PFC/RR-83-11

# LITFIRE USER'S GUIDE

by

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# ON FUSION SAFETY

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# LITFIRE USER'S GUIDE

## Abstract

Instructions for using the current form of the LITFIRE code are summarized in this document. This includes :

- the various modeling options available to the user
- the operational commands needed to execute the code

This guide is designed to be used in conjunction with the following reports :

- MITNE-219
- MIT PFC/RR-80-11
- MIT PFC/RR-83-08

# TABLE OF CONTENTS

# LIST OF FIGURES

# 1. Introduction

The computer code, LITFIRE, generates temperature and pressure time profiles which describe the response of a simulated fusion reactor containment to lithium/ lithium lead eutectic spills. This guide briefly describes the operating sequence of the code. It also discusses the available modeling options, as well as the computer commands required to execute the code.

The present version of LITFIRE currently resides on two computing facilities: the MIT-PFC-VAX and the National Magnetic Fusion Energy Computer Center (MFECC) facilities. It is written in the language of FORTRAN, compatable with the individual computing facilities. LITFIRE is accessable for the public's use, and can be executed by following the instructions listed in this guide.

This guide is not intended to be the only source of information on LITFIRE. As mentioned above, this report's purpose is to introduce to the new user the available modeling options and necessary executable computer commands. If a section in this guide is not sufficiently clear, or a detailed description of the physical models or code verification is required, consult the list of references. A list of nomenclature appears in Appendix A, and a listing of the variable designations in LITFIRE appears in Appendix B.

## 2. Program Description

To assist the new user of LITFIRE in understanding the code, a brief descriptive section is included. This section is broken down into a pre-dynamic cycle portion, and a dynamic cycle part. The dynamic cycle contains the time integrations and most of the calculations which determine the rates of change used in the integrals. The pre-dynamic cycle prepares the code for these calculations.

### 2.1. Pre-Dynamic Cycle

The four parts of the pre-dynamic cycle are :

(i) read in the input data
(ii) write out the input data
(iii) initialize the variables
(iv) spray fire calculation

### 2.1.1. Input Data

The input data consists of titles and headings, control flags, geometry specifications, initial conditions, and properties. In addition to these mandatory inputs, there are various options which can be chosen. These options are discussed in Section 2.3, Modeling Options. For a description of the input variables, see Section 3.1, LITFIRE and Input Data Files.

### 2.1.2. Print out the Input

This section is self-explanatory. It is suggested that in all cases, regardless of the outcome of the computations, the input be carefully examined. This habit can be very valuable in locating errors before they become large problems.

### 2.1.3. Variable Initialization

The initialization section zeros all quantities for the first time step. Constants are defined and initial conditions are applied using the input. In addition, there is a brief sub-section where the units are changed to become consistent with the code's calculations :

BTU , lbm , feet , seconds

### 2.1.4. Spray Fire Calculation

The spray fire calculation assumes that an amount of lithium is consumed as a spray at the initiation of the event. The amount is user specified. Then the only difficulty comes from the fact that the products' specific heats, $c_p$ , are functions of temperature. The lithium is consumed instantaneously, adiabatically, and stoichiometrically, with the equilibrium temperatures being solved by iteration.

## 2.2. Dynamic Cycle

The main purpose of the dynamic cycle in LITFIRE is the generation of time dependent temperature, pressure, and mass profiles. The bulk of this section consists of calculations for the time dependent thermal admittances between nodes, which ultimately yield the temperature rates of change.

The heat flows are determined by analogy with electric circuits :

$$q_{12} = \frac{(T_1 - T_2)}{\sum_i \frac{1}{h_i A_i} + \sum_j \frac{\Delta x}{k_j A_j}} + \sum_k F_k \sigma_k A_k T_k^4 \tag{1}$$

While the temperature rates of change utilize :

$$mc_p\left(\frac{dT}{dt}\right) = q_{in} - q_{out} \tag{2}$$

The consequent integration of the temperature rates of change is through the use of either fourth-order Runge-Kutta method or Simpson's rule. The integration takes on the form of :

$$Y(t) = Y(t_o) + \int_{t_o}^{t} dt' \frac{dY}{dt'} \tag{3}$$

where (dY/dt') is a temperature rate of change calculated in LITFIRE by finite differencing. (See Appendix A for all nomenclature definitions)

In addition to these fundamental calculations, there are many peripheral calculations. The order of appearance in LITFIRE for the many dynamic cycle calculations is as follows :

(i) calculate temperature dependent properties : heat capacities, gas fractions, radiative interchange factors, and emmisivities

(ii) natural convection coefficients

(iii) preliminary thermal admittances

(iv) test for combustion/no combustion

(v) calculate temperature rates of change from combined conduction, convection, and radiation

(vi) overpressure, leakage, and aerosal sticking

(vii) integrals

(viii) checks for terminating execution

(ix) time step control

(x) printing of the output

(xi) error pointers

A brief discussion of these 11 sub-sections follows below :

### 2.2.1. Temperature Dependent Properties

Ideally, all properties should be calculated with respect to their temperature dependence. However, for code simplicity, many properties are assumed constant and appear as input variables. The references for the heat capacity correlations and a description of the derivation of the radiative interchange factors can be found in references 1 and 2.

### 2.2.2. Natural Convection Coefficients

The fundamental equation for convection heat transfer is :

$$Nu = C(GrPr)^{\frac{1}{3}} \tag{4}$$

where :

$$Nu = \frac{\mathrm{h}L}{k} \tag{5}$$

$$Gr = \frac{g\beta \Delta T L^3}{\nu^2} \tag{6}$$

$$Pr = \frac{C_p \mu}{k} \tag{7}$$

The natural convection heat transfer coefficient is calculated from equation (4) using correlations for the various properties occuring in the dimensionless numbers. A separate coefficient is calculated for each of the following :

pool $\mathrm{HB} = \mathrm{HINHB}\ \mathrm{Ra}^{\frac{1}{3}}(\frac{k}{L})$

inner liner wall $\mathrm{HFPGP} = \mathrm{HINGSP}\ \mathrm{Ra}^{\frac{1}{3}}(\frac{k}{L})$

extra heat capacity $\mathrm{HEHCP} = \mathrm{HIN}\ \mathrm{Ra}^{\frac{1}{3}}(\frac{k}{L})$

ambient interface $\mathrm{HA} = \mathrm{HINSAM}\ \mathrm{Ra}^{\frac{1}{3}}(\frac{k}{L})$

where : $\mathrm{Ra} = PrGr$

### 2.2.3. Preliminary Thermal Admittances

This is a small group of calculations, valid for either combustion or no combustion, which is used to generate the temperature rates of change for each option. More of these calculations appear later on, after the two parallel sections of the code rejoin.

### 2.2.4. Test for Combustion or No Combustion

Rates of change within the containment cell are considerably different in form, depending upon whether or not the pool is ignited. Two sets of calculations exist in the code, only one of which is excecuted for a given time step. The conditions which allow ignition are :

(i) lithium must be available
(ii) oxygen or nitrogen must be available
(iii) if no oxygen is available, then the combusiton zone temperature must be in the correct range

### 2.2.5. Temperature Rates of Change

These calculations are based upon the fundamental heat transfer relations for conduction, convection, and radiation, respectively.

$$\frac{dq}{dt} = kA\frac{dT}{dx} \tag{8}$$

$$\frac{dq}{dt} = h_c A(T_1 - T_2) \tag{9}$$

$$\frac{dq}{dt} = \sigma A F_k(T_1^4 - T_2^4) \tag{10}$$

References 1 and 2 have a detailed description of the above mechanics utilized.

### 2.2.6. Overpressure, Leakage, and Aerosol Behavior

The cell gas content and temperature are both quantities which are integrated in the integration section. From these, the cell gas pressure is computed. The leakage and sticking calculations are used to determine the species rates of change.

### 2.2.7. Integrals

All important masses and temperatures are integrated from one time step to the next. The form of these integrals is as follows :

$$P = \mathrm{INTGRL}\left(P_o\,,\ \frac{dP}{dt}\right) \tag{11}$$

where :

$P_o$ = the initial value of function P (mass or temperature)

$\frac{dP}{dt}$ = the time dependent rate of change in P

### 2.2.8. Termination Checks

The possible conditions which terminate execution of the code are :

(i) the lithium pool solidifies or vaporizes

(ii) the cell gas temperature returns to room temperature and no overpressure

### 2.2.9. Time Step Control

There are three techniques currently being used to determine the largest allowable time step. These restrictions are :

(i) the time step must be smaller than the inverse rates of change :

$$\text{DELT} < \text{RELERR T}/\left(\frac{dT}{dt}\right)$$

(ii) the conduction heat transfer limit must be satisfied :

$$\frac{\alpha \Delta t}{(\Delta x)^2} < 0.3$$

(iii) The user imposed maximum allowable time step must be obeyed :

*IF (DELT .GT. [user chosen value (0.03 to 0.3)]) DELT = (0.03 to 0.3)*

This statement is located at approximately line 1028 of the code.

### 2.2.10. Output Section

The output of LITFIRE is formatted in style and is stored during code execution in permanent output data files. Appendix E contains an example of the output from a LITFIRE code execution, corresponding to the input file in Appendix D.

### 2.2.11. Error Pointers

This final section is not actually part of the dynamic cycle. If, however, the code should ever diverge from its normal processing of data, an error message would be printed into the first output file, *out1.* , and code execution would cease.

## 2.3. Modeling Options

The LITFIRE code contains all the necessary equations to adaquately model a variety of spill conditions. There are two basic geometries in which a fire may be modeled : a one cell and a two cell case. In addition to these geometries, the lithium may be spilled into a partially insulated pan, or be allowed to react directly on the compartment floor. Another option which can be used is the concrete combustion or breech of liner subroutine. And finally, the user may model a spill consisting of a lithium/lead eutectic, $Li_7Pb_2$, $LiPb_4$, etc.

There are a number of additional options available which have to do with the mitigation of lithium fires. These include the following :

(i) gas flooding
(ii) emergency space cooling
(iii) emergency floor liner cooling
(iv) aerosol removal
(v) gas injection

Each one of the above options is disscussed below.

### 2.3.1. One Cell

The one cell model is the simplest geometry in which the LITFIRE code may be run. (see figure 2.3.1) This model is the foundation upon which all other subroutines are built. The concrete containment can be user specified for up to twenty (20) individual nodes. The inner liner can be of any material (preferably steel) that the user wishes. The containment gas is of user chosen composition. And finally, the entire structure may take on any physical dimensions the user desires.

The heat transfer equations are fixed by the code, so that meaningful results are obtained. The heat conduction, convection, and radiation equations are all solved simultaneously. The transfer of heat by any of these mechanisms, from node to node, is built into the code. For example : the steel liner accepts heat from the combustion zone, lithium pool, and containment gas through radiation, and through convection from the containment gas. It radiates heat back to these three nodes through radiation, and conducts heat to the concrete node. The above heat transfer mechanisms and their applications are described in references 1, 2, and 3.

### 2.3.2. Two Cell

The two cell option was developed in order to model Tokamak fusion reactors and the effects that lithium fires would have on their structural integrity. This option allows for the inclusion of a second containment gas, separate from the inner cell, and the inclusion of a variable sized, user specified, crack (see figure 2.3.2). The model calculates both the temperature response to a lithium spill, and the pressure fluxuations accompanied by such a spill. High velocity flows have been successfully tested by LITFIRE, as in the case of a vacuum torus spill (see reference 3).

### 2.3.3. Pan

Figure 2.3.3 shows a schematic of the pan option being employed. This subroutine may be used either with the one or two cell geometry, but not with the concrete combustion option. The pan option was conceived and incorporated into LITFIRE to model the HEDL experiments. The pan is user defined, both in dimension and composition. It contains two separate conrete nodes, both of which transfer no heat to their surroundings.

### 2.3.4. Concrete Combustion

The concrete combustion option of breech of floor liner subroutine, allows for the interaction of lithium with the concrete floor. This includes reactions with water, as well as certain components in the concrete. Reference 2 describes the interactions of lithium and concrete in detail.

### 2.3.5. Lithium/Lead Combustion

This option allows for the interaction of lithium/lead eutectics with various materials. In fact, all other options are compatable with this option, with the exception of the pre-dynamic cycle spray fire calculation. Also available with this option is the ability to choose whether a turbulent or layered pool type reaction should be used. This allows for either optomistic or pessimistic results, depending on the user's view of lithium fires. Refernece 3 discusses this option in detail.

### 2.3.6. Mitigation Options

The following is a list of options available to determine the consequences of certain mitigation techniques used in combatting lithium spills :

(i) gas flooding
(ii) emergency space cooling
(iii) emergency floor liner cooling
(iv) aerosol removal
(v) gas injection

Each option allows the user to specify additional heat removal mechanisms, in conjunction with the code's own mechanics. Each mitigation technique is described in detail in MITNE-219 (reference 1).

