# Chilled Water Plant Assessment & Criteria Design

Prepared for:

**Cleveland**
**Airport System**


November 14, 2016

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# Executive Summary

Osborn Engineering Company was requested by Delta Airport Consultants and Cleveland Airport System to evaluate the condition and remaining useful service life of the central cooling plant.

Although the central cooling plant equipment and controls have been well maintained, the original (1978) chillers and pumps are well beyond their expected useful service life of 23 years (2001). The chillers added (1999 and 2001) after the initial building construction/renovation are also nearing the end of their service life. The overall estimated construction and project costs for the first phase system replacement is $5,300,000. The overall project cost includes the following soft costs: 10% for Profit; 10% for General Conditions; 10% for Design Contingency; 10% for Construction Contingency; 7% for Engineering Fees; 5% for Construction Manager and 1.5% for Commissioning. We allowed for 2 years to allocate funding and complete design documents for the plant replacement when calculating construction cost escalation. Average energy savings are estimated to be approximately $ 100,000 per year for the new central plant. After our interviews with the CHIA engineering and maintenance staff and analysis of the age and condition of the plant equipment, it became evident that the best course of action would be a complete chiller plant replacement undertaken as a two-phase project over several years. One chiller, the 750 nominal ton Trane centrifugal chiller tagged CH-2 was deemed to be usable and would be retained for use for the near future. In Phase 1 of the project we recommend replacement of the balance of the chillers, pumps and cooling towers comprising the chilled water plant. Existing CH-2 would remain in place and be incorporated into the new plant to operate as one of three total chillers and be replaced later in Phase 2 when it's useful life ends. This would provide an N+1 configuration where two of the three chillers would be capable of satisfying the current peak chilled water demand and a third chiller would be available as redundant back up.

**Phase 1**

We recommend the following scope for the replacement:

- Replace (3) existing chillers (chillers currently identified as CH-1, CH-3 and CH-4) with (2) new 750 nominal ton centrifugal water cooled chillers.
- Replace seven (7) primary chilled and eight (8) condenser water pumps with new.
- Replace (6) existing cooling towers with (6) new all stainless steel / non-ferrous construction crossflow 475 nominal ton cooling towers.
- Replace and reconfigure the bulk of the chilled water supply and return piping comprising the chilled water plant.
- Replace two (2) approximately 2000 gpm variable speed secondary chilled water pumps.
- Maintain existing CH-2 (the existing Trane 750 ton chiller) for re-use during Phase 1.
- Upgrade / replace control devices (flow meters, control valves, sensors) associated with the chilled water plant with new BACnet compatible devices and tie into the existing Siemens Apogee Building Automation System.

**Phase 2**

Replace existing chiller #2 in 5 to 8 years (planned) or sooner if any significant refrigerant / oil related problems develop.

## Study Scope of Work

Osborn Engineering Company was requested to evaluate the condition and remaining useful service life of the central chilled water plant. The scope of work included:

- Field verification of the chiller and condenser water piping systems to generate an accurate flow diagram of the existing configuration of each. This will identify location and sizes of existing pumps, valves, strainers and other key system components.
- Development of a plan and direction for the detailed chilled water plant design including recommendations for refrigerant utilized by the new plant equipment.
- Determination of system configuration and overall preliminary system capacity. (Final system capacity to be determined during the future detailed design portion of this project when a detailed analysis of run data and load calculations can be performed.)
- Visual inspection and recommendations for structural improvements/modifications necessary during the replacement of the cooling towers.
- Preparation of Design Criteria for owner's use to procure the design services for the detailed design and REVIT modeling of construction documents for the replacement of the Chilled Water Plant for the Main Terminal at Hopkins International Airport.

This report is based upon our review of the existing available drawings of the mechanical systems and inspection of the facilities including identified mechanical equipment. The inspection services were limited to a visual survey of existing conditions and exclude both non-destructive and destructive testing. This type of inspection does not clearly reveal all defects and requires certain engineering assumptions be made to establish condition. These assumptions cannot always be verified without extensive testing, some of which can be destructive. Therefore, this report is not to be considered a guarantee of the exact condition, life and total extent of potential repairs of the facilities inspected.

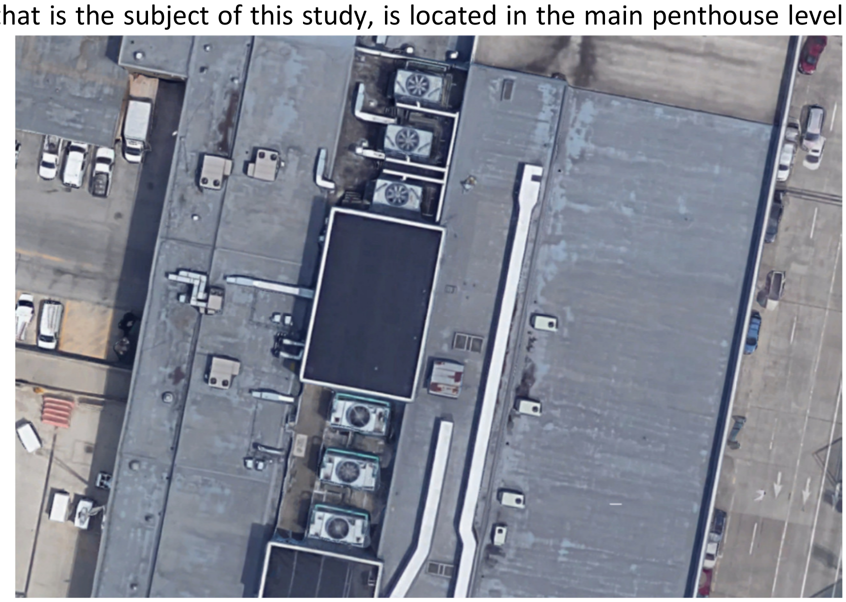
Osborn Engineering does not have control over the cost of labor, materials, or equipment, or Contractor's methods of determining prices, or over competitive bidding, market, or negotiating conditions. Accordingly, Osborn Engineering does not warrant or represent that bids or negotiated prices will not vary from any estimate or evaluation prepared, or agreed to, by Osborn Engineering.

## Overview

Cleveland Hopkins International Airport (CLE) is located just 12 miles southwest of downtown Cleveland and is currently Ohio's busiest airport, serving more than 9 million passengers annually. CLE was the nation's first municipal airport when it initially opened in 1925, and has a long history of leadership in implementing new airport technology. These innovations include the world's first radio-equipped air traffic control tower and the nation's first airfield lighting system. CLE was also the first airport in the nation to have a rail connection (added in 1968) to allow travelers to take commuter rail to/from the airport.

Today, CLE has two parallel runways at 10,000 and 9,000 feet in length as well as a 6,000 foot crosswind runway. It is the 32nd busiest airport in total flights and 43rd busiest in number of passengers in the nation, handling approximately 200,000 take-offs and landings annually. It covers approximately 1402 acres and includes the main terminal and four concourses (A thru D). Concourse A was the first of the airport's original two concourses and was built in 1962, with a major renovation in 1978. Concourse B was built in 1966 and underwent renovations in 1982. Concourse C was added in 1968 and renovated in 1992. Finally, concourse D was added in 1999 to complete the airport's current configuration.

The Central Chilled Water Plant, that is the subject of this study, is located in the main penthouse level mechanical room above the main terminal area of the Airport. This is a critical building system for the function of airport activities as it produces all the mechanical cooling for the main terminal including all ticketing/check-in, baggage claim areas, food court and Concourses A and B.



## Existing Conditions

The Central Chilled Water Plant as it is currently configured, consists of three water-cooled centrifugal chillers and one water-cooled rotary (screw) chiller. Their nominal capacities are 750 (CH-2), 500 (CH-3), 500 (CH-4) and 250 (CH-1) tons respectively giving the total plant a nominal capacity of 2000 tons. Heat rejection for the chillers is provided by six individual crossflow, induced draft cooling towers nominally sized at 400 tons each. This arrangement provides for a level of redundancy and a total of 2,400 connected tons of heat rejection. The current chilled water plant was initially installed during the 1978 renovations to the main terminal and initially consisted of the two 500 ton chillers and the cooling towers as listed above. The chilled and condenser water piping system has been modified several times in the past, most notably with the addition of the 750 ton chiller in approximately 2001. The 250 ton chiller was initially installed during 1999 as part of a baggage handling expansion project for Continental Airlines and was not initially part of the central chilled water plant. The piping and building automation system was modified about two years ago to tie this chiller into the central plant system to allow it to help carry the cooling loads. Documentation for all of these system modifications was incomplete or unable to be located. Therefore, as part of this study, Osborn Engineering created a one line flow schematic of the Central Chilled Water Plant piping and equipment that is provided for reference later in this report.

