### GroundHeatExchanger:Vertical

The EnergyPlus Ground loop heat exchanger is a condenser component. This serves the condenser supply side in addition to the cooling towers and other condensing components. The following figure shows the Ground Heat Exchanger in the simulation environment.

The heat exchanger response is defined by a G-function. This is a non-dimensional function that is used to calculate the response to square heat pulses of different duration. (This function is not the same as ‘G-factors’ referred to in the ASHRAE Applications Handbook). This continuous function is specified by a series of data pairs (LNTTS*i*, GFNC*i*) where,

* LNTTS*i* is the non-dimensional time: *ln(T/Ts)*
* GFNC*i* is the G-function value

The G-function is different for each borehole field configuration (i.e. a 4x4 field has a different response than a 80x80 field) and the borehole thermal resistance. It is also dependant on the ratio of borehole spacing to depth. G-function values, for accurate simulation, have to be calculated for each specific heat exchanger design. This can be done using some commercial ground loop heat exchanger design tool and the like. A reference data set, containing examples input data for 1x2, 4x4 and 8x8 configurations and for both standard and thermally enhanced grout, have also been provided. These data are provided as examples only. Custom G-function values may be generated using an external program such as GLHEPro. For more information about the datasets and GLHEPro, see the Auxiliary Programs document section “G-Function Spreadsheet.”

Further details of the implementation of this model can be found in:

Murugappan, A. *Implementing Ground Source Heat Pump and Ground Loop Heat Exchanger Models in the EnergyPlus Simulation Environment*. M.S. Thesis, Oklahoma State University, December 2002.



Figure 83. Schematic of EnergyPlus Ground Loop Heat Exchanger

The data definition for the ground loop heat exchanger from the Energy+.idd is shown below. The syntax to the specification of Borehole, U-tube and ground are illustrated in the example following.

#### Field: Name

This alpha field contains the identifying name for the ground heat exchanger (GHE).

#### Field: Inlet Node Name

This alpha field contains the ground heat exchanger inlet node name.

#### Field: Outlet Node Name

This alpha field contains the ground heat exchanger outlet node name.

#### Field: Design Flow Rate

This numeric field contains the GHE design flow rate in cubic meters per second {m3/s}.

#### Field: Number of Bore Holes

This numeric field contains the number of bore holes in the GHE installation.

#### Field: Bore Hole Length

This numeric field contains the length of the borehole in meters {m}.

#### Field: Bore Hole Radius

This numeric field contains the radius of the borehole in meters.

#### Field: Ground Thermal Conductivity

This numeric field contains the thermal conductivity of the ground in W/m-K.

#### FieldSet: Ground Thermal Heat Capacity

This numeric field contains the thermal heat capacity of the ground in J/m3-K.

#### Field: Ground Temperature

This numeric field contains the far field temperature of the ground in °C.

#### Field: Grout Thermal Conductivity

This numeric field contains the thermal conductivity of the filler material in W/m-K.

#### Field: Pipe Thermal Conductivity

This numeric field contains the thermal conductivity of the pipe in W/m-K.

#### Field: Pipe Out Diameter

This numeric field contains the outer diameter of the U-tube (pipe) in meters {m}.

#### Field: U-Tube Distance

This numeric field contains the distance between the two legs of the U-tube in meters {m}.

#### Field: Pipe Thickness

This numeric field contains the outer diameter of the U-tube (pipe) in meters.

#### Field: Maximum Length of Simulation

This numeric field contains the maximum number of years of simulation to be carried out.

#### Field: G-Function Reference Ratio

The G-Functions may be formulated slightly differently based on the program which generated them. The “raw” G-Functions are based on an borehole radius to active length ratio of 0.0005. If the physical ratio is different from this, a correction must be applied. EnergyPlus will apply the correction, based on the reference ratio entered in this field. Therefore, therefore two possible input configurations.

If the G-Functions have not had a correction applied, then the G-Functions are still based on a reference of 0.0005, so use a value of 0.0005 in this field. EnergyPlus will adjust the G-Functions internally to create the properly referenced G-Function.

If the correction has already been applied, then the input G-Functions are based on a reference to the actual (physical) radius/length ratio, so enter the physical radius/length in this field. Entering the actual value will nullify any internal corrections, which will avoid re-basing the G-Function set.

The software GLHEPro has been making this “pre-correction” to the data sets since version 3.1 of that software, so this input field should match the actual (physical) radius/length ratio.

