True Optimization® Starts Here

Engineering Site Analysis
OptimumLOOP™

University of Houston
Houston, Texas

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Please note: The ESA document makes multiple references to OptimumLOOP, which is sold under the brand name Johnson Controls Chiller Plant Optimization 30™ (CPO 30™)

EXECUTIVE SUMMARY

The Optimum Energy (Optimum) engineering team recently conducted an Engineering Site Analysis (ESA) of the University of Houston chiller plant, located on the campus at 4800 Calhoun Rd. Houston, TX 77004 for the purpose of implementing an intelligent energy solution uniquely suited to meeting University of Houston's objectives for this chiller plant optimization project. The benefits of chiller plant optimization include lowering energy consumption, reducing chiller plant operating and maintenance costs, and exceeding University of Houston's corporate energy and sustainability goals.

Optimum proposes to convert the chiller plant at University of Houston to an all-variable flow system and implement a chiller plant optimization solution powered by OptimumLOOP software. These retrofits and the optimization solution will improve the chiller plant efficiency from 0.852 kW/ton to 0.651 kW/ton. The resulting savings and estimated project costs for the chiller plant are shown in Tables 1 and 2.

Table 1: Chiller Plant Optimization Utility Savings

OPTIMIZATION UTILITY SAVINGS	
Electrical energy savings	19,243,445 kWh/year
Electrical demand reduction	750.4 kW
Cooling tower water savings	8,767,882 gal/year
CO_2 emission reduction	28,486,555 lbs/year

Table 2: Chiller Plant Optimization Financial Savings

OPTIMIZATION FINANCIAL SAVINGS	
Initial capital investment	$1,303,748
Utility rebates and incentives	$0
Annual operations cost reduction	$1,110,997
Simple payback on investment	1.17 years
Internal rate of return (IRR)	84%
Net present value (NPV)	$6,911,475

The optimization solution will improve the chiller plant efficiency from 0.852 kW/ton to 0.583 kW/ton. The resulting savings and estimated project costs for the chiller plant are shown in Tables 3 and 4.

Table 3: Chiller Replacement Option Optimization Utility Savings

OPTIMIZATION UTILITY SAVINGS	
Electrical energy savings	25,551,176 kWh/year
Electrical demand reduction	1,151.8 kW
Cooling tower water savings	11,543,074 gal/year
CO_2 emission reduction	37,824,047 lbs/year

Table 4: Chiller Replacement Option Optimization Financial Savings

OPTIMIZATION FINANCIAL SAVINGS	
Initial capital investment	$4,697,794
Utility rebates and incentives	$0
Annual operations cost reduction	$1,474,573
Simple payback on investment	3.19 years
Internal rate of return (IRR)	31%
Net present value (NPV)	$6,328,601

Figure 1 shows the current chiller plant efficiency and the projected efficiency with all recommended retrofits and OptimumLOOP installed. Figure 2 shows the current chiller plant efficiency and the projected efficiency with all recommended retrofits and OptimumLOOP installed.

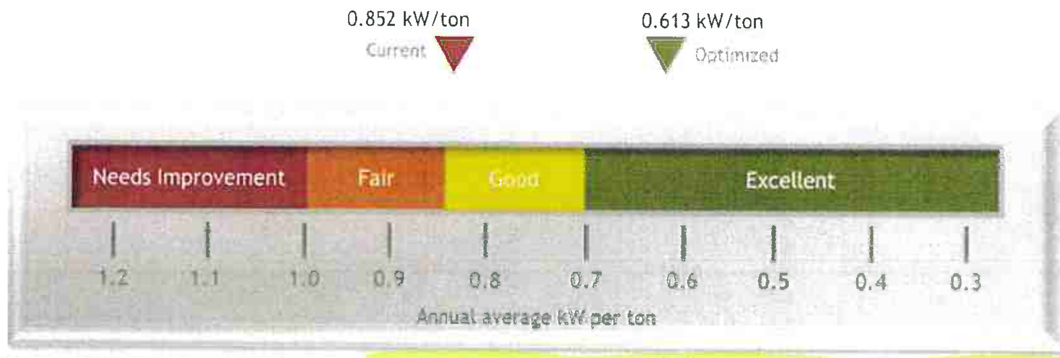


Figure 1: Chiller plant efficiency scale – current University of Houston efficiency vs. optimized chiller plant efficiency.

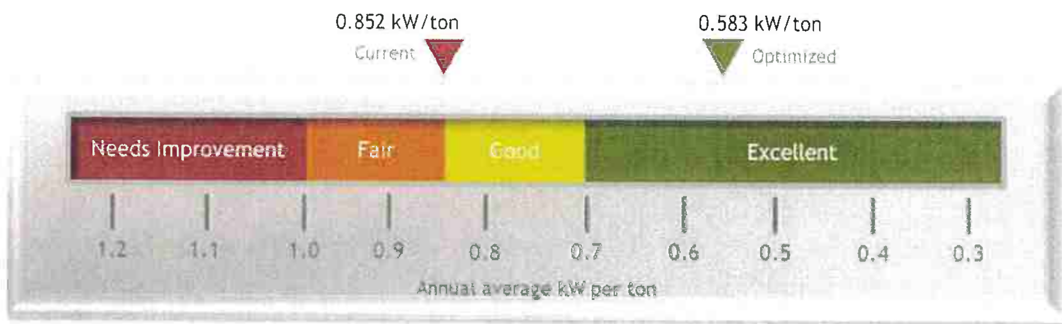


Figure 2: Chiller plant efficiency scale – current University of Houston chiller plant efficiency vs. optimized chiller plant efficiency with new chiller 1.

The retrofits that Optimum proposes include:

- Install variable frequency drives (VFDs) on five (5) condenser water pumps in the central plant.
- Install VFDs on two (2) primary-only chilled water pumps in the central plant.
- Upgrade the existing chiller plant control system to latest firmware and software in both chiller plants (Wonderware Balance of Plant [BOP]).
- Install new temperature sensors in the common chilled water supply and return for south tunnel.
- Chiller replacement option: replace one (1) exising constant speed Carrier Chiller with new variable-speed York chiller.

SECTION 1: ESA OVERVIEW

Thank you for choosing Optimum as your partner and subject matter expert in chiller plant efficiency. Optimum is committed to using integrated software and cloud computing technology to optimize University of Houston to deliver sustained energy reductions automatically and continuously. Optimum stands ready to design an optimization solution that is engineered to meet University of Houston's specific efficiency requirements and goals, year after year.

THE ESA PROCESS

The ESA conducted at University of Houston consisted of five core steps, shown in Figure 3, from initial data collection through presentation of the results found in the ESA Report. Throughout the process, Optimum engineering experts used leading-edge software algorithms and modeling techniques to model chiller plant operation and conduct a comparative predictive analysis. Optimum's engineering team used this comprehensive dataset to compare the chiller plant's operations against the Optimum database of aggregate operating analytics to determine how best to optimize the facility's chiller plant.

ESA REPORT

The ESA Report provides University of Houston with the expected utility cost savings for the facility, any mechanical upgrades that may be required, and the information needed to implement the Optimum solution seamlessly, including the framework to deliver Real-Time Dynamic Commissioning™ (RTDC).

Figure 3: ESA core steps.

The completed ESA Report contains the following:

- Chiller Plant Analysis and Assumptions: A summary description of the facility and current chiller plant, including chiller plant equipment, an analysis of current chiller plant operations, and a variety of trend analysis graphs and charts.
- Scope of Work: A description of mechanical, electrical, and control upgrades required to implement the Optimum optimization solution, as well as a list of owner responsibilities. Section 3: University of Houston Project Scope of Work is intended to aid University of Houston in soliciting bids from contractors for implementing the OptimumLOOP solution for University of Houston.
- Controls Diagrams: Schematic drawings of the chiller plant piping layout, equipment, and significant sensors.

OPTIMUM ESA FOR UNIVERSITY OF HOUSTON

University of Houston purchased an Optimum ESA Click here to enter text. to gain a deeper understanding of Click here to enter text.its chiller plant operation and performance, the issues that impact energy and financial savings, and how to correct those issues so that University of Houston's chiller plants can operate at optimum efficiency. The benefits of implementing OptimumLOOP at University of Houston include:

- Streamlining facility operations
- Improving chiller plant efficiency
- Improving occupant comfort
- Cutting energy consumption
- Lowering carbon emissions
- Meeting social responsibility and environmental sustainability goals
- Meeting regulatory requirements of the State of Texas
- Understanding the operational issues currently impacting energy and financial savings goals
- Developing an optimization project plan and budget

THE OPTIMUM SOLUTION

As experts in delivering integrated software and cloud computing services for optimizing facilities-based mechanical systems, the Optimum team is prepared to design a solution uniquely suited to delivering the sustained energy-reduction goals University of Houston wishes to achieve.

Optimum's holistic optimization platform design delivers continuous RTDC year after year with minimum effort. Because operating chiller plant components at variable speeds instead of fixed speeds can deliver significant energy savings, Optimum deploys the optimization software within the chiller plant via a networked application that acts as a gateway between the BAS and the cloud-based management platform. This holistic approach to chiller plant optimization lays the framework for keeping the chiller plant operating at maximum efficiency.

The chiller plant optimization platform comprises two software applications that work together to deliver RTDC:

OptimumLOOP is patented, state-of-the-art configurable software that provides continuous, system-level optimization of centrifugal chiller plants. Its relational control algorithms automatically calculate the most efficient operation of the chilled water system to minimize total system kW/ton.

The OptiCx™ Platform is a cloud-based offering that integrates operational modules, machine learning, web, and mobile applications as well as Optimum's world-class support services. The OptiCx Platform provides customizable views of chiller plant operations, key performance indicators (KPIs) for chiller plant operational efficiency and alarming, and acts as a continuous feedback loop to provide operators with detailed real-time and historical performance data. The data and accompanying analytics allow operators to quickly detect, diagnose, and resolve HVAC system faults as they occur. With information from OptiCx Platform web and mobile apps, energy engineers, efficiency managers, facilities management, and facility operators can manage to best-in-class KPIs and prevent system performance degradation, helping to ensure sustainable long-term savings.

Figure 4: Real-Time Dynamic Commissioning

OPTIMUM ENERGY DEMAND RESPONSE

Following the OptimumLOOP implementation at University of Houston, Optimum Energy will develop a customized module to help the university take advantage of their unique power purchasing structure and will help automate demand response events, areas in which Optimum is highly qualified. Our engineering and development resources have applied experience in dynamic pricing and demand response, and the Optimum platform and software are already well-suited for such integration.

Optimum presently has resources dedicated to the development of Dynamic Pricing Model Response (DPMR) and demand response (DR) modules within our software suite. The modules are currently undergoing development with beta testing with a select group of clients (references are available upon request). Optimum has also evaluated a number of automatic demand response (ADR) technologies that we believe will benefit our clients in the electrical marketplace, such as integrating the central plant to Synchronized Reserve (SR) and Frequency Regulation (FR) programs.

In addition to an experienced team, Optimum's platform, OptiCx, is well-suited to support pricing and demand response strategies and programs. Primarily, the OptiCx platform has the capability to integrate with real-time pricing providers, utilities, and aggregators. Additional features that support such strategies include:

- Prebuilt APIs within OptiCx allow for easy communication between utilities, aggregators, and customers.
- Unrivaled reporting capabilities provide accurate insight into, and verification of, DR events.
- A robust data, communications, and integration platform allows for real-time information and

historical data of DR events.

- The ability to develop advanced DR algorithms and plug-ins allows many DR possibilities such as Synchronized Reserve and Frequency Regulation.
- The ability to respond to signals and dispatch or affect other equipment and all forms of HVAC equipment and BAS/PLC systems.
- The ability to determine state of system and/or mechanical equipment readiness (with appropriate integration) allows the customer to confidently "buy-in" to deferent DR hourly/daily programs.
- With the available OptiCx Measurement and Verification (M&V) capabilities, Optimum Energy and its customers can determine further DR options and model expected outcomes with the additional energy services that Optimum provides.

Optimum would like to collaborate with University of Houston in cultivating this program to ensure module development is aligned with the university's needs following the success of the OptimumLOOP and OptiCx.

NEXT STEPS

To begin the implementation phase of the optimization project for University of Houston, Optimum has prepared the final optimization project proposal, which includes Optimum's Statements of Work, pricing, contract terms, and licensing agreements. Once the contract is finalized, Optimum can begin implementation.

