Interfacing HAP Simulations with Geothermal WSHP Design Programs

The purpose of this HAP e-Help is to demonstrate how cooling and heating load data required by geothermal water source heat pump (WSHP) design programs can be derived from Carrier HAP energy simulation results.

The design program we will use as an example is GLHEPro. This program was developed as an aid in the design and simulation of the loop heat exchanger. The heat exchanger referred to is the closed water piping loop connecting the WSHP units. GLHEPro was chosen for this HAP e-Help because it is widely available and assists in designing a popular geothermal heat exchanger configuration using a closed loop, which we will explain later. Information about GLHEPro can be obtained from the International Ground Source Heat Pump Association, which is headquartered at Oklahoma State University.

Before we begin the discussion of interfacing HAP with GLHEPro, we will briefly review the various types of WSHP systems starting with a conventional non-geothermal type.

Conventional Closed Loop WSHP System

In a conventional closed loop WSHP system, an indoor piping loop connects the WSHP units to a heat adder (boiler) and heat rejecter (cooling tower). The water in the loop is maintained within a normal operating range of 60 to 90° F. This is a popular system for WSHP units and is sometimes referred to as the California Loop system. Figure 1 depicts intermediate (spring or fall) season operation.

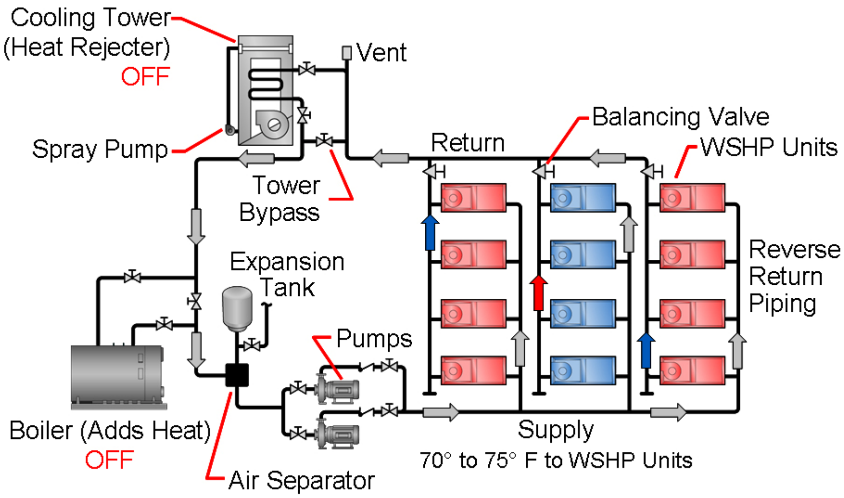


Fig. 1 Closed Loop (California) WSHP System

Units in the core of the building (blue) operate in cooling mode rejecting their heat to the common loop. Units on the perimeter (red) operate in the heating mode and absorb heat from the loop. This transfer of energy from one part of the building to the other via the closed loop increases system efficiency. Tower and/or boiler operation is not required as long as the loop stays within operating range.

HAP e-Help 003 dated October 24, 2005 covers the design and simulation of the California Loop system. In addition, there are other publications available on this topic including the Carrier WSHP System Design Guide (catalog # 795-202), and Carrier Technical Development Program – Water Source Heat Pump Systems catalog # 06-796-71.

Geothermal WSHP Systems

Geothermal WSHP systems take advantage of the fact that the Earth's resources (ground or water) remain at a relatively constant temperature at a certain depth all year long. Instead of a boiler and cooling tower, the ground or water serves to stabilize the WSHP loop. The temperature of the ground or water is relatively constant, (warmer in winter and cooler in summer than ambient air), so the WSHP units can absorb or reject heat very efficiently. At any one time on a typical commercial application, some heat pumps may be operating in heating while others operate in cooling. Even when it is hot outside, the ground or water temperature at a certain depth may be in the 55-60F range. WSHP heat rejection to the cool ground or water can take place at a low condensing temperature resulting in optimum cooling efficiency. In winter, the relatively warm ground or water increases WSHP heating efficiency. In addition, in most geothermal systems, a boiler or tower is not used thus further increasing system efficiency.

Interfacing HAP Simulations with Geothermal WSHP Design Programs

This increased system efficiency results in low operating costs. That is why geothermal WSHP systems are a popular choice for LEED (Leadership in Energy & Environmental Design) certification. LEED is a third party rating system developed by the USGBC (United States Green Building Council) that promotes energy efficiency and green building design.

Open Vs Closed Loop Geothermal

Geothermal water source heat pumps can utilize closed loops or open loop piping systems. Open loops are used with well, river, pond, lake or municipal water (once-thru) supply applications. Open loop design is straight forward and does not require design software like GLHEPro to size the piping. The source water temperature data is input directly into HAP (see figure 3 below).

Open loop systems are losing popularity to closed loops for several reasons. Open loop systems introduce the water directly into the water-cooled heat exchanger in the WSHP units, then discharge it back to the source as shown in figure 2 which is a recirculation well. Once discharged, care must be taken to return the water the source in a manner acceptable to local codes. Thermal pollution is a concern. The source water may have to be filtered and should contain no contaminants. An intermediate heat exchanger may be employed at additional cost to protect the system. Water requirements for an open system (depending on the source) can range from about 1.5-3 gpm per ton which can be prohibitive. Also, open loop systems in certain climates may be susceptible to freezing.

