Better Plants
U.S. DEPARTMENT OF ENERGY

Industrial Process Cooling (Chilled Water) Systems

Virtual INPLT Training & Assessment

Session 3

Thursday – June 16, 2022

10 am – 12:30 pm

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Welcome

- Welcome to the 3rd 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!

Acknowledgments

- US Department of Energy, Advanced Manufacturing Office
  - Oak Ridge National Laboratory
- United Nations Industrial Development Organization
  - National Cleaner Production Center – South Africa
- Hudson Technologies Company
- Dr. Beka Kosanovic – University of Massachusetts, Amherst, MA
- Several industrial clients – both in the US and internationally

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Process Cooling Virtual INPLT Agenda (2022)

- **Week 1 (June 2) – Industrial Chilled Water Systems Fundamentals**
- **Week 2 (June 9) – Review of Chilled Water System Scoping Tool; Efficiency Metrics & Calculations**
- **Week 3 (June 16) – IPLV; Additional Energy Efficiency Metrics; Instrumentation Gap Analysis; CWSAT**
- **Week 4 (June 23) – Using CWSAT to Build a Chilled Water Plant System Model**
- **Week 5 (June 30) – Using CWSAT to Quantify Energy Efficiency Opportunities**
- **Week 6 (July 7) – US DOE MEASUR, 3EPlus, etc.; Undertaking a VINPLT Assessment & Reporting**
- **Week 7 (July 14) – Case Studies; Refrigerants – Past, Present & Future; Reclamation and O&M**
- **Week 8 (July 21) – Industrial Process Cooling (Chilled water) System VINPLT Wrap-up Presentations**

Agenda – Session 3

- Welcome and Introductions
- Safety and Housekeeping
- Today's Content:
  - Review of Session 2 & Homework
  - IPLV and Additional Energy Efficiency Metrics
  - Load profiles
  - Instrumentation Gap Analysis Worksheet
  - Introduction to CWSAT
- Kahoot Quiz Game
- Q&A

Better Buildings is an initiative of the U.S. Department of Energy

Safety and Housekeeping

- Safety Moment
  - Most refrigerants are heavier than air – hence, exercise caution when entering mechanical rooms that are below grade and not ventilated
- 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

Quick Review – Session 2

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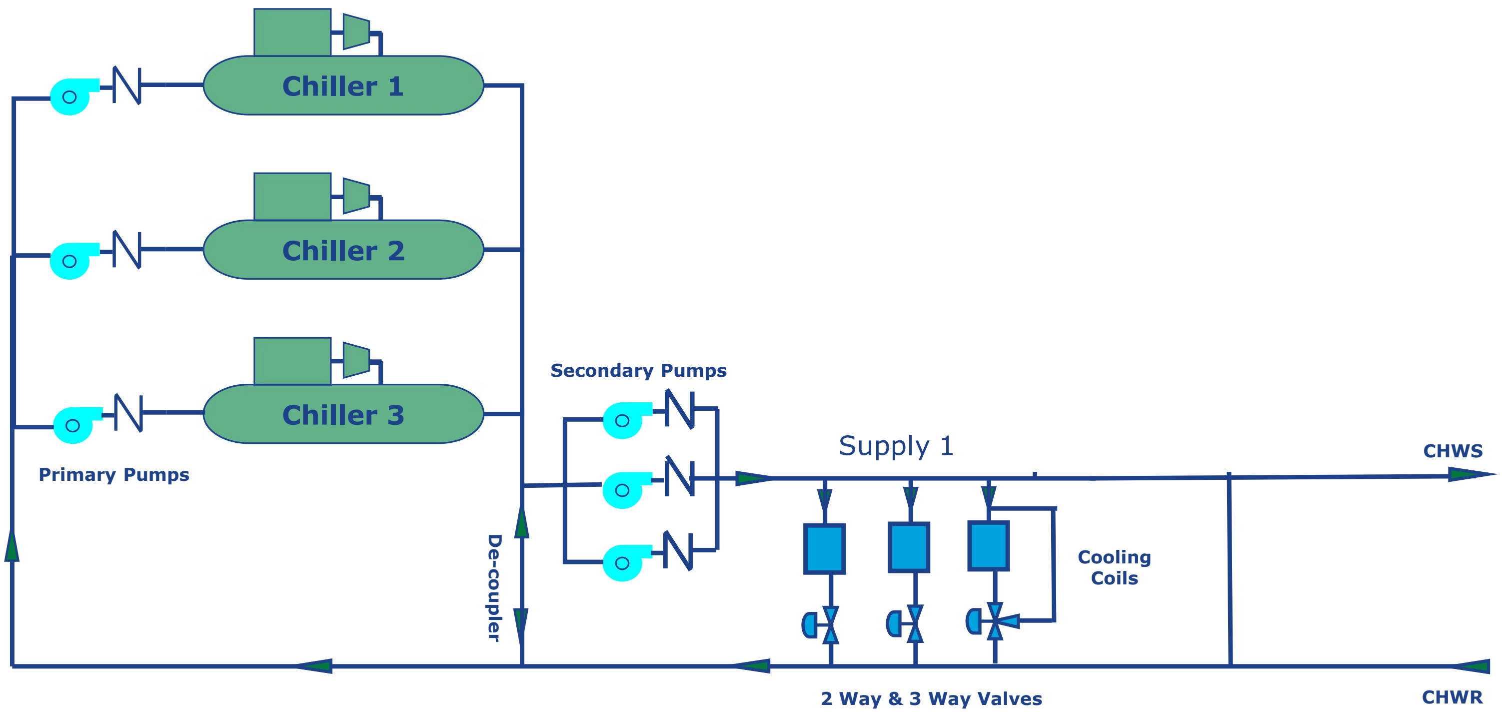
Electric Motor Drives (Variable Frequency)

- May not be a standard option but becoming very prevalent with new chillers and also a retrofit option in some cases
- Provides for very high power factors (>0.97)
- Provides soft start capability
- VFD efficiency is very high >98% and so doesn't introduce any losses
- Compressor flow is controlled by varying the speed of the compressor
- Tremendous ability to match Loads with Lift and provide significant savings at part-load conditions

Primary & Secondary Loops Chiller Plant



* CHWR is always reverse return but shown here as direct return for simplicity

Chilled Water System Scoping Tool (CWST)

Chilled Water System Scoping Tool (CWST) Summary

Points Details	
Maximum Score =	420
Your Score =	420
Best Practices Rating =	100%

Based on plant information, there is low potential and energy savings in the range of 0-10% can be anticipated.

Section	Your Score	Maximum Score	%
General	90	90	100
System Components			
Compressors	80	80	100
Condensers	75	75	100
Evaporators	70	70	100
Cooling Towers	62	62	100
Plate Heat Exchangers/Waterside Economizers	23	23	100
Pumps	20	20	100
Total	420	420	100

Acknowledgments: National Cleaner Production Center, South Africa (UNIDO IEE Project)

Intended CWST Users

- Industrial manufacturers
  - Plant managers
  - Utility managers
  - Plant process engineers

- Energy consultants
  - Energy efficiency experts (high-level)
  - System-focused experts
- Can also be used by institutional, commercial chilled water HVAC users

Interpreting Summary Results

- Maximum possible score: Varies based on your system selections
- The scorecard reflects a general overview of existing bestpractices in the Chilled Water system
  - An average plant would score between 60-75%
- A "line in the sand" effort on potential energy savings possible in the chilled water system is provided based on
  - Past experiences in chilled water systems
  - Data collected over the years from different energy assessments in chilled water systems
  - Consultation with other experts in industry
- This score is "**Qualitative**" in nature and no effort of performance guarantees, promises of savings, etc. should be made based on the results of CWST

Chiller Unit Capacity

- Chiller unit capacity (Tonnage) is the amount of full load cooling capacity provided by the chiller unit at design conditions
- Units of cooling capacity or refrigerating effect are RT (or sometimes TR)
- In the USA and some other places - Refrigeration Ton (RT) is used
  - The amount of thermal energy to be removed from 1 short tonne (2,000 lbs) of water at 32°F to make it into ice at 32°F in one day (24 hr) is 1 RT
- **1 RT = 12,000 Btu/hr**

Unit Performance Metrics

$$kW/RT = \frac{Compressor\ Power\ (kW)}{Cooling\ Load\ (RT)}$$

- Most standard rating in USA for Chilled Water systems - kW/RT
- Amount of compressor power (kW or hp) required to produce 1 RT of cooling or refrigeration

$$COP_{cooling} = EER = \frac{3.517}{(\frac{kW}{RT})}$$

- Conversion between Cooling COP, EER and kW/RT is simple

Example - Determining Chiller Unit Energy and Costs

- Chiller unit information provided
  - Cooling capacity = 1,000 RT
  - Chiller performance (efficiency) = 0.65 kW/RT
  - Annual operation = 6,250 hours
  - Electric power cost = 0.10 $/kWh

$$\textbf{Power} = 1,000 * 0.65 = 650\ \text{kW}$$

$$\textbf{Annual Energy} = 650 * 6,250 = 4,062,500\ \text{kWh}$$

$$\textbf{Operating Cost} = 4,062,500 * 0.10 = \$406,250$$

Example - Determining Chiller System Energy and Costs

$$\text{System Power} = (1,000 * 0.65 + 75 + 15) = 740\ \text{kW}$$

$$\text{System Annual Energy} = 740 * 6,250 = 4,625,000\ \text{kWh}$$

$$\text{System Operating Cost} = 4,625,000 * 0.10 = \$462,500$$

$$\text{System Efficiency} = \text{Total Power} / \text{Cooling Tons}$$

$$= 740 / 1,000 = 0.740$$

Calculating Actual Operating Energy Efficiency

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Chiller Operating Energy Efficiency

$$\text{Cooling Load (RT)} = \dot{M}_{water} * C_p * (T_{return} - T_{supply}) / 12{,}000$$

$$\text{Compressor Power (kW)} = 1.732 * V * I * PF / 1{,}000$$

$$\text{Chiller Performance} = \text{Compressor Power (kW)} / \text{Cooling Load (RT)}$$

Chiller Operating Energy Efficiency

- $\dot{M}_{water}$ – Mass flow rate of chilled water (lb/hr)
  - = Volume flow rate (gpm) X Density (lb/gal) X 60
  - = 500 X gpm
  - If there is glycol or another heat transfer fluid, then use the appropriate density of that fluid instead of water

- C_p – Specific heat of heat transfer fluid (Btu/lb-°F)
  - = 1.0 (for water)
  - If there is glycol or another heat transfer fluid, then use the appropriate specific heat of that fluid instead of water

Chiller Operating Data

- The utility engineer has gathered the following data:
  - Chilled water
    - Supply Temperature = 44.0°F
    - Return Temperature = 54.4°F
    - Chilled water flow rate = 2,310 gpm
  - Compressor motor (3-phase)
    - Voltage = 4,160 V
    - Current = 100 A
    - Power factor = 0.90
- Calculate the chiller tonnage (load) and the operating energy efficiency (kW/RT)