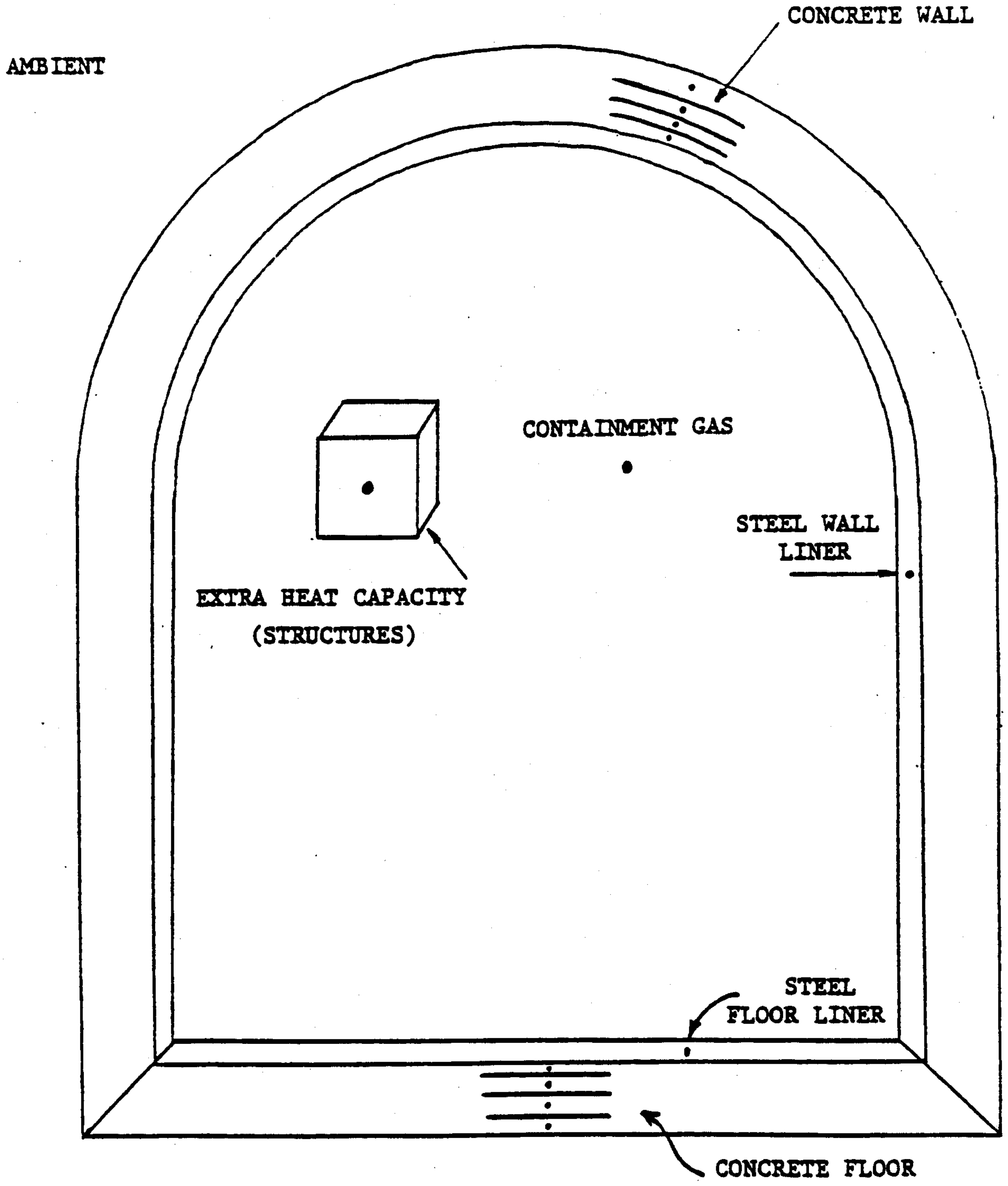

Figure 2.3.1 : One-Cell Geometry

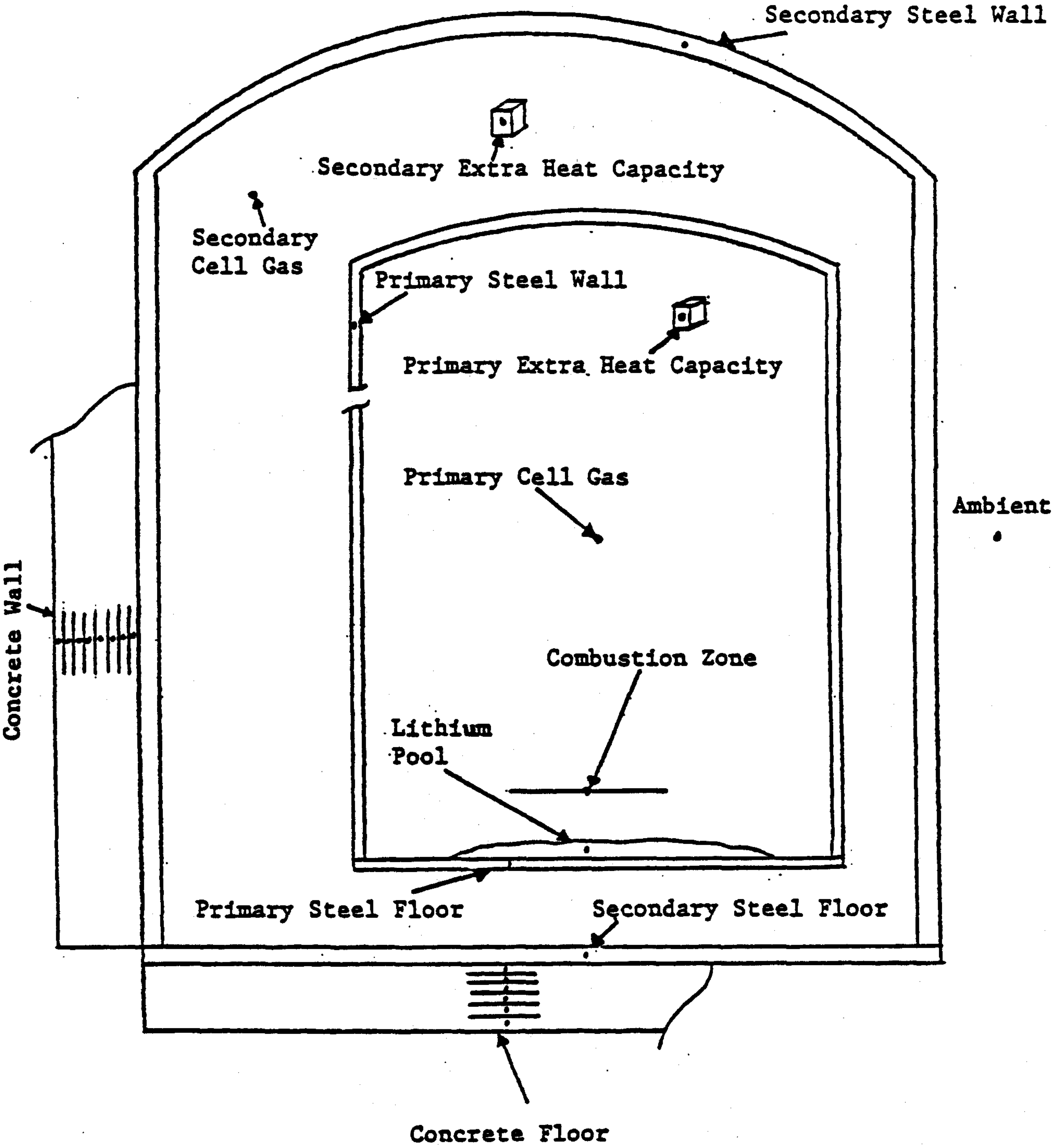

Figure 2.3.2 : Two-Cell Geometry

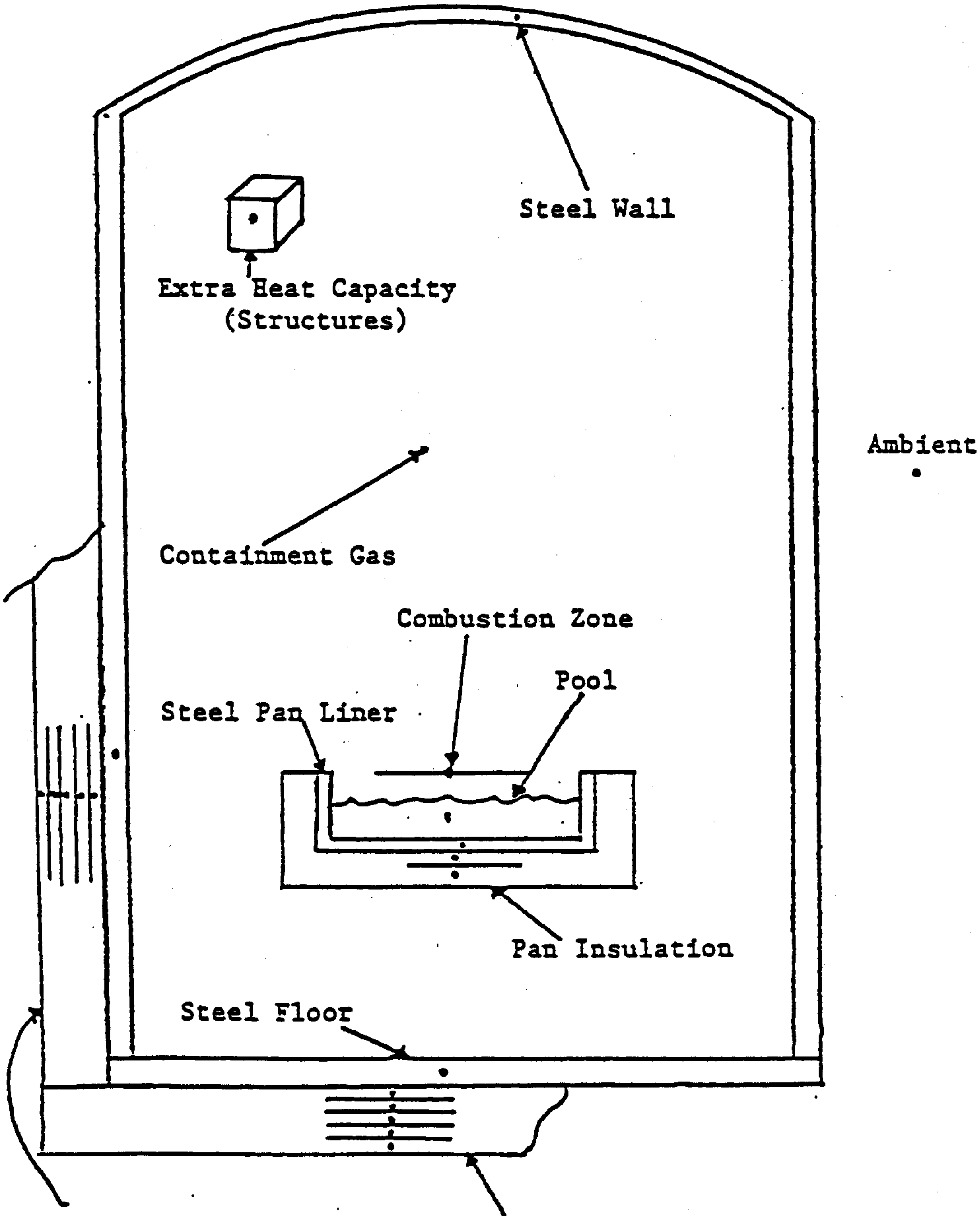

Figure 2.3.3 : One-Cell with Pan Geometry

## 3. Execution of LITFIRE

The execution of the code LITFIRE requires the input of certain system commands. The location of the code on either of the computing facilities necessitates specified commands for the compiling, loading (linking), and running of the code. For organizational purposes, the following will be the order of topic discussion :

(i) Source code and sample input data files
(ii) PFC-VAX
(iii) 7600-CDC <a machine>
(iv) CRAY <c and d machines>

### 3.1. LITFIRE and Input Data Files

There are two locations at which a copy of the source file LITFIRE can be found: the PFC-VAX and the MFECC FILEM disk storage.

To utilize the PFC-VAX copy, one must first have a PFC-VAX account. This may be accomplished by contacting Claude Barsotti at the Plasma Fusion Center, NW16-232, x3-8446, MIT. Introductory information is available for the new user by using the HELP command. This will explain most of the more often used commands, editors, and programs.

To place a copy of LITFIRE in one's filespace, the following command should be used :

```
copy_ [yak] litfirpb._ [username] litfirpb.
```

(where : _ means a space)

This will copy litfirpb. into the new user's directory.

To get copies of the three sample input data files, use the COPY command individually on :

1. *heading.*
2. *uwmak2.w*
3. *uwmak2.x*

For example :

user inputs : *copy_ [yak] heading.*
computer responds : ***To:***
user inputs : *[username] heading.*

After implementing the copy command on these files, the user can either use the TYPE command to view the files, or the EMACS command to edit the files.

To obtain a copy of LITFIRE on one of the MFECC computers, one must first be logged onto the 7600-CDC <a machine>. The user should then use the FILEM command; this gives the user access to the copy of LITFIRE. To copy LITFIRE into a directory type :

```
read_. 14600_ lita
```

This will copy LITFIRE (lita) into the user's directory on the 7600-CDC.

To get the three sample input data files out of FILEM, insert *heading*, *uwmak2.w*, and *uwmak2.x* individually into the *read_. 14600* command, while still in FILEM.

To transfer these files on the 7600-CDC to either of the CRAY's, NETOUT should be used. The following is an example on how to use the NETOUT command to send lita to a CRAY directory:

```
netout_ in = lita,site=cma,user=14600
```

Probably the most important step in the executing of the code, LITFIRE, is the organization of the input files. Depending on the options chosen, certain input files may or may not be used.

Listed below are the options which are available to the user. Each option is discussed separately in its own section.

