Better Plants
U.S. DEPARTMENT OF ENERGY

Industrial Process Cooling (Chilled Water) Systems

Virtual INPLT Training & Assessment

Session 4

Thursday – August 1, 2024

10 am – 12:30 pm

U.S. DEPARTMENT OF ENERGY

Welcome

- Welcome to the 4th Chilled Water Systems Virtual INPLT training series
- Eight, 2-1/2 hour webinars, focused on Industrial Process Cooling (Chilled Water) Systems Energy Assessment and Optimization
- These webinars will help you gain a significant understanding of your industrial process cooling system, undertake an energy assessment using a systems approach, evaluate and quantify energy and cost-saving opportunities using CWSAT and other US DOE tools and resources
- Thank you for your interest!

Process Cooling (Chilled Water Systems) Virtual INPLT Facilitator

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Process Cooling Virtual INPLT Agenda (2024)

- Session 1 (July 17) – Industrial Chilled Water Systems Fundamentals
- Session 2 (July 18) – Review of Chilled Water System Scoping Tool; Efficiency Metrics & Calculations
- Session 3 (July 31) – Introduction to Chilled Water System Assessment Tool (CWSAT)
- **Session 4 (August 1) – Using CWSAT to Quantify Energy Efficiency Opportunities – Part 1**
- **Session 5 (August 14) – Using CWSAT to Quantify Energy Efficiency Opportunities – Part 2**
- **Session 6 (August 15) – US DOE MEASUR, 3EPlus, etc.; Undertaking a VINPLT Assessment & Reporting**
- **Session 7 (August 28) – Case Studies; Refrigerants – Past, Present & Future; Reclamation and O&M**
- **Session 8 (August 29) – Industrial Process Cooling (Chilled water) System VINPLT Wrap-up Presentations**

Agenda – Session 4

- Welcome and Introductions
- Safety and Housekeeping
- Today's Content:
  - Example Chilled Water Plant
  - Modeling in CWSAT – Base Model
- Kahoot Quiz Game
- Q&A

Safety and Housekeeping

- Safety Moment
  - Chillers have oil sumps, filters, etc. – be careful when walking around a chiller – oil may be leaking on the floor or there may be a puddle making the floor extremely slippery – exercise caution, wear proper safety shoes to avoid slipping
- You are welcome to ask questions at any time during the webinar
- When you are not asking a question, please MUTE your mic and this will provide the best sound quality for all participants
- We will be recording all these webinars and by staying on-line and attending the meeting you are giving your consent to be recorded
  - A link to the recorded webinars will be provided, afterwards

Modeling the Example Chilled Water System in CWSAT

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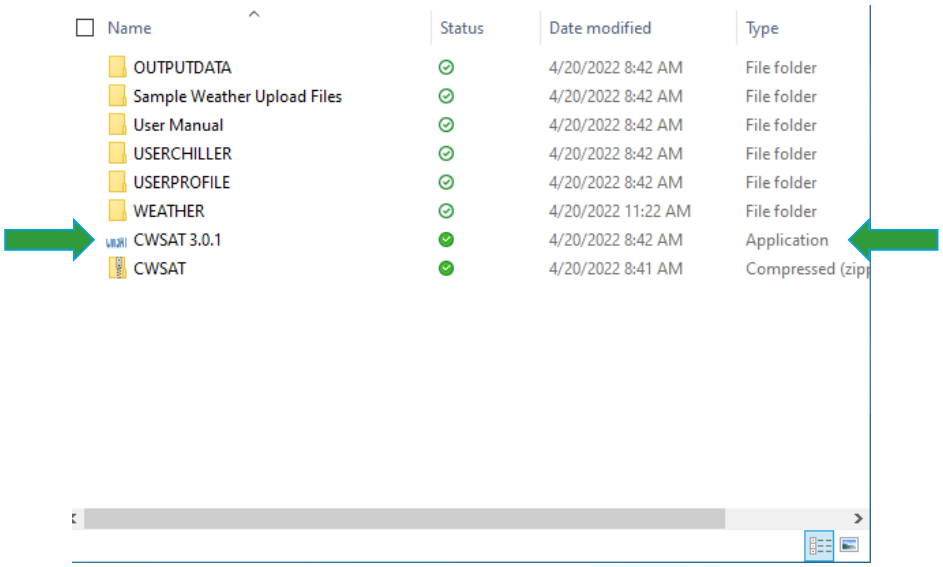
Aim of Student Exercise

- Provide an understanding of an actual industrial chilled water system
- Hands-on exercise to demonstrate operation and functionality of CWSAT in a real-life scenario
- Start from the basics and get into details and build a “Baseline Model” for a central chilled water system
- Students will learn to model their own chilled water plant and develop a baseline for the energy consumption and the breakdown of energy consumed by the individual sub-systems

Start CWSAT 3.0.1



Facility Description

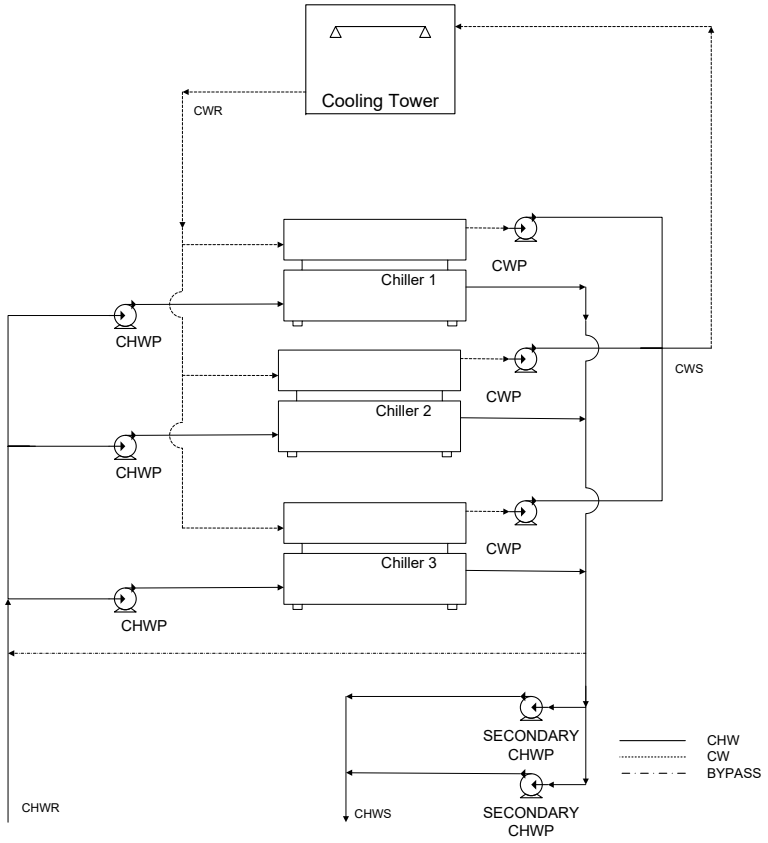
- The plant / facility is a large Food & Beverages plant located in the St. Louis, MO area
- The system selected for the energy assessment provides chilled water for process, packaging, air-conditioning plant areas and warehouse storage
- The plant operates a 3-shift per day operation, 8-hour per shift and runs all year round
- Possible shut-downs are planned for periodic maintenance activities

Description of Chilled Water System

Chilled Water System:

- Water-cooled
- 10 years old
- 3 Chillers
- 2 cell 1-speed Tower (1)
- Primary / Secondary Chilled Water Distribution System

High-level System Schematic



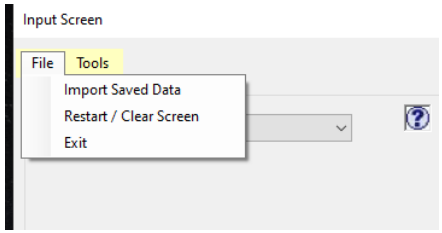
CWSAT INPUT Screenshots

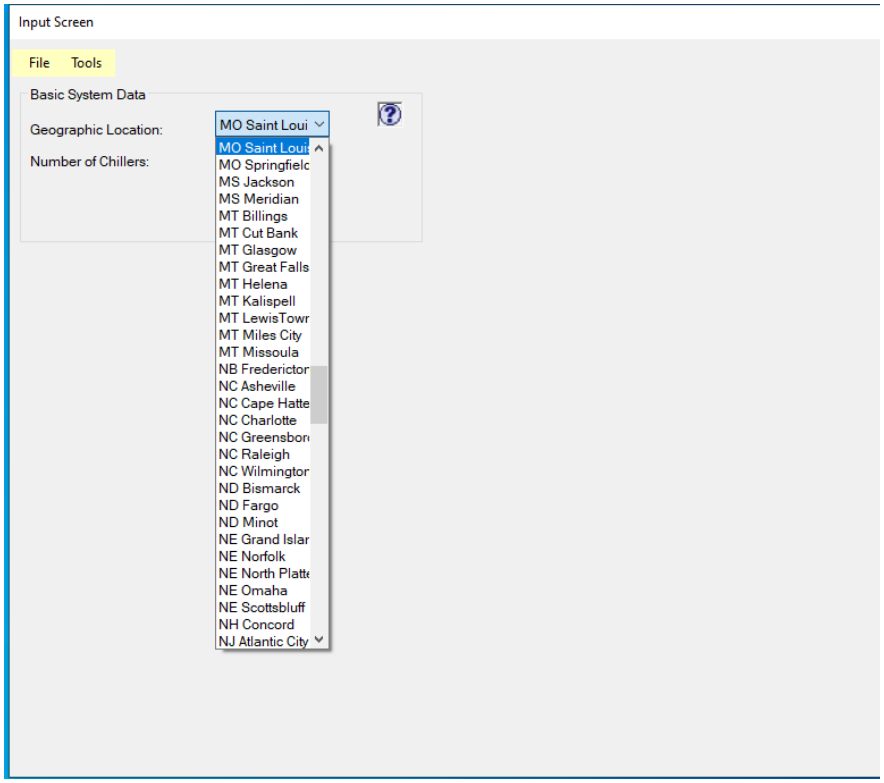
- Geographic location
- System description
- Heat rejection setup
- Pump setups
  - Chilled water
  - Condenser water (if applicable)
- Chiller setup
  - Default
  - Custom
- Utility Cost
- Operation Schedule & Load Profile

