Chilled Water System Analysis Tool (CWSAT)

Version 3.0.1

USER'S MANUAL

January 2014

Developed in Cooperation with:

The University of Massachusetts College of Engineering
Department of Mechanical & Industrial Engineering

The University of Massachusetts Industrial Assessment Center
funded by the U.S. Department of Energy

The Center for Energy Efficiency & Renewable Energy

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Getting Started

Welcome to the New Version of the Chilled Water System Analysis Tool!

This program was created at the University of Massachusetts - Amherst with funding from the U.S. Department of Energy.

The files required to run CWSAT Version 3.0 are:

CWSAT30.exe	The application file created with MS VB.Net Language in Visual Studio 2012. Double click to launch the program.
WEATHER folder	The folder in which weather data is stored. The program reads from this folder. It must be placed in the same directory as CWSAT30.exe.
OUTPUTDATA folder	The folder in which all output data files are stored. The user may use this if interested in looking at the detailed results of the tool analysis.
USERCHILLER folder	The folder in which user defined chiller performance curve files are stored. It must be placed in the same directory as CWSAT30.exe.
USERPROFILE folder	The folder in which user can store saved chilled water system profiles data. This is for organizing user profiles at one place; however user can save the profile at the user specified location.

Your feedback will be used in the development of future upgrades. We are interested in your comments as to the usefulness of the program and suggestions for changes in the next version.

This manual is intended to document the screens and data entry procedures encountered while using the program. While program navigation is intended to be intuitive, this manual may be useful for first-time users.

I hope you find the tool to be beneficial. Good luck!

Questions, suggestions, errors encountered, etc., can be sent to:
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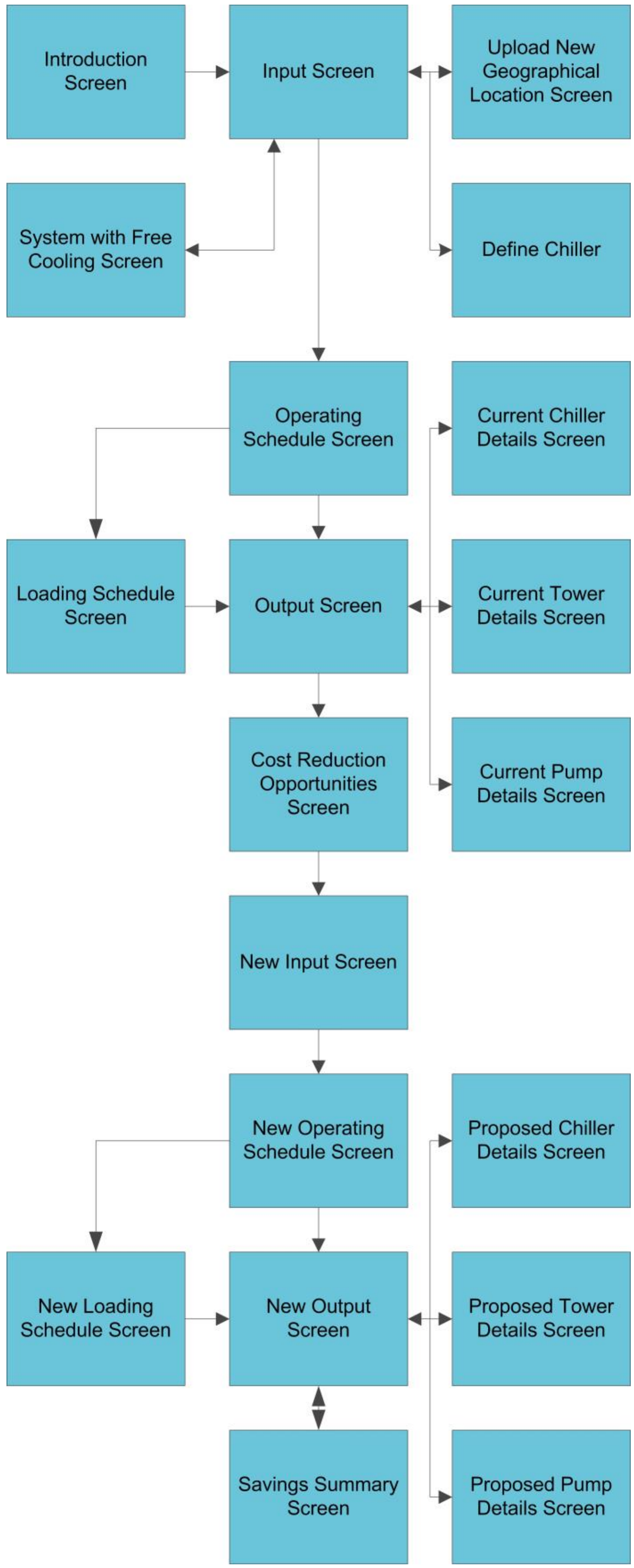
Program Overview

The tool uses graphical screens to provide information to and extract information from you, the program user. The details of the analysis routines (how the program uses the input data to generate output values) are not covered in this manual. However, some technical notes are provided where appropriate as guidance.

The program requests information about the existing chilled water system equipment and operation. The program calls upon several routines to generate energy consumption estimates and provides this information to you. After viewing this information, you may wish to alter the equipment specifications or apply one of several operating cost reduction measures. The program calculates the energy consumption of the proposed system and compares these results with those generated for the existing system. In this way, you receive information about the net benefit of the specific measures proposed. The flowchart below provides an overview of the various program screens and the order in which you will view them.



Introduction Screen
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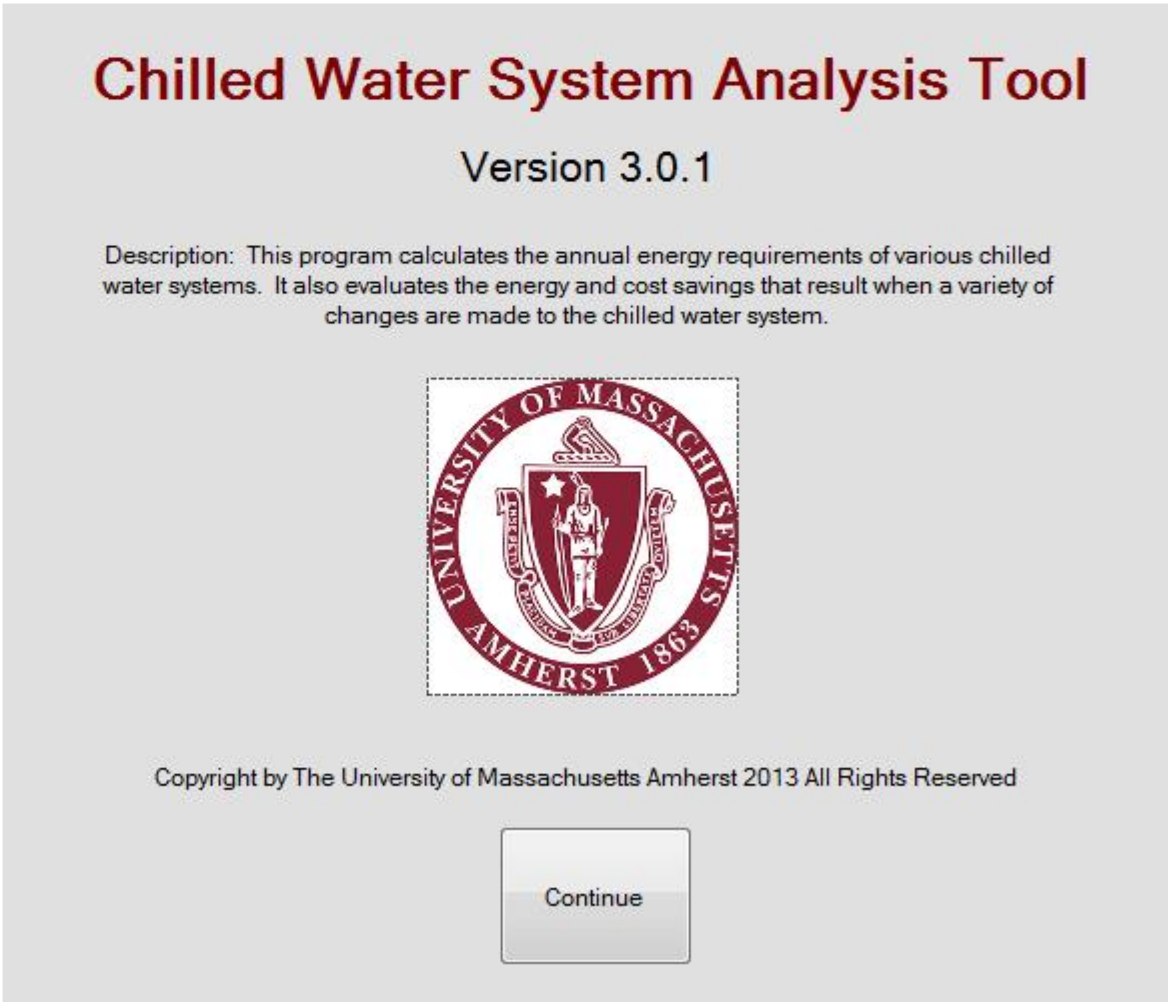
Note that invoking "Alt-Print Screen" copies to the Windows clipboard the active window, which can then be pasted into a Word or other document for printing.

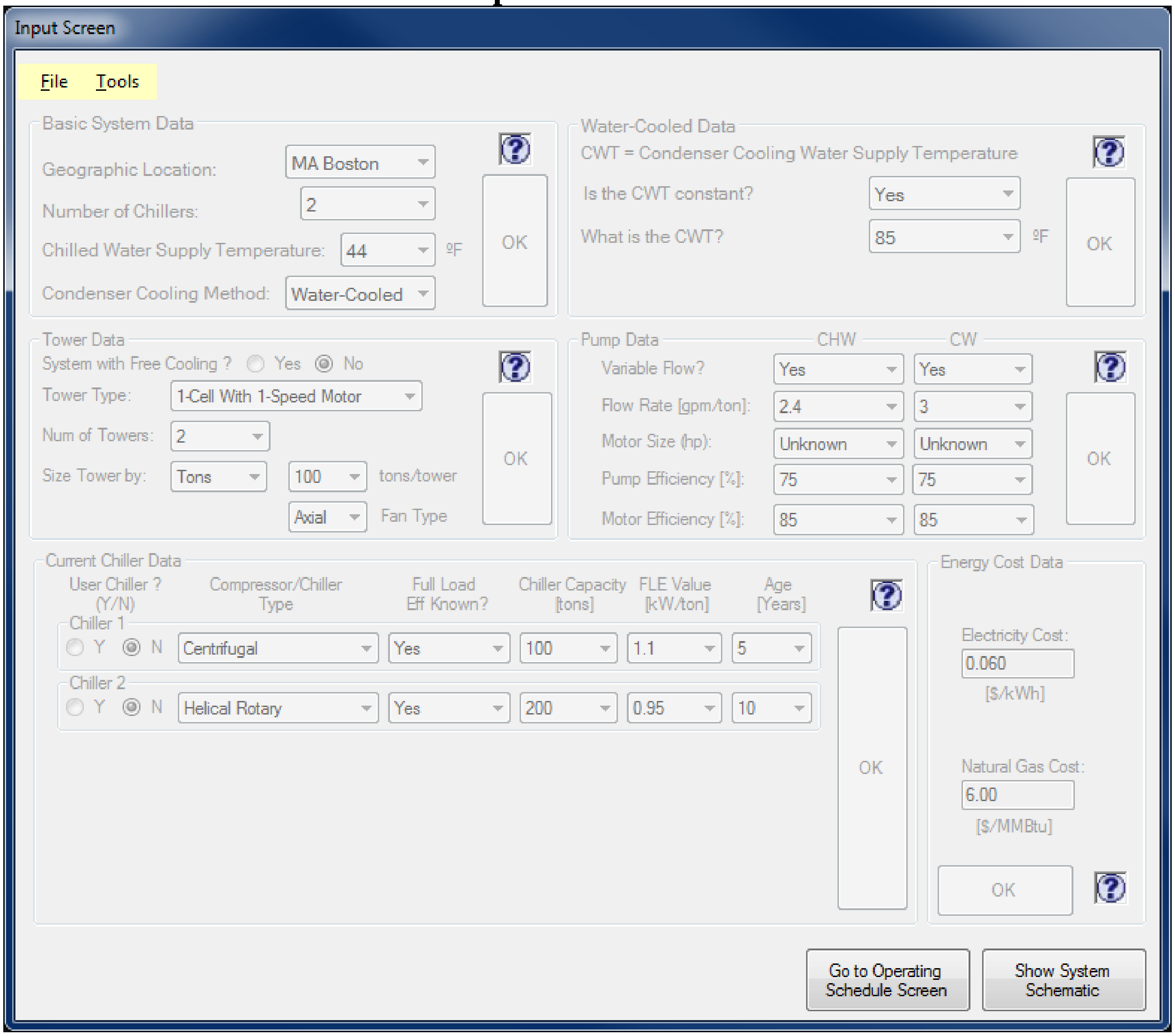
Introduction Screen



The introduction screen identifies the name and version of the software. It provides description of the software.

Options:
CONTINUE

Input Screen



The purpose of this screen is to collect specifications and operational information for the existing chilled water system. The screen is divided into “frames” to simplify the data input process. Each frame collects several input values and, after the user has reviewed and accepted the frame contents by clicking on an OK command button, the next relevant frame appears. The frames used on the Input Screen include Basic System Data, Air-Cooled Data, Water-Cooled Data, Tower Data, Pump Data, Current Chiller Data, and Energy Cost Data. It is noted that the Air-Cooled Data frame and the Water-Cooled Data frame are not simultaneously visible. Further, if the system is air-cooled, the Tower Data frame and some objects within the Pump Data frame are not visible.

Options:
IMPORT SAVED DATA (Under File Dropdown Menu)
RESTART/CLEAR SCREEN (Under File Dropdown Menu)
UPLOAD NEW GEOGRAPHICAL LOCATION (Under Tools Dropdown Menu)

DEFINE CHILLER (Under Tools Dropdown Menu)
GO TO OPERATING SCHEDULE SCREEN
SHOW SYSTEM SCHEMATIC
HELP (Contextual; click on area of interest to invoke)
EXIT (Under File Dropdown Menu)

The information required on the Input Screen is described on the following pages, and is organized by the name of the frame in which the variable menu appears.

1) System Basics Frame

Geographic Location The name of the chilled water system location is used to sort ambient temperature data. Ambient temperature is one of the factors used to determine chilled water system energy consumption. A typical name would be like *MA-Boston*. Select the name of the closest location from the pull-down menu.