*Figure 1: CH-3 and 1 (from left to right)*

The condenser water piping system is made up of eight condenser water pumps and six individual cooling towers that are roughly configured into a North and South side that nearly mirror each other. Each "side" is made up of three cooling towers and four pumps piped together in a common header (three pumps run paired with a cooling tower and the fourth serves as redundant back-up). Each side ties together into a common header that feeds water to all the chillers. In practice it is

*Figure 2: South Condenser Water Pumps*

operated so that the South cooling towers operate in conjunction with CH-1, 3 and 4 and the North cooling towers operate with CH-2.

The chilled water piping is currently configured in a very non-traditional layout. The largest chiller is currently identified as CH-2 and is the 750 ton Trane chiller that was installed in about 2001. There are two chilled water pumps configured lead-lag (tagged P-11 & P-12) that draw water thru this chiller and pump it into a chilled water supply pipe header that feeds to the suction side of the system load pumps (P-16 & P-17). Common industry practice is to pump water through chillers not draw the water through them. (The pumps add a small amount of heat to the chilled water) The two 500 nominal ton chillers (CH-3 and CH-4 installed in 1978) are served by a three pump package (P-13, 14 & 15) that is configured so that P-13 is paired with one chiller and P-15 with the other. P-14 is on a common header with the other two and serves as back-up for either chiller. These chillers and pumps are also piped so the water is drawn through the chillers and then flows in series to the suction of pumps P-16 and P-17. CH-3 is currently being repaired from damage suffered during last winter. The condenser water barrel froze and damaged the tubes. Fortunately, the refrigeration system was not affected by this freeze. The last chiller (CH-1, the 250 nominal ton screw machine) was added into the system a few years ago and is piped to draw water out of the chilled water return header and pump it through chiller 1. It is served by two chilled water pumps in lead/lag configuration and this chiller also has its own lead/lag condenser water pumps. There are also a number of control valves and bypass connections in the chilled water supply and return lines serving this chiller. Lastly, this chiller has its pumps pushing the water through the evaporator barrel, not drawing it through the chiller as all the other chillers are configured. Chiller #1 is also currently being repaired from damage suffered last winter when its condenser barrel froze and damaged the barrel, tubes and refrigeration system.

*Figure 3: Pumps P-11 and P-12 serve CH-2*


*Figure 3: Pumps P-13, P-14 and P-15*

*Figure 5: CH-1 and its Pumps*

Record drawings for the system are incomplete/inaccurate and some modifications to the system have been made where the design and as-built documents are no longer available.

The chilled water plant is controlled by a Siemens Apogee Building Automation System (BAS). The head-end and system interface have been upgraded over the years and are up-to-date and capable of controlling a new chilled water plant. The existing sensors, flow meters, control valves and other control devices have been in service since their initial installation and in need of replacement. The BAS utilizes a graphical user interface that indicates system set-points, temperatures, flow information and equipment run status and alarms. This user interface could be modified to be utilized in a similar, familiar format to control and operate a modified chilled water plant.

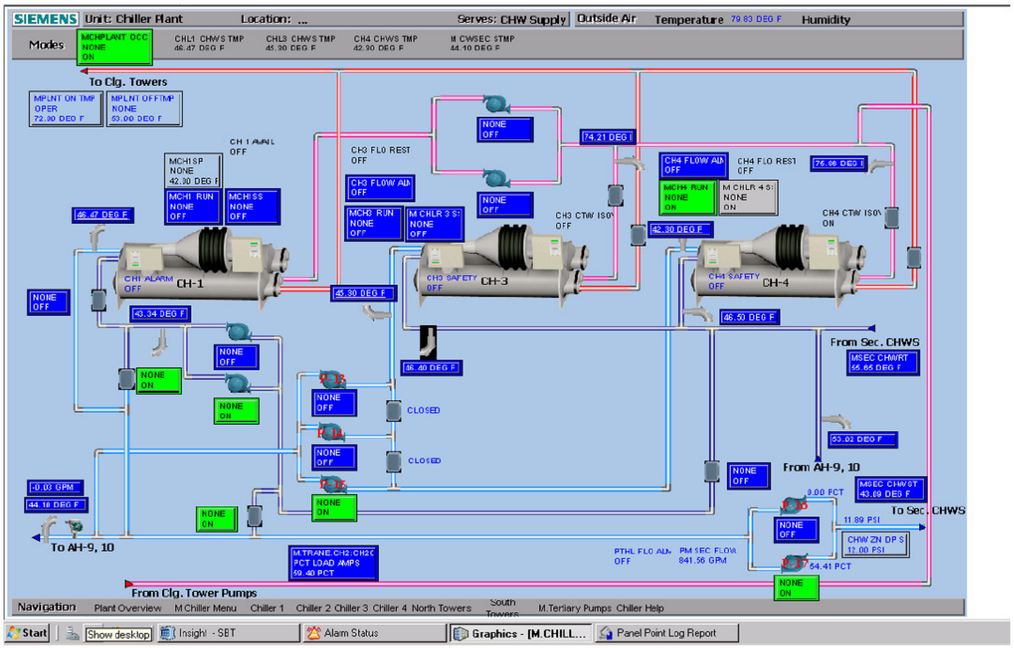



*Figure 6: Control System interface for chillers.*

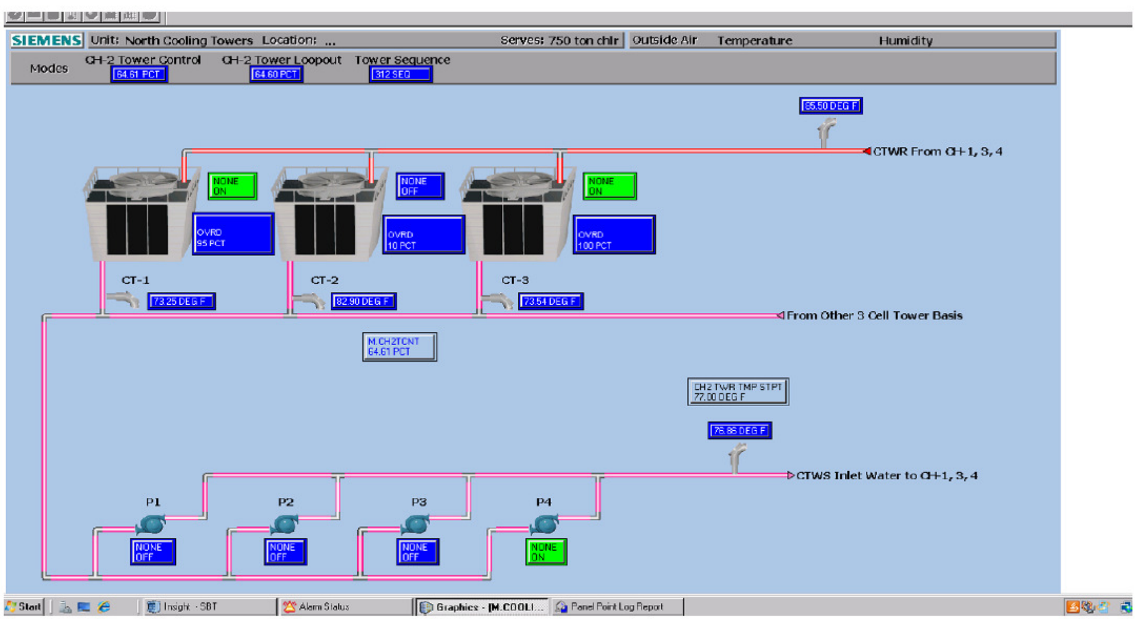



*Figure 7: Control System interface for North Cooling Towers and condenser pumps.*

# Evaluation

The majority of the equipment making up the main chilled water plant is significantly past the median life expectancy as predicted by ASHRAE. The median life expectancy for centrifugal water cooled chillers is 23 years. Chiller #2 (the 750 ton machine) is serving in its 15th year, chillers #3 and #4 (the two 500 nominal ton machines) are in their 38th year of operation and chiller #1 (the 250 ton machine originally installed in 1999) is in its 17th year of operation. The condenser water pumps and the chilled water pumps serving CH-3 and 4 all appear to be original from 1978. The chilled water pumps serving CH-2 appear to have been installed in conjunction with the installation of that chiller and the chilled water and condenser water pumps serving CH-1 were installed with that chiller in 1999. The cooling towers appear to have been replaced or at minimum have had the fill replaced at some point in the past. They are all showing signs that at a minimum the fill is in need of replacement, the hot water basins are leaking and have previously been identified as needing to be replaced or have a major refurbishment performed. ASHRAE indicates the median life expectancy for cooling towers and base mounted pumps to be 20 years. (See Table 1)

