

FINAL REPORT

Demonstration of a High-Efficiency Evaporative Cooler for
Improved Energy Efficiency in DoD Data Centers

ESTCP Project EW-201348

JANUARY 2020

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14. ABSTRACT This report provides a description of a demonstration project under the US DoD Environmental Security Technology Certification Program (ESTCP) aimed at reducing energy use for data center cooling. The technology planned for this demonstration involves hybrid evaporative cooling. Water is cooled in outdoor exchangers that can operate either in a wet or dry mode (hybrid) to maximize energy savings. The planned demonstration site was a data center in Port Hueneme, California. Two different technologies were candidates for use in this project. An analysis of both was completed using an hourly annual analysis. Several different options for integration at the site were evaluated including the addition of thermal storage and integration with direct-to-chip cooling. To achieve energy savings as high as 75% with this technology, the data center temperature must be increased from traditional levels. This report documents the challenges and solutions associated with this. A key factor in performance is the temperature of the circulating water and this, in turn, is affected by the heat transfer characteristics of the indoor air handlers.					
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ABSTRACT

Introduction: This report provides a description of a demonstration project under the US DoD Environmental Security Technology Certification Program (ESTCP) aimed at reducing energy use for data center cooling.

Technology Description: The technology planned for this demonstration involves *hybrid evaporative cooling*. Water is cooled in outdoor exchangers that can operate either in a wet or dry mode (hybrid) to maximize energy savings and minimize water consumption. The planned demonstration site was a data center in Port Hueneme, California. In the pre-existing situation at this site, water is cooled with conventional mechanical chillers circulated through indoor air handler units. In the planned demonstration, the cooling load would be transferred to the lower-energy, hybrid evaporative cooler with the existing mechanical chillers remaining as backup. The indoor air handler units are not changed. Two different fluid cooler technologies were candidates for use in this project. An analysis of both was completed using an hourly annual analysis. Several different options for integration at the site were evaluated including the addition of thermal storage and integration with direct-to-chip cooling.

Performance and Cost Assessment: An analysis was done of the expected energy performance of the two evaporative cooler concepts evaluated in this project and energy savings relative to the baseline mechanical chiller. An analysis of the annual hours for which the hybrid evaporative cooler concept can run in a dry mode and the annual hours for which the hybrid evaporative cooler concept will not be able to meet the cooling load of the data center was also completed. Annual electrical energy savings from 51 to 79% were projected. At this site the number of annual hours for which the evaporative coolers could not nominally meet the data center cooling load ranged from 2 to 111, depending on technology used.

Implementation Issues: To achieve energy savings as high as 75% with this technology, the data center temperature must be increased from traditional levels. This report documents the challenges and solutions associated with this. A key factor in performance is the temperature of the circulating water and this, in turn, is affected by the heat transfer characteristics of the indoor air handlers. The analysis showed that, at the Port Hueneme site, this approach could be used to completely displace the existing mechanical chillers. An extension of this analysis to other climate zones around the US showed that the evaporative chillers may not be able to completely displace the mechanical chillers everywhere, but in many cases can still provide substantial reductions in the data-center energy use.

After completion of a detailed installation design and specifications the decision was made not to proceed with the actual installation.

EXECUTIVE SUMMARY

INTRODUCTION

This report provides a description of a demonstration program under the United States (US) Department of Defense (DoD) Environmental Security Technology Certification Program (ESTCP) aimed at reducing energy use for data center cooling. The technology planned for this demonstration involves hybrid evaporative cooling. Water is cooled in outdoor towers that can operate either in a wet or dry mode (*hybrid*). The cooled water is directed indoors to existing air handlers. Relative to mechanical water chillers this approach of using “free” ambient cooling offers the potential for up to 75% energy-use reduction. The demonstration was planned for the Port Huaneme Naval Base in Ventura County, California. Prior to the installation of the planned equipment, the decision was made not to proceed with the actual hardware installation phase of the project. This report documents the planning and analysis work that was completed prior to the installation. Detailed design plans and construction specifications for the installation have been prepared and are submitted as an annex to this report.

Currently most data center equipment is cooled with standard vapor-compression heating, ventilation, and air conditioning (HVAC) equipment. Conditioned air at 55°F is supplied to computer equipment, which is then returned at 75–80°F, where it is cooled and re-delivered. Consequently, the cooling system is the largest source of inefficiency due to the limitations of the standard refrigeration cycle. Practices such as free cooling, direct-to-chip cooling, and evaporative cooling are being explored to help reduce the energy burden associated with cooling systems. A fortuitous development in modern computing systems is their ability to operate at higher ambient conditions (80–85°F). In fact, in 2008, ASHRAE increased the maximum recommended supply temperature for data centers from 77°F to 80.6 °F. Higher supply temperatures allow the cooling requirements to be reduced and increase the coefficient of performance (COP) of cooling systems. Perhaps most importantly, higher supply temperatures allow the use of alternative refrigeration strategies, such as evaporative cooling systems, which consume *significantly* less energy than traditional refrigerant-based HVAC systems. This trend of increasing electronics/IT operating temperatures is expected to continue.

During this project, two specific evaporative cooler products were considered for the planned demonstration. The first of these is a Polymer Fluid Cooler (PFC) which includes a novel outdoor heat exchanger with small diameter polymer tubes. The second is a Hybrid Cooler with a design optimized to take advantage of sensible (non-evaporative) cooling to the greatest degree possible, minimizing annual water use. At the start of the project the PFC was the planned cooler and much of the installation design work was developed around this unit. Late in 2016, the manufacturer announced that they had made a decision to drop the PFC product from their portfolio and they withdrew from the project. At this point and following a review of the market, a project decision was made to convert the design to the Hybrid Cooler product.

In the PFC system, circulating water enters the cooler and passes through the inside of the tubes in the polymer heat exchanger. Water from a separate source is sprayed over the heat exchanger while outside air is drawn upwards using a variable-speed draft fan. As the spray water evaporates, it cools the fluid in the heat exchanger. Analysis and testing of the PFC system

shows that up to 75% of the difference between dry- and wet-bulb temperature can be achieved with a well-designed PFC system. This enables such a system to meet ASHRAE air supply requirements with significant energy savings. To run the system in dry mode, the spray water is simply turned off, and the water is cooled by heat exchange with the lower-temperature ambient, saving water and reducing energy consumption.

The Hybrid Cooler uses metal heat exchangers to cool the data center circulating water by exchange with outside air. Relative to the PFC this unit is much taller and heavier. This unit has two heat exchangers with circulating water flow in series. The top heat exchanger operates only in a dry mode and the bottom heat exchanger can operate either wet or dry. The system was designed to have a high dry-bulb switchover temperature above which the water sprays on the lower heat exchanger would need to be used. With this unit, during dry mode operation, the spray pump is simply turned off. In wet mode a portion of the cooling load is met with the top heat exchanger in a dry mode, reducing water consumption.

OBJECTIVES

Generally, the objectives of the planned demonstration were to show that: the evaporative cooling system can be integrated with an existing mechanical chiller cooling system; the system can meet the cooling demand of the data center for nearly 100% of the year; and the energy savings and water use targets can be met. Highlights of the project Performance Objectives are listed in Table ES-0-1, below.

Table ES-0-1: Highlights of Project Performance Objectives

Performance Objective	Success Criterion
Ability of the hybrid evaporative cooler to meet the data center cooling load	Required operation of the main mechanical chillers less than 100 hours per year
Cooling Energy Savings	Minimum of 50% energy reduction, annual average
Data Center Peak Load	75% Reduction in peak load during hot conditions in the late summer and fall.
Water Usage	Annual water consumption not greater than that of a conventional, gas-fired power plant with a cooling tower.
Temperature	System capable of control within acceptable range. Current target 81°F.

TECHNOLOGY DESCRIPTION

The Polymer Fluid Cooler (PFC) first planned for use in this project has a series of horizontal, small diameter polymer tubes with building circulating water flowing through in parallel. Water from a separate source is sprayed over the heat exchanger while outside air is drawn upwards using a variable-speed draft fan. As the spray water evaporates, it cools the fluid in the heat exchanger. Up to 75% of the difference between dry- and wet-bulb temperature can be achieved

with the PFC system. The use of a polymer—rather than metal—heat exchanger minimizes issues with fouling and water contamination, which simplifies water treatment and minimizes maintenance. The layout of the PFC is horizontal and the overall height is short. The outside air makes one pass through the polymer tube bundle. To run the system in dry mode, the spray water is simply turned off, and the water is cooled by heat exchange with the lower-temperature ambient, saving water and reducing energy consumption.

Relative to the PFC unit, the Hybrid unit, selected after the PFC was withdrawn by the manufacturer, uses metal heat exchangers to cool the data center circulating water by exchange with outside air. The Hybrid unit, which has two stacked heat exchangers is taller than the PFC unit and it is considerably heavier. The top heat exchanger operates only in a dry mode and the bottom heat exchanger can operate either wet or dry. The system was designed to have a high dry-bulb switchover temperature above which the water sprays on the lower heat exchanger would need to be used.

With the PFC unit, it was originally planned to install a total of four horizontal modules which provides a total nominal capacity of 100 tons. The current cooling load at the NITC data center is on the order of 45 tons and the additional capacity was planned for potential future expansion and to allow for operation in a dry mode for as much of the year as possible. In discussions with the manufacturer of the Hybrid unit, however, it became clear that the cost for their unit at the 100-ton capacity would be much greater than the originally proposed price for the PFC unit. After considerable discussion a decision was made to evaluate a system with a capacity closer to the current actual cooling load at the facility. Table ES-0-2, below, provides a comparison of technical features for the Hybrid unit selected with a two-module PFC unit which would provide a similar capacity. Costs are estimates only for the purchase of the systems, not including installation.

Table ES-0-2: Comparison of Features of the PFC (sized at 50 tons capacity) and the Proposed Hybrid model.

Unit		PFC	Hybrid
Weight (dry)	<i>lbs</i>	3,377	11,712
Weight (wet)	<i>lbs</i>	4,633	15,572
Height	<i>ft</i>	7	16
Width	<i>ft</i>	8	9
Length	<i>ft</i>	15	9
Fan Power	<i>kW</i>	6	15
Pump Power	<i>kW</i>	1	2
Total Power	<i>kW</i>	7	16
Nominal Cooling Capacity	<i>Btu/hr</i>	660,000	756,000
Nominal Cooling Capacity	<i>Tons</i>	55	63
Estimated Capital Cost	<i>\$</i>	75,000	125,800

A very simple plan for the integration of the Hybrid evaporative cooler with the data center chilled water system is illustrated in Figure ES-0-1. With this arrangement, chilled water can be delivered to the indoor loop and CRAH units in one of three ways:

1. Using just the existing mechanical chillers with the hybrid evaporative cooler bypassed.
2. Using just the hybrid evaporative chiller with the chilled water circulating through the heat exchangers on the idle mechanical chillers.
3. Using the hybrid evaporative chiller as a precooling in series with the operating mechanical chillers.

With mechanical chillers the supply water temperature to the indoor CRAH units is 44°F and nominal return to the chillers is 54°F. Chiller flow at nominal maximum capacity of 179 gpm. Nominal flow of each pump is 126 gpm. With the hybrid evaporative coolers, the supply temperature is 70-75°F. The control for the variable speed drives can be adjusted to yield a target return temperature from the data center.

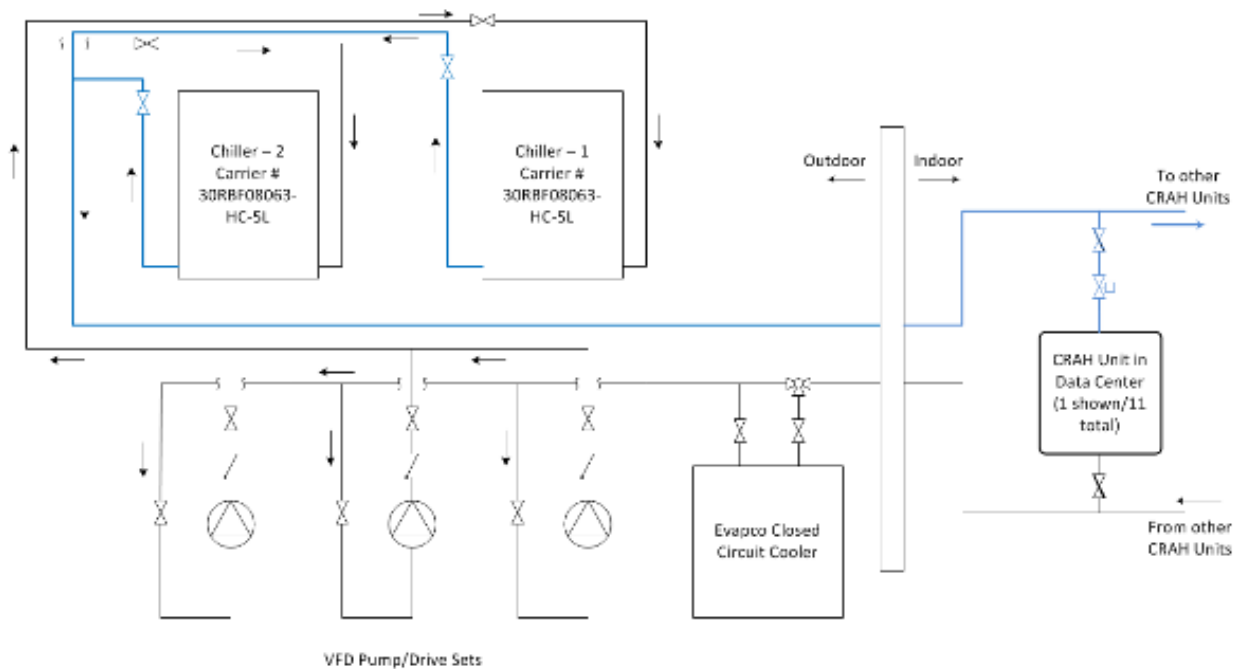


Figure ES-0-1: Basic illustration of the integration of the Hybrid evaporative cooler with the existing chilled water loop.

As an alternative to the planned design, the use of thermal storage to supplement the performance of a hybrid evaporative cooler has also been added. Thermal storage could be cooled to a low temperature either by the evaporative cooler at night or by the mechanical chiller. The mechanical chiller could be the large chillers already in place or a small auxiliary chiller designed only to pre-cool the thermal storage in advance of ambient weather conditions where the evaporative cooler is not likely to be able to meet the data center load. If the thermal storage is cooled by a small auxiliary chiller or by the evaporative cooler at night (for example), the needed for the large mechanical chillers could be completely eliminated.

Also evaluated as an alternative is a direct-to-chip cooling scheme. At the Port Hueneme data center demonstration site, the servers are all air cooled. In parallel with this project, an ESTCP project led by Asetek has been ongoing involving direct-to-chip data center liquid cooling.

Termed RackCDU, the Asetek system captures heat from the hottest part of the rack with direct liquid cooling. During this project a conceptual study was done of the potential for integration of the Asetek system with a hybrid evaporative fluid cooler. This small study was done specifically for the PFC included in the first part of the project.

The primary benefit of Asetek's direct-to-chip liquid-cooling is that it provides free cooling for data centers in any location where 105 °F water can be consistently supplied year-round. The ideal choice for heat-rejection in this system is a *dry cooler*, because of its simple, closed-loop plumbing, low power consumption and zero water use. While a large fraction of DoD data centers around the world have a maximum dry-bulb temperature that will allow the use of a dry-cooler for *RackCDU* year-round, many more do not. For these data centers, one of two options generally exist: 1) integrate a mixing system that taps into the facility's chilled water supply to reduce the *RackCDU* water temperature on those days when the dry-bulb temperature is too high; or 2) use a traditional wet cooling tower to provide heat-rejection.

A hybrid evaporative cooler is seen as an ideal solution to combine with *RackCDU*. During days when the dry-bulb temperature is low enough for a dry-cooler, the system runs in dry mode, offering a zero-water-consumption solution. On those days when the dry-bulb temperature is too high, the unit adds evaporative cooling to achieve the target supply water temperature. While this approach does consume some water, the total water consumption is expected to be dramatically less than a traditional cooling tower, which consume water at all times. Even in locations where dry-coolers are a viable option, an evaporative cooling system will reduce the required footprint of the heat-rejection system, which must always be sized for the hottest day. At the Port Hueneme site, the use of direct-to-chip cooling would eliminate the need for the backup mechanical chillers.

PERFORMANCE ASSESSMENT

An analysis was done of the expected energy performance of the two evaporative cooler concepts evaluated in this project and energy savings relative to the baseline mechanical chiller. An analysis of the annual hours for which the hybrid evaporative cooler concept can run in a dry mode and the annual hours for which the hybrid evaporative cooler concept will not be able to meet the cooling load of the data center was also completed.

For the current mechanical chillers (baseline case) the total annual energy use is estimated at 291,883 kWh. Using \$0.15/kWh the total annual cost of power is \$43,782.

With the PFC unit the projected annual electrical power use would be 61,320 kWh for a reduction of 79% relative to the mechanical chillers. Using \$0.15/kWh the total annual cost of power is \$9,198. The total annual water consumption is estimated to be 1,305,309 gallons per year. This unit is projected to meet the cooling demand of the data center for all but 2 hours of the year.

With the Hybrid evaporative cooler, the annual power consumption is projected to be 143,664 kWh. Using \$0.15/kWh the total annual cost of power is \$21,549. This is a reduction of 51% relative to the mechanical chiller baseline. This nominal performance point is based on a wet-

bulb temperature of 65°F, which is exceeded for 111 hours annually in Port Hueneme, based on TMY data. Annual water consumption is projected to be 403,920 gallons per year.

PLAN FOR TESTING FOR CONFIRMATION OF PERFORMANCE

The following basic test approach has been developed to achieve the objectives stated above.

Fundamental Problem: The use of conventional mechanical cooling equipment to reject data center server-generated heat leads to high electrical energy use. Replacement of this type of cooling equipment with ambient evaporative coolers offers the potential to achieve at least 50% electrical energy savings.

Demonstration Question: Can an evaporative cooler achieve this potential energy savings while meeting the cooling needs of the data center?

Once the hybrid evaporative cooler and sensing/ data acquisition have been installed and verified, the following test approach has been developed to assess the energy savings by using the hybrid evaporative cooler over traditional mechanical chillers.

- *Test Protocol 1 (primary)*: The data center room temperature would be set at a fixed, elevated temperature of 82-85°F. The actual target setpoint would be finalized, based on the initial commissioning. Every two weeks, the hybrid evaporative cooler and the traditional chiller(s) would be alternated to maintain the data center at 85°F. When the chiller is running the hybrid evaporative cooler would be bypassed completely. Similarly, the chillers would be offline when the hybrid evaporative cooler is providing cooling (but made available if the hybrid evaporative cooler cannot satisfy the load). Local weather conditions would be monitored during this time to account for weather variations during the tests. The total test duration would run for a period of at least several months, or ideally one year, to assess the energy savings as a function of ambient conditions and season.
- *Test Protocol 2*: A second test option is to again alternate between the hybrid evaporative cooler and chiller(s) every two weeks, however in this case the data center ambient temperature would be elevated at, say 85°F, for the hybrid evaporative cooler but then reduced to a more typical data center temperature of, say, 72°F when the chiller is engaged. This would give a more realistic estimate of the energy savings for an existing data center run at a typical room temperature of 72°F that is replaced by the hybrid evaporative cooler running at an elevated temperature. Data collection would be identical as in the previous test. Note that the transition time from high to low temperature and back again would need to be determined in coordination with Port Hueneme personnel. Also, although data would be collected during the transition periods, the energy comparisons would only use the steady-state values for the ambient temperature to establish a fair comparison.
- *Test Protocol 3*: A third possible test protocol would be a hybrid approach in which an intermediate interior ambient temperature is set, to 77 or 80°F that the hybrid evaporative cooler could not maintain completely by itself. The chiller would thus run however, the

hybrid evaporative cooler would be used to precool the returning chiller water. Results from this test configuration would be useful for climates in which are only moderately favorable for an evaporative cooler but in which some benefit however from a hybrid evaporative cooler could still be derived, even if it did not carry the entire load the data center completely by itself.

As noted above, a decision was made not to proceed with the installation of the equipment and on-site validation of the projected performance.

SITE INTEGRATION ISSUES

In planning the demonstration of the evaporative cooler at the Port Hueneme site, in discussion with technical staff at the data center, some concerns were raised about the operation. These concerns are related to the plan to raise the data center temperature to 80-85°F needed to achieve the greatest level of energy savings. While these concerns may be unique to this data center, other data centers considering such an energy efficiency conversion may face related concerns.

Operations Center Temperature: The NITC data center has an operations center which is manned 24 hours daily. One of the 11 indoor CCRAH units provides cooling to this operations center. With the hybrid evaporative cooler in operation, the circulating chilled water will be at 70-75°F and the temperature of the operations center will rise above the level associated with the much colder chilled water from the mechanical chillers. Unlike the data center floor, there is no significant source of internal heat gain in the operations center and it is unlikely that the temperature will rise to the 80-85°F level. In this project it was planned to evaluate temperature and comfort in this space during initial tests of the hybrid evaporative cooler system and, based on this, make a decision about the need for additional cooling. If, with the hybrid evaporative cooler, addition temperature control is needed for this space temporary portable air conditioners could be used.

Highly Temperature-Sensitive Server Racks: At the Port Hueneme data center some of the server racks are considered highly temperature sensitive (Tape and SANS Drives) and the data center operators are very reluctant to allow even tests at elevated temperatures. The maximum allowable temperature for these devices was reported by staff personnel to be 100 °F. Running the overall datacenter at an elevated temperature, say 80 or 85 °F rather than 72~74 °F provides less head-room, and thus less reaction time, if there is a failure in the primary cooling system. One option considered for the demonstration was moving these few racks to a different location. After evaluation, however, this was not seen as a feasible option. The path forward selected for this situation was to simply monitor the temperatures during the initial phases of the demonstration to see if, in fact, an acceptable temperature was exceeded for these racks. If this were the case then either the maximum temperature in the data center would be constrained to ensure this temperature is avoided or a single-rack cooling system would be used either temporarily or permanently.

Maintenance Operations in the Data Center: Another concern raised by the data center management staff is exposure of crews doing maintenance in the data center to uncomfortably warm temperatures. For short work project this is not seen as a major concern. Longer

maintenance projects, during the course of the demonstration at least, might need to be scheduled and the system operated on the mechanical chillers for this time period.

COST ASSESSMENT

A decision was made to stop work on this project before requesting bids for the installation work. At the proposal stage an estimate for this, by one of the manufacturers was made at \$125,000. As the design work progressed and better information was available on the complexities of the project, it was recognized that this estimate was too low. The detailed specifications included in Annex I to this report were prepared to enable local installation contractors to bid on the entire scope of the installation. This bid process was not completed. The economics of the overall project for the Port Hueneme site are summarized in Table ES-0-3 below, using an assumption that the installation cost would be \$300,000. This is based on preliminary discussions with potential contractors and also a cursory review by the BNL facilities group.

Table ES-0-3: Summary Cost Analysis

	PFC Unit	Hybrid Unit
Equipment Capital Cost	\$75,000	\$125,000
Estimated Installation Cost	\$300,000	\$300,000
Total Project Cost	\$375,000	\$425,000
Baseline System (mechanical chillers) annual electric cost	\$43,782	\$43,782
Annual electric cost with evaporative cooling system	\$9,198	\$21,549
Annual electric cost savings	\$34,584	\$22,233
Payback (years)	10.8	19.2

This simple payback analysis shown above assumes that the site has an existing mechanical chiller system and the evaporative cooler would be added to this as a cost savings measure. In an alternative scenario in which an evaporative cooler would be used instead of a mechanical chiller either at a new facility or where an existing mechanical chiller is at the end of its life, the payback would likely be zero years as the evaporative cooler would both cost less and use less energy.

DECISION NOT TO PROCEED

As originally planned, the supplier of the major equipment for the demonstration – the evaporative cooler- was to develop detailed designs for the installation, seek bids for the installation work, select the installation contractor, and oversee the installation work. This team member withdrew from the project. Factors which influenced the decision to drop this product included cost relative to alternative technologies, decisions made by a key potential customer, water quality in specific target market areas, and the relatively large footprint of their unit. This team member was replaced by another equipment supplier which was not able to take-on the installation work, leaving this to be managed by the lead organization, BNL. After completion of the installation design work, BNL management reviewed the work to be done and the risks involved. This led to a decision that the management of the subcontracting and oversight of the

installation work was too far from the normal work of the lab so represented an unacceptably high risk.

1.0 INTRODUCTION

This report provides a description of a demonstration program under the United States (US) Department of Defense (DoD) Environmental Security Technology Certification Program (ESTCP) aimed at reducing energy use for data center cooling. The technology planned for this demonstration involves hybrid evaporative cooling. Water is cooled in outdoor towers that can operate either in a wet or dry mode (*hybrid*). The cooled water is directed indoors to existing air handlers. Relative to mechanical water chillers this approach of using “free” ambient cooling offers the potential for up to 75% energy-use reduction. The demonstration was planned for the Port Huaneme Naval Base in Ventura County, California. Prior to the installation of the planned equipment, the decision was made not to proceed with the actual hardware installation phase of the project. This report documents the planning and analysis work that was completed prior to the installation. Detailed design plans and construction specifications for the installation have been prepared and are submitted as an annex to this report.

1.1 BACKGROUND

As our economy and society shifted towards the digital age, data centers have become ubiquitous—they are now key components in nearly every sector of the economy, ranging from small companies to larger companies and governmental systems [1]. In 2014 the energy consumed by data centers in the US was estimated to be 70 billion kilowatt-hours and as computational needs continue to grow, energy demands are expected to increase. In fact, energy costs can account for over 35% of the total cost of ownership (TCO) of data centers [2-4].

Cooling loads, information technology (IT) equipment, and power delivery are the three major constituents of data centers energy budget. Figure 1-1 shows a significant amount of the energy expenditures are owed to cooling the equipment in data centers [5]. The computers in medium to large sized data centers require several hundred kilowatts to tens of megawatts of electricity. With 70% of total electrical power used for computer equipment [6], this requires approximately 0.5–5 MW (140–1,400 tons) of cooling. Specifically in 2006, Brown et al. estimated 74% of the energy use across data centers were associated with cooling and auxiliary infrastructure [7].

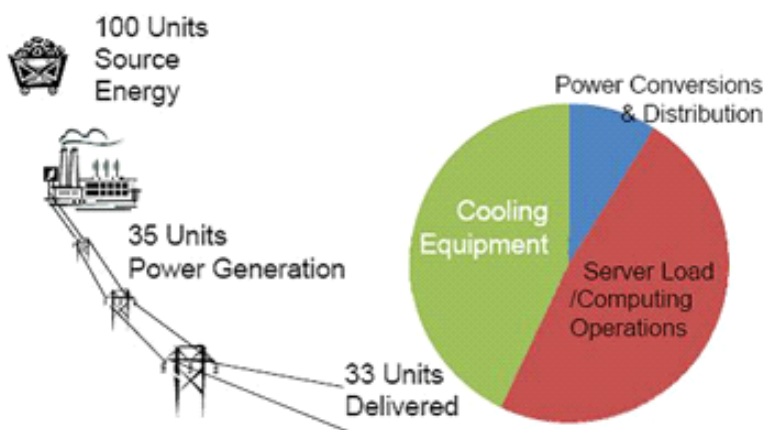


Figure 1-1: Energy associated with data centers

The DOD is the largest energy consumer in the nation and as of 2013 maintained 772 data centers globally [5]. The 2010 Congressional mandate sought to reduce energy burdens by closing several hundred functioning federal data centers, including over fifty centers from the DoD, as data centers represent a significant and growing source of energy consumption [8]. Even with the consolidation of data centers, computational needs continue to grow, and so additional efforts to significantly curb energy usage are being made. However, as data servers become more efficient under the Federal Energy Management Program (FEMP), cooling loads are expected to become the primary constraints to the expansion of computational capacity within a data center [5].

Currently most data center equipment is cooled with standard vapor-compression heating, ventilation, and air conditioning (HVAC) equipment. Conditioned air at 55°F is supplied to computer equipment, which is then returned at 75–80°F, where it is cooled and re-delivered. Consequently, the cooling system is the largest source of inefficiency due to the limitations of the standard refrigeration cycle. Jones reported in 2014 cooling towers and chillers used 100 billion liters of water to cool US data centers [9].

Practices such as free cooling, direct-to-chip cooling, and evaporative cooling are being explored to help reduce the energy burden associated with cooling systems. A fortuitous development in modern computing systems is their ability to operate at higher ambient conditions (80–85°F). In fact, in 2008, ASHRAE increased the maximum recommended supply temperature for data centers from 77°F to 80.6 °F. Higher supply temperatures all the cooling requirements to be reduced and increase the coefficient of performance (COP) of cooling systems. Perhaps most importantly, higher supply temperatures allow the use of alternative refrigeration strategies, such as evaporative cooling systems, which consume *significantly* less energy than traditional refrigerant-based HVAC systems. This trend of increasing electronics/IT operating temperatures is expected to continue.

Free Cooling: Free cooling systems rely on the cool temperature of the outdoor air for heat removal. Specifically, a free cooling systems looks to dissipate heat from the hotter environment (the data center) to a cooler (outdoor) temperature without mechanical refrigeration techniques, but such practices may not be able to meet the cooling demands throughout the entire year [10]. Free cooling systems may be considered direct or indirect. Direct systems rely on controls that have specified set-points that control the operation of dampers and fans that draw in cooler air from the outside if and when available and ventilate out the heated air. However, the drawback of such system includes a lack of humidity control, possible gaseous contaminants, and unwanted particulates [11]. Indirect systems employ a heat exchanger to transfer the heat between the ambient and indoor air temperatures; transferring negligible outdoor air into the data center and eliminating the need for humidity control devices. One very simply approach of free cooling—locating a data center in a cooler climate. One such example is the Verne data center in Iceland where ambient temperatures are near 32°F for most of the year and the “chiller” is an open window [12].

Direct-to-Chip Liquid Cooling: Direct-to-chip cooling in data centers is an emerging form of cooling. The name refers to liquid coolant being fed through small pipes into the servers, to

directly cool their internal mechanisms. In most proposed cooling solutions, servers must be adequately spread out in order to allow for airflow around them. The major benefit of direct-to-chip cooling is that the servers do not rely on air flow for cooling, so they can be packed closely together, allowing the facility to be smaller. However, there is a price to pay to achieve this server packing density though. Direct-to-chip cooling requires every server in the data center to be fitted with individual liquid cooling modules. Having the internal components cooled directly, reduces the burden of cooling the entire facility as heat transfer is enhanced. DigiPlex and the University of Leeds in England found when the chips were placed in direct contact with water or some other liquid, cooling costs were cut by 80% [12]. It is worth noting that the liquid coolant would be a refrigerant, which is harmful to the environment and difficult to dispose of.

Evaporative Cooling: Evaporative cooling is a method used to cool air by utilizing the difference in temperature that occurs when water exposed to higher temperatures changes state from liquid to gas. Unlike traditional cooling methods that use refrigerants as their mediums to exchange heat, evaporative coolers rely solely on water. The process is accomplished through the use of a fan that draws warm air through water-moistened filters made of wood shavings or any material that absorbs and retains the moisture. Water is pumped from a reservoir onto the filters by a pump that recirculates the water as it runs through the filters. The warm air run through the filters is stripped of any particulates, causing the water on the pads to evaporate and simultaneously chill the air as it is ducted into the conditioned space. Integrating an evaporative cooling system into an existing data center must be done with close consideration of the humidity level of the air being supplied, seeing as overly humid air and dry air can both have adverse effects on the equipment.

The following are characteristics of our solution and expected benefits to DoD:

- *Extended lifetime of current mechanical chiller systems.* By offloading cooling requirements from existing DoD data center cooling facilities, the lifetime of key components (compressors, evaporator and condenser systems, related fans, etc.) will be extended proportionately. If the fraction of the data center cooling load met by a Polymer Fluid Cooler (PFC, described in detail below) were only 50%, the life of the current mechanical chiller system would be extended by 2X. With the performance level expected as much as a 3X life extension might be achieved.
- *Significant improvements in overall system efficiency.* Many legacy cooling systems at DoD centers are older units. However, even if the DoD center has new a high efficiency cooling system, the PFC will significantly reduce the cooling energy requirements.
- *Significant energy savings when compared to refrigeration-based HVAC system.* The main energy consumers are only the evaporator fan and fluid pump. The energy efficiency of room air-conditioners (EER) of conventional vapor-compression based air-conditioners is 13-15 where the EER of the proposed device can approach 35-40, depending on outdoor conditions and humidity, while meeting ASHRAE recommended supply conditions.
- *Maximizes 'free cooling'.* In many locations of the country, cool ambient temperatures occur for several months out of the year, particularly in the northern half of the country. During cold weather, the spray evaporation can simply be turned off, while maintaining

coolant circulation. In this fashion, the cool ambient outside temperature is used for heat removal; this saves considerable energy, as the cooling occurs at extremely low cost.

- *Straightforward to retrofit to refrigerant-based HVAC.* Unlike air-to-air evaporative cooling systems, which require extensive ductwork modification to replace a conventional HVAC, the hybrid evaporative cooler water lines can be run through the same or similar chases for existing refrigerant lines.

1.2 OBJECTIVE OF THE DEMONSTRATION

The objective of the project is to reduce energy consumption associated with data centers in DoD facilities. The objectives of the planned demonstration were to show that: the evaporative cooling system can be integrated with an existing mechanical chiller cooling system; the system can meet the cooling demand of the data center for nearly 100% of the year; and the energy savings and water use targets can be met.

2.0 TECHNOLOGY DESCRIPTION

2.1 TECHNOLOGY OVERVIEW

The fluid coolers considered in this project to displace the mechanical chillers can function in two modes. At lower outdoor air temperatures, the coolers reject heat from the circulating water in the data center loop by simple convective heat transfer. At higher outdoor temperatures water is sprayed on the heat exchanger bundles to lower the circulating water temperature below that of the outdoor dry-bulb temperature. In this case, the systems act as indirect cooling towers with the circulating water approaching the outdoor wet-bulb temperature.

During this project, two specific evaporative cooler products were considered for the planned demonstration. The first of these is a Polymer Fluid Cooler (PFC) from the Munters Corporation. The second is a Hybrid Cooler from Evapco, Inc. At the start of the project the PFC was the planned cooler and much of the installation design work was developed around this unit. Late in 2016, Munters Corporation made a decision to drop the PFC product from their portfolio and they withdrew from the project. Factors which influenced this decision included cost relative to alternative technologies, decisions made by a key potential customer, water quality in specific target market areas, and the relatively large footprint of the PFC unit. At this point and following a review of the market, a project decision was made to convert the design to the Evapco unit. In this section both of these technologies are described.

Munters Polymer Fluid Cooler (PFC): The Munters system, termed the *Oasis Polymer Fluid Cooler (PFC)* was designed to operate in both wet and dry conditions, as conditions permit, to maximize energy and water savings. The *Oasis PFC* technology offers unique potential for applications such as data centers because, relative to other building types, they have higher set point temperature, low outside air exchange rates, and lower latent cooling loads. The innovative design of the *Oasis PFC* system minimizes the utilization of water compared to conventional evaporative cooling devices. The use of a polymer—rather than metal—heat exchanger minimizes issues with fouling and water contamination, which simplifies water treatment and minimizes maintenance.

A schematic of the Munters PFC system is shown in Figure 2-1. Cooling fluid (water) enters the cooler and passes through a polymer heat exchanger. Water from a separate source is sprayed over the heat exchanger while outside air is drawn upwards using a variable-speed draft fan. As the spray water evaporates, it cools the fluid in the heat exchanger (Figure 2-1, right). Analysis and testing of the PFC system shows that up to 75% of the difference between dry- and wet-bulb temperature can be achieved with a well-designed PFC system. This enables such a system to meet ASHRAE air supply requirements with significant energy savings. To run the system in dry mode, the spray water is simply turned off, and the water is cooled by heat exchange with the lower-temperature ambient, saving water and reducing energy consumption.

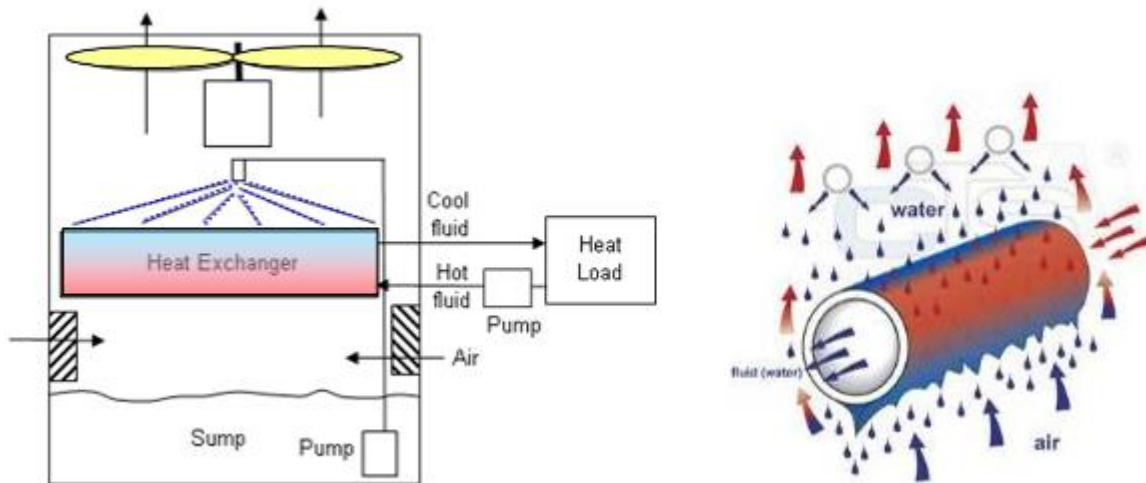


Figure 2-1: Munters Oasis PFC evaporative cooling concept. (left) Chilled water and evaporation water remain separated in a polymer heat exchanger. (right) Evaporation directly on the surface of the heat exchanger maximizes heat transfer from the cooled interior fluid. The system can also be run in dry mode for added energy and water savings by simply turning off the evaporative water spray.

The Munters *Oasis PFC* is a new design, optimized for high-performance, energy savings, and ease of maintenance. The system is shown in Figure 2-2.

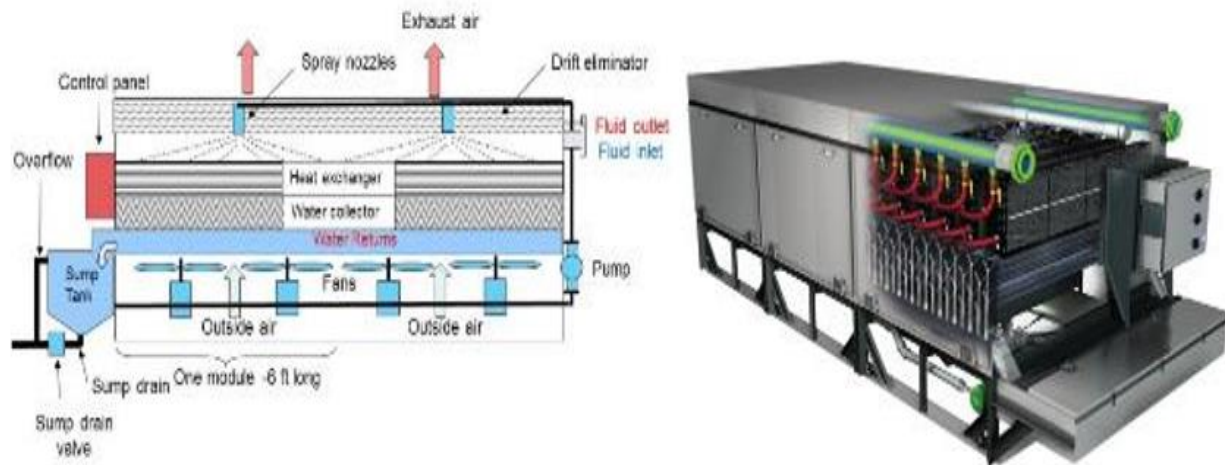


Figure 2-2: PFC Design details. (left) Cross section showing two modules in a single unit. Note fans at bottom underneath water returns. (right) Concept drawing of final unit look and layout.

The innovative design of this system is that it minimizes the utilization of water as compared to conventional evaporative cooling devices. The use of a polymer—rather than metal—heat exchanger minimizes issues with fouling and water contamination, which simplifies water treatment and minimizes maintenance. Being flexible, the polymer tubes tend to shed solid deposits from the evaporation process, as they expand and contract. A single module can incorporate up to four (4) 25-ton cooling modules in a single unit, for a total capacity of up to 100 tons. A unique V-trough design captures any unevaporated water, allowing the fans to be placed underneath, rather than above. High-performance and/or liquid-cooled computer equipment will have chilled water available directly for cooling.

Evapco Hybrid Fluid Cooler: Relative to the Munters unit, the Evapco unit uses metal heat exchangers to cool the data center circulating water by exchange with outside air. The orientation of the Evapco unit is more vertical than the Munters unit and it is considerably heavier.

Figure 2-3 provides a photo and some brochure information on the Evapco unit selected for this project – Model ATWB-H.

eco-ATWB-H Closed Circuit Coolers



 **ATWB-H**

The eco-ATWB-H Hybrid line of Closed Circuit Coolers was designed with the purpose of providing maximum water savings, higher dry bulb switchover temperatures, while achieving plume abatement or elimination.

The eco-ATWB-H is provided with EVAPCO's **ARID fin Pak™** dry coil. Utilizing stainless steel tubes and aluminum manganese fins, the **ARID fin Pak™** maximizes the total surface area available for sensible heat transfer, which results in maximum water savings and higher dry bulb switchover temperatures. Additionally, the eco-ATWB-H is provided with the highly efficient **Ellipti-fin®** coil in series with the **ARID fin Pak™**, achieving both latent and sensible cooling simultaneously. The **Ellipti-fin®** now features **CROSSCOOL™** Internal Tube Enhancement which increases the internal heat transfer coefficient of the coil and thus increases the cooling capacity of the unit. Located in the discharge airstream, the **ARID fin Pak™** heats the saturated discharge air, abating or eliminating plume. Because the coils are in series, a significant portion of the heat load will always be dissipated through the dry cooling coil, saving water whenever it is in operation!

The eco-ATWB-H is the ideal solution for: Maximized Water Savings, Highest Dry Bulb Switchovers, Plume Reduction or Plume Abatement. **This product is designed with IBC Compliant construction and CTI Certified Performance.**

Figure 2-3: Basic commercial information on the Evapco unit selected for this demonstration project.

This Evapco unit has two heat exchangers with circulating water flow in series. The top heat exchanger operates only in a dry mode and the bottom heat exchanger can operate either wet or dry. The system was designed to have a high dry-bulb switchover temperature above which the water sprays on the lower heat exchanger would need to be used. Figure 2-4 provides an illustration of the internal arrangement and operation during wet mode.

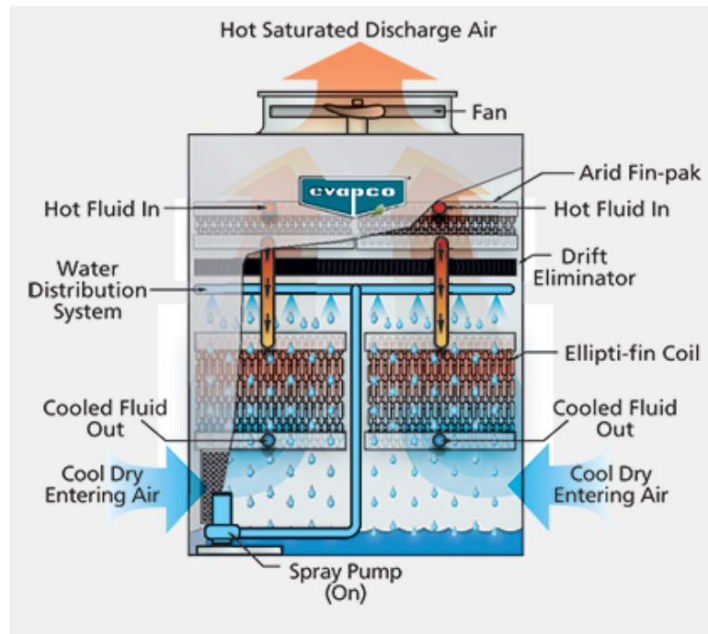


Figure 2-4: Evapco ATWB-H unit, internal arrangement, wet mode operation

With this unit, during dry mode operation, the spray pump is simply turned off. In wet mode a portion of the cooling load is met with the top heat exchanger in a dry mode, reducing water consumption.

Comparison of the Two Units: With the Munters unit, it was planned to install a total of four modules which provides a total nominal capacity of 100 tons. The current cooling load at the NITC data center is on the order of 45 tons and the additional capacity was planned for potential future expansion and to allow for operation in a dry mode for as much of the year as possible. In discussions with Evapco, however, it became clear that the cost for their unit at the 100-ton capacity would be much greater than the originally proposed price for the Munters unit. After considerable discussion with Evapco, and a team visit to their Maryland Headquarters, a decision was made to evaluate a system with a capacity closer to the current actual cooling load at the facility. Evapco proposed three different configurations and a final decision was made to work with their model eco-ATWB-H-9-3K9-Z-U12 with a nominal capacity of 50 tons. Table 2-1 provides a comparison of technical features for this unit with a two module Munters PFC unit which would provide a similar capacity. Costs are estimates only for the purchase of the systems, not including installation.

Table 2-1: Comparison of Features of the Munters PFC (sized at 50 tons capacity) and the Proposed Evapco model.

Manufacturer		Munters	Evapco
Model		<i>PFC</i>	<i>Eco-ATWB</i>
Weight (dry)	<i>lbs</i>	3,377	11,712
Weight (wet)	<i>lbs</i>	4,633	15,572
Height	<i>ft</i>	7	16
Width	<i>ft</i>	8	9
Length	<i>ft</i>	15	9
Fan Power	<i>kW</i>	6	15
Pump Power	<i>kW</i>	1	2
Total Power	<i>kW</i>	7	16
Nominal Cooling Capacity	<i>Btu/hr</i>	660,000	756,000
Nominal Cooling Capacity	<i>Tons</i>	55	63
Estimated Capital Cost	<i>\$</i>	75,000	125,800

2.3 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

Performance Advantages: The use of PFC systems represents the potential for substantial energy savings when compared to refrigeration-based A/C systems and cooling-tower-based evaporative systems. It is furthermore expected that the proposed technology can be implemented on the vast majority of DOD data centers, given the standardization of traditional HVAC system installations, and cooling requirements.

The following are characteristics of our solution and expected benefits to DoD:

- ✓ *Extended lifetime of current mechanical chiller systems.* By offloading cooling requirements from existing DoD data center cooling facilities, the lifetime of key components (compressors, evaporator and condenser systems, related fans, etc.) will be extended proportionately. If the fraction of the data center cooling load met by the PFC were only 50%, the life of the current mechanical chiller system would be extended by 2X. With the performance level expected as much as a 3X life extension might be achieved.
- ✓ *Significant improvements in overall system efficiency.* Many legacy cooling systems at DoD centers are older units. However, even if the DoD center has new a high efficiency cooling system, the PFC will significantly reduce the cooling energy requirements.
- ✓ *Significant energy savings when compared to refrigeration-based HVAC system.* The main energy consumers are only the evaporator fan and fluid pump. The EER of conventional vapor-compression based air-conditioners is 13-15 where the EER of the proposed device can approach 35–40, depending on outdoor conditions and humidity, while meeting ASHRAE recommended supply conditions.
- ✓ *Maximizes ‘free cooling’.* In many locations of the country, cool ambient temperatures occur for several months out of the year, particularly in the northern half of the country.

During cold weather, the spray evaporation can simply be turned off, while maintaining coolant circulation. In this fashion, the cool ambient outside temperature is used for heat removal; this saves considerable energy, as the cooling occurs at extremely low cost.

- ✓ *Straightforward to retrofit to refrigerant-based HVAC.* Unlike air-air evaporative cooling systems, which require extensive ductwork modification to replace a conventional HVAC, the PFC water lines can be run through the same or similar chases for existing refrigerant lines.
- ✓ *Low water utilization.* The innovative design of this system minimizes the utilization of water as compared to conventional evaporative cooling devices.
- ✓ *Use of a polymer heat exchanger.* Minimizes issues with fouling and water contamination, which simplifies water treatment and minimizes maintenance. Being flexible, the polymer tubes will tend to shed solid deposits from the evaporation process.
- ✓ *Bottom-oriented fans/V-troughs.* A unique V-trough design captures all unevaporated water, allowing the fans to be placed underneath, rather than above, the cooling unit.
- ✓ *Modular design.* Depending on the cooling requirements, the unit can incorporate up to five 24-ton¹ cooling modules in one roof-mounted unit.

Cost Advantages: A preliminary estimate of the economic benefit of installing an Oasis™ unit into an existing DoD data center is presented. The analysis performed using the Oasis™ air-to-air unit. An example for Southern California is shown in Figure 2-5, below. The left figure is the bin data for hours out of the year at the given wet-bulb temperature and the right figure represents the fraction of the load provided by the Oasis™ PFC also as a function of the wet-bulb temperature. As can be seen it is nearly 100% for all wet-bulb temperatures. A representative energy calculation for a Munters Oasis (air-air) evaporative cooler is presented in the Table 2-2 below.

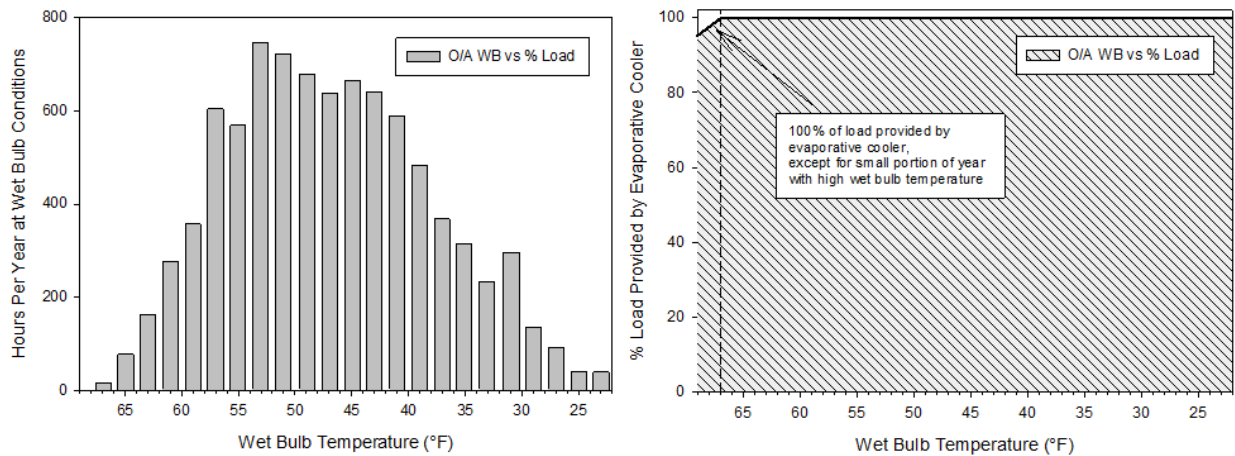


Figure 2-5: Performance analysis of expected Munters PFC unit (based on model results for air-air Oasis unit now in production). Left: annual distribution of web-bulb temperatures for Southern California. Right: Fraction of cooling provided by PFC system as a function of wet-bulb

¹ Nominal cooling capacity is based on 95°DB, 78°WB, 95°F entering water temperature and 85°leaving water temperature. As part of the analysis for this project, the expected performance over a wide range of conditions relevant to the test site has been evaluated.

temperature. As can be seen, the PFC unit can carry 100% of the required cooling load for the majority of conditions throughout the year.

Table 2-2: Cost Analysis of Munters Oasis Units

Parameter	Value
Thermal Load	1000 kW
Capital equipment costs (3 units + install)	\$ 280,000
Annual Oasis cost (electricity + water)	\$ 55,800
Annual DX cooling cost (COP = 4.5)	\$ 253,500
Annual savings	\$ 194,200
Payback period (years)	1.4

This representative analysis is based on a 1000 kW (284 ton) data center load. Electricity costs are taken at the California average of \$0.13/kWh, and water costs are taken at \$3.77/100 ft³. Three Oasis units are implemented for this case, with a per-unit cost of \$70,000 and a total installation cost of \$210,000. Annual operational costs are compared to a standard direct-expansion (DX) system operating with a COP of 4.5. The analysis assumes a hot-side air temperature to the Oasis of 98.6 °F and a return temperature of 75 °F. The results are shown in the Table 2-2 above. As can be seen, the annual savings are significant at \$194,200 per year. Energy use is reduced by 73%, and the system payback happens in less than 18 months. Note that the analysis neglects maintenance costs, water loss pumping costs for the legacy DX system currently on site, and hence the actual savings will likely be larger.

Impact of Time-of-Day Electric Rates: The operating cost savings potential of the PFC technology, relative to a mechanical chiller will depend on operating characteristics, performance curves, outdoor temperature and current electric rates. An exploratory evaluation has been done of the impact of a high peak electric power rate during the hottest part of the day and a low rate during a cold part of the day (night time). This analysis required some key assumptions including:

- For the hot part of the day a peak temperature of 79 F has been assumed and for the cold part of the day the outdoor temperature is 64 F. Both of these are based on TMY data for Point Mugu – warmest September day.
- The peak electric power rate is 22 ¢/kWh and the night electric rate is 9 ¢/kWh.
- The COP of the mechanical chiller is fixed at 4.6. This is the Integrated Part Load Value (IPLV) reported by the manufacturer. Detailed performance curves – COP vs load - are not available for this chiller.
- Cooling load is fixed at 40 tons.
- At the fixed cooling load the PFC total electric power draw is 8 kW.
- Water cost is \$2.40/100 ft³
- PFC water consumption is 1 gal/ton hour for evaporation and sump bleed.

Based on these assumptions, Table 2-3, below provides a summary of the resulting comparison:

Table 2-3: Comparison of On-Peak vs Off-Peak Cases

Case	Electric Power Cost	Mechanical chiller operating cost	PFC operating cost	PFC reduction relative to chiller
	¢/kWh	\$/hr	\$/hr	%
On-Peak	22	6.73	1.89	71.9
Off-Peak	9	2.75	0.86	69.2

The cost savings estimates presented in the last section assume fixed rates. When considering higher mid-day rates savings will be greater.

DoD-Wide Energy Saving Potential: This technology has the potential to be deployed broadly in DoD data centers. In this section an attempt is made to estimate the magnitude of this potential.

Information on the number, size, and cooling energy use by DoD data centers nation-wide is difficult to assemble. In the past 5-10 years, the trends toward data center consolidation, shared data services, and changes in definitions of a data center have contributed to the challenges in this accounting. In a 2012 report on the Federal Data Center Consolidation Initiative, the total number of DoD data centers was put at 772 and the total number of federal government data centers was put at 2094 [11]. In a 2007 report to congress [12] the U.S. EPA estimated that federal data centers and server consumed 6 billion kWh of energy in 2006.

The amount of energy used in DoD data centers nationwide for cooling is roughly estimated here as the EPA 2006 federal amount multiplied by the fraction of federal data centers in DoD. Further it is assumed that half of the energy used by the data center is for cooling. This gives an annual cooling energy use in DoD data centers of 1.1 billion kWh. This estimate is low because it ignores the growth rate of data centers between 2006 and 2015. The EPA estimates had the energy use in data centers at least doubling over this time period and this is assumed here.

The energy savings achievable with the conversion from mechanical chillers to the technology which is the topic of this demonstration will of course depend on the location and site details. Here a savings of 75% is assumed, leading to a maximum potential of 1.65 billion kWh. Using a national average electric power cost of 10.5 ¢/kWh, this leads to an annual cost savings of 173 million dollars at an optimistic 100% market penetration.

Performance Limitations: The performance of a Polymer Fluid Cooler is based on the ambient wet-bulb temperature. When the ambient wet-bulb temperature is greater than the temperature of the dry air to be cooled then no cooling will take place. There are no inherent features of the product that would cause shortened lifetimes below that of standard air conditioning equipment. Maintenance should be less than is required for commercial chiller systems.

In any data center, a new installation the first cost of the Oasis™ PFC system with a vapor-compression assist will have a lower first and operating cost than a conventional vapor-compression cooling system. In retrofit applications, the installation cost will depend on the system and the ability to integrate the Oasis™ into the system.

Social Acceptance: Achieving the full energy savings potential of the PFC technology requires operation of the data center at higher room temperatures than currently implemented with mechanical chillers. During the testing of the PFC impacts of this will be specifically evaluated and the setpoints established. Currently temperatures as high as 82 °F are planned. This higher temperature leads to several concerns. One is comfort of staff who need to do maintenance work in the data center, particularly for extended periods. This has been discussed with site staff several times and it is recognized that there may be a need to establish lower setpoints during such maintenance events. There is also a concern that personnel in the manned operations center may be uncomfortably warm. This is an uncertainty that has also been discussed in some detail and several alternative cooling strategies for this have been evaluated. The current plan is to reexamine this situation after the installation and commissioning have been completed. This may constrain the upper limit of the system operating temperature during some time periods. Occupied space temperatures will not be operated at temperatures higher than ASHRAE-specified limits.

Another possible concern which has been raised, related to the elevated temperatures, is the time required to change cooling systems in event of a PFC failure and the server temperature transients during this time. This is a concern to staff responsible for reliable operation of the data center. To address this, transient recovery tests will be performed during commissioning. From this, the operating temperature limits will be decided cooperatively with the data center operating staff.

Under some weather conditions, the PFC units may produce a visible steam vapor plume. This will not extend beyond the immediate area of the units. The siting of the units was planned to minimize any impacts of a plume on neighboring buildings.

Another consideration for acceptance is water consumption during the severe drought condition now in California. This has been raised during prior project reviews and the case can be made that water use will not be greater than average water consumption associated with the electric power and the current mechanical chillers. During the demonstration, measurement of actual water use and percentage of time the PFC can meet the data center cooling load while operating in a dry mode will be specifically studied. Water consumption has been defined specifically as a performance metric.

3.0 PERFORMANCE OBJECTIVES

For this demonstration project a set of performance objectives was submitted and accepted. These objectives were planned with the Munters PFC as the hybrid cooler to be demonstrated and, as discussed earlier, during the project this was changed to the Evapco Hybrid Fluid Cooler. Below, in

Table 3-1, the defined performance objectives are provided edited to be general rather than specific to the Munters unit where appropriate. This is followed by an expanded discussion of specific objectives.

Table 3-1 Performance Objectives

Performance Objective	Metric	Data Requirements	Success Criteria
Quantitative Performance Objectives			
Ability of the hybrid evaporative cooler to meet the data center cooling load	Number of hours the mechanical chillers must be run to meet the data center cooling load	Operating data on both systems. From fluid cooler internal data and building energy management system data	Required operation of the main mechanical chillers less than 100 hours per year
Cooling Energy Savings	Energy use for cooling with the fluid cooler, compared to the mechanical chillers, normalized for weather conditions.	kWh consumption data	Minimum of 50% energy reduction, annual average.
Power Usage Effectiveness (PUE)	$PUE = \frac{\text{Total Facility Energy}}{\text{IT Equipment Energy}}$	kWh consumption data for servers, lighting, cooling equipment, circulation pumps. Measured or estimated from nominal data.	15% reduction relative to the chiller system, annual average
Partial PUE (pPUE)	Cooling Load/IT load	kWh consumption data for servers, cooling equipment, circulation pumps. Measured or estimated from nominal data	15% reduction relative to the chiller system, annual average
Data Center Peak Load (Monthly)	Sub-Meter Readings (Cooling + IT + Balance of System) and Data Load; data collection every 1 minute	kWh data for fluid cooler and chiller during similar peak weather conditions.	75% Reduction in Peak load during hot (85 degree) ambient conditions in the late summer and fall.
Water Usage	Gallons of Water used/ kWh of cooling delivered	Water consumption on evaporative fluid cooler, time resolved and annual. Review of published data on power plant water consumption	Annual water consumption not greater than that of a conventional, gas-fired

		(available)	power plant with a cooling tower.
Temperature	Server inlet air temperature	Air temperatures as measured with planned, wireless sensors.	System capable of control within acceptable range. Current target 81°F.
Lifecycle GHG Emissions	Total Operating GHG Emissions (metric tons/year)	kWh consumption data, time resolved and annual for chiller and fluid cooler system. Typical GHG emission factors for relevant power plants in the region.	50% reduction
Investment Payback	Simple Payback (PB)	Capital investment (labor, equipment, and materials); Energy cost savings; additional maintenance cost; site power cost structure	Retrofit: PB of <5 years relative to continued operation of existing chiller. New Construction: PB of <2 years relative to replacement of existing chillers
Qualitative Performance Objectives			
Data center temperature	Staff responsible for data center feels temperature profile in data center is acceptable for operations	Feedback from data center operating staff	No complaints about data center temperature

3.1 DISCUSSION OF PERFORMANCE OBJECTIVES

1. *Ability of the Hybrid Evaporative Fluid Cooler to Meet the Data Center Cooling Load* – The target operating mode for this demonstration includes the fluid cooler running, producing chilled water at a temperature less than 75°F and this chilled water, distributed through the existing 11 indoor air handler (CRAH) units meeting the cooling needs of the data center. In this target operating mode, the mechanical chillers would be fully off

although ready to come on-line in the event of a failure of the fluid cooler system to meet the load. Model predictions indicate that the fluid cooler would have the ability to meet the load for nearly all of the year with, perhaps, 20 hours where the chillers might nominally need to run. However, because these peak outdoor wet-bulb temperature conditions are short term the chillers may not need to run at all. However, the ability to achieve this objective depends strongly on the target data center space temperature.

2. *Cooling Energy Savings* – Annual energy consumption reduction to meet the cooling load of the data center. For the mechanical chillers this would include the compressor and condenser fan power. For the fluid cooler operating in evaporative mode this would include the fan and spray water pump power. During the demonstration this power would be measured directly at different times. The total annual energy consumption would be calculated based on the isolated measurement periods for each system. Included in the fluid cooler system, total annual energy consumption would be the power used by the mechanical chillers during those time periods when the fluid cooler does not have adequate capacity. This result would be calculated for the actual space temperature setpoints used in the demonstration and at alternative setpoints. These alternative setpoints would address the potential savings if the data center setpoint temperature could have been set at a higher level.
3. *Power Usage Effectiveness (PUE)* – PUE is the commonly used measure of how efficiency a data center uses energy. It is the ratio of total facility energy to server energy consumption (“IT” load). Total facility energy here includes cooling and ventilation loads as well as lighting and losses in power distribution and UPS components. Average data center PUE values range from 1.8 to 1.9 and the best data centers achieve levels in the 1.1 range. The PUE for the data center which is the focus of this project, with the recent chiller system upgrade, is not known but would be evaluated during the demonstration. PUE is not normalized for outdoor conditions and can be strongly affected by actual server load factor. A data center in a cold climate with a very high server load factor can easily achieve a much higher PUE than a data center in a hot climate with a low server load factor. For this reason, the change in PUE with the hybrid evaporative cooler, relative to a baseline with the mechanical chillers operating, and based on annual average, is being used as the performance objective in this project.
4. *Partial PUE (pPUE)* – In data centers partial PUE is used to highlight one particular portion of the data center energy usage and different metrics for pPUE have been used. Here pPUE is the ratio of (server + cooling system power) to just server power and so it highlights the cooling system performance. Again, this would be based on annual average values and the objective for the fluid cooler performance is set as relative to the mechanical chiller baseline.
5. *Data Center Peak Load (Monthly)* – With mechanical chiller systems peak electric power demand typically occurs at the hottest part of the day when chiller COP is relatively low. This is also typically the time of peak electric power usage on utility systems and, where time-of-day-rates are applied, the time of highest electric power cost. In addition to reducing annual energy consumption, the fluid cooler is expected to have very significant impacts on the peak power demand and a target of 75% reduction at Port Hueneme during the hottest months – August and September have been set. During the

demonstration, peak power demand for both the baseline mechanical chiller system and the hybrid evaporative fluid cooler would be determined for each month.