Click the “OK” Button to proceed to the next Input Sub-block

Input Geographic Location

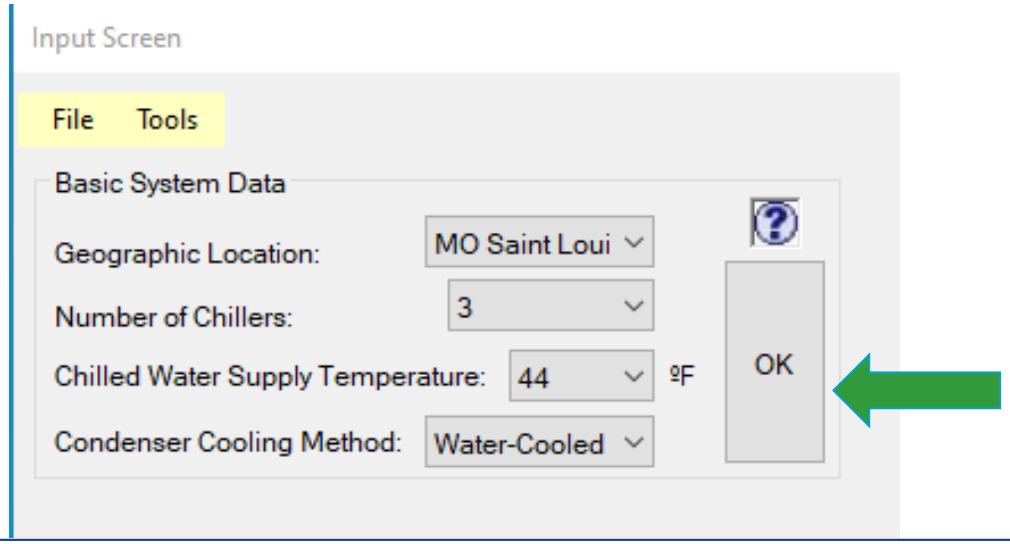
- St. Louis, MO

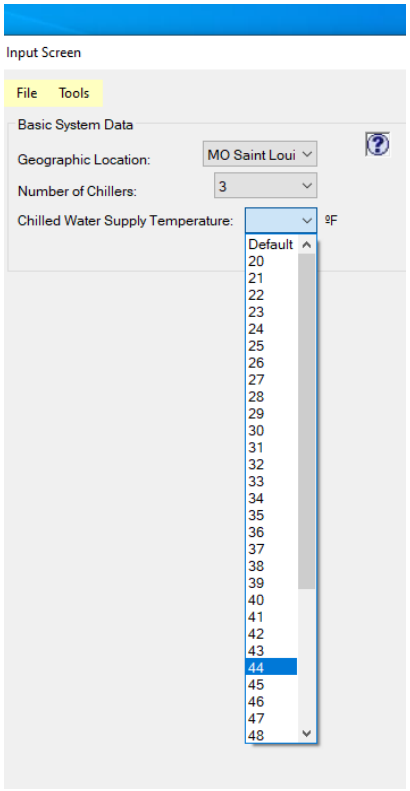




Chiller Plant Information

- Number of Chillers: 3
- Chilled Water Setpoint: 44°F
- Water-Cooled Condensers

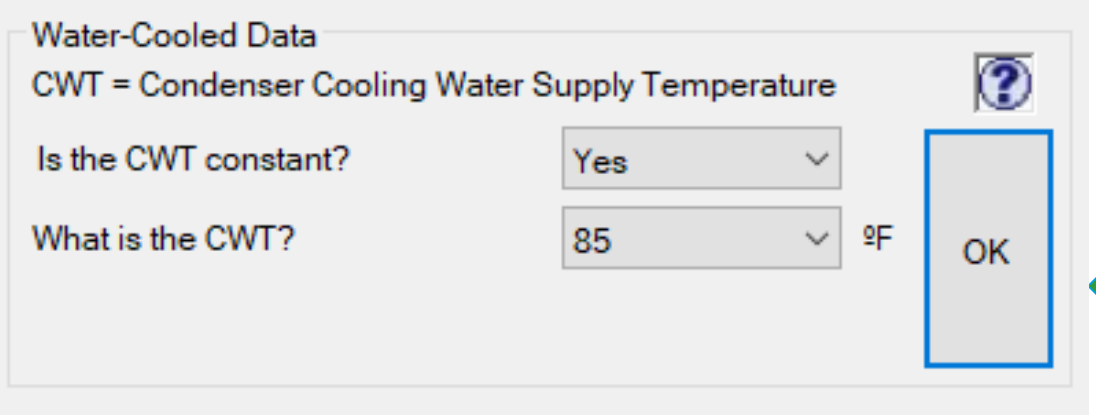


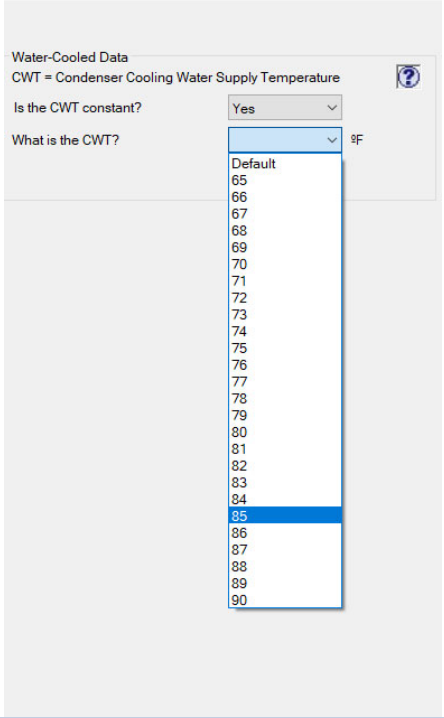


Default

Chiller Plant Information

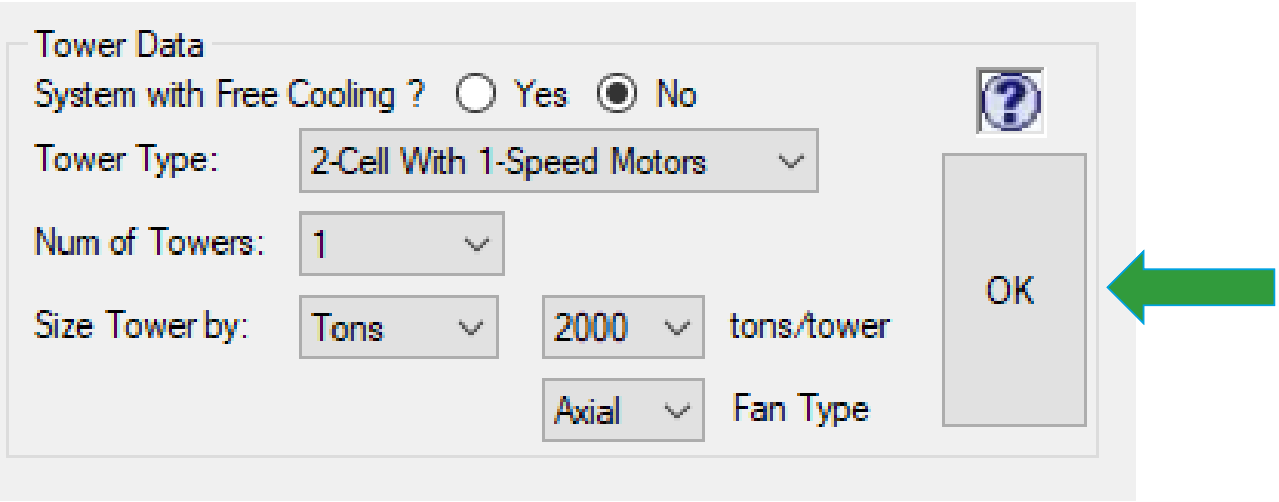
- Cooling Water Supply Temperature is CONSTANT
- Cooling Water Supply Setpoint: 85°F
- Water-Cooled Condensers

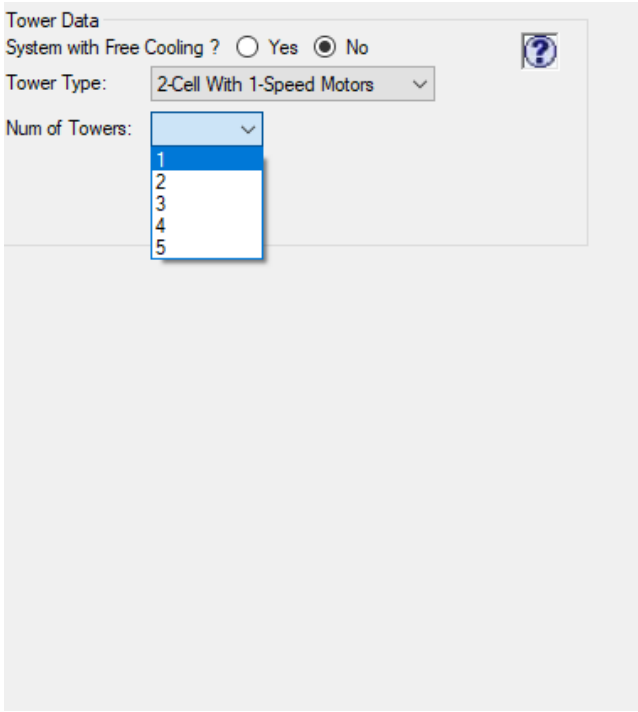




Cooling Tower Information

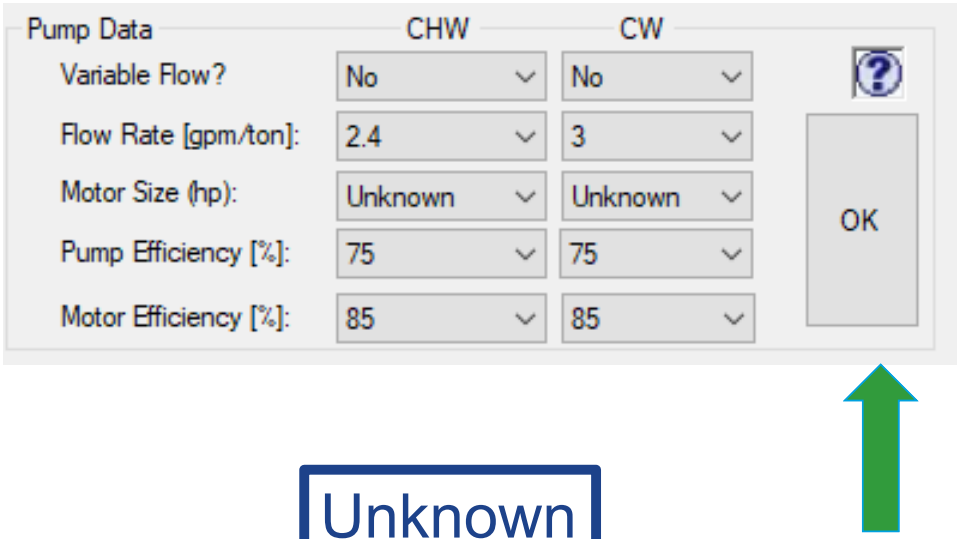
- One tower with 2-cells and 1-speed motor
- Tower rated capacity – 2,000 RT