**ASHRAE Equipment Life Expectancy chart**

ASHRAE is the industry organization that sets the standards and guidelines for most all HVAC-R equipment. For additional info about ASHRAE the website is www.ashrae.org .

| Equipment Item | Median Years |
|---|---|
| Air conditioners | |
| Window unit | 10 |
| Residential single or Split Package | 15 |
| Commercial through-the wall | 15 |
| Water-cooled package | 15 |
| Heat Pumps | |
| Residential air-to-air | 15 |
| Commercial air-to-air | 15 |
| Commercial water-to-air | 19 |
| Roof-top air conditioners | |
| Single-zone | 15 |
| Multi-zone | 15 |
| Boilers, hot water (steam) | |
| Steel water-tube | 24 (30) |
| Steel fire-tube | 25 (25) |
| Cast iron | 35 (30) |
| Electric | 15 |
| Burners | 21 |
| Furnaces | |
| Gas- or oil-fired | 18 |
| Unit heaters | |
| Gas or electric | 13 |
| Hot water or steam | 20 |
| Radiant Heaters | |
| Electric | 10 |
| Hot water or steam | 25 |

| Equipment Item | Median Years |
|---|---|
| Air terminals | |
| Diffusers, grilles, and registers | 27 |
| Induction and fan coil units | 20 |
| VAV and double-duct boxes | 20 |
| Air washers | 17 |
| Ductwork | 30 |
| Dampers | 20 |
| Fans | |
| Centrifugal | 25 |
| Axial | 20 |
| Propeller | 15 |
| Ventilating roof-mounted | 20 |
| Coils | |
| DX, water, or steam | 20 |
| Electric | 15 |
| Heat Exchangers | |
| Shell-and-tube | 24 |
| Reciprocating compressors | 20 |
| Packaged chillers | |
| Reciprocating | 20 |
| Centrifugal | 23 |
| Absorption | 23 |
| Cooling towers | |
| Galvanized metal | 20 |
| Wood | 20 |
| Ceramic | 34 |

| Equipment Item | Median Years |
|---|---|
| Air-cooled condensers | 20 |
| Evaporative condensers | 20 |
| Insulation | |
| Molded | 20 |
| Blanket | 24 |
| Pumps | |
| Base-mounted | 20 |
| Pipe-mounted | 10 |
| Sump and well | 10 |
| Condensate 15 | |
| Reciprocating engines | 20 |
| Steam turbines | 30 |
| Electric motors | 18 |
| Motor starters | 17 |
| Electric transformers | 30 |
| Controls | |
| Pneumatic | 20 |
| Electric | 16 |
| Electronic | 15 |
| Valve actuators | |
| Hydraulic | 15 |
| Pneumatic | 20 |
| Self-contained | 10 |

*Table 1: ASHRAE Equipment Life Expectancy Chart*

For the chillers, there is another important factor to consider. Federal Law regulates the production and use of refrigerants utilized by HVAC equipment to prevent greenhouse gas emissions and limit Global Warming. The four existing chillers utilize three different refrigerants. One of the two oldest chillers (the two 500 ton machines) still utilizes R-11 and the other was refitted at some point in the past to operate on R-123 (when initially installed it operated on R-11). R-11 is a refrigerant that is no longer available and was phased out of production in 2010. It is likely that there was a repair required for this chiller in the past where the scarcity and cost of R-11 made it a better option to convert the machine to use R-123 instead. One problem with this solution is that the chiller is de-rated by approximately 10% (chiller peak capacity is reduced from 500 tons in this case to about 450 tons) by this conversion to an alternate refrigerant. The newest chiller (the 750 ton model) uses R-123 and the smaller 250 ton machine uses R-22. R-123 and R-22 are both HCFC (Hydrochlorofluorocarbon) refrigerants that by EPA regulation are to be phased out in 2020. At that point, manufacturers will no longer be able to manufacture new refrigerant and must use only recycled refrigerant to maintain operation of equipment already in use. Also beginning in 2020, no new refrigeration equipment can be manufactured or sold using either R-123 or R-22. In advance of the phase out, chiller manufacturers have already begun changing refrigerants utilized to more environmentally friendly options. Additionally, the cost of R-22 and R-123 has already begun to increase substantially over the past few years. Using the past as a guide with the CFC (Chlorofluorocarbon) refrigerants phased out in 2010, the cost of the next group being phased out in 2020 can be expected to increase dramatically in the next few years. The Cooling Towers were noted by Gardiner Service (the Airport's service vendor) as having leaking hot water basins and the fill is beginning to fail. They have already provided a proposal for a major cooling tower refurbishment and recommend this work be done in the near future.

Reasons for a complete or phased replacement of the chiller plant include:

- Chillers CH-3 and CH-4, all the cooling towers and the associated pumps are well beyond their useful service life.
- CH-1 and CH-2, while still in running condition with life expectancy remaining, must be planned for replacement due to their refrigerants. These units are beyond their mid-point of operational life so a simple refrigerant replacement to extend service life would not be cost effective. Maintenance costs typically accelerate during the last third of equipment's useful life, but costs for these machines will accelerate even faster due to the rising cost of refrigerant associated with the phase out of R-123 and R-22.
- The chilled water plant operated for all the summer of 2016 with 1250 nominal tons of cooling carrying the building load (Chillers 2 and 4). Plant operations personnel indicated that on days where the outside temperature met or exceeded 90$^{o}$F, they would need to pre-cool the building so the system could keep up with the load during the late afternoon hours. This is a strong indicator that the plant load is slightly above 1250 tons. For means of comparison, ASHRAE 1% cooling design conditions for Cleveland are 91$^{o}$F dry bulb, 83$^{o}$F wet bulb. For this past summer with chillers 1 and 3 off-line undergoing repairs, the system operated with no redundancy in the event of an equipment failure.
- The existing plant equipment and control is not as energy efficient as new chillers with optimized control. The plant efficiency is further degraded by the multiple piping modifications made over the years and the conversion of CH-3 from R-11 to R-123.
- The existing controllers, sensors and control valves are obsolete and in need of replacement.

# Recommendations & Design Criteria

1. Replace chillers 1, 3 and 4. We recommend replacing these three chillers during phase 1 with two new 600 to 750 ton oil-less bearing centrifugal chillers. Oil-less bearing chillers offer substantial long term advantages over traditional oil lubricated machines through lower operation and maintenance activities and costs, as well as higher operating efficiency at partial loads. Planned replacement should be anticipated in approximately 2 to 4 years. Maintain existing Chiller #2 for use with the re-designed chiller plant and incorporate future connection points to allow replacement of this machine when age, maintenance costs and/or scarcity of R-123 refrigerant dictates its replacement. Planned replacement of Chiller #2 (with a new chiller matching the two phase 1 chillers) should be anticipated in approximately 5 to 8 years.
    a. Engage a certified balance contractor to take water flow readings for each of the existing chillers and for the load side chilled water supply. Utilize load side flow data and system temperatures to finalize exact size of chillers to provide for N+1 chiller plant.
    b. Reconfigure piping to improve system efficiency and allow for primary / secondary chilled water loops to be created with a hydraulic / air / dirt separator providing the bridge between the primary and secondary loops. For purposes of this study, we have not assessed the chilled water piping on the load side of the system beyond the supply side of the secondary chilled water pumps. Further evaluation of the chilled water piping in the space needs to be undertaken, as well as evaluation of the condition and remaining service life of the load-side equipment (air handlers, fan coils).
2. Perform a 3D laser scan of the mechanical room surrounding the system equipment and the roof area around the cooling towers and generate a 3D Revit model for new chiller plant. Generate new chiller plant design drawings in Revit and update model with as-built conditions at completion of the project. Turn this model over to Cleveland Airport System for incorporation into the overall Airport Revit model that has been started on other projects recently completed at CHIA.
3. Remove and replace the bulk of the chilled water piping and pumps in the mechanical room and create a primary / secondary arrangement in the chilled water piping to allow for greater control and plant efficiency. Provide new variable frequency drives (VFD) with all new pumps.
4. Remove and replace the condenser water piping and pumps to optimize pumping energy efficiency with the new chillers. Provide VFD’s with all new pumps.
5. Replace the cooling towers with new towers of the same physical size to allow installation onto the existing structural steel with only minimal maintenance / repairs / modifications. During detailed design, evaluate increasing fan size for the towers to allow for lower condenser water supply temperatures to optimize chiller plant efficiency. Provide VFD’s for speed control for each cooling tower. Remove paint from cooling tower structural steel, assess structure in detail and repair/replace any members showing excess corrosion and paint structure with zinc-rich paint.
6. Provide new flow and temperature sensors for each chiller and both the primary and secondary chilled water loops as well as the condenser water north and south piping loops. Upgrade Siemens BAS to efficiently control all aspects of the chiller plant operation including varying number of chillers and cooling towers operating to match load conditions, varying primary chilled water pump flow, cooling tower fan(s) / speed(s), condenser water system flow and system temperatures.

