Passive Autocatalytic Recombiner (PAR) Package Users' Guide

The MELCOR ESF Package models the phenomena for the various engineered safety features (ESFs) in a nuclear power plant. The Passive Autocatalytic Recombiner (PAR) package constitutes a subpackage within the ESF package, and calculates the removal of hydrogen from the atmosphere due to the operation of passive hydrogen reaction devises. This Users' guide provides basic information needed to run the PAR model with the rest of MELCOR, including a detailed explanation of the user input and package output for MELGEN, MELCOR, and HISPLT. Required and optional input, control function arguments, plot variables, and error messages are all covered.

More detailed information on the phenomenological modeling and numerical solution schemes implemented in the PAR package can be found in the PAR Package Reference Manual.

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1. Introduction

The MELCOR ESF package models the thermal-hydraulic behavior of various engineered safety features (ESFs) in nuclear power plants. One such device is the passive autocatalytic hydrogen recombiner.

The MELCOR PAR model is based on the Fischer model (see the PAR Package Reference Manual), which is a parametric model developed for the most common PAR design. The user input provides correlation coefficients for the general mathematical form of the model. These coefficients are used by the code to calculate the total gas flow rate through a PAR unit. From the PAR gas flow rate together with user provided PAR efficiencies, transient relaxation times, delay times, and the internally calculated hydrogen mole fractions, a per-PAR-unit hydrogen reaction rate is calculated. This rate is then multiplied by the current timestep and the user provided number of active PAR units to determine the change in hydrogen, oxygen, and steam masses. These differential masses are then passed to CVH as source/sink terms.

2. Input Requirements

This section gives the input requirements for the MELCOR PAR package, including a short description of the input quantities and their units and default values, if any. Further description of the input variables and their meaning in the models can be found in the PAR Package Reference Manual.

Input record identifiers for the PAR model all begin with the character string "ESFPAR". Multiple hydrogen recombiner types can be specified, and input is grouped into sets for each hydrogen recombiner modeled, identified by the three digits "nnn".

2.1 MELGEN Input

ESFPARnnn00 – Hydrogen Recombiner Name
$1 \leq nnn \leq 999$, where nnn is the PAR number
Required

This record specifies a user-supplied name for the hydrogen recombiner for purposes of easy identification. This record is required. The following character field (limited to 16 characters) must be present:

(1) FPRNAM - PAR name.
(type = character*16, default = none)

ESFPARnnn01 – Hydrogen Recombiner Interface and Control Integers
1≤ nnn ≤ 999, where nnn is the PAR number
Required

This record specifies the control volume to which the PAR unit is interfaced, a control function/flag to switch between the basic model and a user provided model, and a control function/flag to switch between the constant efficiency and a user provided variable efficiency. This record is required, but only the first field must be present.

(1) IPAR - Hydrogen Recombiner control volume number.
(type = integer, default = none, units = none)

(2) IPROPT - Flag for selection of the Hydrogen Recombiner flow model. If this number is specified as zero, the basic Fischer model will be used. Otherwise this field should correspond to the identifier number of a control function that provides the PAR unit total gas volumetric flow rate.
(type = integer, default = 0, units = none)

(3) IETAPR - Flag for selection of the Hydrogen Recombiner efficiency model. If this number is specified as zero, a constant efficiency (EPAR, provided on the 02 record) will be used for the PAR efficiency. Otherwise this field should correspond to the identifier number of a control function that provides the PAR efficiency.
(type = integer, default = 0, units = none)

ESFPARnnn02 – Hydrogen Recombiner Parameters
1 ≤ nnn ≤ 999, where nnn is the PAR number
Optional

This record specifies the Fischer model flow rate correlation coefficients, the transient effect parameters and the PAR multiplicity. This record is optional, but if any of the fields require changes from default values, the entire set of six parameters must be supplied.