(i) one cell
(ii) two cell
(iii) pan, concrete combustion, and lithium lead combustion
(iv) gas flooding, emergency space cooling, emergency floor liner cooling, aerosal removal, and gas injection

### 3.1.1. One Cell Option

The one cell option is the simplest manner in which the LITFIRE code can be run. Below is the order in which the variables must appear in the first input variable file.

| line | variables |
|---|---|
| 1 | FLAGW,IFLAGF,IFLAGP,IFLAG2,IFLAGS,<br>IFLAGC,IFLAGU,IFLAGB,IBLOW,IESC<br>ISFLC,ISWICH,IAROSL,IFLAGD,IFLAGISI |
| 2 | NL,NL1 |
| 3 | L(1) to L(NL) |
| 4 | L1(1) to L1(NL1) |
| 5 | VP,CHP,CPAP,XMOLA |
| 6 | TEHCZP,XMEHCP,AEHCP,CPEHCP,HINECP |
| 7 | THWC,THFC,GAP,KGAP,KLEAK |
| 8 | ESTLWP,CPSWP,KSTLWP,RHSWP,AWP,THWP |
| 9 | ESTLFP,CPSFP,KSTLFP,RHSFP,AFP,THFP |
| 10 | EMLI,CPLI,AKLI,RHLI |
| 11 | EMCONC,CPCON,KCON,RHCON |
| 12 | RHOLIO,RHOLIN,RHOLIH,EMGPF,EMCZ,TAUCZ |
| 13 | QCO1,QCO2,QCN,QCW |
| 14 | RCMBO1,RCMBO2,RCMBN,RCMBW,RCMBH2 |
| 15 | TMELT,TVAP,QVAP,PERCEN |
| 16 | HIN,HINGSP,HINGSS,HINPS,HINSAM,HINFAN |
| 17 | HINFGS,HINFSG |
| 18 | ASLI,SPILL,SPRAY,FRA,RA |
| 19 | TCZI,TGPZER,TSPZER,TSFPI,TA,TLII |
| 20 | PAPZER,WO2P,WWAP,WAP |
| 21 | IMETH,DTMIN,TIMEF,RELERR,DELOUT |

The format for the input is :

| line | variables |
|---|---|
| 1 | (1X,14(I1,1X)) |
| 2 | (I4,I4) |
| 3,4 | (10F5.3) |
| 5-20 | (6F12.4) |
| 21 | (I4,5F12.4) |

An example of this data file would be *uwmak2.w*, which is the data for the physical dimensions and properties of a UWMAK-III reactor design.

#### 3.1.1.1. PFC-VAX

The statement :

*open(unit=2,file='filename',status='old')*

must be included in the litfirpb. code in order for the code to execute. Therefore, if *uwmak2.w* were to be used as the first input variable file, the OPEN statement would read :

*open(unit=2,file='uwmak2.w',status='old')*

The location of the statement in the code is approximately at line 60.

#### 3.1.1.2. 7600-CDC <a machine> and CRAY's <c and d machines>

For these machines, the statement :

*call_ link("unit1=filename,...//")*

must be used.

### 3.1.2. Two Cell Option

If this option is chosen, the following is the variable listing of the second input variable file :

| line | variables |
|---|---|
| 1 | VS,CHS,PASZER,TGSZER,TSSZER,TFSZER |
| 2 | CRACK,WWAS,WO2S,WAS,CPAS |
| 3 | TEHCZS,XMEHCS,AEHCS,CPEHS,HINECS |
| 4 | ESTLWS,CPSWS,KSTLWS,RHWS,AWS,THWS |
| 5 | ESTLFS,CPSFS,KSTLFS,RHSFS,AFS,THFS |
| 6 | TSWICH |

Where the format for all lines is : (6f12.4)

### 3.1.2.1. PFC-VAX

If this option is chosen, the statement :

```
open(unit=3,file='filename',status='old)
```

must be included in the litfirpb. code. An example of this input variable file is the *uwmak2.x* data file, which is for the secondary cell characteristics of a UWMAK-III reactor design.

### 3.1.2.2. 7600-CDC <a machine> and CRAY's <c and d machines>

For these machines, the statement :

```
callL link("unit3=filename,..//")
```

must be used.

### 3.1.3. Pan, Concrete Combustion, and Lithium Lead Combustion

The following is the variable listing for each of above subroutine options :

If the pan option is chosen

| line | variables |
|---|---|
| 1 | KPAN,RHPAN,CPPAN,RHINS,CPINS,EMINS |
| 2 | TPANZO,APAN,BREDTH,AINS,HINGF |
| 3 | THKPAN,THKIN1,THKIN2 |

If the concrete combustion option is chosen :

| line | variables |
|---|---|
| (1) | ZZDIN,QCCONC,CRACON,XMH2OI,TCIGNI,RCMBC |

(1) The pan option cannot be chosen with concrete combustion

If the lithium lead combustion option is chosen :

| line | variables |
|---|---|
| 2(1) | CPLEAD,KLEAD,RHLEAD,ALLOYI,QDISS |

(1) if the concrete combustion option is not chosen

For **all lines**, a (6F12.4) format is used.

#### 3.1.3.1. PFC-VAX

The statement :

```
open(unit=4,file='filename',status='old')
```

must be included if any of the above options is used.

#### 3.1.3.2. 7600-CDC <a machine> and CRAY's <c and d machines>

For these machines, the statement :

```
call_ link("unit4=filename,...//")
```

must be used.

### 3.1.4. Gas Flooding, Emergency Space Cooling, Emergency Floor Liner Cooling, and Gas Injection

Each of these options is included in one input data file. If any of the above options is chosen, the statement :

```
open(unit=5,file='filename',status='old')
```

The line number of each option will vary, depending on which options are chosen. However, the below listing is the order in which the variables would be read, if all the options had been chosen.

| line | variables |
|---|---|
| 1 (gas flooding) | WO2B,WWAB,WN2B,XMOLAB,CPAB,TBLOW |
| 2 (emerg. space cooling) | ESCR,ESCTIN,ESCEND |
| 3 (emerg. floor cooling) | SFLCR,SFLTIN,SFLEND |
| 4 (aerosol removal) | BETA |
| 5 (gas injection) | TONE,TTWO,TTHREE,DP1,DP2,DP3,FCT1,FCT2,FCT3 |

The formats for all options except the gas injection option is (6F12.4). For the gas injection routine it is (3F10.2,6F8.4).

#### 3.1.4.1. PFC-VAX

The statement :

```
open(unit=5,file='filename',status='old')
```

must be included if any of the above options is used.

#### 3.1.4.2. 7600-CDC <a machine> and CRAY's <c and d machines>

For these machines, the statement :

```
call_ link("unit5=filename,...//")
```

must be used.

### 3.2. PFC-VAX (execution)

If running the code LITFIRE on the PFC-VAX, one must first be certain that all necessary OPEN statements are included. This will allow for the proper reading in of data from the included input data files. The input data file, heading., is always required because it contains the various headings used in the output files. Thus, the following OPEN statement will always appear in the LITFIRE code :

```
open(unit=1,file='heading.',status='old')
```

This statement requires that the file, heading. , be in theuser's filespace.

There are three separate steps in executing the source code, litfirpb. :

(i) compiling
(ii) linking
(iii) running

To compile litfirpb. , the command is :

```
fortran_ litfirpb.
```

This will create an object file named , litfirpb.obj .

To link litfirpb.obj , the command line is :

```
link_ litfirpb.obj
```

This will create the executable binary file named, litfirpb.exe .

Finally, to run litfirpb.exe type :

```
run_ litfirpb
```

If the input data files are all properly formatted, the code should run until the time limit is reached, TIMEF, or, until the code stops its execution.

ie. 'temperature of the lithium pool has reached the melting point'

If the code stops for some other reason, refer to Appendix B which discusses troubleshooting.

### 3.3. 7600-CDC <a Machine> (execution)

If running the code, lita , on the <a machine>, the file, heading , must be in the CALL LINK statement :

```
call_ link("unit1=heading,...//")
```

Also, the appropriate input data files must be in this statement. The ten (10) output data files which are in the CALL LINK statement should always be included. DO NOT delete any one of these files, for each one may be necessary, depending on the input options chosen.

The easiest method to compile, load, and execute lita is in the following manner :

1. type :
   ```
   chatr_i=lita,lib=fortlib,x=xlita_/_t_v
   ```
   where : t means the total maximum CPU time allowed
   v determines the priority

for : t = 1 CPU maximum

v = 0.5

priority = t*v = 0.5

CHATR will form an executable binary file, (xlita), which can then be run.

2. type :
   ```
   xlita_/_t_v
   ```

This will run xlita, and depending on the priority, no more than one or two CPU's should be required.

### 3.4. CRAY <c and d machines>

To execute lita on either of the two CRAY's, the same CALL LINK statements should be used as for the 7600-CDC. To compile, load, and execute lita, however, the following commands should be used :

1. `rcft_i=lita,lib=fortlib,x=xlita_/_t_v`
2. `xlita_/_t_v`

Again, no more than one or two CPU's should be required to run xlita.

## 3.5. Sample Input / Output

To check whether the new user of LITFIRE has executed the code correctly, a set of sample input and output files have been included in the Appendices C and D. An execution on any of the three machines (VAX, 7600, CRAY) gives approximately the same results.

Using the input data files :

*heading.*

*uwmak2.w*

*uwmak2.x*

the following output files should be generated :

*out1.*

*out2.*

*out3.*

*out5.*

*out7.*

*out8.*

# APPENDICES

# Appendix A

## Nomenclature

$A_{i,j,k}$ = heat transfer surface areas
$c_p$ = natural convection heat transfer coefficient
$c_p$ = specific heat
$F_k$ = radiation view factor, including emissivity
$g$ = acceleration of gravity
$Gr$ = Grashof number
$h_c$ = coefficient of heat transfer by convection
$k, k_j$ = thermal conductivity
$L$ = linear dimension
$m$ = mass
$Nu$ = Nusselt number
$Pr$ = Prandtl number
$dq/dt$ = heat flow rate
$t$ = time
$T$ = temperature
$x$ = linear distance
$Y$ = general function of time
$\alpha$ = thermal diffusivity
$\beta$ = coefficient of volume expansion
$\mu$ = viscosity
$\nu$ = kinematic viscosity
$\rho$ = gas density
$\sigma, \sigma_k$ = Stefan-Boltzman constant

# Appendix B

## This is the variable glossary for LITFIRE

| | |
|---|---|
| ACTVTY | CALULATES ACTIVITY OF LITHIUM IN LIPB |
| AEHCP | SURFACE AREA OF PRIMARY EXTRANEOUS HEAT CAPACITY (FT2) |
| AEHCS | SURFACE AREA OF SECONDARY EXTRANEOUS HEAT CAPACITY (FT2) |
| AFP | AREA OF THE PRIMARY STEEL FLOOR THAT IS OF INTEREST IN HEAT TRANSFER CALCULATIONS. USUALLY EQUAL TO "ASLI" WHEN LITHIUM IS SPILLED DIRECTLY ONTO FLOOR. |
| AFS | SURFACE AREA OF SECONDARY STEEL FLOOR LINER (FT2) |
| AHT | SURFACE AREA OR HEAT TRANSFER BETWEEN LITHIUM POOL AND PAN (FT2) |
| AINS | OUTSIDE EXPOSED AREA OF INSULATING LAYER ON PAN (FT2)) |
| AKLEAD | THERMAL CONDUCTIVITY OF LEAD (BTU/FT.-SEC-DEG. F.)<br>INPUT AS (BTU/FT. HR. DEG. F.) |
| AKLI | THERMAL CONDUCTIVITY OF LITHIUM (BTU/FT.-SEC-DEG. F.)<br>INPUT AS (BTU/FT. HR. DEG. F.) |
| AK1,AK2,AK3ES,<br>AK3EP,AK4H,AK5 | PROD. OF THERMAL COND. AND PRANDTL NO.<br>(BTU/SEC-FT.-DEG. F.) SEE RELATED FILM TEMPS. "T" |
| ALLOYI | INITIAL ATOM PERCENT OF LI IN LIPB SPILLED |
| ALPHA | USED IN DETERMINING IF LILP SHOULD BE FIXED AT A MINIMUM EQUAL TO AKLI/(RHLI*CPLI) |
| ALPHA2 | USED IN DETERMING PYU. TESTS CONDUCTION LIMIT OF THE PAN OR STEEL LINER ON TIME STEP |
| AMIN1 | A FORTRAN SUPPLIED STATEMENT THAT DETERMINES THE MINIMUM VALUE OF THE ARGUMENTS LISTED. |
| AMLI | ATOMIC MASS OF BREEDER |
| AMPB | ATOMIC MASS OF ALLOY METAL |
| APAN | PAN EXTERNAL AREA FOR HEAT TRANSFER |
| ARE | SURFACE AREA OF BREEDER ELEMENT |
| ASLI | SURFACE AREA OF LITHIUM (FT2) |
| ATI | INNER SURFACE AREA OF COOLANT TUBES IN ELEMENT |
| ATO | OUTER SURFACE AREA OF COOLANT TUBES IN ELEMENT |
| AWP | PRIMARY CONTAINMENT EXPOSED WALL AREA (FT2) |
| AWS | SECONDARY CONTAINMENT EXPOSED WALL AREA (FT2) |
| B | USED IN CALC. THERMAL RESIST. OF LINER-GAP-CONC. (FT.) |
| BB | ANALOGOUS TO B , ONLY FOR FLOOR CONCRETE |
| B1,B2,B3EP,B3ES,<br>B4,B4H,B5 | COEFFICIENT. OF GAS EXPANSION (1/DEG. F.)<br>SEE RELATED FILM TEMPS. "T" |
| BETA | THE INVERSE STICKING COEFFICIENT FOR PARTICLES IMPACTING ON A WALL (SEC) |

