Ground Loop Design

Geothermal Design Studio

User's Guide

(English)

Ground Loop Design 1.1 for Windows®

Copyright Notice

Contents

PREFACE

Before You Begin

This chapter provides an overview of the Ground Loop Design installation procedure and describes the hardware and software requirements for installing Ground Loop Design. It also describes the typical uses and users of the software.

System Requirements for Running Ground Loop Design

This section lists the hardware and software requirements for running Ground Loop Design.

Hardware Requirements

A full installation has the following minimum hardware requirements:

- 32 MB Ram
- 20 MB hard disk space (50 MB recommended)

Software Requirements

Ground Loop Design has the following software requirements:

- System running under Windows®
- Netscape Navigator® or Internet Explorer®

Operating System Requirements

Ground Loop Design will operate under Windows 9X/ME /NT/2000.

Internet Browser Requirements

An Internet browser is required only for viewing the help files, not for general program operation. The following browsers are necessary:

- Netscape Communicator Version 4.0 or later.
- Internet Explorer Version 4.0 or later.

Installation Procedure

This section describes the installation procedure for Ground Loop Design from a CD Rom.

Initial Installation

The software may be installed by clicking on the **Setup.exe** file included on the disk. The installation should start automatically.

The program is set to install in the folder:

(Main Drive):\Program Files\Ground Loop Design

If the user desires another location, the location can be provided within the installation sequence.

Installation of Updated Versions or Re-Installation

If the software is re-installed or replaced with a more recent version, the version initially installed on the computer must first be completely removed (see ***Note*** below). To do this, go to the Windows Start Menu → Settings → Control Panel → Add/Remove Programs. Remove "Ground Loop Design". After the program is removed, the new installation may be conducted as described above. As long as the folders are not deleted, existing work files, pumps, and zone files will not be affected.

Note:

The file **"Pumplist.gld"** in the **\Ground Loop Design\Pumps** folder will be replaced upon re-installation. If the user has added pumps other than those originally included with the program, *this file must be copied or moved to a backup directory* prior to removal and re-installation. After re-installation, the **Pumplist.gld** file can be returned to the **\Ground Loop Design\Pumps** folder *or* its contents can be added to the contents of the new **Pumplist.gld** file using a simple text editor like **Notepad.exe**. The format of the file is provided below.

Pumplist.gld

```
Pump List File
Number of Manufacturers (Integer)

First Manufacturer Name (Text)
Street Address (Text)
City, State, Zip (Text)
Country (Text)
Telephone Number (Text)
Number of Different Series for this Manufacturer (Integer; Example: 2)
Series #1 Name (Text)
Series #1 filename without .hpd extension (Text)
#Date Entered# (Text; Example: #2000-10-05#)
Series #2 Name (Text)
Series #2 filename without .hpd extension (Text)
#Date Entered# (Text; Example: #2000-10-06#)

Second Manufacturer Name (Text)
Street Address (Text)
…
```

Alternatively, any files not included with the setup package may be added from within the program itself using the method described in Chapter 2, under *Adding Pump Sets Obtained from External Sources*.

The actual original heat pump data files (*.hpd), will not be deleted unless their names are identical to those being installed. Thus, all data can be recovered even if the previous version of the **Pumplist.gld** file is overwritten. However, this will either involve editing the **Pumplist.gld** file manually to include the customized data, or by identifying those files within the program itself. In general, if there are only a few pump sets to add, working within the program is best. If there are many, cutting and pasting from the old file using a text editor may prove most efficient. (Remember to modify the number of manufacturers if necessary!)

If the user has created customized heat pump sets, it may be wise to make a backup of all data files prior to removal and re-installation.

Additionally, *customized **help files** should be backed up* before any user-defined menu screens are potentially overwritten.

Intended Users and Scope

Ground Loop Design is intended as a design studio for professional HVAC designers and engineers working in the area of geothermal applications. It is primarily designed for use with light-commercial or commercial installations, since the calculations take into account long-term thermal effects that often determine the necessary design parameters. Additionally, the zone system employed in Ground Loop Design allows for more detailed equipment selection and more specific load distribution so the accuracy of the calculations may be maximized.

This version of Ground Loop Design includes two design modules, one for vertical borehole and one for surface water (pond, lake, etc.) installations. The zone/load data can be shared between modules.

Because of the extensive customization and override features included in the software, Ground Loop Design is also ideally suited for both standard and non-standard applications, which can involve significant variations in equipment, loads, and operational parameters for each zone in the design. The user, who may prefer to add his or her specific images or data sheets, may even customize the help files.

Finally, Ground Loop Design is entirely international in design, allowing for versions to be distributed in any foreign language and direct metric/English unit conversions. This effectively extends the range of the software by making it possible to use and share parameters, equipment, and loads data from any locale and allowing for some level of international standardization.

CHAPTER 1

Ground Loop Design Overview

This chapter is an introduction to the Ground Loop Design software package. It provides an overview of the different features of the software, with information included about the theoretical and experimental basis of the calculations. It will also briefly describe the individual components, including the design modules, the reporting functions, and the help files, which will be covered in greater detail in the chapters that follow.

General Program Features

Ground Loop Design is a geothermal design studio that provides the user with a certain amount of freedom over the limitations of single-purpose software. The program is modularly based, which permits flexibility in the designing process and customization based on designer preferences. Additionally, it has a metric/English unit conversion option, providing applicability to the widest range of equipment and customers. Because the software is available in different languages, it is truly international in its ability to accurately traverse borders.

The Design Studio

The studio is the desktop work area in which the designer conducts his or her project analyses and establishes the basis for designs. As new projects are desired, new windows may be opened or additional projects may be loaded.

Another window may be opened to edit or modify heat pump data, and still others may be used to provide easily accessible graphs or charts that may be required repeatedly through the course of a design. Different but similar design plans can be compared directly, or entirely different designs can be created and varied. Essentially, all of the information a designer would need exists in one convenient location.

Additionally, besides opening and closing windows and taking care of file management, the studio desktop menu bar includes control features which can be applied to more than one different type of project. For example, the metric/English unit conversion can be called to convert a single window without affecting the rest of the open windows. Project reports can also be printed from the studio desktop.

Customization

In Ground Loop Design, the user is allowed a great deal of freedom about how he or she enters and uses information. Rather than conforming designs to the software, this software package allows some modification and variation in its included features.

Some of the most common areas of customization in Ground Loop Design include the entry of loads and the selection of equipment. Although fully automatic modes are available, the user has the ability to customize or override the automatic features. For example, detailed load information may be included for precision designs, while extremely limited data is enough for rough calculations. Additionally, if the data is available, the designing engineer could enter his or her own pump set to take full advantage of the automatic selection procedures. Also, different families of pumps can be used within a single project, and even individual pumps not included in the pre-defined pump sets can be employed as required.

Because the help files are based on HTML, with a simple HTML editor, the user has the complete ability to include any tables, data, pictures, graphs, charts, or any potentially useful information presented in a way with which they are entirely familiar. Files can be added to supplement or replace the help files already provided with Ground Loop Design.

Metric/English Units

One of the features intrinsic to the design of Ground Loop Design is the metric/English unit conversion capability. The metric/English option can be used not only to compare values, but it can also be used to quickly make use of specific equipment or loads data supplied in only one format.

Because the reports and help files are fully aware of the units being used, different reports and data lists can be obtained with the unit selection. This makes presentation and comparison between different engineers and designers a straightforward process.

Internationalization

The final feature mentioned here is the international component of Ground Loop Design. Because the program was designed as a multi-national application, using identical files, accurate results and design parameters can be easily communicated across borders, even if the designers are not necessarily fluent in the language of their counterparts in the foreign country.

Heat Pump and Zone/Loads Models Employed

The underlying framework of Ground Loop Design is based on two models that permit flexibility in the addition and modification of components related to the geothermal design. The first is the heat pump model, which takes a representative amount of data input from the heat pumps and then uses that information for automatic pump selection. The second is the zone/loads model, which determines how the installation can be broken into individual sections that can be combined for the overall calculations. Because these two models are linked, heat pumps may be ideally matched to zones, based on entered loads, in an automatic or manual mode of selection.

With this basis, the zone/loads and the heat pump selection can be connected directly with the various modules available in the studio. Therefore, the same zone and heat pump systems are used for every type of design.

Heat Pump Model

In Ground Loop Design, heat pump data can be entered into a separate module that keeps track of the equipment. Families of heat pumps from various, but separate, manufacturers can be added to lists that can be maintained by the designer. In this way, heat pump data from any source can be easily included within the software in order to take advantage of the automatic equipment sizing features of the Ground Loop Design zone/loads model.

The heat pump model requires certain data from the heat pump specification sheets, or software provided by the heat pump company, to be entered into the

Edit/Add Heat Pumps module. The minimum required data is essentially limited to six data points in both cooling and heating modes, which relate capacity and power to the inlet source temperature. The data is then fit polynomially, which provides an accurate model for the equipment with any given design parameters. By including data from different flow rates and/or modification factors for the capacity and power at different inlet load temperatures, higher levels of accuracy are possible.

The *Edit/Add Heat Pumps* module is covered in detail in Chapter 2.

Zone/Loads Model

Component-style designs are appropriate for geothermal installations, particularly when equipment is available in various sizes, which can be placed near or within the locations to be conditioned. With regard to water source heat pumps, it is often much easier to bring water lines to the equipment instead of providing ductwork or long load lines from a centralized source.

When considering geothermal applications, the precision of the zone/loads model is crucial because it relates directly to the extent of external heat exchanger installation. These costs impact the overall costs of the project. Additionally, if a unit were called only when necessary, or matched well to a zone, its efficiency would be improved over larger units that require more cycling.

Ground Loop Design's input can take peak load information for each of the zones in an installation for different periods during the day. For a buried heat exchanger, annual running time may also be included to improve the accuracy of the calculations. This load information can be extremely simple or complex, depending on the level of detail the designer desires. To facilitate this model, each zone has its own page with its own loads and corresponding equipment.

Entering the zone and loads information is covered in detail in Chapter 3.

Design Modules

Ground Loop Design comes with two design modules, the Borehole Design module and the Surface Water Design module. The Borehole Design module models the lengths of bore required for a vertical borehole exchanger system, while the Surface Water Design module models the length of piping required when closed loop pipe inserted into a body of water acts as the heat exchange medium. Both modules utilize the same zone/loads formalism, as well the identical heat pump list.

Borehole Design Module

Description

The Borehole Design module allows the user to enter various parameters concerning the desired vertical borehole system. Input is arranged in panels that relate to the type of input entered. After all parameters are entered, the software calculates results such as the required bore length, inlet and outlet temperatures, coefficient of performance (COP), etc., based on the input data. Making changes and conducting new calculations are straightforward within this framework.

The input information is organized into nine panels, shown in figure 1.1.

Fig. 1.1 Borehole Design Panel List

These nine panels allow specific information to be entered concerning the project being studied, and include *Calculate, Fluid, Soil, U-Tube, Pattern, Extra Power, Heat Pumps, Loads, and Project Information.*

A more complete description about how to enter data and perform calculations in the Borehole Design module is provided in Chapter 4.

Theoretical Basis

The vertical bore length calculations made in the Borehole Design module employ the cylindrical source solution, and are based on the exact solution to a buried cylindrical pipe in an infinite medium (Kavanaugh, 1991). The solution yields a temperature difference between the outer cylindrical surface and the undisturbed far field soil temperature. It can produce results for a constant heat transfer rate, but has been modified for daily, monthly, and annual time scale. If no pulses were used, the method would produce similar results to the simple line source heat model (Ingersoll, 1954) for longer time intervals.

Additionally, the software calculates the amount of energy absorbed by or withdrawn from the ground using the load information collected from the individual zones and their relationship to the chosen equipment.

The calculations attempt to find the conditions for long-term, steady state operation of borehole fields given the design source inlet temperatures. The combination of parameters must allow for proper absorption or dissipation of energy from or to the earth in the location of interest, in order to prevent system failures.

The most complete description of the calculations and the input data may be found in Chapter 3 of the book, *Ground Source Heat Pumps - Design of Geothermal Systems for Commercial and Institutional Buildings*, by S.P. Kavanaugh and K. Rafferty, 1997. In extensive tests, this model consistently proved to be one of the most accurate when compared with calibrated data from actual installations.

Surface Water Design Module

Description

The Surface Water Design module allows the user to enter various parameters concerning the desired body of water (lake, pond, river, etc.) system. As in the Borehole Module, input is arranged in panels that relate to the type of input entered. After all parameters are entered, the software calculates results such as the required pipe length, circuit number, inlet and outlet temperatures, COP, etc., based on the design requirements. Again, making changes and conducting new calculations are straightforward within this framework.

The input information is organized into nine panels, shown in figure 1.2.

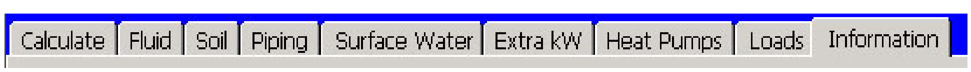

Fig. 1.2 Surface Water Design Panel List

These nine panels allow specific information to be entered concerning the project being studied, and include *Calculate, Fluid, Soil, Piping, Surface Water, Extra Power, Heat Pumps, Loads, and Project Information*. Not only the panel names, but also the panel contents differ from those of the Borehole Design module.

A more complete description about how to enter data and perform calculations in the Surface Water Design module is provided in Chapter 5.

Theoretical Basis

To determine the length of pipe necessary for in different surface water systems, an experiment was conducted for different size pipes, in coiled and "slinky" configurations, for both heating and cooling modes (Kavanaugh, 1997). Ground Loop Design uses a polynomial fit of this experimental data to determine the amount of pipe necessary for different loading conditions.

Additionally, coefficients are used to take into account the effect of the heat transfer in the lengths of the header and branch piping in both the water and the soil between the installation and the submerged circuits. All factors are combined so that the design source inlet temperature at the heat pump is that requested by the designer.

Because the circuit layout is one of the primary concerns for the designer concerned with pumping losses, an additional feature of the Surface Water Design module is the inclusion of head loss estimates for the different piping configurations. In this way, different layouts can be quickly explored to determine the optimum design; both in terms of heat transfer and circulation pump energy losses.

A description of some of the calculations and the input data may be found in Chapter 7 of the book, *Ground Source Heat Pumps - Design of Geothermal Systems for Commercial and Institutional Buildings,* by S.P. Kavanaugh and K. Rafferty, 1997.

Additional Modules

Ground Loop Design's design studio has the potential for additional modules that could be included in later versions. Two of the most requested modules include a Horizontal Design module and an Open Loop Design module. As expected, these modules would also be able to take advantage of the heat pump and zone/loads models.

Reports

Ground Loop Design has some built-in reporting features that allow the designer to make hardcopies of both the data entered and the resulting calculations. These reports can be used not only as a record of the design, but they are also important in straightforward communication of the design to others involved in the projects.

Reports are described in detail in Chapter 6.

Project Reports

Every design module has an associated project report, which can be printed at any time from the design studio desktop. The project report contains all the project information, and includes the parameters chosen, calculation results, and name of the zone file used.

Zone Reports

Within the design modules, the *Loads* panel contains a 'print' button that gives the designer the ability to print the zone-related information in various formats. Because the zones contain information about the zones, the loads, and the equipment, it is often necessary not only to obtain all of the information in a concise form, but also as separate documents.

For example, at one time, a designer may want to quickly see all of the zones with their loads and corresponding equipment. At other times, only a list of the equipment necessary in each zone would be ideal. At this time, Ground Loop Design has five different choices of zone report available, including a long and short version of the complete form, along with reports that list only equipment, loads, or names.

Help Files

Access to the help files requires an Internet browser to be present on the computer on which Ground Loop Design is installed. The program will work without the browser, but the help files will not be accessible.

Metric and English help files are included with Ground Loop Design, which aid in the correct verification and entry of the various parameters. The three topics included under the *Tables* menu in the design studio are *Fluid Properties*, *Soil Properties*, and *Pipe Properties*. A convenient *Conversions* table with metric/English conversions in two different formats is included for reference. Help files can be opened and left as open windows on the desktop, and the user can refer to them as necessary during the designing process.

Realizing that designers and engineers have their own preferred resources, Ground Loop Design employs the HTML browser model so that the user has ultimate control over the files included as help files. The designer must simply create a basic HTML file containing customized data, pictures, graphs, charts, etc. and modify the included top level HTML files to link to their pages. It offers the most flexible way to have access within the program to the information with which the designer is most comfortable.