Optimum's straightforward implementation process has proven successful on multiple projects similar to the one proposed for University of Houston. Throughout this final phase, Optimum works closely with the mechanical, electrical, and controls contractors to ensure that installation, integration, testing, and commissioning are consistent with University of Houston's policies and practices. Once all mechanical, electrical, and controls work have been completed and the OptimumLOOP application is installed and integrated, Optimum will conduct intensive testing to ensure proper operation. After functional testing is completed, Optimum will provide training and remain an on-going part of the optimization support team for the life of the installation.

SECTION 2: UNIVERSITY OF HOUSTON CHILLER PLANT ANALYSIS

FACILITY DESCRIPTION

The ESA commissioned for University of Houston was conducted on May 18 and May 19, 2016. Based on the information gathered, University of Houston is a public university on a 594-acre campus and requires 8,760 hours of cooling annually.

Optimum generated the information in this analysis by reviewing facility utility data, on-site monitoring, Typical Meteorological Year (TMY3) weather data, spot readings, spreadsheet simulations, and accepted engineering calculations.

CHILLER PLANT DESCRIPTION

University of Houston's existing central plant consists of:

- One (1) constant-speed Carrier 2,000-ton electric centrifugal chiller (chiller is inoperable)
- Two (2) constant-speed York 2,250-ton electric centrifugal chillers
- One (1) constant-speed York Titan 4,500-ton electric centrifugal chiller
- One (1) constant-speed York Titan 5,000-ton electric centrifugal chiller
- Three (3) variable-speed York YK 2,270-ton electric centrifugal chillers
- Six (6) constant-speed primary-only chilled water primary pumps: one (1) 200 hp at 4,500 gpm; one (1) 300 hp at 6,000 gpm; one (1) 400 hp at 7,200 gpm; two (2) 450 hp at 9,000 gpm
- Three (3) variable-speed primary-only chilled water primary pumps: three (3) 350 hp at 6,240 gpm
- One (1) dedicated constant-speed chilled water pump: one (1) 300 hp at 4,800 gpm (chiller [CH] 1)
- Five (10) constant-speed condenser water pumps: ten (10) 300 hp at 7,500 gpm
- Five (5) variable-speed cooling towers: 300 hp at 15,000 gpm per tower
- Wonderware PLC BOP

CURRENT PLANT OPERATION MEASUREMENTS

BENCHMARKING

The Chiller Plant Efficiency Scale, shown in Figures 5 and 6, is a measure of chiller plant performance that indicates the energy usage of the entire chiller plant, including chillers, tower fans, condenser pumps, and chilled water pumping. It expresses the average annual chiller plant efficiency in kW/ton. The Chiller Plant Efficiency Scales below compare University of Houston's current chiller plant performance, shown in Figure 5, to optimized chiller plant performance that can be achieved with OptimumLOOP. Figure 6 compares the current chiller plant to optimized plant performance, including a chiller replacement option.

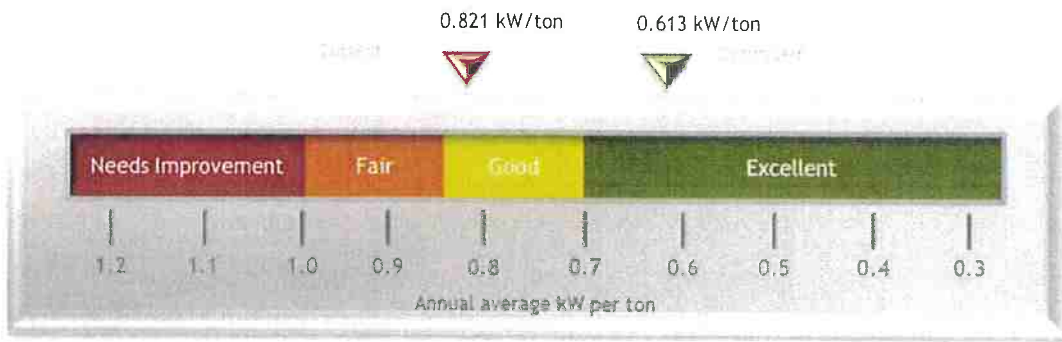


Figure 5: Chiller plant efficiency scale — current University of Houston chiller plant efficiency vs. optimized chiller plant efficiency.

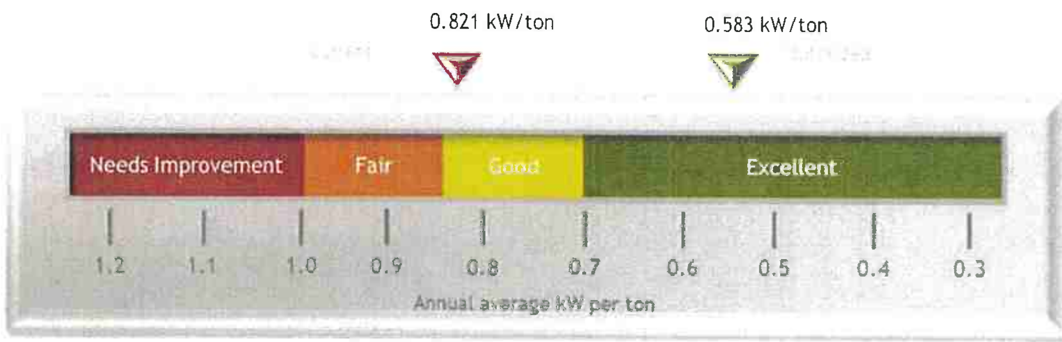


Figure 6: Chiller plant efficiency scale — current University of Houston Central Plant efficiency vs. optimized chiller plant efficiency (with new CH1).

8760 OVERVIEW

The 8760 Report is an hourly simulation of chiller plant performance against existing weather data and load profile for a full year. As part of the ESA, Optimum used the full report to simulate chiller plant energy use. Tables 5 and 6 provide summaries of the simulation of combined chiller plant on a monthly basis as well as the totals for the year. These summaries make it easy to see how the existing chiller plants currently operate versus how they will operate once optimized and the total projected energy and cost savings on an annual basis. The summaries detail the cost/savings relationship, first considering plant optimization and second including a chiller replacement option as a part of plant optimization.

Table 5: 8760 Report Summary

University of Houston		
ECO	Plant Peak (tons)	Opportunity
1	15,985	Upgrade central plant with additional VS CHWP capacity, add VFDs to five of ten CDWPs, and implement CPO 30 based OptimumLOOP control strategy.

Annual Load (ton-hrs)	Optimum LOOP Eff. Savings (kW/ton)	Energy Usage Savings (kWh/yr)	Demand Savings (kW)	CT Water Usage Savings (gal/yr)	Energy Costs Savings ($/yr)	Est. Implementation Cost ($)	Est. Incentive ($)	Final Cost After Incentive ($)	Carbon Footprint Reduction (lbs/yr)	IRR (%)	Simple Payback (yrs)
94,960,919	0.20	19,243,445	750.4	8,767,882	$1,110,997	$1,303,748	$0	$1,303,748	28,486,555	84%	1.17

* Energy costs calculated at $0.055/kWh blended and $6 per kgal for water, chemicals, and sewer
* Energy Cost Savings is based on 100% of time operating within "LOOP MODE" for Post scenario

Savings Summary by Month

		Existing Plant		LOOP Plant		Savings		
Month	Plant Ton-Hours	Plant kWh	Plant kW/ton	Plant kWh	Plant kW/ton	kWh saved	Peak kW saved	$ Savings
January	6,517,603	5,422,729	0.832	3,523,449	0.541	1,899,280	853	$104 460
February	6,020,023	4,997,426	0.830	3,325,794	0.552	1,671,632	863	$91,940
March	6,836,251	5,674,454	0.830	3,849,733	0.563	1,824,721	884	$100 360
April	7,695,715	6,253,380	0.813	4,546,330	0.591	1,707,051	890	$93,888
May	8,843,815	7,525,465	0.851	6,079,065	0.687	1,446,400	699	$79,552
June	9,356,053	8,409,321	0.899	7,150,461	0.764	1,258,861	659	$69,237
July	10,028,116	8,965,346	0.894	7,723,320	0.770	1,242,025	509	$68,311
August	9,891,097	8,749,810	0.885	7,502,411	0.759	1,247,399	451	$68,607
September	8,866,965	7,600,955	0.857	6,213,703	0.701	1,387,252	674	$76,299
October	8,362,904	6,919,576	0.827	5,259,201	0.629	1,660,375	694	$91,321
November	6,573,479	5,451,607	0.829	3,587,973	0.546	1,863,634	851	$102,500
December	5,968,896	4,977,903	0.834	2,943,088	0.493	2,034 816	979	$111,915
Total	94,960,919	80,947,973	0.852	61,704,528	0.650	19,243,445	750	$1,058,389

Table 6: 8760 Report Summary with Chiller Replacement Option

University of Houston											
ECO	Plant Peak (tons)	Opportunity									
1	15,985	Upgrade central plant with additional VS CHWP capacity, add VFDs to five of ten CDWPs, and implement CPO 30 based OptimumLOOP control strategy.									
Annual Load (ton-hrs)	Optimum LOOP Eff. Savings (kW/ton)	Energy Usage Savings (kWh/yr)	Demand Savings (kW)	CT Water Usage Savings (gal/yr)	Energy Costs Savings ($/yr)	Est. Implementation Cost ($)	Est. Incentive ($)	Final Cost After Incentive ($)	Carbon Footprint Reduction (lbs/yr)	IRR (%)	Simple Payback (yrs)
94,960,919	0.27	25,551,176	1151.8	11,543,074	$1,474,573	$4,697,794	$0	$4,697,794	37,824,047	31%	3.19

* Energy costs calculated at $0.055/kWh blended and $6 per kgal for water, chemicals, and sewer
* Energy Cost Savings is based on 100% of time operating within "LOOP MODE" for Post scenario

Savings Summary by Month

		Existing Plant		LOOP Plant		Savings		
Month	Plant Ton-Hours	Plant kWh	Plant kW/ton	Plant kWh	Plant kW/ton	kWh saved	Peak kW saved	$ Savings
January	6,517,603	5,422,729	0.832	3,017,790	0.463	2,404,940	1249	$132,272
February	6,020,023	4,997,426	0.830	2,864,201	0.476	2,133,225	1259	$117,327
March	6,836,251	5,674,454	0.830	3,349,146	0.490	2,325,307	1237	$127,892
April	7,695,715	6,253,380	0.813	3,962,866	0.515	2,290,514	1248	$125 978
May	8,843,815	7,525,465	0.851	5,486,740	0.620	2 038,725	1096	$112,130
June	9,356,053	8,409,321	0.899	6,610,909	0.707	1,798,413	1083	$98,913
July	10,028,116	8,965,346	0.894	7,148,521	0.713	1,816,825	900	$99,925
August	9,891,097	8,749,810	0.885	6,923,604	0.700	1,826,206	1005	$100 441
September	8,866,965	7,600,955	0.857	5,659,353	0.638	1,941,602	1083	$106 788
October	8,362,904	6,919,576	0.827	4,685,681	0.560	2,233,894	1095	$122,864
November	6,573,479	5,451,607	0.829	3,127,341	0.476	2,324,266	1226	$127 835
December	5,968,896	4,977,903	0.834	2,560,646	0.429	2,417,257	1339	$132,949
Total	94,960,919	80,947,973	0.852	55,396,798	0.583	25,551,176	1152	$1,405 315

CHILLER PLANT EFFICIENCY

Figure 7 shows a monthly view of the University of Houston plant pre-retrofit and post-retrofit efficiency and the average outside air temperature for each month.

