEMP-G	temp(n, kg)
9	TEMP-M	temp(n, km)
10	TEMP-F	temp(n, kf)
11	TEMP-I	temp(n, ki)
12	ENER-L	ener(n, kl)
13	ENER-G	ener(n, kg)
14	ENER-M	ener(n, km)
15	ENER-F	ener(n, kf)
16	ENER-I	ener(n, ki)
17	DENS-L	dens(n, kl)
18	DENS-G	dens(n, kg)
19	DENS-M	dens(n, km)
20	DENS-F	dens(n, kf)
21	DENS-I	dens(n, ki)
22	VELU-L	velu(n, kl)
23	VELU-G	velu(n, kg)
24	VELU-M	velu(n, km)
25	VELU-F	velu(n, kf)
26	VELU-I	velu(n, ki)
27	VELV-L	velv(n, kl)
28	VELV-G	velv(n, kg)
29	VELV-M	velv(n, km)
30	VELV-F	velv(n, kf)
31	VELV-I	velv(n, ki)
32	TEMPS	temps(n)
33	XI	xi(n)
34	ALPI	alpi(n)

Table 5.20: List of output variables (continued)

No	Name	Variable
35	WE	we(n)
36	TIG	tempig(n)
37	TIL	tempil(n)
38	EIG	eneig(n)
39	EIL	eneil(n)
40	DEM	dem(n)
41	TIMFRA	timfra(n)
42	GAMMA	gamma(n)
43	MFRAG	mfrag(n)
44	ALPHA*VELU-L	alpha(n, kl)×velu(n, kl)
45	ALPHA*VELU-G	alpha(n, kg)×velu(n, kg)
46	ALPHA*VELU-M	alpha(n, km)×velu(n, km)
47	ALPHA*VELU-F	alpha(n, kf)×velu(n, kf)
48	ALPHA*VELU-I	alpha(n, ki)×velu(n, ki)
49	ALPHA*VELV-L	alpha(n, kl)×velv(n, kl)
50	ALPHA*VELV-G	alpha(n, kg)×velv(n, kg)
51	ALPHA*VELV-M	alpha(n, km)×velv(n, km)
52	ALPHA*VELV-F	alpha(n, kf)×velv(n, kf)
53	ALPHA*VELV-I	alpha(n, ki)×velv(n, ki)
54	ALPHA*VELW-L	alpha(n, kl)×velw(n, kl)
55	ALPHA*VELW-G	alpha(n, kg)×velw(n, kg)
56	ALPHA*VELW-M	alpha(n, km)×velw(n, km)
57	ALPHA*VELW-F	alpha(n, kf)×velw(n, kf)
58	ALPHA*VELW-I	alpha(n, ki)×velw(n, ki)
59	ALPHA*DENS*VELU-L	alpha(n, kl)×dens(n, kl)×velu(n, kl)
60	ALPHA*DENS*VELU-G	alpha(n, kg)×dens(n, kg)×velu(n, kg)
61	ALPHA*DENS*VELU-M	alpha(n, km)×dens(n, km)×velu(n, km)
62	ALPHA*DENS*VELU-F	alpha(n, kf)×dens(n, kf)×velu(n, kf)
63	ALPHA*DENS*VELU-I	alpha(n, ki)×dens(n, ki)×velu(n, ki)
64	ALPHA*DENS*VELV-L	alpha(n, kl)×dens(n, kl)×velv(n, kl)
65	ALPHA*DENS*VELV-G	alpha(n, kg)×dens(n, kg)×velv(n, kg)
66	ALPHA*DENS*VELV-M	alpha(n, km)×dens(n, km)×velv(n, km)
67	ALPHA*DENS*VELV-F	alpha(n, kf)×dens(n, kf)×velv(n, kf)
68	ALPHA*DENS*VELV-I	alpha(n, ki)×dens(n, ki)×velv(n, ki)
69	ALPHA*DENS*VELW-L	alpha(n, kl)×dens(n, kl)×velw(n, kl)
70	ALPHA*DENS*VELW-G	alpha(n, kg)×dens(n, kg)×velw(n, kg)
71	ALPHA*DENS*VELW-M	alpha(n, km)×dens(n, km)×velw(n, km)
72	ALPHA*DENS*VELW-F	alpha(n, kf)×dens(n, kf)×velw(n, kf)
73	ALPHA*DENS*VELW-I	alpha(n, ki)×dens(n, ki)×velw(n, ki)

Table 5.21: List of restart variables

No	Name	Variable
1	ALPHA-F	alpha(n, kf)
2	ALPHA-G	alpha(n, kg)
3	ALPHA-I	alpha(n, ki)
4	ALPHA-L	alpha(n, kl)
5	ALPHA-M	alpha(n, km)
6	DEM	dem(n)
7	ENER-F	ener(n, kf)
8	ENER-G	ener(n, kg)
9	ENER-I	ener(n, ki)
10	ENER-L	ener(n, kl)
11	ENER-M	ener(n, km)
12	MFRAG	mfrag(n)
13	NFRONT	nfront
14	PRES	pres(n)
15	TEMP-F	temp(n, kf)
16	TEMP-G	temp(n, kg)
17	TEMP-I	temp(n, ki)
18	TEMP-L	temp(n, kl)
19	TEMP-M	temp(n, km)
20	TIG	tempig(n)
21	TIL	tempil(n)
22	TIMFRA	timfra(n)
23	TMASS	tmass(n)
24	TMASS0	tmass0(n)
25	VELU-F	velu(n, kf)
26	VELU-G	velu(n, kg)
27	VELU-I	velu(n, ki)
28	VELU-L	velu(n, kl)
29	VELU-M	velu(n, km)
30	VELV-F	velv(n, kf)
31	VELV-G	velv(n, kg)
32	VELV-I	velv(n, ki)
33	VELV-L	velv(n, kl)
34	VELV-M	velv(n, km)
35	XGRID	xgrid(n)
36	XI	xi(n)
37	YGRID	ygrid(n)

5.3 Options and Configuration File

5.3.1 Option Keys

JASMINE-pro has several options controlling the model selection, iteration schemes, finite difference schemes, etc. User can change these options in order to examine the sensitivity of the calculation results on different models and parameters, as well as to find the best numerical scheme for a specific problem. Table 5.22 is a list of the principal options available for JASMINE-pro.

Some of those options can be controlled in the input file, however, others need to be changed directory in the source files where the values are given.

Table 5.22: Option keys

No	Variable	COM./Rout.	Description	Option	Value
1	kenitr	calkey	Iteration scheme option for energy calculation	explicit	0
				semi-implicit	1
				implicit	2
2	keydif_e	calkey	Difference scheme option for energy equation	conservative form	0
				non-conservative form	1
3	keydif_x	calkey	Difference scheme option for energy equation	conservative form	0
				non-conservative form	1
4	keydrg	calkey	Drag calculation option	no calculation	0
				perform the calculation	1
5	keyerr	calkey	Convergence criteria option	maximum value of mass balance error in pc-quation	0
				total sum of the value of mass balance error in pc-equation	1
				maximum value of pressure correction	2
				both mass error and pressure correction	3
6	keyfrg	calkey	Fragmentation calculation option	no calculation	0
				perform the calculation	1
7	keyhtc	calkey	Heat calculation option	no calculation	0
				perform the calculation	1
8	keyint	calkey	Interaction coolant model selection option	model	0
				homogeneous	1
				equation	2
9	keyitr	calkey	Iteration scheme option	explicit	0
				semi-implicit	1
				implicit	2

Table 5.22: Option Keys (continued) (*: not implemented yet)

No	Variable	COM./Rout.	Description	Option	Value
10	keymsb	calkey	Mass conservation check	no check	0
				perform the check	1
11	keypur	calkey	Pouring in inlet condition calculation option	no pouring in	0
				pouring inlet condition	1
12	keyrst	calkey	Restart option	from t = 0	0
				restart from self-files	1
				restart from other's files	2
13	keysln	calkey	Solution scheme	Newton	0
				SIMPLE	1
				SIMPLER	2
14	keysor	calkey	Algebraic equation solution option	solution with TDMA method	0
				solution with SOR method	1
15	keysrp	calkey	Algebraic equation solution option for pressure-correction equation	solution with TDMA method	0
				solution with SOR method	1
16	keytf	calkey	Fragments temperature field calculation scheme option *	thermal non-equilibrium	0
				thermal equilibrium	1
17	keytrg	calkey	Trigger judgement criteria option	no-conditional-trigger	0
				conditional-check	1
				constant	2
18	keyvol	calkey	Total volume fraction unity modification option	vapor phase modified only	0
				phase with largest volume fraction modified only	1
				all phase modified	2
				all but not hot phases modified	3
19	keywal	calkey	Heat transfer calculation on wall	heat adiabatic on all wall	0
				other conditions	1
20	kmsitr	calkey	Iteration scheme option for	Continuity equation	0
				explicit	1
				semi-implicit	2
				implicit	
21	kpritr	calkey	Iteration scheme option for pressure-correction equation solution	explicit	0
				semi-implicit	1
				implicit	2

Table 5.22: Option Keys (continued) (*: not implemented yet)

No	Variable	COM./Rout.	Description	Option	Value
22	model_frag	calkey	Fragmentation model selection option	Carachalios model	0
				ESPROSE model	1
				MC3D model	2
23	model_inte	calkey	Interaction-coolant generation model selection option	JASMINE-pro model	0
24	idim	dimens	Dimension	3D*	1
25	kindpf	fueli	Index for melt material default kinds (fragments)	alumina	1
				corium	2
				alumina-mixture	3
				corium-mixture	4
26	kindpm	fueli	Index for melt material default kinds (melt-droplet)	alumina	1
				corium	2
				alumina-mixture	3
				corium-mixture	4
27	lpoten	initli	Option key for computing initial potential head	no calculation	0
				calculation	1
28	iphase	phase	Phase included	no existence	0
				before existence	1
				existence	
29	kfrag	trigri	Index for initial fragmentation start	before fragmentation start	0
				after fragmentation start	1
30	ktrig	trigri	Index for initial trigger begin	before initial trigger start	0
				during initial trigger forming	1
				after initial trigger formed	
31	initrt	trigri	Option of initial trigger	pressure	0
				velocity	1
32	ltrig	trigri	Option for judgement of the trigger node	from Weber number	0
				from local pressure	1
				from pressure change in space	2
				form pressure change in time	3
				from Weber number or local pressure	4

Table 5.22: Option Keys (continued)

No	Variable	COM./Rout.	Description	Option	Value
33	karvis	solutn	Option of artificial viscosity calculation	no calculation	0
				calculation	1
34	kcnv_im_e	solutn	Option index of iteration scheme for convection term in energy equation	explicit	0
				semi-implicit	1
				implicit	2
35	kcnv_im_m	solutn	Option index of iteration scheme for convection term in energy equation	explicit	0
				semi-implicit	1
				implicit	2
36	kcnv_im_x	solutn	Option index of iteration scheme for convection term in energy equation	explicit	0
				semi-implicit	1
				implicit	2
37	kerrch	voluni	Option for volume fraction check	no check	0
				check	1
38	keybp	coefen	Option for calculation pressure terms in energy equation	no calculation	0
				calculation	1
39	keycnd	convet	Option for calculation of heat conduction	no calculation	0
				calculation	1
40	keyfim	srmml	Option for calculation of film boiling	no calculation	0
				calculation	1
41	keyvis	convev	Option of artificial viscosity calculation	no calculation	0
				calculation	1
42	keyvis	convev	Option of artificial viscosity calculation	no calculation	0
				calculation	1
43	ksou_im_m	solutn	Option index of iteration scheme for source term in mass/energy equation	Explicit	0
				semi-implicit	1
				implicit	2
44	ksou_im_x	solutn	Option index of iteration scheme for source term in mass/energy equation	Explicit	0
				semi-implicit	1
				implicit	2

5.3.2 Debugging Options

Debugging can be performed in most routines. The debug index for each routine is listed in Table 5.23. These debugging information output is controlled in the configuration file (third arguments for `JASMINE-pro`).

By default, debugging is performed in routines where the switch of its debug index (defined by the variable "flag" in the input block "debug") is not zero, at the first iteration step and the last iteration step in each time step.

On the other hand, debugging can be performed in all iteration steps at specified time steps, defined by the variable of "step" in the input block "debug".

Debugging can also be performed for some specified components, which is specified by variable of "k-flag" in the input block "debug". A summary of the debug options is listed in the followings:

step =<value> - debugging at every iteration step in the given time step
flag = <value> - debugging at the routine whose debug index is the given value
k-flag = <value> - debugging only on the component whose index is the given value, when the debug level (i-flag) is less than zero
i-flag = <value> - debugging level which defined in each routine.

The exception for "k-flag" is that when k-frag=-3, all components are debugged.

Table 5.23: DEBUG options

1	<all input routines>			
2	<all grid constants>			
3	chgcor	init		
5	eos	eosn		
6	intera			
7	newtim			
8	intequ			
9	newito			
10	itertn	newcns	newvar	solutn
11	srmpri	srmprn	srmsen	
12	cnothe	sourmo	sourmx	
13	sourmy			
16	srmphs			
20	pritim			
29	svtdma			
30	sor	tdma		
31	coefms	msequ	pricfm	
32	coefen	engequ	pricfe	
33	coefmx	moxequ	pricmx	pricmy
34	coefmy	moyequ		
35	coefpr	pricfp		
36	dpdxcl			
37	preequ			
39	voluni			
40	convet			
41	conveu			
42	convev			
44	uvaver			
46	mxmor	mymor	premor	
48	maschk			
49	primes			

6 Postprocessing with JSMPROplot Script

6.1 What is JSMPROplot?

It is often necessary to present the calculated results graphically. While JASMINE-pro does not have a capability to present its output in a graphical format, it is possible to process its output in order to obtain the information suitable for plotting by other graphical tools. It was for this purpose that a simple script JSMPROplot was written.

In JSMPROplot, a number of specific codes and scripts are called. Since all of them does not require an intervention from the user, the detail on how they interact with each other is omitted. Only the instruction on how to implement JSMPROplot is to be given in this chapter.