Number of Chillers Select the Number Of Chillers in the current chilled water system by selecting a value from the pull-down menu. The allowable value ranges from 1 to 5.

Chilled Water Supply Temperature (ºF) Select the Chilled Water Supply Temperature by selecting a value from the pull-down menu. The allowable value ranges from 20 to 60 degrees Fahrenheit.

Condenser Cooling Method Chillers require cooling of the chiller condenser as part of the refrigeration cycle. The condenser is typically cooled by a fan-driven air stream (Air-Cooled) or water flowing through a heat exchanger (Water-Cooled). All chillers in the system are assumed to use the same condenser cooling method. Select the method of cooling from the pull-down menu.

Clicking the Basic System Data OK command button locks in the above values and makes either the Air-Cooled Data frame or the Water-Cooled Data frame appear. The input values required in each of these frames are described below.

2) Air-Cooled Data Frame (appears if the Method of Cooling is "Air-Cooled")

Outdoor Air Design Temperature (ºF) The outdoor air design temperature is the dry-bulb temperature during full load operation anticipated by the chiller designer. When manufacturers rate air-cooled chillers, they subject them to full load testing using cooling air held at a specific temperature. This is termed the design temperature. It is assumed to be the "worst case scenario" for chiller operation, and is used as the basis for specifying the chiller size at the time of purchase. Select the Outdoor Air Design Temperature from the pull-down menu. The standard industry value is 95 (as specified in Standard 550/590 of the Air-Conditioning and Refrigeration Institute). The allowable value ranges from 80 to 110 degrees Fahrenheit. The value input affects the calculated efficiency of the chiller as a function of the outside operating temperature.

Cooling Air Source The air used to cool the chiller condenser may come from inside or, for remote condensers, from outside of a building. If outdoor air is used, the cooling air temperature will fluctuate with ambient conditions. If indoor air is used, the temperature will be relatively steady because it is controlled by the building's climate control system. Any changes in cooling air temperature will affect chiller performance, and are considered in the analysis. Select either "Inside" or "Outside" from the pull-down menu.

If the Cooling Air Source is "Inside":

Average Indoor Air Temperature The Average Indoor Air Temperature is the average annual temperature of the air cooling the chiller condenser. The expected chiller efficiency, and hence energy consumption, is adjusted for differences between design temperature and actual operating conditions. Select the Average Indoor Air Temperature from the pull-down menu. The allowable value ranges from 60 to 90 degrees Fahrenheit.

Or if the Cooling Air Source is "Outside":

CT follows ambient dry-bulb plus _____ ºF This value is called the following temperature differential, and is the difference between the temperature achieved inside the chiller condenser and the air used to cool the condenser. If the cooling air is supplied from outside the building, chiller performance will be affected by the outdoor temperature conditions. The closer the condenser temperature approaches the cooling air temperature, the more efficiently the chiller will operate. Select the following temperature differential from the pull-down menu. Typical values are 15 to 20 degrees Fahrenheit, and the allowable range is 5 to 30.

If you are satisfied with the selections, click the OK command button to lock in the values and make the Pump Data frame appear.

3) Water-Cooled Data Frame (appears if the Method of Cooling is "Water-Cooled")

Is CW temperature constant? Water-cooled chilled water systems typically use a cooling tower to remove heat from the chiller condenser and reject it to the atmosphere. Towers may operate to maintain a constant condenser cooling water temperature or allow the temperature to vary with the ambient conditions. If the condenser water temperature entering the chiller is held constant, select "Yes" from the pull-down menu. If the condenser water temperature is allowed to vary, select "No".

If the CW temperature is constant:

What is the CWT? The condenser water temperature, or CWT, is the constant cooling water temperature maintained by the cooling tower and supplied to the chiller. Select the constant temperature value from the pull-down menu. A typical value is 85 degrees Fahrenheit. The allowable range is 65 to 90 degrees Fahrenheit.

Or if the CW temperature is not constant:

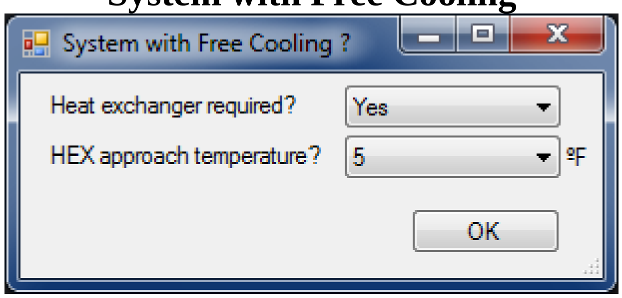
CWT follows ambient wet-bulb plus _____ ºF This value is called the following temperature differential, and is the difference between the condenser cooling water temperature achieved and the wet-bulb temperature of the air entering the cooling tower (the analysis assumes the condenser temperature achieved is equal to the cooling water temperature supplied to the chiller). The closer the condenser water temperature approaches the air wet-bulb temperature through evaporation in the cooling tower, the more efficiently the chiller will operate. Select the condenser following temperature differential from the pull-down menu. Typical values are 5 to 10 degrees Fahrenheit, and the allowable range is 2 to 20.

If you are satisfied with the selections, click the OK command button to lock in the values and make the Tower Data frame appear.

4) Tower Data Frame (appears only if the Method of Cooling is "Water-Cooled")

System with Free Cooling? The first radio button allows user to select the free cooling option in the chilled water system. If "Yes" is selected, a new window "System with Free Cooling?" appears. The default radio button selection is "No". After making selections, the window redirects the user to Input Screen.

System with Free Cooling



System with Free Cooling Window Answer with "Yes" or "No" to the question "Heat Exchanger Required?" If "Yes" is the answer, specify the Heat Exchanger Approach Temperature. Typical values are 5 to 10 degrees Fahrenheit, and the allowable range is 2 to 20. Clicking "OK" button will navigate to the Input Screen.

Tower Type Select the Tower Type from the pull-down menu. Seven options for the cooling tower types are supported. The supported towers are "1-Cell with 1-Speed Motor", "1-Cell with 2-Speed Motor", "2-Cell with 1-Speed Motors", "2-Cell with 2-Speed Motors", "3-Cell with 1-Speed Motors", "3-Cell with 2-Speed Motors", and "Tower with Variable Speed Motor(s)". By choosing one of the first six options, the number of cells per tower is automatically specified as 1, 2, or 3, where a cell is the number of identical zones (i.e. fans) operating within a cooling tower. If the seventh option is selected, an additional menu appears at the bottom of the screen to specify the number of cells per tower. It is believed that these seven options will cover the majority of cooling tower systems encountered.

Number of Towers The Number of Towers is the number of cooling towers (operating in parallel) required to serve the chilled water system. Select the Number of Towers value from the pull-down menu. The allowable range is 1 to 5.

Size Tower by The towers can be sized by tonnage or fan hp. Note that a chiller ton is equal to 12,000 BTU/hr, while a tower ton is equal to 15,000 BTU/hr. The difference accounts for the additional heat generated by inefficiencies in the chiller that must be rejected by the tower. The appropriate match for a 100-ton chiller is a 100-ton tower.

Tons Specify the tower rating in tons. The choices range from 20 to 3,000 tons.

Fan Type The fan type can be specified as axial, centrifugal, or unknown.

Fan Motor Size (hp) The Fan Motor Size is the rated size of the fan motors installed in each cooling tower cell. The program assumes that all cells are identical. Select the Fan Motor Size from the pull-down menu. The allowable range is 1 to 100 horsepower, with common motor sizes supported.

If the Tower Type is "Tower with Variable Speed Motor(s)":

Number of Cells Per Tower The menu for the Number of Cells Per Tower appears upon the selection of the "Tower with Variable Speed Motor(s)" tower type. A cell is the number of identical, independent zones (i.e. fans) within a given cooling tower. Select the Number of Cells Per Tower from the pull-down menu. The allowable range is 1 to 3.

If you are satisfied with the selections, click the OK command button to lock in the values and make the Pump Data frame appear.

5) Pump Data Frame

The Pump Data frame contains menus for both chilled water pumps and condenser water pumps for water-cooled systems, and for chilled water pumps alone for air-cooled systems. The following values apply for both pump types.

Variable Flow? Some chillers are designed to operate with variable chilled and/or condenser water flow rates. At reduced load conditions, the pump flow rate may be reduced to save energy. Select "Yes" from the pull-down menu if the pump flow varies with chiller load, and select "No" if the pump flow rate is constant under all loading conditions. Most applications operate with constant pump flow.

Flow Rate [gpm/ton] The pump flow rate is generally specified as a function of the chiller capacity in tons. For constant flow systems, this value specifies the pump flow rate under all conditions. For variable flow systems, this value specifies the pump flow rate coinciding with full chiller load. Even in variable flow systems, however, the pump flow rate generally remains at 50% of the rated flow or above. Select the pump flow rate from the appropriate pull-down menu. Typical values are 2.4 gpm per ton for chilled water pumps and 3.0 gpm per ton for condenser water pumps. The allowable range for chilled water pumps is 1.6 to 3.0, and the range for condenser water pumps is 2.0 to 4.0.

Motor Size (hp) The pump motor size can be specified or declared to be unknown. If the size is specified, that information will be used to calculate pump energy use. Otherwise, typical system parameters, including the other inputted data will be used for that purpose. If there are multiple pumps running simultaneously, input their combined horsepower.

Pump Efficiency [%] The energy consumed in a given pump application is a function of the efficiency of the pump in converting mechanical energy into hydraulic energy. Select the approximate pump efficiency from the pull-down menu. In a properly designed system, a typical value is 88%. The allowable range is 70 to 95.

Motor Efficiency [%] The energy consumed in a given pump application is a function of the efficiency of the motor in converting electric energy into mechanical energy. Select the approximate motor efficiency from the pull-down menu. In a properly designed system, a typical value is 94%. The allowable range is 80 to 95.

If you are satisfied with the selections, click the OK command button to lock in the values and make the Current Chiller Data frame appear.

6) Current Chiller Data Frame

User Chiller Answer with “Yes” or “No” to the question “User Chiller?” for each chiller in the chilled water system. If “Yes” is the answer, the tool will list the user defined chillers that are stored in the database in the Compressor/Chiller Type dropdown box. The Full Load Efficiency value and Chiller Capacity are automatically displayed up in the respective fields.

Compressor/Chiller Type In the mechanical vapor compression cycle, a compressor increases the energy of the refrigerant by increasing the pressure and temperature of the saturated vapor. The tool supports three compressor types, namely “Centrifugal”, “Reciprocating”, and “Helical Rotary”. It also supports user defined chiller with custom performance curve. Natural gas engine-driven chillers are supported only as replacement equipment (See New Input Screen). Select the Compressor Type from the pull-down menu.

Full Load Efficiency Known? The analysis of chiller performance is dependent on knowledge of the rated efficiency of the chiller. If the rated efficiency of a specific chiller is known, a performance curve can be adapted to this value to predict part load performance. If the full load efficiency is not known, a database value for a generic chiller of equivalent size must be used. This generic value may or may not accurately predict the energy consumption of your chiller. Therefore, it is recommended that the full load efficiency by determined whenever possible. This will improve the accuracy of the analysis results. If the full load efficiency is known select "Yes" from the pull-down menu. Otherwise, select "No".

Chiller Capacity (tons) The cooling capacity of a chiller is quoted in units of refrigeration tons, where one ton of cooling is equivalent to 12,000 Btu per hour of heat removal from the chilled water stream. The nominal tons value is the rated cooling effect of the chiller at full load, and can generally be determined from the chiller nameplate or the chiller model code. Once the compressor type has been specified, the nominal ton ratings supported by the tool are made available for selection. For a water-cooled centrifugal chiller, capacities vary from 200 and 2000. For a water-cooled reciprocating chiller, capacities vary from 20 to 250. For an air-cooled reciprocating chiller, capacities vary from 40 to 450. For a water-cooled helical rotary chiller, capacities vary from 70 to 800. For an air-cooled helical rotary chiller, capacities vary from 70 to 400. Select the Chiller Capacity from the pull-down menu.

If the full load efficiency is known:

Full Load Efficiency (kW/ton) If the full load efficiency is known, enter the value by clicking the up and down arrows adjacent to the FLE text box. Typical values range from 0.6 to 1.0 kW/ton for water-cooled chillers and 1.0 to 1.4 kW/ton for air-cooled chillers. The allowable range is 0.02 to 3, selectable in increments of .01.

Age (Years) The age of a chiller has been shown to affect its performance due to tube fouling. This fouling inhibits heat transfer, and thus reduces the overall efficiency of the chiller. Select the chiller Age from the pull-down menu. The allowable range is 0 to 20. If the chiller has been rebuilt or the tubes are cleaned as part of general maintenance, record the age of the chiller as the time since the last tube cleaning. The program assumes that chiller efficiency is degraded by 1% / year.

If you are satisfied with the selections, click the OK command button to lock in the values and make the Energy Cost Data frame appear.

7) Energy Cost Data Frame

Energy costs ultimately determine the cost to operate a chilled water system. Electricity cost is recorded in $ per kWh. Natural gas cost is recorded in $ per MMBtu, and is used only for replacement equipment (See New Input Screen and New Output Screen).

Electricity Cost ($/kWh) Enter the electricity cost in the text box. Click on the text box to move the cursor and type in the value with the keyboard. The default value is

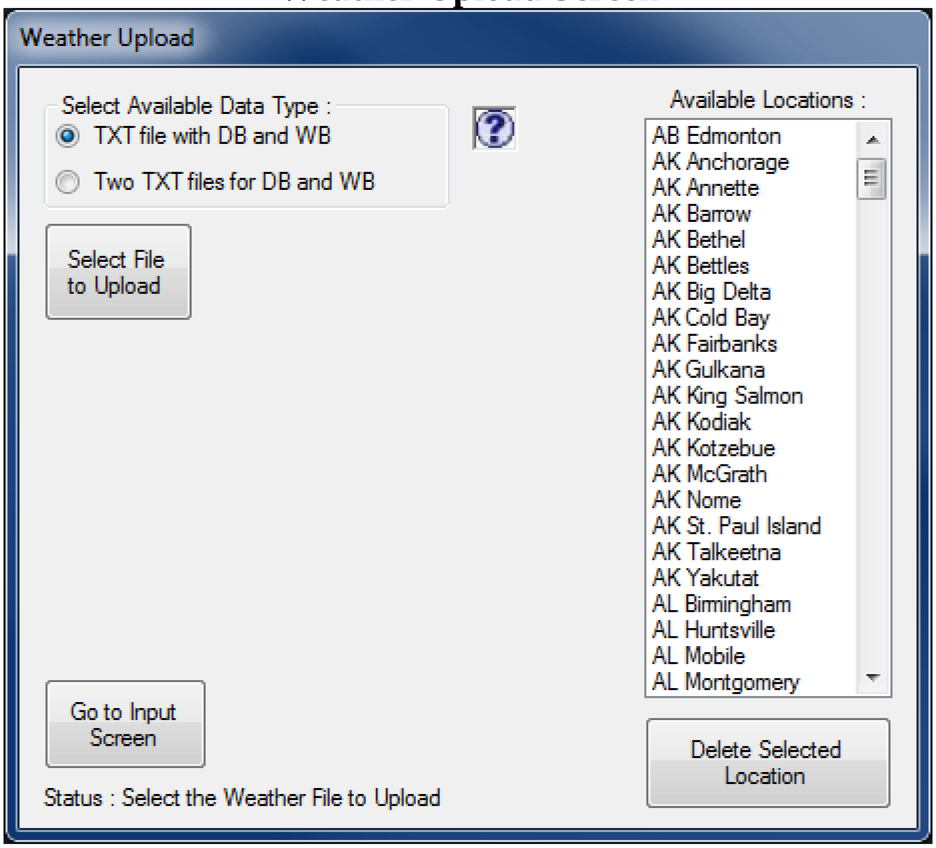
$0.060/kWh. If you have different peak and off-peak rates and/or substantial demand charges, use the average $/kWh value.