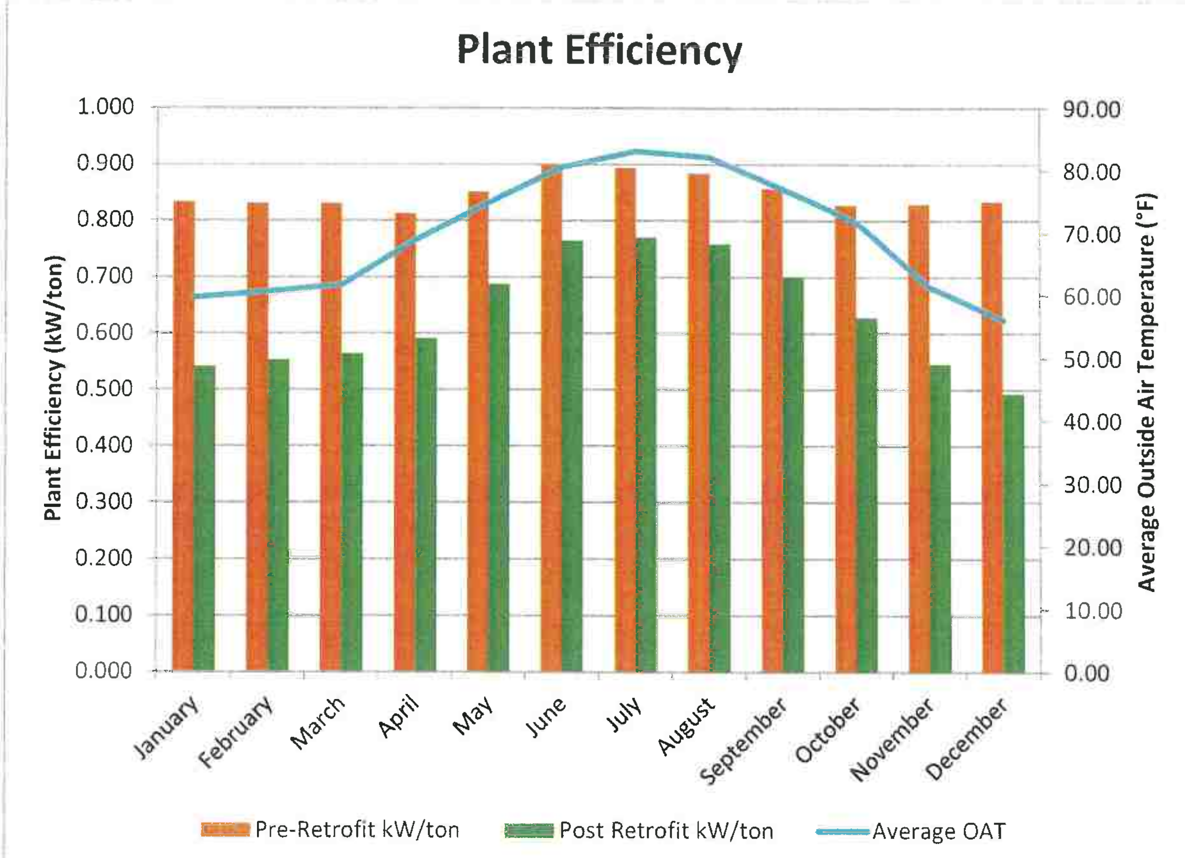


Figure 7: Average plant kW/ton per month and average monthly outside air temperature.

Figure 8 shows a monthly view of the University of Houston plant pre-retrofit and post-retrofit efficiency and the average outside air temperature for each month with new chiller.

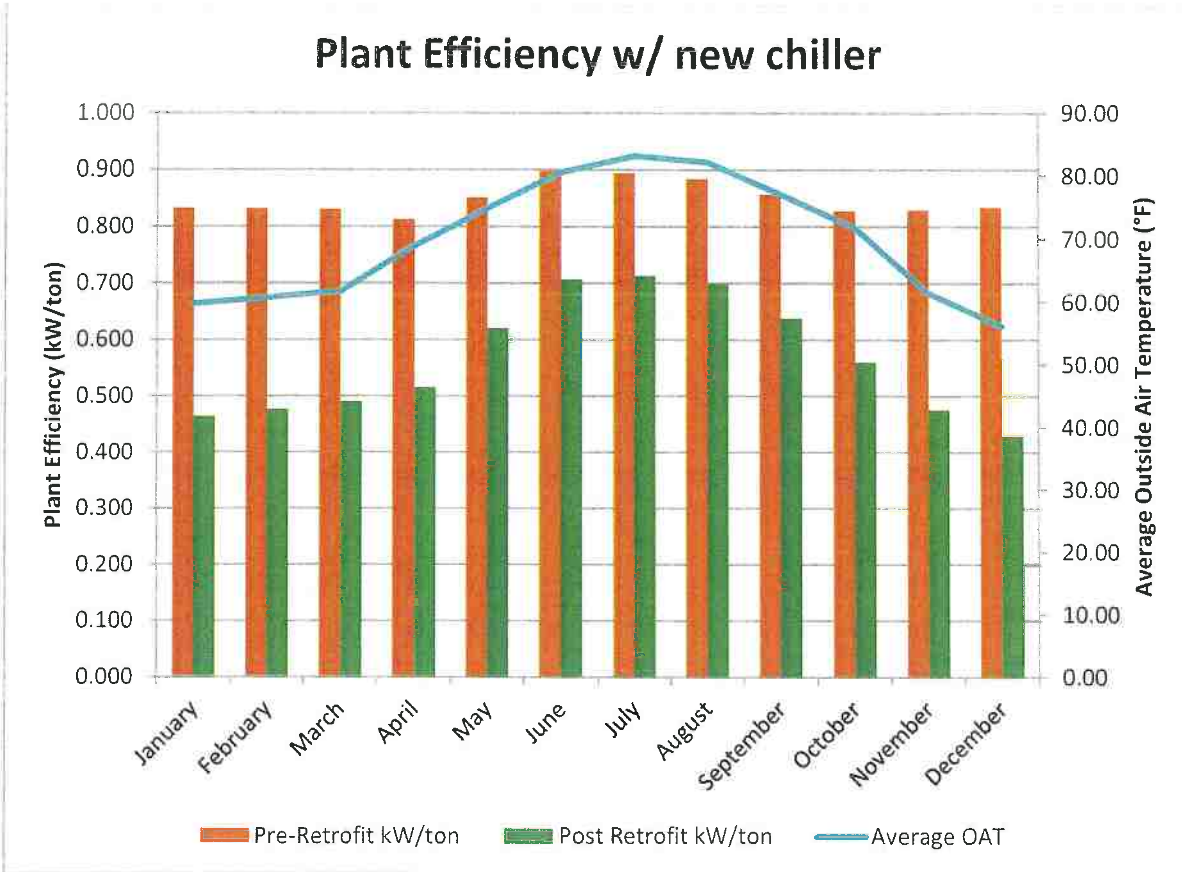


Figure 8: Average central plant kW/ton per month and average monthly outside air temperature with new chiller.

MONTHLY COST SIMULATION

Figure 9 shows the monthly pre-retrofit and post-retrofit utility cost for operating the central plant.

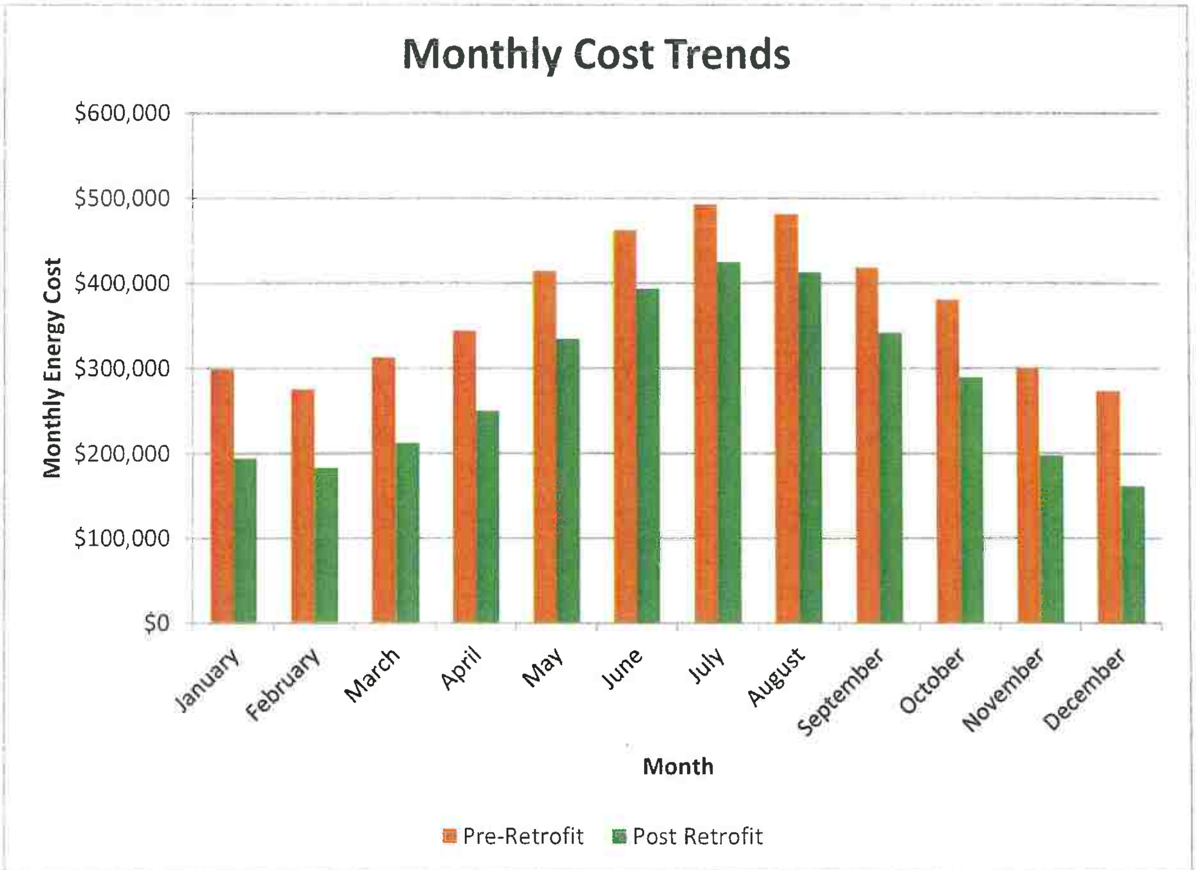


Figure 9: Monthly plant utility cost, pre-retrofit and post-retrofit.

Figure 10 shows the monthly pre-retrofit and post-retrofit utility cost for operating the central plant with the optional addition of the new chiller.

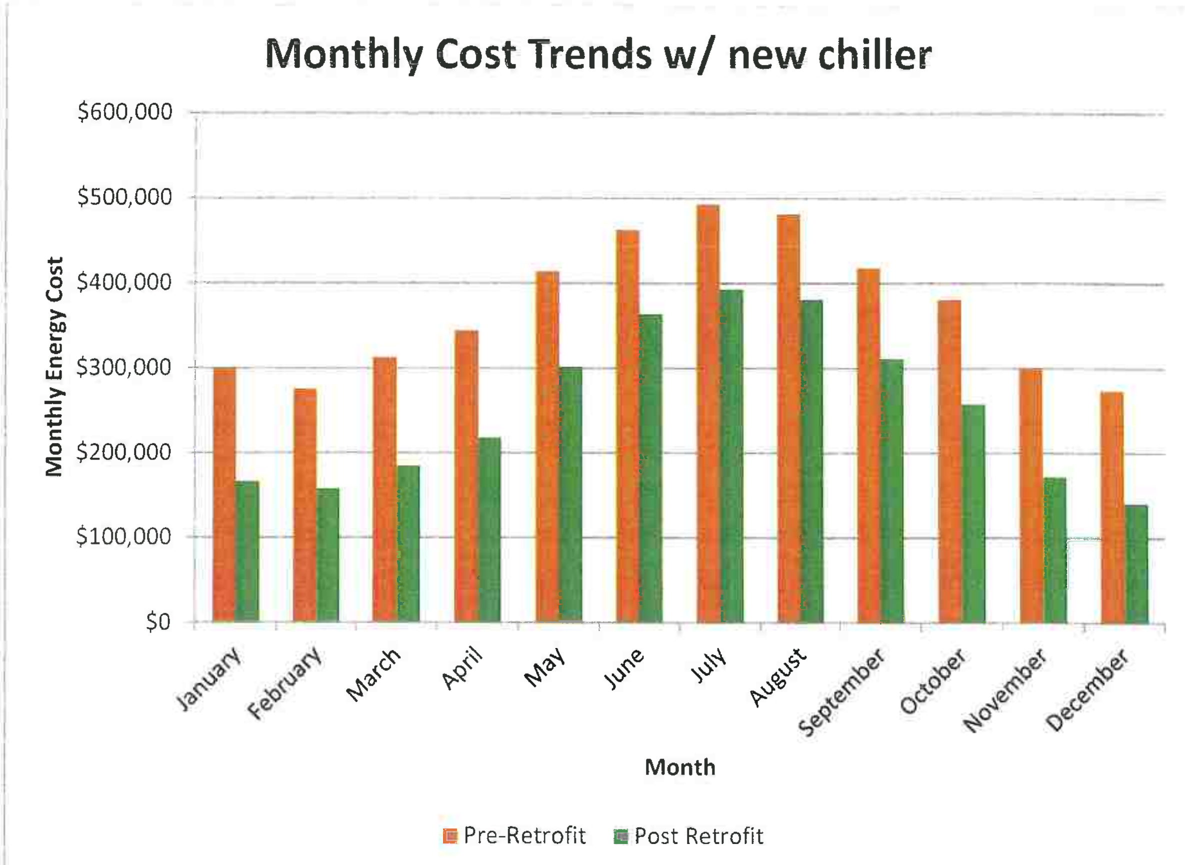


Figure 10: Monthly central plant utility cost, pre-retrofit and post-retrofit.

