A Specifications Guide for Performance Monitoring Systems

ABSTRACT

This product is a specification guide for performance monitoring systems that was developed as part of jointly funded CEC PIER-DOE project intended to assist commercial and institutional building owners in specifying what is required to obtain the information necessary to initiate and sustain an ongoing commissioning activity. The project goal was to facilitate the delivery of specific performance related information to the benefit of both commissioning providers and building owners and operators. A number of large building owners were engaged in order to help create 'market pull' for performance monitoring while producing a specification that met their needs.

The guide discusses the benefits of performance monitoring, identifies key performance metrics and how measurement accuracy requirements relate to the performance metrics that are used in both troubleshooting and routine reporting. An array of examples and resources are provided where applicable. The example specifications provided address the four key aspects of performance monitoring:

- performance metrics
- measurement system requirements
- data acquisition and archiving
- data visualization and reporting

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FOREWORD

Those who evaluate the performance of buildings and their energy using systems have long known that it takes the attention of a knowledgeable and dedicated team, which may include a measurement analyst, instrumentation vendors, an installation contractor and owner's staff, to obtain the quality of data necessary to determine how well a building is actually performing as well as identify means for improving it. The problem is that buildings are not designed for measuring their performance. This is particularly true of flow. It is also believed that obtaining such data is a luxury; that it is not needed for system control or day to day operations.

But, as systems become inherently more complex with the advance of technology, and energy costs continue to rise, owners require better information to benchmark the performance of their buildings and energy using systems and to troubleshoot problems. This is complicated by the fact that few specifying engineers and installation contractors are trained to understand good measurement practice, thus driving costs up when they are specified. It is hoped that building a case for such systems, whether they are applied as part of the direct digital control system or an energy information system, and providing some insight into best practices will promote their use, help educate the user and drive costs down.

One application of this idea is the monitoring based retro-commissioning program that has been implemented by California's investor owned utilities in the University of California and California State University campus systems with funding by the California Public Utilities Commission. It is believed that the installation of permanent instrumentation in conjunction with a disciplined retro-commissioning activity will lead to sustainable energy savings.

Another is the U.S. Green Building Council's Leadership in Energy & Environmental Design (LEED) green building rating system. LEED-EB offers 2 credits for Water Efficiency for monitoring various types of water usage, 3 credits under Energy and Atmosphere for performance monitoring of specific equipment, systems and controls, 4 credits under Indoor Environmental Quality for demonstrating certain IAQ criteria are met, and up to 4 credits under Innovation in Upgrades, Operations and Maintenance that use performance metrics to help demonstrate environmental benefit.

The performance metrics listed in this guide are primarily focused on energy end uses at the whole building and system level. Some metrics are included that can be used to keep track of comfort and IAQ requirements.

ORGANIZATION OF THIS DOCUMENT

The front material contained in this document presents an overview of performance monitoring; recommendations for different levels, or classes, of performance monitoring; and general issues to consider when specifying the requirements for your performance monitoring system.

Overview: What is a performance monitoring system? What are its overall requirements? What are some of its benefits?

Recommended Requirements for Three Classes of Performance Monitoring: Not all buildings will require the same level of monitoring. This section makes recommendations for three classes of monitoring: basic, intermediate, and advanced. These recommendations are a starting point for identifying the requirements for your performance monitoring system.

General Issues to Consider: Several issues must be considered from the outset of planning a performance monitoring system specification including: scope, implementation approach, system rigor, data visualization, commissioning, and training.

The remainder of the document is divided into appendixes that deal with the details of specifying a performance monitoring system that meets your needs.

A. Glossary: A glossary of technical terms used throughout this document.

B. System Performance Capabilities and Functional Requirements: An outline of recommended performance monitoring system capabilities and functional requirements. Most of these capabilities and functional requirements apply to both DDC based systems and those that might be included in or managed by an EIS product.

C. Performance Metrics by Class: Detailed specifications for performance metrics from the whole-building level down to the equipment component level. Each performance metric is defined along with the data points that are necessary for calculating and reporting the metric. This list of performance metrics is categorized under the three classes of performance monitoring: basic, intermediate, and advanced.

D. Example Basic Level General Specifications: A complete example specification for a performance monitoring system based on Class 1 (Basic) requirements. This example can serve as a starting point for developing performance monitoring system specifications for new construction or a control system upgrade. These specifications can be used standalone, integrated into a traditional control system specification, or as an add-on option. Sections of this example include: performance monitoring system description; instrumentation and data acquisition requirements; details of sensors, meters, and calculated values; data point naming convention; required trends; data archival and retrieval requirements; graphic display requirements; commissioning quality assurance tasks; training requirements; and submittal requirements.

E. Options and Add Alternates to Consider: Some options to consider in specifying performance monitoring system requirements.

F. Other Measurements, Metrics and XY Plots to Consider: Some metric and graphics options to consider in specifying performance monitoring system requirements.

G. Example Basic Level Specification Language Based on ASHRAE Guideline 13-2000: Specifying Direct Digital Controls Systems: Example basic level performance monitoring specification language for use in DDC system application that replaces or adds to example

specifications found in ASHRAE Guideline 13-2000: Specifying Direct Digital Controls Systems.

H. Example Graphic and Data Displays: A more concise description of data visualization capabilities than that given as part of Appendix D.

I. Example Point Naming Conventions: A more complete description of a recommended point naming convention than that given as part of Appendix D.

J. Demonstration Site Case Studies

K. Trend Data Extraction Tool Using XML: A batch method for acquiring trend data from direct digital control systems using XML.

L. VizTool: An open-source developmental software toolkit for acquiring and visualizing performance monitored data.

ASSUMPTIONS AND NOTES

1. Floor area is net usable or net rentable space not gross area.
2. This document does not provide a definitive list of points that might be needed for control or other special requirements such as modeling equipment operation. It includes only those points that are required to implement a specific metric. It should be noted that a point might serve multiple requirements.
3. Embedded editor's notes for the user are in *italics* in brackets [].

OVERVIEW

What is a performance monitoring system?

The primary purpose of the performance monitoring system is to provide facility managers and operators with the means to easily assess the current and historical performance of the building/facility as a whole, and its significant energy consuming systems and components. The performance monitoring system includes not only the needed sensors, wiring and data acquisition devices, but also the means to calculate, display and archive resultant parameters. The monitoring system can be contained within a direct digital control (DDC) system or as a separate stand-alone energy information system (EIS), or as a combination of the two. Any of these options offers a viable platform for implementing a performance monitoring system that can provide facility managers and operators with the means to easily assess the current and historical performance of the building/facility as a whole, and its significant energy consuming systems and components. The system can be installed as part of a new construction project or as part of a DDC system installation or upgrade project in an existing building.

What is required?

Increased number of monitoring points. Performance monitoring requires installation and programming of additional monitoring points, including measured, virtual and calculated values, beyond those required for control. Whole building energy, equipment power, air and water flow, and local weather are among the measurements required. By themselves these measurements provide valuable insight into how a building, system, or piece of equipment is operating. But, when combined together in a specific calculated value known as a performance metric, they provide building staff the means to track building and system performance over time and to identify and diagnose problems by comparing measured performance with expected values or benchmarks. These monitoring points and performance metrics need unique identifiers in order to be able to be compared across a system, building or campus. To be of optimum use to building managers and operators, the performance monitoring system should also provide benchmarks that define the range of expected performance for each performance metric.

Improved sensors and through system accuracy. Anytime one needs to compare calculated values over time or with similar values from other buildings, systems or equipment, they should be concerned about the quality or certainty of the measurements. The quality of any measurement is determined by the attributes of the sensor, any signal conditioning if present, the data acquisition system infrastructure including analog-to-digital converters and the connecting wiring, any calibration corrections that are applied, installation technique, and field conditions. Accuracy, repeatability, linearity, drift or stability over time, dynamic or rate of response, range, turn-down, sample or scan rate, resolution, signal-to-noise ratio, engineering unit conversion and math functionality, data storage and retrieval frequency, are all terms used to describe the quality of the measurement system and its components.

The level of measurement rigor required in this specification is intended to provide sufficient data quality over time for identifying / establishing the specified performance metrics and benchmarks.

Enhanced data management and graphical data display capabilities. In order to visualize both current and historical data that may extend over years, in a seamless fashion, a more robust data management system is required as well as improved data visualization techniques.

Recommended capabilities include:

- Unique point names
- Animation and hot links
- Defined data tables
- Trend plots with multiple X and Y axes scales
- Group trend plots
- Multiple group trend plots on single screen
- Special plot types: X-Y, carpet, load frequency distribution

Appendix B provides a detailed list of system functionality and capabilities that should be considered when specifying a performance monitoring system.

Benefits of a Performance Monitoring System

Monitoring main electricity and natural gas meter(s) enable building staff to track building electricity and natural gas use by time of day, facilitating management of peak loads and identification of unnecessary equipment operation during unoccupied periods. It also enables monitoring of power quality supplied to the building and power factor of building load.

Monitoring chilled water plant equipment power meter data enables building staff to track and manage chiller contributions to peak load and monitor chiller health.

Monitoring building chilled water flow meter and chilled water and supply and return temperature data along with plant power enables the monitoring system to calculate the actual heating and cooling delivered by plant chillers. This information is important for a number of reasons. It is used to track and manage growth in chiller capacity requirements that can impact occupant comfort and aids in the detection of anomalous loads that increase operating costs. These measurements enable the tracking of chiller plant efficiencies, which allows the identification of more efficient operating strategies. It also enables the detection of degradations in performance that indicate the need for maintenance in order to minimize operating costs and maximize equipment life.

Use of a high quality weather station provides reliable measurement of outside air temperature supporting the most effective use of free cooling, minimizing chiller use. Reliable measurement of outside wet bulb temperature enables proper cooling tower operation and maximizes chilled water plant efficiency.