6.2 Directory Structure of JSMPROplot Data

Even though the user should be already familiarized with the directory structure of JASMINE-pro, it is deemed necessary that the directory structure for the plotting output is again addressed.

In the calculation directory of JASMINE-pro, it is presumed that there is a sub-directory named JSMPRO.PLOT. This directory is set up so that the output for the plotting can be written to and processed by the prepared script JSMPROplot. If you are only interested in running the calculation but prefer to design your own plotting, you may omit this sub-directory from your directory structure and may skip this chapter.

Assume that the sub-directory JSMPRO.PLOT is used. Under this sub-directory, you will find the following sub-directories that are created for the different plottings, after running JSMPROplot script successfully;

- data
  This is the sub-directory for storing the temporary files created for the variation of the given parameters at the specified positions versus time. No practical final output is expected in this sub-directory.
- data_2dx1
  This sub-directory contains the actual output files for the variation of the given parameters along the y-direction at various specific points in time. This is applicable if the output is only in one direction and is in y-direction. For the system that is specifically one-dimensional, an exceptional assumption is used that prevent the output to be written to this sub-directory. Read the following information for more detail.
- data_2dx2
  This sub-directory contains the actual output files for the variation of the given parameters along the x-direction at various specific points in time. This is applicable if the output is only in one direction and is in x-direction. It must be noted, however, that if the system is specifically one dimensional, the system is always presumed to lie in x-direction. Therefore, the output from the calculation is always put in this sub-directory.
- data_3d
  This sub-directory contains the actual output files for the distribution of the given parame-

ters on the x-y surface at various specific points in time. This is especially applicable when the calculation is of two dimensions.

- `data_node`
  This sub-directory contains the actual output files for the variation of the given parameters at the specified positions versus time.
- `data_temp`
  Another sub-directory for the temporary files created while parsing the input file.
- `data_velu`
  This sub-directory is for the flow velocity distribution over the x-y surface at the specified points in time.
- `data_x1`
  This is the sub-directory for storing the temporary files created for the variation of the given parameters along the y-direction at various specific points in time. No practical final output is expected in this sub-directory.
- `data_x2`
  This is the sub-directory for storing the temporary files created for the variation of the given parameters along the x-direction at various specific points in time. No practical final output is expected in this sub-directory.

In these directories, a number of data files can be found. The exact names and contents are varied due to the different arguments and parameters given to the input file.

6.3 Input File for JSMPROplot

To execute JSMPROplot, the name of the main output file from JASMINE-pro must be passed as an argument to JSMPROplot to process. With this name, JSMPROplot assumes that there is an associated input file of the same name but with ".dat" attached at the end. It is this file that JSMPROplot attempts to read for the information on what parameters are wanted for plotting and how to prepare them. It is up to the user then to prepare the input according to their need. This naming of the input file is required in order to guarantee that the main output file from JASMINE-pro actually exists and that it can be processed.

It must be stated, however, that the actual result generated from JSMPROplot is not necessarily conformed to the input file. In addition to the main output file, it turns out that JASMINE-pro also generates a file called `jsm.mess` which contains the information that overrides the input file. It is, therefore, necessary for the user to be certain that `jsm.mess` which resides in the sub-directory JSMPRO.PLOT really matches the main output that is to be processed. If this cannot be certain, it is recommended to execute JASMINE-pro again before proceed further. When the execution of JSMPROplot is concluded, the user is recommended to check whether there are any differences between the supplied input file and the configuration file created by JSMPROplot in JSMPRO.PLOT sub-directory. Because the newly created configuration file is the modified version of the given input file under the restriction imposed by `jsm.mess`, it should be considered more suitable for further modification.

Nevertheless, as the user may, in most part, control the output from JSMPROplot with the input file, it is necessary that the information in the input file is clearly described. The content of the input file is as given below;

- **line 1: # XXXXX**
  This line contains the general information about the calculation in which the output is to be plotted. The line must always begin with # as the first character with no preceding space. This is to indicate that no parsing is to be done for this line. XXXXX indicates the information for the calculation. It must be completed in one single line and cannot be longer than 256 characters (all white space characters and # included.)

- **line 2:** `Job_no=XXXXX`
  This line details the job title **XXXXX** as given to the calculation.
- **line 3:** `coordinate = XXXXX`
  This line states the coordinating frame of the system. The parameter **XXXXX** is one of the following parameters;
  - `x-cartesian`
    This parameter indicates that the output is one dimensional and is to be represented in the Cartesian coordinate. This is also used for the system in the cylindrical coordinate if the output is of one dimension.
  - `xy-cartesian`
    This parameter indicates that the system is calculated in the Cartesian coordinate. The system is two dimensional and is denoted by the xy surface. The data in the vertical direction are also to be arranged in the ascending order.
  - `xy-cartesian(-x)`
    This parameter indicates that the system is calculated in the Cartesian coordinate. The system is two dimensional and is denoted by the **xy** surface. The data in the vertical direction are also to be arranged in the descending order.
  - `xy-cylindrical`
    This parameter indicates that the system is two dimensional on the rz surface. The data in the vertical direction are also to be arranged in the ascending order.
  - `xy-cylindrical(-x)`
    This parameter indicates that the system is two dimensional on the rz surface. The data in the vertical direction are also to be arranged in the descending order.
- **line 4:** `size=AAAxBBB`
  This line indicates the sizes of the system in general. Here **AAA** and **BBB** are the height and the width in the Cartesian coordinate (height and radius in the cylindrical coordinate).
- **line 5:** `inner_cell=AAAxBBB`
  This line indicates the number of mesh points used along the height, **AAA**, and the width (radius in cylindrical coordinate), **BBB**. It should be reminded that the actual number of mesh points used in `JASMINE-pro`, and subsequently `JSMPROplot`, in each direction is actually equal to the above number plus two additional mesh points. These two mesh points are added on both ends of each direction in order to simulate the boundary conditions in `JASMINE-pro`.
- **line 6:** `list_time_ini=XXXX`
  As the output from `JASMINE-pro` is periodically added and updated at a specific time interval, this line indicates which of the written data set in this periodical order will be the first one to be processed. Here, **XXXX** is any positive non zero integer.
  It should be noted that the parameters from line 6 to line 11 are to be used in presenting the distribution of the obtained data in the physical space at a specific time of interest. Therefore, only a number of these distributions at the various different times are given for comparison.
- **line 7:** `list_time_max=XXXX`
  On the contrary to the previous line, this line indicates the written data set in this periodical order that will be the last one to be processed. Here, **XXXX** is any integer that is greater than `list_time_ini` but is less then the maximum number of data set given by `JASMINE-pro`.
- **line 8:** `list_dtime=XXXX`
  This line indicates that from `list_time_init` to `list_time_max`, **XXXX** data sets are to be skipped for each of the data set that is to be processed. The data in the sub-directory `data_3d` is the main one that is controlled by this parameter.
- **line 9:** `plot_type=x1_plot_max(N1)-x1:AAAAA-x2_plot_max(N2)-x2:BBBBB`

This line indicates the detail for plotting. The integer N1 is the number of mesh points in the vertical direction of the system where the data are to be obtained. Exceptionally, in a system that is one dimensional, N1 is set at zero. Similarly, the integer N2 is the number of mesh points in the horizontal direction. AAAAA and BBBBB describe how the data are to be presented. The actual description for each parameters can be either "average" or "center-average" (for the time being, only "average" can be used for AAAAA). If it is "average," the number of mesh points that are skipped between two subsequent mesh points that are used is roughly equal to the ratio between the total number of mesh points and the given number for plotting. If it is "center-average," two different approaches are used based on the given coordinate system. If the cylindrical coordinate is used, the result is the same as "average." If the Cartesian coordinate is used, the result is similar to "average" but the first mesh point to be used is at the center, not at the beginning.

- **line 10:** `iplot=N`

  This line shows the mesh point numbers in the vertical direction that resulted from the previous line. Due to some complications, the user must always have this line in his configuration file even though it will be actually edited and rewritten. by JSMPROplot in the process.
- **line 11:** `jplot=N`

  This line shows the mesh point numbers in the vertical direction that resulted from the previous line. Due to some complications, the user must always have this line in his configuration file even though it will be actually edited and rewritten. by JSMPROplot in the process.
- **line 12:**

  `node_type=node_max(N1)-node_x1_0(N2)-x1:average-at_y(N3,N4, ...)-x2:given`

  This line describes the positions at which the data obtained over time. N1 is the number of chosen mesh points along the height of the system in which the data are to be obtained. N2 is the starting mesh point to be used. As a result, there are N1 mesh points to be used vertically. They are distributed evenly from the mesh point N2 to the last mesh point in the vertical direction.

  For N3, N4 and other, they are given as the mesh point numbers in the horizontal direction to be used together with the mesh points as specified by N1 and N2 in order to describe the nodes in the system in which the data are to be obtained and presented. If the system is of one dimensional, only N3 is needed and it must be set to 1.

  Unlike the parameters in line 6 to 11, the parameters in line 12 to 16 are to represent the variation in time of the obtained data at the given physical position in the system. Therefore, a limited number of positions (nodes) are given for comparison.
- **line 13:** `x1_node=N1, N2, ...`

  This line shows the mesh point numbers in the vertical direction that resulted from the previous line. Due to some complications, the user must always have this line in his configuration file even though it will be actually edited and rewritten. by JSMPROplot in the process.
- **line 14:** `x2_node=N1, N2, ...`

  This line shows the mesh point numbers in the horizontal direction that resulted from the previous line. Due to some complications, the user must always have this line in his configuration file even though it will be actually edited and rewritten. In addition, if more than one mesh points in the horizontal direction are defined, that equal number of lines, each line for each mesh point, are to be duplicated in this part. In such case, the line number of the following parameters should be also accordingly moved.
- **line 15:** `para_node = A1, A2, ...`

  This line details the data to be plotted. A1, A2 and other can be P (pressure), Ax (volume

fraction), ALPI (the void fraction of the coolant in the interacting region), XI (quality of the coolant at the fuel-coolant interacting region), RHOx (density), Ex (specific enthalpy), Ux, Vx, Wx (velocity components in there princial directions), Tx (temperature), WE (weber number), TS (saturating temperature), TIG (temperature of the vapor in the interacting region), and TIL (temperature of the liquid in the interacting region). For the variables above, x is L for the liquid phase, G for the vapor phase, M for the molten fuel, F for the fragments and I for that in the interacting region.

- **line 16:** para_c_name = A1, A2 , ...
  This line indicates the data for the contour plots. In general, all the variables described previously for normal plotting should still be applicable.

After all the lines describing parameters as mentioned above, the user may include some other information at the end of the configuration file. However, this information is to be treated as only a comment. Therefore, every line must begin with "&" with no preceding white space. This kind of information can be commonly found in the configuration file that is re-generated by JSMPROplot.

6.4 Output from JSMPROplot

With the successful conclusion of JSMPROplot, a number of output files are generated in the different sub-directories under the sub-directory JSMPRO.PLOT. These output files are described in the following list:

- sub-directory data_2dx1
  In this sub-directory, all the output files generated for the parameters as given by para_node described in the previous section are resided. The name of each output is s_N.AAAA where N is the mesh point number on the normal direction and AAAA is the name of the variable as indicated for para_node. As previously stated, the principal direction used for generating the output in this sub-directory is in x direction.
- sub-directory data_2dx2
  The files in this sub-directory are similar to that in data_2dx1 except the principal direction is now in y direction.
- sub-directory data_3d
  The files in this directory are for those variables obtained at the different positions as specified by i_plot and j_plot. The name of each file is sdtNA.dat. From the name, N gives the listed time in which the data were obtained (the actual time in the calculation is contained in the file) according to the parameter list_time_ini and list_time_max. It is logically followed that there are list_time_max number of files for each position and for each variable. For A, it is the variable of interest as indicated for para_node that is previously described.
- sub-directory data_node
  The name of each file in this directory is sn.A where A is that given by para_node. It gives the variation over time of the variable at the positions specified by x1_node and x2_node.
- sub-directory data_velu
  The name of each file in this directory is svtN_A.dat. From the name, N is the listed time in which the data were obtained while A is "L," "F" or "G" which stands for the liquid, the vapor and the fuel respectively. Each of this file gives the detail on the flow of each phase at the positions given by x1_node and x2_node at the listed time indicated by list_time_ini and list_time_max.

6.5 Notes on the Usage of JSMPROplot

In running JSMPROplot, a number of shell scripts and executable binary files are subsequently called and processed. While the shell script JSMPROplot is resided in a sub-directory (calculation directory) of the top directory for JASMINE-pro, other scripts and executable binaries are resided in the sub-directory bin and bin/files of JASMINE-pro top directory. In addition, the C source codes of the executable binaries can be found in the sub-directory source/GRAPHS of JASMINE-pro top directory. In general, there is no need for the user to work on this scripts and executable binaries. If there is a need to do such that, it is recommended that the user copy the needed scripts or the binaries to the other files with the different names and then proceeds to work on the new files instead of the original. In such way, if there are errors, the user still has the original files to rely on.