CO_2 EMISSION PRE-RETROFIT AND POST-RETROFIT PERFORMANCE SIMULATION

Figure 11 shows the monthly pre-retrofit and post-retrofit carbon dioxide emissions generated by operating the chiller plant.

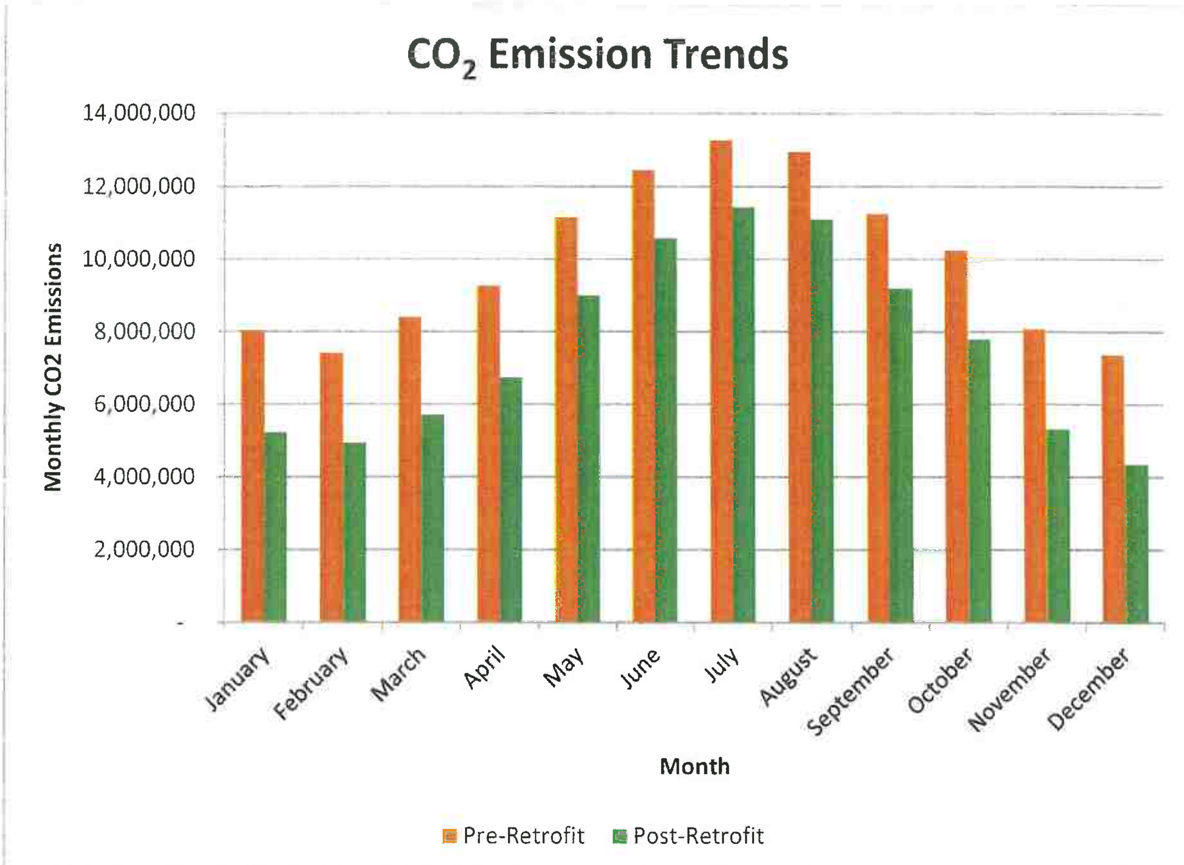


Figure 11: Monthly chiller plant CO_2 emissions, pre-retrofit and post-retrofit.

Figure 12 shows the monthly pre-retrofit and post-retrofit carbon dioxide emissions generated by operating the chiller plant.

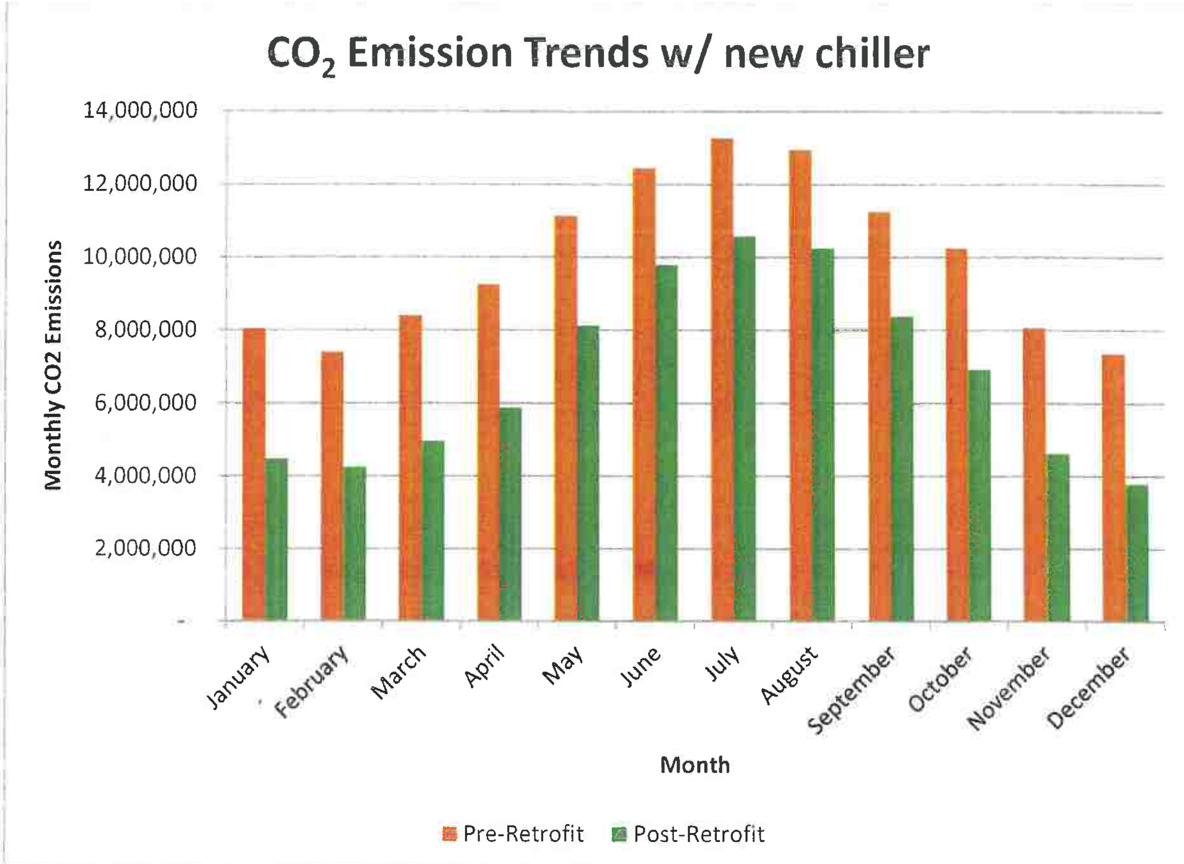


Figure 12: Monthly chiller plant CO_2 emissions, pre-retrofit and post-retrofit.

CHILLER PLANT EFFICIENCY TRENDS

Figure 13 shows the pre-retrofit and post-retrofit plant efficiency vs. chiller plant load.

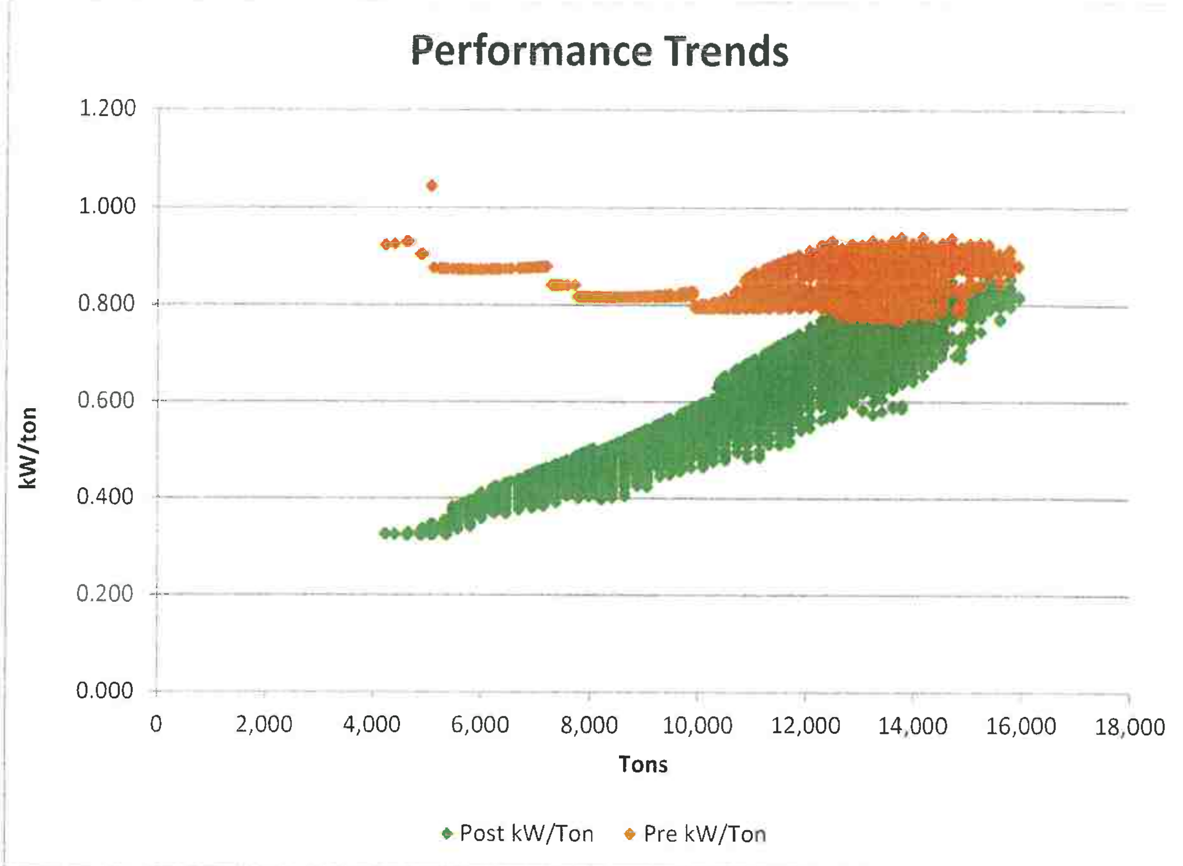


Figure 13: Pre-retrofit and post-retrofit plant efficiency vs. tons.

Figure 14 shows the pre-retrofit and post-retrofit combined plant and central plant efficiency vs. chiller plant load with new chiller.