Detailed information on help files can be found in Chapter 7.

References

Ingersoll, L.R., Zobel, O.J., and Ingersoll, A.C. *Heat conduction with engineering, geological, and other applications*. New York: McGraw-Hill. 1954.

Kavanaugh S.P. and J.D. Deerman. Simulation of vertical U tube ground coupled heat pump system, ASHRAE Transactions, Volume 97, pages 287 – 295, 1991.

Kavanaugh S.P. and Rafferty, K. *Ground Source Heat Pumps - Design of Geothermal Systems for Commercial and Institutional Buildings*, ASHRAE, 1997.

CHAPTER 2

Adding/Editing Heat Pumps

The first step to using any of the design modules included with Ground Loop Design is to understand the system employed to model heat pump data. For the purpose of adding new or editing existing heat pumps, the Add/Edit Heat Pumps Module is included as a separate module in the design studio. This chapter describes the theory of the module and gives an example of how to enter heat pump data.

Heat Pump Model

Description

For convenience, the Borehole or Surface Water design modules in Ground Loop Design predict how heat pumps will respond to changes in the input design parameters. If the designer changes the inlet source or load temperatures, or the system flow rate, the capacity and power data of the units may also change. The easiest and most accurate way of realizing these changes is to employ an internal model, which the software uses to update the pump data automatically. This way, the designer can concentrate on the effects of variations without worrying about how the individual pumps in various zones will react to such changes.

The heat pump model employed in Ground Loop Design attempts to reproduce the complete operational data of any particular unit when supplied with a few representative data points selected across the range of interest. Data for each pump can be entered into the model and grouped together under manufacturer and series. The data need only be input once, but can then be used repeatedly for subsequent modeling sessions. Pump data is stored permanently in the '**pumps**' directory.

In both the heating and cooling modes, the minimum data required for each pump includes capacity and power variations with the source inlet temperature. The model can be further improved by including these same variations at a second flow rate, and still more accurate results can be obtained if correction factors are provided for variations in the load inlet temperature. The level of accuracy depends both on the amount of data available and the time the designer wants to invest in entering it.

Ground Loop Design's heat pump module allows for both water-to-air and water-to-water pumps. *However, because the capacity and power requirement of water-to-water pumps vary greatly with the flow rate on the load side**, different data sets may need to be entered for the same pump with different load side flow rates**.* The designer may choose to create several versions of the same series with different load side flow rates. Although the source side flow rate is a fundamental parameter in the Ground Loop Design design modules, the load side flow rate is not included.

Theoretical Basis

Capacity and Power

Heat pump capacities and power requirements vary smoothly but significantly for differing source inlet temperatures. Three points taken along both the capacity vs. temperature and power vs. temperature curves are fit to a polynomial equation to model these variations. The resulting calculated coefficients are then used to generate capacity or power values for any given source inlet temperature.

The basic polynomial equation used for fitting has the form:

$$y = a + bx + cx^2$$

where a, b, and c are the three coefficients calculated from the fitting routine. For the capacity case, 'y' would represent the capacity, and 'x' would be the desired temperature. For the power input determination, 'y' would be the power and 'x' would again be the temperature. Be aware that these coefficients do change for metric and English units.

The software stores coefficients for each pump, and then uses the coefficients with the source inlet temperatures chosen by the designer to determine the unit capacity and power.

Flow Rate

To model the effect of source flow rate on the calculated capacity and power, data from a second flow rate is used. In general, with different flow rates the shape of the capacity and power curves does not change, but is shifted up or down by a constant factor. This factor is determined for each of the three temperature data points and averaged over those input to obtain the linear flow factor, which is shown on the input screen.

Once the flow factor is determined, the linear capacity or power change per flow unit may be calculated. The program then calculates a new capacity or power at any specified flow rate using the initial values already known from the stored data.

If no second flow rate data points are entered, the flow factor is assumed to be the constant value of 1.0, meaning that there are no capacity or power variations with flow rate.

Load Side Corrections

The Ground Loop Design Edit/Add Heat Pumps module can also include corrections to the capacity or power that result from variations in the load side inlet temperature. They are entered as correction factors across the desired temperature range. The software again uses the polynomial fitting to model these correction factors. In this case, from three to five points are allowed as data input.

Again, if load side correction data is not included, there will be no capacity or power variations with load temperature, and all correction factors will be 1.0, the standard value.

The load side temperature range will generally be considerably different for water-to-air and water-to-water pumps. Ground Loop Design suggests different initial temperature ranges when the user chooses the water-to-air or the water-to-water pump type option.

Entering Data into the Add/Edit Heat Pumps Module

The user can open the Edit/Add Heat Pumps module from the design studio *Heat* Pumps menu. Only one module can be open at a time.

When the module opens, there are two selection boxes present in the upper pane, with no pump data shown in the lower pane. In the left box, the user can either choose to select one of the manufacturers or 'New Series' from the existing list. If a manufacturer is selected, the current list of series available for that particular manufacturer appears in the box on the right. When a series is chosen, the data for that series will appear in the lower panel.

Creating a New Series and/or Manufacturer

If the user chooses 'New Series' from the manufacturer list on the left, the lower pane will become active with another selection box requesting whether or not to use an existing manufacturer or if the new series will require a 'New Manufacturer'. After making a selection, the panel will change to show information about the manufacturer and series. The manufacturer information will be editable if the series belongs to a new manufacturer. The Edit/Add Heat Pumps module with an open 'Pump Information' panel is shown in figure 2.1.

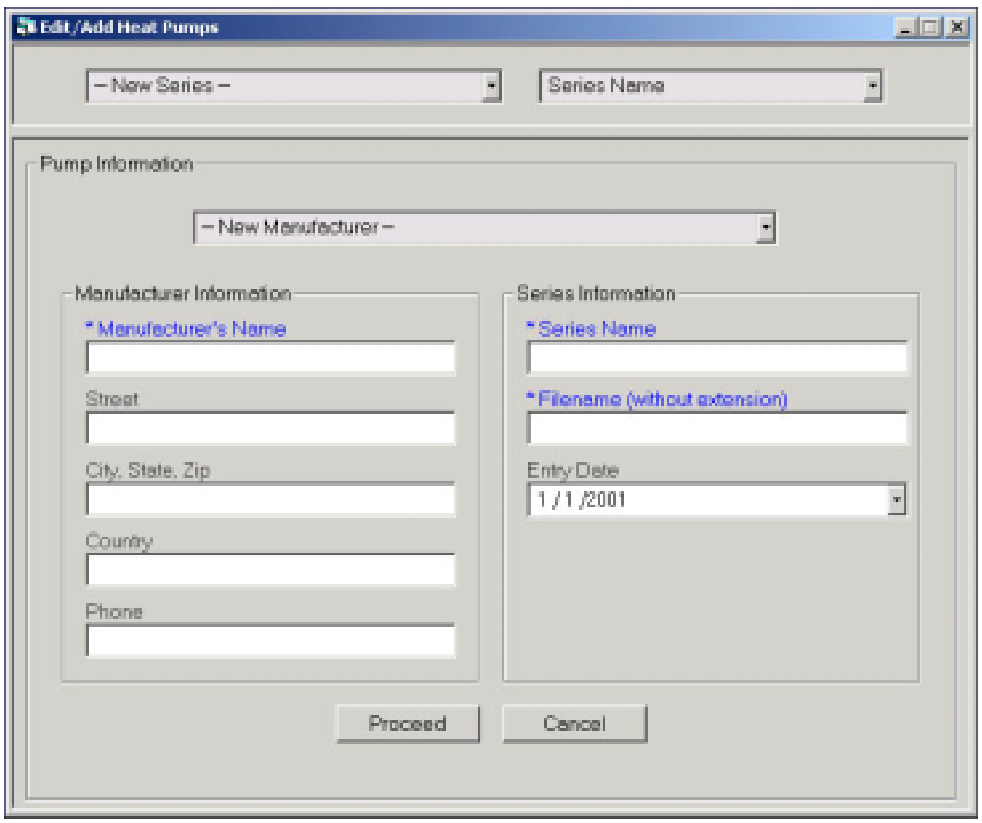

Fig. 2.1 Pump Information Panel

After the information is entered and the 'Proceed' button is clicked, all of the information for the series being added will be stored in the **Pumplist.gld** file. Note that the information marked with an asterisk must be included before the user is allowed to proceed.

Editing Pump Data

Once the pump information is entered for a new pump series, or a pump series is selected from the upper pane when working with an existing series, the Pump Edit Pane will appear in the lower pane of the Edit/Add Pumps module, as shown in figure 2.2. On the left side of the Pump Edit pane is a list of the pumps included in the series, and on the right are the tabbed panels that contain the data for each pump in the list. In the case of a new series, both the list and the panel section will be empty until a new pump is created. The name of the current manufacturer and series are shown in the selection boxes in the upper pane.

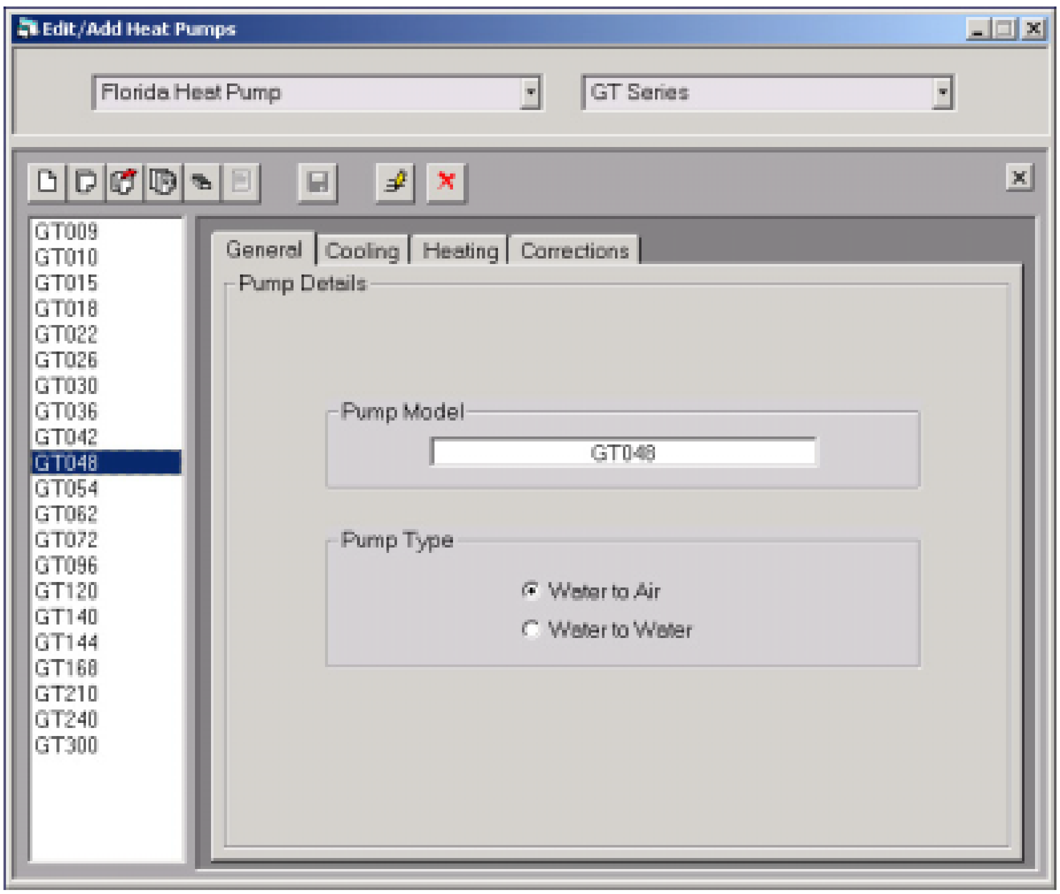

Fig. 2.2 Pump Edit Pane

Pump Series Controls

The Pump Series controls, shown in figure 2.3, are buttons above the list and the pump data panels. They include the Pump Edit controls, which consist of *New*, *Copy*, *Remove*, *Reorder*, *Clear*, and *Summary*, the pump *Save* control, the *Edit Pump Information* control, and the *Delete Series* control.

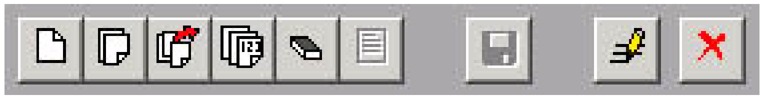

Fig. 2.3 Pump Series Controls

Pump Edit Controls

The Pump Edit Control buttons are designed for working directly with the pump list. New pumps are added by pressing the *New* button. Copies of existing pumps are added with the *Copy* button. *Remove* is used to remove a pump from the list. *Reorder* is pressed to reorganize the list, both alphabetically and numerically. *Clear* is used to delete all pumps from the current list. The *Summary* button is currently not used.

Save Control

The *Save* control button can be used at any time to reserve the current pump information.

Edit Pump Information Control

The *Edit Pump Information* control button allows the user to edit both the series and manufacturer information for a given pump. Note, however, that if the manufacturer information is changed, it will change for every series connected to that manufacturer. 'Proceed' or 'Cancel' will return the user to the Pump Edit Pane.

Delete Series Control

The *Delete Series* control button will delete the current series. If the series is the only series of a manufacturer, the manufacturer will also be deleted.

Note: The actual heat pump file (.hpd) will not be deleted from the* ***pumps*** *directory. If necessary, the series can be restored by creating a 'New Series'. The user need only provide the appropriate manufacturer and series name, and use the deleted '.hpd' filename for the pump set 'Filename'. Incomplete fields will* *be recreated from the *.hpd file. If the original file no longer exists, the program creates a new *.hpd file. Incidently, the same system can be used to add new pump sets obtained from external sources as described below.*

General Information

The General panel, listing the pump details, is the first panel that opens with a new pump. It has an input box for the name of the pump, and in the 'Pump Type' area, the user can select whether the pump should be classified as water-to-air or water-to-water. An example of the pump *General* panel is shown in the lower right of figure 2.2.

Capacity, Power, and Flow Rates

The capacity, power, and flow rate information pertaining to the source side flow for both heating and cooling are entered into the two tabbed panels labeled *Cooling* and *Heating* on the right side of the Pump Edit Pane. An example of the *Cooling* panel is shown below in figure 2.4. The *Heating* panel follows an identical format, but the temperatures would be different.

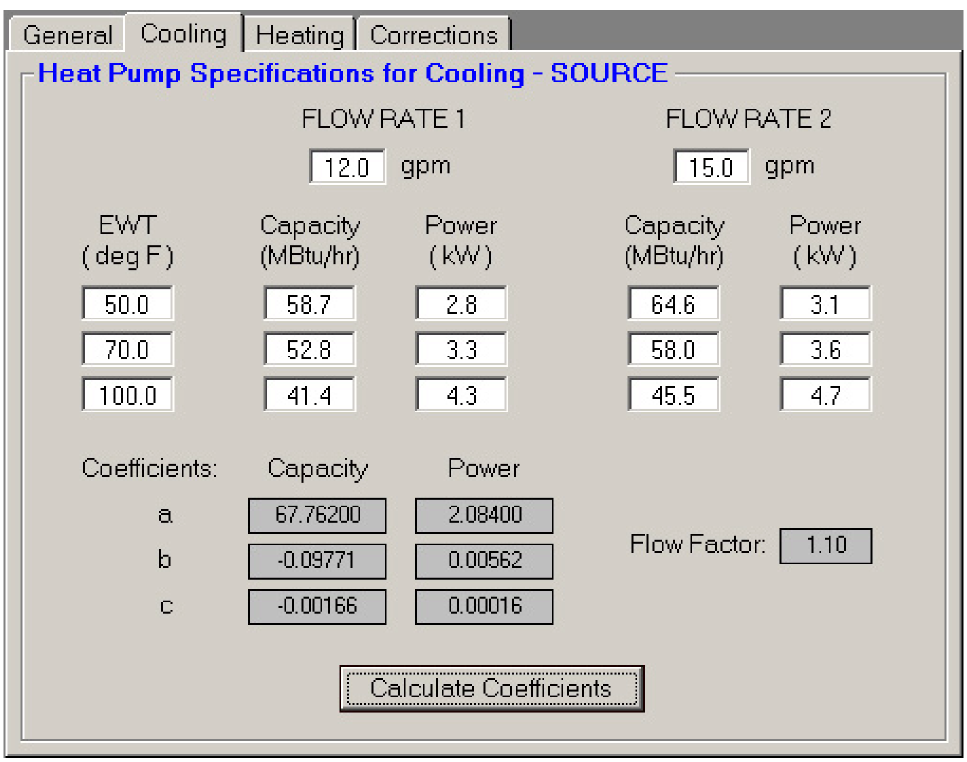

Fig. 2.4 Heat Pump Specifications – Cooling

As can be seen from the figure, the source entering water temperature (EWT) is listed to the left, and the capacity and power requirement of the unit at different flow rates are listed to the right. Once the values are input, the coefficients and flow factor can be calculated from the entered data. The *Calculate Coefficients* button turns red when values are changed, indicating that new coefficients must be calculated before proceeding.