| | |
|---|---|
| BIL | FRACTION CHANGE BETWEEN BILGE AND DELT USED IN DETERMINING MINIMUM TIME STEP. |
| BILGE | EQUAL TO THE MINIMUM VALUE OF DT1, DT2, DT3, DT4, OR DT5 USED IN CALCULATING THE TIME STEP |
| BLIN | TIME AFTER SPILL AT WHICH INERT GAS FLOODING AND EXHAUST BEGINS (SEC) |
| BLOUT | TIME AFTER SPILL AT WHICH FLOODING AND EXHAUST STOPS (SEC) |
| BLOWR | INERT GAS INPUT RATE (LB/SEC) |
| BLOWV | INERT GAS INPUT RATE (FT3/MIN) |
| BREAKS | OUTER CELL TEMP. RATE OF CHANGE DUE TO CELL GAS LEAKAGE |
| BREDTH | LENGTH AROUND THE SIDE OF THE SPILL PAN IN FEET |
| | "C" IS THE INITIAL USED FOR INDICATING A THERMAL DIFFUSIVITY. I.E., A CONDUCTIVITY BETWEEN TWO NODES DIVIDED BY THE HEAT CAPACITY OF ONE OF THOSE NODES |
| C1 | CONTAINMENT GAS TO WALL STEEL IN GAS |
| C2 | PAN TO CONT. GAS IN GAS |
| C3 | STEEL LINER TO CONCRETE WALL IN WALL |
| C4(I) | CONCRETE NODE I TO NODE I+1 IN WALL CONCRETE |
| C5 | CONCRETE WALL TO AMBIENT IN CONCRETE |
| C6 | CONTAINMENT GAS TO WALL STEEL IN STEEL |
| C7 | STEEL LINER TO CONCRETE WALL IN STEEL |
| C8 | STEEL LINER TO CONCRETE FLOOR IN STEEL |
| C9 | STEEL LINER TO CONCRETE FLOOR IN CONCRETE |
| C10(I) | CONCRETE FLOOR NODE I TO NODE I+1 IN FLOOR CONCRETE |
| C11 | STEEL WALL LINER TO AMBIENT (NO CONCRETE OPTION) IN STEEL |
| C12 | STEEL FLOOR LINER TO AMBIENT (NO CONCRETE OPTION) IN STEEL |
| C13 | PAN TO GAS IN PAN |
| C14 | SECONDARY STEEL FLOOR TO SECONDARY GAS IN STEEL |
| C15 | SECONDARY STEEL FLOOR TO SECONDARY GAS IN GAS |
| C16 | PRIMARY STEEL FLOOR TO PRIMARY GAS IN STEEL |
| C17 | PRIMARY STEEL FLOOR TO PRIMARY GAS IN GAS |
| C18 | PRIMARY STEEL FLOOR TO SECONDARY GAS IN STEEL |
| C19 | PRIMARY STEEL FLOOR TO SECONDARY GAS IN GAS |
| C20 | PRIMARY STEEL WALL TO SECONDARY GAS IN STEEL |
| C21 | SECONDARY STEEL LINER TO SECONDARY CELL GAS IN STEEL |
| C22 | PRIMARY STEEL WALL TO SECONDARY GAS IN GAS |
| C23 | SECONDARY STEEL LINER TO SECONDARY CELL GAS IN GAS |
| CCZ | AMOUNT OF HEAT BEING DEVELOPED IN THE COMB. ZONE (BTU/SEC) |
| CCZG | COMBUSTION ZONE TO CONTAINMENT GAS IN GAS |
| CCZP | POOL TO COMBUSTION ZONE IN POOL |
| CD | COEFFICIENT OF DISCHARGE (NEAR UNITY) |
| CEHCGP | THERMAL DIFFUSIVITY BETWEEN PRIMARY EXTR. HEAT CAPACITY AND PRIMARY GAS IN PRIMARY GAS |
| CEHCGS | THERMAL DIFFUSIVITY BETWEEN SECONDARY EXTR. HEAT CAPACITY AND SECONADRY GAS IN SECONDARY GAS |

| | |
|---|---|
| CF | THERMAL IMPEDANCE BETWEEN BREEDER ELEMENTS IN INNER ELEMENT |
| CGCZ | COMBUSTION ZONE TO CONTAINMENT GAS IN COMBUSTION ZONE |
| CGLI | POOL TO CONTAINMENT GAS (NO COMBUSTION) IN POOL |
| CGPEHC | THERMAL DIFFUSIVITY BETWEEN PRIMARY GAS AND PRIMARY EXTRANEOUS HEAT CAPACITY IN EXTR. HEAT CAPACITY |
| CGSEHC | THERMAL DIFFUSIVITY BETWEEN SECONDARY GAS AND SECONDARY EXTRANEOUS HEAT CAPACITY IN EXTR. HEAT CAPACITY |
| CHP | PRIMARY CONTAINMENT HEIGHT (FT.) |
| CHS | SECONDARY CONTAINMENT HEIGHT (FT.) |
| CIN1PN | STEEL PAN TO INNER INSULATION IN INSULATION |
| CIN12 | INNER TO OUTER INSULATION IN INNER INSULATION |
| CIN21 | INNER TO OUTER INSULATION IN OUTER INSULATION |
| CLIG | POOL TO CONTAINMENT GAS (NO COMBUSTION) IN GAS |
| CLIPAN | POOL TO SPILL PAN IN POOL (SUSP. PAN OPTION) |
| CLIST | LITHIUM POOL TO FLOOR STEEL IN LITHIUM |
| CMBR | TOTAL COMBUSTION RATE (LB LI/SEC-FT2) |
| CMBRH | TOTAL COMBUSTION RATE (LB LI/HR.-FT2) |
| CMBRHI | INITIAL COMBUSTION RATE (LB LI/HR-FT2) |
| CMBRN | COMB. RATE FOR NITROGEN REACTION (LB LI/SEC-FT2) |
| CMBRO | COMB. RATE FOR OXYGEN REACTION (LB LI/SEC-FT2) |
| CMBRW | COMB. RATE FOR WATER VAPOR REACTION (LB LI/SEC-FT2) |
| CPA | INERT GAS SPECIFIC HEAT (BTU/LB-DEG. F.) |
| CPAB | SPEC. HEAT OF FLOODING GAS (BTU/LB-DEG. F.) |
| CPANLI | POOL TO PAN IN PAN |
| CPAP | SPECIFIC HEAT OF PRIMARY CELL INERT GAS (BTU/LB-DEG. F.) |
| CPAS | SPECIFIC HEAT OF SECONDARY CELL INERT GAS (BTU/LB-DEG. F.) |
| CPCON | HEAT CAPACITY OF FLOOR AND WALL CONCRETE |
| CPCZ | LITHIUM POOL TO COMBUSTION ZONE IN COMBUSTION ZONE |
| CPEHCP | SPECIFIC HEAT OF PRIMARY EXTRANEOUS HEAT CAPACITY (BTU/LB-DEG. F.) |
| CPEHCS | SPECIFIC HEAT OF SECONDARY EXTRANEOUS HEAT CAPACITY (BTU/LB-DEG. F.) |
| CPFAC | USED IN CALCULATING CPLI (CPFAC = .004938**TLI -6.20741) |
| CPH2 | SPECIFIC HEAT OF HYDROGEN GAS<br>SET TO 3.76 (BTU/LB-DEG. F.) IN PROGRAM |
| CPINS | SPECIFIC HEAT OF INSULATION (BTU/LB-DEG. F.) |
| CPLEAD | SPECIFIC HEAT OF PURE LEAD |
| CPLI | SPECIFIC HEAT OF LI (BTU/LB-DEG. F.) |
| CPLIH | SPECIFIC HEAT OF LITH. HYDROXIDE IN CONT.<br>SET TO 0.67 (BTU/LB-DEG. F.) IN PROGRAM. |
| CPLIN | SPECIFIC HEAT OF LITHIUM NITRIDE (BTU/LB-DEG. F.) |
| CPLINP | SPECIFIC HEAT OF LITH. NITRIDE IN PRIMARY CONT. (BTU/LB-DEG. F.) |
| CPLINS | SPECIFIC HEAT OF LITH. NITRIDE IN SECONDARY CONT. (BTU/LB-DEG. F.) |
| CPLIO | SPECIFIC HEAT OF LITHIUM OXIDE (BTU/LB-DEG. F.) |
| CPLIOH | SPECIFIC HEAT OF LIOH (BTU/LB-MOLE-DEG. F.) |
| CPLIOP | SPECIFIC HEAT OF LITHIUM OXIDE IN PRIMARY (BTU/LB-DEG. F.) |
| CPLIOS | SPECIFIC HEAT OF LITHIUM OXIDE IN SECONDARY (BTU/LB-DEG. F.) |

| | |
|---|---|
| CPLI1 | MEAN HEAT CAPACITY OF BREEDER AS SOLID (BTU/LB-MOLE-DEG. R.) |
| CPMCZ | EFFECTIVE HEAT CAPACITY OF COMB. ZONE (BTU/DEG. F.) |
| CPMH2 | HEAT CAPACITY OF HYDROGEN IN CONTAINMENT (BTU/DEG. F.) |
| CPMLOS | HEAT CAP. OF LITHIUM OXIDE IN PRIMARY CONT. (BTU/DEG. F.) |
| CPMLOP | HEAT CAP. OF LITHIUM OXIDE IN SECONDARY CONT. (BTU/DEG. F.) |
| CPMNIP | HEAT CAPACITY OF NITROGEN IN PRIMARY CONT. (BTU/DEG. F.) |
| CPMNIS | HEAT CAPACITY OF NITROGEN IN SECONDARY CONT. (BTU/DEG. F.) |
| CPMOXP | HEAT CAPACITY OF OXYGEN IN PRIMARY CONTAINMENT (BTU/DEG. F.) |
| CPMOXS | HEAT CAPACITY OF OXYGEN IN SECONDARY CONTAINMENT (BTU/DEG. F.) |
| CPMWA | HEAT CAP. OF WATER VAP. IN (BTU/LB-MOLE) |
| CPMWA | HEAT CAP. OF WATER VAP. IN CONTAINMENT (BTU/DEG. F.) |
| CPNIN1 | THERMAL DIFFUSIVITY OF STEEL PAN TO INNER INSULATION IN PAN |
| CPN2P | SPECIFIC HEAT OF NITROGEN GAS IN PRIMARY CONT. (BTU/LB-DEG. F.) |
| CPN2S | SPECIFIC HEAT OF NITROGEN GAS IN SECONDARY CONT. (BTU/LB-DEG. F.) |
| CPPB | HEAT CAPACITY OF ALLOY METAL IN BREEDER ZONE (BTU/LB-DEG. F.) |
| CPPB1 | MEAN HEAT CAPACITY OF ALLOY METAL SOLID (BTU/LB-MOLE-DEG. R.) |
| CPPL | LIQUID HEAT CAPACITY OF ALLOY METAL (BTU/LB-DEG. F.) |
| CPPZ | HEAT CAPACITY OF ALLOY METAL IN REACTION ZONE (BTU/LB-DEG. F.) |
| CPSTL | HEAT CAPACITY OF STEEL LINER (BTU/LB-DEG. F.) |
| CPWA | SPEC. HEAT OF WATER VAPOR. SET TO 0.44 (BTU/LB.-DEG. F.) |
| CP1 | USED TO CALCULATE CP CHANGE OF ALLOY METAL (BTU/LB-DEG. R.) |
| CP2 | USED TO CALCULATE CP CHANGE OF ALLOY METAL (BTU/LB-DEG. R.) |
| CRACON | AREA OF CONCRETE EXPOSED TO LITHIUM IN CONCRETE COMBUSTION MODEL (FT2) |
| CRACK | AREA OF ORIFICE BETWEEN PRIMARY AND SECONDARY CONTAINMENTS THE UNITS OF CRACK ARE SQUARE INCHES!!! CONVERTED TO (FT2) IN PROGRAM |
| CSBLI | THERMAL DIFFUSIVITY OF LITHIUM POOL TO FLOOR STEEL IN STEEL |
| CT | THERMAL IMPEDANCE BETWEEN BREEDER ELEMENTS IN OUTER ELEMENT |
| DELH | STANDARD HEAT OF HYDROLSIS OF BREEDER (BTU/LB-MOLE) |
| DELMP | FRACTIONAL EXCHANGE RATE OF PRIMARY GAS (IN SEC) USED IN DETERMINING THE MINIMUM TIME STEP |
| DELMS | FRACTIONAL EXCHANGE RATE OF SECONDARY GAS (IN SEC) USED IN DETERMINING THE MINIMUM TIME STEP |
| DELOUT | OUT TIME STEP (SEC) |
| DELT | INTEGRATION TIME STEP (SEC) |
| DFILM | LITHIUM VAPOR FILM THICKNESS (FT.) |
| DFLIPB | DIFFUSION COEFFICIENT FOR LITHIUM THROUGH LEAD FT2/SEC |
| DIFF | DIFFUSION COEFF. TO COMB. ZONE FT2/SEC |
| DIFFLI | LITHIUM VAPOR DIFFUSION COEFFICIENT FT2/SEC |
| DMPBDT | MASS RATE OF CHANGE OF LEAD IN LEAD LAYER (LB/SEC) |
| DPROD | ENTHALPY CHANGE OF REACTION PRODUCTS IN REACTION ZONE |
| DP1,..DP3 | PSIA INCREASE IN CONTAINMENT PRESSURE DUE TO EACH INJECTION |
| DREAC | ENTHALPY CHANGE OF REACTANTS IN REACTION ZONE |
| DTBDT(I) | CONC. FLOOR TEMP. RATE OF CHANGE, NODE I (DEG. F./SEC) |
| DTCDT(I) | CONC. WALL TEMP. RATE OF CHANGE, NODE I (DEG. F./SEC) |