Advanced data calculations and data displays provide operators with effective, standardized ways of viewing the performance of the building and the HVAC system, including comfort. Careful grouping of trend plots and strategic use of various plot types puts all the information required to monitor, and if necessary troubleshoot, each different part of the HVAC system on a single screen. This make it easier to spot and diagnose faults before they become problems,

reducing hot and cold calls and O&M costs, and making it easier to operate the building, freeing up stationary engineers to meet other tenant needs.

RECOMMENDED REQUIREMENTS FOR THREE CLASSES OF PERFORMANCE MONITORING

The most significant driver for selecting appropriate performance metrics is energy use and the key parameters needed to identify opportunities available to improve performance. LEED-EB (Existing Buildings) has simplified this for the user by identifying key points to measure. LEED-NC (New Construction) and ESCO type projects, if they include measurement and verification of the expected energy savings, require specific measurements to be taken in order calculate performance over time. Related metrics are then employed in order to track and sustain performance. The key is to start simple and move toward more advanced performance evaluations as confidence in obtaining value from the effort is achieved.

To help the specifications user, Table 1 lists recommended performance monitoring requirements for three levels, or classes, of performance monitoring based on building type and user needs: basic, intermediate and advanced.

- Basic: typically applied to a single building that may have built up systems including air handlers, boilers and a chilled water plant; owner desires essential monitoring requirements
- Intermediate: typically applied to conventional buildings with built up systems which include air handlers, boilers and a chilled water plant; owner desires progressive monitoring requirements
- Advanced: typically applied to exotic buildings, campuses or critical facilities with special requirements, which have complex systems such as co-generation or self-generation; owner desires sophisticated monitoring requirements.

The metrics listed in Table 1 are detailed in Appendix C. The owner or his/her representative should reconfigure this list and resulting specification as needed to meet specific owner project requirements.

Table 1 – Recommended Performance Monitoring Requirements

Requirement	Class 1 - Basic	Class 2 - Intermediate	Class 3 – Advanced Diagnostics
Data Displays			
Equipment/ System Graphic	Floor plan with zone temperatures; system graphic with performance data; equipment graphic	Add performance data to equipment graphic	
Data Tables	Building air handler summary table, metrics results table	Expand building air handler summary table, add floor zone table, expand metrics results table to include additional metrics	Expand metric results table to include additional metrics
Time Series Group Trend Plots	System performance plots	Add equipment performance plots	Add system and equipment diagnostic plots
XY Group Trend Plots	1. ChW Plant Delta-T, ChW Plant tons vs. OA Temp 2. ChW Plant kW vs. ChW Plant tons 3. ChW Plant kW/ton vs. OA Temp, OA Wb Temp, ChW Plant tons 4. HVAC Power vs. OA Temp, OA Wb Temp, ChW Plant tons 5. Total NaGas Flow vs. OA Temp 6. OA Temp Fraction vs. OA Damper Fraction 7. Whole Bldg Electric EUI; Whole Bldg HVAC electric only EUI; Whole Bldg NaGas EUI , Whole Bldg Water EUI vs. Avg. Daily OA Temp	Add X-Y plots: 1. Chiller # kW/ton vs. Condenser EW Temp, Chiller # tons 2. Chiller # kW vs. # Chiller tons 3. ChW Plant Delta-T, ChW Plant tons vs. OA Temp-ChW On 4. Whole Bldg HVAC Electric only EUI, Total Boiler NaGas EUI, Whole Bldg Lighting EUI, Whole Bldg Plug EUI vs. Avg Daily OA Temp	Add X-Y plot diagnostics: 1. Avg Daily ChW Supply Temp, Daily ChW Plant Eff, Daily Total ChW Plant Electric Usage vs. Avg Daily OA Temp-ChW On 2. Avg Daily Boiler Eff , Daily Total Blr Heating System kBtus, Daily Total HVAC NaGas Usage (cu. ft.), Daily Total HVAC NaGas Energy (kBtus) vs. Avg Daily OA Temp-HoW On 3. Daily Total Air Handler Volume, Avg Daily Air Handler Eff, Daily Total Air Handler Electric Usage vs. Avg Daily OA Temp-AH On 4.Avg Daily Building Power vs. Avg Daily OA Temp 5. Whole Building Daily HVAC EUI vs. Avg Daily OA Temp, Avg Daily OA Temp-AH On 6. Avg. Bldg AH VFD Freq, Avg. Bldg Duct Static Pressure vs. OA Temp-AH On
Points			
Measured	(S1) Outside Air Temp; (S2) Outside Air Wb-Temp; (S5) Main Natural Gas Flow; (S7) Main Power;	Add: (S3) Air Handler or RTU # Duct Static Pres; (S42) Air Handler or RTU #	Add: (S8) RTU # NaGas Flow; (S30) HVAC Heater # NaGas Flow

	(S39) Main Water Flow; (S12) Chiller # Power; (S13-S16) Other ChW plant equipment power; (S20) Plant ChW (loop #) ChWS Temp; (S21) Plant ChW (loop #) ChWR Temp; (S22) Plant ChW (loop #) Flow (gpm); (S26) Air handler # SA Flow (cfm); (S33) Air handler # SF Power; (S34) Air handler # RF Power; (S35) Air handler # MA Temp; (S36) Air handler # RA Temp; (S37) Air handler # SA Temp; (S44) Air Handler # SF Status; (S9) Zone temperatures Add if dual duct: (S45) Air Handler # SA-Ho Temp	Terminal Unit # SA Flow; (S43) Air Handler or RTU # SA Temp; (S4) RTU # Power; (S6) Other HVAC equipment power; (S10) Plug Circuit # Power; (S11) Lighting Circuit # Power; (S17) Chiller # ChWS Temp; (S18) Chiller # ChWR Temp; (S19) Chiller # ChW Flow (gpm); (S23) Boiler # HoWS Temp; (S24) Boiler # HoWR Temp; (S25) Boiler # HoW Flow (gpm); (S32) Boiler # NaGas Flow; (S27) Air Handler # SF VFD Freq (Hz); (S39) Plant CondW (loop #) S Temp; (S40) Plant CondW (loop #) R Temp; (S41) Plant CondW (loop #) Flow (gpm) (S48) Air Handler # OA Flow (cfm) Add if dual duct: (S46) Air Handler # SA-Ho Static Pres; (S47) Air Handler # SA-Ho Flow	
Virtual	(V1) Air Handler # Outside Air Damper %; (V2) Air Handler # Return Damper %; (V3) Air Handler # ChW Valve %; (V4) Air Handler # SF Mode; (V5) Air Handler # SA TempSp Add if pre-heat or dual duct: (V6) Air Handler # SA-Ho TempSp; (V7) Air Handler # HoW Valve %	(V8) Chiller # ChWS TempSp (V9) Air Handler # Duct Static PresSp, (V10) Air Handler # VFD SpeedSp; (V11) Terminal Unit # Clg TempSp; (V12) Terminal Unit # Htg TempSp; (V13) Terminal Unit # Clg PID%; (V14) Terminal Unit # Htg PID% Add if dual duct: (V15) Air Handler # SA-Ho Static PresSp	
Calculated – Whole Building	(M8) Avg Daily OA Temp; (M1) Whole Bldg Max Power; (M4) Whole Bldg Electric	Add: (M3) Avg Bldg Duct Static Pressure;	Add: (M29) Avg Daily OA Temp-ChW On;

	EUI; (M6) Whole Bldg NaGas EUI; (M70) Whole Bldg Water EUI	(M2) Total HVAC Electric Power; (M9) Whole Bldg Lighting Power; (M11) Whole Bldg Plug Power; (M7) Whole Bldg HVAC Electric-only EUI; (M10) Whole Bldg Lighting EUI; (M12) Whole Bldg Plug EUI	(M30) Avg Daily OA Temp-HoW On; (M31) Avg Daily OA Temp-AH On; (M32) Avg Daily Building Power (kW) (M65) Total HVAC Natural Gas EUI; (M71) Total HVAC Demand; (M72) Whole Bldg HVAC EUI
Calculated – Chilled Water	(M15) ChW Plant (loop #) Delta-T; (M16) ChW Plant Power; (M17) ChW Loop # tons; (M67) Total ChW Plant tons; (M18) ChW Plant Efficiency (kW/ton)	Add: (M13) Chiller # tons; (M14) Chiller Efficiency (kW/ton); (M34) Plant CondW Loop # tons (M66) Total Chiller Power; (M68) Total ChW Plant Heat of Rejection (tons); (M69) ChW Plant Heat Balance	Add: (M33) Avg Daily ChW Supply Temp; (M37) Daily Total ChW Plant Electric Usage; (M38) Daily ChW Plant Energy; (M39) Max Daily ChW Plant Energy; (M41) Avg Daily ChW Plant Efficiency
Calculated Natural Gas Equipment	(M5) WB NaGas Heatrate (Therms/min)	Add: (M19) Boiler # Output (Btu/hr); (M56) Boiler # Efficiency (COP); (M21) Total Boiler NaGas Flow; (M57) Total Boiler NaGas EUI; (M20) Total Boiler Output; (M22) Total Boiler Efficiency (COP)	Add: (M48) Avg Daily Boiler Efficiency (M58) Total RTU NaGas Flow; (M59) Total HVAC Unit NaGas Flow; (M60) Total HVAC NaGas Flow; (M73) Daily Total HVAC NaGas Usage; (M74) Daily Total HVAC NaGas Energy; (M75) Max Daily HVAC NaGas Energy
Calculated – Supply Air	(M26) Total Air Handler Power; (M27) Total Air Handler Flow; (M28) Air Handling System Specific Power (kW/cfm); (M63) Air Handler # Outside Air Temp Fraction (M64) Air Handler # Outside Air Damper Fraction	Add: (M23) Inst Avg Bldg AH SF VFD Freq (M24) Air Handler # Total Power (M25) Air Handler # Specific Power (kW/cfm); (M76) Air Handler # Outside Air Flow Fraction	Add: (M52) Daily Total Air Handler Electric Usage; (M53) Daily Total Air Handler Volume; (M54) Max Daily Air Handler Volume; (M55) Avg Daily Air Handler Specific Power (kW/cfm)
Database Software	Upgraded Database	Upgraded Database	Time Series Database
Assumptions	Measurement of HVAC system equipment power is easily accomplished; System is capable of calculating time based metrics and displaying X-Y plots.		