Natural Gas Cost ($/MMBtu) Enter the natural gas cost in the text box. Click on the text box to move the cursor and type in the value with the keyboard. The default value is $6.00/MMBtu.

If you are satisfied with the selections, click the OK command button to lock in the values and make the GO TO OPERATING SCHEDULE command button appear.

The two useful windows of "Upload New Geographical Location" and "Define Chiller" can be accessed from the Input Screen from "Tools" dropdown menu.

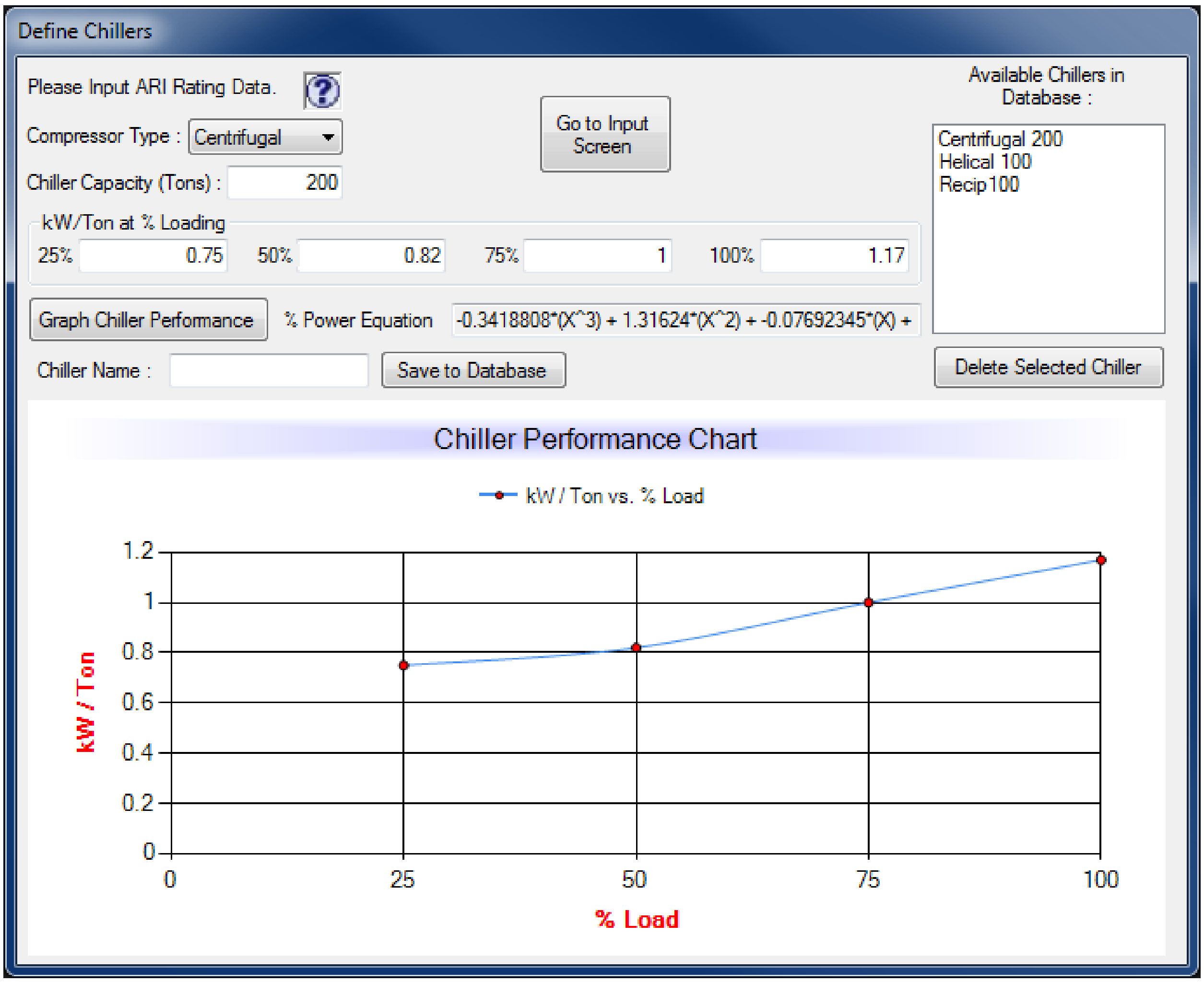
Weather Upload Screen



The purpose of this screen is to allow user to upload 8,760 hours of yearly weather data of any location to the tool database which can be used by selecting weather location on input screen for system analysis. The module can use either of two types of weather data files; one text file with both Dry-bulb (°F) and Wet-bulb (°F) data store in tab separated form and two text files, each contains Dry-bulb (°F) temperature and Wet-bulb (°F) temperature separately. The module reads and stores the uploaded file data assuming it starts from 1st hour of January; therefore make sure that the data arranged in such a manner. Once file read by the module without error, name the location and click UPLOAD FILE to save it to the tool database, which can be seen on the list of "Available Locations" on the right side of the screen. The location can also be deleted from this list by selecting the location and clicking DELETE SELECTED LOCATION. However, note that the original locations stored in the database cannot be deleted. Once the Upload task finishes, click GO TO INPUT SCREEN to return to the Input Screen.

Options:
TXT FILE WITH DB AND WB
TWO TXT FILE FOR DB AND WB
SELECT FILE TO UPLOAD
GO TO INPUT SCREEN
DELETE SELECTED LOCATION

Define Chillers Screen

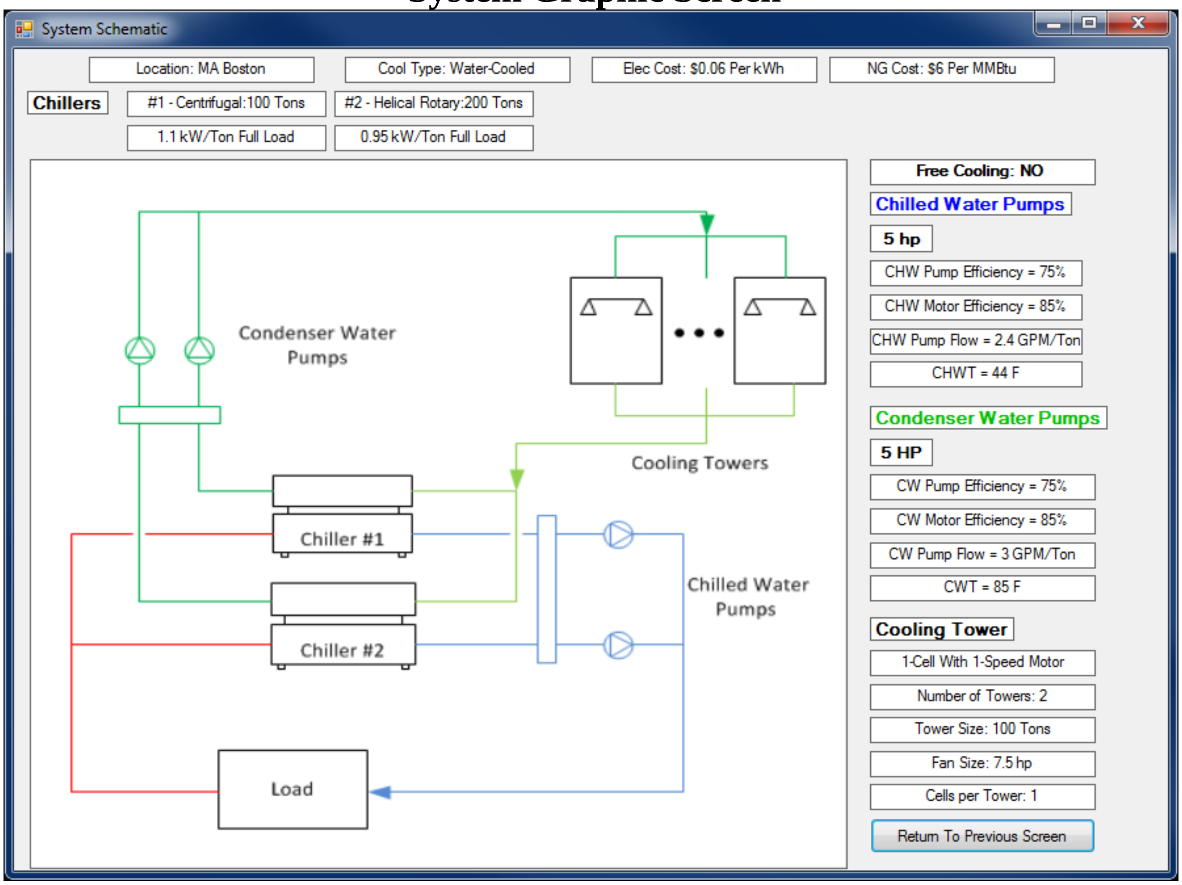


The purpose of this screen is to allow the user to define specific chiller performance and save it to the tool database which can be used by selecting the “Yes” radio button in the Current Chiller Data frame on the main input screen.

Select the compressor type in the drop-down box. Specify the Chiller Capacity (Tons). Specify efficiency values (kW/Ton) at 25%, 50%, 75% and 100% loadings as per ARI 550/590 Specification. Click the GRAPH CHILLER PERFORMANCE to generate performance curve of the chiller. The percentage power unloading equation and efficiency curve chart can be seen on the screen. Name the chiller and click SAVE TO DATABASE to save it to the tool database, which can be seen on the list of "Available Chillers in Database" on the right side of the screen. The chillers can also be deleted from this list by selecting the location and clicking DELETE SELECTED LOCATION. Once the Define Chiller task finishes, click GO TO INPUT SCREEN to return to the Input Screen.

Options:
SAVE TO DATABASE
GO TO INPUT SCREEN
DELETE SELECTED CHILLER

System Graphic Screen

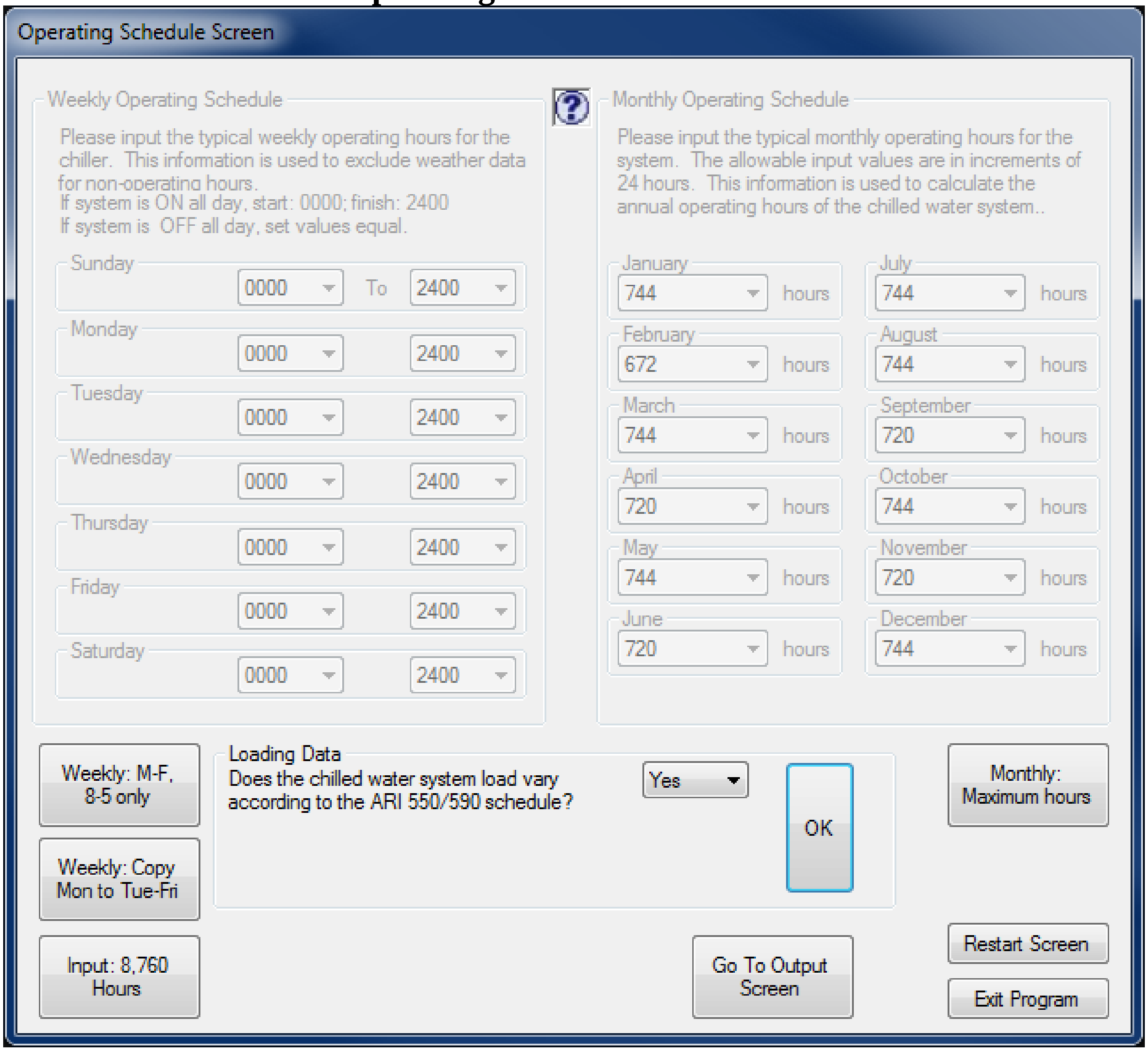


This screen shows a visual of the system as inputted, and can be used to verify the accuracy of the data.