6. *Water Usage* – A clear area of attention with the hybrid evaporative fluid cooler is the consumption of water for enhanced cooling. This is the water evaporated from the spray on the polymer tubes to achieve cooling. A water evaporation rate of 1 gal/ton hour is the nominal value for the Munters PFC. However, the water consumption needs to be determined on an annual basis because, for most hours of the year the system will be able to operate in a dry mode with the sprays turned off. The actual fraction of the year for dry mode operation depends to a great degree on the target circulating water temperature which depends strongly on the actual cold aisle setpoints. These would be initially set during commissioning and revisited together with the data center technical staff through the demonstration. The target here is for annual hybrid evaporative fluid cooler water use to be less than that of a conventional gas-fired power plant with a cooling tower. This hypothetical plant would be providing the power to the mechanical chillers in the baseline case. Typical values for water use per kW for power plants in the Southwest are available and would be used to evaluate this metric. The target here is based on projections which indicate it would be met during the demonstration.
7. *Temperature (Server Inlet Air)* – To meet the cooling load in the data center and maintain the servers at an acceptable operating temperature, the fluid cooler must be able to maintain a target cold aisle temperature in the range of 81 to 85 °F. As discussed above, the current target is 81°F but this would be reevaluated through the demonstration. Clearly a higher cold aisle temperature would lead to better fluid cooler system (and mechanical chiller) performance. There is however, concern about the time required for a switch-over to the chillers in the event of a failure or lack of performance situation with the fluid cooler. This could occur, for example, during a time period of rapidly increasing outdoor temperatures. With a higher setpoint temperature in the cold aisle, the time available for a switch-over to the backup chillers would be reduced, leading to a concern that an overheat situation could occur. This would be the subject of strong focus during commissioning. During periods when the fluid cooler is not able to achieve the setpoint condition, the system would be configured to automatically switch back to the mechanical chillers.
8. *Lifecycle Green House Gas (GHG) Emissions* – The achieved reduction in GHG emissions is directly linked to the reduction in electric power use. The annual percentage reduction would be determined from actual measured consumption data as well as to projections to other operating conditions. For example, assuming the demonstration is conducted with a cold aisle maximum temperature of 81°F – projections to what the power use at 85°F would be were planned to be made to explore the achievable reductions in GHG emissions and power at that condition. GHG emission factors for relevant power plants in the region would be used to derive GHG reductions in tons/year. Several different scenarios for the power plant would be considered.
9. *Investment Payback* – A simple payback analysis for the application of a hybrid evaporative fluid cooler at this site would be completed. Included in this would be capital equipment cost, installation cost, energy cost savings, and addition maintenance cost. The capital and installation cost during the demonstration would be adjusted to consider the cost associated with instrumentation and special provisions included just for test

purposes. Two different scenarios would be considered. The first is the actual case at the Port Hueneme site where the fluid cooler is installed and operated in place of existing chillers. In this case the target payback is less than five years. The second scenario is that of “new construction” where there is an existing mechanical chiller system that must be replaced. The comparison would be made between installation of a new chiller system or the hybrid evaporative fluid cooler. However, with the fluid cooler option different scenarios for backup cooling capacity would also be explored. This might include, for example a single smaller chiller which could serve to boost the capacity of the fluid cooler if needed. In this second scenario both the installation cost and energy cost could be lower than for the mechanical chiller option. A target payback period for this second option of two years or less has been set as the target.

10. *Data Center Temperature (Qualitative Performance Objective)* – For the hybrid evaporative cooler technology to be accepted it is important for operating staff to feel that the energy savings have not been achieved in a way which negatively impacts routine operations. Potential areas of concern could include: the need to make arrangements to schedule larger data center maintenance operations when only the mechanical chillers are operating; uncomfortable data center conditions for short-term, unplanned maintenance and tests; elevated temperatures in the operations center; or noise or plume impacts. Near the end of the demonstration a formal poll of the data center staff was planned to be conducted to evaluate their opinions on these potential concerns. The target here is a minimum level of concern about the fluid cooler impacts.

4.0 FACILITY/SITE DESCRIPTION

4.1 FACILITY/SITE LOCATION AND OPERATIONS

After considering several options, the data center selected for this demonstration project the *NAVFAC Information Technology Center (NITC)* located at the Naval Base Ventura County, Port Hueneme, California. The room cooling system at the Port Hueneme data center is very typical for facilities of this type. The system consists of 11 computer-room air handlers (CRAHs) that reside inside the air-conditioned space with the servers. Chilled water from a central facility flows into the CRAH to cool the air stream passing through it, resulting in a corresponding increase in the discharge water temperature, which is then returned the central facility outdoors to be re-cooled and the process repeated. Figure 4-1 provides an illustration of the existing chilled water-cooling system at the NITC data center.

The CRAH units are all manufactured by Liebert Corporation and discharge cooled air downward into an underfloor plenum. The data center is built with a cold isle structure with cold air from the underfloor plenum discharging upward between server racks. Warmer air at the top of the data center flows back to the top inlet of the CRAH units. Ten of the Liebert units are Model FH200C-CAEI and one is Model MMD92C3CHELF.

Shortly after the decision was made, in 2013, to have the demonstration at the Port Hueneme site, an upgrade to the chillers was implemented. This had been planned for some time. The chillers selected are Carrier 30 RBF08063-HC-51 and two identical chillers were installed. These

units have a nominal capacity of 76.0 refrigeration tons with a full load EER of 9.8. The systems use scroll compressors with R-410A refrigerant and variable speed condenser fans. Full load electric power consumption is 93.4 kW, for a full load nominal COP of 2.85.

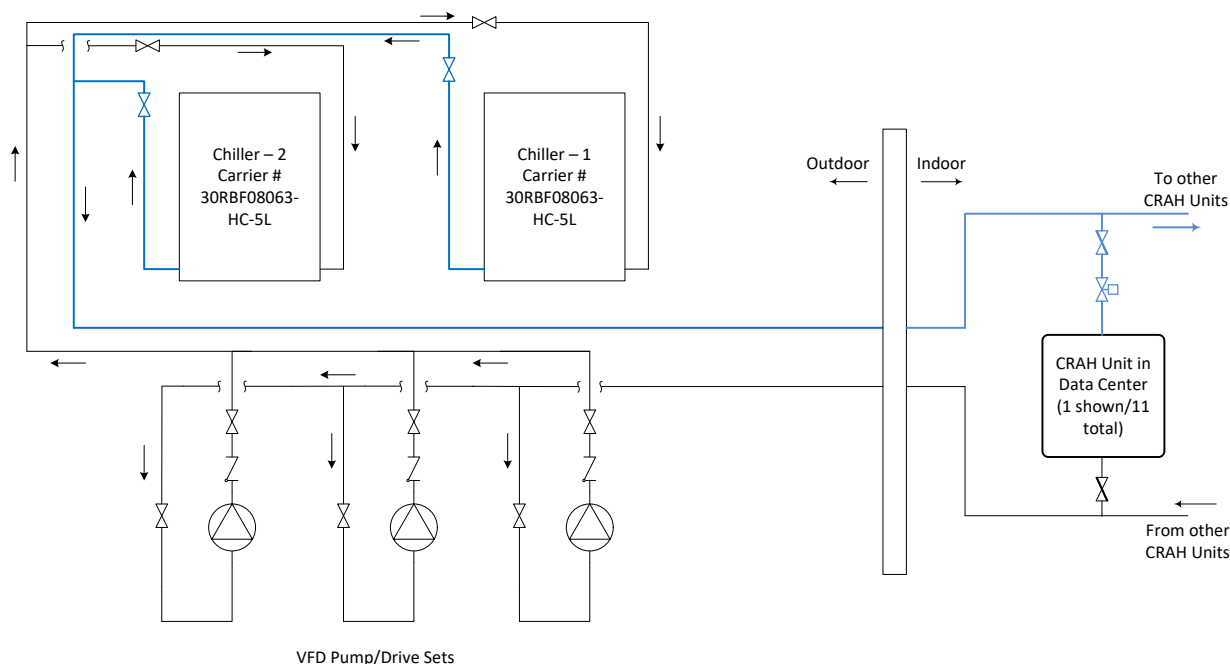


Figure 4-1: Illustration of the existing chilled water-cooling system at the NITC data center

The existing chillers are located outside, immediately adjacent to the data center. The chilled water system with the 11 CRAH units provides cooling to the floor of the data center, an operations/control room just off the data center floor and another separate room which can be used for special data processing projects.

The cooling load on the chillers can vary as the configuration of the data center changes but, based on information from the data center the nominal load at present is about 45 tons. The chilled water pumps and chillers are operated alternately to provide balanced usage over time. The data center is a critical facility and opportunities for down-time for operations to the chilled water system are rare. The data center is manned with operational staff 24/7.

Nominal chiller entering water temperature is 54°F and leaving water temperature is 44°F. The nominal air flow of each of the data center floor CRAH units is 6050 cfm with leaving air dry-bulb at 72°F nominal. Nominal chilled water flow to each CRAH unit is 24.3 GPM.

4.2 FACILITY/SITE CONDITIONS

Ventura County is a “Marine” climate zone according to the U.S. Department of Energy Building America climate zone system. It is International Energy Conservation Code (IECC) Zone 3 and IECC Moisture Region C [13]. In overview, Ventura County receives 17 inches of rain annually and 0 inches of snow. The average high temperature in July is 82°F and the average low in January is 44°F.

Typical Meteorological Year (TMY) 3 weather data is available for Point Mugu Naval Air Station which is essentially adjacent to the Port Hueneme Naval Base. Figure 4-2 provides an annual distribution of dry-bulb temperature for this site and Figure 4-3 provides a distribution of wet-bulb temperature.

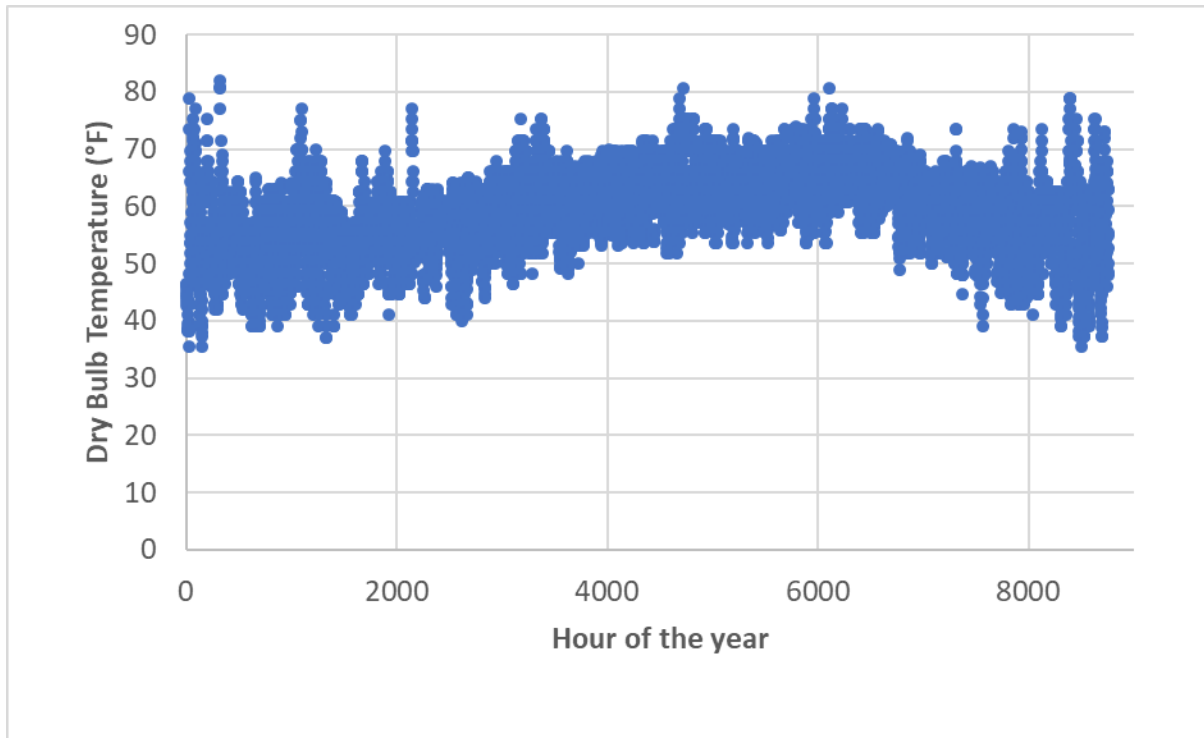


Figure 4-2: Annual distribution of dry-bulb temperature for the planned demonstration site, based on Point Mugu TMY3 data.

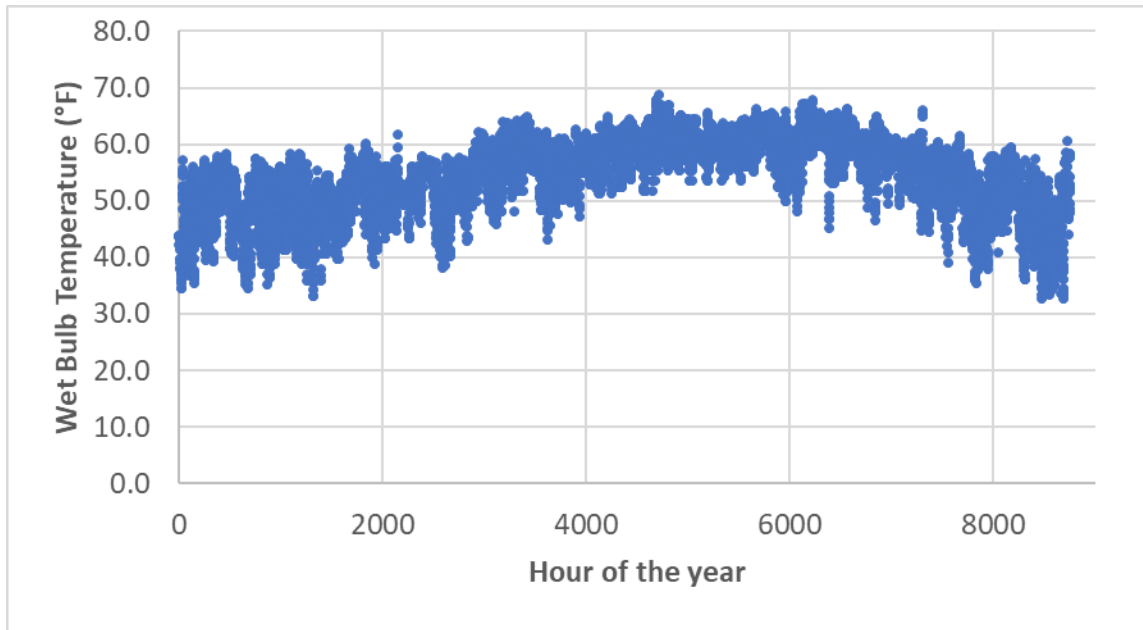


Figure 4-3: Annual distribution of wet-bulb temperature for the planned demonstration site, based on Point Mugu TMY3 data.

In determining the ability of an evaporative/hybrid cooler to meet the required load, the wet-bulb temperature is most important. Figure 4-4 shows the cumulative distribution of wet-bulb temperature over the year.

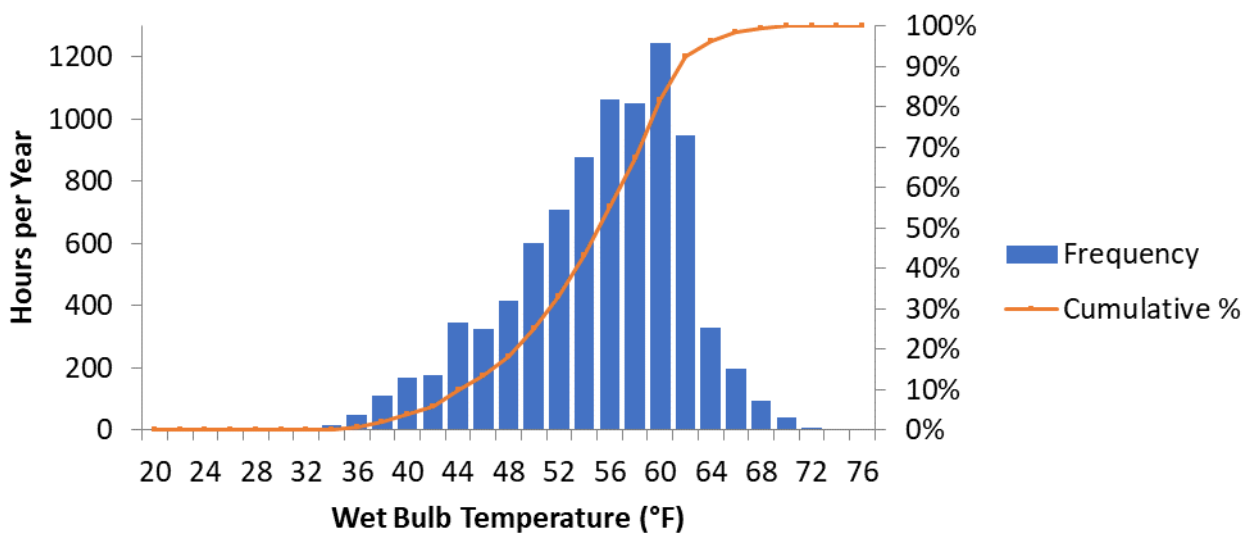


Figure 4-4: Wet bulb temperature distribution and cumulative distribution.

Figure 4-5 provides an illustration of the number of annual hours that wet-bulb temperatures are exceeded at the top end of the wet-bulb temperature range. This is used below in an analysis of the ability of evaporative/hybrid coolers to meet the data center load.

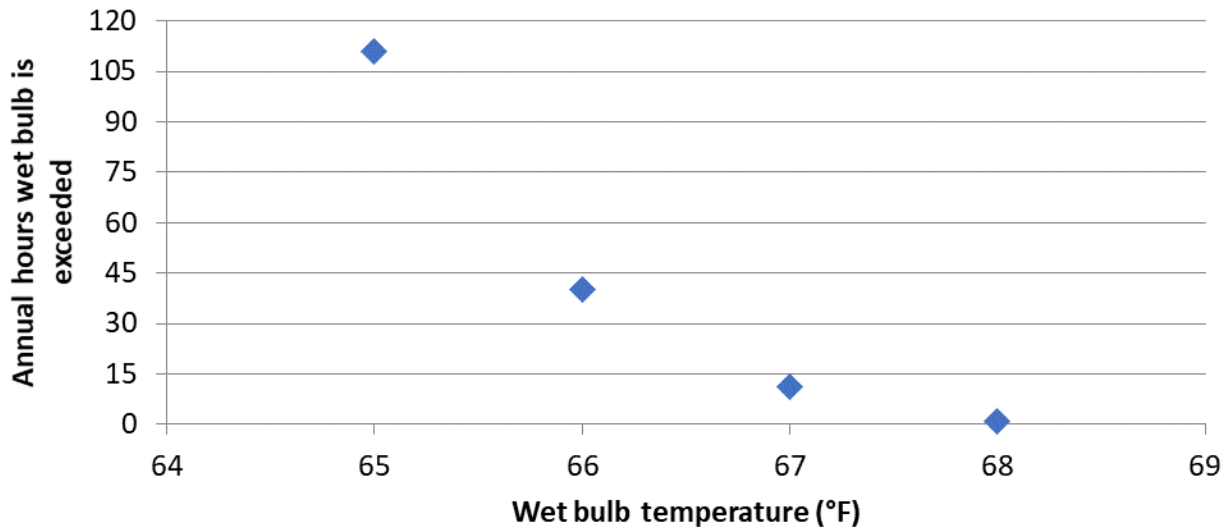


Figure 4-5: Annual hours wet-bulb temperatures at the top end of the range are exceeded.

In this review, wet-bulb temperature was calculated from dry-bulb temperature and humidity in the TMY data using the method of Stull [14].

5.0 TEST DESIGN

5.1 CONCEPTUAL TEST DESIGN

Methods of Integrating: A very simple plan for the integration of the Evapco hybrid evaporative cooler with the data center chilled water system is illustrated in Figure 5-1. This is a modification of Figure 4-1.

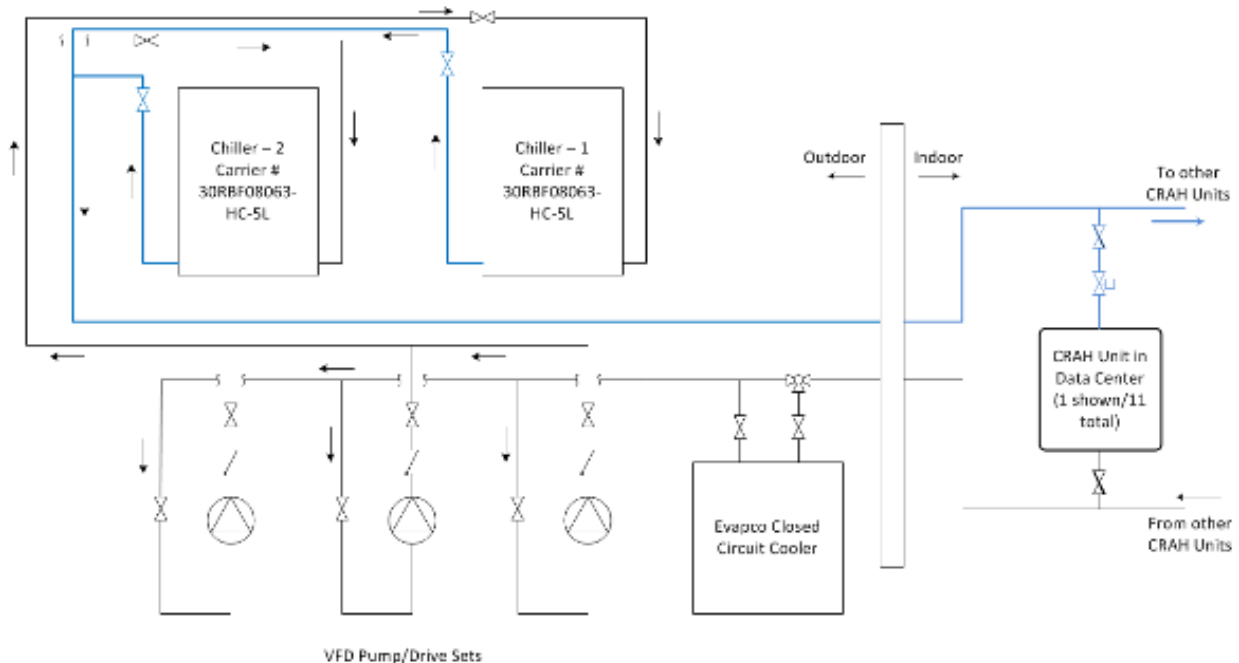


Figure 5-1 Basic illustration of the integration of the Evapco hybrid fluid cooler with the existing chilled water loop.

With this arrangement, chilled water can be delivered to the indoor loop and CRAH units in one of three ways:

1. Using just the existing mechanical chillers with the hybrid evaporative cooler bypassed.
2. Using just the hybrid evaporative chiller with the chilled water circulating through the heat exchangers on the idle mechanical chillers.
3. Using the hybrid evaporative chiller as a precoolers in series with the operating mechanical chillers.

With mechanical chillers the supply water temperature to the indoor CRAH units is 44°F and nominal return to the chillers is 54°F. Chiller flow at nominal maximum capacity of 179 gpm. Nominal flow of each pump is 126 gpm. With the hybrid evaporative coolers, the supply temperature is 70-75°F. The control for the variable speed drives can be adjusted to yield a target return temperature from the data center.

In normal operation only one mechanical chiller is operated at a time and the operation of these is cycled to balance cumulative run times.

A consideration in the development of this arrangement is response to upset conditions. In the event of a failure of the hybrid evaporative cooler or if this system is just not meeting the load and the data center temperature is rising above acceptable levels, the mechanical chiller can simply be activated by the building Energy Management System (EMS).

Discussion of the Indoor CRAH Units: With mechanical chillers the supply water temperature to the indoor CRAH units is 44°F and nominal return to the chillers is 54°F. Chiller flow at their nominal maximum capacity of 74.7 tons is 179 gpm. Nominal flow of each pump is 126 gpm. With the hybrid evaporative coolers, the supply temperature is 70-75°F. The control for the variable speed drives can be adjusted to yield a target return temperature from the data center.

A really important question with the use of the hybrid evaporative coolers at this data center is the performance of the indoor CRAH units. With the higher temperature of the water in the cooling loop and the higher data center temperature will these units be able to remove the required amount of heat? For a preliminary evaluation the CRAH Log Mean Temperature Difference (LMTD) was evaluated for different assumptions about operating conditions. Figure 5-2 illustrates this for one case using the Munters PFC. Here the LMTD was calculated as a heat exchanger in cross flow.

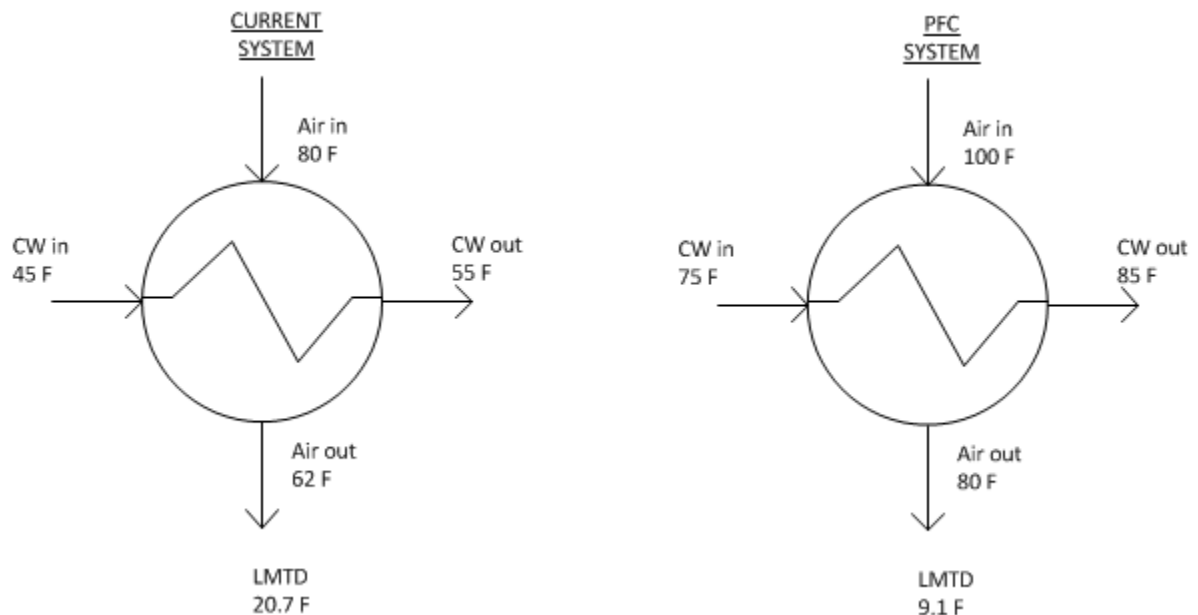


Figure 5-2 Illustration of CRAH LMTD determination for current system and a hybrid evaporative cooler configuration

In this case the LMTD of the hybrid evaporative cooler is 44% of that of the current chiller case and the heat transfer performance could be expected to be reduced by this amount. The nominal installed capacity of the indoor CRAH units is 103 tons and the current cooling demand of the data center is a nominal 45 tons. Given this, the CRAH units nominally have the capacity to meet the demand with these assumed conditions. This is discussed further in the report section Analysis of Expected Performance where different conditions are evaluated. If the capacity of the CRAH units is not adequate the addition of more indoor CRAH units or upgrades to the CRAH fans or heat exchangers could be considered.

Addition of Thermal Storage: It is expected that a reasonably sized hybrid evaporative cooler may not be able to meet the full heat demand of the connected data center for the entire year. Therefore, the use of thermal storage could be considered to enable operation without the mechanical chillers for the very small number of hours each year that the wet-bulb temperature is above the point at which the evaporative cooler can meet the data center load.

In this section, consideration is given to the option of water tank-thermal storage and three different configurations are shown in Figure 5-3 to Figure 5-5.

Figure 5-3 shows a case where the existing mechanical chillers remain in the system. These mechanical chillers can be used for redundancy or for cooling the storage tank. To explain the operation: starting with the assumption that the tank is chilled to 65°F or lower, and the wet-bulb temperature is too high. Under this scenario, the evaporative chiller would produce water that could be several degrees higher than required to meet the data center load (nominal 73°F is assumed). The three-way control valve in this case would auto-position to blend water from the tank and the water from the evaporative chiller to meet the required supply temperature. The storage tank could be cooled during night hours with the evaporative cooler when the wet-bulb temperature is much lower. In this case, the evaporative cooler might produce water at 65°F, lower than required for the data center load. Assuming that the storage tank is warm, roughly 75°F, the flow from the evaporative cooler would pass partially to the storage tank and partially through the three-way valve, yielding a mix temperature of 70 – 75°F to meet the data center cooling load. The storage tank would be fed at the top with the 65°F water.

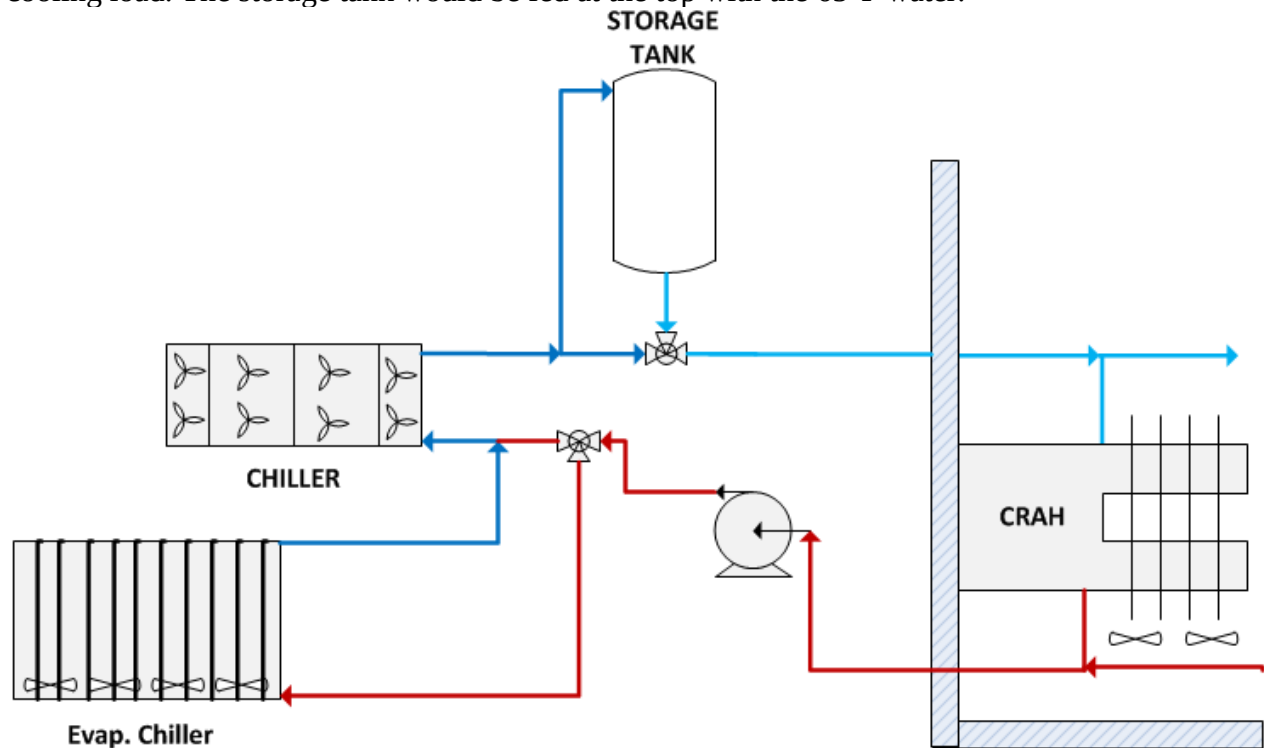


Figure 5-3 Arrangement with integrated storage and backup chillers in place

The storage tank could also be cooled with the mechanical chiller to achieve a significantly lower storage tank temperature. It should be noted that the tank and piping need to be thermally insulated, and it is expected that the storage tank would be charged overnight, when the electric rates and wet-bulb temperature are low.

Figure 5-4, shows a similar configuration to that shown in Figure 5-3, except the chillers are removed and the evaporative cooler + storage tank meet the load without the redundancy of the mechanical chiller. Here, again, the evaporative cooler would cool the storage tank to $\sim 65^{\circ}\text{F}$ at night. Without the capability to cool the tank to much lower temperatures, the storage volume would need to be larger. This is discussed further below.

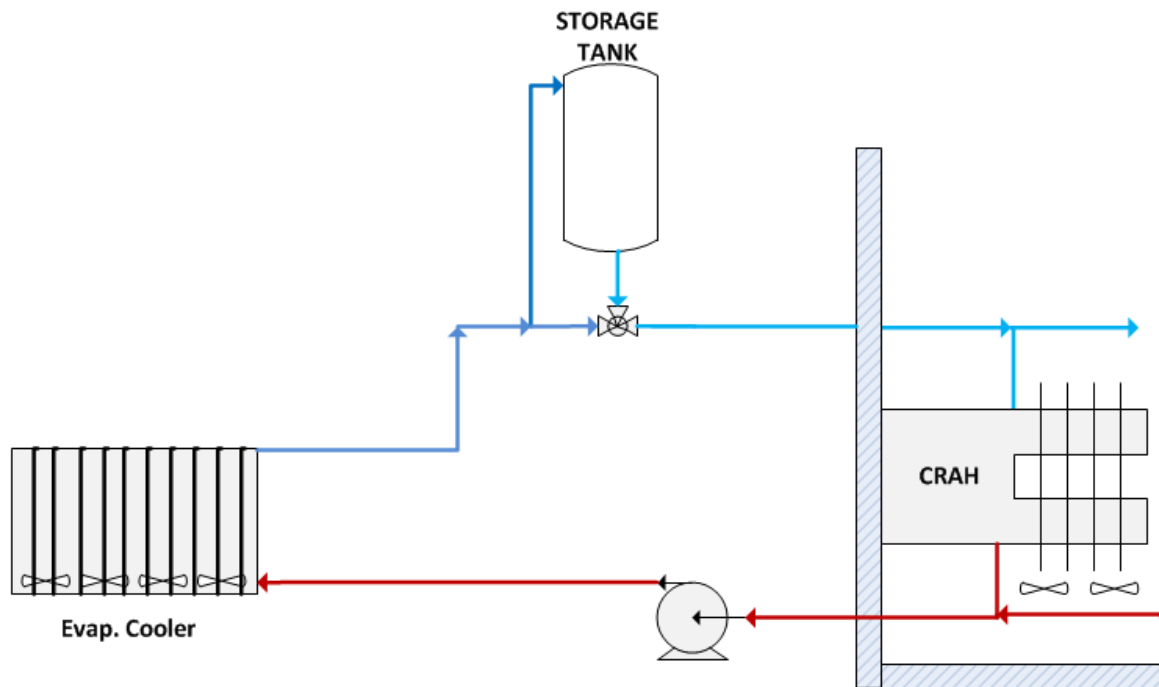


Figure 5-4 Arrangement with integrated storage and backup chillers removed.

In Figure 5-5 a relatively small chiller has been added only to keep the storage tank at a much lower temperature ($\sim 40^{\circ}\text{F}$). The advantage of this approach is that the larger temperature difference during charge and recharge of the storage tank would result in a smaller storage requirement. The system should be well insulated and again, the chiller is expected to be operated at night or whenever electric rates are the cheapest including demand charges.

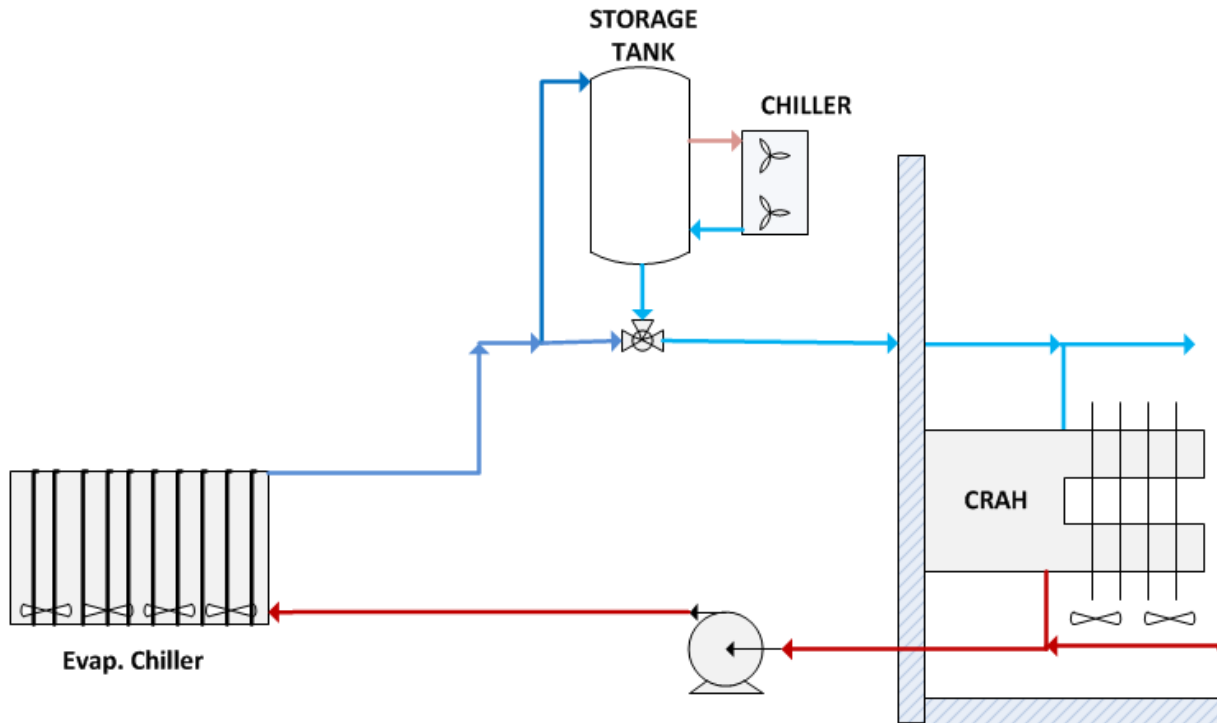


Figure 5-5 Arrangement with separate, smaller chiller only to cool storage tank.

Analysis of Cases: The current design basis assumes that the data center load can be met with supply from the evaporative chiller at a temperature of 75°F. The most significant unknown is the actual performance of the current CRAH units and it is recognized this may have to be adjusted as actual field data becomes available. The evaporative chiller can achieve a 7°F approach to the wet-bulb temperature, or the target supply of 75°F can be achieved when the wet-bulb is 68°F or lower. TMY data for the Port Hueneme area (Point Mugu) has been used in this analysis. Table 5-1, below, shows the number of annual hours that a specific wet-bulb temperature is likely to be exceeded.

Table 5-1 Annual Hours That Specific Wet-Bulb Temperatures are Likely to be Exceeded Based on Point Mugu TMY Data

Wet-Bulb Temperature (°F)	Annual Hours Wet-Bulb Temperature is Exceeded
65	111
66	40
67	11
68	1

Based on this and the design criteria, there is only one hour a year when the evaporative cooler is expected to not be able to meet the load. For the purposes of this storage, analysis, however, it is assumed that a lower supply temperature would have to be achieved. This is based on uncertainty over the actual CRAH units' current condition and performance. The assumption used in the balance of this analysis is that the evaporative chiller will not be able to meet the load if a wet-bulb of 66°F is exceeded and this occurs for 40 hours each year.

A review of the TMY data shows that the times of exceeding the 66°F wet-bulb criterion occur in the summer and that the maximum number of hours on any day in which this occurs is 5. Figure 5-6 shows the wet-bulb temperature distribution for one such summer day over the entire 24-hour period.

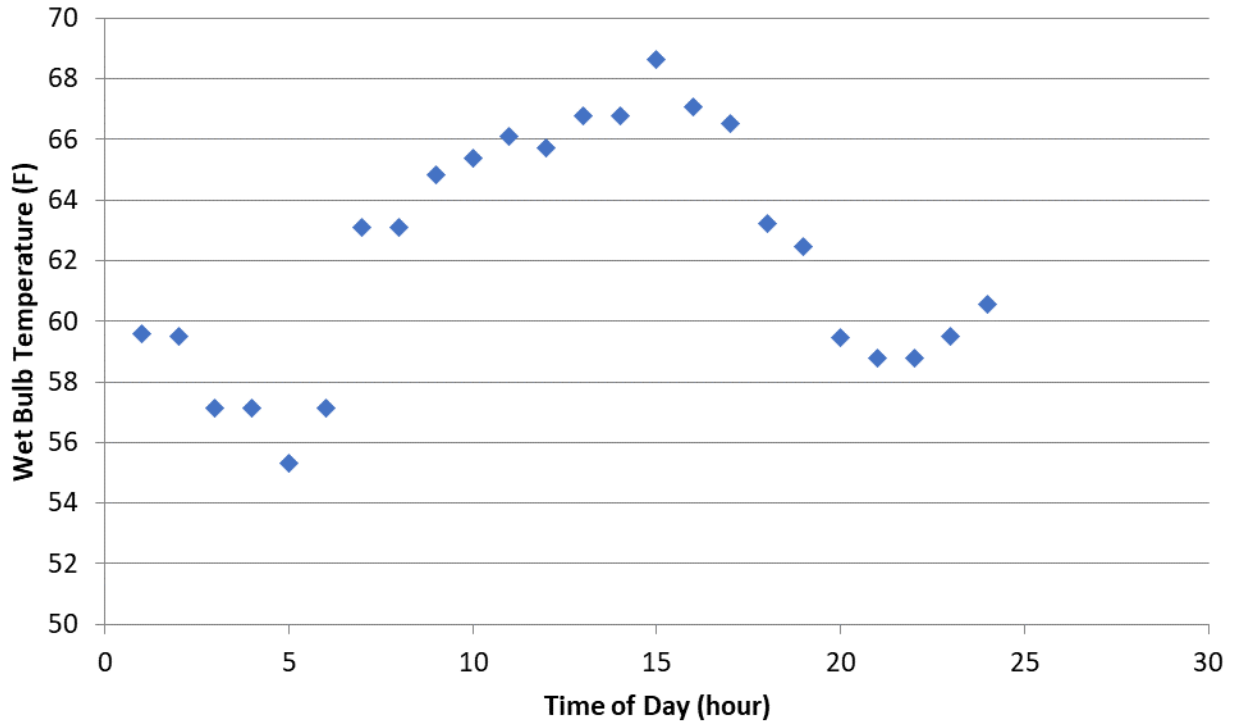


Figure 5-6 Example summer day in which the wet-bulb temperature of 66 F is exceeded. Wet-bulb temperature profile

With the concept illustrated in Figure 5-3 and Figure 5-4, the storage tank could be cooled at night when the evaporative chiller can produce a cooler supply temperature than the data center requires. Based upon the wet-bulb temperatures realized at night, from Figure 5-6, it is here assumed that the storage tank can be cooled to 65°F. During the day time period when the 66°F wet-bulb is exceeded; the wet-bulb does not exceed this by more than 2°F for nearly all of the 5-hour period. Here it is assumed that, for storage size determination, the evaporative chiller supply will need to be cooled by 2°F from the storage tank for the five-hour period.

Integration of Hybrid Evaporative Cooler with Direct Board Cooling: At the Port Hueneme data center demonstration site, the servers are all air cooled. In parallel with this project, an ESTCP project led by Asetek has been ongoing involving direct-to-chip data center liquid cooling. Termed RackCDU, the Asetek system captures heat from the hottest part of the rack with direct liquid cooling. During this project a conceptual study was done of the potential for integration of the Asetek system with a hybrid evaporative fluid cooler. This small study was done specifically for the Munters PFC included in the first part of the project.

The primary benefit of Asetek’s direct-to-chip liquid-cooling is that it provides free cooling for data centers in any location where 105 °F water can be consistently supplied year-round. The

ideal choice for heat-rejection in this system is a *dry cooler*, because of its simple, closed-loop plumbing, low power consumption and zero water use. While a large fraction of DoD data centers around the world have a maximum dry-bulb temperature that will allow the use of a dry-cooler for *RackCDU* year-round, many more do not. For these data centers, one of two options generally exist: 1) integrate a mixing system that taps into the facility's chilled water supply to reduce the *RackCDU* water temperature on those days when the dry-bulb temperature is too high; or 2) use a traditional wet cooling tower to provide heat-rejection.

While a mixing system is effective, it negatively impacts overall data center efficiency, because energy-intensive compressive cooling is used. In addition, there is a significant increase in complexity of the facilities plumbing system, which increases up-front costs and reduces ROI. While cooling towers are very efficient, and can even increase overall energy efficiency of *RackCDU* over dry-coolers, the increased plumbing complexity adds up-front capital costs. In addition, the added maintenance and water consumption of cooling towers is highly undesirable, particularly in hot, dry locations where they are needed most. In fact, many DoD installations in extreme environments are eliminating cooling towers all together for these reasons.

A hybrid evaporative cooler is seen as an ideal solution to combine with *RackCDU*. During days when the dry-bulb temperature is low enough for a dry-cooler, the system runs in dry mode, offering a zero-water-consumption solution. On those days when the dry-bulb temperature is too high, the unit adds evaporative cooling to achieve the target supply water temperature. While this approach does consume some water, the total water consumption is expected to be dramatically less than a traditional cooling tower, which consume water at all times. Even in locations where dry-coolers are a viable option, an evaporative cooling system will reduce the required footprint of the heat-rejection system, which must always be sized for the hottest day.

In the concept integration, the PFC would reject heat from the much higher temperature water returning from the *RackCDU* units. Because the *RackCDU* units only capture heat from the server processors and memory, there will still remain an important heat load from the other server components, which will need to be removed through the CRAH units. The direct-chip cooling will be done by the water leaving the CRAH units. With a much higher return water temperature to the PFC (roughly 130 °F), heat rejection to the ambient will occur using only sensible cooling, with no water usage. An integration concept for this is illustrated in Figure 5-7. The Munters PFC unit includes four separate modules. In this integration concept, three of these would be used for dry cooling and one would be used for evaporative cooling when needed. If this concept were to be extended to the Evapco unit a similar approach could be implemented with the wet and dry heat exchanger sections.

This concept would likely eliminate the need for water at Port Hueneme and eliminate the need for keeping mechanical chillers as backup.

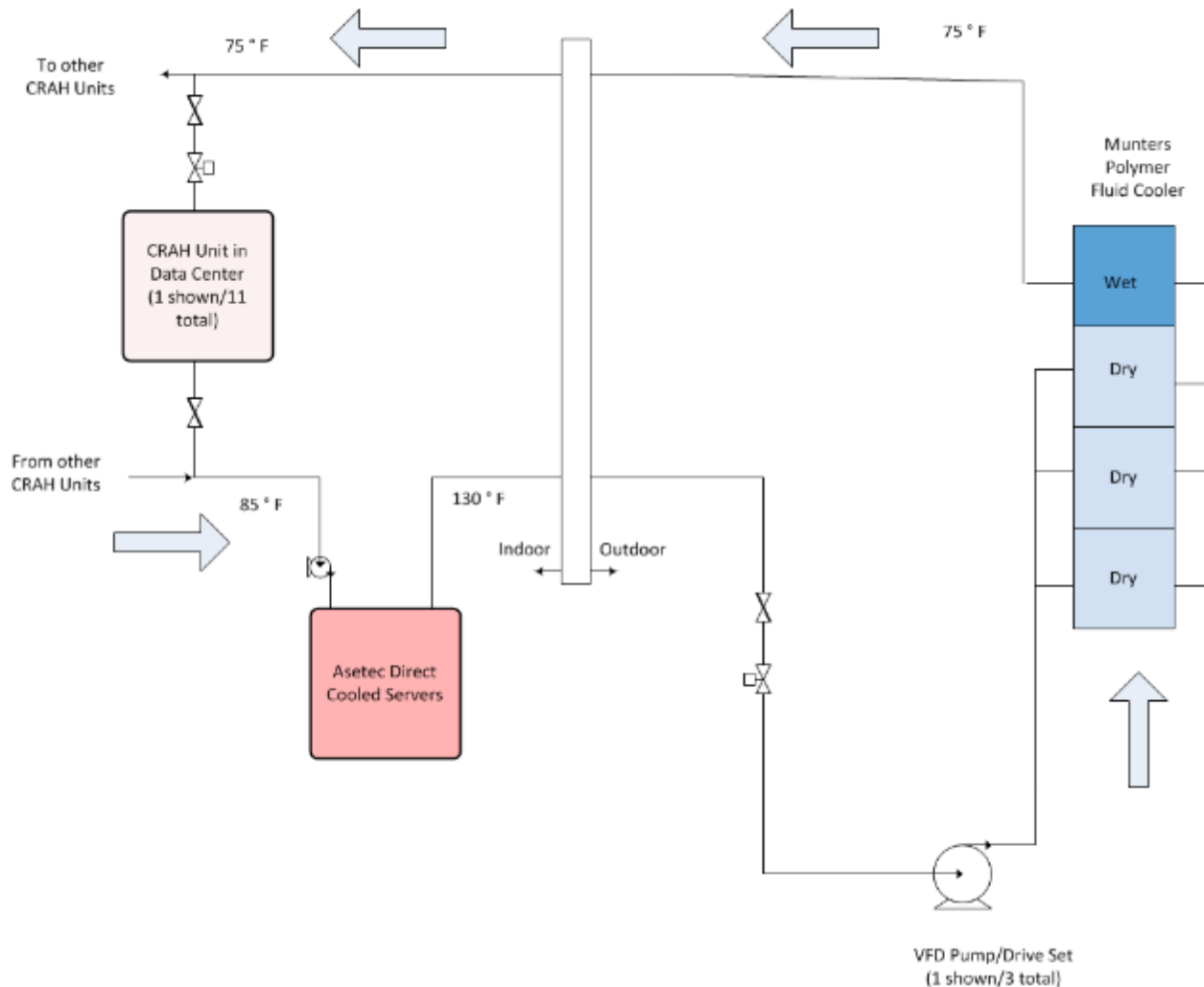


Figure 5-7 Concept for integrating direct chip cooling with a hybrid evaporative cooler

Site Integration Issues: In planning the demonstration of the evaporative cooler at the Port Hueneme site, in discussion with technical staff at the data center, some concerns were raised about the operation. These concerns are related to the plan to raise the data center temperature to 80-85°F needed to achieve the greatest level of energy savings. While these concerns may be unique to this data center, other data centers considering such an energy efficiency conversion may face related concerns. In this section these concerns are discussed along with potential solution approaches.

Operations Center Temperature: The NITC data center has an operations center which is manned 24 hours daily. One of the 11 indoor CRAH units through the common underfloor air distribution system, provides cooling to this operations center. With the hybrid evaporative cooler in operation, the circulating chilled water will be at 70-75°F and the temperature of the operations center will rise above the level associated with the much colder chilled water from the mechanical chillers. Unlike the data center floor, there is no significant source of internal heat gain in the operations center and it is unlikely that the temperature will rise to the 80-85°F level. ASHRAE Standard 55-2017, Thermal Environmental Conditions for Human Occupancy states

that for human comfort indoor temperatures can range between 67 and 82°F. In this project it was planned to evaluate temperature and comfort in this space during initial tests of the hybrid evaporative cooler system and, based on this, make a decision about the need for additional cooling.

If, with the hybrid evaporative cooler, addition temperature control is needed for this space temporary portable air conditioners could be used. An example product is the *MovinCool 14* with a cooling capacity of 13,200 Btu/hr and retail price of ~ \$2,700. This would require the addition of a warm air duct to the outside. Numerous other product options are available of this type. For a more permanent solution a mini-split non-ducted heat pump system could be installed for this space.

Highly Temperature Sensitive Server Racks: As discussed above, data centers can operate at considerably higher temperatures than is considered acceptable for human comfort. However, at the Port Hueneme data center some of the server racks are considered highly temperature sensitive (Tape and SANS Drives) and the data center operators are very reluctant to allow even tests at elevated temperatures. The maximum allowable temperature for these devices was reported by staff personnel to be 100 °F. Running the overall datacenter at an elevated temperature, say 80 or 85 °F rather than 72~74 °F provides less head-room, and thus less reaction time, if there is a failure in the primary cooling system. The tape/SANS drive racks represent only two rows of racks at this specific data center. One option considered for the demonstration was moving these few racks to a different location. After evaluation, however, this was not seen as a feasible option. The path forward selected for this situation was to simply monitor the temperatures during the initial phases of the demonstration to see if, in fact, an acceptable temperature was exceeded for these racks. If this were the case then either the maximum temperature in the data center would be constrained to ensure this temperature is avoided or a single-rack cooling system would be used either temporarily or permanently. This single rack cooling system is essentially a small (1/2 ton) air conditioner mounted at the bottom of the rack to provide cooling to just a single rack. One example of such a product is a SRCOOL7KRM cooler from TripLite company. Approximate cost is \$10,000. Such a product would allow a heat sensitive rack to operate a lower temperature than the rest of the data center. These small auxiliary cooling units could also be tied into the existing backup UPS, if desired, to ensure some cooling capability in the event of a main-system power failure.

Maintenance Operations in the Data Center: Another concern raised by the data center management staff is exposure of crews doing maintenance in the data center to uncomfortably warm temperatures. For short work project this is not seen as a major concern. Longer maintenance projects, during the course of the demonstration at least, might need to be scheduled and the system operated on the mechanical chillers for this time period.

Hybrid Evaporative Cooler Vapor Plume: With any evaporative cooler there is the potential for a vapor plume during the time periods in which it is operating in an evaporative (vs. dry) mode. To address this possible concern the location of the hybrid cooler as selected to be as far from the base housing in the vicinity of the data center.

Analysis of Expected Performance: In this section an analysis is presented of the energy performance of the two-hybrid evaporative cooler concepts evaluated in this project and energy savings relative to the baseline mechanical chiller. Also presented is an analysis of the annual hours for which the hybrid evaporative cooler concept can run in a dry mode and the annual hours for which the hybrid evaporative cooler concept will not be able to meet the cooling load of the data center.

Existing Baseline Mechanical Chillers: As discussed in the section above, Description of the Data Center, the existing mechanical chillers are Carrier Model 30RB-80. From the manufacturer's product data these units have a full load COP of 2.9 and an Integrated Part Load Value (IPLV) for COP of 4.2. These values are based on rating tests done to Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Standard 510. The entering/leaving water temperatures for these tests are 54°F and 44°F respectively. The outside air temperature for the full load test is 95°F.

The IPLV is based on a weighted average of measurements at 100%, 75%, 50%, and 25% of full load with the weighting factor for each load at 0.01, 0.42, 0.45, and 0.12 respectively. This is obviously heavily weighted to the mid load range. With a typical load at the Port Hueneme data center at 40 tons this is 52% of the maximum capacity of each of the two installed chillers.

The higher value for the IPLV COP is influenced strongly by a lower condensing temperature. The assumption is that a single chiller meets the load of the building and load decreases when the outdoor temperature decreases. The rating at 50% of full load is based on the assumption of an outdoor temperature of 65°F. This approach does not apply to the data center where the load can be taken as fixed at 40 tons, independent of the outdoor air temperature.

The COP of the mechanical chillers at the Port Hueneme data center will be a function of outdoor air temperature with fixed load. A procedure for developing this relationship was adopted here from the work of Yu and Chan in which this was studied specifically for reciprocating, air-cooled chillers [15]. The developed relationship, used here, is shown in Figure 5-8. It should be noted that the actual relationship between outdoor temperature and COP will depend on the chiller characteristics and control strategy and measurements during the developed demonstration project have been included in planning.

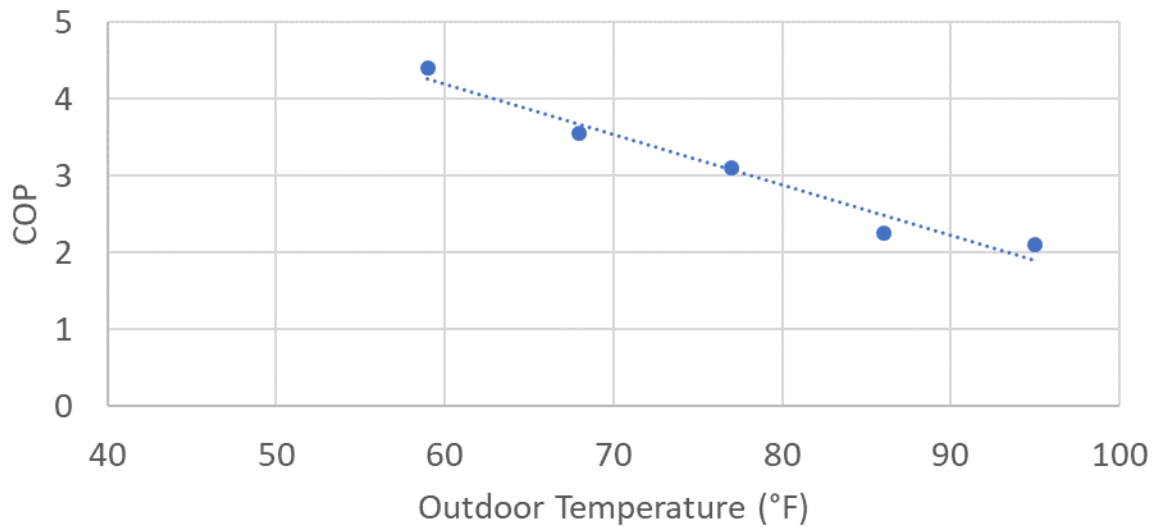


Figure 5-8 Relationship between outdoor temperature and COP at a 0.5 load fraction.

Using this and the annual distribution of outdoor dry-bulb temperature at the Port Hueneme location, the annual distribution of expected COP for the mechanical chiller is shown in Figure 5-9.

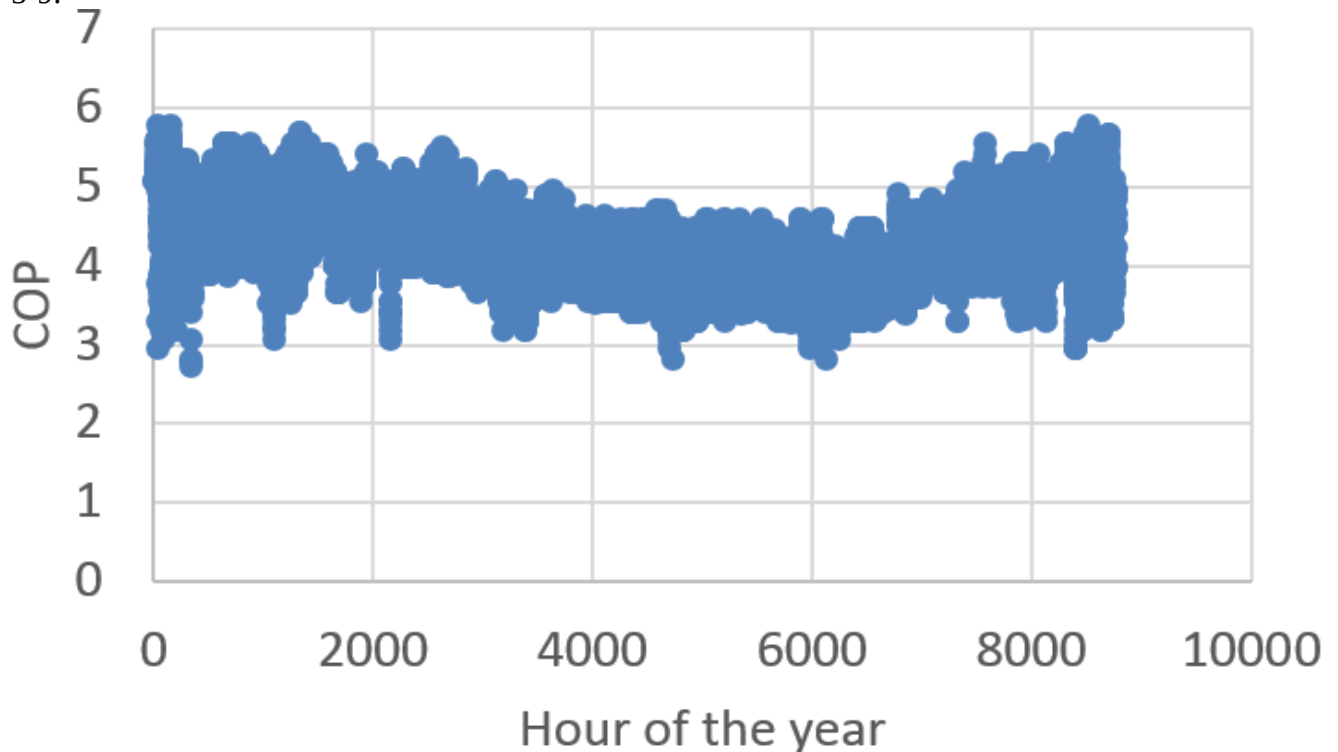


Figure 5-9 Annual distribution of expected COP at the Port Hueneme site for the mechanical chillers

Based on this the annual average COP is 4.2 and the total annual chiller energy use is 291,883 kWh. Using \$0.15/kWh the total annual cost of power is \$43,782.

Munters Polymer Fluid Cooler: A basic description of the Munters PFC was provided in the section above in Description of the Hybrid Evaporative Cooler Technology. This unit was available in modules of 25 tons capacity each and it was planned to install four of these for a total capacity of 100 tons. This high installed capacity was planned for two reasons: 1) to allow for future expansion of the use of the data center with increased cooling load and 2) to provide additional heat exchanger surface to explore the potential to achieve even higher performance with all 4 units running. For the demonstration, it was planned that only two modules would normally be operated and this performance section is based on this assumption.

When operating in a wet mode, the achievable chilled water temperature with this unit nominally is 75% of the difference between the dry-bulb and wet-bulb temperatures. Based on TMY data this temperature was calculated for the Port Hueneme site and is illustrated in Figure 5-10.

