Ground Loop Design: Residential Edition

Geothermal Design Studio

User's Manual

(English)

Ground Loop Design™ Residential Version 5.1 for Windows®

Gaia Geothermal

www.gaiageo.com

Copyright Notice

Ground Loop Design^{TM} Residential 5.1 User Manual

END USER SOFTWARE LICENSE AGREEMENT

**PLEASE READ THIS END USER SOFTWARE LICENSE AGREEMENT ("End User Agreement")
CAREFULLY BEFORE USING THE SOFTWARE.**

**BY USING THIS SOFTWARE, YOU ARE AGREEING TO USE THE SOFTWARE SOLELY IN
ACCORDANCE WITH ITS INTENDED USE AND YOU ARE CONSENTING TO BE BOUND BY THIS END
USER AGREEMENT. IF YOU DO NOT AGREE TO ALL OF THE TERMS OF THIS END USER
AGREEMENT, PROMPTLY RETURN AND DO NOT USE THE SOFTWARE**.

Single User License. Subject to the terms and conditions of this End User Agreement, Celsia, LLC, doing business as
Gaia Geothermal ("Gaia") and its suppliers grant to you ("Customer") a non-exclusive, non-transferable dongle-based
license to use the Ground Loop Design ™ software program in object code form and all related materials included
herewith, including written materials, binders and other containers (hereinafter the "Software") on supported operating
systems.

Use. Upon: a) receipt of full payment by Gaia, or a Gaia authorized reseller of the applicable license fees, Customer
will be able to use this Software, pursuant to the limitations set forth herein.

Limitations. Customer's full use of this Software is limited to the number of authorized licenses Customer has
purchased. Customer agrees to use reasonable efforts to protect the Software from any unauthorized use, modification,
reproduction, distribution and publication. Customer may not transfer any of the rights granted to Customer hereunder,
unless Customer receives prior written authorization from Gaia and only if Customer transfers all of Customer's rights
granted hereunder, without retaining any of the Software, or any copies thereof or any rights thereto. Except as
otherwise expressly provided under this End User Agreement, Customer shall have no right, and Customer specifically
agrees not to:

(i)   make error corrections to or otherwise modify or adapt the Software nor create derivative works based upon
        the Software, or to permit third parties to do the same; or

(ii)   copy, in whole or in part, decompile, translate, reverse engineer, disassemble or otherwise reduce the
        Software to human-readable form.

Upgrades and Additional Copies. For purposes of this End User Agreement, "Software" shall also include (and the
terms and conditions of this End User Agreement shall apply to) any upgrades, updates, bug fixes or modified versions
(collectively, "Upgrades") or backup copies of the Software licensed or provided to Customer by Gaia or an authorized
distributor for which Customer has paid the applicable license fees and holds the corresponding software keys.
Notwithstanding the foregoing, Customer acknowledges and agrees that Gaia shall have no obligation to provide any
Upgrades under this End User Agreement. If Upgrades are provided, Customer acknowledges and agrees that:
(i) Customer has no license or right to use any such additional copies or Upgrades unless Customer, at the time of
acquiring such copy or Upgrade, already holds a valid license to the original Software.

Notices of Proprietary Rights. Customer agrees to maintain and reproduce all trademark, copyright, patent, and
notices of other proprietary rights on all copies, in any form, of the Software in the same form and manner that such
trademark, copyright, patent, and notices of other rights are included on the Software. Except as expressly authorized
in this End User Agreement, Customer shall not make any copies or duplicates of any Software without the prior
written permission of Gaia. Customer may make such backup copies of the Software as may be necessary for
Customer's lawful use, provided Customer affixes to such copies all trademark, copyright, patent, and notices of other
proprietary rights that appear on the original.

Proprietary Rights. Customer shall own the physical media on which the Software is recorded, but the Software is and
will remain the sole and exclusive property of Gaia. Gaia's rights under this Section will include, but not be limited to:
(i) all copies of the Software, in whole and in part; and (ii) all Intellectual Property Rights in the Software. For
purposes herein, "Intellectual Property Rights" means patent rights (including patent applications and disclosures),
copyrights (including, but not limited to, rights in audiovisual works and moral rights), trade secret rights, rights of
priority and any other intellectual property right recognized in any country or jurisdiction in the world. "Moral Rights"
means any right to claim authorship to or to object to any distortion, mutilation, or other modification or other
derogatory action in relation to a work, whether or not such would be prejudicial to the author's reputation, and any

similar right, existing under common or statutory law or any country in the world or under any treaty, regardless of whether or not such right is denominated or generally referred to as a "moral right".

Confidential Information. Customer agrees that Customer will not disclose or, except as expressly permitted in this End User Agreement, use any Software or other technical information disclosed to Customer by Gaia ("Confidential Information"), and that Customer will take all reasonable measures to maintain the confidentiality of all Confidential Information in Customer's possession or control, which will in no event be less than the measures Customer uses to maintain the confidentiality of Customer's own information of equal importance. Confidential Information will not include information that: (i) is in or enters the public domain without breach of this End User Agreement; (ii) Customer receives from a third party without restriction on disclosure and without breach of a nondisclosure obligation; or (iii) Customer develops independently, which Customer can prove with written evidence. Customer acknowledges that the Software is a trade secret of Gaia, the disclosure of which would cause substantial harm to Gaia that could not be remedied by the payment of damages alone. Accordingly, Gaia will be entitled to preliminary and permanent injunctive relief and other equitable relief for any breach of this Section.

Limited Warranty. Gaia warrants that the Software will substantially conform to its published specifications for a period of thirty (30) days from the later of receipt of the Software or receipt of access to the Software. Gaia further warrants that the media on which the Software is contained will be free from defects for a period of thirty (30) days from the later of receipt of the Software or receipt of access to the Software. This limited warranty extends only to Customer as the original licensee. Provided that (a) Customer has notified Gaia of such substantial non-conformance or defect during the applicable warranty period, and (b) Gaia has confirmed such Software or media to be substantially non-conforming or defective, as Customer's sole and exclusive remedy and Gaia's and its suppliers' entire liability under this limited warranty, Gaia will, at its option, repair, replace, or refund the Software free of charge. Except as expressly provided in this End User Agreement, the Software is provided "AS IS" without warranty of any kind. Gaia does not warrant that the Software is error free or that Customer will be able to operate the Software without problems or interruptions. Gaia reserves the right to charge additional fees for repairs or replacements performed outside of the limited warranty period.

This warranty does not apply if the Software (i) is licensed for beta, evaluation, testing or demonstration purposes for which Gaia does not receive a license fee, (ii) has been altered, except by Gaia, (iii) has not been installed, operated, repaired, or maintained in accordance with instructions supplied by Gaia, (iv) has been subjected to abnormal physical or electrical stress, misuse, negligence, or accident, or (v) is used in ultrahazardous activities.

The authorized distributors of the Software, who are appointed by Gaia, are not permitted to alter the terms of this End User Agreement in any manner.

Disclaimer. EXCEPT AS SPECIFIED IN THIS WARRANTY, ALL EXPRESS OR IMPLIED CONDITIONS, REPRESENTATIONS, AND WARRANTIES INCLUDING, WITHOUT LIMITATION, ANY IMPLIED WARRANTY OR CONDITION OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, NONINFRINGEMENT, SATISFACTORY QUALITY OR ARISING FROM A COURSE OF DEALING, USAGE, OR TRADE PRACTICE, ARE HEREBY EXCLUDED TO THE EXTENT ALLOWED BY APPLICABLE LAW.

IN NO EVENT WILL GAIA OR ITS SUPPLIERS BE LIABLE FOR ANY LOST REVENUE, PROFIT, OR DATA, OR FOR SPECIAL, INDIRECT, CONSEQUENTIAL, INCIDENTAL, OR PUNITIVE DAMAGES HOWEVER CAUSED AND REGARDLESS OF THE THEORY OF LIABILITY ARISING OUT OF THE USE OF OR INABILITY TO USE THE SOFTWARE EVEN IF GAIA OR ITS SUPPLIERS HAVE BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. IN NO EVENT SHALL GAIA'S OR ITS SUPPLIERS' TOTAL LIABILITY TO CUSTOMER, WHETHER IN CONTRACT, TORT (INCLUDING NEGLIGENCE), OR OTHERWISE, EXCEED THE PRICE PAID BY CUSTOMER. THE FOREGOING LIMITATIONS SHALL APPLY EVEN IF THE ABOVE-STATED WARRANTY FAILS OF ITS ESSENTIAL PURPOSE. BECAUSE SOME STATES OR JURISDICTIONS DO NOT ALLOW LIMITATION OR EXCLUSION OF CONSEQUENTIAL OR INCIDENTAL DAMAGES, THE ABOVE LIMITATION MAY NOT APPLY TO CUSTOMER.

Term and Termination. This End User Agreement is effective until terminated. Customer's license rights under this End User Agreement will terminate immediately without notice from Gaia if Customer fails to comply with any provision of this End User Agreement. Upon termination, Customer must destroy all copies of Software and the corresponding keys in its possession or control.

Compliance With Law. Each party agrees to comply with all applicable laws, rules and regulations in connection with its activities under this End User Agreement. Without limiting the foregoing, Customer acknowledges and agrees that the Software, including technical data, is subject to United States export control laws, including the United States

Export Administration Act and its associated regulations, and may be subject to export or import regulations in other countries. Customer agrees to comply strictly with all such regulations and acknowledges that Customer has the responsibility to obtain licenses to export, re-export, or import the Software.

Restricted Rights. The Software shall be classified as "commercial computer software" as defined in the applicable provisions of the Federal Acquisition Regulation (the "FAR") and supplements thereto, including the Department of Defense (DoD) FAR Supplement (the "DFARS"). The parties acknowledge that the Software was developed entirely at private expense and that no part of the Software was first produced in the performance of a Government contract. If the Software is supplied for use by DoD, the Software is delivered subject to the terms of this End User Agreement and either (i) in accordance with DFARS 227.702-1(a) and 227.7202-3(a), or (ii) with restricted rights in accordance with DFARS 252.227-7013(c)(1)(ii) (OCT 1988), as applicable. If the Software is supplied for use by a Federal agency other than DoD, the Software is restricted computer software delivered subject to the terms of this End User Agreement and (i) FAR 12.212(a); (ii) FAR 52.227-19; or (iii) FAR 52.227-14 (ALT III), as applicable.

General. This End User Agreement will bind and inure to the benefit of each party's successors and assigns, provided that Customer may not assign or transfer this End User Agreement, in whole or in part, without Gaia's written consent. This End User Agreement shall be governed by and construed in accordance with the laws of the State of California, United States of America, as if performed wholly within the state and without giving effect to the principles of conflict of law. No failure of either party to exercise or enforce any of its rights under this End User Agreement will act as a waiver of such rights. If any portion hereof is found to be void or unenforceable, the remaining provisions of this End User Agreement shall remain in full force and effect. This End User Agreement is the complete and exclusive agreement between the parties with respect to the subject matter hereof, superseding and replacing any and all prior agreements, communications, and understandings (both written and oral) regarding such subject matter.

Conventions Used in This Document

The following symbols are used in this document to highlight certain information and features included in the **User's Guide** and **Ground Loop Design** software program.
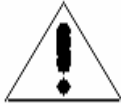
⚠	This caution symbol notifies the user that care must be taken at the specified location.
☆ NEW	This star-shaped symbol highlights new features in Residential Version 5.1
TIP	The round symbol highlights suggestions for using the program more effectively or for improving designs.

Contents

Before You Begin

This chapter describes the typical uses and users of the software. It also describes the installation procedure and hardware and software requirements for the Ground Loop Design™ program. Additionally, the chapter introduces the licensing system.

Introduction: Typical Uses and Users

Ground Loop Design Residential Version 5.1 is intended as a Design Studio for HVAC designers working in the area of geothermal applications. It is primarily designed for use with residential installations since the program can be used to design systems with peak loads of up to 200 kBtu/hr. Systems with larger peak loads often are characterized as commercial systems, and generally require more advanced loads calculations to take into account both internal heat gains/losses as well as long-term thermal effects that determine the necessary design requirements.

For systems that are greater than 200 kBtu/hr tons, consider upgrading to our commercial ground loop design product, which offers a wide range of additional and advanced design features as well as no limit on peak load tonnage.

The Residential Version of Ground Loop Design includes three design modules: one for vertical borehole, one for horizontal and one for surface water (pond, lake, etc.) installations. It also includes the Zone Manager loads module.

Loads data can be shared between the loads module and the design modules, enabling a designer to simultaneously compare and contract multiple heat exchanger designs using the same loads data. In addition, loads data from external loads programs, the GeoXergy Plug-In, as well as from Excel files conveniently can be imported into the loads module.

With instant, direct metric/English unit conversions and foreign language capabilities, Ground Loop Design is a truly international program. With Ground Loop Design, communicating project parameters, equipment requirements and loads data with coworkers, partners, and vendors anywhere in the world is efficient and easy.

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:

- 256 MB Ram
- 70 MB hard disk space (140 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/XP/VISTA.

Internet Browser Requirements

An Internet browser is required only for viewing the data reference files, and not for general program operation. To access the data reference files, at least one of the following browsers is necessary:

- Netscape Communicator Version 5.1 or later.

- Internet Explorer Version 5.1 or later.

Installation Procedure

If you have problems installing Ground Loop Design, please visit the support page at http://www.gaiageo.com or contact your distributor. Note that you can also download Ground Loop Design from the internet at http://www.gaiageo.com. The downloadable version always will be the most recent release.

Initial Installation

For CD versions of GLD, installation should start automatically. If not, the software may be installed by clicking on the **Setup.exe** file included on the disk.

The program is set to install in the folder:

 (Main Drive):\Program Files\Gaia Geothermal\Ground Loop Design Residential

If desired, the user can specify a different location during the installation sequence.

Installation of Updated Versions or Re-Installation

If the user re-installs or replaces the software with a more recent version, the user either can uninstall the program or can just update a current version. To completely remove a version, go to the Windows Start Menu → Settings → Control Panel → Add/Remove Programs and choose to remove "Ground Loop Design". After removing the program, please conduct the new installation as described above. As long as the user does not manually delete folders, existing work files, pumps, and zone files will not be affected.