Chiller Operating Energy Efficiency

$$\text{Cooling Load (RT)} = \dot{M}_{water} * C_p * (T_{return} - T_{supply}) / 12{,}000$$

*Cooling Load (RT) = 2,310 * 500 * 1.0 * (54.4 – 44.0) / 12,000*

Cooling Load (RT) = 1,000 RT

*Compressor Power (kW) = 1.732 * V * I * PF / 1,000*

*Compressor Power (kW) = 1.732 * 4,160 * 100 * 0.9 / 1,000*

Compressor Power (kW) = 648.5 kW

Chiller Operating Data

Chiller Energy Efficiency = Compressor Power (kW) / Cooling Load (RT)

Chiller Energy Efficiency = 648.5 / 1,000

Chiller Energy Efficiency = 0.649 kW/RT

Chiller Plant (System) Operating Efficiency

- Cooling Load = 1,000 RT
  - Compressor
    - Amps: 100 A
    - Voltage: 4,160 V
    - Power factor: 0.9
    - Power = 648.5 kW (from previous example)
  - Parasitic Load
    - Primary and secondary loop pumps: 75 hp ~ 56 kW
    - Cooling tower pumps: 20 hp ~ 15 kW
    - Cooling tower fans: 25 hp ~ 18.5 kW
    - Total Parasitic Load = 90 kW
  - Total Power = 648.5 + 89.5 = 738 kW

Chiller Plant (System) Operating Efficiency

System Energy Efficiency = Total Power (kW) / Cooling Load (RT)

System Energy Efficiency = 738 / 1,000

System Energy Efficiency = 0.738 kW/RT

NOTE: Chiller Energy Efficiency = 0.649 kW/RT

Seasonal Energy Efficiency Metrics

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Chiller Design Specifications

- In the US, each chiller can be tested at the manufacturer's testing facility per AHRI Standard 550
  - There maybe an extra charge for this test
  - There maybe limitations based on size of chiller and testing facility capability
- Performance (kW/RT) for typical commercially available packaged chiller units
  - Water cooled – 0.4 – 0.8
  - Air cooled – 0.7 – 1.3
- Full load design rating conditions versus seasonal operating rating conditions
- ASHRAE Standard 90.1 provides minimum performance requirements for chillers

Seasonal Energy Efficiency of the Chiller System

- The efficiency of chilled water systems is dependent on several factors:
  - Cooling Load
  - Cooling supply temperature
  - Heat rejection temperature
  - Compressor efficiency
  - Control mechanisms
  - Variable Frequency Drives
  - Number of operating chiller units
  - Heat exchanger surface areas
  - Other site-specific factors

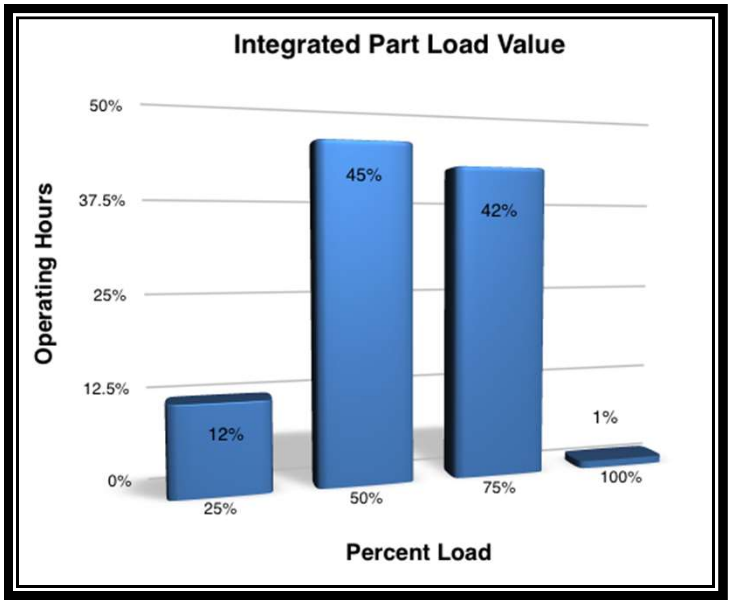
Integrated Part Load Value

- Integrated Part Load Value (IPLV) is defined by AHRI in the AHRI Standard 550/590
- It is accepted by the ASHRAE and compliant with ASHRAE 90.1
- IPLV is a weighted value of 4 standard loads and Entering Condenser Water Temperatures (ECWT):
  - 100% load @ 85°F ECWT
  - 75% load @ 75°F ECWT
  - 50% load @ 65°F ECWT
  - 25% load @ 65°F ECWT

Integrated Part Load Value

- Generally, a chiller operates at <u>full load design conditions</u> for 1% of the total operating hours **ONLY**

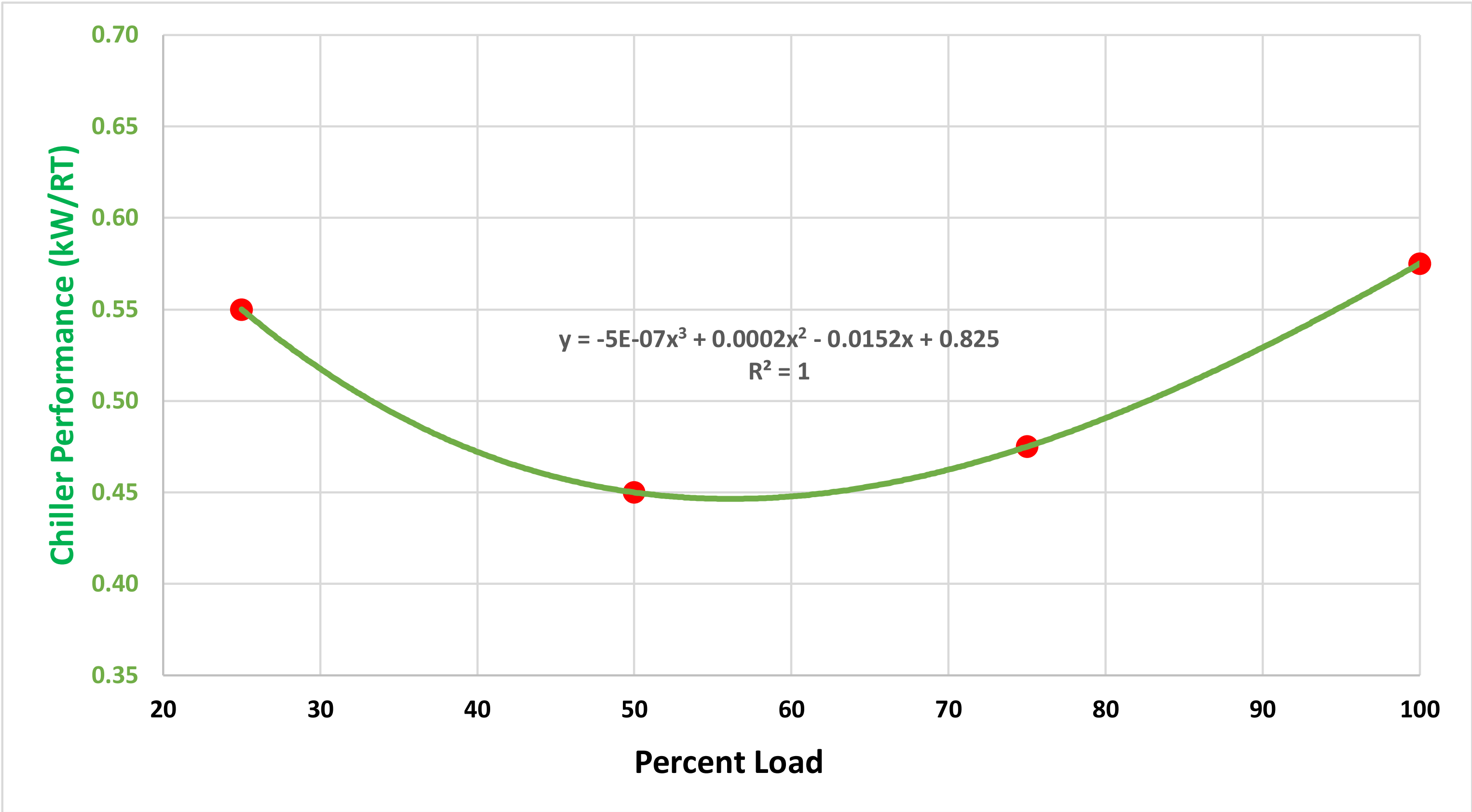
- Hence, no decisions should be based on the design efficiency but instead they should be used as a guide to reach optimal solutions



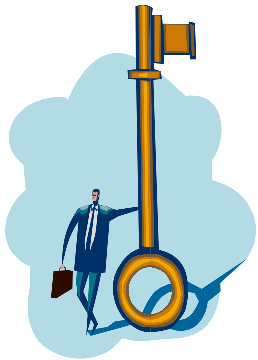
Chiller Full Load Design Specifications

Chiller ID	Chiller #6		Chiller Manufacturer	JCI
Year Commissioned	2005		Chiller Type	Constant Speed Centrifugal
Model Number	YKY4Y4J75DJF		Serial Number	YX24584BC
Refrigerant	R134a		Capacity	2,000 RT
Design Efficiency	0.625		IPLV	0.541
Full Load Amps	198		Volts	4160
Evaporator Entering Water Temperature	55°F		Condenser Entering Water Temperature	85°F
Evaporator Leaving Water Temperature	44°F		Condenser Leaving Water Temperature	95°F
Evaporator Flow	4,800 gpm		Condenser Flow	6,000 gpm
Evaporator Pressure Drop	10 psid		Condenser Pressure Drop	10 psid

Overall Chiller (Plant) Performance



Key Points / Action Items



1. kW / RT is the energy efficiency metric used for the chiller and the system

2. System Efficiency includes power consumed by the chiller compressor motor, chilled water pumps, cooling tower pumps, fans and other parasitic users

3. Chiller manufacturers design, specify and test chillers

4. IPLV is most commonly used to determine average seasonal energy efficiency rating

Additional Metrics in Chilled Water Systems

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Additional Performance Metrics