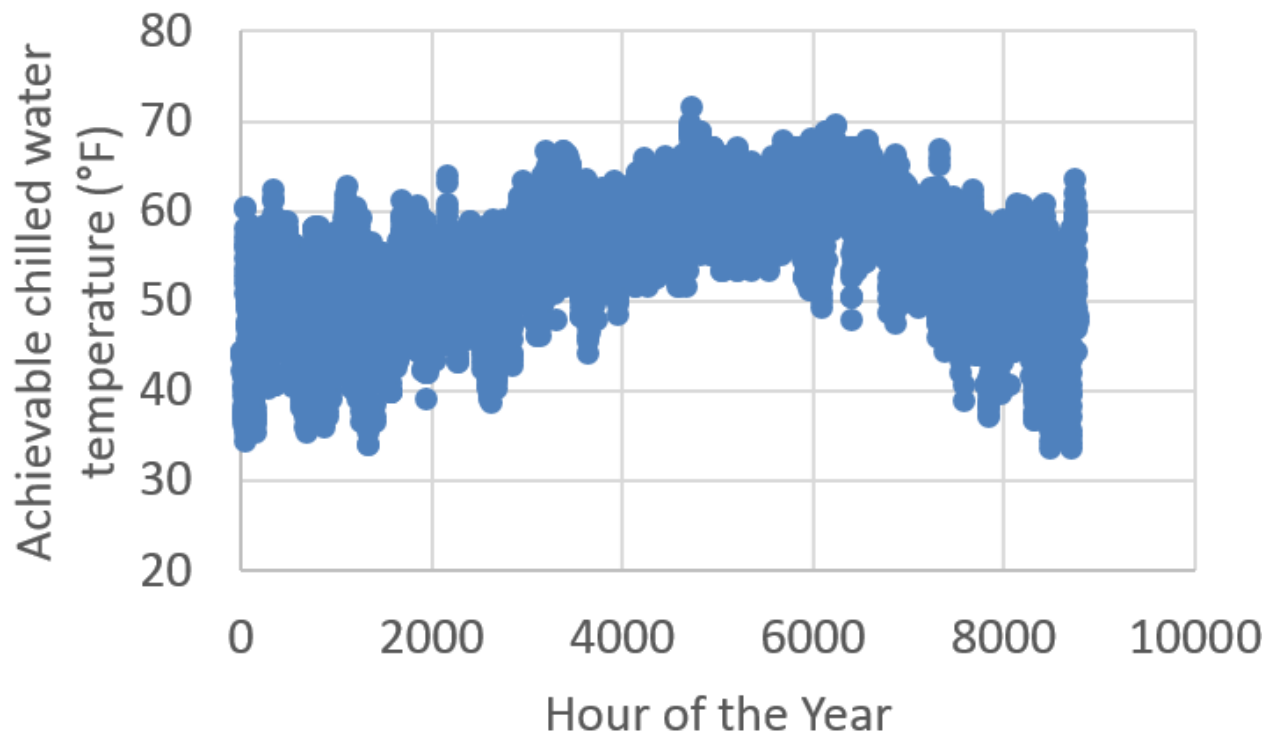


Figure 5-10 Annual distribution of chilled water temperature that can be produced at Port Hueneme

Based on this criterion, the PFC achievable chilled water temperature exceeds 70°F only two hours per year.

When operating in a dry mode, the achievable approach temperature is nominally 23°F. In this mode a target temperature of 70°F chilled water temperature can be achieved when the dry-bulb is lower than 47°F and this occurs 612 hours per year. The unit then would operate in a wet mode 8,148 hours per year. If the chilled water temperature were raised to 75°F, the number of hours in the dry mode would increase to 1,624 hours.

The power consumption of the unit can be taken as the same in a wet and dry mode. For a 50-ton capacity it is 7kW. Using this for 8760 hours per year the annual electrical power use would be 61,320 kWh for a reduction of 79% relative to the mechanical chillers. Using \$0.15/kWh the total annual cost of power is \$9,198.

In a wet mode, the nominal water consumption with this unit is 2.67 gpm. Considering operation in a dry mode for 612 hours per year, this give a total annual water consumption of 1,305,309 gallons per year.

Evapco “eco-ATWB-H3 Hybrid Closed Circuit Cooler”: A basic description of the Evapco unit was also provided in the section Description of the Hybrid Evaporative Cooler Technology, above. In this design study it was assumed that a single, 50-ton capacity cooler would be installed.

The manufacturer developed performance estimates specifically for this project. With an entering water temperature of 80.5°F and leaving water at 70.0°F, nominal electric power consumption is 16.4 kW. This gives an annual power consumption of 143,664 kWh. Using \$0.15/kWh the total annual cost of power is \$21,549. This is a reduction of 51% relative to the mechanical chiller baseline. This nominal performance point is based on a wet-bulb temperature of 65°F, which is exceeded for 111 hours annually in Port Hueneme, based on TMY data.

This unit can operate under this entering and leaving water temperature condition in a dry mode at dry-bulb temperature under 53.8°F. At this site it can operate in a dry mode for 2,160 hours per year.

In a wet operating mode, the water consumption is nominally 1.02 gpm. Considering the dry operating hours, this gives an annual water consumption of 403,920 gallons.

Test Design: The following basic test approach has been developed to achieve the objectives stated above.

Fundamental Problem: The use of conventional mechanical cooling equipment to reject data center server-generated heat leads to high electrical energy use. Replacement of this type of cooling equipment with ambient evaporative coolers offers the potential to achieve at least 50% electrical energy savings.

Demonstration Question: Can an evaporative cooler achieve this potential energy savings while meeting the cooling needs of the data center?

Once the hybrid evaporative cooler and sensing/ data acquisition have been installed and verified, the following test approach has been developed to assess the energy savings by using the hybrid evaporative cooler over traditional mechanical chillers.

- *Test Protocol 1 (primary)*: The data center room temperature would be set at a fixed, elevated temperature of 82-85°F. The actual target setpoint would be finalized, based on the initial commissioning. Every two weeks, the hybrid evaporative cooler and the

traditional chiller(s) would be alternated to maintain the data center at 85°F. When the chiller is running the hybrid evaporative cooler would be bypassed completely. Similarly, the chillers would be offline when the hybrid evaporative cooler is providing cooling (but made available if the hybrid evaporative cooler cannot satisfy the load). Local weather conditions would be monitored during this time to account for weather variations during the tests. The total test duration would run for a period of at least several months, or ideally one year, to assess the energy savings as a function of ambient conditions and season.

- *Test Protocol 2:* A second test option is to again alternate between the hybrid evaporative cooler and chiller(s) every two weeks, however in this case the data center ambient temperature would be elevated at, say 85°F, for the hybrid evaporative cooler but then reduced to a more typical data center temperature of, say, 72°F when the chiller is engaged. This would give a more realistic estimate of the energy savings for an existing data center run at a typical room temperature of 72°F that is replaced by the hybrid evaporative cooler running at an elevated temperature. Data collection would be identical as in the previous test. Note that the transition time from high to low temperature and back again would need to be determined in coordination with Port Hueneme personnel. Also, although data would be collected during the transition periods, the energy comparisons would only use the steady-state values for the ambient temperature to establish a fair comparison.
- *Test Protocol 3:* A third possible test protocol would be a hybrid approach in which an intermediate interior ambient temperature is set, to 77 or 80°F that the hybrid evaporative cooler could not maintain completely by itself. The chiller would thus run however, the hybrid evaporative cooler would be used to precool the returning chiller water. Results from this test configuration would be useful for climates in which are only moderately favorable for an evaporative cooler but in which some benefit however from a hybrid evaporative cooler could still be derived, even if it did not carry the entire load the data center completely by itself.

5.2 BASELINE CHARACTERIZATION

An important part of the planned demonstration is developing high quality data on energy consumption under different outdoor conditions with the baseline system (mechanical chillers). This section provides some discussion of the basic plan for this.

- *Reference Conditions:* Measurements required include outdoor temperature and humidity conditions, temperature of the air delivered to the cold aisles, CRAH unit return air temperatures, CRAH unit fan speed settings, chilled water supply and return temperature and flow rate, server electric power consumption, and mechanical chiller electric power consumption. Notes are also required on ongoing operations at the time at which baseline data is collected. This includes number of people in the operations center, on-going maintenance operations, and any other events.
- *Baseline Collection Period:* Some of the required baseline data would be obtained through a pre-install review of available operating data. The project team would work with the energy management staff at the NITC Data Center to obtain data on the

operation of the chiller, chilled water loop, air handlers, and data center temperatures. This initial effort would serve to: confirm the data available from the current Automated Logic Energy Management System (EMS), identify additional data points not already planned, exercise the process of downloading and sharing the basic data, provide a preliminary assessment of the effectiveness of the current CRAH units (air-to-chilled water approach temperature), and provide a general overview of the current operating conditions. This would include one week of operating data.

- Most of the data that would be used to evaluate performance against the stated objectives would be collected during the test program as the system is cycled between mechanical chiller and hybrid evaporative cooler operation during different seasons.
- *Existing Baseline Data:* Through the project the team would review historical energy use data at the data center and temperature data available on the Energy Management System but it is not expected that this data would be very useful for the quantitative performance evaluation planned.

5.3 DESIGN AND LAYOUT OF TECHNOLOGY COMPONENTS

The Annex to this report provides considerable detail on the design work which was done in preparation for the demonstration.

5.4 OPERATIONAL TESTING

The following test plan was been developed for this demonstration:

Brookhaven National Laboratory (BNL) with support from the State University of New York (SUNY) Stony Brook is responsible for the test plan, data analysis and reporting for this project.

Key aspects of the planned test program are as follows:

- The planned tests are focused on demonstrating reduced energy consumption with the hybrid evaporative cooler while meeting data center cooling needs.
- Testing is planned with intermittent operation of baseline chiller/hybrid evaporative cooler system over different seasons.
- Key measurements include electric power to cooling equipment and servers and data center temperatures.
- Considerable additional data needed to understand water use and opportunities for system optimization.
- There is concern about the operation of the data center with chilled water and air temperatures higher than has traditionally been used. An important aspect of this test plan is evaluation of the practical operating limits and the system response in the event of a major component failure. Occupied space temperatures would not be operated at temperatures higher than ASHRAE-specified limits.

Once the hybrid evaporative cooler and sensing/data acquisition have been installed and verified, the following test plan is proposed to assess the energy savings by using the hybrid evaporative cooler over traditional mechanical chillers.

Test Design: The test program has been planned in the phases listed below.

1. *Phase 1 – Pre-Install Review of Available Operating Data*

The project team would work with the energy management staff at the NITC Data Center to obtain data on the operation of the chiller, chilled water loop, air handlers, and data center temperatures. This initial effort would serve to: confirm the scope and capabilities of the current Automated Logic EMS, identify additional data points not already planned, exercise the process of downloading and sharing the basic data, provide a preliminary assessment of the effectiveness of the current CRAH units (air-to-chilled water approach temperature), and provide a general overview of the current operating conditions. This would include one week of operating data.

2. *Phase 2 – Post-Install, On-Site Testing*

This phase of testing would be done over a one-week period following installation, startup and basic commissioning of the hybrid evaporative cooler unit and installation of additional data acquisition points. For this at least one manufacturer's representative and one Stony Brook or BNL representative would be on-site for the period. A detailed plan for this test period would be prepared in advance and submitted to the data center operations staff for approval. Tests planned for execution during this period include:

- i. *Baseline chiller operation* – Data to be collected includes pre-installed data available from the EMS, additional data available from the hybrid evaporative cooler and added test sensor points. This additional data would flow through the Automated Logic EMS, hybrid evaporative cooler, or added data acquisition module. As needed, additional data would be collected manually by the project team. During this test period testing would be done during which the temperature of the chilled loop water would be raised. Temperatures of cold isle air, control room air, and return water temperature would be measured. This would provide a first evaluation of the potential impacts of higher chilled water temperature. This test is planned for a four-hour period. An important outcome of this test would be the target setpoint for the hybrid evaporative cooler water temperature in normal operation. It is expected that this temperature decision would be reevaluated as the demonstration continues. Also, with the chiller operating at its normal temperature setpoint, a chiller failure would be emulated with the second chiller starting automatically. The key purpose of this specific test is to evaluate the transition time and the peak air and water temperatures observed during this period.
- ii. *Hybrid Evaporative Cooler Performance Tests* – The hybrid evaporative cooler would be operated for a period of three days over which basic performance data would be obtained. This would serve to confirm the basic operation of the hybrid evaporative cooler, validate the function of all sensors, and to identify any additional data points needed. During the test period analysis of “live” data would be done to provide a preliminary assessment of operating energy consumption with the hybrid evaporative cooler vs. the chiller system. **Note** – at all times the hybrid evaporative cooler is running the system control would be setup to switch on the chiller if the hybrid evaporative cooler is not able to achieve the target loop chilled water temperature.

- iii. *Hybrid evaporative cooler Failure Mode Response Test* – A test would be done to confirm the switch over from the hybrid evaporative cooler back to the chillers in the event the hybrid evaporative cooler system is not able to meet the target temperatures. This would be done by changing the trip-over set points (chilled water and cold isle temperature) to temperatures below those which the hybrid evaporative cooler is meeting at the time. Confirmation of the switch over as well as the time response of the system would be studied.
- iv. *Test Program Review* – An on-site project meeting would be held with the NITC operating staff, the base energy management team, and the project team to review the results and to review the plans for the next phase of testing. The NITC and base staff would be an important part of the project, implementing the planned switch over periods, downloading and sharing the collected data, management of time periods where the test plan must be interrupted for operational reasons (e.g. data center service), and monitoring for operational problems.

3. *Phase 3 – Cyclic System Testing Part 1*

- i. The baseline chiller system and the hybrid evaporative cooler system would be operated in a periodic manner with each running for two-week periods. This would allow for direct comparison of energy consumption between the two systems under similar ambient conditions. It is planned to run this way initially for a period of two months, so two hybrid evaporative cooler operating periods and two chiller baseline operating periods.

During the hybrid evaporative cooler test period, this unit would be evaluated in two different modes. In mode 1, the hybrid evaporative cooler would be set to deliver a specific target water temperature to the CRAH units. This would be consistent with the planned upper limit on the cold isle air temperature. The target water temperature would be as-set in Phase 2. In mode 2, the hybrid evaporative cooler would be operated to achieve the lowest possible supply water temperature. It is recognized that mode 2 is not the most energy efficient mode but it is seen as important to quantify the lowest achievable supply temperature at different outdoor conditions to help evaluate the potential use of the hybrid evaporative cooler concept in other climate zones and with other data centers.

- ii. *Test Program Review Meeting* - following the first two months of operation an on-site review meeting would be held to review any operational issues or issues with data collection. The energy savings observed from the first two months of the test would be reviewed along with any changes needed in the testing protocol.
- iii. *Testing of the Chillers at a Higher Set point* – with the project team members still on-site from the review meeting, a special test would be done in which the chillers would be operated but with a higher chilled water set point temperature. The target set point temperature would be considerably higher than the chiller normal setpoint temperature (e.g. 60 vs. 45°F)

- iv. Two-Week Test with Chiller at Higher Set point – Based on the results of the step 3 tests, the chiller would be operated for two weeks at the higher set point temperature. Data would be collected as normal to allow energy impact of the higher set point to be evaluated.
 - v. Two-Week Test with Chiller at Normal Set point – An additional two-week test period with the chiller at its normal set point would be conducted. This would be done to allow evaluation of performance under this condition with any changes in the test measurement or operating protocol resulting from step 2 above.
4. *Phase 4 – Normal Hybrid Evaporative Cooler Operation*
During this phase of the testing the hybrid evaporative cooler would be operated in a normal mode and the chiller system would be operated only in cases where the hybrid evaporative cooler is not able to meet the cooling demands or there are special operational needs such as data center manned service. All data collection would continue during this period for performance analysis. Of particular concern during this period is identification of time periods during which the hybrid evaporative cooler cannot meet the load and the ambient conditions at which this occurs.
5. *Phase 5 – Cyclic System Testing – Part 2*
Additional test periods are planned in which the hybrid evaporative cooler system is cycled off and the chillers only are operated for a two-week period. The purpose of these tests is to obtain baseline data under different outdoor weather conditions with the baseline system. At least one of these periods is planned and the timing would be decided based on actual timing of the demonstration. If, because of operational needs at the data center, the system is switched back to the chillers for discrete periods, it may not be necessary to plan definite periods when chiller-only tests are run. It is important, however, that some chiller-only data be obtained during different outdoor conditions.
6. *Phase 6 – Hybrid System Operation/Reduced Water Flow*
In this approach the hybrid evaporative cooler would be operated in its maximum cooling capacity mode and the chiller would also be operated in series to reduce the supply temperature to the CRAH units to a lower level. This approach might be used, for example if a lower cold isle target temperature is needed, e.g. 75°F, but the hybrid evaporative cooler is simply not able to produce cold enough water. In this case, the load carried by the hybrid evaporative cooler would depend on the return water temperature from the CRAH units. This hybrid approach would be most successful with a higher temperature rise of the chilled water across the CRAH units. During the planned two-week hybrid mode test the performance of the CRAH units with reduced water flow rates and increased Delta T would be evaluated. This can be achieved by changing the Delta-P set point on the variable frequency drive (VFD) control loop for the circulating pumps, or simply throttling the flow to one CRAH unit for a specific test. It is recognized that some data in this hybrid mode may be obtained earlier in the demonstration if the hybrid evaporative cooler is not able to meet the cooling demand of the data center. This phase is planned to ensure that data in this mode is obtained in a controlled manner.

7. *Decommissioning* – At the end of the project the installed equipment would be transferred to the host site.

6.0 POTENTIAL APPLICATION TO OTHER CLIMATE REGIONS

At the Port Hueneme demonstration site, it has been shown that the hybrid evaporative cooler can meet the data center load for *essentially* the entire year. In this section, the analysis of the portion of the year that such a cooler can meet the load in other climate areas is presented.

In any application, factors other than the specific evaporative cooler used can have very strong impacts on this parameter. The temperature of the chilled water needed to meet the load is critical and this is affected by the temperature setpoint that would be acceptable in the data center and also the water to air heat transfer hardware being used. For a give data center acceptable temperature, the temperature of the chilled water will be higher with more heat transfer surface in the air handlers. At the Port Hueneme data center for example improved performance of the CRAH units could be achieved by adding additional CRAH units, upgrading the internal heat exchangers of the CRAH units or increasing their fan capacity. Certainly, alternative air exchanger designs could be considered. For the analysis presented here, two simple assumptions have been made. One is that the circulating water must be 70°F or lower to meet the cooling load and the other is that 75°F or lower is adequate to meet the load. Further it is assumed that the performance of the hybrid evaporative chiller is similar to that used in the Port Hueneme analysis. In a wet mode the chiller can achieve water temperatures lower than the dry-bulb by 75% of the difference between the dry-bulb and wet-bulb temperatures.

In a dry mode it is assumed that the approach is 23°F, i.e. the chilled water will be 23°F higher than that of the dry-bulb temperature. This is an important parameter that will vary with manufacturer and can have a significant effect on the dry switch-over temperature. The Evapco unit, for example, states a better approach value of 17°F.

For the specific locations included in this evaluation, TMY3 weather data was used for dry-bulb temperature and humidity, hourly for a year. Wet-bulb temperature was again determined by calculation.

Table 6-1, below, provides a summary of the results in the form of hours per year that the cooling load of a data center could be met with evaporative cooling and the hours per year for dry cooling. This is presented for both the 70 and 75°F assumptions. The same results are presented in Table 6-2, below, but in a format of % of the hours of the year.

Table 6-1 Hybrid Evaporative Cooler Performance in Different Locations, Hours

	Annual hours cooler can meet load at 70°F water temp	Annual hours cooler can meet load at 75°F water temp	Annual hours of dry cooling at 70°F	Annual hours of dry cooling at 75°F
City				
Seattle	8718	8760	3101	4578
Fort Worth NAS	5876	7387	1403	2125
Baltimore	7358	8299	2957	3703
Norfolk NAS	6658	7896	1988	2751
Las Vegas	7485	8327	1515	2344
Maxwell AFB, ALA	5673	7233	1773	2387
Point Mugu	8758	8760	612	1624
Boise	7358	8299	2957	3703
Pensacola NAS	4927	6636	949	1432

Table 6-2 Hybrid Evaporative Cooler Performance in Different Locations, Percent

	Annual percent cooler can meet load at 70°F water temp	Annual percent cooler can meet load at 75°F water temp	Annual percent with dry cooling at 70°F	Annual percent with dry cooling at 75°F
City				
Seattle	99.5	100.0	35.4	52.3
Fort Worth NAS	67.1	84.3	16.0	24.3
Baltimore	84.0	94.7	33.8	42.3
Norfolk NAS	76.0	90.1	22.7	31.4
Las Vegas	85.4	95.1	17.3	26.8
Maxwell AFB, ALA	64.8	82.6	20.2	27.2
Point Mugu	100.0	100.0	7.0	18.5
Boise	84.0	94.7	33.8	42.3
Pensacola NAS	56.2	75.8	10.8	16.3

7.0 COST ASSESSMENT

7.1 COST MODEL

A decision was made to stop work on this project before requesting bids for the installation work. At the proposal stage an estimate for this, by one of the manufacturers was made at \$125,000. As the design work progressed and better information was available on the complexities of the project, it was recognized that this estimate was too low. The detailed specifications included in Annex I to this report were prepared to enable local installation contractors to bid on the entire scope of the installation. This bid process was not completed. The economics of the overall project for the Port Hueneme site are summarized in Table 7-1 below, using an assumption that the installation cost would be \$300,000. This is based on preliminary discussions with potential contractors and a cursory review by the BNL facilities group.

Table 7-1: Summary Cost Analysis

	PFC Unit	Hybrid Unit
Equipment Capital Cost	\$75,000	\$125,000
Estimated Installation Cost	\$300,000	\$300,000
Total Project Cost	\$375,000	\$425,000
Baseline System (mechanical chillers) annual electric cost	\$43,782	\$43,782
Annual electric cost with evaporative cooling system	\$9,198	\$21,549
Annual electric cost savings	\$34,584	\$22,233
Payback (years)	10.8	19.2

This simple payback analysis shown above assumes that the site has an existing mechanical chiller system and the evaporative cooler would be added to this as a cost savings measure. In an alternative scenario in which an evaporative cooler would be used instead of a mechanical chiller either at a new facility or where an existing mechanical chiller is at the end of its life, the payback would likely be zero years as the evaporative cooler would both cost less and use less energy.

8.0 CONCLUSIONS

Overall this study has shown the feasibility and strong energy savings potential associated with using an evaporative cooler to displace use of conventional mechanical chillers in data center applications. This application is particularly well-suited to this technology since the operating temperature can be higher than is commonly used for human comfort. It has been shown here that energy savings of 75% are achievable at the specific site chosen for the demonstration.

Implementing evaporative cooling creates some challenges and while these may be unique to the specific site selected, it is more likely that most sites will have some similar concerns. The increase in the data center temperature reduces the margin of temperature for an upset condition. Careful planning for system response to equipment failures is needed. At this site the cooling system serves not only the data center but also a manned operation center. In the long term, a separate cooling system for this may need to be implemented. Finally, elevation of the data center floor temperature can cause some concerns for maintenance operations.

An analysis of other climate zones has shown that the ability of an evaporative cooler to fully displace mechanical chillers will not be realized everywhere. Optimizing the heat transfer performance of the indoor water-to-air exchangers would seem to be a necessary part of a site conversion plan.

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APPENDICES

Appendix A: Points of Contact

POINT OF CONTACT Name	ORGANIZATION Name Address	Phone Fax E-mail	Role in Project
Dr. Thomas Butcher	Brookhaven National Laboratory Building 815 Upton, N.Y. 11973	(631) 344 7916 butcher@bnl.gov	Principal Investigator
Dr. Jon Longtin	Department of Mechanical Engineering, Stony Brook University Stony Brook, New York 11790	(631) 632 9436 jon.longtin@stonybrook.edu	Technical Lead
Vern Novstrup	Environmental Technology Development Branch Head NAVFAC EXWC	1100 23 rd Ave. Port Hueneme, CA 93043	DoD Technical Advisor

ANNEX



***Use of an Evaporative Fluid Cooler
to Reduce Energy Cost at a Data Center***

**Annex to Project Report – Detailed Specifications Prepared
for Installation of the Evapco Hybrid Fluid Cooler at the
NITC Data Center, Port Hueneme California**

Dr. Thomas A. Butcher¹, Rebecca Trojanowski¹, Dr. Jon Longtin²

**¹Sustainable Energy Technologies Department
Energy Conversion Group
Brookhaven National Laboratory**

²Department of Mechanical Engineering
State University of New York at Stony Brook

submitted to the:

**U.S. Department of Defense
Environmental Security Technology Certification Program
Project EW-201348**

July 2019

**Specifications-Request for Bids
Installation of a Hybrid Fluid Cooler at the
Naval Station Ventura County**

**Bids Requested by Brookhaven National Lab
Upton, N.Y.**

Overview Brookhaven National Labs (BNL) has teamed with Evapco Corporation and Stony Brook University for a demonstration project that uses an outdoor Hybrid Fluid Cooler (HFC) to achieve dramatic reductions in energy use at the Naval Base Ventura County (NBVC) Port Hueneme data center. This document defines the site specific design requirements for the HFC installation, controls/electrical integration, sensor/monitoring points, and physical changes to the data center that are required for a successful outcome.

This project is being done as part of a Department of Defense (DoD) Environmental Security Technology Certification Program (ESTCP) demonstration project. At the base data center – NAVFAC Information Technology Center (NITC) - cooling for the data center is currently provided by two mechanical chillers. In this demonstration project, the HFC will be installed in the chilled water loop to enable operation with just the HFC or the HFC and mechanical chillers together.

The final connection to the existing chilled water system and all electrical power shutdowns/tie-ins must be done in close coordination with the base data center staff. No unscheduled interruptions of the data center cooling or power can be tolerated.

Scope of Work

The project includes the site installation of all equipment and tie-in to the existing utilities and chilled water system as specified in the attached drawings in Section 1 and Specifications in Section 2. The project requires close coordination with the site facilities staff, as specified in Section 3. The project includes connection of all sensors and controls provided with the Evapco Hybrid Fluid Cooler ‘CH3’ (shipped loose), refer to attached Evapco submittal in Section 4.

Alternatives to specific components specified can be used with approval by the Technical Representative - T. Butcher (631) 344 7916. Bids must include statements of qualification and prior, relevant experience.

Exclusions:

1. Procurement of the Evapco Hybrid Fluid Cooler ‘CH-3’ (owner-furnished contractor-installed)
2. Startup of the Evapco Hybrid Fluid Cooler ‘CH-3’ (by Evapco factory representative, under separate contract)
3. Building Automation System hardware and programming modifications (by owner’s preferred controls contractor, under separate contract).

Contents

Section 1. Installation Design Drawings p. 3

Section 2. Specifications p.23

Section 3. Site Specific Contractor Requirements p.118

Section 4. Specifications of Evapco eco-ATWB-H-9-3K9-Z-U12 hybrid chiller p.123

Section 1. Installation Design Drawings

SUMMARY SCOPE OF WORK

PHASE 1: PRE-INSTALLATION WORK (DURING SCHEDULED DATA CENTER SHUTDOWN)

- 1.0 MECHANICAL – MODIFICATIONS TO EXISTING PIPING
 - 1.1 ISOLATE AND DRAIN EXISTING CHW FLUID FROM AFFECTED PIPING PRIOR TO START OF WORK; HANDLE, TRANSPORT, AND DISPOSE OF HAZARDOUS CHEMICALS PER NAVFAC REQUIREMENTS
 - 1.2 INSTALL (2) 6" TEES, (2) 6" ISOLATION VALVES, AND (1) 6" BYPASS VALVE IN THE EXISTING 6" CHWR PIPING AT THE INLET TO THE CHWS PUMPS (FOR FUTURE CONNECTION TO NEW CH-3 FLUID COOLER)
 - 1.3 INSTALL (2) 1" WELDOLETS AND (2) 1" BALL VALVES IN THE EXISTING 6" CHWR PIPING WHERE IT EXITS THE BUILDING (FOR FUTURE INSERTION-TYPE FLOW SENSORS)
 - 1.4 <OPTIONAL> INSTALL (2) 6" TEES AND (4) 6" ISOLATION VALVES IN THE EXISTING 6" CHWS AND 6" CHWR PIPING RUNS CLOSE TO THE BLDG ENTRANCE (FOR EMERG./TEMP. BACKUP CHILLER CONNECTION)
 - 1.5 LEAK CHECK, PRESSURE TEST, FLUSH, PURGE, AND RE-FILL PIPING SYSYTEM WITH CHW FLUID PER NAVFAC REQUIREMENTS
- 2.0 ELECTRICAL – NEW POWER FEEDER AND RELOCATE EXISTING UNDERGROUND ANODE
 - 2.1 INSTALL (1) 480VAC/3/60-60A CB AND FEEDER (FOR FUTURE CONNECTION TO NEW CH-3 FLUID COOLER)
 - 2.2 INSTALL (1) 120VAC/1/60-20A CB AND FEEDER (FOR FUTURE CONNECTION TO NEW CH-3 FLUID COOLER)

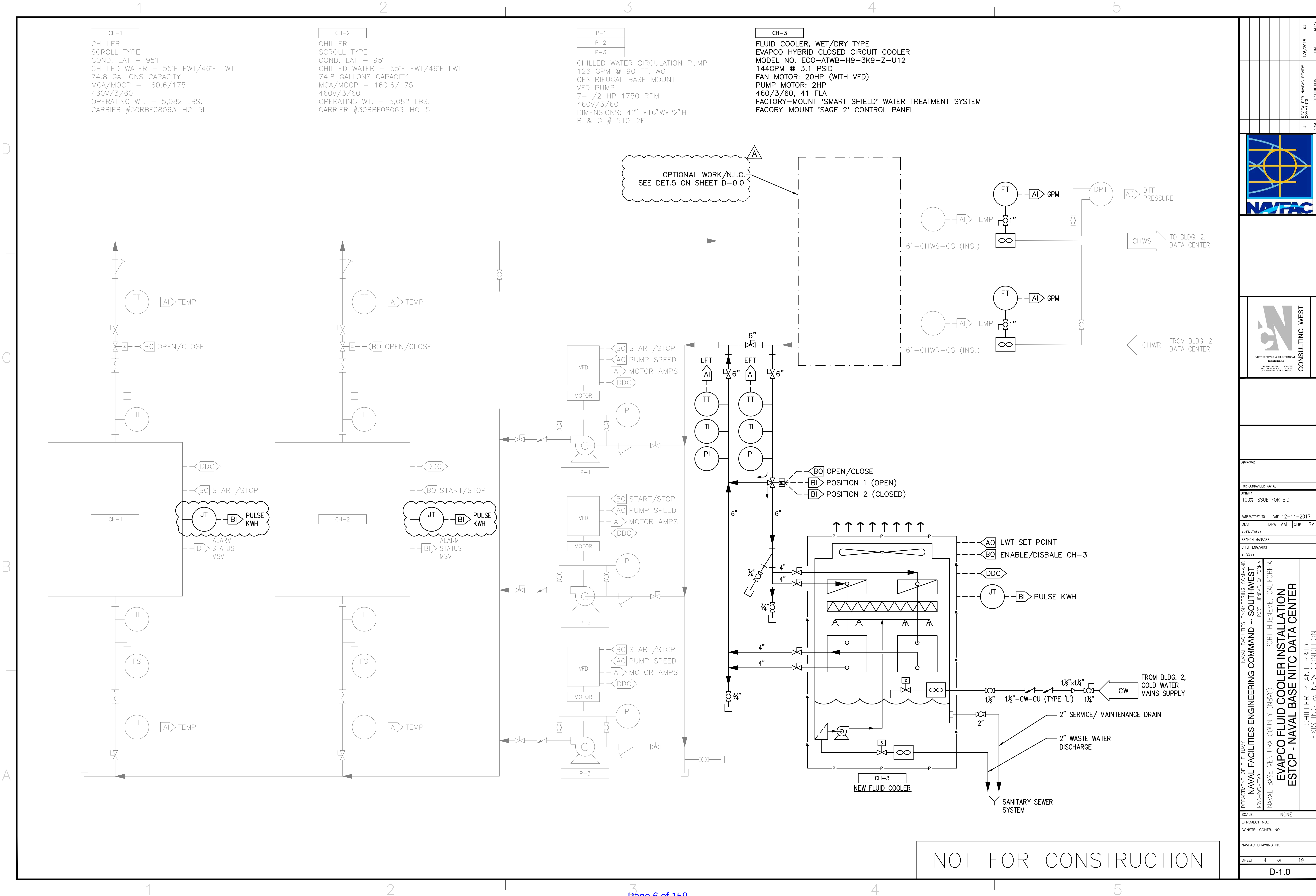
PHASE 2: CH-3 INSTALLATION WORK (SCHEDULE TBD)

- 3.0 SITE WORK
 - 3.1 SAW CUT AND REMOVE EXISTING ASPHALT; INSTALL NEW CONCRETE FOUNDATION PER STRUCTURAL DWGS. (NOTE: UTILITY LOCATOR SERVICE REQUIRED PRIOR TO START OF WORK)
 - 3.2 PRESERVE AND PROTECT IN PLACE TWO (2) EXISTING UNDERGROUND "ANODE" AND CONNECTIONS TO UNDERGROUND CORROSION PROTECTION SYSTEM IN EQUIPMENT YARD
 - 3.3 SAW CUT AND REMOVE EXISTING ASPHALT; INSTALL NEW 24"x24" CATCH BASIN AND NEW 6" SANITARY DRAIN PIPE UNDERGROUND TO TIE-IN AT EXISTING MANHOLE NEAR BLDG 2; OR ALTERNATE LOCATION NEAR BLDG. 19, PER PLUMBING SITE PLAN P-1.0 (NOTE: UTILITY LOCATOR SERVICE REQUIRED)
 - 3.4 INSTALL NEW 7'-0" GATE AT BLDG. 2 EQUIP. YARD CHAIN LINK FENCE ENCLOSURE PER LOCATION INDICATED ON M-2.0
 - 3.5 OFFLOAD AND RIG IN PLACE NEW OWNER-FURNISHED CH-3 FLUID COOLER, AND INSTALL STRUCTURAL / SEISMIC ANCHORAGE PER STRUCTURAL DWGS
 - 3.6 INSTALL NEW PIPE SUPPORTS PER STRUCTURAL DWGS
- 4.0 MECHANICAL
 - 4.1 INSTALL (2) 6" CHWS/R PIPING EXTENSIONS TO THE NEW CH-3 FLUID COOLER, INCLUDING WYE STRAINER, INLET/OUTLET VALVES, DRAIN/VENT VALVES, TEMPERATURE SENSOR PORTS, TEMPERATURE & PRESSURE INDICATORS AND, INSULATION WITH ALUMINUM-JACKET
 - 4.2 INSTALL (1) 6" MOTORIZED 2-POSITION 3-WAY DIVERTER VALVE (IN THE NEW 6" CHWR PIPING SECTION), WITH ON-BOARD PROXIMITY LIMIT SWITCHES FOR POSITION FEEDBACK
 - 4.3 INSTALL 2" SUMP WATER SERVICE/MAINTENANCE DRAIN PIPING, FROM THE NEW CH-3 FLUID COOLER TO DISCHARGE INTO THE ADJACENT (NEW) 24"x24" CATCH BASIN
 - 4.4 INSTALL 2" SUMP OVERFLOW / WASTE WATER DISCHARGE PIPING, FROM THE NEW CH-3 FLUID COOLER TO DISCHARGE INTO THE ADJACENT (NEW) SANITARY DRAIN PIPE, INCLUDING WATER FLOW METER (SHIPPED LOOSE WITH CH-3)
 - 4.5 INSTALL 1-1/2" MAKE-UP WATER SUPPLY PIPING, FROM THE EXISTING BLDG. 2 UTILITY WATER SUPPLY IN THE EQUIPMENT YARD TO THE NEW CH-3 FLUID COOLER, INCLUDING WATER FLOW METER (SHIPPED LOOSE WITH CH-3), AND NEW SOV & BFP.
- 5.0 ELECTRICAL
 - 5.1 FINAL CONNECTIONS AND TERMINATIONS OF 480VAC/3/60-60A POWER FEEDER AND EQUIPMENT GROUNDING FROM THE NEW FEEDER TO THE NEW CH-3 FLUID COOLER
 - 5.2 FINAL CONNECTIONS AND TERMINATIONS OF 120VAC/1/60-20A POWER FEEDER AND EQUIPMENT GROUNDING FROM THE NEW FEEDER TO THE NEW CH-3 FLUID COOLER

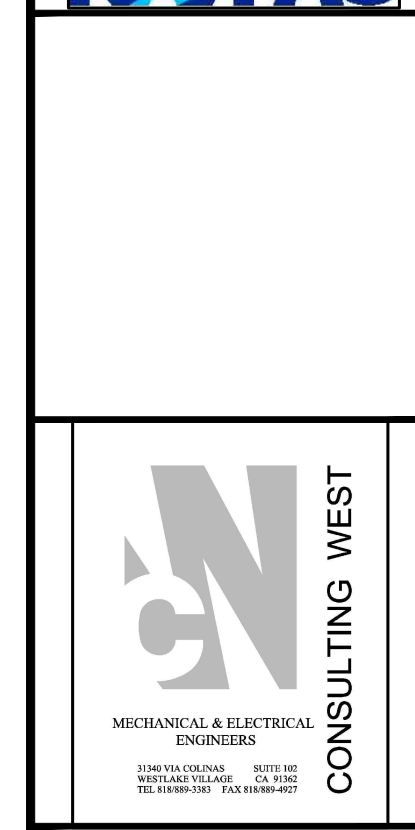
PHASE 3: BUILDING AUTOMATION WORK (SCHEDULE TBD)

- 6.0 BAS CONTROLS
- 6.1 INSTALL NEW ALC ME812U CONTROLLER FOR NEW CH-3 FLUID COOLER; INCLUDING ARCNET 156 COMMUNICATIONS NETWORK CABLE TO EXISTING BAS CONTROLLER 'LGR-1000'
- 6.2 EXTEND NEW BACNET MS/TP COMMUNICATIONS NETWORK CABLE(S) FROM NEW CH-3 FLUID COOLER ON-BOARD PLC (SIEMENS PLC) IN BLDG. 2 EQUIPMENT YARD, TO EXISTING BAS CONTROLLER 'LGR-1000,' TO MONITOR NEW DATA POINTS
- 6.3 INSTALL NEW MODBUS COMMUNICATIONS NETWORK CABLE(S) FROM EXISTING UPS CONTROLS IN BLDG 2 EQUIPMENT YARD ELECTRICAL ROOM, TO EXISTING BAS CONTROLLER 'LGR-1000'
- 6.4 INSTALL (5) NEW ALLEN-BRADLEY 1408 POWER MONITORS; INCLUDING MODBUS COMMUNICATIONS NETWORK CABLE TO EXISTING BAS CONTROLLER 'LGR-1000'
- 6.5 INSTALL (2) NEW CHWS/R FLOW SENSORS; INCLUDING LV SIGNAL CABLES TO THE NEW ALC ME812U CONTROLLER
- 6.6 INSTALL (1) NEW CHWR DIVERTER VALVE ACTUATOR; INCLUDING (3) PAIRS LV SIGNAL CABLES TO THE NEW ALC ME812U CONTROLLER
- 6.7 INSTALL (2) NEW CHWS/R TEMPERATURE SENSORS; INCLUDING LV SIGNAL CABLES TO THE NEW ALC ME812U CONTROLLER
- 6.8 INSTALL (1) DISCRETE BINARY OUTPUT (ON/OFF) ENABLE/DISABLE COMMAND OUTPUT TO CH-3 (SIEMENS PLC)
- 6.9 INSTALL (1) DISCRETE ANALOG OUTPUT (4/20MA) TEMPERATURE SET POINT COMMAND OUTPUT TO CH-3 (SIEMENS PLC)
- 6.10 PROGRAMMING, START-UP, DE-BUG, TEST, AND COMMISSION ALL CONTROLS SYSTEM MODIFICATIONS AND NEW DEVICES PER SEQUENCE OF OPERATIONS AND CONTROLS POINTS LISTS
- 6.11 INSTALL NEW DATA ACQUISITION PC WORKSTATION/SERVER, INCLUDING E-NET/CAT-5 COMMUNICATIONS CABLE TO EXISTING BAS CONTROLLER 'LGR-1000.' PROVIDE DATA ACQUISITION, MONITORING, ALARMS, REPORTING, AND DATA STORAGE, AS DEFINED BY NAVFAC/BROOKHAVEN/EVAPCO.

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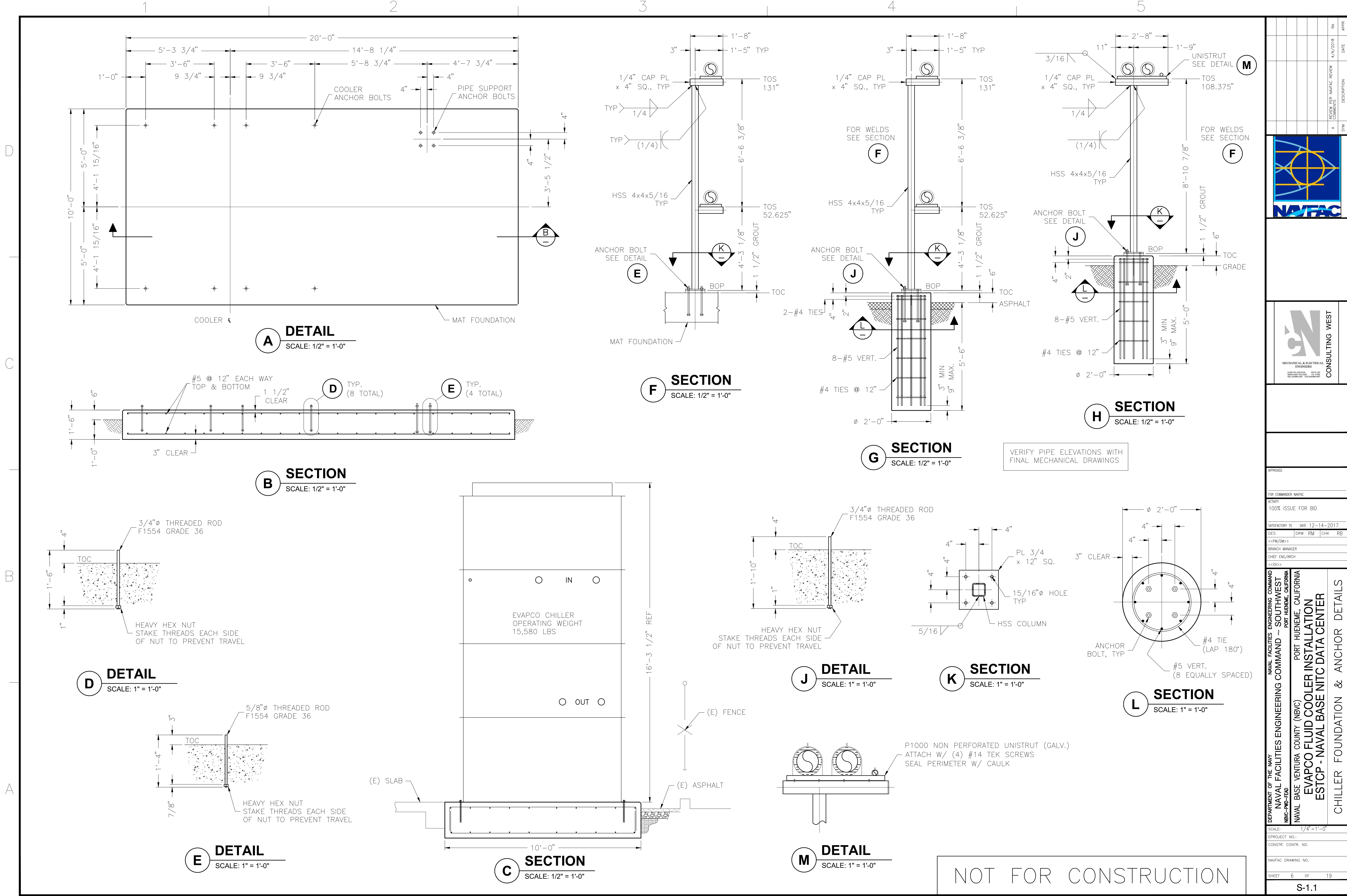
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NAVAL BASE VENTURA COUNTY (NBVC)
PORT HUENEME, CALIFORNIA
EVAPCO FLUID COOLER INSTALLATION
ESTCP - NAVAL BASE NTC DATA CENTER
CHILLER PLANT P&ID
EXISTING & NEW CONDITION

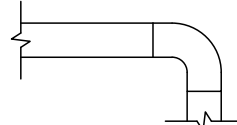
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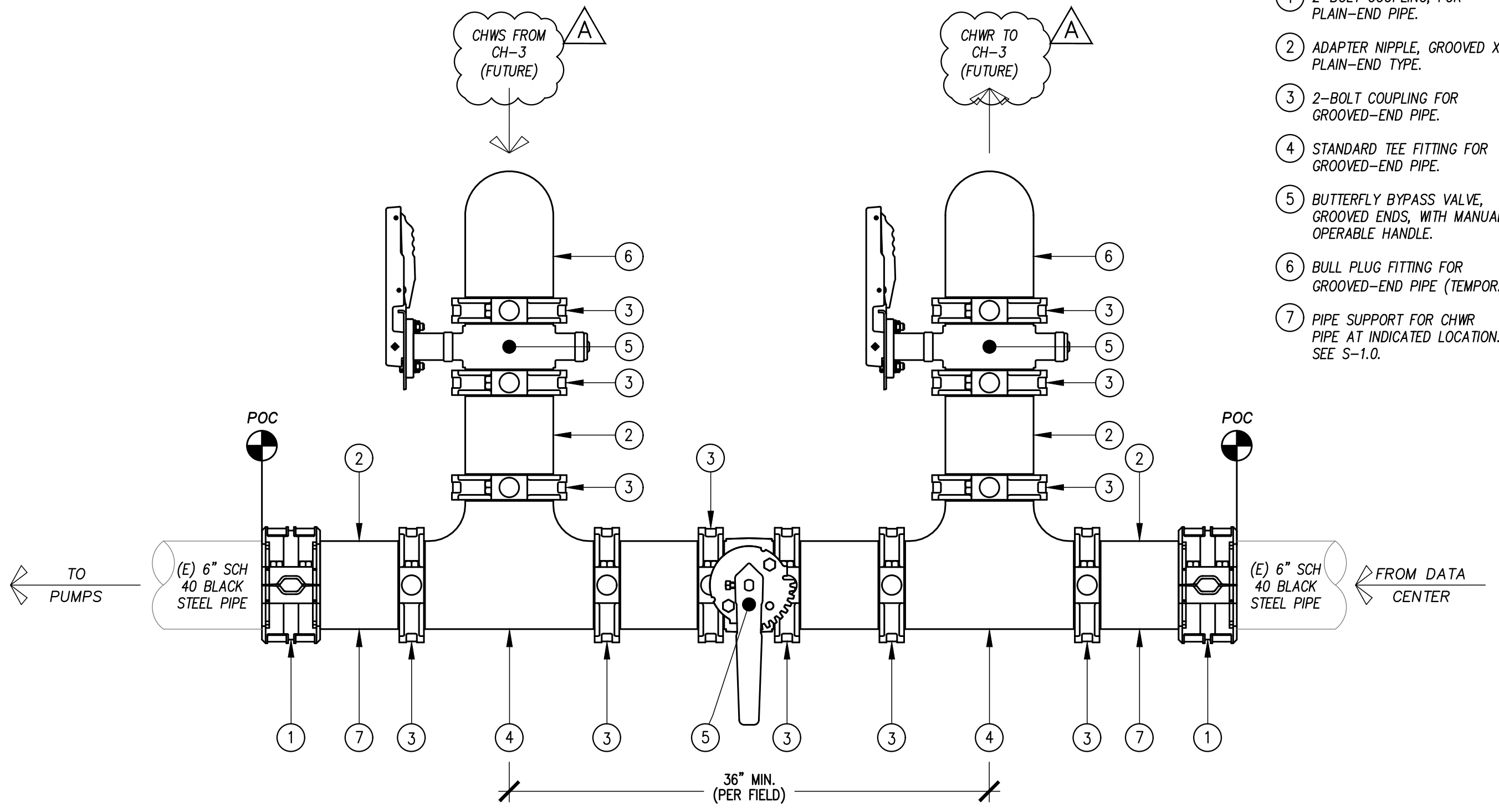
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ABBREVIATION/DEFINITION														GENERAL NOTES									
ABBREV		DEFINITION		ABBREV		DEFINITION		SYMBOL		ABBREV		DEFINITION											
ABV	ABOVE	IN	INCHES											1. SEE G-0.1 FOR SCOPE OF WORK. 2. COORDINATE WORK SCHEDULE WITH NAVFAC TO MINIMIZE INTERRUPTIONS OF DATA CENTER OPERATIONS. 3. SYMBOLS AND ABBREVIATIONS ARE SHOWN FOR REFERENCE; NOT ALL SYMBOLS AND ABBREVIATIONS MAY BE USED.									
AD	ACCESS DOOR	KW	KILOWATT							POD		POINT OF DISCONNECTION											
AFF	ABOVE FINISHED FLOOR	L	LONG																				
AHU	AIR HANDLING UNIT	LAT	LEAVING AIR TEMPERATURE							POC		POINT OF CONNECTION											
AP	ACCESS PANEL	LBS	POUNDS																				
ATC	AUTOMATIC TEMPERATURE CONTROL	LBS/HR	POUNDS/HOUR																				
ARCH	ARCHITECT	LAT	LEAVING AIR TEMPERATURE																				
AF	AIR FILTER	LDB	LEAVING DB TEMPERATURE																				
AS	AIR SEPARATOR	LWT	LEAVING WATER TEMPERATURE							T		THERMOSTAT											
BHP	BRAKE HORSEPOWER	LVG	LEAVING																				
BEL	BELOW	MAX	MAXIMUM																				
B&G	BELL AND GOSSET	MBH	MEGA BTU'S PER HOUR																				
BLDG	BUILDING	MCA	MINIMUM CIRCUIT AMPACITY							CV		CHECK VALVE											
BOP	BOTTOM OF PIPE	MCC	MOTOR CONTROL CENTER																				
BTU	BRITISH THERMO UNITS	MECH	MECHANICAL							STR		STRAINER											
BTU/HR	BRITISH THERMO UNITS PER HOUR	MOC	MAXIMUM OVERCURRENT PROTECTION																				
CAH	COMPUTER ROOM AIR HANDLER	MIN	MINIMUM																				
CC	COOLING COIL	MSTP	MASTER-SLAVE/TOKEN-PASSING																				
CD	CEILING DIFFUSER	MV	MOTOR OPERATED VALVE							BV		BUTTERFLY VALVE											
CFM	CUBIC FEET PER MINUTE	MVD	MANUAL VOLUME DAMPER							BLV		BALL VALVE											
CH	CHILLER	NC	NORMALLY CLOSED																				
CHW	CHILLED WATER	NIC	NOT IN CONTRACT																				
CHWR	CHILLED WATER RETURN	NO	NORMALLY OPEN							U		UNION											
CHWS	CHILLED WATER SUPPLY	NPLV	NON-STANDARD PART LOAD VALUE																				
CHWP	CHILLED WATER PUMP	NTS	NOT TO SCALE																				
CONT	CONTINUATION	O.C.	ON CENTER																				
COMP	COMPRESSOR	OSA	OUTSIDE AIR																				
CONC	CONCRETE	P	PUMP																				
COP	COEFFICIENT OF PERFORMANCE	PD	PRESSURE DROP							CHWS		CHILLED WATER SUPPLY											
CLG	COOLING	PP	PETE'S PLUG																				
CR	CEILING REGISTER	PH	PHASE							CHWR		CHILLED WATER RETURN											
CU	CONDENSING UNIT	PRESS	PRESSURE																				
CV	CHECK VALVE	PRV	PRESSURE REDUCING VALVE																				
CSFD	COMBINATION SMOKE FIRE DAMPER	PS	PRESSURE SWITCH																				
D	DROP	PSI	POUNDS PER SQUARE INCH																				
DB	DRY BULB	PSIA	PSI ABSOLUTE																				
DBa	DECIBELS	PSID	PSI DIFFERENTIAL																				
DIA	DIAMETER	PSIG	PSI GAUGE																				
DIFF	DIFFERENCE	PT	PLUGGED TEE																				
DL	DOOR LOUVER	PTR	PRESSURE-TEMPERATURE RELIEF VALVE																				
DET	DETAIL																						
DEG	DEGREES	PVC	POLYVINYL CHLORIDE PIPE																				
DN	DOWN	PLBG	PLUMBING																				
DR	DRAIN	PLC	PROGRAMMABLE LOGIC CONTROLLER																				
DWG	DRAWING	POC	POINT OF CONNECTION																				
E(NAME)	EXISTING PIPE	POD	POINT OF DISCONNECTION																				
EER	ENERGY EFFICIENCY RATION	QTY	QUANTITY																				
ESP	EXTERNAL STATIC PRESSURE	R	RISE																				
EA	EXHAUST AIR	RLA	ROTOR LOCK AMPS																				
EAT	ENTERING AIR TEMPERATURE	RA	RETURN AIR																				
EAR	EXHAUST AIR REGISTER	RAR	RETURN AIR REGISTER																				
EF	EXHAUST FAN	REG	REGISTER																				
EFF	EFFICIENCY	REQ	REQUIRED																				
EG	EXHAUST GRILLE	RF	RETURN FAN																				
EL	ELEVATION	RG	RETURN GRILLE																				
ENT	ENTERING	RHC	REHEATING COIL																				
ENCL	ENCLOSURE	RM	ROOM																				
EMBED	EMBEDMENT	RPM	REVOLUTIONS PER MINUTE																				
ET	EXPANSION TANK	RV	RELIEF VALVE																				
EWT	ENTERING WATER TEMPERATURE	SA	SUPPLY AIR																				
EXH	EXHAUST	SAD	SUPPLY AIR DIFFUSER																				
EXIST	EXISTING	SAR	SUPPLY AIR REGISTER																				
F°	FAHRENHEIT	SCL	SENSIBLE COOLING LOAD																				
FA	FRESH AIR	SEC	SECONDS																				
FC	FAN COIL	SF	SUPPLY FAN																				
FCU	FAN COIL UNIT	S.S.	STAINLESS STEEL																				
FLA	FULL LOAD AMPERAGE	SMACNA	SHEET METAL & AC NATIONAL ASSOCIATION																				
FLEX	FLEXIBLE																						
FD	FIRE DAMPER	SOV	SHUT OFF VALVE																				
FPM	FEET PER MINUTE	SQ FT	SQUARE FOOT																				
FIG.	FIGURE	STL	STEEL																				
FIN	FINISH	SHT	SHEET																				
FLR	FLOOR	SP	STATIC PRESSURE																				
FT	FLASH TANK	TCL	TOTAL COOLING LOAD																				
FT.	FEET	TEFC	TOTAL ENCLOSED FAN COOLED																				
FT./SEC	FEET PER SECOND	TC	TEMPERATURE CONTROL																				
GA	GAUGE	TG	TRANSFER GRILLE																				
GAL	GALLONS	TEMP	TEMPERATURE																				
GAL.	GALVANIZED	TON	TONNAGE																				
GPM	GALLONS PER MINUTE	TSP	TOTAL STATIC PRESSURE																				
GPH	GALLONS PER HOUR	TYP	TYPICAL																				
H	HIGH	VOL	VOLUME																				
HC	HEATING COIL	UH	UNIT HEATER																				
HWR	HOT WATER RETURN	VOLT	VOLTAGE																				
HWS	HOT WATER SUPPLY	VFD	VARIABLE FREQUENCY DRIVE																				
HP	HORSEPOWER	VD	VOLUME DAMPER																				
HR	HOOR	W	WIDE																				
HVAC	HEATING, VENTILATING AND AIR CONDITIONING	WB	WET BULB																				
HW	HOT WATER	WG	WATER GAUGE (PRESSURE)																				
HWP	HOT WATER PUMP	W/	WITH																				
HX	HEAT EXCHANGER	W/O	WITHOUT																				
HC	HEATING COIL	UPS	UNINTERRUPTED POWER SUPPLY																				
HTG	HEATING																						
HZ	HERTZ																						
ICW	INDUSTRIAL COLD WATER																						

NOT FOR CONSTRUCTION

DEPARTMENT OF THE NAVY
NAVAL FACILITIES ENGINEERING COMMAND ~ SOUTHWEST
NAVFAC-PWD-1240
PORT HUENEME, CALIFORNIA
NAVAL BASE VENTURA COUNTY (NBVC)
PORT HUENEME, CALIFORNIA
EVAPCO FLUID COOLER INSTALLATION
ESTCP - NAVAL BASE NITC DATA CENTER
GENERAL NOTES, SYMBOLS & ABBREVIATION

SCALE: NONE
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CONSTR. CONTR. NO.
NAVFAC DRAWING NO.
SHEET 7 OF 19
M-0.0



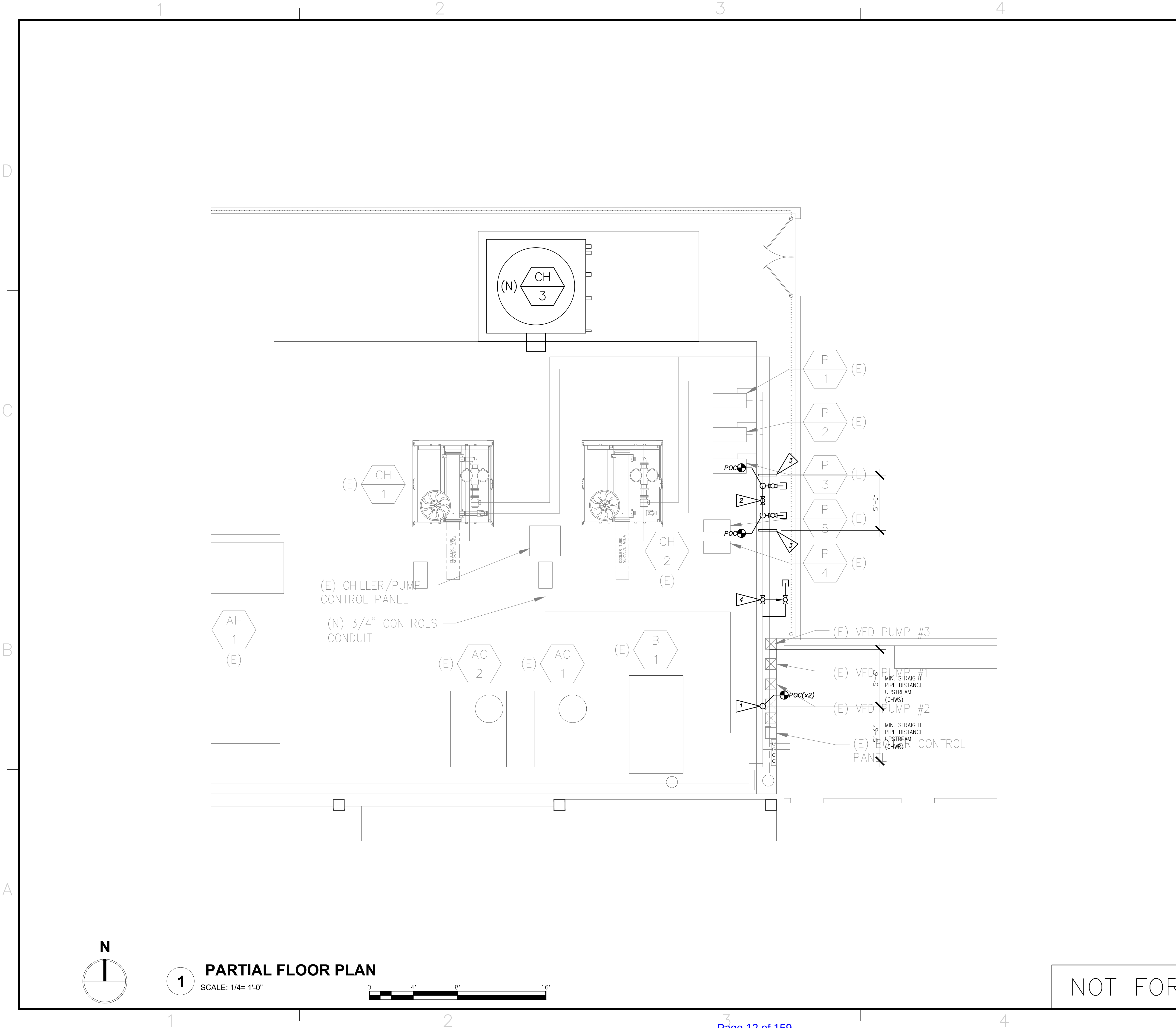
- ### KEY NOTES:
- 1 2-BOLT COUPLING, FOR PLAIN-END PIPE.
 - 2 ADAPTER NIPPLE, GROOVED X PLAIN-END TYPE.
 - 3 2-BOLT COUPLING FOR GROOVED-END PIPE.
 - 4 STANDARD TEE FITTING FOR GROOVED-END PIPE.
 - 5 BUTTERFLY BYPASS VALVE, GROOVED ENDS, WITH MANUAL OPERABLE HANDLE.
 - 6 BULL PLUG FITTING FOR GROOVED-END PIPE (TEMPORARY).
 - 7 PIPE SUPPORT FOR CHWR. PIPE AT INDICATED LOCATION.. SEE S-1.0.

2 CHWR PIPING MODIFICATION W/ ISOLATION/SHUT-OFF & BYPASS VALVES
SCALE: N.T.S.

NEW FLUID COOLER	
TAG	CH-3
LOCATION	BLDG. 2 EQUIP. YARD
MANUFACTURER	EVAPCO
MODEL NO.	ECO-ATWB-H9-3K9-Z-U12
TYPE	HYBRID WET/DRY
DESIGN EAT	65°F
DESIGN EWT/LWT	80.5°F/70.0°F
CAPACITY	144 GPM/937 MBH
FRICTION LOSS	3.1 PSID
AIRFLOW	50,600 CFM
FAN QTY/HP	(1) x 20 HP
SPRAY WATER FLOW	410 GPM
SPRAY PUMP HP	(1) x 2 HP
HEATERS QTY/KW / 1x7 KW	(1) x 7KW
POWER	460 VAC/3/60, 41 FLA
MCA/MOCP	37.2/40 AMPS
EVAPORATION RATE	4 GPM
REQUIRED OPTIONS:	
1.) SAGE 2 CONTROL PANEL (460 VAC)	
2.) SMART SHIELD PACKAGE (FMF-6-4, BCF-10, 120 VAC)	
3.) FACTORY CROSSEVER PIPING	
4.) ARID FIN-PAK (2)	
5.) CROSS-COOL COIL	
6.) PREM. EFFY./ INVERTER-DUTY FAN MOTOR	
7.) IBC STD. STRUCTURAL DESIGN	
8.) ESA-COMPLIANT PUMP MOTOR	
9.) FACTORY WATER METERS (INLET & OUTLET)	
10.) 316 STAINLESS STEEL UPPER	
11.) 316 WELDED STAINLESS STEEL BASIN	
12.) ALUMINUM LADDER	
13.) ON-SITE ASSEMBLY OF ALL COMPONENTS "SHIPPED LOOSE"	
14.) ON-SITE INSTALLATION SUPERVISION & START-UP ASSISTANCE	
NOTE: FLUID COOLER FURNISHED BY OWNER, INSTALLED BY CONTRACTOR.	