(1) APAR - Hydrogen Recombiner correlation coefficient.
(type = real, default = 0.67, units = m^3/s)

(2) BPAR - Hydrogen Recombiner exponential parameter.
(type = real, default = 0.307, units = none)

(3) EPAR - Hydrogen Recombiner efficiency.
(type = real, default = 0.85, units = none)

(4) TAUPAR - Hydrogen Recombiner transient relaxation time.
(type = real, default = 1800.0, units = s)

(5) TPARD - Hydrogen Recombiner operation delay time.
(type = real, default = 0.0, units = s)

(6) FPARD - Number of hydrogen recombiners of this type. Note that this does not have to be a whole number of units. The degraded operation of one or more units can be simulated by using a fraction of a PAR unit.
(type = real, default = 1.0, units = none)

ESFPARnnn03 – Hydrogen Recombiner Combustion Limit Data
$1 \leq nnn \leq 999$, where nnn is the PAR number
Required

This record specifies the on/off reactant concentration limits of the PAR unit. The first two fields specify the minimum hydrogen mole fraction for which the unit will start operating (startup point) and the minimum hydrogen mole fraction to which the unit will reduce the hydrogen concentration (shutoff point). The 3rd and 4th fields specify the same values for the oxygen concentration limits. This record is optional, but if any of the fields require changes from default values the entire set of four parameters must be supplied.

NOTE: Care must be exercised to ensure that the shutoff concentrations are always less than the startup concentrations. Also, due to lack of data, the default values used here are not technically defensible.

(1) HPAR0 - Minimum H_2 mole fraction for PAR startup.
(type = real, default = 0.02, units = none)

(2) HPARR - Minimum H_2 mole fraction for PAR shutdown.
(type = real, default = 0.005, units = none)

(1) OPAR0 - Minimum O_2 mole fraction for PAR startup.
(type = real, default = 0.03, units = none)

(2) OPARR - Minimum O_2 mole fraction for PAR shutdown.
(type = real, default = 0.005, units = none)

2.2 MELCOR Input

No input for the H_2 recombiner model is processed during MELCOR execution.

3. Sensitivity Coefficients

Because the required model parameters are all accessible through the input record, sensitivity coefficients for the Hydrogen Recombiner model are not required.

4. Plot Variables and Control Function Arguments

The plot variables and control function arguments currently included in the PAR model are listed below, along with a brief description. Within slashes (/ /) a 'p' indicates a plot variable and a 'c' indicates a control function argument.

ESF-PAR-DMH2.n	/pc/	Per PAR unit H_2 removal rate for PAR n. (units = kg/s)
ESF-PAR-INH2.n	/pc/	Total H_2 removed for all FPARD units of PAR n. (units = kg)
ESF-PAR-DVOL.n	/pc/	Per PAR unit total gas flow rate for PAR n. (units = m^3/s)
ESF-PAR-IVOL.n	/pc/	Total volume of gas processed in all FPARD units of PAR n. (units = m^3)
ESF-PAR-TOUT.n	/pc/	Outlet gas temperature for PAR n. (units = m^3/s)
ESF-PAR-FMOL.n	/pc/	Outlet gas H_2 mole fraction for PAR n. (units = m^3)

5. Example Input

The following are sample MELGEN input records for the PAR model. No MELCOR input records are necessary to run the PAR model.

```
*     PASSIVE AUTOCATALYTIC RECOMBINER INPUT
*
ESFPAR10100    'NISPAR1'
*
*               IPAR     IPROPT   IETAPR
ESFPAR10101     100       101      102
*
*                APAR      BPAR     EPAR    TAUPAR   TPARD   FPARD
ESFPAR10102      0.75     0.300     0.75    1800.0    0.0     20.0
*
*               HPAR0      HPARR     OPAR0     OPARR
ESFPAR10103     0.01       0.001      0.02     0.001
*
```

```
**
*
*       CONTROL FUNCTION FOR H2 RECOMBINER FLOW RATE
*
*       PAR GAS FLOW RATE USING FISHER MODEL (NO TRANSIENT)
*     FOR CONTROL VOLUME 100 @ HYDROGEN AS MATERIAL 6.
*
CF10100  'PAR-FLOW'  POWER-R  1  0.67  0.0
CF10103  0.307
CF10110  1.0  0.0  CVH-X.6.100
*
*
*       CONTROL FUNCTION FOR H2 RECOMBINER EFFICIENCY
*
*       PAR EFFICIENCY USING A CONSTANT
*
CF10200  'PAR-EFF'  EQUALS  1  1.0  0.0
CF10210  0.0  0.75  TIME
*
```

6. PAR Model Output

In general, the PAR model output is self-explanatory. The hydrogen removal rate, gas flow rate, total reacted hydrogen, total volume of processed gas, PAR outlet gas temperature and H_2 mole fraction are output for each PAR unit.

7. Diagnostic and Error Messages

Diagnostics and error messages generated during MELGEN are concerned with input processing and are generally self-explanatory. Currently, no messages are generated during MELCOR execution.