#### Field: Number of Data Pairs of the G Function

The borehole response is defined by a non-dimensional ‘G-function’. This is specified as a series of data points giving values of non-dimensional time *vs* G-function value (LNTTS1, GFUNC1), (LNTTS2, GFUNC2), (LNTTS3, GFUNC3) …….. (LNTTS*n*, GFUNC*n*), This numeric field contains the number of data pairs to be read in (*n*).

#### Field: G-Function Ln(T/Ts) Value <x>

This numeric field contains the natural log of time/steady state time: *ln(T/Ts)*

#### Field: G-Function 'G' Value <x>

This numeric field contains the G-function value of the corresponding LNTTS.

The following is an example input:

GroundHeatExchanger:Vertical,

Vertical Ground Heat Exchanger, !- Name

GHE Inlet Node, !- Inlet Node Name

GHE Outlet Node, !- Outlet Node Name

0.00330000, !- Design Flow Rate {m3/s}

120, !- Number of Bore Holes

76.2, !- Bore Hole Length {m}

.635080E-01, !- Bore Hole Radius {m}

.692626E+00, !- Ground Thermal Conductivity {W/m-K}

.234700E+07, !- Ground Thermal Heat Capacity {J/m3-K}

13.375, !- Ground Temperature {C}

.692626E+00, !- Grout Thermal Conductivity {W/m-K}

.391312E+00, !- Pipe Thermal Conductivity {W/m-K}

2.66667E-02, !- Pipe Out Diameter {m}

2.53977E-02, !- U-Tube Distance {m}

2.41285E-03, !- Pipe Thickness {m}

2, !- Maximum Length of Simulation

0.0005, !- G-Function Reference Ratio

35, !- Number of Data Pairs of the G Function

! The G-function is defined by the following data pairs

-15.2996, -0.348322, ! G-Function Ln(T/Ts) Value 1, G-Function G Value 1

-14.201, 0.022208, ! G-Function Ln(T/Ts) Value 2, G-Function G Value 2

-13.2202, 0.412345, ! G-Function Ln(T/Ts) Value 3, G-Function G Value 3

-12.2086, 0.867498, ! G-Function Ln(T/Ts) Value 4, G-Function G Value 4

-11.1888, 1.357839, ! G-Function Ln(T/Ts) Value 5, G-Function G Value 5

-10.1816, 1.852024, ! G-Function Ln(T/Ts) Value 6, G-Function G Value 6

-9.1815, 2.345656, ! G-Function Ln(T/Ts) Value 7, G-Function G Value 7

-8.6809, 2.593958, ! G-Function Ln(T/Ts) Value 8, G-Function G Value 8

-8.5, 2.679, ! etc, etc.

-7.8, 3.023,

-7.2, 3.32,

-6.5, 3.681,

-5.9, 4.071,

-5.2, 4.828,

-4.5, 6.253,

-3.963, 7.894,

-3.27, 11.82,

-2.864, 15.117,

-2.577, 18.006,

-2.171, 22.887,

-1.884, 26.924,

-1.191, 38.004,

-0.497, 49.919,

-0.274, 53.407,

-0.051, 56.632,

0.196, 59.825,

0.419, 62.349,

0.642, 64.524,

0.873, 66.412,

1.112, 67.993,

1.335, 69.162,

1.679, 70.476,

2.028, 71.361,

2.275, 71.79,

3.003, 72.511; !- 35 PAIRS

### Vertical Ground Heat Exchanger Outputs

HVAC,Average,Ground Heat Exchanger Average Borehole Temperature [C]

HVAC,Average,Ground Heat Exchanger Heat Transfer Rate [W]

HVAC,Average,Ground Heat Exchanger Inlet Temperature [C]

HVAC,Average,Ground Heat Exchanger Outlet Temperature [C]

HVAC,Average,Ground Heat Exchanger Mass Flow Rate [kg/s]

HVAC,Average,Ground Heat Exchanger Average Fluid Temperature [C]

#### Ground Heat Exchanger Average Borehole Temperature [C]

This is the model result for the average temperature of the borehole heat exchanger.

#### Ground Heat Exchanger Heat Transfer Rate [W]

This is the rate of heat transfer between the working fluid and the ground heat exchanger, in Watts.

#### Ground Heat Exchanger Inlet Temperature [C]

This is the temperature of the working fluid entering the ground heat exchanger.

#### Ground Heat Exchanger Outlet Temperature [C]

This is the temperature of the working fluid leaving the ground heat exchanger.

#### Ground Heat Exchanger Mass Flow Rate [kg/s]

This is the mass flow rate of the working fluid through the heat exchanger.

#### Ground Heat Exchanger Average Fluid Temperature [C]

This is the average temperature of the working fluid inside the heat exchanger.