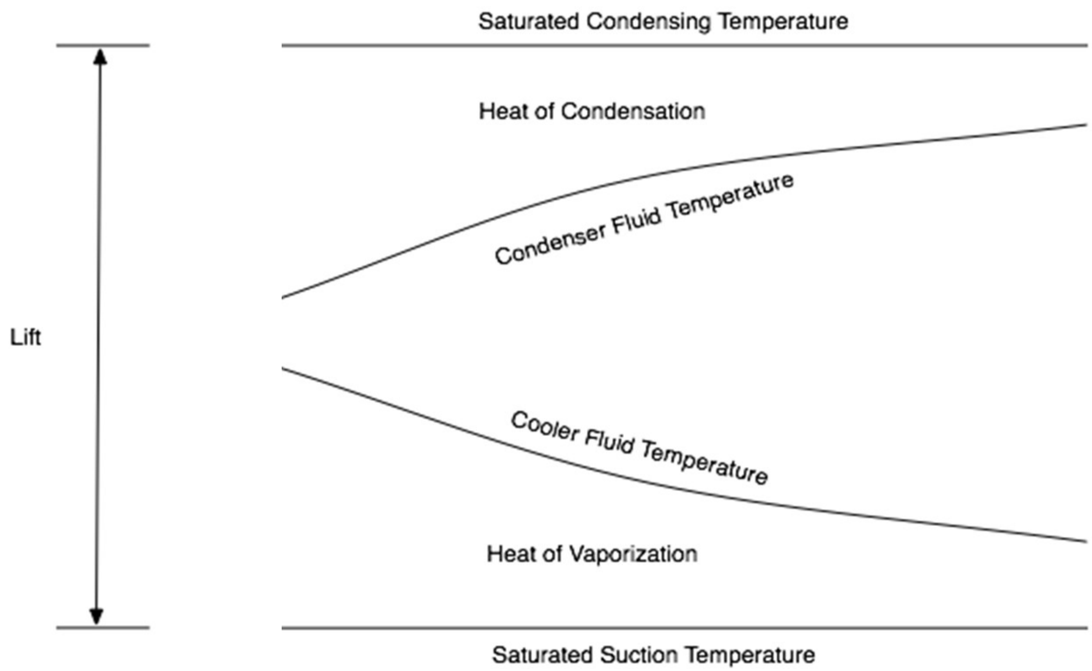
- Generally needed for more detailed analysis
- Periodic assessment (if not continuous) is recommended
- Provides a good baseline and identifies a problem before failures
- SMART algorithms can implement these metrics for trending performance
  - Closed-loop feedback controls are programmed into chilled water system controllers that optimize the operations of the chilled water system real-time

General Chiller System Performance Metrics

- Overall chiller system plant performance
  - Total cooling load
  - Total kW (including chillers and auxiliaries)
- Chiller Lift
- Chiller efficiency
  - Carnot efficiency
  - Chiller actual efficiency (kW / RT)
- Compressor isentropic efficiency
  - Suction and discharge temperatures
  - Suction and discharge pressures
- Heat exchanger effectiveness
  - Approach temperatures
  - ΔT on chilled water and cooling tower water

Chiller Lift

- Difference between Saturated Condensing Temperature and the Saturated Suction (Evaporating) Temperature



Carnot Efficiency

$$Carnot\ Efficiency = \frac{T_{cold}}{T_{reject} - T_{cold}}$$

- Ideal Carnot Efficiency
  - Dependent of cooling supply temperature and heat rejection temperature ONLY
  - All temperatures should be in the absolute temperature scale (R)
    - Absolute Temperature (R) = Temperature (°F) + 460

Compressor Isentropic Efficiency

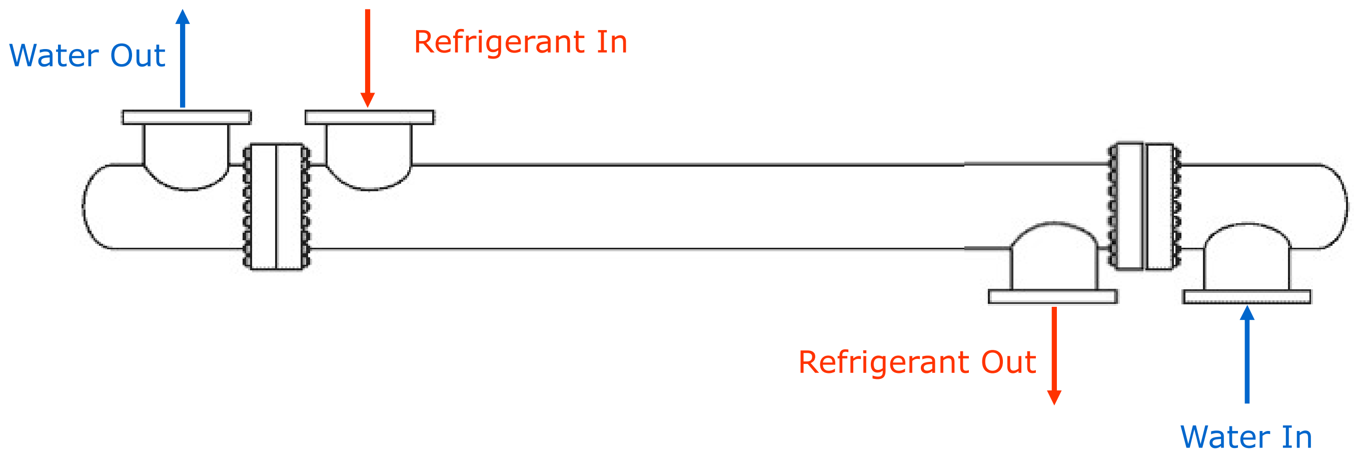
- Information required
  - Suction and discharge temperatures
  - Suction and discharge pressures

- Comparison of work done by ideal compressor (isentropic) versus the actual compressor

- Measure of energy lost in temperature increase compared to just pressure increase

- Lower efficiency implies higher compressor discharge temperatures and higher compressor power!

- Principle of Conservation of Energy
  - First Law of Thermodynamics
  - Energy Flow In = Energy Flow Out



- Heat Exchanger Performance
  - Design Information
    - Operating Temperatures, Pressures, Flows
    - Fluid information
    - Heat exchanger area, Log Mean Temperature Difference, Fouling coefficient, Overall Heat Transfer coefficient (U)
    - Heat Duty
  - Log Mean Temperature Difference (LMTD)
    - Determines the driving force available for heat transfer
    - Higher LMTD's imply inefficiency and losses

Heat Exchangers

- Refrigerant Approach Temperatures (RAT)
  - RAT = Absolute (Leaving Water Temperature - Saturated Refrigerant Temperature)
- Saturated Refrigerant Temperature refers to the refrigerant being heated (evaporator) or cooled (condenser)
- Every chiller unit has a manufacturer full load design Evaporator RAT and Condenser RAT
- When RAT increases for the same heat load, it indicates an increase in heat exchanger fouling (heat transfer resistance)

Key Points / Action Items

1. Actual operating performance calculations for chiller systems will require temperatures, pressures, flows and power information

2. It is important to calculate both overall chiller plant and individual chiller operating efficiency

3. The other chiller plant efficiency metrics include: Lift, Isentropic compressor efficiency, Heat Exchanger effectiveness, etc.

4. Fouling impact in heat exchangers has to be determined and related to reduction in efficiency and increase in operating costs

5. Refrigerant Approach Temperature (RAT) serves as a good proxy for LMTD (driving force)

Chilled Water System Load Profile

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Load Profile

- Chilled water systems will NEVER have a constant cooling load
- Most high-level analysis (ASHRAE Level 1, plant walk-through) can be done using design information with a load factor approach
- Every chilled water system energy efficiency and optimization analysis will need to consider the cooling load profile of the system
- Level of detail and time intervals will vary based on several factors – availability of data, time-based sensitivity of the load, repeatable patterns and significant factors, etc.

Chilled Water System Load Profile

- Every chilled water system and industrial plant is UNIQUE
- Nevertheless, the shape of the load profile may coincide across similar plants
- Determination of a true load profile is very difficult in a real-world scenario but there are several techniques and methods to define and develop a load profile for any chilled water system
- Every chilled water energy efficiency assessment should require the inclusion of a representative load profile

Chilled Water System Load Profile

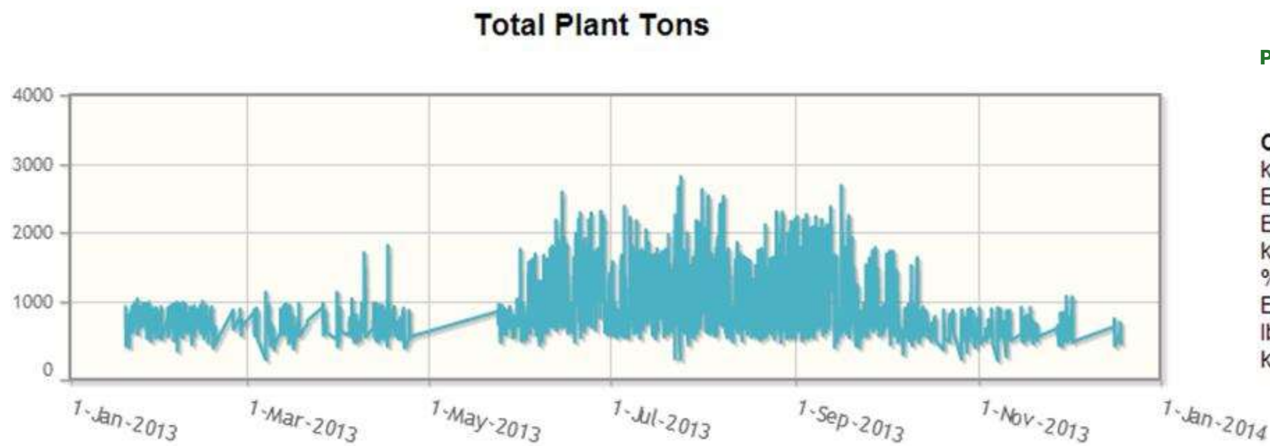
- Developing a load profile requires data collection

- Load profile should be developed for a certain time period
  - Annual – most common by using daily averages or hourly averages
  - Seasonal – production dependent; weather dependent
  - Monthly, Weekly, Daily – load is independent of weather and is strictly a function of product throughput

- Load profile can also be simulated using process modeling as well as using historian data and statistical analysis

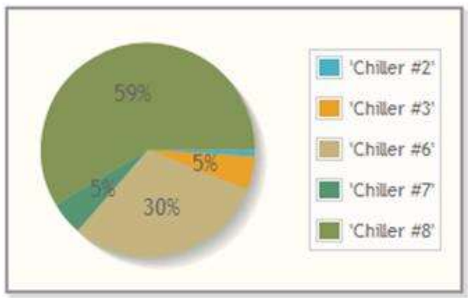
- Actual real-time operating data – state-of-the-art