Key	# in point name indicates possibility for more than one measurement of this type (M##) indicates a calculated point; see Appendix C for a complete description

GENERAL ISSUES TO CONSIDER

Project Scope

If an owner desires to include performance monitoring as part of their project requirements, the specification will need to define the functional capability that is desired. This would include the necessary monitoring points and performance metrics; required through system accuracy; and enhanced data management and graphical data displays. Detailed example specifications can be found in Appendix D and Appendix G.

Approaches – DDC upgrade vs. EIS

Though direct digital control (DDC) systems are not true data acquisition systems, they provide a reasonable platform for acquiring the required data, calculating and displaying the resultant metrics, and storing all data in a robust database. Special consideration should be given to performance monitoring applications, due to the additional bandwidth required to gather one-minute data on all points. Access to historical data is limited to the size of memory and database type. Their most limiting factor is that most manufacturers do not provide the ability to display X-Y type plots.

Energy Information Systems (EIS) on the other hand are 3rd party systems that use the latest database technologies to scavenge data from a variety of data sources including the DDC system, and store it in a database separate from the DDC system.

System Rigor: Accuracy of the Measurement, Network Architecture, Sampling, and Data Recording, Archiving and Storage

The quality of any measurement is determined by the attributes of the sensor, any signal conditioning if present, the data acquisition system and the connecting wiring, any calibration corrections that are applied, sensor installation and field conditions. Specifying higher quality sensors may be required when implementing a performance monitoring system in order to obtain desired accuracy and repeatability of measured and calculated performance metric indices. Sensor accuracy is also dependent upon proper sensor placement.

Accuracy, repeatability, linearity, drift or stability over time, dynamic or rate of response, range, turn-down, sample or scan rate, resolution, signal-to-noise ratio, engineering unit conversion and math functionality, data storage and retrieval frequency are all terms used to describe the quality of the measurement system and its components. Performance monitoring applications require that the system be capable of performing a variety of math functions and calculations on an interval basis. Special consideration should be given to the network architecture of performance monitoring applications, due to the additional bandwidth required to gather one-minute data on all points.

The level of measurement rigor suggested in this guide specification is intended to provide sufficient data quality over time for identifying / establishing the specified performance metrics and benchmarks. Through-system measurement accuracy goals for individual measurement points and metrics are provided in Table 2. Individual instrumentation requirements are suggested in the instrumentation subsection of the example specifications in

order to meet these goals. A detailed list of performance monitoring system capabilities and functional requirements is provided in Appendix B.

Table 2 – Through-System Measurement Accuracy Goals.

Measurement Point or Metric	Accuracy Goal
Outside air temperature (ºF)	0.2ºF
Outside air wet bulb temperature (ºF)	0.2ºF
Zone temperature (ºF)	0.5°F
HVAC electric only energy use (kWh)	1.5% of reading
Water temperatures (ºF)	0.1ºF, if ≥ 5ºF delta T
Water delta temperature (ºF)	2% of reading
Water flow (gpm)	2% of reading, > 20-1 turndown
Natural gas flow (scfm)	2% of reading, > 10-1 turndown, w/ pressure and temperature compensation; Using an average heat content of the gas to convert to kBtu introduces a ~2% error
Air flow (cfm)	5% of reading down to 150 ft/min, > 10-1 turndown
Power (kW)	2% of reading
Chiller cooling output (tons)	3% of reading
Chiller cooling energy (ton-hrs)	3% of reading
Boiler heating output (kBtu/hr)	3% of reading
Boiler heating energy (kBtu)	3% of reading
Electric energy use (kWh)	2% of reading
Total HVAC energy use (kWh) (includes air side, water side and natural gas)	3% of reading
Chiller performance (kW/ton)	4% of reading
ChW Plant performance (kW/ton)	4% of reading
Total boiler performance ($kBtu_o/kBtu_i$) (COP)	4% of reading
Total air handler performance (kW/cfm)	6% of reading
Net Usable Building floor area	2%

Data Visualization and Graphical Data Displays

The data visualization requirements of performance monitoring systems take the graphical data display capabilities of the typical DDC system to another level. Much of the functionality required to acquire and display data has been there for some time, but has rarely been used to its fullest extent. Graphical data displays are valuable tools for presenting building performance results to the user. They are invaluable when used for commissioning HVAC systems and diagnosing problems. Data display types include campus, building, floor-plan, system and equipment graphic screens, logic block program sequence screens, time-weighted point screens, tabular multi-point data screens, time-series point trend plots, time-series group trend plots and X-Y group trend plots. Not all DDC system manufacturers provide the capability to do X-Y plots. Example data displays are provided in Appendix H.

Need for Point Naming Convention

As the shear number of points that can be made available to the user has climbed, DDC manufacturers and installing contractors have searched for ways to simplify the set-up

graphics and sequences. This is particularly true where a significant number of similar unit types are present, such as air-handler or VAV terminal box controls in a large building or campus. The temptation is to name each similar point the same and allow the page header to define the equipment. But, unless the header information is carried throughout the programming, the ability to compare similar points in data displays for commissioning and diagnostic purposes is thwarted. It is possible to not require unique point naming in systems that employ high-end database structures, or use XML, to map from one database to another (such as in EIS products), but these are not common.

Until standard open system tools such as the BACnet Web Services standard provide a proven capability to compare similar points, it is highly recommend for those users who intend to employ their DDC system for performance monitoring to specify a point naming convention. This unique name should be required in all cases of its use: drawings, graphics, sequences, alarms, etc. This is an excellent training aid that will reinforce to the user the relevance of each point and where it physically exists. An example point naming convention, which includes specific point names and block trends, is provided in Appendix I.

Commissioning

Performance monitoring applications have an increased level of programming that will require additional checks and tests including point set-up and graphical data displays. Sensor and performance metric through system accuracy will need to be verified. This is one of the more difficult aspects of this effort. Data throughput and archive integrity should also be tested.

Training

It is very important that the building superintendent, facility management staff and the current HVAC maintenance contractor and tenants, if necessary, be trained in accessing DDC HVAC control system information, making adjustments to setpoints and schedules, responding to and adjusting alarms, adding new trends as needed and diagnosing minor system upsets using trend reports. When a performance monitoring system is added, a more thorough review of why the system was installed and how to use and maintain it needs to be included in the training curricula. Particular attention should be given to utilizing the data, instrumentation and database maintenance, and adding new points, trends, trend groups and X-Y plots.

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Glenn	Friedman	Taylor Engineering
Jeff	Haberl	Texas A&M
Adam	Hinge	Sustainable Energy Partnerships
David	Jump	QuEST
Mark	Levi	GSA
Mike	MacDonald	ORNL
Erin	McConahey	Arup Partners
Larry	Morgan	Oracle
Lance	Muller	California DGS
Tony	Springman	Target Corp.
Adrienne	Thomle	Honeywell
Steve	Tom	Automated Logic Corp.
Tom	Webster	UC Berkeley
Scott	Williams	Target Corp.

APPENDIX A: GLOSSARY

accuracy: an indication of how close some value is to the true value of the quantity in question. The term could also be used in reference to a model, or a set of measured data or to describe a measuring instrument's capability.

error: deviation of measurements from the true value.

refresh rate: the interval of time between display updates.

repeatability: the indication of the closeness of agreement among repeated measurements of the same physical quantity under the same conditions.

resolution: the smallest indicated increment in the value of a measured quantity that can be measured and reported by a recording instrument.

scan rate: an indication of how fast a recording instrument proceeds from measurement to measurement within a given sample interval.

sample interval: an indication of how often all data points can be acquired and placed in memory to be displayed or added to a trend file before the process is repeated.

throughput rate: the maximum rate the entire data acquisition system can accept, process and transfer data.

uncertainty: the range or interval of doubt surrounding a measured or calculated value within which the true value is expected to fall within some degree of confidence.

value –

instantaneous measured value: a single data sample that has been measured within 1 minute of its first data display, report or archival in memory.

average concurrent value: the average of a group of samples, whose individual values have been measured within 1 minute of the time the average was calculated.

APPENDIX B: SYSTEM PERFORMANCE CAPABILITIES AND FUNCTIONAL REQUIREMENTS

The following outline provides a list of recommended performance monitoring system capabilities and functional requirements. Most apply to both DDC based systems and those that are included in or managed by an EIS product.

