Transfer Process (TP) Package
Users' Guide

The Transfer Process (TP) package provides a standard interface for a MELCOR package to send mass and its associated enthalpy to one or more other packages. The identities of materials may change across the TP package.

This document provides a short description of the TP package, including the default identity translation matrix and the user input requirements for MELGEN and MELCOR, respectively, with some examples.

Contents

1. Introduction

The TP package provides a standard interface for a physics package to transfer mass and energy to one or more other packages. In other words, the TP package essentially functions as a sophisticated bookkeeper for inter-package mass and energy transfers. (The CVH package provides its own utility interface for control volume fluid mass and energy transfers involving other packages; the TP package is not involved.)

There are two types of transfer processes: *in* and *out*. An *in* transfer process sends information to the TP package where it is stored. On request, the TP package retrieves the information, processes it, and sends it to a calling *out* transfer process. User input defines the relationships between the *in* and *out* transfer processes. Currently, required input to the TP package is prescribed by the COR, CAV, and RN packages, and optionally by the FDI, HS, and SPR packages. (See the corresponding users' guides for details.) Eventually, much of this transfer of information will be made transparent to the user and obviate the need for TP input.

Masses may change identities across the TP package. This capability was originally intended for such uses as conversion of the materials called steel and steel oxide in the Core package into the materials called iron, chromium, nickel, and carbon and their oxides in the Cavity package. This particular use has been eliminated by inclusion of the material composition information (specified via Core package input) in a separate TP interface array that is used directly by the Cavity package to break the steel and steel oxide into their constituent components. This will allow definition of time-dependent steel compositions sometime in the future. The material conversion feature of the TP package is now used only to handle imperfect interfaces between packages or between a package and an external data file.

The user must specify a translation matrix to relate materials in the *out* process to those in the *in* process through the matrix equation.

$$\textit{mass out} = \textit{translation matrix} \times \textit{mass in}$$

The total mass of a material is conserved only if the elements in all translation matrix columns for the material sum to one. Thus, it is possible for mass to be retained or created by the TP package, which might be necessary because of imperfect interfaces between packages. For example, if the Core package ejects B_4C and the Cavity package does not recognize that material (as is currently the case), it must be retained by the TP package by using the translation matrix to eliminate the B_4C from the output masses:

Any mass retained or created by the TP package is printed in MELCOR output in terms of the *in* process masses.

UO_2		1	0	0	0	0	0		UO_2
Zr		0	1	0	0	0	0		Zr
Steel	=	0	0	1	0	0	0	X	Steel
ZrO_2		0	0	0	1	0	0		ZrO_2
St. Ox.		0	0	0	0	1	0		St. Ox.
									B_4C

The translation matrix may also be used to accommodate *in* processes defined by external data files that do not have the precise format expected by the *out* process. For example, a 7-group (Reactor Safety Study, WASH-1400) source of fission products could be partitioned into the default 15 groups expected by the RN package through an appropriate translation matrix with 15 rows and 7 columns:

Noble gases		1	0	0	0	0	0	0		Noble Gases
Alk. Metals		0	0	1	0	0	0	0		Halogens
Alk. Earths		0	0	0	1	0	0	0		Alk. Metals
Halogens		0	1	0	0	0	0	0		Alk. Earths
Chalcogens		0	0	0	0	.967	0	0	X	Te Group
Platinoids		0	0	0	0	0	.53	0		Trans. Metals
Trans. Metals		0	0	0	0	0	.47	.002		Lanthanides
Tetravalents	=	0	0	0	0	0	0	.702		
Trivalents		0	0	0	0	0	0	.296		
Uranium		0	0	1	0	0	0	0		
As, Sb		0	0	0	0	.033	0	0		
Sn, Ag		0	0	0	0	0	0	0		
Boron		0	0	0	0	0	0	0		
Water		0	0	0	0	0	0	0		
Concrete		0	0	0	0	0	0	0		

The total enthalpy of materials transferred from one package to another via the TP package may not be conserved, either because masses may not be conserved or because of differences in equation-of-state representations between the two packages. The *out* package that receives masses also receives thermodynamic variables to calculate the enthalpy of the masses it has just received and transmits that information back to the TP package. For example, the Core package may use temperature for the thermodynamic variable and calculate an enthalpy of 2 MJ for a mass. The Cavity package may receive the mass and temperature but calculate an enthalpy of 2.7 MJ. The Cavity package transmits the 2.7 MJ value back to the TP package, which will log an enthalpy difference of 0.7 MJ. The enthalpy differences are also printed in MELCOR output.