Large Commercial Central Plant

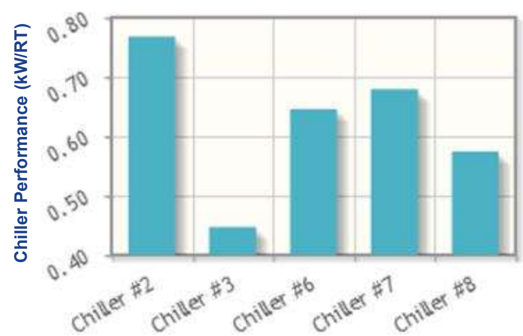


Plant Cooling Capacity - 6,000 RT

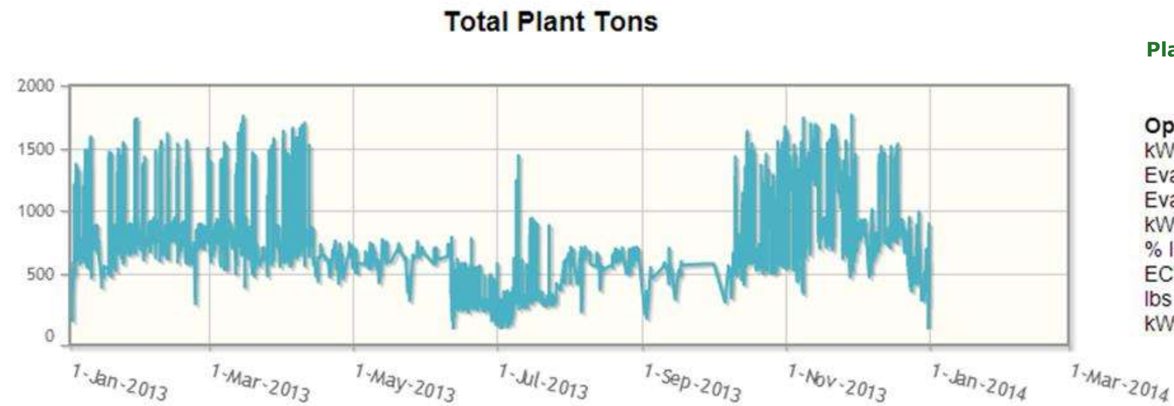
Operating Averages
kW = 410.53
Evaporator tons = 690
Evaporator Δ °F = 6.77
kW/ton = 0.596
% Input Power = 68.27
ECWT °F = 75.28
lbs CO2 Eq. produced = 562.43
kWh Cost = 24.63 per Hour



Cooling Load Hours (Tonhours) Contribution of Operating Chillers

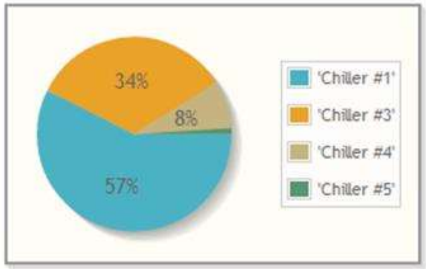


Food Manufacturing Plant Seasonal Operation

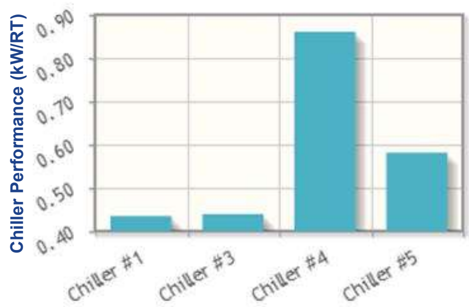


Plant Cooling Capacity - 3,500 RT

Operating Averages
kW = 273.83
Evaporator tons = 584
Evaporator Δ °F = 9.35
kW/ton = 0.515
% Input Power = 66.27
ECWT °F = 75.53
lbs CO_2 Eq. produced = 375.14
kWh Cost = 13.69 per Hour

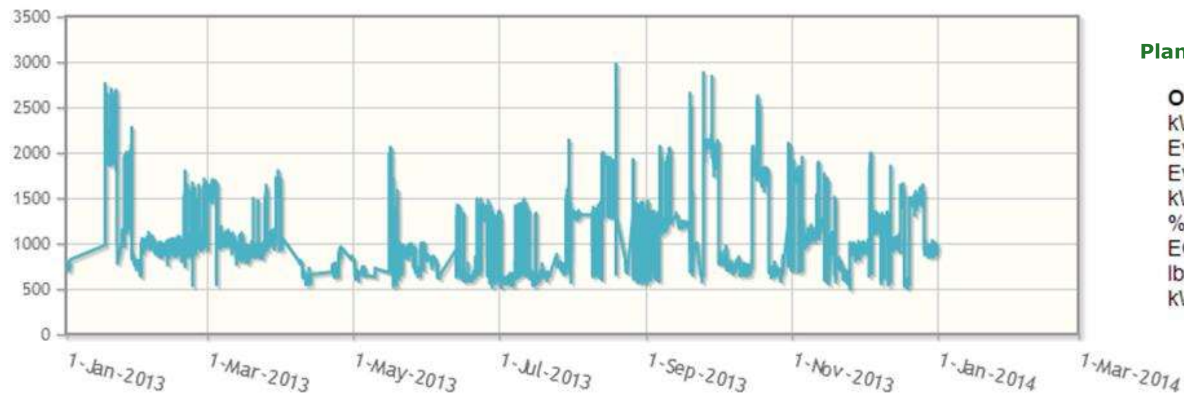


Cooling Load Hours (Tonhours) Contribution of Operating Chillers



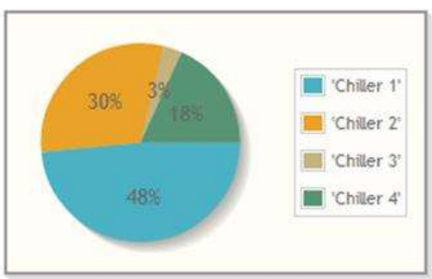
Data Center Central Plant

Total Plant Tons

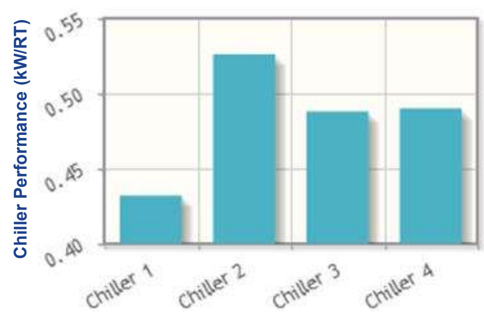


Plant Cooling Capacity - 4,500 RT

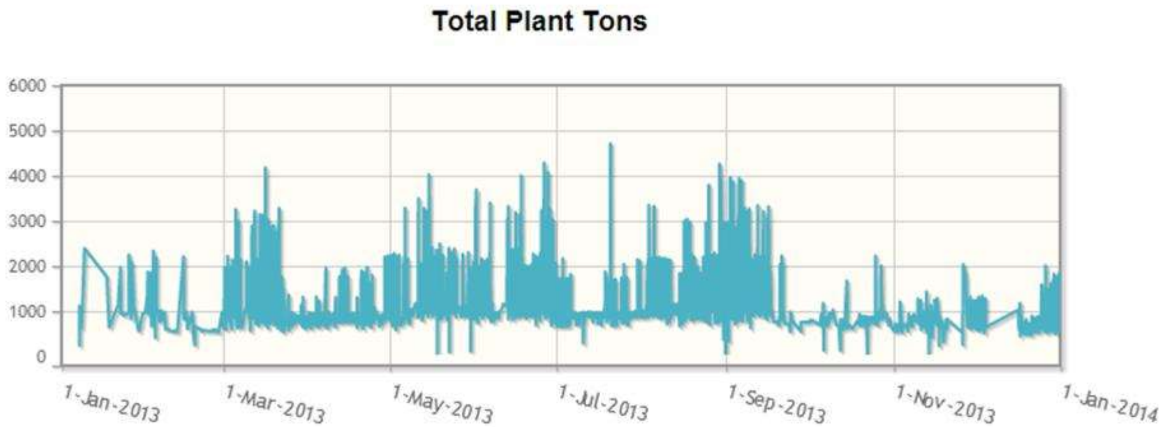
Operating Averages
kW = 391.85
Evaporator tons = 822
Evaporator Δ °F = 11.67
kW/ton = 0.481
% Input Power = 56.03
ECWT °F = 73.75
lbs CO2 Eq. produced = 1359.71
kWh Cost = 25.47 per Hour



Cooling Load Hours (Tonhours) Contribution of Operating Chillers

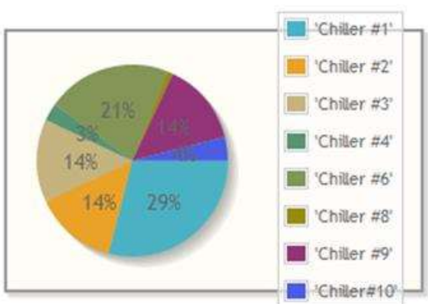


Casino Operation

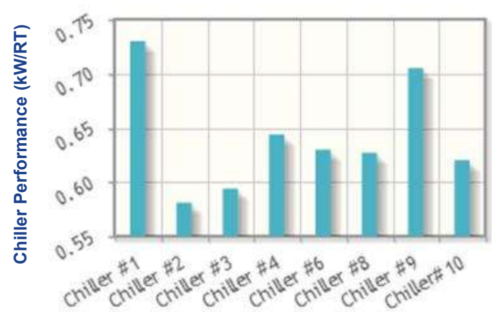


Plant Cooling Capacity - 43,000 RT

Operating Averages
kW = 585.97
Evaporator tons = 912
Evaporator Δ °F = 9.28
kW/ton = 0.663
% Input Power = 83.07
ECWT °F = 76.06
lbs CO2 Eq. produced = 802.77
kWh Cost = 64.46 per Hour



Cooling Load Hours (Tonhours) Contribution of Operating Chillers



Instrumentation GAP Analysis for a VINPLT – Process Cooling

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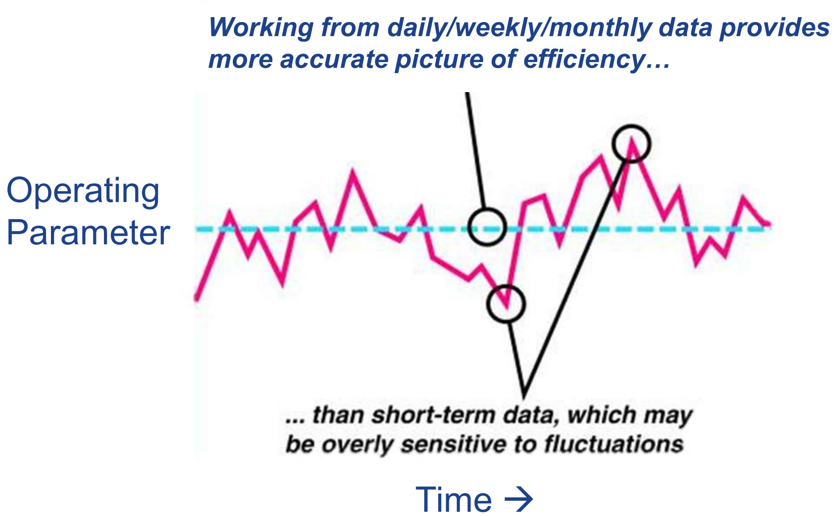
Chilled Water Plant Operating Data

- There are several different data points that are required for a chiller plant assessment
  - Evaporator and Condenser Entering and Leaving Water Temperatures
  - Evaporator and Condenser Water Flow Rates / Delta Pressure
  - Evaporator and Condenser Refrigerant Pressures
  - Compressor suction and discharge temperatures
  - Amps, Volts and Power Factor (Input kW) or equivalent data for steam turbine horsepower
  - Pumping power (primary, secondary)
  - Cooling tower fan power
- This data can be collected at regular intervals
  - Manually through log sheets
  - By the BAS/EMS

Field Measurements

- Instantaneous measurements
- Historical data
- Measurements spread over multiple time intervals

Data Gathering – Snapshot or Movie?