Sub-System Information

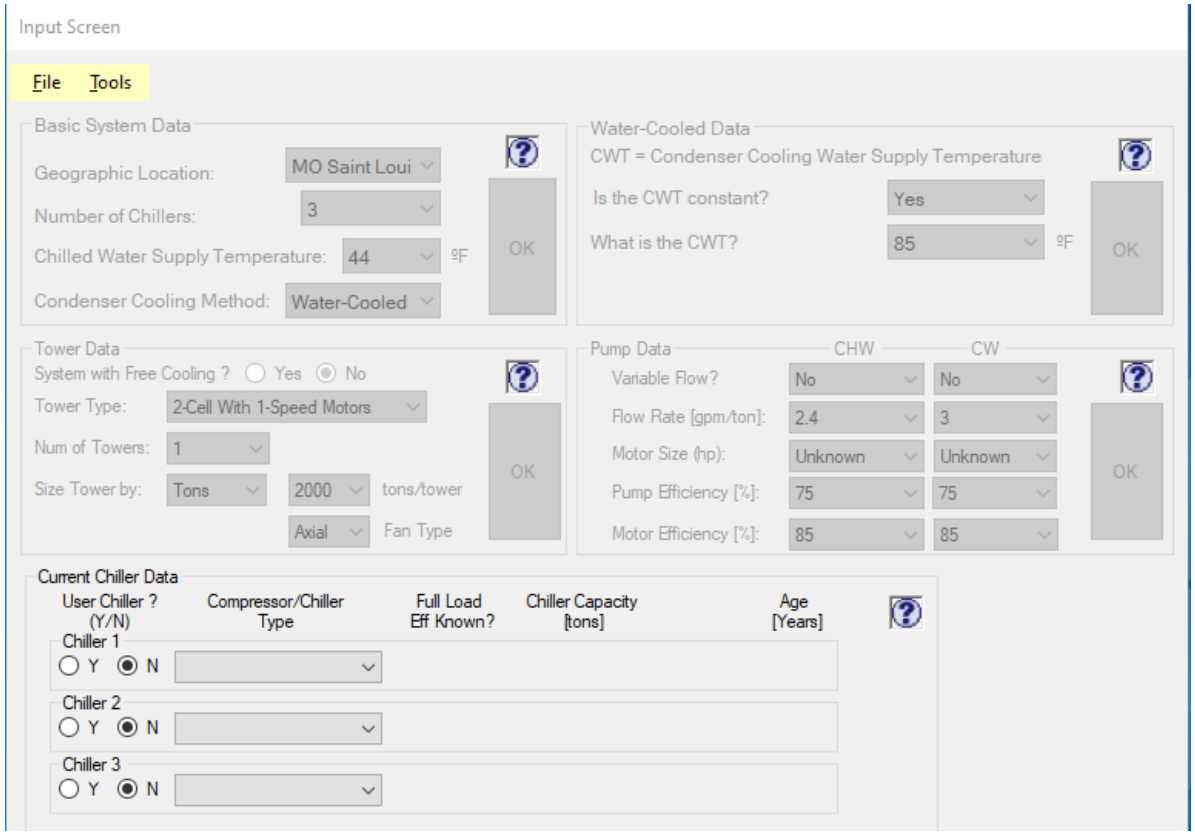
- Chilled Water Pumps
  - Primary
    - 3 x 15 hp Constant Speed
    - Flow rate based on 2.40 gpm/RT
  - Secondary
    - 2 x 20 hp Variable Speed
- Condenser Water Pumps
  - 3 x 10 hp Constant Speed
  - Flow rate based on 3.0 gpm/RT



Unknown

Default

Sub-System Information



System Information

- Chillers:
  - 2 Centrifugals and 1 Screw machine (constant speed)
    - Centrifugals - 1,000 RT each
    - Screw - 350 RT
  - Rated Full Load Efficiency (kW/RT)
    - Centrifugals – 0.65
    - Screw – 0.75
  - Age: 10 years
  - Chilled Water Setpoint – 44°F
  - Condenser Water Supply Temperature – 85°F

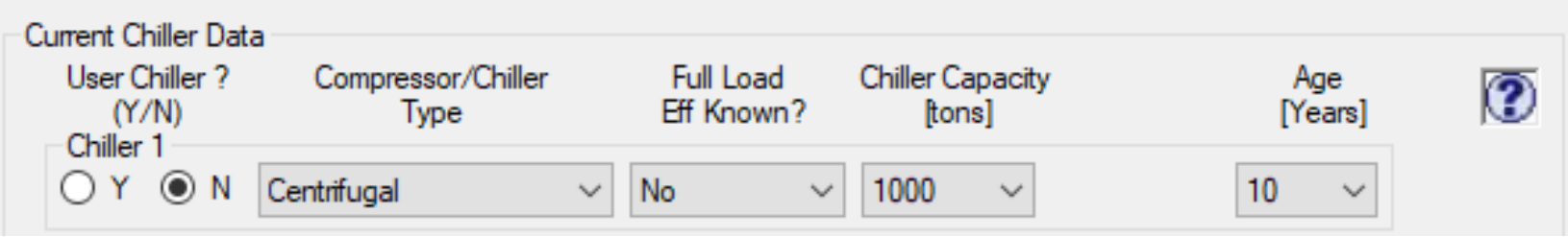
System Information

- There are 3 methods to specify chillers in CWSAT
- Each chiller is specified independently and can be done in either of the 3 ways
- How you specify a chiller depends on how much information you have on the chiller
- CWSAT is built w/default information

Chiller Specification Methodology – Method 1

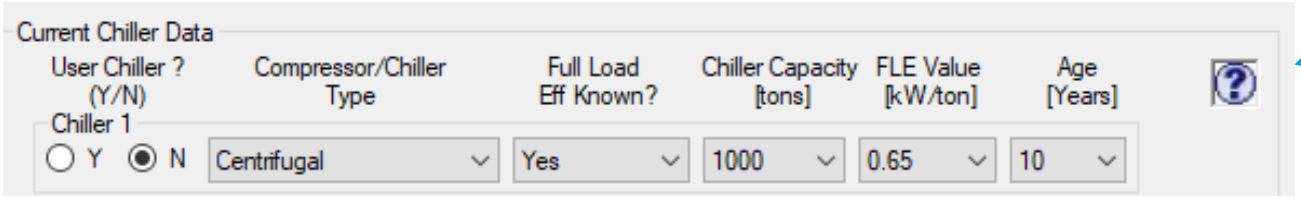
- No information about performance is known

- Following information is enough to use the default performance curves within CWSAT
  - Compressor type – Centrifugal, Screw (helical rotary), Reciprocating
  - Chiller Design Capacity (RT)
  - Age of chiller (years)



Chiller Specification Methodology – Method 2

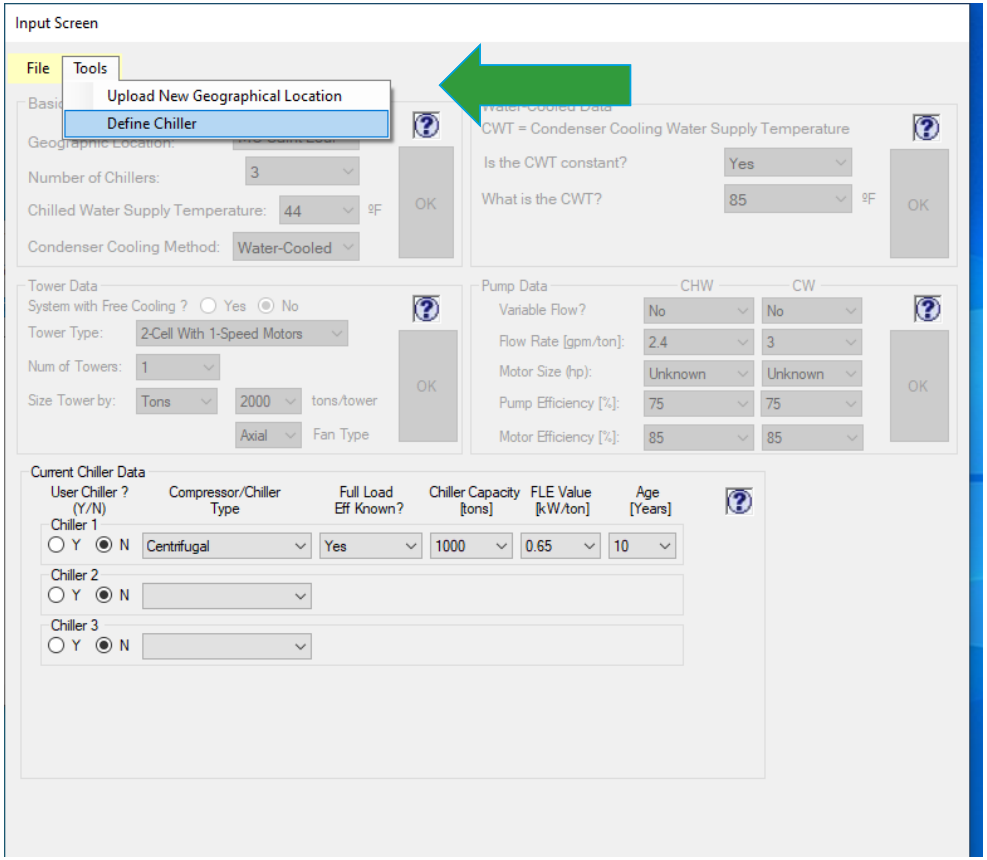
- Full Load performance (kW/RT) is known but part-load information is not available
- Following information is enough to use the default performance curves within CWSAT
  - Compressor type – Centrifugal, Screw (helical rotary), Reciprocating
  - Chiller Design Capacity (RT)
  - Full Load Efficiency (kW/RT)
  - Age of chiller (years)



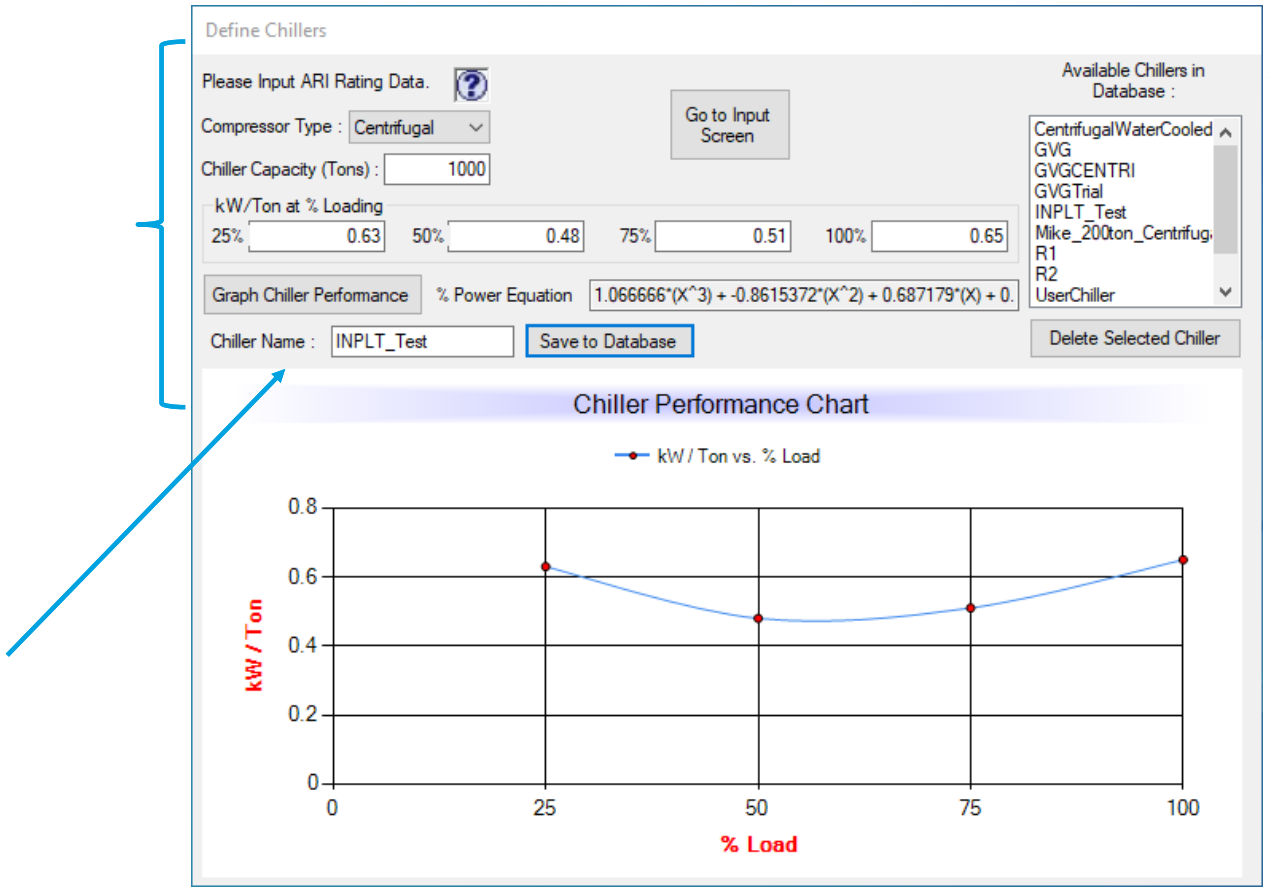
Chiller Specification Methodology – Method 3