If the equations of state for a material are the same for two packages except for a difference in reference point, there will be no real energy error if temperature is used as the thermodynamic variable. If the equations of state are not the same, there is an energy discrepancy that cannot be resolved (without choosing one equation or the other as "right"),

and there will be either an energy error if temperature is held constant during the transfer or a temperature jump if energy is held constant during the transfer. For the former case, the energy error will be on the order of the uncertainty in the equation of state (hence the difference in state formulations) as long as the temperature at which material is transferred is not on one side of a phase transition for one equation and on the other side of the phase transition for the other equation. MELCOR currently uses this approach to avoid step changes in temperature during debris ejection from the core to the cavity.

2. Default Translation Matrices

The commonly used identity translation matrix is available for use as default matrix number 1. It is square and all its elements are zero except for ones along the diagonal. This matrix preserves all characteristics of the incoming material when it is passed to the *out* transfer process.

3. MELGEN User Input

The user defines the *in* and *out* transfer processes and the matrices that convert the *in* materials to the *out* materials. Every *in* process must be associated with at least one *out* process. Every translation matrix must be associated with at least one *out* process.

The following input descriptions are generic in nature. Several MELCOR packages (the COR, FDI, CAV, and RN packages) have specific requirements for TP package input. Details regarding the specific input required for these packages may be found in their respective users' guides.

TPINnnn00 – *In* Transfer Process

$001 \leq nnn \leq 999$, nnn is the transfer process number.
Required

This record defines an *in* transfer process, the number of masses in and the number of thermodynamic variables in. Enthalpy calculated using the thermodynamic variables is also transferred, but is itself not one of those variables.

(1) NMSIN - Number of masses in.
(type = integer, default = none, units = none)

(2) NTHRM - Number of thermodynamic variables.
(type = integer, default = none, units = none)

TPINnnn01 – Connection to External Data File

$001 \leq nnn \leq 999$, nnn is the transfer process number.

Optional

This record allows association of an *in* transfer process with an external data file. (See the External Data File (EDF) Package Users' Guide.) It may be used to write out a history of the *in* process; this allows data from one MELCOR run to be saved for later use. Conversely, it may be used to read in such a history, and to generate appropriate mass transfers from it; this allows data from a previous MELCOR run (or those from another simulation code) to be used to generate sources of debris or radionuclides as though they had been received through an *in* transfer process.

If a file is written, each record will contain NMSIN cumulative masses, the cumulative enthalpy, and NTHRM thermodynamic variables (i.e., NMSIN + NTHRM + 1 EDF channels). The masses and the thermodynamic variables will be in the order defined by the package which will use this *in* process. See the description of NTPCOR on input record COR00004, or of NFDTPI on input record FDInn00 for debris transfers.

Note that a second transfer process for associated radionuclides will ordinarily be defined, with a user number exactly 500 greater than that for the debris. It will have NMSIN = NUMCLS (described for input record RN1001) and NTHRM = 1. Each record in the file will contain NUMCLS + 2 channels (dependent variables) since a cumulative enthalpy will also be written.

If a file is read, it is assumed to have the same format, although differences in the number and order of masses from the MELCOR transfer process it replaces may be accommodated through proper definition of the translation matrix using TPMnnnkkkk input.

(1) DIRECT - Direction of connection. This may be either 'WRITE' to write a history file or 'READ' to read a file.
(type = character*5, default = none, units = none)

(2) IP2EDF - User number of associated EDF file.
If DIRECT = 'WRITE', this must be the number of a valid "PUSH" file containing exactly NMSIN + 1 + NTHRM channels.

If DIRECT = 'READ', this must be the number of a valid "READ" file containing at least NMSIN + 1 + NTHRM channels, of which the first NMSIN + 1 + NTHRM will be used.

See the EDF Users' Guide for further input requirements, including file names and record frequency for output files.

TPOTnnn00 – *Out* Transfer Process Record

001 ≤ nnn ≤ 999, nnn is the transfer process number.
Required

This record defines an *out* transfer process, the number of masses passed back to the calling subroutine and the associated *in* transfer process number.