Note: If data for only one flow rate is available, only the first capacity and power requirement data must be included, under the section entitled 'FLOW RATE 1'. The data under 'FLOW RATE 2' can be left as zeroes, and the program will ignore them, leaving the flow factor as 1.0.

Load Side Corrections

Corrections resulting from the variation in inlet temperature of the load side can be entered in the *Corrections* tabbed panel of the Pump Edit Pane. Both the cooling and heating information for a single flow rate are entered on the same panel, an example of which is shown in figure 2.5.

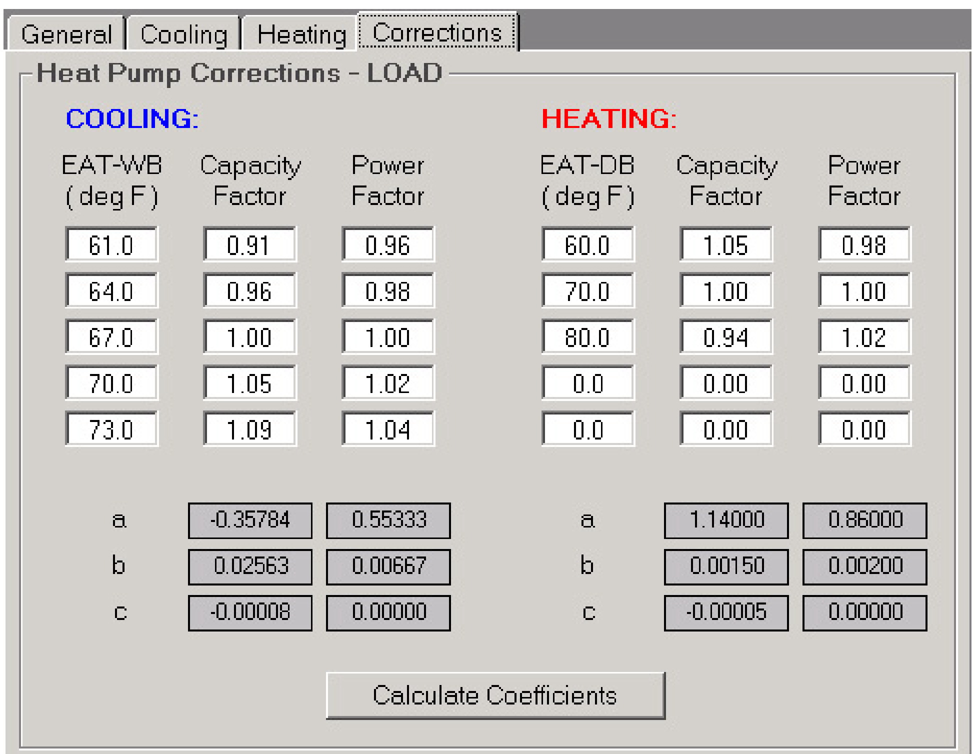

Fig. 2.5 Heat Pump Load Side Corrections

The factors shown in figure 2.5 were calculated from a manufacturer's list of capacities provided for the different temperatures, using the capacity at the selected temperature as the numerator and the capacity at 67°F (or 70°F for heating) as the denominator. The 67°F (70°F) capacity values were those used for the inlet source data on the *Cooling* and *Heating* tabbed panels described previously. Occasionally, manufacturers will provide capacity values at the standard temperature with a table of correction factors that can be entered into the Ground Loop Design *Corrections* panel directly.

Notice how in figure 2.5 five points of data are included for cooling but only three are included for heating. The software only requires three points for its coefficient calculation. *Other temperature **and** coefficient values must be set to zero in this case.*

Note: If correction factors are unknown or unnecessary, they can all be left at the constant value of 1.0, which is the initial condition that exists when a new pump is first added.

Exiting the Edit/Add Heat Pumps Module

After editing or adding heat pumps, and calculating all necessary coefficients, the user should make sure that the pumps are saved by clicking the *Save* button on the Pump Series control bar. When the pumps are securely saved, the *Save* button will become disabled.

Clicking the close button in the corner of the lower pane closes the Pumps Edit Pane, and clicking the close button in the upper right hand corner of the window closes the Edit/Add Heat Pumps module. Closing without saving edited data will result in the appearance of a message box that queries the user if the data should or should not be saved before closing.

Heat Pump File Descriptions

There are two types of files created by the Edit/Add Heat Pumps module. The first is the **Pumplist.gld** file, which maintains the current list of manufacturers and the series associated with those manufacturers. The **Pumplist.gld** file also includes the filenames (without the '.hpd' extension) of the heat pump data files associated with the individual series.

The second type of file is the '.hpd', heat pump data file for each individual series of pumps. This file type keeps track of all the data input by the user as well as the pump names and the coefficients calculated within the module. Since '.hpd' files cannot be deleted by the program (unless they are accidentally overwritten), many difficulties can usually be overcome by just adding new pump sets or, if necessary, directly editing the **Pumplist.gld** file. The format of the **Pumplist.gld** file is given in the Preface, page 3.

Adding Pump Sets Obtained From External Sources

To provide the greatest amount of flexibility for the user, Ground Loop Design allows heat pump data files (*.hpd files) not only to be created internally, but also to be obtained from external sources. For example, a heat pump set may be copied from a fellow designer, or even downloaded from a participating heat pump manufacturer's website.

Since the original **Pumplist.gld** file does not contain a reference to the externally obtained data set, it must be added manually. The procedure for this is as follows:

1. Place the '*.hpd' file into the **\Ground Loop Design\Pumps** folder.
2. Add a 'New Series'.
    a. If the series belongs to an existing manufacturer, choose the appropriate manufacuturer.
    b. If the series belongs to an unlisted manufacturer, choose 'New Manufacturer' from the list.
3. Provide the 'Series Name' and 'Manufacturer Name', as required.
4. Under 'Filename', **type the *existing* filename** of the series to be added.
5. Click "Proceed".

Ground Loop Design will open the heat pump file for editing and will include it in the list of files. Additionally, if this is a new manufacturer, any included manufacturer information will become visible for this pump set. Since the **Pumplist.gld** file has been modified, it will register the new pumps for use in all design modules opened thereafter.

CHAPTER 3

Loads and Zones

All of the calculations performed in Ground Loop Design are fundamentally based on loads provided by the designer. This chapter describes how to define separate zones and how to enter the loads in the design modules. Additionally, it explains the pump matching capabilities intrinsic to the Ground Loop Design *Loads* panel, and operation both in automatic and manual modes.

The Zone/Loads Model

For commercial, non-centralized installations, it is often better to divide loads into separate zones that are individually served by specific heat pumps. Besides generally lower installation and servicing costs, this type of system has many advantages, including an almost ideal method of matching the loads to the ground heat exchanger. From the time-dependent zone loads data provided, Ground Loop Design determines the maximum heating and cooling loads of the entire system, and then uses these values to calculate the length of heat exchanger required.

Although centralized loads data may always be provided to the software as a single zone, the designer can further refine the model by dividing the installation into separate regions, or zones. The information within each zone is combined during the calculation procedure. The designer ultimately decides what sort of data will be provided and how it will be used, but Ground Loop Design offers the flexibility to accept and work with almost any preferred system.

Zone Model

Zones in Ground Loop Design are organized in a list on the left side of the *Loads* panel. Each zone contains information relating to that particular zone, including a zone name, the loads information for that zone, and the information about the heat pump selected for that zone.

Using the list, the designer can bring up and modify any particular zone by clicking on its name. Various summaries of zone data can be printed as reports.

Loads Model

According to the model used within Ground Loop Design, average peak load data for every hour of a twenty-four hour day could be included if desired. However, for simplification, average design day peak loads can be input for up to four separate times of the day. These include morning (8 a.m. to 12 noon), afternoon (12 noon to 4 p.m.), evening (4 p.m. to 8 p.m.) and night (8 p.m. to 8 a.m.). This method of input identifies when the installation is in use for the heat exchanger calculations.

Additionally, in the case of a vertical borehole design, the annual heating and cooling hours are included in terms of the peak values, so that the yearly requirements of the system are properly calculated. Also with the borehole systems, the number of days occupied per week is included for additional refinement.

Surface water systems do not have long-term energy buildup, so the annual and weekly values are not used in the calculations and need not be included.

Zone Files

Zone files are stored as ***.zon** files in the Ground Loop Design '**zones'** directory. They have a general format that can be read into any design module, and once saved, they can be read into more than one of the same type of design module for simultaneous designing.

New zone files can be created by clicking the *New* button on the *Loads* panel in the active design module, or by clearing all of the current zone information with the *Clear* button, followed by the *New* button. New zone files are given a name by the designer when they are saved.

Zone files can be opened and saved using the *Open* and *Save* buttons on the Loads panel.

Entering Zone Data

Zone data is entered in the *Loads* panel of the design modules. The Borehole and Surface Water Design modules are discussed in detail in Chapters 4 and 5, respectively. (A new Borehole or Surface Water Design Project may be opened by choosing 'New Borehole' or 'New Surface Water' from the *File* menu of the design studio.)

On the *Loads* panel, there are two panes below the zone control buttons. The left pane contains the zone list, and the right contains the zone data window. Selecting the zone name in the zone list may change the active zone. An example of the *Loads* panel for the Borehole Design module is shown in figure 3.1. (The Surface Water *Loads* panel is essentially the same.)

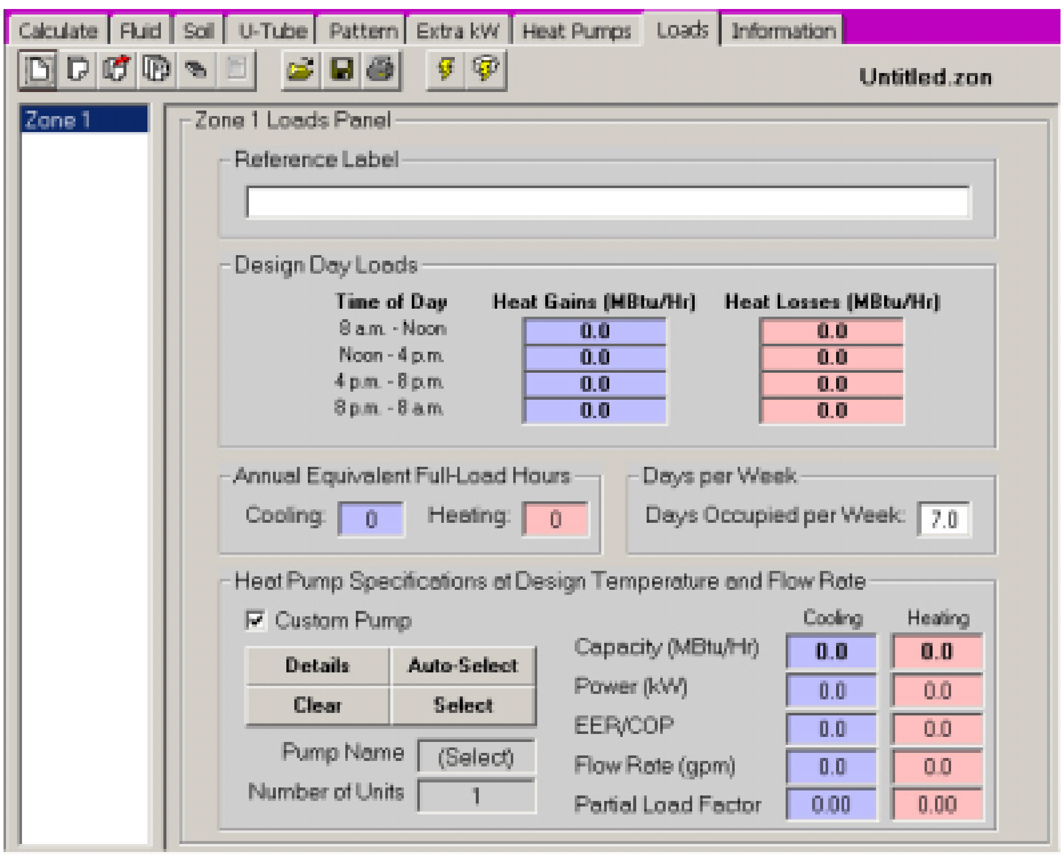

Fig. 3.1 Loads Panel

Zone Controls

The buttons along the top of the *Loads* panel are used to work with the zones. A closer view of them is shown in figure 3.2.

Fig. 3.2 Zone Control Buttons

The buttons on the left are zone-editing controls, and include *New*, *Copy*, *Remove*, *Renumber*, and *Clear*. (The sixth button, *Summary*, currently has no function.) In the center are the *Open* and *Save* buttons, for opening and saving the zone files, along with the *Print* button, for printing various zone reports. The buttons on the far right are for pump selection across the entire set of zones, and include *Auto-Select All* and *Update/Reselect*, which will be discussed in more detail below.

Managing Zones

The different buttons at the top of the *Loads* panel allow management of the zone list. Aside from opening and saving, the buttons give the designer the ability to add, delete, and renumber the zones.

New and *Copy*

A new zone may be created at any time from the *Loads* panel by clicking the *New* button. Identical zones may be created from any existing zone by bringing up that zone's data window and clicking the *Copy* button.

Remove and *Clear*

Zones may also be deleted from the list. Any zone may be removed from the list by bringing up the zone's data window and pressing the *Remove* button. To delete all of the zones in the list, press the *Clear* button.

Renumber

If many zones are added or removed from the list, clicking the Renumber button can reorganize the zones. This button renumbers the existing zones from one, starting with the first zone in the current list.

Entering Loads

Loads may be entered directly on the individual zone data windows in the *Loads* panel. A sample for a vertical borehole design is shown in figure 3.3.

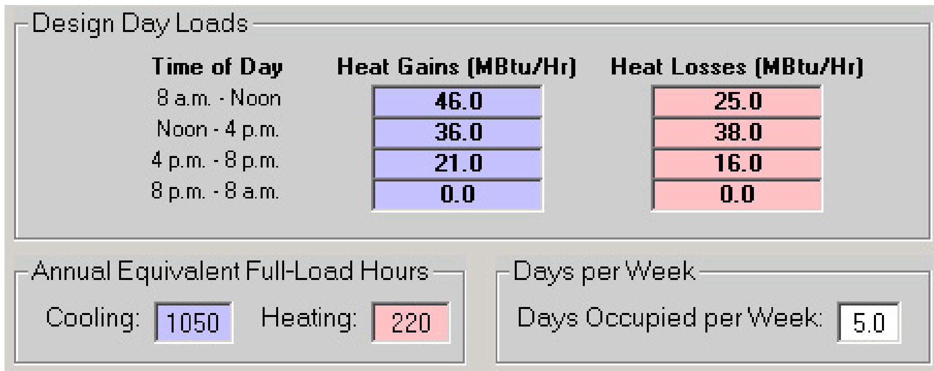

Fig. 3.3 Sample Loads Input Data

Design Day Loads

As mentioned previously, these are the average hourly peak loads during four-hour periods on the design day, or the heaviest usage day of the year for both cooling (heat gains) and heating (heat losses) modes of operation.

In the example, the building is scheduled to be operational only during the day, so no night loads are entered. If less detailed information was available, some information could be left out or assumed without greatly affecting the main calculation routines. For example, if only one peak value during the day was provided to the designer, it could be entered into one or several of the time slots, depending on how the loads would be expected to change during the course of a day. Slightly reduced values could be added for off-peak hours if the building were still in operation but not at full load. Other time slots could be left at zero.

However, if only one peak load value is provided per zone, the designer would need to be consistent in placing it in the same time slot for every zone. This is because the software loops through all of the zones to determine which time of day has the highest loading requirements prior to performing its calculations.

If only cooling or only heating loads data are to be used, all of the other's slots may remain as zeroes. Only the side with the loads provided will be calculated.