# Operating and Maintenance Savings

## Operating Costs

### BASELINE - EXISTING

| | |
|---|---|
| 1,400 | tons, peak chilled water demand |
| 1,750 | EFLH, equivalent full load hours |
| **2,450,000** | **ton-hours, estimated annual chilled water consumption** |
| 0.80 | kW per ton, chiller average annual efficiency |
| 0.093 | kW per ton, primary chilled water pump average annual efficiency |
| 0.124 | kW per ton, secondary chilled water pump average annual efficiency |
| 0.149 | kW per ton, cooling tower fan average annual efficiency |
| 0.124 | kW per ton, condenser water pump average annual efficiency |
| **1.29** | **kW/ton, average annual plant efficiency** |
| **3,163,236** | **kWh per year, average annual electricity consumption** |
| $0.060 | $/kWh, electricity rate - 2016 CEI |
| **$189,794** | **$/year, average annual electricity cost** |

### PROPOSED

| | |
|---|---|
| **2,450,000** | **ton-hours, estimated annual chilled water consumption** |
| 0.31 | kW per ton, chiller average annual efficiency |
| 0.062 | kW per ton, primary chilled water pump average annual efficiency |
| 0.076 | kW per ton, secondary chilled water pump average annual efficiency |
| 0.064 | kW per ton, cooling tower fan average annual efficiency |
| 0.099 | kW per ton, condenser water pump average annual efficiency |
| **0.61** | **kW/ton, average annual plant efficiency** |
| **1,487,050** | **kWh per year, average annual electricity consumption** |
| $0.060 | $/kWh, electricity rate - 2016 CEI |
| **$89,223** | **$/year, average annual electricity cost** |

| | |
|---|---|
| **$100,571** | **$/year, average annual electricity cost savings** |

## Maintenance Costs (Comparison of Oil-Less to Standard Centrifugal Chillers)

**Maintenance Costs**

| | Oil-Less Chillers | | | Standard Chillers | | | |
|---|---|---|---|---|---|---|---|
| Year | Chillers PM $ | Annual Outsource $ | Maintenance Total $ | Chillers PM $ | Annual Outsource $ | Maintenance Total $ | Savings |
| 1 | $ 8,125 | $ - | $ 8,125 | $ 10,500 | $ - | $ 10,500 | **$ (2,375)** |
| 2 | $ 8,125 | $ 8,125 | $ 16,250 | $ 10,500 | $ 10,500 | $ 21,000 | **$ (4,750)** |
| 3 | $ 8,125 | $ 8,125 | $ 16,250 | $ 10,500 | $ 10,500 | $ 21,000 | **$ (4,750)** |
| 4 | $ 8,125 | $ 8,125 | $ 16,250 | $ 10,500 | $ 10,500 | $ 21,000 | **$ (4,750)** |
| 5 | $ 8,125 | $ 8,125 | $ 16,250 | $ 10,500 | $ 10,500 | $ 21,000 | **$ (4,750)** |
| 6 | $ 8,875 | $ 15,531 | $ 24,406 | $ 11,500 | $ 20,125 | $ 31,625 | **$ (7,219)** |
| 7 | $ 8,875 | $ 15,531 | $ 24,406 | $ 11,500 | $ 20,125 | $ 31,625 | **$ (7,219)** |
| 8 | $ 8,875 | $ 15,531 | $ 24,406 | $ 11,500 | $ 20,125 | $ 31,625 | **$ (7,219)** |
| 9 | $ 8,875 | $ 15,531 | $ 24,406 | $ 11,500 | $ 20,125 | $ 31,625 | **$ (7,219)** |
| 10 | $ 8,875 | $ 15,531 | $ 24,406 | $ 11,500 | $ 20,125 | $ 31,625 | **$ (7,219)** |
| 11 | $ 10,500 | $ 26,250 | $ 36,750 | $ 13,700 | $ 34,250 | $ 47,950 | **$ (11,200)** |
| 12 | $ 10,500 | $ 26,250 | $ 36,750 | $ 13,700 | $ 34,250 | $ 47,950 | **$ (11,200)** |
| 13 | $ 10,500 | $ 26,250 | $ 36,750 | $ 13,700 | $ 34,250 | $ 47,950 | **$ (11,200)** |
| 14 | $ 10,500 | $ 26,250 | $ 36,750 | $ 13,700 | $ 34,250 | $ 47,950 | **$ (11,200)** |
| 15 | $ 10,500 | $ 26,250 | $ 36,750 | $ 13,700 | $ 34,250 | $ 47,950 | **$ (11,200)** |
| 16 | $ 14,400 | $ 46,800 | $ 61,200 | $ 18,700 | $ 60,775 | $ 79,475 | **$ (18,275)** |
| 17 | $ 14,400 | $ 46,800 | $ 61,200 | $ 18,700 | $ 60,775 | $ 79,475 | **$ (18,275)** |
| 18 | $ 14,400 | $ 46,800 | $ 61,200 | $ 18,700 | $ 60,775 | $ 79,475 | **$ (18,275)** |
| 19 | $ 14,400 | $ 46,800 | $ 61,200 | $ 18,700 | $ 60,775 | $ 79,475 | **$ (18,275)** |
| 20 | $ 14,400 | $ 46,800 | $ 61,200 | $ 18,700 | $ 60,775 | $ 79,475 | **$ (18,275)** |
| | **$ 209,500** | **$ 475,406** | **$ 684,906** | **$ 272,000** | **$ 617,750** | **$ 889,750** | **$ (204,844)** |

The operating efficiency of oil-less (magnetic bearing in this example) chillers is better at part load conditions than standard design chillers (Integrated Part Load Value of about .305kW/T compared to .343kW/T). Total plant annual energy savings anticipated based on 2016 electric rates:

**2,450,000 Ton Hours x (.343-.305 kW/Th) x 0.06 $/KWH = $ 5,586.00 savings per year**

The probable premium cost for oil-less over standard chillers is approximately $30,000. When operational savings is combined with anticipated maintenance savings, the simple payback of the premium cost would be realized in less than four years. Note that in the event the electric rates increases, payback would be realized even sooner.

# Probable Construction Cost Estimate

| | | | | |
|---|---|---|---|---|
| **ESTIMATE WORKSHEET** | ORIGINATING OFFICE<br>Osborn Engineering | DATE SUBMITTED<br>10/17/16 | PROJECT NO.<br>J20160465.000 | CONTRACT NO. |
| | PROJECT AND CITY<br>Cleveland Hopkins International Airport<br>**Chilled Water Plant Study & Criteria Design**<br>Cleveland, Ohio | | PURPOSE<br>Opinion of Probable Construction Cost<br>ITEM<br>Summary by Sheet | **STUDY** |
| ESTIMATE VALID TO:<br>06/30/17 | ESTIMATED BY:<br>JHP | Labor Rate:<br>$ 75.00 | PSLCF<br>**1.15** | **Chilled Water Plant Phase 1** |

| DESCRIPTION OF WORK | | MATERIAL PER UNIT | MATERIAL SUBTOTAL | LABOR PER UNIT | LABOR SUBTOTAL | SUBTOTALS | ECCA | EXTENDED |
|---|---|---|---|---|---|---|---|---|
| **COST SUMMARY BY SHEET** | | | | | | | | |
| Piping Demolition | | | 9,100 | | 61,903 | $ 71,003 | $ 99,231 | $ 123,890 |
| Chilled Water Piping | | | 189,959 | | 180,916 | $ 370,875 | $ 518,317 | $ 647,119 |
| Condenser Water Piping | | | 409,071 | | 394,803 | $ 803,874 | $ 1,123,454 | $ 1,402,632 |
| New Mechanical Equipment | | | 1,218,390 | | 82,283 | $ 1,300,673 | $ 1,817,755 | $ 2,269,467 |
| General Trades | | | 33,750 | | 33,750 | $ 67,500 | $ 94,335 | $ 117,777 |
| Subs (Electrical, Testing & Balance, BAS, Insulation, Rigging) | | | 201,415 | | 213,780 | $ 415,195 | $ 580,256 | $ 724,449 |
| | | | | | | | $ - | $ - |
| | | | | | | $ - | $ - | $ - |
| SUBTOTAL 1 | | | 2,061,685 | | 967,435 | $3,029,120 | $4,233,347 | $5,285,333 |
| PROFIT | 10.0% | | | | | $302,912 | | |
| SUBTOTAL 2 | | | | | | $3,332,032 | | |
| GENERAL CONDITIONS | 10.0% | | | | | $333,203 | | |
| SUBTOTAL 3 | | | | | | $3,665,235 | | |
| ESCALATION TO MIDPOINT OF CONSTRUCTION | 5.0% | | | | | $183,262 | | |
| SUBTOTAL 4 | | | | | | $3,848,497 | | |
| DESIGN CONTINGENCY | 10.0% | | | | | $384,850 | | |
| **SUBTOTAL 5 - ECCA (Estimated Construction Cost at Award)** | | | | | | **$4,233,347** | **ECCA** | **$ 4,300,000** |
| CONSTRUCTION CONTINGENCY | 10.0% | | | | | $423,335 | | |
| **SUBTOTAL 6 - ECC (Estimated Construction Cost)** | | | | | | **$4,656,681** | **ECC** | **$ 4,700,000** |
| ENGINEERING FEES | 7.0% | | | | | $325,968 | | |
| CONSTRUCTION MANAGER | 5.0% | | | | | $232,834 | | |
| COMMISSIONING | 1.50% | | | | | $69,850 | | |
| | | | | | **TOTAL PROJECT COST** | **$ 5,285,333** | | |
| | | | | | **TOTAL PROJECT COST ROUNDED UP** | **$ 5,300,000** | | |