Options:

RETURN TO PREVIOUS SCREEN

Operating Schedule Screen



The OPERATING SCHEDULE SCREEN represents the typical hours of the day and months of the year that the chilled water system will operate. Chilled water system energy consumption is a function of 1) the ambient conditions and 2) the cooling load placed on the system. The chilled water system operating schedule, in combination with the temperature data obtained from the Weather file addresses the first of these two factors. The second factor is addressed by the Loading Schedule Screen, or sufficient data may be obtained on the Operating Schedule Screen to estimate annual system loading. The Operating Schedule Screen is divided into three frames: the Weekly Operating Schedule frame, the Monthly Operating Schedule frame, and the Loading Data frame.

Options:
INPUT: Weekly: M-F, 8-5 only
INPUT: Weekly: Copy Mon to Tue-Fri

INPUT: 8,760 HOURS (Loads values for a year-round 24/7 application)
INPUT: Maximum Monthly Hours
GO TO OUTPUT SCREEN (this choice offered if loading follows ARI schedule)
GO TO LOADING SCHEDULE SCREEN (this choice offered if loading follows non-ARI schedule)
RESTART
EXIT

Enter the typical starting and stopping times for the chiller for each day of the week via the pull-down menus in the Weekly Operating Schedule frame. This information is used to remove non-operating daily hours from the temperature data. After seven starting times and seven stopping times are provided, the Monthly Operating Schedule frame appears.

Click on “Weekly M-F 8-5 only” to quickly input some typical working hours. Alternatively, enter desired hours for Monday and then click on “Weekly: Copy Mon to Tue-Fri” to copy those values to the rest of the workweek.

Enter the number of operating hours for each month of the year via the pull-down menus in the Monthly Operating Schedule frame. To simplify data entry, the input value is limited to increments of 24-hours. This information is used to remove non-operating seasonal hours from the temperature data.

Click on “Maximum Monthly Hours” to quickly input those data.

The Loading Data frame acquires yes or no responses to questions about the chiller loading scheme employed by the chilled water system. This information is used to customize the Loading Schedule Screen or to allow you to skip the Loading Schedule Screen altogether.

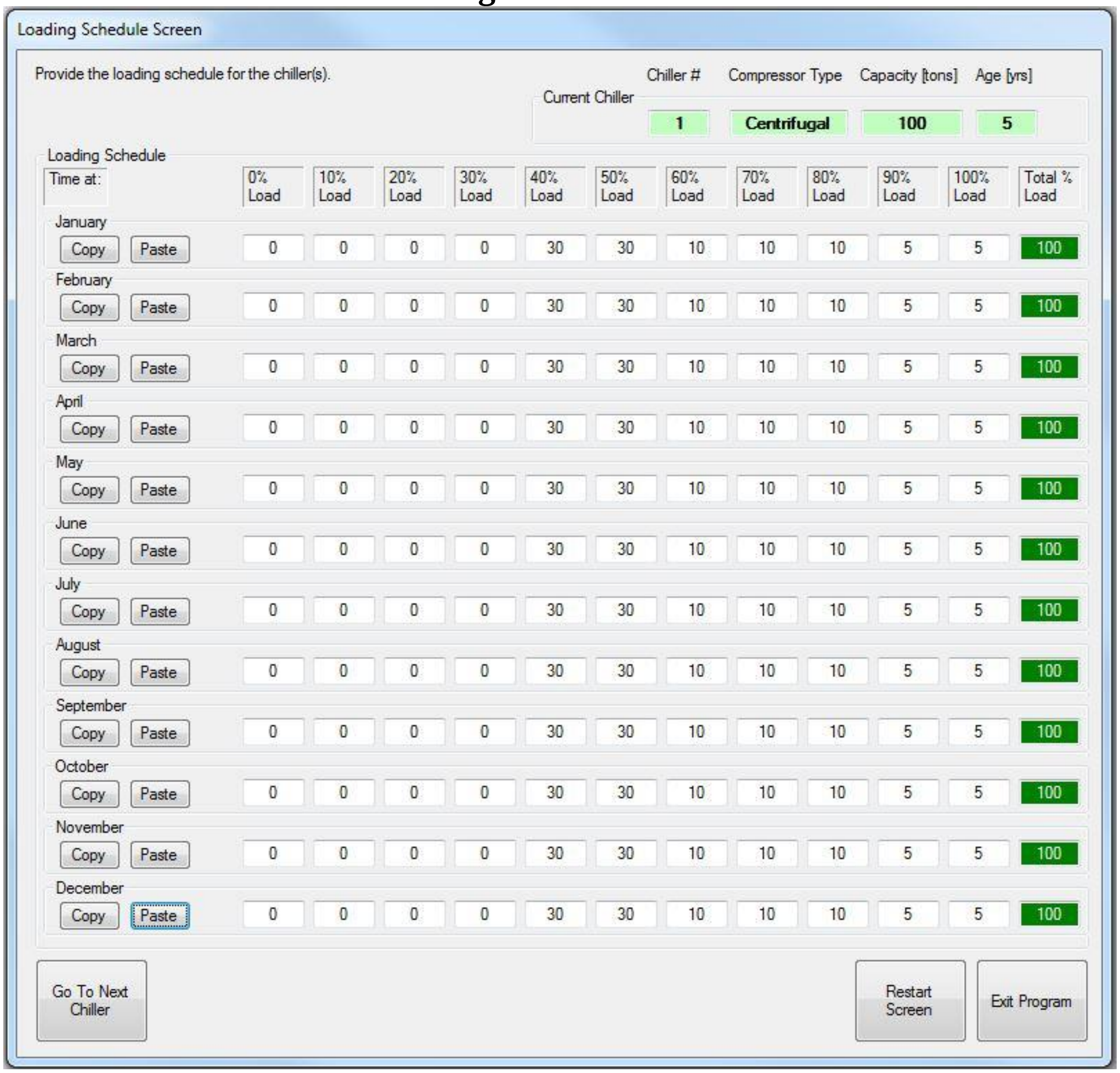
Does the chilled water system operate according to the ARI 550/590 schedule? The Air-Conditioning and Refrigeration Institute (ARI) has developed a typical load profile for chillers used in air-conditioning applications. If the chilled water system is used primarily for this application, select “Yes” from the pull-down menu. The two remaining questions are bypassed and the OK command button appears within the frame. Click the OK command button to make the GO TO OUTPUT SCREEN command button visible. Select “No” from the pull-down menu if you wish to enter the loading schedule yourself.

Does chiller loading vary from month to month? This question is relevant to systems that operate seasonally. Select either “Yes” or “No” from the pull-down menu.

Does chiller loading vary from chiller to chiller? This question is relevant for multi-chiller systems that operate for extended periods with unequal chiller loading. If the system employs only one chiller, this question will not appear. Select either “Yes” or “No” from the pull-down menu.

After responses to the relevant questions are recorded, the OK command button appears within the frame. Click the OK command button to make the GO TO LOAD SCHEDULE SCREEN command button appear.

Loading Schedule Screen



Time at:		0% Load	10% Load	20% Load	30% Load	40% Load	50% Load	60% Load	70% Load	80% Load	90% Load	100% Load	Total % Load
January	Copy Paste	0	0	0	0	30	30	10	10	10	5	5	100
February	Copy Paste	0	0	0	0	30	30	10	10	10	5	5	100
March	Copy Paste	0	0	0	0	30	30	10	10	10	5	5	100
April	Copy Paste	0	0	0	0	30	30	10	10	10	5	5	100
May	Copy Paste	0	0	0	0	30	30	10	10	10	5	5	100
June	Copy Paste	0	0	0	0	30	30	10	10	10	5	5	100
July	Copy Paste	0	0	0	0	30	30	10	10	10	5	5	100
August	Copy Paste	0	0	0	0	30	30	10	10	10	5	5	100
September	Copy Paste	0	0	0	0	30	30	10	10	10	5	5	100
October	Copy Paste	0	0	0	0	30	30	10	10	10	5	5	100
November	Copy Paste	0	0	0	0	30	30	10	10	10	5	5	100
December	Copy Paste	0	0	0	0	30	30	10	10	10	5	5	100

The loading schedule represents the fraction of the operating hours spent at a given loading condition, where the loading of a chiller is specified as the fraction of rated cooling provided. The loading fraction combined with the number of hours the chiller provides this level of cooling constitutes a loading schedule. The appearance of the Loading Schedule Screen is determined by the responses to the questions posed in the Loading Data frame of the Operating Schedule Screen. If the loading schedule varies by month, then input text boxes are provided for each month rather than just a single representative frame. If the loading schedule varies by chiller, then data must be entered in chiller-specific frames. Further, an additional frame appears containing a description of the current chiller.

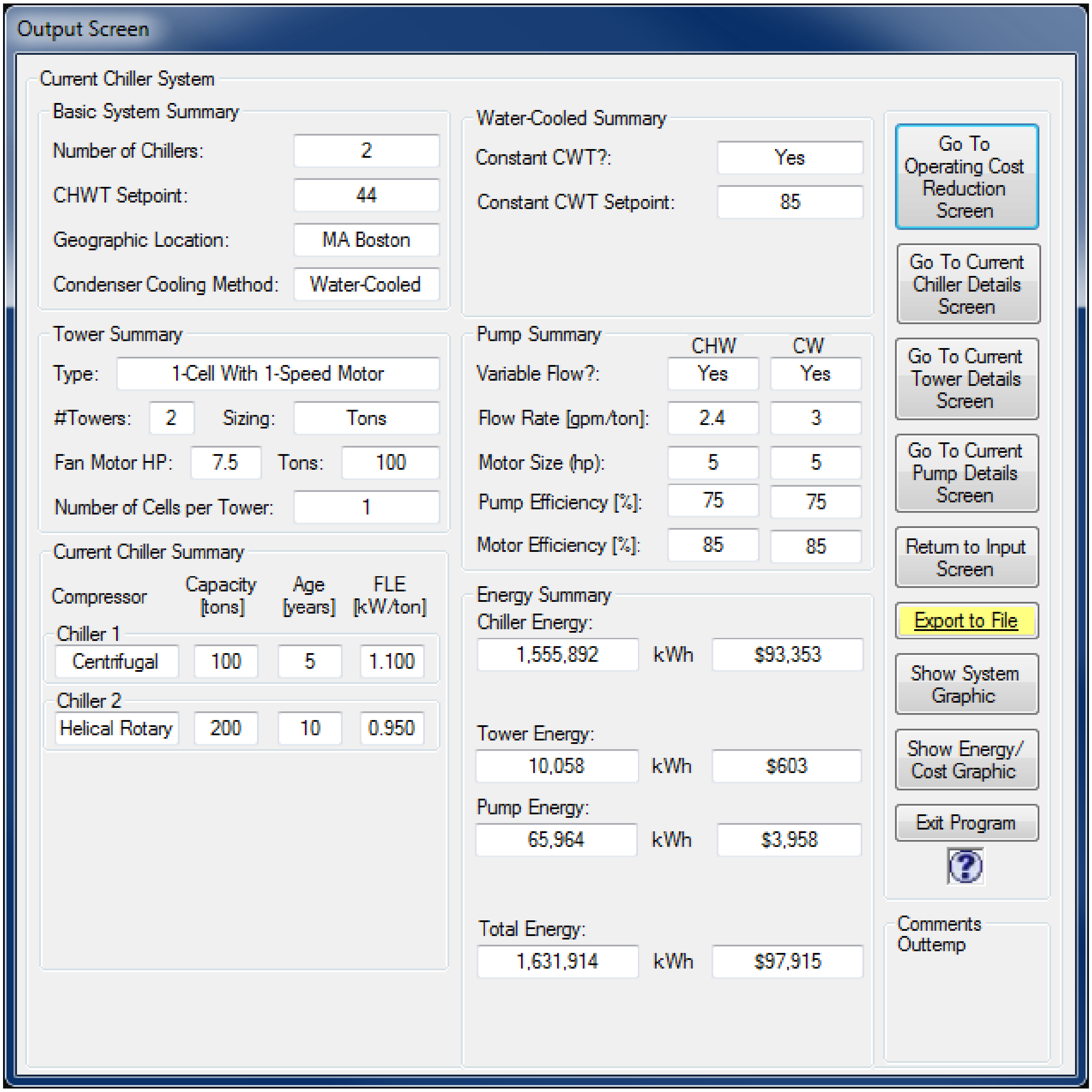
Options:

GO TO NEXT CHILLER (If chiller loading varies from chiller to chiller)
GO TO OUTPUT SCREEN
COPY
PASTE
RESTART
EXIT
Enter the percentage of hours at a given load (and during a given month if appropriate) by clicking on the text box to move the cursor and typing in an integer value between 0 and 100. The values you enter are added across columns. Make sure the total is 100% for all the rows. The background color of the Total % Load is green for 100% of the % Load sum across columns and red if not.

To duplicate one month's loading data to other months, click "Copy" at the row of the month to be copied and "Paste" at the row(s) to copy to.

If loading varies by chiller, click the GO TO NEXT CHILLER command button to advance to the next chiller frame. Clicking the GO TO NEXT CHILLER command button after the last chiller makes the GO TO OUTPUT SCREEN command button appear. Click the GO TO OUTPUT SCREEN command button to hide the Loading Schedule Screen and show the Output Screen.