| | |
|---|---|
| DTMIN | MINIMUM TIME STEP TO BE USED (SEC) |
| DT1,..DT4 | USED IN CALCULATING TIME STEP (SEC) |
| DT1 | POOL TIME STEP (TEMP./RATE OF CHANGE OF TEMP.) |
| DT2 | CONT. GAS TIME STEP |
| DT3 | STEEL WALL TIME STEP |
| DT4 | COMBUSTION RATE TIME STEP |
| DT5 | COMBUSTION ZONE TEMP. TIME STEP |
| DYNAMI | SUBROUTINE USED IN CONTROLLING INTEGRATION LOOPS |
| D1,D2,DEP,D3ES, D4,D4H,D5 | KINEMATIC VISCOSITY OF CELL GAS (SQUARED) (FT4/SEC2) SEE RELATED FILM TEMPS "T" |
| EFILM | FILM DEPTH OF DEPLETED ZONE ABOVE COMB. ZONE (IN INCHES) |
| EMCONC | THERMAL EMISSIVITY OF CONCRETE |
| EMCZ | THERMAL EMISSIVITY OF COMBUSTION ZONE |
| EMF | USED IN FIXING MINIMUM THERMAL EMISSIVITY OF LI POOL SET EQUAL TO .9 IN PROGRAM |
| EMGP | THERMAL EMISSIVITY OF PRIMARY CELL GAS MINIMUM VALUE OF .005 IN PROGRAM |
| EMGS | THERMAL EMISSIVITY OF SECONDARY CELL GAS MINIMUM VALUE OF .005 IN PROGRAM |
| EMINS | THERMAL EMISSIVITY OF INSULATION AROUND PAN |
| EMLI | THERMAL EMISSIVITY OF LITHIUM POOL |
| EMSTL | THERMAL EMISSIVITY OF STEEL LINER |
| ESCR | HEAT REMOVAL RATE BY EMERGENCY SPACE COOLING (BTU/SEC) |
| ESCTIN | TIME AFTER SPILL WHEN ESCR BEGINS (SEC) |
| EXHSTR | RATE OF CONTAINMENT GAS EXHAUST (LB/SEC) |
| EXHSTV | RATE OF CONTAINMENT GAS EXHAUST (FT3/SEC) |
| EXX | USED IN CALC. MASS & HEAT TRANSF. COEFF. (1/FT3) |
| EX1,EX2 | EX3EP,EX3ES,EX4H,EX5 USED IN CALCULATING MASS & HEAT TRANSF. COEFF. (1/FT.) SEE RELATED FILM TEMPS "T" |
| FCT1,FCT2,FCT3 | FRACTION OF NITROGEN PRESENT IN EACH INJECTION (BY NO.) |
| FF1,FF2 | USED IN HEAT BALANCE EQS. FOR SPRAY FIRE (BTU) |
| FMLEAK | FRACT. OF MASS LEAKED OUT OF CONTAINMENT |
| FMLEFT | FRACTION OF MASS STILL WITHIN CONTAINMENT |
| FNIP | WT. FRACTION OF NITROGEN IN PRIMARY CELL GAS |
| FNIS | WT. FRACTION OF NITROGEN IN SECONDARY CELL GAS |
| FOUTP | LOSS RATE OF PRIMARY CONT. GAS WHICH EITHER LEAKS OR IS EXHAUSTED |
| FOUTS | LOSS RATE OF SECONDARY CONT. GAS WHICH EITHER LEAKS OR IS EXHAUSTED |
| FOUTT | TOTAL LEAKAGE FROM OUTERMOST CONTAINMENT (FOUTS + LEAK) |
| FOXP | WT. FRACTION OF OXYGEN IN PRIMARY CELL GAS |
| FOXS | WT. FRACTION OF OXYGEN IN SECONDARY CELL GAS |
| FPG | RADIATIVE VIEW FACTOR FROM POOL TO GAS (1.0 IF NO PAN, 0.23 IF PAN) |
| FPW | RAD. VIEW FACTOR FROM POOL TO WALL (1.0 IF NO PAN, 0.384 IF PAN) |
| FRA | FRACTION OF COMBUSTION PRODUCTS EVOLVED INTO CELL GAS |
| FWAP | WT. FRACTION OF WATER VAPOR IN PRIMARY CELL GAS |
| FWAS | WT. FRACTION OF WATER VAPOR IN SECONDARY CELL GAS |

| | |
|---|---|
| GAP | AIR GAP BETWEEN STEEL LINER AND CONCRETE FLOOR (INPUT AS FT.) |
| GAMMA | RATIO OF SPECIFIC HEATS Cp/Cv (SET = 1.4) |
| GIN | GRAVITATIONAL CONSTANT 32.2 (FT./SEC**2) |
| HGWP | INTERIOR FILM COEF. (BTU/SEC-FT2-DEG. F.) |
| HA | EXTERIOR FILM COEF. (BTU/SEC-FT2-DEG. F.) |
| HB | HEAT TRANSFER COEFFICIENT TO POOL (BTU/SEC-FT2-DEG. F.) |
| HBINF | EQUILIBRIUM VALUE OF HB |
| HCO | HEAT TRANSFER COEFICIENT OF BOILING WATER (BTU/SEC-FT2-DEG. F.) |
| HEHCP | HEAT TRANSFER COEFFICIENT OF PRIMARY CELL EXTRANEOUS HEAT CAPACITY TO PRIMARY GAS (BTU/SEC-FT2-DEG. F.) |
| HEHCS | HEAT TRANSFER COEFFICIENT OF SECONDARY CELL EXTRANEOUS HEAT CAPACITY TO SECONDARY CELL GAS (BTU/SEC-FT2-DEG. F.) |
| HF | GAS TRANSPORT COEFF. TO POOL FT./SEC |
| HFPGP | HEAT TRANSFER COEFFICIENT FROM PRIMARY FLOOR STEEL TO PRIMARY CELL GAS (BTU/SEC-FT2-DEG. F.) |
| HFPGAS | HEAT TRANSFER COEFFICIENT FROM PRIMARY FLOOR STEEL TO SECONDARY CELL GAS (BTU/SEC-FT2-DEG. F.) |
| HFINF | EQUILIBRIUM VALUE OF HF |
| HIN | CORRELATION FOR HEAT TRANSFER COEFFICIENT (H, HB, HF) |
| HINECP | CORRELATION FOR HEAT TRANSFER COEFFICIENT FOR PRIMARY CELL EXTRANEOUS HEAT CAPACITY DIMENSIONLESS |
| HINECS | CORRELATION FOR HEAT TRANSFER COEFFICIENT FOR SECONDARY CELL EXTRANEOUS HEAT CAPACITY DIMENSIONLESS |
| HINFGS | CORRELATION FOR HEAT TRANSFER COEFFICIENT (HFPGAS) |
| HINGSP | CORRELATION FOR HEAT TRANSFER COEFFICIENT (HGWP) |
| HINGSS | CORRELATION FOR HEAT TRANSFER COEFFICIENT (HSEC) |
| HINPS | CORRELATION FOR HEAT TRANSFER COEFFICIENT (HWPGAS) |
| HINBAM | CORRELATION FOR HEAT TRANSFER COEFFICIENT (HAWBAM) |
| HINSAM | CORRELATION FOR HEAT TRANSFER COEFFICIENT (HA) |
| HPAN | HEAT TRANSFER COEFFICIENT TO PAN (BTU/SEC-FT2-DEG. F.) |
| HSEC | HEAT TRANSFER COEFFICIENT FROM SECONDARY STEEL WALL LINER TO SECONDARY CELL GAS (BTU/SEC-FT2-DEG. F.) |
| HTCPGP | HEAT CAPACITY OF PRIMARY CONTAINMENT ATMOSPHERE BTU/DEG.F |
| HTCPGS | HEAT CAPACITY OF SECONDARY CONTAINMENT ATMOSPHERE BTU/DEG.F |
| HWPGAS | HEAT TRANSFER COEFFICIENT FROM PRIMARY STEEL WALL TO SECONDARY CELL GAS (BTU/SEC-FT2-DEG. F.) |
| I | GENERAL PURPOSE DO LOOP INDEX |
| IAM | DO LOOP INDEX FOR FLOOR AND WALL CONCRETE NODE INITIALIZATION |
| IB | DO LOOP INDEX USED FOR FLOOR CONCRETE ITERATIONS |
| INIT | INITIALIZING SUBROUTINE FOR INTEGRATION CALCULATIONS |
| INJEC1,INJEC2,INJEC3 | FLAGS FOR GAS INJECTION ... INJEC=1 INDICATES THAT THE PARTICULAR INJECTION HAS OCCURRED |
| INTGRL | ARITHMETIC STATEMENT FUNCTION FOR FINDING INTEGRALS |
| IPAGE | NUMBER OF OUTPUT LINES PER PAGE (BETWEEN HEADINGS) |
| IPASS | SEE SUBROUTINE VARIABLE LIST |

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| J1 = 1 | IF LITHIUM IS BREEDER |
| J2 = 1 | IF HYDROGEN IS EVOLVED |
| KLEAK | LEAK RATE CONSTANT FROM CONTAINMENT (INCHES/((LB**0.5)*SEC)) NOTE: UNITS HAVE BEEN INFERRED FROM THE PROGRAM AND MAY NOT BE CORRECT. REFERENCE INPUT VALUE: 2.588E(-09) |
| KCON | THERMAL CONDUCTIVITY OF THE FLOOR AND WALL CONCRETE CONVERTED TO (BTU/SEC-FT.-DEG. F.) IN PROGRAM |
| KFILM | THERM. COND. OF LI POOL/COMB. ZONE FILM (BTU/SEC-FT.-DEG. F.) |
| KGAP | THERMAL COND. OF THE AIR GAP BETWEEN THE LINER AND CONCRETE CONVERTED TO (BTU/SEC-FT.-DEG. F.) IN PROGRAM |
| KIN1 | THERMAL CONDUCTIVITY OF INNER INSULATION - CALC. IN PROGRAM |
| KIN2 | THERMAL CONDUCTIVITY OF OUTER INSULATION - CALC. IN PROGRAM |
| KPAN | THERMAL CONDUCTIVITY OF LI PAN (BTU/HR-FT.-DEG. F.) CONVERTED TO (BTU/SEC-FT.-DEG. F.) IN PROGRAM |
| KSTL | THERMAL CONDUCTIVITY OF THE STEEL LINER (BTU/HR-FT.-DEG. F.) CONVERTED TO (BTU/SEC-FT.-DEG. F.) IN PROGRAM |
| L | CONCRETE WALL ELEMENT THICKNESS (FT.) |
| LBN | DISTANCE BETWEEN TWO BREEDER ELEMENTS |
| LEAK | CELL GAS LEAKAGE RATE FROM OUTERMOST CONTAINMENT (1/SEC) |
| LEAKO | INITIAL CELL GAS LEAKAGE RATE FROM OUTERMOST CONTAINMENT (1/SEC) |
| LIBP | LITHIUM BURNED IN POOL FIRE (LB) |
| LIL | AMOUNT OF LI LEFT IN POOL, BUT NOT ALLOWED TO BE LESS THAN LIT/10 FOR NUMERICAL STABILITY IN HEAT TRANSFER CALC. |
| LILNI | AMOUNT OF LITHIUM NITRIDE IN POOL (LB) |
| LILOX | AMOUNT OF LITHIUM OXIDE IN POOL (LB) |
| LILP | TRUE AMOUNT OF LITHIUM IN POOL (LB) |
| LIS | LITHIUM USED IN SPRAY FIRE (LB) |
| LIT | MASS OF LITHIUM IN POOL INITIALLY (LB) |
| L1 | CONCRETE FLOOR ELEMENT THICKNESS (FT.) |
| MAIP | INITIAL MASS OF INERT GAS IN PRIMARY CONTAINMENT (LB) |
| MAIS | INITIAL MASS OF INERT GAS IN SECONDARY CONTAINMENT (LB) |
| MAIRP | WT. OF PRIMARY CELL GAS (LB) |
| MAIRS | WT. OF SECONDARY CELL GAS (LB) |
| MAP | WT. OF INERT GAS IN PRIMARY CELL (LB) |
| MAS | WT. OF INERT GAS IN SECONDARY CELL (LB) |
| MB | MASS OF BREEDER ELEMENT (LB-MOLES) |
| MCZ | REACTION ZONE MASS (LB-MOLES) |
| MCZ1 | INITIAL REACTION ZONE MASS (LB-MOLES) |
| MH2P | WT. OF HYDROGEN IN PRIMARY CONT. CELL GAS (LB) |
| MH2S | WT. OF HYDROGEN IN SECONDARY CONT. CELL GAS (LB) |
| MLEAD | MASS OF LEAD IN LEAD LAYER ABOVE LIPB POOL (LB) |
| MLIHP | WT. OF LITHIUM HRYDROXIDE IN PRIMARY CONT. GAS (LB) |
| MLIHS | WT. OF LITHIUM HRYDROXIDE IN SECONDARY CONT. GAS (LB) |
| MLINIP | INITIAL MASS OF LITHIUM NITRIDE IN PRIMARY CONT. (LB) |
| MLINIS | INITIAL MASS OF LITHIUM NITRIDE IN SECONDARY CONT. (LB) |

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| MLINP | WT. OF LITHIUM NITRIDE IN PRIMARY CONT. GAS CELL (LB) |
| MLINS | WT. OF LITHIUM NITRIDE IN SECONDARY CONT. GAS CELL (LB) |
| MLIOH | MASS OF LIOH PRODUCT IN (LB) MOLES |
| MLIOIP | INITIAL MASS OF LITHIUM OXIDE IN PRIMARY CONT. (LB) |
| MLIOIS | INITIAL MASS OF LITHIUM OXIDE IN SECONDARY CONT. (LB) |
| MLIOP | WEIGHT OF LITHIUM OXIDE IN PRIMARY CELL GAS. ALL OF THE SPRAY FIRE PRODUCT REMAINS IN THE CELL GAS. A FRACTION OF THE PRODUCTS FROM THE POOL FIRE IS ADDED (LB) |
| MLIOS | WT. OF LITHIUM OXIDE IN SECONDARY CELL GAS. (LB) (ZERO) |
| MNIINJ | RATE OF INJECTION OF NITROGEN DURING A 60 SEC INTERVAL USED TO MODEL HEDL PROCEDURE (LB/SEC) |
| MNIIP | INITIAL WEIGHT OF NITROGEN IN PRIMARY CONTAINMENT (LB) |
| MNIIS | INITIAL WEIGHT OF NITROGEN IN SECONDARY CONTAINMENT (LB) |
| MNIP | WEIGHT OF NITROGEN IN PRIMARY CONT. CELL GAS (LB) |
| MNIS | WEIGHT OF NITROGEN IN SECONDARY CONT. CELL GAS (LB) |
| MNINJ1,MNINJ2,MNINJ3 | MASS OF NITROGEN INJECTED (LB) |
| MOINJ1,MOINJ2,MOINJ3 | MASS OF OXYGEN INJECTED (LB) |
| MOXINJ | RATE OF INJECTION OF OXYGEN USED TO MODEL HEDL EXPERIMENTAL PROCEDURE. OCCURS DURING A 60 SEC INTERVAL (LB/SEC) |
| MOXIP | INITIAL WEIGHT OF OXYGEN IN PRIMARY CONT. (LB) |
| MOXIS | INITIAL WEIGHT OF OXYGEN IN SECONDARY CONT. (LB) |
| MOXP | WEIGHT OF OXYGEN IN PRIMARY CELL GAS (LB) |
| MOXS | WEIGHT OF OXYGEN IN SECONDARY CELL GAS (LB) |
| MPB | MASS OF ALLOY METAL PRODUCT IN (LB-MOLES) |
| MWAP | WEIGHT OF WAT. VAP. IN PRIMARY CONTAINMENT CELL GAS (LB) |
| MWAS | WEIGHT OF WAT. VAP. IN SECONDARY CONTAINMENT CELL GAS (LB) |
| MWAIP | INITIAL MASS OF WATER VAPOR IN PRIMARY CONT. CELL GAS (LB) |
| MWAIS | INITIAL MASS OF WATER VAPOR IN SECONDARY CONT. CELL GAS (LB) |
| N | INDICE USED TO TRANSFER CONTROL IN SUBROUTINES |
| NA | NUMBER OF ELEMENTS IN BREEDER ZONE |
| NAME(I) | INPUT CONTAINING PROGRAM TITLE AND HEADING |
| NL | NUMBER OF CONCRETE WALL NODES |
| NL1 | NUMBER OF CONCRETE FLOOR NODES |
| NLM1,NL1M1 | WALL AND FLOOR CONCRETE NUMBER OF NODES MINUS ONE |
| NUMCTD | NUMBER OF COOLANT TUBES DAMAGED |
| OUTINT | FRACTION OF THE OUTERMOST CONTAINMENT GAS LEAKED TO AMBIENT |
| OVERP | CONTAINMENT OVER PRESSURE (PSIG) |
| OVERPP | PRIMARY CONTAINMENT OVERPRESSURE (PSIG) |
| OVERPS | SECONDARY CONTAINMENT OVERPRESSURE (PSIG) |
| OXLB | OXYGEN BURNED (LB) |
| OXLBI | OXYGEN BURNED INITIALLY (LB) |
| OXLFS | OXYGEN LEFT AFTER SPRAY FIRE (LB) |
| PAP | GAS PRESSURE IN PRIMARY CELL (PSIA) |
| PAPZER | INITIAL PRIMARY CELL PRESSURE (PSIA) |
| PAS | GAS PRESSURE IN SECONDARY CELL (PSIA) |