*Customized **data reference files** should be backed up* before any user-modified Ground Loop Design menu HTML documents are replaced. The linked HTML documents themselves will not be overwritten.

Program Licensing

This section describes the USB dongle and license transfer options available in Ground Loop Design Residential Version 5.1.

Software License Dongle

Your GLD software license is stored on the USB dongle that came with your program. This dongle enables you effortlessly to transfer GLD from one computer to another. Please be careful not to misplace this dongle. Lost dongles can not be replaced without the purchase of a new license.

If the dongle is not attached to your computer, GLD will function as a trial version, which is fully functional except for a few design parameters that are locked at certain values.

When you insert the dongle into a free USB port on your computer for the first time, your computer most likely will recognize the dongle and after a few seconds, the dongle light will turn on. When it turns on, your license will activate. However, if your computer indicates that the dongle is "new hardware" you have two options for installing the dongle driver:

How to Install the Dongle Driver:

Windows Vista, XP and Windows 2000 users with internet access:

If your computer has access to the internet, your computer can automatically install the drivers. Follow along with the Windows new hardware wizard to install the drivers. The process takes a few minutes. When the installation is complete, the dongle light will turn on.

All other users:

Via Windows Explorer, navigate to:

(Main Drive):\Program Files\Gaia Geothermal\Ground Loop Design Residential\Extras

In the Extras folder you will find a HASPUserSetup.exe program.

Run the program to install the dongle driver. When the installation is complete, the dongle light will turn on.

After Dongle Installation is Complete:

Now that the dongle is installed, you can access the full functionality of the GLD version that you purchased. If you remove the dongle, the program will revert to demo mode. If you reattach the dongle, the program will reactivate again.

How To Transfer the Program Between Computers

The dongle licensing system allows the user to transfer the license from one computer to another. If a user decides to transfer Ground Loop Design from one computer to another, all he or she has to do is the following:

- Install Ground Loop Design onto the target computer.

- After the "demo version" of the program is running on the new computer, attach the dongle and follow the above instructions regarding dongle driver installation.

CHAPTER 1

Ground Loop Design Overview

This chapter is an introduction to the Ground Loop Design Residential software package. It introduces new features, the Design Studio, the Heat Pump and Loads Modules, the Borehole, Horizontal and Surface Water Design Modules, the reporting functions, and the data reference files. There is also an explanation of the theoretical and experimental basis for the program's calculations.

General Program Features

Ground Loop Design Residential is a "Geothermal Design Studio" that provides the user with a freedom that single-purpose software cannot offer. The program is modular and permits flexibility in the designing process and customization based on designer preferences. Additionally, it has an English/metric 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 traverse national borders as well as language and cultural barriers.

New in Residential Version 5.1

Ground Loop Design Residential Version 5.1 adds a range of features to the program including:

- fixed temperature and fixed length design modes in the borehole design module. In fixed temperature mode, designers specify inlet temperatures and the program calculates bore lengths. In fixed length mode, designers specify a loopfield length (borehole length x number of boreholes) and then have the program calculate heating and cooling inlet temperatures

- Compatibility with the GeoXergy Plug-In, a program that offers loads calculations, energy analysis and cost comparison, cash flow payback, and a greenhouse gas emissions reduction calculator. See the GeoXergy Plug-In documentation for more information.

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. When additional projects are desired, new windows may be opened or existing projects may be loaded. The Loads module holds and displays the information for the particular installation. Other windows may be opened concurrently. For example, one window may be used to design a vertical heat exchanger, another design a horizontal heat exchanger, and still others to provide easily accessible graphs or charts that may be required repeatedly through the course of a design. Similar design plans can be compared directly, or entirely different designs can be created and varied. All of the information a designer needs exists in one convenient location within Ground Loop Design.

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

Customization

Ground Loop Design offers the user a great deal of freedom in 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. For example, 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.

Another area where customization is possible is in the data reference files, which are based on HTML. With a simple HTML editor the user can include any tables, data, pictures, graphs, charts, or any other useful information that meets the user's needs. User-added files can supplement or replace the data reference files already provided with Ground Loop Design.

Metric/English Units

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

Because the reports and data reference files automatically recognize the selected units, users can obtain different reports and data lists depending on the state of the Design Studio. Sharing of project information with designers, contractors, subcontractors, architects, and building owners is now a straightforward process.

Internationalization

The final major feature of Ground Loop Design is the international component. Because the program is multi-language capable, users easily can communicate accurate results and design parameters across borders, even when the designers are not proficient in the technical language of their foreign counterparts.

Currently, French, Japanese, Chinese, Korean, Italian, Spanish, Russian, Czech, Lithuanian, and Romanian versions are available.

Zone Loads Module Introduction

The zone loads module provides an organized method for entering the heat gains or losses for an installation. In the zone loads module, users also match heat pumps to the loads automatically or manually. This module can then be linked to design modules using the *Studio Link* system (Chapter 3). **With this system, one type of loads and heat pump data can be used to compare multiple heat exchanger designs.** The zone manager can import loads data from the GeoXergy Plug-In as well as from Excel files (and therefore is compatible with any loads program that can output the appropriate data to Excel).

Zone Manager Loads Module

Component-style designs often are more appropriate for geothermal installations, particularly when equipment is available in various sizes. The units 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. Heat exchanger costs impact the overall costs of a project. Additionally, a unit that is called only when necessary or is well

matched to a zone will be more efficient than a larger unit that may cycle more often.

Inputs for Ground Loop Design's Zone Manager Loads module include peak load information for each of the zones in an installation. These loads data can be matched automatically to heat pumps stored within Ground Loop Design's Heat Pump Database. Therefore, ideal and rapid sizing is possible. The annual running time (0-100%) also may be included for a buried heat exchanger. This loading information can be simple or complex, depending on the level of detail the designer desires. To facilitate this model, the zones can be viewed either independently or together on the summary panel.

Design Modules

The Ground Loop Design Geothermal Design Studio consists of the following three design modules:

- The **Borehole Design Module** – In fixed temperature mode, this module calculates the lengths of bore required for a vertical borehole exchanger system. In fixed length mode, it models the inlet temperatures for a user-defined borehole field length.

- The **Horizontal Design Module** – This module determines the length of piping required for a horizontal/slinky exchanger system in trench or pit configurations.

- The **Surface Water Design Module** - This module determines the length of piping required when a closed loop of pipe inserted into a body of water acts as the heat exchange medium.

All three modules are linked to zone loads module using the *Studio Link* system.

Borehole Design Module

Description

The Borehole Design module allows the user to enter various parameters with respect to the desired vertical borehole system. Input is arranged in panels corresponding to the type of input as shown in figure 1.1.

Results | Fluid | Soil | U-Tube | Pattern | Extra kW | Information

Fig. 1.1 Borehole Design Panel List

Using these seven panels (*Results, Fluid, Soil, U-Tube, Pattern, Extra kW, and Information)*, the user enters the project-specific information.
After the user enters all parameters, the software calculates results based on the input data. Within this framework, it is straightforward and easy to make changes and conduct new calculations.

In Residential Version 5.1, the Borehole Design module allows for two types of design methodologies: **fixed temperature** and **fixed length** designs. Fixed temperature designs should be familiar to users that upgraded from earlier versions of GLD. Fixed temperature refers to the design process in which users specify target inlet temperatures (designers set, or fix, the temperatures themselves) and then have the program calculate results such as the required bore length, the outlet temperatures and the coefficient of performance (COP), etc., based on the input data.

With fixed length designs, designers specify the required borefield length by inputting the number of boreholes in the design and then defining the borehole length (fixing the total design length) After entering these data as well as the other design parameters, the software calculates results such as, the inlet and outlet temperatures and the coefficient of performance (COP), etc., based on the input data. The fixed length feature is well suited for designing when land resources are limited, when drilling costs beyond a certain depth become exorbitant, when a designer wishes to quickly reverse engineer a malfunctioning system, etc.

A more complete description about how to enter data and perform calculations in the Borehole Design module is provided in Chapter 3.

Theoretical Basis

The theory behind the vertical borehole module is based on the cylindrical source model and allows for quick but accurate length or temperature calculations based on limited data input.

The vertical bore length equations used in the Borehole Design module are based upon the solution for heat transfer from a cylinder buried in the earth. The method was developed and tested by Carslaw and Jaeger (Carslaw and Jaeger, 1947). The solution yields a temperature difference between the outer cylindrical surface and the undisturbed far field soil temperature. Ingersoll suggested using the equation and its solution for the sizing of ground heat exchangers in cases where the extraction or rejection occurs in periods of less than six hours (where the simple line source model fails) (Ingersoll, 1954). The borehole module's equations include the suggestions of Kavanaugh and Deerman, who adjusted the

methods of Ingersoll to account for U-tube arrangement and hourly heat variations (Kavanaugh and Deerman, 1991). It also employs the borehole resistance calculation techniques suggested by Remund and Paul to account for pipe placement, grout conductivity, and borehole size (Paul, 1997).

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 equipment selected.

The calculations find the conditions for long-term, steady state operation of borehole fields based on the desired heat pump inlet temperatures. In order to provide an optimum design and prevent system failure, the combination of parameters must allow for proper extraction or dissipation of energy from or to the earth at the location of interest.

The most complete description of the calculations and input data can 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 the most accurate when compared with calibrated data from actual installations (Hughes and Shonder, 1998).

Horizontal Design Module

Description

The Horizontal Design module, similar to the Borehole Design module, allows the user to enter parameters necessary to describe a horizontal buried pipe and trench configuration. Again, the interface is arranged in panels corresponding to the type of input.

After the user enters all parameters, the software calculates results such as the required trench and pipe lengths, the inlet and outlet temperatures, the coefficient of performance (COP), etc., based on the input data.

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

| Results | Fluid | Soil | Piping | Configuration | Extra kW | Information |

Fig. 1.2 Horizontal Design Panel List

Using these seven panels (*Results, Fluid, Soil, Piping, Configuration, Extra kW, and Information)*, the user enters the project-specific information.

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

Theoretical Basis

The horizontal trench length equations used in the Horizontal Design module are based upon the Carslaw and Jaeger solution for heat transfer from cylinders buried in the earth, as described in the single vertical case above. Again, this method properly models shorter time periods of heat extraction or rejection, where the simple line source model fails. Since a number of pipes may be buried in close proximity, this model must be modified to account for all mutual pipe interactions. A major benefit derived from using this model, besides its ability to accurately assess heat-transfer, is that both the horizontal and the vertical design modules can operate under the same loads formalism.

In 1948, Ingersoll and Plass demonstrated that the Kelvin line source theory could be used to estimate the change in temperature of a buried pipe in which heat is being absorbed or rejected (Ingersoll and Plass, 1948). In a ground coupling system, an apparent thermal resistance between the circulating fluid and the undisturbed ground dominates the overall resistance. In 1985, in the *ASHRAE Design/Data Manual for Ground-Coupled Heat Pumps,* Parker et. al. outlined a method by which this "field resistance" or "soil resistance" could be estimated and applied to determine piping and trench length requirements for a buried pipe system. In the case of horizontal pipe systems located near the ground surface, the mathematics necessitate the inclusion of "mirror image" pipes into the calculations. These "mirror image" pipes are located the same distance above the surface as the buried pipes are below it. In a multiple pipe system, the soil temperature in the vicinity of any single pipe is determined by both the undisturbed earth temperature and by the thermal interference from other pipes in the same and in adjacent trenches. (Parker, Bose, and McQuiston, 1985).

The current Horizontal Module effectively employs a combination of the cylindrical model of Carslaw and Jaeger and the multiple pipe methodology of Parker et. al. Additionally, as in the Borehole Module, the equations also include modifications suggested by Kavanaugh and Deerman that adjust the methods of Ingersoll to account for physical arrangement and hourly heat variations (Kavanaugh and Deerman, 1991).

However, time-step-based rates of rejection and extraction also previously were discussed in some depth by Parker et. al.

The two "Slinky" options available on the Configuration panel partially are based on the above formalism. Because of the complexity of the solution to the heat transfer equation for coiled loops of pipe, the design procedure used for the "Slinky" options is actually only a theoretical approximation. This approximation is recommended in *Closed-loop Geothermal Systems: Slinky Installation Guide* and is based on a specific set of tests conducted on 36" diameter Slinky coils (Jones, 1995). In the approximation, the program first calculates the total trench length required for a single U-Tube buried at the specified trench depth. It then divides the calculated length by 250 ft and multiplies the result by a factor determined from both the run fraction and the Slinky pitch (distance between adjoining loops). The horizontal Slinky configuration employs the same calculation procedure as that of the vertical. However, in the case of the horizontal Slinky, the U-tube depth is lowered such that the average depth of the vertical Slinky would be equal to that of a flat horizontal Slinky. The pitch and run fraction function is obtained from a two-dimensional interpolation over the surface determined from the experimentally determined data points provided in the Slinky manual.

Surface Water Design Module

Description

The Surface Water Design module allows the user to enter various parameters concerning the body of water (lake, pond, river, etc.) system. As in the Borehole Module, inputs are arranged in panels that relate to the type of input. After the user enters all parameters, the software calculates the required pipe length, the circuit number, the inlet and outlet temperatures and the COP, etc., based on the design specifications. Again, within this framework, it is straightforward to make changes and recalculate results, especially when using the expanded user interface.

The input information is organized into seven panels, shown in figure 1.3.
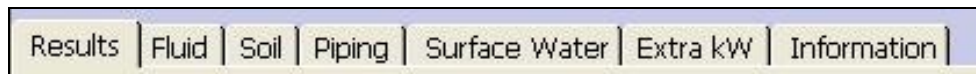
Fig. 1.3 Surface Water Design Panel List

These seven panels include *Results, Fluid, Soil, Piping, Surface Water, Extra kW* and *Information*. The panel names and many of the panel input parameters 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 6.

Theoretical Basis

To determine the length of pipe necessary for different surface water systems, experiments were 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 the branch piping that are in both the water and the soil between the installation and the submerged circuits. The program combines all factors so that the loop system provides the source inlet temperature at the heat pump requested by the designer.