Annual Equivalent Full-Load Hours

The hours entered into the lower left section of figure 3.3 are determined from detailed annual loads data for the system being designed. They represent the annual number of hours the system would be running if operating at full load, and are a measure of the system running time.

For example, if the loads report provided the number of Btu required by this zone each month, the hours per month would be obtained by dividing the monthly Btu requirement by the peak Btu/h value. The resulting number would be the monthly equivalent full-load hours. To get the annual full-load hours, the value would need to be obtained for every month that required heating or cooling, and then combined to form the annual equivalent heating or cooling hours. Some loads software packages provide this information.

The software will actually calculate heat exchanger lengths without this information, but if exact values are not available, an estimate should be made with regard to the expected running time of the unit in each particular zone. Estimates of time must be reduced, of course, from actual running time since the 'annual equivalent full-load hours' would be the running time if the system were operating continuously at full load, which is not generally the case.

Days per Week

This value would be the occupation or up time of the installation, in days per week. The building in the example is only occupied during weekdays, so the value 5.0 was entered. Decimal values can be used for partial occupations, and the amount can vary between zones.

Pump Matching and Selection

Every zone has heat pump equipment associated with it. Equipment matching and selection is done within the zone data window, in the lower section entitled, "Heat Pump Specifications at Design Temperature and Flow Rate". In this section, the designer has three choices when matching a pump to a zone:

- Automatic selection based on the active heat pump series
- Manual selection from a list of all available pumps
- Custom input of pump data

Once selected, the zone retains all of the information associated with the pump chosen. This information includes the pump name, the number of pumps, and the capacity, power consumption, EER/COP, flow rate, and partial load factor in both cooling and heating modes. If obtained from the list of available pumps, detailed information is also available, including the manufacturer and series name, the pump type, and the inlet load temperatures.

Figure 3.4 shows the pump selection section of the zone data window with sample data matched to the loads data of figure 3.3.

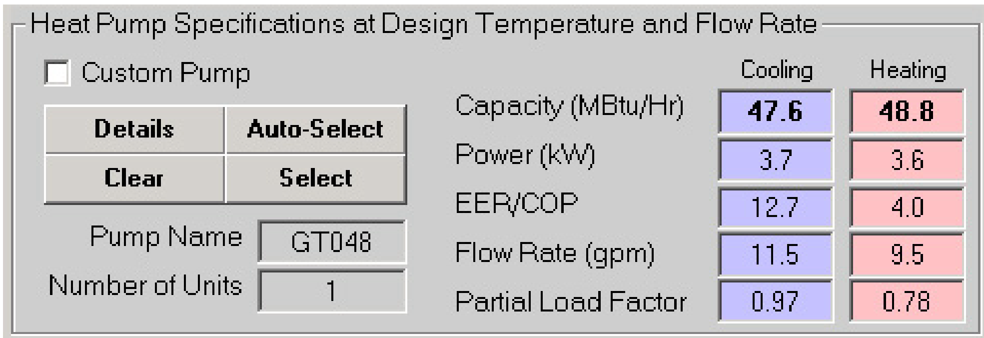

Fig. 3.4 Sample Pump Selection Section with Data

Several buttons are located on the pump selection section. These include *Auto-Select*, *Select*, *Details*, and *Clear*. A checkbox is also included to indicate when the pump is a 'custom pump', or a pump not included in Ground Loop Design's internal list of pumps.

Auto-Select

This option is by far the easiest method of matching a pump to the loads in a particular zone. By clicking the *Auto-Select* button, Ground Loop Design utilizes the information stored for the active pump family and determines which pump within the list would be best suited for the zone. If the list of pumps is too small for the zone loads, it keeps increasing the number of pumps of each size until a match is achieved.

The pump selection process uses information from the current project. This includes the chosen inlet source temperature, the flow rate, the heat pump series, and initial inlet load temperatures. The active heat pump series and load temperatures may be changed on the *Heat Pumps* panel in any design module.

Select

If an automatically selected heat pump is for any reason undesirable, or a different pump series from the same or even a different manufacturer is required, the *Select* button may be used. This button allows the designer to choose any of the stored pumps. As with the *Auto-Select* button, all of the associated fields are calculated automatically once the pump is selected.

When the *Select* button is pressed, the selection panel appears, as shown in figure 3.5. After a pump is chosen, pressing *Select Pump* will place the pump in the zone and automatically calculate all of the associated parameters. *Cancel* will return to the main display with no changes.

Note: Unlike with Auto-Select, *a pump that is manually selected may or may not match the loads in the zone. It is the responsibility of the designer to make sure the pumps match the zones.*

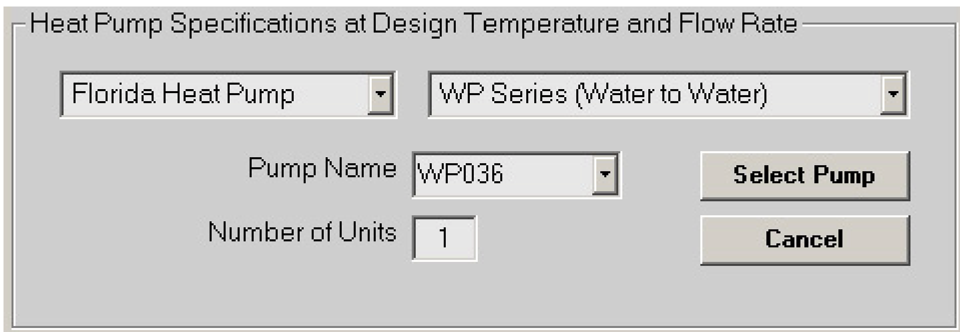

Fig. 3.5 Pump Selection Panel

Details

Specific details about a given pump may be obtained by clicking the *Details* button. Additionally, the details panel is where the designer may vary the loads input temperature for that particular pump. *Upon return, variations in the input load temperature do affect the pump parameters listed on the main pump selection area.* A sample details panel is shown in figure 3.6.

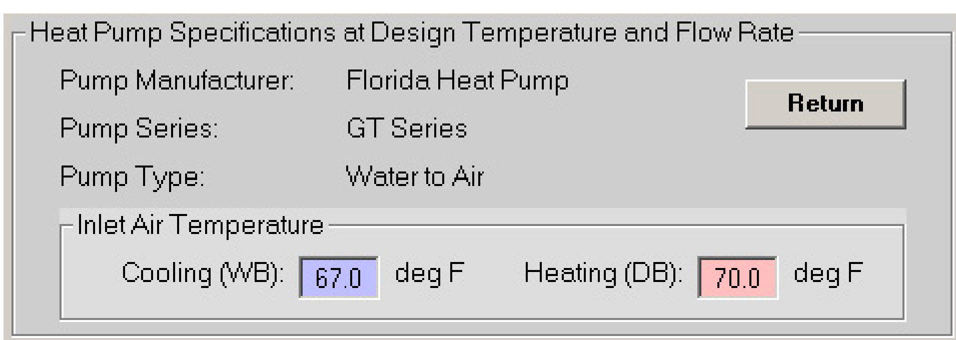

Fig. 3.6 Pump Details Panel

Clear

Clicking on the *Clear* button may clear the current pump in a zone. All values are reset to the initial state, allowing the user to reselect or enter a pump for the zone.

Custom Pump (Customization)

If the designer must include a heat pump unit that is not stored in the program's internal list of pumps, customized pumps may be added by simply entering values directly into the boxes on the pump selection section of the zone data window. This allows the user to override the automatic selection features, and a check appears next to the "Custom Pump" label, which signifies that the pump information is from an external source. The details section no longer contains information about the pump manufacturer, series, or type.

The calculation portion of Ground Loop Design will require at least the capacity and power data to utilize the pump properly. Other information may be added for the designer's reference.

Note: When a custom pump is included, its values will remain unchanged during the designing process. Variations in inlet source or load temperatures, or system flow rate, will not affect a customized pump's data.

Automatic Heat Pump Selection Options for the Entire Zone Set

Two controls are included with Ground Loop Design that allow for an automatic selection of pumps throughout the entire set of zones. This feature is useful in cases when the pump sets need to be compared or changed, or modifications are required throughout the existing set. These controls are necessary so that large sets of pumps can be changed or updated without having to step through each individual zone.

Auto-Select All Pumps

The *Auto-Select All Pumps* control performs the same function as the *Auto-Select* button in the pump selection section of the zone data window, except it performs the selection on all of the zones. It uses the active heat pump series selected on the *Heat Pumps* panel of the design modules.

Note: Auto-Select All Pumps *will overwrite all currently selected pumps, including custom pumps already stored in the system.*

Update/Reselect Current Pumps

The *Update/Reselect Current Pumps* control reselects the pumps in all zones after determining the current series used in each particular zone. For example, if most of the pumps belonged to the same water-to-air series, but one was a water-to-water pump, this control would determine the difference and update the pumps accordingly.

Custom pumps are not affected when the *Update/Reselect Current Pumps* control is activated. They remain unaffected.

Pump Continuous Update Feature

The *Update/Reselect Current Pumps* control is called automatically when changes are made to the inlet source temperature or the system flow rate within the design modules. In this way, the designer does not have to worry about updating the pumps already matched to the zones in Ground Loop Design.

However, the designer must be aware that sometimes this may result in a new pump size assignment due to capacity changes related to variations in temperature or flow. Also, for proper modeling, any customized pumps must be edited separately by the designer after the design parameters have been established.

CHAPTER 4

The Borehole Design Module

This chapter describes the features and operation of the Borehole Design module. This module is used in the design of systems using vertical boreholes. It is one of two design modules included with Ground Loop Design.

Overview

Any design will only be as good as the quality of the data that goes into it. This is certainly the case with the Ground Loop Design Borehole Design module. Although based on one of the best theoretical models available, the most accurate results will naturally result from the most accurate input parameters. Because the calculations conducted here involve the combination of a large number of input parameters, care must be taken to assure that proper values are verified before use. Assuming reasonable values are provided to the software, the software should be able to provide reasonable results.

General Features

To aid in the entry process, the Borehole Design module in Ground Loop Design consists of a set of panels, grouped by subject, where the designer can enter and edit the input variables efficiently. For example, parameters related to the soil are listed on the *Soil* panel, while heat pump choices are listed on the *Heat Pumps* panel. The idea is that everything related to a project is presented simultaneously and is easily accessible at any time during the design process.

The Borehole Design module includes several additional features:

- Metric and English unit conversion
- Printed reports of all input and calculated data
- Convenient buttons to bring up tables of parameter data
- A 'Calculate' button used to refresh the calculations

Opening Projects

It is possible to open Borehole Design projects in either of two ways. One is by using the 'New Borehole' command from the design studio *File* menu, and the other is by opening an existing Borehole Design project (***.gld**) file. Files cannot be opened if other modules with the same name are already open. As many files can be opened as the system's memory permits.

New Projects

New projects may be opened at any time from the design studio by choosing 'New Borehole'. New projects open with standard parameter values that must be edited for new projects. The module opens directly into the Information panel, initially allowing the designer to enter information about the new project.

In new projects, no zone files (*.zon) are loaded. The user must create new zones, or load an existing zone file.

Existing Projects

Existing projects may be opened at any time from the design studio by choosing 'Open' from the design studio *File* menu. The file automatically opens into a new Borehole Design Project module.

If a zone file (*.zon) is associated with the loaded project, the zone file will be automatically loaded with the project file. However, if the associated zone file cannot be found, the user will be notified and the automatic zone file loading will not occur.

Saving Projects

Projects may be saved at any time using 'Save' or 'Save As' from the design studio *File* menu. On closing the program or module, the program will automatically ask if the user would like to save the project file.

Typical Operation

Although individual styles will vary with users, the typical operation of the Borehole Design module would include the zone (loads) entry and pump selection, a stepwise modification of the input parameters listed in each panel, followed by an initial calculation. Various parameters would then be modified, and the effect of the modifications would be seen in successive recalculations until the designer has established the optimal system. Afterwards, the project could be saved and/or printed, and modified later if necessary.

Entering Data into the Tabbed Panels

The tabbed panel system is Ground Loop Design's solution to the problem of organization and direct access to the relatively large number of design parameters. This section describes the *Information, Heat Pumps, Extra kW, Pattern, U-Tube, Soil, Fluid, and Calculate* panels. The *Loads* panel was discussed in detail in Chapter 3.

Information

The contents of the *Information* panel are shown in figure 4.1. All of the information related to the project is stored in this panel. This primarily includes the project name, dates, and the designer's name. Additionally, reference data concerning the client may be included on this page, so that all relevant project information is located in one convenient location.

In addition to generalized project information, specialized comments may be included in the 'Comments' section of the *Information* panel. This area allows the designer to make any notes particular to the specific project that may not necessarily fit in the topics provided.

All of the data in the information panel is optional, but completing the page is recommended for the sake of organization. All of the reports utilize the project information as a way of distinguishing one project from another.

Except for the dates, the information panel input boxes contain only text, and any desired format may be used when filling out the form.

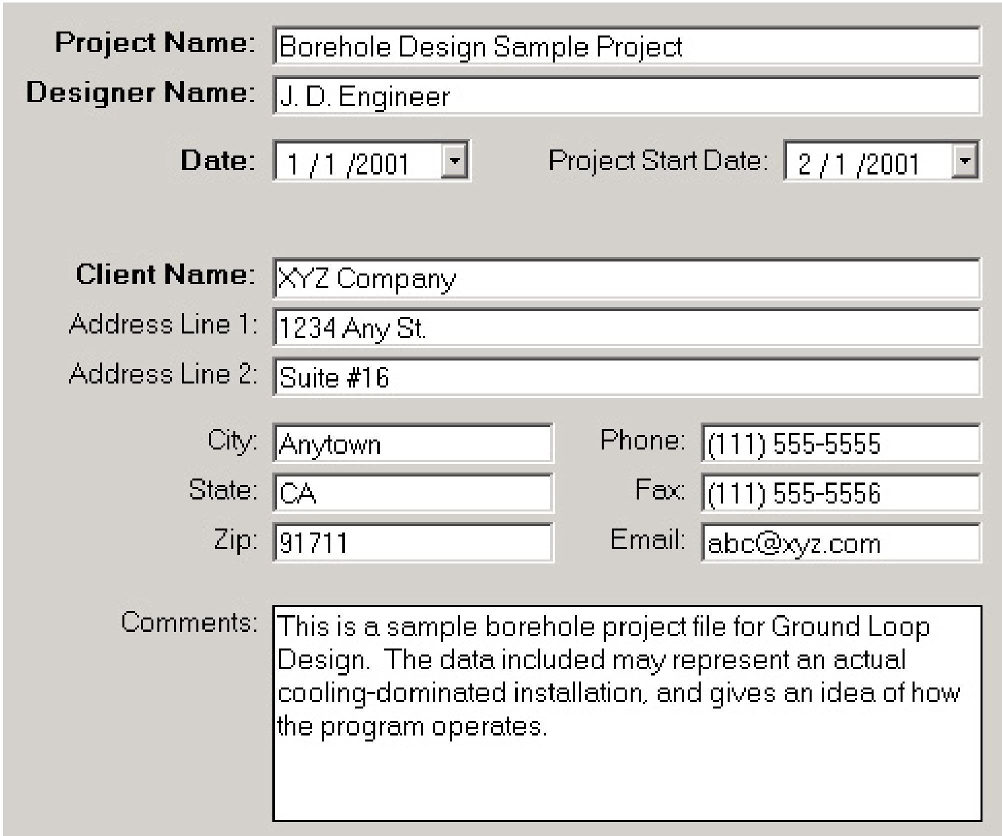

Fig. 4.1 *Information* Panel Contents

Heat Pumps

The active heat pump series may be selected using the *Heat Pumps* panel, as shown in figure 4.2. Additionally, initial values for the loads inlet temperatures may be entered here.

Choosing the Active Series

The active heat pump series is the series of heat pumps used by the *Auto-Select* features in the *Loads* panel. It represents the primary heat pump family utilized by the designer for a particular project. Although this is the primary series, other pumps may still be selected for certain zones using either the *Select* button or by defining a custom pump. Specific details about pump selection may be found in Chapter 3.

To choose a pump series, select a manufacturer, followed by the desired series of that manufacturer. A list of available pumps appears in the list box.

Inlet Load Temperatures

Values for the initial inlet load temperatures for both water-to-air and water-to-water pumps may be entered in the appropriate boxes. If necessary, these values may be changed for individual pumps in the *Loads* panel. For water-to-air pumps, 'WB' refers to "Wet Bulb" and 'DB' refers to "Dry Bulb" temperatures.

