Fan Cooler (FCL) Package
Users' Guide

The MELCOR ESF Package models the phenomena for the various Engineered Safety Features (ESFs) in a nuclear power plant. The Fan Cooler (FCL) package constitutes a subpackage within the ESF Package, and calculates the heat and mass transfer associated with operation of the fan coolers. This Users' Guide provides basic information needed to run the FCL 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, sensitivity coefficients, 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 FCL package can be found in the FCL Package Reference Manual.

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1. Introduction

The MELCOR fan cooler model is based on the fan cooler model in the MARCH 2.0 code. An effective heat transfer area is calculated in MELGEN from the rated primary and secondary flows and temperatures, and from the heat transfer coefficient and cooler capacity at those conditions. The actual heat transfer rate during a transient is calculated based on the effective area, the heat transfer coefficient for the current steam mole fraction, and the average temperatures of the primary gas and secondary coolant, which are themselves implicit functions of the heat transfer rate. Details of the model can be found in the FCL Package Reference Manual.

Several extensions to the model have been made. The user may optionally specify a separate discharge control volume for the fan cooler outlet air flow. The user may also specify a control function to control operation of the cooler by turning it on or off. Finally, the MELCOR implementation roughly partitions the total heat transfer coefficient into separate convection and condensation components to try to account for the effects of noncondensible gases and superheated atmosphere. The user can control how this partitioning is made by adjusting the sensitivity coefficients used in the heat transfer correlation.

2. Input Requirements

This section gives the input requirements for the MELCOR FCL 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 FCL Package Reference Manual.

Input record identifiers for the FCL model all begin with the character string “ESFFCL”. Multiple fan coolers can be specified, and input is grouped into sets for each fan cooler modeled, identified by the three digits “nnn”.

2.1 MELGEN Input

ESFFCLnnn00 - Fan Cooler Name

$1 \leq nnn \leq 999$, where nnn is the fan cooler number
Required

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

(1) FCNAME - Fan cooler name.
(type = character*16, default = none)

ESFFCLnnn01 - Fan Cooler Interface and Control Integers
$1 \leq nnn \leq 999$, where nnn is the fan cooler number
Required

This record specifies the control volumes to which the fan cooler is interfaced, a control function to turn the cooler on or off, and a flag to control the phenomenological model that is used (currently, only the MARCH-based model is available). This record is required, but only the first field must be present; the remaining three fields are optional.

(1) ICVI - Fan cooler inlet control volume number.
(type = integer, default = none, units = none)

(2) ICVD - Fan cooler discharge control volume number. If this field is omitted, the discharge volume is the same as the inlet volume, i.e., the fan coolers sits entirely within a control volume. If this field is different from the inlet volume, the fan cooler operates somewhat like a flow path with a constant volumetric flow (that is cooled or dehumidified) from the inlet volume to the discharge volume.
(type = integer, default = ICVI, units = none)

(3) ICF - The number of the fan cooler logical control function that determines whether the fan cooler is on or off. This control function should return a value of .TRUE. whenever the fan cooler should be on. If this field is omitted, the fan cooler is always on.
(type = integer, default = none, units = none)

(4) IOPT - Fan cooler model flag. Currently, only IOPT=0, designating the MARCH-based model, is allowed.
(type = integer, default = 0, units = none)

ESFFCLnnn02 - Fan Cooler Rated Flows and Temperatures
$1 \leq nnn \leq 999$, where nnn is the fan cooler number
Required

This record specifies the rated primary and secondary flow rates and inlet temperatures. This record is required. NOTE: Care must be exercised to ensure that rated flows and temperatures are consistent with the rated cooler capacity.

(1) XVFGSR - Rated fan cooler gas volumetric flow rate.
(type = real, default = none, units = m^3/s)

(2) XMFSER - Rated fan cooler secondary coolant mass flow rate.
(type = real, default = none, units = kg/s)

(3) TSECIR - Rated fan cooler secondary coolant inlet temperature.
(type = real, default = none, units = K)

(4) TPR - Rated fan cooler inlet gas temperature.
(type = real, default = none, units = K)

ESFFCLnnn03 - Additional Fan Cooler Rated Conditions
$1 \leq nnn \leq 999$, where nnn is the fan cooler number
Required

This record specifies additional fan cooler rated conditions. This record is required. NOTE: Care must be exercised to ensure that rated flows and temperatures are consistent with the rated cooler capacity.