Because the circuit layout is of primary importance to the designer concerned with pumping losses, the head loss estimation feature for different piping configurations is included in the Surface Water Design module. Users can quickly explore different layouts to determine the optimum design in terms of both heat transfer and circulation pump energy losses.

A description of some of the calculations and the input data can 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 may be included in later versions. These modules would also be able to take advantage of the Design Studio's heat pump and loads models.

Reports

Ground Loop Design's reporting features allow the designer to make hardcopies of both the data entered and the resulting calculations. These reports are design records, and are valuable when communicating the design to others involved in the projects.

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, the calculation results, and the name of the zone file used.

Zone Reports

A 'print' button in the loads modules allows the designer to print the loads-related information in various formats. Because the zones contain information about the zones, the loads, and the equipment, it is often necessary to obtain reports of the information in separate as well as combined 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, the designer may only need to see a list of the equipment for each zone. Ground Loop Design offers five different zone report options including:

- A concise zone report
- A detailed zone report
- An equipment list report
- A loads report
- A zone names report

Reports are described in detail in Chapter 7.

Data Reference Files

To access the data reference files the user must have an internet browser present in the Ground Loop Design-enabled computer. The program will work without the browser, but the data reference files may not be accessible.

Metric and English reference files are included with Ground Loop Design. These files aid in the correct verification and entry of the various parameters. The three main topics/design aids currently 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 as well. Reference files can be opened and left as open windows on the desktop, and the user can refer to them as necessary during the design 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 reference files. The designer simply creates a basic HTML file containing customized data, pictures, graphs, charts, etc. and then modifies the included top level HTML files to link to their pages. The system requires a very basic knowledge of HTML, but it offers an extremely flexible system for user customization.

Detailed information on reference files and sample HTML can be found in Chapter 8.

Program Help and Support

Ground Loop Design contains a comprehensive, searchable database of help topics. Access this feature from the Design Studio *Help* menu. Through the *Help* menu it is also possible to access the latest web resources and updates. If these resources do not answer your question, please contact your vendor for support.

References

Carslaw, H.S. and Jaeger, J.C. *Conduction of Heat in Solids.* Oxford: Claremore Press, 1947.

Hughes, P.J. and Shonder, J.A. *The Evaluation of a 4000-Home Geothermal Heat Pump Retrofit at Fort Polk, Louisiana: Final Report*. Oak Ridge National Laboratory, TN. ORNL/CON-460. 1998

Ingersoll, L.R. and Plass, H.J. "Theory of the ground pipe heat source for the heat pump." *Heating, Piping, and Air Conditioning.* 20:7 (July). 1948.

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

Jones, F.R. *Closed-Loop Geothermal Systems: Slinky Installation Guide.* Rural Electric Research, National Rural Electric Cooperative Association, Oklahoma State University,

International Ground Source Heat Pump Association, and Electric Power Research Institute, 1995.

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.

Parker, J.D., Bose, J.E., and McQuiston, F.C. *ASHRAE Design/Data Manual for Ground-Coupled Heat Pumps.* ASHRAE Research Project RP-366, 1985.

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 2

Heat Pumps

Ground Loop Design has hundreds of heat pumps from a number of manufacturers loaded into its Heat Pump Database. Although the Heat Pump Database is not modifiable in the residential version of Ground Loop Design, it is important to understand how the system models heat pump data. This chapter describes the theory of the module.

Heat Pump Model

Description

For convenience, the Loads modules in Ground Loop Design predict how heat pump characteristics will vary with 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 and database, which the software uses to update the pump data automatically. Using Ground Loop Design, 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 and database employed in Ground Loop Design reproduces the complete operational data of any particular unit when supplied with a few representative data points selected from across the range of interest. Data for each pump has been entered into the model and database and grouped together under manufacturer and series headings. Pump data are stored permanently in the '**pumps**' directory. Many popular pumps from major manufacturers already are included with the program.

In both heating and cooling modes, the *minimum* data required is the capacity and power variations with source inlet temperature. To increase the modeling accuracy, these same variations have to be included at a second flow rate. Even more accurate results can be obtained if correction factors are provided for variations in the load inlet temperature and flow rate. The level of accuracy depends on the amount of data available from the manufacturer.

Note that Ground Loop Design's heat pump module allows for both water-to-air and water-to-water pumps.

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' represents the capacity and 'x' is the desired temperature. For the power-input determination, 'y' is the power and 'x' again is the temperature.

The software stores coefficients for each pump in the database, 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 the source flow rate on the calculated capacity and power, data from a second flow rate are used. Generally speaking, with different flow rates the shape of the capacity and power curves does not change significantly, 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.

Considering the size of the variations (generally only a few percent), this simple model is accurate enough for most pumps. A completely accurate model of the flow rate variations for all possible pumps would require significantly more data entry.

Load Side Corrections

The Ground Loop Design Pumps database also can include corrections to the capacity or power that result from variations in the load side inlet temperature or flow rate. They are entered as correction factors across the desired temperature or flow range. The software again uses the polynomial fitting to model these correction factors. In these cases, a four-coefficient model is used to better model the types of variations that may occur.

.

CHAPTER 3

The Zone Loads Module

All of the calculations performed in Ground Loop Design fundamentally are based on loads provided by the designer. This chapter describes the Ground Loop Design loads system, and how to enter the loads into the zone loads module. Additionally, it explains the pump matching capabilities and operation both in automatic and in manual modes. At the end of the chapter there is an explanation of how to import external loads files as well as a brief review of the program's loads input methodology.

Zone Files

Zone (loads) files are stored as ***.zon** files in the Ground Loop Design Residential '**zones**' directory. They have a general format that can be read into the loads module, and they **can be used simultaneously** in different design modules. However, if this is done, it may be wise to save any changes under different filenames.

Loads files are entirely independent of project design files. This means that an entire installation loading design can be entered, matched with pumps, optimized, and saved without ever opening a design module. This is valuable for users who wish to keep the loads entry and pump selection completely separate from the studio's geothermal design modules. Now users can work on designs and load

inputs at different times, and can use the same loads files for various projects/styles of project.

New zone files can be created by clicking the '*New'* button in any loads module, or by clearing all of the current loads information with the *Clear* button, followed by the '*New'* button. The designer provides a filename when the zone file is saved.

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

The Zone Manager Loads Module

Small residential systems may have a single zone and a single heat pump. Somewhat larger residential systems may have a single zone and several heat pumps. Even larger residential systems may have multiple zones and multiple heat pumps. The Ground Loop Design zone manager loads module provides the designer with enough flexibility to accept loads data for a range of residential systems.

GLD Residential Version 5.1 can be used to design systems with peak loads of up to 300 kBtu/hr. Systems with larger peak loads often are characterized as commercial systems, and generally require more advanced loads calculations to take into account both internal heat gains/losses as well as long-term thermal effects that determine the necessary design requirements. Such systems generally require more advanced engineering capacity. Ground Loop Design Premier Version 5.0 provides significantly enhanced functionality for such systems. Contact your distributor for more information.
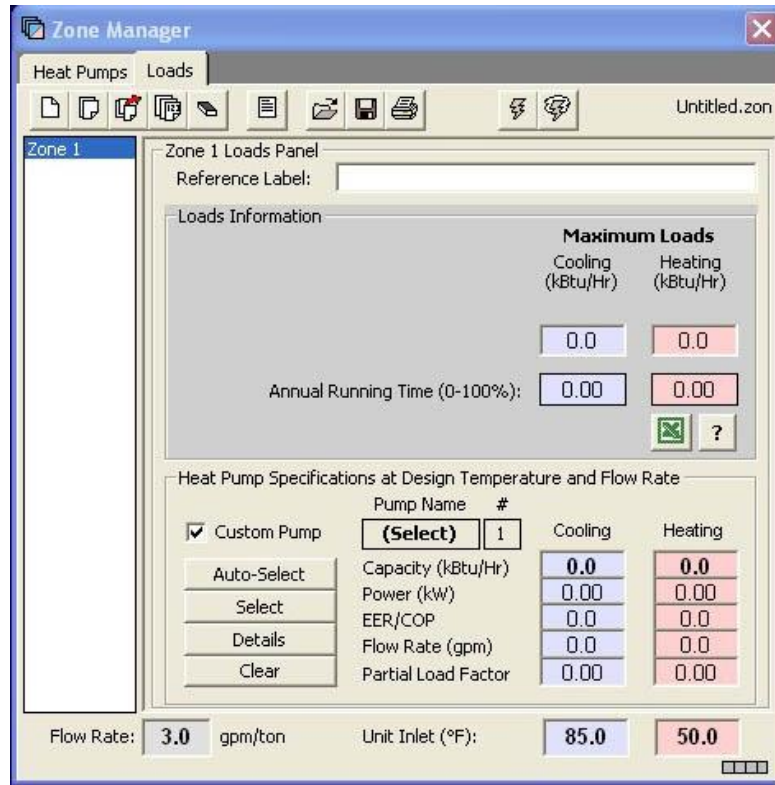
Fig. 3.1 Zone Manager Loads Module, Main View

The Zone Manager loads module can be opened either from the *Loads* Menu or by clicking the Zone Manager toolbar button. An example of the module opened to the *Loads* tabbed panel is shown in figure 3.1. The *Heat Pumps* tabbed panel will be discussed shortly.

In the *Main View*, Zones in Ground Loop Design are organized in a list on the left side of the *Loads* tabbed panel. Each zone panel contains information relating to the working zone, including a zone name, the loading information, and the information about any heat pumps selected for that zone. Selecting a different zone name in the zone list changes the working zone.

Using the list, the designer can bring up and modify any particular zone by clicking on its name. An essentially equivalent but more compact summary of the input data can be obtained in the *Summary View*, obtained by clicking on the *Summary View* toggle button. Different representations of zone data can also be printed as reports.

Managing Zones in the *Loads* Tabbed Panel

The buttons along the top of the *Zone Manager* are used to work with the zones. A closer view is shown in figure 3.2.
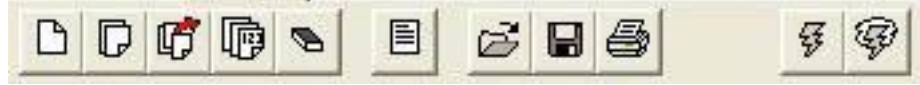
Fig. 3.2 Zone Manager Control Buttons

The five buttons on the left side are zone-editing controls, and they include *New*, *Copy*, *Remove*, *Renumber*, and *Clear*. A *Summary* view of all the zones can be obtained by hitting the sixth, or *Summary View,* toggle button. The next three buttons are the *Open* and *Save* buttons, for opening and saving the zone files, and the *Print* button, for printing various zone reports. The final two buttons on the far right are for pump selection across the entire set of zones, and include *Auto-Select All* and *Update/Reselect,* which are discussed in more detail below.

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 also can be deleted from the list. Any zone can 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 several zones are added or removed from the list, click the Renumber button to reorganize the zones. This button renumbers the existing zones from one, starting with the first zone in the current list.

Summary View Toggle Button

With the *Summary View* toggle button, the user can at any time simultaneously look at the group of zones. This view provides lists of the heat pump data in both cooling and heating modes as well as collective information about the set of chosen pumps. This information includes the peak loads and the total combined capacity, the peak demand, and the average efficiency of the selected equipment. Although individual pumps cannot be added or removed in the *Summary View*, changes made across the entire pump selection are directly observable. A sample *Summary* panel is shown in figure 3.3. Note that more than one type of pump series is listed.
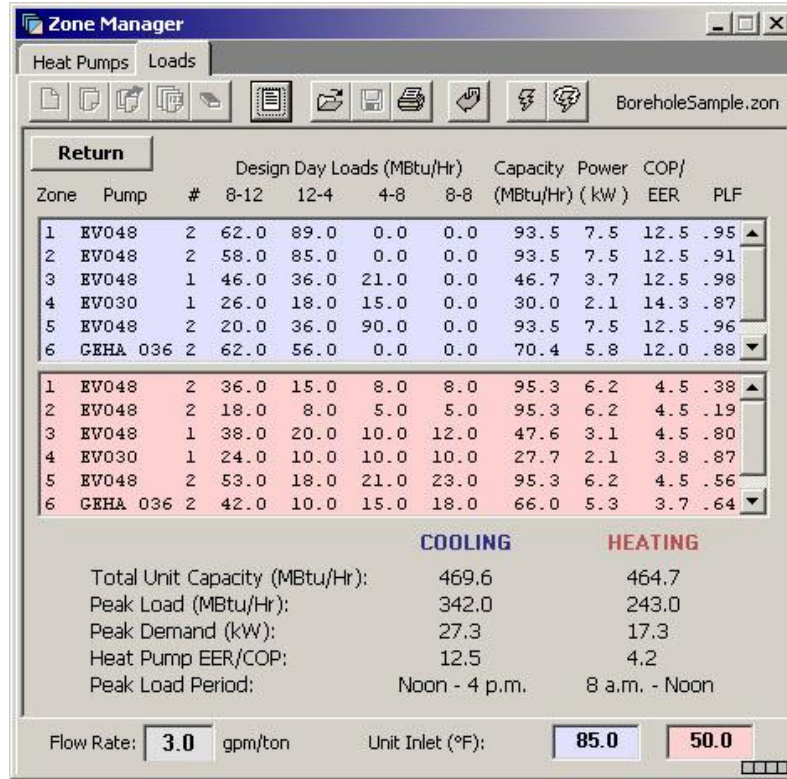
Fig. 3.3 Zone Manager Summary View

Entering Loads

Loads can be entered directly in the individual zone data windows back in the M*ain View* of the *Loads* tabbed panel. A sample entry is shown in figure 3.4.

Maximum Loads

The peak/maximum hourly load for the design day, or the day of heaviest usage in the year for both cooling (heat gains) and heating (heat losses) modes of operation, can be input. In figure 3.4 below, peak hourly cooling and heating loads are 25 kBtu/hr and 36 kBtu/hr, respectively.