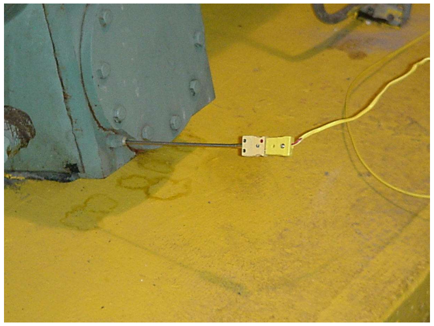


Calibration & Accuracy of Sensors

- To calculate chilled water system performance metrics, the operating data must be accurate
- All sensors drift over time
- Regular calibration is required
- Sensor Accuracy (General guidelines):
  - Temperature sensors must be accurate to within 0.2 °F
  - Differential pressures (dP) must be accurate to 0.25 psid
  - Water flows must be accurate to within 2.0%
  - Refrigerant pressures must be accurate to within 0.5%

Temperature Measurements

- Different types
  - Thermometers
  - Thermocouples
  - RTD's
  - Infrared gun / camera

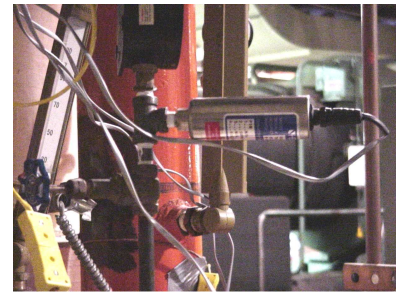


- Differential measurement can be done via a thermopile

- Load calculations require a "difference in two temperatures" – ΔT - accuracy very important

Pressure Measurements

- Most common
  - Bourdon-tube gage
  - Capacitative

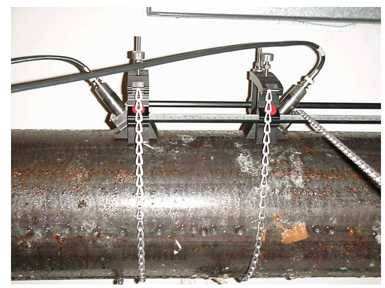


- Pressure transducers used very frequently for data monitoring

- Pressure monitoring devices will require specific ranges – understanding operating range of the chiller is required

Flow Measurements

- There are different kinds of flowmeters
  - Orifice plate / Annubar / Pitot tube
  - Turbine type
  - Vortex shedder
  - Magnetic
  - Ultrasonic (non-intrusive), etc.

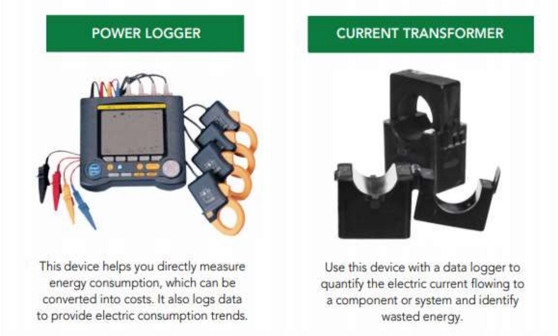


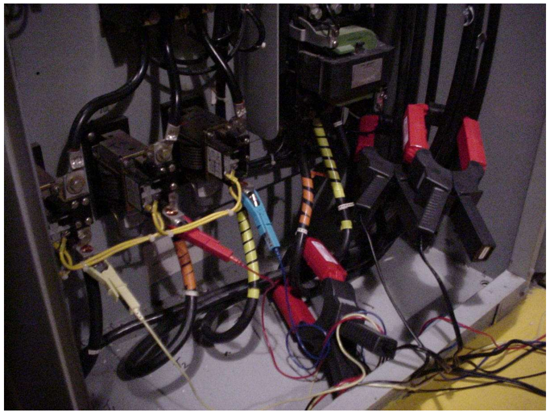
- Flow can also be measured using pressure drop (ΔP) in heat exchangers and comparing it to design flow and design pressure drop

$$Flow_{actual} = Flow_{design} \times \sqrt{\frac{\Delta Pactual}{\Delta Pdesign}}$$

Power Measurements

- Power meter is the common device for measuring power
- It will require simultaneous measurements of
  - Current on each phase
  - Voltage on each phase
  - Power factor
- First-order estimate can be made from current measurements
- Current Transducers (CTs) are very common





Long-Term Measurement / Historian

- Remember – Load as well as ambient conditions vary and the chiller unit (plant) operation varies to accommodate the varying conditions

- Collect data over a long-term time interval
  - Most cases annual (or typical seasonal / production based)
  - Representative seasonal / off-season (high / low production) times
  - Depends on availability of historian and data storage capability

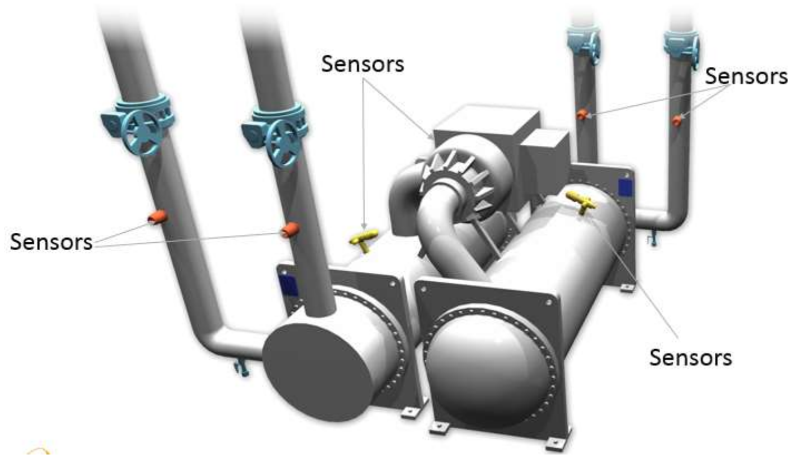
- Collect data at a reasonable frequency
  - Remember – steady state steady flow – we are NOT interested in start-up/shut-down or upset conditions
  - Hourly averages sufficient for energy assessment type work
  - 15-minute averages for detailed project analysis maybe required
  - Aim for average readings, if possible, within the interval

Measurement Locations for a Chiller Unit

Evaporator
1. Water Inlet Temp
2. Water Outlet Temp
3. Water Flow
4. Refrigerant Pressure

Condenser
5. Water Inlet Temp
6. Water Outlet Temp
7. Water Flow
8. Refrigerant Pressure

Power
9. Chiller Amps
10. Chiller Volts
11. Chiller Power Factor



Auxiliaries
12. Primary (& Secondary) CHW Pump kW
13. Primary CW Pump kW
14. Cooling Tower Fans kW

Weather - Optional
15. Outside Air Temperature
16. Relative Humidity

Planning for Measurement & Data Collection

- Use a template
- Characterize the measurement
  - Local sensor
  - Data Acquisition
  - Historian
- **Instrumentation GAP Analysis Worksheet**
- Tick mark the appropriate boxes
- Complete for the chiller system
- Define final plan

	Chiller #1		
Chiller Capacity (RT)			
Refrigerant			
Chiller Manufacturer			
Chiller Model Number			
	Local Sensor	Data Acquisition	Historian
Condenser			
Saturation Temperature (°F)			
Condenser Pressure (psig)			
Inlet Water Temperature (°F)			
Outlet Water Temperature (°F)			
Water Flow rate (gpm)			
SubCooler			
Refrigerant Outlet Temperature (°F)			
Water Inlet Temperature (°F)			
Water Outlet Temperature (°F)			
Water Flow rate (gpm)			
Economizer			
Economizer Pressure (psig)			
Evaporator			
Saturation Temperature (°F)			
Evaporator Pressure (psig)			

Better Plants Diagnostic Equipment Program (DEP)

Better Plants® U.S. DEPARTMENT OF ENERGY

Diagnostic Equipment Program (DEP)

The Better Plants **Diagnostic Equipment Program (DEP)** allows partners to borrow over 22 different kinds of tools to collect energy data and improve equipment performance in their facilities.

Through this program, partners have the opportunity to test tools firsthand before deciding to purchase a piece of equipment on their own. This not only allows for the improved testing and collection of energy data, but also helps to demonstrate the value of certain tools in different applications throughout a facility.

EXPLORE SOME OF THE TOOLS THAT YOU CAN BORROW THROUGH BETTER PLANTS:

FULL SUITE OF DIAGNOSTIC TOOLS

- Anemometer
- Combustion Analyzer
- Conductivity Meter
- Current Transformer
- Digital Manometer
- Digital Thermometer
- Infrared Camera
- Infrared Thermometer
- Laser Distance Meter
- Light Meter
- Pitot Tube
- Power Logger
- Pressure Transducer
- Pyrometer
- Sonic Imager
- Strobe Tachometer
- Temp/RH logger
- Thermocouple
- Thermocouple Logger
- Time of Use Logger
- Ultrasonic Flow Meter
- Ultrasonic Leak Detector

POWER LOGGER

This device helps you directly measure energy consumption, which can be converted into costs. It also logs data to provide electric consumption trends.

CURRENT TRANSFORMER

Use this device with a data logger to quantify the electric current flowing to a component or system and identify wasted energy.

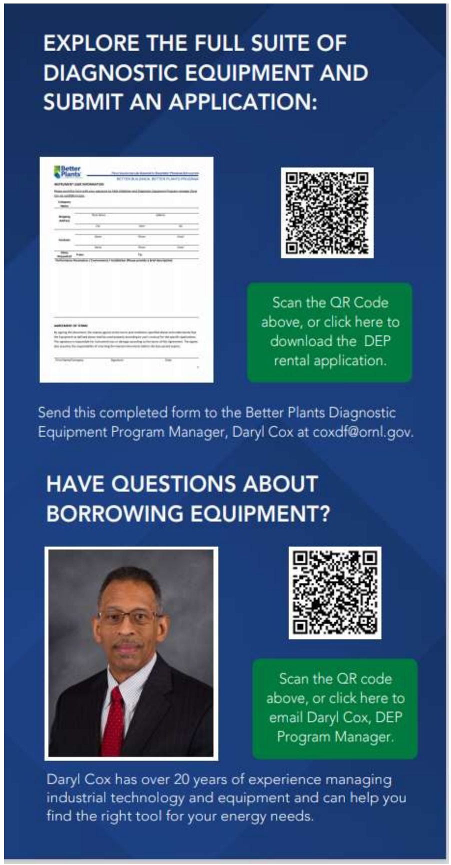
COMBUSTION ANALYZER

This analyzer quantifies excess oxygen in boilers and combustion process exhausts, helping you save fuel and heat energy.

LEAK DETECTOR

This device helps you identify leaks in compressed air or steam systems using high frequencies that are undetectable to the human ear.

betterbuildingssolutioncenter.energy.gov/better-plants/diagnostic-tools @BetterPlantsDOE linkedin.com/showcase/better-plants



EXPLORE THE FULL SUITE OF DIAGNOSTIC EQUIPMENT AND SUBMIT AN APPLICATION:

Scan the QR Code above, or click here to download the DEP rental application.