| | | | | | |
|---|---|---|---|---|---|
| | ORIGINATING OFFICE | DATE SUBMITTED | 10/17/2016 | PROJECT NO. | CONTRACT NO. |
| | Osborn Engineering | | | | |
| ESTIMATE | PROJECT AND CITY | | | PURPOSE | STUDY |
| WORKSHEET | Cleveland Hopkins International Airport | | | Opinion of Probable Construction Cost | |
| | Chilled Water Plant Study & Criteria Design | | | ITEM | |
| | Cleveland, Ohio | | | | |
| ESTIMATE VALID TO: | ESTIMATED BY: | LABOR RATE: | PSLCF | | |
| 06/30/17 | | $ 75.00 /HR | 1.15 | SHEET NO. 1 | OF 1 |

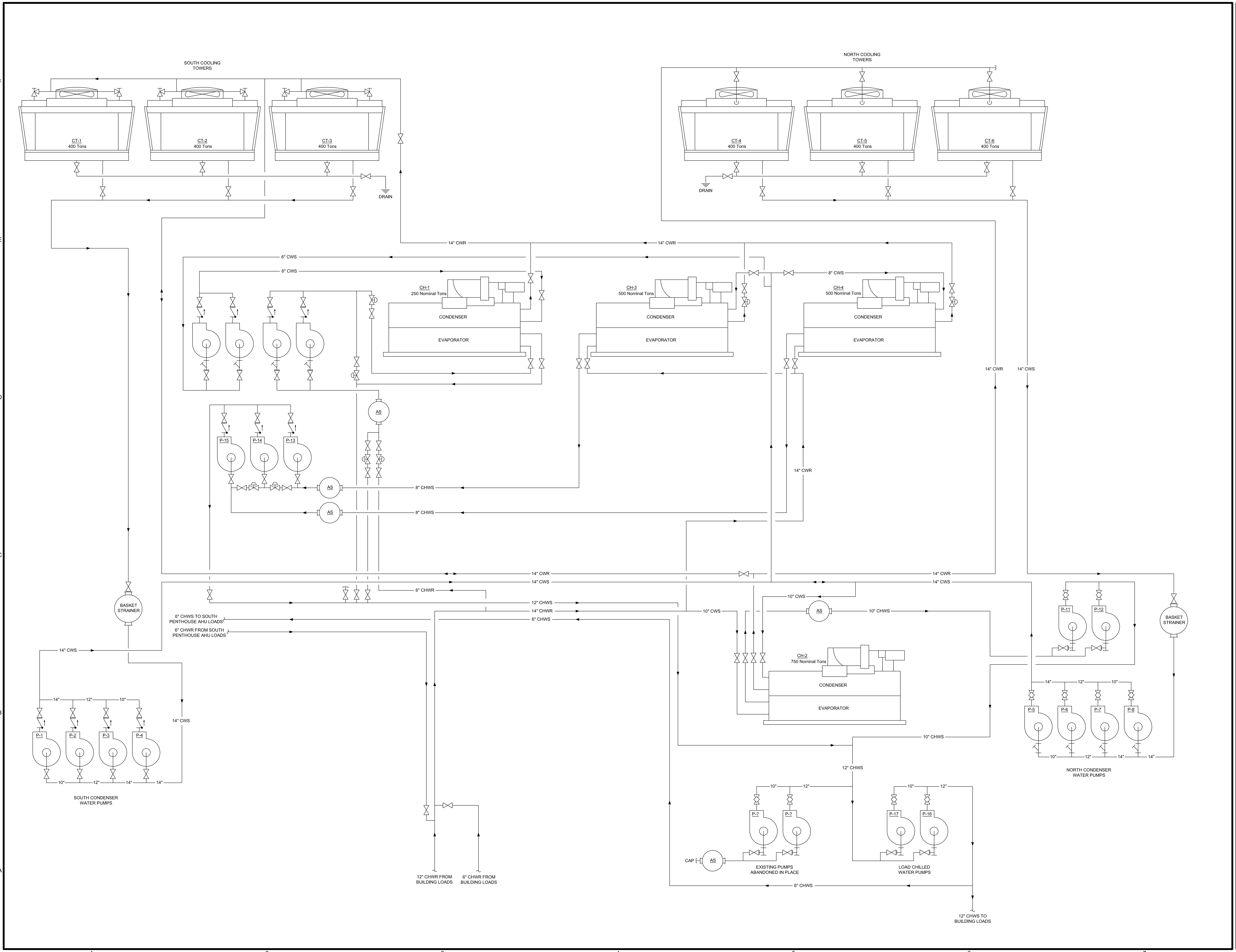
| DESCRIPTION OF WORK | | QUANTITY NO. UNITS | QUANTITY UNIT MEAS. | MATERIAL PER UNIT | MATERIAL SUBTOTAL | OT (y/n) | LABOR HRS PER UNIT | LABOR SUBTOTAL | SUBTOTALS | ECCA | Extended |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Demolition** | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| CHW Piping Demo | | 500.0 | Lot | 5.00 | 2500 | n | 0.267 | 11514 | $ 14,014 | $ 19,586 | $ 24,453 |
| CW Piping Demo | | 660.0 | Lot | 5.00 | 3300 | n | 0.267 | 15199 | $ 18,499 | $ 25,853 | $ 32,278 |
| Demo of Chillers | | 3.0 | Ea | 250.00 | 750 | n | 32.000 | 8280 | $ 9,030 | $ 12,620 | $ 15,756 |
| Demo of Pumps | | 21.0 | Ea | 50.00 | 1050 | n | 8.000 | 14490 | $ 15,540 | $ 21,718 | $ 27,115 |
| Demo Cooling Towers | | 6.0 | Ea | 250.00 | 1500 | n | 24.000 | 12420 | $ 13,920 | $ 19,454 | $ 24,288 |
| **Subtotal** | | | | | 9100 | n | | 61903 | $ 71,003 | $ 99,231 | $ 123,890 |
| | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| **New Equipment** | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| Chillers | 750 ton | 2.0 | EA | 235,000 | 470000 | n | 36.000 | 6210 | $ 476,210 | $ 665,527 | $ 830,911 |
| Primary CHW Pump | | 4.0 | EA | 4,910 | 19640 | n | 18.000 | 6210 | $ 25,850 | $ 36,127 | $ 45,104 |
| Secondary/Load CHW Pump | | 2.0 | EA | 12,360 | 24720 | n | 24.000 | 4140 | $ 28,860 | $ 40,333 | $ 50,356 |
| CWPump | | 8.0 | EA | 4,760 | 38080 | n | 18.000 | 12420 | $ 50,500 | $ 70,576 | $ 88,114 |
| 16" Air/Dirt/Hydraulic Separator | | 1.0 | EA | 30,700 | 30700 | n | 16.000 | 1380 | $ 32,080 | $ 44,833 | $ 55,975 |
| Primary CHW Pump - VFD | | 4.0 | EA | 11,000 | 44000 | n | 1.000 | 345 | $ 44,345 | $ 61,974 | $ 77,375 |
| Secondary/Load CHW Pump - VFD | | 2.0 | EA | 18,000 | 36000 | n | 1.000 | 173 | $ 36,173 | $ 50,553 | $ 63,115 |
| CW Pump - VFD | | 8.0 | EA | 11,000 | 88000 | n | 1.000 | 690 | $ 88,690 | $ 123,949 | $ 154,750 |
| CW Expansion Tank w/ Air Fittings | | 2.0 | EA | 4,250 | 8500 | n | 12.000 | 2070 | $ 10,570 | $ 14,772 | $ 18,443 |
| Basket Strainer - 14" Flanged | | 2.0 | EA | 31,000 | 62000 | n | 18.000 | 3105 | $ 65,105 | $ 90,987 | $ 113,598 |
| Cooling Tower | 475 ton | 6.0 | EA | 63,500 | 381000 | n | 48.000 | 24840 | $ 405,840 | $ 567,182 | $ 708,126 |
| CHW Make Up Water Piping Modifications | | 1.0 | Lot | 2,000 | 2000 | n | 40.000 | 3450 | $ 5,450 | $ 7,617 | $ 9,509 |
| Chemical Treatment System Mods | | 1.0 | Lot | 3,500 | 3500 | n | 40.000 | 3450 | $ 6,950 | $ 9,713 | $ 12,127 |
| CW Make Up Water Piping Mods | | 2.0 | Lot | 2,000 | 4000 | n | 40.000 | 6900 | $ 10,900 | $ 15,233 | $ 19,019 |
| **Subtotal** | | | | | 1212140 | n | | 75383 | $ 1,287,523 | $ 1,799,377 | $ 2,246,522 |
| | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| **Refrigerant Monitor & Exhaust** | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| Exhaust Fan | | 1.0 | Ea | 2750.00 | 2750 | n | 40.000 | 3450 | $ 6,200 | $ 8,665 | $ 10,818 |
| Refrigetant Monitor & Controls | | 1.0 | Ea | 3500.00 | 3500 | n | 40.000 | 3450 | $ 6,950 | $ 9,713 | $ 12,127 |
| **Sub Total** | | | | | 6250 | n | | 6900 | $ 13,150 | $ 18,378 | $ 22,945 |