Fig. 3.4 Sample Loads Input Data

Annual Running Time (0- 100%)

The percentage values entered into the lower section of figure 3.4 are determined from annual loads data for the system being designed. They represent the percentage of the year that the system would be running if operating at full load, and are a measure of the system running time (0% means the system is not running at all during the year and where 100% means the system is running at peak load 100% of the year).

This system represents the total energy input to the ground in terms of the peak load. Below is an example of how to calculate the Annual Running Time:

Example Calculation

Total annual cooling kBtus: 18500 kBtu

peak: 25 kBtu/hour

(18500 kBtu) / (25 kBtu/hour) =740 hours

(740 hours) / (8760 hours/year) = 8.5% annual running time.

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 running time' represents the running time if the system were operating continuously at full load, which is not generally the case.

Remember that although the vertical bore length calculation results are not extremely dependent on the running hours within one zone for multi-zone designs, the total number of running hours across the zones can certainly affect the required bore length. The user should attempt to enter the annual running time as accurately as possible.

Equivalent hours are unnecessary for a surface water design, since long-term buildup effects are unimportant. If a loads module is linked to a Surface Water Design module, the hours will not be visible.

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

Several buttons can be found in 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.

Fig. 3.5 Sample Pump Selection Section with Data

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 series and determines which pump within the list is best suited to the zone in question. If the listed pumps are too small for the zone loads, the software increases the number of pumps of each size until an acceptable match is achieved.

The pump selection process uses information from the Zone Manager loads module. This includes the chosen inlet source temperature, the flow rate, the heat pump series, and the initial inlet load temperatures. The flows and load temperatures can be entered at the bottom of the module, and the active heat pump series and load temperatures may be changed on the *Heat Pumps tabbed* panel.

Manual Select

If an automatically selected heat pump is for any reason undesirable, or a different pump series from the same manufacturer, or even from 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 3.6. 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 the user to the main display without changing any pumps.

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. 3.6 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 temperatures or flows for that particular pump. *After the user presses the return button, variations in the input load temperature will affect the pump parameters listed on the main pump selection area.* A sample details panel is shown in figure 3.7.

Fig. 3.7 Pump Details Panel

Clear

Pressing the *Clear* button clears 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 Ground Loop Design's Heat Pump Database, he or she may add customized pumps simply by entering values directly into the boxes on the pump selection section of the zone data window. When the user does this and overrides the automatic selection features, a check appears next to the "Custom Pump" label, indicating that the pump information is from an external source. The details section will no longer contain 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. *The actual COP used in the calculations is determined from the capacity and the power, not the input text box.* 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 when the pump set needs to be compared or changed, or when 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 sequentially through all of the zones. It uses the active heat pump series selected on the *Heat Pumps* tabbed panel.

Note: Auto-Select All Pumps *will overwrite all currently selected pumps, **including custom pumps***.

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.

Note: Custom pumps are not affected when the Update/Reselect Current Pumps *control is activated.*

Working Series Selection in the Heat Pumps Tabbed Panel

Figure 3.8 Shows the Zone Manager opened to the *Heat Pump* tabbed panel. This panel is used to specify the working series for all of the automatic selection features described for the *Loads* tabbed panel. In the *Heat Pump* tabbed panel, the user simply selects the pump series that he or she intends to use for the matching session. The selection may be changed at any time without affecting previously automatically selected units. **However, if the 'Auto-Select All**

Pumps' button on the *Loads* panel is pressed, every zone will be replaced with the current working series. Additionally, in this panel the user may define an inlet load temperature to be used in any automatic selection.

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.
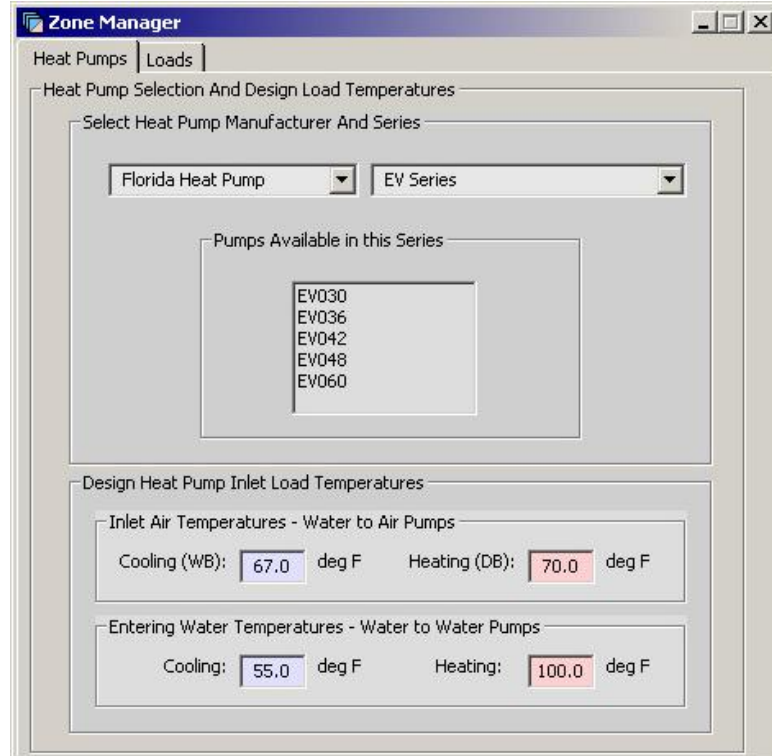
Fig. 3.8 Heat Pumps Tabbed Panel

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. 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.

Pump Continuous Update Feature

The *Update/Reselect Current Pumps* control is called automatically when changes are made to either the inlet source temperature or the system flow rate from within the Zone Manager or the design modules. In this way, the designer does not have to worry about updating the pumps already matched to 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. If this is problematic, custom pumps may be used to lock pump values into a zone. However, for proper modeling, any customized pumps must be edited separately by the designer after the design parameters have been established.

The Studio Link System

The *Studio Link* system is a powerful feature in Ground Loop Design that gives users the ability to link or to unlink the loads module to or from the design modules. When a loads module is linked to a Borehole, Horizontal or Surface Water Design module, all of the data in that loads module is transferred to the design module. Once the connection is established, the pertinent information is stored within the design module, which makes transfers in from or out to the loads module as necessary. Since the information is now held in the design module, it is possible to add multiple design modules with only a single loads module open. When studio links are established, the information shown in the loads module will correspond to the active design project.

As long as a link is active, design modules retain information about the type of link and the filename of the associated zone '.zon' file. This information is stored in saved project '.gld' files, so that the appropriate loads module can be opened and loaded when a project file is opened.

Making a Link

The most direct method of making a link between a loads and a design module is to open both modules to be linked, activate (click on) the design module, and then press the 'Link' button on the toolbar. Another option is to choose "Link" from the Ground Loop Design *Loads* menu. If there is only one type of loads module open, a link will be established with that module. If more than one type of loads module is open, Ground Loop Design will query the user for his or her linking preference.

Alternative systems for linking exist, but they are more indirect. For example, if only one unlinked design module is present, a link may be established from any open loads module, since Ground Loop Design automatically recognizes the user's intention. If more than one unlinked design module exists, however, pressing the link button from an active loads module will have no effect.

The link status lights in the corners of the modules indicate when a link has been formed. Colors indicate the type of link. Link status lights are described in more detail below.

Unlinking

To break a link between modules, simply activate (click on) the design module to be disconnected and click the 'Unlink' button on the toolbar. Equivalently, the user can choose "Unlink" from the Ground Loop Design *Loads* menu. The link will be broken, and all related loads information for the design module will be cleared. However, the information still exists in the loads module, and can be recovered by linking again if necessary.

If only one design module is linked to a particular loads module, unlinking from the loads module is also possible. If more than one linked design window is open, however, clicking the unlink button from a loads module will have no effect, since Ground Loop Design cannot determine which project should be disconnected.

The link status lights in the corners of the modules indicate when links are broken. Link status lights are described in more detail below.

Studio Link Status Lights

Studio Link status lights are used to indicate when links are made, when data transfer occurs, and when links are broken. They are located in the lower left hand corner of the design modules, and the lower right hand corner of the loads modules.

Connection Established - First Light from Left

The light furthest to the left indicates both whether or not a connection is established and the type of connection. If the light is off, no connection is established. Magenta indicates a link to an Average Block Loads module, while light blue indicates a link to a Zone Manager loads module.
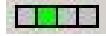
Receiving Data - Second Light from Left

The second light from the left indicates when the module is receiving data from the other module. It is green in color.

Sending Data - Third Light from Left

The third light from the left indicates when the module is sending data to the other module. It is yellow in color.

Broken Connection – Rightmost Light

The light on the right turns red whenever a connection is broken. It turns off again when connections are reestablished.

Importing Loads Data From External Programs

With Ground Loop Design, users easily can import loads data from both loads programs such as the GeoXergy Plug-In and Excel files directly into the loads modules.

Using the Import Excel Button for the GeoXergy Plug-In and Excel

To import data from the GeoXergy Plug-In and Excel files, follow these guidelines:

Ground Loop Design expects the Excel data to be in the following column order and units:

	Cooling	**Heating**
Peak (kBtu or kW)		
Annual Running Time		

To import the Excel data, simply highlight the two columns and two rows in the Excel spreadsheet that contain the data and copy them onto the clipboard (Ctrl-C). **Note: highlight only the numeric data. DO NOT highlight the column and row descriptions.** Then click on the *Excel* icon. The data will be imported.

TIP

Note that it is possible to import a single column of data. Following the column order listed above, put the single column of data in the correct position. Fill the remaining columns with zeros and then copy all four columns to the clipboard.

Surface Water Design Loads

The Surface Water Design Module does not require the loads input detail of the other design modules. Since there is no long-term build-up of heat in the water, the only values that are actually required are the peak demand of the installation.

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 vertical borehole systems. It is one of the three design modules included with Ground Loop Design.

Overview

A design is only 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 Ground Loop Design utilizes the best theoretical models available today, 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 that reasonable values are provided to the software, the software will provide reasonable results.

General Features

To aid in the data entry process, the Borehole Design module in Ground Loop Design consists of a set of panels, grouped by subject, through which the designer can enter and edit the input variables efficiently. For example, parameters related to the soil are listed on the *Soil* panel, while piping choices are listed on the *U-tube* 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 and calculators
- A 'Calculate' button used to refresh the calculations

Opening Projects

There are two ways to open Borehole Design projects. One is by using the 'New Borehole' command from the Design Studio *File* menu or toolbar, 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' from either the Design Studio *File* menu or the toolbar. New projects open with standard parameter values that must be edited for new projects. The module opens directly into the Information panel, through which the designer enters information about the new project.

In new projects, no loads files (*.zon) are loaded. The user must create a new loads file or open an existing loads file into one of the loads modules. Links may be established using the Studio Link system described in Chapter 3.

Existing Projects

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

If a loads file (*.zon) is associated with the loaded project, the loads file automatically will be loaded into the appropriate loads module and opened along with the project file. However, if the associated loads file cannot be found, the user will be notified and the automatic 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 or by clicking the save button on the toolbar. When the user closes the program or module, the program automatically asks the user if he or she wants to save the project and associated loads files.

Typical Operation

Although each user will have his or her own unique style, the typical operation of the Borehole Design module would include the following steps:

1. Enter Loads and select pump(s) in the Zone Manager module
2. Form a link between the loads module and the design module
3. Modify step-by-step the input parameters listed in each panel
4. Perform initial calculation
5. Modify various parameters and recalculate to determine the effects of the modifications
6. Establish an optimal system
7. Save and/or print the project and associated zone file

Entering Data into the Tabbed Panels

Ground Loop Design's innovative tabbed panel system provides for easy organization of and direct access to the relatively large number of design parameters associated with a particular project. This section describes the *Information, Extra kW, Pattern, U-Tube, Soil, Fluid, and Results* panels (See Chapter 3 for a discussion of Loads entry).

Information

The contents of the *Information* panel are shown in figure 4.1. All of the descriptive information related to the project is stored in this panel. This primarily includes the names of the project and designer and the dates. Reference data concerning the client also can be included on this page, so that all relevant project information is in one convenient location.

In addition to generalized project information, specialized comments can 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 under any of the other topics provided.

All of the data in the information panel is optional, but completing the page is recommended for the sake of organization. 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**

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 4.2.

This panel is included for entire system average efficiency calculations. The entry box, "Circulation Pumps", is for the energy required by the system circulation pumps.

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' values directly. However, if the pump motor efficiency is set to 100%, the 'Pump Power' and 'Required Input Power' will be the same.
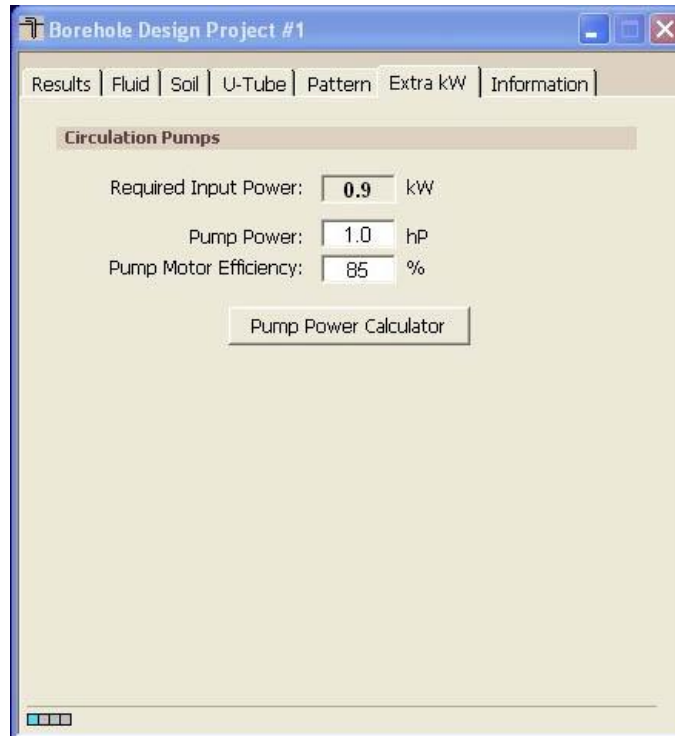
Fig. 4.2 *Extra kW* Panel Contents

⚠ *Note: To make a kilowatt entry in the 'Pump Power' box, switch to metric units, enter the kilowatt value, and then return to English units.*

Pump Power Calculator

If the pump efficiency, system flow rate and head loss are known, the *Pump Power Calculator* can be used to determine the pump power. An image of the pump power calculator is shown in figure 4.3.
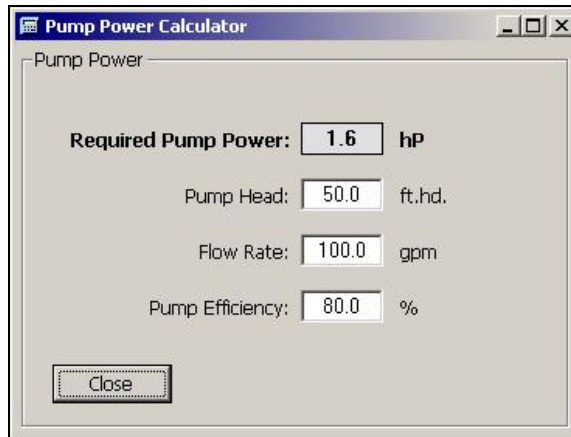
Fig. 4.3 Pump Power Calculator

Pattern

Information pertaining to the ground field arrangement is in the *Pattern* panel. This includes the fixed borehole length design option, the vertical boreholes pattern and the borehole separation,. The input screen is shown in figure 4.4.