Send this completed form to the Better Plants Diagnostic Equipment Program Manager, Daryl Cox at coxdf@ornl.gov.

HAVE QUESTIONS ABOUT BORROWING EQUIPMENT?

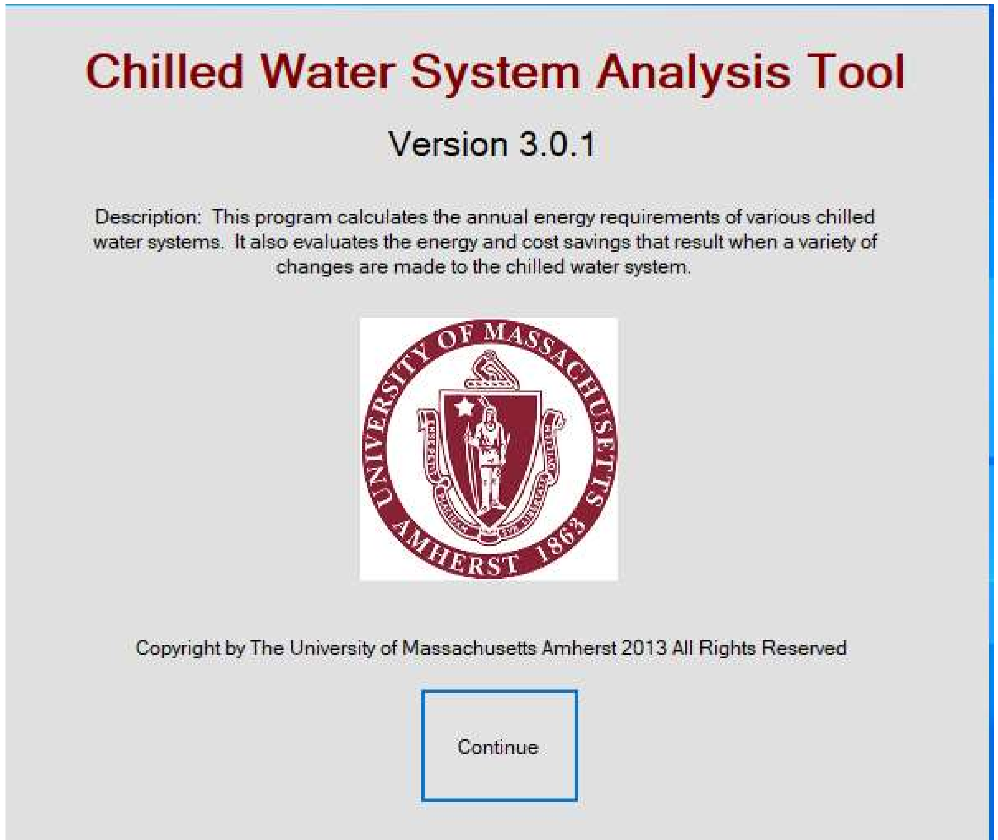
Scan the QR code above, or click here to email Daryl Cox, DEP Program Manager.

Daryl Cox has over 20 years of experience managing industrial technology and equipment and can help you find the right tool for your energy needs.

Chilled Water System Assessment Tool (CWSAT)

U.S. DEPARTMENT OF ENERGY

Introducing CWSAT 3.0.1



Introducing CWSAT 3.0.1

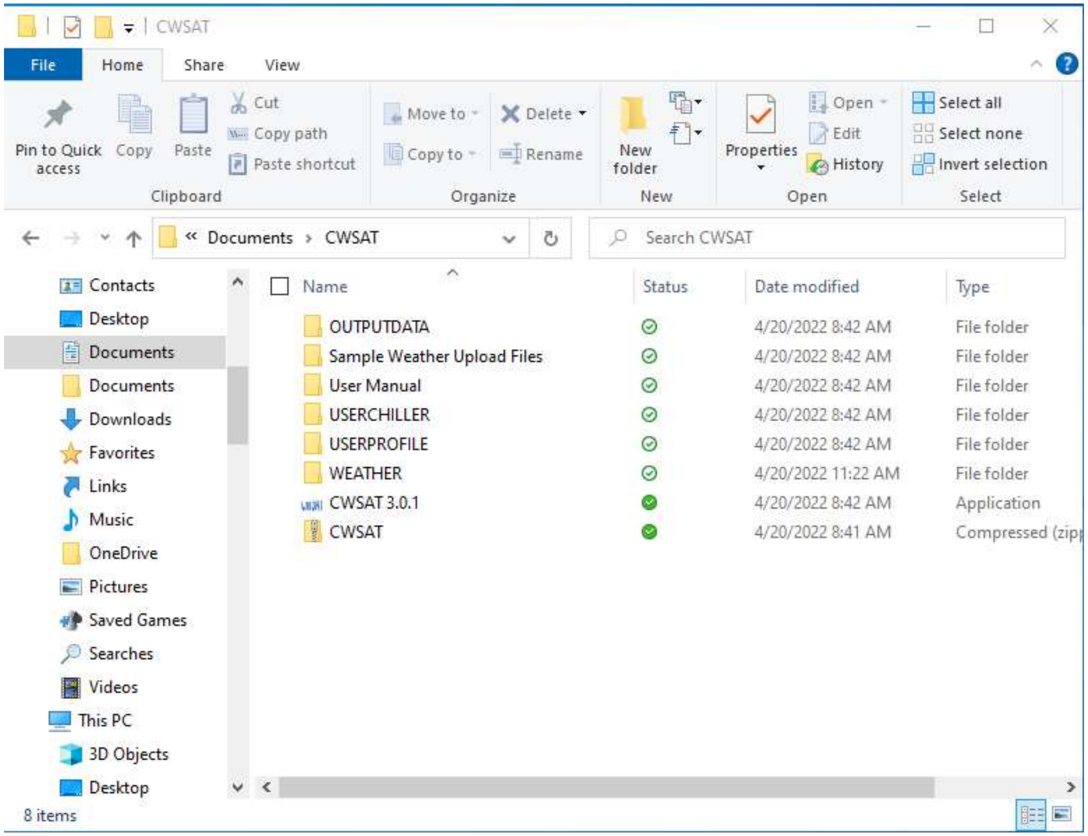
CWSAT INTRODUCTION

- A central chilled water system may account for a quarter to a third of facility energy consumption.
- The main goals of any cooling system
  - Provide adequate cooling to process or comfort load
  - Reduce energy consumption of the chilled water SYSTEM
- CWSAT IS NOT intended to determine system energy use down to the last kWh
- CWSAT IS intended to direct analysis effort toward the most promising cost reduction opportunities

Installation of CWSAT

- Available on the Better Plants / ORNL website
- Minimum system requirements
  - Windows-based PC
- Extract all the files from the zipped folder and store in CWSAT folder
- Administrative privileges maybe required for computer
- CWSAT has been developed by the University of Massachussetts

CWSAT Folder & Files



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
  - NOTE: 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 open, move any other files and folders

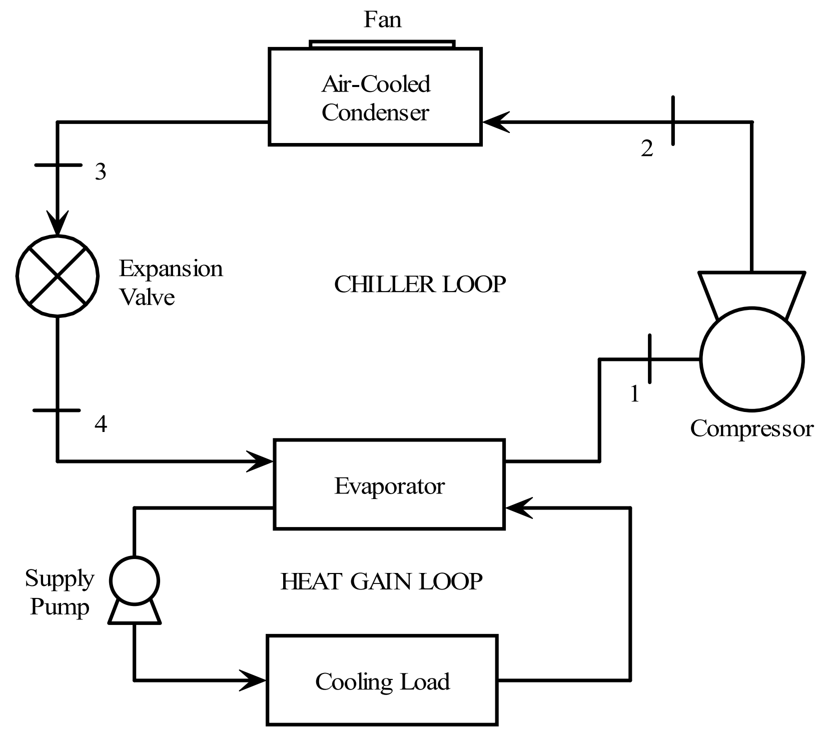
ACRONYMS

- CHWS: Chilled Water Supply
- CHWR: Chilled Water Return
- CWS: Condenser Water Supply
- CWR: Condenser Water Return

- FLE: Full Load Efficiency

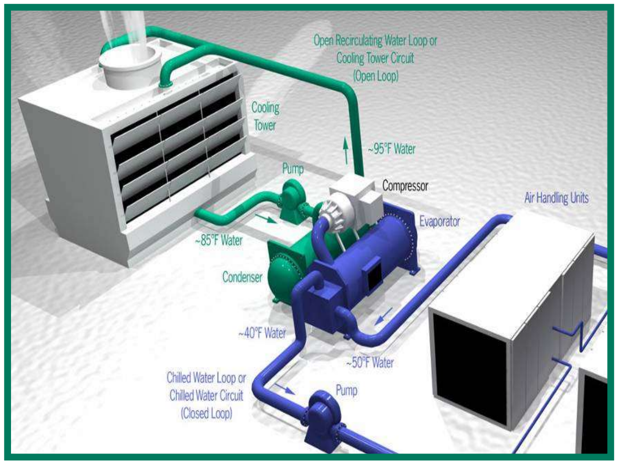
CWSAT System Configurations

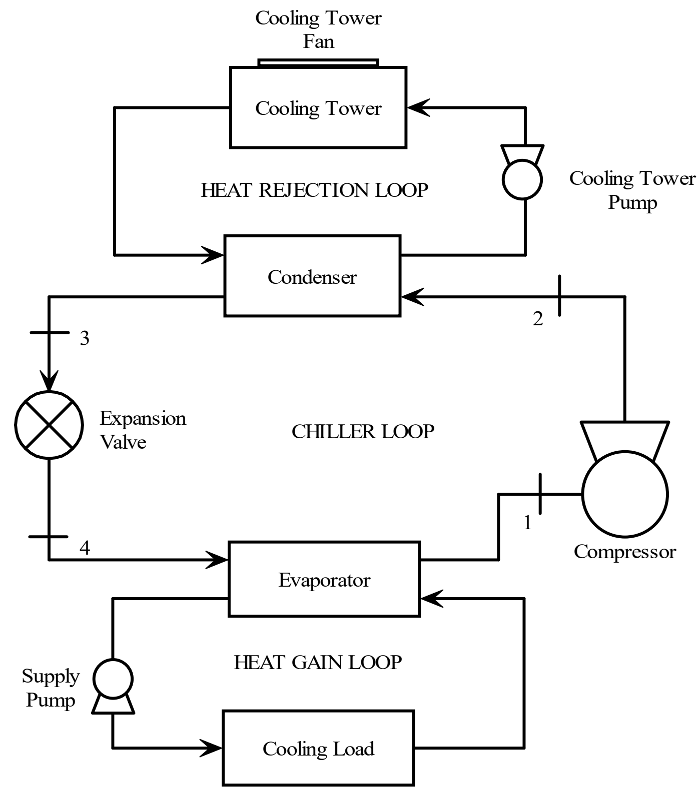
- Air-Cooled Chilled Water System:
  - Single Chiller
  - Multiple Chillers (maximum 5)