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| PASZER | INITIAL SECONDARY CELL PRESSURE (PSIA) |
| PAZERO | INITIAL CELL PRESSURE (PSIA) |
| PBMELT | MELTING POINT OF ALLOY METAL (DEG. R.) |
| PERCEN | PERCENTAGE BY NUMBER OF PEROXIDE (VS. MONOXIDE) FORMED IN COMBUSTION |
| PLIV | PARTIAL PRESSURE OF LITHIUM VAPOR (PSIA) |
| PYU | USED IN SETTING THE MINIMUM TIME STEP CALCULATED FROM CONDUCTION RATE FROM PAN OR STEEL LINER FROM POOL |
| PZEROP | PRIMARY CONTAINMENT PRESSURE AFTER SPRAY FIRE (PSIA) |
| QC | FORCED CONVECTIVE COOLING HEAT FLOW |
| QCCONC | HEAT OF COMB. FOR CONCRETE REACTION (BTU/LB LI) |
| QCN | HEAT OF COMB. FOR NITROGEN REACTION (BTU/LB LI) |
| QCO | HEAT OF COMBUSTION FOR OXYGEN REACTION (BTU/LB LI) |
| QCO1 | HEAT OF COMBUSTION FOR MONOXIDE REACTION (BTU/LB LI) |
| QCO2 | HEAT OF COMBUSTION FOR PEROXIDE REACTION (BTU/LB LI) |
| QCW | HEAT OF COMB. FOR REACTION WITH WATER VAPOR (BTU/LB LI) |
| QIN | HEAT ADDITION TO CELL GAS FROM SPRAY FIRE (BTU) |
| QLIOH | LATENT HEAT OF MELTING FOR LIOH (BTU/LB-MOLE) |
| QMELT | HEAT OF FUSION OF BREEDER (BTU/LB-MOLE) |
| QMELTP | HEAT OF FUSION OF ALLOY METAL (BTU/LB-MOLE) |
| QOUT1,2,3,4 | USED IN HEAT BALANCE EQS. FOR SPRAY FIRE (BTU) |
| QRAD | INDICATES A RADIATIVE HEAT FLOW (BTU/SEC) |
| QRADB | FROM STEEL FLOOR (PAN) TO FLOOR CONC. OR TO AMBIENT |
| QRADC | FROM STEEL WALL TO WALL CONCRETE OR TO AMBIENT |
| QRADCG | FROM SPILL PAN TO CELL GAS |
| QRADFS | FROM PRIMARY STEEL FLOOR TO SECONDARY STEEL WALL |
| QRADG | FROM LI POOL TO GAS (NO COMB.) OR FROM COMB ZONE TO CELL GAS |
| QRADP | FROM COMB. ZONE TO LITHIUM POOL (COMB. ZONE MODEL ONLY) |
| QRADPG | FROM PRIMARY STEEL WALL TO SECONDARY CELL GAS |
| QRADPS | FROM PRIMARY STEEL WALL TO SECONDARY STEEL WALL |
| QRADS | FROM SPILL PAN TO STEEL FLOOR |
| QRADW | FROM COMB ZONE TO WALL STEEL OR FROM LI POOL TO WALL STEEL |
| QVAP | HEAT OF VAPORIZATION OF LITHIUM (BTU/LB) |
| QWA | HEAT OF REACTION OF BREEDER WITH WATER |
| RA | MEAN RADIUS OF COMBUSTION PRODUCT PARTICLES (MICRONS) |
| RAREA | SURFACE AREA OF REACTION ZONE |
| | THE SYMBOL "R" DESIGNATES A TEMPERATURE RATE OF CHANGE IN SOME NODE DUE TO RADIATION HEAT TRANSFER BETWEEN THAT NODE AND SOME OTHER NODE |
| RADB | IN FLOOR STEEL DUE TO RAD. TO FLOOR CONC. OR TO AMBIENT |
| RADC | IN WALL STEEL DUE TO RAD. TO CONCRETE OR TO AMBIENT |
| RADCB | IN FLOOR CONCRETE FROM STEEL FLOOR (PAN) |
| RADCC | IN WALL CONCRETE FROM STEEL WALL |
| RBREAK | TEMP. RATE OF CHANGE OF PRIMARY CELL GAS DUE TO GAS LEAKAGE |
| RCMBH2 | STOICH. COMB. RATIO FOR H2O VAPOR REACT. (LB LI/LB H2) |

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| RCMBN | STOICH. COMB. RATIO OF NITROGEN REACT. (LB LI/LB N) |
| RCMBO | STOICH. COMB. RATIO FOR OXYGEN REACTION (LB LI/LB O) |
| RCMBO1 | STOICH. COMB. RATIO FOR MONOXIDE REACTION (LB LI/LB O) |
| RCMBO2 | STOICH. COMB. RATIO FOR PEROXIDE REACTION (LB LI/LB O) |
| RCMBW | STOICH. COMB. RATIO FOR WAT. VAP. REACT. (LB LI/LB H2O) |
| RCZG | IN GAS FROM COMBUSTION ZONE |
| RCZP | IN LITHIUM POOL FROM COMBUSTION ZONE |
| RCZW | IN WALL STEEL FROM COMBUSTION ZONE |
| RELERR | MAXIMUM ALLOWABLE FRACTIONAL TEMP. CHANGE ACROSS A SINGLE INTEGRATION STEP. USED TO VARY TIME STEP. |
| RGASPA | IN PAN DUE TO RAD. TO CONTAINMENT GAS |
| RGLI | IN POOL DUE TO RAD. TO GAS (NO COMB) |
| RHCON | DENSITY OF FLOOR AND WALL CONCRETE |
| RHINS | DENSITY OF INSULATING LAYER ON PAN |
| RHLEAD | DENSITY OF PURE LEAD (LB/FT3) |
| RHLI | DENSITY OF LITHIUM (LB/FT3) |
| RHOAIP | INITIAL DENSITY OF PRIMARY CELL GAS (LB/FT3) |
| RHOAIS | INITIAL DENSITY OF SECONDARY CELL GAS (LB/FT3) |
| RHOAP | DENSITY PRIMARY CELL GAS (LB/FT3) |
| RHOAS | DENSITY SECONDARY CELL GAS (LB/FT3) |
| RHOLIH | DENSITY OF LITHIUM HYDROXIDE (LB/FT3) |
| RHOLIN | DENSITY OF LITHIUM NITRIDE (LB/FT3) |
| RHOLIO | DENSITY OF LITHIUM OXIDE (LB/FT3) |
| RHOLIV | LITHIUM VAPOR DENSITY ABOVE POOL (LB/FT3) |
| RHPAN | DENSITY OF LI SPILL PAN (LB/FT3) |
| RHPB | DENSITY OF ALLOY METAL (LB-MOLE/FT3) |
| RHSTL | DENSITY OF STEEL LINER (LB/FT3) |
| RIFCZG | RADIATIVE INTERCHANGE FACTOR BETWEEN COMB. ZONE AND THE PRIMARY CELL GAS |
| RIFCZP | RADIATIVE INTERCHANGE FACTOR BETWEEN COMB. ZONE AND THE POOL SURFACE |
| RIFCZW | RADIATIVE INTERCHANGE FACTOR BETWEEN COMB. ZONE AND CONTAINMENT WALLS |
| RIFFPS | RADIATIVE INTERCHANGE FACTOR BETWEEN PRIMARY STEEL FLOOR AND SECONDARY STEEL FLOOR |
| RIFPAG | RADIATIVE INTERCHANGE FACTOR PAN TO GAS |
| RIFPAS | RADIATIVE INTERCHANGE FACTOR PAN TO STEEL FLOOR |
| RIFPG | RAD. INT. FAC. BETWEEN POOL AND PRIMARY CELL GAS |
| RIFPGA | RAD. INT. FAC. BETWEEN PRIMARY STEEL WALL AND SECONDARY GAS |
| RIFPS | RAD. INT. FAC. BETWEEN PRIMARY AND SECONDARY CELLS |
| RIFPW | RAD. INT. FAC. BETWEEN POOL AND WALL |
| RIFSLC | RADIATIVE INTERCHANGE FACTOR BETWEEN STEEL LINER AND CONCRETE SURFACE |
| RIN | UNIVERSAL GAS CONSTANT 1545 (FT.-LBF./LB-MOLE-DEG. F.) |
| RINP | PRIMARY CELL RIN |

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| RINS | SECONDARY CELL RIN |
| RLIG | IN GAS DUE TO RAD. FROM POOL (NO COMBUSTION) |
| RLIW | IN WALL STEEL FROM LITHIUM POOL (NO COMB) |
| RNILB | RATE OF NITROGEN CONSUMPTION (LB/SEC) |
| RN2 | DEGREE TO WHICH NITROGEN-LI REACTION OCCURS. VALUE IS BETWEEN ZERO AND ONE (=0 FOR NO REACTION, =1 FOR COMPLETE) |
| ROXLB | RATE OF OXYGEN CONSUMPTION BY POOL FIRE (LB/SEC) |
| RPAGAS | IN CELL GAS DUE TO RAD. FROM LI PAN |
| RPANST | IN WALL STEEL DUE TO RAD. FROM LITHIUM PAN |
| RRAD | INITIAL RADIUS OF REACTION ZONE (FT.) |
| RSTPAN | IN PAN DUE TO RAD. TO FLOOR STEEL |
| RTLI,RTG,RADB, RADW,RADCB,RADCW | VARIOUS RATES OF TEMP. CHANGE OF NODES (DEG. F./SEC) |
| RVOL | INITIAL REACTION ZONE VOLUME (FT3) |
| RVOL1 | REACTION ZONE VOLUME (FT3) |
| RWALB | RATE OF WATER VAPOR CONSUMPTION (LB/SEC) |
| RWCZ,RCZW,RCZG,RADB,RADW, RADCB,RADCW,RLIW,RGLI,RLIG, RSPGS,RWLI,RWPGAS,RWPWS,RWSWP | VARIOUS RATES OF TEMP. CHANGE OF NODES (DEG. F./SEC) |
| RWLI | IN LITHIUM POOL FROM RAD. TO WALL STEEL (NO COMB) |
| R1 | COEFFICIENT OF BREEDER IN WATER REACTION EQUATION |
| R2 | COEFFICIENT OF ALLOY METAL IN WATER REACTION EQUATION |
| SFLCR | HEAT REMOVAL RATE BY EMERGENCY COOLING OF STEEL FLOOR LINER (BTU/SEC) |
| SFLEND | TIME AFTER SPILL WHEN SFLCR ENDS (SEC) |
| SFLTIN | TIME AFTER SPILL WHEN SFLCR BEGINS (SEC) |
| SIGMA | STEPHAN-BOLTZMAN CONSTANT ... 0.1713E-8 (BTU/FT2/HR/DEG. R.**4) |
| SPILL | TOTAL WEIGHT OF LITHIUM SPILLED (LB) |
| SPRAY | WEIGHT FRACTION OF LITHIUM CONSUMED IN THE SPRAY FIRE |
| STICK | RATE AT WHICH AEROSOLS ARE REMOVED FROM PRIMARY DUE TO STICKING TO THE WALL. IF STICK > 1.0 EXECUTION IS STOPPED STICK MAY BE DECREASED BY INCREASING "BETA". |
| TA | AMBIENT TEMPERATURE (DEG. F.) |
| TAU | TIME CONSTANT FOR TRANSIENT NATURAL CONVECTION |
| TAUCZ | USED TO MODEL COMBUSTION ZONE-POOL COUPLING IN THE RADIATIVE INTERCHANGE FACTORS INSTEAD OF (1.-EMCZ) (DIMENSIONLESS) |
| TB(I) | TEMP. OF ITH NODE OF CONCRETE FLOOR (DEG. R.) |
| TBIC(I) | INITIAL TEMP. OF ITH NODE OF CONCRETE FLOOR (DEG. R.) |
| TBF,TCF,TGF, ETC. | CORRESPONDING TEMP. IN DEGREES FAHRENHEIT |
| TBLOW | INERT GAS INLET TEMP. (DEG. R.) |
| TC(I) | TEMP. OF ITH NODE OF CONCRETE WALL (DEG. R.) |
| TCIC(I) | INITIAL TEMP. OF ITH NODE OF CONCRETE WALL (DEG. R.) |
| TCIGNI | IGNITION TEMPERATURE OF CONCRETE LITHIUM REACTION IN CONCRETE COMBUSTION MODEL (DEG. R.) |
| TCON | CONCRETE COMBUSTION ZONE TEMPERATURE IN |