For comparison and as an example, Fig. 6.1 displays an example of the input file as used in JSMPROplot.

```
# sample 12
Job_no= 0903-14a**0903-14a-1
coordnate= x-cartesian
size= 1.6x0.1
inner_cell= 40x1
list_time_ini= 1
list_time_max= 10
list_dtime= 5
plot_type=x1_plot_max(0)-x1:average-x2_plot_max(1)-x2:center-average
i_plot= 0
j_plot=      1
node_type=node_max(6)-node_x1_0(11)-x1:average-at_y(1)-x2:given
x1_node=     16,  21,  26,  31,  36,  41
x2_node=      1,   1,   1,   1,   1,   1
para_name= p, ti, ai, al, ag, af, uf, ug
para_c_name= p
&====================== job: 0930-8a ======================
& Calculation begin from
&Tue Oct  5 13:04:07 JST 1999
& Calculation begin end at
&Tue Oct  5 14:13:54 JST 1999
&====================== job: 0930-8a ======================
& Calculation begin from
&Tue Oct  5 13:04:07 JST 1999
& Calculation begin end at
&Tue Oct  5 14:13:54 JST 1999
&================================================================================
&                     Sample 8) KROTOS-28   1D
&                        1999.9.20
& --------------------(   0920-11A      --------------------
& X-CYLINDRIC-(x)        Size( 1.600x0.100)  Cell( 40x  1)
&   DT (   0.500E-02 ms )
&   Relax-p.b.r.rg(   0.10  0.10  0.10  0.10 )  Relax-u,v,ug(   0.10 0.10  0.10 )
&   Relax-a,t,d.i(  0.10  0.10  0.10  0.00 )
&   omega-p.m.e.u.v(   0.10  0.50  1.00  1.00  1.00 )
&   iter-o.i( 200  100 ) Err-p.s.t.g( 100.0 0.5000E-01 0.1000E-04 0.000 )
&   fragmentation: C-frag,-fi, Wecri(   0.2500    1.000    10.00)
&  Trigger at    0(,  0  0) P_trig, ALPG_trig=  0.8500E+07  0.9500
& Interaction-coolant: tau_1,tau_2 delta_il(mm) =  0.2000E-04 0.1000E-03  0.1000
&   Consti: C-rad,h-lg,-li,-gi,-ll,d-lg,d-mg,d-ml( 0.80 1.0 1.0 1.0 1.0 1.0 1.0 1.0 )
&  Diameter (mm): l.g.m.f.i( 3.00 10.00  6.00  0.06 3.00 )
&  Radiation  epstrs ( 0.60 )
&================================================================================
&  FRAGMENTATION AT TIME =     0.00     ms STEP=   -1
&  FRAGMENTATION AT NODE =    40   40    1
&  FRAGMENTATION AT NODE =    41   41    1
&................................................................................
& END
```

Figure 6.1: Sample input file for JSMPROplot

References

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[7] C. Brayer and G. Berthoud. First vapor explosion calculations performed with MC3D thermal-hydraulic code. In *Proc. CSNI Specialists Meeting on Fuel-Coolant Interactions, Tokai-mura, Japan, 1997*, pages 391–408, 1997. JAERI-Conf 97-011, NEA/CSNI/R(97)26.

A Source Code Information

A.1 List of Subprograms

Subprograms are listed and brief description of their fuctions are given in the following tables. These tables are arranged for every subdirectory of the JASMINE-pro source tree. Note that functions for the thermal properties of water are not included.

Subprograms in PRE directory

No	Routine	File	Description
1	arrc	functi	Sets initial value for an string array
2	arri	functi	Sets initial value for an integer array
3	arrr	functi	Sets initial value for an real array
4	chgcor	chgcor	Changes coordinate direction, used in the case when the input data is different from the default setting
5	cmplt0	cmplt0	Compares and completes block name
6	cmplt1	cmplt1	Compares and completes variable name
7	cmplt2	cmplt2	Compares and completes variable options name
8	cnidbd	cnidbd	Sets boundary cell type index (for boundaries defined in the input file)
9	cniden	cniden	Sets cell type index (default)
10	cnothe	cnothe	Sets other constants
11	cnsgrd	cnsgrd	Sets grid constants
12	cnsnum	cnsnum	Sets grid numbers
13	consta	consta	Sets constants in the code
14	dbwrr	dbwrr	Writes a real array for debugging
15	defalt	defalt	Initialize common parameter default value
16	errhd	errhd	Prints error message for input file
17	finish	finish	Prints the end message and ceases the job

18	getlin	getlin	Reads one line from input file and split the variables and values
19	grdset	grdset	Sets cell/grid sizes and locations
20	grdset	grdset	Sets cell/grid sizes and locations
21	grdvol	grdvol	Computes cell volumes
22	ibndar	ibndar	Inputs boundary areas (block: "boundary-area")
23	ibndcd	ibndcd	Inputs boundary conditions (block: "boundary")
24	icnseq	icnseq	Inputs constitutive relation data (block: "constitutive")
25	icord	icord	Inputs read coordinate data and component data (block: "coordinate")
26	idchck	idchck	Checks the input data and sets some default values
27	idebg	idebg	Inputs debug options (block: "debug")
28	ifrgmt	ifrgmt	Inputs fragmentation model data (block: "fragmentation")
29	ifuel	ifuel	Inputs fuel property data (block: "fuel-property")
30	ihist	ihist	Inputs history file data (block: "history-file")
31	iinar	iinar	Inputs inner area data (block: "inner-area")
32	iintl	iintl	Inputs initial distribution (block: "inital")
33	iiter	iiter	Inputs iteration data (block: "iteration")
34	ilist	ilist	Inputs list file data (block: "list-file")
35	ilwchar	functi	Change the string to lower char and count the length
36	imesh	imesh	Inputs grid decretisation data (block: "imesh")
37	imsbal	imsbal	Inputs mass balance file data (block: "mass-balance")
38	inifrg	inifrg	Sets initial fragmentation condition
39	init	init	Sets initial variable values
40	initrg	initrg	Sets initial trigger condition
41	inpjob	inpjob	Reads input file-1 about job message
42	input	input	Reads input files
43	irest	irest	Inputs restart file data (block: "restart-file")
44	isort	isort	Sorts integer array
45	itchck	itchck	Checks table data range
46	itime	itime	Inputs time control data (block: "time")

47	ititl	ititl	Inputs job title and name (block: "title")
48	itrigr	itrigr	Inputs triggering data (block: "trigger")
49	iupchar	functi	Changes string to upper char and count the length
50	jsmpro	main	Main program of JASMINE-pro
51	leng	functi	Deletes space in the string ends and counts the length
52	mesare	mesare	Prints message about initial and boundary area
53	mesbnd	mesbnd	Prints message about boundary condition
54	mescor	mescor	Prints message about geometry and components
55	mescst	mescst	Prints message about constitutive relationship options
56	mesful	mesful	Prints message about melt fuel properties
57	mesini	mesini	Prints message about initial conditions
58	mesitr	mesitr	Prints message about iteration controls
59	meslis	meslis	Prints message about output files
60	mesmsh	mesmsh	Prints message about discrete grid
61	mespri	mespri	Prints initial conditions and constants
62	messch	messch	Prints message about calculation schemes
63	mestab	mestab	Prints message about input table
64	mestim	mestim	Prints message about time controls
65	mestrg	mestrg	Prints message about triggering and fragmentation options
66	nodare	nodare	Computes cell surface area
67	nodset	nodset	Sets node and neighbor nodes index
68	openfl	openfl	Opens input and debug output file
69	potenp	potenp	Computes initial gravity potential head
70	priint	priint	Prints print initial principal variables
71	print0	print0	Prints major options
72	readc	readc	Reads a string data
73	readi	readi	Reads an integer data
74	readn	readn	Reads an pre-defined name (area, phs. Parameter or table)
75	readr	readr	Reads a real data
76	reginb	region	Finds the grid range for a boundary area

77	region	region	Finds the grid range for a inner area
78	reloc	grdset	Sets cell/grid sizes and locations
79	reloc	grdset	Sets cell/grid sizes and locations
80	rinit	rinit	Reads initial data from the restart file of one previous calculation
81	rinit0	rinit0	Checks the restart steps of the previous calculation to find the start point of the expected recording step
82	rsort	rsort	Sorts a read array
83	sample	sample	Reads sample input list file
84	stflnm	stflnm	Sets default output file name
85	stphyn	stphyn	Sets variable names for various output purpose
86	timset	timset	Initializes time & step control data
87	zrclrc	zrclrc	Clears arrays to zero

Subprograms in SOLVER directory

No	Routine	File	Description
1	arearel	arearel	Computes the relative interfacial area between components
2	artvis	artvis	Velocity modification by the artificial viscosity
3	bmascl	bmascl	Computes the mass balance term in pressure-correction equation
4	bndpur	boundt	Checks the pouring boundary condition
5	boundt	boundt	Sets boundary conditions for variables on p-cell
6	boundu	boundu	Sets boundary conditions for variables on u-cell
7	boundv	boundv	Sets boundary conditions for variables on v-cell
8	boundy	boundy	Sets boundary conditions
9	coefbn	coefbn	Sets boundary modification for coefficients in all algebraic equations
10	coefen	coefen	Computes coefficients in the discretized energy equation
11	coefms	coefms	Computes coefficients in the discretized continuity equation
12	coefmx	coefmx	Computes coefficients in the discretized x-momentum equation
13	coefmy	coefmy	Computes coefficients in the discretized y-momentum equation
14	coefpr	coefpr	Computes coefficients in the discretized pressure-

			correction equation
15	conchk	conchk	Checks the conservation degree for mass and energy
16	convet	convet	Computes convection terms on p-cell
17	conveu	conveu	Computes convection terms on u-cell
18	convev	convev	Computes convection terms on v-cell
19	datchk	datchk	Checks if the coefficient values are reasonable
20	dpdxcl	dpdxcl	Computes pressure gradient field
21	enemor	enemor	Modifies energy for super-heated or subcooling condition
22	engequ	engequ	Solves energy equation
23	eos	eos	Computes physical proprieties
24	eosn	eosn	Calls EOS on each cell
25	errchk	errchk	Checks accuracy for each iteration step
26	fnbfrag	neighb	Checks the fragmented cells in neighbor nodes
27	fragme	fragme	Fragmentation check and calculation
28	intequ	intequ	Solves interaction coolant equation
29	intera	intera	Computes interaction coolant properties
30	iprok	newvar	Checks if need to print debug message
31	iprok	newvar	Checks if need to print debug message
32	itertn	itertn	Controls iteration flow
33	maschk	maschk	Checks mass conservation degree
34	moxequ	moxequ	Solves x-momentum equation
35	moyequ	moyequ	Solves y-momentum equation
36	msequ	msequ	Solves continuity equation
37	mxmor	mxmor	Corrects u-velocity
38	mymor	mymor	Corrects v-velocity
39	neighb	neighb	Finds the node numbers of neighbor cells
40	newcns	newcns	Sets initial constants for a new time step
41	newito	newito	Sets initial values for a new iteration step
42	newtim	newtim	Sets a new time step
43	newvar	newvar	Sets initial values for a new time step
44	pcntem	proplg	Determines physical properties for coolant components

45	preequ	preequ	Solves pressure-correction equation
46	premor	premor	Corrects pressure
47	pricfe	pricfe	Prints debug message in computing the coefficients in energy equation
48	pricfm	pricfm	Prints debug message in computing the coefficients in mass equation
49	pricfp	pricfp	Prints debug message in computing the coefficients in pressure-correction equation
50	pricmx	pricmx	Prints debug message in computing the coefficients in x-momentum equation
51	pricmy	pricmy	Prints debug message in computing the coefficients in y-momentum equation
52	primes	primes	Prints node debug message in one iteration step
53	prinod	primes	Prints node debug message in one iteration step
54	prismx	prismx	Prints debug message in computing x-momentum source terms
55	prismy	prismy	Prints debug message in computing y-momentum source terms
56	prisol	prisol	Print all main parameter arrays in one iteration step
57	pritim	pritim	Print time step message
58	propcp	proplg	Determines specific heat capacity
59	propene	proplg	Determines inner enthalpy versus temperature
60	proplg	proplg	Determines physical properties for coolant components
61	prpdns	proplg	Determines physical properties for coolant components
62	solutn	solutn	Controls the total solution flow at one iteration step
63	solve	solve	Solve equation for all time step
64	sor	sor	Solves an algebraic equation by using of the SOR method
65	sourmo	sourmo	Computes momentum interaction between different components
66	sourmx	sourmx	Computes x-momentum source
67	sourmy	sourmy	Computes y-momentum source
68	srmgf	srmgf	Computers heat transfer between outer-vapor and fragments
69	srmifl	srmifl	Computes heat and mass flow between interaction-coolant, fragments and outer-liquid

70	srmig	srmig	Computers heat/mass transfer between outer-vapor and interaction-coolant
71	srmint	srmint	Computes the inner energy and properties inside interaction-coolant
72	srmkey	srmkey	Judges if the calculation of the interaction between each two components is necessary
73	srmlg	srmlg	Computers heat/mass transfer between outer-vapor and liquid
74	srmmf	srmmf	Computers heat/mass transfer between melt-droplets and fragments
75	srmmg	srmmg	Computers heat transfer between melt-droplets and outer-vapor
76	srmmi	srmmi	Computers heat transfer between melt-droplets and interaction coolant
77	srmml	srmml	Computers heat transfer between melt-droplets and outer-liquid
78	srmpc	srmpc	Computers the condensation and evaporation due to pressure decrease
79	srmphs	srmphs	Controls the computation flow for heat/mass exchange between components at each cell
80	srmpri	srmpri	Prints heat/mass source term calculation debug message (1)
81	srmprn	srmprn	Prints heat/mass source term calculation debug message (2)
82	srmsen	srmsen	Computes heat/mass source terms
83	surint	intera	Computes interaction coolant properties
84	svtdma	svtdma	Solves algebraic equations on one line by TDMA
85	tdma	tdma	Solves algebraic equations with TDMA method
86	timech	timech	Change the time start point
87	uvaver	uvaver	Computes average node values on u/v-cell
88	voluni	voluni	Solves volume fraction unity equation

Subprograms in POST directory

No	Routine	File	Description
1	cpyvar	cpyvar	Copy a real variable to an array
2	cpyvri	cpyvar	Copy a real variable to an array
3	error	error	Error message output
4	hsctrl	hsctrl	History output
5	lsctrl	lsctrl	List file output
6	mesout	mesout	Message output for this job
7	msbtrl	msbtrl	Output mass conservation check results
8	namvar	namvar	Copies an array to destined variables for restart input
9	post	post	Controls the post calculation flow for output print
10	prvari	prvari	Print an integer array
11	prvarr	prvarr	Print a real array
12	redord	redord	Reads a command during the calculation and decides if some parameter will be changed
13	rsctrl	rsctrl	Output the restart data
14	varnam	varnam	Copy variables to an array for output
15	varnam1	varnam1	Copy results to an array for output

A.2 List of Common Variables

Following tables list the COMMON blocks and variables with brief descriptions.