3 MECHANICAL EQUIPMENT SCHEDULES
SCALE: N.T.S.

NOT FOR CONSTRUCTION

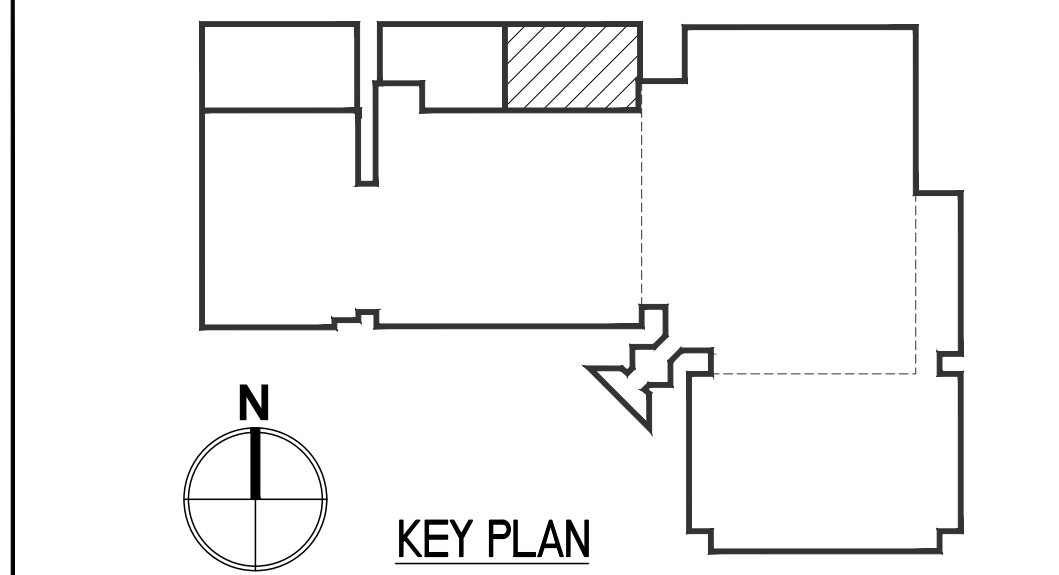


PLAN NOTES

- 1 INSTALL NEW 1" WELDOLET & 1" BALL VALVE (FOR FLOW SENSORS) IN EXISTING 6" CHWS AND CHWR. SEE DETAIL 1, SHEET M-0.1. VERIFY EXACT LOCATION IN FIELD.
- 2 INSTALL NEW 6" SOV & BYPASS VALVES (FOR CONNECTION TO NEW FLUID COOLER 'CH-3') IN EXISTING 6" CHWR PIPING. SEE DETAIL 2, SHEET M-0.1.
- 3 SEE S-1.0 FOR (N) STRUCTURAL PIPING SUPPORT DETAILS.
- 4 FUTURE LOCATION FOR MANUAL SHUT-OFF/BYPASS VALVES FOR EMERGENCY/TEMPORARY CHWS/R CONNECTIONS, SHOWN FOR REFERENCE ONLY (N.I.C.)

GENERAL NOTES

- 1. PRIOR TO START OF WORK, CONTRACTOR SHALL MARK ALL PROPOSED LOCATIONS OF NEW COMPONENTS, AND ALL PROPOSED ROUTING OF PIPING & CONDUITS FOR REVIEW & APPROVAL BY OWNER'S REP. (NAVFAC).
- 2. ALL WORK SHALL COMPLY WITH NAVFAC STANDARD SPECIFICATIONS AND SITE-SPECIFIC REQUIREMENTS.
- 3. ALL NEW WORK IS SHOWN IN BOLD LINETYPE. EXISTING CONDITIONS ARE SHOWN IN LIGHT GRAY. (E) = EXISTING (N) = NEW WORK



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REVIEW PER NAVFAC REVIEW COMMENTS		DATE	APPROVED
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NAVAL FACILITIES ENGINEERING COMMAND			
NAVAL FACILITIES ENGINEERING COMMAND - SOUTHWEST			
PORT HUENEME, CALIFORNIA			
NAVAL BASE VENTURA COUNTY (NBVC)			
PORT HUENEME, CALIFORNIA			
EVAPCO FLUID COOLER INSTALLATION			
ESTCP - NAVAL BASE NITC DATA CENTER			
MODIFICATIONS TO EXISTING CHWR PIPING			
SCALE: 1/4" = 1'-0"			
PROJECT NO.			
CONSTR. CONTR. NO.			
NAVFAC DRAWING NO.			
SHEET 9 OF 19			
M-1.0			

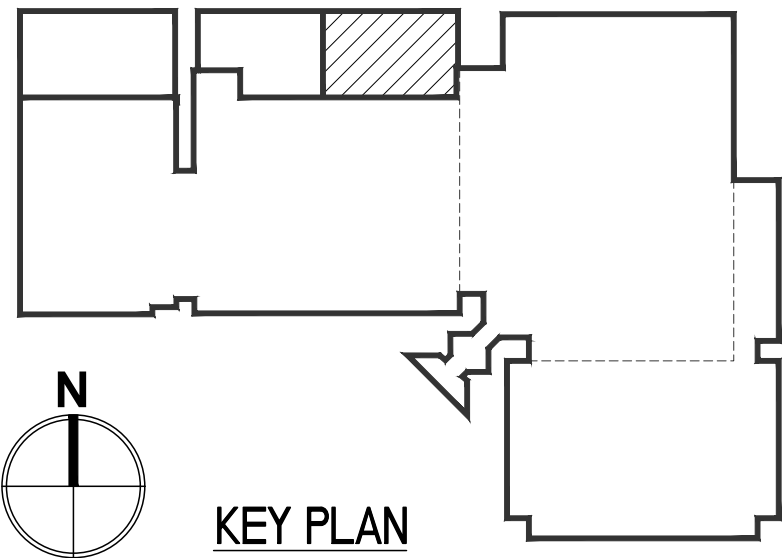
NOTE:
UTILITY LOCATOR SERVICE REQUIRED PRIOR TO ALL DIGGING > 12" DEPTH. COORDINATE WITH
OWNER TO APPLY FOR AND OBTAIN A DIG PERMIT. MINIMUM 21-DAY ADVANCE NOTICE REQUIRED.

PLAN NOTES

- NEW 6" CHW IN/OUT PIPING FROM BLDG. 2 CHWR PIPE (E) BOP=86" TO NEW 'CH-3' FLUID COOLER (IN/OUT CONNECTIONS BOP=72.88"). INCLUDE WYE STRAINER AND MANUAL DRAIN/ISOLATION/BYPASS VALVES PER D-1.0.
- INSTALL NEW 3-WAY 2-POSITION DIVERTING VALVE (PROVIDED BY CONTROLS CONTRACTOR) PER D-1.0.
- MAKE UP WATER SOURCE: PROVIDE P.O.C. TO EXISTING 1 1/2" WATER STAND-PIPE AND EXTEND OVERHEAD, USING EXISTING OR NEW RACK SUPPORTS, TO 'CH-3'.
- WATER MAKE UP FINAL CONNECTION: INCLUDE SOV AND BACKFLOW DEVICE.
- PROVIDE NEW CHAIN LINK FENCE ACCESS GATE, 7'-0" WIDE, HINGED, DOUBLE-SIDED, WIT LOCKABLE LATCH HARDWARE (PADLOCK BY OTHERS).
- EXISTING ACCESS GATE, SHOWN FOR REFERENCE.
- FUTURE LOCATION FOR MANUAL SHUT-OFF/BYPASS VALVES FOR EMERGENCY/TEMPORARY CHWS/R CONNECTIONS, SHOWN FOR REFERENCE ONLY (N.I.C.).
- SEE S-1.0 FOR (N) STRUCTURAL PIPING SUPPORT DETAILS.
- 3" OVERFLOW AND BLOWDOWN. PROVIDE EXTENSION TO SITE DRAIN SYSTEM, CONTINUED ON P-1.0.
- 2" BASIN DRAIN: PROVIDE EXTENSION TO SITE DRAIN SYSTEM, CONTINUED ON P-1.0.

GENERAL NOTES

- PRIOR TO START OF WORK, CONTRACTOR SHALL MARK ALL PROPOSED LOCATIONS OF NEW COMPONENTS, AND ALL PROPOSED ROUTING OF PIPING & CONDUITS FOR REVIEW & APPROVAL BY OWNER'S REP. (NAVFAC).
- ALL WORK SHALL COMPLY WITH NAVFAC STANDARD SPECIFICATIONS AND SITE-SPECIFIC REQUIREMENTS.
- EXISTING CHWS/R PIPE MATERIAL IS SCH 40 BLACK STEEL WITH 1" THICK INSULATION, VAPOR BARRIER, AND ALUM. JACKET.
- NEW PIPING SHALL MATCH EXISTING.



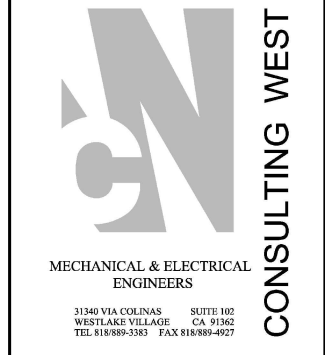
PARTIAL FLOOR PLAN

SCALE: 1/4" = 1'-0"



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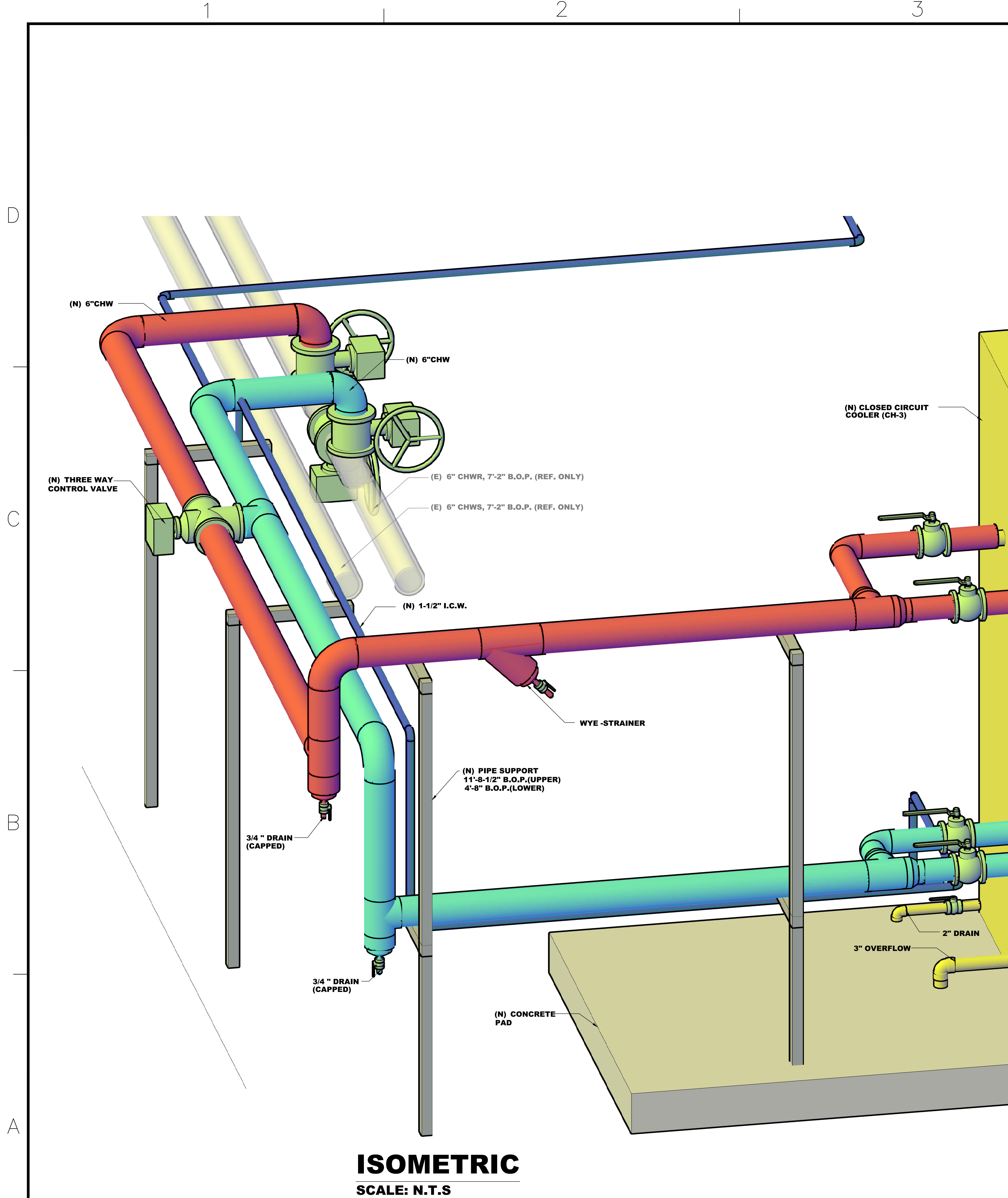


MECHANICAL & ELECTRICAL ENGINEERS
CONSULTING WEST
10000 VAN DYKE BLVD., SUITE 100
VAN DYKE, CA 94134
TEL: 415.435.1000 FAX: 415.435.1001

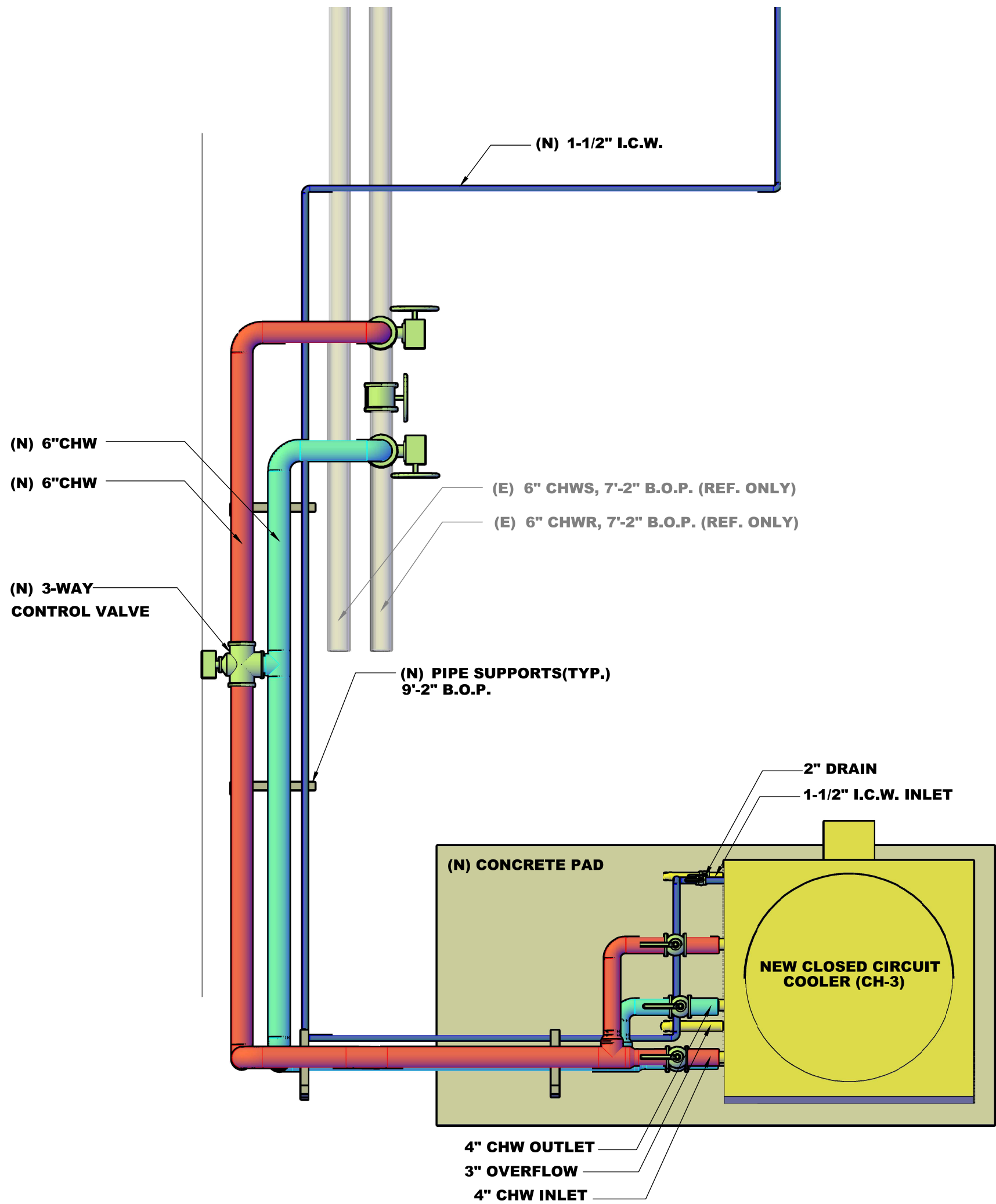
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ACTIVITY	100% ISSUE FOR BID
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BRANCH MANAGER	
CHIEF ENG/ARCH	
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DEPARTMENT OF THE NAVY
NAVAL FACILITIES ENGINEERING COMMAND ~ SOUTHWEST
PORT HUENEME, CALIFORNIA
NAVAL BASE VENTURA COUNTY (NBVC)
PORT HUENEME, CALIFORNIA
EVAPCO FLUID COOLER INSTALLATION
ESTCP - NAVAL BASE NITC DATA CENTER
NEW FLUID COOLER 'CH-3' TIE-IN

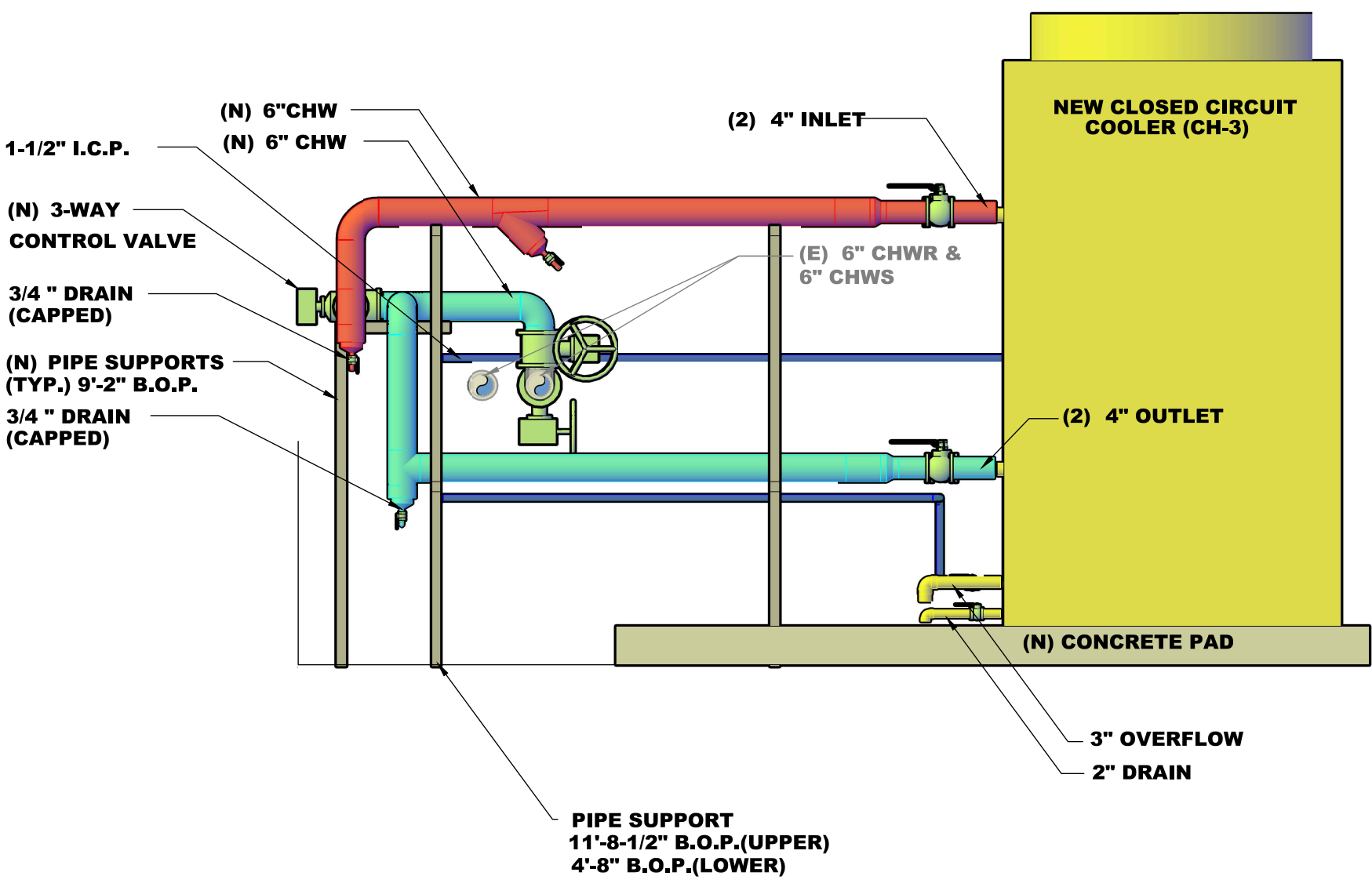
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CONSTR. CONTR. NO.	
NAVFAC DRAWING NO.	
SHEET	10 OF 19
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ISOMETRIC
SCALE: N.T.S



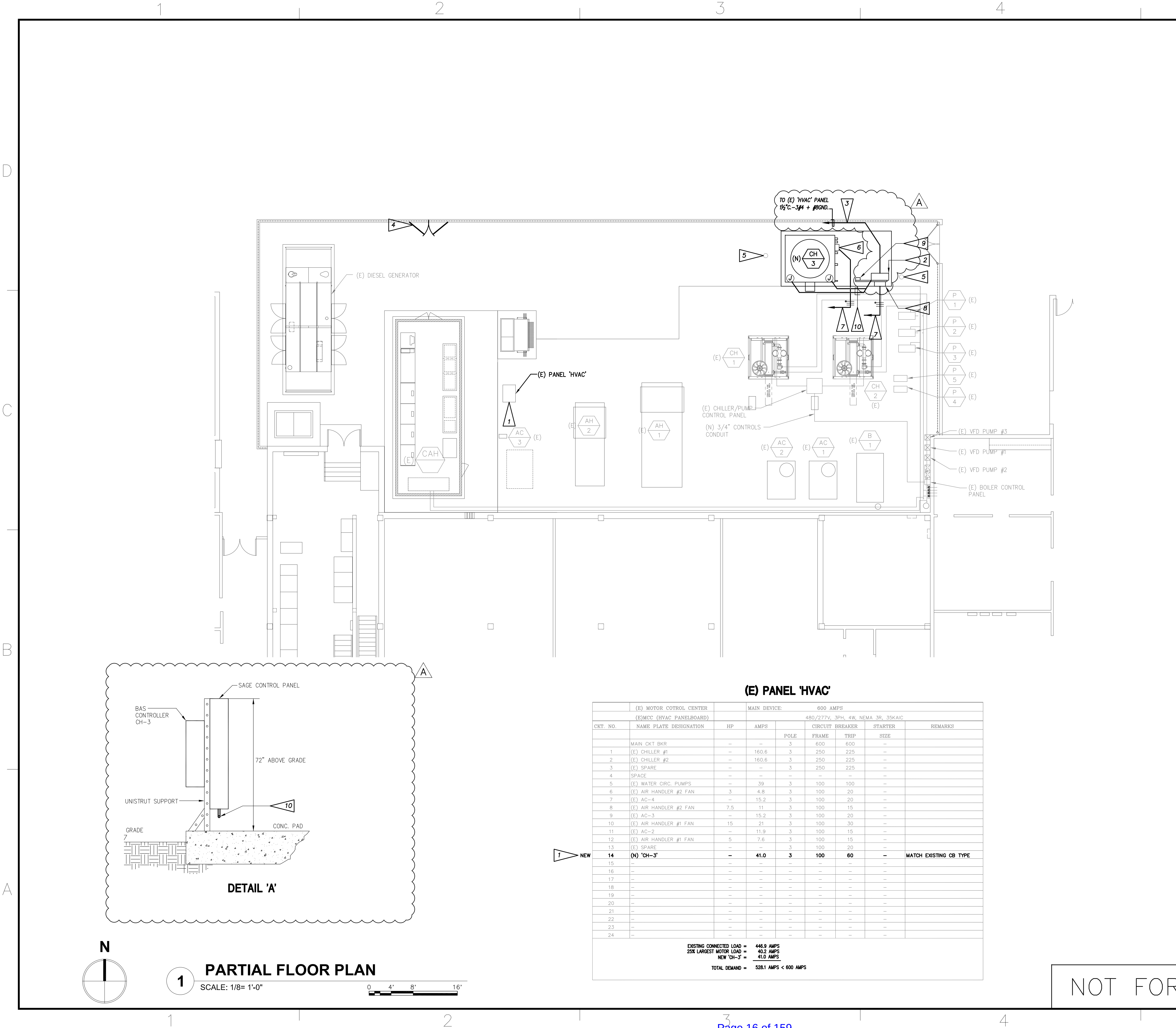
TOP
SCALE: 1/4\"-1'



PROFILE
SCALE: 1/4\"-1'

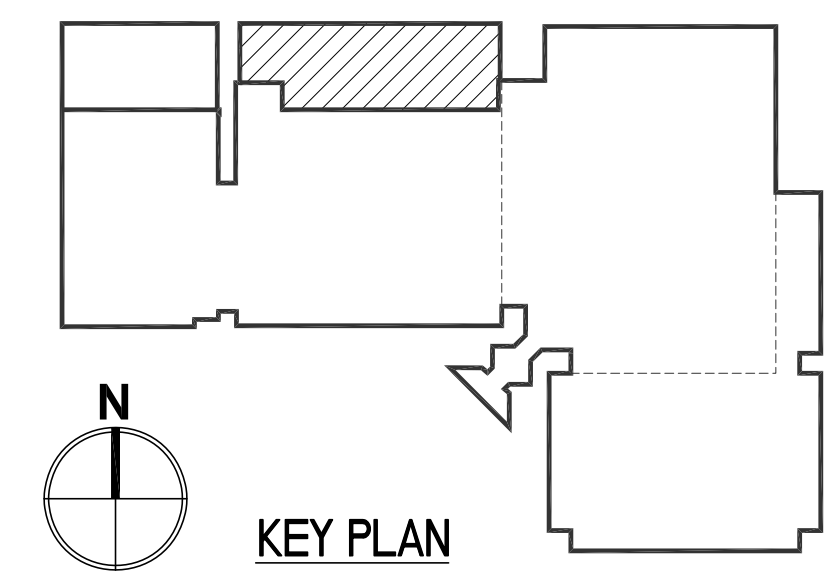
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NAVAL FACILITIES ENGINEERING COMMAND			
NAVAL FACILITIES ENGINEERING COMMAND - SOUTHWEST			
PORT HUENEME, CALIFORNIA			
NAVAL BASE VENTURA COUNTY (NBVC)			
PORT HUENEME, CALIFORNIA			
EVAPCO FLUID COOLER INSTALLATION			
ESTCP - NAVAL BASE NITC DATA CENTER			
NEW FLUID COOLER 'CH-3' PIPING DETAILS			
SCALE: AS SHOWN			
PROJECT NO.:			
CONSTR. CONTR. NO.			
NAVFAC DRAWING NO.			
SHEET 10 OF 19			
M-4.0			



- ### PLAN NOTES
- 1 PROVIDE NEW CUTLER-HAMMER 100AF-60AT 3-POLE-35KAIC CIRCUIT BREAKER IN THE AVAILABLE SPACE AT EXISTING PANEL 'HVAC'. MATCH EXISTING ADJACENT BREAKERS. VERIFY IN FIELD.
 - 2 SAGE CONTROL PANEL: PROVIDE FINAL CONNECTION TO MAIN CIRCUIT BREAKER IN CONTROL PANEL. VERIFY LOCATION IN FIELD. (PROVIDED WITH CH-3)
 - 3 PROVIDE NEW OVERHEAD CONDUIT & WIRING FROM 'HVAC' PANEL TO 'CH-3' CONTROL PANEL. USE SEMI-RIGID CONDUIT SUITABLE FOR EXPOSED OUTDOOR WET LOCATIONS. SUPPORT CONDUITS USING UNISTRUT SYSTEM. EXISTING PIPE/CONDUIT RACKS MAY BE UTILIZED WHERE APPROPRIATE. VERIFY CONDITIONS IN FIELD.
 - 4 NEW CHAIN LINK FENCE ACCESS GATE, SHOWN FOR REFERENCE.
 - 5 EXISTING "ANODE" TRAFFIC COVER FOR UNDERGROUND CORROSION PROTECTION SYSTEM, TO REMAIN.
 - 6 EVAPCO CONDUCTIVITY CONTROLLER: 120V-1Ø-100VA. MAKE FINAL CONNECTION AS REQUIRED.
 - 7 3/4"C-3#12 W/ GND. HOME RUN TO NEAREST 120V-1Ø SOURCE PANEL. OBTAIN APPROVAL OF 'NAVFAC' PRIOR TO TIE-IN. (2 LOCATIONS)
 - 8 NEW BAS CONTROLLER 'CH-3' SEE DETAIL "A" FOR MOUNTING DETAILS. 120-1Ø-250VA MAKE FINAL CONNECTION. (PROVIDED BY CONTROLS CONTRACTOR).
 - 9 FUSED DISCONNECT SWITCH (PROVIDED WITH CH-3)
 - 10 FIELD CONDUIT & WIRING FOR CH-3 POWER & CONTROLS. MULTIPLE POINTS OF CONNECTION (VERIFY IN FIELD) REFER TO CH-3 MANUFACTURER'S INSTALLATION DOCUMENTS FOR DETAILED REQUIREMENTS.

- ### GENERAL NOTES
- 1. PRIOR TO START OF WORK, CONTRACTOR SHALL MARK ALL PROPOSED LOCATIONS OF NEW COMPONENTS, AND ALL PROPOSED ROUTING OF PIPING & CONDUITS FOR REVIEW & APPROVAL BY OWNER'S REP. (NAVFAC).
 - 2. ALL WORK SHALL COMPLY WITH NAVFAC STANDARD SPECIFICATIONS AND SITE-SPECIFIC REQUIREMENTS.



REVIEW BY: NAVFAC REVIEW
DATE: 4/19/2018
SYN

APPROVED
FOR COMMANDER NAVFAC
ACTIVITY: 100% ISSUE FOR BID
SATISFACTORY TO: DATE: 12-14-2017
DES: <<PM/DM>>
BRANCH MANAGER
CHIEF ENG/ARCH
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NAVFAC DRAWING NO.
SHEET 13 OF 19
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PORT HUENEME, CALIFORNIA
EVAPCO FLUID COOLER INSTALLATION
ESTCP - NAVAL BASE NTC DATA CENTER
NEW ELECTRICAL FEEDERS

SCALE: 1/8" = 1'-0"
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CONSTR. CONTR. NO.:
NAVFAC DRAWING NO.:
SHEET 13 OF 19
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PARTIAL FLOOR PLAN

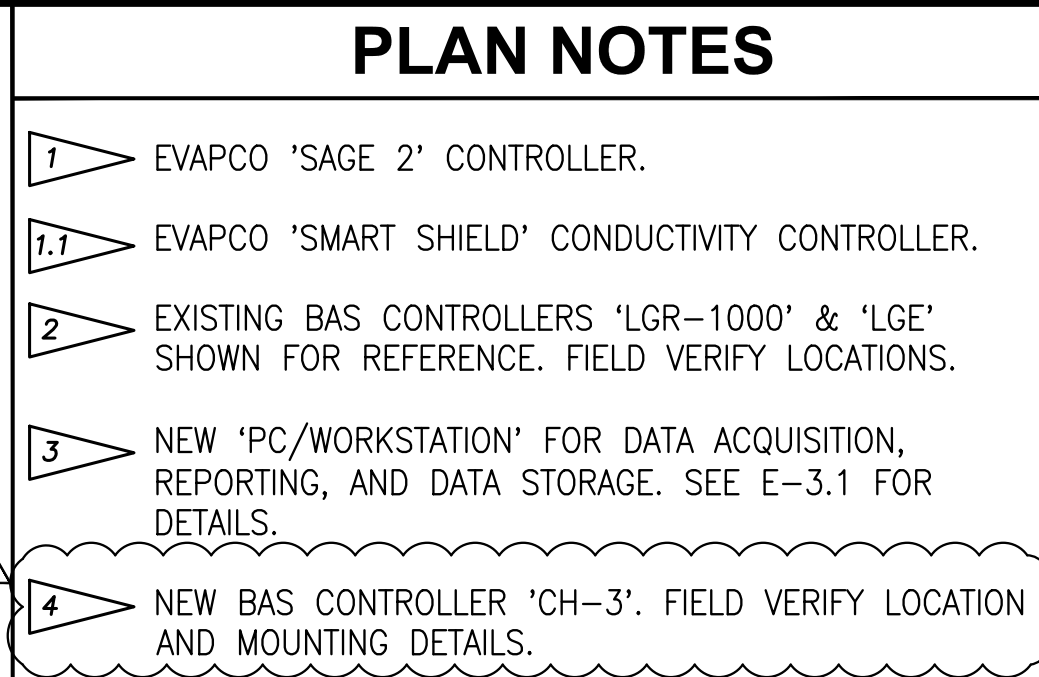
SCALE: 1/8" = 1'-0"

(E) PANEL 'HVAC'

(B) MOTOR CONTROL CENTER		(E) MOTOR CONTROL CENTER		MAIN DEVICE: 600 AMPS				REMARKS	
(E)MCC (HVAC PANELBOARD)		480/277V, 3PH, 4W, NEMA 3R, 35KAIC							
CKT. NO.	NAME PLATE DESIGNATION	HP	AMPS	CIRCUIT BREAKER	STARTER	SIZE			
			POLE	FRAME	TRIP	SIZE			
	MAIN CKT BKR	—	—	3	600	600	—		
1	(E) CHILLER #1	—	160.6	3	250	225	—		
2	(E) CHILLER #2	—	160.6	3	250	225	—		
3	(E) SPARE	—	—	3	250	225	—		
4	SPACE	—	—	—	—	—	—		
5	(E) WATER CIRC. PUMPS	—	39	3	100	100	—		
6	(E) AIR HANDLER #2 FAN	3	4.8	3	100	20	—		
7	(E) AC-4	—	15.2	3	100	20	—		
8	(E) AIR HANDLER #2 FAN	7.5	11	3	100	15	—		
9	(E) AC-3	—	15.2	3	100	20	—		
10	(E) AIR HANDLER #1 FAN	15	21	3	100	30	—		
11	(E) AC-2	—	11.9	3	100	15	—		
12	(E) AIR HANDLER #1 FAN	5	7.6	3	100	15	—		
13	(E) SPARE	—	—	3	100	20	—		
14	(N) 'CH-3'	—	41.0	3	100	60	—		
15	—	—	—	—	—	—	MATCH EXISTING CB TYPE		
16	—	—	—	—	—	—	—		
17	—	—	—	—	—	—	—		
18	—	—	—	—	—	—	—		
19	—	—	—	—	—	—	—		
20	—	—	—	—	—	—	—		
21	—	—	—	—	—	—	—		
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24	—	—	—	—	—	—	—		

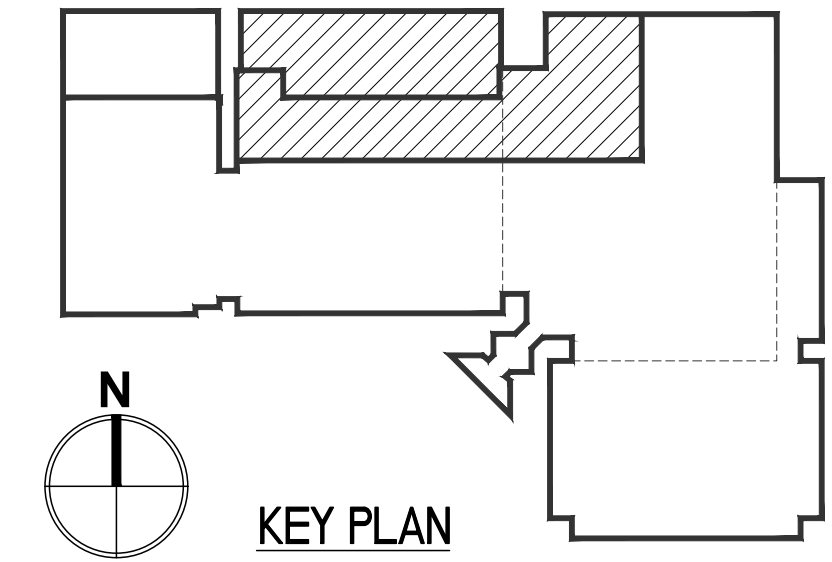
EXISTING CONNECTED LOAD = 446.9 AMPS
25% LARGEST MOTOR LOAD = 40.2 AMPS
NEW 'CH-3' = 41.0 AMPS
TOTAL DEMAND = 528.1 AMPS < 600 AMPS

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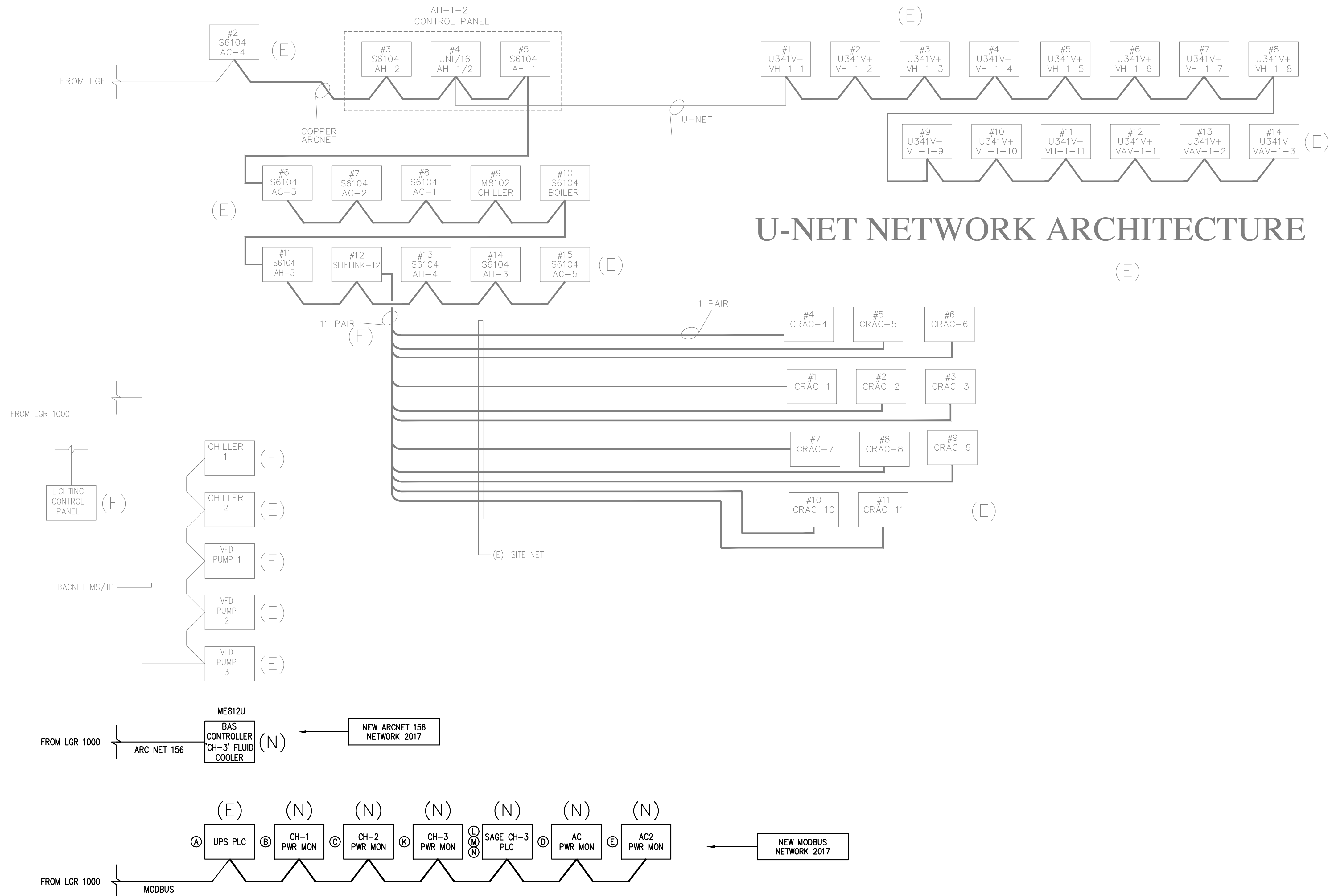


GENERAL NOTES

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2. ALL WORK SHALL COMPLY WITH NAVFAC STANDARD SPECIFICATIONS AND SITE-SPECIFIC REQUIREMENTS.



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NETWORK ARCHITECTURE

NOT FOR CONSTRUCTION

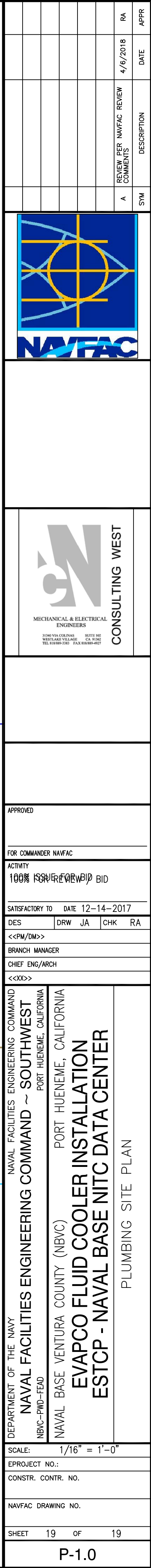
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FOR COMMANDER NAVFAC			
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BRANCH MANAGER			
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DEPARTMENT OF THE NAVY
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NAVFAC PWD-PCO
NAVAL BASE VENTURA COUNTY (NBVC)
PORT HUENEME, CALIFORNIA
EVAPCO FLUID COOLER INSTALLATION
ESTCP - NAVAL BASE NTC DATA CENTER
NETWORK ARCHITECTURE

SCALE:		NONE	
PROJECT NO.:			
CONSTR. CONTR. NO.:			
NAVFAC DRAWING NO.:			
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Section 2. Specifications

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DIVISION 22 - PLUMBING

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23 05 15 COMMON PIPING FOR HVAC
23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS
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SECTION 01 33 00

SUBMITTAL PROCEDURES

PART 1 GENERAL

1.1 DEFINITIONS

1.1.1 Submittal Descriptions (SD)

Submittals requirements are specified in the technical sections. Submittals are identified by Submittal Description (SD) numbers and titles as follows:

[SD-01 Preconstruction Submittals](#)

Submittals which are required prior to start of construction

Certificates of insurance

List of proposed Subcontractors

List of proposed products

Construction progress schedule

Submittal register

Health and safety plan

Work plan

Quality Control(QC) plan

Environmental protection plan

[SD-02 Shop Drawings](#)

Drawings, diagrams and schedules specifically prepared to illustrate some portion of the work.

Diagrams and instructions from a manufacturer or fabricator for use in producing the product and as aids to the Contractor for integrating the product or system into the project.

Drawings prepared by or for the Contractor to show how multiple systems and interdisciplinary work will be coordinated.

[SD-03 Product Data](#)

Catalog cuts, illustrations, schedules, diagrams, performance charts, instructions and brochures illustrating size, physical appearance and other characteristics of materials, systems or equipment for some portion of the work.

Samples of warranty language when the contract requires extended product warranties.

SD-06 Test Reports

Report signed by authorized official of testing laboratory that a material, product or system identical to the material, product or system to be provided has been tested in accord with specified requirements. Unless specified in another section, testing must have been within three years of date of contract award for the project.

Report which includes findings of a test required to be performed by the Contractor on an actual portion of the work or prototype prepared for the project before shipment to job site.

Report which includes finding of a test made at the job site or on sample taken from the job site, on portion of work during or after installation.

Investigation reports.

Daily logs and checklists.

Final acceptance test and operational test procedure.

SD-07 Certificates

Statements printed on the manufacturer's letterhead and signed by responsible officials of manufacturer of product, system or material attesting that product, system or material meets specification requirements. Must be dated after award of project contract and clearly name the project.

Document required of Contractor, or of a manufacturer, supplier, installer or Subcontractor through Contractor. The document purpose is to further promote the orderly progression of a portion of the work by documenting procedures, acceptability of methods or personnel qualifications.

SD-11 Closeout Submittals

Documentation to record compliance with technical or administrative requirements or to establish an administrative mechanism.

Submittals required for Guiding Principle Validation (GPV) or Third Party Certification (TPC).

Special requirements necessary to properly close out a construction contract. For example, Record Drawings and as-built drawings. Also, submittal requirements necessary to properly close out a major phase of construction on a multi-phase contract.

1.1.2 Approving Authority

Office or designated person authorized to approve submittal.

1.1.3 Work

As used in this section, on- and off-site construction required by contract documents, including labor necessary to produce submittals, construction,

materials, products, equipment, and systems incorporated or to be incorporated in such construction.

1.2 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for Designer of Record approval.

1.3 SUBMITTAL CLASSIFICATION

Submittals are classified as follows:

1.3.1 Designer of Record Approved (DA)

Designer of Record (DOR) approval is required for extensions of design, critical materials, any deviations from the solicitation, the accepted proposal, or the completed design, equipment whose compatibility with the entire system must be checked, and other items as designated by the Contracting Officer. Within the terms of the Contract Clause SPECIFICATIONS AND DRAWINGS FOR CONSTRUCTION, they are considered to be "shop drawings." Contractor to provide the Government with the number of copies designated hereinafter of all DOR approved submittals. The Government may review any or all Designer of Record approved submittals for conformance to the Solicitation, Accepted Proposal and the completed design. The Government will review all submittals designated as deviating from the Solicitation or Accepted Proposal, as described below.

1.3.2 Government Approved (G)

Government approval is required for extensions of design, critical materials, deviations, equipment whose compatibility with the entire system must be checked, and other items as designated by the Contracting Officer. Government approval is required for any deviations from the Solicitation or Accepted Proposal and other items as designated by the Contracting Officer. Within the terms of the Contract Clause SPECIFICATIONS AND DRAWINGS FOR CONSTRUCTION, they are considered to be "shop drawings."

1.4 FORWARDING SUBMITTALS REQUIRING GOVERNMENT APPROVAL

1.4.1 Submittals Required from the Contractor

As soon as practicable after award of contract, and before procurement of fabrication, forward to the Architect-Engineer: Consulting West Engineers, submittals required in the technical sections of this specification, including shop drawings and product data. Forward one copy of the transmittal form for all submittals to the Resident Officer in Charge of Construction.

The Architect-Engineer for this project will review and approve for the Contracting Officer those submittals reserved for Contracting Officer approval to verify submittals comply with the contract requirements.

1.5 PREPARATION

1.5.1 Transmittal Form

Transmit submittals with transmittal form prescribed by Contracting Administrator and standard for project. On the transmittal form identify Contractor, indicate date of submittal, and include information prescribed by transmittal form and required in paragraph IDENTIFYING SUBMITTALS of this section.

1.5.2 Identifying Submittals

When submittals are provided by a Subcontractor, the Prime Contractor is to prepare, review and stamp with Contractor's approval all specified submittals prior to submitting for Government approval.

Identify submittals with the following information permanently adhered to or noted on each separate component of each submittal and noted on transmittal form. Mark each copy of each submittal identically, with the following:

- a. Project title and location.
- b. Construction contract number.
- c. Date of the drawings and revisions.
- d. Name, address, and telephone number of subcontractor, supplier, manufacturer and any other subcontractor associated with the submittal.
- e. Section number of the specification section by which submittal is required.
- f. Submittal description (SD) number of each component of submittal.
- g. When a resubmission, add alphabetic suffix on submittal description, for example, submittal 18 would become 18A, to indicate resubmission.
- h. Product identification and location in project.

1.5.3 Format for SD-02 Shop Drawings

Shop drawings are not to be less than 8 1/2 by 11 inches nor more than 30 by 42 inches, except for full size patterns or templates. Prepare drawings to accurate size, with scale indicated, unless other form is required. Drawings are to be suitable for reproduction and be of a quality to produce clear, distinct lines and letters with dark lines on a white background.

Present 8 1/2 by 11 inches sized shop drawings as part of the bound volume for submittals required by section. Present larger drawings in sets.

Include on each drawing the drawing title, number, date, and revision numbers and dates, in addition to information required in paragraph IDENTIFYING SUBMITTALS.

Number drawings in a logical sequence. Contractors may use their own number system. Each drawing is to bear the number of the submittal in a uniform location adjacent to the title block. Place the Government contract number in the margin, immediately below the title block, for each drawing.

Reserve a blank space, no smaller than 1.0 inches on the right hand side of each sheet for the Government disposition stamp.

Dimension drawings, except diagrams and schematic drawings; prepare drawings demonstrating interface with other trades to scale. Use the same unit of measure for shop drawings as indicated on the contract drawings. Identify materials and products for work shown.

Include the nameplate data, size and capacity on drawings. Also include applicable federal, military, industry and technical society publication references.

Submit drawings PDF format.

1.5.4 Format of SD-03 Product Data

Present product data submittals for each section as a complete, bound volume. Include table of contents, listing page and catalog item numbers for product data.

Indicate, by prominent notation, each product which is being submitted; indicate specification section number and paragraph number to which it pertains.

Include the manufacturer's name, trade name, place of manufacture, and catalog model or number on product data. Also include applicable federal, military, industry and technical society publication references.

Where equipment or materials are specified to conform to industry and technical society reference standards of the organizations such as American National Standards Institute (ANSI), ASTM International (ASTM), National Electrical Manufacturer's Association (NEMA), Underwriters Laboratories (UL), and Association of Edison Illuminating Companies (AEIC), submit proof of such compliance. The label or listing by the specified organization will be acceptable evidence of compliance. In lieu of the label or listing, submit a certificate from an independent testing organization, competent to perform testing, and approved by the Contracting Officer. State on the certificate that the item has been tested in accordance with the specified organization's test methods and that the item complies with the specified organization's reference standard.

Collect required data submittals for each specific material, product, unit of work, or system into a single submittal and marked for choices, options, and portions applicable to the submittal. Mark each copy of the product data identically. Partial submittals will be accepted for expedition of construction effort.

Submit manufacturer's instructions prior to installation.

1.5.5 Format of SD-06 Test Reports

Provide reports on 8 1/2 by 11 inches paper in a complete bound volume.

Indicate by prominent notation, each report in the submittal. Indicate specification number and paragraph number to which it pertains.

1.5.6 Format of SD-01 and SD-11 Preconstruction and Closeout Submittals

When submittal includes a document, which is to be used in project or become part of project record, other than as a submittal, do not apply Contractor's approval stamp to document, but to a separate sheet accompanying document.

1.5.7 Source Drawings for Shop Drawings

The entire set of Source Drawing files (DWG) will not be provided to the Contractor. Only those requested by the Contractor to prepare shop drawings may be provided. Request the specific Drawing Number only for the preparation of Shop Drawings. These drawings may only be provided after award.

1.5.7.1 Terms and Conditions

Data contained on these electronic files must not be used for any purpose other than as a convenience in the preparation of construction data for the referenced project. Any other use or reuse shall be at the sole risk of the Contractor and without liability or legal exposure to the Government. The Contractor must make no claim and waives to the fullest extent permitted by law, any claim or cause of action of any nature against the Government, its agents or sub consultants that may arise out of or in connection with the use of these electronic files. The Contractor must, to the fullest extent permitted by law, indemnify and hold the Government harmless against all damages, liabilities or costs, including reasonable attorney's fees and defense costs, arising out of or resulting from the use of these electronic files.

These electronic Source Drawing files are not construction documents. Differences may exist between the Source Drawing files and the corresponding construction documents. The Government makes no representation regarding the accuracy or completeness of the electronic Source Drawing files, nor does it make representation to the compatibility of these files with the Contractor hardware or software. In the event that a conflict arises between the signed and sealed construction documents prepared by the Government and the furnished Source Drawing files, the signed and sealed construction documents govern. The Contractor is responsible for determining if any conflict exists. Use of these Source Drawing files does not relieve the Contractor of duty to fully comply with the contract documents, including and without limitation, the need to check, confirm and coordinate the work of all contractors for the project. If the Contractor uses, duplicates or modifies these electronic Source Drawing files for use in producing construction data related to this contract, remove all previous indicia of ownership (seals, logos, signatures, initials and dates).

1.6 QUANTITY OF SUBMITTALS

Provide submittals in electronic format. In addition to the electronic submittal, provide three hard copies of the submittals. Compile the submittal file as a single, complete document, to include the Transmittal Form described within. Name the electronic submittal file specifically according to its contents, coordinate the file naming convention with the Contracting Officer. Electronic files must be of sufficient quality that all information is legible. Electronic format shall be in PDF, unless otherwise specified or directed by the Contracting Officer. Generate PDF files from original documents with bookmarks so that the text included in the PDF file is both searchable and can be copied. If documents are scanned, Optical Character Resolution (OCR) routines are required. Index and bookmark files

exceeding 30 pages to allow efficient navigation of the file. When required, the electronic file must include a valid electronic signature, or scan of a signature.

Email electronic submittal documents fewer than 10MB to an email address as directed by the Contracting Officer. Provide electronic documents over 10MB through an electronic file sharing system such as the AMRDEC SAFE Web Application located at the following website:
<https://safe.amrdec.army.mil/safe/>.

Provide hard copies of submittals when requested by the Contracting Officer. Up to two additional hard copies of any submittal may be requested at the discretion of the Contracting Officer, at no additional cost to the Government.

1.7 VARIATIONS

Variations from contract requirements require both Designer of Record (DOR) and Government approval pursuant to contract Clause FAR 52.236-21 and will be considered where advantageous to Government.

1.7.1 Considering Variations

Discussion with Contracting Officer prior to submission, after consulting with the DOR, will help ensure functional and quality requirements are met and minimize rejections and re-submittals. When contemplating a variation which results in lower cost, consider submission of the variation as a Value Engineering Change Proposal (VECP).

Specifically point out variations from contract requirements in transmittal letters. Failure to point out deviations may result in the Government requiring rejection and removal of such work at no additional cost to the Government.

1.7.2 Proposing Variations

When proposing variation, deliver written request to the Contracting Officer, with documentation of the nature and features of the variation and why the variation is desirable and beneficial to Government, including the DOR's written analysis and approval. If lower cost is a benefit, also include an estimate of the cost savings. In addition to documentation required for variation, include the submittals required for the item. Clearly mark the proposed variation in all documentation.

1.7.3 Warranting that Variations are Compatible

When delivering a variation for approval, Contractor, including its Designer(s) of Record, warrants that this contract has been reviewed to establish that the variation, if incorporated, will be compatible with other elements of work.

1.7.4 Review Schedule is Modified

In addition to normal submittal review period, a period of 10 working days will be allowed for consideration by the Government of submittals with variations.

1.8 SUBMITTAL REGISTER

Prepare and maintain submittal register, as the work progresses. Do not change data which is output in columns (c), (d), (e), and (f) as delivered by Government; retain data which is output in columns (a), (g), (h), and (i) as approved. A submittal register showing items of equipment and materials for which submittals are required by the specifications is provided as an attachment. This list may not be all inclusive and additional submittals may be required.

Column (c): Lists specification section in which submittal is required.

Column (d): Lists each submittal description (SD No. and type, e.g. SD-02 Shop Drawings) required in each specification section.

Column (e): Lists one principal paragraph in specification section where a material or product is specified. This listing is only to facilitate locating submitted requirements. Do not consider entries in column (e) as limiting project requirements.

Column (f): Indicate approving authority for each submittal.

Thereafter, the Contractor is to track all submittals by maintaining a complete list, including completion of all data columns, including dates on which submittals are received and returned by the Government.

1.8.1 Use of Submittal Register

Submit submittal register. Submit with QC plan and project schedule. Verify that all submittals required for project are listed and add missing submittals. Coordinate and complete the following fields on the register submitted with the QC plan and the project schedule:

Column (a) Activity Number: Activity number from the project schedule.

Column (g) Contractor Submit Date: Scheduled date for approving authority to receive submittals.

Column (h) Contractor Approval Date: Date Contractor needs approval of submittal.

Column (i) Contractor Material: Date that Contractor needs material delivered to Contractor control.

1.8.2 Contractor Use of Submittal Register

Update the following fields in the Government-furnished submittal register program or equivalent fields in program utilized by Contractor with each submittal throughout contract.

Column (b) Transmittal Number: Contractor assigned list of consecutive numbers.

Column (j) Action Code

Column (k) Date of action used to record Contractor's review when forwarding submittals to Designer of Record.

Column (l) List date of submittal transmission.

Column (q) List date approval received.

1.8.3 Approving Authority Use of Submittal Register

Update the following fields in the Government-furnished submittal register program or equivalent fields in program utilized by Contractor.

Column (b) Transmittal Number: Contractor assigned list of consecutive numbers.

Column (m) List date of submittal receipt.

Column (n) through (p) List Date related to review actions.

Column (r) List date returned to Contractor.

1.8.4 Action Codes

Entries for columns (j) and (o), are to be used as follows (others may be prescribed by Transmittal Form):

1.8.4.1 Government Review Action Codes

"A" - "Approved as submitted"; "Completed"

"B" - "Approved, except as noted on drawings"; "Completed"

"C" - "Approved, except as noted on drawings; resubmission required";
"Resubmit"

"D" - "Returned by separate correspondence"; "Completed"

"E" - "Disapproved (See attached)"; "Resubmit"

"F" - "Receipt acknowledged"; "Completed"

"G" - "Other (Specify)"; "Resubmit"

"X" - "Receipt acknowledged, does not comply with contract requirements"; "Resubmit"

1.8.4.2 Contractor Action Codes

NR - Not Received

AN - Approved as noted

A - Approved

RR - Disapproved, Revise, and Resubmit

1.8.5 Copies Delivered to the Government

Deliver one copy of submittal register updated by Contractor to Government with each invoice request.

1.9 SCHEDULING

Schedule and submit concurrently submittals covering component items forming a system or items that are interrelated. Include certifications to be submitted with the pertinent drawings at the same time. No delay damages or time extensions will be allowed for time lost in late submittals.

- a. Coordinate scheduling, sequencing, preparing and processing of submittals with performance of work so that work will not be delayed by submittal processing. Allow for potential resubmittal of requirements.
- b. Submittals called for by the contract documents will be listed on the register. If a submittal is called for but does not pertain to the contract work, the Contractor is to include the submittal in the register and annotate it "N/A" with a brief explanation. Approval by the Contracting Officer does not relieve the Contractor of supplying submittals required by the contract documents, but which have been omitted from the register or marked "N/A."
- c. Re-submit register and annotate monthly by the Contractor with actual submission and approval dates. When all items on the register have been fully approved, no further re-submittal is required.
- d. Carefully control procurement operations to ensure that each individual submittal is made on or before the Contractor scheduled submittal date shown on the approved "Submittal Register."
- e. Except as specified otherwise, allow review period, beginning with receipt by approving authority, that includes at least 15 working days for submittals for Designer of Record approval and 20 working days for submittals for Contracting Officer approval. Period of review for submittals with Contracting Officer approval begins when Government receives submittal from Designer of Record.
- f. Period of review for each resubmittal is the same as for initial submittal.

1.9.1 Reviewing, Certifying, Approving Authority

The Designer of Record is responsible for reviewing and certifying that submittals are in compliance with contract requirements. Approving authority on submittals is Designer of Record unless otherwise specified for specific submittal. At each "Submittal" paragraph in individual specification sections, a notation "G," following a submittal item, indicates Contracting Officer is approving authority for that submittal item. A "DA" following a submittal item, indicates that the Designer of Record is the approving authority, and that a copy of the approved submittal must be provided to the Designer of Record.

1.9.2 Constraints

Conform to provisions of this section, unless explicitly stated otherwise for submittals listed or specified in this contract.

Submit complete submittals for each definable feature of work. Submit at the same time components of definable feature interrelated as a system.

When acceptability of a submittal is dependent on conditions, items, or materials included in separate subsequent submittals, submittal will be returned without review.

Approval of a separate material, product, or component does not imply approval of assembly in which item functions.

1.9.3 Designer of Record Responsibilities

- a. Note date on which submittal was received from Contractor on each submittal.
- b. Review each submittal; and check and coordinate each submittal with requirements of work and contract documents.
- c. Review submittals for conformance with project design concepts and compliance with contract documents.
- d. Act on submittals, determining appropriate action based on Designer of Record 's review of submittal.
 - (1) When Designer of Record is approving authority, take appropriate action on submittal from the possible actions defined in paragraph APPROVED SUBMITTALS.
 - (2) When Contracting Officer is approving authority or when variation has been proposed, forward submittal to Government with certifying statement or return submittal marked "not reviewed" or "revise and resubmit" as appropriate. The Designer of Record 's review of submittal determines appropriate action.
- e. Ensure that material is clearly legible.
- f. Stamp each sheet of each submittal with DOR certifying statement or approving statement, except that data submitted in bound volume or on one sheet printed on two sides may be stamped on the front of the first sheet only.
 - (1) When approving authority is Contracting Officer, Designer of Record will certify submittals forwarded to Contracting Officer with the following certifying statement:

"I hereby certify that the (equipment) (material) (article) shown and marked in this submittal is that proposed to be incorporated with contract Number (____), is in compliance with the contract drawings and specification, can be installed in the allocated spaces, and is submitted for Government approval.

Certified by Submittal Reviewer _____, Date _____
(Signature when applicable)

Certified by Designer of Record _____, Date _____"
(Signature)

- (2) When approving authority is Designer of Record, DOR will use the following approval statement when returning submittals to Contractor as "Approved" or "Approved as Noted."

"I hereby certify that the (material) (equipment) (article) shown and marked in this submittal and proposed to be incorporated with contract Number (____), is in compliance with the contract drawings and specification, can be installed in the allocated spaces, and is approved for use.

Certified by Submittal Reviewer _____, Date _____
(Signature when applicable)

Approved by Designer of Record _____, Date _____"
(Signature)

- g. Sign certifying statement or approval statement. The Designer of Record designated in the approved QC plan is the person signing certifying statements. The use of original ink for signatures is required. Stamped signatures are not acceptable.
- h. Update submittal register as submittal actions occur and maintain the submittal register at project site until final acceptance of all work by Contracting Officer.
- i. Retain a copy of approved submittals at project site, including Contractor's copy of approved samples.

1.10 GOVERNMENT APPROVING AUTHORITY

When approving authority is Contracting Officer, the Government will:

- a. Note date on which submittal was received from Designer of Record.
- b. Review submittals for approval within scheduling period specified and only for conformance with project design concepts and compliance with contract documents.
- c. Identify returned submittals with one of the actions defined in paragraph REVIEW NOTATIONS and with markings appropriate for action indicated.

Upon completion of review of submittals requiring Government approval, stamp and date submittals. Two copies of the submittal will be retained by the Contracting Officer and one copy of the submittal will be returned to the Contractor. If the Government performs a conformance review of other Designer of Record approved submittals, the submittals will be so identified and returned, as described above.

1.10.1 Review Notations

Submittals will be returned to the Contractor with the following notations:

- a. Submittals marked "approved" or "accepted" authorize the Contractor to proceed with the work covered.

- b. Submittals marked "approved as noted" "or approved, except as noted, resubmittal not required," authorize the Contractor to proceed with the work covered provided he takes no exception to the corrections.
- c. Submittals marked "not approved" or "disapproved," or "revise and resubmit," indicate noncompliance with the contract requirements or design concept, or that submittal is incomplete. Resubmit with appropriate changes. No work shall proceed for this item until resubmittal is approved.
- d. Submittals marked "not reviewed" will indicate submittal has been previously reviewed and approved, is not required, does not have evidence of being reviewed and approved by Contractor, or is not complete. A submittal marked "not reviewed" will be returned with an explanation of the reason it is not reviewed. Resubmit submittals returned for lack of review by Contractor or for being incomplete, with appropriate action, coordination, or change.

1.11 REJECTED SUBMITTALS

Contractor shall make corrections required by the Contracting Officer. If the Contractor considers any correction or notation on the returned submittals to constitute a change to the contract drawings or specifications; notice as required under the Contract clause CHANGES, is to be given to the Contracting Officer. Contractor is responsible for the dimensions and design of connection details and construction of work. Failure to point out deviations may result in the Government requiring rejection and removal of such work at the Contractor's expense.

If changes are necessary to submittals, make such revisions and submission of the submittals in accordance with the procedures above. No item of work requiring a submittal change is to be accomplished until the changed submittals are approved.

1.12 APPROVED SUBMITTALS

The Contracting Officer's approval or acceptance of submittals is not to be construed as a complete check, and indicates only that the general method of construction, materials, detailing and other information are satisfactory.