1. Data types/sources
    a. Analog inputs
    b. Digital/binary inputs
    c. Calculated values
    d. Via computer bus, gateway or interface

2. Selectable engineering units (IP or SI)
    a. none (blank)
    b. %
    c. Volts (voltage)
    d. Amps (current)
    e. kW (power)
    f. pf (power factor)
    g. Hz (frequency)
    h. rpm (angular velocity)
    i. °F or °C (temperature)
    j. in.w.c., psig or psia, or Pa (pressure)
    k. kft^3 or m^3 (volume)
    l. ft/min or m/s (linear velocity)
    m. gpm or L/s (liquid flow rate)
    n. cfm, scfm or L/s (air flow rate)
    o. kWh, kBtu or ton-hr (energy use)
    p. kBtu/hr, tons or kW (thermal load)
    q. $kBtu_i$/hr/$kBtu_o$/hr (1/COP), kW/ton or COP (performance)
    r. kW/cfm or kW/L/s (specific power)
    s. kWh/ft^2 or kWh/m^2, $kBtu/hr/ft^2$, gal/ft^2 or L/ft^2 (EUI)

3. Data Acquisition
    a. In order to meet through system accuracy goals, the data acquisition system's analog to digital converter (A/D) must have a rated instrument full scale accuracy of 0.1%. Repeatability must be within 0.05% of full scale. The minimum resolution must be within 0.025% of full scale range and one second for time.
    b. It is recommended that the A/D be a factory calibrated monolithic successive approximating A/D or a SAR converter A/D to at least native 10 bit or better with a minimum drift of 30ppm/deg C and minimum resolution of 2.44 mV/bit. 8 bit devices using software or algorithms to achieve 10-bit resolution are not acceptable. 12-bit resolution is preferable.

c. The data acquisition system, including control network and field panels, must be capable of collecting all point data at a minimum sampling interval of one minute without measurably affecting control performance. Continuous sampling is preferred.
d. Pulse output devices must provide a pulse value that is less than or equal to 1/256 times full scale (>=8 bit, >= 4.27 Hz) and the smallest scalar resolution possible (0.0001) must be used for the input function.

4. Point naming
   a. Names need to be unique. Format is a four-element string including Location, System, Equipment, and Function. Equipment and function can be interchanged if desired. Each of the four elements in a name should include a number if required for uniqueness.
   b. Provide 256 alpha-numeric character maximum string lengths.
   c. Ability to use defined names or abbreviations. If for some reason a name is too long, the abbreviated string should include a capitalized first letter of each element, or other delimiter as appropriate (e.g., a period). Be as clear as possible, using as much of the original name as possible. Do not omit a word or first letter.
   d. When using uppercase letters as delimiters, do not use uppercase letters other than for the first letter of an element word.
   e. Do not use the same capitalized letter for different meanings, except for an existing site-specific designation or defined abbreviations.

5. Data calculations.
   a. Math and data functions:
      1) Addition, subtraction, multiplication, division, square root
      2) Average, minimum, maximum, total (value integrated over time) and standard deviation of a single input or a calculated value over a predefined time interval (recording interval, hourly, daily, weekly, monthly, yearly)
      3) Running average (low pass filter) over a predefined time interval
      4) Instantaneous sum and average of a group of inputs and/or calculated values
      5) Allow use of predefined constants in calculations
      6) Logic triggered data sampling/archive based on any given event
   b. Adjustable resolution of calculated data
   c. Standard means of:
      1) Converting line current to 3 phase power
      2) Calculating instantaneous thermal load (Btu/hr and $tons_R$) and efficiency (COP and kW/ton)
      3) Calculating instantaneous wet bulb temperature
      4) Calculating instantaneous chilled water plant heat balance quotient

6. Data trending, archiving, and retrieval.
   a. Ability to trend the following:
      1) All specified analog and digital input and output values

2) All setpoints
3) All PID loop input and output values
4) All calculated values
5) All alarm setpoints

b. Network architecture and bandwidth must allow all data to be sampled and archived as necessary within a one minute basis without impacting control, calculations or data display updates.
c. Data that is to be used in a calculated result, such as an average of multiple inputs or difference between two inputs, must be sampled within a one minute of each other.
d. Allow user (with appropriate security access level) to create/modify trend display appearance and which data points are used in the trending.
e. Stand alone or formal database integrated or in parallel to the EMCS
f. Data needs to be stored in SQL compliant database format or time series format.
g. Internal applications
   1) Seamless access to historical and real-time data for visualization and plotting
h. Application program access:
   1) The database needs to allow other application programs read access to historical and real-time data with appropriate password protection while the database is running.
   2) The database must not require shutting down in order to access or have data added.
   3) Data needed for third party or EMCS routines need to be able to be read from the database without interrupting the continuous storage and calculation of trend data being carried in the EMCS.
i. Trend data storage interval and quality
   1) Trend data must be archived in a database from field equipment in time intervals no less than once per day.
   2) Storage on the field equipment must be reset once data is exported to allow for trending in communication is disrupted.
   3) Data must be uploaded once communication is re-established.
   4) Blank or null values in the database must be replaced with actual data. Calculations and other metrics must be updated once controller data is uploaded.
   5) This overall system update to check for new data should be automated to run once a day.
j. All data must be able to be stored in database file format for direct use by third-party application programs. Operation of system needs to stay completely online with instantaneous updates during all graphing operations. New data is added to the screens once the database is updated.
k. Sufficient data storage capacity to store at least two years of data for all data points. Allow data compression of one year of data for maintenance.

l. Time Stamps must be collected on all data. The timestamp depending on system architecture will be captured at the field controller or system controller and directed to the database archive.
   1) Field Controller including control network and field panels must be capable of collecting and storing all point data at a uniform sampling interval of one minute without measurably affecting control performance, refresh rates and two way control signaling. Data safeguards for loss of communication need to be established where up to 24 hours or data will be stored if access to the database is lost.
      i) Time stamp for the point data must be assigned at the controller and passed to the storage depository.
      ii) The storage depository must use the database time index and manage data from multiple fields and systems.
   2) Field Controller to PC / System Controller time stamp must be utilized if field controller does not have storage or an internal clock. Field controller must send data to System controller or embedded computer for data archiving and then data will be exported once on-board memory is 75% used or transferred at a minimum of once a day to the database. This assumes that a stand alone database will be integrated within the EMCS or linked via ODBC, XML or other protocol for data to be stored. Data safeguards for loss of communication must be established where up to 24 hours or data will be stored if access to the database is lost.
      i) The time stamp is assigned by the field controller or System Controller / embedded computer depending on system hierarchy, infrastructure and bandwidth. Time must not exceed $1/5^{th}$ of a second between event and time sampling.
      ii) The storage depository must use the database time index and manage data from multiple fields and systems.
   3) Field Controller to PC / System Controller to Server with database. Point data is stored and sent to a multiple cursor database. Data in this configuration is sent directly to the database. The data time stamp is used and managed by the database time index. Data safeguards for loss of communication must be established where up to 24 hours or data will be stored if access to the database is lost.

m. User accounts for the terminal, remote and web-based clients need to be divided as follows.
   1) Guest must be able to view the system and update displays. No controls adjustments, programming or administrative tools should be available to Guest.
   2) Operator must be able to operate “Guest” functions and also be able to export data from existing database tables and queries, review control settings and check system status.
   3) Programmer must be able to operate “Guest” and “Operator” functions and also be able to change database variables, time intervals and enable and start new trends.

4) Administrator must be able to change and add new user categories and enable/disable available functions. The administrator is the only user that should be able to delete data.

n. Access to Data:

1) Data must to be available through the Owner's intranet and/or internet (with appropriate security clearance)

2) System server must be capable of periodically gathering performance data stored in real time in the field equipment and automatically archiving these data without operator intervention.

3) All performance data required to generate the graphic displays listed must be archived.

4) Archive files must be appended with new data, allowing data to be accumulated.

5) Systems that write over archived data must not be allowed unless limited file size is specified and automatic archiving is employed on a scheduled basis to prevent loss of data.

6) Performance data must be capable of being displayed in user selectable engineering units including both English and SI units.

o. Trend Data Export for Analysis by Other Software

1) Historical and current data held in temporary memory must be exportable as specified by owner to one or more formats for analysis by external software. Examples include:

i) Text (Comma or tab delimited with "" text delimiters)

ii) MS Excel

iii) MS Access

iv) ODBC Shared source

v) dBase

vi) SQL Server

vii) My SQL

viii) Oracle

ix) OSI PI Server

2) Exported data characteristics:

i) Exported data must contain no duplicate records or duplicate time stamps in output files. Each date/time stamp for a specific point must be unique. The export query is for a specific point or multiple points in a defined group. The user should be able to add, modify or view depending on access level.

ii) Date/Time fields must be in a single column, in a format automatically recognized by common spreadsheet or database software tools (*be specific*). The date/time stamp column can be split into two columns as an available user defined output. The date and time identifiers should also be split to maintain the column and row. The single date/time column is the default condition.

iii) The data must be fully contained in a single file or table for each point. Data must not be allowed to span multiple files or database tables. Users should have the option to modify export file start and end file date span depending on third party program requirements to evaluate the data.

iv) Each field of data must have one and only one unique identifier. The label must be in the first row of the file. Labels should not be repeated in the stream of data. No unit row is the default. The user can select if this row is activated in the export.

v) Each table or file must have a single date/time stamp. Multiple fields that are sampled on the same time stamp can be combined in a single file or table provided that they have the same number of records and are stored in the following format:

Example Export Default:

Date/Time	Field 1	Field2	Field n
DateTimeValue1	Value 11	Value 21	Value n1
…			
DateTimeValuej	Value 1j	Value 2j	Value nj

Example Export Optionally selected by user:

Date	Time	Field 1	Field2	Field n
Date	Time	Unit 11	Unit 21	Unit n1
Date Value	TimeValue	Value 12	Value 22	Value n2
…				
Date Value	TimeValuej	Value 1j	Value 2j	Value nj

p. Data transfer must be by ODBC or Web Services.

1) User with the adequate access level must be able to change the performance monitoring setup. This includes the meters to be logged, meter pulse value, and the type of energy units to be logged. All points on the system must be capable of being displayed, archived, and re-displayed from archive.

2) Archiving program must follow password levels requirements for users to delete, modify or change archive parameters.