No	Block	Name	Array	Description
1	AREAC	cbarea	mbarmx	String array for name of boundary area
2		ciarea	miarmx	String array for name of inner area
1	AREAI	ibarea	mbarmx,7	Index of the boundary area
2		iiarea	miarmx,6	Array about initial area
3		nbarea	1	Number of the boundary area
4		niarea	1	Number of the inner area
1	BCIDEN	indt	0:mdmax	Index of p-cell property
2		indu	0:mdmax	Index of u-cell property
3		indv	0:mdmax	Index of v-cell property
4		indw	0:mdmax	Index of w-cell property
1	BMASSCI	ibmsmx	1	Node with max. mass conservation error
2		nbmsmx	1	Component with cell max. mass conserv. error
3		nbmspt	1	Component with total max. mass conserv. error
1	BMASSC	bmasmx	1	Max. error on cell mass conservation
2		bmassn	mdmax	Mass conservation error in pressure-correction
3		erbmst	1	Total error on all cell mass conservation
1	CALKEY	kenitr	1	Iteration scheme option for energy calculation
2		keydif_e	1	Difference scheme option for energy equation
3		keydif_x	1	Difference scheme option for energy equation
4		keydrg	1	Drag calculation option
5		keyerr	1	Convergence criteria option
6		keyfrg	1	Fragmentation calculation option
7		keyhtc	1	Heat calculation option
8		keyint	1	Interaction coolant model selection option
9		keyitr	1	Iteration scheme option
10		keymsb	1	Mass conservation check
11		keypur	1	Pouring in inlet condition calculation option
12		keyrst	1	Restart option
13		keysln	1	Solution scheme option
14		keysor	1	Algebraic equation solution option
15		keysrp	1	Option for pressure-correction equation
16		keytf	1	Fragments temperature calc. scheme option
17		keytrg	1	Trigger judgement criteria option
18		keyvol	1	Volume modification option
19		keywal	1	Heat transfer form at wall
20		kmsitr	1	Iteration scheme option for continuity equation
21		kpritr	1	Iteration scheme option for pressure-correction
22		model_frag	1	Fragmentation model selection option
23		model_inte	1	Fragmentation model selection option
1	CASES	case_name	20	String name of the samples
2		ccase	20	String array for title of the sample
3		icase	1	Current sample case index
4		mcase	1	Total sample number
1	CMPLTC	ccmplt	50	String for reading input
1	CMPLTI	ncmplt	1	Constant for reading input

1	COFCF	cdrg	1	Default multiplier applied to drag coefficient
2		cd_wall	1	Multiplier applied to friction on wall
3		cfd	mphase,mphase	Multiplier applied to drag coefficients
4		cfrag	1	Default value for multiplier applied to fragmentation rate coefficients
5		ch	mphase,mphase	Multiplier applied to heat transfer coefficients
6		cheat	1	Default value for multiplier applied to heat transfer coefficients
7		chrad	mphase,mphase	Multiplier applied to heat radiation coefficients
8		cinte	1	Multiplier applied to interaction-coolant model
9		crad	1	Default value for multiplier applied to heat radiation coefficients
1	DEBUG	idebug	50	Debug index of each routine
2		idebug0	50	Initial value of debug index
3		inode	1	Number of the nodes for debugging
4		ipdbug	50	Component for debugging in each routine
5		nprit	10	Nodes for debugging
1	DEBUGI	iditer	50	Iteration step list for debugging
2		idnext	1	Next debug time/step index
3		idtime	mdbtmx	Time step list for debugging
4		ldtime	1	Type of debugging check (0: check time step, 1: check time)
5		nditer	1	Total iteration steps for debugging
6		ndtime	1	Total time steps for debugging
1	DEBUGR	rdtime	mdbtmx	Time list for debugging
1	DIMENS	cdimn	1	String of coordinate name
2		grav	1	Gravity resultant
3		gravx	1	Gravity on x-axis direction
4		gravy	1	Gravity on y-axis direction
5		gravz	1	Gravity on z-axis direction
6		icylnd	1	Option for coordinate selection
7		idim	1	Geometric dimension
1	DPDX	dpx	mdmax	Pressure change between two neighbor nodes in x-direction
2		dpxy	mdmax	Resultant of pressure change on space
3		dpy	mdmax	Pressure change between two neighbor nodes in y-direction
1	FILEC	ctitle	1	Title of the calculation
2		hafile	1	ASCII-file name for output file: [xx].hisa
3		hbfile	1	Binary-file name for output file: [xx].hisa
4		lsfile	1	File-name for output file: [xx].list
5		lsfile2	1	File name for output file : [xx].recd
6		messfl	1	File name for output file: [xx].mess
7		msfile	1	File name for output file: [xx].msba
8		rifile	1	File name for restart input file: [xx].rin
9		ripref	1	File name for restart input file: [xx].rinp
10		rofile	1	File name for restart output file: [xx].rest
1	FILES	lin	3	File passage numbers for input files (1: for jsmpro.in, 2: for sample-[xxxx].in)

2		lorder	1	File passage number for the input file: order.in
3		lp	1	File passages number for the output message file: outdat
4		lperr	1	File passage number for error message output file
5		lpr	10	File passage numbers for output files
1	FRONT	cfront	1	Front name
2		nfront	1	Front node
1	FUELI	ipropf	1	Option of fragment property calculation
2		ipropm	1	Option of melt-droplet property calculation
3		kindpf	1	Index of fragment material type
4		kindpm	1	Index of melt-droplet material type
1	FUELM	elsatm	1	Saturate enthalpy of melt liquid
2		essatm	1	Saturate enthalpy of melt solid
3		hlsm	5	Latent heat of melt solidification
4		rcondm1	5	Conductivity of melt in liquid
5		rcondm2	5	Conductivity of melt in solid
6		rcvm1	5	Heat capacity of melt in liquid
7		rcvm2	5	Heat capacity of melt in solid
8		rrhom1	5	Density of melt in liquid
9		rrhom2	5	Density of melt in solid
10		rviscm1	5	Viscosity of melt in liquid
11		rviscm2	5	Viscosity of melt in vapor
12		sigmam	5	Surface tension of melt
13		tmeltm1	5	Saturate temperature 1 of melt
14		tmeltm2	5	Saturate temperature 2 of melt
1	FUELF	elsatf	1	Saturate enthalpy of fragment liquid
2		essatf	1	Saturate enthalpy of fragment solid
3		hlsf	5	Latent heat of fragment solidification
4		rcondf1	5	Conductivity of fragments in liquid
5		rcondf2	5	Conductivity of fragments in solid
6		rcvf1	5	Heat capacity of fragments in liquid
7		rcvf2	5	Heat capacity of fragments in solid
8		rrhof1	5	Density of fragments in liquid
9		rrhof2	5	Density of fragments in solid
10		rviscf1	5	Viscosity of fragments in liquid
11		rviscf2	5	Viscosity of fragments in vapor
12		sigmaf	5	Surface tension of fragments
13		tmeltf1	5	Saturate temperature 1 of fragments
14		tmeltf2	5	Saturate temperature 2 of fragments
1	GRDARE	areaim	mdmax	Cell area on surface at grid (i-1)
2		areaip	mdmax	Cell area on surface at grid (i+1)
3		areajm	mdmax	Cell area on surface at grid (j-1)
4		areajp	mdmax	Cell area on surface at grid (j-1)
5		areakm	mdmax	Cell area on surface at grid (k-1)
6		areakp	mdmax	Cell area on surface at grid (k-1)
1	GRID	dvt	mdmax	P-cell volume size
2		dvu	mdmax	U-cell volume size
3		dvv	mdmax	V-cell volume size
4		dvw	mdmax	W-cell volume size
5		dx	mxmax	Space step in x-axis on p/v-cell

6		dxu	mxmax	Space step in x-axis on u-cell
7		dy	mymax	Space step in y-axis on p/u-cell
8		dyv	mymax	Space step in y-axis on v-cell
9		dz	mzmax	Space step in z-axis on p/u/v-cell
10		dzw	mzmax	Space step in z-axis on w-cell
11		r	mymax	Radius of the cell center
12		rim	mxmax	Ratio of the half cell size surfacing (i-1) side on u-cell
13		rip	mxmax	Ratio of the half cell size surfacing (i+1) side on u-cell
14		rjm	mymax	Ratio of the half cell size surfacing (j-1) side on v-cell
15		rjp	mymax	Ratio of the half cell size surfacing (j+1) side on v-cell
16		rkm	mzmax	Ratio of the half cell size surfacing (k-1) side on w-cell
17		rkp	mzmax	Ratio of the half cell size surfacing (k+1) side on w-cell
18		rv	mymax	Radius of the cell at (j+1) side
1	GRID1	dyp	0:mdmax	[to be defined]
2		rdx	mxmax	[to be defined]
3		rdxc	mxmax	[to be defined]
4		rdy	mymax	[to be defined]
5		rdyc	mymax	[to be defined]
6		rdz	mzmax	[to be defined]
7		rdzc	mzmax	[to be defined]
8		rr	mymax	[to be defined]
9		rrc	mymax	[to be defined]
10		rrcdy	mymax	[to be defined]
11		rrdy	mymax	[to be defined]
12		x	mxmax	Cell location on x-axis at (i+1) side
13		xc	mxmax	Cell location on x-axis at cell center
14		y	mymax	Cell location on y-axis at (j+1) side
15		yc	mymax	Cell location on y-axis at cell center
16		z	mzmax	Cell location on z-axis at (k+1) side
17		zc	mzmax	Cell location on z-axis at cell center
1	GRIDC	xgrid	mxmax,8	Array for cell size constants on x-axis
2		ygrid	mymax,14	Array for cell size constants on y/r-axis
3		zgrid	mzmax,8	Array for cell size constants on z-axis
1	HISTI	ihcell	mhismx,3	Cell grid index for history output
2		ihend	1	Time step end for history output
3		ihint	1	Time step interval for history output
4		ihnext	1	Next time step index for history output
5		ihphys	50	Physical variable index for history output
6		ihstrt	1	Time step start for history output
7		lhouta	1	Option key for ASCII-data output (history)
8		lhoutb	1	Option key for binary-data output (history)
9		lhtime	1	Option to checking the time (0: time step; 1: time) for history output
10		nhcell	1	Total cell number for history output

11		nhphys	1	Total physical variables for history output
1	HISTR	rhend	1	Time end for history output
2		rhint	1	Time interval for history output
3		rhnext	1	Next time for history output
4		rhstrt	1	Time start for history output
1	INITLI	ipoten	1	Base line for computing initial potential head
2		lpoten	1	Option key for computing initial potential head
3		minit	mintmx	The inner area index of initial region
4		ninit	1	Total number of initial region
1	INITL	alpha0	mintmx,mphase	Initial volume fraction
2		pres0	mintmx	Initial pressure
3		temp0	mintmx,mphase	Initial temperature
4		velu0	mintmx,mphase	Initial x-direction velocity
5		velv0	mintmx,mphase	Initial y-direction velocity
6		velw0	mintmx,mphase	Initial z-direction velocity
1	INTE1	alpi	mdmax	Internal void fraction of the interaction-coolant
2		alpip	mdmax	Internal void fraction of the interaction-coolant at previous time step
3		delta_il	1	Thermal thickness on the l-il boundary
4		eneig	mdmax	Enthapy of internal vapor of interaction-coolant
5		eneigp	mdmax	Enthapy of internal vapor of interaction-coolant at previous time step
6		eneil	mdmax	Enthapy of internal liquid of interaction-coolant
7		eneilp	mdmax	Enthapy of internal liquid of interaction-coolant at previous time step
8		sur_il	mdmax	Interfacial surface area between interation-coolant with outer-liquid in unit volume
9		tau_1	1	Transient time constant at the fragment surface
10		tau_2	1	Transient time constant at the fragment surface
11		tempig	mdmax	Temperature of inner-liquid
12		tempil	mdmax	Temperature of inner-vapor
13		xi	mdmax	Internal quality of the interaction coolant
14		xip	mdmax	Internal quality of the interaction coolant at previous time step
1	INTE2	gamailg	mdmax	Evaporation rate inside interaction coolant
2		gamali	mdmax	Entrainment rate from outer-liquid to interaction-coolant
3		gamamf	mdmax	Fragmentation rate from melt-droplet to fragments
4		qigl	mdmax	Heat transfer from internal vapor to liquid
5		timfra	mdmax	Time last after the cell starting fragmentation
1	ITERATI	iterou	1	Outer iteration number in each time step
2		iter_last	1	Identifier of the last iteration step
3		itrend	1	Identifier of the convergent degree for each iteration step
4		itrimx	1	Maximum limit of the inner iteration steps in solving algebraic equation
5		itromi	1	Minimum limit of the outer iteration steps in one time step
6		itromx	1	Maximum limit of the outer iteration steps in

				one time step
1	ITERAT	epsalw	1	Error allowance
2		epsnwp	1	Convergence criterion for cell maximum of pressure-correction
3		epsnws	1	Convergence criterion for cell maximum error of mass conservation
4		epsnwt	1	Convergence criterion for total cell error of mass conservation
5		epssor	1	Convergence criterion for solving algebraic equation
1	LISTI	ilnext	1	Index for next time step for list output
2		ilphys	mlismx	Physical variable index for list output
3		iltime	mlismx	Time step list for list output
4		llout	1	Option for list output
5		lltime	1	Option to checking the time (0: time step; 1: time) for list time
6		nlphys	1	Total number of physical variables for list output
7		nlsect	1	Surface index for list output
8		nltime	1	Total output times for list output
1	LISTR	rltime	mlismx	Time list for list output
1	MASS	emass	1	Error of the total mass away from the total mass at previous time step
2		emass0	1	Error of the total mass away from the initial total mass
3		emassi	mphase	Error of the total mass in one component away from its total mass at previous time step
4		emassp	1	Error of the total mass at previous time step
5		etotm	1	Total energy change for melt components
6		rmass	mdmax,mphase	Cell mess of each component
7		rmassn	mdmax	Cell mass of all components
8		talph	mphase	Average volume fraction of each component
9		tkine	1	Total kinetic energy
10		tkinec	1	Total kinetic energy of coolant
11		tmass	mphase	Total mass of each component
12		tmassp	mphase	Total mass of each component at previous time step
13		tmasst	1	Total mass
14		tmast0	1	Total initial mass
15		tmastp	1	Total mass at previous time step
16		tvmix	1	Volume of mixture region
17		tvtot	1	Total volume of the system
18		tvwat	1	Total volume of water
1	MAXPAR	erbpre	1	Max. value of cell pressure-correction
2		errvlm	1	Max. error on sum of volume fractions
3		wemax	1	Max. weber number
1	MAXPAI	iervlm	1	Cell with max. error on sum of volume fractions
2		ipremi	1	Cell with min. pressure
3		ipremx	1	Cell with max. pressure
4		iprrmx	1	Cell with max. pressure-correction
5		iuelmx	1	Cell with max. u-velocity