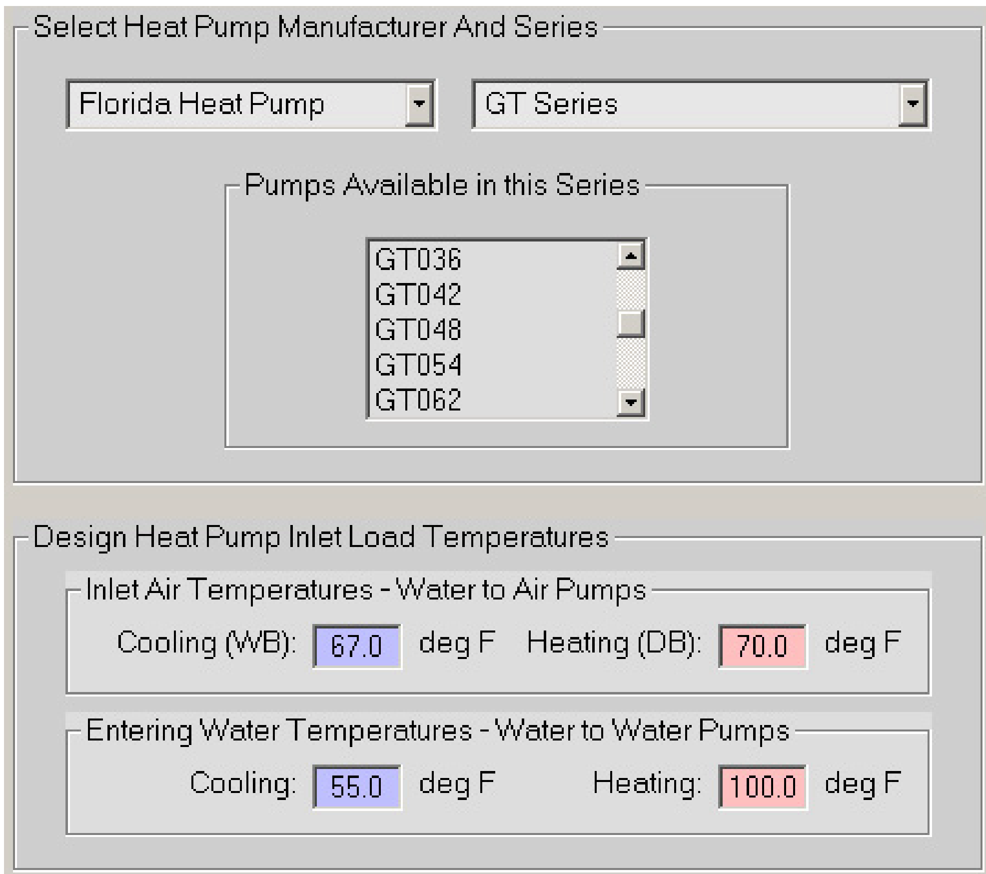

Fig. 4.2 *Heat Pumps* Panel Contents

Extra kW

Additional energy that is utilized by the system can be entered in the *Extra kW* panel. The entry boxes are shown in figure 4.3.

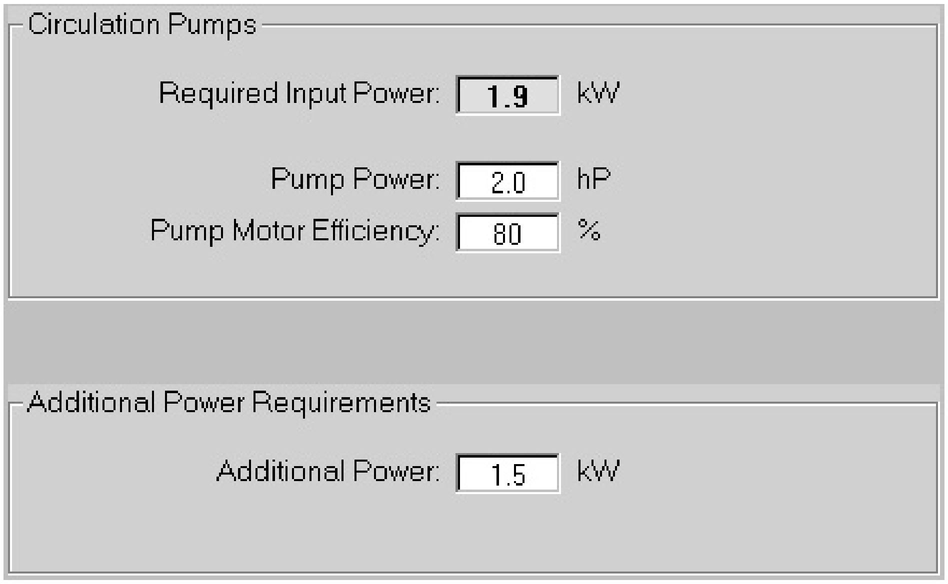

Fig. 4.3 *Extra kW* Panel Contents

This panel is included for calculations of the average efficiency for the entire system. The top entry box, 'Circulation Pumps' is for the energy required by the system circulation pumps, while the 'Additional Power Requirements' box is for all other elements in the system that may require energy input besides the heat pump units. For example, blowers or cooling towers require additional energy that could be recorded on this panel so that it could be used in the overall calculation of System EER/COP.

In the 'Circulation Pumps' section, the 'Required Input Power' is calculated from the 'Pump Power' required by the pump(s) for the system in question and the average 'Pump Motor Efficiency'. It is not possible to edit the 'Required Input Power' value directly, however, if the pump motor efficiency is set to 100%, the 'Pump Power' and 'Required Input Power' will be the same.

The 'Additional Power' may be added as necessary.

Note: A kilowatt entry may be made in the 'Pump Power' box by switching to metric units, entering the kilowatt value, and then returning to English units.

Pattern

Information pertaining to the ground field arrangement can be found in the *Pattern* panel. This includes the pattern of the vertical boreholes, the borehole separation, the number of boreholes per parallel loop, and the modeling time. The input screen is shown in figure 4.4.

Vertical Grid Arrangement

Currently, the Borehole Design module is only configured to accept equally spaced rectangular patterns based on an x, y coordinate system. The theoretical model employed allows flexibility in the ground field arrangement, but this would require a much more complicated input screen. To simplify, the more common rectangular system is employed.

Separation between Vertical Bores

This value is the center-to-center distance between adjacent bores. For optimal use of space, the current calculations allow only one spacing distance between vertical bores in either direction.

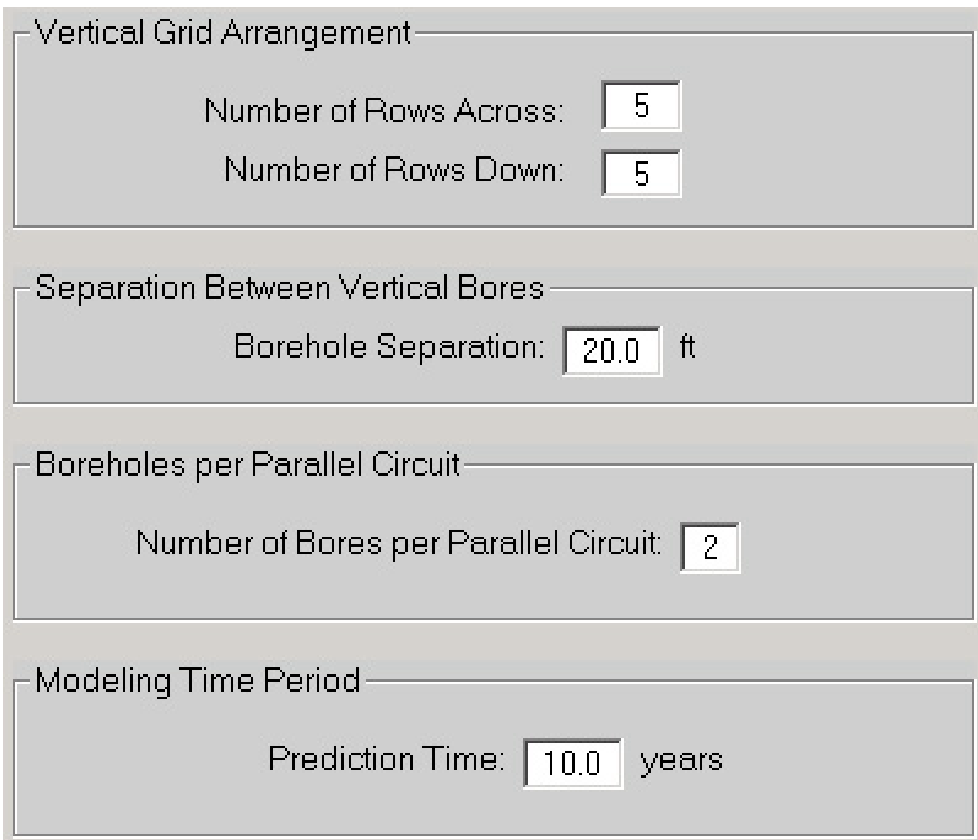

Fig. 4.4 *Pattern* Panel Contents

Boreholes per Parallel Loop

The 'number of boreholes per parallel loop' refers to the piping arrangement within the borehole pattern. The calculation will give slightly different bore lengths depending on whether one, two, or more boreholes are included in one parallel circuit. However, pumping costs would increase as the pipe lengths per parallel circuit become longer.

Modeling time Period

Ten years is used as a standard length of time for the ground temperature to stabilize, although longer time periods may be entered if desired. If excessive ground water movement is known to occur, one year is sometimes used as the modeling time period, meaning that the ground temperatures would be assumed to stabilize after a single year due to the effects of ground water movement.

U-Tube

The *U-Tube* panel contains information related to the pipe and bore. The main purpose of the panel is to obtain a value for the borehole thermal resistance, calculated according to the method of Remund and Paul (Paul, 1996), which takes into account the pipe parameters and positioning, the borehole diameter, and the grout thermal conductivity. If desired, an experimentally determined value of the borehole resistance may also be entered into the textbox, which then overrides all calculations. The panel contents are shown in figure 4.5.

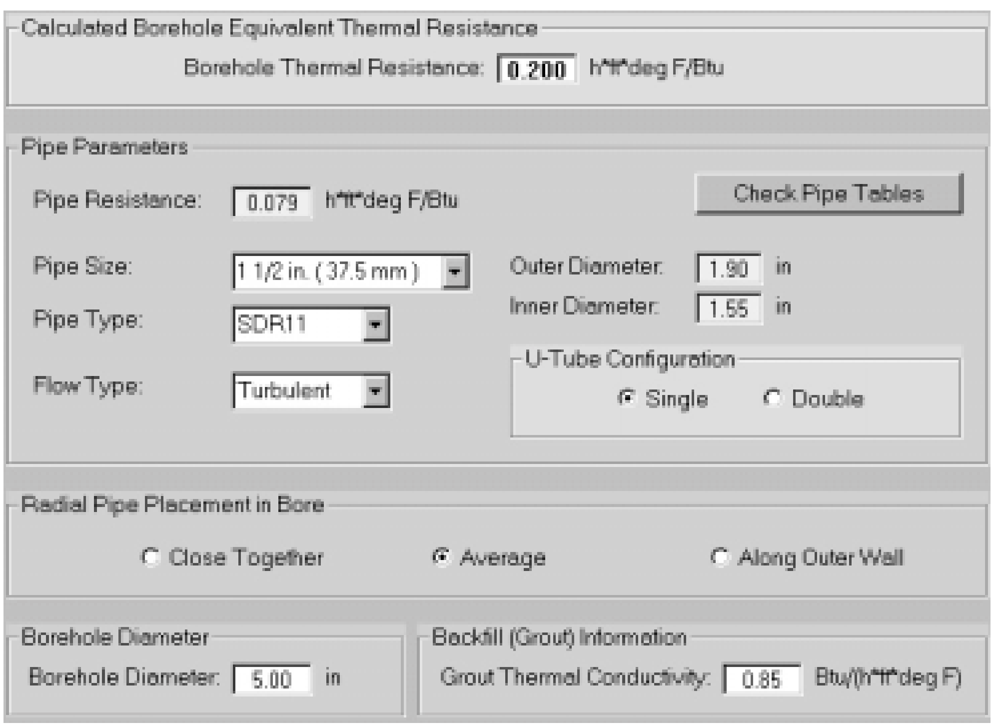

Fig. 4.5 *U-Tube* Panel Contents

Pipe Parameters

The pipe parameters are entered in the 'Pipe Parameters' section. They include the pipe resistance and pipe outside diameter, followed by the configuration and placement of the pipe in the bore.

Ground Loop Design calculates the convective resistance using the Dittus-Boelter correlation for turbulent flow in a circular tube (Incropera and DeWitt, 1990). The calculations use aveage values of the Reynolds number to represent the different types of flow, with values of Re = 1600, 3150, or 10000 for laminar, transition, and turbulent, respectively. They also use average values of viscosity and Prandtl number for water, taken at a temperature of 70 F.

Using the standard expression for resistance of a hollow cylinder (Incropera and DeWitt, 1990), the program can calculate an approximate value for the pipe resistance. It assumes HDPE pipe with a conductivity of 0.225 Btu/h"ft*F.

The pipe resistance varies with the pipe style and flow. The user can select the size and type of pipe from the appropriate selection boxes. If another pipe diameter is required, it can be entered directly into the text boxes as needed.

Note: By pressing the 'Check Pipe Tables' button, the 'Pipe Properties' tables will open, and one of the included links produces a table listing all inside/outside diameters for common pipe sizes.

If the user wants to enter an experimentally determined pipe resistance, or if he or she requires more precise calculations, he or she can enter these values directly into the 'Pipe Resistance' text box, overriding all pipe resistance calculations.

The user also selects the U-tube configuration and radial placement in the bore the designed installation. A single U-tube would refer to two pipes placed in the bore, while a double U-tube refers to four pipes placed in the bore. The radial pipe placement can be 'Close together', which represents a 1/8" average distance between the pipes, 'Average' which means that the pipes are centered at a point halfway between the wall and the center of the bore, or 'Along outer wall', which signifies placement of the pipes against the outer wall.

Note: The 'Double' U-tube configuration at this stage is added more for reference than for practical use. Currently, the values Ground Loop Design uses are based on experimental data and a new theoretical model accounting for a lower pipe and convective resistance, and a larger *displacement of the grout. The designer should be aware of this fact, and remember that a 'single' U-tube is the standard option.*

Borehole Diameter and Backfill (Grout) Information

The user can enter the borehole diameter directly into the borehole diameter text box, and the grout thermal conductivity in its associated text box. If cuttings are used for the backfill, the average soil conductivity should be entered here.

Soil

Input parameters relating to the soil are located in the *Soil* panel, as shown in figure 4.6. These include the average ground temperature and the soil thermal properties.

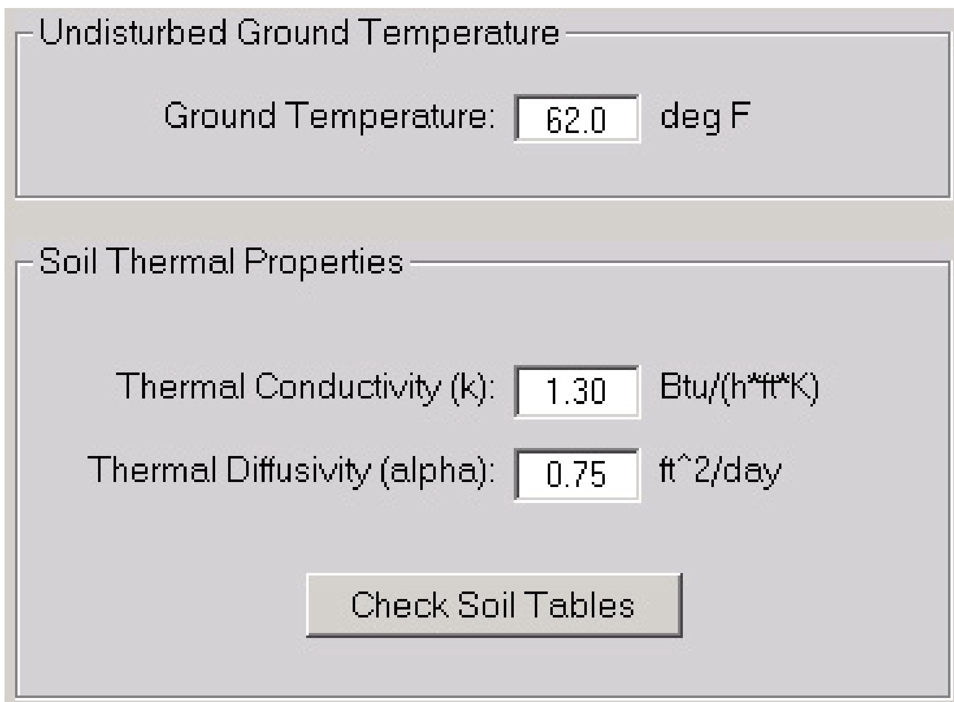

Fig. 4.6 *Soil* Panel Contents

The undisturbed ground temperature refers to the temperature of the soil below the surface layer, where there is no longer a seasonal swing. This value may be determined from regional data or by recording the actual stabilized temperature of water circulated through pipe in a test bore.