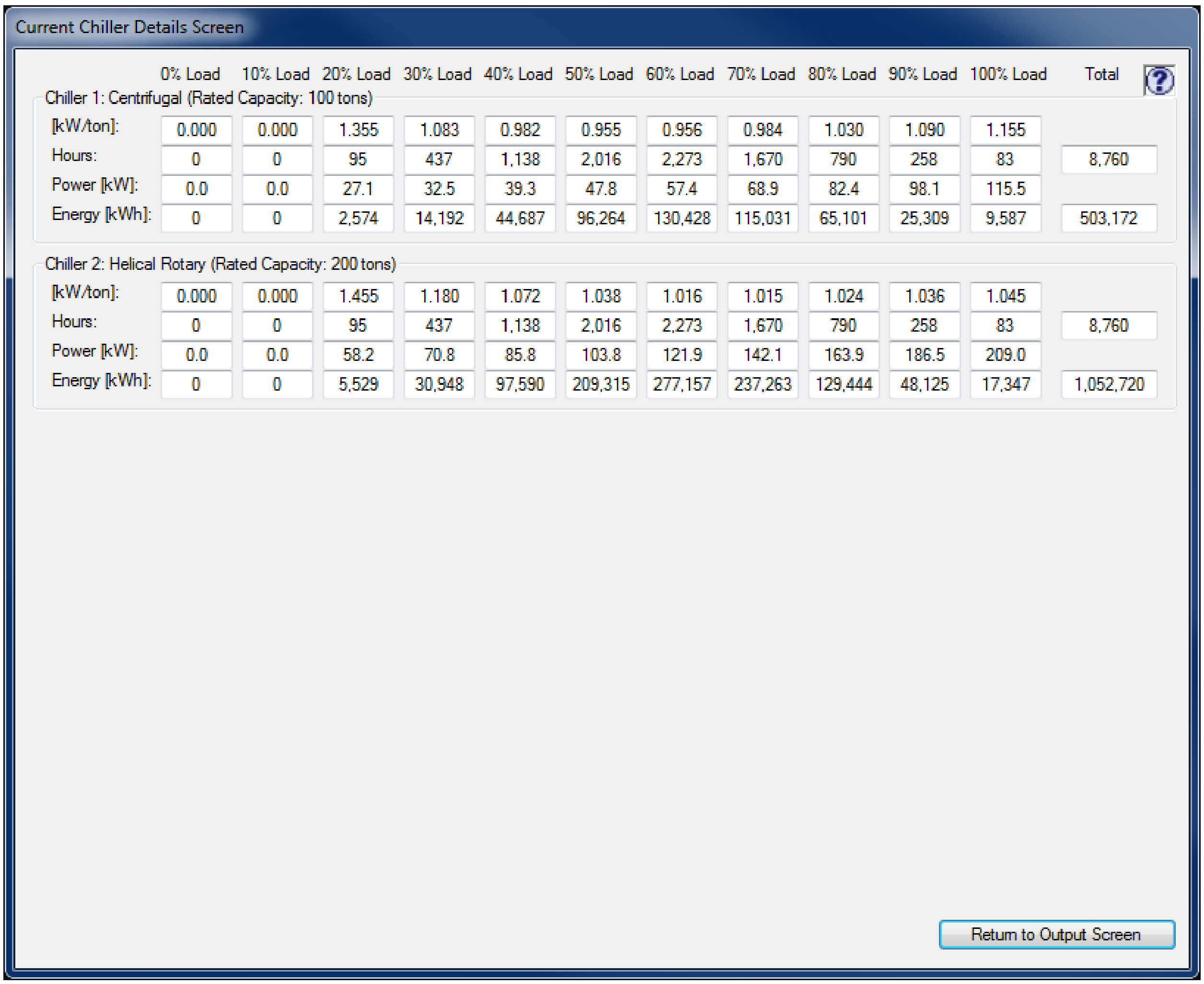
Output Screen



The output data is presented on the Output Screen. The screen is reached by clicking the GO TO OUTPUT SCREEN command button on the Operating Schedule Screen or the Loading Schedule Screen. The frames presented on the Output Screen summarize the input data provided on the Input Screen, and an estimate of the energy consumption of the chilled water system. Displaying these values along with the energy consumption information contained in the Energy Summary frame assist in the interpretation of the results of the analysis. The Energy Summary frame includes the energy for each system component (chillers, tower if applicable, and pumps) and a total for the system. The costs associated with these values are also shown. The command buttons at the bottom of the screen provide your options as to how to proceed.

Options:
GO TO OPERATING COST REDUCTION SCREEN
GO TO CURRENT CHILLER DETAILS SCREEN
GO TO CURRENT TOWER DETAILS SCREEN (If the chillers are water-cooled)
GO TO CURRENT PUMP DETAILS SCREEN
RETURN TO INPUT SCREEN
SHOW SYSTEM GRAPHIC
SHOW ENERGY / COST GRAPHIC
EXPORT TO FILE (Copy the output values to a text file)
HELP
EXIT

Current Chiller Details Screen



Chiller 1: Centrifugal (Rated Capacity: 100 tons)

	0% Load	10% Load	20% Load	30% Load	40% Load	50% Load	60% Load	70% Load	80% Load	90% Load	100% Load	Total
[kW/ton]:	0.000	0.000	1.355	1.083	0.982	0.955	0.956	0.984	1.030	1.090	1.155	
Hours:	0	0	95	437	1,138	2,016	2,273	1,670	790	258	83	8,760
Power [kW]:	0.0	0.0	27.1	32.5	39.3	47.8	57.4	68.9	82.4	98.1	115.5	
Energy [kWh]:	0	0	2,574	14,192	44,687	96,264	130,428	115,031	65,101	25,309	9,587	503,172

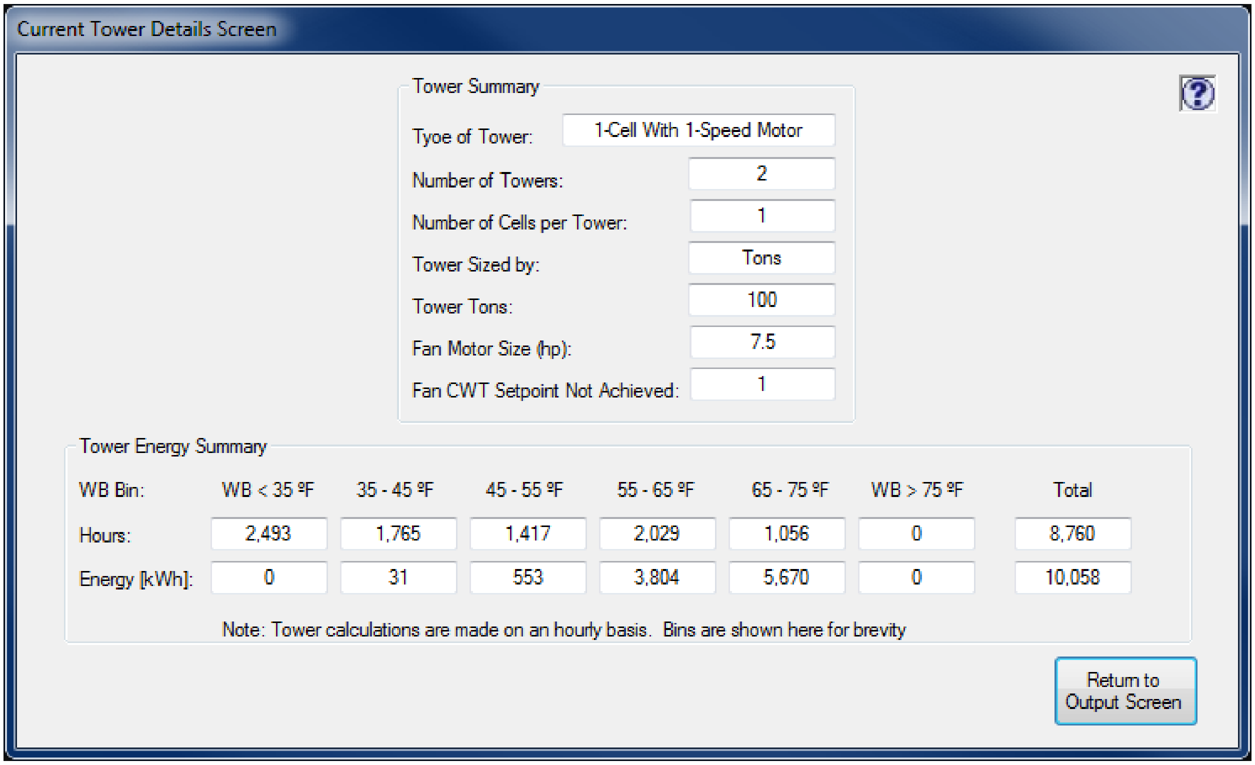
Chiller 2: Helical Rotary (Rated Capacity: 200 tons)

	0% Load	10% Load	20% Load	30% Load	40% Load	50% Load	60% Load	70% Load	80% Load	90% Load	100% Load	Total
[kW/ton]:	0.000	0.000	1.455	1.180	1.072	1.038	1.016	1.015	1.024	1.036	1.045	
Hours:	0	0	95	437	1,138	2,016	2,273	1,670	790	258	83	8,760
Power [kW]:	0.0	0.0	58.2	70.8	85.8	103.8	121.9	142.1	163.9	186.5	209.0	
Energy [kWh]:	0	0	5,529	30,948	97,590	209,315	277,157	237,263	129,444	48,125	17,347	1,052,720

The Current Chiller Details Screen shows chiller efficiency, hours, power, and energy for each chiller at loads of 0% to 100% of rated capacity in increments of 10%. The total annual operating hours and energy consumption are also shown. The caption of each chiller frame is updated with the chiller number, compressor type and capacity for clarity. The screen is useful for reviewing the energy consumption values used to determine the totals shown on the Output Screen. After reviewing the data, you may click the RETURN TO OUTPUT SCREEN command button.

Options:
RETURN TO OUTPUT SCREEN
HELP

Current Tower Details Screen

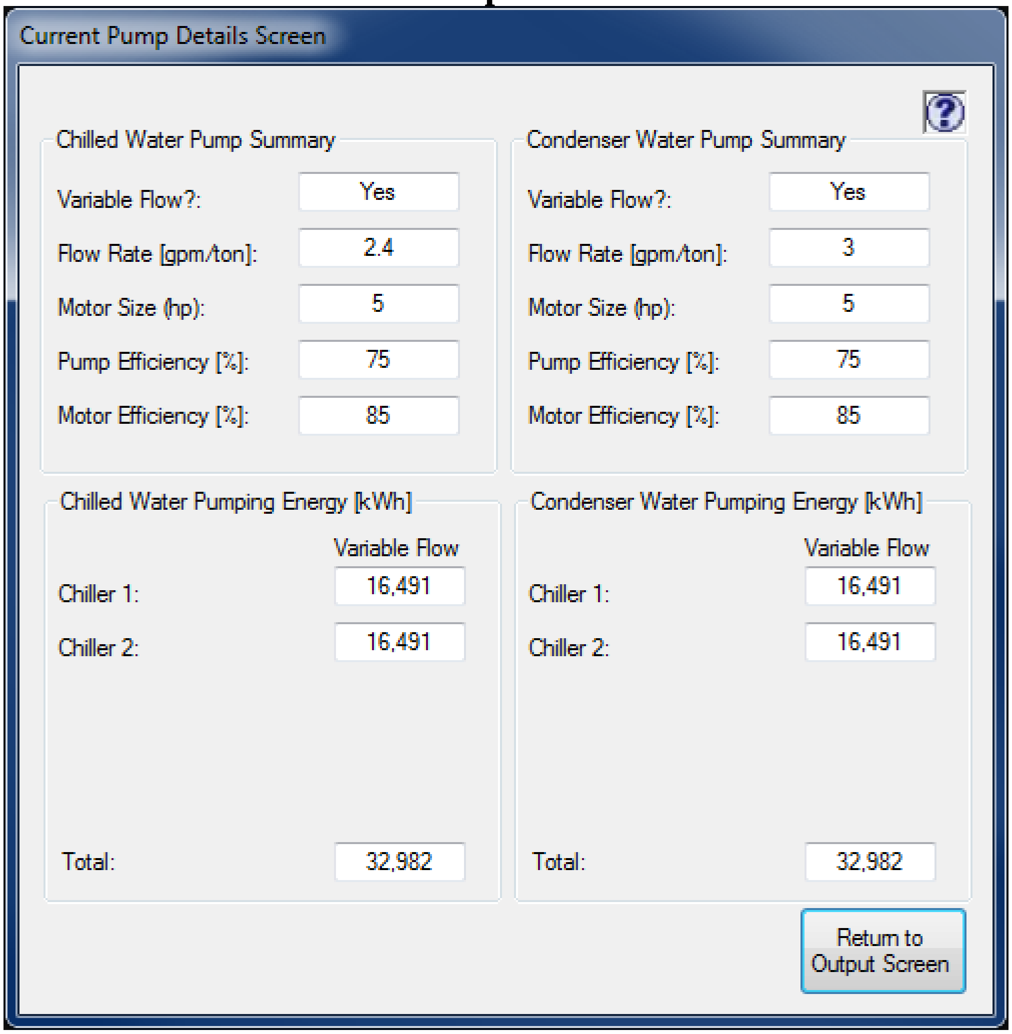


The Current Tower Details Screen contains two frames showing the tower specifications from the Input Screen and the hours of operation and energy consumed by the tower at various ambient wet-bulb temperatures. To simplify the display, the hours and energy values are grouped into “bins”. Six bins are used, namely “WB < 35ºF, “35 – 45ºF”, “45 – 55ºF”, “55 – 65ºF”, “65 – 75ºF”, and “WB > 75ºF”. The total hours of operation and the total energy consumed by the tower(s) are also displayed. It is noted that the calculations used to arrive at the values are completed using bins of 1ºF. The 10ºF bins are used only to reduce the amount of information to be displayed. The Current Tower Details Screen is useful for reviewing the energy consumption values used to determine the values displayed on the Output Screen. After reviewing the data, click the RETURN TO OUTPUT SCREEN command button. It is noted that the tool uses weighted average tower tonnage for hourly calculation in multi-tower configuration. Therefore, for different tower or fan size in the same chilled water system, user has to specify the average size of the fan in the Tower Data Frame in the Input Screen. This will affect the accuracy of the tower calculations based on the input.