6		ivelmx	1	Cell with max. v-velocity
1	MESSGC	cdimen	1	String of coordinate name
2		cphnam	1	Name of components
3		date	1	String for job date
4		jobnam	1	Job name
1	MESSGR	xleng	1	Geometry length on x-direction
2		yleng	1	Geometry length on y-direction
1	MSBAPI	imnext	1	Index for next time step for mass-balance output
2		imtime	mmsbmx	Time step list for mass-balance output
3		lmout	1	Option for mass-balance output
4		lmtime	1	Option checking the mass-balance (0: time step; 1: time)
5		nmtime	1	Total output times for mass-balance output
1	MSBAPR	rmtime	mmsbmx	Time list for list output
1	NODE	ix	mdmax	Node grid number in x-axis
2		jy	mdmax	Node grid number in y-axis
3		kz	mdmax	Node grid number in z-axis
4		nim	0:mdmax	Node index on previous node (i-1)
5		nip	0:mdmax	Node index on next node (i+1)
6		njm	0:mdmax	Node index on previous node (j-1)
7		njp	0:mdmax	Node index on next node (j+1)
8		nodet	mxmax, mymax,mzmax	Node index
1	NODECN	mdx	1	All nodes in x-axis
2		mdxy	1	All nodes on xy-surface
3		mdxyz	1	All node number
4		mdy	1	All nodes in y-axis
5		mdyz	1	[to be defined]
6		mdz	1	All nodes in z-axis
7		mdzx	1	[to be defined]
8		ndx	1	Inner nodes in x-axis
9		ndxyz	1	[to be defined]
10		ndy	1	Inner nodes in y-axis
11		ndz	1	Inner nodes in z-axis
1	OUTBCI	ioubc1	mibcmx, mphase,5	Table index for boundary area (1)
2		ioubc2	mobcmx,5	Table index for boundary area (2)
3		noutbc	1	Total boundary regions with the values specified by user
1	OUTBCR	roubc1	mobcmx, mphase,5	Values list at boundary area specified by user (1)
2		roubc2	mobcmx,5	Values list at boundary area specified by user (2)
3		totmms	1	Total mass of melt in the system
1	PHASE	cphase	1	Character index of the component
2		iphase	5	Option for existence of the component
3		nphase	1	Component number
1	PHSIZE	de	mphase	Size in particle form
2		dem	mdmax	Melt-droplet size
3		demp	mdmax	Melt-droplet size at previous time step
1	PHYSC	cphys	1	Name of the variables for output

2		cphy_grd	1	Grid property of the variables ('P', 'U','V')
3		cphy_typ	1	Grid property of the variables ('P', 'U','V')
4		cpphys	1	Additional physical variable name for list output
5		cpphy_grd	1	Grid property of the additional physical variable name ('P', 'U','V')
6		cpphy_typ	1	Grid property of the additional physical variable name ('P', 'U','V')
1	PHYS	iphy_frm	100	Property of the additional physical variable name (0: scale variable; 1: 1d-array; 2: 2d-array)
2		ipphy_frm	100	Property of the additional physical variable name (0: scale variable; 1: 1d-array; 2: 2d-array)
3		nphys	1	Total variables for output (principle varibles)
4		npphys	1	Total additional variables for output
1	PROPVA	cond	mdmax, mphase	Thermal conductivity
2		cp	mdmax, mphase	Special heat capacity
3		egs	mdmax	Saturate steam enthalpy
4		els	mdmax	Saturate liquid enthalpy
5		sigmamf	1	Surface tension of melt-drop and fragments
6		ts	mdmax	Saturate temperature
7		visc	mdmax, mphase	Viscosity
1	PROP0	e0	mphase	Enthalpy base reference
2		t0	mphase	Temperature related to enthalpy base reference
1	READNC	cblock	1	Temporal string in reading input file
2		text	1	Temporal string in reading input file
1	READNI	npare	1	Data parts used in reading input file
2		npt	50, 4	Constants used in reading input file
1	RELAX	dpplus	1	Estimated multiplier for pressure increase
2		epsvis	1	Coefficient in artifice viscosity
3		omega0	1	Default value of the relaxation factor
4		omegae	1	Relaxation factor for energy equation
5		omegam	1	Relaxation factor for continuity equation
6		omegap	1	Relaxation factor for pressure-correction
7		omegau	1	Relaxation factor for x-momentum equation
8		omegav	1	Relaxation factor for y-momentum equation
9		omegaw	1	Relaxation factor for z-momentum equation
10		relaxa	1	Relaxation factor for volume faction
11		relaxb	1	Relaxation factor for mass balance
12		relaxd	1	Relaxation factor for density
13		relaxg	1	Relaxation factor for mass generation
14		relaxi	1	Relaxation factor for internal quality of the interaction-coolant
15		relaxp	1	Relaxation factor on pressure correction
16		relaxr	1	Relaxation factor on pressure
17		relaxt	1	Relaxation factor on energy
18		relaxu	1	Relaxation factor on u-velocity
19		relaxug	1	Relaxation factor on u-velocity of vapor
20		relaxv	1	Relaxation factor on v-velocity
21		relaxw	1	Relaxation factor on w-velocity
22		relxrg	1	Relaxation factor for vapor in pressure term in

				momentum equations
1	RELAXO	relaxa0	1	Initial value of relaxa
2		relaxb0	1	Initial value of relaxb
3		relaxd0	1	Initial value of relaxd
4		relaxi0	1	Initial value of relaxi
5		relaxp0	1	Initial value of relaxp
6		relaxr0	1	Initial value of relaxr
7		relaxt0	1	Initial value of relaxt
8		relaxu0	1	Initial value of relaxu
9		relaxug0	1	Initial value of relaxug
10		relaxv0	1	Initial value of relaxv
11		relxrg0	1	Initial value of relxrg
1	RESTI	irnext	1	Index for next time step for restart output
2		irphys	50	Physical variable index for restart output
3		irtime	mresmx	Time step list for restart output
4		lrout	1	Option for restart output
5		lrtime	1	Option the restart time (0: time step; 1: time)
6		nrphys	1	Total physical variables used for restart output
7		nrtime	1	Total output times for restart output
1	RESTR	rrtime	mresmx	Time list for list output
1	SMEN	nprsrm	1	Cell for debugging
1	SMEN1	egsk	1	Local vapor saturate enthalpy
2		elsk	1	Local liquid saturate enthalpy
3		epsrad	1	Absorbed ratio of the radiation heat
4		epstrs	1	Transparent ratio of the radiation heat
5		fp_cri	1	Pressure factor array for sub-critical conditions
6		hfg	1	Latent heat
7		pre	1	Local pressure
8		sigmar	1	Stefan-Boltzmann constant ($5.668x10--8$)
9		tsat	1	Local saturate temperature
1	SMEN2	aerden	mphase,mphase	Local product of density and interfacial area in unit volume
2		alp	mphase	Local volume fractions
3		alpe	mphase, mphase	Relative volume fraction
4		area	mphase	Relative face area between phase *ip* and phase *jp*
5		arearl	mphase,mphase	Relative interfacial area between two components
6		area_rad	mphase,mphase	Relative face area between phase *ip* and phase *jp*
7		cnd	mphase	Local thermal conductivity
8		cpk	mphase	Local heat capacity
9		dek	mphase	Particle size
10		den	mphase	Local density
11		derel	mphase, mphase	Relative size between each two components
12		e	mphase	Local enthalpy
13		epsa	mphase, mphase	Relative area function
14		hq	mphase, mphase	Heat transfer coeffient per unit volume
15		omega	mphase, mphase	Relative area function
16		pr	mphase	Prantl number
17		q	mphase, mphase	Heat flux per unit volume
18		re	mphase, mphase	Re number between two phases
19		t	mphase	Local temperature

20		u	mphase	Local velcosity in x-direaction
21		ut	mphase	Local resultant of velocity
22		v	mphase	Local velcosity in y-direaction
23		vis	mphase	Local viscosity
1	SMEN3	cdig_	1	thermal conductivity of inner-vapor of interaction-coolant
2		cpig_	1	special heat capacity of inner-vapor of interaction-coolant
3		dnsig_	1	density of inner-vapor interaction-coolant
4		eig_	1	enthalpy of inner-vapor interaction-coolant
5		eil_	1	enthalpy of inner-liquid interaction-coolant
6		prig_	1	Prandtl number of inner-vapor interaction-coolant
7		tig_	1	temperature of inner-vapor interaction-coolant
8		til_	1	temperature of inner-liquid interaction-coolant
9		vsig_	1	viscosity of inner-liquid interaction-coolant
1	SOURCE	senera	mdmax, mphase	Energy source coefficient on A_k part
2		senerb	mdmax, mphase	Energy source coefficient on B_k part
3		smascx	mdmax, mphase	Source term for mass exchange in x-momentum
4		smascy	mdmax, mphase	Source term for mass exchange in y-momentum
5		smass	mdmax, mphase	Mass obtained from other component
6		smomxa	mdmax, mphase	X-momentum source coefficient on A_k part
7		smomxb	mdmax, mphase	X- momentum source coefficient on B_k part
8		smomya	mdmax, mphase	Y-momentum source coefficient on A_k part
9		smomyb	mdmax, mphase	Y-momentum source coefficient on B_k part
10		sourms	mdmax, mphase	Mass exchange from each two components
1	STRCTI	nxdiv	mparmx	X-grid number in one section
2		nxpart	1	Section number in x-direction
3		nydiv	mparmx	Y-grid number in one section
4		nypart	1	Section number in y-direction
5		nzdiv	mparmx	Z-grid number in one section
6		nzpart	1	Section number in z-direction
1	STRCTR	xdiv	mparmx, 4	Section length on x-direction
2	STRCTR	ydiv	mparmx, 4	Section length on y-direction
3		zdiv	mparmx, 4	Section length on z-direction
1	TABLEC	ctable	mtabmx	String used for table input
1	TABLEI	itable	mtabmx	Constant used for table input
2		ntable	1	Constant used for table input
1	TABLER	rtable	mtabmx, 100, 2	Constant used for table input
2		table	mtabmx, 2	The table used for table input
1	TIMEI	idttbl	1	Table used for irregular time step
2		iend	1	Total time steps in current calculation
3		istart	1	Initial time step for calculation
4		lauto	1	Option for selecting time step (0: constant; 1:table; 2: auto)
5		ltime	1	Option for starting (0: step-start; 1: time-start; 3: restart)
6		maxstp	1	Limit of the time step
1	TIMER	csafe	1	Courant number limit
2		dtmax	1	Maximum limit for time step

3		dtmin	1	Minimum limit for time step
4		rend	1	Calculation time end point
5		rstart	1	Calculation time start point
1	TIMES	dtime	1	Time step
2		irstp	1	Restart step
3		ispmax	1	End of the time step
4		istep	1	Number of time step
5		rdt	1	Reverse of time step
6		time	1	Calculation time
1	TRIGRI	idpxymx	1	Node having the maximum pressure gradient
2		initrt	1	Option of initial trigger type (0: pressure; 1: velocity)
3		istep_trg	1	Number of time step
4		itimdel	1	Option for the fragmentation time delay (0: time delay; 1: time delay)
5		itrg	mintmx	Identifier of the initial trigger area
6		kfrag	1	Index for initial fragmentation start
7		ktrig	1	Index for initial trigger begin
8		ltrig	1	Trigger type
9		mfrag	mdmax	Identifier for local fragmentation (≤ 0 : before, > 0 : after fragmentation)
10		mmain	1	Reference area index for initial trigger area before trigger beginning
11		mtrig	1	Area of the initial trigger region
12		npstep	1	Step for initial trigger increase
13		ntrig	1	Node of the initial trigger location
1	TRIGRR	alm_min	1	Minimum value of melt-drop volume fraction to cause fragmentation
2		dpdcri	1	Critical pressure change to cause fragmentation
3		dpxymx	1	Maximum pressure change value
4		ifrag	mdmax	Identifier for local fragmentation condition (0: before ; 1: during fragmentation)
5		itrig	mdmax	Identifier for local triggering condition 0: before trigger arrival 1: trigger arrivals, during the time delay 2: after trigger arrival
6		prescr	1	Critical pressure for fragmentation
7		timdel	1	Time delay since the trigger arrived to the beginning of the fragmentation
8		timetr	mdmax	Local time recording from the beginning of the trigger arrived
9		timfrg	1	Local time recording from the beginning of the fragmentation
10		trgini	1	Time start of initial trigger
11		trgtme	1	Initial trigger time last
12		vrmax	1	Maximum value for velocity difference in fragmentation model
13		vrmin	1	Minimum value for velocity difference in fragmentation model
14		vtrg	1	Initial trigger velocity