The soil thermal properties are a little harder to define, and care must be taken to provide accurate values, especially for the thermal conductivity. The thermal diffusivity relates to the density of the soil and its moisture content. Typical values of thermal conductivity and diffusivity for sand, clay, and different types of rocks can be found in the 'Soil Properties' tables. However, actual tests of the soil at the location would be the recommended procedure for obtaining these values. *The thermal conductivity in particular has a large effect on the calculated bore length, and should be determined with care through in-situ tests or comparison with other projects installed in the local vicinity.*

Fluid

The circulating fluid parameters may be entered in the *Fluid* panel. A sample input screen is shown in figure 4.7.

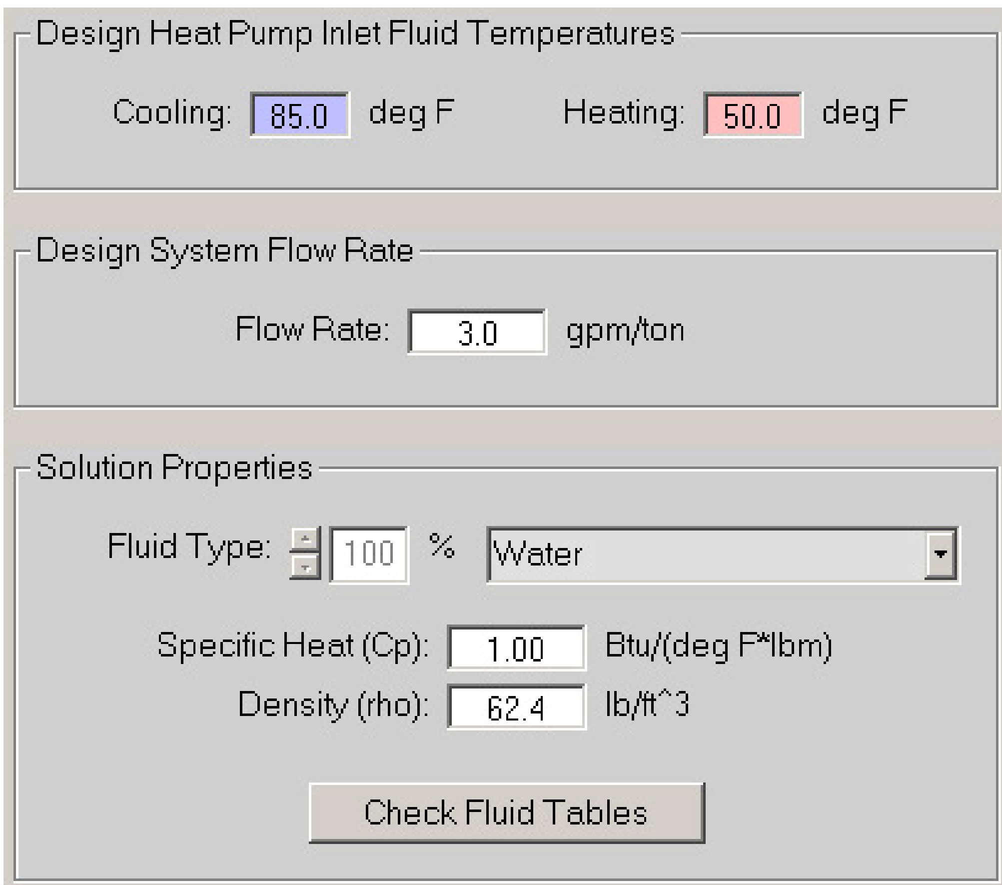

Fig. 4.7 *Fluid* Panel Contents

Design Heat Pump Inlet Fluid Temperatures

The heat pump inlet fluid temperatures are included in the *Fluid* panel. The designer can input the desired inlet source temperatures for both heating and cooling here. *When changes are made to these values, the* *heat pumps in all zones are updated automatically.* Since the new calculated equipment capacities can lead to changes in selected equipment, the designer must be aware that changes are being made. Customized pump values must be manually adjusted.

Design System Flow Rate

The system flow rate per installed ton is included on the *Fluid* panel. *This is the system flow rate per ton of peak load, not installed capacity*. (This is because it is assumed that units would not be running at full load simultaneously, even in the peak load condition.) Optimized systems generally operate in the range from 2.5 to 4.0 gpm/ton, with the most ideal system flow rate somewhere around 3.0 gpm/ton. Again, if the flow rate is changed, the selected heat pumps are updated.

Solution Properties

The solution properties are also included in the *Fluid* panel. These include the *specific heat* and *density* of the circulating fluid. Also, a reference label is included so that the designer knows the percentage of antifreeze and antifreeze type; however, this reference label is not currently linked to the other input parameters.

The specific heat and density values of the antifreeze are used for the calculation of the heat pump outlet temperature, which in turn is used for the bore length calculation.

Additionally, the viscosity of the solution may affect the flow type in the pipe, which was selected on the *U-Tube* panel. The designer must be aware of any changes made.

Note: Since solution properties vary considerably and non-linearly with type and percentage of additive, Ground Loop Design does not include detailed automatic antifreeze information. Generalized tables of data may be found in the 'Fluid Properties' tables. ***The designer must manually enter the desired values in the input text boxes.***

Calculate

All results of the calculations for both heating and cooling can be viewed at any time on the *Calculate* panel. This panel has no inputs, only outputs. After all data has been entered or any changes have been made, the user can calculate interim or final results using the 'Calculate' button. A sample screen for this panel can be seen in figure 4.8.

There are actually two reports shown on the *Calculate* panel, one for heating and one for cooling. Although all of the numbers shown are valid and respond to changes, the side with the longer length is printed in bold type, so that it stands out. The longer length determines the installation size, and for this reason the shorter-length system results lose relevance.

The report is separated into four sections. The first deals with the bores, including the total length, the borehole number, and the borehole length for one bore. One common method of adjusting the borehole length to a desired value is to change the borehole number or pattern on the *Pattern* panel.

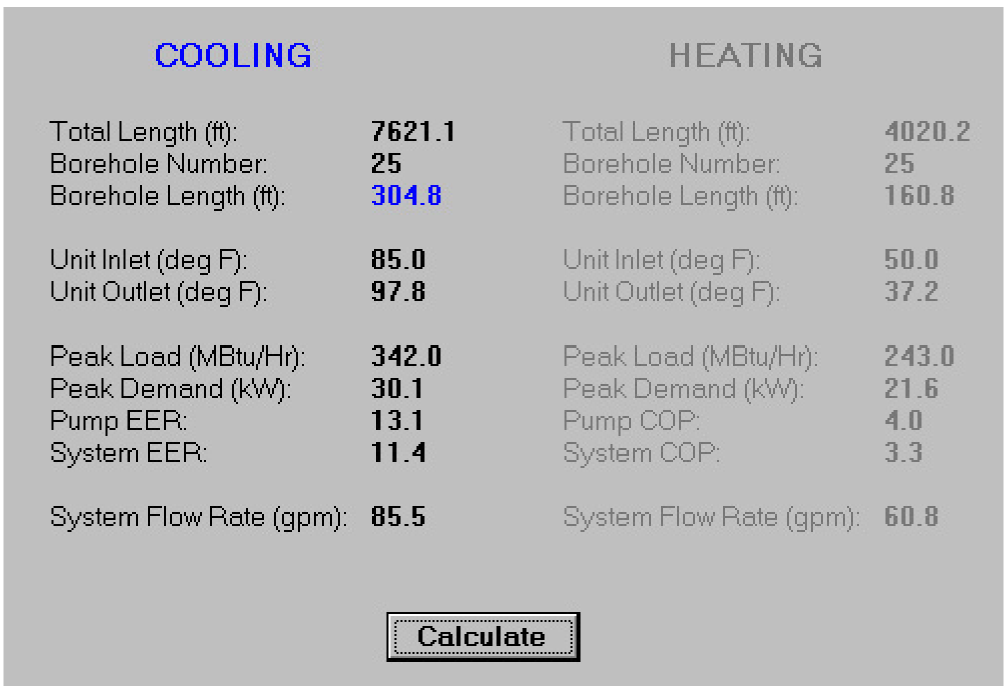

Fig. 4.8 *Calculate* Panel Contents

The second section of the report lists the heat pump inlet and outlet temperatures of the circulating fluid.

The third section lists the peak loads and demand of all the equipment, and the calculated heat pump and system efficiencies. The peak load is the maximum, determined from whichever time period across all the zones has the highest load. The peak demand includes all pumps and external energy requirements, including those listed in the *Extra kW* panel. However, care must be exercised when equipment energy requirements listed in the *Extra kW* panel refer to only heating or only cooling types of equipment. In these cases, the pump efficiency would be fine, but the system efficiency might be incorrect.

Finally, the system flow rate is listed in its own section. The system flow rate is calculated from the peak load divided by 12,000 Btu/ton, and then multiplied by the flow rate in gpm/ton chosen on the *Fluid* panel. It represents the flow rate from the installation out to the buried pipe system.

Printing Reports

Reports of the active project can be printed at any time from the design studio *File* menu → *Print*.

The information printed includes all of the input parameters from the design module, along with the associated results. The zone and loads information is not included with the report, but must be printed separately from the *Loads* panel. The filename of the ***.zon** file associated with the project report is listed on the report.

More information on reports can be found in Chapter 7.

References

Incropera, F. and Dewitt, D. *Introduction to Heat Transfer, 2nd Edition.* p. 456, p. 98. John Wiley and Sons, New York. 1990.

Paul, N. *The Effect of Grout Thermal Conductivity on Vertical Geothermal Heat Exchanger Design and Performance.* M.S. Thesis, South Dakota State University. 1996.

CHAPTER 5

The Surface Water Design Module

This chapter describes the features and operation of the Surface Water Design module. This module is used in the design of systems using bodies of water, including ponds, rivers, lakes, oceans, etc. It is one of the two design modules included with Ground Loop Design.

Overview

As with the Borehole Design module, the calculations made in the Surface Water Design module involve the combination of a large number of input parameters, and care must be taken to assure that proper values are verified before use. Assuming reasonable values are provided to the software, a reasonable output should result.

General Features

The Surface Water Design module in Ground Loop Design also includes a set of panels, grouped by subject, where the designer can enter and edit the input variables in a fast, straightforward, and efficient manner. For example, parameters related to the body of water are listed on the *Surface Water* panel, while heat pump choices are listed on the *Heat Pumps* panel. Everything related to a project is presented simultaneously and should therefore be easily accessible during the design process.

The Surface Water Design module includes several additional features:

- Metric and English unit conversion
- Printed reports of all input and calculated data
- Convenient buttons to bring up tables of parameter data

- A ‘Calculate’ button used to refresh the calculations
- A system to monitor header and branch piping head losses

Opening Projects

It is possible to open Surface Water Design projects in either of two ways. One is by using the ‘New Surface Water’ command from the design studio *File* menu, and the other is by opening an existing Surface Water Design project (***.gld**) file. Files cannot be opened if other modules with the same name are already open. As many files can be opened as the system’s memory permits.

New Projects

New projects may be opened at any time from the design studio by choosing ‘New Surface Water’. New projects open with standard parameter values that must be edited for new projects. The module opens directly into the Information panel, initially allowing the designer to enter information about the new project.

In new projects, no zone files (*.zon) are loaded. The user must create new zones, or load an existing zone file.

Existing Projects

Existing projects may be opened at any time from the design studio by choosing ‘Open’ from the design studio *File* menu. The file automatically opens into a new Surface Water Design Project module.

If a zone file (*.zon) is associated with the loaded project, the zone file will be automatically loaded with the project file. However, if the associated zone file cannot be found, the user will be notified and the automatic zone file loading will not occur.

Saving Projects

Projects may be saved at any time using ‘Save’ or ‘Save As’ from the design studio *File* menu. On closing the program or module, the program will automatically ask if the user would like to save the project file.

Typical Operation

Although styles will vary with individual users, the typical operation of the Surface Water Design module would include the zone (loads) entry and pump selection, a stepwise modification of the input parameters listed in each panel, followed by an initial calculation. Various parameters would then be modified, and the effect of the modifications would be seen in successive recalculations until the designer has established the optimal system. Afterwards, the project could be saved and/or printed, and modified later if necessary.

The theoretical model, which is based on experimental data and non-laminar flow, requires a minimum system flow rate of 3.0 gpm/ton in the pipes to achieve proper heat transfer. Minimum flow rates through the circuit piping are also required to maintain the non-laminar flow with different antifreeze solutions. Thus, there is a limit on the maximum recommended number of parallel circuits required in the system, which determines the length of an individual circuit.

Changing the pipe size requires a change in the minimum required flow rates, which can either increase or decrease the maximum recommended number of parallel circuits and their lengths. However, this also can have substantial effects on the piping head losses, which must also be considered in order to reduce the pumping costs.

To fully optimize a system in the Surface Water Design module, the designer must thoroughly understand the relationship between the system flow rate, the minimum required flow rates, the pipe size, the head loss per length of pipe, and the preferred number of parallel circuits. Ground Loop Design can conveniently make all the appropriate calculations, but the designer must first have a grasp of all of the individual inputs required and their interrelationships.

So, unlike the Borehole Design module, the Surface Water module includes a piping calculation component to assist the designer in selecting the best pipe sizes and circuit lengths. The surface water designing process actually involves an additional stage of optimization not included with the Borehole Design module.

Entering Data into the Tabbed Panels

The tabbed panel system is Ground Loop Design's solution to the problem of organization and direct access to the relatively large number of design parameters. This section describes the *Surface Water, Piping, Soil, Fluid, and Calculate* panels. The *Information, Heat Pumps,* and *Extra kW* panels are identical to those included in the Borehole Design module described in Chapter 4, so the reader is referred there for detailed information. The *Loads* panel was discussed in detail in Chapter 3.

Surface Water

The Surface Water panel is used to enter data related to the body of water being used as the heat transfer medium. Figure 5.1 shows the associated input screen.

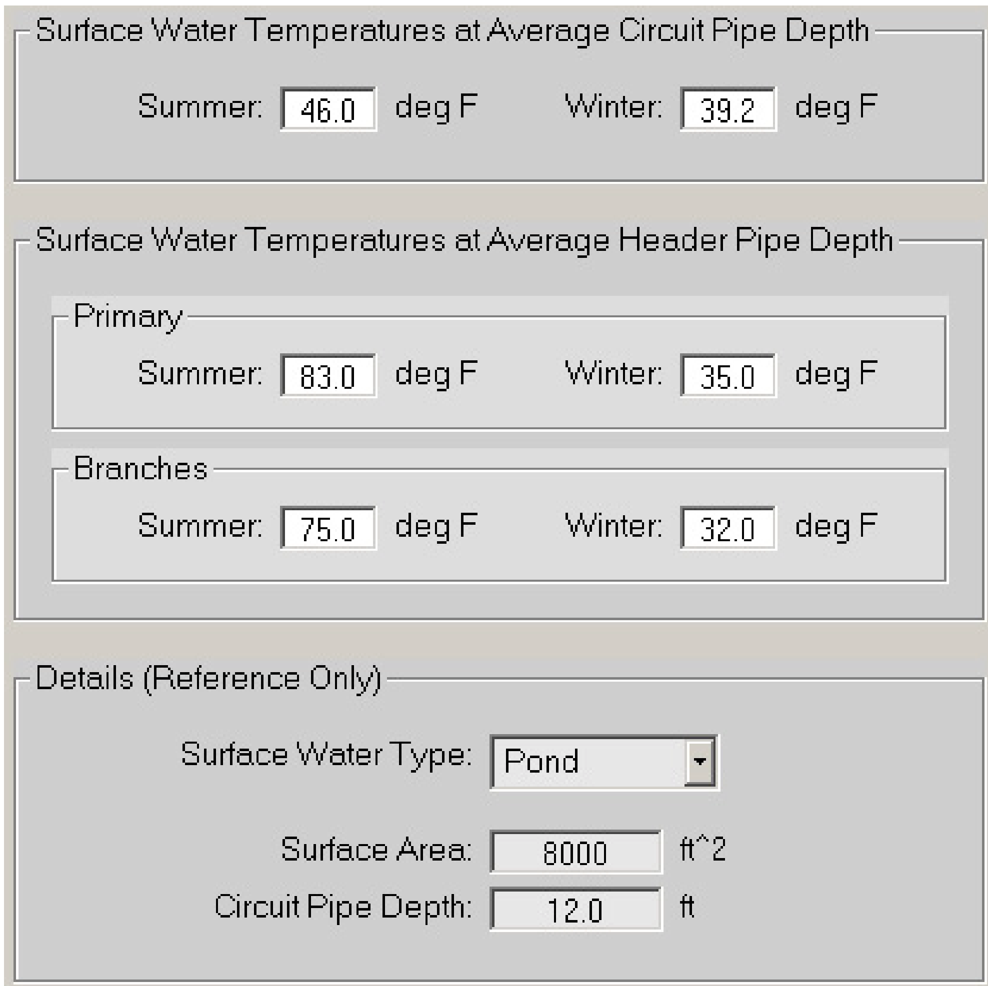

Fig. 5.1 *Surface Water* Panel Contents

Surface Water Temperatures at Average Circuit Pipe Depth

These are the temperatures in the body of water at the depth where the majority of the pipe will reside. The “Circuit Pipe” refers to the main heat exchanger portion of the pipe, and does not include the header pipe leading from the surface.