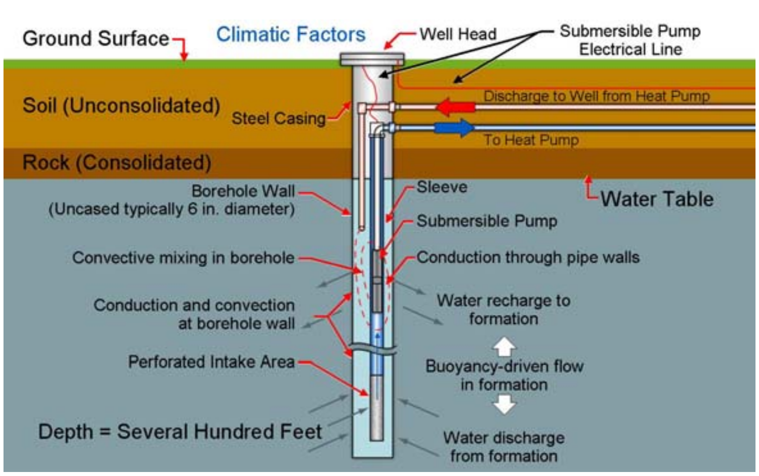


Fig. 2 Open Loop (Well) Application

(Photo courtesy Building and Environmental Thermal Systems Group Oklahoma State University)

For open loop analysis, HAP requires the user to enter the average source water temperatures for each month of the year as shown in figure 3. During energy simulations, HAP assumes source water at this temperature is available for all equipment operating hours. HAP e-Help 002 dated October 1, 2005 discusses the modeling of open loop WSHP systems in detail. River, sea or well water is used as the heat source or sink.

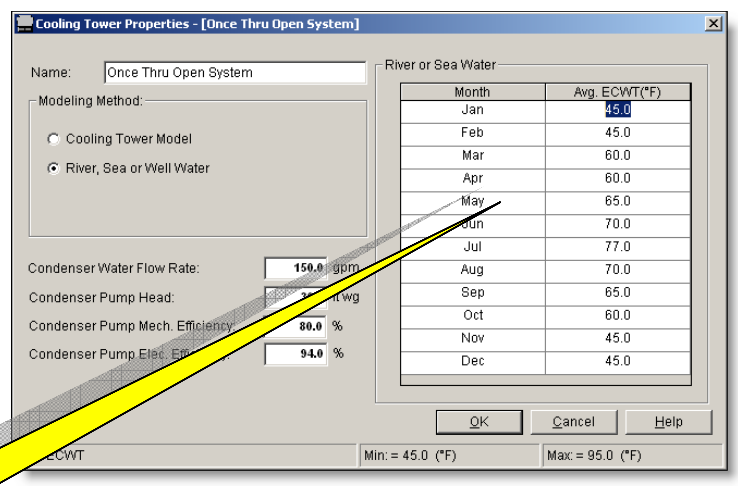


Fig 3. Modeling Open Loop Systems In HAP

Interfacing HAP Simulations with Geothermal WSHP Design Programs

Closed Loop Heat Exchanger Designs

Closed loop designs are more complex than open loop so design software like GLHEPro may be utilized. Closed loops can be installed submerged in a pond or lake, horizontal ground, or vertical ground configurations. All three alternatives operate with similar efficiency. Closed-loop systems consist of an underground (or underwater) heat exchange network of sealed, high-strength, high-density polyethylene (HDPE) plastic pipes and a pumping arrangement. When in the cooling mode, the loop fluid temperature will rise, and rejected heat is dissipated into the ground or water. Conversely, while heating, the loop fluid temperatures fall, and heat is absorbed from the ground or water. The pump module continually circulates the water/anti-freeze fluid within the piping system. Pond or lake loops are economical to install, however local codes may not permit the use of a lake or pond for heat transfer. Unlike an open system, the water in the closed loop piping never mixes with ground or surface water.

Spool Configuration

Fig. 4 Pond or Lake Closed Loop

Fig. 5 Horizontal Closed Loop in Trench

A horizontal closed loop (also called ground loop) is considered when adequate land area is available. The overall land area required can range up to 1500 ft^2 per system ton or even higher! That limits the applications for many horizontal loop designs. The pipes are placed in trenches which are excavated to a depth of 4 to 6 ft., spaced 6 to 10 ft. apart. Depending on the design, one to six pipes are installed in each trench.

Interfacing HAP Simulations with Geothermal WSHP Design Programs

Vertical closed ground loops are a popular choice for many projects. The land area required for commercial vertical ground loop designs can range from 200- 400 ft^2 per system ton.

Drilling equipment as shown in figure 6, is used to bore small diameter vertical holes. The holes typically extend to a depth of several hundred feet. The temperature in the ground at that depth is relatively constant during the course of the year resulting in stabile and efficient heat transfer from the ground to the fluid in the loop piping. A common design uses two pipes joined together with a U-Bend fitting and inserted into the vertical bore. The space around the pipe is filled with a grout material. This provides support and also promotes heat exchange between the pipe and the ground. In many cases, a thermally enhanced grout can be used to improve heat transfer and reduce the number of bores required. GLHEPro software was developed to aid in vertical closed loop designs.