15		we	mdmax	Weber number
16		wecri	1	Critical Weber number for fragmentation
1	VAR	alpha	mdmax, mphase	Volume fraction
2		dens	mdmax, mphase	Density
3		pres	0:mdmax	Pressure
4		velu	mdmax, mphase	X-direction velocity
5		velv	mdmax, mphase	Y-direction velocity
1	VAR1	ener	mdmax, mphase	Special enthalpy
2		temp	mdmax, mphase	Temperature
3		velw	mdmax, mphase	Z-direction velocity
1	VAR2	gama	mdmax, mphase	Mass generation rate for each component
1	VARP	alphap	mdmax, mphase	Volume fraction in previous time step
2		densp	mdmax, mphase	Density in previous time step
3		presp	mdmax	Pressure in previous time step
4		velup	mdmax, mphase	X-direction velocity in previous time step
5		velvp	mdmax, mphase	Y-direction velocity in previous time step
1	VARP1	enerp	mdmax, mphase	Enthalpy in previous time step
2		prespp	mdmax	Pressure in step before previous time step
3		tempp	mdmax, mphase	Temperature in previous time step

A.3 List of Principal Variables

Principal variables used in JASMINE-pro are listed in the following tables. The indices for the arrays are put with the rules below.

i - grid location on the x-axis
ia - initial area number
ik, jk, kk - specified integer constant
ip, jp - components
is - geometical section number
j - grid location on the y-axis
k - grid location on the z-axis
n - node number

No	Name	Notation in eqs.	Description	Unit
1	aerden(ip,jp)	–	Local product of density and interfacial area in unit volume	kg/m^4
2	alm_min	–	Minimum value of melt-drop volume fraction to cause fragmentation	
3	alp(ip)	$\alpha_{n,k}$	Local volume fractions	
4	alp(n)	–	Volume faction at one node	
5	alpe(ip)	–	Relative volume fraction	
6	alpha(n,ip)	α	Volume fraction	
7	alpha0(ia)	α_0	Initial volume fraction	
8	alphap(n,ip)	α^{t-1}	Volume fraction in previous time step	
9	alpi(n)	α_I	Internal void fraction of the interaction-coolant	
10	alpip(n)	α_I^{t-1}	Internal void fraction of the interaction-coolant at previous time step	
11	area_rad(ip, jp)	$A_{k,k'}^{rad}$	Relative face area between phase *ip* and phase *jp*	
12	area(n)	–	Particle surface area at one node	
13	areaim(n)	A_{im}	Cell area on surface at grid (i-1)	m^2
14	areaip(n)	A_{ip}	Cell area on surface at grid (i+1)	m^2
15	areajm(n)	A_{jm}	Cell area on surface at grid (j-1)	m^2
16	areajp(n)	A_{jp}	Cell area on surface at grid (j-1)	m^2
17	areakm(n)	A_{km}	Cell area on surface at grid (k-1)	m^2
18	areakp(n)	A_{jp}	Cell area on surface at grid (k-1)	m^2
19	areal(ip, jp)	–	Relative contact area between phase *ip* and phase *jp*	
20	arearl(ip,jp)	–	Relative interfacial area between each two components	1/m
21	bmasmx	–	Maximum error on cell mass conservation	
22	bmassn(n)	–	Error on cell mass conservation in pressure-correction equation	
23	case_name(ik)	–	String name of the samples	
24	cbarea(ik)	–	String array for name of boundary area	
25	cblock	–	Temporal string in reading input file	
26	ccase(ik)	–	String array for title of the sample	

27	ccmplt(ik)	–	String for reading input	
28	cd_wall	–	Multiplier applied to friction on wall	
29	cdig_	λ_{ig}	Local thermal conductivity of inner-vapor of interaction-coolant	W/(m·K)
30	cdil_	λ_{il}	Local thermal conductivity of inner-liquid of interaction-coolant	W/(m·K)
31	cdimen	–	String of coordinate name	
32	cdimn	–	String of coordinate name	
33	cdrg	–	Default multiplier applied to drag coefficient	
34	cfd(ip, jp)	–	Multiplier applied to drag coefficients	
35	cfrag	–	Default value for multiplier applied to fragmentation rate coefficients	
36	cfront	–	Front name	
37	ch(ip, jp)	–	Multiplier applied to heat transfer coefficients	
38	cheat	–	Default value for multiplier applied to heat transfer coefficients	
39	chrad(ip, jp)	–	Multiplier applied to heat radiation coefficients	
40	ciarea(ik)	–	String array for name of inner area	
41	cinte	–	Multiplier applied to interaction-coolant model	
42	cnd(ip)	$\lambda_{n,k}$	Local thermal conductivity	W/(m·K)
43	cond(n, ip)	λ	Thermal conductivity	W/(m·K)
44	cp(n, ip)	C_p	Special heat capacity	J/(kg·K)
45	cphase(ip)	–	Character index of the component	
46	cphnam(ip)	–	Name of components	
47	cphy_grd(ik)	–	Grid property of the variables ('P', 'U','V')	
48	cphy_typ(ik)	–	Data type of the variables ('R','I')	
49	cphys(ik)	–	Name of the variables for output	
50	cpig_	Cp_{ig}	Local special heat capacity of inner-vapor of interaction-coolant	J/(kg·K)
51	cpil_	Cp_{il}	Local special heat capacity of inner-liquid of interaction-coolant	J/(kg·K)
52	cpk(ip)	–	Local heat capacity	
53	cpphy_grd(ik)	–	Grid property for the additional physical variable name ('P', 'U','V')	
54	cpphy_typ(ik)	–	Data type property of the physical variable name ('R','I')	
55	cpphys(ik)	–	Additional physical variable name for list output	
56	crad	–	Default value for multiplier applied to heat radiation coefficients	
57	csafe	–	Courant number limit	
58	ctable(ik)	–	String used for table input	
59	ctitle	–	Title of the calculation	
60	date	–	String for job date	
61	de(n,ip)	d_k	Size in particle form	m

62	dek(ip)	–	Particle size	m
63	delta_il	δ_{il}	Thermal thickness on the l-il boundary	m
64	dem(n)	d_m	Melt-droplet size	m
65	demp(n)	d_m	Melt-droplet size at previous time step	m
66	den(ip)	$\rho_{n,k}$	Local density	kg/m^3
67	dens(n, ip)	ρ	Density	kg/m^3
68	densp(n, ip)	–	Density in previous time step	kg/m^3
69	derel(ip,jp)	–	Relative size between each two components	m^2
70	dnsig_	ρ_{ig}	Local density of inner-vapor of interaction-coolant	kg/m^3
71	dnsil_	ρ_{il}	Local density of inner-liquid of interaction-coolant	kg/m^3
72	dpdcri	–	Critical pressure change to cause fragmentation	N/m^2
73	dpplus	–	Estimated multiplier for pressure increase	
74	dpx(n)	δp_x	Pressure change in two neighbor nodes on x-direction	N/ m^2
75	dpxy(n)	δp	Resultant of pressure change on space	N/ m^2
76	dpxymx	–	Maximum pressure change value	N/m^2
77	dpy(n)	δp_y	Pressure change in two neighbor nodes on y-direction	N/ m^2
78	dtime	δt	Time step	s
79	dtmax	–	Maximum limit for time step	s
80	dtmin	–	Minimum limit for time step	s
81	dvt(n)	ΔV_p	P-cell volume size	m^3
82	dvu(n)	ΔV_u	U-cell volume size	m^3
83	dvv(n)	ΔV_v	V-cell volume size	m^3
84	dvw(n)	ΔV_w	W-cell volume size	m^3
85	dx(i)	Δx	Space step in x-axis on p/v-cell	m
86	dxu(i)	Δx_u	Space step in x-axis on u-cell	m
87	dxw(i)	Δz_w	Space step in x-axis on w-cell	m
88	dy(j)	Δy	Space step in y-axis on p/u-cell	m
89	dyv(j)	Δy_v	Space step in y-axis on v-cell	m
90	dz(k)	Δz	Space step in z-axis on p/u/v-cell	m
91	dzw(k)	Δz_w	Space step in z-axis on w-cell	m
92	e(ip)	–	Local enthalpy	J/kg
93	e0(ip)	–	Enthalpy base reference	J/kg
94	egs(n)	h_{gs}	Saturate steam enthalpy	J/kg
95	egsk	–	Local vapor saturate enthalpy	
96	eig_	h_{ig}	Local enthalpy of inner-vapor of interaction-coolant	J/kg
97	eil_	h_{il}	Local enthalpy of inner-liquid of interaction-coolant	J/kg
98	els(n)	h_{ls}	Saturate liquid enthalpy	J/kg
99	elsatf	–	Saturate enthalpy of fragment liquid	J/kg
100	elsatm	–	Saturate enthalpy of melt liquid	J/kg
101	elsk	–	Local liquid saturate enthalpy	
102	emass	–	Error of the total mass away from the total mass at previous time step	kg

103	emass0	–	Error of the total mass away from the initial total mass	kg
104	emassi(ip)	–	Error of the total mass in one component away from its total mass at previous time step	kg
105	emassp	–	Error of the total mass at previous time step	kg
106	eneig(n)	e_{ig}	Enthapy of internal vapor of interaction-coolant	J/kg
107	eneigp(n)	e_{ig}^{t-1}	Enthapy of internal vapor of interaction-coolant at previous time step	J/kg
108	eneil(n)	e_{il}	Enthapy of internal liquid of interaction-coolant	J/kg
109	eneilp(n)	e_{il}^{t-1}	Enthapy of internal liquid of interaction-coolant at previous time step	J/kg
110	ener(n, ip)	–	Special enthalpy	J/kg
111	ener0(ia)	h_0	Initial enthalpy	J/kg
112	enerig(n)	h_{ig}	Enthalpy of inner-vapor	J/kg
113	eneril(n)	h_{il}	Enthalpy of inner-liquid	J/kg
114	enerp(n,ip)	h^{t-1}	Enthalpy in previous time step	J/kg
115	epsa(ip,jp)	–	Relative area function	
116	epsalw	–	Error allowance	
117	epsgas	–	Convergence accuracy in solving algebraic equation	
118	epsnwp	–	Convergence criterion for cell maximum of pressure-correction	
119	epsnws	–	Convergence criterion for cell maximum error of mass conservation	
120	epsnwt	–	Convergence criterion for total cell error of mass conservation	
121	epsrad	–	Absorbed ratio of the radiation heat	
122	epssor	–	Convergence criterion for solving algebraic equation	
123	epstrs	–	Transparent ratio of the radiation heat	
124	epsvis	–	Coefficient in artifice viscosity	
125	erbmst	–	Total error on all cell mass conservation	
126	erbpre	–	Maximum of cell value of pressure-correction	
127	errvlm	–	Maximum of the error on sum of volume fractions	
128	essatf	–	Saturate enthalpy of fragment solid	J/kg
129	essatm	–	Saturate enthalpy of melt solid	J/kg
130	etotm	–	Total energy change for melt components	J/m^3
131	fp_cri	–	Pressure factor array from sub-critical pressure conditions	
132	gama(n,ip)	–	Mass generation rate for each component	kg/m^3 s
133	gamailg(n)	$\Gamma_{il\to ig}$	Evaporation rate inside interaction coolant	kg/m^3s
134	gamali(n)	$\Gamma_{l\to i}$	Entrainment rate from outer-liquid to interaction-coolant	kg/m^3s

135	gamamf(n)	$\Gamma_{m\to f}$	Fragmentation rate from melt-droplet to fragments	kg/m^{3}s
136	gammailg(n)	$\Gamma_{l\to ig}$	Evaporation rate from liquid to internal vapor	kg/m^{3}s
137	grav	–	Gravity resultant	m/s^2
138	gravx	g_x	Gravity on x-axis direction	m/s^2
139	gravy	g_y	Gravity on y-axis direction	m/s^2
140	gravz	g_z	Gravity on z-axis direction	m/s^2
141	hafile	–	ASCII-file name for output file: [xx].hisa	
142	hbfile	–	Binary-file name for output file: [xx].hisa	
143	hfg	–	Latent heat	J/kg
144	hlsf(ik)	–	Latent heat of fragment solidification	J/gk
145	hlsm(ik)	–	Latent heat of melt solidification	J/gk
146	hq(ip)	h_q	Heat transfer coeffient per unit volume	J/K m^5
147	ibarea(ik,jk)	–	Index of the boundary area	
148	ibmsmx	–	Node having maximum error on mass conservation	
149	icase	–	Current sample case index	
150	icylnd	–	Option for coordinate selection	
151	idebug(ik)	–	Debug index of each routine	
152	idebug0(ik)	–	Initial value of debug index	
153	idim	–	Geometric dimension	
154	idim	–	Dimension option	
155	iditer(ik)	–	Iteration step list for debugging	
156	idnext	–	Next debug time/step index	
157	idpxymx	–	Node having the maximum pressure gradient	
158	idtime(ik)	–	Time step list for debugging	
159	idttbl	–	Table used for irregular time step	
160	iend	–	Total time steps in current calculation	
161	iervlm	–	Cell with maximum of the error on sum of volume fractions	
162	ifrag(n)	–	Identifier for local fragmentation condition (0: before fragmentation; 1: in fragmentation)	
163	ihcell(ik,jk)	–	Cell grid index for history output	
164	ihend	–	Time step end for history output	
165	ihint	–	Time step interval for history output	
166	ihnext	–	Next time step index for history output	
167	ihphys(ik)	–	Physical variable index for history output	
168	ihstrt	–	Time step start for history output	
169	iiarea(ia)	–	Array about initial area	
170	iiarea(ik,jk)	–	Index of the inner area	
171	ilnext	–	Index for next time step for list output	
172	ilphys	–	Physical variable index for list output	
173	iltime	–	Time step list for list output	
174	imnext	–	Index for next time step for mass-balance output	
175	imphys	–	Physical variable index for mass-balance output	