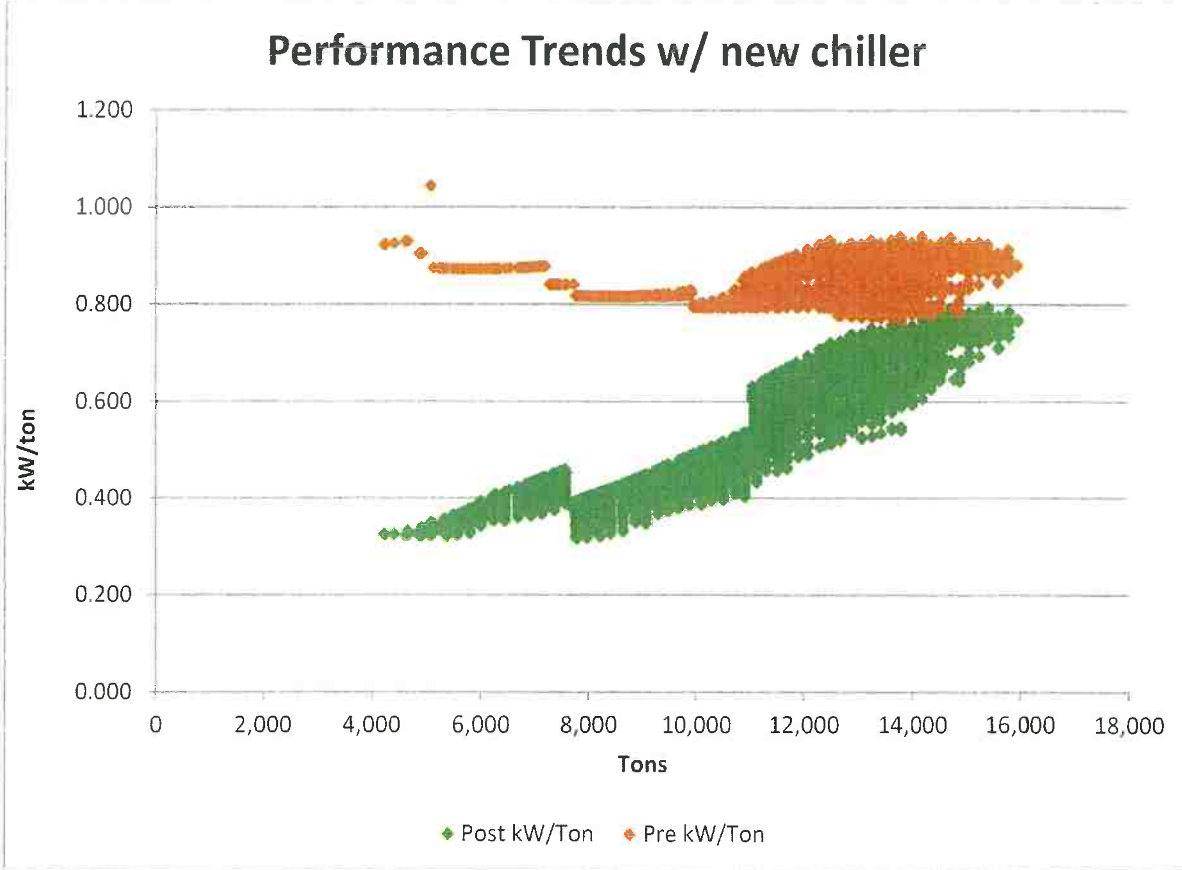


Figure 14: Pre-retrofit and post-retrofit plant efficiency vs. tons with new chiller.

UNIVERSITY OF HOUSTON TREND ANALYSIS

LOAD ANALYSIS

Figure 15 displays the amount of cooling the central plant produces and plots it against the outside air wet bulb temperature (OSA WB) at that time for a full year.

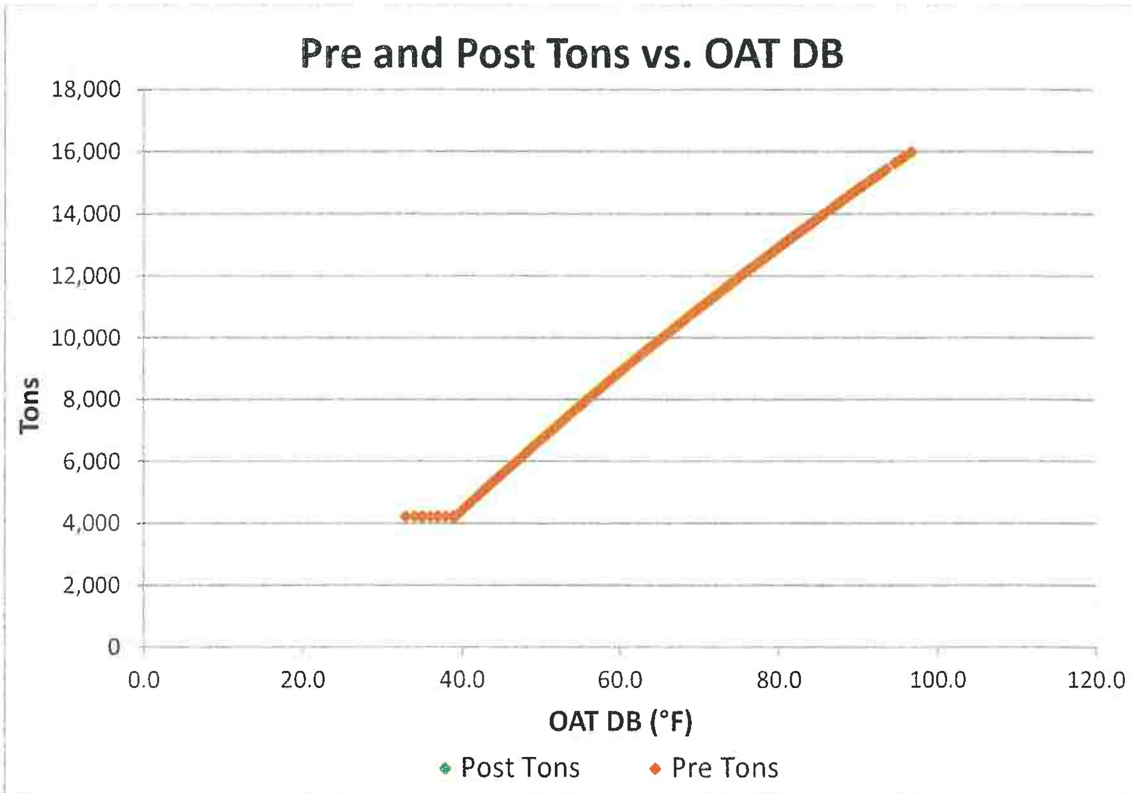


Figure 15: Central plant tons vs. OSA DB.

Figure 16 shows the central plant chiller power (kW) before optimization. Figure 17 shows the central plant chiller power (kW) after optimization.

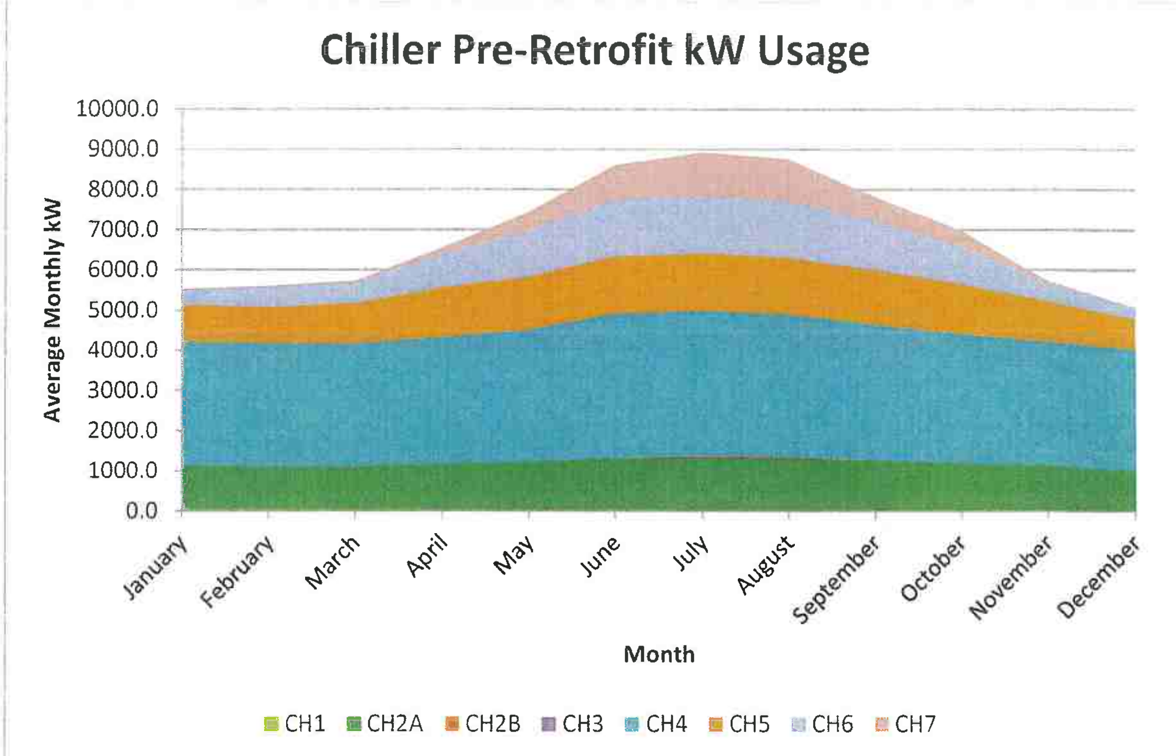


Figure 16: Central plant chiller power (kW) pre-retrofit.

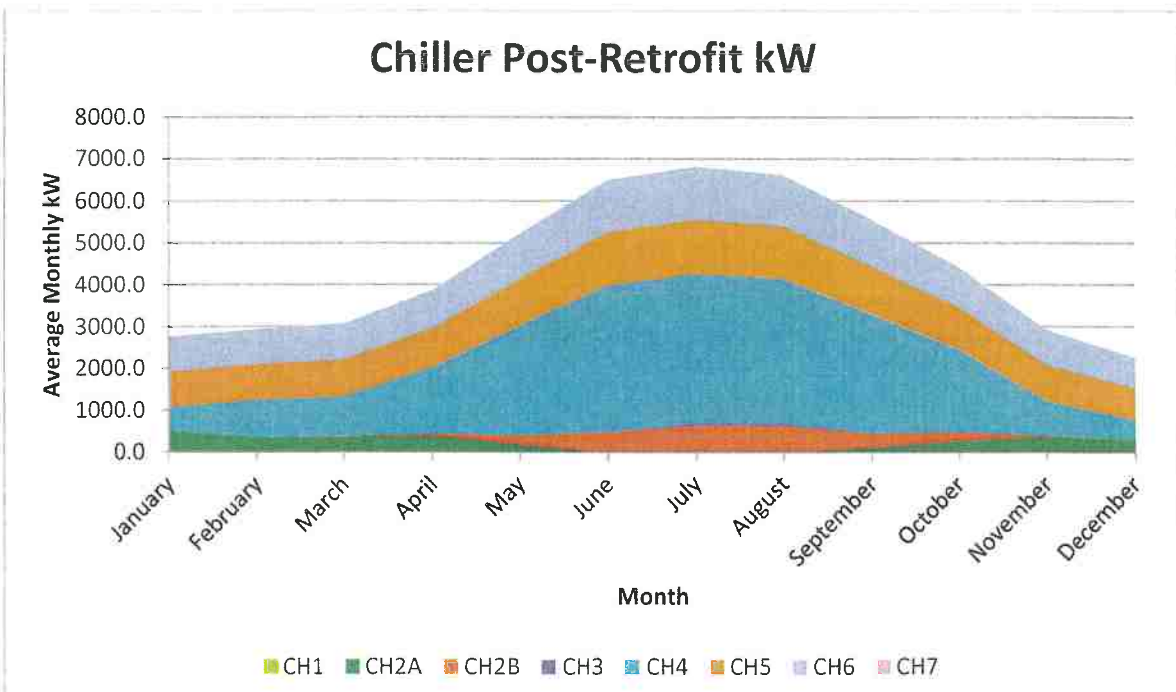


Figure 17: Central plant chiller power (kW) post-retrofit.

Figure 18 shows the central plant chiller power (kW) after optimization with new chiller.