Temperatures in bodies of water naturally change from summer to winter. Both temperatures, at the circuit pipe depth, should be included in this section.

Surface Water Temperatures at Average Header Pipe Depth

These are the summer and winter temperatures in the body of water at the average depth where the submerged portion of the header pipes reside. “Header Pipe” refers to the section of pipe leading from the surface to the main heat exchanger (circuit) portion of the loop. Further distinctions are described below.

Primary Header

This is the standard “header”, which would most likely come either directly from the installation or from a manifold that comes from the installation main supply and return lines.

Branches

These would be any branches that split from the primary headers. Generally they would be smaller in size than the primary header.

Details (Reference Only)

The surface water details are not used in any calculations. They are included for the designer’s reference. Several different types of water bodies are included, but the designer can type anything in the selection box.

Piping

The *Piping* panel contains all information regarding the circuit piping and the piping selected for the primary header(s) and up to one level of branching off the primary header(s). The heat exchanger circuits actually dominate the heat transfer, but if the supply and return lines are long or exposed to different design conditions, care must be taken with the header heat transfer. The input screen for the piping panel is shown in figure 5.2.

Circuit Parameters

Circuit Pipe Size

This is the size of the pipe used in the primary heat transfer circuits. Although better heat transfer is possible in large pipes, smaller sizes (3/4”, 1”) are preferred because of ease of handling and lower pipe costs.

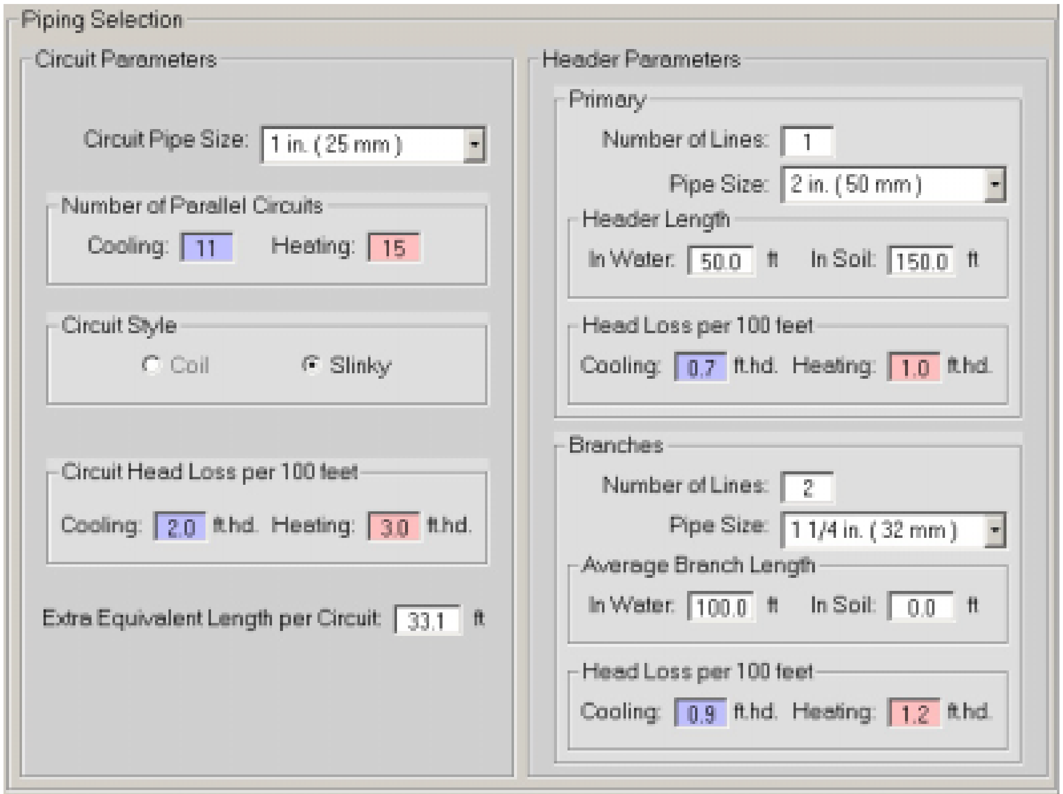

Fig. 5.2 *Piping* Panel Contents

Number of Parallel Circuits

This is the number of circuits required in parallel to maintain the required minimum flow rates defined by the designer. If the number of circuits entered here is greater than the allowed number of circuits, this value will be automatically overwritten with the limiting value when the calculations are performed.

Even if the circuits are split into equivalent groups, such as, for example, three groups with ten circuits each, the total number of parallel circuits (the smallest unit) will not change.

Circuit Style

Two styles are available, loose bundled coils or “slinky” (spread out). If extensive spacers are used in a coil style arrangement, the slinky model may provide more accurate results, but the loose coil option would provide the most conservative results.

Circuit Head Loss per 100 feet

This is the head loss for the particular style of pipe. *These values are not entered automatically*. Instead, they come from designer's charts. A chart in English units is included with Ground Loop Design in the "Pipe Tables" section. The designer must be aware that this value changes with pipe size, temperature, and flow rate.

Extra Equivalent Length per Circuit

This is an average pipe length value included per circuit to take into account all fittings (elbows, tees, etc.). It is only necessary for the head loss calculations.

Header Parameters

The Ground Loop Design Surface Water module assumes a standard supply and return line design will consist of mains, followed by a manifold that splits the mains into the headers. Headers are generally the first pipes to enter the ground or water. They can then branch off once more if necessary (branch lines). For small systems, the mains may be the headers, and may not even have branches. For larger systems, there may be many headers and branches off the branches.

In the *Piping* panel, the model employed allows for multiple headers and multiple first-level branches off of those headers. If further branching were required, the head loss calculations would need to be calculated and added separately, although their effect on the calculated piping length, which could not be included, would depend on their length. All headers are assumed to have an identical pipe size, and an approximately equivalent flow. The same is true for the branch lines.

If there are no branches, the number of branches should be set to zero. The Surface Water Design module starts with only a single primary header.

Ground Loop Design uses the header information so that the heat transfer losses or gains are taken into account. The software then uses this corrected value iteratively to modify the length of the circuit loop piping, so that the desired entering water temperature for the heat pumps is provided. These calculations depend directly on the header-depth surface water and soil temperatures obtained from the *Surface Water* and *Soil* panels.

Additionally, the program calculates the average head losses of the system when provided with the head losses per 100 ft. for each type of pipe in the system. *These values vary with pipe size, freeze protection solution, and flow rate.* A few graphs are provided with the program to help determine these values for pure water and standard solutions, but the designer is finally responsible for making sure the appropriate values are entered. *These head loss calculations also require the one-way length of the header, which is doubled within the program to account for both the supply and return lines.*

Because the inputs to headers and branches are similar, they are described together below.

Number of Lines

This is the number of header or branch lines in the system.

Pipe Size

This is the size of the pipe used in the primary header or branches. For pumping reasons, the size of the primary header is generally larger than the circuit and branch pipe sizes, and branches are generally larger than the circuit pipe size.

Header Length / Average Branch Length

This is the designer-defined one-way length of the pipe from the installation to the water line, and then from the water to the circuit pipes. Different heat transfer calculations are used for the header pipe buried in the soil and the header pipe submerged in the water.

If a primary header enters the water, it is automatically assumed that the branches have no soil component. Likewise, if branches enter the soil, it is assumed that the primary header has no water component.

Head Loss per 100 feet

This is the head loss for the particular style of r pipe. *These values are not entered automatically.* Instead, they come from designer's charts. A chart in English units is included with Ground Loop Design in the "Pipe Tables" section. As mentioned above, the designer must be aware that this value changes with pipe size, temperature, and flow rate.

Soil

The *Soil* panel is included only for the heat transfer calculations for the portion of the header pipe in the soil. The model uses the undisturbed ground temperature of the soil and several parameters associated with the installation location to determine the temperature at the depth of the pipe on the coolest and warmest days of the year. This temperature is then used to determine how much heat is transferred from the header pipe to the soil or vice versa.

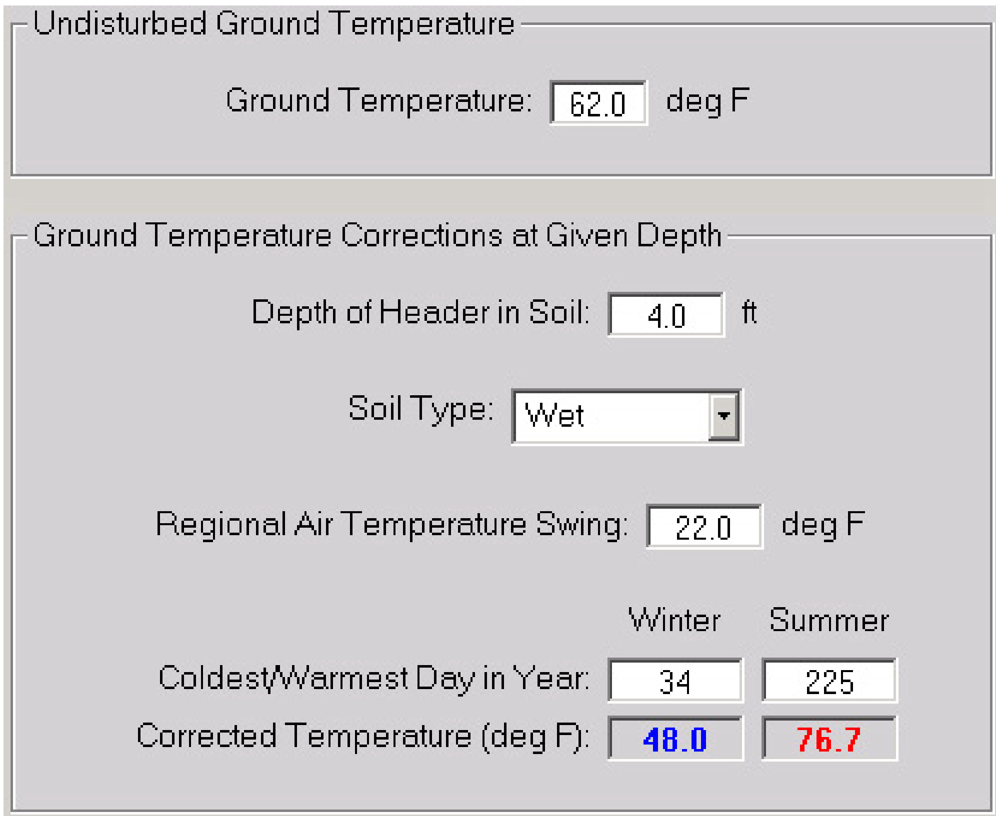

Fig. 5.3 *Soil* Panel Contents

Once the amount of heat transfer from or to the soil is known, the length of circuit pipe calculated from the surface water data can modified to provide fluid with the desired inlet source temperature to the heat pumps.

The *Soil* panel input screen is shown in figure 5.3.

Ground Temperature Corrections at Given Depth

Depth of Header in Soil

This is simply the average depth at which the primary header or branches will be buried in the soil, starting at the water's edge and leading to the installation.

Soil Type

The soil type can have one of three values: wet, dry, or average. Ground Loop Design uses this to assign an approximate diffusivity value to the soil to be used in the temperature model.

Regional Air Temperature Swing

This is the temperature swing for the location of interest. It's a measure of the average temperature variation of the region during the warmest and coolest months as compared to the yearly average temperature. Places with temperate climates will have a lower temperature swing than places that have large differences between summer and winter temperatures.

Coldest/Warmest Day in Year

These are the actual days of the year, on a 365-day scale, when the temperature is usually coldest or warmest. For example, if February 3 were approximately the coldest day of the year, the value entered would be '34' (31 days in January, plus 3 days of February).

The program then uses these days to determine the soil temperature at the given depth at these times of the year.

Corrected Temperature

These are the corrected temperatures at the depth specified, calculated automatically from the undisturbed temperature and the other input values provided. These values are used in the heat transfer calculation between the header or branch pipes and the soil.

Fluid

The fluid panel is essentially the same as that described for the Borehole Design module in Chapter 4. *Note once again that changes in the inlet source temperature or the system flow rate will cause an automatic update of the selected pumps.* Only one section is different, the minimum required circuit flow rate in the lower, 'Minimum Circuit Flow Rate and Solution Properties' section. The added section is shown in figure 5.4

Fig. 5.4 Minimum Circuit Flow Rate Section of the *Fluid* Panel

This information is used in combination with the system flow rate by Ground Loop Design in order to establish the maximum number of parallel circuits. The flow rates required non-laminar flow for several antifreeze solutions are included as a table in the 'Fluid Properties' set, although exact values for a particular mixture may need to be determined independently by the designer.

Calculate

The Surface Water Design module's *Calculate* panel is similar to the Borehole Design module's, but contains a few significant differences. These differences relate to the nature of the calculations, as well as the inclusion of the head loss calculation results. Figure 5.5 shows a typical view of the *Calculate* panel.

Again, there are two reports shown on the *Calculate* panel, one for heating and one for cooling. Although all of the numbers resulting from both sets of calculations are valid, the side with the longer length is printed in bold type, so that it stands out. The longer length usually determines the installation size, and for this reason the shorter-length system results lose relevance. *However, in cases where the cooling and heating lengths are similar, care must be taken to assure the safest design.*

The surface water report is separated into five sections. The first deals with the circuit pipe, and includes the total length, the length for one circuit, the circuit number, and the maximum allowable number of parallel circuits (shown in red). If the maximum allowable number of parallel circuits exceeds the actual number of circuits, this value may be increased in the *Piping* panel to reduce the individual circuit lengths and thus reduce head losses. However, this type of reduction is not always necessary or desirable. Other ways of increasing the maximum allowable number of parallel circuits include changing the system flow rate or the minimum circuit flow rate for non-laminar flow.