176	imtime	－	Time step list for mass-balance output	
177	indt(n)	－	Index of p-cell property	
178	indu(n)	－	Index of u-cell property	
179	indv(n)	－	Index of v-cell property	
180	indw(n)	－	Index of w-cell property	
181	initrt	－	Option of initial trigger type (0: pressure; 1: velocity	
182	inode	－	Number of the nodes for debugging	
183	ioubc1(ik,ik)	－	Table index for boundary area (1)	
184	ioubc2(ik,ik)	－	Table index for boundary area (2)	
185	ip	k	Index of component	
186	ipdbug(ik)	－	Component for debugging in each routine	
187	iphase(ip)	－	Option for existence of the component	
188	iphy_frm(ik)	－	Data type property for the additional physical variable name (0: scale variable; 1: 1d-array; 2: 2d-array)	
189	ipoten	－	Base line for computing initial potential head	
190	ipphy_frm(ik)	－	Data type property for the additional physical variable name (0: scale variable; 1: 1d-array; 2: 2d-array)	
191	ipremi	－	Cell with minimum pressure	
192	ipremx	－	Cell with maximum pressure	
193	ipropf	－	Option of fragment property calculation	
194	ipropm	－	Option of melt-droplet property calculation	
195	iprrmx	－	Cell with maximum pressure-correction	
196	irnext	－	Index for next time step for restart output	
197	irphys(ik)	－	Physical variable index for restart output	
198	irstp	－	Restart step	s
199	irtime	－	Time step list for restart output	
200	ispmax	－	End of the time step	
201	istart	－	Initial time step for calculation	
202	istep	－	Number of time step	
203	itable(ik)	－	Constant used for table input	
204	iter_last	－	Identifier of the last iteration step	
205	iterou	－	Outer iteration number in each time step	
206	itimdel	－	Option for the fragmentation time delay (0: time delay; 1: time delay)	
207	itrend	－	Identifier of the convergent degree for each iteration step	
208	itrg(ia)	－	Identifier of the initial trigger area	
209	itrgsm	－	Maximum of iteration times in solving algebraic equation	
210	itrig(n)	－	Identifier for local triggering condition (0: before trigger arrival; 1: trigger arrivals, during the time delay; 2: after trigger arrival)	
211	itrimx	－	Maximum limit of the inner iteration steps in solving algebraic equation	

212	itromi	－	Minimum limit of the outer iteration steps in one time step
213	itromx	－	Maximum limit of the outer iteration steps in one time step
214	itromx	－	Maximum limit of the outer iteration steps in one time step
215	iuelmx	－	Cell with maximum u-velocity
216	ivelmx	－	Cell with maximum v-velocity
217	ix(n)	i	Node grid number in x-axis
218	jobnam	－	Job name
219	jy(n)	j	Node grid number in y-axis
220	kcnv_im_e	－	Option index of iteration scheme for convection term in energy equation
221	kcnv_im_x	－	Option index of iteration scheme for convection term in momentum equation
222	kenitr	－	Iteration scheme option for energy calculation
223	keydif_e	－	Difference scheme option for energy equation
224	keydif_x	－	Difference scheme option for momentum equation
225	keydrg	－	Drag calculation option
226	keyerr	－	Convergence criteria option
227	keyfrg	－	Fragmentation calculation option
228	keyhtc	－	Heat calculation option
229	keyint	－	Interaction coolant model selection option
230	keyitr	－	Iteration scheme option
231	keyjet	－	Jet calculation option
232	keymix	－	Mixing process calculation option
233	keymsb	－	Mass conservation check
234	keypur	－	Pouring in inlet condition calculation option
235	keyrst	－	Restart option
236	keysln	－	Solution scheme option
237	keysor	－	Algebraic equation solution option
238	keysrp	－	Algebraic equation solution option for pressure-correction equation
239	keytf	－	Fragments temperature field calculation scheme option
240	keytrg	－	Trigger judgement criteria option
241	keyvol	－	Volume modification option
242	keywal	－	Heat transfer form at wall
243	kfrag	－	Index for initial fragmentation start
244	kindpf	－	Index of fragment material type
245	kindpf	－	Index of fragment material type
246	kindpm	－	Index of melt-droplet material type
247	kindpm	－	Index of melt-droplet material type
248	kmsitr	－	Iteration scheme option for continuity equation

249	kpritr	–	Iteration scheme option for pressure-correction equation solution
250	ktrig	–	Index for initial trigger begin
251	kz(n)	k	Node grid number in z-axis
252	lauto	–	Option for selecting time step (0: constant; 1:table; 2: auto)
253	ldtime	–	Type of debugging check (0: check time step, 1: check time)
254	lhouta	–	Option key for ASCII-data output (history)
255	lhoutb	–	Option key for binary-data output (history)
256	lhtime	–	Option to checking the time (0: time step; 1: time) for history output
257	lin(ik)	–	File passage numbers for input files (1: for jsmpro.in, 2: for sample-[xxxx].in)
258	llout	–	Option for list output
259	lltime	–	Option to checking the time (0: time step; 1: time) for list time
260	lmout	–	Option for mass-balance output
261	lmtime	–	Option to checking the time (0: time step; 1: time) for mass-balance time
262	lorder	–	File passage number for the input file: order.in
263	lp	–	File passages number for the output message file: outdat
264	lperr	–	File passage number for error message output file
265	lpoten	–	Option key for computing initial potential head
266	lpr(ik)	–	File passage numbers for output files
267	lrout	–	Option for restart output
268	lrtime	–	Option to checking the time (0: time step; 1: time) for restart time
269	lsfile	–	File-name for output file: [xx].list
270	lsfile2	–	File name for output file : [xx].recd
271	ltime	–	Option for start form (0: step-start; 1: time-start; 3: restart)
272	ltrig	–	Trigger type
273	maxstp	–	Limit of the time step
274	mcase	–	Total sample number
275	mdx	–	All nodes in x-axis
276	mdxy	–	All nodes on xy-surface
277	mdxyz	–	All node number
278	mdy	–	All nodes in y-axis
279	mdz	–	All nodes in z-axis
280	messfl	–	File name for output file: [xx].mess
281	mfrag	–	Identifier for local fragmentation (:$\leq$ 0: before fragmentation; >0: after fragmentation

282	minit(ia)	－	The inner area index of initial region	
283	mmain	－	Reference area index for initial trigger area before trigger beginning	
284	model_frag	－	Fragmentation model selection option	
285	model_inte	－	Interaction-coolant model selection option	
286	msfile	－	File name for output file: [xx].msba	
287	mtrig	－	Area of the initial trigger region	
288	nbarea	－	Number of the boundary area	
289	nbmsmx	－	Component having maximum error on cell mass conservation	
290	nbmspt	－	Component having maximum error on all cell mass conservation	
291	ncmplt	－	Constant for reading input	
292	nditer	－	Total iteration steps for debugging	
293	ndtime	－	Total time steps for debugging	
294	ndx	－	Inner nodes in x-axis	
295	ndy	－	Inner nodes in y-axis	
296	ndz	－	Inner nodes in z-axis	
297	nfront	－	Front node	
298	nhcell	－	Total cell number for history output	
299	nhphys	－	Total physical variables for history output	
300	niarea	－	Number of the inner area	
301	nim	*im*	Node index on previous node (i-1)	
302	ninit	－	Total number of initial region	
303	nip	*ip*	Node index on next node (i+1)	
304	njm	*jm*	Node index on previous node (j-1)	
305	njp	*jp*	Node index on next node (j+1)	
306	nlphys	－	Total number of physical variables for list output	
307	nlsect	－	Surface index for list output	
308	nltime	－	Total output times for list output	
309	nmphys	－	Total number of physical variables for mass-balance output	
310	nmsect	－	Surface index for mass-balance output	
311	nmtime	－	Total output times for mass-balance output	s
312	nodet	*n*	Node index	
313	noutbc	－	Total boundary regions with the values specified by user	
314	npare	－	Data parts used in reading input file	
315	nphase	－	Component number	
316	nphys	－	Total variables for output (principal varibles)	
317	npphys	－	Total additional variables for output	
318	nprit(ik)	－	Nodes for debugging	
319	nprsrm	－	Cell for debugging	
320	npstep	－	Step for initial trigger increase	
321	npt	－	Constants used in reading input file	
322	nrphys	－	Total physical variables used for restart output	

323	nrtime	－	Total output times for restart output	
324	ntable	－	Constant used for table input	
325	ntrig	－	Node of the initial trigger location	
326	nxdiv(ns)	－	X-grid number in one section	
327	nxpart	－	Section number in x-direction	
328	nydiv(ns)	－	Y-grid number in one section	
329	nypart	－	Section number in y-direction	
330	nzdiv(ns)	－	Z-grid number in one section	
331	nzpart	－	Section number in z-direction	
332	omega(ip,jp)	－	Relative area function ??	
333	omega0	－	Default value of the relaxation factor in solving equation	
334	omegae	－	Relaxation factor in solving energy equation	
335	omegam	－	Relaxation factor in solving continuity equation	
336	omegap	－	Relaxation factor in solving pressure-correction equation	
337	omegau	－	Relaxation factor in solving x-momentum equation	
338	omegav	－	Relaxation factor in solving y-momentum equation	
339	omegaw-	－	Relaxation factor in solving z-momentum equation	
340	omiga	－	Default value for relaxation factor in solving algebraic equation	
341	omigae	－	Relaxation factor in solving energy algebraic equation	
342	omigam	－	Relaxation factor in solving mass algebraic equation	
343	omigap	－	Relaxation factor in solving pressure-correction algebraic equation	
344	omigau	－	Relaxation factor in solving x-momentum algebraic equation	
345	omigav	－	Relaxation factor in solving y-momentum algebraic equation	
346	pf	f	Index of fragment phase	
347	pg	v	Index of vapor phase	
348	pi	i	Index of interaction-coolant phase	
349	pim	π	Index of interaction-coolant phase	
350	pl	l	Index of liquid phase	
351	pm	m	Index of melt-droplet phase	
352	pr(ip)	Pr	Prantl number	
353	pre	－	Local pressure	N/m^2
354	pres(n)	－	Pressure	N/m^2
355	pres0(ia)	p_0	Initial pressure	N/m^2
356	prescr	－	Critical pressure for fragmentation	N/m^2
357	presp(n,ip)	p^{t-1}	Pressure in previous time step	N/m^2
358	prespp(n)	－	Pressure in step before previous time step	N/m^2

359	prig_	Pr_{ig}	Local Pranlt number of inner-vapor of interaction-coolant	
360	q(ip)	–	Heat flux per unit volume	J/m^5
361	qigl(n)	$Q_{ig \to l}$	Heat transfer from internal vapor to liquid	J/m^3
362	r(j)	–	Radius of the cell center	m
363	rcondf1(ik)	–	Conductivity of fragments in liquid	W/(m·K)
364	rcondf2(ik)	–	Conductivity of fragments in solid	W/(m·K)
365	rcondm1(ik)	–	Conductivity of melt in liquid	W/(m·K)
366	rcondm2(ik)	–	Conductivity of melt in solid	W/(m·K)
367	rcvf1(ik)	–	Heat capacity of fragments in liquid	J/(kg·K)
368	rcvf2(ik)	–	Heat capacity of fragments in solid	J/(kg·K)
369	rcvm1(ik)	–	Heat capacity of melt in liquid	J/(kg·K)
370	rcvm2(ik)	–	Heat capacity of melt in solid	J/(kg·K)
371	rdt	$1/\delta t$	Reverse of time step	1/s
372	rdtime(ik)	–	Time list for debugging	
373	re(ip, jp)	–	Re number between two phases	
374	relaxa	–	Relaxation factor on volume faction	
375	relaxa	–	Relaxation factor on volume faction	
376	relaxa0	–	Initial value of relaxa	
377	relaxa0	–	Initial value of relaxa	
378	relaxb	–	Relaxation factor on pressure-correction mass balance term	
379	relaxb0	–	Initial value of relaxb	
380	relaxd	–	Relaxation factor on density	
381	relaxd0	–	Initial value of relaxd	
382	relaxg	–	Relaxation factor on mass generation rate	
383	relaxg0	–	Initial value of relaxg	
384	relaxi	–	Relaxation factor on internal quality of the interaction-coolant	
385	relaxi0	–	Initial value of relaxi	
386	relaxp	–	Relaxation factor on pressure correction	
387	relaxp0	–	Initial value of relaxp	
388	relaxr	–	Relaxation factor on pressure	
389	relaxr0	–	Initial value of relaxr	
390	relaxt	–	Relaxation factor on energy	
391	relaxt0	–	Initial value of relaxt	
392	relaxu	–	Relaxation factor on u-velocity	
393	relaxu0	–	Initial value of relaxu	
394	relaxug	–	Relaxation factor on velocity of vapor component	
395	relaxug0	–	Initial value of relaxug	
396	relaxv	–	Relaxation factor on v-velocity	
397	relaxv0	–	Initial value of relaxv	
398	relaxw	–	Relaxation factor on w-velocity	
399	relaxw0	–	Initial value of relaxw	
400	relxrg	–	Relaxation factor for vapor components in pressure term in momentum equations	
401	relxrg0	–	Initial value of relxrg	
402	rend	–	Calculation time end point	s
403	rhend	–	Time end for history output	