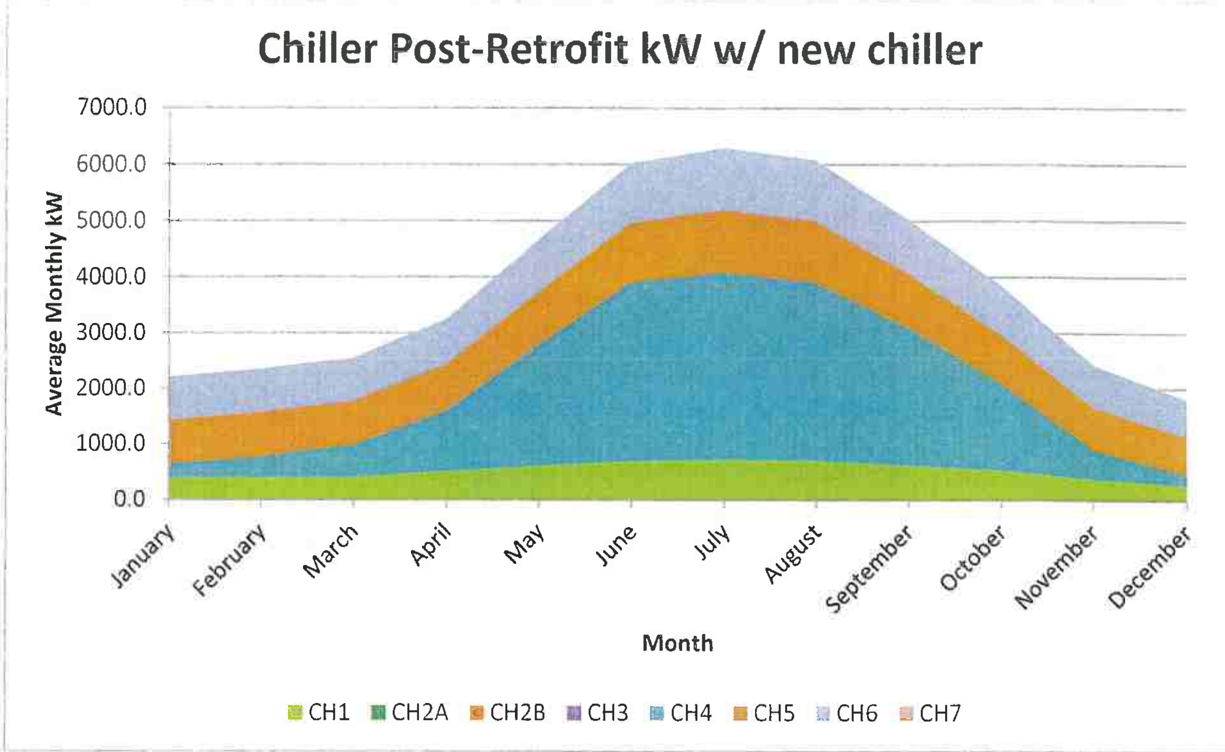


Figure 18: Central plant chiller power (kW) post-retrofit with new chiller.

SECTION 3: UNIVERSITY OF HOUSTON PROJECT SCOPES OF WORK

MECHANICAL SCOPE OF WORK

1. Install new chilled water temperature sensors. Install in existing taps or provide new hot taps (if necessary) two (2) new immersion thermistor chilled water (CHW) temperature sensors. Install one (1) temperature sensor in the common chilled water supply pipe for the south tunnel and one (1) temperature sensor in the common CHW return pipe for the south tunnel. Temperature sensors to be supplied by controls contractor. Install all sensors per the manufacturer's installation instructions. Refer to Appendix 1: OptimumLOOP Controls Diagram for proposed sensor locations. Coordinate exact sensor locations with owner and Optimum.

2. Properly insulate all piping changes (from flow meter hot tap, etc.).

3. Properly remove and dispose of all demolition.

4. Provide all documentation and manuals for installed equipment.

5. Provide one (1)-year parts and labor warranty for installed equipment and two (2)-year parts and labor warranty for VFDs (pumps and fans).

6. Provide all necessary permits to complete the scope.

7. Provide all necessary engineering to complete the above scope.

8. *Optional Two Chilled Water Pump replacement:* New primary chilled water pumps CHWP5 and CHWP6. Furnish, install, line up, and startup two (2) new primary chilled water pumps with motors. New motors shall be premium efficiency inverter duty motors suitable for variable frequency operation (VFDs to be furnished and installed by electrical contractor). New pumps to be installed on existing equipment pads. Provide any pipe bends, offsets, and pump accessories for complete installation. Reinsulate to match. Pump bases of design: capacity = 6,240 gpm; head 165 ft; 350 hp motor; manufacturer to match existing CHWP8-10 or approved equal.

9. *Optional Chiller Replacement:* Remove and replace Carrier CS 2,000-ton chiller 1 (CH1) with York YK 2,750-ton variable speed (VS) chiller. Provide piping modifications and connections as required for the new chiller. Reinsulate pipe changes to match existing. Chiller to be furnished and power to be provided by others.

ELECTRICAL SCOPE OF WORK

1. Electrical contractor is responsible for the coordination of all work with the owner to limit any disruption in chilled water production to acceptable period scheduled by the owner and coordinated with the chiller plant staff to complete all the work during chiller plant scheduled downtime.

2. Electrical contractor is responsible for all electrical 110 V and higher. The controls contractor is responsible for all low-voltage electrical (less than 110 V).

3. Install new OptimumLOOP hardware. Install, mount, and provide 110 V power for the two (2) new OptimumLOOP Networked Optimization Appliance (NOA) enclosures (one [1] new NOA in the central plant and one [1] new NOA in the central plant – for a total of two [2] NOA enclosures) supplied by Optimum. The enclosure dimensions are: width, 12.5"; depth, 6.5"; and height, 24.5". Work with the controls contractor to locate unit near the Andover building automated system (BAS).

4. Provide power for new Balance Of Plant (BOP) hardware. Provide 110 V power for one (1) new PLC controller (PLC controller to be supplied and installed by controls contractor); dedicated for OptimumLOOP integration within the chiller plants. Coordinate locations and requirements with the controls contractor for new equipment requiring 110 V power connection.

5. Install new condenser water pump (CDWP) VFDs. Furnish, install, and startup five (5) new 460 V VFDs for the following CDWP motors. VFDs to be provided with network cards for communication with the Wonderware PLC BOP. VFDs shall be located within the associated chiller plant in place of existing CDWP disconnects (or other suitable locations as determined in the field). Modify and re-connect power to new VFDs as required for variable-speed control of each CDWP motor. Re-use existing motors. Provide new wire and conduit as necessary. Electrical contractor to confirm all motor sizes and design criteria prior to ordering VFDs.

   a. CDWP1A: 300 hp, 460 V, 3 PH
   b. CDWP2A: 300 hp, 460 V, 3 PH
   c. CDWP3A: 300 hp, 460 V, 3 PH
   d. CDWP4A: 300 hp, 460 V, 3 PH
   e. CDWP5A: 300 hp, 460 V, 3 PH

   REQUIRED: VFD must have kW available as a network point. If not available, a new correctly sized kW meter must be installed (to be furnished and installed by electrical contractor). The Veris 8000 series power meter is an example of an acceptable power meter. True RMS, three (3)-phase, integrated equipment, stand-alone analog or networked power meter. Accuracy must meet the following standard: +/-1.5% of rated current CT or +/-10% of kW reading if from the VFD.

6. Install new chilled water pump (CHWP) VFDs. Furnish, install, and startup two (2) new 460 V VFDs for the following CHWP motors in the central plant. VFDs to be provided with network cards for communication with the Wonderware PLC BOP. VFDs shall be located within the chiller plant in place of existing chilled water pump disconnects (or other suitable locations as determined in the field). Modify and re-connect power to new VFDs as required for variable-speed control of each CHWP motor. Re-use existing motors. Provide new wire and conduit as necessary. Electrical contractor to confirm all motor sizes and design criteria prior to ordering VFDs.

   a. CHWP 5: 450 hp, 460 V, 3 PH
   b. CHWP 6: 400 hp, 460 V, 3 PH

   REQUIRED: VFD must have kW available as a network point. If not available, a new correctly sized kW meter must be installed (to be furnished and installed by electrical contractor). The Veris 8000 series power meter is an example of an acceptable power meter. True RMS, three (3)-phase, integrated equipment, stand-alone analog or networked power meter. Accuracy must meet the following standard: +/-1.5% of rated current CT or +/-10% of kW reading if from the VFD.

7. *Option 1:* Replace existing CHWP5 and CHWP6 with new pump and motor, equal in design criteria to existing variable-speed CHWP8 – CHWP10: 350 hp, 6,250 gpm, 165 feet head. New primary chilled water pump CHWP5 and CHWP6. Furnish, install, align and startup two (2) new premium efficiency, inverter duty motors with shaft-grounding kits for the following equipment:
    a. PCHWP5 and PCHWP6: 350 hp, 460 V, 3 PH, 60 Hz primary chilled water pump

8. Properly insulate all piping changes (from flow meter hot tap, etc.).

9. Properly remove and dispose of all demolition.

10. Provide all documentation and manuals for installed equipment.

11. Provide one (1)-year parts and labor warranty for installed equipment and two (2)-year parts and labor warranty for VFDs (pumps and fans).

12. Provide all necessary permits to complete the scope.

13. Provide all necessary engineering to complete the above scope.

14. *Optional Chiller Replacement:* Remove and replace all electrical supply components from existing Carrier CS 2,000-ton CH1 to new York YK 2,750-ton VS chiller. Modify existing 4,160 V electrical service to allow 460 V required by new VS chiller, connect power to one (1) new 2,750 ton, York Model YKZSZSK7-DJGS. Furnish all new electrical equipment, conduit, power wire, etc. required for new chiller. New chiller is rated at:
    a. Estimated new chiller design electrical parameters: 1,544 kW, 460 V, 3 PH, 60 Hz to match existing CH5, CH6, and CH7.

15. Coordinate with chiller manufacturer for all requirements.

CHILLER SCOPE OF WORK

1. Ensure (and reconfigure as necessary) existing chiller evaporator and condenser differential pressure (DP) sensors (flow-proving devices) are set up for variable water flow through each chiller's evaporator and condenser bundle (one [1] evaporator flow switch and one [1] condenser water flow device per chiller for a total of twelve [12] flow-proving sensors). Flow switches should be set up per the York specification of 0.66 ft/sec. Document each unit's trip point in delta P (psi) and flow (gpm) and send written report to owner and Optimum. Published York allowable flows are as follows:

Condenser:

CH1: minimum 2,255 gpm, maximum 9,021 gpm
CH2A: minimum 3,327 gpm, maximum 8,620 gpm
CH2B: minimum 3,327 gpm, maximum 8,620gpm
CH3: minimum 7,000 gpm, maximum 21,250 gpm
CH4: minimum 6,500 gpm, maximum 18,000 gpm
CH5: minimum 3,950 gpm, maximum 10,978 gpm
CH6: minimum 3,950 gpm, maximum 10,978 gpm
CH7: minimum 3,950 gpm, maximum 10,978 gpm

Evaporator:

CH1: minimum 2,132 gpm, maximum 8,529 gpm
CH2A: minimum 2,556 gpm, maximum 7,400 gpm
CH2B: minimum 2,556 gpm, maximum 7,400 gpm
CH3: minimum 4,000 gpm, maximum 13,250 gpm
CH4: minimum 5,750 gpm, maximum 14,000 gpm
CH5: minimum 2,870 gpm, maximum 7,907 gpm
CH6: minimum 2,870 gpm, maximum 7,907 gpm
CH7: minimum 2,870 gpm, maximum 7,907 gpm

2. Network connection to chiller control panels: York to work with the controls controls contractor to map all chiller points shown in Tables 7 and 8 (at a minimum) to the BOP. **All points are very important and must be provided.**

3. Clear surge maps on all chillers before and after testing and OptimumLOOP commissioning are completed.

4. Calibrate vanes and ensure refrigerant level control is properly tuned for all chillers.

Table 7: VS Chiller Network Points

CHILLER NETWORK POINTS (Required Points)	
POINT DESCRIPTION	TYPE
Chilled Water Supply Temperature	AV
Chilled Water Return Temperature	AV
Entering Condenser Water Temperature	AV
Leaving Condenser Water Temperature	AV
Condenser Refrigerant Pressure	AV
Condenser Refrigerant Temperature	AV
Evaporator Refrigerant Pressure	AV
Evaporator Refrigerant Temperature	AV
Chiller Alarm/Fault Message	AV
Total Chiller kW	AV
Chiller State	AV
Chilled Water Supply Setpoint Adjust	AV
Chiller % Motor Current	AV
Compressor Discharge Temperature	AV
Compressor Surge Count	AV
Guide Vane Position	AV
VFD Output Frequency	AV
Chiller Start/Stop	BV

Table 8: CS Chiller Network Points

CHILLER NETWORK POINTS (Required Points)	
POINT DESCRIPTION	TYPE
Chilled Water Supply Temperature	AV
Chilled Water Return Temperature	AV
Entering Condenser Water Temperature	AV
Leaving Condenser Water Temperature	AV
Condenser Refrigerant Pressure	AV
Condenser Refrigerant Temperature	AV
Evaporator Refrigerant Pressure	AV
Evaporator Refrigerant Temperature	AV
Chiller Alarm/Fault Message	AV
Total Chiller kW	AV
Chiller State	AV
Chilled Water Supply Setpoint Adjust	AV
Chiller % Motor Current	AV
Compressor Discharge Temperature	AV
Compressor Surge Count	AV
Guide Vane Position	AV
Chiller Start/Stop	BV

5. ***Optional Chiller Replacement***: Remove and replace Carrier CS 2,000-ton CH1 with York YK 2,750-ton VS chiller. Provide piping modifications and connections as required for the new chiller. Reinsulate pipe changes to match existing. Chiller to be furnished and power to be provided by others.