Options:

RETURN TO OUTPUT SCREEN
HELP

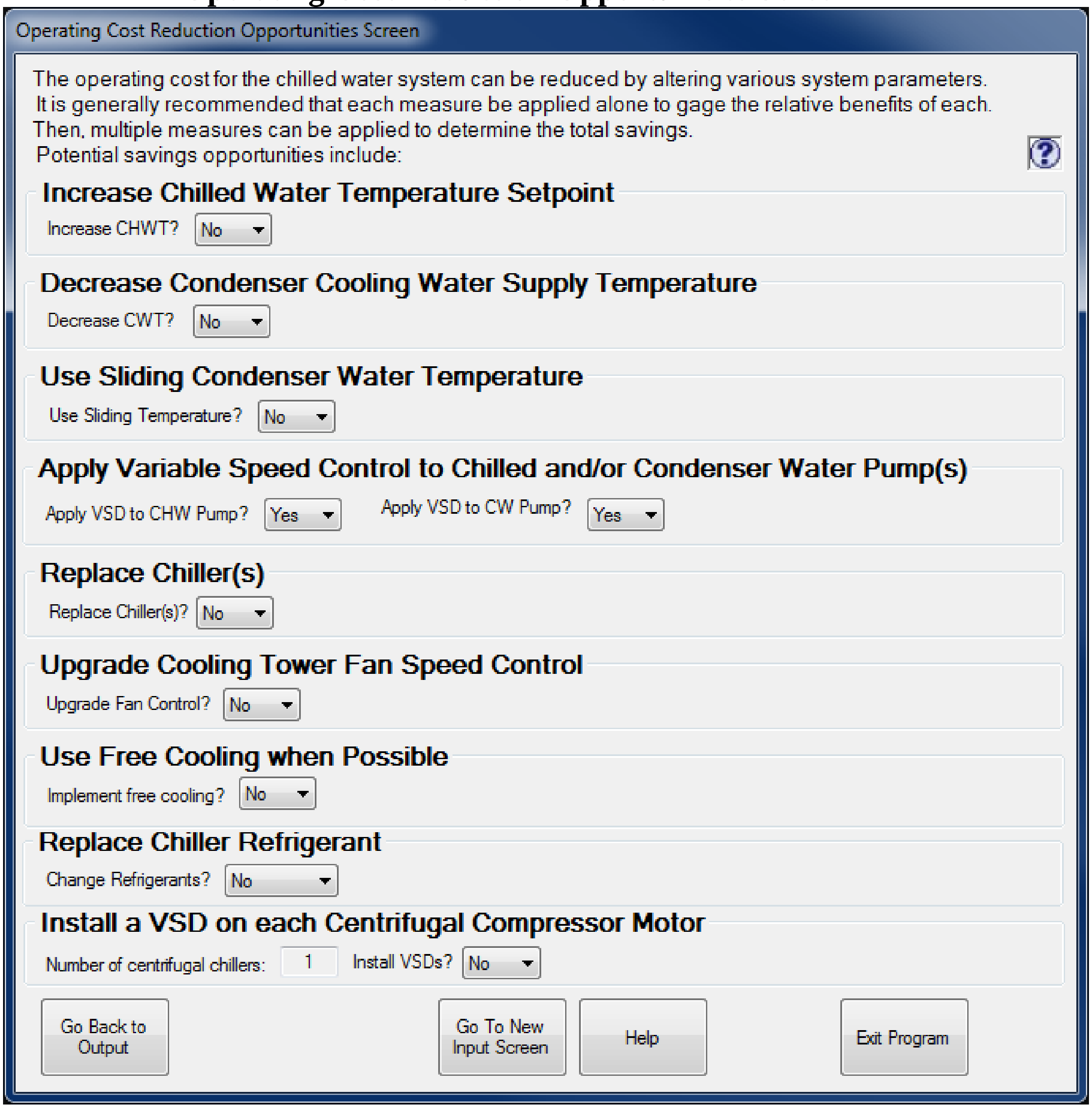
Current Pump Details Screen



The Current Pump Details Screen displays two frames for each pumping loop. If the chillers in the system have air-cooled condensers, the two frames for displaying condenser water loop information are not shown. For each of the pumping loops, the first frame echoes the pumping specifications provided on the Input Screen. The values displayed include whether the pump flow varies with chiller load, the pump flow rate, the pump efficiency, and the pump motor efficiency. The second frame provides the pumping energy estimate for each chiller and the total pumping energy for the pumping loop. The Current Pump Details Screen is useful for reviewing the energy consumption values used to determine the value displayed on the Output Screen. After reviewing the data, click the RETURN TO OUTPUT SCREEN command button. The pump energy calculation routine finds the next higher motor size from the size estimated by assuming same size of pump per chiller is utilized in multi-chiller configuration. The size estimation if motor size is unknown is calculated considering the pump flow rate provided by user, 30 feet of static head and pump efficiency. The motor size either provided by user or estimated from the routine is used to find the input power to the motor considering motor efficiency.

Options:
RETURN TO OUTPUT SCREEN
HELP

Operating Cost Reduction Opportunities Screen



The Operating Cost Reduction Opportunities Screen describes cost reduction measures. The screen contains several frames, each representing a specific cost reduction measure. The measures are increasing the chilled water temperature, decreasing the condenser water temperature, use sliding condenser water temperature, replacing the chillers, applying variable speed control to the circulation pump motors, and upgrading the tower motor controls to 2-speed or variable speed, replacing the chiller refrigerant, installing a variable speed drive on each centrifugal compressor and using free cooling. The visible frames are dependent on the characteristics of the chilled water system. For example, the frame titled Install a VSD on each Centrifugal Compressor Motor only appears if one or more of the chillers has a centrifugal compressor. Similarly, the frame titled Use Free Cooling When Possible appears only for water-cooled systems (i.e. systems with a cooling tower). Also, selecting a sliding condenser water temperature, hides the decrease condenser water temperature, and vice versa.

Options:
GO TO NEW INPUT SCREEN
GO BACK TO OUTPUT
HELP
EXIT PROGRAM

1. Increase Chilled Water Temperature

In certain systems, it may be possible to raise the chilled water temperature without any negative results. For example, in some industrial settings chilled water flow is throttled to reduce the flow rate for a particular process. Instead of reducing the flow via valve control, significant energy savings may be possible if the full flow is used, but at an increased temperature. In this case, the amount of cooling provided by the chilled water can remain unchanged. A new chilled water supply temperature results in new chiller efficiency (kW/ton) for each load point. Raising the chilled water temperature set point 1°F typically saves 1% to 2% of the chiller compressor energy.

2. Decrease Condenser Water Temperature

NOTE: When selecting to decrease the condenser water temperature, using a sliding condenser water temperature cannot be used and vice versa.

Lowering the condenser temperature results in less energy required in the compression cycle. In water cooled systems, lowering the temperature is accomplished by increasing the speed of the cooling tower fans or by increasing the number of cooling tower fans running, both of which increase cooling tower energy usage. In air-cooled systems, lowering the condenser temperature is accomplished by operating the cooling fans more frequently. There is a greater potential for condenser temperature reduction in water cooled systems since the condenser cooling water temperature leaving the tower approaches the ambient wet-bulb while the air-cooled temperature approaches the outdoor dry-bulb temperature. At typical design conditions, a chiller will consume five to ten times as much energy as the cooling tower and therefore trading increased cooling tower energy for more efficient chiller operation is frequently justified.

3. **Use Sliding Condenser Water Temperature**

   NOTE: When using a sliding condenser water temperature you can not select the decrease condenser water option and vice versa.

   Using sliding condenser water temperature allows the condenser water to vary according to the outside wet-bulb temperature. The program uses a "following temperature differential" which is the difference between the condenser cooling water temperature achieved and the wet-bulb temperature of the air entering the cooling tower. The closer the condenser water temperature approaches the air wet-bulb temperature through evaporation in the cooling tower, the more efficiently the chiller will operate.

4. **Apply VSDs to System Pumps**

   Typically, chilled water systems are designed for constant chilled and condenser water flow rates, usually 2.4 gpm/ton and 3.0 gpm/ton respectively. In some cases, however, the chiller design allows variation of the chilled and/or condenser water flow rates with chiller load. This variation may result in significant pumping energy reductions. For example, reducing the condenser water flow rate from 3.0 gpm per ton to 2.0 gpm per ton will reduce pumping energy by 25% to 30% in a typical system. Applying VSDs to the chilled water supply pumps and condenser water pumps gives significant energy savings if the chiller can accommodate variable water flow rates.

5. **Replace Chiller(s)**

   A chiller's FLE decreases with age while advancement in technology may offer some more efficient chiller systems. This option can be used to compare the current chilled water system with the replacement of either the same type of chiller or with a different type of chiller.

6. **Upgrade Cooling Tower Fan Speed Control**

   In cooling towers with single speed motors, fans often operate at higher speeds than required. According to the fan affinity laws, fan motor power has a cubic relationship with fan motor speed. This cubic relationship between power and speed implies that small reductions in fan speed will result in much larger reduction in motor power. A cooling tower with high flexibility in matching fan speed to actual air flow requirements, such as towers with 2-speed or variable speed fans, will minimize power and thus energy consumption.

7. **Use Free Cooling**

   During low outdoor wet-bulb conditions or low system loads, it may be possible to shut down the chiller loop and use cooling tower water exclusively to provide the necessary process cooling. The potential for free cooling is dependent on the temperature difference between the supply of cooling water from the tower and the temperature of water to be cooled. A typical cooling tower is capable of cooling the entering water to within 5-10ºF of the outdoor wet-bulb temperature. The energy savings from this measure can be significant depending on the amount of cooling required during times of the year when the outside temperature is low. The addition of a heat exchanger between the tower loop and the chilled water loop may be required to avoid contamination of the chilled water system

8. Replace Chiller Refrigerant

The cost reduction frame located in the left-center region of the screen is called Replace Chiller Refrigerant. Older chillers frequently use refrigerant that is being phased out of use, and replacement refrigerants may have different performance characteristics than the current refrigerant.

If you wish to consider the impact of replacing the refrigerant, select "Yes" from the pull-down menu located beside the prompt "Change Refrigerants?" The default value is "No". If the response is "Yes", the prompt "Current Refrigerant?" appears along with a pull-down menu. Select a refrigerant name from the pull-down menu. The seven supported refrigerants are R-11, R-12, R-123, R-134a, R-22, and R-717. After a refrigerant is selected, the prompt "Proposed Refrigerant?" appears along with a pull-down menu. Select a proposed refrigerant name from the pull- down menu. Note that all chillers cannot operate with all refrigerant types, and that replacing the refrigerant usually results in an increase in energy consumption for the chiller.

9. Install a VSD on each Centrifugal Compressor Motor

The cost reduction frame located in the lower left region of the screen is called Install a VSD on each Centrifugal Compressor Motor. Centrifugal chillers have been shown to operate more efficiently if cooling capacity control is achieved through the use of a variable speed drive, or VSD, on the compressor motor.

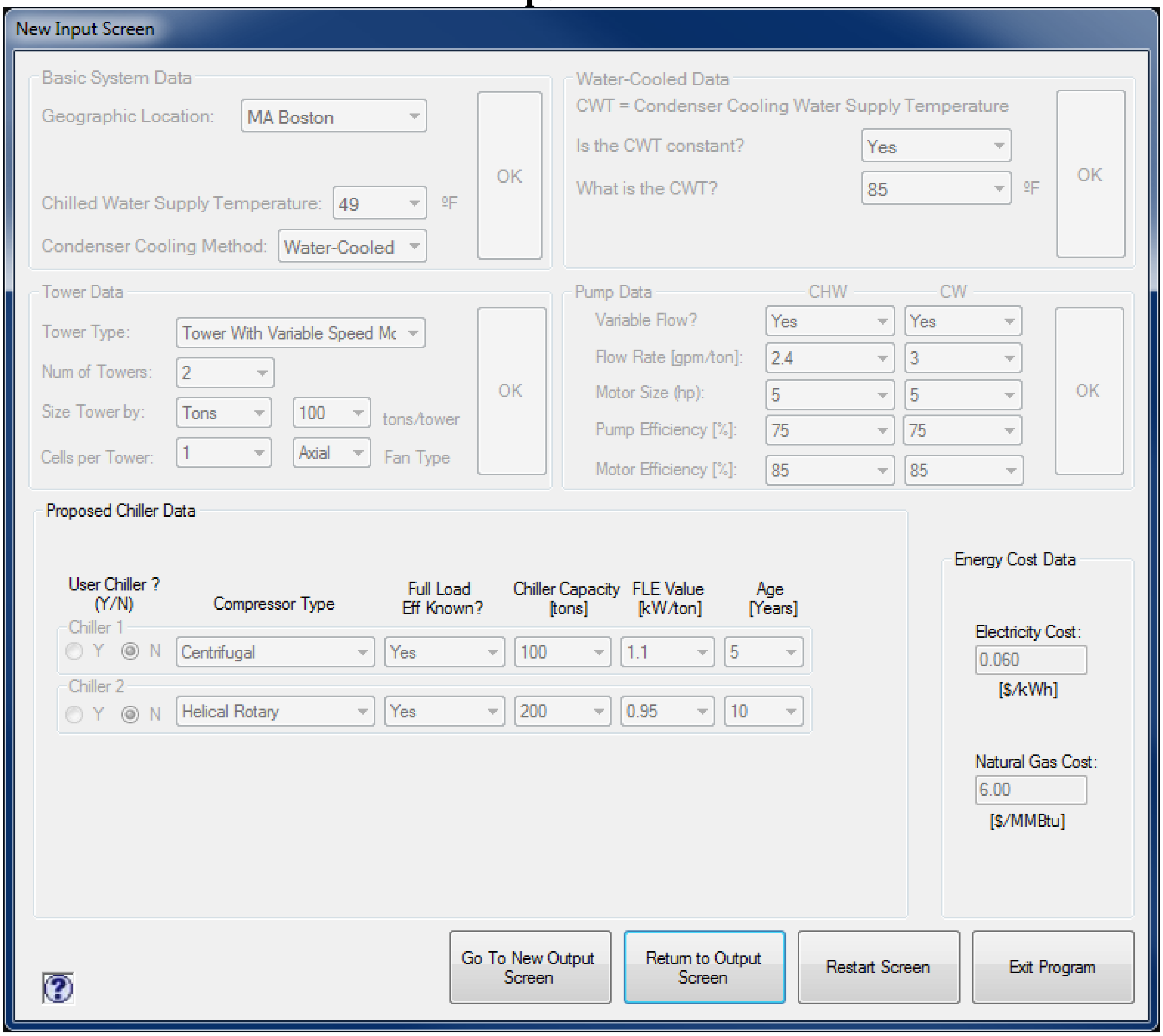
Within the frame, a text box provides the number of centrifugal chillers specified on the Input Screen. Below this text box, the prompt "Install VSDs?" appears along with a pull-down menu. If you wish to consider the impact of VSD control of centrifugal chillers, select "Yes" from the pull-down menu. The default value is "No".

10. Use Free Cooling When Possible

The cost reduction frame located in the lower right region of the screen is called Use Free Cooling When Possible. Free cooling, or tower cooling, is possible when the cooling tower alone can provide water at the desired chilled water temperature. Under these conditions, the chillers may be shut off to reduce energy consumption. This strategy is particularly effective at low loads or low ambient wet-bulb temperatures. In some cases, the chilled water stream must remain isolated from the atmosphere. In these cases, a heat exchanger must be used to transfer heat from the chilled water stream and that passing through the cooling tower. Note that the approach of the heat exchanger will decrease the number of hours that free cooling is possible.

If you wish to consider the impact of free cooling, select “Yes” from the pull-down menu located besides the “Implement free cooling?” prompt. The default value is “No”. If the response is “Yes”, the prompt “Heat exchanger required?” appears along with a pull-down menu. Select “Yes” or “No”. If the response is “Yes”, the prompt “HEX approach temperature?” appears along with a pull-down menu. The range of approach temperatures is 5 to 20 degrees Fahrenheit.