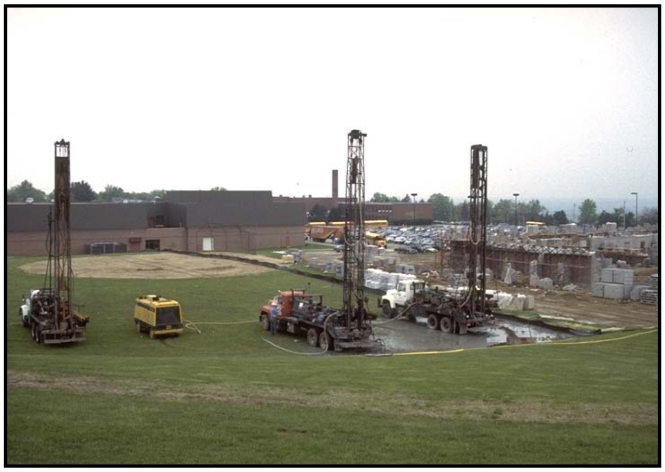


Fig. 6 Vertical Closed Loop Boring

HAP Interface To Design Software For Closed Loop Systems

Now that we have become familiar with the types of geothermal loops, we can discuss the interface of HAP to geothermal design software. Software like GLHEPro must consider many variables in order to configure the loop piping. For example, in the design of a vertical loop system, borehole depth, spacing, and quantity, along with piping lengths, soil thermal conductivity, and fluid properties, must be considered. In addition, localized ground conditions and the load requirements of the project must be considered.

The role of HAP is to generate the load data the geothermal program requires so it can be used to optimize the design of the heat exchanger. Both cumulative loads and peak loads for all months of the year are required.

GLHEPro Load Requirements:

1.	Total monthly cooling coil load	(kBTU)	(cumulative effects)
2.	Total monthly heating coil load	(kBTU)	
3.	Maximum hourly cooling coil load	(BTUH)	(peak magnitude)
4.	Maximum hourly heating coil load	(BTUH)	

Items 1 and 2 can be obtained directly from the HAP Monthly Simulation Results report for a WSHP air system shown in figure 9 on page 6.The Monthly Simulation Results contains monthly totals of loads and energy consumption for the system.

Finding items 3 and 4 is more involved. The procedure is summarized below and then demonstrated with a detailed example.

1. Create the geothermal WSHP system model in HAP.

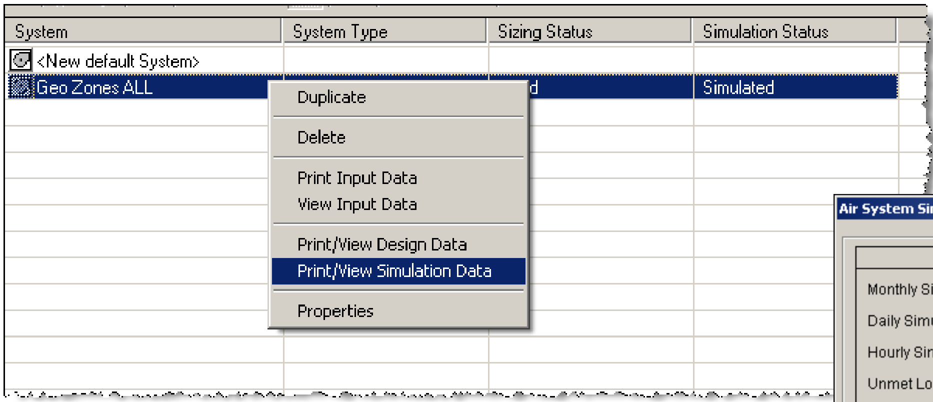
Interfacing HAP Simulations with Geothermal WSHP Design Programs

2. Run energy simulation for geothermal WSHP system in HAP and generate the Monthly Simulation Results (tabular version) and Hourly Simulation Results (ASCII text version, Jan 1 thru Dec 31).
3. Use the Monthly Simulation Results report to obtain the monthly cooling and heating load totals.
4. Use Excel to import the TXT file containing the Hourly Simulation Results into an XLS spreadsheet template provided by Carrier. Click here to download this file.
5. Use the summary table at the bottom of the XLS spreadsheet to obtain the monthly peak cooling and heating loads. This table uses the Excel MAX function to identify the peak load for each 1-month block of results.
6. Enter the monthly cooling and heating loads plus the monthly peak cooling and heating loads into GLHEPro to perform the heat exchanger sizing analysis.

The following example demonstrates the creation and transfer of load data.

Step 1: Set up the geothermal WSHP HAP model per HAP e-Help 002 dated October 1, 2005, "How to Model WSHP/GSHP Systems Using Carrier HAP Software." Pay special attention to example C. Ground Coupled WSHP System on page 3.

Step 2: Right click on the WSHP air system and Print View Simulation data. Our example air system is called Geo Zones All.



Print/View Simulation Data For Geothermal Loads

Step 3: Ask for the Monthly Simulation results and the Hourly Simulation Results TXT file. Hourly results must be for all year.