CWSAT System Configurations

- Water-Cooled Chilled Water System:
  - Single Chiller





  - Multiple Chillers (Maximum 5)

Polling Question 1

Polling Questions

1) How many chillers do you have in your chilled water plant where you will be doing your energy assessment?
   A. 1 - 3
   B. 4 - 5
   C. > 5
   D. Don't know yet

CWSAT Supported Equipment Types

- Mechanical vapor compression chillers (Centrifugal, reciprocating, and twin-screw helical rotary compressors)
- Air or water-cooled condensers
- Direct contact towers
- Mechanical draft towers (crossflow or counterflow)
- Shell-and-tube evaporators (other designs are limited to low capacity applications)
- Simple pump control configurations on primary circuit

CWSAT Equipment Types NOT Supported

- Absorption chillers
- Single Screw, Scroll, or Troichoidal compressors
- Evaporative condensers
- Indirect contact towers such as wet/dry or dry towers
- Natural or spray-induced draft towers
- Secondary pumping circuit (on chilled water or condenser water loop)
- Chillers connected in series

CWSAT Energy Calculations

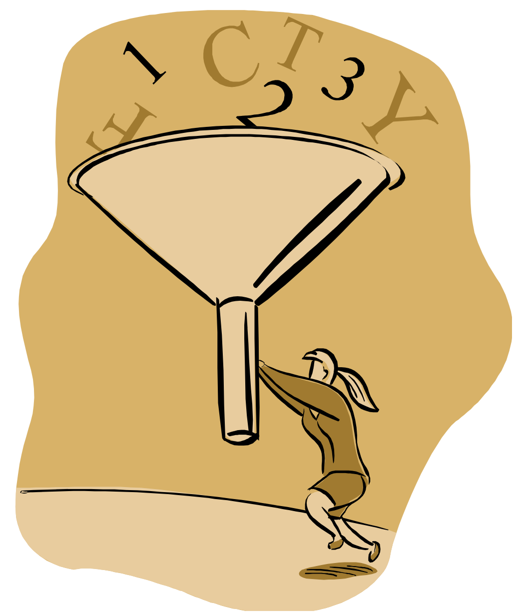
- Chillers
  - Uses catalog & manufacturer's data to follow typical performance curves
  - Uses correlations to adjust for actual condenser water (where applicable) and chilled water temperature
  - Uses schedules to determine hours at given load

- Cooling Towers
  - Uses iterative process and prototypical performance correlation to determine fan energy
  - Correlation inputs rely on weather data, chiller load, and condenser pump flow rate

- Pumps
  - Uses power provided as an input or utilizes pump energy equation to estimate pump horsepower & energy

Data Collection from Site

- Basic System Data (Observation)
  - Understand and observe the need for cooling/chilled water requirement
  - Number of Chillers & Chiller Type (Centrifugal, Reciprocating, Screw)
  - Number of Chilled Water Pumps
  - Number of Condenser Water Pumps
  - System Type – Air Cooled or Water Cooled
    - Location of Cooling Tower
      - Dedicated
      - Supplies to other processes
  - Number of towers / air-cooled condensers



Data Collection from Site

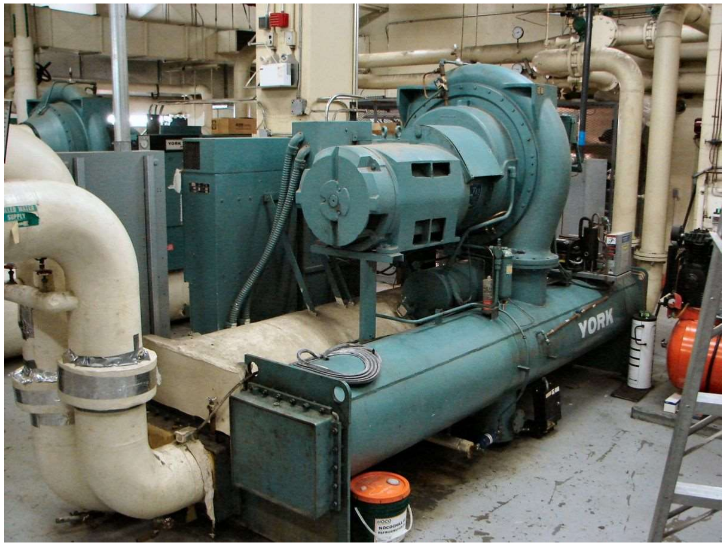
- Nameplate data
  - Chiller manufacturer & model number
    - Cooling Capacity (kW)
    - Efficiency
    - Age
  - Cooling Tower manufacturer & model number
    - Tower size (kW)
    - Efficiency
    - Tower type (# fans / # cells / motor control)
  - Pump & Pump Motor manufacturer & model number
    - Pump Curve (flow rate, efficiency)
    - Motor kW & Efficiency

Data Collection from Site

- General Operating Parameters (conversations with facility personnel, chiller control panels, temperature sensors, observations)
  - Chilled Water Supply Temperature (setpoint)
  - Condenser Water Supply Temperature (setpoint and/or strategy)
  - Chilled Water Supply Flow Control (constant or variable, primary/secondary system)
  - Condenser Water Supply Flow Control (constant or variable, Heat exchanger used)

Chilled Water System Components

- Components Covered by CWSAT
  - Chiller Types:
    - Centrifugal
    - Helical Rotary / Screw
    - Reciprocating
  - Condenser Types:
    - Water Cooled with Cooling Towers
    - Air Cooled
  - Other Equipment:
    - Pumps
    - Fans
    - Piping & Valves
    - Heat Exchangers

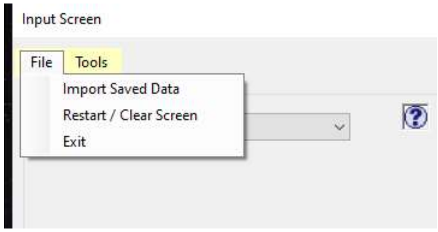


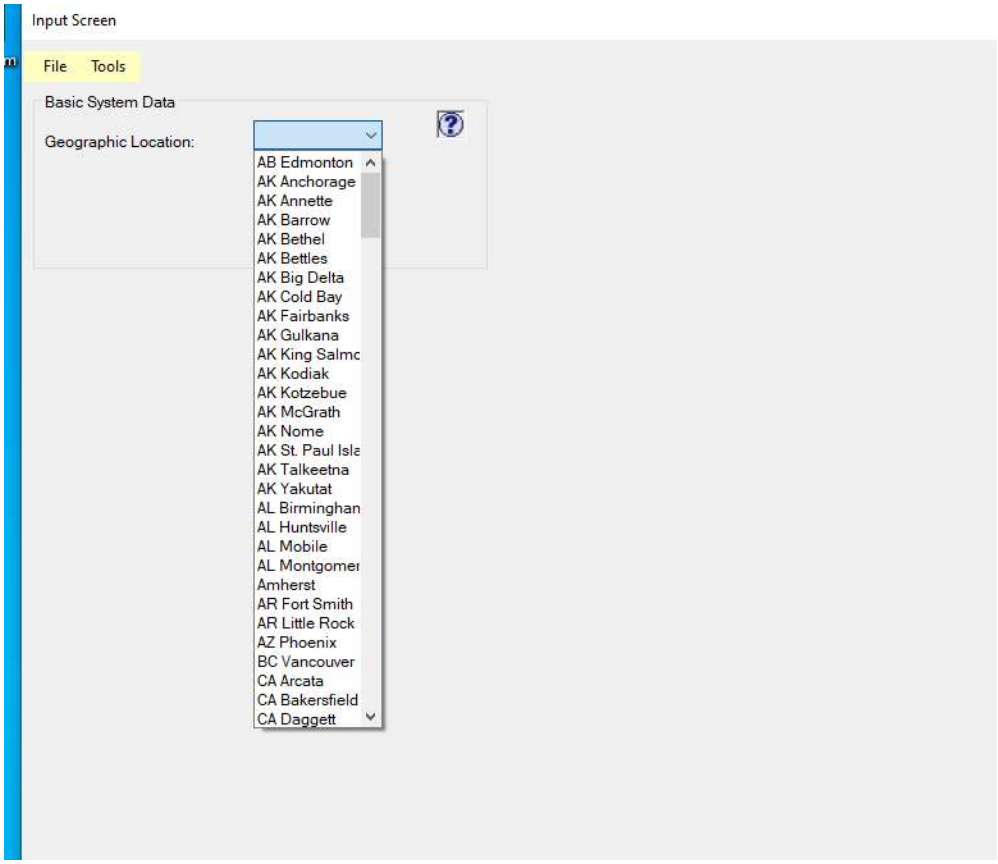
CWSAT INPUT Screenshots

- 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

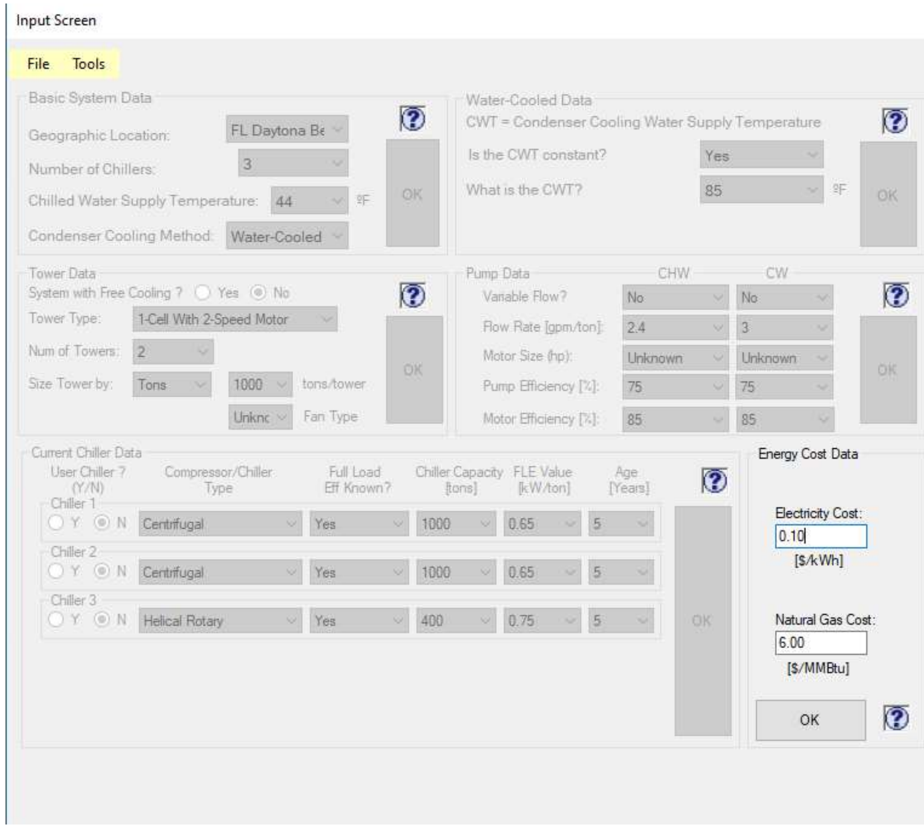
Click the “OK” Button to proceed to the next Input Sub-block