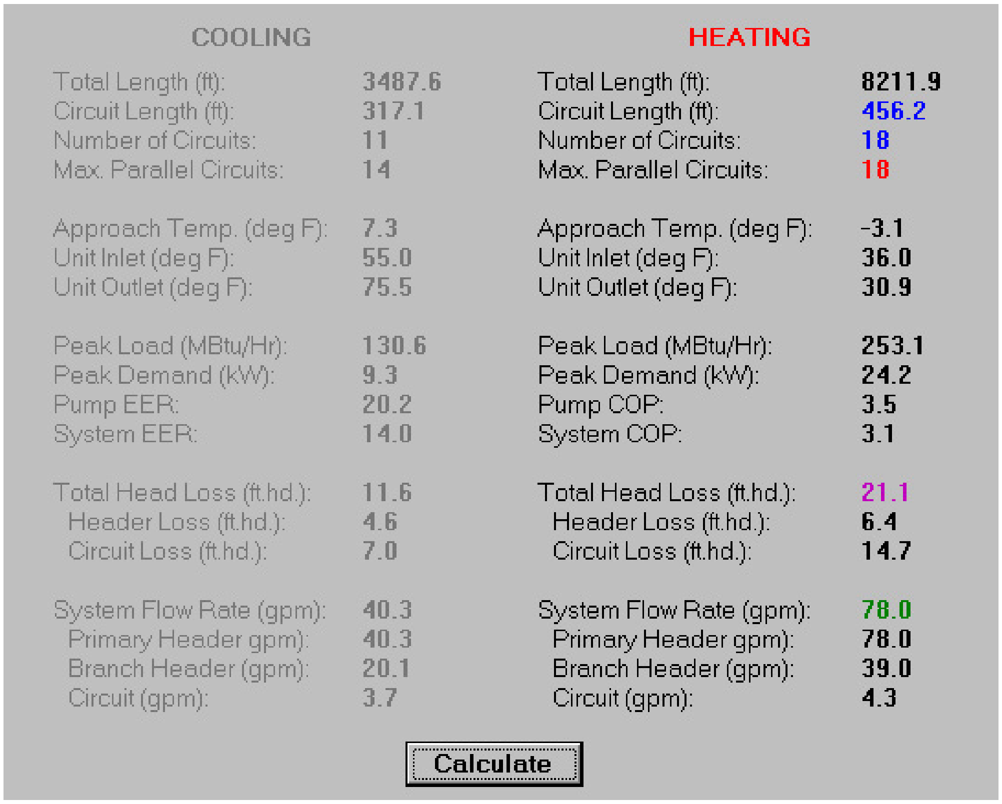

Fig. 5.5 *Calculate* Panel Contents

The second section lists different temperature variables. The first of these is the approach temperature, which is the difference between the pond temperature and the desired inlet source temperature. The source inlet and outlet temperatures follow.

Note: In surface water heating applications, although the solution within the pipe may not freeze, the freezing temperature of the body of water is generally 32°F. ***If the heat pump outlet temperature were too far below this value, the water would tend to freeze on the pipe, greatly reducing its heat transfer characteristics and potentially leading to system failure.*** *The designer must always pay attention to the outlet temperature value for this reason.*

As with the Borehole Design module, the third section lists the peak loads and demand of all the equipment, followed by the calculated heat pump and system efficiencies. The peak load is the maximum, determined from whichever time period across all the zones has the highest load. The peak demand includes all pumps and external energy requirements, including those listed in the *Extra kW* panel. *However, care must be exercised when equipment energy requirements listed in the Extra kW panel refer to only heating or only cooling types of equipment.* In these cases, the pump efficiency would be fine, but the system efficiency might be incorrect.

The fourth section lists the total head loss calculation results, as well as the individual losses for the header and circuit pipe. It does not include any losses for the heat pump equipment, which must be considered separately. This section is convenient for determining the optimum pumping arrangement for the system.

Finally, the system flow rate is listed along with the flow rates in the primary and branch headers, and the flow in the individual circuits. The system flow rate is calculated from the peak load divided by 12,000 Btu/ton, and then multiplied by the system flow rate in gpm/ton (as given on the *Fluid* panel). The primary header flow rate is calculated from the system flow rate divided by the number of primary headers, and the branch flow rate is obtained from the primary header flow rate divided by the number of branches (as given on the *Piping* panel). The circuit flow rate is obtained by dividing the system flow rate by the total number of circuits (also provided on the *Piping* panel).

Printing Reports

Reports of the active project can be printed at any time from the design studio *File* menu → *Print*.

The information printed includes all of the input parameters from the design module, along with the associated results. The zone and loads information is not included with the report, but must be printed separately from the *Loads* panel. The filename of the ***.zon** file associated with the project report is listed on the report.

More information on reports can be found in Chapter 7.

CHAPTER 6

Reports

This chapter covers the report creation and printing features of Ground Loop Design. It includes both project and zone reports.

Overview

Ground Loop Design includes basic reporting features. These features have been added for professionals who need to keep records of their designs and communicate them to others. Because there are seven different report styles included with the package, this chapter provides an explanation of each type of report and its potential uses.

The Report Preview Window

When a particular report is selected, a report preview window opens to show a preview of the report. Report preview windows have a zoom feature that allows adjustment of the magnification. Additionally, reports may be sent to a printer or exported as various file types, including text or html. Multiple reports may be opened simultaneously, even if they originate from the same project.

Report preview windows do not react directly to metric/English unit conversion. Instead, a report opens with the same units used by its parent design module. If another system of units is required, the user must first change the unit system of the design module (using the design studio ‘Units’ menu), and then open a new report.

Project Reports

Project reports may be opened at any time from the design studio *File* menu by selecting *Print*. The report doesn't print automatically, but instead creates the report preview window, where the report can be reviewed prior to printing. Printing can be done by clicking on the printer icon in the upper left hand corner of the report preview window.

Project reports contain four main sections:

- **Information**
- **Calculation Results**
- **Input Parameters**
- **Comments**

Information

This section contains the information from the design module's *Information* panel. The project and designer's names, dates, client's name and address, etc. appear here. This section is included in its own section at the top of every report.

Calculation Results

This section lists the results of the calculation. This is essentially the same information shown on the *Calculate* panel of the design module. The most important results, such as the total length of pipe required, are highlighted and boxed in order to stand out from the background. Results of both heating and cooling calculations are shown side by side.

Input Parameters

This section contains all of the parameters entered by the designer during the design process. Parameters are placed into sections with names identical to the panels in the design modules. The filename of the zone file associated with the project is listed under the *Loads* heading.

Comments

This section, at the end of the report, is reserved for any additional information that the designer would like to include with the project but may not fit into any of the other categories.

Zone Reports

Zone reports are printed directly from the *Loads* panels of the design modules. They include only the project information and data from the zones, presented in different formats. Five different zone reports exist, containing complete or specific information about the zones.

Zone reports work in conjunction with project reports, but are actually a separate entity. They are representative of the actual installation rather than the heat exchanger portion of the system. Zone delineation, loads, and equipment are separate from the heat exchanger system. It is for this reason that the designer would necessarily want to view and consider this information apart from the specific heat exchanger details. For example, if the design were a building, the zone reports would cover everything within the building, while the project report would contain information about everything outside, or external from the building.

A zone report is printed from the *Loads* panel of a design module by clicking the printer button in the zone controls. A dialog window appears, giving the designer the list of available report styles. After the making a choice, click 'OK' to bring up the report window.

There are five different zone reports included with Ground Loop Design:

- **Long Form (Detailed)**
- **Short Form (Detailed)**
- **Equipment List**
- **Loads List**
- **Names List**

Long Form

The *Long Form* report is the most detailed zone report. It lists all of the information included in every zone, along with full descriptors that describe exactly the meaning of the listed parameters. The format is open and easy to read. However, the full detail included in this form requires a much longer printed report than any of the more compact versions.

Short Form

The *Short Form* report contains most of the detail of the long report, but it is packed into a smaller space. It does not include zone names, occupation days, detailed pump information (manufacturer, series, and type), or full descriptors of the items listed. It does, however, contain important information about the loads and the operational parameters of the equipment matched to those loads.

Equipment List

The *Equipment List* lists only the equipment associated with each zone. It provides detailed pump information, including name, number, manufacturer, series, and type, plus all of the operational data associated with that pump. It is an ideal report for engineers or contractors who require equipment lists but do not necessarily need to know further details about the design.

Loads List

The *Loads List* lists only the loads associated with each zone. It provides the design day loads at the different periods during the day in both heating and cooling modes. For the Borehole Design module, the Loads report includes the annual hours and weekly occupation information.

Names List

The *Names List* is just a list of the full reference names of the different zones, combined with the zone number, pump name, and number of pumps required for the zone. It makes a convenient, compact link between zone name and number, and is especially useful when the project consists of many separate zones.

Concluding Remarks

There is no data in Ground Loop Design that is not expressible in a printed form. This allows the designer the complete ability to organize and share information after a design is complete, or during its developmental stages.

CHAPTER 7

Tables and Help Files

This chapter covers the tables and help files of Ground Loop Design. It starts with a description of the included files, and then explains how the user may add customized files to the existing set.

Overview

Every designer has his or her own way of working. Favorite references are like an old but comfortable pair of sneakers. Although this software package attempts to provide some handy information in the included tables, it may never replace the old standards. So, rather than try to impose a particular system onto the users of the software, Ground Loop Design employs a system which uses technological advances to give the new shoes the ability to fit like the old pair of sneakers.

The help files included with Ground Loop Design are minimal. They include only a few tables or graphs that should aid in the selection of the requested parameters. However, all files are written in open HTML (Hypertext Mark-up Language) files, which the designer can edit and add to as desired, to essentially create a customized reference library within the design studio environment.

Essentially, as with the heat pump and zones/loads models, the help files model is another customizable element of the geothermal design studio that the user has the option to control.

Tables Included with Ground Loop Design

Several tables are included with Ground Loop Design. They are separated into three broad categories from which most questions will arise. These include:

- **Fluid Properties**
- **Soil Properties**
- **Pipe Properties**

Another table, which is included with the software, is called **Conversions**, which is just a pair of metric-to-English units conversion tables that answer most common engineering conversion problems.

The other three sections just present a menu screen with choices, as links, for various tables that have been included in the package. Below is a description of the included files.

Fluid Properties

Fluid properties refer to any data related to the circulation fluid. The five *Fluid Properties* tables in Ground Loop Design include a density and specific heat list, the minimum required flow rate for non-laminar flow, and various head loss charts for different antifreeze solutions. Some of these charts could have also been placed with the Pipe Properties tables, but because they vary primarily with solution type, they were placed here.

Table 1: Densities and Specific Heats of Various Solutions

Table 2: Minimum Required Flow Rate for Nonlaminar Flow

(Tables 3-5 included only in English Units)

Table 3: Head Loss in SDR 11 HDPE Pipe - 20% Propylene Glycol

Table 4: Head Loss in SDR 11 HDPE Pipe - 20% Methanol

Table 5: Head Loss in SDR 11 and 17 HDPE Pipe - Pure Water

Ideally, the *Fluid Properties* tables would include all of the graphs, charts, and tables for all of the parameters of all possible antifreeze combinations. However, because these variations are difficult to predict for every project, only partial information has been included. For the most accurate designs, designers are encouraged to seek out their own favorite antifreeze combinations, and determine the specific heat, density, and minimum required flow rate for non-laminar flow.

Soil Properties

Soil properties refer to any data related to the soil. The *Soil Properties* tables included with Ground Loop Design are simply generic tables that provide various soil parameters, including ranges for thermal conductivity, ***k***, and thermal diffusivity, α, for various types of soils. A sand and clay table is provided, as well as a rock table. They are listed below.

Table 1: Thermal Conductivity and Diffusivity of Sand and Clay Soils

Table 2: Thermal Properties of Rocks at 77 deg F

These tables should not be considered accurate for a given location; however, they should provide the designer with a realistic range within which their own measurement results should fall.

Pipe Properties

Pipe properties refer to any data related to the piping. The *Pipe Properties* tables included with Ground Loop Design are related to either the borehole thermal resistance or the pipe physical data. They are listed below.

Table 1: Equivalent Diameters and Thermal Resistances (*Rb*) for HDPE U-Tubes

Table 2: Thermal Resistance Adjustments for Other Borehole Backfills or Grouts

Table 3: Thermal Conductivities of Typical Grouts and Backfills

Table 4: Pipe and Tube Dimensions

The first two tables included in the *Pipe Properties* tables are not really necessary, since the borehole thermal resistance is calculated automatically from other parameters. However, they are included for comparison against calculated results. The third table provides thermal conductivities for some typical grouts. The fourth table lists the physical dimensions (inner and outer diameter) for common pipe sizes in various types of pipe.

Conversions

The Conversions table has two separate lists of metric to English conversions, placed together as one file. As already mentioned, the user can obtain multipliers for most common metric/English unit changes by going through the listed conversions.

Adding Customized Help Files

The user can create customized help files by editing the existing HTML files with the table lists, and making new links. The process is simple, but it requires a very basic knowledge of HTML

Original Model

The original model included with Ground Loop Design consists of these files:

English	**Metric**
FluidTables.html	**FluidTablesMetric.html**
FluidTable1.html	**FluidTable1Metric.html**
FluidTable2.html	**FluidTable2Metric.html**
FluidTable3.html	
FluidTable4.html	
FluidTable5.html	
SoilTables.html	**SoilTablesMetric.html**
SoilTable1.html	**SoilTable1Metric.html**
SoilTable2.html	**SoilTable2Metric.html**
PipeTables.html	**PipeTablesMetric.html**
PipeTable1.html	**PipeTable1Metric.html**
PipeTable2.html	**PipeTable2Metric.html**
PipeTable3.html	**PipeTable3Metric.html**
PipeTable4.html	**PipeTable4Metric.html**

To add a new file, the **FluidTables.html**, **SoilTables.html**, or **PipeTables.html** must be edited. A new link must be created to the HTML file created by the user, which contains the table, graph, or image that the user would like to have available in Ground Loop Design.]

*Note: Ground Loop Design requires the **FluidTables.html**, **SoilTables.html**, and **PipeTables.html** files (and their metric counterparts, **FluidTablesMetric.html**, **SoilTablesMetric.html**, and **PipeTablesMetric.html)** as the initial files when opening the associated tables. They can be edited, but if they are deleted the tables cannot be opened at all.*

HTML Files

HTML refers to HyperText Mark-up Language. It is the language used on web pages, and commonly used in software to quickly provide linked information to users. HTML files can be created with an HTML editor, like those distributed with common browsers, or with a simple text editor. They must, however, follow a certain format and have the '.htm' or '.html' extension.

Editing Existing Files

Existing files may be edited by simply opening up the original file into a text editor or HTML editor, making changes, and then saving the file again. For example, if someone wished to add a new pipe table to the list, it would need to be created (i.e. PipeTable5.html) and then added as a link to the PipeTables.html file.

Additionally, if someone wished to add additional information to an existing table or figure, they would only have to open the appropriate HTML file in a text editor or HTML editor and make and save the changes desired.

For example, if adding a new link, **PipeTables5.html**, to the **PipeTables.html** file, one might add this new link with the name "Table 5: New Pipe Table" by typing the new link at the end of the **PipeTables.html** file into a text editor as follows (the added section is in **bold** type):

```
.
.
.
<li>
<a href="PipeTable4.html">Table 4: Pipe and Tube Dimensions</a></li>
</ul>

<li>
<a href="PipeTable5.html">Table 5: New Pipe Table</a></li>
</ul>

</body>
</html>
```

PipeTables.html (edited version)

Making a Table

A new table can be made at any time by creating one as an HTML file. The easiest way to do this is to use an HTML editor. Although it is possible, tables are much more difficult to organize using plain HTML in a text editor.

Although any name is valid, tables can be added to the appropriate group by just extending the naming sequence already being used. For example, the name **PipeTable5.html** could be used as the name for a new file.

Adding a Picture, Graph, or Figure

If an image is stored as either ***.jpg** or ***.gif**, it can be imported into an HTML page. The HTML page can be linked directly to the Ground Loop Design help files.

As an example, let's assume that an engineer scanned an image of his favorite density vs. percent solute graph for Calcium Chloride and saved it in the Help Files directory as a ***jpeg*** image, called **CaCl2Density.jpg**. A very simple HTML file could be created with a text editor, and called **FluidTable5.html**. The entire **FluidTable5.html** file would be as follows:

```
<html>
<head></head>
<body>
<img SRC="CaCl2Density.jpg" >
</body>
</html>
```

FluidTable5.html

Remember, the **FluidTables.html** file would have to be edited to include the new link to the **FluidTable5.html** file, similar to the example given in *Editing Existing Files*, above.

If everything goes properly, when 'Fluid Properties' is selected from the *Tables* menu in the design studio, 'Table 5' will appear as a link in the list of available tables. By clicking on the link, the CaCl2 density image, **CaCl2Density.jpg**, will appear, and can be used as a convenient internal reference.

Taking Care with Updates

Updated versions of Ground Loop Design may have new help files and new versions of **FluidTables.html**, **SoilTables.html**, or **PipeTables.html**. If this is the case, then any custom changes to these files made by the user may be overwritten during a new installation. ***Although the linked files will remain, the user would be advised to make backup files of all important customized help files before new Ground Loop Design installations.***

Concluding Remarks

The help files in Ground Loop Design are added entirely for the user's convenience. Designers should find the customizable geothermal design studio an ideal, familiar work environment where they can conduct their work with the highest levels of efficiency and confidence.