| | | | | | |
|---|---|---|---|---|---|
| OSBORN ENGINEERING | ORIGINATING OFFICE | DATE SUBMITTED | 10/17/2016 | PROJECT NO. | CONTRACT NO. |
| | Osborn Engineering | | | | |
| ESTIMATE | PROJECT AND CITY | | | PURPOSE | STUDY |
| WORKSHEET | Cleveland Hopkins International Airport | | | Opinion of Probable Construction Cost | |
| | Chilled Water Plant Study & Criteria Design | | | ITEM | |
| | Cleveland, Ohio | | | | |
| ESTIMATE VALID TO: | ESTIMATED BY: | LABOR RATE: | PSLCF | | |
| 06/30/17 | JHP | $ 75.00 /HR | 1.15 | SHEET NO. 1 | OF 1 |

| DESCRIPTION OF WORK | | QUANTITY NO. UNITS | UNIT MEAS. | MATERIAL PER UNIT | MATERIAL SUBTOTAL | LABOR OT (y/n) | HRS PER UNIT | LABOR SUBTOTAL | SUBTOTALS | ECCA | Extended |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Rigging** | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| Stage Materials and Tools to Roof | | 2.0 | Crane Day | 1,250.00 | 2500 | n | 36.000 | 6210 | $ 8,710 | $ 12,173 | $ 15,198 |
| Rig Down Old Equipment & Rig New Into Place | | 2.0 | Crane Day | 2,250.00 | 4500 | n | 80.000 | 13800 | $ 18,300 | $ 25,575 | $ 31,931 |
| Rig Down Demo'd Piping and Misc | | 1.0 | Crane Day | 1250.00 | 1250 | n | 36.000 | 3105 | $ 4,355 | $ 6,086 | $ 7,599 |
| **Rigging Sub-Total** | | | | | **8250** | n | | **23115** | **$ 31,365** | **$ 43,834** | **$ 54,727** |
| | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| **Building Automation** | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| Demo of existing | | 1.0 | Lot | 15000.00 | 15000 | n | | 0 | $ 15,000 | $ 20,963 | $ 26,173 |
| Flow Meter | | 12.0 | Ea | 2300.00 | 27600 | n | | 0 | $ 27,600 | $ 38,572 | $ 48,158 |
| Temperature Sensor | | 20.0 | Ea | 625.00 | 12500 | n | | 0 | $ 12,500 | $ 17,469 | $ 21,811 |
| dP Sensor | | 20.0 | Ea | 935.00 | 18700 | n | | 0 | $ 18,700 | $ 26,134 | $ 32,629 |
| Water Meter | | 5.0 | Ea | 1150.00 | 5750 | n | | 0 | $ 5,750 | $ 8,036 | $ 10,033 |
| 32 Point Controllers | | 3.0 | Ea | 5200.00 | 15600 | n | | 0 | $ 15,600 | $ 21,802 | $ 27,220 |
| Eng Labor | | 96.0 | Point | 90.00 | 8640 | n | | 0 | $ 8,640 | $ 12,075 | $ 15,075 |
| Prog & Start Up Labor | | 96.0 | Point | 115.00 | 11040 | n | | 0 | $ 11,040 | $ 15,429 | $ 19,263 |
| Chiller Programming | | 3.0 | Ea | 1550.00 | 4650 | n | | 0 | $ 4,650 | $ 6,499 | $ 8,114 |
| Tower Programming | | 6.0 | Ea | 550.00 | 3300 | n | | 0 | $ 3,300 | $ 4,612 | $ 5,758 |
| Graphics Programming | | 1.0 | Lot | 3750.00 | 3750 | n | | 0 | $ 3,750 | $ 5,241 | $ 6,543 |
| kW Transducer | | 3.0 | Ea | 1300.00 | 3900 | n | | 0 | $ 3,900 | $ 5,450 | $ 6,805 |
| **Building Automation SubTotal** | | | | | **130430** | n | | **0** | **$ 130,430** | **$ 182,282** | **$ 227,580** |
| | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| **General Trades** | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| Minor repairs and Paint Tower Structure | | 6.0 | Ea | 5000.00 | 30000 | n | | 0 | $ 30,000 | $ 41,927 | $ 52,345 |
| Re-work Chiller Housekeeping Pad | | 3.0 | Ea | 1500.00 | 4500 | n | | 0 | $ 4,500 | $ 6,289 | $ 7,852 |
| Re-work Pump Housekeeping Pads | | 14.0 | Ea | 750.00 | 10500 | n | | 0 | $ 10,500 | $ 14,674 | $ 18,321 |
| Pump Inertia Bases | | 14.0 | Ea | 1500.00 | 21000 | n | | 0 | $ 21,000 | $ 29,349 | $ 36,642 |
| Exp Tank Inertia Base | | 1.0 | Ea | 1500.00 | 1500 | n | | 0 | $ 1,500 | $ 2,096 | $ 2,617 |
| **General Trades SubTotal** | | | | | **67500** | n | | **0** | **$ 67,500** | **$ 94,335** | **$ 117,777** |
| | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| **Water Testing & Balancing** | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| Pre-testing for Design | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| Chillers | | 4.0 | Ea | 275.00 | 1100 | n | | 0 | $ 1,100 | $ 1,537 | $ 1,919 |
| Cooling Towers | | 6.0 | Ea | 210.00 | 1260 | n | | 0 | $ 1,260 | $ 1,761 | $ 2,198 |
| Pumps | | 19.0 | Ea | 145.00 | 2755 | n | | 0 | $ 2,755 | $ 3,850 | $ 4,807 |
| Load Side Check | | 1.0 | Ea | 1500.00 | 1500 | n | | 0 | $ 1,500 | $ 2,096 | $ 2,617 |
| Post Install Test & Balance - Chillers | | 3.0 | Ea | 545.00 | 1635 | n | | 0 | $ 1,635 | $ 2,285 | $ 2,853 |
| Cooling Towers | | 6.0 | Ea | 420.00 | 2520 | n | | 0 | $ 2,520 | $ 3,522 | $ 4,397 |
| Pumps | | 14.0 | Ea | 285.00 | 3990 | n | | 0 | $ 3,990 | $ 5,576 | $ 6,962 |
| Load Side Check | | 1.0 | Ea | 1500.00 | 1500 | n | | 0 | $ 1,500 | $ 2,096 | $ 2,617 |
| **Test & Balance SubTotal** | | | | | **16260** | n | | **0** | **$ 16,260** | **$ 22,724** | **$ 28,371** |
| | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| **Electrical** | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| Disc & Demo Feeder to Pump | | 21.0 | Ea | 984.00 | 20664 | n | | 0 | $ 20,664 | $ 28,879 | $ 36,055 |
| Disc & Demo Feeder to Chiller | | 3.0 | Ea | 9031.00 | 27093 | n | | 0 | $ 27,093 | $ 37,864 | $ 47,273 |
| Disc & Demo Feeder to CT | | 6.0 | Ea | 4950.00 | 29700 | n | | 0 | $ 29,700 | $ 41,507 | $ 51,822 |
| Re-Feed Power to new Chiller | 750 ton | 2.0 | Ea | 21400.00 | 42800 | n | | 0 | $ 42,800 | $ 59,815 | $ 74,679 |
| Re-Feed Power to new Cooling Tower | 25 HP | 6.0 | Ea | 6225.00 | 37350 | n | | 0 | $ 37,350 | $ 52,198 | $ 65,170 |
| Provide 120v Circuit for Outlet or Control use | | 6.0 | Ea | 900.00 | 5400 | n | | 0 | $ 5,400 | $ 7,547 | $ 9,422 |
| Re-Feed Power to Pump 100.00 | HP | 2.0 | Ea | 4000.00 | 8000 | n | | 0 | $ 8,000 | $ 11,180 | $ 13,959 |
| Re-Feed Power to Pump 30.00 | HP | 4.0 | Ea | 2250.00 | 9000 | n | | 0 | $ 9,000 | $ 12,578 | $ 15,704 |
| Re-Feed Power to Pump 25.00 | HP | 8.0 | Ea | 2250.00 | 18000 | n | | 0 | $ 18,000 | $ 25,156 | $ 31,407 |
| All VFD's furnished in Mech Scope | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| **Electrical SubTotal** | | | | | **198007** | n | | **0** | **$ 198,007** | **$ 276,725** | **$ 345,491** |
| | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| **Insulation** | | | | | 0 | n | | 0 | $ - | $ - | $ - |
| 14" Pipe, 2" thick fiberglass w/ asj | | 400.0 | lf | 11.05 | 4420 | n | 0.267 | 9212 | $ 13,632 | $ 19,051 | $ 23,785 |
| 14" 90 Ell, pvc cover w/ ins insert | | 48.0 | Ea | 17.80 | 854 | n | 0.242 | 1002 | $ 1,856 | $ 2,594 | $ 3,239 |
| 14" Tee, pvc cover w/ ins insert | | 24.0 | Ea | 24.50 | 588 | n | 0.356 | 737 | $ 1,325 | $ 1,852 | $ 2,312 |
| 10" Pipe, 2" thick fiberglass w/ asj | | 400.0 | lf | 7.65 | 3060 | n | 0.229 | 7901 | $ 10,961 | $ 15,318 | $ 19,124 |
| 10" 90 Ell, pvc cover w/ ins insert | | 42.0 | Ea | 10.75 | 452 | n | 0.216 | 782 | $ 1,234 | $ 1,725 | $ 2,153 |
| 10" Tee, pvc cover w/ ins insert | | 22.0 | Ea | 18.25 | 402 | n | 0.333 | 632 | $ 1,033 | $ 1,444 | $ 1,803 |
| 14" Pipe, 0.016 Alum jacket | | 180.0 | lf | 4.38 | 788 | n | 0.174 | 2701 | $ 3,490 | $ 4,877 | $ 6,089 |
| 14" 90 Ell, 0.016 Alum jacket | | 12.0 | Ea | 73.48 | 882 | n | 0.268 | 277 | $ 1,159 | $ 1,620 | $ 2,023 |
| 14" Tee, 0.016 Alum jacket | | 12.0 | Ea | 60.00 | 720 | n | 0.421 | 436 | $ 1,156 | $ 1,615 | $ 2,017 |
| 10" Pipe, 0.016 Alum jacket | | 120.0 | lf | 3.49 | 419 | n | 0.163 | 1687 | $ 2,106 | $ 2,943 | $ 3,674 |
| 10" 90 Ell, 0.016 Alum jacket | | 12.0 | Ea | 51.50 | 618 | n | 0.242 | 250 | $ 868 | $ 1,214 | $ 1,515 |
| 10" Tee, 0.016 Alum jacket | | 4.0 | Ea | 45.50 | 182 | n | 0.381 | 131 | $ 313 | $ 438 | $ 547 |
| **Insulation SubTotal** | | | | | **13384** | n | | **25749** | **$ 39,133** | **$ 54,690** | **$ 68,281** |