7. Graphics, data visualization and plotting
   a. In general, standard system and equipment graphics must:
      1) Show basic equipment such as filters, coils, valves, dampers, pumps, major equipment and pertinent data
      2) Provide visual indication of actual equipment status not just its command
      3) Use point-naming convention, as defined above, for equipment labels and pertinent data
      4) Indicate when a manual reset of equipment is required
      5) Indicate what systems are in override.
      6) Graphic presentations for ancillary equipment such as exhaust fans must be hot-linked via text links to graphic presentations of related systems and/or building graphics.
      7) Sensor locations must be identified on all graphics where appropriate.
      8) Each graphic must match the actual configuration of the unit or system such that the graphic screen print out an operator can visit the unit and visually be able to identify ductwork and devices. A generic flow schematic is not acceptable.
      9) Graphic links: When specified, each graphic display shall include "hot spots" on the graphics presented that:
         i) On a "Mouse-over" displays the name of a new screen that will be presented if the hot-spot is clicked.
         ii) If "clicked" a new screen will be displayed. For example, if a building graphic shows an isometric of a 3-story building, and if each of the floors is a "hot-spot", then if the user "mouses-over" the second floor portion of the building isometric, the name of the "second floor" display should appear. If the user "clicks" on the second floor portion of the building isometric, then the software program control needs to display a new "Floor Level" display.
         iii) Advanced feature: A user, with applicable access security level, must be able to: create new, or modify existing graphics screens (those that have been prepared by the supplier/service provider); create/modify all graphics attributes including numerical data, animated graphics, system diagrams, equipment outline/ detailed graphics, instrumentation. schemes/graphics, piping systems and electrical scheme/graphics information (i.e., a graphics screen builder functionality); create/modify screens to the same complexity level as the supplier/service provider, including "hot-spots" for "mouse-over" displays, with "click-on" capability to transfer the user to a new, linked display screen.
      10) Time-Series Charts and Energy Use Intensity (EUI) Charts: for these chart types, the user shall be able to select from the following time-series options: (1) a 1-day 24-hour period; (2) a 1-week 7-day period, (3) a 1-month period, with appropriate days for the month selected; or (4) a 1-year

period. The user must be able to select the beginning and ending period for each time series chart, within the time domain of the database being used.

i) floor plan with zone temps; temp range status indicated by color
ii) automated real time update, refresh graphic display within 1 minute

b. Plots
1) individualized plot name
2) automated real time update, refresh graphic display within 1 minute
3) time series group trend plots – allow up to 20 independent y-axis inputs per page in 4 sub-groups of 5 each
4) display X-Y plots that include multiple y-axis and/or x-axis inputs
5) provide means to indicate reasonable range of expected values
6) fill in digital and COV values so that a value is always indicated on a plot

APPENDIX C: PERFORMANCE METRICS BY CLASS

This appendix defines performance metrics as those aspects of performance that must be measured, calculated and reported. Each performance metric is defined below, including the control data points that are necessary for calculating and reporting the metric.

C1. Class 1 Basic Performance Metrics and Data Points

a. Site Weather.

   i) (S1) Outdoor Air Temperature (ºF): instantaneous measured value obtained external to the building

   ii) (S2) Outdoor Air Wet Bulb Temperature (ºF): instantaneous measured value obtained external to the building

b. (M8) Average Daily Outdoor Air Temperature (°F): 24 hour average during calendar day. This performance metric requires the following measurement data point:

   i) (S1) Outdoor Air Temperature (°F): instantaneous measured value.

c. (M1) Whole-Building Peak Power (kW): peak electricity use as defined by supplying utility's rate structure applicable to this building in a given time period; typically the billing cycle. This performance metric requires the following measurement data point:

   i) (S7) Main Electric Power (kW): instantaneous measured value

d. (M4) Whole-Building Area-Normalized Electric Energy Use Intensity (EUI) (kWh/ft^2/?): the consumed electric energy per unit of building floor area per unit of time. This performance metric requires the following measurement data point and constant:

   i) (S7) Main Electric Power (kW): instantaneous measured value from the main electric meter; this values is integrated over a given time interval; provide values (kWh) for a day, week, month and year.

   ii) (C1) Building Floor Area (ft^2): sum of building floor areas within the outside faces of the exterior walls for all stories that have floor surfaces, excluding courtyards, light wells, and atrium floor areas except interior enclosed area of the floor level of such multi-story spaces; this is constant #C1 (see Appendix D4.3.). Owner shall provide this value.

e. (M6) Whole-Building Gas Energy Use Intensity (EUI) (therms/ft^2/?): the consumed volume of natural gas converted to therms per unit of building floor area per unit of time. This performance metric requires the following measurement data points and constant:

   i) (M5) Whole Building Natural Gas Heat Rate (therms/hr): the consumed volume of natural gas per unit of building floor area per unit

of time converted to therms by constant #C2 (see Appendix D4.3.); this value is integrated over a given time interval; provide values (therms) for a day, week, month and year.

ii) (C1) Building Floor Area (ft^2): sum of building floor areas within the outside faces of the exterior walls for all stories that have floor surfaces, excluding courtyards, light wells, and atrium floor areas except interior enclosed area of the floor level of such multi-story spaces; this is constant #C1 (see Appendix D4.3.), which shall be provided by Owner.

f. (M70) Whole-Building Area-Normalized Water Use Intensity (EUI) ($kgal/ft^2/?$): the consumed volume of water per unit of building floor area per unit of time. This performance metric requires the following measurement data points and constant:

i) (S39) Total Water Flow (kgal/min): instantaneous measured value from the main water meter; this value is integrated over a given time interval; provide values (kgal) for a day, week, month and year.

ii) (C1) Building Floor Area (ft^2): sum of building floor areas within the outside faces of the exterior walls for all stories that have floor surfaces, excluding courtyards, light wells, and atrium floor areas except interior enclosed area of the floor level of such multi-story spaces; this is constant #C1, which shall be provided by Owner.

g. (M15x) Chilled Water (Loop #) Delta T (°F): differential temperature measured between chilled water return and supply or difference of chilled water return temperature and chilled water supply temperature. If more than one chilled water loop exists and a single supply and return temperature measurements can not be obtained, measure loops independently. This performance metric requires the following measurement data points:

i) (S20) Chilled Water Return Temperature (°F): instantaneous measured value

ii) (S21) Chilled Water Supply Temperature (°F): instantaneous measured value

h. (M17x) Chilled Water Plant (Loop #) Thermal Cooling Load (tons): calculated value of the instantaneous thermal cooling load met by a chilled water loop. It is the product of chilled water loop delta-T, flow and constant #C4 (see Appendix D4.3.). If multiple loops are present and the total load cannot be uniquely measured, individual loop loads must be measured. This performance metric requires the following calculated and measurement data points:

i) (S20) Chilled Water Return Temperature (°F): instantaneous measured value

ii) (S21) Chilled Water Supply Temperature (°F): instantaneous measured value

iii) (S22) Chilled Water (Loop #) Flow (gpm): instantaneous measured value

i. (M67) Total Chilled Water Plant Thermal Cooling Load (tons): calculated sum of the instantaneous cooling loads met by all chilled water loops. This performance metric requires the following calculated data points:

i) (M17x) Chilled Water (Loop #) Thermal Cooling Load (tons): calculated value.

j. (M18) Chilled Water Plant Efficiency (kW/ton): instantaneous power input per cooling output. This performance metric requires the following calculated data points.

i) (M16) Chilled Water Plant Power (kW): instantaneous sum of concurrently measured values of plant equipment power input including chillers, primary and secondary chilled water pumps, cooling tower fans, and condenser water pumps.

ii) (M67) Total Chilled Water Plant Thermal Cooling Load (tons): calculated sum of the instantaneous thermal cooling loads met by all chilled water loops.

k. (M5) Whole Building Natural Gas Heat Rate (therms/hr): the consumed volume of natural gas per unit of building floor area per unit of time converted to therms by constant #C2 (see Appendix D4.3.). This performance metric requires the following measurement data points and constant:

i) (S5) Main Natural Gas Flow (scfm): instantaneous measured value from the main water meter.

l. (M26) Total Air Handler Power (kW): sum of the concurrently measured values of the supply and return fans power inputs for all air handling units.

i) (S33) Air Handler # Supply Fan Power (kW): instantaneous measured value

ii) (S34) Air Handler # Return Fan Power (kW): instantaneous measured value

m. (M27) Total Air Handler Flow (cfm): instantaneous sum of concurrently measured values of the supply fan air flow rate for all air handling units.

i) (S26) Air Handler # Air Flow (cfm): instantaneous measured value

n. (M28) Total Air Handler Specific Power (kW/cfm): total concurrent power input per air distribution system flow output for all air handling units. This performance metric requires the following calculated data points.

i) (M26) Total Air Handler Power (kW): instantaneous sum of concurrently measured values of the supply and return fans power inputs for all air handling units.

ii) (M27) Total Air Handler Flow (cfm): instantaneous sum of concurrently measured values of the supply fan air flow rate for all air handling units.

o. (M63) Air Handler # Outside Air Temperature Fraction: current difference of mixed air and outside air temperatures divided by the difference of mixed air and return air temperatures

i) (S35) Air Handler # Mixed Air Temperature (°F): instantaneous measured value.

ii) (S1) Outside Air Temperature (°F): instantaneous measured value.

iii) (S36) Air Handler # Return Air Temperature (°F): instantaneous measured value.

p. (M64) Air Handler # Outside Air Damper Fraction: current calculated value of outside air damper position divided by the sum of outside air damper position and return air damper position.

i) (V1) Air Handler # Outside Air Damper Position (% open):

ii) (V2) Air Handler # Return Air Damper Position (% open)

q. Zone Temperatures (ºF): all zone temperatures that are available from installed monitoring system. This performance metric requires the following measurement data points:

i) (S9) Zone # Temperature (ºF): instantaneous measured value for each specified zone

C2. Class 2 Intermediate Performance Metrics and Data Points

a. (M3) Average Building Duct Static Pressure (iwc): average concurrent duct static pressure for all air handling and roof top packaged units. This performance metric requires the following measurement data points:

i) (S3x) Air Handler # and/or RTU # Duct Static Pressure (iwc): instantaneous measured value.