Approval or acceptance will not relieve the Contractor of the responsibility for any error which may exist, as the Contractor under the Contractor Quality Control (CQC) requirements of this contract is responsible for dimensions, the design of adequate connections and details, and the satisfactory construction of all work design, dimensions, all design extensions, such as the design of adequate connections and details, etc., and the satisfactory construction of all work.

After submittals have been approved or accepted by the Contracting Officer, no resubmittal for the purpose of substituting materials or equipment will be considered unless accompanied by an explanation of why a substitution is necessary.

PART 2 PRODUCTS

Not Used

PART 3 EXECUTION

Not Used

-- End of Section --

SECTION 22 00 00

PLUMBING, GENERAL PURPOSE

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASSE 1013 (2011) Performance Requirements for Reduced Pressure Principle Backflow Preventers and Reduced Pressure Fire Protection Principle Backflow Preventers - (ANSI approved 2010)

ASME INTERNATIONAL (ASME)

ASME A112.1.2 (2012) Standard for Air Gaps in Plumbing Systems (For Plumbing Fixtures and Water-Connected Receptors)

ASME B16.18 (2012) Cast Copper Alloy Solder Joint Pressure Fittings

ASME B16.22 (2013) Standard for Wrought Copper and Copper Alloy Solder Joint Pressure Fittings

ASME B16.34 (2013) Valves - Flanged, Threaded and Welding End

ASTM INTERNATIONAL (ASTM)

ASTM B88 (2014) Standard Specification for Seamless Copper Water Tube

ASTM D1785 (2012) Standard Specification for Poly Vinyl Chloride (PVC), Plastic Pipe, Schedules 40, 80, and 120

ASTM D2564 (2012) Standard Specification for Solvent Cements for Poly Vinyl Chloride (PVC) Plastic Piping Systems

ASTM D2855 (1996; R 2010) Standard Practice for Making Solvent-Cemented Joints with Poly Vinyl Chloride (PVC) Pipe and Fittings

INTERNATIONAL CODE COUNCIL (ICC)

ICC IPC (2012) International Plumbing Code

MANUFACTURERS STANDARDIZATION SOCIETY OF THE VALVE AND FITTINGS INDUSTRY (MSS)

MSS SP-110	(2010) Ball Valves Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends
MSS SP-58	(1993; Reaffirmed 2010) Pipe Hangers and Supports - Materials, Design and Manufacture, Selection, Application, and Installation
MSS SP-69	(2003; Notice 2012) Pipe Hangers and Supports - Selection and Application (ANSI Approved American National Standard)
MSS SP-80	(2013) Bronze Gate, Globe, Angle and Check Valves

1.2 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for Contractor Quality Control approval. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Material, Equipment, and Fixture Lists; G

SD-02 Shop Drawings

Fabrication Drawings; DA

Installation Drawings; DA

SD-03 Product Data

Pipe and Fittings; DA

Piping Specialties; DA

Valves; DA

Miscellaneous Materials; DA

Supporting Elements; DA

SD-06 Test Reports

Leak/Pressure Tests, Flushing and Disinfection; DA

Test reports in booklet form showing all field tests performed to adjust each component and all field tests performed to prove compliance with the specified performance criteria, completion and testing of the installed system. Each test report shall indicate the final position of controls.

Test of Backflow Prevention Assemblies; DA

Certification of proper operation shall be as accomplished in accordance with state regulations by an individual certified by the

state to perform such tests. If no state requirement exists, the Contractor shall have the manufacturer's representative test the device, to ensure the unit is properly installed and performing as intended. The Contractor shall provide written documentation of the tests performed and signed by the individual performing the tests.

1.3 STANDARD PRODUCTS

Specified materials and equipment shall be standard products of a manufacturer regularly engaged in the manufacture of such products. Specified equipment shall essentially duplicate equipment that has performed satisfactorily at least two years prior to bid opening. Standard products shall have been in satisfactory commercial or industrial use for 2 years prior to bid opening. The 2-year use shall include applications of equipment and materials under similar circumstances and of similar size. The product shall have been for sale on the commercial market through advertisements, manufacturers' catalogs, or brochures during the 2-year period.

1.4 DELIVERY, STORAGE, AND HANDLING

Handle, store, and protect equipment and materials to prevent damage before and during installation in accordance with the manufacturer's recommendations, and as approved by the Contracting Officer. Replace damaged or defective items.

1.5 REGULATORY REQUIREMENTS

Unless otherwise required herein, plumbing work shall be in accordance with ICC IPC. Energy consuming products and systems shall be in accordance with PL 109-58 and ASHRAE 90.1 - IP

1.6 PROJECT/SITE CONDITIONS

The Contractor shall become familiar with details of the work, verify dimensions in the field, and advise the Contracting Officer of any discrepancy before performing any work.

1.7 ACCESSIBILITY OF EQUIPMENT

Install all work so that parts requiring periodic inspection, operation, maintenance, and repair are readily accessible. Install concealed valves, expansion joints, controls, dampers, and equipment requiring access, in locations freely accessible through access doors.

PART 2 PRODUCTS

2.1 MATERIALS

Materials for various services shall be in accordance with the drawings. Pipe schedules shall be selected based on service requirements. Pipe fittings shall be compatible with the applicable pipe materials.

2.1.1 Water Piping

Copper tubing, ASTM B88, Type L.

2.1.2 Drain Piping

PVC, ASTM D1785, SCH 40.

2.1.3 Pipe Joint Materials

Solder containing lead shall not be used with copper pipe. Joints and gasket materials shall conform to the following:

- a. Solder Material: Solder metal shall conform to [ASTM B32](#).
- b. Solder Flux: Flux shall be liquid form, non-corrosive, and conform to [ASTM B813](#), Standard Test 1.
- c. PTFE Tape: PTFE Tape, for use with Threaded Metal or Plastic Pipe.
- d. Plastic Solvent Cement for PVC Plastic Pipe: [ASTM D2564](#) and [ASTM D2855](#).
- e. Press fittings for Copper Pipe and Tube: Copper press fittings shall conform to the material and sizing requirements of [ASME B16.18](#) or [ASME B16.22](#) and performance criteria of [IAPMO PS 117](#). Sealing elements for copper press fittings shall be EPDM, FKM or HNBR. Sealing elements shall be factory installed or an alternative supplied fitting manufacturer. Sealing element shall be selected based on manufacturer's approved application guidelines.

2.2 PIPE HANGERS, INSERTS, AND SUPPORTS

Pipe hangers, inserts, and supports shall conform to [MSS SP-58](#) and [MSS SP-69](#).

2.3 VALVES

Valves shall be provided on supplies to equipment and fixtures. Valves [2-1/2 inches](#) and smaller shall be bronze with threaded bodies for pipe and solder-type connections for tubing. Valves [3 inches](#) and larger shall have flanged iron bodies and bronze trim. Pressure ratings shall be based upon the application. Grooved end valves may be provided if the manufacturer certifies that the valves meet the performance requirements of applicable MSS standard. Valves shall conform to the following standards:

Description	Standard
Ball Valves Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends	MSS SP-110
Bronze Gate, Globe, Angle, and Check Valves	MSS SP-80

2.4 BACKFLOW PREVENTERS

Backflow prevention devices must be approved by the State or local regulatory agencies. If there is no State or local regulatory agency requirements, the backflow prevention devices must be listed by the Foundation for Cross-Connection Control & Hydraulic Research, or any other approved testing

laboratory having equivalent capabilities for both laboratory and field evaluation of backflow prevention devices and assemblies.

Reduced pressure principle assemblies, double check valve assemblies, atmospheric (non-pressure) type vacuum breakers, and pressure type vacuum breakers shall be meet the above requirements.

Backflow preventers with intermediate atmospheric vent shall conform to ASSE 1012. Reduced pressure principle backflow preventers shall conform to ASSE 1013. Hose connection vacuum breakers shall conform to ASSE 1011. Pipe applied atmospheric type vacuum breakers shall conform to ASSE 1001. Pressure vacuum breaker assembly shall conform to ASSE 1020. Air gaps in plumbing systems shall conform to ASME A112.1.2.

2.5 DRAINS

2.5.1 Area Drains

Area drains shall be plain pattern with polished stainless steel perforated or slotted grate and bottom outlet. The drain shall be circular or square with a 12-inch nominal overall width or diameter and 10-inch nominal overall depth. Drains shall be cast iron with manufacturer's standard coating. Grate shall be easily lifted out for cleaning. Outlet shall be suitable for inside caulked connection to drain pipe. Drains shall conform to ASME A112.6.3.

2.5.2 Floor Sinks

Floor sinks shall be square, with 12-inch nominal overall width or diameter and 10-inch nominal overall depth. Floor sink shall have an acid-resistant enamel interior finish with cast-iron body, aluminum sediment bucket, and perforated grate of cast iron in industrial areas and stainless steel in finished areas. The outlet pipe size shall be as indicated or of the same size as the connecting pipe.

2.6 MISCELLANEOUS PIPING ITEMS

2.6.1 Escutcheon Plates

Provide one piece or split hinge metal plates for piping entering floors, walls, and ceilings in exposed spaces. Provide chromium-plated on copper alloy plates or polished stainless steel finish in finished spaces. Provide paint finish on plates in unfinished spaces.

2.6.2 Pipe Sleeves

Provide where piping passes entirely through walls, ceilings, roofs, and floors. Sleeves are not required where drain, waste, and vent (DWV) piping passes through concrete floor slabs located on grade, except where penetrating a membrane waterproof floor.

2.6.2.1 Sleeves in Masonry and Concrete

Provide steel pipe sleeves or schedule 40 PVC plastic pipe sleeves. Sleeves are not required where drain, waste, and vent (DWV) piping passes through concrete floor slabs located on grade. Core drilling of masonry and concrete

may be provided in lieu of pipe sleeves when cavities in the core-drilled hole are completely grouted smooth.

2.6.2.2 Sleeves Not in Masonry and Concrete

Provide 26 gage galvanized steel sheet or PVC plastic pipe sleeves.

2.6.3 Pipe Hangers (Supports)

Provide **MSS SP-58** and **MSS SP-69**, Type 1 with adjustable type steel support rods, except as specified or indicated otherwise. Attach to steel joists with Type 19 or 23 clamps and retaining straps. Attach to Steel W or S beams with Type 21, 28, 29, or 30 clamps. Attach to steel angles and vertical web steel channels with Type 20 clamp with beam clamp channel adapter. Attach to horizontal web steel channel and wood with drilled hole on centerline and double nut and washer. Attach to concrete with Type 18 insert or drilled expansion anchor. Provide Type 40 insulation protection shield for insulated piping.

2.6.4 Nameplates

Provide **0.125 inch** thick melamine laminated plastic nameplates, black matte finish with white center core, for equipment, gages, thermometers, and valves; valves in supplies to faucets will not require nameplates. Accurately align lettering and engrave minimum of **0.25 inch** high normal block lettering into the white core. Minimum size of nameplates shall be **1.0 by 2.5 inches**. Key nameplates to a chart and schedule for each system. Frame charts and schedules under glass and place where directed near each system. Furnish two copies of each chart and schedule.

2.7 UNDERGROUND WARNING TAPE

Detectable underground warning tape, 5.0 mil overall thickness, 6" width, .0035" thick aluminum foil core with polyethylene jacket bonded to both sides. Color code tape and print caution along with name of buried service in bold letters on face of tape. Thor Enterprises Magnatec or equal by Carlton, MSI Marking Services, Seton.

2.8 UNDERGROUND TRACER WIRE

All underground non-metallic sewers/mains and water services/mains shall be provided with tracer wire installations. Tracer wire installations shall conform with Section 182.0715(2r) of Wisconsin Statutes and prevailing Department of Safety and Professional Services Chapter 384 requirements. Tracer wire shall be continuous solid copper or steel plastic coated with split bolt or compression-type connectors.

2.9 BEDDING AND BACKFILL

2.9.1 Bedding

Bedding up to a point 12" inches above the top of the pipe shall be thoroughly compacted sand or crushed stone chips meeting the following gradations:

Gradation for Bedding Sand

<u>Sieve Size</u>	<u>% Passing (by Wt)</u>
1 inch	100
No. 16	45 - 80
No. 200	2 - 10

Gradation for Crushed Stone Chip Bedding

<u>Sieve Size</u>	<u>% Passing (by Wt)</u>
1/2 inch	100
No. 4	75 - 100
No. 100	10 - 25

2.9.2 Backfill

Backfill above the bedding under existing and future utilities, paving, sidewalks, curbs, roads and buildings shall be granular materials, pit run sand, gravel, or crushed stone, free from large stones, organic, perishable, and frozen materials.

PART 3 EXECUTION

3.1 GENERAL INSTALLATION REQUIREMENTS

The plumbing system shall be installed complete with necessary fixtures, fittings, traps, valves, and accessories. Sewer and water pipes shall be laid in separate trenches, except when otherwise shown. Exterior underground utilities shall be at least 12 inches below the finish grade or as indicated on the drawings. If trenches are closed or the pipes are otherwise covered before being connected to the service lines, the location of the end of each plumbing utility shall be marked with a stake or other acceptable means. Valves shall be installed with control no lower than the valve body.

3.1.1 Water Pipe, Fittings, and Connections

3.1.1.1 Utilities

The piping shall be extended to fixtures, outlets, and equipment. The supply line to each item of equipment or fixture, except faucets, flush valves, or other control valves which are supplied with integral stops, shall be equipped with a shutoff valve to enable isolation of the item for repair and maintenance without interfering with operation of other equipment or fixtures.

3.1.1.2 Cutting and Repairing

The work shall be carefully laid out in advance, and unnecessary cutting of construction shall be avoided. Damage to building, piping, wiring, or equipment as a result of cutting shall be repaired by mechanics skilled in the trade involved.

3.1.1.3 Protection of Fixtures, Materials, and Equipment

Pipe openings shall be closed with caps or plugs during installation. Fixtures and equipment shall be tightly covered and protected against dirt, water, chemicals, and mechanical injury. Upon completion of the work, the fixtures, materials, and equipment shall be thoroughly cleaned, adjusted, and operated. Safety guards shall be provided for exposed rotating equipment.

3.1.1.4 Mains, Branches, and Runouts

Piping shall be installed as indicated. Pipe shall be accurately cut and worked into place without springing or forcing. Structural portions of the

building shall not be weakened. Aboveground piping shall run parallel with the lines of the building, unless otherwise indicated. Branch pipes from service lines may be taken from top, bottom, or side of main, using crossover fittings required by structural or installation conditions. Supply pipes, valves, and fittings shall be kept a sufficient distance from other work and other services to permit not less than 1/2 inch between finished covering on the different services. Bare and insulated water lines shall not bear directly against building structural elements so as to transmit sound to the structure or to prevent flexible movement of the lines. Water pipe shall not be buried in or under floors unless specifically indicated or approved. Changes in pipe sizes shall be made with reducing fittings. Use of bushings will not be permitted except for use in situations in which standard factory fabricated components are furnished to accommodate specific accepted installation practice. Change in direction shall be made with fittings, except that bending of pipe 4 inches and smaller will be permitted, provided a pipe bender is used and wide sweep bends are formed. The center-line radius of bends shall be not less than six diameters of the pipe. Bent pipe showing kinks, wrinkles, flattening, or other malformations will not be acceptable.

3.1.2 Joints

Installation of pipe and fittings shall be made in accordance with the manufacturer's recommendations. Mitering of joints for elbows and notching of straight runs of pipe for tees will not be permitted. Joints shall be made up with fittings of compatible material and made for the specific purpose intended.

3.1.2.1 Threaded

Threaded joints shall have American Standard taper pipe threads conforming to ASME B1.20.1. Only male pipe threads shall be coated with graphite or with an approved graphite compound, or with an inert filler and oil, or shall have a polytetrafluoroethylene tape applied.

3.1.2.2 Copper Tube and Pipe

- b. Soldered. Soldered joints shall be made with flux and are only acceptable for piping 2 inches and smaller. Soldered joints shall conform to ASME B31.5 and CDA A4015.
- d. Press connection. Copper press connections shall be made in strict accordance with the manufacturer's installation instructions for manufactured rated size. The joints shall be pressed using the tool(s) approved by the manufacturer of that joint. Minimum distance between fittings shall be in accordance with the manufacturer's requirements.

3.1.2.3 Plastic Pipe

PVC pipe shall have joints made with solvent cement.

3.1.2.4 Other Joint Methods

3.1.3 Dissimilar Pipe Materials

Connections between ferrous and non-ferrous copper water pipe shall be made with dielectric unions or flange waterways. Dielectric waterways shall have

temperature and pressure rating equal to or greater than that specified for the connecting piping. Waterways shall have metal connections on both ends suited to match connecting piping. Dielectric waterways shall be internally lined with an insulator specifically designed to prevent current flow between dissimilar metals. Dielectric flanges shall meet the performance requirements described herein for dielectric waterways. Connecting joints between plastic and metallic pipe shall be made with transition fitting for the specific purpose.

3.1.4 Supports

3.1.4.1 General

Hangers used to support piping 2 inches and larger shall be fabricated to permit adequate adjustment after erection while still supporting the load. Pipe guides and anchors shall be installed to keep pipes in accurate alignment, to direct the expansion movement, and to prevent buckling, swaying, and undue strain. Piping subjected to vertical movement when operating temperatures exceed ambient temperatures shall be supported by variable spring hangers and supports or by constant support hangers. In the support of multiple pipe runs on a common base member, a clip or clamp shall be used where each pipe crosses the base support member. Spacing of the base support members shall not exceed the hanger and support spacing required for an individual pipe in the multiple pipe run. Threaded sections of rods shall not be formed or bent.

3.1.4.2 Pipe Hangers, Inserts, and Supports

Installation of pipe hangers, inserts and supports shall conform to MSS SP-58 and MSS SP-69, except as modified herein.

- a. Types 5, 12, and 26 shall not be used.
- b. Type 3 shall not be used on insulated pipe.
- c. Type 18 inserts shall be secured to concrete forms before concrete is placed. Continuous inserts which allow more adjustment may be used if they otherwise meet the requirements for type 18 inserts.
- d. Type 19 and 23 C-clamps shall be torqued per MSS SP-69 and shall have both locknuts and retaining devices furnished by the manufacturer. Field-fabricated C-clamp bodies or retaining devices are not acceptable.
- e. Type 20 attachments used on angles and channels shall be furnished with an added malleable-iron heel plate or adapter.
- f. Type 24 may be used only on trapeze hanger systems or on fabricated frames.
- g. Type 39 saddles shall be used on insulated pipe 4 inches and larger when the temperature of the medium is 60 degrees F or higher. Type 39 saddles shall be welded to the pipe.
- h. Type 40 shields shall:
 - (1) Be used on insulated pipe less than 4 inches.

- (2) Be used on insulated pipe 4 inches and larger when the temperature of the medium is 60 degrees F or less.
- (3) Have a high density insert for all pipe sizes. High density inserts shall have a density of 8 pcf or greater.
- i. Horizontal pipe supports shall be spaced as specified in MSS SP-69 and a support shall be installed not over 1 foot from the pipe fitting joint at each change in direction of the piping. Pipe supports shall be spaced not over 5 feet apart at valves. Operating temperatures in determining hanger spacing for PVC or CPVC pipe shall be 120 degrees F for PVC and 180 degrees F for CPVC. Horizontal pipe runs shall include allowances for expansion and contraction.
- j. Vertical pipe shall be supported at each floor, except at slab-on-grade, at intervals of not more than 15 feet nor more than 8 feet from end of risers, and at vent terminations. Vertical pipe risers shall include allowances for expansion and contraction.
- k. Type 35 guides using steel, reinforced polytetrafluoroethylene (PTFE) or graphite slides shall be provided to allow longitudinal pipe movement. Slide materials shall be suitable for the system operating temperatures, atmospheric conditions, and bearing loads encountered. Lateral restraints shall be provided as needed. Where steel slides do not require provisions for lateral restraint the following may be used:
 - (1) On pipe 4 inches and larger when the temperature of the medium is 60 degrees F or higher, a Type 39 saddle, welded to the pipe, may freely rest on a steel plate.
 - (2) On pipe less than 4 inches a Type 40 shield, attached to the pipe or insulation, may freely rest on a steel plate.
 - (3) On pipe 4 inches and larger carrying medium less than 60 degrees F a Type 40 shield, attached to the pipe or insulation, may freely rest on a steel plate.
- l. Pipe hangers on horizontal insulated pipe shall be the size of the outside diameter of the insulation. The insulation shall be continuous through the hanger on all pipe sizes and applications.
- m. Where there are high system temperatures and welding to piping is not desirable, the type 35 guide shall include a pipe cradle, welded to the guide structure and strapped securely to the pipe. The pipe shall be separated from the slide material by at least 4 inches or by an amount adequate for the insulation, whichever is greater.
- n. Hangers and supports for plastic pipe shall not compress, distort, cut or abrade the piping, and shall allow free movement of pipe except where otherwise required in the control of expansion/contraction.

3.1.4.3 Structural Attachments

Attachment to building structure concrete and masonry shall be by cast-in concrete inserts, built-in anchors, or masonry anchor devices. Inserts and anchors shall be applied with a safety factor not less than 5. Supports shall not be attached to metal decking. Supports shall not be attached to

the underside of concrete filled floor or concrete roof decks unless approved by the Contracting Officer. Masonry anchors for overhead applications shall be constructed of ferrous materials only.

3.1.5 Pipe Cleanouts

Pipe cleanouts shall be the same size as the pipe except that cleanout plugs larger than 4 inches will not be required. A cleanout installed in connection with cast-iron soil pipe shall consist of a long-sweep 1/4 bend or one or two 1/8 bends extended to the place shown. An extra-heavy cast-brass or cast-iron ferrule with countersunk cast-brass head screw plug shall be caulked into the hub of the fitting and shall be flush with the floor. Cleanouts in connection with other pipe, where indicated, shall be T-pattern, 90-degree branch drainage fittings with cast-brass screw plugs, except plastic plugs shall be installed in plastic pipe. Plugs shall be the same size as the pipe up to and including 4 inches. Cleanout tee branches with screw plug shall be installed at the foot of soil and waste stacks, at the foot of interior downspouts, on each connection to building storm drain where interior downspouts are indicated, and on each building drain outside the building. Cleanout tee branches may be omitted on stacks in single story buildings with slab-on-grade construction or where less than 18 inches of crawl space is provided under the floor. Cleanouts on pipe concealed in partitions shall be provided with chromium plated bronze, nickel bronze, nickel brass or stainless steel flush type access cover plates. Round access covers shall be provided and secured to plugs with securing screw. Square access covers may be provided with matching frames, anchoring lugs and cover screws. Cleanouts in finished walls shall have access covers and frames installed flush with the finished wall. Cleanouts installed in finished floors subject to foot traffic shall be provided with a chrome-plated cast brass, nickel brass, or nickel bronze cover secured to the plug or cover frame and set flush with the finished floor. Heads of fastening screws shall not project above the cover surface. Where cleanouts are provided with adjustable heads, the heads shall be plastic.

3.3 IDENTIFICATION SYSTEMS

3.3.1 Identification Tags

Identification tags made of brass, engraved laminated plastic, or engraved anodized aluminum, indicating service and valve number shall be installed on valves, except those valves installed on supplies at plumbing fixtures. Tags shall be 1-3/8 inch minimum diameter, and marking shall be stamped or engraved. Indentations shall be black, for reading clarity. Tags shall be attached to valves with No. 12 AWG, copper wire, chrome-plated beaded chain, or plastic straps designed for that purpose.

3.4 TESTS, FLUSHING AND DISINFECTION

3.4.1 Plumbing System

The following tests shall be performed on the plumbing system in accordance with ICC

- b. Building Sewers Tests. Non pressure plumbing and drainage systems shall be subjected to an internal hydrostatic test pressure not less than 10-foot static head of water, and not less than one-half hour.

- c. Water Supply Systems Tests. Water supply piping systems shall be subjected to an internal hydrostatic test pressure not less than 1.5 times the design operating pressure of the system, and not less than one hour.

3.4.1.1 Test of Backflow Prevention Assemblies

Backflow prevention assembly shall be tested using gauges specifically designed for the testing of [backflow prevention assemblies](#).

Backflow prevention assembly test gauges shall be tested annually for accuracy in accordance with the requirements of State or local regulatory agencies. If there is no State or local regulatory agency requirements, gauges shall be tested annually for accuracy in accordance with the requirements of University of Southern California's Foundation of Cross Connection Control and Hydraulic Research or the American Water Works Association Manual of Cross Connection (Manual M-14), or any other approved testing laboratory having equivalent capabilities for both laboratory and field evaluation of backflow prevention assembly test gauges. Report form for each assembly shall include, as a minimum, the following:

Data on Device	Data on Testing Firm
Type of Assembly	Name
Manufacturer	Address
Model Number	Certified Tester
Serial Number	Certified Tester No.
Size	Date of Test
Location	
Test Pressure Readings	Serial Number and Test Data of Gauges

If the unit fails to meet specified requirements, the unit shall be repaired and retested.

3.4.2 Defective Work

If inspection or test shows defects, such defective work or material shall be replaced or repaired as necessary and inspection and tests shall be repeated. Repairs to piping shall be made with new materials. Caulking of screwed joints or holes will not be acceptable.

3.4.3 System Flushing

3.4.3.1 During Flushing

Before operational tests or disinfection, potable water piping system shall be flushed with potable water. Sufficient water shall be used to produce a

water velocity that is capable of entraining and removing debris in all portions of the piping system. This requires simultaneous operation of all fixtures on a common branch or main in order to produce a flushing velocity of approximately 4 fps through all portions of the piping system. Contractor shall provide adequate personnel to monitor the flushing operation and to ensure that drain lines are unobstructed in order to prevent flooding of the facility. Contractor shall be responsible for any flood damage resulting from flushing of the system. Flushing shall be continued until entrained dirt and other foreign materials have been removed and until discharge water shows no discoloration.

3.4.3.2 After Flushing

System shall be drained at low points. Strainer screens shall be removed, cleaned, and replaced. After flushing and cleaning, systems shall be prepared for testing by immediately filling water piping with clean, fresh potable water. Any stoppage, discoloration, or other damage to the finish, furnishings, or parts of the building due to the Contractor's failure to properly clean the piping system shall be repaired by the Contractor.

3.5 EXCAVATION AND BACKFILL

Perform all excavation and backfill work necessary to accomplish indicated plumbing systems installation. Excavate to bottom of pipe and structure bedding, 4" in stable soils, 6" in rock or wet trenches and 8" in unstable soil. Finish bottoms of excavations to true, level surface.

Tunnel or remove sidewalk and curb in areas of excavation to the nearest joint. Remove pavements, curbs and gutters to neat and straight lines to the limits of removal. Make sawcut lines parallel to existing joints, or parallel or perpendicular to pavement edges to form a neat patch. Carefully remove remaining pavement within the sawcut area. Leave existing base materials between the area disturbed by the work and the sawcut line undisturbed by the saw cutting, pavement removal, or pavement replacement processes.

Strip topsoil from area to be excavated, free from subsoil and debris, and store for later re-spreading.

At no time place excavated materials where they will impede surface drainage unless such drainage is being safely rerouted away from the excavation.

Excavate whatever materials are encountered as required to place at the elevations shown, all pipe, manholes, and other work. Remove debris and rubbish from excavations before placing bedding and backfill material.

Remove surplus excavated materials from site.

Verify the locations of any water, drainage, gas, sewer, electric, telephone or steam lines which may be encountered in the excavation. Underpin and support all lines. Cut off service connections encountered which are to be removed at the limits of the excavation and cap.

Provide and maintain all fencing, barricades, signs, warning lights, and/or other equipment necessary to keep all excavation pits and trenches and the entire subgrade area safe under all circumstances and at all times. No excavation shall be left unattended without adequate protection.

Elevations shown on the plans are subject to such revisions as may be necessary to fit field conditions. No adjustment in compensation will be made for adjustments up to two (2) feet above or below the grades indicated on the plans.

Install lines passing under foundations with minimum of 1-1/2 inch clearance to concrete and insure there is no disturbance of bearing soil.

Bed pipe up to a point 12" above the top of the pipe. Take care during bedding, compaction and backfill not to disturb or damage piping.

Mechanically compact bedding and backfill to prevent settlement. The initial compacted lift to not exceed 24" compacted to 95% density per Modified Proctor Test (ASTM D-1557). Subsequent lifts under pavements, curbs, walks and structures are not to exceed 12" and be compacted to 95% density per Modified Proctor Test. In all other areas where construction above the excavation is not anticipated within 2 years, mechanically compact backfill in lifts not exceeding 24" to 90% density per Modified Proctor Test. Route the equipment over each lift of the material so that the compaction equipment contacts all areas of the surface of the lift.

3.6 SHEETING, SHORING AND BRACING

Provide shoring, sheet piling and bracing in conformance with the applicable code to prevent earth from caving or washing into the excavation. Shore and underpin to properly support adjacent or adjoining structures. Abandon in place shoring, sheet piling and underpinning below the top of the pipe, or, if approved in advance by the engineer, maintained in place until other permanent support approved by the engineer is provided.

3.7 DEWATERING

Provide, operate and maintain all pumps and other equipment necessary to drain and keep all excavation pits, trenches and the entire subgrade area free from water under all circumstances. Obtain general permit from the city district office for discharge of construction dewatering effluent. Obtain well permit from the city district office for dewatering wells discharging more than 70 GPM. Comply with permit requirements.

3.8 ROCK EXCAVATION

Remove rock encountered in the excavation to a minimum dimension of six (6) inches outside the pipe. Rock excavation includes all hard, solid rock in ledges, bedded deposits and unstratified masses, all natural conglomerate deposits so firmly cemented as to present all the characteristics of solid rock; which material is so hard or so firmly cemented that in the opinion of the Engineer it is not practical to excavate and remove same with a power shovel except after thorough and continuous drilling and blasting. Rock excavation includes rock boulders of 1/2 cubic yard or more in volume.

Rock excavation will be computed on the basis of the depth of rock removed and a trench width two (2) feet larger than the outside diameter of the pipe where one (1) pipe is laid in the trench and three (3) feet larger than the combined outside diameter where two (2) pipes are laid in the trench. Include 6" pipe and structure bedding in rock excavation. Include rock excavation shown on the plans in the Base Bid.

3.9 SURFACE RESTORATION

Completely restore the surface of all disturbed areas to a like condition of the surface prior to the work. Level off all waste disposal areas and clean up all areas used for the storage of materials or the temporary deposit of excavated earth. Remove all surplus material, tools and equipment.

3.10 CONCRETE WORK

Cast-in-place concrete within the building will be performed by the Division 3 Contractor unless otherwise noted. Provide all layout drawings, anchor bolts, metal shapes, and/or templates required to be cast into concrete or used to form concrete for support or installation of plumbing piping, fixtures, specialties and equipment. Coordinate locations of equipment, pipe penetrations in wet areas, etc. with the Division 3 Contractor.

Plumbing related cast-in-place concrete on the exterior of the building to be provided by this Contractor in conformance with requirements of Division 3. This includes piping thrust restraints, pipe supports, hydrant supports, manholes, catch basins, grease traps, septic tanks, distribution boxes, valve pits, meter pits, cleanout cover pads, yard hydrant pads, etc.

For minor concrete work, provide cast in place concrete for equipment pads, manhole bases and thrust blocks. Concrete to be 3,000 psi at 28 days, 3/4 inch aggregate, five bags cement, three inch slump, air entraining admixture. The ACI 614 Recommended Practice for Measuring, Mixing and Placing of Concrete shall constitute the execution requirements.

3.11 COORDINATION

Coordinate all work with other contractors prior to installation. Any work that is not coordinated and that interferes with other contractor's work shall be removed or relocated at the installing contractor's expense.

-- End of Section --

SECTION 23 03 00

BASIC MECHANICAL MATERIALS AND METHODS

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

ASTM B117 (2011) Standard Practice for Operating Salt Spray (Fog) Apparatus

1.2 QUALITY ASSURANCE

1.2.1 Material and Equipment Qualifications

Provide materials and equipment that are standard products of manufacturers regularly engaged in the manufacture of such products, which are of a similar material, design and workmanship. Standard products must have been in satisfactory commercial or industrial use for 2 years prior to bid opening. The 2-year use must include applications of equipment and materials under similar circumstances and of similar size. The product must have been for sale on the commercial market through advertisements, manufacturers' catalogs, or brochures during the 2 year period.

1.2.2 Modification of References

In each of the publications referred to herein, consider the advisory provisions to be mandatory, as though the word, "must" had been substituted for "should" wherever it appears. Interpret references in these publications to the "authority having jurisdiction", or words of similar meaning, to mean the Contracting Officer.

1.2.2.1 Definitions

For the International Code Council (ICC) Codes referenced in the contract documents, advisory provisions must be considered mandatory, the word "should" is interpreted as "must." Reference to the "code official" must be interpreted to mean the "Contracting Officer." For Navy owned property, references to the "owner" must be interpreted to mean the "Contracting Officer." For leased facilities, references to the "owner" must be interpreted to mean the "lessor." References to the "permit holder" must be interpreted to mean the "Contractor."

1.2.2.2 Administrative Interpretations

For ICC Codes referenced in the contract documents, the provisions of Chapter 1, "Administrator," do not apply. These administrative requirements are covered by the applicable Federal Acquisition Regulations (FAR) included in this contract and by the authority granted to the Officer in Charge of

Construction to administer the construction of this project. References in the ICC Codes to sections of Chapter 1, must be applied appropriately by the Contracting Officer as authorized by his administrative cognizance and the FAR.

1.3 DELIVERY, STORAGE, AND HANDLING

Handle, store, and protect equipment and materials to prevent damage before and during installation in accordance with the manufacturer's recommendations, and as approved by the Contracting Officer. Replace damaged or defective items.

1.4 ACCESSIBILITY

Install all work so that parts requiring periodic inspection, operation, maintenance, and repair are readily accessible. Install concealed valves, expansion joints, controls, dampers, and equipment requiring access, in locations freely accessible through access doors.

PART 2 PRODUCTS

Not Used

PART 3 EXECUTION

3.1 PAINTING OF NEW EQUIPMENT

New equipment painting must be factory applied or shop applied, and must be as specified herein, and provided under each individual section.

3.1.1 Factory Painting Systems

Manufacturer's standard factory painting systems may be provided subject to certification that the factory painting system applied will withstand 125 hours in a salt-spray fog test, except that equipment located outdoors must withstand 500 hours in a salt-spray fog test. Salt-spray fog test must be in accordance with [ASTM B117](#), and for that test the acceptance criteria must be as follows: immediately after completion of the test, the paint must show no signs of blistering, wrinkling, or cracking, and no loss of adhesion; and the specimen must show no signs of rust creepage beyond [0.125 inch](#) on either side of the scratch mark.

The film thickness of the factory painting system applied on the equipment must not be less than the film thickness used on the test specimen. If manufacturer's standard factory painting system is being proposed for use on surfaces subject to temperatures above [120 degrees F](#), the factory painting system must be designed for the temperature service.

3.1.2 Shop Painting Systems for Metal Surfaces

Clean, pretreat, prime and paint metal surfaces; except aluminum surfaces need not be painted. Apply coatings to clean dry surfaces. Clean the surfaces to remove dust, dirt, rust, oil and grease by wire brushing and solvent degreasing prior to application of paint, except metal surfaces subject to temperatures in excess of [120 degrees F](#) must be cleaned to bare metal.

Where more than one coat of paint is specified, apply the second coat after the preceding coat is thoroughly dry. Lightly sand damaged painting and retouch before applying the succeeding coat. Color of finish coat must be aluminum or light gray.

- a. Temperatures Less Than 120 Degrees F: Immediately after cleaning, the metal surfaces subject to temperatures less than 120 degrees F must receive one coat of pretreatment primer applied to a minimum dry film thickness of 0.3 mil, one coat of primer applied to a minimum dry film thickness of 1 mil; and two coats of enamel applied to a minimum dry film thickness of 1 mil per coat.
- b. Temperatures Between 120 and 400 Degrees F: Metal surfaces subject to temperatures between 120 and 400 degrees F must receive two coats of 400 degrees F heat-resisting enamel applied to a total minimum thickness of 2 mils.
- c. Temperatures Greater Than 400 Degrees F: Metal surfaces subject to temperatures greater than 400 degrees F must receive two coats of 600 degrees F heat-resisting paint applied to a total minimum dry film thickness of 2 mils.

-- End of Section --

SECTION 23 05 15

COMMON PIPING FOR HVAC

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN INSTITUTE OF STEEL CONSTRUCTION (AISC)

AISC 325 (2011) Steel Construction Manual

AMERICAN WELDING SOCIETY (AWS)

AWS WHB-2.9 (2004) Welding Handbook; Volume 2, Welding Processes, Part 1

ASME INTERNATIONAL (ASME)

ASME B16.1 (2010) Gray Iron Pipe Flanges and Flanged Fittings Classes 25, 125, and 250

ASME B16.9 (2012) Standard for Factory-Made Wrought Steel Buttwelding Fittings

ASME B31.3 (2014) Process Piping

ASME BPVC SEC IX (2010) BPVC Section IX-Welding and Brazing Qualifications

ASTM INTERNATIONAL (ASTM)

ASTM A126 (2004; R 2014) Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings

ASTM A183 (2014) Standard Specification for Carbon Steel Track Bolts and Nuts

ASTM A234/A234M (2013; E 2014) Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service

ASTM A307 (2014) Standard Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength

ASTM A53/A53M (2012) Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless

ASTM A563	(2007a; R2014) Standard Specification for Carbon and Alloy Steel Nuts
ASTM B117	(2011) Standard Practice for Operating Salt Spray (Fog) Apparatus
ASTM B62	(2015) Standard Specification for Composition Bronze or Ounce Metal Castings
ASTM D2000	(2012) Standard Classification System for Rubber Products in Automotive Applications
ASTM F104	(2011) Standard Classification System for Nonmetallic Gasket Materials

MANUFACTURERS STANDARDIZATION SOCIETY OF THE VALVE AND FITTINGS
INDUSTRY (MSS)

MSS SP-58	(1993; Reaffirmed 2010) Pipe Hangers and Supports - Materials, Design and Manufacture, Selection, Application, and Installation
MSS SP-67	(2011) Butterfly Valves
MSS SP-72	(2010a) Ball Valves with Flanged or Butt-Welding Ends for General Service

U.S. GENERAL SERVICES ADMINISTRATION (GSA)

CID A-A-1922	(Rev A; Notice 2) Shield, Expansion (Caulking Anchors, Single Lead)
CID A-A-1923	(Rev A; Notice 2) Shield, Expansion (Lag, Machine and Externally Threaded Wedge Bolt Anchors)
CID A-A-1924	(Rev A; Notice 2) Shield, Expansion (Self Drilling Tubular Expansion Shell Bolt Anchors)
CID A-A-1925	(Rev A; Notice 2) Shield Expansion (Nail Anchors)
CID A-A-55614	(Basic; Notice 2) Shield, Expansion (Non-Drilling Expansion Anchors)
CID A-A-55615	(Basic; Notice 2) Shield, Expansion (Wood Screw and Lag Bolt Self-Threading Anchors)

1.2 GENERAL REQUIREMENTS

Submit [Fabrication Drawings](#) for pipes, valves and specialties consisting of fabrication and assembly details to be performed in the factory.

Submit [Material, Equipment, and Fixture Lists](#) for pipes, valves and specialties including manufacturer's style or catalog numbers, specification and drawing reference numbers, warranty information, and fabrication site information. Provide a complete list of construction equipment to be used.

1.3 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability Notebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Material, Equipment, and Fixture Lists; G

SD-02 Shop Drawings

Fabrication Drawings; DA

Installation Drawings; DA

SD-03 Product Data

Pipe and Fittings; DA

Piping Specialties; DA

Valves; DA

Miscellaneous Materials; DA

Supporting Elements; DA

SD-06 Test Reports

System Operation Tests; G

1.4 QUALITY ASSURANCE

1.4.1 Material and Equipment Qualifications

Provide materials and equipment that are standard products of manufacturers regularly engaged in the manufacture of such products, which are of a similar material, design and workmanship. Provide standard products in satisfactory commercial or industrial use for 2 years prior to bid opening. The 2-year use includes applications of equipment and materials under similar circumstances and of similar size. Ensure the product has been for sale on the commercial market through advertisements, manufacturers' catalogs, or brochures during the 2 year period.

1.4.2 Alternative Qualifications

Products having less than a two-year field service record are acceptable if a certified [record of satisfactory field operation](#) for not less than 6000 hours, exclusive of the manufacturer's factory or laboratory tests, can be shown.

1.4.3 Service Support

Ensure the equipment items are supported by service organizations. Submit a certified [list of qualified permanent service organizations](#) for support of the equipment which includes their addresses and qualifications. Select service organizations that are reasonably convenient to the equipment installation and able to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.

1.4.4 Manufacturer's Nameplate

Provide a nameplate on each item of equipment bearing the manufacturer's name, address, model number, and serial number securely affixed in a conspicuous place; the nameplate of the distributing agent is not acceptable.

1.4.5 Modification of References

In each of the publications referred to herein, consider the advisory provisions to be mandatory, as though the word, "shall" had been substituted for "should" wherever it appears. Interpret references in these publications to the "authority having jurisdiction," or words of similar meaning, to mean the Contracting Officer.

1.4.5.1 Definitions

For the International Code Council (ICC) Codes referenced in the contract documents, advisory provisions are considered mandatory, the word "should" is interpreted as "shall." Reference to the "code official" is interpreted to mean the "Contracting Officer." For Navy owned property, interpret references to the "owner" to mean the "Contracting Officer." For leased facilities, references to the "owner" is interpreted to mean the "lessor." References to the "permit holder" are interpreted to mean the "Contractor."

1.4.5.2 Administrative Interpretations

For ICC Codes referenced in the contract documents, the provisions of Chapter 1, "Administrator," do not apply. These administrative requirements are covered by the applicable Federal Acquisition Regulations (FAR) included in this contract and by the authority granted to the Officer in Charge of Construction to administer the construction of this project. References in the ICC Codes to sections of Chapter 1, are applied as appropriate by the Contracting Officer and as authorized by his administrative cognizance and the FAR.

1.5 DELIVERY, STORAGE, AND HANDLING

Handle, store, and protect equipment and materials to prevent damage before and during installation in accordance with the manufacturer's recommendations, and as approved by the Contracting Officer. Replace damaged or defective items.

1.6 ACCESSIBILITY

Install all work so that parts requiring periodic inspection, operation, maintenance, and repair are readily accessible. Install concealed valves,

expansion joints, controls, dampers, and equipment requiring access, in locations freely accessible through access doors.

PART 2 PRODUCTS

2.1 PIPE AND FITTINGS

Submit equipment and performance data for **pipe and fittings** consisting of corrosion resistance, life expectancy, gage tolerances, and grade line analysis. Submit design analysis and calculations consisting of surface resistance, rates of flow, head losses, inlet and outlet design, required radius of bend, and pressure calculations. Also include in data pipe size, shape, and dimensions, as well as temperature ratings, vibration and thrust limitations minimum burst pressures, shut-off and non-shock pressures and weld characteristics.

2.1.1 Type BCS, Black Carbon Steel

Ensure pipe **1/8 through 12 inches** is Schedule 40 black carbon steel, conforming to **ASTM A53/A53M**.

2.1.2 Grooved Pipe Couplings and Fittings

Provide housing for all couplings, fabricated in two or more parts, of black, ungalvanized malleable iron castings. Ensure coupling gasket is molded synthetic rubber, conforming to **ASTM D2000**. Ensure coupling bolts are oval-neck, track-head type, with hexagonal heavy nuts conforming to **ASTM A183**.

Fabricate all pipe fittings used with couplings of black, ungalvanized malleable iron castings. Where a manufacturer's standard-size malleable iron fitting pattern is not available, approved fabricated fittings may be used.

Fabricate fittings from Schedule 40 or **0.75-inch** wall **ASTM A53/A53M**, Grade B seamless steel pipe; long radius seamless welding fittings with wall thickness to match pipe, conforming to **ASTM A234/A234M** and **ASME B16.9**.

2.2 VALVES

Submit equipment and performance data for **valves** consisting of corrosion resistance and life expectancy. Submit design analysis and calculations consisting of rates of flow, head losses, inlet and outlet design, and pressure calculations. Also include in data, pipe dimensions, as well as temperature ratings, vibration and thrust limitations, minimum burst pressures, shut-off and non-shock pressures and weld characteristics.

2.2.1 Ball and Butterfly Valves

Ensure ball valves conform to **MSS SP-72** and are rated for service at not less than **175 psig at 200 degrees F**. For valve bodies in sizes **2 inches** and smaller, use screwed-end connection-type constructed of Class A copper alloy. Balls and stems of valves **2 inches** and smaller are manufacturer's standard with hard chrome plating finish. Balls and stems of valves **2-1/2 inches** and larger are manufacturer's standard Class C corrosion-resistant steel alloy with hard chrome plating. Balls of valves **6 inches** and larger may be Class D with 900 Brinell hard chrome plating. Ensure valves are suitable for flow from either direction and seal equally tight in either direction. Valves

with ball seals held in place by spring washers are not acceptable. Ensure all valves have adjustable packing glands. Seats and seals are fabricated from tetrafluoroethylene.

Ensure butterfly valves conform to MSS SP-67 and are the wafer type for mounting between specified flanges. Ensure valves are rated for 150-psig shutoff and nonshock working pressure. Select bodies of cast ferrous metal conforming to ASTM A126, Class B, and to ASME B16.1 for body wall thickness. Seats and seals are fabricated from resilient elastomer designed for field removal and replacement.

2.2.2 Drain, Vent, and Gage Cocks

Provide lever handle drain, vent, and gage cocks, ground key type, with washer and screw, constructed of polished ASTM B62 bronze, and rated 125-psig. Ensure end connections are rated for specified service pressure.

Ensure pump vent cocks, and where spray control is required, are UL umbrella-hood type, constructed of manufacturer's standard polished brass. Ensure cocks are 1/2-inch ips male, end threaded, and rated at not less than 125 psi at 225 degrees F.

2.3 MISCELLANEOUS MATERIALS

Submit equipment and performance data for miscellaneous materials consisting of corrosion resistance, life expectancy, gage tolerances, and grade line analysis.

2.3.1 Bolting

Ensure flange and general purpose bolting is hex-head and conforms to ASTM A307, Grade B (bolts, for flanged joints in piping systems where one or both flanges are cast iron). Heavy hex-nuts conform to ASTM A563. Square-head bolts and nuts are not acceptable. Ensure threads are coarse-thread series.

2.3.2 Flange Gaskets

Provide compressed non-asbestos sheets, conforming to ASTM F104, coated on both sides with graphite or similar lubricant, with nitrile composition, binder rated to 750 degrees F.

2.3.3 Pipe Thread Compounds

Use polytetrafluoroethylene tape not less than 2 to 3 mils thick in potable and process water and in chemical systems for pipe sizes to and including 1-inch ips. Use polytetrafluoroethylene dispersions and other suitable compounds for all other applications upon approval by the Contracting Officer; however, do not use lead-containing compounds in potable water systems.

2.4 SUPPORTING ELEMENTS

Submit equipment and performance data for the supporting elements consisting of corrosion resistance, life expectancy, gage tolerances, and grade line analysis.

Provide all necessary piping systems and equipment supporting elements, including but not limited to: building structure attachments; supplementary steel; hanger rods, stanchions, and fixtures; vertical pipe attachments; horizontal pipe attachments; anchors; guides; and spring-cushion, variable, or constant supports. Ensure supporting elements are suitable for stresses imposed by systems pressures and temperatures and natural and other external forces normal to this facility without damage to supporting element system or to work being supported.

Ensure supporting elements conform to requirements of [ASME B31.3](#), and [MSS SP-58](#), except as noted.

Ensure attachments welded to pipe are made of materials identical to that of pipe or materials accepted as permissible raw materials by referenced code or standard specification.

Ensure supporting elements exposed to weather are hot-dip galvanized or stainless steel. Select materials of such a nature that their apparent and latent-strength characteristics are not reduced due to galvanizing process. Electroplate supporting elements in contact with copper tubing with copper.

Type designations specified herein are based on [MSS SP-58](#). Ensure masonry anchor group-, type-, and style-combination designations are in accordance with [CID A-A-1922](#), [CID A-A-1923](#), [CID A-A-1924](#), [CID A-A-1925](#), [CID A-A-55614](#), and [CID A-A-55615](#). Provide support elements, except for supplementary steel, that are cataloged, load rated, commercially manufactured products.

2.4.1 Horizontal Pipe Attachments

2.4.1.1 Single Pipes

Support piping in sizes to and including [2-inch ips](#) by [MSS SP-58](#) Type 6 solid malleable iron pipe rings, except that, use split-band-type rings in sizes up to [1-inch ips](#).

Support piping in sizes through [8-inch ips](#) inclusive by [MSS SP-58](#) Type attachments.

Use [MSS SP-58](#) Type 1 and Type 6 assemblies on vapor-sealed insulated piping and have an inside diameter larger than pipe being supported to provide adequate clearance during pipe movement.

Where thermal movement of a point in a piping system [4 inches](#) and larger would cause a hanger rod to deflect more than 4 degrees from the vertical or where a horizontal point movement exceeds [1/2 inch](#), use [MSS SP-58](#) Type pipe rolls.

Support piping in sizes larger than [8-inch ips](#) with [MSS SP-58](#) Type pipe rolls.

Use [MSS SP-58](#) Type 40 shields on all insulated piping. Ensure area of the supporting surface is such that compression deformation of insulated surfaces does not occur. Roll away longitudinal and transverse shield edges from the insulation.

Provide insulated piping without vapor barrier on roll supports with [MSS SP-58](#) Type 39 saddles.

Provide spring supports as indicated.

2.4.1.2 Parallel Pipes

Use trapeze hangers fabricated from structural steel shapes, with U-bolts, in congested areas and where multiple pipe runs occur. Ensure structural steel shapes be of commercially available, proprietary design, rolled steel.

2.4.2 Vertical Pipe Attachments

Ensure vertical pipe attachments are [MSS SP-58](#) Type 8.

Include complete fabrication and attachment details of any spring supports in shop drawings.

2.4.3 Hanger Rods and Fixtures

Use only circular cross section rod hangers to connect building structure attachments to pipe support devices. Use pipe, straps, or bars of equivalent strength for hangers only where approved by the Contracting Officer.

Provide turnbuckles, swing eyes, and clevises as required by support system to accommodate temperature change, pipe accessibility, and adjustment for load and pitch. Rod couplings are not acceptable.

2.4.4 Supplementary Steel

Where it is necessary to frame structural members between existing members or where structural members are used in lieu of commercially rated supports, design and fabricate such supplementary steel in accordance with [AISC 325](#).

PART 3 EXECUTION

3.1 PIPE INSTALLATION

Submit certificates for pipes, valves and specialties showing conformance with test requirements as contained in the reference standards contained in this section. Provide certificates verifying [Surface Resistance](#), [Shear and Tensile Strengths](#), [Temperature Ratings](#), [Bending Tests](#), [Flattening Tests](#) and [Transverse Guided Weld Bend Tests](#).

Fabricate and install piping systems in accordance with [ASME B31.3](#), [MSS SP-58](#), and [AWS WHB-2.9](#).

Submit [Installation Drawings](#) for pipes, valves and specialties. Drawings include the manufacturer's design and construction calculations, forces required to obtain rated axial, lateral, or angular movements, installation criteria, anchor and guide requirements for equipment, and equipment room layout and design. Ensure drawings specifically advise on procedures to be followed and provisions required to protect expansion joints during specified hydrostatic testing operations.

Ream all pipe ends before joint connections are made.

Make screwed joints with specified joint compound with not more than three threads showing after joint is made up.

Apply joint compounds to the male thread only and exercise care to prevent compound from reaching the unthreaded interior of the pipe.

Securely support piping systems with due allowance for thrust forces, thermal expansion and contraction. Do not subject the system to mechanical, chemical, vibrational or other damage as specified in [ASME B31.3](#).

Ensure field welded joints conform to the requirements of the [AWS WHB-2.9](#), [ASME B31.3](#), and [ASME BPVC SEC IX](#).

Accomplish preheat and postheat treatment of welds in accordance with [ASME BPVC SEC IX](#) and [ASME B31.3](#).

Take all necessary precautions during installation of flexible pipe and hose including flushing and purging with water, steam, and compressed air to preclude bellows failure due to pipe line debris lodged in bellows. Ensure installation conforms to manufacturer's instructions.

3.2 VALVES

Provide valves in piping mains and all branches and at equipment where indicated and as specified.

Provide valves to permit isolation of branch piping and each equipment item from the balance of the system.

3.3 SUPPORTING ELEMENTS INSTALLATION

Provide supporting elements in accordance with the referenced codes and standards.

Support piping from building structure. Do not support piping from roof deck or from other pipe.

Run piping parallel with the lines of the building. Space and install piping and components so that a threaded pipe fitting may be removed between adjacent pipes and so that there is no less than [1/2 inch](#) of clear space between the finished surface and other work and between the finished surface of parallel adjacent piping. Arrange hangars on different adjacent service lines running parallel with each other in line with each other and parallel to the lines of the building.

Install piping support elements at intervals specified hereinafter, at locations not more than [3 feet](#) from the ends of each runout, and not over [1 foot](#) from each change in direction of piping.

Base load rating for all pipe-hanger supports on insulated weight of lines filled with water and forces imposed. Deflection per span is not exceed slope gradient of pipe. Ensure supports are in accordance with the following minimum rod size and maximum allowable hanger spacing for specified pipe. For concentrated loads such as valves, reduce the allowable span proportionately:

[PIPE SIZE](#)
[INCHES](#)

[ROD SIZE](#)
[INCHES](#)

[STEEL PIPE](#)
[FEET](#)

[COPPER PIPE](#)
[FEET](#)

1 and smaller	3/8	8	6
1-1/4 to 1-1/2	3/8	10	8
2	3/8	10	8
2-1/2 to 3-1/2	1/2	12	12
4 to 5	5/8	16	14
6	3/4	16	16
8 to 12	7/8	20	20
14 to 18	1	20	20
20 and over	1-1/4	20	20

Support vertical risers independently of connected horizontal piping, whenever practicable, with fixed or spring supports at the base and at intervals to accommodate system range of thermal conditions. Ensure risers have guides for lateral stability. For risers subject to expansion, provide only one rigid support at a point approximately one-third down from the top. Place clamps under fittings unless otherwise specified. Support carbon-steel pipe at each floor and at not more than 15-foot intervals for pipe 2 inches and smaller and at not more than 20-foot intervals for pipe 2-1/2 inches and larger.

3.4 OPERATION AND MAINTENANCE

Provide Operation and Maintenance Manuals consistent with manufacturer's standard brochures, schematics, printed instructions, general operating procedures and safety precautions. Submit test data that is clear and readily legible.

3.5 PAINTING OF NEW EQUIPMENT

Factory or shop apply new equipment painting, as specified herein, and provided under each individual section.

3.5.1 Factory Painting Systems

Manufacturer's standard factory painting systems may be provided subject to certification that the factory painting system applied withstands 125 hours in a salt-spray fog test, except that equipment located outdoors withstand 500 hours in a salt-spray fog test. Conduct salt-spray fog test is in accordance with ASTM B117, and for that test the acceptance criteria is as follows: immediately after completion of the test, the inspected paint shows no signs of blistering, wrinkling, or cracking, and no loss of adhesion; and the specimen shows no signs of rust creepage beyond 0.125 inch on either side of the scratch mark.

Ensure the film thickness of the factory painting system applied on the equipment is not less than the film thickness used on the test specimen. If manufacturer's standard factory painting system is being proposed for use on surfaces subject to temperatures above 120 degrees F, design the factory painting system for the temperature service.

3.5.2 Shop Painting Systems for Metal Surfaces

Clean, pretreat, prime and paint metal surfaces; except aluminum surfaces need not be painted. Apply coatings to clean dry surfaces. Clean the surfaces to remove dust, dirt, rust, oil and grease by wire brushing and solvent degreasing prior to application of paint, except clean to bare metal, surfaces subject to temperatures in excess of 120 degrees F.

Where more than one coat of paint is specified, apply the second coat after the preceding coat is thoroughly dry. Lightly sand damaged painting and retouch before applying the succeeding coat. Selected color of finish coat is aluminum or light gray.

- a. Temperatures Less Than 120 Degrees F: Immediately after cleaning, the metal surfaces subject to temperatures less than 120 degrees F receives one coat of pretreatment primer applied to a minimum dry film thickness of 0.3 mil, one coat of primer applied to a minimum dry film thickness of one mil; and two coats of enamel applied to a minimum dry film thickness of one mil per coat.
- b. Temperatures Between 120 and 400 Degrees F: Metal surfaces subject to temperatures between 120 and 400 degrees F Receives two coats of 400 degrees F heat-resisting enamel applied to a total minimum thickness of 2 mils.
- c. Temperatures Greater Than 400 Degrees F: Metal surfaces subject to temperatures greater than 400 degrees F receives two coats of 600 degrees F heat-resisting paint applied to a total minimum dry film thickness of 2 mils.

-- End of Section --

SECTION 23 07 00

THERMAL INSULATION FOR MECHANICAL SYSTEMS

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only. At the discretion of the Government, the manufacturer of any material supplied will be required to furnish test reports pertaining to any of the tests necessary to assure compliance with the standard or standards referenced in this specification.

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING
ENGINEERS (ASHRAE)

ASHRAE 90.1 - IP (2010; ERTA 2011-2014; Thru INT 24 2015) Energy
Standard for Buildings Except Low-Rise
Residential Buildings

ASTM INTERNATIONAL (ASTM)

ASTM A580/A580M (2015) Standard Specification for Stainless
Steel Wire

ASTM B209 (2014) Standard Specification for Aluminum and
Aluminum-Alloy Sheet and Plate

ASTM C1136 (2012) Standard Specification for Flexible, Low
Permeance Vapor Retarders for Thermal
Insulation

ASTM C1710 (2011) Standard Guide for Installation of
Flexible Closed Cell Preformed Insulation in
Tube and Sheet Form

ASTM C195 (2007; R 2013) Standard Specification for
Mineral Fiber Thermal Insulating Cement

ASTM C450 (2008) Standard Practice for Fabrication of
Thermal Insulating Fitting Covers for NPS
Piping, and Vessel Lagging

ASTM C647 (2008; R 2013) Properties and Tests of Mastics
and Coating Finishes for Thermal Insulation

ASTM C795 (2008; R 2013) Standard Specification for
Thermal Insulation for Use in Contact with
Austenitic Stainless Steel

ASTM C916 (2014) Standard Specification for Adhesives for
Duct Thermal Insulation

ASTM C920	(2014a) Standard Specification for Elastomeric Joint Sealants
ASTM C921	(2010) Standard Practice for Determining the Properties of Jacketing Materials for Thermal Insulation
ASTM D2863	(2013) Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)
ASTM D5590	(2000; R 2010; E 2012) Standard Test Method for Determining the Resistance of Paint Films and Related Coatings to Fungal Defacement by Accelerated Four-Week Agar Plate Assay
ASTM D882	(2012) Tensile Properties of Thin Plastic Sheeting
ASTM E2231	(2015) Specimen Preparation and Mounting of Pipe and Duct Insulation Materials to Assess Surface Burning Characteristics
ASTM E84	(2015a) Standard Test Method for Surface Burning Characteristics of Building Materials
ASTM E96/E96M	(2014) Standard Test Methods for Water Vapor Transmission of Materials
FM GLOBAL (FM)	
FM APP GUIDE	(updated on-line) Approval Guide http://www.approvalguide.com/
INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)	
ISO 2758	(2014) Paper - Determination of Bursting Strength
MIDWEST INSULATION CONTRACTORS ASSOCIATION (MICA)	
MICA Insulation Stds	(1999) National Commercial & Industrial Insulation Standards
U.S. DEPARTMENT OF DEFENSE (DOD)	
MIL-A-24179	(1969; Rev A; Am 2 1980; Notice 1 1987) Adhesive, Flexible Unicellular-Plastic Thermal Insulation
MIL-A-3316	(1987; Rev C; Am 2 1990) Adhesives, Fire-Resistant, Thermal Insulation
MIL-PRF-19565	(1988; Rev C) Coating Compounds, Thermal Insulation, Fire- and Water-Resistant, Vapor-Barrier

UNDERWRITERS LABORATORIES (UL)

UL 723 (2008; Reprint Aug 2013) Test for Surface Burning Characteristics of Building Materials

UL 94 (2013; Reprint Jan 2015) Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances

1.2 SYSTEM DESCRIPTION

1.2.1 General

Provide field-applied insulation and accessories on mechanical systems as specified herein.

1.2.2 Recycled Materials

Provide thermal insulation containing recycled materials to the extent practicable, provided that the materials meet all other requirements of this section. The minimum recycled material content of the following insulation are:

Rock Wool	75 percent slag of weight
Fiberglass	20-25 percent glass cullet by weight
Rigid Foam	9 percent recovered material

1.3 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for Contractor Quality Control approval. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Material and Equipment; G

SD-03 Product Data

Pipe Insulation Systems; DA

1.4 QUALITY ASSURANCE

1.4.1 Installer Qualification

Qualified installers shall have successfully completed three or more similar type jobs within the last 5 years.

1.5 DELIVERY, STORAGE, AND HANDLING

Materials shall be delivered in the manufacturer's unopened containers. Materials delivered and placed in storage shall be provided with protection from weather, humidity, dirt, dust and other contaminants. The Contracting Officer may reject insulation material and supplies that become dirty, dusty, wet, or contaminated by some other means. Packages or standard containers of insulation, jacket material, cements, adhesives, and coatings delivered for use, and samples required for approval shall have manufacturer's stamp or label attached giving the name of the manufacturer and brand, and a description of the material, date codes, and approximate shelf life (if applicable). Insulation packages and containers shall be asbestos free.

PART 2 PRODUCTS

2.1 STANDARD PRODUCTS

Provide materials which are the standard products of manufacturers regularly engaged in the manufacture of such products and that essentially duplicate items that have been in satisfactory use for at least 2 years prior to bid opening. Submit a complete list of materials, including manufacturer's descriptive technical literature, performance data, catalog cuts, and installation instructions. The product number, k-value, thickness and furnished accessories including adhesives, sealants and jackets for each mechanical system requiring insulation shall be included. The product data must be copyrighted, have an identifying or publication number, and shall have been published prior to the issuance date of this solicitation. Materials furnished under this section shall be submitted together in a booklet.

2.1.1 Insulation System

Provide insulation systems in accordance with the approved MICA National Insulation Standards plates as supplemented by this specification. Provide field-applied insulation for heating, ventilating, and cooling (HVAC) air distribution systems and piping systems that are located within, on, under, and adjacent to buildings; and for plumbing systems. Provide CFC and HCFC free insulation.

2.1.2 Surface Burning Characteristics

Unless otherwise specified, insulation must have a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with [ASTM E84](#). Flame spread, and smoke developed indexes, shall be determined by [ASTM E84](#) or [UL 723](#). Test insulation in the same density and installed thickness as the material to be used in the actual construction. Prepare and mount test specimens according to [ASTM E2231](#).

2.2 MATERIALS

Provide insulation that meets or exceeds the requirements of [ASHRAE 90.1 - IP](#). Insulation exterior shall be cleanable, grease resistant, non-flaking and non-peeling. Materials shall be compatible and shall not contribute to corrosion, soften, or otherwise attack surfaces to which applied in either wet or dry state. Materials to be used on stainless steel surfaces shall meet [ASTM C795](#) requirements. Calcium silicate shall not be used on chilled or cold water systems. Materials shall be asbestos free. Provide product recognized under [UL 94](#) (if containing plastic) and listed in [FM APP GUIDE](#).

2.2.1 Adhesives

2.2.1.1 Acoustical Lining Insulation Adhesive

Adhesive shall be a nonflammable, fire-resistant adhesive conforming to [ASTM C916](#), Type I.