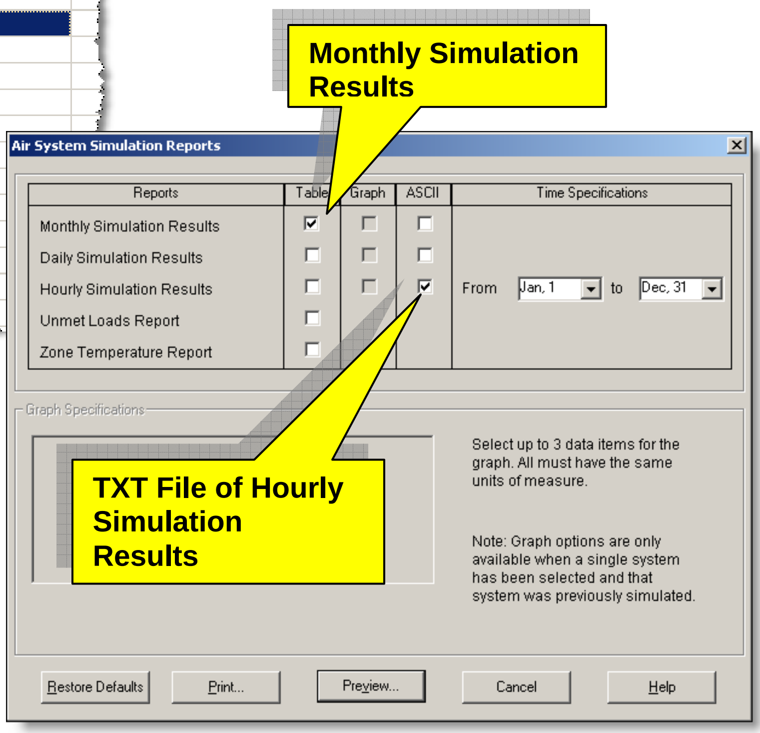


Fig. 8 Required Air System Simulation Reports

Interfacing HAP Simulations with Geothermal WSHP Design Programs

Step 4: Collect the monthly air system coil loads from the WSHP Cooling Coil and Heating Coil Load columns. These values can now be transferred directly into the geothermal design software. This data can be captured by highlighting it with the mouse then hitting the **Ctrl** and **C** (copy) keys simultaneously, and then it can be pasted into another document.

Monthly Simulation Results for Geo Zones ALL

Project Name: Geothermal Loads For HAP e-Help — 09/20/2006
Prepared by: Carrier Software — 10:07PM

Air System Simulation Results (Table 1) :

Month	WSHP Cooling Coil Load (kBTU)	WSHP Eqpt Cooling Load (kBTU)	WSHP Clg Compressor (kWh)	WSHP Heating Coil Load (kBTU)	WSHP Eqpt Heating Load (kBTU)	WSHP Htg Compressor (kWh)	WSHP Aux Htg Load (kBTU)
January	21771	19528	1038	44174	43993	3026	181
February	21423	19287	1026	23360	[illegible]	[illegible]	[illegible]
March	38318	35620	2240	10439	[illegible]	[illegible]	[illegible]
April	77491	74603	4614	640	[illegible]	[illegible]	[illegible]
May	116241	112980	7242	56	[illegible]	[illegible]	[illegible]
June	143776	140062	9375	0	[illegible]	[illegible]	[illegible]
July	170696	165951	11885	0	[illegible]	[illegible]	[illegible]
August	144057	140192	9367	0	0	0	0
September	115027	111647	7188	4	4	0	0
October	70143	67054	4184	1240	1240	84	0
November	31578	29277	1557	11313	11313	796	0
December	23294	20834	1105	36117	36085	2502	33
Total	973815	937034	60820	127343	127108	8781	235

Transfer these two columns of data directly to the geothermal design program. This comprises 24 of the 48 required loads from HAP

Fig. 9 Required Loads from Monthly Simulation Results

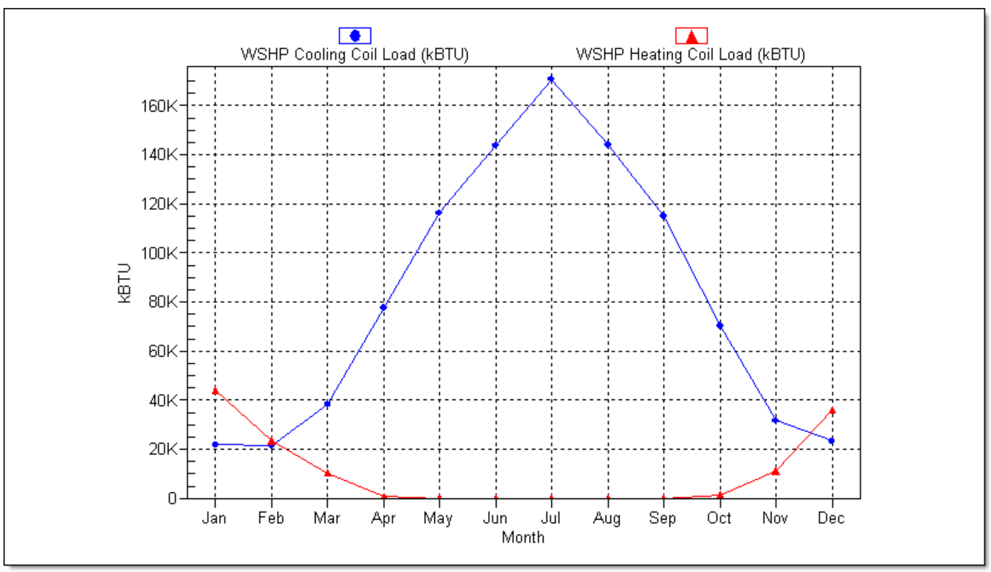


Fig. 10 Monthly Simulation Results Graph

SIDEBAR: If we graph the monthly simulation results, we can see the much more heat rejection (cooling load) is required than heat absorption (heating load). This is typical of commercial buildings. A supplemental cooling tower can be used as a way of decreasing the length of the loop heat exchanger piping required to handle all the heat rejection. This is called a hybrid system.