| | | | | | |
|---|---|---|---|---|---|
| OSBORN ENGINEERING | ORIGINATING OFFICE<br>Osborn Engineering | DATE SUBMITTED | 10/17/2016 | PROJECT NO. | CONTRACT NO. |
| ESTIMATE WORKSHEET | PROJECT AND CITY<br>Cleveland Hopkins International Airport<br>Chilled Water Plant Study & Criteria Design<br>Cleveland, Ohio | | | PURPOSE<br>Opinion of Probable Construction Cost<br>ITEM | STUDY |
| ESTIMATE VALID TO:<br>06/30/17 | ESTIMATED BY:<br>JHP | LABOR RATE:<br>$ 75.00 /HR | PSLCF<br>1.15 | SHEET NO. 1 | OF 1 |

| DESCRIPTION OF WORK | QUANTITY NO. UNITS | QUANTITY UNIT MEAS. | MATERIAL PER UNIT | MATERIAL SUBTOTAL | OT (y/n) | LABOR HRS PER UNIT | LABOR Labor Hrs SUBTOTAL |
|---|---|---|---|---|---|---|---|
| **Chiller Drop** | | | | 0 | n | | 0 |
| **Chilled Water** | | | | 0 | n | | 0 |
| 8" CS Pipe, Sch 40 | 30.0 | LF | 69.90 | 2097 | n | 0.828 | 24.84 |
| 8" 90 Ell | 6.0 | EA | 200.00 | 1200 | n | 6.400 | 38.40 |
| 8" SS Braided Flex Conn | 2.0 | EA | 670 | 1340 | n | 3.200 | 6.40 |
| 8" 150# WN Flange | 10.0 | EA | 35.00 | 350 | n | 5.300 | 53.00 |
| 3/4" TOL | 6.0 | EA | 15.00 | 90 | n | 1.000 | 6.00 |
| Adjustable Angle Thermometer | 2.0 | EA | 30.00 | 60 | n | 0.750 | 1.50 |
| 8" Flow Meter | 1.0 | EA | 3500.00 | 3500 | n | 8.000 | 8.00 |
| TCC Temp Sensor | 2.0 | EA | 5.00 | 10 | n | 0.750 | 1.50 |
| 8" B-Fly Valve | 2.0 | EA | 465.00 | 930 | n | 5.330 | 10.66 |
| 8" Motor Op B-Fly Valve | 1.0 | EA | 790.00 | 790 | n | 7.250 | 7.25 |
| **Subtotal** | | | | 10367 | n | | 157.55 |
| **Condenser Water** | | | | 0 | n | | 0 |
| 10" CS Pipe, Sch 40 | 30.0 | LF | 90.80 | 2724 | n | 1.000 | 30.00 |
| 10" 90 Ell | 6.0 | EA | 400.00 | 2400 | n | 8.000 | 48.00 |
| 10" SS Braided Flex Conn, Flg x Flg | 2.0 | EA | 735.00 | 1470 | n | 3.500 | 7.00 |
| 10" 150# Weld Flange | 10.0 | EA | 42.00 | 420 | n | 6.960 | 69.60 |
| 3/4" TOL | 6.0 | EA | 25.00 | 150 | n | 1.250 | 7.50 |
| Adjustable Angle Thermometer | 2.0 | EA | 75.00 | 150 | n | 0.750 | 1.50 |
| 10" Flow Meter | 1.0 | EA | 5000.00 | 5000 | n | 12.000 | 12.00 |
| TCC Sensor | 2.0 | EA | 10.00 | 20 | n | 1.250 | 2.50 |
| 10" B-Fly Valve | 2.0 | EA | 559.00 | 1118 | n | 6.000 | 12.00 |
| 10" Motor Op B-Fly Valve | 1.0 | EA | 1100.00 | 1100 | n | 8.000 | 8.00 |
| | | | | 0 | n | | 0.00 |
| **Chiller Drop Sub-Total** | | | | 14552 | n | | 198.10 |
| | | | | 0 | n | | 0 |
| **Secondary CW Pump (12" Suc x 10" Disch)** | | | | 0 | n | | 0 |
| 12" 90 ell | 2.0 | EA | 590.00 | 1180 | n | 9.600 | 19.20 |
| 12" Lug Body B-Fly Valve | 2.0 | EA | 1525.00 | 3050 | n | 8.000 | 16.00 |
| 12" Tri-Duty Valve | 1.0 | EA | 7675.00 | 7675 | n | 11.400 | 11.40 |
| 12" SS Braided Flex, Flg x Flg | 2.0 | EA | 950.00 | 1900 | n | 4.000 | 8.00 |
| 12 x 10 Conc Weld Reducer | 1.0 | EA | 398.00 | 398 | n | 8.000 | 8.00 |
| 12" 150# WN Flange | 8.0 | EA | 105.00 | 840 | n | 8.250 | 66.00 |
| 10" Same | 1.0 | EA | 82.00 | 82 | n | 6.960 | 6.96 |
| 12" Suction Diffuser | 1.0 | EA | 5100.00 | 5100 | n | 14.000 | 14.00 |
| Pressure Gauge | 1.0 | EA | 75.00 | 75 | n | 0.750 | 0.75 |
| 12" CS Pipe, Sch 40 | 21.0 | LF | 106.91 | 2245 | n | 1.260 | 26.46 |
| **Subtotal** | | | | 22545 | n | | 176.77 |
| | | | | 0 | n | | 0 |
| **Primary CHW Pump** | | | | 0 | n | | 0 |
| 10" Lug Body B-Fly Valve | 2.0 | EA | 1100.00 | 2200 | n | 6.000 | 12.00 |
| 10" Tri-Duty Valve | 1.0 | EA | 4250.00 | 4250 | n | 10.900 | 10.90 |
| 10" SS Braided Flex, Flg x Flg | 2.0 | EA | 625.00 | 1250 | n | 2.670 | 5.34 |
| 10 x 8 Conc Weld Reducer | 1.0 | EA | 377.00 | 377 | n | 8.000 | 8.00 |
| 10" 150# WN Flange | 8.0 | EA | 82.00 | 656 | n | 6.960 | 55.68 |
| 8" Same | 1.0 | EA | 75.00 | 75 | n | 5.300 | 5.30 |
| 10" Suction Diffuser | 1.0 | EA | 3875.00 | 3875 | n | 11.000 | 11.00 |
| Pressure Gauge | 1.0 | EA | 75.00 | 75 | n | 0.750 | 0.75 |
| 10" CS Pipe, Sch 40 | 21.0 | LF | 90.80 | 1907 | n | 1.000 | 21.00 |
| 10" 90 Ell | 2.0 | EA | 418.40 | 837 | n | 8.000 | 16.00 |
| **Subtotal** | | | | 15502 | n | | 145.97 |
| | | | | 0 | n | | 0 |
| **Cooling Tower Piping** | | | | 0 | n | | 0 |
| 10" CS Pipe, Sch 40 | 42.0 | LF | 90.80 | 3814 | n | 1.000 | 42.00 |
| 12" CS Pipe, Sch 40 | 21.0 | LF | 106.91 | 2245 | n | 1.260 | 26.46 |
| 1-1/2" Pipe, L Copper | 20.0 | LF | 14.35 | 287 | n | 0.154 | 3.08 |
| 10" 90 Ell | 6.0 | EA | 418.40 | 2510 | n | 8.000 | 48.00 |
| 12" 90 Ell | 1.0 | EA | 590.00 | 590 | n | 9.600 | 9.60 |
| 1-1/2" 90 Ell | 3.0 | EA | 40.50 | 122 | n | 0.615 | 1.85 |
| 12" Lug Body B-Fly Valve - 150# | 1.0 | EA | 1525.00 | 1525 | n | 8.000 | 8.00 |
| 10" Lug Body B-Fly Valve - 150# | 2.0 | EA | 1100.00 | 2200 | n | 6.000 | 12.00 |
| 1-1/2" Ball Valve | 1.0 | EA | 70.00 | 70 | n | 0.700 | 0.70 |
| 12" Flange, WN - 150# | 3.0 | EA | 105.00 | 315 | n | 8.250 | 24.75 |
| 10" Flange, WN - 150# | 6.0 | EA | 82.00 | 492 | n | 6.960 | 41.76 |
| 1-1/2" Union Brass | 1.0 | EA | 185.00 | 185 | n | 1.060 | 1.06 |
| **Subtotal** | | | | 14355 | n | | 219.26 |