CONTROLS CONTRACTOR SCOPE OF WORK

Support of the Optimum all-variable speed OptimumLOOP implementation at University of Houston chiller plant.

1. The controls contractor is responsible for coordination of all work with owner to ensure adequate cooling is provided for the facility during the following chiller plant modifications.

2. Provide new chilled water temperature sensors. Furnish two (2) new immersion thermistor temperature sensors for the chilled water supply and return south tunnel loop. Sensors to be installed by mechanical contractor. Connect two (2) new temperature sensors to the BOP using new conduit and control wire. Temperature sensors shall have ranges appropriate for chilled water application and provide end-to-end precision within +/-0.1°F over the entire span and be calibrated to within +/-0.5 °F accuracy and compared to existing chiller chilled water supply and return sensors. Sensors will be used to measure the headered chilled water supply and return temperatures of the chilled water plant.

3. **REQUIRED:** Connect seven (7) existing chiller power meter kW values to the BOP using new conduit and control wire. Existing chiller power meters located in the electrical room. Connect the following existing power meters: CH2A, CH2B, CH3, CH4, CH5, CH6, and CH7.

4. Network connections to the chiller control panels for York chillers CH2A, CH2B, CH3, CH4, CH5, CH6, CH7. Ensure (furnish and install all programming, DDC conduit with communication wire, etc. as necessary) network connection for seven (7) chillers to the BOP is up to date and all required chiller points are available. Map all points in Tables 9 and 10 to the BOP.

5. Automate plant. Furnish and implement all necessary programming for reliable and dynamic automatic operation of the primary-only, variable-flow, chilled water plant configuration. The speed of the chilled water pumps, condenser water pumps, and cooling tower fans; number of chillers, chilled water pumps, condenser water pumps, and cooling towers; and the chilled water supply temperature shall be automatic. All start/stop, lead/lag, fail-over-safe modes, and alarms shall be fully automatic. Prove to owner reliable lead/lag changeover of equipment and starting and stopping of chillers.

6. Connect (provide conduit with communication wire) the following new and existing chilled water pump, condenser water pump, and cooling tower fan motor VFDs to the BOP (VFDs to be furnished and installed by electrical contractor). VFD required points are start/stop, status, speed setting, and kW. **All points are very important and must be obtained.**

    a. CDWP1A: 300 hp, 460 V, 3 PH
    b. CDWP2A: 300 hp, 460 V, 3 PH
    c. CDWP3A: 300 hp, 460 V, 3 PH
    d. CDWP4A: 300 hp, 460 V, 3 PH
    e. CDWP5A: 300 hp, 460 V, 3 PH
    f. CHWP 5: 450 hp, 460 V, 3 PH
    g. CHWP 6: 400 hp, 460 V, 3 PH
    h. CHWP 8: 350 hp, 460 V, 3 PH
    i. CHWP 9: 350 hp, 460 V, 3 PH
    j. CHWP 10: 350 hp, 460 V, 3 PH
    k. CT1: 300 hp, 460 V, 3 PH
    l. CT2: 300 hp, 460 V, 3 PH
    m. CT3: 300 hp, 460 V, 3 PH
    n. CT4: 300 hp, 460 V, 3 PH
    o. CT5: 300 hp, 460 V, 3 PH

Provide all necessary hardware, software, and programming for automatic 0–100% control of the pump and cooling tower fan motor VFDs. In BOPMODE, control the condenser water pumps at a static speed (operator adjustable at GUI) to provide design flow through each operating chiller.

REQUIRED: VFDs must have kW available as a network point. If not available, a new correctly sized kW meter must be installed (to be furnished and installed by electrical contractor). The Veris 8000 series power meter is an example of an acceptable power meter.

7. Install a PLC BOP controller dedicated to the OptimumLOOP system integration. Provide all software, hardware, networking, cabling, and programming as necessary for low latency (for example, fast communications and fast data polling rates) and in order to complete the scope below. **Refresh rates of 15 seconds or faster are required.**

8. Furnish, install, and program Modbus RTU interface to OptimumLOOP controller software. Provide Modbus RTU interface and wiring between the new Optimum NOA, supplied by Optimum in one enclosure, and the BOP.

9. Furnish and install all necessary cabling, switches, modems, etc. in order to integrate and network the NOA (provided by Optimum) with the BAS.

10. Install, mount, and provide 110 V power for the NOA enclosure. The enclosure dimensions are: width, 12"; depth, 6"; and height, 20".

11. Provide all points listed in Table 9 and Appendix 1: University of Houston OptimumLOOP Controls Diagram. If any of the listed points are not available, furnish, install, and field verify any instrumentation or communication cards (if not already present) to accomplish points. **All points listed in Table 9 are required and must be provided. Please ensure the availability of these points.**

12. Provide installation, conduit, wire, supervision, scheduling, programming, checkout, commissioning, and testing. Work shall be done according to appropriate code.

13. The Wonderware PLC BOP system will always be and will remain the primary control for the chiller plant, but will provide ("write") the real-time integration points to the NOA via BACnet/IP. This will allow OptimumLOOP to make operating requests back to the chiller plant control system.

Table 9: Example of Required BAS Points

EQUIPMENT	POINTS
Each cooling tower fan VFD	Start/stop, VFD output frequency, operating kW, status, and alarm/fault status (BAS alarm)
Each condenser water pump VFD	Start/stop, VFD output frequency, operating kW, status, and alarm/fault status (BAS alarm)
Each chilled water pump VFD	Start/stop, VFD output frequency, operating kW, status, and alarm/fault status (BAS alarm)

<table>
<tr><td>Two (2) VS York Chillers</td><td><table>
<tr><th colspan="2">CHILLER NETWORK POINTS
(Required Points)</th></tr>
<tr><th>POINT DESCRIPTION</th><th>TYPE</th></tr>
<tr><td>Chilled Water Supply Temperature</td><td>AV</td></tr>
<tr><td>Chilled Water Return Temperature</td><td>AV</td></tr>
<tr><td>Entering Condenser Water Temperature</td><td>AV</td></tr>
<tr><td>Leaving Condenser Water Temperature</td><td>AV</td></tr>
<tr><td>Condenser Refrigerant Pressure</td><td>AV</td></tr>
<tr><td>Condenser Refrigerant Temperature</td><td>AV</td></tr>
<tr><td>Evaporator Refrigerant Pressure</td><td>AV</td></tr>
<tr><td>Evaporator Refrigerant Temperature</td><td>AV</td></tr>
<tr><td>Chiller Alarm/Fault Message</td><td>AV</td></tr>
<tr><td>Total Chiller kW</td><td>AV</td></tr>
<tr><td>Chiller State</td><td>AV</td></tr>
<tr><td>Chilled Water Supply Setpoint Adjust</td><td>AV</td></tr>
<tr><td>Chiller % Motor Current</td><td>AV</td></tr>
<tr><td>Compressor Discharge Temperature</td><td>AV</td></tr>
<tr><td>Compressor Surge Count</td><td>AV</td></tr>
<tr><td>Guide Vane Position</td><td>AV</td></tr>
<tr><td>VFD Output Frequency</td><td>AV</td></tr>
<tr><td>Chiller Start/Stop</td><td>BV</td></tr>
</table>
Chiller in alarm and chiller failed alarm (Wonderware BOP controller)</td></tr>
<tr><td>Four (4) constant speed (CS) York Chillers</td><td><table>
<tr><th colspan="2">CHILLER NETWORK POINTS
(Required Points)</th></tr>
<tr><th>POINT DESCRIPTION</th><th>TYPE</th></tr>
<tr><td>Chilled Water Supply Temperature</td><td>AV</td></tr>
<tr><td>Chilled Water Return Temperature</td><td>AV</td></tr>
<tr><td>Entering Condenser Water Temperature</td><td>AV</td></tr>
<tr><td>Leaving Condenser Water Temperature</td><td>AV</td></tr>
<tr><td>Condenser Refrigerant Pressure</td><td>AV</td></tr>
<tr><td>Condenser Refrigerant Temperature</td><td>AV</td></tr>
<tr><td>Evaporator Refrigerant Pressure</td><td>AV</td></tr>
<tr><td>Evaporator Refrigerant Temperature</td><td>AV</td></tr>
<tr><td>Chiller Alarm/Fault Message</td><td>AV</td></tr>
<tr><td>Total Chiller kW</td><td>AV</td></tr>
<tr><td>Chiller State</td><td>AV</td></tr>
<tr><td>Chilled Water Supply Setpoint Adjust</td><td>AV</td></tr>
<tr><td>Chiller % Motor Current</td><td>AV</td></tr>
<tr><td>Compressor Discharge Temperature</td><td>AV</td></tr>
<tr><td>Compressor Surge Count</td><td>AV</td></tr>
<tr><td>Guide Vane Position</td><td>AV</td></tr>
<tr><td>Chiller Start/Stop</td><td>BV</td></tr>
</table>
Chiller in alarm and chiller failed alarm (Wonderware BOP controller)</td></tr>
<tr><td>All chiller isolation valves</td><td>Valve position (0—100%)</td></tr>
<tr><td>All chilled water temperature sensors</td><td>All chilled water supply and return temperatures</td></tr>
<tr><td>All condenser water temperature sensors</td><td>Headered condenser water supply and return temperatures</td></tr>
<tr><td>All chilled water system pressure transducers</td><td>Chilled water system differential pressure</td></tr>
<tr><td>All chilled water system flow meters</td><td>Scaled gpm from each chilled water flow meter</td></tr>
<tr><td>Chilled water low-flow bypass valve</td><td>Valve position (0—100%)</td></tr>
<tr><td>All Cooling tower bypass valves</td><td>Valve position (0—100%)</td></tr>
<tr><td>Outside air ambient conditions</td><td>Outside air temperature (dry bulb) and relative humidity (% RH)</td></tr>
</table>

14. Map and forward the points listed in Table 11 through Modbus RTU to the new NOA.

15. Program the BOP to monitor the Modbus RTU communications between the BOP and the NOA. If there is a failure of communications, the BOP will automatically revert back and control the chiller plant system using fully dynamic set point controls. Once communication has been reliably re-established, the BOP may resume following NOA set points.

16. Work with Optimum to integrate and implement the control application and provide points in the BOP to support the all-variable speed, demand-based control algorithms. The algorithms to determine optimally efficient equipment speeds and settings according to the OptimumLOOP design will be processed by the NOA and communicated via a Modbus RTU signal to the BOP. The BOP will be modified to incorporate ("read") these signals into its existing strategy and control of the chiller plant.

17. The normal mode of operation for the chillers and chiller plant auxiliary equipment will be determined by the facility BOP, including all individual equipment enables, failures, safeties, and alarms. In the event of a communication failure with the NOA, the BOP will be able to run the chilled water system in a fully functioning, dynamic BOPMODE; that is, smoothly revert back to the control logic and sequencing to produce the cooling and reliability required for the building.

18. Furnish programming and updated graphics for this new scope of work on the operator workstation GUI.

19. Functional testing of integration control sequences. Verify that all physical points mapped through the system operate correctly and that the OptimumLOOP set points are read and followed accurately.

20. Create and provide as-built drawings to provide customer with adequate system documentation.

21. Furnish a one (1)-year parts and labor warranty for new controls furnished and installed by contractor.

22. Provide training of building staff on upgrade and changes.

23. *Optional Chiller Replacement:* Provide network connection to the new York YK 2,750-ton VS chiller control panel. Furnish and install all programming, direct digital control (DDC) conduit with communication wire, etc. as necessary to provide network connection for new chiller to the BOP. Map all points in Table 9 to the BOP.