Interfacing HAP Simulations with Geothermal WSHP Design Programs

Next we will retrieve the remaining load data. The Hourly Simulation Results TXT file is created by checking the box in the Air System Simulation Reports.

Step 5: Open the blank Excel worksheet (GSHP Max Monthly Coil Loads.xls).

This Excel file has been provided as a convenience. It is used to import the TXT file created in step 3. It has been configured to accept the TXT file import from HAP and find the maximum hourly heating and cooling load for each month of the year.

Step 6: Highlight the upper left cell in the Excel worksheet (A1).

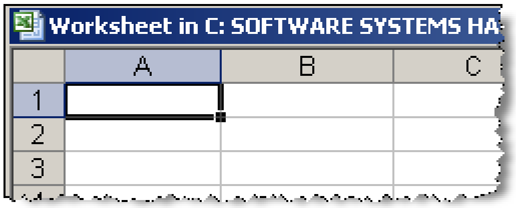


Fig. 11 Highlight The A1 Cell In Excel

Step 7: Go to: Data > Import External Data >Edit Text Import in the Excel worksheet. **Hit Edit Text Import**

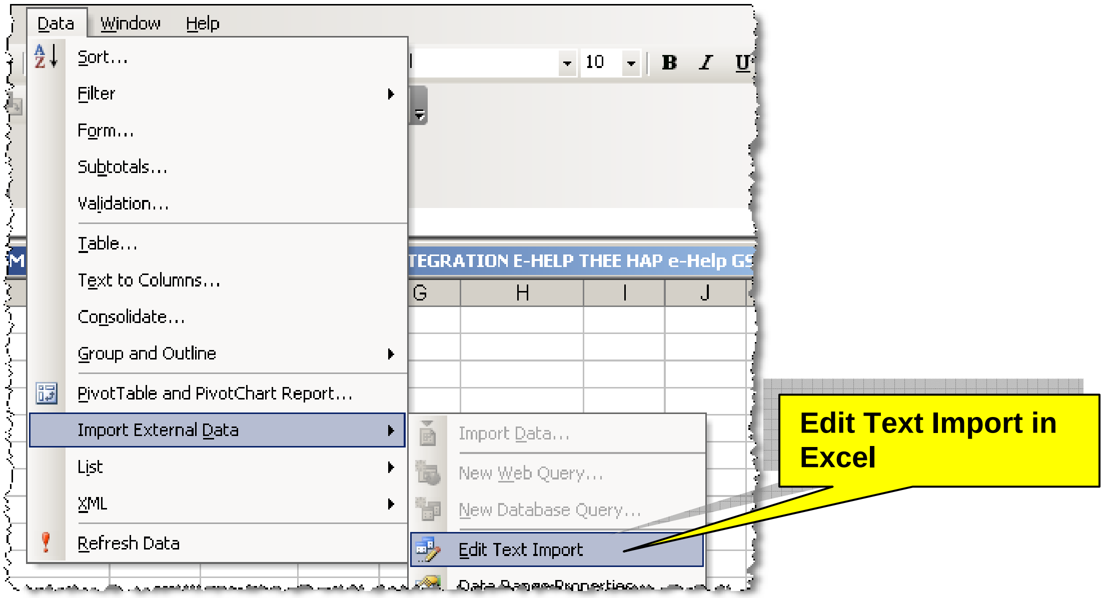


Fig. 12 Edit Text Import In Excel

Interfacing HAP Simulations with Geothermal WSHP Design Programs

Step 8: Browse to the TXT file of the appropriate HAP Project folder under E20-II and **import it.** When you generate the ASCII report as we did in Step 3, the program tells you where the file is located.