b. (M2) Total HVAC Electric Power (kW): instantaneous sum of concurrently measured electric power of all HVAC equipment. This performance metric requires the following measurement data points:

i) (S4x) RTU # Power (kW): instantaneous measured value for each unit

ii) (S6x) Other HVAC Equipment Power (kW): instantaneous measured value for each unit

iii) (M16) Chilled Water Plant Power (kW): instantaneous sum of concurrently measured values of plant equipment power input including chillers, primary and secondary chilled water pumps, cooling tower fans, and condenser water pumps.

iv) (M26) Total Air Handler Power (kW): instantaneous sum of the concurrent measured values of the supply and return fans power inputs for all air handling units.

c. (M7) Whole Building HVAC Electric Only End-Use Area-Normalized Electric Energy Use Intensity (EUI) (kWh/ft2): the consumed electric energy for HVAC loads per unit of building floor area. This performance metric requires the following measurement data points and constant:

   i) (M2) Total HVAC Electric Power (kW): instantaneous sum of concurrently measured values of HVAC electric loads; this value is integrated over a given time interval; provide values (kWh) for a day, week, month and year. If multiple meters are used, individual values must be summed.

   ii) (C1) Building Floor Area (ft^2): sum of building floor areas within the outside faces of the exterior walls for all stories that have floor surfaces, excluding courtyards, light wells, and atrium floor areas except interior enclosed area of the floor level of such multi-story spaces; this is constant #C1, which is to be provided by the Owner.

d. (M9) Whole Building Lighting End-Use Area-Normalized Electric Energy Use Intensity (EUI) (kWh/ft2): the consumed electric energy for lighting per unit of building floor area. This performance metric requires the following measurement data points and constant:

   i) (S11x) Lighting Electric Power (kW): instantaneous sum of concurrently measured values of electric lighting loads; this value is integrated over a given time interval; provide values (kWh) for a day, week, month and year. If multiple meters are used, individual values must be summed.

   ii) (C1) Building Floor Area (ft^2): sum of building floor areas within the outside faces of the exterior walls for all stories that have floor surfaces, excluding courtyards, light wells, and atrium floor areas except interior enclosed area of the floor level of such multi-story spaces; this is constant #C1. Owner shall provide this value.

e. (M11) Whole Building Plug End-Use Area-Normalized Electric Energy Use Intensity (EUI) (kWh/ft2): the consumed electric energy for plug loads per unit of building floor area. This performance metric requires the following measurement data points and constant:

   i) (S10x) Plug Electric (kW): instantaneous sum of concurrently measured values of electric plug loads; this value is integrated over a given time interval; provide values (kWh) for a day, week, month and year. If multiple meters are used, individual values must be summed.

   ii) (C1) Building Floor Area (ft^2): sum of building floor areas within the outside faces of the exterior walls for all stories that have floor surfaces, excluding courtyards, light wells, and atrium floor areas

except interior enclosed area of the floor level of such multi-story spaces; this is constant #C1, which is to be provided by the Owner.

f. (M14) Chiller # Efficiency (kW/ton): instantaneous power input per cooling output of each chiller. This performance metric requires the following calculated data points.

   i) (S12) Chiller # Power (kW): instantaneous measured value of power input; Class 2.

   ii) (M13) Chiller # Chilled Water Output (tons): calculated value of the instantaneous chilled water cooling output provided by chiller. It is the product of chiller delta T, chiller flow and constant #C4.

g. (M66) Total Plant Chiller Power (kW): the instantaneous sum of all chiller power inputs.

   i) (S12x) Chiller # Power (kW): instantaneous measured value.

h. (M34x) Plant Condenser Water (Loop #) Thermal Load (tons): calculated value of the instantaneous thermal load met by a condenser water loop. It is the product of condenser water loop delta T, flow and constant #C4. If multiple loops are present and the total load cannot be uniquely measured, individual loop loads must be measured. This performance metric requires the following calculated and measurement data points:

   i) (S40) Condenser Water (Loop #) Return Temperature (°F): instantaneous measured value

   ii) (S39) Condenser Water (Loop #) Supply Temperature (°F): instantaneous measured value

   iii) (S41) Condenser Water (Loop #) Flow (gpm): instantaneous measured value

h. (M68) Total Chilled Water Plant Heat of Rejection (tons): instantaneous sum of concurrently calculated heat rejected by all chilled water plant condenser water loops. If multiple loops are present, and a single supply and return temperature and flow measurement can not be made, individual values must be measured and summed. This performance metric requires the following measurement data points:

   i) (M34x) Condenser Water Loop # Output (tons): calculated value of the instantaneous thermal load met by a condenser water loop. It is the product of condenser water delta T, loop flow and constant #C6 (see Appendix D4.3.).

i. (M69) Chilled Water Plant Heat Balance: instantaneous sum of total plant chiller power converted to tons and total plant thermal cooling output in tons dividend by the total plant heat of rejection in tons. This performance metric requires the following measurement data points:

   i) (M66) Total Plant Chiller Power (kW): instantaneous calculated value.

ii) (M67) Total Plant Chilled Water Thermal Cooling Load (tons): instantaneous calculated value.

iii) (M68) Total Chilled Water Plant Heat of Rejection (tons): instantaneous calculated value.

j. (M19) Boiler # Output (kBtu/hr): calculated value of the instantaneous heating output provided by the boiler. It is the product of the boiler delta T, flow and constant #5. This performance metric requires the following measurement data points:

i) (S23) Boiler # Supply Water Temperature (°F): instantaneous measured value.

ii) (S24) Boiler # Return Water Temperature (°F): instantaneous measured value.

iii) (25) Boiler # Gas Flow (gpm): instantaneous measured value.

k. (M56x) Boiler # Efficiency (COP): instantaneous heating output ($kBtu_o$/hr) per heating value of fuel input ($kBtu_i$/hr) for each boiler. This performance metric requires the following calculated data points.

i) (S25x) Boiler # Gas Flow (scfm): instantaneous measured values from boiler gas meters; this value is converted to kBtu/hr by constant #2 (see Appendix D4.3.).

ii) (M19x) Boiler # Output (kBtu/hr): calculated value of the instantaneous heating output provided by the boiler.

l. (M20) Total Boiler Output (kBtu/hr): calculated sum of the instantaneous heating output provided by each boiler.

i) (M19x) Boiler # Output (kBtu/hr): calculated value of the instantaneous heating output provided by the boiler.

m. (M21) Total Boiler Gas Flow (scfm): instantaneous sum of concurrently measured natural gas input to all boilers.

i) (S25x) Boiler # Gas Flow (scfm): instantaneous measured value.

n. (M57) Total Boiler Gas Energy Use Intensity EUI (Therms/ft^2/?): the consumed of boiler natural gas energy per unit of building floor area per unit of time. This performance metric requires the following measurement data points and constant:

i) (M21) Total Boiler Gas Flow (std. ft^3/min): calculated sum of the instantaneous natural gas input to each boiler; this value is converted to therms by constant #C2 (see Appendix D4.3.)

ii) (C1) Building Floor Area (ft^2): sum of building floor areas within the outside faces of the exterior walls for all stories that have floor surfaces, excluding courtyards, light wells, and atrium floor areas except interior enclosed area of the floor level of such multi-story spaces; this is constant #C1, which is to be provided by the Owner.

o. (M22) Total Boiler Efficiency (COP): total instantaneous heating output per heating value of fuel input for all boilers. This performance metric requires the following calculated data points.

   i) (M21) Total Boiler Gas Flow (scfm): instantaneous sum of concurrently measured natural gas input to all boilers; this value is converted to kBtu/hr by constant #C2.

   ii) (M20) Total Boiler Output (kBtu/hr): calculated value of the instantaneous heating output provided by heating system. If multiple boilers are present, individual values must be measured and summed.

p. (M23) Instantaneous Average Building Air Handler VFD Frequency (Hz): instantaneous average of the concurrently measured frequencies of all building supply fans.

   i) (S27x) Air Handler Supply Fan # VFD Frequency (Hz): instantaneous measured value.

q. (M24x) Air Handler # Total Power (kW): sum of the concurrent measured values of the supply and return fan power inputs.

   i) (S33x) Air Handler # Supply Fan Power (kW): instantaneous measured value.

   ii) (S34x) Air Handler # Return Fan Power (kW): instantaneous measured value.

r. (M25x) Air Handler # Specific Power (kW/cfm): instantaneous power input per air distribution system flow output for each air handling unit. This performance metric requires the following calculated data points.

   i) (M24x) Air Handler # Power (kW): instantaneous sum of concurrently measured values of the supply and return fan power inputs.

   ii) (S26x) Air Handler # Flow (cfm): instantaneous measured value of the supply fan air flow rate.

s. (M76) Air Handler # Outside Air Flow Fraction: outside air flow divided by the supply air flow

   i) (S48) Air Handler # OA Flow: instantaneous measured value.

   ii) (S26) Air handler # SA Flow: instantaneous measured value.