2.2.1.2 Mineral Fiber Insulation Cement

Cement shall be in accordance with [ASTM C195](#).

2.2.1.3 Lagging Adhesive

Lagging is the material used for [thermal insulation](#), especially around a cylindrical object. This may include the insulation as well as the cloth/material covering the insulation. To resist mold/mildew, lagging adhesive shall meet [ASTM D5590](#) with 0 growth rating. Lagging adhesives shall be nonflammable and fire-resistant and shall have a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with [ASTM E84](#). Adhesive shall be [MIL-A-3316](#), Class 1, pigmented white and be suitable for bonding fibrous glass cloth to faced and unfaced fibrous glass insulation board; for bonding cotton brattice cloth to faced and unfaced fibrous glass insulation board; for sealing edges of and bonding glass tape to joints of fibrous glass board; for bonding lagging cloth to thermal insulation; or Class 2 for attaching fibrous glass insulation to metal surfaces. Lagging adhesives shall be applied in strict accordance with the manufacturer's recommendations for pipe and duct insulation.

2.2.1.4 Contact Adhesive

Adhesives may be any of, but not limited to, the neoprene based, rubber based, or elastomeric type that have a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with [ASTM E84](#). The adhesive shall not adversely affect, initially or in service, the insulation to which it is applied, nor shall it cause any corrosive effect on metal to which it is applied. Any solvent dispersing medium or volatile component of the adhesive shall have no objectionable odor and shall not contain any benzene or carbon tetrachloride. The dried adhesive shall not emit nauseous, irritating, or toxic volatile matters or aerosols when the adhesive is heated to any temperature up to [212 degrees F](#). The dried adhesive shall be nonflammable and fire resistant. Flexible Elastomeric Adhesive: Comply with [MIL-A-24179](#), Type II, Class I. Provide product listed in [FM APP GUIDE](#).

2.2.2 Caulking

[ASTM C920](#), Type S, Grade NS, Class 25, Use A.

2.2.3 Fittings

Fabricated Fittings are the prefabricated fittings for flexible elastomeric pipe insulation systems in accordance with [ASTM C1710](#). Together with the flexible elastomeric tubes, they provide complete system integrity for retarding heat gain and controlling condensation drip from chilled-water and refrigeration systems. Flexible elastomeric, fabricated fittings provide thermal protection (0.25 k) and condensation resistance (0.05 Water Vapor

Transmission factor). For satisfactory performance, properly installed protective vapor retarder/barriers and vapor stops shall be used on high relative humidity and below ambient temperature applications to reduce movement of moisture through or around the insulation to the colder interior surface.

2.2.4 Finishing Cement

ASTM C450: Mineral fiber hydraulic-setting thermal insulating and finishing cement. All cements that may come in contact with Austenitic stainless steel must comply with **ASTM C795**.

2.2.5 Jackets

2.2.5.1 Aluminum Jackets

Aluminum jackets shall be corrugated, embossed or smooth sheet, **0.016 inch** nominal thickness; **ASTM B209**, Temper H14, Temper H16, Alloy 3003, 5005, or 3105. Corrugated aluminum jacket shall not be used outdoors. Aluminum jacket circumferential seam bands shall be **2 by 0.016 inch** aluminum matching jacket material. Bands for insulation below ground shall be **3/4 by 0.020 inch** thick stainless steel, or fiberglass reinforced tape. The jacket may, at the option of the Contractor, be provided with a factory fabricated Pittsburgh or "Z" type longitudinal joint. When the "Z" joint is used, the bands at the circumferential joints shall be designed by the manufacturer to seal the joints and hold the jacket in place.

2.2.5.2 Polyvinyl Chloride (PVC) Jackets

Polyvinyl chloride (PVC) jacket and fitting covers shall have high impact strength, ultraviolet (UV) resistant rating or treatment and moderate chemical resistance with minimum thickness **0.030 inch**.

2.2.5.3 Vapor Barrier/Weatherproofing Jacket

Vapor barrier/weatherproofing jacket shall be laminated self-adhesive, greater than 3 plies standard grade, silver, white, black and embossed or greater than 8 ply (minimum **2.9 mils** adhesive); with 0.0000 permeability when tested in accordance with **ASTM E96/E96M**, using the water transmission rate test method; heavy duty, white or natural; and UV resistant. Flexible Elastomeric exterior foam with factory applied, UV Jacket made with a cold weather acrylic adhesive. Construction of laminate designed to provide UV resistance, high puncture, tear resistance and excellent Water Vapor Transmission (WVT) rate.

2.2.5.4 Vapor Barrier/Vapor Retarder

Apply the following criteria to determine which system is required.

- a. On ducts, piping and equipment operating below **55 degrees F** or located outside shall be equipped with a vapor barrier.
- b. Ducts, pipes and equipment that are located inside and that always operate above **55 degrees F** shall be installed with a vapor retarder where required as stated in paragraph VAPOR RETARDER REQUIRED.

2.2.6 Vapor Retarder Required

ASTM C921, Type I, minimum puncture resistance 50 Beach units on all surfaces where a minimum puncture resistance of 25 Beach units is acceptable. Minimum tensile strength, **35 pounds/inch** width. **ASTM C921**, Type II, minimum puncture resistance 25 Beach units, tensile strength minimum **20 pounds/inch** width. Jackets used on insulation exposed in finished areas shall have white finish suitable for painting without sizing. Based on the application, insulation materials that require manufacturer or fabricator applied pipe insulation jackets are cellular glass, when all joints are sealed with a vapor barrier mastic, and mineral fiber. All non-metallic jackets shall have a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with **ASTM E84**. Flexible elastomerics require (in addition to vapor barrier skin) vapor retarder jacketing for high relative humidity and below ambient temperature applications.

2.2.6.1 White Vapor Retarder All Service Jacket (ASJ)

ASJ is for use on hot/cold pipes, ducts, or equipment indoors or outdoors if covered by a suitable protective jacket. The product shall meet all physical property and performance requirements of **ASTM C1136**, Type I, except the burst strength shall be a minimum of **85 psi**. **ASTM D2863** Limited Oxygen Index (LOI) shall be a minimum of 31.

In addition, neither the outer exposed surface nor the inner-most surface contacting the insulation shall be paper or other moisture-sensitive material. The outer exposed surface shall be white and have an emittance of not less than 0.80. The outer exposed surface shall be paintable.

2.2.6.2 Vapor Retarder/Vapor Barrier Mastic Coatings

2.2.6.2.1 Vapor Barrier

The vapor barrier shall be self-adhesive (minimum **2 mils** adhesive, **3 mils** embossed) greater than 3 plies standard grade, silver, white, black and embossed white jacket for use on hot/cold pipes. Permeability shall be less than 0.02 when tested in accordance with **ASTM E96/E96M**. Products shall meet **UL 723** or **ASTM E84** flame and smoke requirements and shall be UV resistant.

2.2.6.2.2 Vapor Retarder

The vapor retarder coating shall be fire and water resistant and appropriately selected for either outdoor or indoor service. Color shall be white. The water vapor permeance of the compound shall be 0.013 perms or less at **43 mils** dry film thickness as determined according to procedure B of **ASTM E96/E96M** utilizing apparatus described in **ASTM E96/E96M**. The coating shall be nonflammable, fire resistant type. To resist mold/mildew, coating shall meet **ASTM D5590** with 0 growth rating. Coating shall meet **MIL-PRF-19565** Type II (if selected for indoor service) and be Qualified Products Database listed. All other application and service properties shall be in accordance with **ASTM C647**.

2.2.6.3 Laminated Film Vapor Retarder

ASTM C1136, Type I, maximum moisture vapor transmission 0.02 perms, minimum puncture resistance 50 Beach units on all surfaces except concealed ductwork; where Type II, maximum moisture vapor transmission 0.02 perms, a minimum

puncture resistance of 25 Beach units is acceptable. Vapor retarder shall have a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with [ASTM E84](#). Flexible Elastomeric exterior foam with factory applied UV Jacket. Construction of laminate designed to provide UV resistance, high puncture, tear resistance and an excellent WVT rate.

2.2.6.4 Polyvinylidene Chloride (PVDC) Film Vapor Retarder

The PVDC film vapor retarder shall have a maximum moisture vapor transmission of 0.02 perms, minimum puncture resistance of 150 Beach units, a minimum tensile strength in any direction of [30 lb/inch](#) when tested in accordance with [ASTM D882](#), and a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with [ASTM E84](#).

2.2.6.5 Polyvinylidene Chloride Vapor Retarder Adhesive Tape

Requirements must meet the same as specified for Laminated Film Vapor Retarder above.

2.2.6.6 Vapor Barrier/Weather Barrier

The vapor barrier shall be greater than 3 ply self-adhesive laminate -white vapor barrier jacket- superior performance (less than 0.0000 permeability when tested in accordance with [ASTM E96/E96M](#)). Vapor barrier shall meet [UL 723](#) or [ASTM E84](#) 25 flame and 50 smoke requirements; and UV resistant. Minimum burst strength [185 psi](#) in accordance with [ISO 2758](#). Tensile strength [68 lb/inch](#) width (PSTC-1000). Tape shall be as specified for laminated film vapor barrier above.

2.2.7 Vapor Retarder Not Required

[ASTM C921](#), Type II, Class D, minimum puncture resistance 50 Beach units on all surfaces except ductwork, where Type IV, maximum moisture vapor transmission 0.10, a minimum puncture resistance of 25 Beach units is acceptable. Jacket shall have a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with [ASTM E84](#).

2.2.8 Wire

Soft annealed [ASTM A580/A580M](#) Type 302, 304 or 316 stainless steel, 16 or 18 gauge.

2.2.9 Insulation Bands

Insulation bands shall be [1/2 inch](#) wide; 26 gauge stainless steel.

2.2.10 Sealants

Sealants shall be chosen from the butyl polymer type, the styrene-butadiene rubber type, or the butyl type of sealants. Sealants shall have a maximum permeance of 0.02 perms based on Procedure B for [ASTM E96/E96M](#), and a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with [ASTM E84](#).

PART 3 EXECUTION

3.1 APPLICATION - GENERAL

Insulation shall only be applied to unheated and uncooled piping and equipment. Flexible elastomeric cellular insulation shall not be compressed at joists, studs, columns, ducts, hangers, etc. The insulation shall not pull apart after a one hour period; any insulation found to pull apart after one hour, shall be replaced.

3.1.1 Installation

Except as otherwise specified, material shall be installed in accordance with the manufacturer's written instructions. Insulation materials shall not be applied until tests specified in other sections of this specification are completed. Material such as rust, scale, dirt and moisture shall be removed from surfaces to receive insulation. Insulation shall be kept clean and dry. Insulation shall not be removed from its shipping containers until the day it is ready to use and shall be returned to like containers or equally protected from dirt and moisture at the end of each workday. Insulation that becomes dirty shall be thoroughly cleaned prior to use. If insulation becomes wet or if cleaning does not restore the surfaces to like new condition, the insulation will be rejected, and shall be immediately removed from the jobsite. Joints shall be staggered on multi-layer insulation. Mineral fiber thermal insulating cement shall be mixed with demineralized water when used on stainless steel surfaces. Insulation, jacketing and accessories shall be installed in accordance with **MICA Insulation Stds** plates except where modified herein or on the drawings.

3.1.2 Installation of Flexible Elastomeric Cellular Insulation

Install flexible elastomeric cellular insulation with seams and joints sealed with rubberized contact adhesive. Flexible elastomeric cellular insulation shall not be used on surfaces greater than **220 degrees F**. Stagger seams when applying multiple layers of insulation. Protect insulation exposed to weather and not shown to have vapor barrier weatherproof jacketing with two coats of UV resistant finish or PVC or metal jacketing as recommended by the manufacturer after the adhesive is dry and cured.

3.1.2.1 Adhesive Application

Apply a brush coating of adhesive to both butt ends to be joined and to both slit surfaces to be sealed. Allow the adhesive to set until dry to touch but tacky under slight pressure before joining the surfaces. Insulation seals at seams and joints shall not be capable of being pulled apart one hour after application. Insulation that can be pulled apart one hour after installation shall be replaced.

3.1.2.2 Adhesive Safety Precautions

Use natural cross-ventilation, local (mechanical) pickup, and/or general area (mechanical) ventilation to prevent an accumulation of solvent vapors, keeping in mind the ventilation pattern must remove any heavier-than-air solvent vapors from lower levels of the workspaces. Gloves and spectacle-type safety glasses are recommended in accordance with safe installation practices.

-- End of Section --

SECTION 23 25 00

CHEMICAL TREATMENT OF WATER FOR MECHANICAL SYSTEMS

PART 1 GENERAL

1.1 SUMMARY

This section covers the provisions and installation procedures necessary for a complete and totally functional water system(s) chemical treatment. Provide and install the system with all necessary System Components, Accessories, Piping Components, and Supplemental Components/Services.

1.2 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for Contractor Quality Control approval. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Material and Equipment; G

SD-03 Product Data

Water Treatment Procedure; G

1.3 QUALITY CONTROL

1.3.1 Safety

Exposed moving parts, parts that produce high operating temperature, parts which may be electrically energized, and parts that may be a hazard to operating personnel shall be insulated, fully enclosed, guarded, or fitted with other types of safety devices. Install safety devices so that proper operation of equipment is not impaired.

1.4 DELIVERY, STORAGE, AND HANDLING

Protect all equipment delivered and placed in storage from the weather, humidity and temperature variations, dirt and dust, or other contaminants.

PART 2 PRODUCTS

2.1 STANDARD PRODUCTS

- a. Provide materials and equipment which are standard products of a manufacturer regularly engaged in the manufacturing of such products, that are of a similar material, design and workmanship and that have been in satisfactory commercial or industrial use for two years prior to bid opening.

- b. The two-year use shall include applications of equipment and materials under similar circumstances and of similar size. The two years' experience shall have been satisfactorily completed by a product which has been sold or is offered for sale on the commercial market through advertisements, manufacturer's catalogs, or brochures. Products having less than a two-year field service record will be acceptable if a certified record of satisfactory field operation, for not less than 6000 hours exclusive of the manufacturer's factory tests, can be shown.
- c. All products shall be supported by a service organization. Submit a certified list of qualified permanent service organizations for support of the equipment, including their addresses and qualifications. These service organizations shall be reasonably convenient to the equipment installation and shall be able to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.
- d. The selected service organization shall provide the chemicals required, the concentrations required, and the water treatment equipment sizes and flow rates required. The company shall provide all chemicals required for the chilled water systems and fill the systems with chemicals to the levels specified. The chemical shall meet the requirements of this specification as well as the recommendations from the manufacturers of the existing chillers and CRAH units. Acid treatment chemicals shall not be used.

2.2 CHILLED WATER SYSTEM

2.2.1 Chilled Water Treatment

Treat chilled water with chemicals in accordance with approved site-specific preventative maintenance procedures.

PART 3 EXECUTION

3.1 EXAMINATION

After becoming familiar with all details of the work, verify all dimensions in the field, and advise the Contracting Officer of any discrepancy, before performing any work.

3.2 INSTALLATION

Provide all chemicals, equipment and labor necessary to bring all system waters in conformance with the specified requirements. Perform all work in accordance with the manufacturer's published diagrams, recommendations, and equipment warranty requirements.

-- End of Section --

SECTION 23 64 26

CHILLED, CHILLED-HOT, AND CONDENSER WATER PIPING SYSTEMS

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN WATER WORKS ASSOCIATION (AWWA)

AWWA C606 (2015) Grooved and Shouldered Joints

AMERICAN WELDING SOCIETY (AWS)

AWS D1.1/D1.1M (2010; Errata 2011) Structural Welding Code - Steel

AWS Z49.1 (2012) Safety in Welding and Cutting and Allied Processes

ASME INTERNATIONAL (ASME)

ASME B1.20.1 (2013) Pipe Threads, General Purpose (Inch)

ASME B16.1 (2010) Gray Iron Pipe Flanges and Flanged Fittings Classes 25, 125, and 250

ASME B16.11 (2011) Forged Fittings, Socket-Welding and Threaded

ASME B16.21 (2011) Nonmetallic Flat Gaskets for Pipe Flanges

ASME B16.3 (2011) Malleable Iron Threaded Fittings, Classes 150 and 300

ASME B16.39 (2014) Standard for Malleable Iron Threaded Pipe Unions; Classes 150, 250, and 300

ASME B16.9 (2012) Standard for Factory-Made Wrought Steel Buttwelding Fittings

ASME B31.9 (2014) Building Services Piping

ASME BPVC SEC IX (2010) BPVC Section IX-Welding and Brazing Qualifications

ASTM INTERNATIONAL (ASTM)

ASTM A106/A106M (2014) Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service

ASTM A183	(2014) Standard Specification for Carbon Steel Track Bolts and Nuts
ASTM A47/A47M	(1999; R 2014) Standard Specification for Ferritic Malleable Iron Castings
ASTM A53/A53M	(2012) Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM A536	(1984; R 2014) Standard Specification for Ductile Iron Castings
ASTM A733	(2003; E 2009; R 2009) Standard Specification for Welded and Seamless Carbon Steel and Austenitic Stainless Steel Pipe Nipples
ASTM B117	(2011) Standard Practice for Operating Salt Spray (Fog) Apparatus
ASTM D2000	(2012) Standard Classification System for Rubber Products in Automotive Applications
ASTM D3308	(2012) PTFE Resin Skived Tape
ASTM D520	(2000; R 2011) Zinc Dust Pigment
ASTM E84	(2015a) Standard Test Method for Surface Burning Characteristics of Building Materials

MANUFACTURERS STANDARDIZATION SOCIETY OF THE VALVE AND FITTINGS
INDUSTRY (MSS)

MSS SP-110	(2010) Ball Valves Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends
MSS SP-25	(2013) Standard Marking System for Valves, Fittings, Flanges and Unions
MSS SP-58	(1993; Reaffirmed 2010) Pipe Hangers and Supports - Materials, Design and Manufacture, Selection, Application, and Installation
MSS SP-67	(2011) Butterfly Valves
MSS SP-69	(2003; Notice 2012) Pipe Hangers and Supports - Selection and Application (ANSI Approved American National Standard)
MSS SP-72	(2010a) Ball Valves with Flanged or Butt- Welding Ends for General Service
MSS SP-80	(2013) Bronze Gate, Globe, Angle and Check Valves

1.2 SYSTEM DESCRIPTION

Provide the water systems having the minimum service (design) temperature-pressure rating indicated. Provision of the piping systems, including materials, installation, workmanship, fabrication, assembly, erection, examination, inspection, and testing shall be in accordance with the required and advisory provisions of ASME B31.9 except as modified or supplemented by this specification section or design drawings. This specification section covers the water systems piping which is located within, on, and adjacent to building(s) within the building(s) 5 foot line.

1.3 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for Contractor Quality Control approval. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Material and Equipment; G

SD-03 Product Data

Grooved Mechanical Connections for Steel; DA

SD-06 Test Reports; G

Piping Welds NDE Report

SD-07 Certificates; G

Employer's Record Documents (For Welding)

Welding Procedures and Qualifications

Certificates shall be submitted showing conformance with the referenced standards contained in this section.

1.4 MODIFICATIONS TO REFERENCES

In each of the publications referred to herein, consider the advisory provisions to be mandatory, as though the word, "shall" had been substituted for "should" wherever it appears. Interpret references in these publications to the "authority having jurisdiction", or words of similar meaning, to mean the Contracting Officer.

1.4.1 Definitions

For the International Code Council (ICC) Codes referenced in the contract documents, advisory provisions shall be considered mandatory, the word "should" shall be interpreted as "shall." Reference to the "code official" shall be interpreted to mean the "Contracting Officer." For Navy owned property, references to the "owner" shall be interpreted to mean the "Contracting Officer." For leased facilities, references to the "owner" shall be interpreted to mean the "lessor." References to the "permit holder" shall be interpreted to mean the "Contractor."

1.4.2 Administrative Interpretations

For ICC Codes referenced in the contract documents, the provisions of Chapter 1, "Administrator," do not apply. These administrative requirements are covered by the applicable Federal Acquisition Regulations (FAR) included in this contract and by the authority granted to the Officer in Charge of Construction to administer the construction of this project. References in the ICC Codes to sections of Chapter 1, shall be applied appropriately by the Contracting Officer as authorized by his administrative cognizance and the FAR.

1.5 SAFETY REQUIREMENTS

Exposed moving parts, parts that produce high operating temperature, parts which may be electrically energized, and parts that may be a hazard to operating personnel shall be insulated, fully enclosed, guarded, or fitted with other types of safety devices. Safety devices shall be installed so that proper operation of equipment is not impaired.

1.6 DELIVERY, STORAGE, AND HANDLING

Protect stored items from the weather, humidity and temperature variations, dirt and dust, or other contaminants. Proper protection and care of all material both before and during installation shall be the Contractor's responsibility. Any materials found to be damaged shall be replaced at the Contractor's expense. During installation, cap piping and similar openings to keep out dirt and other foreign matter. Any porous materials found to be contaminated with mold or mildew will be replaced at the Contractor's expense. Non-porous materials found to be contaminated with mold or mildew will be disinfected and cleaned prior to installation.

1.7 PROJECT/SITE CONDITIONS

1.7.1 Verification of Dimensions

The Contractor shall become familiar with all details of the work, verify all dimensions in the field, and advise the Contracting Officer of any discrepancy before performing any work.

1.7.2 Drawings

Because of the small scale of the drawings, it is not possible to indicate all offsets, fittings, and accessories that may be required. The Contractor shall carefully investigate the plumbing, fire protection, electrical, structural and finish conditions that would affect the work to be performed and shall arrange such work accordingly, furnishing required offsets, fittings, and accessories to meet such conditions.

1.7.3 Accessibility

Install all work so that parts requiring periodic inspection, operation, maintenance, and repair are readily accessible. Install concealed valves, expansion joints, controls, dampers, and equipment requiring access, in locations freely accessible through access doors.

PART 2 PRODUCTS

2.1 STANDARD COMMERCIAL PRODUCTS

Materials and equipment shall be standard products of a manufacturer regularly engaged in the manufacturing of such products, which are of a similar material, design and workmanship. The standard products shall have been in satisfactory commercial or industrial use for 2 years prior to bid opening.

The two year use shall include applications of equipment and materials under similar circumstances and of similar size. The 2 years' experience shall be satisfactorily completed by a product which has been sold or is offered for sale on the commercial market through advertisements, manufacturer's catalogs, or brochures.

Products having less than a 2 year field service record shall be acceptable if a certified record of satisfactory field operation, for not less than 6000 hours exclusive of the manufacturer's factory tests, can be shown. System components shall be environmentally suitable for the indicated locations.

The equipment items shall be supported by service organizations. These service organizations shall be reasonably convenient to the equipment installation and able to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.

2.2 STEEL PIPING

Water piping shall be steel pipe or copper tubing. Provide steel piping with a ANSI/ASME Class 125 service rating, which for 150 degrees F, the pressure rating is 175 psig.

2.2.1 Pipe

Steel pipe, conform to ASTM A53/A53M, Schedule 40, Type E or S, Grades A or B. Do not use Type F pipe.

2.2.2 Fittings and End Connections (Joints)

Piping and fittings 1 inch and smaller shall have threaded connections. Piping and fittings larger than 1 inch and smaller than 3 inches shall have either threaded, or welded connections. Piping and fittings 3 inches and larger shall have grooved, welded, or flanged connections. The manufacturer of each fitting shall be permanently identified on the body of the fitting in accordance with MSS SP-25.

2.2.2.1 Threaded Connections

Use threaded valves and pipe connections conforming to ASME B1.20.1. Used threaded fitting conforming to ASME B16.3. Use threaded unions conforming to ASME B16.39. Use threaded pipe nipples conforming to ASTM A733.

2.2.2.2 Flanged Connections

Flanges shall conform to ASME B16.1, Class 125. Gaskets shall be nonasbestos compressed material in accordance with ASME B16.21, 1/16 inch thickness, full face or self-centering flat ring type. These gaskets shall contain aramid

fibers bonded with styrene butadiene rubber (SBR) or nitrile butadiene rubber (NBR). Bolts, nuts, and bolt patterns shall conform to [ASME B16.1](#).

2.2.2.3 Welded Connections

Welded valves and pipe connections (both butt-welds and socket-welds types) shall conform to [ASME B31.9](#). Butt-welded fittings shall conform to [ASME B16.9](#). Socket-welded fittings shall conform to [ASME B16.11](#). Welded fittings shall be identified with the appropriate grade and marking symbol.

2.2.2.4 Grooved Mechanical Connections for Steel

Rigid grooved mechanical connections may only be used in serviceable aboveground locations where the temperature of the circulating medium does not exceed [230 degrees F](#). Flexible grooved connections shall be used only as a flexible connector with grooved pipe system. Unless otherwise specified, grooved piping components shall meet the corresponding criteria specified for the similar welded, flanged, or threaded component specified herein.

Each grooved mechanical joint shall be a system, including coupling housing, gasket, fasteners, all furnished by the same manufacturer. Joint installation shall be in compliance with joint manufacturer's written instructions.

Use fitting and coupling houses of malleable iron conforming to [ASTM A47/A47M](#), Grade 32510; ductile iron conforming to [ASTM A536](#), Grade 65-45-12; or steel conforming to [ASTM A106/A106M](#), Grade B or [ASTM A53/A53M](#). Use gaskets of molded synthetic rubber with central cavity, pressure responsive configuration and conforming to [ASTM D2000](#) Grade No. 2CA615A15B44F17Z for circulating medium up to [230 degrees F](#) or Grade No. M3BA610A15B44Z for circulating medium up to [200 degrees F](#). Grooved mechanical connections shall conform to [AWWA C606](#). Coupling nuts and bolts shall be steel and shall conform to [ASTM A183](#). Pipe connections and fittings shall be the product of the same manufacturer. Provide joint installation be in compliance with joint manufacturer's written instructions.

2.3 VALVES

Provide valves with a ANSI/ASME Class 125 service rating, which for [150 degrees F](#), the pressure rating is [175 psig](#).

Valves in sizes larger than [1 inch](#) and used on steel pipe systems, may be provided with rigid grooved mechanical joint ends. Such grooved end valves shall be subject to the same requirements as rigid grooved mechanical joints and fittings and, shall be furnished by the same manufacturer as the grooved pipe joint and fitting system.

2.3.1 Butterfly Valve

Butterfly valves shall conform to [MSS SP-67](#), Type 1 and shall be either the wafer or lug type. Valves smaller than [8 inches](#) shall have throttling handles with a minimum of two locking positions. Valves [8 inches](#) and larger shall have totally enclosed manual gear operators with adjustable balance return stops and position indicators.

2.3.2 Ball Valve

Full port design. Ball valves 1/2 inch and larger shall conform to MSS SP-72 or MSS SP-110 and shall be cast iron or bronze with threaded, soldered, or flanged ends. Valves 8 inches or larger shall be provided with manual gear operators with position indicators. Ball valves may be provided in lieu of gate valves.

2.3.3 Drain Valves

Valves, MSS SP-80 gate valves. Valve shall be manually-operated, 3/4 inch pipe size and above with a threaded end connection. Provide valve with a water hose nipple adapter.

2.3.4 Air Venting Valves

Manually-operated general service type air venting valves, brass or bronze valves that are furnished with threaded plugs or caps. Air venting valves on water coils shall have not less than 1/8 inch threaded end connections. Air venting valves on water mains shall have not less than 3/4 inch threaded end connections. Air venting valves on all other applications shall have not less than 1/2 inch threaded end connections.

2.4 PIPING ACCESSORIES

2.4.1 Pipe Hangers, Inserts, and Supports

Pipe hangers, inserts, guides, and supports: to MSS SP-58 and MSS SP-69.

2.5 PAINTING OF NEW EQUIPMENT

New equipment painting shall be factory applied or shop applied, and shall be as specified herein, and provided under each individual section.

2.5.1 Factory Painting Systems

Manufacturer's standard factory painting systems may be provided. The factory painting system applied will withstand 125 hours in a salt-spray fog test, except that equipment located outdoors shall withstand 500 hours in a salt-spray fog test.

Salt-spray fog test shall be in accordance with ASTM B117, and for that test, the acceptance criteria shall be as follows: immediately after completion of the test, the paint shall show no signs of blistering, wrinkling, or cracking, and no loss of 0.125 inch on either side of the scratch mark. The film thickness of the factory painting system applied on the equipment shall not be less than the film thickness used on the test specimen.

If manufacturer's standard factory painting system is being proposed for use on surfaces subject to temperatures above 120 degrees F, the factory painting system shall be designed for the temperature service.

2.5.2 Shop Painting Systems for Metal Surfaces

Clean, retreat, prime and paint metal surfaces; except aluminum surfaces need not be painted. Apply coatings to clean dry surfaces. Clean the surfaces to remove dust, dirt, rust, oil and grease by wire brushing and solvent degreasing prior to application of paint, except metal surfaces subject to temperatures in excess of 120 degrees F shall be cleaned to bare metal.

Where hot-dip galvanized steel has been cut, resulting surfaces with no galvanizing shall be coated with a zinc-rich coating conforming to [ASTM D520](#), Type I.

Where more than one coat of paint is specified, apply the second coat after the preceding coat is thoroughly dry. Lightly sand damaged painting and retouch before applying the succeeding coat. Color of finish coat shall be aluminum or light gray.

- a. Temperatures Less Than [120 Degrees F](#): Immediately after cleaning, the metal surfaces subject to temperatures less than [120 degrees F](#) shall receive one coat of pretreatment primer applied to a minimum dry film thickness of [0.3 mil](#), one coat of primer applied to a minimum dry film thickness of [one mil](#); and two coats of enamel applied to a minimum dry film thickness of [one mil](#) per coat.
- b. Temperatures Between [120 and 400 degrees F](#): Metal surfaces subject to temperatures between [120 and 400 degrees F](#) shall receive two coats of [400 degrees F](#) heat-resisting enamel applied to a total minimum thickness of [2 mils](#).
- c. Temperatures Greater Than [400 degrees F](#): Metal surfaces subject to temperatures greater than [400 degrees F](#) shall receive two coats of [600 degrees F](#) heat-resisting paint applied to a total minimum dry film thickness of [2 mils](#).

2.6 FACTORY APPLIED INSULATION

Factory insulated items installed outdoors are not required to be fire-rated. As a minimum, factory insulated items installed indoors shall have a flame spread index no higher than 25 and a smoke developed index no higher than 50. Factory insulated items (no jacket) installed indoors and which are located in air plenums, in ceiling spaces, and in attic spaces shall have a flame spread index no higher than 25 and a smoke developed index no higher than 50. Flame spread and smoke developed indexes shall be determined by [ASTM E84](#).

Insulation shall be tested in the same density and installed thickness as the material to be used in the actual construction. Material supplied by a manufacturer with a jacket shall be tested as a composite material. Jackets, facings, and adhesives shall have a flame spread index no higher than 25 and a smoke developed index no higher than 50 when tested in accordance with [ASTM E84](#).

2.7 RELATED COMPONENTS/SERVICES

2.7.1 Field Applied Insulation

Requirements for field installed insulation is specified in Section [23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS](#), except as supplemented and modified by this specification section.

PART 3 EXECUTION

3.1 INSTALLATION

Cut pipe accurately to measurements established at the jobsite, and work into place without springing or forcing, completely clearing all windows, doors, and other openings. Cutting or other weakening of the building structure to facilitate piping installation is not permitted without written approval. Cut pipe or tubing square, remove burrs by reaming, and fashion to permit free expansion and contraction without causing damage to the building structure, pipe, joints, or hangers.

Notify the Contracting Officer in writing at least 15 calendar days prior to the date the connections are required. Obtain approval before interrupting service. Furnish materials required to make connections into existing systems and perform excavating, backfilling, compacting, and other incidental labor as required. Furnish labor and tools for making actual connections to existing systems.

3.1.1 Welding

Provide welding work specified this section for piping systems in conformance with [ASME B31.9](#), as modified and supplemented by this specification section and the accompanying drawings. The welding work includes: qualification of welding procedures, welders, welding operators, brazers, brazing operators, and nondestructive examination personnel; maintenance of welding records, and examination methods for welds.

3.1.1.1 Employer's Record Documents (For Welding)

Submit for review and approval the following documentation. This documentation and the subject qualifications shall be in compliance with [ASME B31.9](#).

- a. List of qualified welding procedures that is proposed to be used to provide the work specified in this specification section.
- b. List of qualified welders, brazers, welding operators, and brazing operators that are proposed to be used to provide the work specified in this specification section.
- c. List of qualified weld examination personnel that are proposed to be used to provide the work specified in this specification section.

3.1.1.2 Welding Procedures and Qualifications

- a. Specifications and Test Results: Submit copies of the welding procedures specifications and procedure qualification test results for each type of welding required. Approval of any procedure does not relieve the Contractor of the responsibility for producing acceptable welds. Submit this information on the forms printed in [ASME BPVC SEC IX](#) or their equivalent.
- b. Certification: Before assigning welders or welding operators to the work, submit a list of qualified welders, together with data and certification that each individual is performance qualified as specified. Do not start welding work prior to submitting welder, and welding operator qualifications. The certification shall state the type of welding and positions for which each is qualified, the code and procedure under which each is qualified, date qualified, and the firm and individual certifying the qualification tests.

3.1.1.3 Examination of Piping Welds

Conduct non-destructive examinations (NDE) on piping welds and brazing and verify the work meets the acceptance criteria specified in [ASME B31.9](#). NDE on piping welds covered by [ASME B31.9](#) is visual inspection only. Submit a [piping welds NDE report](#) meeting the requirements specified in [ASME B31.9](#).

3.1.1.4 Welding Safety

Welding and cutting safety requirements shall be in accordance with [AWS Z49.1](#).

3.1.2 Fittings and End Connections

3.1.2.1 Threaded Connections

Threaded connections shall be made with tapered threads and made tight with PTFE tape complying with [ASTM D3308](#) or equivalent thread-joint compound applied to the male threads only. Not more than three threads shall show after the joint is made.

3.1.2.2 Welded Connections

Branch connections shall be made with welding tees or forged welding branch outlets. Pipe shall be thoroughly cleaned of all scale and foreign matter before the piping is assembled. During welding, the pipe and fittings shall be filled with an inert gas, such as nitrogen, to prevent the formation of scale. Beveling, alignment, heat treatment, and inspection of weld shall conform to [ASME B31.9](#). Weld defects shall be removed and rewelded at no additional cost to the Government. Electrodes shall be stored and dried in accordance with [AWS D1.1/D1.1M](#) or as recommended by the manufacturer. Electrodes that have been wetted or that have lost any of their coating shall not be used.

3.1.2.3 Grooved Mechanical Connections

Prepare grooves in accordance with the coupling manufacturer's instructions. Pipe and groove dimensions shall comply with the tolerances specified by the coupling manufacturer. The diameter of grooves made in the field shall be measured using a "go/no-go" gauge, vernier or dial caliper, or narrow-land micrometer, or other method specifically approved by the coupling manufacturer for the intended application. Groove width and dimension of groove from end of pipe shall be measured and recorded for each change in grooving tool setup to verify compliance with coupling manufacturer's tolerances. Grooved joints shall not be used in concealed locations, such as behind solid walls or ceilings, unless an access panel is shown on the drawings for servicing or adjusting the joint.

3.1.2.4 Flanges and Unions

Except where copper tubing is used, union or flanged joints shall be provided in each line immediately preceding the connection to each piece of equipment or material requiring maintenance such as coils, pumps, control valves, and other similar items. Flanged joints shall be assembled square end tight with matched flanges, gaskets, and bolts. Gaskets shall be suitable for the intended application.

3.1.3 Valves

Isolation gate or ball valves shall be installed on each side of each piece of equipment, at the midpoint of all looped mains, and at any other points indicated or required for draining, isolating, or sectionalizing purpose. Isolation valves may be omitted where balancing cocks are installed to provide both balancing and isolation functions. Each valve except check valves shall be identified. Valves in horizontal lines shall be installed with stems horizontal or above.

3.1.4 Air Vents

Air vents shall be provided at all high points, on all water coils, and where indicated to ensure adequate venting of the piping system.

3.1.5 Drains

Drains shall be provided at all low points and where indicated to ensure complete drainage of the piping. Drains shall be accessible and shall consist of nipples and caps or plugged tees unless otherwise indicated.

3.1.6 Pipe Hangers, Inserts, and Supports

Pipe hangers, inserts, and supports shall conform to MSS SP-58 and MSS SP-69, except as supplemented and modified in this specification section. Pipe hanger types 5, 12, and 26 shall not be used. Hangers used to support piping 2 inches and larger shall be fabricated to permit adequate adjustment after erection while still supporting the load. Piping subjected to vertical movement, when operating temperatures exceed ambient temperatures, shall be supported by variable spring hangers and supports or by constant support hangers.

3.1.6.1 Hangers

Type 3 shall not be used on insulated piping. Type 24 may be used only on trapeze hanger systems or on fabricated frames.

3.1.6.2 Inserts

Type 18 inserts shall be secured to concrete forms before concrete is placed. Continuous inserts which allow more adjustments may be used if they otherwise meet the requirements for Type 18 inserts.

3.1.6.3 C-Clamps

Type 19 and 23 C-clamps shall be torqued per MSS SP-69 and have both locknuts and retaining devices, furnished by the manufacturer. Field-fabricated C-clamp bodies or retaining devices are not acceptable.

3.1.6.4 Angle Attachments

Type 20 attachments used on angles and channels shall be furnished with an added malleable-iron heel plate or adapter.

3.1.6.5 Saddles and Shields

Where Type 39 saddle or Type 40 shield are permitted for a particular pipe attachment application, the Type 39 saddle, connected to the pipe, shall be used on all pipe 4 inches and larger when the temperature of the medium is 60 degrees F or higher. Type 40 shields shall be used on all piping less than 4 inches and all piping 4 inches and larger carrying medium less than 60 degrees F. A high density insulation insert of cellular glass shall be used under the Type 40 shield for piping 2 inches and larger.

3.1.6.6 Horizontal Pipe Supports

Horizontal pipe supports shall be spaced as specified in MSS SP-69 and a support shall be installed not over 1 foot from the pipe fitting joint at each change in direction of the piping. Pipe supports shall be spaced not over 5 feet apart at valves.

3.1.6.7 Vertical Pipe Supports

Vertical pipe shall be supported at each floor, except at slab-on-grade, and at intervals of not more than 15 feet, not more than 8 feet from end of risers, and at vent terminations.

3.1.6.8 Pipe Guides

Type 35 guides using, steel, reinforced polytetrafluoroethylene (PTFE) or graphite slides shall be provided where required to allow longitudinal pipe movement. Lateral restraints shall be provided as required. Slide materials shall be suitable for the system operating temperatures, atmospheric conditions, and bearing loads encountered.

3.1.6.9 Steel Slides

Where steel slides do not require provisions for restraint of lateral movement, an alternate guide method may be used. On piping 4 inches and larger, a Type 39 saddle shall be used. On piping under 4 inches, a Type 40 protection shield may be attached to the pipe or insulation and freely rest on a steel slide plate.

3.1.6.10 Multiple Pipe Runs

In the support of multiple pipe runs on a common base member, a clip or clamp shall be used where each pipe crosses the base support member. Spacing of the base support members shall not exceed the hanger and support spacing required for an individual pipe in the multiple pipe run.

3.1.6.11 Seismic Requirements

Piping and attached valves shall be supported and braced to resist seismic loads per structural drawings, notes, and details.

3.1.6.12 Structural Attachments

Attachment to building structure concrete and masonry shall be by cast-in concrete inserts, built-in anchors, or masonry anchor devices. Inserts and anchors shall be applied with a safety factor not less than 5. Supports shall not be attached to metal decking. Supports shall not be attached to the underside of concrete filled floors or concrete roof decks unless approved by the Contracting Officer. Masonry anchors for overhead

applications shall be constructed of ferrous materials only. Structural steel brackets required to support piping, headers, and equipment, but not shown, shall be provided under this section. Material used for support shall comply with structural drawings, notes, and details.

3.1.7 Pipe Anchors

Anchors shall be provided where indicated. Unless indicated otherwise, anchors shall comply with the requirements specified. Anchors shall consist of heavy steel collars with lugs and bolts for clamping and attaching anchor braces, unless otherwise indicated. Anchor braces shall be installed in the most effective manner to secure the desired results using turnbuckles where required.

Supports, anchors, or stays shall not be attached where they will injure the structure or adjacent construction during installation or by the weight of expansion of the pipeline. Where pipe and conduit penetrations of vapor barrier sealed surfaces occur, these items shall be anchored immediately adjacent to each penetrated surface, to provide essentially zero movement within penetration seal.

3.2 CLEANING AND ADJUSTING

Pipes shall be cleaned free of scale and thoroughly flushed of all foreign matter. A temporary bypass shall be provided for all water coils to prevent flushing water from passing through coils. Strainers and valves shall be thoroughly cleaned. Prior to testing and balancing, air shall be removed from all water systems by operating the air vents. Temporary measures, such as piping the overflow from vents to a collecting vessel shall be taken to avoid water damage during the venting process. Air vents shall be plugged or capped after the system has been vented. Control valves and other miscellaneous equipment requiring adjustment shall be adjusted to setting indicated or directed.

3.3 FIELD TESTS

Field tests shall be conducted in the presence of the QC Manager or his designated representative to verify systems compliance with specifications. Any material, equipment, instruments, and personnel required for the test shall be provided by the Contractor.

3.3.1 Pressure Tests

Each piping system shall be hydrostatically tested. The hydrostatic test pressure shall not be less than 1.5 times the design operating pressure of the system. Leaks shall be repaired, and piping retested until test requirements are met.

Leaks shall be repaired by rewelding or replacing pipe or fittings. Caulking of joints will not be permitted. Concealed and insulated piping shall be tested in place before concealing.

Submit for approval [pressure tests reports](#) covering the above specified piping pressure tests; describe the systems tested, test results, defects found and repaired, and signature of the pressure tests' director. Obtain approval from the QC Manager before concealing piping or applying insulation to tested and accepted piping.

-- End of Section --

SECTION 26 00 00.00

BASIC ELECTRICAL MATERIALS AND METHODS

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

ASTM D709 (2013) Laminated Thermosetting Materials

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 100 (2000; Archived) The Authoritative Dictionary of IEEE Standards Terms

IEEE C2 (2012; Errata 2012; INT 1-4 2012; INT 5-7 2013; INT 8 2014) National Electrical Safety Code

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250 (2014) Enclosures for Electrical Equipment (1000 Volts Maximum)

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70 (2014; AMD 1 2013; Errata 1 2013; AMD 2 2013; Errata 2 2013; AMD 3 2014; Errata 3-4 2014; AMD 4-6 2014) National Electrical Code

1.2 RELATED REQUIREMENTS

This section applies to certain sections of Divisions 20 and 23, PLUMBING and HEATING VENTILATING AND AIR CONDITIONING. This section applies to all sections of Division 26, ELECTRICAL, of this project specification unless specified otherwise in the individual sections.

1.3 DEFINITIONS

- a. Unless otherwise specified or indicated, electrical and electronics terms used in these specifications, and on the drawings, shall be as defined in IEEE 100.
- b. The technical sections referred to herein are those specification sections that describe products, installation procedures, and equipment operations and that refer to this section for detailed description of submittal types.
- c. The technical paragraphs referred to herein are those paragraphs in PART 2 - PRODUCTS and PART 3 - EXECUTION of the technical sections that

describe products, systems, installation procedures, equipment, and test methods.

1.4 ADDITIONAL SUBMITTALS INFORMATION

Submittals required in other sections that refer to this section must conform to the following additional requirements as applicable.

1.4.1 Shop Drawings (SD-02)

Include wiring diagrams and installation details of equipment indicating proposed location, layout and arrangement, control panels, accessories, piping, ductwork, and other items that must be shown to ensure a coordinated installation. Wiring diagrams shall identify circuit terminals and indicate the internal wiring for each item of equipment and the interconnection between each item of equipment. Drawings shall indicate adequate clearance for operation, maintenance, and replacement of operating equipment devices.

1.4.2 Product Data (SD-03)

Submittal shall include performance and characteristic curves.

1.5 QUALITY ASSURANCE

1.5.1 Regulatory Requirements

In each of the publications referred to herein, consider the advisory provisions to be mandatory, as though the word, "shall" had been substituted for "should" wherever it appears. Interpret references in these publications to the "authority having jurisdiction," or words of similar meaning, to mean the Contracting Officer. Equipment, materials, installation, and workmanship shall be in accordance with the mandatory and advisory provisions of **NFPA 70** unless more stringent requirements are specified or indicated.

1.5.2 Standard Products

Provide materials and equipment that are products of manufacturers regularly engaged in the production of such products which are of equal material, design and workmanship. Products shall have been in satisfactory commercial or industrial use for 2 years prior to bid opening. The 2-year period shall include applications of equipment and materials under similar circumstances and of similar size. The product shall have been on sale on the commercial market through advertisements, manufacturers' catalogs, or brochures during the 2-year period. Where two or more items of the same class of equipment are required, these items shall be products of a single manufacturer; however, the component parts of the item need not be the products of the same manufacturer unless stated in the technical section.

1.5.2.1 Alternative Qualifications

Products having less than a 2-year field service record will be acceptable if a certified record of satisfactory field operation for not less than 6000 hours, exclusive of the manufacturers' factory or laboratory tests, is furnished.

1.5.2.2 Material and Equipment Manufacturing Date

Products manufactured more than 3 years prior to date of delivery to site shall not be used, unless specified otherwise.

1.6 WARRANTY

The equipment items shall be supported by service organizations which are reasonably convenient to the equipment installation in order to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.

1.7 POSTED OPERATING INSTRUCTIONS

Provide for each system and principal item of equipment as specified in the technical sections for use by operation and maintenance personnel. The operating instructions shall include the following:

- a. Wiring diagrams, control diagrams, and control sequence for each principal system and item of equipment.
- b. Start up, proper adjustment, operating, lubrication, and shutdown procedures.
- c. Safety precautions.
- d. The procedure in the event of equipment failure.
- e. Other items of instruction as recommended by the manufacturer of each system or item of equipment.

Print or engrave operating instructions and frame under glass or in approved laminated plastic. Post instructions where directed. For operating instructions exposed to the weather, provide weather-resistant materials or weatherproof enclosures. Operating instructions shall not fade when exposed to sunlight and shall be secured to prevent easy removal or peeling.

1.8 MANUFACTURER'S NAMEPLATE

Each item of equipment shall have a nameplate bearing the manufacturer's name, address, model number, and serial number securely affixed in a conspicuous place; the nameplate of the distributing agent will not be acceptable.

1.9 FIELD FABRICATED NAMEPLATES

ASTM D709. Provide laminated plastic nameplates for each equipment enclosure, relay, switch, and device; as specified in the technical sections or as indicated on the drawings. Each nameplate inscription shall identify the function and, when applicable, the position. Nameplates shall be melamine plastic, **0.125 inch** thick, white with black center core. Surface shall be matte finish. Corners shall be square. Accurately align lettering and engrave into the core. Minimum size of nameplates shall be **one by 2.5 inches**. Lettering shall be a minimum of **0.25 inch** high normal block style.

1.10 ELECTRICAL REQUIREMENTS

Electrical installations shall conform to **IEEE C2**, **NFPA 70**, and requirements specified herein.

PART 2 PRODUCTS

2.1 FACTORY APPLIED FINISH

Electrical equipment shall have factory-applied painting systems which shall, as a minimum, meet the requirements of NEMA 250 corrosion-resistance test.

PART 3 EXECUTION

3.1 FIELD APPLIED PAINTING

Paint electrical equipment as required to match finish of adjacent surfaces or to meet the indicated or specified safety criteria. Painting shall be as specified in the section specifying the associated electrical equipment.

3.2 FIELD FABRICATED NAMEPLATE MOUNTING

Provide number, location, and letter designation of nameplates as indicated. Fasten nameplates to the device with a minimum of two sheet-metal screws or two rivets.

-- End of Section --

SECTION 26 05 00.00

COMMON WORK RESULTS FOR ELECTRICAL

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

ASTM D709 (2013) Laminated Thermosetting Materials

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE Stds Dictionary (2009) IEEE Standards Dictionary: Glossary of Terms & Definitions

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

ANSI Z535.1 (2006; R 2011) American National Standard for Safety--Color Code

ANSI/NEMA OS 1 (2013) Sheet-Steel Outlet Boxes, Device Boxes, Covers, and Box Supports

NEMA FB 1 (2012) Standard for Fittings, Cast Metal Boxes, and Conduit Bodies for Conduit, Electrical Metallic Tubing, and Cable

NEMA KS 1 (2013) Enclosed and Miscellaneous Distribution Equipment Switches (600 V Maximum)

NEMA RN 1 (2005; R 2013) Polyvinyl-Chloride (PVC) Externally Coated Galvanized Rigid Steel Conduit and Intermediate Metal Conduit

NEMA TC 2 (2013) Standard for Electrical Polyvinyl Chloride (PVC) Conduit

NEMA TC 3 (2013) Standard for Polyvinyl Chloride (PVC) Fittings for Use With Rigid PVC Conduit and Tubing

NEMA WD 1 (1999; R 2005; R 2010) Standard for General Color Requirements for Wiring Devices

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70 (2014; AMD 1 2013; Errata 1 2013; AMD 2 2013; Errata 2 2013; AMD 3 2014; Errata 3-4 2014; AMD 4-6 2014) National Electrical Code

UNDERWRITERS LABORATORIES (UL)

UL 1	(2005; Reprint Jul 2012) Standard for Flexible Metal Conduit
UL 1242	(2006; Reprint Mar 2014) Standard for Electrical Intermediate Metal Conduit -- Steel
UL 489	(2013; Reprint Mar 2014) Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures
UL 6	(2007; Reprint Nov 2014) Electrical Rigid Metal Conduit-Steel
UL 797	(2007; Reprint Dec 2012) Electrical Metallic Tubing -- Steel
UL 870	(2008; Reprint Feb 2013) Standard for Wireways, Auxiliary Gutters, and Associated Fittings

1.2 DEFINITIONS

- a. Unless otherwise specified or indicated, electrical and electronics terms used in these specifications, and on the drawings, are as defined in [IEEE Std's Dictionary](#).
- b. The technical sections referred to herein are those specification sections that describe products, installation procedures, and equipment operations and that refer to this section for detailed description of submittal types.

1.3 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for Contractor Quality Control approval. Submit the following in accordance with Section [01 33 00 SUBMITTAL PROCEDURES](#):

[SD-01 Preconstruction Submittals](#)

[Material and Equipment; G](#)

[Arc Flash Coordination Study; DA](#)

[SD-03 Product Data](#)

[Conduits and Raceways; DA](#)

[Wire and Cable; DA](#)

[Splices and Connectors; DA](#)

[Switches; DA](#)

[Circuit Breakers; DA](#)

SD-06 Test Reports

Continuity Test; G

Insulation Resistance Test; G

SD-07 Certificates

Certification; G

1.4 QUALITY ASSURANCE

Submit [certification](#) required to install equipment components and system packages.

1.5 ARC FLASH ANALYSIS AND COORDINATION

1.5.1 Coordination Study

Provide arc flash coordination study for the modifications to the electrical distribution system. The coordination study shall be submitted to the Engineer of Record for approval. Submittal shall be on or before date of circuit breaker and equipment submittals. The study shall meet the requirements of NFPA 70.

1.5.2 Arc Flash Labels

Provide labels (Hazard Risk Categories) affixed to all equipment per NFPA-70E 1EE-1584.

PART 2 PRODUCTS

2.1 EQUIPMENT

Provide the standard cataloged materials and equipment of manufacturers regularly engaged in the manufacture of the products. For [material, equipment, and fixture lists](#) submittals, show manufacturer's style or catalog numbers, specification and drawing reference numbers, warranty information, and fabrication site.

2.1.1 Conduits and Raceways

2.1.1.1 Rigid Steel Conduit

Ensure rigid steel conduit complies with [UL 6](#) and is galvanized by the hot-dip process. Use polyvinylchloride (PVC) coated rigid steel conduit in accordance with [NEMA RN 1](#), where underground and in corrosive areas, or painted with bitumastic.

Use threaded fittings for rigid steel conduit.

Use solid gaskets. Ensure conduit fittings with blank covers have gaskets, except in clean, dry areas or at the lowest point of a conduit run where drainage is required.

Ensure covers have captive screws and are accessible after the work has been completed.

2.1.1.2 Electrical Metallic Tubing (EMT)

Ensure EMT is in accordance with [UL 797](#) and is zinc coated steel. Provide zinc-coated couplings and connectors that are raintight, gland compression with insulation throat. Crimp, spring, or setscrew type fittings are not acceptable.

2.1.1.3 Flexible Metallic Conduit

Ensure flexible metallic conduit is galvanized steel and complies with [UL 1](#).

Ensure fittings for flexible metallic conduit are specifically designed for such conduit.

Provide liquidtight flexible metallic conduit with a protective jacket of PVC extruded over a flexible interlocked galvanized steel core to protect wiring against moisture, oil, chemicals, and corrosive fumes.

Specifically design fittings for liquidtight flexible metallic conduit for such conduit.

2.1.1.4 Intermediate Metal Conduit

Ensure intermediate metal conduit is galvanized steel and complies with [UL 1242](#).

2.1.1.5 Rigid Nonmetallic Conduit

Ensure rigid nonmetallic conduit complies with [NEMA TC 2](#) and [NEMA TC 3](#) with wall thickness not less than Schedule 40.

2.1.1.6 Wireways and Auxiliary Gutters

Ensure wireways and auxiliary gutters are a minimum [4 by 4-inch](#) trade size conforming to [UL 870](#).

2.1.1.7 Surface Raceways and Assemblies

Ensure surface metal raceways and multi-outlet assemblies conform to [NFPA 70](#). Receptacles conform to [NEMA WD 1](#), Type 5-20R.

2.1.2 Wire and Cable

Use copper 600-volt type THHN for conductors installed in conduit. Ensure all conductors [AWG No. 8](#) and larger, are stranded. All conductors smaller than [AWG No. 8](#) are stranded.

Ensure flexible cable is Type SO and contain a grounding conductor with green insulation.

Ensure conductors installed in plenums are marked plenum rated.

2.1.3 Switches

2.1.3.1 Safety Switches

Ensure safety switches comply with **NEMA KS 1**, and are the heavy-duty type with enclosure, voltage, current rating, number of poles, and fusing as indicated. Switch construction is such that, when the switch handle in the "ON" position, the cover or door cannot be opened. Cover release device is coinproof and so constructed that an external tool is used to open the cover. Make provisions to lock the handle in the "OFF" position. Ensure the switch is not capable of being locked in the "ON" position.

Provide switches of the quick-make, quick-break type. Approve terminal lugs for use with copper conductors.

Ensure safety color coding for identification of safety switches conforms to **ANSI Z535.1**.

2.1.4 Outlets, Outlet Boxes, and Pull Boxes

Ensure outlet boxes for use with conduit systems are in accordance with **NEMA FB 1** and **ANSI/NEMA OS 1** and are not less than 1-1/2 inches deep. Furnish all pull and junction boxes with screw-fastened covers.

2.1.5 Circuit Breakers

Ensure circuit-breaker interrupting rating is not less than existing adjacent devices, and in no event less than 20,000 amperes root-mean-square (rms) symmetrical at 208 volts, respectively. Multipole circuit breakers are the common-trip type with a single handle. Molded case circuit breakers are bolt-on type conforming to **UL 489**.

2.1.6 Manufacturer's Nameplate

Ensure each item of equipment has a nameplate bearing the manufacturer's name, address, model number, and serial number securely affixed in a conspicuous place; the nameplate of the distributing agent is not acceptable.

PART 3 EXECUTION

3.1 PREPARATION

Clean and paint conduit, supports, fittings, cabinets, pull boxes, and racks installed in exposed outdoor locations.

Protect metallic materials against corrosion. Provide equipment enclosures with the standard finish by the manufacturer suitable for indoor locations or exposed outdoor locations, as applicable. Do not use aluminum when in contact with earth or concrete and, where connected to dissimilar metal, protect by approved fittings and treatment. Provide hot-dip galvanized ferrous metals such as, but not limited to, anchors, bolts, braces, boxes, bodies, clamps, fittings, guards, nuts, pins, rods, shims, thimbles, washers, and miscellaneous not of corrosion-resistant steel except where other equivalent protective treatment is specifically approved in writing.

3.2 INSTALLATION

3.2.1 Conduits, Raceways, and Fittings

Conduit runs between outlet and outlet, between fitting and fitting, or between outlet and fitting cannot contain more than the equivalent of three 90-degree bends, including those bends located immediately at the outlet or fitting.

Do not install crushed or deformed conduit. Avoid trapped conduit runs where possible. Take care to prevent the lodgment of foreign material in the conduit, boxes, fittings, and equipment during the course of construction. Clear any clogged conduit of obstructions or be replaced.

Conduit and raceway runs concealed in or behind walls, above ceilings, or exposed on walls and ceilings 5 feet or more above finished floors and not subject to mechanical damage may be electrical metallic tubing (EMT).

3.2.1.1 Rigid Steel Conduit

Make field-made bends and offsets with approved hickey or conduit bending machine. Use long radius conduit for elbows larger than 2-1/2 inches.

Provide all conduit stubbed-up through concrete floors for connections to free-standing equipment with the exception of motor-control centers, cubicles, and other such items of equipment, with a flush coupling when the floor slab is of sufficient thickness. Otherwise, provide a floor box set flush with the finished floor. For conduits installed for future use, terminate with a coupling and plug set flush with the floor.

3.2.1.2 Electrical Metallic Tubing (EMT)

Ground EMT in accordance with NFPA 70, using pressure grounding connectors especially designed for EMT.

3.2.1.3 Flexible Metallic Conduit

Use flexible metallic conduit to connect recessed fixtures from outlet boxes in ceilings, transformers, and other approved assemblies.

Use bonding wires in flexible conduit as specified in NFPA 70, for all circuits. Flexible conduit is not considered a ground conductor.

Make electrical connections to vibration-isolated equipment with flexible metallic conduit.

Use liquidtight flexible metallic conduit in wet and oily locations and to complete the connection to motor-driven equipment.

3.2.1.4 Intermediate Conduit

Make all field-made bends and offsets with approved hickey or conduit bending machine. Use intermediate metal conduit only for indoor installations.

3.2.1.5 Rigid Nonmetallic Conduit

Ensure rigid PVC conduit is direct buried.

Install a green insulated copper grounding conductor in conduit with conductors and solidly connect to ground at each end. Size grounding wires in accordance with NFPA 70.

3.2.1.6 Wireway and Auxiliary Gutter

Bolt together straight sections and fittings to provide a rigid, mechanical connection and electrical continuity. Close dead ends of wireways and auxiliary gutters. Plug all unused conduit openings.

Support wireways for overhead distribution and control circuits at maximum 5-foot intervals.

Ensure auxiliary gutters used to supplement wiring spaces for equipment not contained in a single enclosure contains no switches, overcurrent devices, appliances, or apparatus and is not more than 30 feet long.

3.2.1.7 Surface Raceways and Assemblies

Mount surface raceways plumb and level, with the base and cover secured. Minimum circuit run is three-wire, with one wire designated as ground.

3.2.2 Wiring

Color code feeder and branch circuit conductors as follows:

CONDUCTOR	COLOR AC
Phase A	match existing site conditions
Phase B	match existing site conditions
Phase C	match existing site conditions
Neutral	White
Equipment Grounds	Green

Use conductors up to and including AWG No. 2 that are manufactured with colored insulating materials. For conductors larger than AWG No. 2, have ends identified with color plastic tape in outlet, pull, or junction boxes.

Splice in accordance with the NFPA 70. Provide conductor identification within each enclosure where a tap, splice, or termination is made and at the equipment terminal of each conductor. Match terminal and conductor identification as indicated.

Where several feeders pass through a common pullbox, tag the feeders to clearly indicate the electrical characteristics, circuit number, and panel designation.

3.2.3 Safety Switches

Securely fasten switches to the supporting structure or wall, utilizing a minimum of four each 1/4 inch bolts. Do not use sheet metal screws and small machine screws for mounting. Do not mount switches in an inaccessible location or where the passageway to the switch may become obstructed. Mounting height 5 feet above floor level, when possible.

3.2.4 Boxes and Fittings

Furnish and install pullboxes where necessary in the conduit system to facilitate conductor installation. For conduit runs longer than 100 feet or with more than three right-angle bends, install a pullbox at a convenient intermediate location.

Securely mount boxes and enclosures to the building structure with supporting facilities independent of the conduit entering or leaving the boxes.

3.2.5 Field Fabricated Nameplates

Ensure nameplates conform to ASTM D709. Provide laminated plastic nameplates for each equipment enclosure, relay, switch, and device, as specified in the technical sections or as indicated on the drawings. Each nameplate inscription identifies the function and, when applicable, the position. Provide nameplates that are melamine plastic, 0.125 inch thick, white with black center core and a matte finish surface. Accurately align lettering and engrave into the core. Minimum size of nameplates is 1 by 2.5 inches. Lettering is a minimum of 0.25 inch high normal block style.

3.2.6 Identification Plates and Warnings

Furnish and install identification plates for lighting and power panelboards, motor control centers, all line voltage heating and ventilating control panels, fire detector and sprinkler alarms, door bells, pilot lights, disconnect switches, manual starting switches, and magnetic starters. Attach identification plates to process control devices and pilot lights.

Furnish identification plates for all line voltage enclosed circuit breakers, identifying the equipment served, voltage, phase(s) and power source. For circuits 480 volts and above, install conspicuously located warning signs in accordance with OSHA requirements.

3.3 FIELD QUALITY CONTROL

Submit Test Reports in accordance with referenced standards in this section.

After completion of the installation and splicing, and prior to energizing the conductors, perform wire and cable continuity and insulation tests as herein specified before the conductors are energized.

Provide all necessary test equipment, labor, and personnel to perform the tests, as herein specified.

Isolate completely all wire and cable from all extraneous electrical connections at cable terminations and joints. Use substation and switchboard feeder breakers, disconnects in combination motor starters, circuit breakers in panel boards, and other disconnecting devices to isolate the circuits under test.

Perform insulation-resistance test on each field-installed conductor with respect to ground and adjacent conductors. Applied potential is 500 volts dc for 300 volt rated cable and 1000 volts dc for 600 volt rated cable. Take readings after 1 minute and until the reading is constant for 15 seconds. Minimum insulation-resistance values are not less than 25 Megohms for 300

volt rated cable and 100 Megohms for 600 volt rated cable. For circuits with conductor sizes 8AWG and smaller insulation resistance testing is not required.

Perform [continuity test](#) to insure correct cable connection (i.e. correct phase conductor, grounded conductor, and grounding conductor wiring) end-to-end. Repair and re-verify any damages to existing or new electrical equipment resulting from mis-wiring. Receive approval for all repairs from the Contracting Officer prior to commencement of the repair.

Final acceptance requires the successful performance of wire and cable under test. Do not energize any conductor until the final test reports are reviewed and approved by the Contracting Officer.

-- End of Section --

SECTION 26 05 19.00

INSULATED WIRE AND CABLE

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASSOCIATION OF EDISON ILLUMINATING COMPANIES (AEIC)

AEIC CS8 (2013) Specification for Extruded Dielectric
Shielded Power Cables Rated 5 Through 46 kV

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 383 (2003; R 2008) Standard for Qualifying Class 1E
Electric Cables and, Field Splices for Nuclear
Power Generating Stations 2004

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA WC 70 (2009) Power Cable Rated 2000 V or Less for the
Distribution of Electrical Energy--S95-658

1.2 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for Contractor Quality Control approval. Submit the following in accordance with Section **01 33 00** SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Material and Equipment; G

SD-03 Product Data

Wire and Cable; DA

Splices and Connectors; DA

SD-06 Test Reports

Continuity Test; G

Insulation Resistance Test; G

SD-07 Certificates

Certification; G

1.3 DELIVERY, STORAGE, AND HANDLING

Furnish cables on reels or coils. Each cable and the outside of each reel or coil, shall be plainly marked or tagged to indicate the cable length, voltage rating, conductor size, and manufacturer's lot number and reel number. Each coil or reel of cable shall contain only one continuous cable without splices. Cables for exclusively dc applications, as specified in paragraph HIGH VOLTAGE TEST SOURCE, shall be identified as such. Shielded cables rated 2,001 volts and above shall be reeled and marked in accordance with Section I of AEIC CS8 or AEIC CS8, as applicable. Reels shall remain the property of the Contractor.