- Full Load performance (kW/RT) is known
- Part-load information is also available
- The following information is used to build a performance curve for the specific chiller in CWSAT
  - Compressor type – Centrifugal, Screw (helical rotary), Reciprocating
  - Chiller Design Capacity (RT)
  - Efficiency (kW/RT) at the following load conditions
    - 25% load
    - 50% load
    - 75% load
    - 100% load

Chiller Specification Methodology – Method 3



Chiller Specification Methodology – Method 3



- Provide Chiller Name and it will now show up in the database

Chiller Specification Methodology

- Method 3 is the ideal way to specify chillers in CWSAT
- It will require some due diligence and information gathering but to build confidence in the assessment and results thereafter, it is well worth the extra effort
- Nevertheless, it should not be a show-stopper and if getting the information is delayed, use Method 2 – FLE required
- Method 1 should NOT be used for assessments and quantifying energy efficiency opportunities but can be used for scoping purposes

System Information

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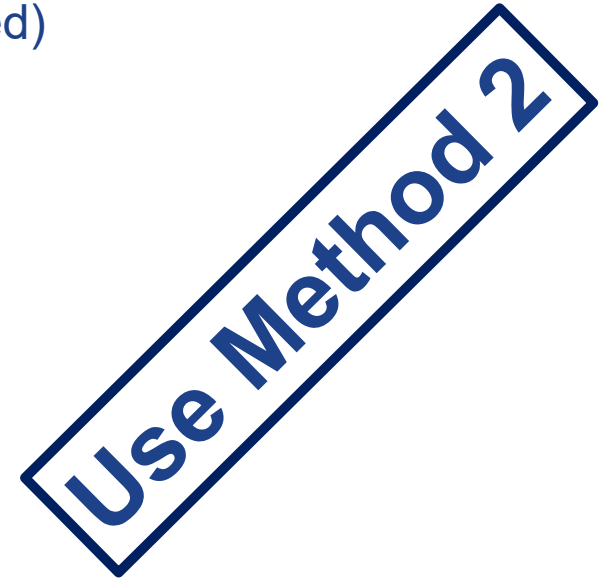
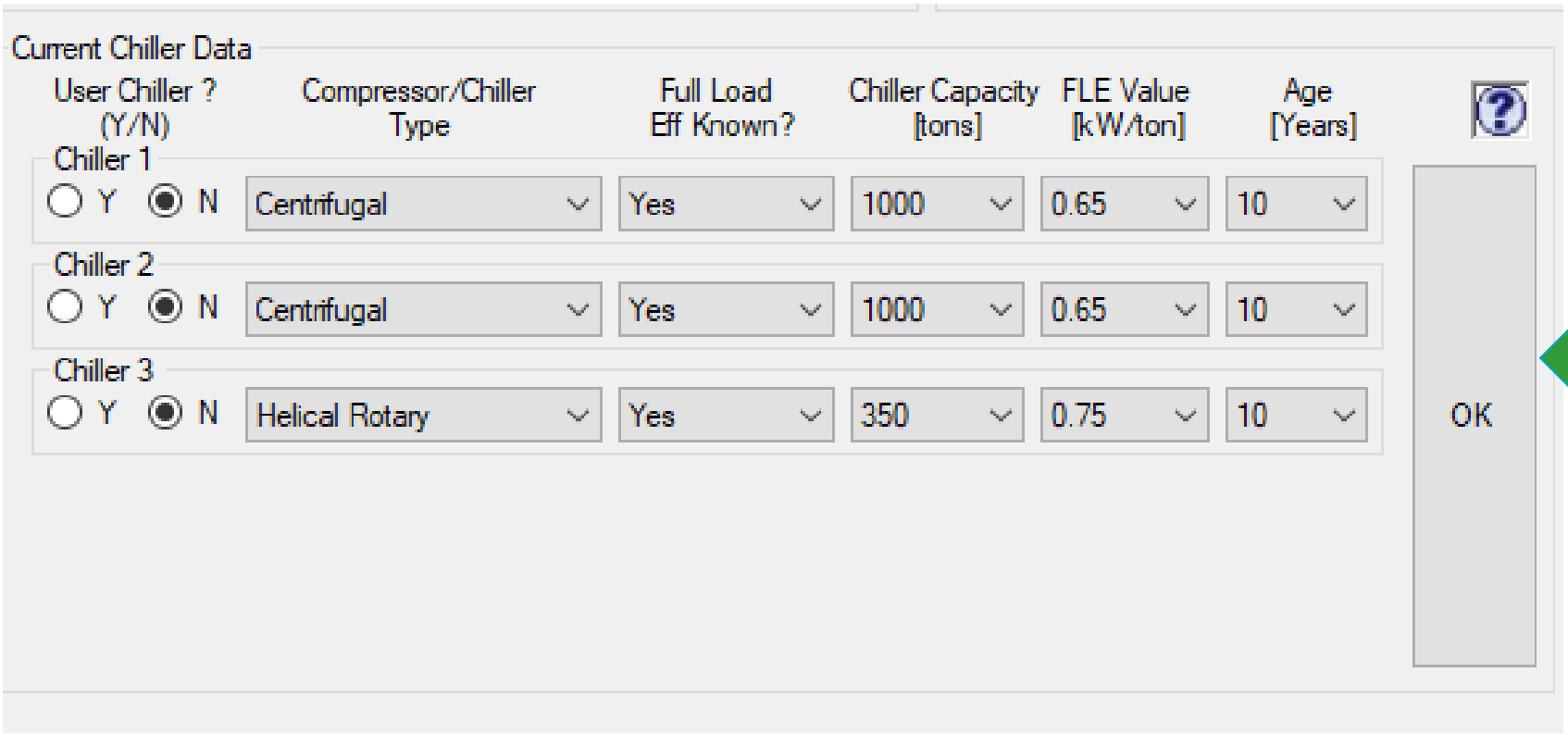
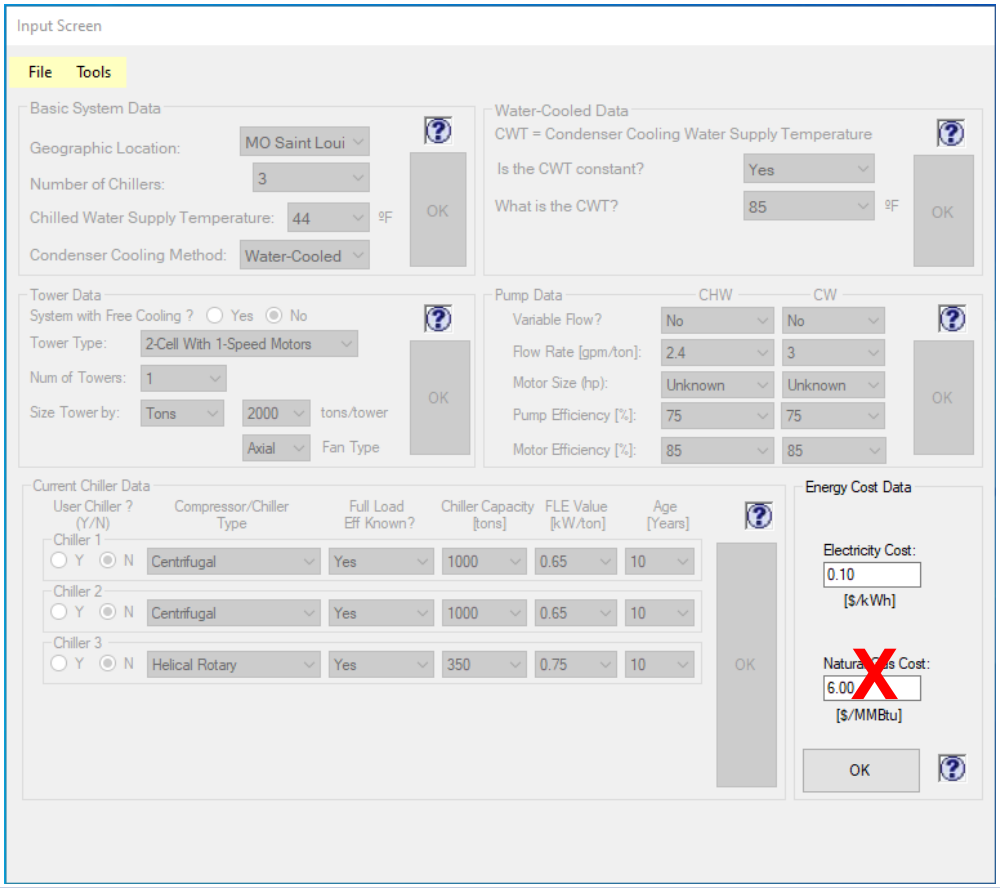


System Information

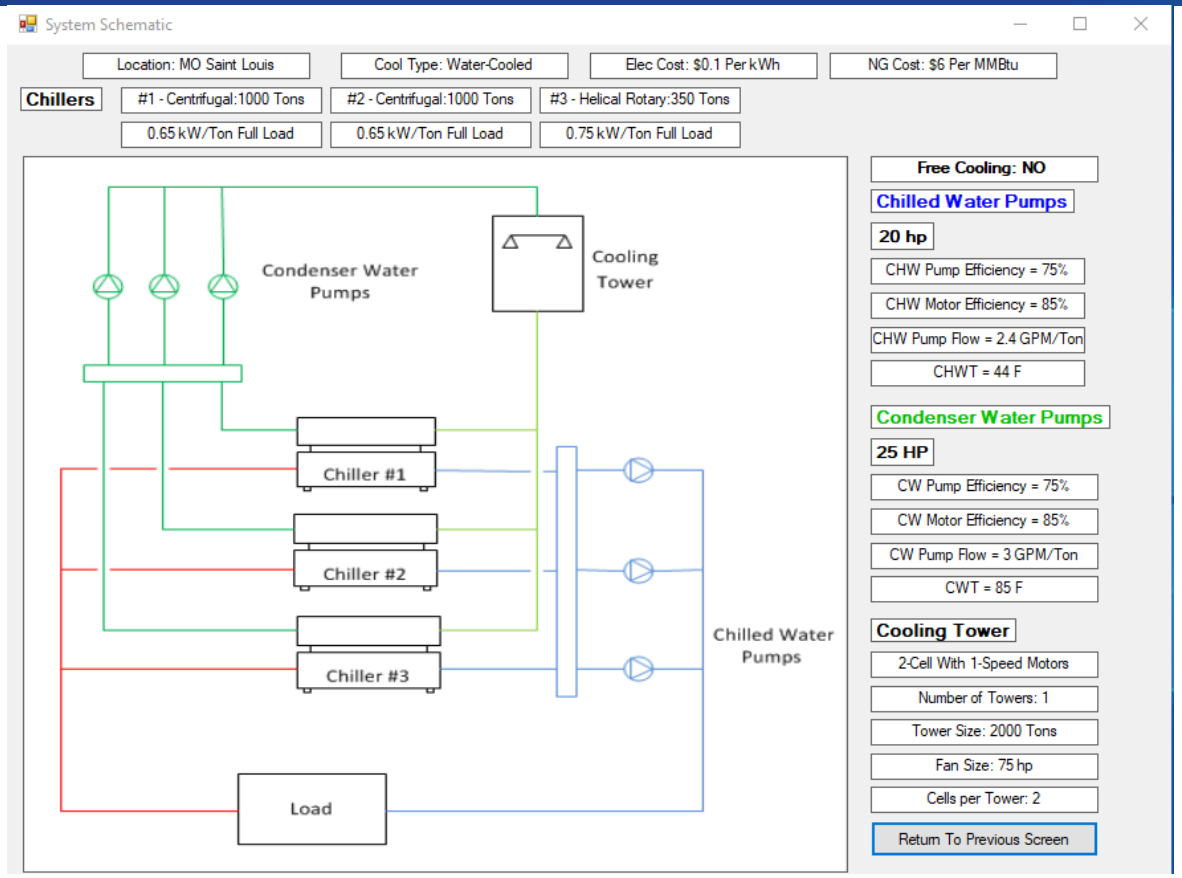


System Information



- The electricity utility rate is a very important number
- For CWSAT – a bundled cost (annual average) should be used
- For more detailed analysis, multiple bin models can be developed
- Natural gas cost can be ignored