(1) NMSOT - Number of masses associated with this *out* transfer process.
(type = integer, default = none, units = none)

(2) NPOTOI - Associated *in* transfer process number.
(type = integer, default = none, units = none)

(3) OUTMTX - Associated translation matrix.
In process masses are multiplied by a translation matrix to generate the *out* process masses. Each *out* transfer process has a translation matrix associated with it. OUTMTX must be specified in the form of KEYWORD.IOTMTX, where KEYWORD must be the character string DEF or UIN, and where IOTMTX is the number of the translation matrix used for this *out* transfer process. DEF is used to specify a default translation matrix (see Section 2). Currently, only DEF.1, the identity matrix, is available. UIN is used if the user defines a translation matrix via user input. For example, UIN.200 would specify user-defined matrix 200. Refer to the TPMnnnkkkk input records described below.
(type = character, default = none, units = none)

TPMnnn0000 – Translation Matrix

001 ≤ nnn ≤ 999, nnn is the translation matrix number.
Optional

This record defines a translation matrix. It defines the number of rows and columns of the matrix. All nonzero elements of the matrix must be defined using input record TPMnnnkkkk below.

(1) NROW - Number of rows.
(type = integer, default = none, units = none)

(2) NCOL - Number of columns.
(type = integer, default = none, units = none)

TPMnnnkkkk – Define Translation Matrix

001 ≤ nnn ≤ 999, nnn is the translation matrix number.
0001 ≤ kkkk ≤ ZZZZ, kkkk is a collocation field

Optional

This record defines the nonzero elements of a translation matrix. The input is in the form of data pairs. The first element of the data pair is of the form NROW/NCOL where NROW is the row number and NCOL is the column number of the translation matrix. The second number is a real number that is the value of the NROW-th, NCOL-th element of the matrix. An arbitrary number of data pairs may be defined on a single record but a data pair may not be split across two records. If an element of the matrix is defined more than once, then the last value is retained.

(1) NROW/
NCOL - Character string with NROW equal the row number and NCOL equal to the column number. For example 3/5 is the third row and fifth column.
(type = character, default = none, units = none)

(2) VALUE - Value of the NROW-th row and NCOL-th column in the matrix.
(type = real, default = 0, units = none)

4. MELCOR User Input

For a given *out* transfer process, the user may redefine the associated *in* transfer process number and translation matrix. The elements of a translation matrix may be redefined. No new *in* transfer processes, *out* transfer processes, or translation matrices may be defined in MELCOR. Every *in* process must be associated with at least one *out* process.

TPOTnnn00 – *Out* Transfer Process Record
001 ≤ nnn ≤ 999, nnn is the transfer process number.
Optional

For an existing *out* transfer process, this record may redefine the associated *in* transfer process number, and the associated translation matrix.

(1) NMSOT - Number of masses associated with this *out* transfer process. This may not be changed in MELCOR.
(type = integer, default = none, units = none)

(2) NPOTOI - Associated *in* transfer process number.
(type = integer, default = none, units = none)

(3) OUTMTX - Associated translation matrix.
In process masses are multiplied by a translation matrix to generate the *out* process masses. Each *out* transfer process has

a translation matrix associated with it. OUTMTX must be specified in the form of KEYWORD.IOTMTX, where KEYWORD must be the character string DEF or UIN, and where IOTMTX is the number of the translation matrix used for this *out* transfer process. DEF is used to specify a default translation matrix (see Section 2). Currently, only DEF.1, the identity matrix, is available. UIN is used if the user defines a translation matrix via user input. For example, UIN.200 would specify user-defined matrix 200. Refer to the TPMnnnkkkk input records described below. Any redefinition of translation matrices must be done so that the number of rows and columns do not change, whether default or user-defined matrices are used.
(type = character, default = none, units = none)

TPMnnn0000 – Translation Matrix

$001 \leq nnn \leq 999$, nnn is the translation matrix number.
Optional

This record defines the size of a translation matrix, and may be input in MELCOR for a matrix already defined in MELGEN. However, the number of rows and columns of a matrix cannot be changed in MELCOR. If this record is input without any TPMnnnkkkk records, all elements of matrix nnn are set to zero, and all information will be lost.

(1) NROW - Number of rows.
(type = integer, default = none, units = none)

(2) NCOL - Number of columns.
(type = integer, default = none, units = none)

TPMnnnkkkk – Define Translation Matrix

$001 \leq nnn \leq 999$, nnn is the translation matrix number.
$0001 \leq kkkk \leq ZZZZ$, kkkk is a collocation field.
Optional

This record defines the nonzero elements of a translation matrix that has been defined in MELGEN. If any TPMnnnkkkk records are input, all elements of matrix nnn not defined in TPMnnnkkkk records are set to zero. The input is in the form of data pairs. The first element of the data pair is of the form NROW/NCOL, where NROW is the row number and NCOL is the column number of the translation matrix. The second number is a real number that is the value of the NROW-th, NCOL-th element of the matrix. An arbitrary number of data pairs may be defined on a single record but a data pair may not be split across two records. If an element of the matrix is defined more than once, then the last value is retained.