C3. Class3 Advanced Performance Metrics and Data Points

a. (M29) Average Daily Outdoor Ambient Temperature – Chilled Water On (°F): average outdoor temperature that includes values that have been sampled only during chilled water plant operation (plant output > 3% full-scale) over a 24 hour calendar day period or any chilled water pump running. This performance metric requires the following measurement data point:

i) (S1) Outdoor Ambient Dry Bulb Temperature (°F): instantaneous measured value.

ii) (M67) Total Chilled Water Plant Thermal Cooling Output (tons).

b. (M30) Average Daily Outdoor Ambient Temperature – Hot Water On (°F): average outdoor temperature that includes values that have been sampled only during boiler-heating system operation (total output > 3% full-scale) over a 24 hour calendar day period or any hot water pump running. This performance metric requires the following measurement data point:

i) (S1) Outdoor Ambient Dry Bulb Temperature (°F): instantaneous measured value.

ii) (M20) Total Boiler Output (kBtu/hr).

c. (M31) Average Daily Outdoor Ambient Temperature – Air Handler On (°F): average outdoor temperature that includes values that have been sampled only during air handler operation (total flow > 3% full-scale) over a 24 hour calendar day period or any air-handler fan running. This performance metric requires the following measurement data point:

i) (S1) Outdoor Ambient Dry Bulb Temperature (°F): instantaneous measured value.

ii) (M27) Total Air Handler Flow (cfm) or (S44) Air Handler # Supply Fan Status.

d. (M32) Average Daily Main Electric Power (kW): average building power during a 24 hour calendar day period. This performance metric requires the following measurement data point:

i) (S7) Main Electric Power (kW): instantaneous measured value from the main electric meter.

e. (M65) Whole-Building Area-Normalized Total HVAC Gas Energy Use Intensity (EUI) (kWh/ft2): the consumed electric energy per unit of building floor area. This performance metric requires the following calculated data point and constant:

i) (M58) Total HVAC Gas Flow (scfm): instantaneous sum of concurrently measured natural gas fuel flow in scfm by A/C unit, boiler, and heater gas meters converted to therms/hr by constant #C2 and then integrated over a given time interval; provide values (therms) for a day, week, month and year.

ii) (C1) Building Floor Area (ft^2): sum of building floor areas within the outside faces of the exterior walls for all stories that have floor surfaces, excluding courtyards, light wells, and atrium floor areas except interior enclosed area of the floor level of such multi-story spaces; this is constant #C1, which is to be provided by the Owner.

f. (M71) Total HVAC Demand (kW): instantaneous sum of HVAC equipment power (electric on air side and water side and gas w/ gas usage in Btu/hr

converted to kW by constant #C3). This performance metric requires the following calculated data points:

i) (M2) Total HVAC Electric Input (kW): instantaneous sum of the concurrently measured electric power of all HVAC equipment.

ii) (M60) Total HVAC Gas Flow (scfm): instantaneous sum of concurrently measured natural gas fuel inputs in scfm by all A/C unit, boiler, and heater gas meters converted to Btu/hr by constant #C2.

g. (M72) Whole-Building Area-Normalized Total HVAC Energy Use Intensity (EUI) (kWh/ft2): the consumed electric energy per unit of building floor area. This performance metric requires the following calculated data point and constant:

i) (M71) Total HVAC Demand (kW): sum of Total HVAC Electric Power and Total HVAC Gas Demand converted to kW by constant #3 and then integrated over a given time interval; provide values (kWh) for a day, week, month and year.

ii) (C1) Building Floor Area (ft^2): Sum of building floor areas within the outside faces of the exterior walls for all stories that have floor surfaces, excluding courtyards, light wells, and atrium floor areas except interior enclosed area of the floor level of such multi-story spaces; this is constant #C1. Owner shall provide this value.

h. (M33) Average Daily Chilled Water Supply Temperature (°F): average chilled water supply temperature during a 24 hour calendar day period. This performance metric requires the following measurement data point:

i) (S21x) Chilled Water Supply Temperature (°F): instantaneous measured value.

i. (M37) Daily Chilled Water Plant Electric Usage (kWh): instantaneous sum of concurrently plant equipment power input integrated over a 24 hour calendar day period. This performance metric requires the following measurement data point:

i) (M16) Chilled Water Plant Power (kW): instantaneous sum of concurrently measured values of plant equipment power inputs including chiller, primary and secondary chilled water pumps, cooling tower fans, and condenser water pumps.

j. (M38) Daily Chilled Water Plant Thermal Cooling Energy (ton-hrs): total chilled water plant cooling output integrated over a 24 hour calendar day period. This performance metric requires the following measurement data point:

i) (M67) Total Plant Chilled Water Thermal Cooling Load (tons).

k. (M39) Maximum Daily Chilled Water Plant Thermal Cooling Energy (ton-hrs): maximum 24 hour total of chilled water plant cooling output over a given time period. Provide maximums for weekly, monthly, and yearly time

intervals. This performance metric requires the following calculated data point:

i) (M38) Daily Chilled Water Plant Thermal Cooling Energy (ton-hrs): total chilled water plant cooling output provided in a 24 hour calendar day period.

l. (M41) Average Daily Chilled Water Plant Efficiency (kW/ton): average chilled water plant efficiency over a 24 hour calendar day period. This performance metric requires the following calculated data point:

i) (M18) Chilled Water Plant Efficiency (kW/ton): instantaneous power input per cooling output

m. (M48) Average Daily Total Boiler Efficiency (scfm/kBtu/hr): instantaneous heating system efficiency averaged over a 24 hour calendar day period. This performance metric requires the following calculated data point:

i) (M22) Total Boiler Efficiency (scfm/kBtu/hr): instantaneous fuel input per heating output for all boilers.

n. (M58) Total RTU Gas Flow (scfm): instantaneous sum of concurrently measured natural gas flow rates for all measured HVAC equipment. This performance metric requires the following measurement data points:

i) (S8) Package RTU # Gas Flow (scfm): instantaneous measured value.

o. (M59) Total HVAC Heater Gas Flow (scfm): instantaneous sum of concurrently measured natural gas flow rates for all measured HVAC heaters. This performance metric requires the following measurement data points:

i) (S30) HVAC Heater Unit # Gas Flow (scfm): instantaneous measured value.

p. (M60) Total HVAC Gas Flow (scfm): instantaneous sum of all concurrently measured natural gas fuel inputs by A/C unit, boiler, and heater gas meters. Individual values must be measured and summed. This performance metric requires the following measurement data points:

i) (M21) Total Boiler Gas Flow (scfm): the instantaneous calculated sum of concurrently measured values from all boiler gas meters.

ii) (M58) Total RTU Gas Flow (scfm): instantaneous calculated sum of concurrently measured values from all packaged unit and furnace gas meters; Class 1

iii) (M59) Total HVAC Heater Unit Gas Flow (scfm): instantaneous calculated sum of concurrently measured values from all heater gas meters.

q. (M73) Daily Total HVAC Natural Gas Usage (cf): instantaneous heating system natural gas input integrated over a 24 hour calendar day period. This performance metric requires the following calculated data point:

i) (M60) Total HVAC Gas Flow (scfm): instantaneous sum of concurrently measured natural gas fuel inputs in scfm by all A/C unit, boiler, and heater gas meters.

r. (M74) Daily Total HVAC Heating Energy (therms): total HVAC natural gas usage in therms in a 24 hour calendar day period. This performance metric requires the following calculated data point and constant:

i) (M73) Daily Total HVAC Natural Gas Usage (cf): instantaneous heating system natural gas input integrated over a 24 hour calendar day period converted to therms by constant #C2.

s. (M75) Maximum Daily Total Boiler Heating Energy (kBtu): maximum 24 hour total of total boiler output over a given time period. Provide maximums for weekly, monthly, and yearly time intervals. This performance metric requires the following calculated data point:

i) (M74) Daily Total HVAC Heating Energy (therms): instantaneous heating system output integrated over a 24 hour calendar day period.

t. (M52) Daily Total Air Handler Electric Usage (kWh): the instantaneous sum of concurrently measured values of the supply and return fans power inputs for all air handling units integrated over a 24 hour calendar day period. This performance metric requires the following calculated data point:

i) (M26) Total Air Handler Power (kW): instantaneous sum of concurrently measured values of the supply and return fans power inputs for all air handling units.

u. (M53) Daily Total Air Handler Volume (cf): instantaneous sum of concurrently measured air handler flows of all measured air handlers integrated over a 24 hour calendar day period. This performance metric requires the following measurement data point:

i) (M27) Total Air Handler Flow (cfm): instantaneous sum of concurrent measured values of the supply fan air flow rates for all air handling units.

v. (M54) Maximum Daily Air Handler Volume (cf): maximum 24 hour total of total air handler volume over a given time period. Provide maximums for weekly, monthly, and yearly time intervals. This performance metric requires the following calculated data point:

i) (M53) Daily Total Air Handler System Volume (cf): instantaneous sum of concurrently measured air handler flows of all measured air handlers integrated over a 24 hour calendar day period.

w. (M55) Average Daily Total Air Handler System Specific Power (kW/cfm) instantaneous power input per air distribution system flow output for all air handling units averaged over a 24 hour calendar day period. This performance metric requires the following calculated data point:

i) (M28) Total Air Handler System Specific Power (kW/cfm): total instantaneous power input per air distribution system flow output for all air handling units.

APPENDIX D: EXAMPLE BASIC LEVEL GENERAL SPECIFICATIONS

The example specification language provided in this section is based on Class 1 requirements described earlier. It is intended to be used in specifying a DDC system that includes a performance monitoring system. The numbering and headers will need to be edited to conform to the actual project specification. These specifications also need to be coordinated with Division 1 and pertinent sections of Division 15 and 16. Sections in this example are categorized as follows:

- 1 defines a general description of the work included
- 2 a general description of the monitoring system.
- 3 defines instrumentation and data requirements.
- 4 defines the sensor inputs virtual points and calculated values
- 5 provides a description of the Data Point Naming Convention.
- 6 identifies required trends and their characteristics.
- 7 defines data archiving and retrieval requirements.
- 8 describes the graphic display requirements on the operator's monitor for each facility feature, system, component, data point, and trend or other output result covered by this specification.
- 9 describes the particular quality assurance tasks required to commission the performance monitoring system.
- 10 defines particular training requirements for operating and maintaining the performance monitoring system
- 11 defines particular submittal requirements.