System Schematic

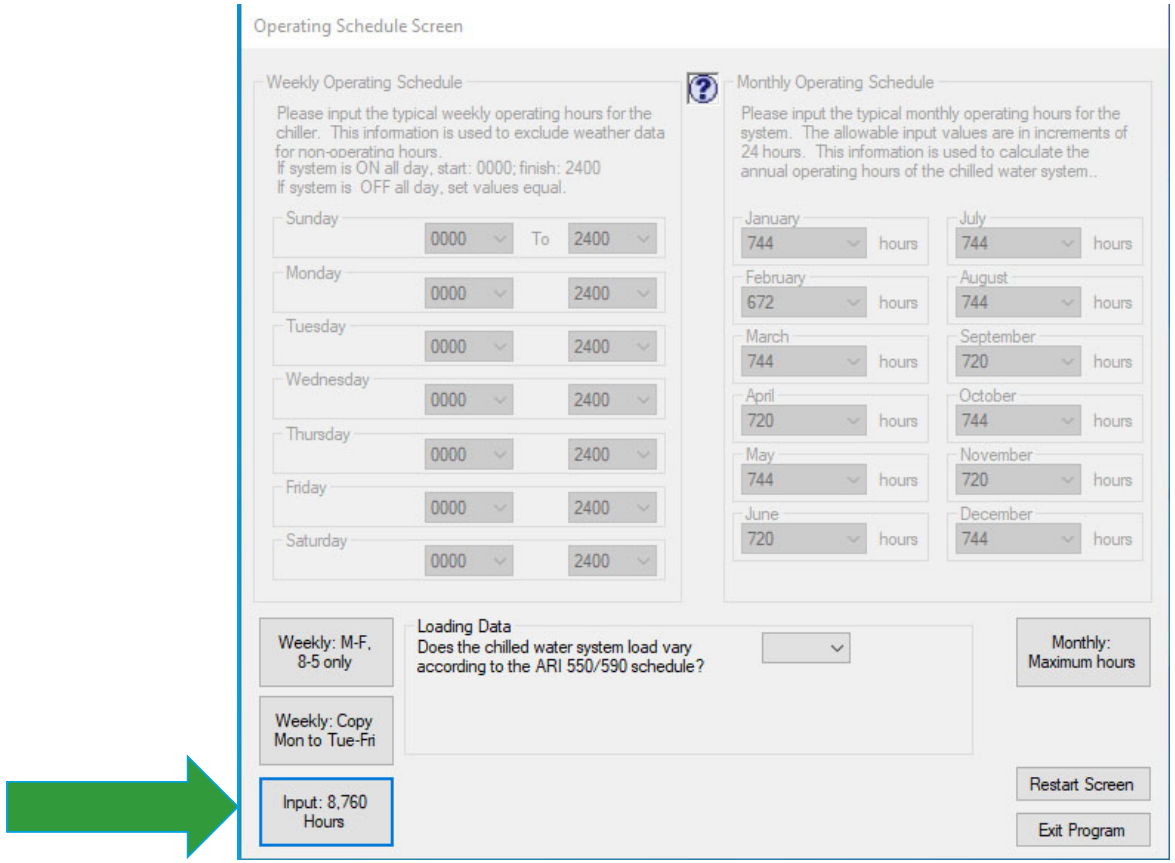


Review

Operating Schedule Information

- Operating Schedule provides information on when the chilled water plant is ON or OFF.
- Simplest option – plant is ON all year round (24x7) – 8,760 hours
- ONLY if the chilled water plant is turned OFF manually or if it is on an automatic ON/OFF schedule based on day of the week, shift schedule, etc. should this operating schedule screen be used for details
- If a chiller turns OFF automatically because the chilled water system load is met, that information is captured on the load profile

Operating Schedule Information



Individual Chiller Load Profile

- The geographic location's weather data, load profile along with the operating schedule allows the CWSAT to allocate actual cooling load (RT) for each hour of operation to each chiller
- CWSAT does a very detailed chilled water system analysis – 8,760 individual runs representing each specific hour of the year
- CWSAT has an algorithm to match every hour of the year with the actual operating load and corresponding efficiency based on the system

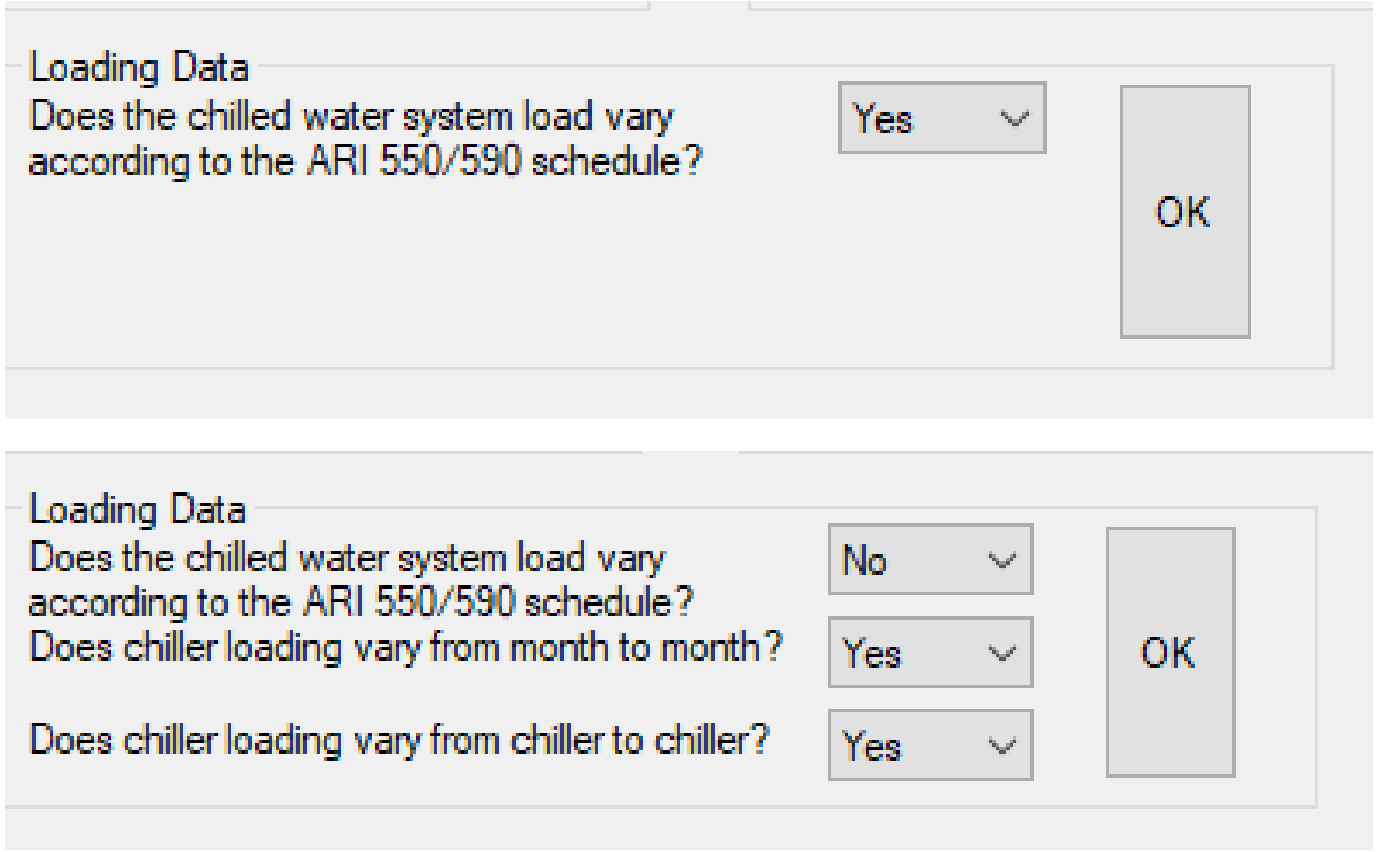
Individual Chiller Load Profile

- CWSAT offers a default AHRI chiller load profile

- This can be used when
  - The cooling load is purely HVAC (or predominantly HVAC > 90%)
  - Chiller load information is not available yet but it is clear that a major portion of the load (50% or so) is comfort cooling for personnel and environment

Chiller Loading Schedule											
Chiller	0% load	10% Load	20% load	30% load	40% load	50% load	60% load	70% load	80% load	90% load	100% load
ARI	0%	0%	1%	5%	13%	23%	26%	19%	9%	3%	1%