(1) NROW/
NCOL - Character string with NROW equal the row number and NCOL equal to the column number. For example 3/5 is the third row and fifth column.
(type = character, default = none, units = none)

(2) VALUE - Value of the NROW-th row and NCOL-th column in the matrix.
(type = real, default = 0.0, units = none)

5. Example Input

5.1 Example 1

Example 1 below provides input to define two *in* transfer processes, three *out* transfer processes, and two translation matrices. The first *in* transfer process has three masses in and one thermodynamic variable. The second *in* transfer process has four masses and two thermodynamics variables. The first *out* transfer process is associated with the first *in* transfer process, has three masses out and uses the default identity translation matrix. The second and third *out* transfer process are associated with the second *in* transfer process. Note that the sum of the fourth column of the two matrices do not add to one, so the total mass in will not be equal to the total mass out.

```
TPIN10100  3  1    * MASSES THERMO
TPIN10200  4  2    * MASSES THERMO
*
TPOT20100  3  101  DEF.1     * MASSES, IN PROCESS, DEFAULT MATRIX 1
TPOT20200  6  102  UIN.100   * MASSES, IN PROCESS, USER MATRIX 100
TPOT20300  4  102  UIN.101   * MASSES, IN PROCESS, USER MATRIX 101
*
*              | .8   0    0    0  |
*              | .1   0    0    0  |
* MATRIX 100:  |.08   0    0    0  |
*              |.02   0    0    0  |
*              | 0    1    0    0  |
*              | 0    0    1    0  |

TPM1000000    6 4                      * 6X4 MATRIX
TPM1000001    1/1  .8                  * ROW 1, COLUMN 1
TPM1000002    2/1  .1                  * ROW 2, COLUMN 1
TPM1000003    3/1  .08                 * ROW 3, COLUMN 1
TPM1000004    4/1  .02                 * ROW 4, COLUMN 1
TPM1000005           5/2  1.           * ROW 5, COLUMN 2
TPM1000006                  6/3  1.  * ROW 6, COLUMN 3
*
```

```
*               |  0    0    0    0  |
* MATRIX 101:   |  0    0    0    0  |
*               |  0    0    0    0  |
*               |  0    0    0   .9  |
*
TPM1010000 4  4                        * 4X4 MATRIX
TPM1010001 4/4    .9                   * DEFINE NONZERO ELEMENTS
```

5.2 Example 2

Example 2 provides sample input for the COR, FDI, CAV, and TP packages for a typical plant calculation. To help make sense of this input, let 1 = COR, 2 = FDI, 3 = CAV, and 9 = TP in the various *in* and *out* transfer process numbers, so that all *out* transfer process numbers begin with 9 (or 59 for 3-digit RN TP numbers) and all *in* transfer process numbers end with 9. For example, TP #29 is an *in* transfer process describing masses passed in to TP from FDI.

```
* COR, FDI, AND CAV PACKAGE INPUT
* NO INPUT REQUIRED FOR RN PACKAGE
*          COR'IN'TP
COR00004   19
*          NCV    NCAV      FDI'IN'TP    FDI'OUT'TP
FDI0500    500    10        29           92
*          CAV'OUT'TP
CAV10TP    93
*
* 'IN' TRANSFER PROCESS FOR COR PACKAGE
*             NMSIN         NTHRM
TPIN01900     6             9
* 'OUT' TRANSFER PROCESS FOR FDI PACKAGE
*             NMSOT         NPOTOI   IOTMTX
TPOT09200     5             19       UIN.506
* 'IN' TRANSFER PROCESS FOR FDI PACKAGE
*             NMSIN         NTHRM
TPIN02900     5             9
* 'OUT' TRANSFER PROCESS FOR CAV PACKAGE
*             NMSOT         NPOTOI   IOTMTX
TPOT09300     5             29       DEF.1
*
* COR-FDI TRANSLATION MATRIX
* *** NOTE *** CONTROL POISON MASS IS NOT CONSERVED
*             NROW          NCOL
TPM5060000    5             6
*             NROW/NCOL     VALUE
TPM5060001    1/1           1.0      * UO2 MASS
TPM5060002    2/2           1.0      * ZR MASS
TPM5060003    3/3           1.0      * STEEL MASS
```

```
TPM5060004   4/4          1.0     * ZRO2 MASS
TPM5060005   5/5          1.0     * STEEL OXIDE MASS
*
* TRANSFER PROCESSES FOR RADIONUCLIDE TRANSFER
* RN TP NUMBERS MUST BE COR, FDI, CAV TP NUMBERS + 500
TPIN51900  15     1
TPIN52900  15     1
TPOT59200  15     519      DEF.1
TPOT59300  15     529      DEF.1
```