Fixed Length Mode

By selecting fixed length mode, the designer can specify the loop field length (*number of boreholes* x *length per borehole*) and have Ground Loop Design calculate the entering water temperatures. When in fixed length mode, it is important to note that both cooling and heating lengths are identical, unlike in the fixed temperature mode (where designers specify temperatures and calculate lengths). When fixed length mode is not selected, the program operates in fixed temperature mode (in which the designer specifies the number of boreholes and the target inlet temperatures so that the program can calculate borehole lengths).

Vertical Grid Arrangement

The standard Borehole Design module is configured to accept equally spaced borehole patterns based on an x, y coordinate system. For rectangular systems, users can enter the pattern directly into the *rows across* and *rows down* boxes.

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.
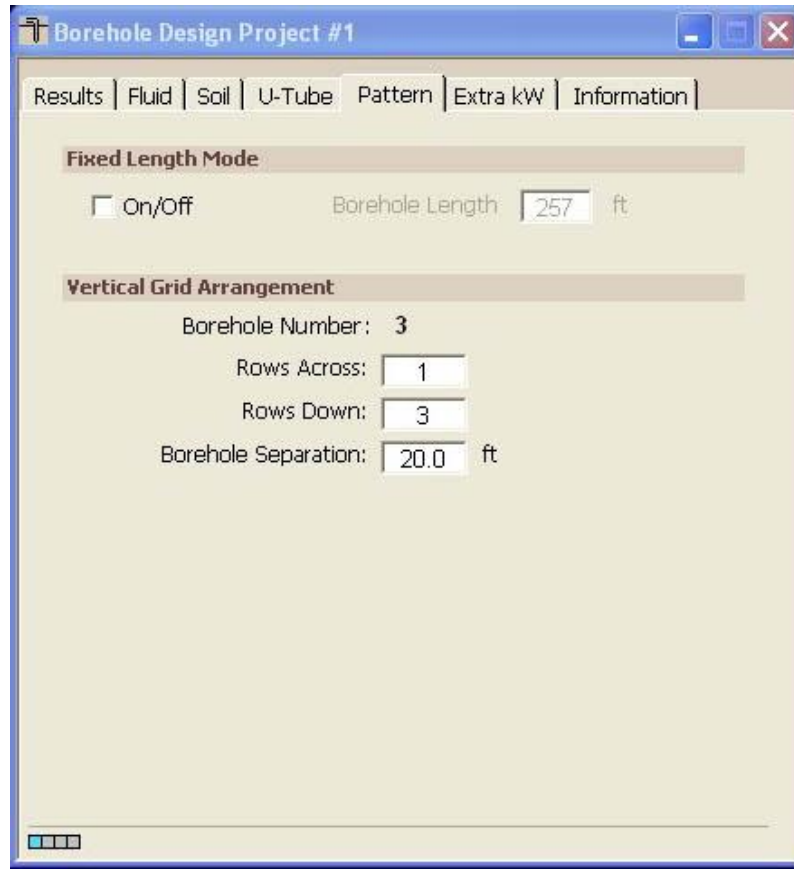
Fig. 4.4 *Pattern* **Panel Contents**

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, which is calculated according to the method of Paul and Remund (Paul, 1996), The panel contents are shown in figure 4.5.
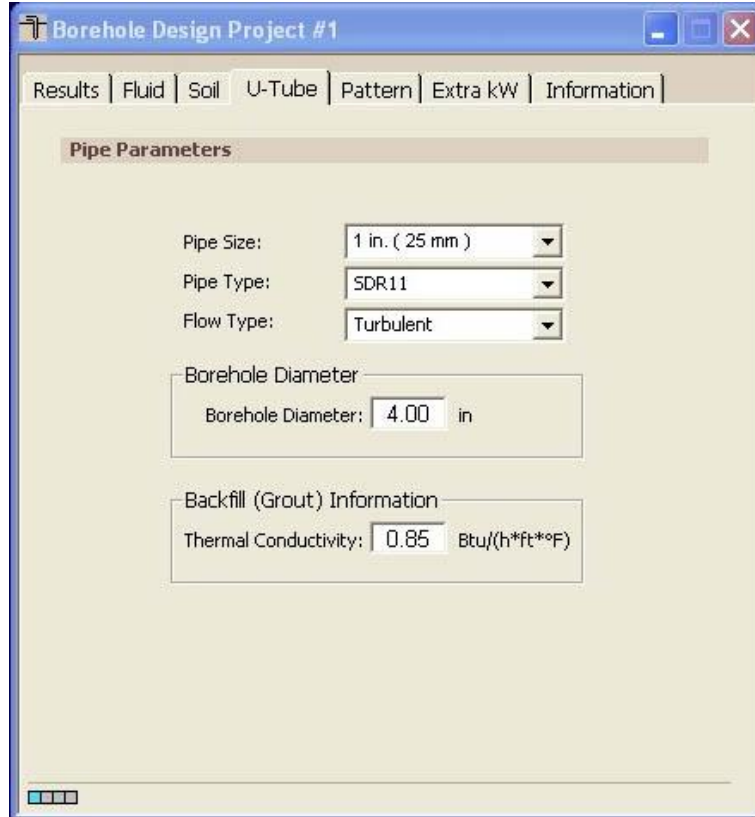
Fig. 4.5 *U-Tube* Panel Contents

Pipe Parameters

The pipe parameters are entered in the 'Pipe Parameters' section. They include the pipe size, pipe type and pipe flow.

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 average 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. The calculations also use average values of viscosity and the 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, please contact support.

Borehole Diameter and Backfill (Grout) Information

The user can enter the borehole diameter and the grout thermal conductivity directly into their respective text boxes. **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, the soil thermal properties and the modeling time period.
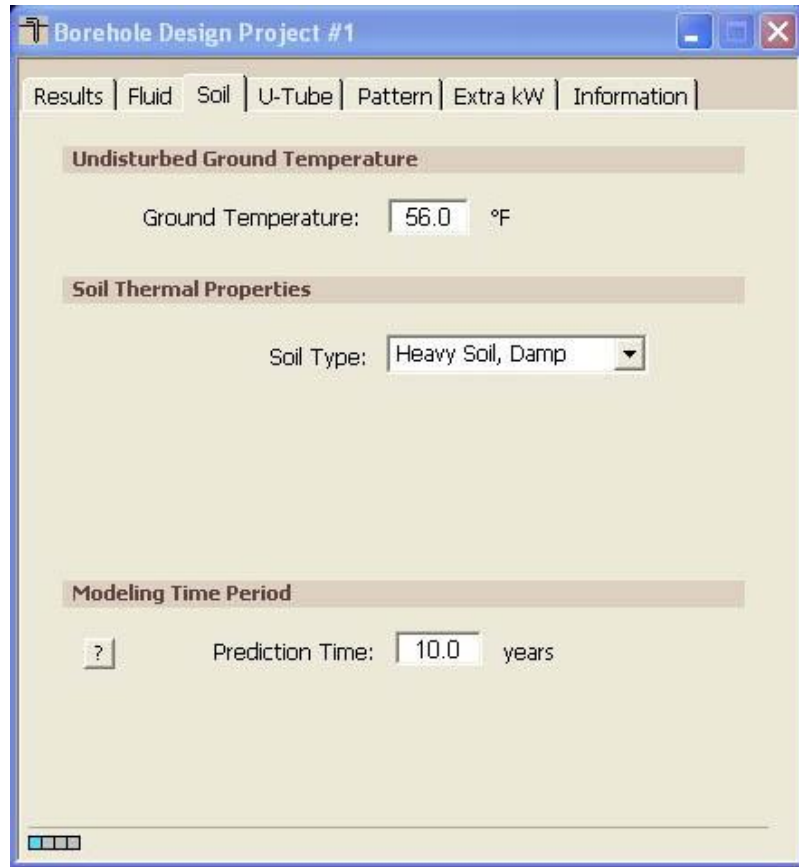
Fig. 4.6 *Soil* Panel Contents

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 (thermal conductivity and thermal diffusivity) are a little harder to define, and care must be taken to select the correct soil type. In the residential version of Ground Loop Design, users can select the soil type that best matches the target installation soil environment.

The thermal conductivity in particular has a large effect on the calculated bore length, and therefore soil type should be determined with care.

The following chart lists the conductivity and diffusivity values associated with each soil type option:

Soil Type	Conductivity Btu/(h*ft*^{0}F)	Diffusivity ft^2/day
Light Soil, Dry	0.20	0.26
Light Soil, Damp	0.50	0.48
Heavy Soil, Dry	0.50	0.48
Heavy Soil, Damp	0.75	0.60
Heavy Soil, Saturated	1.40	0.84
Solid Masonry	0.75	0.60
Dense Concrete	1.00	0.79
Average Rock	1.40	0.96
Dense Rock	2.00	1.20

Modeling time Period

In Ground Loop Design, 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. When excessive ground water movement is known to occur, one year is sometimes used as the modeling time period. In this case, it is assumed that the ground temperature stabilizes in a single year due to the neutralizing effects of the ground water movement. For very shallow boreholes, shorter modeling time periods may be used as well due to the neutralizing effects of the atmosphere.

Fluid

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

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 of the changes**. Customized pump values must be manually adjusted.

Note: inlet temperatures can only be modified in fixed temperature mode.

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 all units will not be running at full load simultaneously, even in the peak load condition).
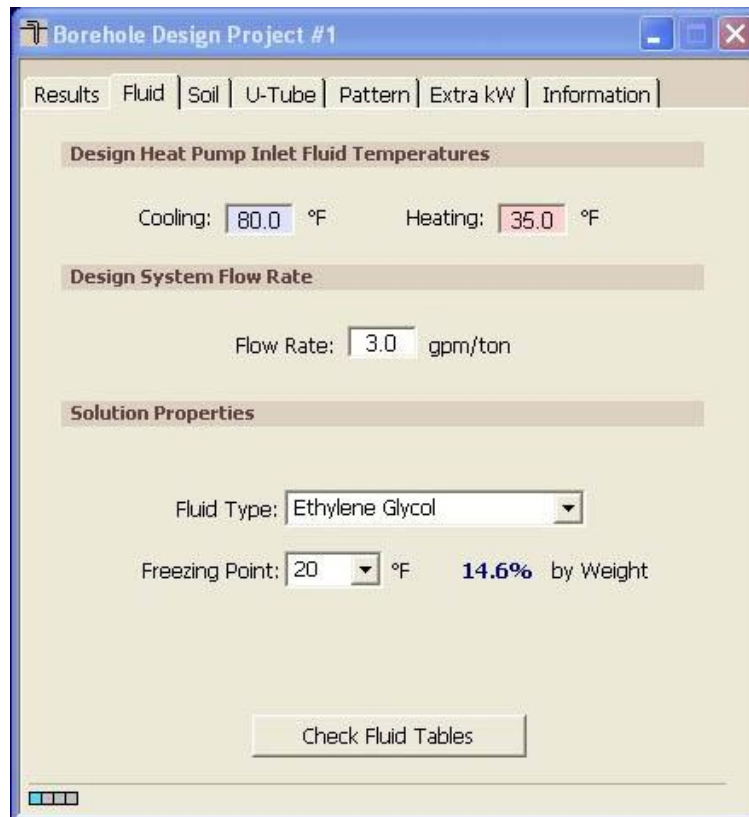
Fig. 4.7 *Fluid* Panel Contents

Optimized systems generally operate in the range from 2.5 to 4.0 gpm/ton, while the ideal system flow rate is somewhere around 3.0 gpm/ton. Again, if the flow rate is changed, the selected heat pumps are updated in the loads modules.

Solution Properties

Solution properties are also included in the *Fluid* panel. 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 user first selects the fluid type and then selects the desired freezing temperature. Ground Loop Design automatically incorporates the specific heat and density for the fluid selection into the calculations. See Fluid Properties table under the Table dropdown menu for the specific heat and density values for each fluid selection.

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 trench 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 for all conditions. Generalized tables of data may be found in the 'Fluid Properties' tables.

Results

All results for both the heating and the cooling calculations can be viewed at any time on the *Results* panel. 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.

The two lists on the *Results* panel are for heating and cooling. Although all of the numbers shown are valid and respond to changes, the side with the longer required 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. In fixed length mode, since both heating and cooling are of equal length, neither side is highlighted.