404	rhint	－	Time interval for history output	
405	rhnext	－	Next time for history output	
406	rhstrt	－	Time start for history output	
407	rifile	－	File name for restart input file: [xx].rin	
408	rim(i)	－	Ratio of the half cell size surfacing (i-1) side on u-cell	
409	rip(i)	－	Ratio of the half cell size surfacing (i+1) side on u-cell	
410	ripref	－	File name for restart input file: [xx].rinp	
411	rjm(j)	－	Ratio of the half cell size surfacing (j-1) side on v-cell	
412	rjp(j)	－	Ratio of the half cell size surfacing (j+1) side on v-cell	
413	rkm(k)	－	Ratio of the half cell size surfacing (k-1) side on w-cell	
414	rkp(k)	－	Ratio of the half cell size surfacing (k+1) side on w-cell	
415	rltime	－	Time list for list output	
416	rmass(n,ip)	－	Cell mess of each component	kg
417	rmassn(n)	－	Cell mass of all components	kg
418	rmtime	－	Time list for list output	s
419	rofile	－	File name for restart output file: [xx].rest	
420	roubc1(ik,ik)	－	Values list at boundary area specified by user (1)	
421	roubc2(ik,ik)	－	Values list at boundary area specified by user (2)	
422	rrhof1(ik)	－	Density of fragments in liquid	kg/m^3
423	rrhof2(ik)	－	Density of fragments in solid	kg/m^3
424	rrhom1(ik)	－	Density of melt in liquid	kg/m^3
425	rrhom2(ik)	－	Density of melt in solid	kg/m^3
426	rrtime(ik)	－	Time list for list output	
427	rstart	－	Calculation time start point	s
428	rtable(ik,jk,kk)	－	Constant used for table input	
429	rv(j)	r_{jp}	Radius of the cell at (j+1) side	
430	rviscf1(ik)	－	Viscosity of fragments in liquid	$N/m^2 \cdot s$
431	rviscf2(ik)	－	Viscosity of fragments in vapor	$N/m^2 \cdot s$
432	rviscm1(ik)	－	Viscosity of melt in liquid	$N/m^2 \cdot s$
433	rviscm2(ik)	－	Viscosity of melt in vapor	$N/m^2 \cdot s$
434	senera(n, ip)	S_a^{eng}	Energy source coefficient on A_k part	
435	senerb(n, ip)	S_b^{eng}	Energy source coefficient on B_k part	
436	sigmaf	－	Surface tension of fragments	N/m
437	sigmaf(5)	σ_f		
438	sigmam	－	Surface tension of melt	N/m
439	sigmam(5)	σ	surface tension of melt-drop	N/m
440	sigmam(5)	σ	surface tension of melt-drop	N/m
441	sigmam(5)	σ	surface tension of melt-drop	N/m
442	sigmamf	σ_{mf}	Surface tension of melt-drop and fragments	N/m
443	sigmar	σ_b	Stefan-Boltzmann constant ($= 5.668x10--8$)	W/m^2K^4

444	smascx	–	Source term due to mass exchange in x-momentum equation	
445	smascy	–	Source term due to mass exchange in y-momentum equation	
446	smass(n, ip)	Γ	Mass obtained from other component	
447	smomxa(n, ip)	F_a^{mx}	X-momentum source coefficient on A_k part	
448	smomxb(n, ip)	F_b^{mx}	X- momentum source coefficient on B_k part	
449	smomya(n,ip)	F_a^{my}	Y-momentum source coefficient on A_k part	
450	smomyb(n, ip)	F_b^{my}	Y-momentum source coefficient on B_k part	
451	sourms(ip, jp)	$\Gamma_{k,k'}$	Mass exchange from each two components	
452	sur_il(n)	A_{li}	Interfacial surface area between interation-coolant with outer-liquid in unit volume	1/m
453	t(ip)	$T_{n,k}$	Local temperature	K
454	t0(ip)	–	Temperature related to enthalpy base reference	K
455	table(ik,jk)	–	The table used for table input	
456	talph(ip)	–	Average volume fraction of each component	
457	tau_1	τ_1	Transient time constant at the fragment surface	s
458	tau_2	τ_2	Transient time constant at the interaction-coolant surface	s
459	temp(n,ip)	–	Temperature	K
460	temp0(i,ip)	T_0	Initial temperature	K
461	tempig(n)	T_{ig}	Temperature of inner-liquid	K
462	tempil(n)	T_{il}	Temperature of inner-vapor	K
463	tempp(n,ip)	t^{t-1}	Temperature in previous time step	K
464	text	–	Temporal string in reading input file	
465	tig_	T_{ig}	Local temperature of inner-vapor of interaction-coolant	K
466	til_	T_{il}	Local temperature of inner-liquid of interaction-coolant	K
467	timdel	–	Time delay between the trigger arrived to beginning of the fragmentation	s
468	time	–	Calculation time	s
469	timetr(n)	–	Local time recording from the beginning of the trigger arrived	s
470	timfra(n)	τ_{frag}	Time last after the cell starting fragmentation	s
471	timfrg	–	Local time recording from the beginning of the fragmentation	s
472	timpig(n)	T_{ig}	Temperature of internal vapor of interaction-coolant	K
473	timpil(n)	T_{il}	Temperature of internal liquid of interaction-coolant	K

474	tkine	–	Total kinetic energy	J
475	tkinec	–	Total kinetic energy of coolant	J
476	tmass(ip)	–	Total mass of each component	kg
477	tmassp(ip)	–	Total mass of each component at previous time step	kg
478	tmasst	–	Total mass	kg
479	tmast0	–	Total initial mass	kg
480	tmastp	–	Total mass at previous time step	kg
481	tmeltf1(ik)	–	Saturate temperature 1 of fragments	K
482	tmeltf2(ik)	–	Saturate temperature 2 of fragments	K
483	tmeltm1(ik)	–	Saturate temperature 1 of melt	K
484	tmeltm2(ik)	–	Saturate temperature 2 of melt	K
485	totmms	–	Total mass of melt in the system	kg
486	trgini	–	Time start of initial trigger	s
487	trgtme	–	Initial trigger time last	s
488	ts (n)	T_{sat}	Saturate temperature	K
489	tsat	–	Local saturate temperature	K
490	tvmix	–	Volume of mixture region	m^3
491	tvtot	–	Total volume of the system	m^3
492	tvwat	–	Total volume of water	m^3
493	u(ip)	–	Local velcosity in x-direaction	m/s
494	ut(ip)	u_T	Local resultant of velocity	m/s
495	v(ip)	–	Local velcosity in y-direaction	m/s
496	velu(n,ip)	–	X-direction velocity	m/s
497	velu0(ia)	u_0	Initial x-direction velocity	m/s
498	velup(n,ip)	u^{t-1}	X-direction velocity in previous time step	m/s
499	velv(n,ip)	–	Y-direction velocity	m/s
500	velv0(ia)	v_0	Initial y-direction velocity	m/s
501	velvp(n,ip)	v^{t-1}	Y-direction velocity in previous time step	m/s
502	velw(n,ip)	–	Z-direction velocity	m/s
503	velw0(ia)	w_0	Initial z-direction velocity	m/s
504	vis(ip)	$\mu_{n,k}$	Local viscosity	$N/m^2 \cdot s$
505	visc(n, ip)	μ	Viscosity	$N/m^2 \cdot s$
506	vrmax	–	Maximum value for velocity difference in fragmentation model	m/s
507	vrmin	–	Minimum value for velocity difference in fragmentation model	m/s
508	vsig_	μ_{ig}	Local viscosity of inner-liquid of interaction-coolant	$N/m^2 \cdot s$
509	vtrg	–	Initial trigger velocity	m/s
510	we(n)	–	Weber number	
511	wecri	–	Critical Weber number for fragmentation	
512	wemax	–	Maximum of weber number	
513	x(i)	x_{ip}	Cell location on x-axis at (i+1) side	
514	xc(i)	x_c	Cell location on x-axis at cell center	
515	xdiv(ns)	–	Section length on x-direction	m
516	xgrid(n,8)	–	Array for cell size constants on x-axis	
517	xi(n)	x_I	Internal quality of the interaction coolant	
518	xip(n)	x_I^{t-1}	Internal quality of the interaction coolant at previous time step	

519	xleng	–	Geometry length on x-direction	m
520	y(i)	y_{ip}	Cell location on y-axis at (j+1) side	
521	yc(j)	y_c	Cell location on y-axis at cell center	
522	ydiv(ns)	–	Section length on y-direction	m
523	ygrid(n,14)	–	Array for cell size constants on y/r-axis	
524	yleng	–	Geometry length on y-direction	m
525	z(k)	z_{kp}	Cell location on z-axis at (k+1) side	
526	zc(k)	z_c	Cell location on z-axis at cell center	
527	zdiv(ns)	–	Section length on z-direction	m
528	zgrid(n,8)	–	Array for cell size constants on z-axis	

国際単位系 (SI) と換算表

表 1　SI 基本単位および補助単位

量	名称	記号
長さ	メートル	m
質量	キログラム	kg
時間	秒	s
電流	アンペア	A
熱力学温度	ケルビン	K
物質量	モル	mol
光度	カンデラ	cd
平面角	ラジアン	rad
立体角	ステラジアン	sr

表 2　SI と併用される単位

名称	記号
分，時，日	min，h，d
度，分，秒	°，′，″
リットル	l，L
トン	t
電子ボルト	eV
原子質量単位	u

1 eV = 1.60218 × 10^{-19} J

1 u = 1.66054 × 10^{-27} kg

表 5　SI 接頭語

倍数	接頭語	記号
10^{18}	エクサ	E
10^{15}	ペタ	P
10^{12}	テラ	T
10^{9}	ギガ	G
10^{6}	メガ	M
10^{3}	キロ	k
10^{2}	ヘクト	h
10^{1}	デカ	da
10^{-1}	デシ	d
10^{-2}	センチ	c
10^{-3}	ミリ	m
10^{-6}	マイクロ	μ
10^{-9}	ナノ	n
10^{-12}	ピコ	p
10^{-15}	フェムト	f
10^{-18}	アト	a

表 3　固有の名称をもつ SI 組立単位

量	名称	記号	他の SI 単位による表現
周波数	ヘルツ	Hz	s^{-1}
力	ニュートン	N	m·kg/s^2
圧力，応力	パスカル	Pa	N/m^2
エネルギー，仕事，熱量	ジュール	J	N·m
工率，放射束	ワット	W	J/s
電気量，電荷	クーロン	C	A·s
電位，電圧，起電力	ボルト	V	W/A
静電容量	ファラド	F	C/V
電気抵抗	オーム	Ω	V/A
コンダクタンス	ジーメンス	S	A/V
磁束	ウェーバ	Wb	V·s
磁束密度	テスラ	T	Wb/m^2
インダクタンス	ヘンリー	H	Wb/A
セルシウス温度	セルシウス度	℃	
光束	ルーメン	lm	cd·sr
照度	ルクス	lx	lm/m^2
放射能	ベクレル	Bq	s^{-1}
吸収線量	グレイ	Gy	J/kg
線量当量	シーベルト	Sv	J/kg

表 4　SI と共に暫定的に維持される単位

名称	記号
オングストローム	Å
バーン	b
バール	bar
ガル	Gal
キュリー	Ci
レントゲン	R
ラド	rad
レム	rem

1 Å = 0.1 nm = 10^{-10} m

1 b = 100 fm^2 = 10^{-28} m^2

1 bar = 0.1 MPa = 10^5 Pa

1 Gal = 1 cm/s^2 = 10^{-2} m/s^2

1 Ci = 3.7 × 10^{10} Bq

1 R = 2.58 × 10^{-4} C/kg

1 rad = 1 cGy = 10^{-2} Gy

1 rem = 1 cSv = 10^{-2} Sv

（注）

1. 表 1 − 5 は「国際単位系」第 5 版，国際度量衡局 1985 年刊行による。ただし，1 eV および 1 u の値は CODATA の 1986 年推奨値によった。
2. 表 4 には海里，ノット，アール，ヘクタールも含まれているが日常の単位なのでここでは省略した。
3. bar は，JIS では流体の圧力を表わす場合に限り表 2 のカテゴリーに分類されている。
4. EC 閣僚理事会指令では bar，barn および「血圧の単位」mmHg を表 2 のカテゴリーに入れている。

換算表

力	N(=10^5 dyn)	kgf	lbf
	1	0.101972	0.224809
	9.80665	1	2.20462
	4.44822	0.453592	1

粘度　1 Pa·s(N·s/m^2) = 10 P(ポアズ)(g/(cm·s))

動粘度　1 m^2/s = 10^4 St(ストークス)(cm^2/s)

圧力	MPa(=10 bar)	kgf/cm^2	atm	mmHg(Torr)	lbf/in^2(psi)
	1	10.1972	9.86923	7.50062 × 10^3	145.038
	0.0980665	1	0.967841	735.559	14.2233
	0.101325	1.03323	1	760	14.6959
	1.33322 × 10^{-4}	1.35951 × 10^{-3}	1.31579 × 10^{-3}	1	1.93368 × 10^{-2}
	6.89476 × 10^{-3}	7.03070 × 10^{-2}	6.80460 × 10^{-2}	51.7149	1

エネルギー・仕事・熱量	J(=10^7 erg)	kgf·m	kW·h	cal(計量法)	Btu	ft·lbf	eV
	1	0.101972	2.77778 × 10^{-7}	0.238889	9.47813 × 10^{-4}	0.737562	6.24150 × 10^{18}
	9.80665	1	2.72407 × 10^{-6}	2.34270	9.29487 × 10^{-3}	7.23301	6.12082 × 10^{19}
	3.6 × 10^6	3.67098 × 10^5	1	8.59999 × 10^5	3412.13	2.65522 × 10^6	2.24694 × 10^{25}
	4.18605	0.426858	1.16279 × 10^{-6}	1	3.96759 × 10^{-3}	3.08747	2.61272 × 10^{19}
	1055.06	107.586	2.93072 × 10^{-4}	252.042	1	778.172	6.58515 × 10^{21}
	1.35582	0.138255	3.76616 × 10^{-7}	0.323890	1.28506 × 10^{-3}	1	8.46233 × 10^{18}
	1.60218 × 10^{-19}	1.63377 × 10^{-20}	4.45050 × 10^{-26}	3.82743 × 10^{-20}	1.51857 × 10^{-22}	1.18171 × 10^{-19}	1

1 cal = 4.18605 J (計量法)

= 4.184 J (熱化学)

= 4.1855 J (15 °C)

= 4.1868 J (国際蒸気表)

仕事率　1 PS (仏馬力)

= 75 kgf·m/s

= 735.499 W

放射能	Bq	Ci
	1	2.70270 × 10^{-11}
	3.7 × 10^{10}	1

吸収線量	Gy	rad
	1	100
	0.01	1

照射線量	C/kg	R
	1	3876
	2.58 × 10^{-4}	1

線量当量	Sv	rem
	1	100
	0.01	1

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