Screen Shots of CWSAT Inputs

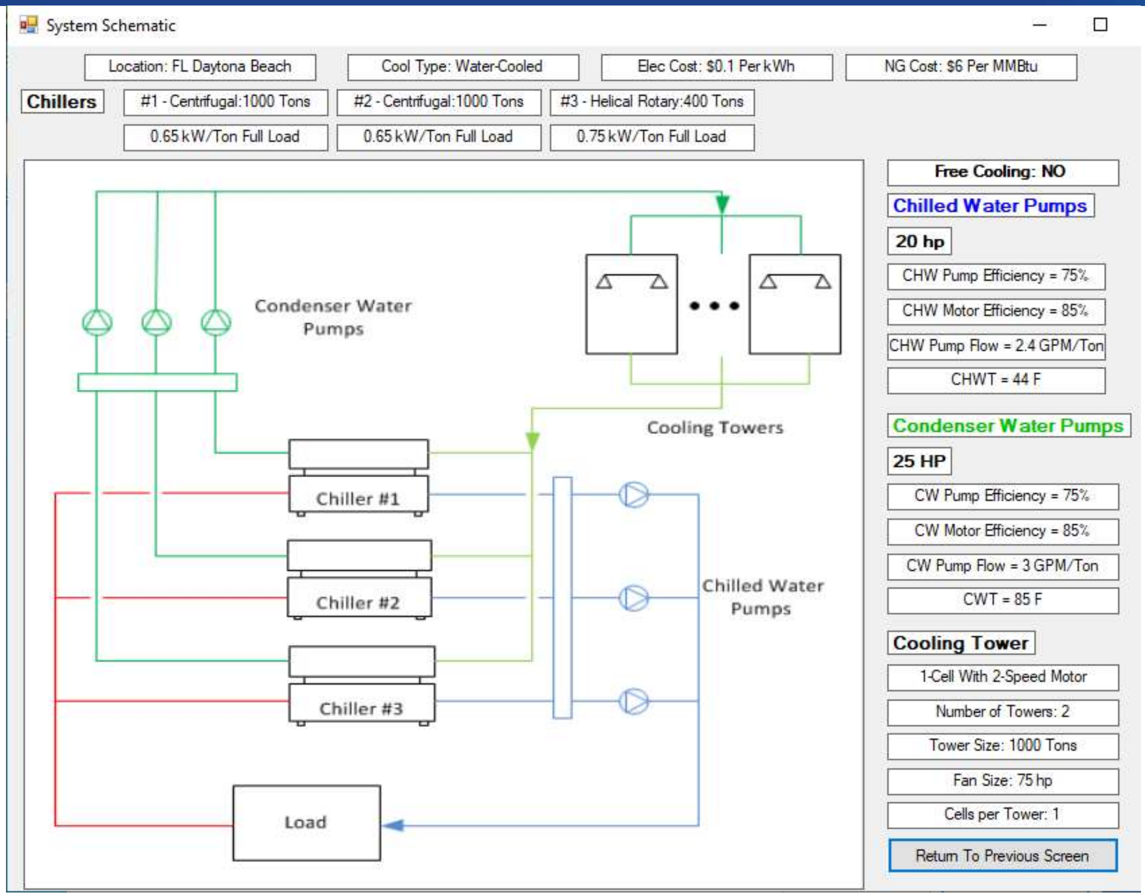




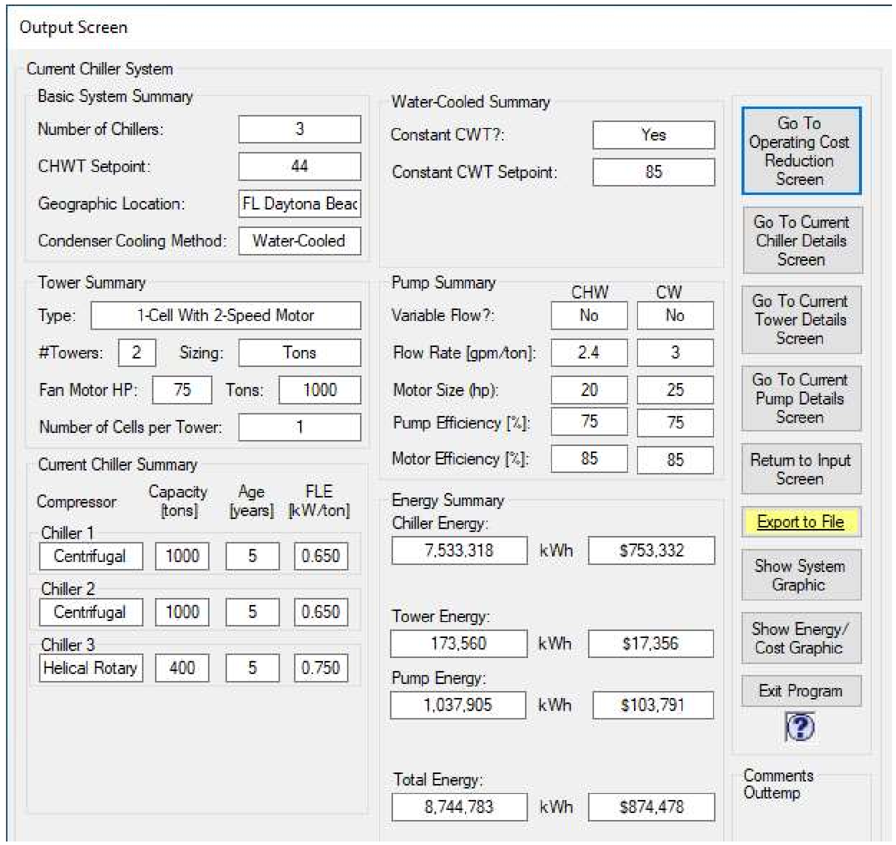
Screen Shots of CWSAT Inputs



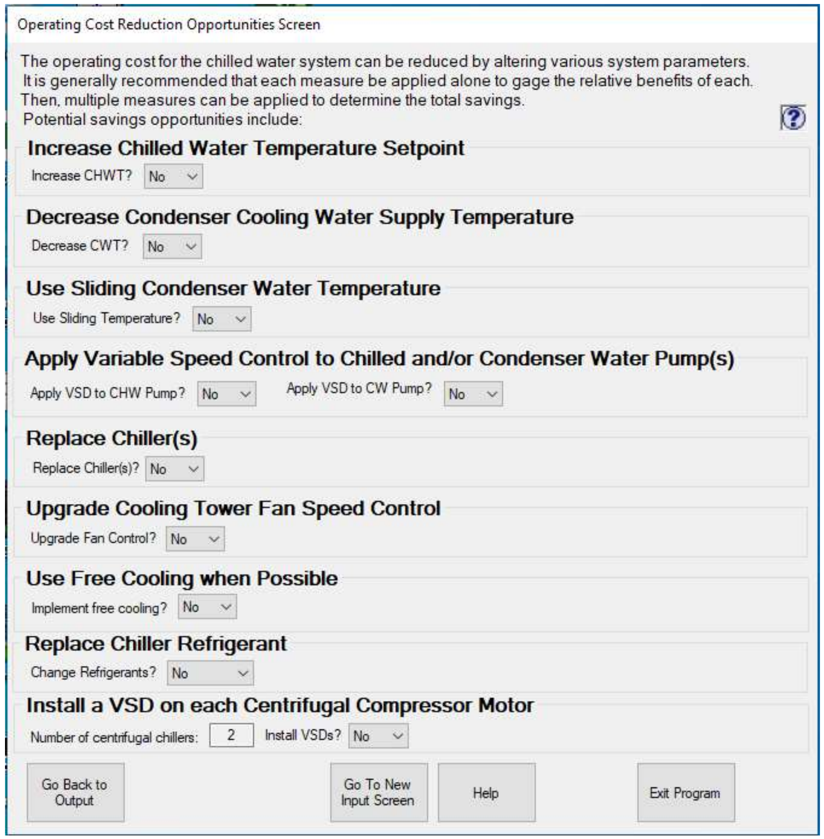
CWSAT System Schematic



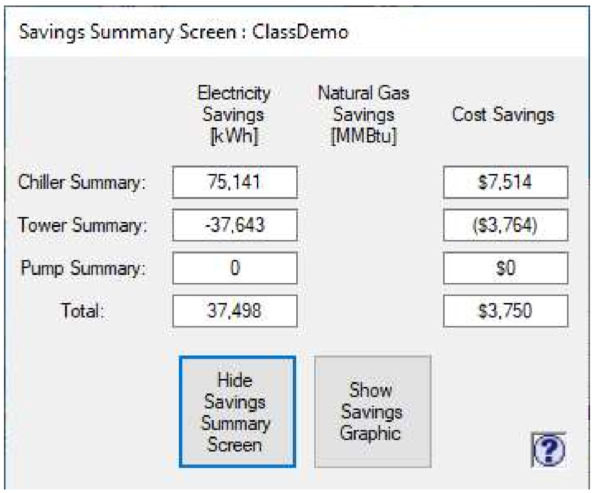
CWSAT (Base Model) Output



CWSAT Energy Efficiency Opportunities



CWSAT Summary Results



Homework #3

- Review the Instrumentation Gap Analysis worksheet and complete it for the Chilled Water Plant that is going to be assessed
- Review the instrumentation available from the Better Plants ORNL Loan program and identify any instruments that you will need to get from ORNL for the VINPLT assessment
- Download the CWSAT software from the US DOE / ORNL website
- Install (unzip) the CWSAT

- For the Brave Hearts - Attempt to build a chilled water system model in CWSAT of your own chilled water plant

Kahoot Quiz Time

Thank You all for attending today's webinar.

See you all on next Thursday – June 23, 2022 – 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 rapapar@c2asustainable.com

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