Calculate Button Results

TIP

The reporting section is separated into four subsections. The first deals with the bores, including the total length, the borehole number, and the borehole length for one bore. A common way to adjust the borehole length to a desired value is to change the borehole number or pattern on the *Pattern* panel.
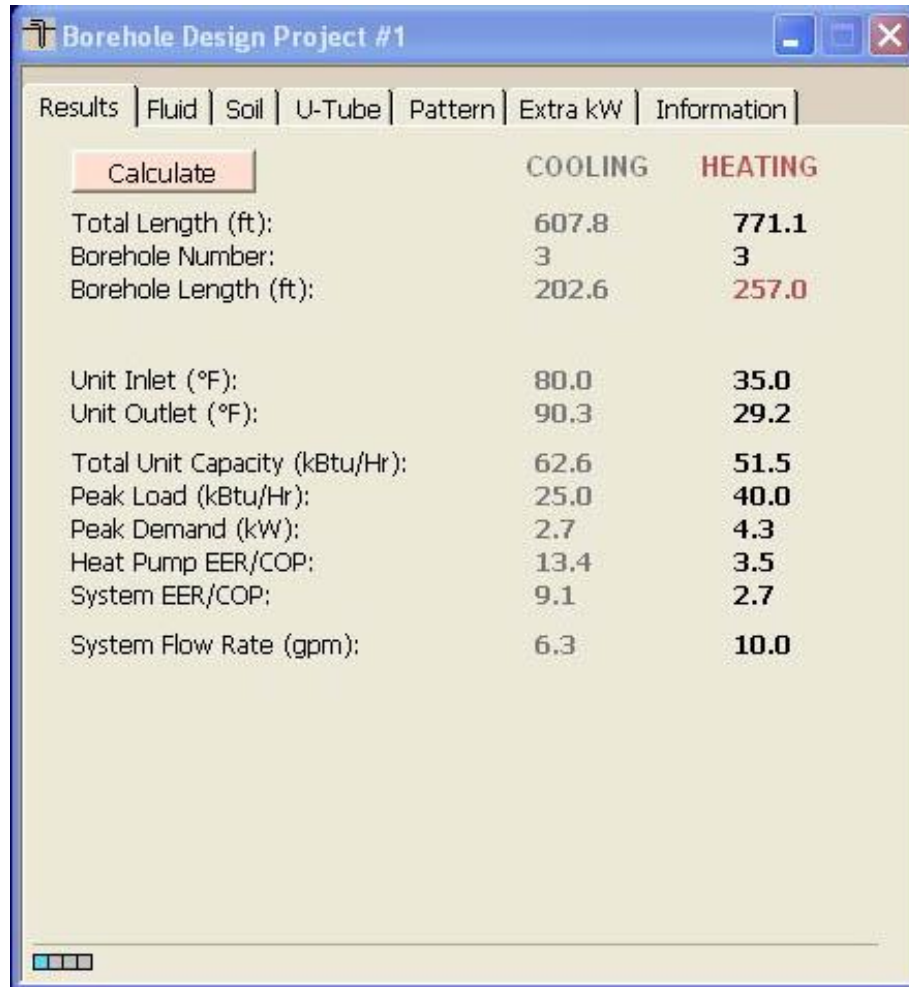
Fig. 4.8 *Results* Panel Contents

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

The third subsection lists the total unit capacity, the peak loads and demand of all the equipment, and the calculated heat pump and system efficiencies. The peak load is the maximum and is 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.

Finally, the system flow rate is listed in its own subsection. 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

A report of the active project can be printed at any time from the Design Studio using the toolbar print button or from the *File* menu → *Print*.

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, and must be printed separately from the *Loads* panel. The filename of the ***.zon** file associated with the project report is also listed on the reports.

More information on reports can be found in Chapter 7.

References

Francis, E., Editor. *Refrigeration and Air Conditioning, 3rd Edition.* Air-Conditioning and Refrigeration Institute. p.186. Prentice Hall, New Jersey, 1997.

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 Horizontal Design Module

This chapter describes the features and operation of the Horizontal Design module. This module is used in the design of near-surface horizontal systems. It is one of the three design modules included with Ground Loop Design.

Overview

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

General Features

The Horizontal Design module in Ground Loop Design also includes a set of panels, grouped by subject, through which the designer can enter and edit the input variables in a straightforward and efficient manner. For example, parameters related to trench configuration are listed on the Configuration panel, while piping choices are listed on the *Piping* panel. Everything related to a project is presented simultaneously and easily is accessible throughout the design process.

The Horizontal Design module includes several additional features:

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

Opening Projects

There are two ways to open Horizontal Design projects. One is by using the 'New Horizontal' command from the Design Studio *File* menu or toolbar, and the other is by opening an existing Horizontal 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 Horizontal' from either the Design Studio *File* menu or the toolbar. New projects open with standard parameter values that must be edited for new projects.

In new projects, no loads files (*.zon) are loaded. The user must create a new loads file or open an existing loads file into one of the loads modules. Links may be established using the Studio Link system described in Chapter 3.

Existing Projects

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

If a loads file (*.zon) is associated with the loaded project, the loads file automatically will be loaded into the appropriate loads module and opened along with the project file. However, if the associated loads file cannot be found, the user will be notified and the automatic 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 or by clicking the save button on the toolbar. When the user closes the program or module, the program automatically asks the user if he or she wants to save the project and associated loads files.

CHAPTER 5: The Horizontal Design Module

Typical Operation

Although each user will have his or her own unique style, the typical operation of the Horizontal Design module would include the following steps:

1. Enter Loads and select pumps in the Zone Manager module
2. Form a link between the loads module and the design module
3. Modify step-by-step the input parameters listed in each panel
4. Perform initial calculation
5. Modify various parameters and recalculate to determine the effects of the modifications
6. Establish an optimal system
7. Save and/or print the project and associated zone file

Entering Data into the Tabbed Panels

Ground Loop Design's innovative tabbed panel system provides for easy organization of and direct access to the relatively large number of design parameters associated with a particular project. This section describes the *Information, Extra kW, Configuration, Piping, Soil, Fluid, and Results* panels. The *Information* 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. See Chapter 3 for a discussion of Loads entry.

Configuration

Information pertaining to the trench configuration is in the *Configuration* panel. This includes the trench layout and the pipe configuration in the trenches. The input screen is shown in figure 5.1. Note that this configuration panel can be used for both trench and pit systems. Click the *?* Button in the *Configuration* panel for more information.

Trench Layout

This is the section where the user enters all parameters regarding the physical size and placement of the trenches. The number of trenches may be modified at any time using the up-down arrows, and "Separation" refers to the center-to-center distance between adjacent trenches. The program assumes all trenches will be equal in separation, length, depth and width. Note that if the selected piping configuration does not fit into the selected trench size, the program will automatically adjust the size of the trench to accommodate the selection.
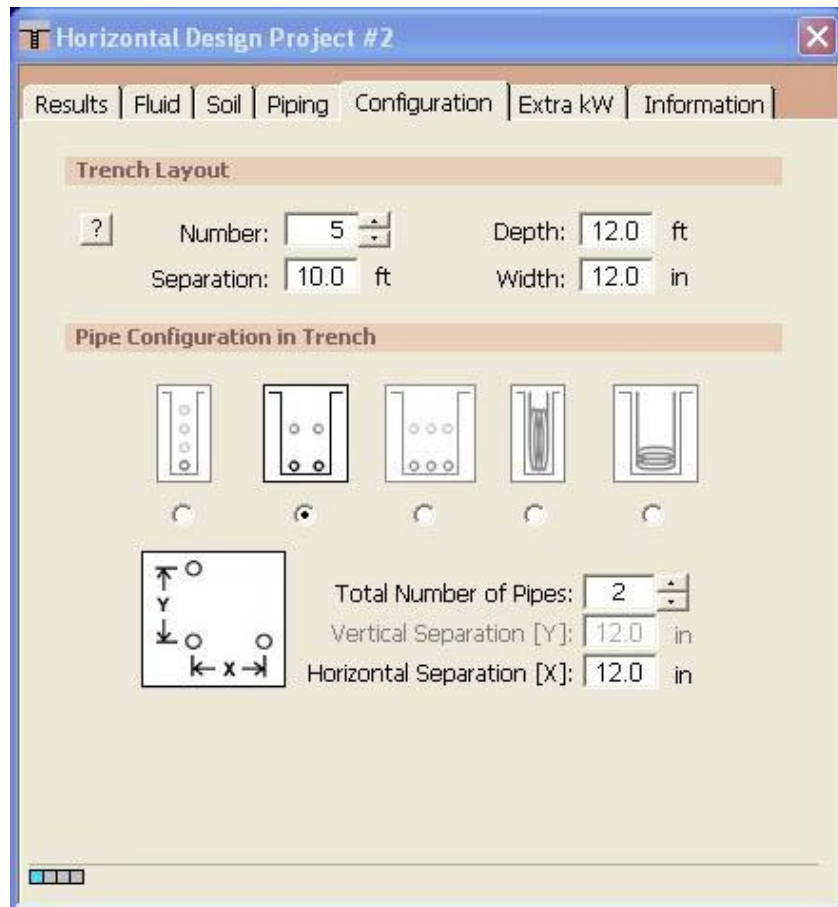
Fig. 5.1 Configuration Panel Contents

Pipe Configuration in Trench

The designer defines the physical arrangement of pipe in the trenches in this section.

STRAIGHT PIPE CONFIGURATIONS

In the case of the three straight-pipe configurations, the user also provides the total number of pipes and the horizontal [X] and vertical [Y] separation of the pipes in the trench. An additional offset, meaning a horizontal shift between adjacent vertical layers, can be included if desired.

Single-Pipe Vertical Alignment

In this arrangement, the user creates a single column of pipes. The number of pipes chosen defines how many layers will be included. Each pipe is separated from its neighbor by the given vertical separation [Y], starting from the bottom of the trench. If the 'Offset' box is checked, each pipe layer will be shifted from the pipe layer below by the given horizontal separation [X].

Two-Pipe Vertical Alignment
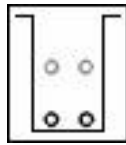
In this arrangement, the user creates two-pipe layers. The number of pipes chosen defines how many layers will be included (2, 4, 6, etc.). Each vertical layer is separated from the one above or below by the given vertical separation [Y]. If the 'Offset' box is checked, each pipe layer will be shifted from the pipe layer below by one-half the given horizontal separation [X/2].

Three-Pipe Vertical Alignment
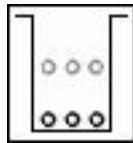
In this arrangement, the user defines three pipe layers. The number of pipes chosen defines how many layers will be included (3, 6, 9, etc.). Each vertical layer is separated from the one above or below by the given vertical separation [Y]. If the 'Offset' box is checked, every layer will be shifted from the layer below by one-half the given horizontal separation [X/2].

SLINKY PIPE CONFIGURATIONS

In the case of the horizontal and vertical slinky configurations, the user
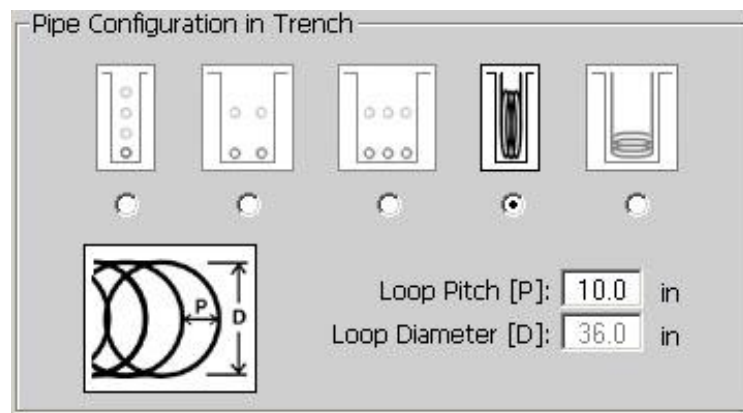
Fig. 5.2 Slinky Variables

may define the pitch and diameter of the Slinky. Because of the limited model employed, the pitch must be between 10 and 56 inches, and the diameter must be 36 inches. See figure 5.2.

Vertical Slinky

In this arrangement, the slinky is placed vertically within a trench and is resting at the bottom. The trench may be as narrow as the pipe and soil allow.

Horizontal Slinky
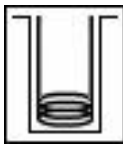
In this arrangement, the slinky is placed horizontally at the bottom of the trench. The minimum trench width depends on the slinky diameter.

Piping

The *Piping* panel contains all the information related to the particular pipe chosen for the buried heat exchanger. The program uses information about the pipe size and flow type to determine the associated pipe resistance, which ultimately is used in the length calculations. The input screen for the piping panel is shown in figure 5.3.

Pipe Parameters

The pipe characteristics are entered in the 'Pipe Parameters' section. They include the pipe size, the pipe type and the flow type.

As in the Borehole Design module, 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 average values of the Reynolds number to represent the different types of flow, with values of Re = 1600, 3150, and 10000 for laminar, transition, and turbulent, respectively. The calculations also use average viscosity values and the Prandtl number for water, taken at a temperature of 70°F.
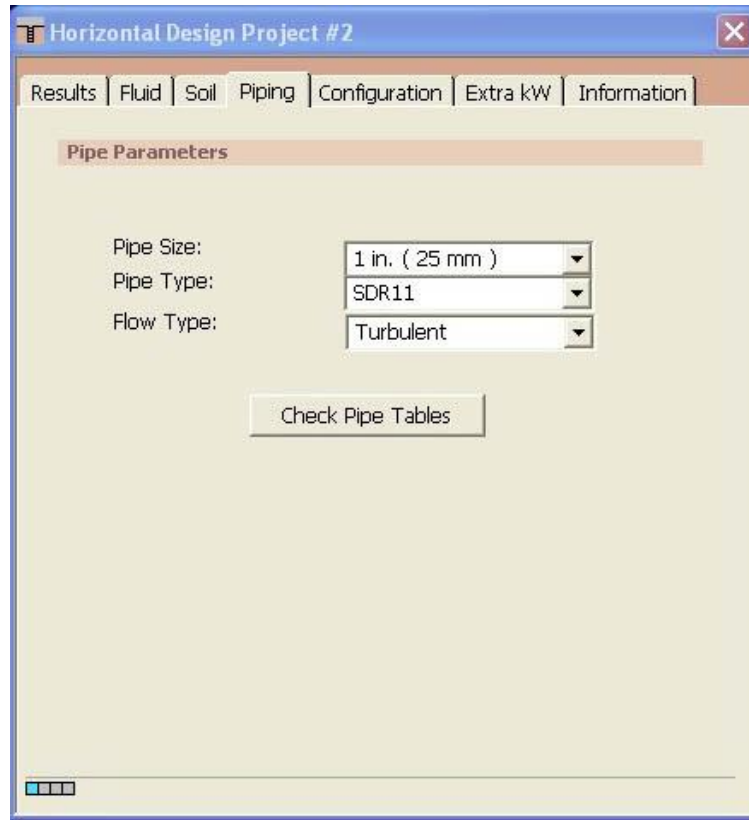
Fig. 5.3 *Piping* Panel Contents

Using the standard expression for resistance of a hollow cylinder (Incropera and DeWitt, 1990), the program calculates 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, contact support.**

Note: By pressing the 'Check Pipe Tables' button, the 'Pipe Properties' tables will open.