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| | CONCRETE COMBUSTION MODEL (DEG. R.) |
| TCONF | CONCRETE COMBUSTION ZONE TEMPERATURE IN CONCRETE COMBUSTION MODEL (DEG. F.) |
| TCZ | COMBUSTION ZONE TEMPERATURE (DEG. R) |
| TCZF | COMBUSTION ZONE TEMP. (DEG. F.) |
| TCZI | INITIAL VALUE OF COMB. ZONE TEMP. (DEG. R.) |
| TE | EQUILIBRIUM TEMP. RESULTING FROM SPRAY FIRE (DEG. R.) |
| TEHCP | TEMP. OF PRIMARY EXTRANEOUS HEAT CAPACITY NODE (DEG. R.) |
| TEHCPF | TEMP. OF PRIMARY EXTRANEOUS HEAT CAPACITY NODE (DEG. F.) |
| TEHCS | TEMP. OF SECONDARY EXTRANEOUS HEAT CAPACITY NODE (DEG. R.) |
| TEHCSF | TEMP. OF SECONDARY EXTRANEOUS HEAT CAPACITY NODE (DEG. F.) |
| TEHCZP | INITIAL TEMP. OF PRIMARY EXTRANEOUS HEAT CAPACITY NODE (DEG. R.) |
| TEHCZS | INITIAL TEMP. OF SECONDARY EXTRANEOUS HEAT CAPACITY NODE (DEG. R.) |
| TET1 | USED IN CALCULATING THERMAL CONDUCTIVITY OF INNER PAN INSULATION SEE KIN1 |
| TET2 | USED IN CALCULATING THERMAL CONDUCTIVITY OF OUTER PAN INSULATION SEE KIN2 |
| TEZ | AVERAGE OF COMBUSTION ZONE TEMP. AND LITHIUM POOL TEMP. USED IN TEST FOR COMBUSTION CONDITION |
| TFEFF | NORMALIZED TEMP. OF LI POOL/COMB. ZONE FILM |
| TGF | CONTAINMENT GAS TEMP. IN FARENHEIT |
| TGP | PRIMARY CELL GAS TEMP. AFTER SPRAY FIRE (DEG. R.) |
| TGPF | PRIMARY CELL GAS TEMP. (DEG. F.) |
| TGPZER | INITIAL PRIMARY CELL GAS TEMP. (DEG. R.) |
| TGS | SECONDARY CONT. CELL GAS TEMP. (DEG. R.) |
| TGSF | SECONDARY CONT. CELL GAS TEMP. (DEG. F.) |
| TGSZER | INITIAL SECONDARY CELL GAS TEMP. (DEG. R.) |
| THFC | CONCRETE FLOOR THICKNESS INPUT AS FT. |
| THFP | PRIMARY STEEL FLOOR THICKNESS INPUT AS FT. |
| THFS | SECONDARY STEEL FLOOR THICKNESS INPUT AS FT. |
| THKIN1 | INNER INSULATION THICKNESS INPUT AS FT. |
| THKIN2 | OUTER INSULATION THICKNESS INPUT AS FT. |
| THKPAN | SPILL PAN THICKNESS IN FEET INPUT AS FT. |
| THPB | THICKNESS OF LEAD LAYER ABOVE LIPB POOL |
| THWC | CONCRETE WALL THICKNESS INPUT AS FT. |
| THWP | PRIMARY STEEL WALL THICKNESS INPUT AS FT. |
| THWS | SECONDARY STEEL WALL THICKNESS INPUT AS FT. |
| TIME | TIME AFTER SPILL HAS OCCURRED (SEC) |
| TIMEF | STOP INTEGRATION TIME (SEC) |
| TIMEO | OUTPUT TIME INDICATOR (SEC) |
| TINS1 | TEMP. OF INNER NODE OF INSULATION (DEG. R.) |
| TINS1F | TEMP. OF INNER NODE OF INSULATION (DEG. F.) |
| TINS1I | INITIAL TEMP. OF INNER NODE OF INSULATION (DEG. R.) |
| TINS2 | TEMP. OF OUTER NODE OF INSULATION (DEG. R.) |
| TINS2F | TEMP. OF OUTER NODE OF INSULATION (DEG. F.) |

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| TINS2I | INITIAL TEMP. OF OUTER NODE OF INSULATION (DEG. R.) |
| TLEAD | TEMP. OF LEAD LAYER IN POOL (DEG. R.) |
| TLEADF | TEMP. OF LEAD LAYER IN POOL (DEG. F.) |
| TLEADI | INITIAL TEMP. OF LEAD LAYER IN POOL (DEG. R.) |
| TLI | LITHIUM TEMP. IN POOL (DEG. R.) |
| TLIBS | LITHIUM TEMPERATURE BEFORE SPRAY FIRE (DEG. R.) |
| TLIF | LITHIUM POOL TEMP. IN FARENHEIT |
| TLII | INITIAL LITHIUM POOL TEMP. (DEG. R) |
| TLIO | INITIAL LITHIUM POOL TEMP. (DEG. R.) |
| TMELT | MELTING TEMP. OF LITHIUM (DEG. R.) |
| TN | TEMPERATURE OF BREEDER ZONE ELEMENT (DEG. R.) |
| TO | TEMP. OF CELL GAS BEFORE SPRAY FIRE (DEG. R.) |
| TONE,TTWO,TTHREE | TIME IN SECONDS AT WHICH EACH INJECTION OCCURS |
| TPAN | LITHIUM PAN TEMP SUSP. PAN OPTION (DEG. R.) |
| TPANF | LITHIUM PAN TEMP (DEG. F.) |
| TPANZO | INITIAL PAN TEMPERATURE IN DEGREES R. |
| TSFP | PRIMARY STEEL FLOOR LINER TEMP. (DEG. R.) |
| TSFPF | PRIMARY FLOOR STEEL LINER TEMPERATURE (DEG. F.) |
| TSFPI | INITIAL PRIMARY STEEL FLOOR LINER TEMP. (DEG. R.) |
| TSFSI | INITIAL SECONDARY CELL FLOOR LINER TEMP. (DEG. R.) |
| TSP | PRIMARY CELL STEEL WALL LINER TEMP. (DEG. R.) |
| TSPF | PRIMARY CELL STEEL WALL LINER TEMP. (DEG. F.) |
| TSPZER | INITIAL PRIMARY CELL STEEL WALL LINER TEMP. (DEG. R.) |
| TSS | SECONDARY CELL STEEL WALL LINER TEMP. (DEG. R.) |
| TSSF | SECONDARY CELL STEEL WALL LINER TEMP. (DEG. F.) |
| TSSZER | INITIAL SECONDARY CELL STEEL WALL LINER TEMP. (DEG. R.) |
| TVAP | BOILING POINT OF LITHIUM (DEG. R.) |
| T1 | FILM TEMP. BETWEEN PRIMARY CELL GAS AND POOL (DEG. R.) |
| T2 | FILM TEMP. BETWEEN PRIMARY CELL GAS AND STEEL WALL LINER ((DEG. R.)) |
| T3EP | FILM TEMP. BETWEEN PRIMARY CELL GAS AND EXTR. HEAT CAP. DEG. R. |
| T3ES | FILM TEMP. BETWEEN SECONDARY CELL GAS AND EXTR. HEAT CAP. (DEG. R.) |
| T4 | FILM TEMP. BETWEEN SECONDARY GAS AND SECONDARY STEEL WALL (DEG. R.) |
| T4H | FILM TEMP. BETWEEN AMBIENT AND OUTSIDE STEEL OR CONCRETE WALL DEPENDING IF THERE IS CONCRETE PRESENT (DEG. R.) |
| T5 | FILM TEMP. BETWEEN PRIMARY STEEL WALL AND SECONDARY GAS (DEG. R.) |
| T6 | FILM TEMP. BETWEEN SECONDARY CELL GAS AND PRIMARY FLOOR (DEG. R.) |
| T7 | FILM TEMP. BETWEEN AMBIENT AND OUTSIDE STEEL FLOOR OR CONCRETE FLOOR DEPENDING IF THERE IS CONCRETE PRESENT (DEG. R.) |
| USUBA | HEAT TRANSF. COEFF., CONTAINMENT-AMBIENT (BTU/SEC-FT2-DEG. F.) |
| VCONC | VOLUME OF CONCRETE IN FIRST NODE OF CONCRETE IN THE CONCRETE COMBUSTION MODEL (FT3) |
| VP | PRIMARY CONTAINMENT CELL FREE VOLUME (FT3) |
| VS | SECONDARY CONTAINMENT CELL FREE VOLUME (FT3) |
| VOL | VOLUME OF BREEDER ELEMENT (FT3) |
| WAB | WEIGHT FRACTION OF INERT GAS IN FLOODING GAS |

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| WAP | WT. FRACTION OF INERT GAS IN PRIMARY ATMOSPHERE |
| WAS | WT. FRACTION OF INERT GAS IN SECONDARY ATMOSPHERE |
| WATER | AMOUNT OF WATER THAT SHOULD BE LEFT IN CONCRETE TOP NODE ACCORDING TO THE CORRELATION USED (LB/FT3) |
| WFP | THICKNESS OF PRIMARY FLOOR STEEL LINER (INPUT AS FT.) |
| WN2P | WEIGHT FRACTION OF NITROGEN IN PRIMARY ATMOSPHERE |
| WN2S | WEIGHT FRACTION OF NITROGEN IN SECONDARY ATMOSPHERE |
| WN2B | WEIGHT FRACTION OF NITROGEN IN FLOODING GAS |
| WO2P | WEIGHT FRACTION OF OXYGEN IN PRIMARY ATMOSPHERE |
| WO2S | WEIGHT FRACTION OF OXYGEN IN SECONDARY ATMOSPHERE |
| WO2B | WEIGHT FRCTION OF OXYGEN IN FLOODING GAS |
| WP | THICKNESS OF PRIMARY STEEL POOL LINER INPUT AS FT. |
| WS | THICKNESS OF SECONDARY STEEL POOL LINER INPUT AS FT. |
| WWAB | WT. FRACTION OF WATER VAPOR IN FLOODING GAS |
| WWAP | WT. FRACTION OF WATER VAPOR IN PRIMARY CONTAINMENT ATMOSPHERE |
| WWAS | WT. FRACTION OF WATER VAPOR IN SECONDARY CONTAINMENT ATMOSPHERE |
| XALLOY | ATOM PERCENT LITHIUM IN LIPB POOL |
| XBLOW | USED IN CONJUNCTION WITH IBLOW |
| XESC | USED IN CONJUNCTION WITH IESC |
| XLI | WEIGHT FRACTION OF LITHIUM IN LIPB ALLOY |
| XLIDOT | MASS FLOW RATE OF LITHIUM THROUGH LEAD LAYER ABOVE LIPB POOL (LB/SEC) |
| XMAIRP | AMOUNT OF GAS IN PRIMARY CONTAIMENT AFTER SPRAY (LB-MOLES) |
| XMAIRS | AMOUNT OF GAS IN SECONDARY CONTAIMENT AFTER SPRAY (LB-MOLES) |
| XMDOT | MASS FLOW RATE OF GAS BETWEEN PRIMARY AND SECONDARY CONT. (LB/SEC) |
| XMEHCP | MASS OF PRIMARY EXTRANEOUS HEAT CAPACITY (LB) |
| XMEHCS | MASS OF SECONDARY EXTRANEOUS HEAT CAPACITY (LB) |
| XMH2OI | INITIAL MASS OF WATER IN CONCRETE IN CONCRETE COMBUSTION OPTION (LB) |
| XMOLP | MOL. WEIGHT OF PRIMARY CONTAINMENT GAS (LB/LB-MOLE) |
| XMOLS | MOL. WEIGHT OF SECONDARY CONTAINMENT GAS (LB/LB-MOLE) |
| XMOLA | MOLECULAR WT. OF INERT GAS (LB/LB-MOLE) |
| XMOLAB | MOL. WT. OF INERT FLOODING GAS |
| XPB | WEIGHT FRACTION OF ALLOY METAL |
| XSFL | INDICATES EMERGENCY COOLING OF FLOOR STEEL (1/SEC)<br>XSFL = 0. FOR NO COOLING , XSFL = 1. FOR COOLING |
| YALICZ | EFFECTIVE THERMAL ADMITTANCE, FILM-COMB. ZONE (BTU/SEC-DEG. F.) |
| YALIG | EFFECTIVE THERMAL ADMITTANCE, POOL-CELL GAS (BTU/SEC-DEG. F.) |
| YAPCZ | EFFECTIVE THERMAL ADMITTANCE POOL-COMB. ZONE (BTU/SEC-DEG. F.) |
| YPAGAS | EFFECTIVE THERMAL ADMITTANCE PAN-PRIMARY CELL GAS (BTU/SEC-DEG. F.) |
| ZLI | THICKNESS OF LITHIUM NODE (FT.) |
| ZP | USED TO DETERMINE EMLI IF EMLI .LT. 0.9 |
| ZZ | TEMPERATURE RATE OF CHANGE IN BREEDER ELEMENT |
| ZZ1 | POOL TEMP. RATE OF CHANGE (DEG. F./SEC) |
| ZZ2 | LI SPILL PAN TEMP. RATE OF CHANGE (DEG. R./SEC) |
| ZZ3 | SECONDARY CELL GAS TEMPERATURE RATE OF CHANGE (DEG. R./SEC) |

| | |
|---|---|
| ZZ4 | PRIMARY CELL GAS TEMP. RATE OF CHANGE (DEG. F./SEC) |
| ZZ5 | STEEL WALL LINER TEMP. RATE OF CHANGE (DEG. F./SEC) |
| ZZ6 | COMB. ZONE TEMP. RATE OF CHANGE (DEG. F./SEC) |
| ZZ7 | FLOOR STRUCTURE TEMP. RATE OF CHANGE (DEG. F./SEC) |
| ZZ8 | INNER INSULATION TEMP. RATE OF CHANGE (SUSP. PAN OPTION) |
| ZZ9 | OUTER INSULATION TEMP. RATE OF CHANGE (SUSP. PAN OPTION) |
| ZZ99 | USED TO ENSURE POSITIVE COMBUSTION RATE |
| ZZEP | PRIMARY CELL EXTRANEOUS HEAT CAPACITY TEMP. RATE OF CHANGE DEG.R./SEC |
| ZZES | SECONDARY CELL EXTRANEOUS HEAT CAPACITY TEMP. RATE OF CHANGE (DEG. R./SEC) |
| ZZPB | LEAD LAYER ABOVE LIPB POOL TEMPERATURE RATE OF CHANGE (DEG. R./SEC) |
| ZZS | SECONDARY CONTAINMENT CELL STEEL WALL TEMPERATURE RATE OF CHANGE (DEG. R./SEC) |