PART 2 PRODUCTS

2.1 MATERIALS

2.1.1 Wire Table

Furnish wire and cable as specified per drawings, conforming to the detailed requirements specified herein.

2.1.2 Rated Circuit Voltages

All wire and cable shall have minimum rated circuit voltages in accordance with NEMA WC 70.

2.1.3 Conductors

2.1.3.1 Material for Conductors

Conductors shall conform to all the applicable requirements of NEMA WC 70, as applicable, and shall be annealed copper. Copper conductors may be bare, or tin- or lead-alloy-coated, if required by the type of insulation used.

2.1.3.2 Size

Minimum wire size shall be No. 12 AWG for power and lighting circuits; No. 10 AWG for current transformer secondary circuits; No. 14 AWG for potential transformer, relaying, and control circuits; No. 16 AWG for annunciator circuits; and No. 19 AWG for alarm circuits. Minimum wire sizes for rated circuit voltages of 2,001 volts and above shall not be less than those listed for the applicable voltage in NEMA WC 70, as applicable.

2.1.3.3 Stranding

Conductor stranding classes cited herein shall be as defined in NEMA WC 70, as applicable. Lighting conductors No. 10 AWG and smaller shall be solid or have Class B stranding. Any conductors used between stationary and moving devices, such as hinged doors or panels, shall have Class H or K stranding. All other conductors shall have Class B or C stranding, except that conductors shown on the drawings, or in the schedule, as No. 12 AWG may be 19 strands of No. 25 AWG, and conductors shown as No. 10 AWG may be 19 strands of No. 22 AWG.

2.1.3.4 Conductor Shielding

Use conductor shielding conforming to NEMA WC 70, as applicable, on power cables having a rated circuit voltage above 2,000 volts. In addition, conductor shielding for shielded cables shall also comply with Section C of AEIC CS8 or AEIC CS8. Strict precautions shall be taken after application of the conductor shielding to prevent the inclusion of voids or contamination between the conductor shielding and the subsequently applied insulation.

2.1.3.5 Separator Tape

Where conductor shielding, strand filling, or other special conductor treatment is not required, a separator tape between conductor and insulation is permitted.

2.1.4 Insulation

2.1.4.1 Insulation Material

Provide insulation which is a cross-linked thermosetting polyethylene (XLPE) type, meeting the requirements of NEMA WC 70, as applicable, or an ethylene-propylene rubber (EPR) type meeting the requirements of NEMA WC 70. For shielded cables of rated circuit voltages above 2,000 volts, the following provisions shall also apply:

- a. XLPE, if used, shall be tree-retardant.
- b. Insulation shall be chemically bonded to conductor shielding.
- c. The insulation material and its manufacturing, handling, extrusion and vulcanizing processes, shall all be subject to strict procedures to prevent the inclusion of voids, contamination, or other irregularities on or in the insulation. Insulation material shall be inspected for voids and contaminants. Inspection methods, and maximum allowable void and contaminant content shall be in accordance with Section B of AEIC CS8 or AEIC CS8, as applicable.
- d. Cables with repaired insulation defects discovered during factory testing, or with splices or insulation joints, are not acceptable.

2.1.4.2 Insulation Thickness

The insulation thickness for each conductor shall be based on its rated circuit voltage.

- a. Power Cables/Single-Conductor Control Cables, 2,000 Volts and Below - The insulation thickness for single-conductor cables rated 2,000 volts and below shall be as required by NEMA WC 70, as applicable. Some thicknesses of NEMA WC 70 will be permitted only for single-conductor cross-linked thermosetting polyethylene insulated cables without a jacket. NEMA WC 70 ethylene-propylene rubber-insulated conductors shall have a jacket.
- b. Power Cables, rated 2,001 Volts and Above - Thickness of insulation for power cables rated 2,001 volts and above shall be in accordance with the following:
 - (1) Non-shielded cables, 2,001 to 5,000 volts, shall comply with NEMA WC 70, as applicable.

- (2) Shielded cables rated 2,001 volts and above shall comply with Column B of Table B1, of **AEIC CS8** or **AEIC CS8**, as applicable.

- c. Multiple-Conductor Control Cables - The insulation thickness of multiple-conductor cables used for control and related purposes shall be as required by **NEMA WC 70**, as applicable.

2.1.4.3 Insulation Shielding

Unless otherwise specified, provide insulation shielding for conductors having rated circuit voltages of 2,001 volts and above. The voltage limits above which insulation shielding is required, and the material requirements, are given in **NEMA WC 70**, as applicable. The material, if thermosetting, shall meet the wafer boil test requirements as described in Section D of **AEIC CS8** or **AEIC CS8**, as applicable. The method of shielding shall be in accordance with the current practice of the industry; however, the application process shall include strict precautions to prevent voids or contamination between the insulation and the nonmetallic component. Voids, protrusions, and indentations of the shield shall not exceed the maximum allowances specified in Section C of **AEIC CS8** or **AEIC CS8**, as applicable. The cable shall be capable of operating without damage or excessive temperature when the shield is grounded at both ends of each conductor. All components of the shielding system shall remain tightly applied to the components they enclose after handling and installation in accordance with the manufacturer's recommendations. Shielding systems which require heat to remove will not be permitted unless specifically approved.

2.1.5 Jackets

All cables shall have jackets meeting the requirements of **NEMA WC 70**, as applicable, and as specified herein. Individual conductors of multiple-conductor cables shall be required to have jackets only if they are necessary for the conductor to meet other specifications herein. Jackets of single-conductor cables and of individual conductors of multiple-conductor cables, except for shielded cables, shall be in direct contact and adhere or be vulcanized to the conductor insulation. Multiple-conductor cables and shielded single-conductor cables shall be provided with a common overall jacket, which shall be tightly and concentrically formed around the core. Repaired jacket defects found and corrected during manufacturing are permitted if the cable, including jacket, afterward fully meets these specifications and the requirements of the applicable standards.

2.1.5.1 Jacket Material

The jacket shall be one of the materials listed below. Polyvinyl chloride compounds will not be permitted.

a. General Use

- (1) Heavy-duty black neoprene (**NEMA WC 70**).
- (2) Heavy-duty chlorosulfonated polyethylene (**NEMA WC 70**).
- (3) Heavy-duty cross-linked (thermoset) chlorinated polyethylene (**NEMA WC 70**).

- b. Accessible Use Only, 2,000 Volts or Less - Cables installed where they are entirely accessible, such as cable trays and raceways with removable covers, or where they pass through less than 10 feet of exposed conduit only, shall have jackets of one of the materials specified in above paragraph GENERAL USE, or the jackets may be of one of the following:

- (1) General-purpose neoprene (NEMA WC 70).
- (2) Black polyethylene (NEMA WC 70).
- (3) Thermoplastic chlorinated polyethylene (NEMA WC 70).

2.1.5.2 Jacket Thickness

The minimum thickness of the jackets at any point shall be not less than 80 percent of the respective nominal thicknesses specified below.

- a. Multiple-Conductor Cables - Thickness of the jackets of the individual conductors of multiple-conductor cables shall be as required by NEMA WC 70, and shall be in addition to the conductor insulation thickness required by Column B of Table 3-1 of the applicable NEMA publication for the insulation used. Thickness of the outer jackets or sheaths of the assembled multiple-conductor cables shall be as required by NEMA WC 70.
- b. Single-Conductor Cables - Single-conductor cables, if nonshielded, shall have a jacket thickness as specified in NEMA WC 70. If shielded, the jacket thickness shall be in accordance with the requirements of NEMA WC 70.

2.1.6 Metal-Clad Cable

2.1.6.1 General

The metallic covering shall be corrugated metal, conforming to the applicable requirements of NEMA WC 70. If the covering is of ferrous metal, it shall be galvanized. Copper grounding conductor(s) conforming to NEMA WC 70 shall be furnished for each multiple-conductor metal-clad cable. Assembly and cabling shall be as specified in paragraph CABLING. The metallic covering shall be applied over an inner jacket or filler tape. The cable shall be assembled so that the metallic covering will be tightly bound over a firm core.

2.1.6.2 Jackets

Metal-clad cables may have a jacket under the armor, and shall have a jacket over the armor. Jackets shall comply with the requirements of NEMA WC 70. The outer jacket for the metal-clad cable may be of polyvinyl chloride only if specifically approved.

2.2 CABLE IDENTIFICATION

2.2.1 Color-Coding

Insulation of individual conductors of multiple-conductor cables shall be color-coded in accordance with NEMA WC 70, except that colored braids will not be permitted. Only one color-code method shall be used for each cable construction type. Control cable color-coding shall be in accordance with NEMA WC 70. Power cable color-coding shall be black for Phase A, red for

Phase B, blue for Phase C, white for grounded neutral, and green for an insulated grounding conductor, if included. Other individual conductors shall be color-coded as indicated on the contract drawings, but such color-coding may be accomplished by applying colored plastic tapes or sleeving at terminations.

2.2.2 Shielded Cables Rated 2,001 Volts and Above

Marking shall be in accordance with Section H of [AEIC CS8](#) or [AEIC CS8](#), as applicable.

2.2.3 Cabling

Individual conductors of multiple-conductor cables shall be assembled with flame-and moisture-resistant fillers, binders, and a lay conforming to [NEMA WC 70](#), except that flat twin cables will not be permitted. Fillers shall be used in the interstices of multiple-conductor round cables with a common covering where necessary to give the completed cable a substantially circular cross section. Fillers shall be non-hygroscopic material, compatible with the cable insulation, jacket, and other components of the cable. The rubber-filled or other approved type of binding tape shall consist of a material that is compatible with the other components of the cable and shall be lapped at least 10 percent of its width.

2.2.4 Dimensional Tolerance

The outside diameters of single-conductor cables and of multiple-conductor cables shall not vary more than 5 percent and 10 percent, respectively, from the manufacturer's published catalog data.

PART 3 EXECUTION

3.1 [INSTALLATION INSTRUCTIONS](#)

Submit cable manufacturing data. The following information shall be provided by the cable manufacturer for each size, conductor quantity, and type of cable furnished:

- a. Minimum bending radius, in inches - For multiple-conductor cables, this information shall be provided for both the individual conductors and the multiple-conductor cable.
- b. Pulling tension and sidewall pressure limits, in [pounds](#).
- c. Instructions for stripping semiconducting insulation shields, if furnished, with minimum effort without damaging the insulation.
- d. Upon request, compatibility of cable materials and construction with specific materials and hardware manufactured by others shall be stated. Also, if requested, recommendations shall be provided for various cable operations, including installing, splicing, terminating, etc.

3.2 [TESTS, INSPECTIONS, AND VERIFICATIONS](#)

3.2.1 Cable Data

Manufacture of the wire and cable shall not be started until all materials to be used in the fabrication of the finished wire or cable have been approved by the Contracting Officer. Cable data shall be submitted for approval including dimensioned sketches showing cable construction, and sufficient additional data to show that these specifications will be satisfied.

3.2.2 Inspection and Tests

Inspection and tests of wire and cable furnished under these specifications shall be made by and at the plant of the manufacturer, and shall be witnessed by the Contracting Officer or his authorized representative, unless waived in writing. The Government may perform further tests before or after installation. Testing in general shall comply with [NEMA WC 70](#). Specific tests required for particular materials, components, and completed cables shall be as specified in the sections of the above standards applicable to those materials, components, and cable types. Tests shall also be performed in accordance with the additional requirements specified below.

3.2.2.1 High-Voltage Test Source

Where the applicable standards allow a choice, high-voltage tests for cables to be used exclusively on dc circuits shall be made with dc test voltages. Cables to be used exclusively on ac circuits shall be tested with ac test voltages. If both ac and dc will be present, on either the same or separate conductors of the cable, ac test voltages shall be used.

3.2.2.2 Shielded Cables Rated 2,001 Volts or Greater

The following tests shall be performed in addition to those specified above. Section or paragraph references are to [AEIC CS8](#) or [AEIC CS8](#) as applicable, unless otherwise stated.

- a. High potential test voltages shall be as required by Table B1 of [AEIC CS8](#) or [AEIC CS8](#) as applicable, rather than by [NEMA WC 70](#).
- b. If high potential testing is done with an ac test voltage as specified in paragraph HIGH-VOLTAGE TEST SOURCE, an additional test shall be made using a dc test voltage rated at 75 percent of the specified full dc test voltage, for 5 consecutive minutes.
- c. Production sampling tests shall be performed in accordance with Section D. Sampling frequency and failure contingencies shall be in accordance with paragraph G.3. Unless otherwise approved, samples shall not be taken from the middle of extruder runs of insulation or shielding made only for one continuous shipping length of cable, if such sampling will result in the need to repair the sampled area.
- d. Partial discharge tests shall be performed in accordance with Section E, paragraph E.2, and Section F.

3.2.2.3 Flame Tests

All multiple-conductor and single-conductor cable assemblies shall pass [IEEE 383](#) flame tests, paragraph 2.5, using the ribbon gas burner. Single-conductor cables and individual conductors of multiple-conductor cables shall pass the flame test of [NEMA WC 70](#). If such tests, however, have previously been made on identical cables, these tests need not be repeated. Instead,

certified reports of the original qualifying tests shall be submitted. In this case the reports furnished under paragraph REPORTS, shall verify that all of each cable's materials, construction, and dimensions are the same as those in the qualifying tests.

3.2.2.4 Independent Tests

The Government may at any time make visual inspections, continuity or resistance checks, insulation resistance readings, power factor tests, or dc high-potential tests at field test values. A cable's failure to pass these tests and inspections, or failure to produce readings consistent with acceptable values for the application, will be grounds for rejection of the cable.

3.2.2.5 Reports

Furnish results of tests made. No wire or cable shall be shipped until authorized. Lot number and reel or coil number of wire and cable tested shall be indicated on the test reports.

-- End of Section --

SECTION 26 05 71.00

LOW VOLTAGE OVERCURRENT PROTECTIVE DEVICES

PART 1 GENERAL

Section 26 00 00.00 20 BASIC ELECTRICAL MATERIALS AND METHODS applies to work specified in this section.

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250	(2014) Enclosures for Electrical Equipment (1000 Volts Maximum)
NEMA AB 3	(2013) Molded Case Circuit Breakers and Their Application
NEMA FU 1	(2012) Low Voltage Cartridge Fuses
NEMA ICS 1	(2000; R 2008; E 2010) Standard for Industrial Control and Systems: General Requirements
NEMA ICS 2	(2000; R 2005; Errata 2008) Standard for Controllers, Contactors, and Overload Relays Rated 600 V

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2014; AMD 1 2013; Errata 1 2013; AMD 2 2013; Errata 2 2013; AMD 3 2014; Errata 3-4 2014; AMD 4-6 2014) National Electrical Code
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UNDERWRITERS LABORATORIES (UL)

UL 489	(2013; Reprint Mar 2014) Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit- Breaker Enclosures
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1.2 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for Contractor Quality Control approval. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Material and Equipment; G

SD-03 Product Data

Wire and Cable; DA

Splices and Connectors; DA

PART 2 PRODUCTS

2.1 SYSTEM DESIGN

Submit [Connection Diagrams](#) showing the relations and connections of control devices and protective devices by showing the general physical layout of all controls, the interconnection of one system (or portion of system) with another, and internal tubing, wiring, and other devices.

2.2 CIRCUIT BREAKERS

Provide circuit breakers that conform to [UL 489](#), and [NEMA AB 3](#).

2.2.1 Molded-Case Circuit Breakers

Provide molded case, manually operated, trip-free, circuit breakers, with inverse-time thermal-overload protection and instantaneous magnetic short-circuit protection as required. Completely enclose circuit breakers in a molded case, with the calibrated sensing element factory-sealed to prevent tampering.

Locate thermal-magnetic tripping elements in each pole of the circuit breaker, and provide inverse-time-delay thermal overload protection and instantaneous magnetic short-circuit protection. Provide instantaneous magnetic tripping element, that is adjustable and accessible from the front of the breaker on frame sizes larger than 100 amperes.

Size breaker as required for the continuous current rating of the circuit. Provide breaker class as required.

Provide sufficient interrupting capacity of the panel and lighting branch circuit breakers, to successfully interrupt the maximum short-circuit current imposed on the circuit at the breaker terminals. Provide circuit breaker interrupting capacities with a minimum of 10,000 amperes and that conform to [NEMA AB 3](#).

Provide the common-trip type multipole circuit breakers having a single operating handle and a two-position on/off indication. Provide circuit breakers with temperature compensation for operation in an ambient temperature of [104 degrees F](#). Provide circuit breakers that have root mean square (rms) symmetrical interrupting ratings sufficient to protect the circuit being supplied. Interrupting ratings may have selective type tripping (time delay, magnetic, thermal, or ground fault).

Provide phenolic composition breaker body capable of having such accessories as handle-extension, handle-locking, and padlocking devices attached where required.

For circuit breakers used for meter circuit disconnects, meet the applicable requirements of [NFPA 70](#) and are the motor-circuit protector type.

For circuit breakers used for service disconnection, provide an enclosed circuit-breaker type with external handle for manual operation. Provide sheet metal enclosures with a hinged cover suitable for surface mounting.

2.2.2 Enclosed Molded-Case Circuit Breakers

For enclosed circuit breakers, provide thermal-magnetic molded-case circuit breakers in surface-mounted, nonventilated enclosures conforming to the appropriate articles of NEMA 250 and UL 489.

Provide enclosed circuit breakers in non-hazardous locations as follows:

- b. Contain circuit breakers installed in unprotected outdoor locations, in NEMA Type 3R, weather-resistant sheet steel enclosures that are splashproof, weatherproof, sleetproof, and moisture resistant.

2.3 FUSES

Provide a complete set of fuses for all switches and switchgear. Rate fuses that have a voltage rating of not less than the circuit voltage.

Make no change in continuous-current rating, interrupting rating, and clearing or melting time of fuses unless written permission is first obtained by the Contracting Officer.

Provide nonrenewable cartridge type fuses for ratings 30 amperes, 125 volts or less. Provide renewable cartridge type fuses for ratings above 30 amperes 600 volts or less with time-delay dual elements, except where otherwise indicated. Conform to NEMA FU 1 for fuses.

Install special fuses such as extra-high interrupting-capacity fuses, fuses for welding machines, and capacitor fuses where required. Plug fuses are not permitted.

Label fuses showing UL class, interrupting rating, and time-delay characteristics, when applicable. Additionally, clearly list fuse information on equipment drawings.

Provide porcelain fuse holders when field-mounted in a cabinet or box. Do not use fuse holders made of such materials as ebony asbestos, Bakelite, or pressed fiber for field installation.

2.4 FACTORY TESTING

Perform factory tests on control and low voltage protective devices in accordance with the manufacturer's recommendations.

2.5 FINISH

Protect metallic materials against corrosion. Provide equipment with the standard finish by the manufacturer suitable for indoor locations or exposed outdoor locations, as applicable.

PART 3 EXECUTION

3.1 INSTALLATION

Install **Control devices** and **protective devices** that are not factory installed in equipment, in accordance with the manufacturer's recommendations. Field adjust and operations test the control and protective devices. Conform to **NFPA 70**, **NEMA ICS 1** and **NEMA ICS 2** requirements for installation of control and protective devices.

-- End of Section --

Section 3. Site Specific Contractor Requirements

On-site Construction Manager for this contract is Jeffrey Chung (NAVFAC SW, PW FEAD) 805-982-1921

User point of contact for this project is Gerry Warrick (805) 982-6094 or Carlos Perez (805) 982-5638. NITC PH-2 Data Center.

National Environmental Policy Act (NEPA) - A NEPA Categorical Exclusion (CATEX) is required. Point of contact is Chad Lousen [805-989-5634]

Digging, Trenching, or Excavating – An excavation permit is required. A valid Excavation Permit is required for any work involving digging, trenching, soil borings, or excavation. A utility locator service will be required as part of this process. Point of contact is Dig Alert at 511.

Fire – Specific requirements include:

Life safety: Specific compliance with NFPA CODES 1,13,70,72,101,241; National Fire Codes; National Electrical Codes; Unified Facilities Criteria (UFC); NBVCINST 11320.1

Hot Work Permits (Contact Fire Department (805) 207-3818 for any open flame and/or spark producing device)

Do not obstruct Fire Lane Emergency Access, 20 ft clearance required

Do not obstruct any Fire Dept. Equipment, Hydrants, FACP (Fire Alarm Control Panel), Fire Department Connections, Risers, PIV's (Post Indicator Valves), etc.

Notify PW FEAD for any road closures, and request approvals for staging area for all materials/equipment.

Fire Comments: Follow NFPA 101 Life Safety Code, NFPA 70 National Electrical Code, NFPA 241 Safeguarding Construction, Alteration, and Demolition Operations, NFPA 90B Installation of Warm Air Heating and Air-Conditioning Systems, Obtain Hot Work Permits as needed, all cracks and voids made in walls shall be filled with fire resistive caulking.

Point of contact is: Veronica Mijares (805) 989-0109.

Industrial Hygiene – Specific requirements include:

A legible MSDS for all hazardous materials or equipment brought on base for a job

A legible worksite workplan which states in detail how the work will be done, a description of the operations that use the hazardous materials, a description of the worksite controls that will be used to control noise, vapors, fumes, dust, etc., when the work will occur (e.g. date, shift), and emergency procedures in the event of a spill/mishap.

Ensure personnel in adjacent areas are not impacted by this work.

Industrial Hygiene Comments: Please notify safety and industrial hygiene if there are any indoor air quality issues associated with testing.

Safety: Specific requirements include:

ACCIDENT PREVENTION PLAN (APP), EM 385-1-1, Appendix A-1. See sheet A-13. Contractor provisions must be job specific and address unusual/unique aspects of the project. Compliance is a contractor requirement. The APP shall interface with OPNAV 5100.23 Series, Navy Safety & Occupational Health Program: portions that are referenced in the APP may be included as appropriate. These documents shall be available at the work site.

ACTIVITY HAZARD ANALYSIS (AHA), EM 385-1-1, Appendix 8, depicts Job Steps, Hazards, Controls, Risk Assessment, Equipment, Training, and Inspections. See HQUSACE Safety Office website for electronic version. Document shall be available at the work site.

LOCK OUT/TAG OUT is required of all Contractors.

WEIGHT HANDLING EQUIPMENT must be certified and insured. Operators must be licensed.

PERSONAL PROTECTIVE EQUIPMENT for face, eyes, hearing, foot, hand, and body is required as noted in the Material Safety Data Sheet and job requirements. Respirators are for protection against potential inhalation of hazardous dusts, fumes, gases, or vapors. Users must be qualified.

Security: - All contractors need to get DBIDS badges or one day passes. In the event of any EMERGENCY situation, immediate response can be obtained by dialing 9-1-1 from a landline phone at Port Hueneme. Call from a cell phone for emergency responses can be obtained by calling (805) 982-4591.

Water Quality – Any connections or alterations to the potable water lines require inspection by the NBVC Public Works (PW) Shops Water Distribution Operators. They MUST be present to inspect connection disinfection. For NBVC contact Steve Latting, (805) 207-4055 or Larry Jones (805) 207-9448. Record backflow device location and/or other pertinent potable water system alterations and coordinate with PW Planning to determine needed GIS information.

All construction projects must implement an effective combination of stormwater Best Management Practices (BMPs). No construction wastewater of any kind is to be discharged into the storm drains or sanitary sewer system. All wastewater discharges must be contained and disposed of properly. All requests to dispose industrial wastewater to the sanitary sewer must be approved by the Water Quality Program staff (805) 982-1962. Examples of BMPs to protect storm drains are straw wattles anchored down with sand or gravel bags, visqueen fabric (a.k.a. polyethylene/geotextile fabric), and a double row of sand or gravel bags properly installed at the storm drain. For additional BMP information visit the CASQA California Stormwater BMP Handbook web site at <http://www.cabmphandbooks.com/>.

Point of contact is: Steve George at (805) 982-1962.

Hazardous Materials (HM)/Hazardous Wastes (HW) - Specific requirements include:

ALL Hazardous Materials (HM) brought aboard NBVC **MUST** be screened through the Hazardous Materials Minimization (HAZMIN) Center, Building PH-382, (805) 982-3370. Contact the HAZMIN Center for acquisition of Hazardous Materials (HM) for military, Self-Help, and Public Works projects.

If contractor(s) are going to generate hazardous wastes they must apply for a temporary EPA ID# and they shall properly, manage and dispose of their own hazardous waste per Federal, State and Local Environmental Regulations.

Waste Diversion/Recycling - Specific requirements include:

Per Executive Order 13101 of 14 September 1998 (Greening the Government Through Waste Prevention, Recycling, and Federal Acquisition), contractors/in-house personnel shall recycle all non-preventable solid wastes at government-owned facilities. This includes recycling of construction & demolition debris, green waste, dirt, scrap metals, concrete/asphalt/cement, clean wood or other material diverted from solid waste disposal.

Solid wastes shall be minimized through source reduction and/or recycling. During construction, report to Mr. Jose Amuchastegui the weight of all recycled materials by the 25th of each month.

Point of contact is: Mr. Jose Amuchastegui

Cultural Resources – This project does not require consultation with the California Office of Historic Preservation. If the scope of work changes, please contact the NBVC Cultural Resources Program Manager immediately, as consultation may be required. Consultation will take a minimum of 120 days to complete.

Environmental Management System (EMS) - Specific requirements include:

Project has potential to impact an environmental aspect as noted below. Project managers, site workers and/or contractors performing the work must complete additional training requirements per environmental program via ECATTS at <https://navfac.ecatts.com/>. Please forward a list with all personnel names and training completion dates to Shirin Tolle at (805) 982-5963 for record keeping. These can be sent via the PW FEAD Construction Manager or Engineering Technician.

Specific environmental aspects include:

- Water/storm water quality
- Hazardous waste
- Waste diversion/recycling
- Cultural resources

Project managers, site workers and/or contractors performing the work must complete EMS Awareness training via ECATTS at <https://navfac.ecatts.com/>. Please forward a list with all personnel names and training completion dates to Shirin Tolle at (805) 982-5963 for record keeping.

Utility Outages – Utility outage requests require a Coordination Meeting with the Public Works Utility and Energy Management Branch prior to submitting a request with a minimum of 21 calendar days' notice.

Section 4. Specifications of Evapco eco-ATWB-H-9-3K9-Z-U12 hybrid chiller to be installed

Closed Circuit Cooler Data Sheet



Steve Zenda
TOWER ENTERPRISES OF NY AND NJ, LLC
256 West 36th Street
5th Floor
New York, NY 10018
USA
Phone: 212-594-4340
Fax: 212-594-4341
Email: stevez@towerenterprises.net

Project : Fort Hueneme
Equipment Reference:
Product Type : eco-ATWB-H Hybrid Closed Circuit Cooler

Date: 5/12/2017

Page: 1

Selection Criteria		IBC Design Criteria	
Capacity (Tons):	50	Importance Factor (IP)	1.0
Capacity (MBH):	756.00	Seismic (Sds)	up to 1.0 g
Fluid Type:	Water	Wind Load (P)	up to 288.3 psf
Flow (GPM):	144.0	:	
Entering Fluid Temp (°F):	80.5		
Leaving Fluid Temp (°F):	70.0		
Wet Bulb (°F):	65.0		
Dry Switchover Temp (°F):	53.8		
Dry Load (%):	16		

Product line is CTI/ECC certified for water, propylene glycol or ethylene glycol as process fluid. Selection is rated in accordance with CTI Standard 201 RS.

Qty	Model	Capacity (MBH)	Percent Capacity
1	eco-ATWB-H 9-3K9-Z-U12	937.423	124.0

All Weights, Dimensions and Technical Data are Shown per Unit

Fans:	1		
# Fan Motors @ HP:	(1) @ 20.00 (460/3/60)	Overall Length:	8' 11.500"
# Pump Motors @ HP:	(1) @ 2.00	Overall Width:	8' 5.500"
# Heaters @ kW:	(1) @ 7.00	Overall Height:	16' 3.500"
Air Flow (CFM)	50,600		
Spray Water Flow (gpm)	410.0	Operating Weight (lbs):	15,572
Pressure Drop Through Coil (psi):	3.1	Shipping Weight (lbs):	11,712
Evaporated Water Rate (gpm):	1.02	Heaviest Section (lbs):	8,102
Riser Pipe Diameter (inch):	4		

Options Selected

Sage 2 Control Panel [460V]

Factory Mounted Crossover Piping

(2) ARID Fin-Pak

CrossCool Coil

Fan Motor: Inverter Capable, Premium Efficient

Fan Motor: Space Heaters

IBC Standard Structural Design

Pump Motor: ESA Compliant

Series Flow Operation

304 Welded Stainless Steel Cold Water Basin

Aluminum Ladder

Contactors w/Transformer and Disconnect for Heater Package

El. Heaters (0F / -18C ambient) (1) 7 kW

5-Probe Electronic Water Level Control Package

Ladder Extension; 3 Feet

Note: Sage Water and Energy Control Panel Start Up

SECTION 23 65 00

CLOSED CIRCUIT COOLERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. This Section includes factory assembled and tested, closed circuit mechanical induced-draft vertical discharge closed circuit cooler.

1.3 SUBMITTALS

- A. Product Data: For each type of product indicated. Include rated capacities, pressure drop, performance curves with selected points indicated, furnished specialties, and accessories.
- B. Shop Drawings: Complete set of manufacturer's prints of evaporative equipment assemblies, control panels, sections and elevations, and unit isolation. Include the following:
 - 1. Assembled unit dimensions.
 - 2. Weight and load distribution.
 - 3. Required clearances for maintenance and operation.
 - 4. Sizes and locations of piping and wiring connections.
 - 5. Wiring Diagrams: For power, signal, and control wiring. Differentiate between manufacturer installed and field installed wiring.
- C. Operation and Maintenance Data: Each unit to include, operation, and maintenance manual.

1.4 QUALITY ASSURANCE

- A. Verification of Performance:
 - 1. The thermal performance shall be certified by the Cooling Technology Institute in accordance with CTI Certification Standard STD-201. Lacking such certification, a field acceptance test shall be conducted within the warranty period in accordance with CTI Acceptance Test Code ATC-105, by a Certified CTI Thermal Testing Agency. The Evaporative Heat Rejection Equipment shall comply with the energy efficiency requirements of ASHRAE Standard 90.1.
 - 2. Unit Sound Performance ratings shall be tested according to CTI ATC-128 standard. Sound ratings shall not exceed specified ratings.
- B. Unit shall meet or exceed energy efficiency per ASHRAE 90.1

1.5 WARRANTY

- A. Submit a written warranty executed by the manufacturer, agreeing to repair or replace components of the unit that fail in materials and workmanship within the specified warranty period.
 - 1. Fan Motor/Drive System: Warranty Period shall be Five (5) years from date of unit shipment from Factory (fan motor(s), fan(s), bearings, mechanical support, sheaves, bushings and belt (s)).
 - 2. The Entire Unit shall have a comprehensive five (5) year warranty against defects in materials and workmanship from date of shipment.
 - 3. Heat Transfer Coil: Warranty Period shall be One (1) year from date of unit shipment from Factory.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide closed circuit coolers manufactured by one of the following:

1. EVAPCO Model eco-ATWB-H 9-3K9-Z-U12
2. Approved Substitute

2.2 THERMAL PERFORMANCE

- A. Each unit shall be capable to cool 144.00 GPM of water entering at 80.50° F leaving at 70.00° F at a design wet bulb of 65.00° F with a pressure drop across the coil not to exceed 3.07 psi.
- B. Each unit shall be capable to cool 144.00 GPM of water entering at 80.50° F leaving at 70.00° F at a design ambient dry bulb of 53.76° F with the spray pump(s) de-energized.

2.3 IBC COMPLIANCE

A. The unit structure shall be designed, analyzed, and constructed in accordance with the latest edition of International Building Code (IBC) for: IP = 1.0, SDS = 1.0, P = 288.3 psf.

2.4 COMPONENTS

A. Description: Factory assembled and tested, induced draft counter flow closed circuit cooler complete with fan, coil, louvers, accessories and rigging supports

B. Materials of Construction

1. All cold water basin components including vertical supports, air inlet louver frames and panels up to rigging seam shall be constructed of Type 304 Stainless Steel. All factory cold water basin seams shall be welded for water tight construction. "Series 300" stainless steel shall not be acceptable as equivalent to Type 304 Stainless Steel.
2. Upper Casing, channels and angle supports shall be constructed of heavy gauge mill hot-dip galvanized steel. Fan cowl and guard shall be constructed of galvanized steel. All galvanized steel shall be coated with a minimum of 2.35 ounces of zinc per square foot of area (G-235 Hot-Dip Galvanized Steel designation). During fabrication, all galvanized steel panel edges shall be coated with a 95% pure zinc-rich compound.

C. Fan(s):

1. Fan(s) shall be high efficiency axial propeller type with aluminum wide chord blade construction. Each fan shall be dynamically balanced and installed in a closely fitted cowl with venturi air inlet for maximum fan efficiency.

D. Drift Eliminators

1. Drift eliminators shall be constructed entirely of Polyvinyl Chloride (PVC) in easily handled sections. Design shall incorporate three changes in air direction and limit the water carryover to a maximum of 0.001% of the recirculating water rate.

E. Water Distribution System

1. Spray nozzles shall be zero-maintenance precision molded ABS with large 1-1/4" diameter orifice threaded into branch piping with internal sludge ring to eliminate clogging. Spray header, branches, and riser shall be Schedule 40 Polyvinyl Chloride (PVC) for corrosion resistance.

F. Heat Transfer Media

1. Heat transfer coil shall be elliptical tubes of prime surface steel, encased in steel framework with entire assembly hot-dip galvanized after fabrication. All coil rows shall feature extended surface fins designed with sloping tubes for liquid drainage and air pressure tested to 390 psig. ASME/ANSI B31.5.

2. Dry Heat Transfer Coil shall be constructed of 5/8" diameter Type 304L Stainless Steel round tubing with carbon steel connections. Marine grade aluminum fins with a fin density of 10 fins per inch. Tubing shall be hydraulically expanded into the fin plate for consistent contact. Coil shall be pressure tested to 390 psig. Dry coil shall be piped in series with heat transfer coil and designed for full unit flow. ASME/ANSI B31.5.

G. Pump

1. Unit shall have EISA close-coupled centrifugal pump with mechanical seal. The pump shall be installed in a vertical position so that water will drain from the pump when the cold water basin is emptied. Pump motor shall be totally enclosed with protective canopy for outdoor operation.

H. Bleed-off

1. Unit shall have a waste water bleed line with a manual adjustable valve provided.

I. Air Inlet Louvers

1. The air inlet louver screens shall be constructed from UV inhibited polyvinyl chloride (PVC) and incorporate a framed interlocking design that allows for easy removal of louver screens for access to the entire basin area for maintenance. The louver screens shall have a minimum of two changes in air direction and shall be of a non-planar design to prevent splash-out and block direct sunlight & debris from entering the basin.

J. Electronic Water Level Control

1. Electronic water level control package shall have five (5) stainless steel water level sensors (one (1) high level, one (1) high level alarm, one (1) low level, one (1) low level alarm and one (1) ground) with a NEMA 4x enclosure mounted in a cleanable Schedule 40 PVC external standpipe with slow closing solenoid valve(s) and "Y" strainer(s). Wiring is not included and components must be field mounted. Valves shall be sized for 25 psi minimum to 125 psi maximum pressure. Standpipe may require heat tracing by others in cold weather applications.

K. Pan Strainer

1. Pan Strainer(s) shall be all Type 304 Stainless Steel construction with large area removable perforated screens.

2.5 MOTORS AND DRIVES

A. General requirements for motors are specified in Division 23 Section "Motors"

B. Fan Motor

1. Fan motor(s) shall be totally enclosed, ball bearing type electric motor(s) suitable for moist air service. Motor(s) are Premium Efficient, Class F insulated, 1.15 service factor design. Inverter rated per NEMA MG1 Part 31.4.4.2 and suitable for variable torque applications and constant torque speed range with properly sized and adjusted variable frequency drives.
2. Fan motor(s) shall include strip-type space heaters with separate leads brought to the motor conduit box.

C. Fan Drive

1. The fan drive shall be multigroove, solid back V-belt type with QD tapered bushings designed for 150% of the motor nameplate power. The belt material shall be neoprene reinforced with polyester cord and specifically designed for evaporative equipment service. Fan sheave shall be aluminum alloy construction. Belt adjustment shall be accomplished from the exterior of the unit.

D. Fan Shaft

1. Fan shaft shall be solid, ground and polished steel. Exposed surface shall be coated with rust preventative.

E. Fan Shaft Bearings

1. Fan Shaft Bearings shall be heavy-duty, self-aligning ball type bearings with extended lubrication lines to grease fittings located on access door frame. Bearings shall be designed for a minimum L-10 life of 100,000 hours.

2.6 MAINTENANCE ACCESS

A. Fan Section

1. Access door shall be hinged and located in the fan section for fan drive and water distribution system access. Swing away motor cover shall be hinged for motor access.

B. Basin Section

1. Framed removable louver panels shall be on all four (4) sides of the unit for pan and sump access.

C. Internal Working Platform

1. Internal working platform shall provide easy access to complete water distribution system. The coil surface shall be an acceptable means of accessing these components.

D. Ladder

1. An aluminum sloped ladder shall be provided for access to the motor access door.

2.7 ACCESSORIES

A. Basin Heater Package

1. Cold water basin shall be fitted with copper element, electric immersion heater(s) with a separate thermostat and low water protection device. Heaters shall be selected to maintain +40° F pan water at 0° F ambient temperature.
2. Electric immersion heater package shall include a factory-supplied NEMA 4x enclosure containing a magnetic contactor with 120 VAC control circuit, transformer, and main power disconnect. Control package wired by others.

PART 3 - Water and Energy Conservation Control System For The Closed Circuit Cooler

Part 1 – General

A. Scope

1. The Closed Circuit Cooler Manufacturer shall furnish an industrial control panel for use with the specified closed circuit cooler.
2. Terminology
 - a. HMI – Human Machine Interface
 - b. PLC – Programmable Logic Controller
 - c. BAS – Building Automation System
 - d. NCDC – National Climatic Data Center
 - e. VFD – Variable Frequency Drive
 - f. I/O – Input(s)/Output(s)
 - g. SCCR – Short Circuit Current Rating
3. The Closed Circuit Cooler Manufacturer shall not be responsible for field wiring between the control panel and field devices, between control panels or between the control panel(s) and the Building Automation System (BAS) as indicated by the drawings.

B. Device Description

The closed circuit cooler control system shall control all motor driven and optional electrically operated equipment including (but not limited to) the fan motor(s), pump motor(s), basin heater(s), vibration switch(es), damper actuators, manufacturer supplied water treatment equipment, and manufacturer supplied electronic water level controller. The operation of all driven components shall be manually overridden for equipment startup or troubleshooting. The status of all equipment shall be clearly displayed on a 10 inch panel mounted Human Machine Interface (HMI) with a color touch screen display.

C. Submittals and Operations Manuals

1. Submittals shall include the following as a minimum:
 - a. System design information sheet.
 - b. Description of system operation.
 - c. Control panel drawing with list of operator interfaces.
 - d. Electrical power and control-wiring diagram
 - e. Name and address of factory trained Service Company.
 - f. A predictive energy and/or water usage analysis based on 5 year NCDC weather data and applicable load profile.
2. Submittals, which are not job specific and designed to meet the requirements of this section, shall not be acceptable.
3. Provide an electronic copy of the submittal to the consulting engineer for approval.
4. Provide an electronic copy of the Operation and Maintenance Manual prior to system start-up.

D. Electrical

1. General
 - a. No wire splicing shall be permitted in cable ducts or anywhere in a panel except on identified terminal blocks.
 - b. Wiring shall be landed to individual terminals, as indicated on the drawings.
 - c. Wires shall be labeled at each end for identification as shown on the drawings using wraparound laminated-type markers.
 - d. Each branch circuit in the control panel shall be individually protected with either fuses or circuit breakers.
2. Wiring (Field Required)
 - a. Refer to Manufacturers drawings and contract documents for all required field wiring.
 - b. All discrete control wiring shall be a minimum of #14 AWG, 600 V minimum insulation and 75°C minimum temperature rating.
 - c. All signal wires (i.e. 4-20 mA) shall be #18 AWG stranded copper, shielded, twisted pair unless otherwise specified.
 - d. All 120 VAC and 480 VAC wiring shall be run in separate conduits from 24 VAC, 4-20 mA and Ethernet wiring, with a minimum spacing of 6 inches. Conduit runs of different voltages shall cross each other at right angles to avoid electrical noise interference.
 - e. All wiring shall have the same ground reference for all connected control panels.
 - f. VFD rated cables shall be used between the VFD in the control panel and the corresponding motor.
 - g. Motor leads shall be connected using approved mechanical fasteners.
 - h. Analog and signal wires (i.e. 4-20mA) shall be shielded individually and only grounded on the panel side.

- i. A CAT5 Ethernet cable with internet connection shall be provided (by others) to the Remote Access Device.

Part 2 – Products

A. General Description

1. Closed Circuit Cooler Control System shall be provided by the Closed Circuit Cooler Manufacturer.
2. Closed Circuit Cooler Control System design and performance shall meet requirements specified on the attached datasheet

B. Design Requirements

1. The control panel manufacturer shall be listed by Underwriters Laboratories as an approved manufacturer of industrial control panels. Use of commercial grade controllers from the building automation contractor shall not be acceptable.
2. The control panel enclosure shall meet NEMA 4x requirements and include control cabinet heating and cooling to regulate enclosure temperature and humidity.
3. The closed circuit cooler control system shall have a Short Circuit Current Rating (SCCR) of 65 kA at 460 VAC.
4. Control Panel shall include the following equipment:
 - a. Modbus over RS-485, 2-wire connection for Building Automation System (BAS)
 - b. Programmable Logic Controller (PLC) with 15 percent spare I/O terminals
 - c. Fluid Inlet Temperature Sensor(s) [1 per cell. Refer to contract documents for quantity and location] - Field Installed
 - d. Fluid Outlet Temperature Sensor(s) [1 per coil outlet connection. Multiple cell and multiple unit configurations require an addition outlet sensor for common outlet temperature. Refer to contract documents for quantity and location] - Field Installed
 - e. Basin Temperature Sensor(s) [1 per basin. Refer to contract documents for quantity and location] – Field Installed
 - f. Ambient Dry Bulb Sensor(s) [1 per unit. Refer to contract documents for quantity and location]- Field Installed
 - g. Variable Frequency Drive (VFD) for each Fan Motor
 - h. Recirculating Pump Motor Starter(s)
 - i. Main Circuit Breaker Disconnect
 - j. DC Power Supply For The PLC And Instrumentation
 - k. Heater Package Controls with Contactor(s) and Overload Protection
 - l. Control Power Transformer
 - m. 5- Probe Electronic Water Level Control (EWLC) Package
 - n. High Basin Water Level Alarm Contact(s)
 - o. Low Basin Water Level Alarm Contact(s)
 - p. Fan Motor: Space Heater Control(s)
 - q. Relays, Fuses and Circuit Breakers for All Unit Equipment
 - r. Enclosure Heating Controlled by Thermostat
 - s. Enclosure Humidity Controlled by Hygrometer

- t. Enclosure Air Conditioner Controlled by Integrated Thermostat
 - u. Ethernet Switch To Connect PLC, HMI and VFD(s)
 - v. 10" Human Machine Interface (HMI) color touch screen display
 - w. Remote Access Device
5. The following controls shall be included for optional accessories when provided with the Closed Circuit Cooler:
- a. Discharge Hood Damper Controls
 - b. Vibration Switch Controls
6. Control panel shall include the following programming features:
- a. Ability to remotely enable/disable make-up valve for extended dry operation
 - b. Power failure recovery timer with ability to restart at previous mode of operation
 - 1) The control system shall restart the unit to the previous unit mode of operation if the duration of a power outage is less than the user defined period of time. If the power outage duration is longer than the user defined period, the control system shall initiate the unit sequence of operation.
 - c. Ability to perform fan and pump motor(s) bump testing
 - d. Visual I/O status display of all components and accessories
 - e. Backup of both user and factory settings
 - f. Pump run time counter
 - g. Fan motor run time counter
 - h. Automatic or manual initiation of louver de-icing sequence
 - i. Cycle Pumps routine to ensure all basin water pumps operate at least once per day when basin is full of water, to ensure adequate water treatment.
 - j. Water Treatment Enable/Disable for each cell (when provided by manufacturer)
 - k. Louver de-icing sequence (manually and automatically enabled)
 - 1) In the manual louver de-icing mode, the fan shall be operated in reverse direction at half speed for a user defined period of time.
 - 2) In the automatic louver de-icing mode, the user shall be able to pre-program the duration of the sequence as well as the basin water temperature in which the louver de-icing sequence begins.
- C. The PLC shall provide the following values to the Building Automation System:
- 1. Basin Heater Control Temperature Set Point
 - 2. Louver De-icing Sequence Start Temperature
 - 3. Duration Between De-icing Sequence
 - 4. Process Return Water Temperature
 - 5. Process Supply Water Temperature
 - 6. Average Supply Water Temperature
 - 7. Ambient Air Temperature

8. Basin Water Temperature
9. Pump Run Time Hours
10. Make-up Water Meter (Provided By Others)
11. Drain Water Meter (Provided By Others)
12. Conductivity (Provided By Others)
13. Active Temperature Set Point Control (HMI or BAS Control)
14. PLC Mode Of Operation (Manual or Auto)
15. Cycle Pump(s)- Time Left
16. Hot Start- Time Left
17. Louver De-icing Sequence- Time Left
18. Louver De-icing Sequence- Time Left To Begin Sequence
19. Pump Locked On - Time Left
20. VFD Speed
21. Fan Run Time(s)

D. The PLC shall provide the following indicators to the BAS:

1. Local Or Remote Temperature Setpoints
2. System Enable
3. Unit Mode of Operation
4. Make-up Solenoid (Off/On)
5. Pump Status (on/off)
6. Pump Locked On (Locked On/Unlocked)
7. Basin Heater(s)
8. Discharge Damper Actuator(s)
9. Damper Limit Switch(es) (Open/Closed)
10. Louver Deicing Sequence (Active/Non-Active)
11. Cycle Pump(s) Routine (Active/Non-Active)
12. Hot Start (Active/Non-Active)
13. VFD Running (off/on)
14. Fan Motor Space Heaters
15. Real Time Clock Low Battery Alarm
16. Heater Low Water Alarm
17. Heater Contactor Alarm
18. Pump Contactor Fault Alarm
19. Pump Overcurrent Alarm

20. High Basin Water Alarm
21. Low Basin Water Level Alarm
22. Low Basin Water Temperature Alarm
23. High Process Return Water Temperature Alarm
24. Low Process Return Water Temperature Alarm
25. High Ambient Temperature Alarm
26. Low Ambient Temperature Alarm
27. Low Process Return Water Temperature Alarm
28. VFD Fault Alarm
29. Damper Limit Switch Alarm(s)
30. Fan Vibration Alarm(s)
31. High Enclosure Temperature Alarm

E. The PLC shall provide the following values with remote modification to the BAS

1. Building Automation System (BAS) Temperature Set point
2. High Process Return Water Temperature Alarm Set Point
3. Low Process Return Water Temperature Alarm Set Point
4. Process Supply High Water Temperature Alarm Set Point
5. Process Supply Low Water Temperature Alarm Set Point
6. Ambient High Temperature Alarm Set Point
7. Ambient Low Temperature Alarm Set Point
8. Low Basin Water Temperature Alarm Set Point

F. The PLC shall provide the following indicators with remote modification to the BAS

1. Unit Priority (Water Savings or Energy Savings)
2. Building Automation System (BAS) Start/Stop
3. Pump Run Time Reset
4. Make-Up Water Meter Reset (Provided By Others)
5. Drain Water Meter Reset (Provided By Others)
6. Fan Run Time Reset
7. Acknowledge Alarms
8. Make-up Disable (Enabled/Disabled)

G. Circuit Breaker Disconnect

Molded case circuit breaker disconnect shall provide circuit overcurrent protection with inverse time and instantaneous tripping characteristics and shall be adequately sized for all loads present in the panel enclosure. Circuit breaker shall be UL 489 Listed, CSA, IEC certified/rated and CE marked for global acceptance.

H. Branch Circuit Protection

1. All branch circuits shall be protected by circuit breakers or fuses.
 - a. Fuse holders shall be finger safe.

I. Pump Starters

All pump starters shall be full-voltage, non-reversing and contain a UL label. The contactor coil shall be 120 VAC, 60 Hz. Motor protector shall have an adjustable range for the current limit trip point.

J. Variable Frequency Drives (VFD)

Each fan motor shall have its own Variable Frequency Drive (VFD). The VFD shall be controlled by a PLC to automatically adjust the fan speed to maintain the desired process supply water temperature. The VFD shall provide alarm indication to the PLC. The VFD direction shall be dictated by the PLC and will be controlled during operation. VFD shall meet the following:

- a. Logic Control Ride Through: 0.5 seconds Minimum, 2 seconds Typical
- b. Overload Current: 110% for 60 seconds and 150% for 3 seconds
- c. Efficiency: 97.5% Typical

K. Relays

1. Relays shall be of the plug-in base or terminal block type with integral LED indicator light. Relays shall be rated for continuous duty operation. The relays shall have gold plated contacts for corrosion resistance and reliable switching of low energy loads.

L. Alarms

1. High and low water level alarm outputs shall be included with the water level control package. Alarm outputs shall automatically reset once the water level returns to normal operating conditions.
2. Real Time Clock Low Battery Alarm
3. High and low process fluid, basin and ambient temperature alarms outputs shall be included. Alarm outputs shall automatically reset once the process fluid temperature returns to normal operating conditions.
4. Alarm settings are to be operator adjustable via the HMI or through the Building Automation System. Alarms shall be enabled or disabled via the HMI or over the Building Automation System.
5. Alarms shall remain active until condition returns to design operating range. Upon alarm deactivation, alarms shall be stored as part of the alarm history log.
6. The following list of alarms shall be monitored as part of the closed circuit cooler control system:
 - a. Heater Low Water Alarm
 - b. Heater Contactor Alarm
 - c. Pump Contactor Fault Alarm
 - d. Pump Overcurrent Alarm
 - e. High Basin Water Level Alarm
 - f. Low Basin Water Level Alarm
 - g. Low Basin Water Temperature Alarm
 - h. High Process Supply Water Temperature Alarm

- i. Low Process Supply Water Temperature Alarm
- j. High Ambient Temperature Alarm
- k. Low Ambient Temperature Alarm
- l. High Process Return Water Temperature Alarm
- m. Low Process Return Water Temperature Alarm
- n. VFD Fault Alarm
- o. Damper Limit Switch Alarm(s)
- p. Fan Vibration Alarm(s)
- q. High Enclosure Temperature Alarm

M. Human Machine Interface (HMI)

1. The operator display shall be provided as a stand-alone component with a separate programmable logic controller for control. Use of a computer for the process control shall not be acceptable.
2. The HMI shall be provided with a weather-tight cover mounted on the door of a NEMA 4x enclosure so that it will maintain the enclosure's NEMA 4x rating.
3. The HMI shall include a 10" color display and a resistive touch screen rated for at least 1,000,000 touches.
4. The HMI shall be industrially rated and certified for the following conditions:
 - a. Relative Humidity: 5 to 95% (Non-condensing)
 - b. HMI shall be rated for 50,000 hours of life
 - c. The HMI shall be industrially rated and certified for UL/CUL.

N. Remote Access Device

1. The Remote Access Device shall provide secure access between the PLC, HMI, VFD(s) and EVAPCO thru a private Virtual Private Network (VPN).
 - a. A CAT5 Ethernet cable with internet connection shall be provided (by others) to the Remote Access Device.
2. The Remote Access Device shall require a hardwired Ethernet connection to the Internet, which can be connected or removed at the Customer's discretion.
3. The Remote Access Device shall allow the manufacturer to access the Ethernet connected control components via a cloud server on the Internet for program changes, modifications and troubleshooting if necessary.

O. Operation

1. The Closed Circuit Cooler Manufacturer shall furnish a description of the Sequence of Operation for the provided control system.
2. For all supported modes of operation, the panel shall utilize adaptive logic to allow for automatic adjustment between unit modes of operation based on real time system load and ambient temperature conditions.
3. Each cell shall be able to automatically switch between the following unit modes of operation based on the real time load, ambient conditions and temperature set point as well as the desired unit priority:
 - a. Evaporative Mode – In Evaporative Mode, the Closed Circuit cooler shall operate with the basin water circulation pump(s) energized and the fan motor(s) running. The fan speed shall be modulated based on real time load and ambient conditions for maximum energy efficiency.

- b. Dry Mode – In Dry Mode, the Closed Circuit Cooler shall operate with the basin water circulation pump(s) de-energized and the fan motor(s) running. The fan speed shall be modulated based on real time load and ambient conditions for maximum water and energy efficiency.
- 4. The unit shall be capable of prioritizing between a water savings priority and an energy savings priority based on user preference.
 - a. Water Savings Priority – In the Water Savings Priority, while ensuring the desired process supply water temperature is achieved, the control system shall be able to modulate between the various unit modes of operation in the most water efficient manner possible. This shall consist of (but not be limited to) de-energizing the unit spray pump(s) and adjusting fan motor(s) speed at the system load and or ambient conditions change.
 - b. Energy Savings Priority – In the Energy Savings Priority, while ensuring the desired process supply water temperature is achieved, the control system shall modulate between the various modes of operation in the most energy efficient manner possible. This shall consist of (but not be limited to) de-energizing the unit spray pump(s) and adjusting fan motor(s) speed as the system load and or ambient conditions change. The PLC shall be capable of evaluating the fan motor(s) power at various speeds as well as evaluating the basin water spray pump(s) power and determine when it is more energy efficient to de-energize the spray pump(s) and increase the fan motor(s) speed.

P. Network Capabilities

The Programmable Logic Controller (PLC) shall include a MODBUS over RS-485, 2-wire connection to a Building Automation System (BAS).

3.3 Installation

- A. All wiring to the control panel shall be installed by a licensed electrician. The National Electrical Code and all applicable state and local codes shall be followed when installing this equipment. Power, control and sensor field wiring between the control panel and the closed circuit cooler must be provided by others.
- B. Control panel enclosure mounting brackets/stand may be necessary (by others). Refer to manufacturer's panel enclosure drawing to ensure adequate clearance around the enclosure.
- C. Factory trained technician shall be on-site for Manufacturer's supplied control panel start-up and commissioning. These services include panel start-up, PLC tuning, BAS integration and owner training. Support shall consist of up to two separate trips. Each trip shall consist of up to two consecutive, 8 hour work days.

3.4 Testing/Commissioning

A. Factory Testing

- 1. All inputs and outputs to the PLC shall be tested for proper function at the point of field wiring.
- 2. The PLC and HMI programs shall be tested and setup to the customer's specific job.
- 3. VFD(s) shall be programmed and tested for proper operation.
- 4. If multiple control panels are provided for the same project, all control panels shall be temporarily wired together and tested as a system and not individually.
- 5. User and Factory Backups shall be saved prior to shipping.

B. On-Site Commissioning (By Manufacturer)

- 1. All VFD parameters shall be verified per the electrical drawings.
- 2. All field wiring between multiple control panels (if necessary) shall be verified according to best wiring practices.
- 3. All field wiring to remote sensors and devices shall be verified according to recommended wiring practices as detailed in manufacturer's wiring diagram.

4. Rotation of all motors shall be verified for correct direction.
5. Fan and pump motor(s) amperage shall be measured and confirmed to be within motor ratings.
6. Integration with Building Automation System (if necessary) shall be verified for correct operation and monitoring.
7. Job specific set points shall be programmed according to Customer's requirements.
8. Proper operation between the Manufacturer's supplied control system and unit shall be verified.
9. Control system shall be "tuned" for the customer's specific system.
10. Connection to the Manufacturer's remote access device shall be verified.
11. Ethernet cabling between connected components shall be tested.

C. Field Wiring (By Others)

1. Refer to Manufacturer's electrical drawings for all required field wiring.
2. Electrical wiring best practices shall be followed
3. All discrete control wiring shall be a minimum of #14 AWG, 600 V minimum insulation and 75°C minimum temperature rating.
4. All signal wires (i.e. 4-20 mA) shall be #18 AWG stranded copper, shielded, twisted pair unless otherwise specified.
5. All 120 VAC and 480 VAC wiring shall be run in separate conduits from 24 VAC, 4-20 mA and Ethernet wiring, with a minimum spacing of 6 inches. Conduit runs of different voltages shall cross each other at right angles to avoid electrical noise interference.
6. All field wiring shall have the same ground reference for all connected control panels.
7. VFD rated cables shall be used between the VFD in the control panel and the corresponding motor.
8. Motor leads shall be connected using approved mechanical fasteners.
9. Analog and signal wires (i.e. 4-20mA) shall be shielded individually and only grounded on the panel side.
10. A CAT5 Ethernet cable with internet connection shall be provided (by others) to the Remote Access Device.

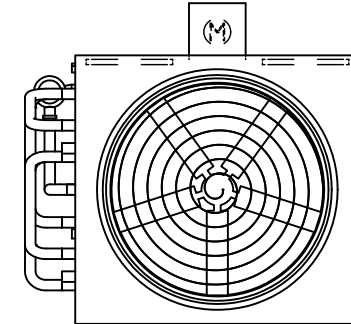
UNIT	CLOSED CIRCUIT COOLER	MODEL #	eco-ATWB-H 9-3K9-Z-U12	SCALE	N.T.S.	DWG. #	EGH0909MR-DRB-SF	REV.	-	DATE	5/12/2017	SERIAL #	
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NOTES:

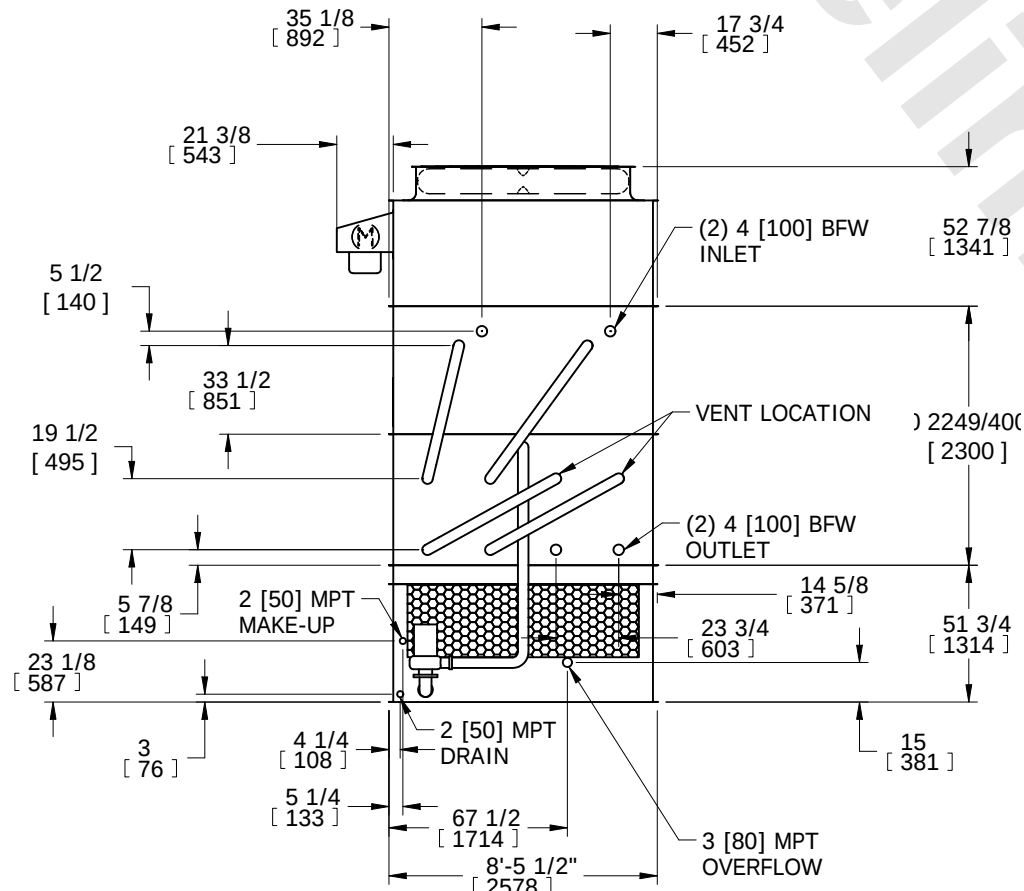
1. (M)- FAN MOTOR LOCATION
2. HEAVIEST SECTION IS COIL SECTION
3. MPT DENOTES MALE PIPE THREAD
FPT DENOTES FEMALE PIPE THREAD
BFW DENOTES BEVELED FOR WELDING
4. +UNIT WEIGHT DOES NOT INCLUDE ACCESSORIES (SEE ACCESSORY DRAWINGS)
5. MAKE-UP WATER PRESSURE
20 psi MIN [137 kPa], 50 psi MAX [344 kPa]

6. DIMENSIONS LISTED AS FOLLOWS:
ENGLISH IN
[METRIC] [mm]
7. * - APPROXIMATE DIMENSIONS DO NOT USE FOR PRE-FABRICATION OF CONNECTING PIPING.