Soil

Input parameters relating to the soil are located in the *Soil* panel, as shown in figure 5.4. These include the average ground temperature, the soil thermal properties, and the ground temperature corrections at a given depth.
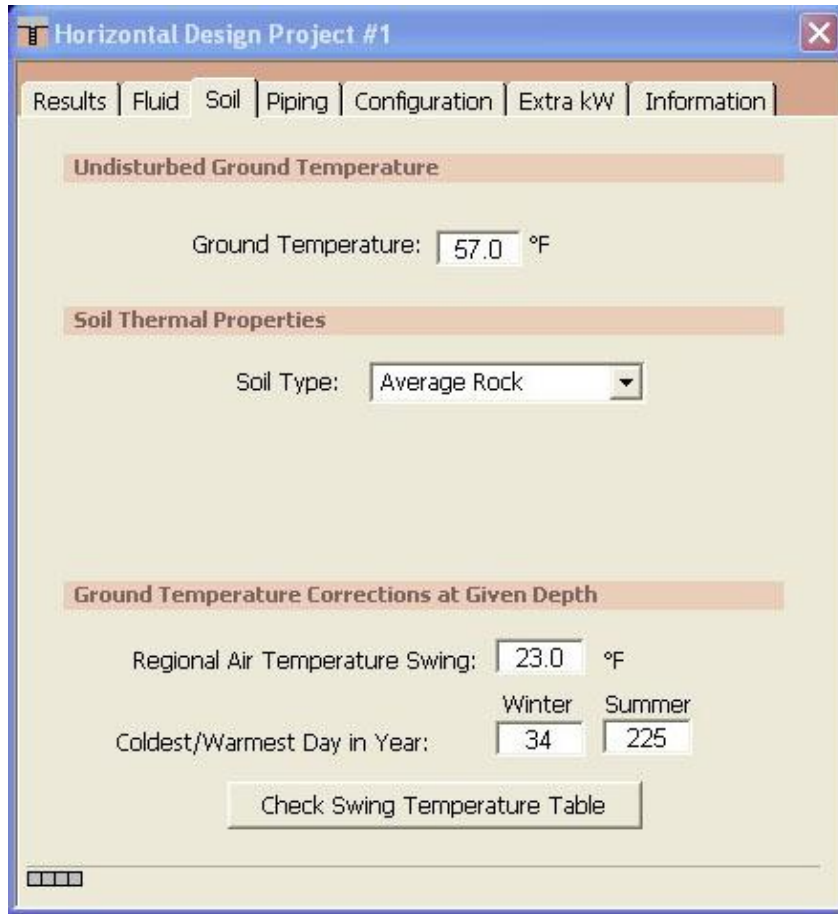
Fig. 5.4 *Soil* Panel Contents

Undisturbed Ground Temperature

TIP

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.

Soil Thermal Properties

The soil thermal properties (thermal conductivity and thermal diffusivity) are a little harder to define, and care must be taken to select the correct soil type. In the residential version of Ground Loop Design, users can select the soil type that best matches the target installation soil environment.

⚠

The thermal conductivity in particular has a large effect on the calculated bore length, and therefore soil type should be determined with care.

57

The following chart lists the conductivity and diffusivity values associated with each soil type option:

Soil Type	Conductivity Btu/(h*ft*^{0}F)	Diffusivity ft^2/day
Light Soil, Dry	0.20	0.26
Light Soil, Damp	0.50	0.48
Heavy Soil, Dry	0.50	0.48
Heavy Soil, Damp	0.75	0.60
Heavy Soil, Saturated	1.40	0.84
Solid Masonry	0.75	0.60
Dense Concrete	1.00	0.79
Average Rock	1.40	0.96
Dense Rock	2.00	1.20

Ground Temperature Corrections at Given Depth

In a horizontal configuration, the ground temperature around buried pipes can vary significantly simply due to the proximity to the surface. To account for this variation at different depths, the regional 'Swing' temperature and phase shift are used in a sinusoidal equation. The program determines the depth of each pipe in the chosen configuration, and then calculates the expected temperature at that depth.

Regional Air Temperature Swing

This is the temperature swing for the location of interest. It is a measure of the average temperature variation of the region during the warmest and coolest months as compared to the yearly average temperature. Regions with temperate climates have a lower temperature swing than regions 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 is approximately the coldest day of the year, the value entered will be '34' (31 days in January, plus 3 days of February).

Fluid

The circulating fluid parameters may be entered in the *Fluid* panel. A sample input screen is shown in figure 5.5.

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 of the changes**. Customized pump values must be adjusted manually.

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 all units will 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, while the ideal system flow rate is somewhere around 3.0 gpm/ton. Again, if the flow rate is changed, the selected heat pumps are updated in the loads modules.
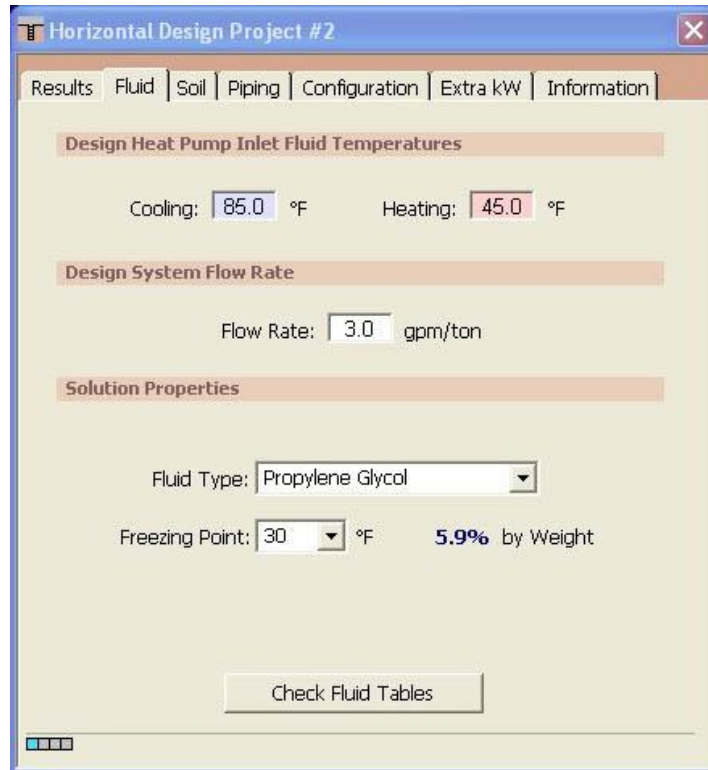
Fig. 5.5 *Fluid* Panel Contents

Solution Properties

Solution properties are also included in the *Fluid* panel. 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 user first selects the fluid type and then selects the desired freezing temperature. Ground Loop Design automatically incorporates the specific heat and density for the fluid selection into the calculations. The specific heat and density values of the antifreeze used can be found in the Soil Properties tables that can be accessed from the Tables dropdown menu.

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 trench length calculation.

Additionally, the viscosity of the solution may affect the flow type in the pipe, which was selected on the *Piping* 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

60

detailed automatic antifreeze information for all conditions. Generalized tables of data may be found in the 'Fluid Properties' tables.

Results

All results for both the heating and the cooling calculations can be viewed at any time on the *Results* panel. 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 the *Results* panel can be seen in figure 5.6.

Fig. 5.6 *Results* Panel Contents

The two lists on the *Results* panel are for heating and cooling. Although all of the numbers shown are valid and respond to changes, the side with the longer required 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.

Reporting Section

TIP

The reporting section is separated into several subsections. The first deals with the trenches, including the total length, the number of trenches, and the length for one trench. A common way to adjust the trench length to a desired value is to change the trench number on the *Configuration* panel.

The associated pipe length, both total and for a single trench, directly follow the reported trench lengths. The pipe lengths are a function of the selected configuration of pipe in the trench, so the length of trench is always less than the length of pipe when anything other than a single pipe configuration is chosen.

The following subsection of the report lists the heat pump inlet and outlet temperatures of the circulating fluid.

The next subsection lists the total unit capacity, the peak loads and demand of all the equipment, and the calculated heat pump and system efficiencies. The peak load is the maximum and is 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.

Finally, the system flow rate is listed in its own subsection. 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

A report of the active project can be printed at any time from the Design Studio using the toolbar print button or from the *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, and must be printed separately from the *Loads* panel. The filename of the ***.zon** file associated with the project report is also listed on the report.

More information on reports can be found in Chapter 7.

References

Francis, E., Editor. *Refrigeration and Air Conditioning, 3ʳᵈ Edition.* Air-Conditioning and Refrigeration Institute. p.186. Prentice Hall, New Jersey, 1997.

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.*

CHAPTER 6

The Surface Water Design Module

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

Overview

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

General Features

The Surface Water Design module in Ground Loop Design also includes a set of panels, grouped by subject, through which the designer can enter and edit the input variables in a straightforward and efficient manner. For example, parameters related to the body of water are listed on the *Surface Water* panel, while piping choices are listed on the *Piping* panel. Everything related to a project is presented simultaneously and easily is accessible throughout 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 and calculators
- A 'Calculate' button used to refresh the calculations
- A system to monitor header piping head losses

Opening Projects

There are two ways to open Surface Water Design projects. 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' from the Design Studio *File* menu or the toolbar. New projects open with standard parameter values that must be edited for new projects.

In new projects, no loads files (*.zon) are loaded. The user must create a new loads file or open an existing loads file into one of the loads modules. Links may be established using the Studio Link system described in Chapter 3.

Existing Projects

Existing projects may be opened at any time from the Design Studio by choosing 'Open' from the Design Studio *File* menu or toolbar. The file automatically opens into a new Surface Water Design Project module.

If a loads file (*.zon) is associated with the loaded project, the loads file will be loaded automatically into the appropriate loads module and opened along with the project file. However, if the associated loads file cannot be found, the user will be notified and the automatic 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 or by clicking the save button on the toolbar. When the user

closes the program or module, the program automatically asks the user if he or she would like to save the project file.

Typical Operation

Although each user has his or her own style, the typical operation of the Surface Water Design module would include the following steps:

1. Enter Loads and select pump in either the Average Block Loads module or the Zone Manager module
2. Form a link between the loads module and the design module
3. Modify step-by-step the input parameters listed in each panel
4. Perform initial calculation
5. Modify various parameters and recalculate to determine the effects of the modifications
6. Establish an optimal system
7. Save and/or print the project and associated zone file

Before You Begin

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 also are 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 in turn 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 thoroughly must 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 the relationships among them.

Finally, the surface water designing process actually involves an additional stage of optimization that is not included with 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.

Entering Data into the Tabbed Panels

Ground Loop Design's innovative tabbed panel system provides for easy organization of and direct access to the relatively large number of design parameters associated with a particular project. This section describes the *Surface Water, Piping, Soil, Fluid, and Calculate* panels. The *Information* 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. See Chapter 3 for a discussion of Loads entry.

Surface Water

Use the Surface Water panel to enter data related to the body of water being used as the heat transfer medium. Figure 6.1 shows the associated input screen.

Fig. 6.1 *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.

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 the information related to the circuit piping and the piping selected for 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 circuit panel is shown in figure 6.2. Figure 6.3 is the input screen for the piping header panel.
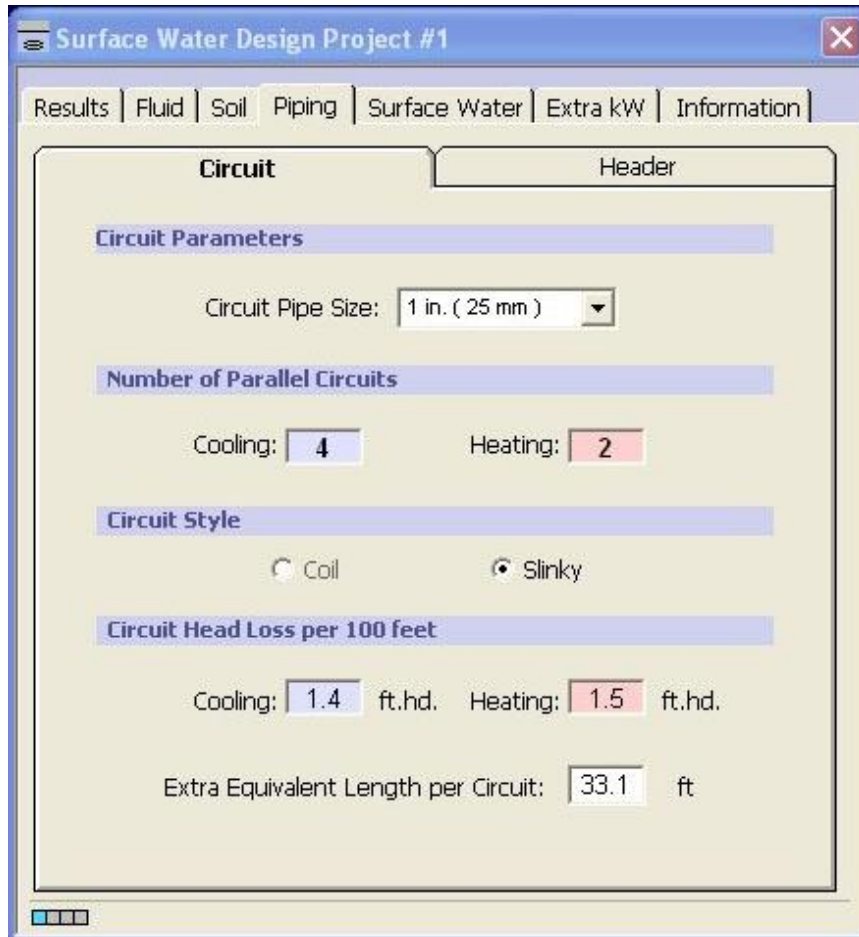
Fig. 6.2 *Piping* **Circuit Panel Contents**

Circuit Parameters

Circuit Pipe Size

This is the size of the pipe used in the primary heat transfer circuits. Although larger pipes offer better heat transfer, designers generally prefer smaller sizes (3/4", 1") because of ease of handling and lower pipe costs.