OSBORN ENGINEERING
1100 Superior Avenue - Suite 300 | Cleveland, OH 44114
441 Wolf Ledges Parkway - Suite 300 | Akron, OH 44311
(216) 861-2020 www.osborn-eng.com


Cleveland Hopkins International Airport Main Terminal Chilled Water Plant Acessment

Cleveland Airport System

5300 Riverside Drive
PO Box 81009
Cleveland, OH 44181-0009
(216) 265-xxxx

| TAG | ISSUED | DATE |
|---|---|---|
| | Final Report Review | 10/20/16 |
| | Prelim Owner Review | 9/8/16 |



DRAWN BY JHP
CHECKED BY -
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Main Terminal Existing Chilled Water Plant Flow Diagram

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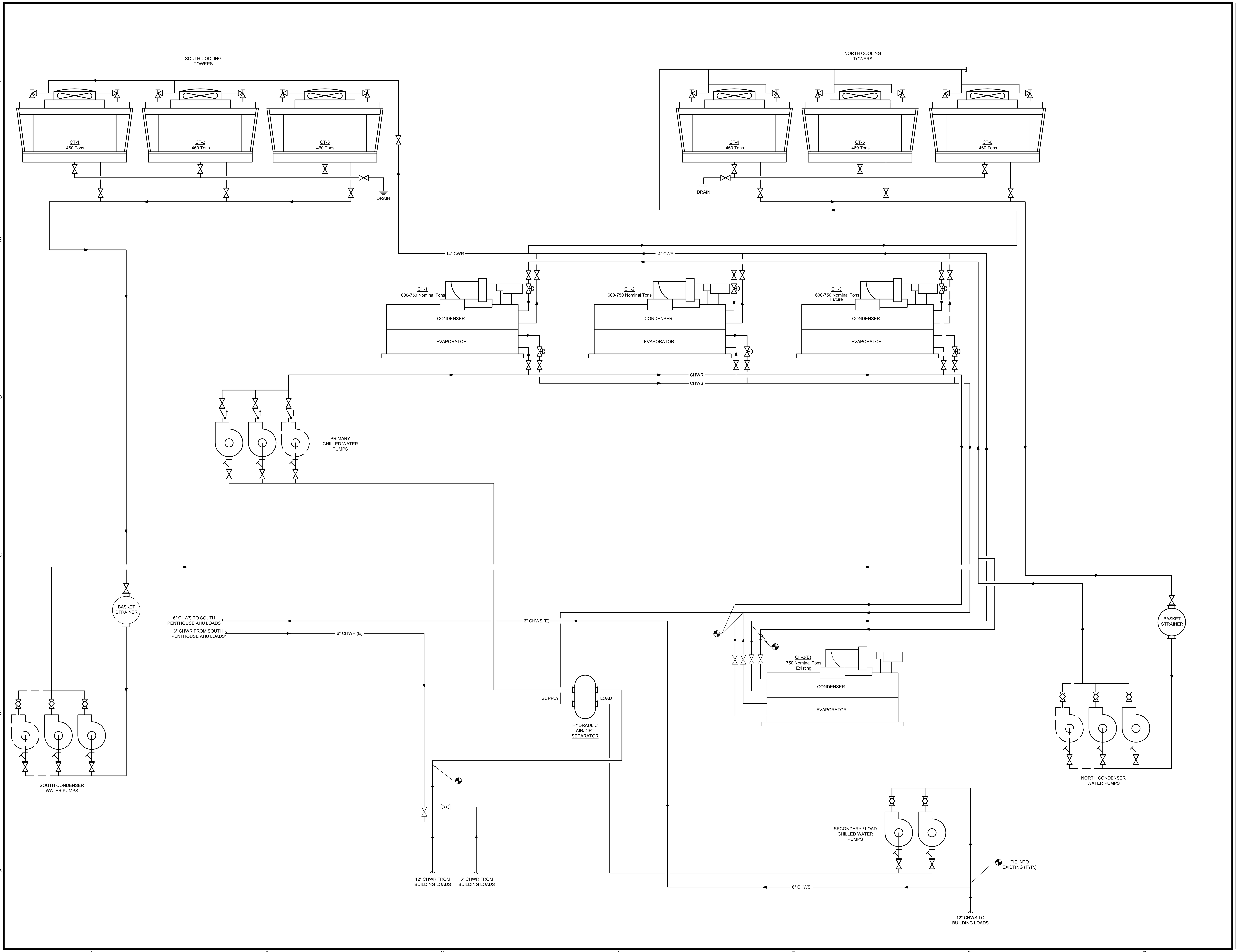
10/20/2016 12:34 PM Price, Jim

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10/20/2016 12:36 PM Price, Jim

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Cleveland Hopkins International Airport Main Terminal Chilled Water Plant Acessment

Cleveland Airport System

5300 Riverside Drive
PO Box 81009
Cleveland, OH 44181-0009
(216) 265-xxxx

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| | Final Report Review | 10/20/16 |
| | Prelim Owner Review | 9/8/16 |



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# Main Terminal Proposed Chilled Water Plant Flow Diagram

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