New Input Screen



The New Input Screen allows you to make changes to the information entered on the Input Screen. By running an analysis for the revised system, the energy consumption of the proposed system can be compared to that of the current system. The screen is very similar in appearance to the Input Screen; however several differences must be noted: 1) the Number of Chillers selection menu has been moved the Proposed Chiller Data frame, 2) the

Geographic Location and Condenser Cooling Method values cannot be changed, 3) you must choose whether the chillers should change or remain the same, 4) natural gas engine-driven centrifugal chillers may now be selected, and 5) the energy prices entered in the Energy Cost Data frame cannot be changed. All other inputs can be changed.

Options:
GO TO NEW OPERATING SCHEDULE SCREEN (If chillers are changed)
GO TO OUTPUT SCREEN (If chillers remain unchanged)
RESTART SCREEN
EXIT PROGRAM
HELP

The frames of the New Input Screen are viewed in sequential order. Review the data in each, make any changes using the pull-down menus, and click the OK command button to lock in the values and move on to the next frame.

When the Proposed Chiller Data frame appears, two command buttons will be shown:

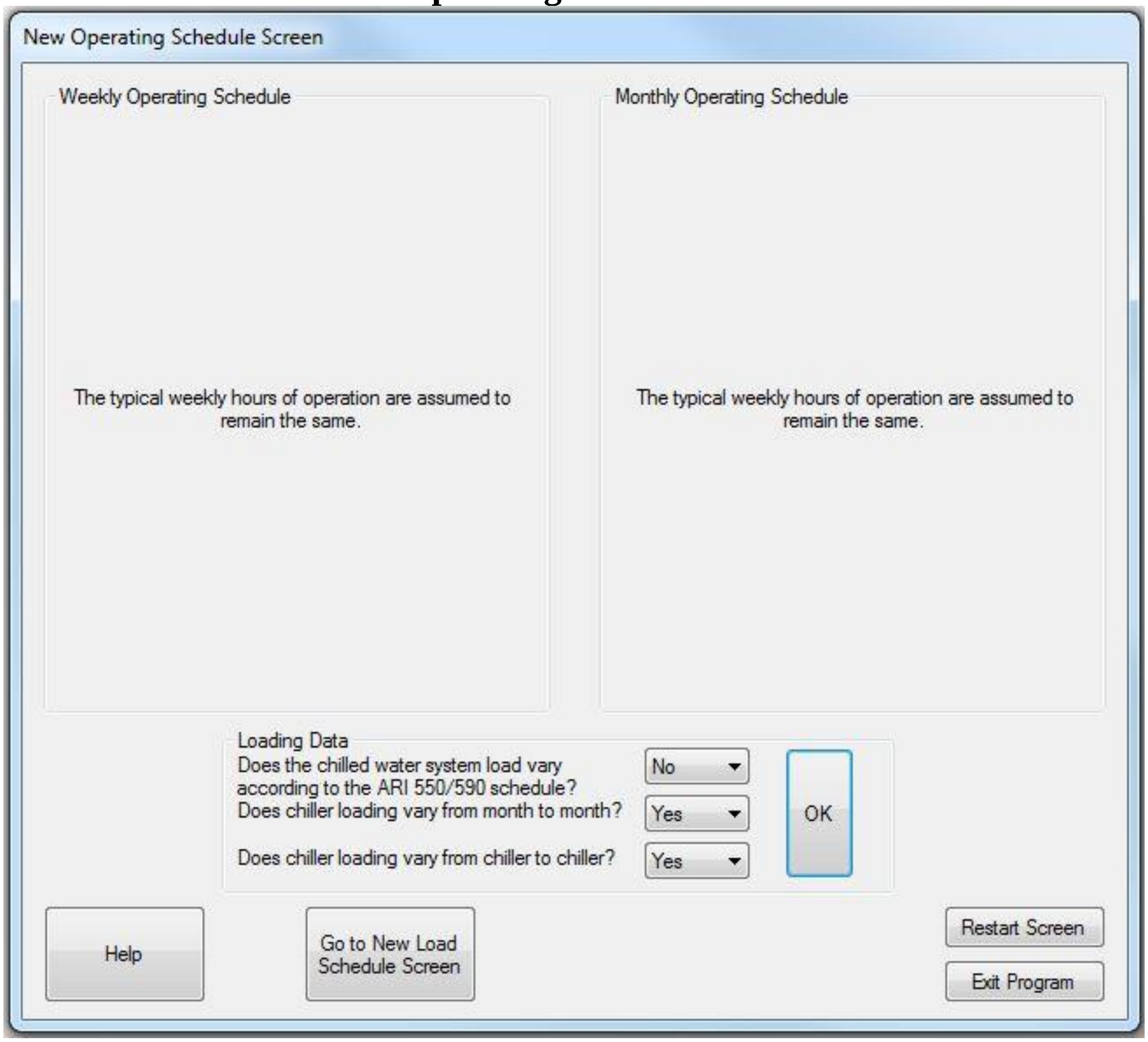
If you wish to leave the chillers unchanged:

Click the SAME CHILLER SELECTIONS command button. The OK command button and the previously selected chiller specifications will be shown. Click the OK command button. Because the chillers have not been changed, the chiller loading is assumed unchanged and the New Operating Schedule Screen and New Loading Schedule Screen will be bypassed. Click the GO TO NEW OUTPUT SCREEN command button.

If you wish to change the chiller specifications:

Clicking the NEW CHILLER SELECTIONS command button. Select the new Number of Chillers from the pull-down menu. The number of frames for entering new chiller data is dependent on the number of chillers selected. Select values describing the new chillers as you did in the Input Screen. It is noted that two new chiller types are available. Under the Compressor Type pull-down menu, the user may now choose natural gas engine-driven centrifugal chillers. The two types differ in that one uses heat recovery from the engine and the other does not; efficiencies of the two types vary slightly, with the "HR" type typically more efficient. The new variable values are specified as "NG Engine" and "NG Engine w/ HR". Click OK. Click the GO TO NEW OPERATING SCHEDULE SCREEN command button.

New Operating Schedule Screen

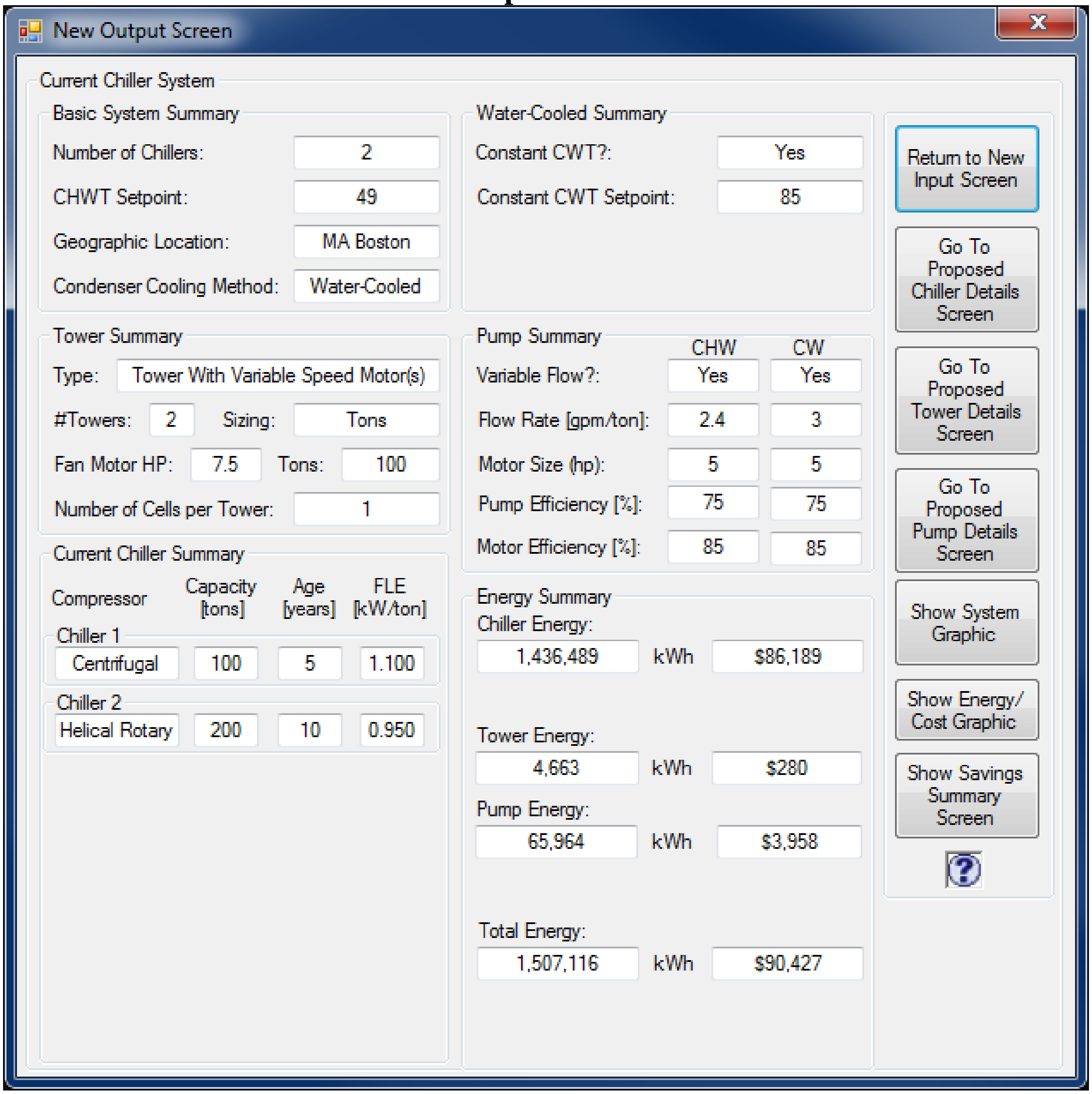


The New Operating Schedule Screen does not require you to enter weekly or monthly loading schedule information. The daily starting and finishing times and the annual hours of operation for the proposed system are assumed equal to those entered for the current system. If you wish to investigate the effect of schedule changes on energy consumption, run the program for each case. The Loading Data frame process is identical to that described in the Operating Schedule Screen section of this manual.

Options:
GO TO OUTPUT SCREEN (Chiller loading follows ARI schedule)
GO TO NEW LOAD SCHEDULE SCREEN
RESTART SCREEN
EXIT PROGRAM

The appearance and data entry process for the New Loading Schedule Screen is identical to that described in the Loading Schedule Screen section of this manual.

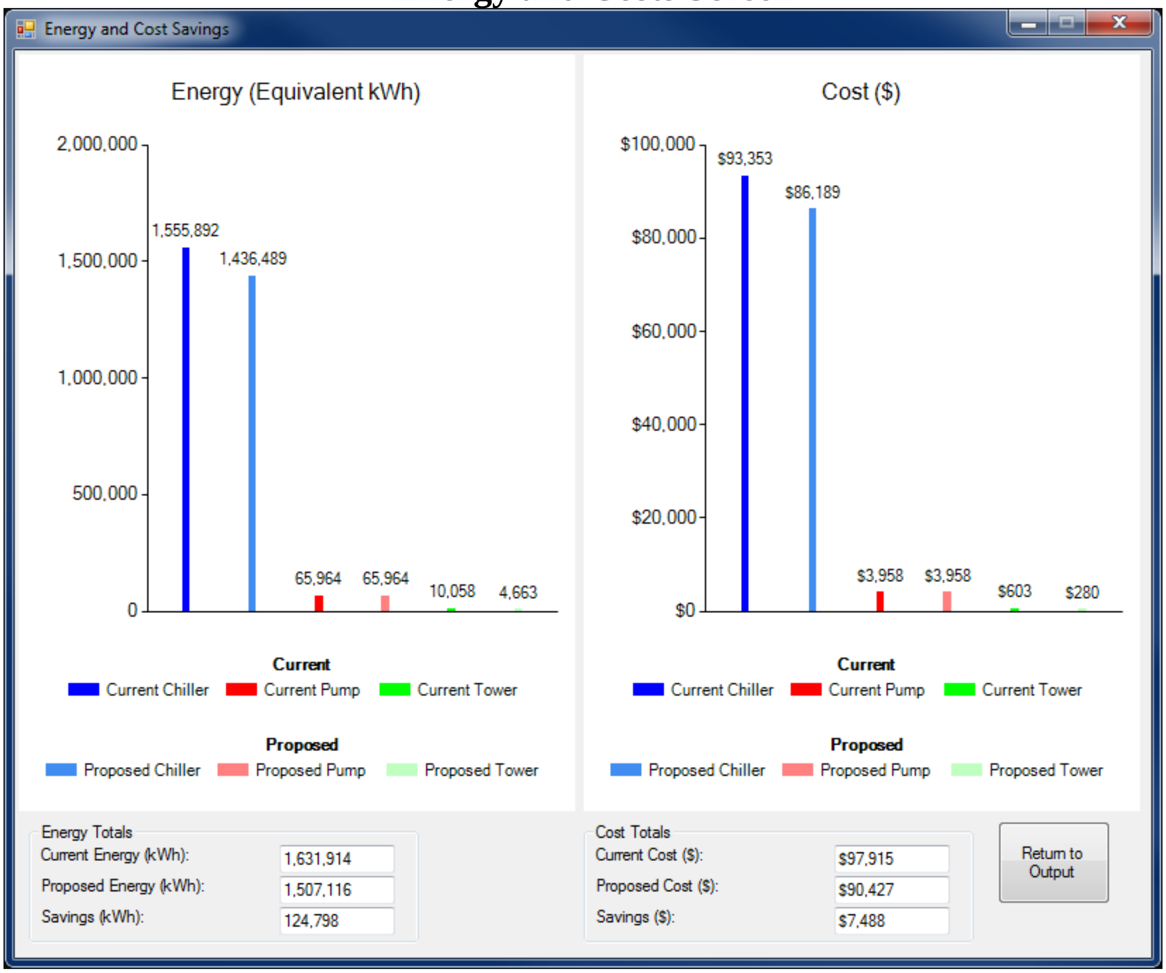
New Output Screen



The New Output Screen displays the results of the new energy analysis. The original Output Screen is displayed adjacent to the New Output Screen for comparison. The principal area of interest might be the “Energy Summary” frame. The main difference between the two screens is the addition of text boxes in the Energy Summary frame of the New Output Screen to accommodate natural gas engine-driven chillers. The RETURN TO NEW INPUT SCREEN command button restarts the data input process. With this button, you may investigate alternative operating cost reduction measures without reentering all of the current system information.