## PROGRAM DECISION FLAGS

| | |
|---|---|
| IAROSL | = 1 AEROSOL REMOVAL FROM PRIMARY CONTAINMENT DUE TO AEROSOLSTICKING TO THE WALL.<br>= 0 NO AEROSOL REMOVAL. |
| IBLOW | = 1 FLOOD CONTASINMENT WITH INERT GAS<br>= 0 NO CONTAINMENT FLOODING |
| ICMB | = 0 NO OXYGEN LEFT AFTER SPRAY FIRE.<br>= 1 THERE IS STILL OXYGEN LEFT AFTER SPRAY FIRE. SET INITIALLY TO 1 AND THEN RESET TO 0 WHEN THE PROGRAM CALCULATES THAT THE OXYGEN HAS RUN OUT. |
| ICNI | = 1 NITROGEN REACTIONS POSSIBLE.<br>= 0 NITROGEN REACTIONS NOT POSSIBLE. |
| ICZ | = 1 COMBUSTION ZONE MODEL USED<br>= 0 COMBUSTION ZONE MODEL NOT USED |
| IESC | = 1 EMERGENCY SPACE COOLING OPTION<br>= 0 NO EMERGENCY SPACE COOLING |
| ILIT | = 0 NO LITHIUM LEFT TO BURN.<br>= 1 LITHIUM LEFT TO BURN (INITIAL CONDITION). |
| IMETH | = 1 RUNGE-KUTTA METHOD OF INTEGRATION USED.<br>= 3 SIMPSON'S RULE METHOD OF INTEGRATION USED. |
| ISFLC | = 1 EMERGENCY COOLING OF STEEL FLOOR LINER OPTION<br>= 0 NO EMERGENCY COOLING OF STEEL FLOOR LINER |
| ISWICH | = 1 CRACK SIZE BECOMES ZERO AFTER INNER AND OUTER CELL PRESSURES EQUILIBRATE IN TWO CELL CALCULATION.<br>= 0 CRACK SIZE REMAINS CONSTANT. |

| | |
|---|---|
| FLAG2 = .TRUE. | TWO CELL CALCULATION (DEFAULTS TO 1 CELL IF FALSE) |
| FLAGAS = .TRUE. | INJECTIONS OF DRY GAS DURING RUN |
| FLAGC = .TRUE. | CONCRETE COMBUSTION (BREACH OF STEEL LINER) |
| FLAGD = .TRUE. | CONCRETE COMBUSTION HAS STOPPED |
| FLAGDF = .TRUE. | LIPB LAYERED POOL COMBUSTION MODEL IN USE |
| FLAGF = .TRUE. | FLOOR CONCRETE |
| FLAGL = .TRUE. | LILP IS FIXED AT A MINIMUM |
| FLAGM = .TRUE. | SONIC FLOW BETWEEN CONTAINMENTS (CALCULATED IN PROGRAM) |
| FLAGN = .TRUE. | SETS N = 1 IN SUBROUTINES IN ORDER TO PROPERLY TRANSFER FLOW THROUGH SUBROUTINES |
| FLAGPB = .TRUE. | LIPB POOL COMBUSTION MODEL IN USE |
| FLAGPN = .TRUE. | YES ON SUSPENDED PAN GEOMETRY |
| FLAGSI = .TRUE. | IF USER WISHES INPUT/OUTPUT IN SI UNITS |
| FLAGW = .TRUE. | WALL CONCRETE |

# Appendix C

## Troubleshooting (D.A. Dube 5/22/78)

"There exists no large computer code which runs perfectly 100% of the time."
*-ANONYMOUS*

The user of this code will no doubt run into troubles along the way, hopefully not. The most common error is :

*'EXX IS NEGATIVE - CANNOT TAKE ROOT'*

Whenever this error occurs, it usually means that the program has diverged and that the combustion zone temperature has decresed to less than absolute zero. This may arise because the temperature rate of change of the combustion zone is relatively large because of the heat capacity of the zone. If this occurs, try a lower value of EMCZ. A number of corrective measures have been taken and the problem seems to have disappeared for this particular condition. In addition, this error statement was found to occur when the combustion rate, CMBRH , was quite small. (ie. $<< 1.0 lbmLI/HR/ft^2$) This could happen when the oxygen and nitrogen concentrations are rather low for example, or when the gas pressure is quite small. It has also occurred when values of EXHSTV exceed 40,000. In general, the combustion zone temperature should be greater than the lithium pool temperature. If not, this is a possible indication of trouble.

When the liquid lithium is depleted, or other conditions are reached, combustion stops. The calculations then proceed from the section in the program marked, *"COMPUTATIONS USING COMBUSTION ZONE MODEL"* to *"COMPUTATIONS WITHOUT COMBUSTION ZONE MODEL"*. This is indicated on the printed output by CMBRH going to zero. Since the liquid lithium is now non-existent one would expect something to happen to TLIF i.e. the lithium pool temperature.

Another error which may occur is the *"DIVIDE CHECK"* error from the computer itself which interrupts the calculations and is printed out on the output.

The error indicates that an attempt was made to divide by zero or something close to zero. This may indicate problems with the containment gas. It may occur if the value of EXHSTV is too high or LILP too low. The problem can be corrected to a certain extent, if it arises, by decresing DTMIN, the minimum time step. This unfortunately increases the computation time.

If the statement *"LITHIUM TEMP. ABOVE BOILING POINT"* occurs, this may indicate that for some reason, the temperature rate of change of lithium was very large. Possibly because the combustion zone temperature diverged to a large value. It generally arises as the value of LILP approaches zero.

The other error pointers in the code do not indicate serious problems but merely point out that situations have arisen where there is no reason to continue with the calculations. Such as when the temperature of lithium drops below its melting point, or when the gas temperature and pressure return to normal.

For the vast majority of calculations there should be no problems. Always watch for conditions when the containment gas weight decreases rather fast (MNI, MOX), or when the combustion zone temperature, TCZF ; combustion rate, CMBRH ; or the time step, DELT ; oscillate. In general, the value of DELT after time = 0 should steadily increase, them possibly decrease until the end of combustion. Then it will change greatly, possibly oscillate and eventually reach a steady value. Sudden changes in DELT mean that the temperature rates of change are varying abnormally. For the most part, the temperature rate of change of the combustion zone or lithium pool controls the value of DELT. If there is uncertainty as to the source of the error, print out the values of TCZ, CMBRH, ZZ5, and ZZ6 as functions of time.

# Appendix D

This is the sample input data file, uwmak2.w :

```
 1 1 0 1 0 0 1 0 0 0 0 0 0 1
   8    8
  .10  .10  .10  .15  .15  .15  .15  .10
  .10  .10  .10  .15  .15  .15  .15  .10
    950.00        6.20      522.0000     40.00
    543.0      12300.000      0.0       502.000      0.00
     00.254      00.635       0.0076      0.026      0.00
      0.85       502.0000    51.9       7970.000   650.00      0.050
      0.85       502.0000    51.9       7970.000   150.00      0.050
      0.2       4170.0000    48.44       480.55
      0.9        653.0000     1.73      2306.66
   1986.29      1392.6400  2562.95         0.04      0.10       0.50
  42936.7          0.0     9464.16     31974.0
      0.8764       0.0        1.487        0.383     0.00
    453.7       1615.00   19370.0          0.0
      0.12         0.12       0.120        0.070     0.07       0.07
      0.07         0.07
    150.000    22000.00       0.0000       0.750   300.0
    723.0        722.0      723.0        723.0     300.0      723.0
    101.4          0.2316     0.0000       0.0000
00030000000.03000044444.0000000000.00600002000.0000
```

This is the sample input data file, uwmak2.x :

```
0255000.00000000045.00000000101.40000000300.00000000300.00000000300.0000
   1000.00       00.00        0.232        0.0       522.0000
    300.0      11500.0       50.00       502.00        0.09
      0.85       502.0000    51.90       7970.0    17000.00     0.0060
      0.85       502.0000    51.90       7970.0     6000.00     0.0060
    350.00
```

# Appendix E

The following are parts of the output files LITFIRE produces :

## OUT2.

```
  TIME     DELT    TCZF     TLIF     TGPF      PAP     TSPF    TSFPF

  100.1    3.00   449.84   449.83   448.26   101.34   442.31   442.80
 1002.2    3.00   592.36   468.96   467.21    75.75   388.25   422.37
 5001.2    3.00   454.30   423.56   334.17    35.94   269.11   392.47
10401.2    3.00   344.29   344.25   253.39    33.71   204.84   327.39
15201.2    3.00   287.12   287.09   214.16    44.28   172.66   275.49
20002.8    3.00   299.07    65.35   196.85    56.48   149.94   250.07
25402.8    3.00   229.45   229.43   168.93    62.49   133.66   222.13
30201.2    3.00   264.84   206.26   153.20    77.75   121.27   197.10
38001.2    3.00   180.76   180.75   133.13    87.89   106.76    176.09
```

## OUT3.

```
  TIME    TGSF    TFSF    PAS    XMDOT       MOXS       MNIS

  100.1   281.2   271.6   101.8  .3211E-2   1.529E+5   5.062E+5
 1002.2   374.7   285.4   104.9  .2617E-1   1.529E+5   5.062E+5
 5001.2   609.2   343.0   112.8  .3526E-1   1.528E+5   5.059E+5
10401.2   670.1   405.5   114.8  .3555E-1   1.528E+5   5.056E+5
15201.2   651.0   438.9   114.1  .3543E-1   1.526E+5   5.053E+5
20002.8   620.6   458.3   113.0  .3523E-1   1.526E+5   5.050E+5
25402.8   590.4   471.9   111.9  .3399E-1   1.525E+5   5.046E+5
30201.2   566.4   477.0   111.0  .2790E-1   1.524E+5   5.044E+5
38001.2   535.9   479.1   109.9  .2269E-1   1.523E+5   5.0405+5
```

## OUT5.

| TIME | MNIP | MOXP | RN2 | CMBRH | LIBP |
|---|---|---|---|---|---|
| 100.1 | 355.7 | 107.2 | 0 | 0.7560 | 0 |
| 1002.2 | 287.7 | 45.38 | 0.3623 | 4.504 | 174.0 |
| 5001.2 | 176.0 | 15.34 | 0.3145 | 1.288 | 549.8 |
| 10401.2 | 191.4 | 15.47 | 0 | 0.6301 | 683.8 |
| 15201.2 | 261.8 | 33.17 | 0 | 0.6627 | 683.8 |
| 20002.8 | 362.5 | 25.28 | 0.07671 | 1.047 | 769.3 |
| 25402.8 | 435.2 | 19.68 | 0 | 0.6130 | 808.1 |
| 30201.2 | 544.5 | 44.75 | 0.03843 | 1.476 | 821.7 |
| 38001.2 | 658.2 | 39.13 | 0 | 0.8123 | 884.0 |

## OUT7.

| TIME | TB(1) | TB(2) | TB(4) | TB(6) | TB(8) |
|---|---|---|---|---|---|
| 100.1 | 27.00 | 27.00 | 27.00 | 27.00 | 27.00 |
| 1002.2 | 27.02 | 27.00 | 27.00 | 27.00 | 27.00 |
| 5001.2 | 27.42 | 27.13 | 27.00 | 27.00 | 27.00 |
| 10401.2 | 28.38 | 27.62 | 27.09 | 27.00 | 27.00 |
| 15201.2 | 29.30 | 28.24 | 27.30 | 27.02 | 27.00 |
| 20002.8 | 30.15 | 28.89 | 27.60 | 27.07 | 27.00 |
| 25402.8 | 31.00 | 29.62 | 28.01 | 27.16 | 27.02 |
| 30201.2 | 31.66 | 30.22 | 28.40 | 27.27 | 27.07 |
| 38001.2 | 32.54 | 31.00 | 29.07 | 27.52 | 27.16 |

## OUT8.

| TIME | TC(1) | TC(2) | TC(4) | TC(6) | TC(8) |
|---|---|---|---|---|---|
| 100.1 | 27.01 | 27.00 | 27.00 | 27.00 | 27.00 |
| 1002.2 | 27.40 | 27.17 | 27.01 | 27.00 | 27.00 |
| 5000.2 | 30.59 | 29.47 | 28.08 | 27.21 | 27.04 |
| 10401.2 | 33.37 | 32.18 | 30.29 | 28.30 | 27.62 |
| 15201.2 | 34.83 | 33.76 | 31.89 | 29.55 | 28.62 |
| 20002.8 | 35.73 | 34.00 | 33.10 | 30.77 | 29.72 |
| 25402.8 | 36.38 | 35.60 | 34.12 | 31.96 | 30.88 |
| 30201.2 | 36.79 | 36.12 | 34.81 | 32.83 | 31.76 |
| 38001.2 | 37.24 | 36.71 | 35.63 | 33.92 | 32.88 |

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