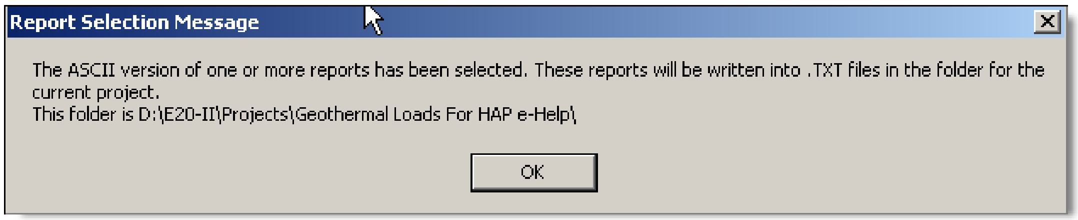


Fig. 13 TXT file Automatically Sent To D:\E20-II\Project Name

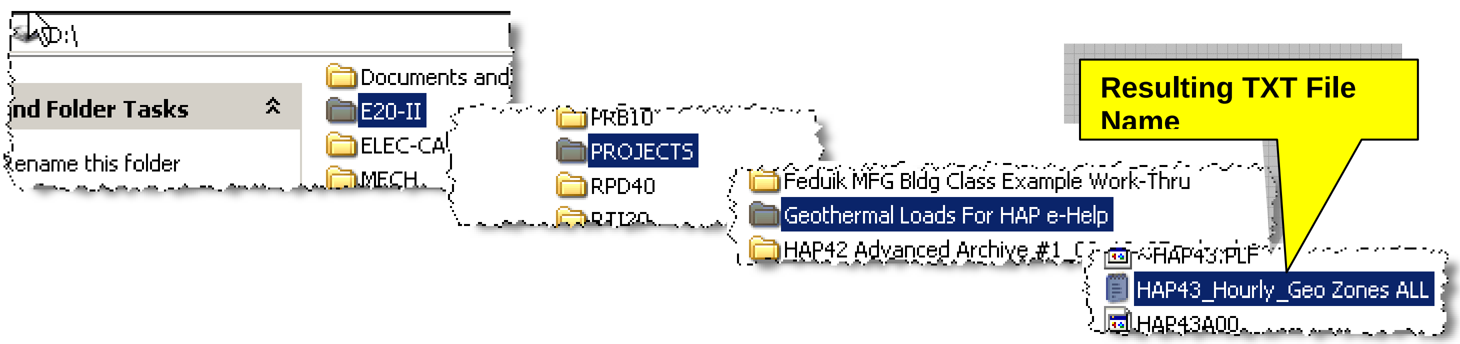


Fig. 14 Browse to the TXT File

The TXT file name will always start with program name ("HAP43") followed by the report type ("Hourly") followed by the air system name (in this example, our air system was named "Geo Zones All").

Interfacing HAP Simulations with Geothermal WSHP Design Programs

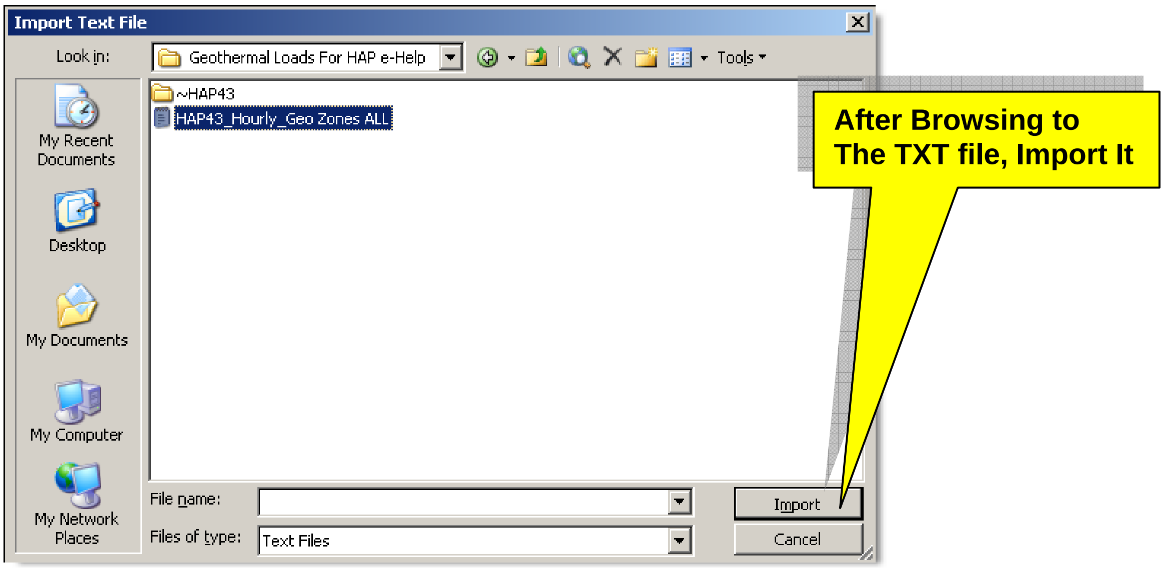


Fig. 15 Importing the TXT File into Excel from HAP

Step 9: This launches a 3-step import Wizard in Excel. Just press **"Next" twice then "Finish"** using all default import settings.