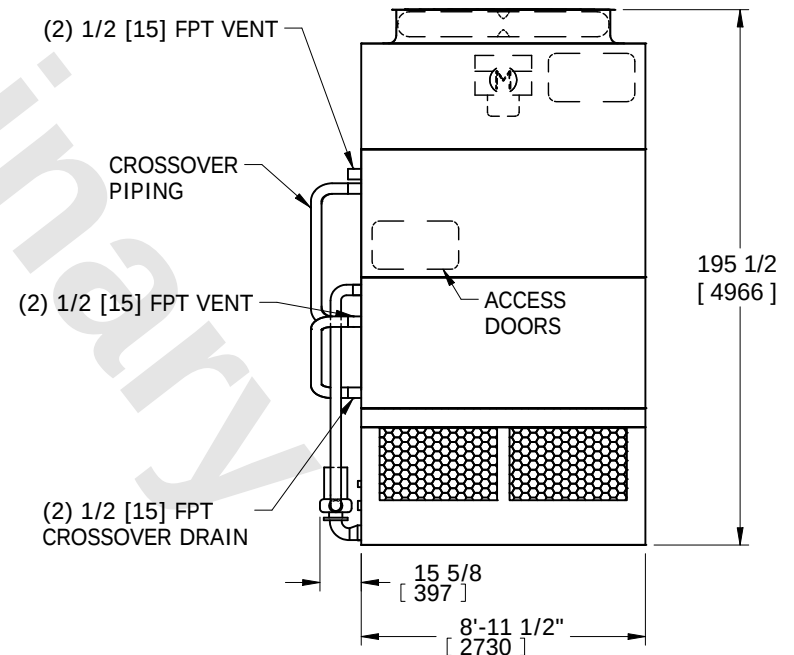
**FACE 2
PLAN VIEW**



FACE 1



FACE 2

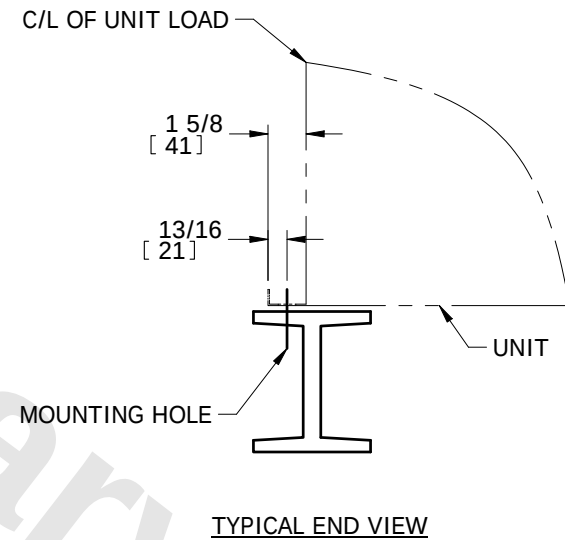
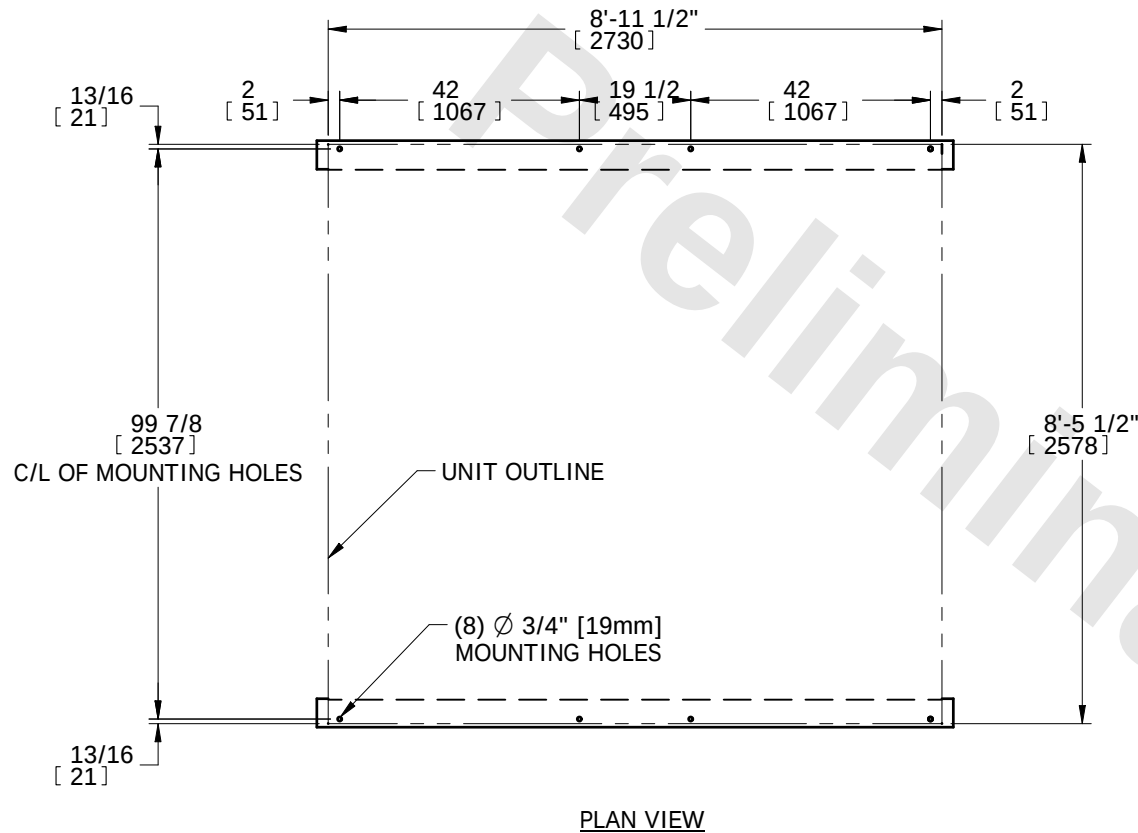


FACE 1

SHIPPING WEIGHT	11720 lbs+[5315] kg+	OPERATING WEIGHT	15580 lbs+[7065] kg+	HEAVIEST SECTION WEIGHT	8110 lbs+[3680] kg+	NO. OF SHIPPING SECTIONS	3	DRAWN BY:	SFR
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TITLE	STEEL SUPPORT CONFIGURATION	UNIT:	8.5x9 INDUCED DRAFT COOLER/CONDENSERS	DWG. #	SLAW0909-DD
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**NOTES:**

1. BEAMS SHOULD BE SIZED IN ACCORDANCE WITH ACCEPTED STRUCTURAL PRACTICES. MAXIMUM DEFLECTION OF BEAM UNDER UNIT TO BE 1/360 OF UNIT LENGTH NOT TO EXCEED 1/2" [13mm].
2. DEFLECTION MAY BE CALCULATED BY USING 55% OF THE OPERATING WEIGHT AS A UNIFORM LOAD ON EACH BEAM. SEE CERTIFIED PRINT FOR OPERATING WEIGHT.
3. SUPPORT BEAMS AND ANCHOR HARDWARE ARE TO BE FURNISHED BY OTHERS. ANCHOR HARDWARE TO BE ASTM - A325 5/8" [16mm] BOLT OR EQUIVALENT.
4. BEAMS MUST BE LOCATED UNDER THE FULL LENGTH OF THE PAN SECTION.
5. SUPPORTING BEAM SURFACE MUST BE LEVEL. DO NOT LEVEL THE UNIT BY PLACING SHIMS BETWEEN THE UNIT MOUNTING FLANGE AND THE SUPPORTING BEAM.
6. ANCHORING ARRANGEMENT SHOWN HAS A MAXIMUM WIND RATING OF 145 PSF [6.94 KPa] ON CASSED VERTICAL SURFACES.
7. THE FACTORY RECOMMENDED STEEL SUPPORT CONFIGURATION IS SHOWN. CONSULT THE FACTORY FOR ALTERNATE SUPPORT CONFIGURATIONS.
8. UNIT SHOULD BE POSITIONED ON STEEL SUCH THAT THE ANCHORING HARDWARE FULLY PENETRATES THE BEAM'S FLANGE AND CLEARS THE BEAM'S WEB.

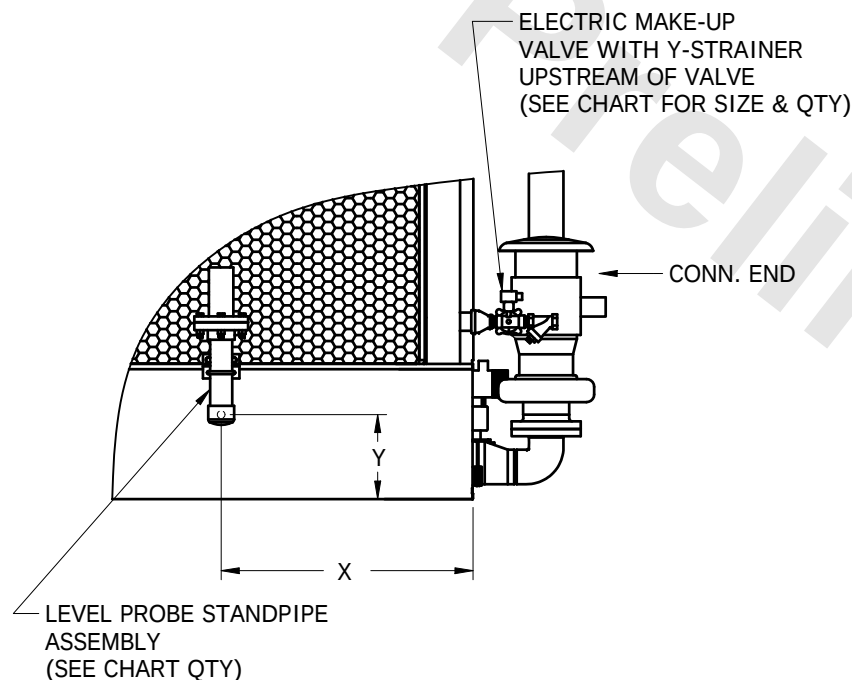
EVAPCO, INC.



TITLE ELECTRIC WATER LEVEL CONTROL LOCATION

UNIT: eco-ATWB-H 9-3K9-Z-U12 INDUCED DRAFT CONDENSER/COOLER

DWG. # 5/12/2017 FLEGHMWML-DB



UNIT SELECTED	BOX SIZE	VALVE			Y-STRAINER			STANDPIPE		
		QTY	SIZE	PART NO.	QTY	SIZE	PART NO.	QTY	X	Y
☐	8.5,2.4Mx9	1	1 [25]	017-00153P	1	1 [25]	017-00280P	1	42 1/2 [1080]	9 [229]
☐	8.5,2.4Mx12	1	1 [25]	017-00153P	1	1 [25]	017-00280P	1	54 1/2 [1385]	9 [229]
☐	8.5,2.4Mx14	1	1 1/2 [40]	017-00154P	1	1 1/2 [40]	017-00281P	1	62 1/2 [1588]	9 [229]
☐	8.5,2.4Mx18	1	1 1/2 [40]	017-00154P	1	1 1/2 [40]	017-00281P	1	93 [2362]	9 [229]
☐	8.5,2.4Mx21	1	1 1/2 [40]	017-00154P	1	1 1/2 [40]	017-00281P	1	97 [2464]	9 [229]
☐	2.4Mx24	2	1 [25]	017-00153P	2	1 [25]	017-00280P	1	48 [1219]	9 [229]
☐	2.4Mx28	2	1 1/2 [40]	017-00154P	2	1 1/2 [40]	017-00281P	1	59 [1499]	9 [229]
☐	2.4Mx36	2	1 1/2 [40]	017-00154P	2	1 1/2 [40]	017-00281P	1	93 [2362]	9 [229]
☐	2.4Mx42	2	1 1/2 [40]	017-00154P	2	1 1/2 [40]	017-00281P	1	97 [2464]	9 [229]
☐	12,3Mx12	1	1 1/2 [40]	017-00154P	1	1 1/2 [40]	017-00281P	1	108 [2743]	11 1/2 [292]
☐	12x14	1	1 1/2 [40]	017-00154P	1	1 1/2 [40]	017-00281P	1	121 [3073]	11 1/2 [292]
☐	12,3Mx18	1	2 [50]	017-00155P	1	2 [50]	017-00282P	1	82 [2083]	11 1/2 [292]
☐	12x20	1	2 [50]	017-00155P	1	2 [50]	017-00282P	1	90 [2286]	11 1/2 [292]
☐	12,3Mx24	2	1 1/2 [40]	017-00154P	2	1 1/2 [40]	017-00281P	1	108 [2743]	11 1/2 [292]
☐	12x28	2	1 1/2 [40]	017-00154P	2	1 1/2 [40]	017-00281P	1	121 [3073]	11 1/2 [292]
☐	12,3Mx36	2	2 [50]	017-00155P	2	2 [50]	017-00282P	1	82 [2083]	11 1/2 [292]
☐	12x40	2	2 [50]	017-00155P	2	2 [50]	017-00282P	1	90 [2286]	11 1/2 [292]

NOTES:

1. PIPING BY OTHERS.
2. LEVEL PROBE STANDPIPE ASSEMBLY, MAKE-UP VALVE AND Y-STRAINER TO SHIP LOOSE FOR FIELD MOUNTING BY OTHERS.
3. SEE CERTIFIED PRINT FOR MAKE-UP LOCATION.
4. STANDPIPE TO BE HEAT TRACED AND INSULATED FOR WINTER OPERATION (BY OTHERS).
5. THE ELECTRONIC WATER LEVEL CONTROL ON THIS UNIT WILL MAINTAIN THE PROPER OPERATING WATER LEVEL.
HOWEVER, BEFORE INITIAL START-UP THE UNIT MUST BE MANUALLY FILLED TO WITHIN 1" OF THE OVERFLOW.
6. FOR EASE OF MAINTENANCE, A SHUT-OFF VALVE IS RECOMMENDED UPSTREAM OF Y-STRAINER.
7. DIMENSIONS LISTED AS FOLLOWS: ENGLISH IN
[METRIC] [mm]

Sage²® & Sage³® Selection Worksheet

To Be Completed Prior To Quotation

Project Name:
Serial #:

Location:
Model #:

Electrical Information (Select one for each):

High Voltage Panel Enclosure:

- ☐ 460 VAC/3Ø/60 Hz (standard)
☐ 208 VAC/3Ø/60 Hz (Contact Factory)
☐ 230 VAC/3Ø/60 Hz (Contact Factory)
☐ 575 VAC/3Ø/60 Hz (Contact Factory)

Low Voltage Panel Enclosure:

- ☐ 120 VAC/1Ø/60 Hz (standard)
☐ 208 VAC/1Ø/60 Hz (Contact Factory)
☐ 230 VAC/1Ø/60 Hz (Contact Factory)
☐ 460 VAC/1Ø/60 Hz (Contact Factory)
☐ 575 VAC/1Ø/60 Hz (Contact Factory)

{The standard arrangement requires a dedicated 120 VAC feed for the Low Voltage panel. Matching the voltage requirement of the Low Voltage panel to the High Voltage may be beneficial if 120 VAC service is not available at the location of the SAGE panels – Contact the factory for pricing and availability}

Ambient Temperature Environment of Sage Control System:

- ☐ 0 to 100 °F (standard) ☐ Other _____ (Contact Factory)

{The stated ambient temperature range must represent the temperature extremes the SAGE panels will be exposed to during operation. This will ensure the heating and cooling requirements for the SAGE panel are correctly sized.}

Short Circuit Current Rating (SCCR):

- ☐ 65k amps at 460V (standard) ☐ Other (Contact Factory)

{The SCCR is primarily affected by the level of circuit protection upstream of the device, i.e. number of circuit breakers between the power transformer and the SAGE panel.}

Start-up & Training Visits:

- ☐ (1st Trip) 2 Consecutive 8 hour days for Sage start-up +
 (2nd Trip) 2 Consecutive 8 hour days for commissioning and owner training (Standard)
☐ [or]
☐ Custom [Example: Site visit for multiple commissioning events] (Contact Factory)

Number of Panels Per Unit (Select one of the below):

Single Cell ≤ 30HP Fan Motor:

- ☐ [1 Panel Total]

Multi-Cell Unit:

- ☐ [1 High Voltage per cell & 1 Low Voltage per unit]

Single Cell ≥ 40HP Fan Motor:

- ☐ [1 High Voltage & 1 Low Voltage]

Custom: (Contact Factory)

- ☐ [Example: 1 Double Wide Panel Per 2-cells]

{As standard there is one disconnect per High Voltage panel allowing each cell to be de-energized independently. If multiple cells are combined into one large enclosure there will only be one disconnect for both cells. Therefore, power to one cell cannot be isolated from the other and the entire system is powered together.}

Sage²® & Sage³® Selection Worksheet

To Be Completed Prior To Quotation

Other (Select one for each line, describe Custom in special notes section):**One Hand-Off-Auto Switch for Entire Unit:**☐ Yes (standard)☐ Custom (Contact Factory)
[Example: 1 HOA Switch per Fan/Pump]

{With one HOA switch, in “Hand” all VFD’s are run at 100% fan speed and all spray pumps are energized. If the unit is equipped with a VFD bypass, then all fan motors will run across the line when the HOA is in “Bypass”. As custom, extra On-Off switches can be added to the SAGE allowing the user to turn on or off each motor when in “Hand/Bypass”.}

One VFD per Fan Motor:☐ Yes (standard)☐ Custom (Contact Factory)
[Example: 1 VFD Total for a 2-Cell Unit]

{In the rare occurrence that a VFD would fail or trip having separate VFD’s will allow the remaining VFD to continue running. In the same instance if a shared VFD would fail then all connected motors would not be operable.}

VFD Bypass (Bypass would allow the fan motor to operate in the event of a VFD failure): (Std. On 1-Fan Units)☐ No (standard)☐ Yes (Contact Factory)

{Without a VFD bypass, a rare VFD fault would cause the fan motor to be inoperable whether the HOA switch was in “Hand” or “Auto”. A VFD bypass will allow the motor to energize, independent of the VFD. VFD bypasses are standard on single cell, single fan units.}

VFD Filters (Reduces Panel Harmonics – Investigate on Data Center Application): (Mandatory for 575V)☐ No (standard)☐ Yes (Contact Factory)

{Information on whether filters are required on VFD’s is usually found in the controls or VFD specifications for the project. In most instances input filters are not necessary due to the size of the closed circuit cooler fan motor compared to the overall electrical load present at the site. Keeping the SAGE panel relatively close to the closed circuit cooler will also reduce the need for VFD output filters. However, all projects will 575 VAC motors must have VFD output filters.}

Redundant Pump (Spare Pump Assembly):☐ No (standard)☐ Yes (Contact Factory)

{Redundant pump is a backup spray pump and riser pipe connected to the main spray system header. This option will utilize additional code alternating the operation of the two spray pumps. The SAGE will energize one pump for a set number of days (adjustable) and then switch operation to the backup pump, and this is then repeated. The SAGE will also transition to the backup pump if the main pump becomes inoperable.}

Sage²® & Sage³® Selection Worksheet

To Be Completed Prior To Quotation

Multiple Cell Operation:☐ Together (standard)☐ Separate Loops (Contact Factory)

{As standard, multi-cell units will be operated on the same system loop with common headers for all inlets and outlets. In this instance an extra RTD sensor will be provided to be installed in the common outlet header. This temperature will be used for adjusting the thermal output of the closed circuit cooler. However, if the cells of a multi-cell unit should be independent of one another then custom code will need to be added to the SAGE controller and the common header RTD will not be provided.}

Communications Protocol:☐ MODBUS☐ BACNET (RS-485)
+ \$800 Net per PLC☐ Other (Contact Factory)

{MODBUS is the standard operating protocol and can communicate with the building over a RS-485 connection. For additional cost a MODBUS to BACNET converter can be added inside the SAGE. This converter allows a BACNET connection with the building via 2-wire, RS-485 wiring. It is possible other configuration may be integrated into the SAGE but will be determined after contacting Evapco.}

PLC Redundancy (Backup PLC in Event of Failure):☐ No (standard)☐ Yes (Contact Factory)

{It is possible to add additional functionality to the SAGE in the rare instance the PLC becomes inoperable due to a failure or fault. These solutions will allow the SAGE to continue operation without downtime. The level of redundancy will be handled on a job by job basis. As such, detailed conversations with the factory are required way before quoting and pricing the SAGE panel.}

High Radio Frequency Area (Nearby Cell Phone Towers, etc.):☐ No (standard)☐ Yes (Contact Factory)

{Areas of high radio frequency can cause unwanted interference with standard SAGE temperature sensors. High radio frequency can be given off from TV and communications antennas in close proximity to the SAGE.}

Special Notes:

EVAPCO, INC.



TITLE

SAGE PANEL CONFIGURATION

DESCRIPTION:

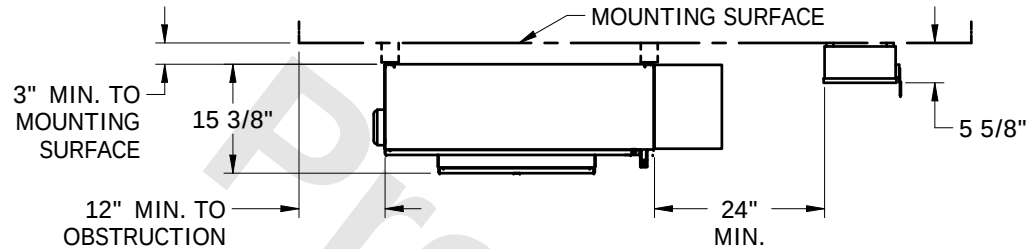
eco-ATWB-H 9-3K9-Z-U12

PANEL LAYOUT - 1 PANEL

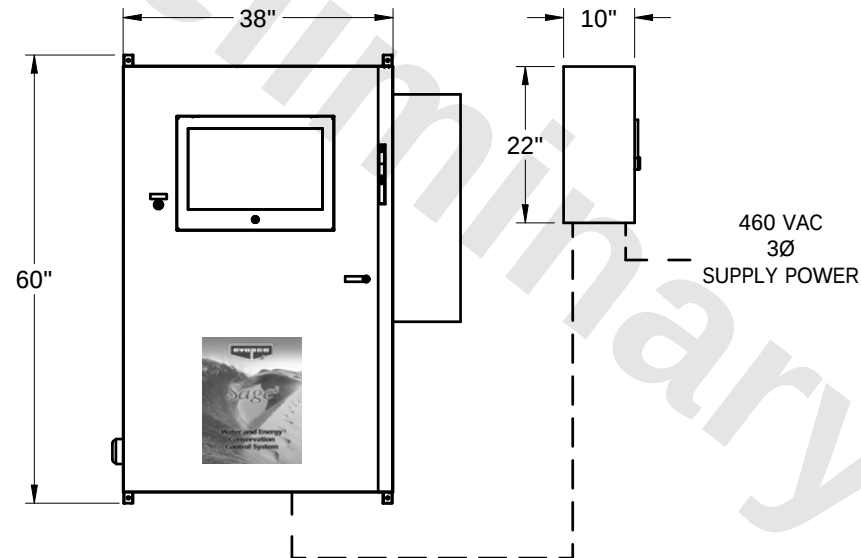
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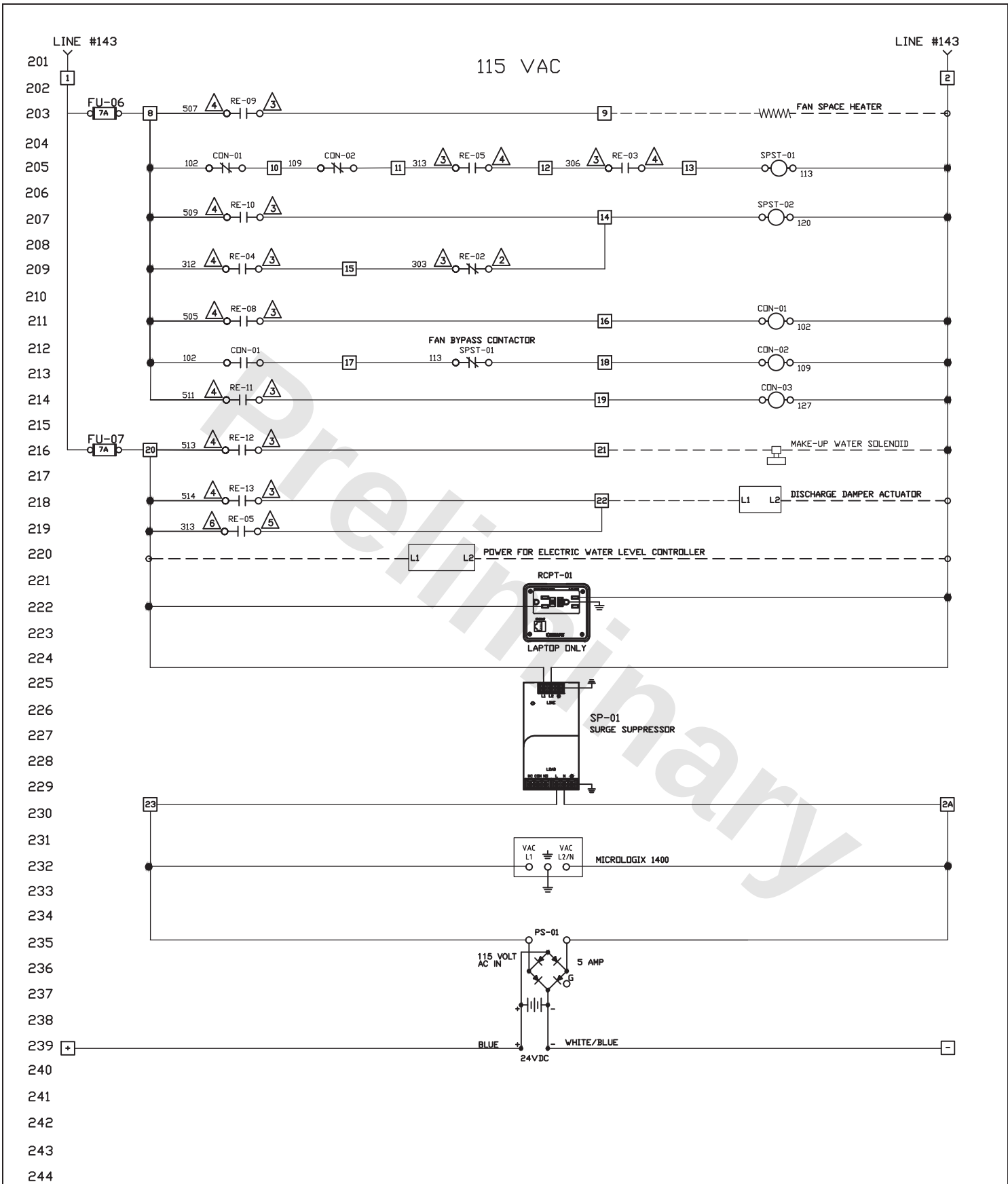
CONTROL PANEL: P1 FUSED DISCONNECT



**PER
UNIT**

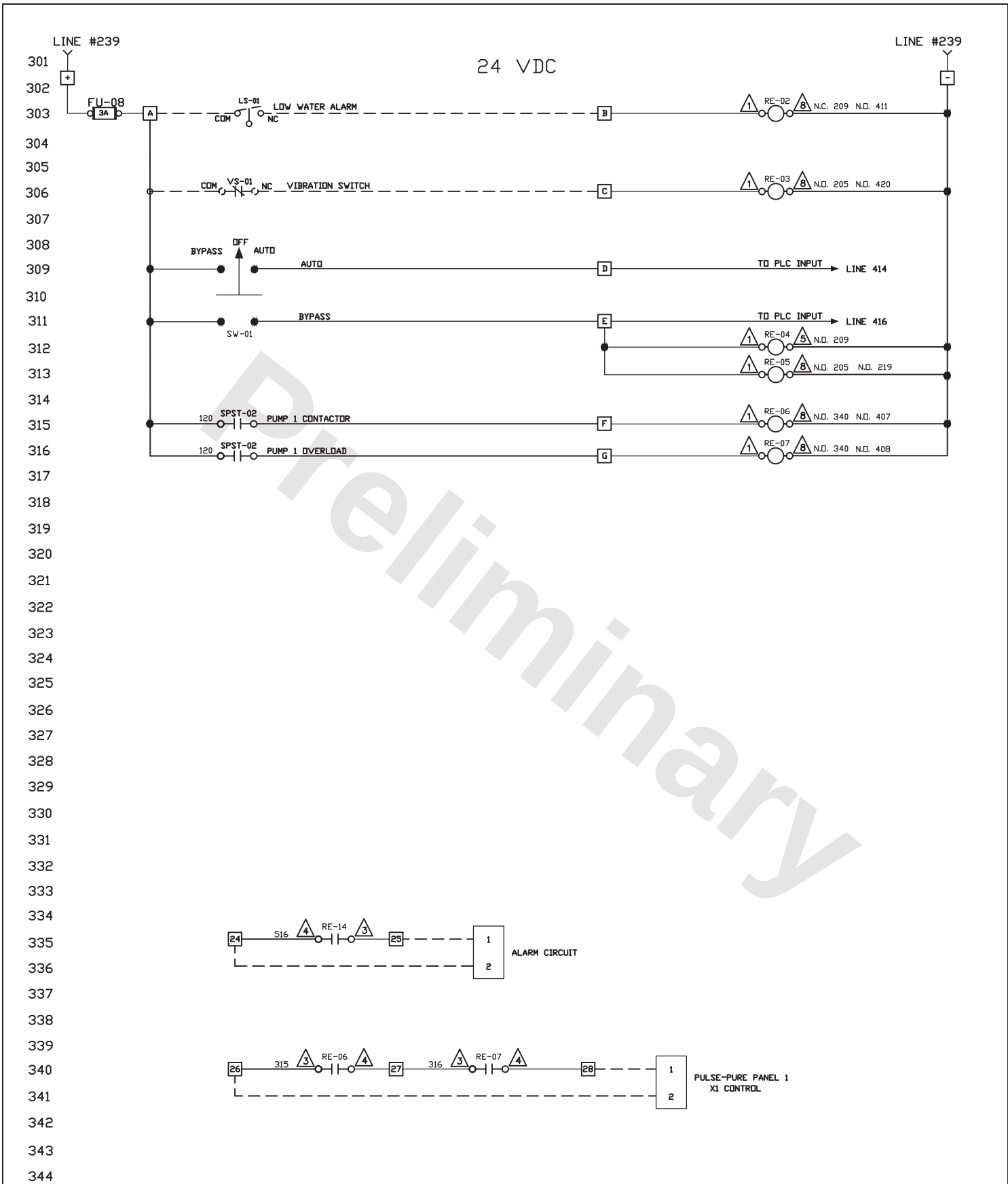
NOTES:

1. DASHED LINES INDICATE WIRING BY OTHERS.
2. INSTALLATION SHOULD COMPLY WITH NATIONAL, STATE, AND LOCAL CODES.
3. DO NOT MOUNT ENCLOSURE WITH A SOUTHERN EXPOSURE.
4. CONDUIT CONNECTIONS MUST GO THROUGH BOTTOM OF ENCLOSURE ONLY.
5. PANELS WILL SHIP LOOSE FOR FIELD MOUNTING AND WIRING.
6. APPROXIMATE DIMENSIONS SHOWN.
7. CONFIGURATION SHOWN IS PER UNIT.

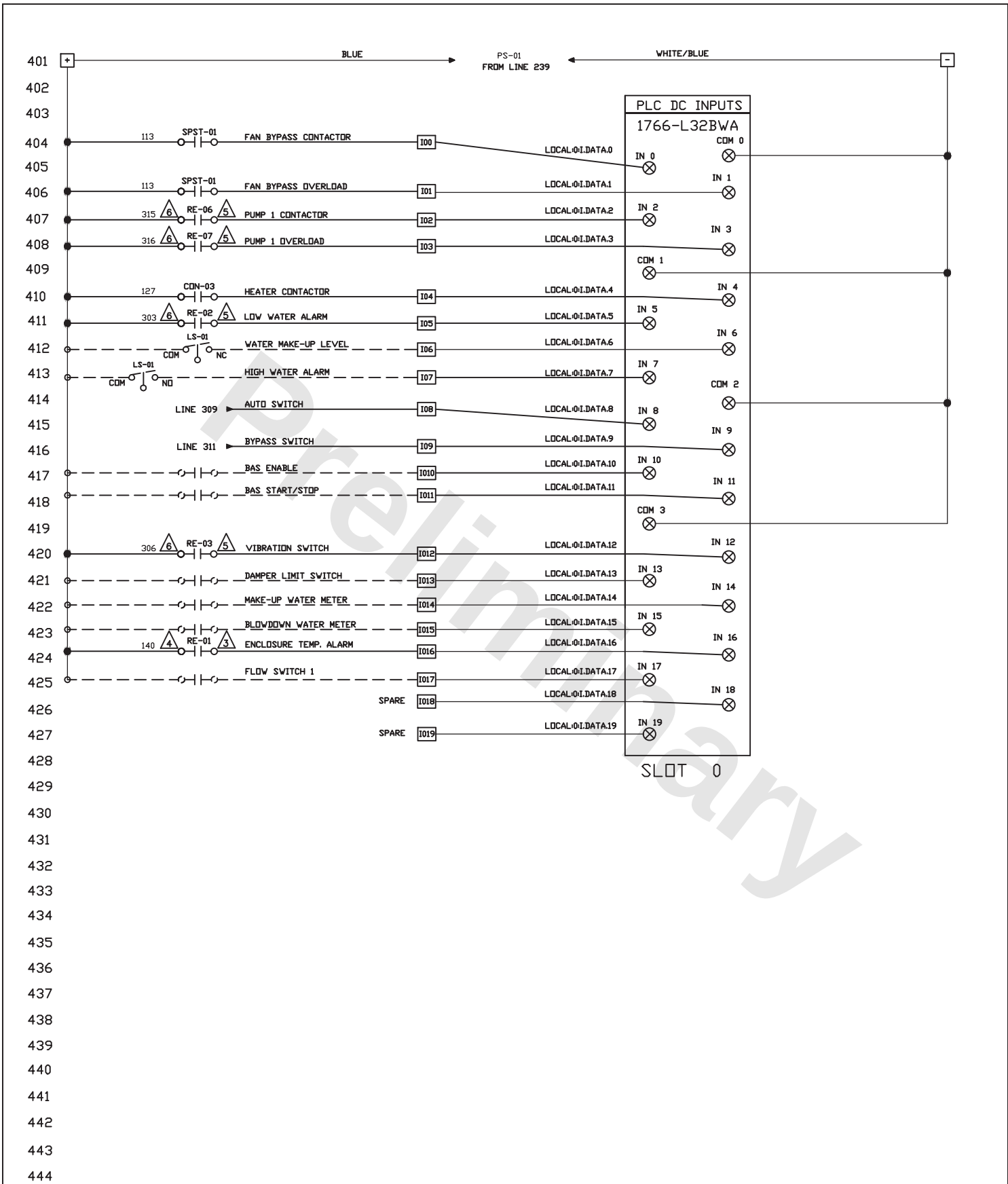


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REV.	DESCRIPTION	BY	TITLE MOTOR CONTROL AND POWER SUPPLY WIRING				REV. NO.
			JOB	DATE 9/2/2014	ORDER NO.	SCALE	
			MAT'L NO.	DRWN BY JPM			
			CHKD BY		N.C. INFO.		
				PART NO. S2WRSC1AB5Z-UA			

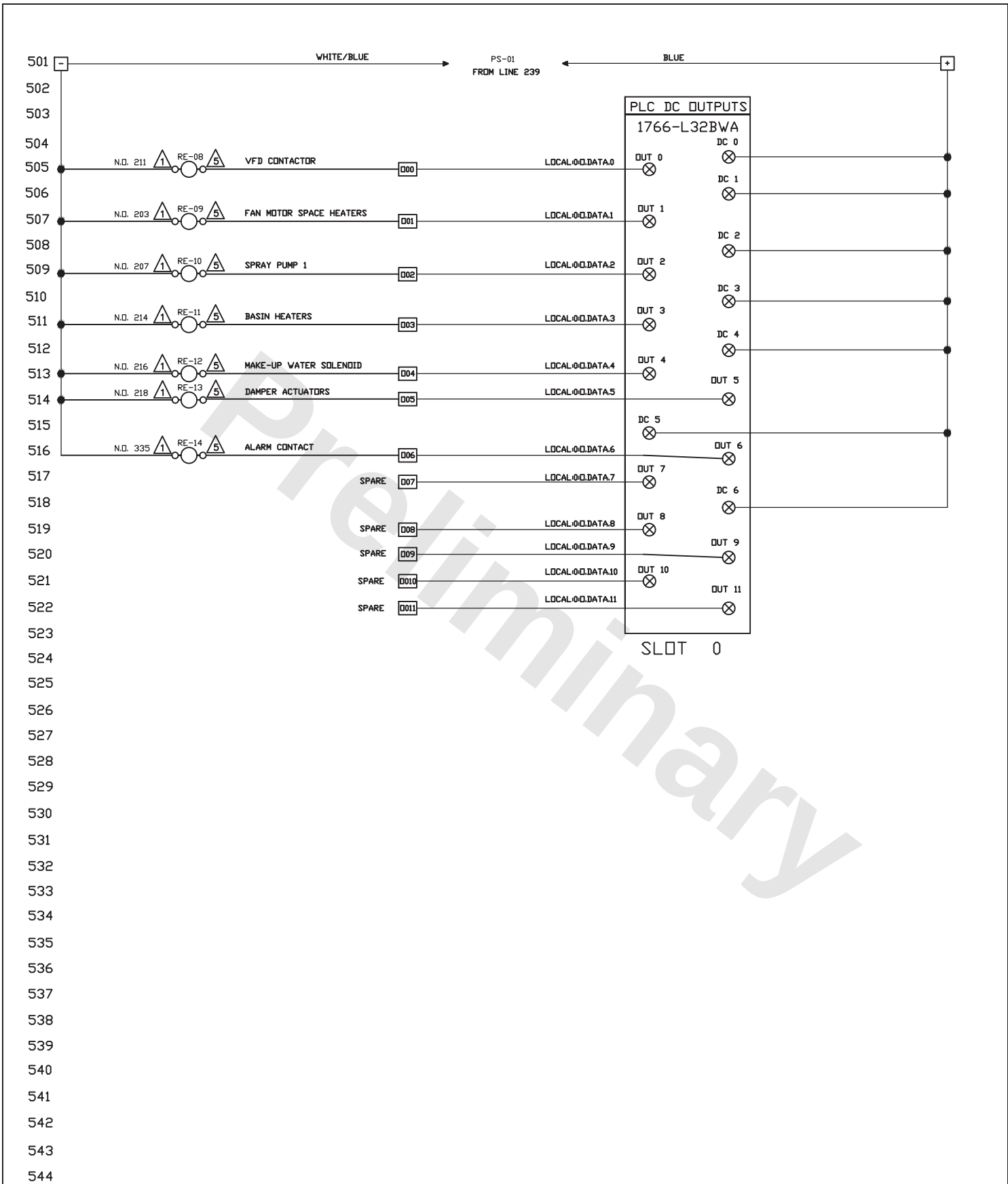


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						JOB	DATE 9/2/2014	ORDER	
						MAT'L NO.	DRWN BY JPM	SCALE	
							CHKD BY	N.C. INFO.	
							PART NO.	S2WRSC1AB5Z-UA	REV. NO.
		REV.	DESCRIPTION		BY				



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			JOB	DATE	ORDER NO.	REV. NO.
			MAT'L NO.	9/2/2014		
			CHKD BY	JPM	SCALE	
					N.C. INFO.	
					PART NO.	
					S2WRSC1AB5Z-UA	

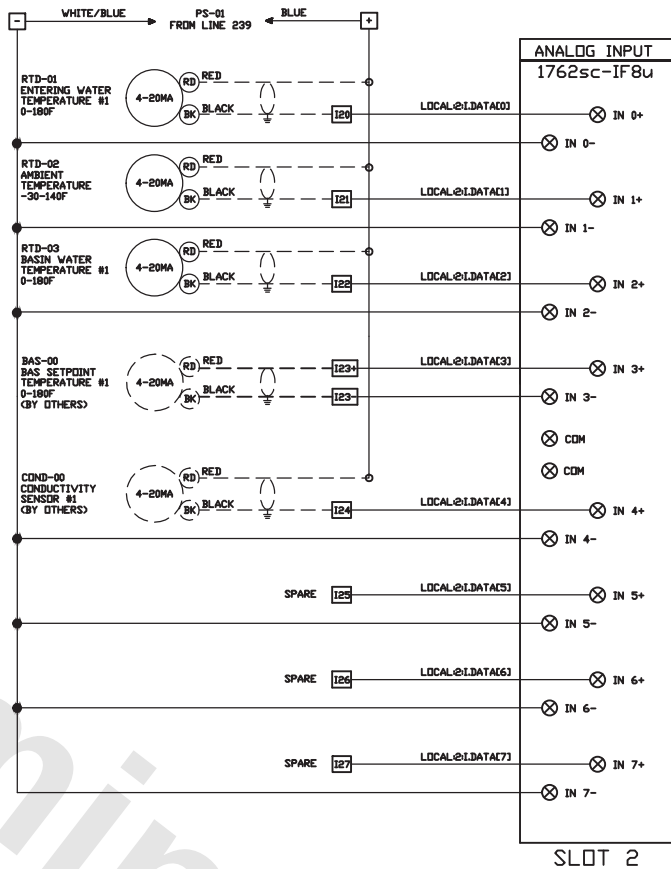
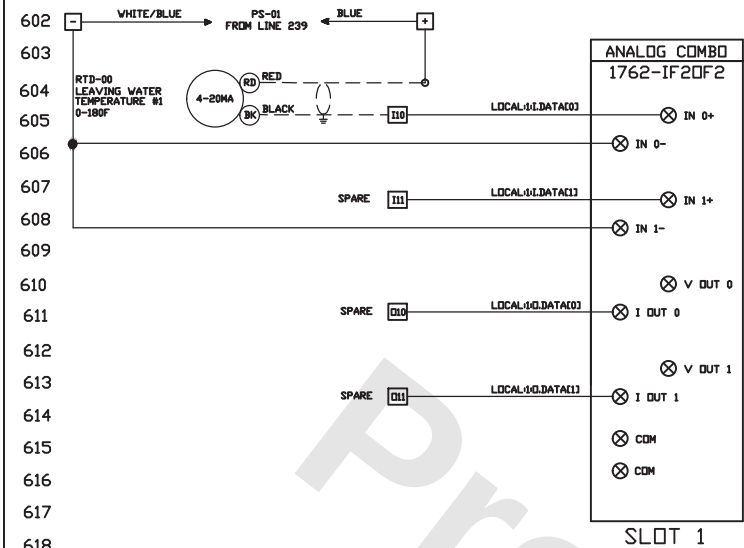


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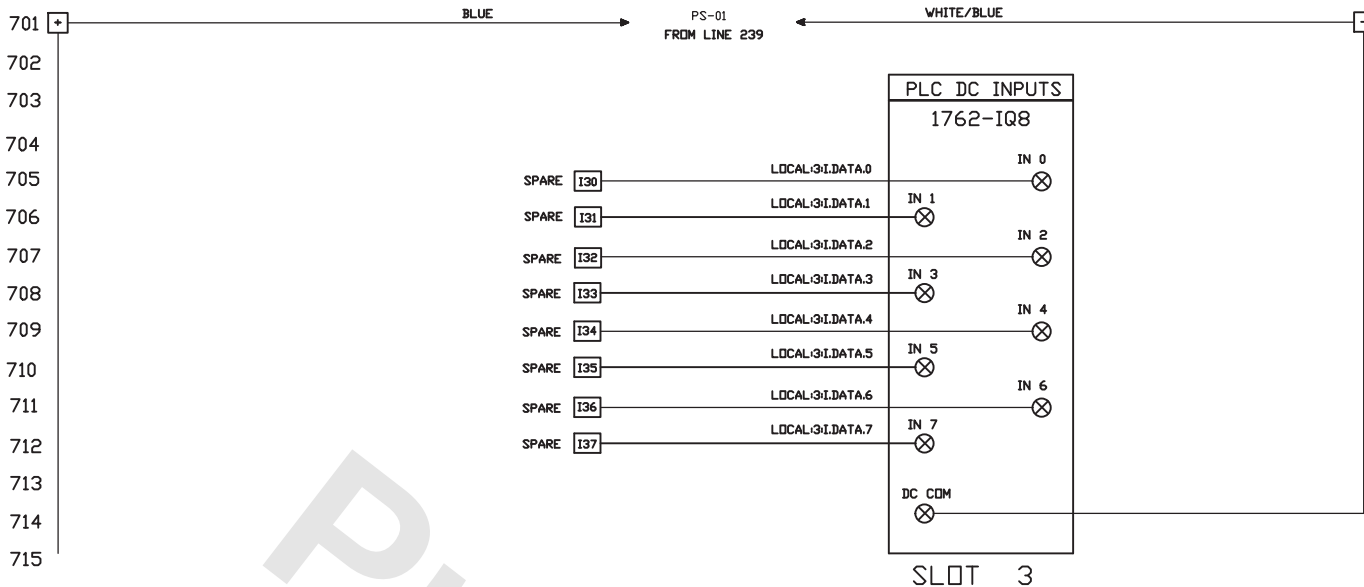
TITLE DIGITAL OUTPUT WIRING FOR 1766-L32BWA			
JOB	DATE 9/2/2014	ORDER NO.	
MAT'L NO.	DRWN BY JPM	SCALE	
CHKD BY	N.C. INFO.		
PART NO. S2WRSC1AB5Z-UA		REV. NO.	

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REVISIONS					TITLE				ALOG WIRING FOR 1762-IF20F2 AND 1762SC-IF8U			
					JOB	DATE	9/2/2014	ORDER NO.				
					MAT'L NO.	DRWN BY	JPM	SCALE				
						CHKD BY		N.C. INFO.				
						PART NO.						REV. NO.
	REV.	DESCRIPTION		BY	 S2WRSC1AB5Z-UA							

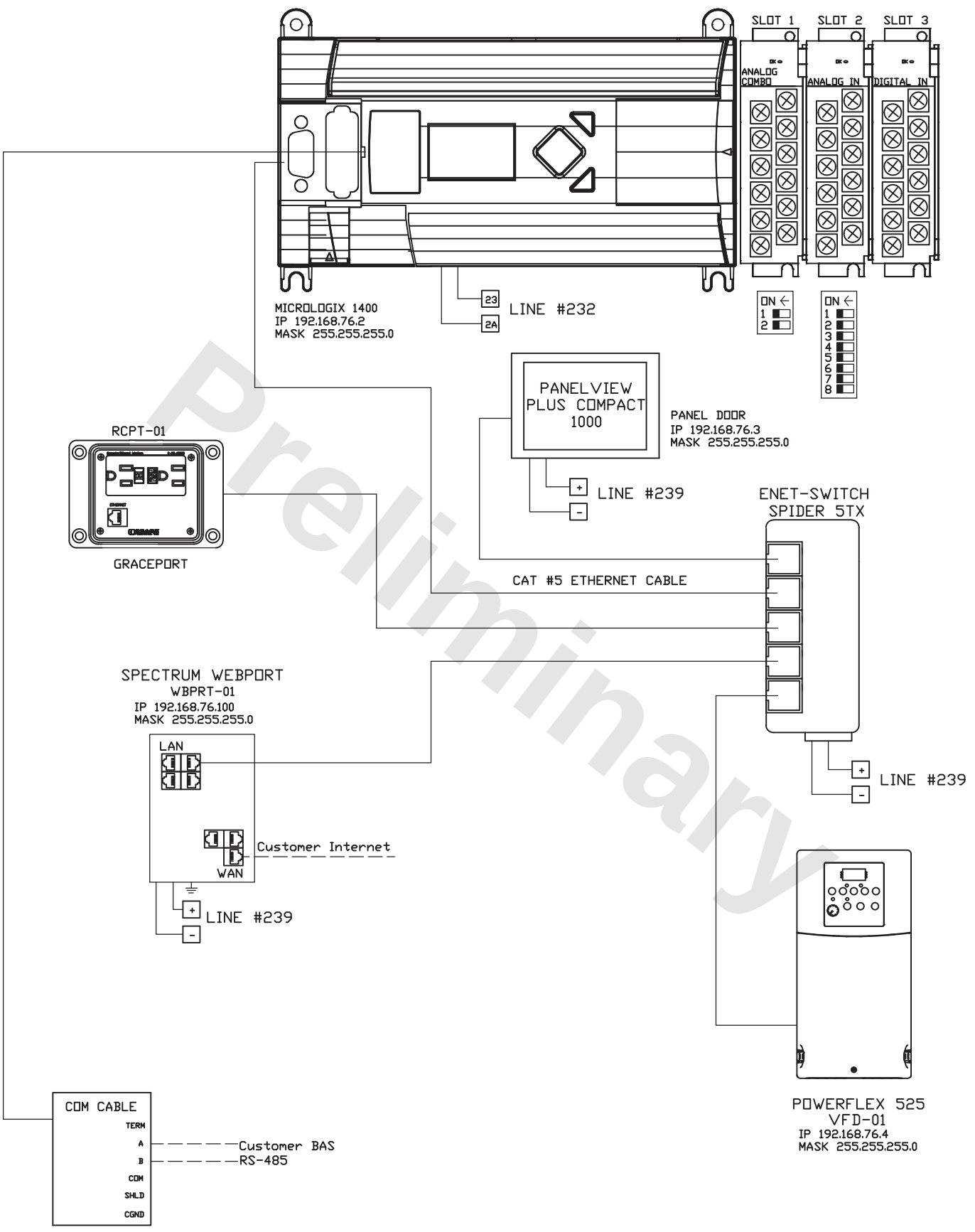


Preliminary

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REVISIONS		TITLE			
REV.	DESCRIPTION	BY	DIGITAL INPUT WIRING FOR 1762-IQ8		
			JOB	DATE 9/2/2014	ORDER NO.
			MAT'L NO.	DRWN BY JPM	SCALE
			CHKD BY	N.C. INFO.	
			PART NO.	S2WRSC1AB5Z-UA	
				REV. NO.	

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REVISIONS		TITLE			
REV.		ETHERNET WIRING BETWEEN COMPONENTS			
DESCRIPTION		JOB		DATE 9/2/2014	
		MATERIAL NO.		ORDER NO.	
		BY JPM		SCALE	
		CHKD BY		N.C. INFO.	
		PART NO.		REV. NO.	
		S2WRSC1AB5Z-UA			

901			MIN. WIRE REQ'D	REFERENCE 1		REFERENCE 2	
902	ID	DESCRIPTION		ENCL.	LINE #	ENCL.	LINE #
903	MAIN VOLTAGE, 3 PHASE CIRCUITS						
904	MFD-01	MAIN SOURCE POWER WITH GROUND	THHN	P1	101-103		
905	CB-01	MAIN SOURCE POWER WITH GROUND	THHN	P1	101-103		
906	MT-01	FAN MOTOR POWER	VFD CABLE	P1	108-110		
907	MT-02	SPRAY PUMP MOTOR 1	THHN	P1	119-121		
908	BH-01	BASIN HEATER 1	THHN	P1	126-128		
909	BH-02	BASIN HEATER 2 (IF REQUIRED)	THHN	P1	126-128		
910	120 VOLT CIRCUITS (INDIVIDUAL WIRES)						
911	9	FAN MOTOR SPACE HEATER	THHN	P1	203		
912	2	FAN MOTOR SPACE HEATER	THHN	P1	203		
913	21	MAKE-UP SOLENOID VALVE	THHN	P1	216		
914	2	MAKE-UP SOLENOID VALVE	THHN	P1	216		
915	22	DISCHARGE DAMPER ACTUATOR POWER (IF REQUIRED)	THHN	P1	218		
916	2	DISCHARGE DAMPER ACTUATOR POWER (IF REQUIRED)	THHN	P1	218		
917	20	ELECTRONIC WATER LEVEL CONTROLLER POWER	THHN	P1	220		
918	2	ELECTRONIC WATER LEVEL CONTROLLER POWER	THHN	P1	220		
919	24 VOLT CIRCUITS						
920	A	LOW WATER ALARM (ELECTRONIC WATER LEVEL)	THHN	P1	303		
921	B	LOW WATER ALARM (ELECTRONIC WATER LEVEL)	THHN	P1	303		
922	A	FAN VIBRATION SWITCH	THHN	P1	306		
923	C	FAN VIBRATION SWITCH	THHN	P1	306		
924	+	MAKE-UP LEVEL (ELECTRONIC WATER LEVEL CONTROLELR)	THHN	P1	412		
925	I06	MAKE-UP LEVEL (ELECTRONIC WATER LEVEL CONTROLELR)	THHN	P1	412		
926	+	HIGH WATER ALARM (ELECTRONIC WATER LEVEL)	THHN	P1	413		
927	I07	HIGH WATER ALARM (ELECTRONIC WATER LEVEL)	THHN	P1	413		
928	+	BAS ENABLE CONTACT (CUSTOMER OPTION)	THHN	P1	417		
929	I010	BAS ENABLE CONTACT (CUSTOMER OPTION)	THHN	P1	417		
930	+	BAS START/STOP SIGNAL (CUSTOMER OPTION)	THHN	P1	418		
931	I011	BAS START/STOP SIGNAL (CUSTOMER OPTION)	THHN	P1	418		
932	+	DISCHARGE DAMPER LIMIT SWITCH (IF REQUIRED)	THHN	P1	421		
933	I013	DISCHARGE DAMPER LIMIT SWITCH (IF REQUIRED)	THHN	P1	421		
934	+	MAKE-UP WATER METER (CUSTOMER OPTION)	THHN	P1	422		
935	I014	MAKE-UP WATER METER (CUSTOMER OPTION)	THHN	P1	422		
936	+	BLOWDOWN WATER METER (CUSTOMER OPTION)	THHN	P1	423		
937	I015	BLOWDOWN WATER METER (CUSTOMER OPTION)	THHN	P1	423		
938	+	SPRAY PUMP 1 FLOW SWITCH	THHN	P1	425		
939	I017	SPRAY PUMP 1 FLOW SWITCH	THHN	P1	425		
940	COMMUNICATION CABLES						
941	WBPRT-01	WEBPORT REMOTE VPN (CUSTOMER INTERNET CONNECTION)	CAT5	P1	830		
942	BAS	MODBUS COMMUNICATIONS, RS-485 (CUSTOMER OPTION)	2-WIRE	P1	840		

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			evapco							
			FIELD WIRING REFERENCE							
			REV. NO.							

1001			MIN. WIRE REQ'D	REFERENCE 1		REFERENCE 2	
1002	ID	DESCRIPTION		ENCL.	LINE #	ENCL.	LINE #
1003	SENSORS & OTHER						
1004	24	ALARM CONTACT (CUSTOMER OPTION)	THHN	P1	335		
1005	25	ALARM CONTACT (CUSTOMER OPTION)	THHN	P1	335		
1006	26	PULSE~PURE RUN CONTACT (IF REQUIRED)	THHN	P1	340		
1007	28	PULSE~PURE RUN CONTACT (IF REQUIRED)	THHN	P1	340		
1008	+	LEAVING WATER TEMPERATURE SENSOR	8760	P1	604		
1009	I10	LEAVING WATER TEMPERATURE SENSOR	8760	P1	605		
1010	+	ENTERING WATER TEMPERATURE SENSOR	8760	P1	604		
1011	I20	ENTERING WATER TEMPERATURE SENSOR	8760	P1	605		
1012	+	AMBIENT AIR TEMPERATURE SENSOR	8760	P1	607		
1013	I21	AMBIENT AIR TEMPERATURE SENSOR	8760	P1	608		
1014	+	BASIN WATER TEMPERATURE SENSOR	8760	P1	609		
1015	I22	BASIN WATER TEMPERATURE SENSOR	8760	P1	610		
1016	I23+	BAS TEMPERATURE SETPOINT (CUSTOMER OPTION)	8760	P1	613		
1017	I23-	BAS TEMPERATURE SETPOINT (CUSTOMER OPTION)	8760	P1	614		
1018	+	CONDUCTIVITY (CUSTOMER OPTION)	8760	P1	616		
1019	I24	CONDUCTIVITY (CUSTOMER OPTION)	8760	P1	617		
1020							
1021							
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REVISIONS			TITLE FIELD WIRING REFERENCE			
			JOB		DATE 9/2/2014	ORDER NO.
			MAT'L NO.		DRAWN BY JPM	SCALE
			CHKD BY		N.C. INFO.	
			evapco		PART NO. S2WRSC1AB5Z-UA	
	REV.	DESCRIPTION	BY	REV. NO.		

1101 RECOMMENDED WIRING PRACTICES

1102

1103 ● ALL WIRING MUST BE IN COMPLIANCE WITH NEC AND LOCAL CODES.

1104

1105 ● THE PANEL DOOR MUST BE CLEAR OF OBSTRUCTIONS AND THE PANEL VENTILATION SYSTEM MUST HAVE A
1106 MINIMUM OF 18 INCHES OF CLEARANCE.

1107

1108 ● CONDUIT ENTRANCES MUST ONLY BE THROUGH THE BOTTOM OF THE CONTROL PANEL.

1109

1110 ● THE CONTROL PANEL MUST BE LOCATED AS CLOSE TO THE UNIT AS POSSIBLE TO ELIMINATE VOLTAGE DROP
1111 AND STANDING WAVES BETWEEN THE VFD AND FAN MOTOR.

1112

1113 ● ALL WIRING MUST HAVE THE SAME GROUND REFERENCE.

1114

1115 ● TRIMMED INSULATION AT WIRE TERMINALS MUST HAVE NO EXPOSED SECTIONS OF BARE WIRE SHOWING.

1116

1117 ● ALL WIRE CONNECTION POINTS MUST BE TORQUED TO THE MANUFACTURER'S SPECIFICATIONS.

1118

1119 ● THE VFD CABLE MUST BE BELDEN VFD CABLE 295XX (XX DENOTES GAUGE) OR EQUIVALENT THAT HAS THE
1120 SHIELD GROUNDED AT BOTH THE MOTOR AND THE VFD.

1121

1122 ● MOTOR LEADS MUST BE CONNECTED ONLY USING APPROVED MECHANICAL FASTENERS.

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1124 ● LINES LESS THAN 50 VOLTS MUST BE SEPARATED FROM HIGH VOLTAGE LINES BY 6 INCHES OR MORE.

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1126 ● SIGNAL OR DATA LINES MUST CROSS POWER CONDUCTORS AT A RIGHT ANGLE TO AVOID ELECTRICAL NOISE
1127 INTERFERENCE.

1128

1129 ● ANALOG AND SIGNAL WIRES (IE, 4-20 MA) MUST BE SHIELDED INDIVIDUALLY AND ONLY GROUNDED ON THE
1130 PANEL SIDE.

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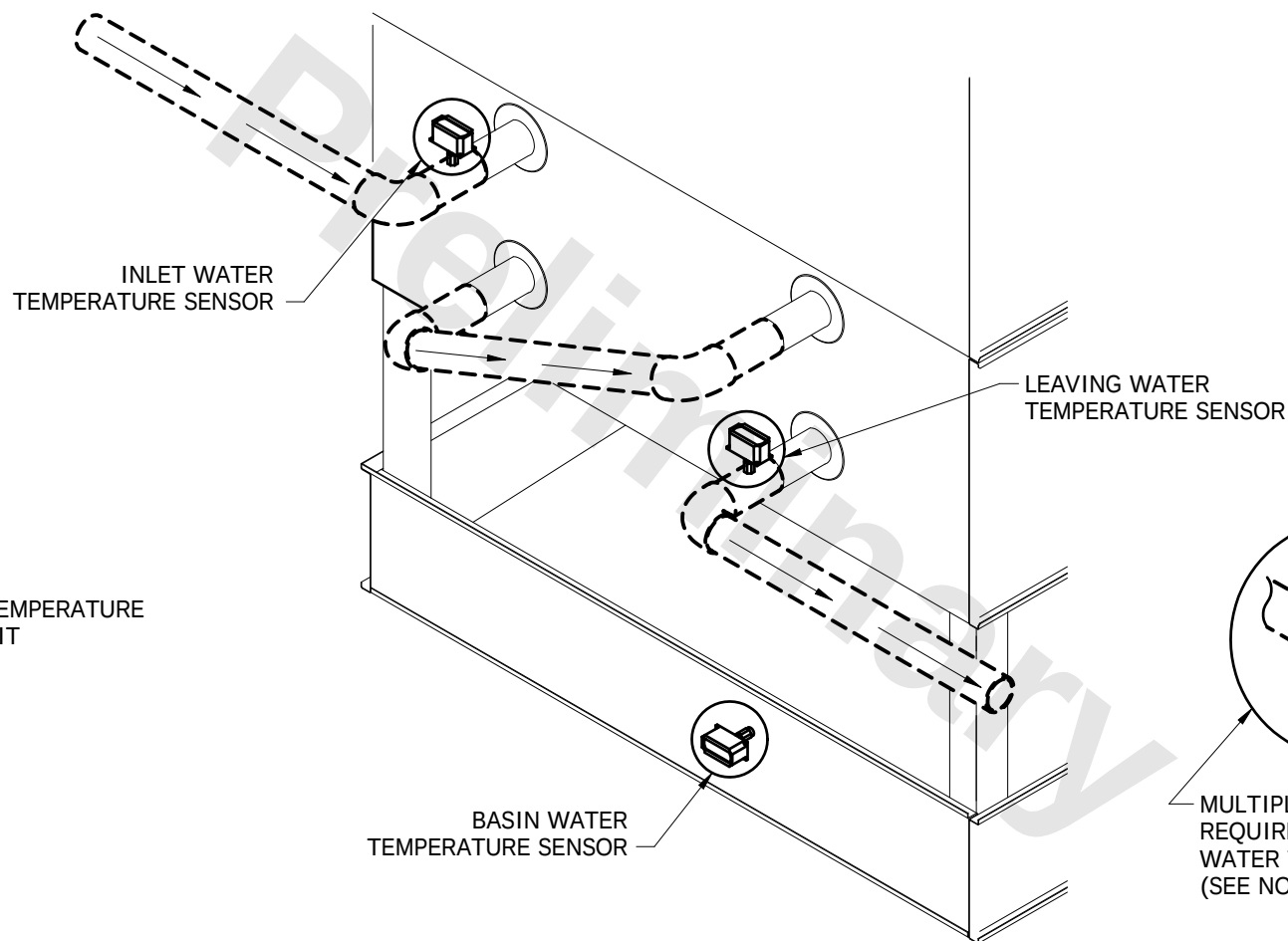
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REVISIONS			TITLE RECOMMENDED WIRING PRACTICES	
	REV.	DESCRIPTION	JOB	DATE 9/2/2014
			MAT'L NO.	SCALE
			CHKD BY	N.C. INFO.
				PART NO. S2WRSC1AB5Z-UA
			BY	REV. NO.



**PER
CELL**

NOTES:

1. AMBIENT AIR TEMPERATURE SENSORS MUST BE MOUNTED TO AVOID DIRECT SUNLIGHT.
2. AMBIENT AIR TEMPERATURE SENSOR PLACEMENT MUST BE IN CLOSE PROXIMITY TO THE AIR ENTERING THE UNIT.
3. QUANTITIES OF WATER TEMPERATURE SENSORS ARE SHOWN PER UNIT/CELL.
4. MULTIPLE UNITS/CELLS WITH A COMMON LEAVING WATER HEADER REQUIRE AN ADDITIONAL SENSOR LOCATED AFTER COIL FLOW HAS BEEN MIXED.
5. SENSOR PLACEMENT SUBJECT TO CHANGE PER JOB LAYOUT.
6. FOR ACTUAL SENSOR QUANTITY, PLEASE REFER TO DETAILED WIRING DIAGRAM.
7. ALL SENSORS MUST BE FIELD INSTALLED AND WIRED BY OTHERS.

Sage Heater Location Placeholder

This is a custom engineering drawing.

eco-ATWB-H 9-3K9-Z-U12

5/12/2017

Preliminary



Sound Pressure Levels (SPL) in dB RE 0.0002 Microbar
Sound Power Levels (PWL) in dB RE 10-12 Watt

MODEL eco-ATWB-H 9-3K9-Z-U12
MOTOR 20.00 HP
MOTORS 1
SPEED: Full Speed

1 CELL DATA

BAND	SOUND PRESSURE LEVEL (dB)										SOUND POWER LEVEL (dB)	
	End		Motor Side		Opp End		Opp Mtr. Side		Top			
	5 ft (1.5m)	50 ft (15.2m)	5 ft (1.5m)	50 ft (15.2m)	5 ft (1.5m)	50 ft (15.2m)	5 ft (1.5m)	50 ft (15.2m)	5 ft (1.5m)	50 ft (15.2m)		
63 HZ	79	71	79	72	79	71	79	71	80	71		103
125 HZ	81	70	82	71	81	70	81	70	87	70		102
250 HZ	81	70	82	72	81	70	81	70	87	74		103
500 HZ	76	61	77	63	76	61	76	61	80	70		97
1 KHZ	70	56	72	58	70	56	70	57	76	61		90
2 KHZ	67	51	69	53	67	51	67	53	73	59		87
4 KHZ	68	48	69	51	68	48	68	50	72	57		85
8 KHZ	69	47	70	48	69	47	69	48	69	55		82
CALC dBA	79	65	80	66	79	65	79	65	83	71		99

Sound option(s) selected: None

- REMARKS:
1. Sound Pressure Levels are according to CTI Standard ATC-128
 2. Sound Power Levels are calculated according to the Small Units Section 8
 3. Sound from free-field conditions over a reflecting plane with +/-2 db(A) tolerance
 4. Noise levels can increase with variable frequency drives depending on the drive manufacturer and the drive configuration
 5. Complete unit sound data with all fans operating