Number of Parallel Circuits

This is the number of parallel circuits required 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 overwritten automatically with the limiting value when the calculations are performed.**

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

Circuit Style

Both loose bundled coils and "slinky" (spread out) styles are available. If extensive spacers are used in a coil style arrangement, the slinky model may provide more accurate results, but the loose coil option will provide the more 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.
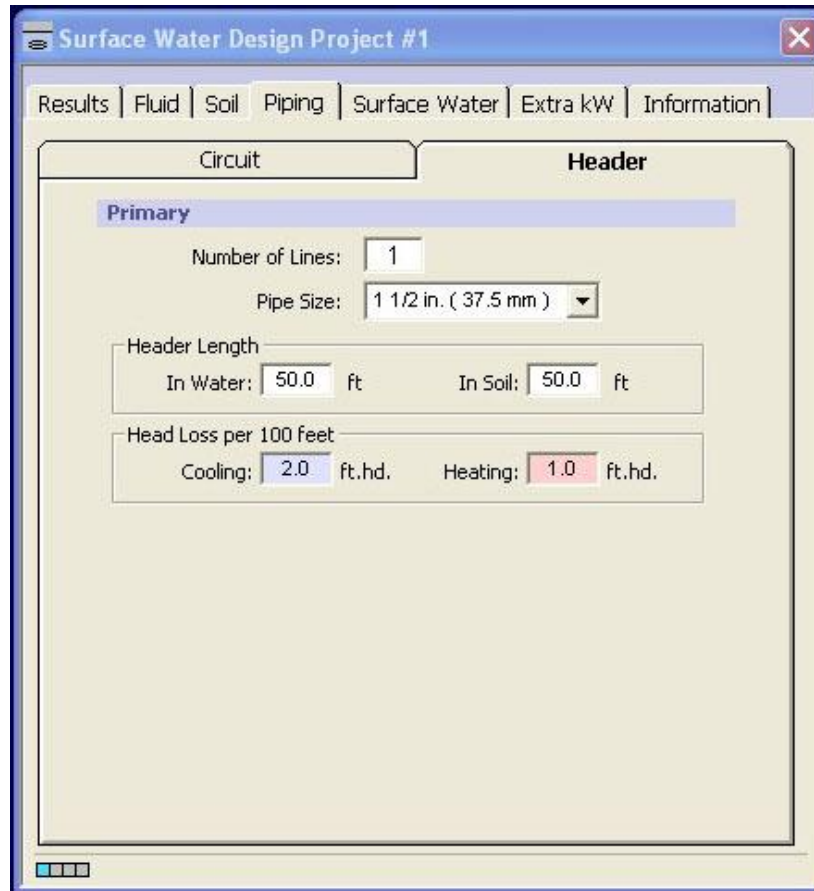
Fig. 6.3 *Piping* Header Panel Contents

Header Parameters

The Ground Loop Design Surface Water module assumes that 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.

In the *Piping* panel, the model employed allows for multiple headers. If further branching is required, the head loss calculations will need to be calculated and added separately. Their effect on the calculated piping length, which cannot be included, will depend on their length. **All headers are assumed to have an identical pipe size, and an approximately equivalent flow**.

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.

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, antifreeze, and flow rate.* Several graphs are provided with the program to help determine these values for pure water and standard solutions**, but the designer is ultimately 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.*

Number of Lines

This is the number of header lines in the system.

Pipe Size

This is the size of the pipe used in the primary headers. For pumping reasons, the size of the primary header is generally larger than the circuit pipe sizes.

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.

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**. 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 associated with the portion of the header pipe in the soil. The model uses the undisturbed ground temperature of the soil. This temperature then is used to determine how much heat is transferred from the header pipe to the soil or vice versa.

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

The *Soil* panel input screen is shown in figure 6.6.
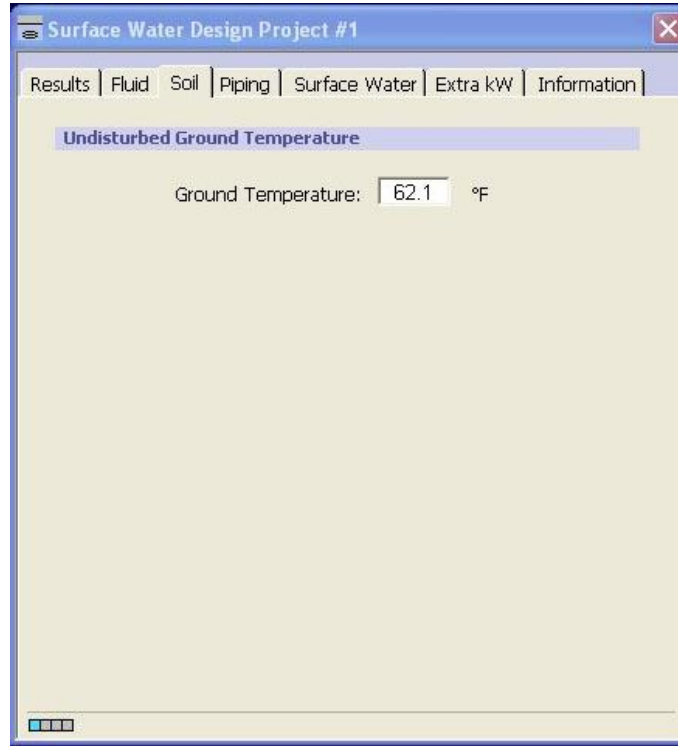
Fig. 6.6 *Soil* Panel Contents

Fluid

The fluid panel is identical to the one described for the Borehole Design module in Chapter 4 except for one addition. That addition is the minimum required circuit flow rate in the lower 'Minimum Circuit Flow Rate and Solution Properties' section. The added section is shown in figure 6.7. As in the other modules, the inlet temperatures can be viewed and modified from the expanded interface, as seen in figure 6.8
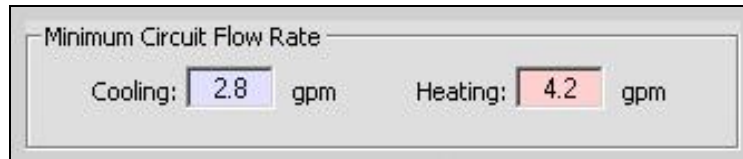
Fig. 6.7 Minimum Circuit Flow Rate Section of the *Fluid* Panel

Ground Loop Design uses this information in conjunction with the system flow rate to establish the maximum number of parallel circuits. The flow rates required for non-laminar flow for several antifreeze solutions are included as a table in the 'Fluid Properties' set. **Exact values for a particular mixture may need to be determined independently by the designer**.

Note once again that changes in the inlet source temperature or the system flow rate will cause an automatic update of the selected pumps.

Results

There are several significant differences between the Surface Water Design module's *Results* panel and the Borehole Design module's *Results* panel. These differences relate to the nature of the calculations, as well as to the inclusion of the head loss calculation results. Figure 6.9 shows a typical view of the *Results* panel.

Again, there are two lists shown on the *Results* 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.*

Fig. 6.9 *Calculate* **Panel Contents**

Reporting Section

The surface water report has five sections. The first deals with the circuit pipe, and includes the total length, the length for one circuit, the number of circuits, 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, the actual number of circuits 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.

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

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 is too far below this value, the water may***

75

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 total unit capacity, the peak loads and the 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. *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 could 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 rate in the primary header, as well as 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. 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

A report of the active project can be printed at any time from the Design Studio using the toolbar print button or from the *File* menu → *Print*.

The information printed includes all of the input parameters from the design module, along with the associated results. Zone and loads information can be printed separately from the *Loads* panel. The filename of the ***.zon** file associated with the project report is also listed on the report.

More information on reports can be found in Chapter 7.

CHAPTER 7

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 reporting features. These features have been added for professionals who need to keep records of their designs and communicate them to others. There are nine different report styles included within the package, and this chapter provides an explanation of as well as suggested uses for each type of report.

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 and 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

77

the design module (using the Design Studio 'Units' menu), and then open a new report.

Project Reports

A project reports may be opened at any time from the Design Studio *File* menu by selecting *Print*. One project report for each heat exchanger module is available. The report contains full project information..

The report does not print automatically, but instead creates the report preview window, in which 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.

In general, project reports contain several 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 at the top of every report. Concise reports only include the project name and start date.

Calculation Results

This section lists the results of the calculations and essentially is 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. The report presents results of both the heating and the cooling calculations.

Input Parameters

This section contains all of the parameters entered by the designer during the design process. Parameters are placed into sections with names taken directly from 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.

Zone Reports

Zone (or loads) reports are printed directly from the *Loads* 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 is a building, the zone reports will cover everything within the building, while the project report essentially will contain information about everything outside, or external to the building.

A zone report is printed from the *Loads* panel of the Zone Manager or directly from an Average Block Loads module by clicking the printer button in the 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:

- **Detailed Form**
- **Concise Form**
- **Equipment List**
- **Loads List**
- **Names List**

Detailed Form

The *Detailed Form* zone report is the most detailed zone report. It lists all of the information included in every zone, along with full explanations of the listed parameters. The format is open and easy to read. However, as with the project reports, the detailed form produces a much longer printed report than any of the more compact versions.

Concise Form

The *Concise Form* zone 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 descriptions 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. The designer can organize and share information both during the developmental stages of a project and after the design is complete.

CHAPTER 8

Tables and Reference Files

This chapter covers the tables and reference 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

Ground Loop Design employs a technologically sophisticated system that allows the user to customize the reference files as much as he or she desires.

The reference files included with Ground Loop Design are minimal, consisting of a few tables and graphs that should aid in the selection of requested parameters. All files are written in open HTML (Hypertext Mark-up Language) files. The designer can edit and add to them as he or she desires to create a customized reference library within the Design Studio environment.

As with the heat pump and loads models, the reference 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 several broad categories from which most questions will arise. These include:

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

The first three sections present a menu screen with hyper-links to various tables that have been included in the package. The fourth section consists of a pair of metric-to-English units conversion tables that answer most common engineering conversion problems. 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 are the following:

Table 1: Densities and Specific Heats of Various Solutions

Table 2: Minimum Required Flow Rate for Non-laminar 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

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.

In an ideal world, 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 specific projects, 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 three reference files are listed below.

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

Table 2: Thermal Properties of Rocks at 77^0 F

Table 3: Earth Temperatures, Soil Swing and Phase Constants for U.S. and Canadian Cities

The first two *Soil Properties* tables included with Ground Loop Design provide various soil parameters, including ranges for thermal conductivity (k) and thermal diffusivity (α) for various types of soils.

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.

The third table contains mean earth temperatures and other parameters for U.S. cities. This table particularly may be useful for horizontal designs.

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: Thermal Conductivities of Typical Grouts and Backfills

Table 2: Pipe and Tube Dimensions

Table 3: Required Flow Rates to Achieve 2 ft/s – SDR11 Pipe

The first table provides thermal conductivities for some typical grouts. The second lists the physical dimensions (inner and outer diameter) for common pipe sizes in various types of pipe. The third, although unnecessary for the associated calculations, provides some convenient flow rates required for proper purging of a piping system.

Conversions

The Conversions table has two separate lists of metric to English conversions, placed together in 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 Reference Files

The user can create customized reference files by editing the existing HTML files with the table lists, and making new links. The process is simple and requires only 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**
    SoilTable3.html   **SoilTable3Metric.html**

PipeTables.html   **PipeTablesMetric.html**
    PipeTable1.html   **PipeTable1Metric.html**
    PipeTable2.html   **PipeTable2Metric.html**
    PipeTable3.html   **PipeTable3Metric.html**

To add a new file, the **FluidTables.html**, the **SoilTables.html**, or the **PipeTables.html** must be edited. The user must create a link in one of the three aforementioned *.html files to the new file (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 associated 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 a '.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 a user wishes to add a new pipe table to the list, he or she first will create the table (i.e. PipeTable4.html) and then will add a link to it on the PipeTables.html file.

Additionally, if the user wishes to add additional information to an existing table or figure, he or she only has to open the appropriate HTML file in a text editor or HTML editor and make and save the desired changes. For example, if adding a new link, **PipeTables4.html**, to the **PipeTables.html** file, one might add this new link with the name "Table 4: 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="PipeTable3.html">Table 3: Required Flow Rates to Achieve
2ft/s – SDR 11 Pipe</a></li>
</ul>

<li>
<a href="PipeTable4.html">Table 4: 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. It is much more difficult to make a table using plain HTML in a text editor.

Although any name is valid for a table, tables can be added to the appropriate group by just extending the naming sequence already being

used. For example, the name **PipeTable4.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 reference files.

As an example, let's assume that an engineer scans an image of his favorite density vs. percent solute graph for Calcium Chloride and saves it in the Help Files directory as a *jpeg* image, called **CaCl2Density.jpg**. A very simple HTML file can be created with a text editor, and called **FluidTable6.html**. The entire **FluidTable6.html** file would be as follows:

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

FluidTable6.html

Remember, the **FluidTables.html** file would have to be edited to include the new link to the **FluidTable6.html** file, similar to the example given in *Editing Existing Files*, above.

If everything is done properly, when 'Fluid Properties' is selected from the *Tables* menu in the Design Studio, 'Table 6' 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 reference 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 is advised to make backup files of all customized reference files before new Ground Loop Design installations or updates.*

Concluding Remarks

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