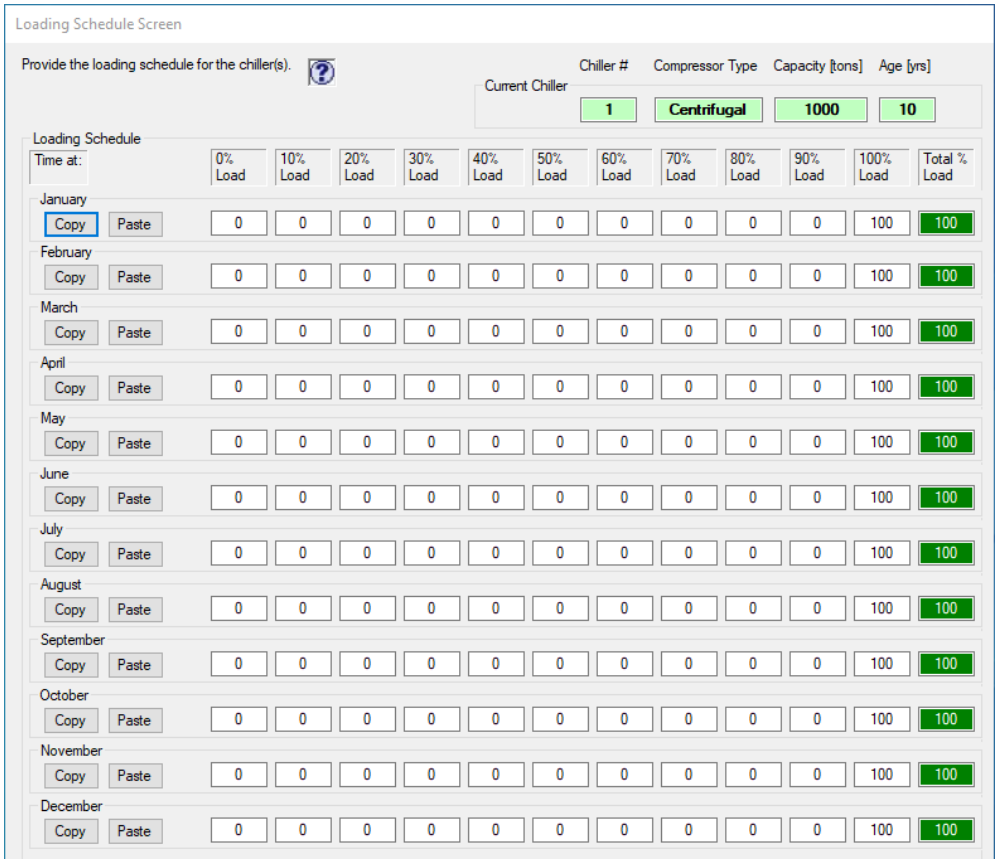
Individual Chiller Load Profile



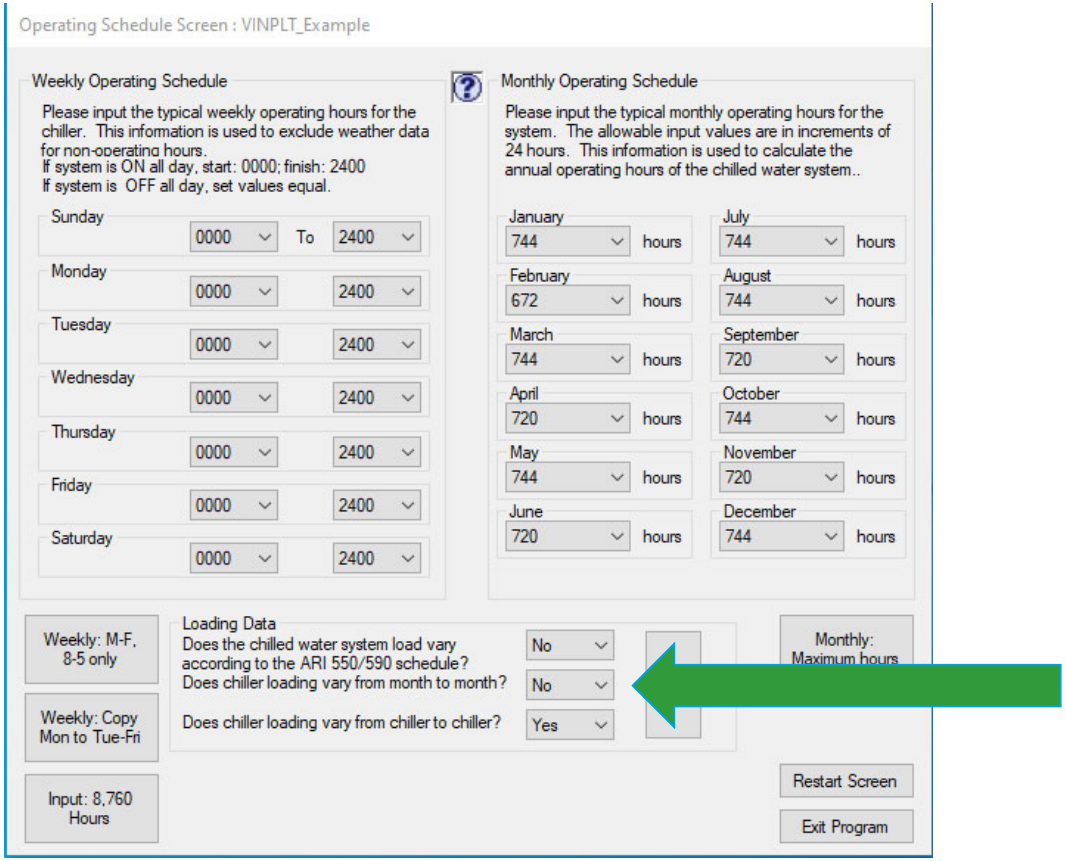
- AHRI Load profile selection
- Chiller load variation – month to month
- Load variation between chillers

Individual Chiller Load Profile

- Most Complex
- Most Detailed
- Recommended for Assessments
- Can capture seasonality of operations, weather impacts, etc.

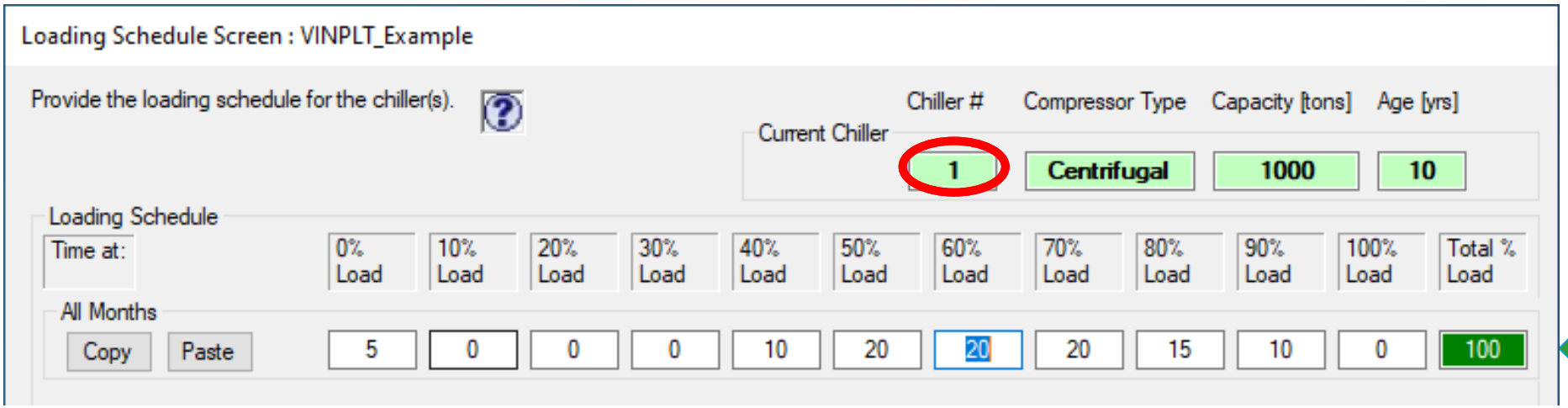


Example System Chiller Load Profile



Centrifugal Chillers Load Profile

- There are 2 centrifugal chillers that are operated in a manner such that they are at similar load conditions all the time unless there is maintenance activity on one of them



Centrifugal Chillers Load Profile

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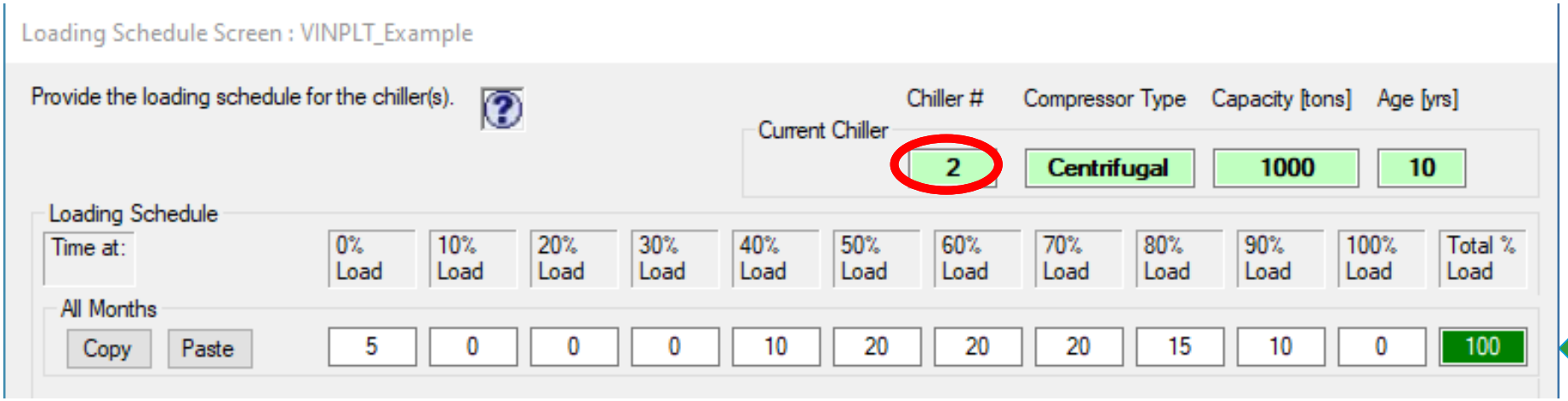
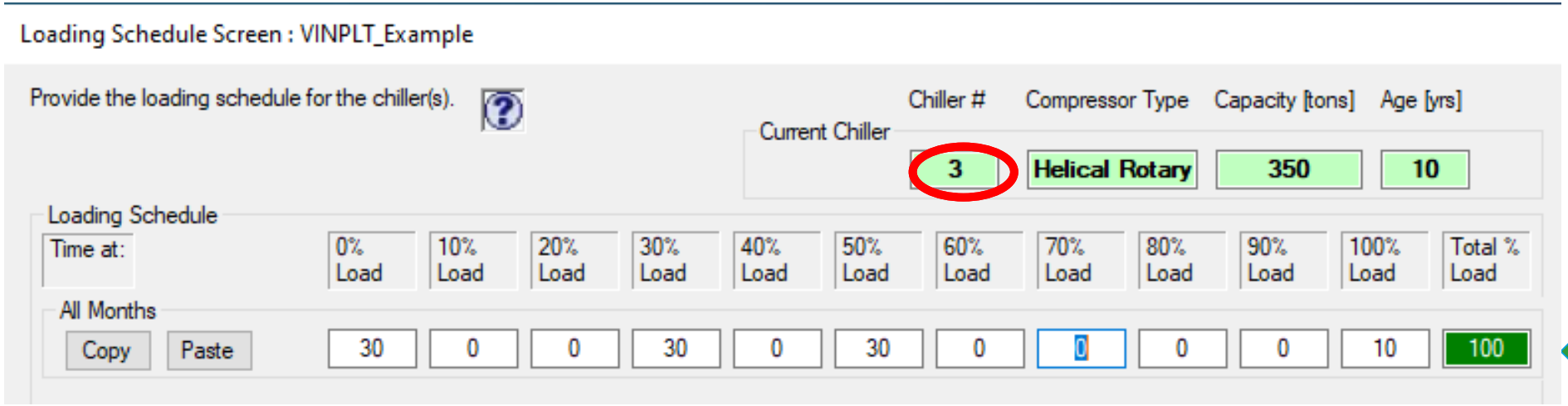


Screw Chiller Load Profile

- Chiller #3 is a screw chiller that does come ON periodically when loads are high or when one of the centrifugal chillers is down for maintenance