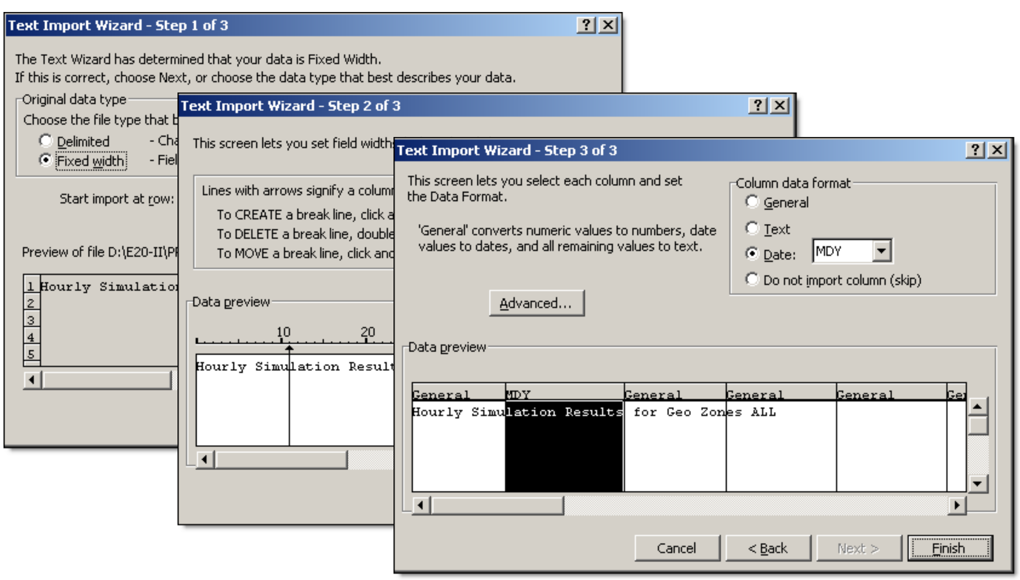
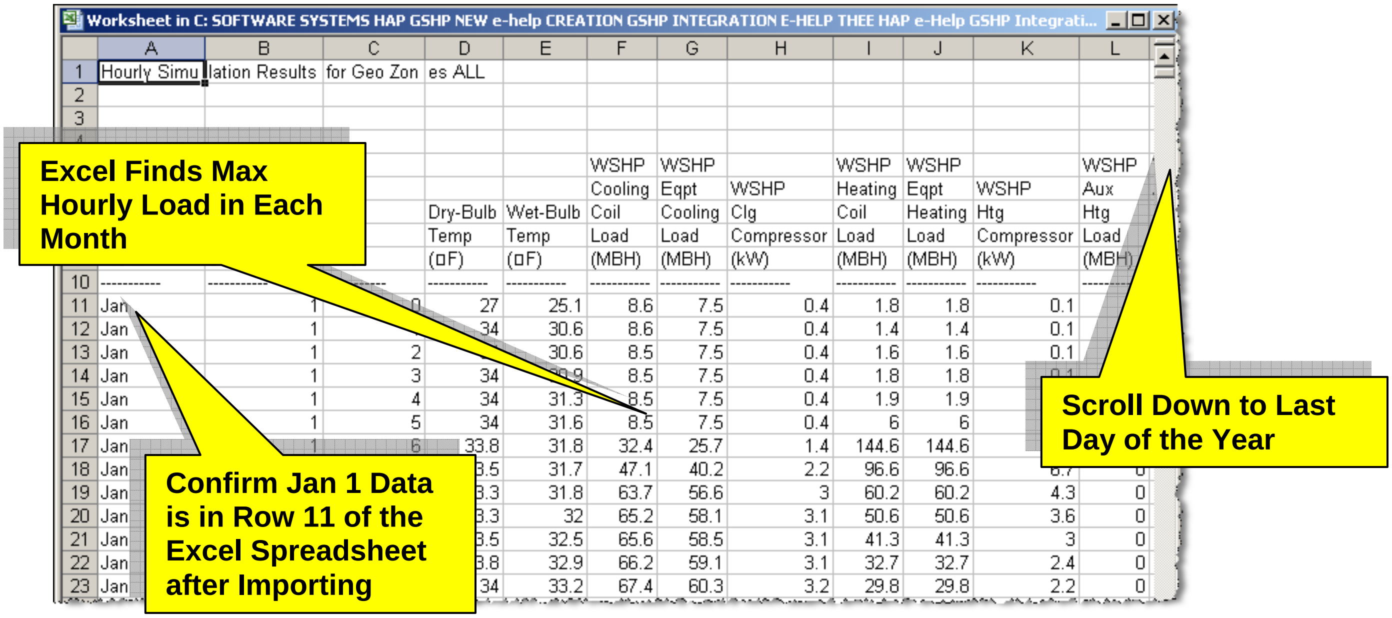


Fig. 16 Use All Default Settings in the Excel Wizard

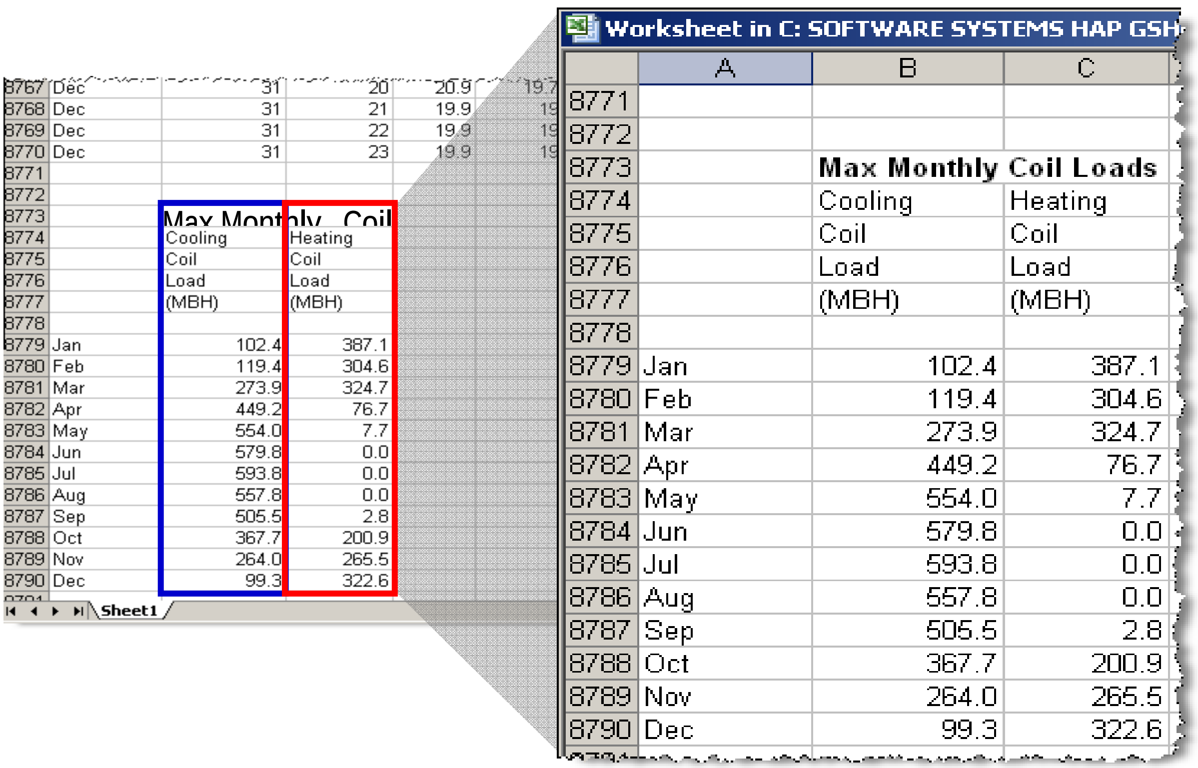
Interfacing HAP Simulations with Geothermal WSHP Design Programs