5.3 Example 3

Example 3 provides sample input to split ejected core debris into two separate reactor cavities for molten core-concrete interactions. Seventy-five percent of the debris is discharged to cavity 2, and the remainder is discharged to cavity 3. The numbering scheme for transfer process numbers is similar to that for Example 2, with 1 = COR, 2 = CAV2, 3 = CAV3, and 9 = TP.

```
* COR AND CAV PACKAGE INPUT
*          COR'IN'TP
COR00004   19
*          CAV2'OUT'TP
CAV02TP    92
*          CAV3'OUT'TP
CAV03TP    93
*
* 'IN' TRANSFER PROCESS FOR COR PACKAGE
*          NMSIN  NTHRM
TPIN01900  6      9
* 'OUT' TRANSFER PROCESSES FOR CAV PACKAGE
*          NMSOT  NPOTOI    IOTMTX
TPOT09200  5      19        UIN.2
TPOT09300  5      19        UIN.3
*
* COR-CAV TRANSLATION MATRICES
* 0.75 TO CAVITY 2, 0.25 TO CAVITY 3
* *** NOTE *** CONTROL POISON MASS IS NOT CONSERVED
*          NROW   NCOL
TPM0020000 5      6
*           NROW/NCOL       VALUE
TPM0020001 1/1              0.75     * UO2 MASS
TPM0020002 2/2              0.75     * ZR MASS
TPM0020003 3/3              0.75     * STEEL MASS
TPM0020004 4/4              0.75     * ZRO2 MASS
TPM0020005 5/5              0.75     * STEEL OXIDE MASS
*
*          NROW   NCOL
```

```
TPM0030000 5     6
*          NROW/NCOL       VALUE
TPM0030001 1/1             0.25    * UO2 MASS
TPM0030002 2/2             0.25    * ZR MASS
TPM0030003 3/3             0.25    * STEEL MASS
TPM0030004 4/4             0.25    * ZRO2 MASS
TPM0030005 5/5             0.25    * STEEL OXIDE MASS
*
* TRANSFER PROCESSES FOR RADIONUCLIDE TRANSFER
* RN TP NUMBERS MUST BE COR AND CAV TP NUMBERS + 500
TPIN51900  15    1
TPOT59200  15    519       UIN.12
TPOT59300  15    519       UIN.13

* MATRIX 12 IS 15 X 15 IDENTITY MATRIX TIMES 0.75
*          NROW  NCOL
TPM0120000 15    15
*          NROW/NCOL       VALUE
TPM0120001 1/1             0.75
TPM0120002 2/2             0.75
TPM0120003 3/3             0.75
TPM0120004 4/4             0.75
TPM0120005 5/5             0.75
TPM0120006 6/6             0.75
TPM0120007 7/7             0.75
TPM0120008 8/8             0.75
TPM0120009 9/9             0.75
TPM0120010 10/10           0.75
TPM0120011 11/11           0.75
TPM0120012 12/12           0.75
TPM0120013 13/13           0.75
TPM0120014 14/14           0.75
TPM0120015 15/15           0.75
*
* MATRIX 13 IS 15 X 15 IDENTITY MATRIX TIMES 0.25
*          NROW  NCOL
TPM0130000 15    15
*          NROW/NCOL       VALUE
TPM0130001 1/1             0.25
TPM0130002 2/2             0.25
TPM0130003 3/3             0.25
TPM0130004 4/4             0.25
TPM0130005 5/5             0.25
TPM0130006 6/6             0.25
TPM0130007 7/7             0.25
TPM0130008 8/8             0.25
TPM0130009 9/9             0.25
```

```
TPM0130010  10/10          0.25
TPM0130011  11/11          0.25
TPM0130012  12/12          0.25
TPM0130013  13/13          0.25
TPM0130014  14/14          0.25
TPM0130015  15/15          0.25
```