OWNER SCOPE OF WORK

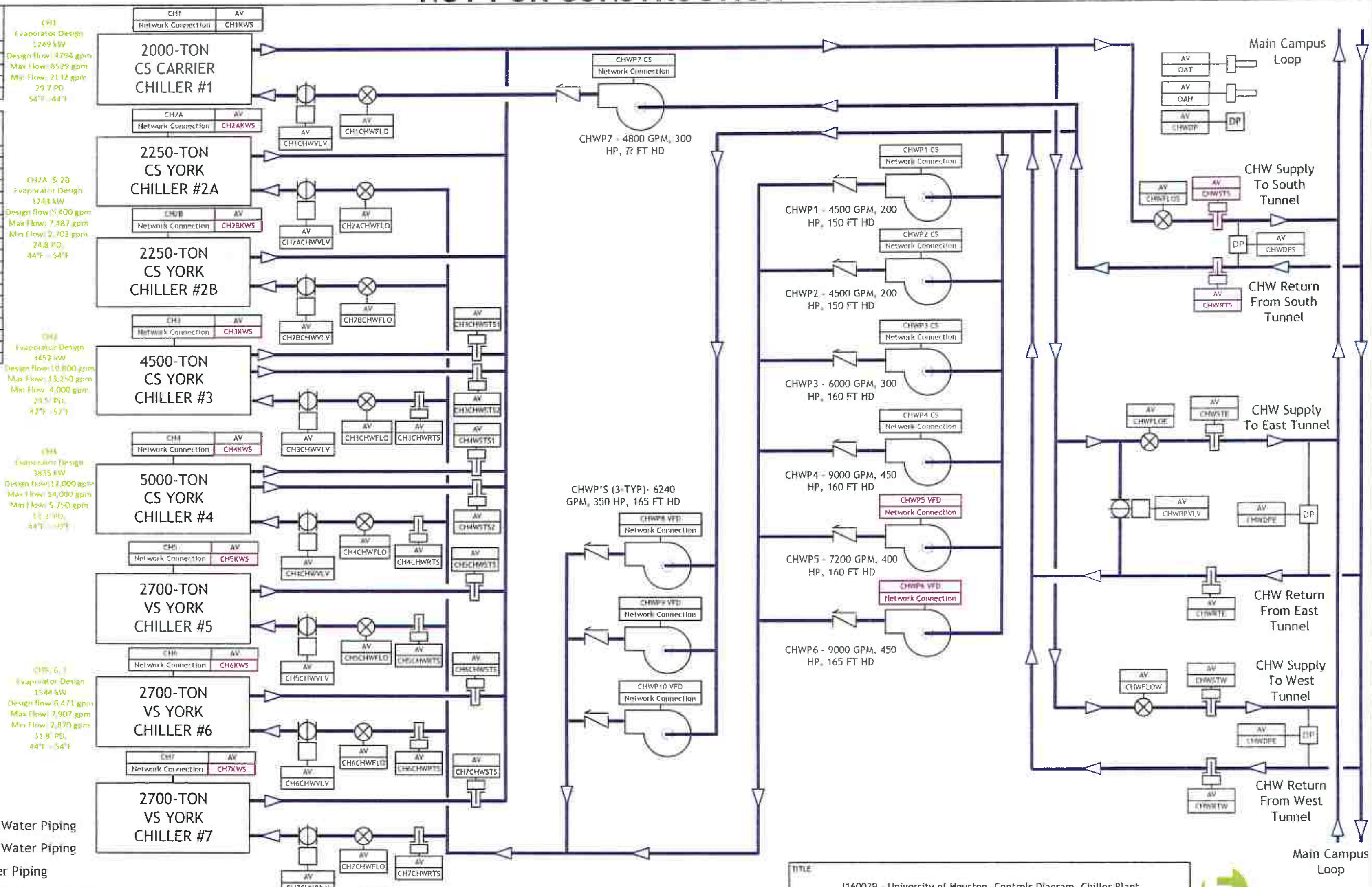
1. Optimum offers a wireless VPN as the standard option for connecting the NOA to the OptiCx platform. Optimum will ship the NOA and associated equipment when owner provides approval to Optimum for the wireless connection. If the owner prefers a site-to-site VPN over the wireless VPN provided by Optimum, the owner shall inform Optimum of the preference and provide a high-speed internet connection with a static IP address and access through ports 3011 and 1911, bi-directionally enabled. Only gateway-to-gateway VPN connections are acceptable in this case.
2. Provide information on any facility standards for VFDs, wiring, etc.
3. Furnish all construction documents, engineering drawings and schematics, piping changes, and final as-builts for the job.
4. Provide all existing HVAC information and drawings.
5. Facilitate access to facility, tenant spaces, use of chiller plant, piping, and air-handler systems.
6. Assist in functional testing as necessary.
7. Schedule staff for training on OptimumLOOP system.
8. Accept completed system.

APPENDIX 1: UNIVERSITY OF HOUSTON OPTIMUMLOOP CONTROLS DIAGRAM

NOT FOR CONSTRUCTION

VFD POINTS (Required Points)	
POINT DESCRIPTION	TYPE
VFD Output Frequency	AV
VFD kW	AV
VFD Status	BV
VFD Start/Stop	BV

CHILLER NETWORK POINTS (Required Points)	
POINT DESCRIPTION	TYPE
Chilled Water Supply Temperature	AV
Chilled Water Return Temperature	AV
Entering Condenser Water Temperature	AV
Leaving Condenser Water Temperature	AV
Condenser Refrigerant Pressure	AV
Condenser Refrigerant Temperature	AV
Evaporator Refrigerant Pressure	AV
Evaporator Refrigerant Temperature	AV
Chiller Alarm/Fault Message	AV
Total Chiller kW	AV
Chiller State	AV
Chilled Water Supply Setpoint Adjust	AV
Chiller - Motor Current	AV
Compressor Discharge Temperature	AV
Compressor Surge Count (York CHs Only)	AV
Guide Vane Position	AV
VFD Output Frequency (VS CHs Only)	AV
Chiller Start/Stop	BV



LEGEND

- Primary Chilled Water Piping
- Primary Chilled Water Piping
- Condenser Water Piping
- Automatically Operated Valves
- Normally Closed Manual Shutoff Valves
- Check Valve

Notes:
1. All pumps are operated by variable speed drives. Drives are set to limit current to maximum motor nameplate rating including service factor.
2. All pumps incorporate check valves to prevent reverse flow through pumps
3. Network connections for Variable Speed Drives shall include at a minimum: On/Off Control, Speed Control, Output Frequency, Drive Status, and Drive kW output.

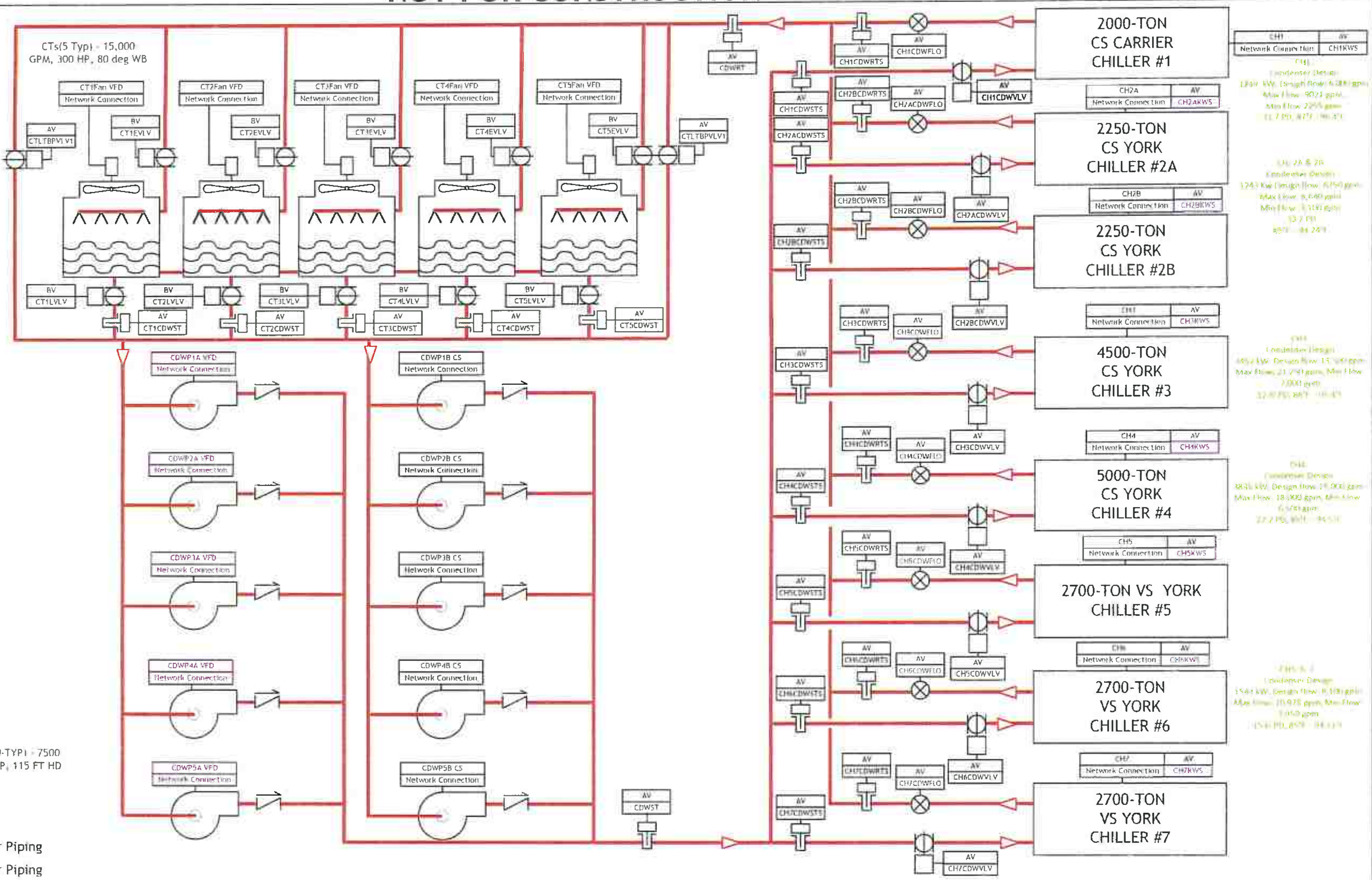
TITLE					
J160029 - University of Houston, Controls Diagram, Chiller Plant					
DESCRIPTION: CONTROLS DIAGRAM, CHILLER PLANT					
DRAWN BY	SCALE	PAGE	DRAWING NUMBER	Revision	DATE OF ISSUE
Ben Cottrell	None	1 OF 2			07/21/2016

TMP-DP03-001 v1.0

NOT FOR CONSTRUCTION

CHILLER NETWORK POINTS (Required Points)	
POINT DESCRIPTION	TYPE
Chilled Water Supply Temperature	AV
Chilled Water Return Temperature	AV
Entering Condenser Water Temperature	AV
Leaving Condenser Water Temperature	AV
Condenser Refrigerant Pressure	AV
Condenser Refrigerant Temperature	AV
Evaporator Refrigerant Pressure	AV
Evaporator Refrigerant Temperature	AV
Chiller Alarm/Fault Message	AV
Total Chiller kW	AV
Chiller State	AV
Chilled Water Supply Setpoint Adjust	AV
Chiller - Motor Current	AV
Compressor Discharge Temperature	AV
Compressor Surge Count	AV
Guide Vane Position	AV
VFD Output Frequency	AV
Chiller Start/Stop	BV

VFD POINTS (Required Points)	
POINT DESCRIPTION	TYPE
VFD Output Frequency	AV
VFD kW	AV
VFD Status	BV
VFD Start/Stop	BV



CDWP'S (10-TYP) - 7500 GPM, 300 HP, 115 FT HD

LEGEND

- Primary Chilled Water Piping
- Primary Chilled Water Piping
- Condenser Water Piping
- Automatically Operated Valves
- Normally Closed Manual Shutoff Valves
- Check Valve

Notes:
1. All pumps are operated by variable speed drives. Drives are set to limit current to maximum motor nameplate rating including service factor.
2. All pumps incorporate check valves to prevent reverse flow through pumps
3. Network connections for Variable Speed Drives shall include at a minimum: On/Off Control, Speed Control, Output Frequency, Drive Status, and Drive kW output.

TITLE: J160029 - University of Houston, Controls Diagram, Chiller Plant

DESCRIPTION: CONTROLS DIAGRAM, CHILLER PLANT

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