Step 10: Using the vertical slider **scroll down to the bottom (below row 8760)** and you see a table for each of the 12 months containing max cooling and heating coil loads for each month!



	A	B	C	D	E	F	G	H	I	J	K	L
1	Hourly Simulation Results for Geo Zones ALL											
5						WSHP Cooling Coil Load (MBH)	WSHP Eqpt Cooling Load (MBH)	WSHP Clg Compressor (kW)	WSHP Heating Coil Load (MBH)	WSHP Eqpt Heating Load (MBH)	WSHP Htg Compressor (kW)	WSHP Aux Htg Load (MBH)
				Dry-Bulb Temp (oF)	Wet-Bulb Temp (oF)							
10	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------
11	Jan	1	0	27	25.1	8.6	7.5	0.4	1.8	1.8	0.1	[illegible]
12	Jan	1	[illegible]	34	30.6	8.6	7.5	0.4	1.4	1.4	0.1	[illegible]
13	Jan	1	2	[illegible]	30.6	8.5	7.5	0.4	1.6	1.6	0.1	[illegible]
14	Jan	1	3	34	[illegible]	8.5	7.5	0.4	1.8	1.8	[illegible]	[illegible]
15	Jan	1	4	34	31.3	8.5	7.5	0.4	1.9	1.9	[illegible]	[illegible]
16	Jan	1	5	34	31.6	8.5	7.5	0.4	6	6	[illegible]	[illegible]
17	Jan	1	6	33.8	31.8	32.4	25.7	1.4	144.6	144.6	[illegible]	[illegible]
18	Jan	[illegible]	[illegible]	[illegible]	31.7	47.1	40.2	2.2	96.6	96.6	[illegible]	0
19	Jan	[illegible]	[illegible]	[illegible]	31.8	63.7	56.6	3	60.2	60.2	4.3	0
20	Jan	[illegible]	[illegible]	[illegible]	32	65.2	58.1	3.1	50.6	50.6	3.6	0
21	Jan	[illegible]	[illegible]	[illegible]	32.5	65.6	58.5	3.1	41.3	41.3	3	0
22	Jan	[illegible]	[illegible]	[illegible]	32.9	66.2	59.1	3.1	32.7	32.7	2.4	0
23	Jan	[illegible]	[illegible]	34	33.2	67.4	60.3	3.2	29.8	29.8	2.2	0

Fig. 17 8760 Hourly Data Imported Into Excel



8767	Dec	31	20	20.9	19.7
8768	Dec	31	21	19.9	19
8769	Dec	31	22	19.9	19
8770	Dec	31	23	19.9	19

	A	B	C
8771			
8772			
8773		Max Monthly Coil Loads	
8774		Cooling	Heating
8775		Coil	Coil
8776		Load	Load
8777		(MBH)	(MBH)
8778			
8779	Jan	102.4	387.1
8780	Feb	119.4	304.6
8781	Mar	273.9	324.7
8782	Apr	449.2	76.7
8783	May	554.0	7.7
8784	Jun	579.8	0.0
8785	Jul	593.8	0.0
8786	Aug	557.8	0.0
8787	Sep	505.5	2.8
8788	Oct	367.7	200.9
8789	Nov	264.0	265.5
8790	Dec	99.3	322.6

Fig. 18 (24) Maximum Monthly Coil Loads

Interfacing HAP Simulations with Geothermal WSHP Design Programs

Conclusion

There is a complex and dynamic heat exchange process that occurs between the ground and the circulating fluid in a geothermal closed loop piping system. The heat exchanger loop is designed with both cumulative and maximum load conditions taken into account. Geothermal design software like GLHEPro which is available from the International Ground Source Heat Pump Association uses this load data to assist in the design of the piping loop.

The cumulative load requirements can be read directly from the HAP Monthly Simulation Results. These 24 values (12 for cooling and 12 for heating) affect the temperature of the ground over time.

The maximum load conditions can be found by running the HAP Hourly Simulation Results for the entire year and importing the 8760 hour load values into Excel to find the 12 cooling peaks, and the 12 heating peaks.

Armed with this load data from HAP, the geothermal design software simulates the ground loop heat exchanger and determines fluid temperatures, power consumption of the heat pumps, and borehole depth to maintain the proper WSHP unit range of operation.

Need more help?
Contact Software Systems Technical Support at
software.systems@carrier.utc.com
1-800-253-1794