(1) QRAT - Rated fan cooler capacity.
(type = real, default = none, units = W)

(2) FMLSTR - Steam mole fraction at rated conditions.
(type = real, default = none, units = none)

ESFFCLnnn04 - Fan Cooler Actual Flows and Temperatures
$1 \leq nnn \leq 999$, where nnn is the fan cooler number
Optional

This record specifies the actual primary volumetric flow rate and secondary mass flow rate and inlet temperature during the transient if different from the rated values. If zero or a negative number is input for a field, it defaults to the rated value.

(1) XVFGSI - Actual fan cooler gas volumetric flow rate.
(type = real, default = XVFGSR, units = m^3/s)

(2) XMFSEC - Actual fan cooler secondary coolant mass flow rate.
(type = real, default = XMFSER, units = kg/s)

(3) TSECIN - Actual fan cooler secondary coolant inlet temperature.
(type = real, default = TSECIR, units = K)

2.2 MELCOR Input

No input for the fan cooler model is processed during MELCOR execution.

3. Sensitivity Coefficients

The *sensitivity coefficient* feature in MELCOR is a powerful feature that gives the user the ability to change selected parameters in the physics models that would otherwise require modification of the Fortran source code. Their use is described in Section 7 of the MELCOR EXEC Users' Guide.

3.1 FCL Sensitivity Coefficients

This section lists the sensitivity coefficients in the FCL model that are accessible to the user, along with a brief description, and gives their default values, units, and EQUIVALENCE names.

9001 - Coefficients for MARCH Fan Cooler Heat Transfer Correlation

These coefficients are used to calculate the effective heat transfer coefficient (W/m^2-K), as a function of the steam mole fraction X_{H2O}. The total heat (energy) transferred results from sensible and latent heat transfers. The sensible heat portion of the heat transfer coefficient, h_H is calculated by:

$$h_H = C9001(1) \cdot C9001(2)$$

The latent heat portion of the heat transfer coefficient, h_M, is calculated by:

$$h_M = h_L + C9001(1) \cdot [1 - C9001(2)]$$

where

$$h_L = C9001(4) \cdot X_{H2O},\ X_{H2O} \le C9001(3)$$

$$h_L = C9001(3) \cdot C9001(4) + C9001(5)[X_{H2O} - C9001(3)],\ X_{H2O} > C9001(3)$$

The default values are taken from the MARCH correlation.

(1) - sensible heat transfer coefficient
(default = 590.54, units = W/m^2-K, equiv = HSEN)

(2) - sensible heat transfer multiplier
(default = 1.0, units = none, equiv = FSEN)

(3) - steam mole fraction (boundary) in latent heat transfer coefficient correlation
(default = 0.26, units = none, equiv = FMLSCR)

(4) - coefficient in latent heat transfer coefficient correlation for low steam mole fractions
(default = 3603.4, units = W/m^2-K, equiv = DHLAT1)

(5) - coefficient in latent heat transfer coefficient correlation for high steam mole fractions
(default = 2325.25, units = W/m^2-K, equiv = DHLAT2)

4. Plot Variables and Control Function Arguments

The plot variables and control function arguments currently included in the FCL 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-QFC-RAT.n	/pc/	Heat transfer rate for fan cooler n. (units = W)
ESF-QFC-TOT-n.	/pc/	Total energy transfer for fan cooler n. (units = J)
ESF-MFC-RAT.n	/pc/	Condensation rate for fan cooler n. (units = kg/s)
ESF-MFC-TOT.n	/pc/	Total steam condensed for fan cooler n. (units = kg)

5. Example Input

The following are sample MELGEN input records for the FCL model for a fan cooler treated by the MARCH-based model. No MELCOR input records are necessary to run the FCL model.

```
*     FAN COOLER INPUT
*
ESFFCL10100     'MARCH1'
*
```

```
*                ICVI     ICVD      ICF       IOPT
ESFFCL10101      100      100       20        0
*
*                XVFGSR   XMFSER    TSECIR    TPR
ESFFCL10102      100.0    65.0      294.0     339.0
*
*                QRAT     FMLSTR
ESFFCL10103      1.9E6    0.693
*
*                XVFGSI   XMFSEC    TSECIN
ESFFCL10104      -1.      -1.       314.0
**
*
*           CONTROL FUNCTION FOR FAN COOLER
*
*           TURN FAN COOLER ON WHEN TIME GT 100.
*
CF02000       'ON100'  L-GT 2  1.0
CF02001       .FALSE.
CF02010      1.0   0.0  TIME
CF02011      0.0 100.0  TIME
*
```

6. FCL Model Output

In general, the FCL model output is self-explanatory. The heat transfer and condensation rates and the total cumulative energy transferred and steam condensed are output for each fan cooler.

7. Diagnostics 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.