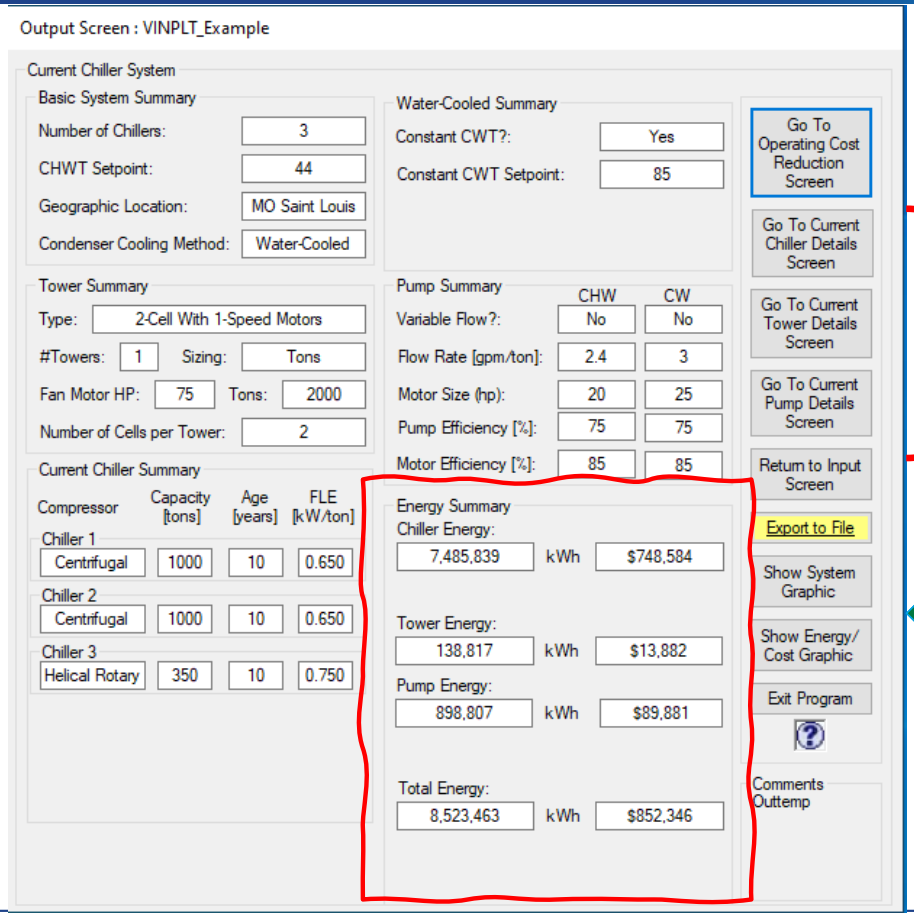


All INPUT is COMPLETE!

- At this point in CWSAT – all the inputs required for modeling the chilled water system are completed
- The next step is to “Go to Output Screen”
- The Output Screen is a high-level summary of the overall chilled water plant operations
- It has options to go into details of the sub-systems

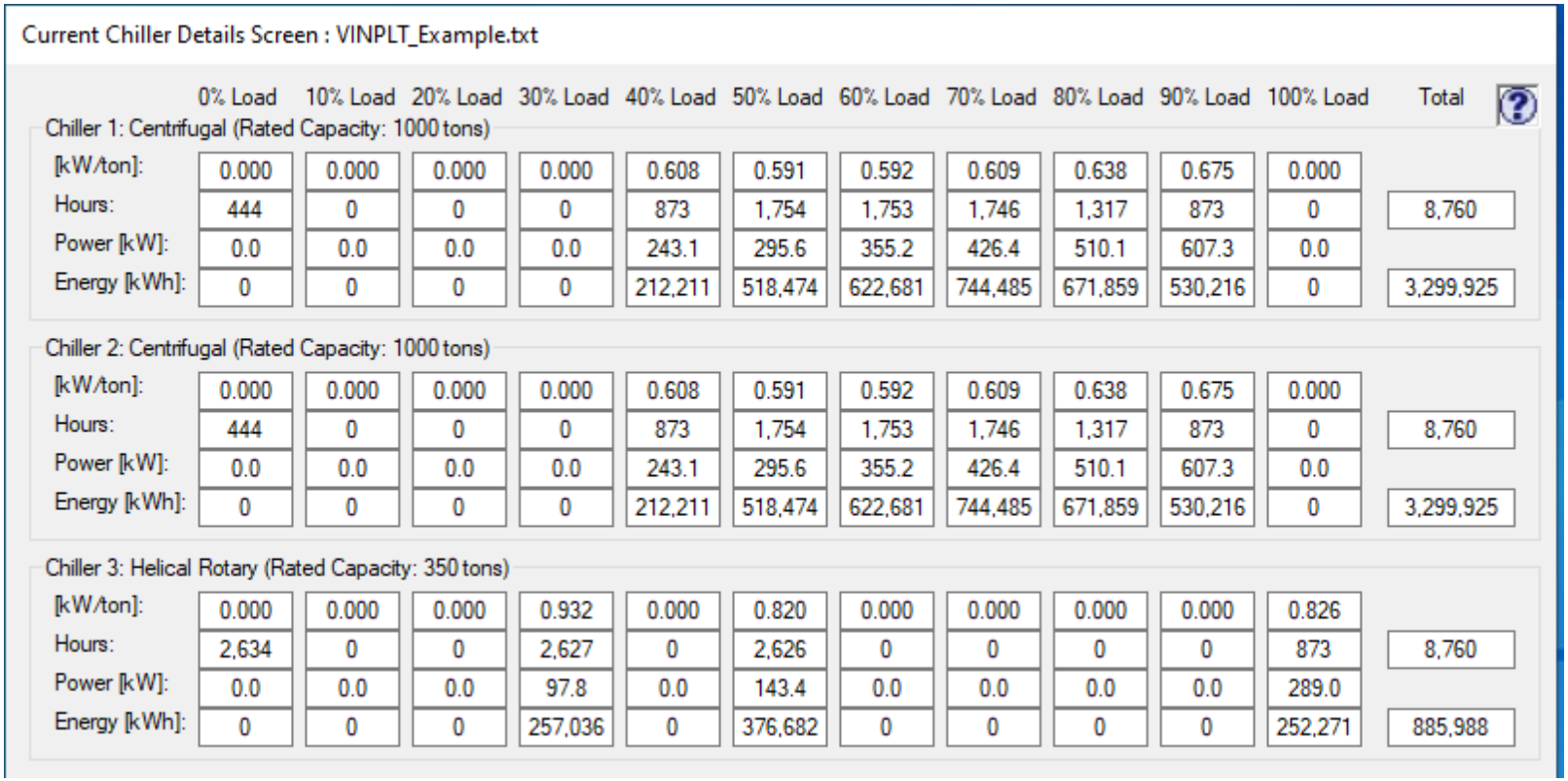
Output Screen (Baseline)

- All the major inputs are shown here
- Annual energy consumption (kWh)
- Annual operating cost ($)
- System graphic
- Energy / Cost graphic



Energy Usage & Cost Graphic (Baseline)

Chiller Operating Details Screen (Baseline)

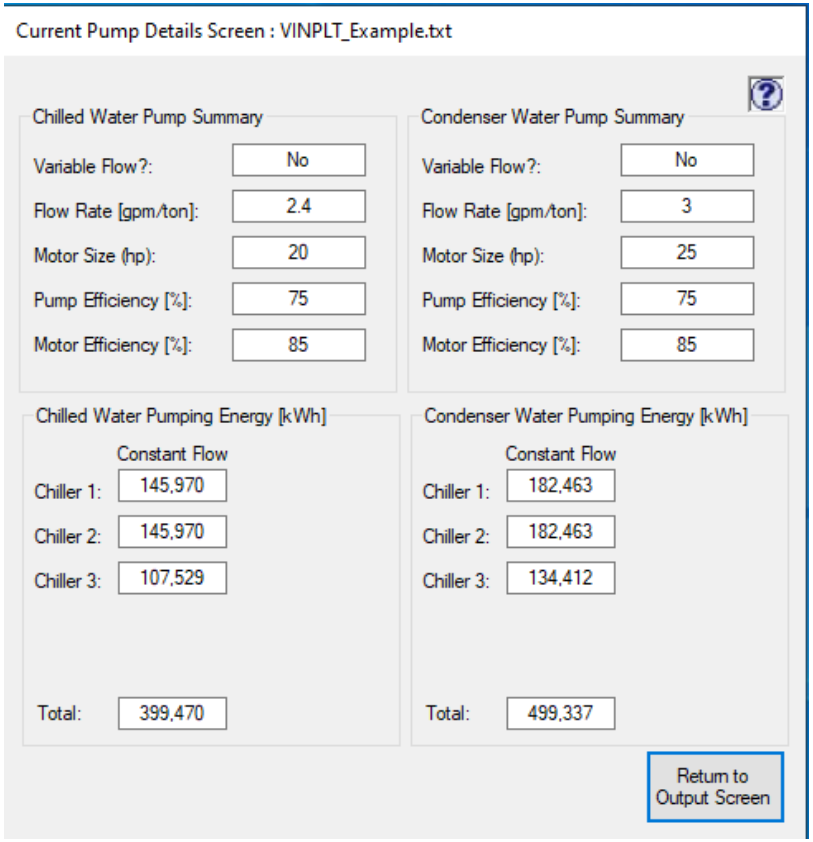


Current Chiller Details Screen : VINPLT_Example.txt

	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: 1000 tons)												
[kW/ton]:	0.000	0.000	0.000	0.000	0.608	0.591	0.592	0.609	0.638	0.675	0.000	
Hours:	444	0	0	0	873	1,754	1,753	1,746	1,317	873	0	8,760
Power [kW]:	0.0	0.0	0.0	0.0	243.1	295.6	355.2	426.4	510.1	607.3	0.0	
Energy [kWh]:	0	0	0	0	212,211	518,474	622,681	744,485	671,859	530,216	0	3,299,925
Chiller 2: Centrifugal (Rated Capacity: 1000 tons)												
[kW/ton]:	0.000	0.000	0.000	0.000	0.608	0.591	0.592	0.609	0.638	0.675	0.000	
Hours:	444	0	0	0	873	1,754	1,753	1,746	1,317	873	0	8,760
Power [kW]:	0.0	0.0	0.0	0.0	243.1	295.6	355.2	426.4	510.1	607.3	0.0	
Energy [kWh]:	0	0	0	0	212,211	518,474	622,681	744,485	671,859	530,216	0	3,299,925
Chiller 3: Helical Rotary (Rated Capacity: 350 tons)												
[kW/ton]:	0.000	0.000	0.000	0.932	0.000	0.820	0.000	0.000	0.000	0.000	0.826	
Hours:	2,634	0	0	2,627	0	2,626	0	0	0	0	873	8,760
Power [kW]:	0.0	0.0	0.0	97.8	0.0	143.4	0.0	0.0	0.0	0.0	289.0	
Energy [kWh]:	0	0	0	257,036	0	376,682	0	0	0	0	252,271	885,988