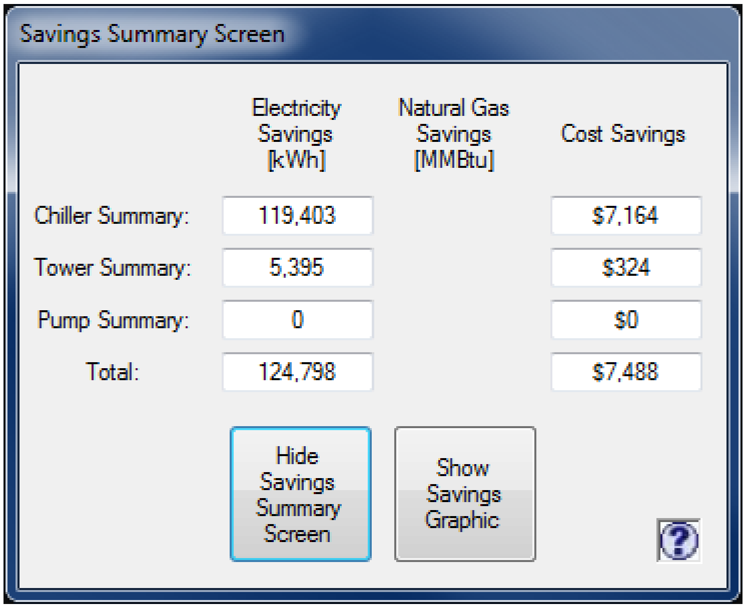
Options:
RETURN TO NEW INPUT SCREEN
GO TO PROPOSED CHILLER DETAILS SCREEN
GO TO PROPOSED TOWER DETAILS SCREEN (If the chillers are water-cooled)
GO TO PROPOSED PUMP DETAILS SCREEN
SHOW SAVINGS SUMMARY SCREEN
HELP

Energy and Costs Screen



This screen shows a “before and after” graphic of the system’s energy consumption and costs for each chiller and the combined pumps and towers. For each type of equipment, the darker-colored column to the left shows the system as originally specified, while the lighter column to the right shows the modified system. Note that all the data are “normalized”, or scaled, to fit the screen, so two completely different systems with greatly varying energy use and costs might visually appear similar, although of course the data shown would reflect their dissimilarity. Note also that, because of the aforementioned scaling, the column for, say, a tower, which typically uses much less energy than the chillers, could if properly scaled be so short as to be invisible. The program uses instead a minimum column height for such situations, so the displayed text should instead be relied upon to judge consumption.

Savings Summary Screen

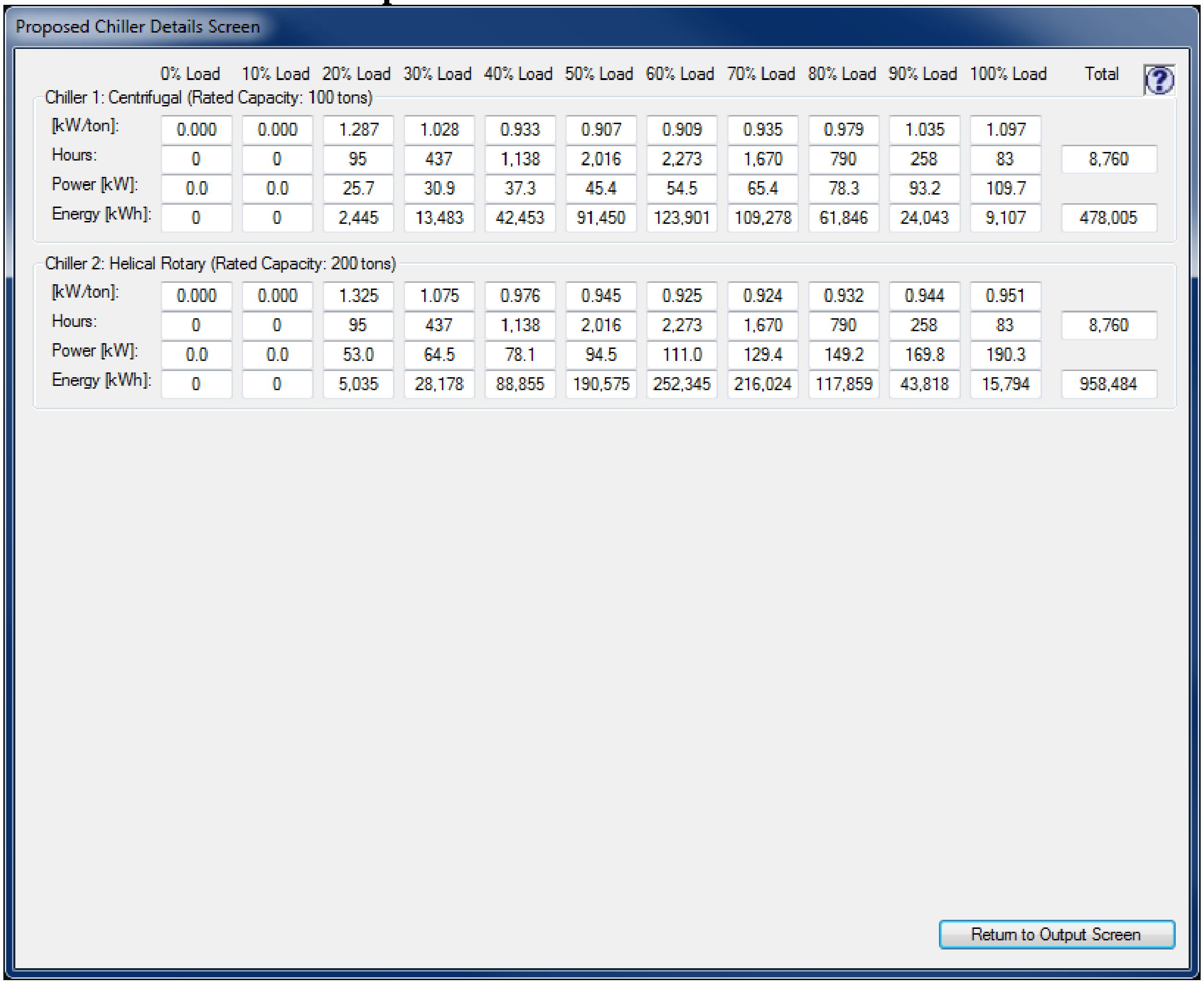


The Savings Summary Screen displays an energy and cost comparison between the current and proposed systems. The values shown are in the form of savings, meaning the values are positive if the proposed system uses less energy or has lower cost than the current system. The screen appears upon the loading of the New Output Screen.

It can be reloaded with the command button on the New Output Screen.

Options:
HIDE SAVINGS SUMMARY SCREEN
SHOW SAVINGS GRAPHIC
HELP

Proposed Chiller Details Screen

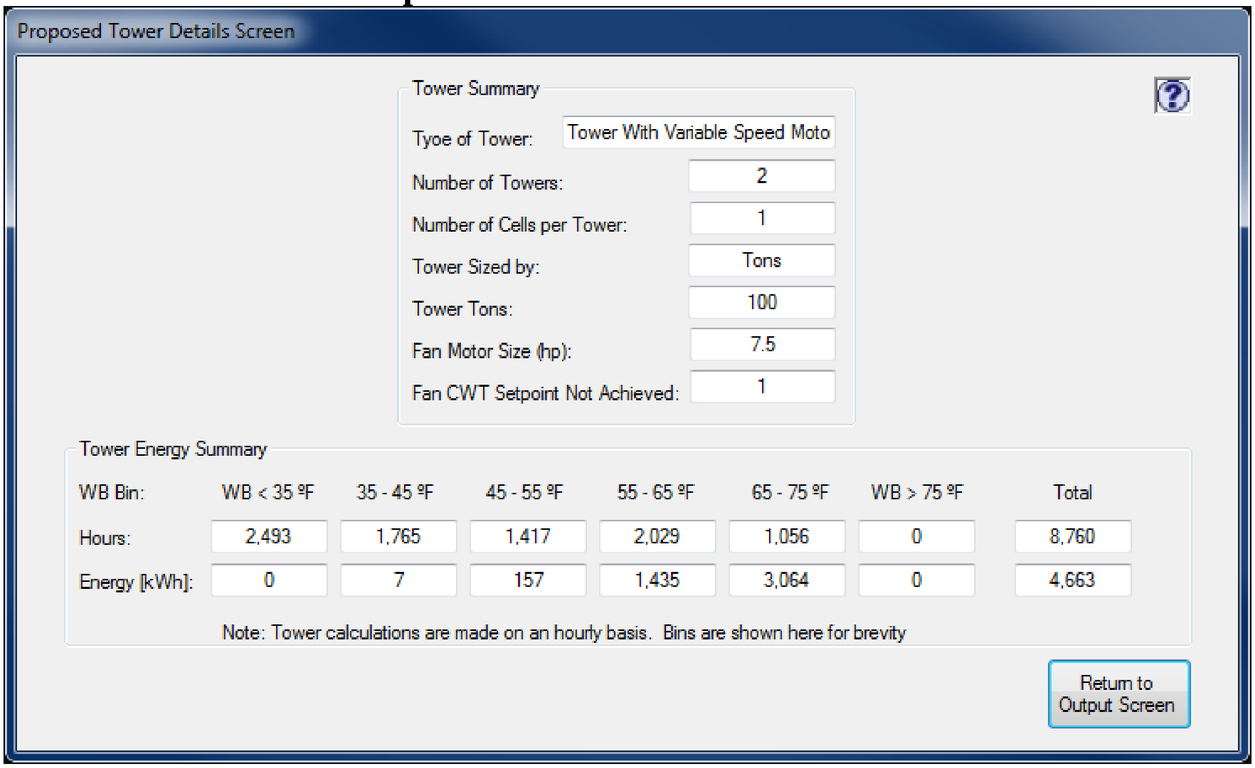


	0% Load	10% Load	20% Load	30% Load	40% Load	50% Load	60% Load	70% Load	80% Load	90% Load	100% Load	Total
Chiller 1: Centrifugal (Rated Capacity: 100 tons)												
[kW/ton]:	0.000	0.000	1.287	1.028	0.933	0.907	0.909	0.935	0.979	1.035	1.097	
Hours:	0	0	95	437	1,138	2,016	2,273	1,670	790	258	83	8,760
Power [kW]:	0.0	0.0	25.7	30.9	37.3	45.4	54.5	65.4	78.3	93.2	109.7	
Energy [kWh]:	0	0	2,445	13,483	42,453	91,450	123,901	109,278	61,846	24,043	9,107	478,005
Chiller 2: Helical Rotary (Rated Capacity: 200 tons)												
[kW/ton]:	0.000	0.000	1.325	1.075	0.976	0.945	0.925	0.924	0.932	0.944	0.951	
Hours:	0	0	95	437	1,138	2,016	2,273	1,670	790	258	83	8,760
Power [kW]:	0.0	0.0	53.0	64.5	78.1	94.5	111.0	129.4	149.2	169.8	190.3	
Energy [kWh]:	0	0	5,035	28,178	88,855	190,575	252,345	216,024	117,859	43,818	15,794	958,484

The appearance of the Proposed Chiller Details Screen is identical to that described in the Current Chiller Details Screen section of this manual.

Options:
RETURN TO OUTPUT SCREEN
HELP

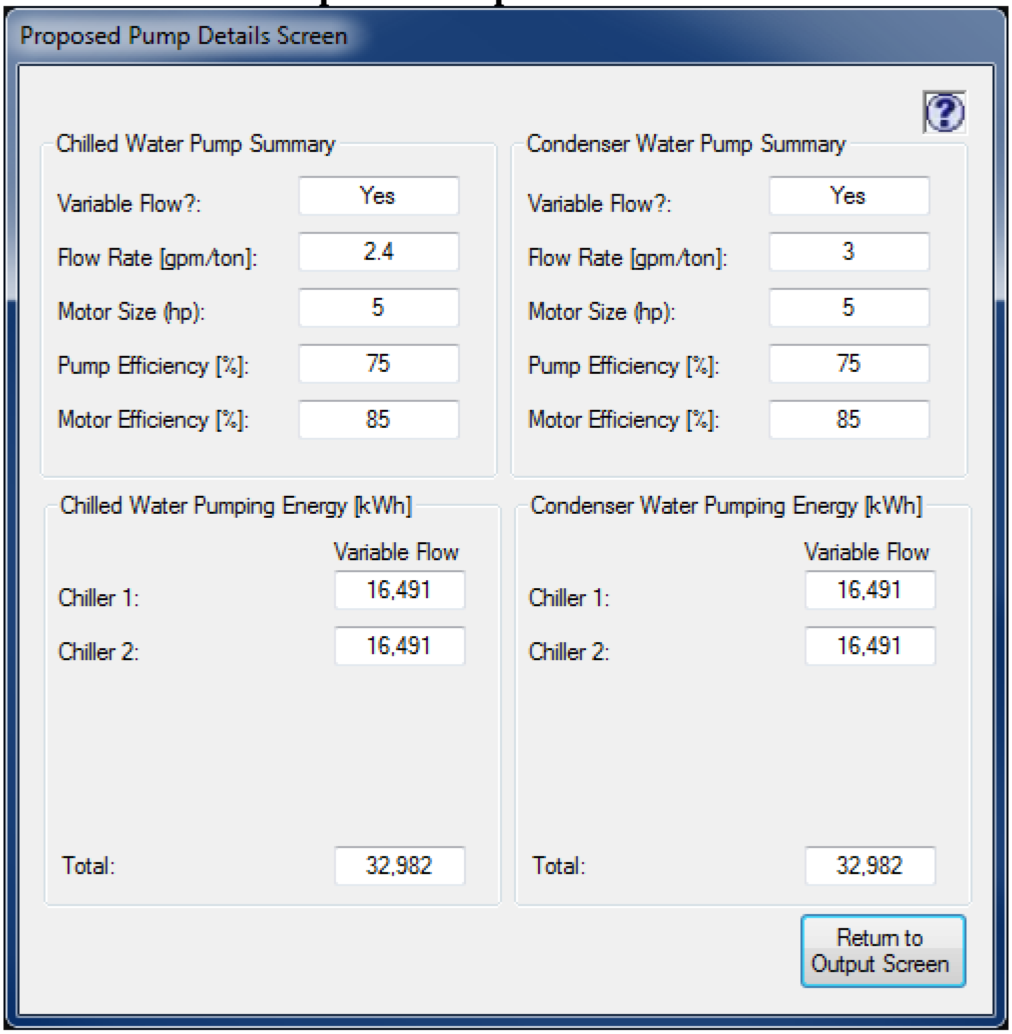
Proposed Tower Details Screen



The appearance of the Proposed Tower Details Screen is identical to that described in the Current Tower Details Screen section of this manual.

Options:
RETURN TO OUTPUT SCREEN
HELP

Proposed Pump Details Screen



The appearance of the Proposed Pump Details Screen is identical to that described in the Current Pump Details Screen section of this manual.

Options:
RETURN TO OUTPUT SCREEN
HELP