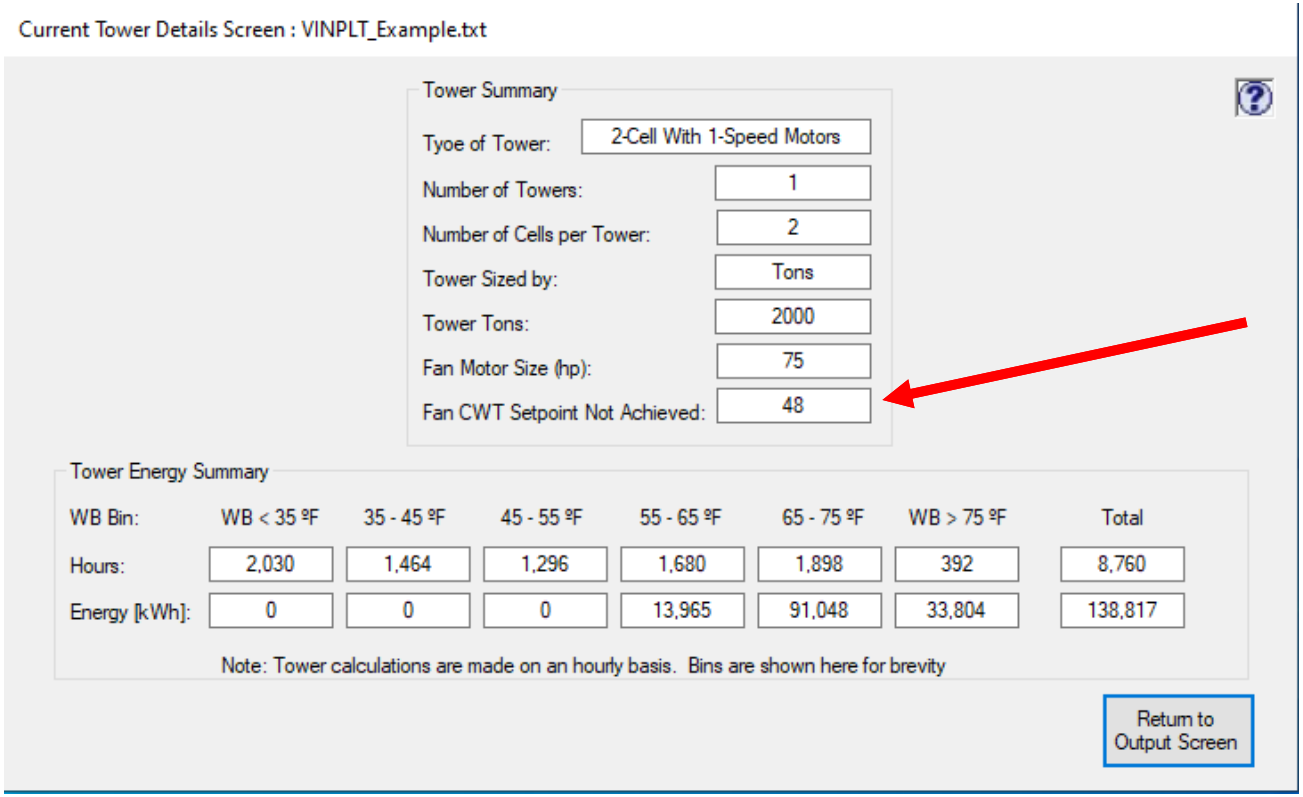
Pumps Operating Details Screen (Baseline)

- Be careful with this output – water flow rate allocation is an issue
- It's a good estimate but actual operation may be different
- Assumes no flow when chiller is OFF
- Primary loop ONLY



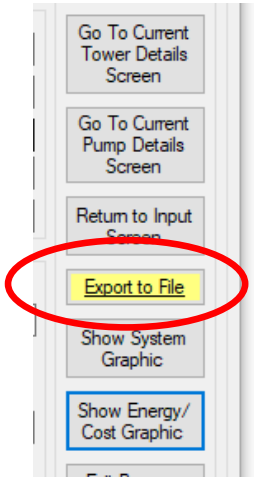
Tower Operating Details Screen (Baseline)

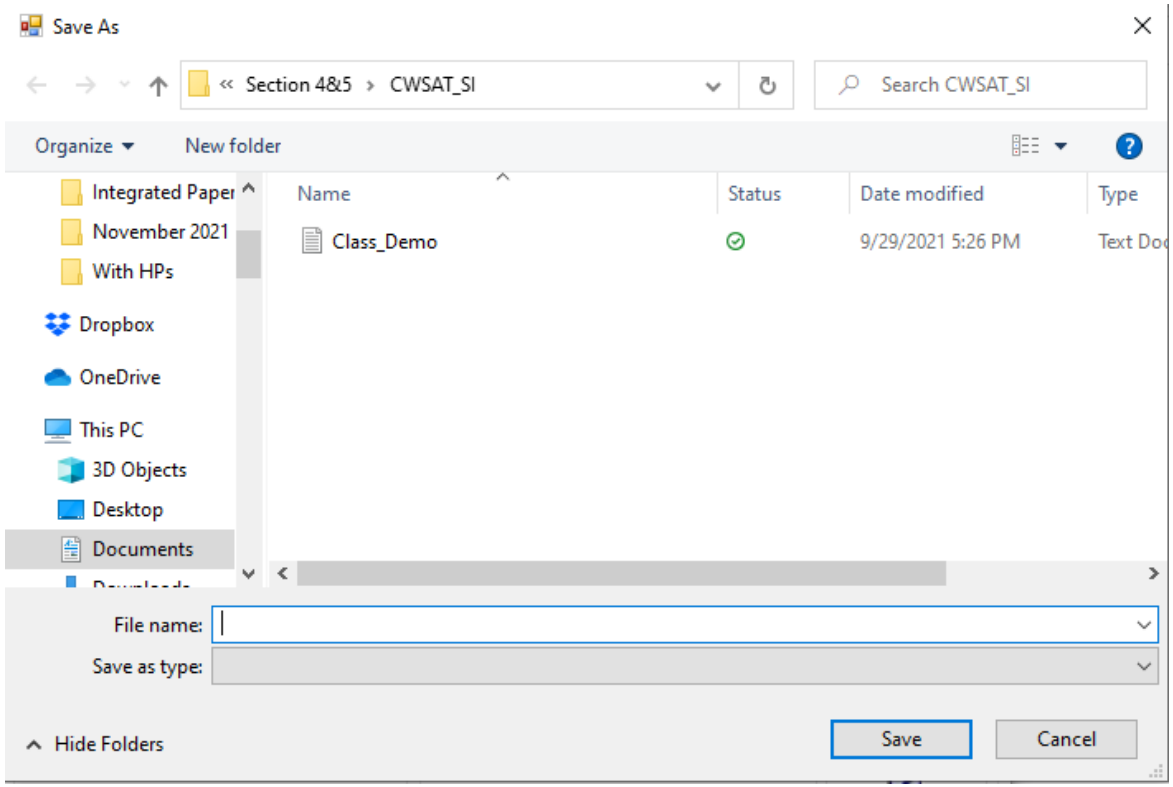
- Model provides good results when the cooling towers are within reasonable design limits
- Look for number of hours when the tower setpoint is NOT achieved



Saving the Baseline Model file – MOST IMPORTANT!

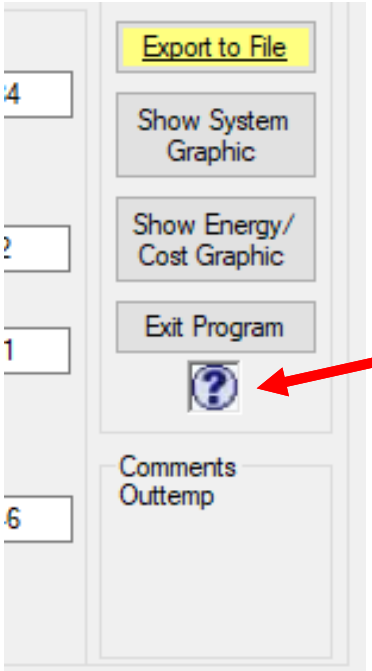
- Output Screen

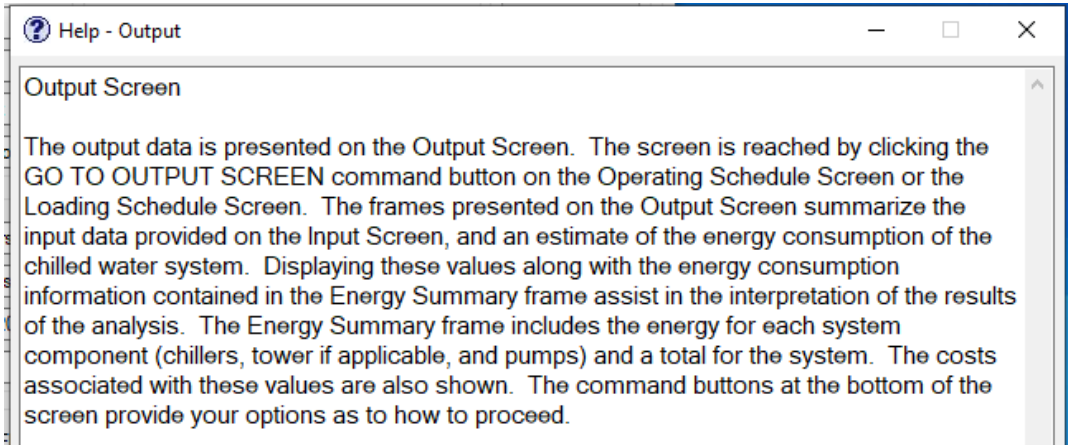




The HELP Button

- Use it as often as you need





Additional CWSAT Topics

- Installing and weather folder location / use
- Input Sensitivity
- Hourly text files output
- Detailed results screens
- Tool Benefits:
  - Energy end-use distribution
  - Identify areas to examine for conservation
  - “What-if” analyses

CWSAT Folder & Files

- CWSAT 3.0.1 – Application file which runs CWSAT
- Folder – USERCHILLER – Stores data of all user-defined chillers and their performance curves so that one can retrieve them for modeling in the chilled water system
  - Ideal when user has all the information about their chillers and DO NOT want to use the default performance curve built-in in CWSAT
- Folder – WEATHER – Stores weather data for all the geographical locations that can be used by CWSAT (pull down menu on INPUT screen)
  - One can add more weather data in this folder using the same format provided in any of the weather files
  - WEATHER folder is weather files for cities in US/Canada

CWSAT Folder & Files

- Folder – OUTPUTDATA – Stores all the Output data in an extremely detailed hour-by-hour (8,760) manner
  - Can be used when user wants to export results, operational information to another program (for example - Excel)
  - Ability to debug and additionally, parse data for specific day/time operation
- Chilled water plant models can be stored anywhere on your computer - They don't need to be in a specific location
  - SUGGESTION – Make your personal model folder within the CWSAT main folder and store all your work there – easier to reach the files since they will all be in one place and will minimize searching
- Please DO NOT move any other files and folders

Key Points / Action Items

1. *A chilled system consists of multiple chillers and NOT all chillers have the same performance curves – full load and part-load*

2. *To do an accurate model, it is important to have the part-load design performance of each chiller and define the chillers in CWSAT*

3. *CWSAT can model a chilled water system and provide significant details to understand overall operations of the plant*

Homework #4

- Attempt to build a chilled water system model in CWSAT of your own chilled water plant
- Use default information of CWSAT wherever your information is not available
- Compare the CWSAT annual energy usage and costs with information that you may have on your plant
- Identify areas that you had difficulty in understanding and modeling
- Identify discrepancies and shortcomings, if any, in the CWSAT software

Thank You all for attending today's webinar.

See you all on Wednesday – August 14, 2024 – 10 am ET

If you have specific questions, please stay online and we will try and answer them.

Alternately, you can email questions to me at paparra@ornl.gov

U.S. DEPARTMENT OF ENERGY

Kahoot Quiz Time