If the user desires a more formal specification structure it is recommended that they consider using ASHRAE's Guideline 13: Specifying Direct Digital Control Systems. Example specification language that is based on this guideline is found in Appendix G.

1. Work Included

1.1. The contractor shall provide equipment, software, installation, programming, functional testing, documentation, training, and training documentation capable of meeting the performance monitoring requirements listed below.

2. System Description

2.1. ***Performance Monitoring System Requirements:*** The system shall include instrumentation, data communication hardware and software, and additional programmed and operational software capable of collecting and archiving all data sufficient to generate, report, store and retrieve all measured, virtual and calculated points listed in Section 4.

2.2. ***Graphic Requirements*:** The performance monitoring system shall include software for analyzing and displaying equipment graphics and related data, data tables, time series group trend plots and XY group trend plots as described in Section 6.

2.3. ***Measurement Accuracy*.** A complete measurement system shall be provide, from sensor to graphic screen and data storage, such that the through system measurement accuracy requirements in Table 2 are met.

2.3.1. **Table 2 – Through-System Measurement Accuracy Requirements.**

Measurement Point or Metric	Accuracy Required
Outside air temperature (ºF)	0.2ºF
Outside air wet bulb temperature (ºF)	0.2ºF
Zone temperature (ºF)	0.5°F
HVAC electric only energy use (kWh)	1.5% of reading
Water temperature (ºF)	0.1ºF, if ≥ 5ºF delta T
Water delta temperature (ºF)	2% of reading
Water flow (gpm)	2% of reading, > 20-1 turndown
Natural gas flow (scfm)	2% of reading, > 10-1 turndown, w/ pressure and temperature compensation; [*Editor's note: Using an average heat content of the gas to convert to kBtu introduces a ~2% error*]
Air flow (cfm)	5% of reading down to 150 ft/min, > 10-1 turndown
Power (kW)	1.5% of reading
Chiller cooling output (tons)	3% of reading
Chiller cooling energy (ton-hrs)	3% of reading
Boiler heating output (kBtu/hr)	3% of reading
Boiler heating energy (kBtu)	3% of reading
Electric energy use (kWh)	1.5% of reading
Total HVAC energy use (kWh) (includes air side, water side and natural gas)	3% of reading
Chiller performance (kW/ton)	4% of reading
ChW Plant performance (kW/ton)	4% of reading
Total boiler performance ($kBtu_o/kBtu_i$) (COP)	4% of reading
Total air handler performance (kW/cfm)	6% of reading
Net usable building floor area	2%

3. Instrumentation and Data Requirements

3.1. General

3.1.1. All equipment shall be labeled as described in Table 3.

3.1.2. All instrumentation shall be covered by manufacturer's transferable two-year warranty. If manufacturer warranty is not available the installer shall provide the same.

3.1.3. All sensors shall be identified including required placement dimensions as specified in this section on pertinent construction drawings, which adhere to the manufacturer's published minimum placement guide and installation instructions.

3.2. Main Electric Meter

3.2.1. Use existing meter if available. Interface existing meter with the EMCS using the appropriate computer bus, gateway or interface (*be specific*) and provide access to all available data from meter.

3.2.2. If existing meter is not available, provide a new meter per approved submittal. Interface new meter with the EMCS using the appropriate computer bus, gateway or interface (*be specific*) and provide access to all available data from meter.

3.3. Main Natural Gas Meters

3.3.1. Each flow meter shall have rated instrument accuracy within +/-2.0% of reading, with a minimum of a 10:1 turndown over the range of flow. Repeatability shall be within ±1.0 % of reading. Resolution shall be within ±0.1% of reading. These requirements are for the end-to-end measurement system including the sensor, transmitter and any signal conditioning.

3.3.2. Pressure and temperature compensated

3.3.3. Continuous data output

3.3.4. V-Bar or equivalent per approved submittal

3.4. Liquid Flow Meters

3.4.1. Each flow meter shall have a rated instrument accuracy within ± 1% of reading from 3.0 through 30 ft/s and ± 2% of reading from 0.4 ft/s through 3.0 ft/s velocity. Repeatability shall be within ±1.0 % of reading. Resolution of any signal conditioning and readout device shall be within ±0.1% of reading. The instrument shall be capable of measuring flow within the stated accuracy over the entire range of flow. Flow meter shall be rated for line pressure up to 400 PSI. These requirements are for the end-to-end measurement system including the sensor, transmitter and any signal conditioning. [*Editor: On an annual basis, most main loop flow is most likely operated well below 6* ft/s*, so low end accuracy is very important.*]

3.4.2. Each flow meter shall be individually wet calibrated against a volumetric standard accurate to within 0.1% and traceable to the U.S. National Institute of Standards and Technology (NIST). Flow meter accuracy shall be within ± 0.5% at calibrated typical flow rate. A certificate of calibration shall be provided with each flow meter.

3.4.3. When dictated by multiple elbows and other disturbances upstream and short available pipe runs, the flow measurement station shall provide compensation for rotational distortion in the velocity flow profile.

3.4.4. Insertion style flow meters shall be provided with all installation hardware necessary to enable installation and removal of flow meter without system shutdown. No special tools shall be required for insertion or removal of the meter.

3.4.5. Inline style flow meters shall be installed with a bypass assembly and isolation valves to enable installation and removal of the flow meter without system shutdown.

3.4.6. Dual Turbine, Vortex Shedding, or Magnetic Flowmeter per approved submittal. [*Editor's note: Insertion turbine and vortex shedding meters are not recommended in open cooling tower loops or where dirty water conditions exist.*]

3.4.7. Magnetic Full Bore Meter (Preferred): Sensor shall be installed in a location clear from obstruction 5 pipe diameters upstream and 2 pipe diameters downstream including pipe elbows, valves and thermowells

3.4.8. Insertion Vortex Shedding Meter: Sensor shall be installed in a location clear from obstruction 10 pipe diameters upstream and 5 pipe diameters downstream including pipe elbows, valves and thermowells.

3.4.9. Dual Turbine Meter. Flow sensing turbine rotors shall be non-metallic and not impaired by magnetic drag. Sensor shall be installed in a location clear from obstruction 10 pipe diameters upstream and 5 pipe diameters downstream including pipe elbows, valves and thermowells.

3.4.10. Verify that air vents or other air removal equipment exists in the system piping. If none exists, install appropriate air removal equipment upstream of flow meter.

3.5. Fluid Temperature Measurement Devices

3.5.1. Each temperature measurement device shall have a rated instrument accuracy within 0.1 ºF. Repeatability shall be within 0.1 ºF. Resolution of any signal conditioning and readout device shall be within 0.05 ºF. These requirements are for the end-to-end measurement system including the sensor, transmitter and any signal conditioning.

3.5.2. Temperature measurement devices, which includes any signal conditioning, shall be bath-calibrated (NIST traceable) for the specific temperature range for each application.

3.5.3. Temperature measurement devices used in calculating differential temperature shall be documented matched pairs with similar coefficients and

calibrated together by the manufacturer. The calculated differential temperature used in the energy calculation shall be accurate to within 2% of the difference (including the error from individual temperature sensors, sensor matching, signal conditioning, and calculations).

3.5.4. All piping immersion temperature sensors shall be inserted in newly installed brass or stainless steel wells located downstream of flow meter placement that allows for the removal of the sensor from the well for verifying calibration in the field. Allow for at least six pipe diameters upstream and four pipe diameter downstream clear of obstructions. The well shall penetrate the pipe at least two inches up to half the pipe diameter. The use of direct immersion sensors is not acceptable.

3.5.5. All piping immersion temperature sensors shall be coated with heat or (thermal) paste prior to being inserted in the wells. The paste shall be rated and keep consistency over the expected temperature range. A thermal conducting metal oxide, dielectric silicon based compound is commercially available with an operational range of -65 to 400 °F.

3.6. Air Flowmeters

3.6.1. Duct and plenum mounted sensors

3.6.1.1. Single or multiple point air flow station mounted in air distribution duct or plenum.

3.6.1.2. Flowmeter selection is dependent on application, air parameters, size of duct and length of duct run and manufacturer's published guidelines and recommendations. Measurement devices include volumetric duct-averaging airflow and temperature measurement devices including Airflow / Temperature Measurement Devices, Vortex Shedding and Pitot anemometers per approved submittal. [*Editor's note: velocity pressure-based technologies and non-directional thermal anemometers are more susceptible to errors due to irregular profiles or turbulence. Conditions or duct devices creating turbulence should be avoided. Never place a measurement device downstream of a modulating damper, unvaned elbow, humidifier, wetted coil or sound attenuator.*]

3.6.1.3. When dictated by disturbances upstream of inlet and short available air flow paths, the flow measurement station shall provide compensation for rotational distortion in the velocity flow profile.

3.6.1.4. Each Air flowmeter shall provide an isolated analog output (4-20 mA or 0-10 VDC) for air flow. Output shall be selectable from the instrument display or jumper selectable. No other cables, interface devices or software is required. As an alternative to the analog outputs, the air flow meter shall provide serial communications compatible with the data acquisition system. Interface meter to data acquisition system providing access to all available data.

3.6.1.5. The air flowmeter transmitters shall be housed in a steel or approved alternate material NEMA rated enclosure and shall include a front panel

mounted two-line alphanumeric LCD display for local indication of air flow. NEMA enclosures and display mounting for application will need to be approved by submittal. A single 24 VAC, 24VDC or 120VAC connection to the air flowmeter shall provide power to the meter electronics and to the flowmeter. Each air flowmeter shall be factory programmed for its specific application. The air flowmeter shall be re-programmable by the user using the front panel keypad (no special interface device or computer required) or alternate method approved by submittal.

3.6.1.6. Flowmeter sensors shall be rated for temperature up to 140 ºF. Flowmeter transmitters shall be rated for temperatures up to 120 ºF. [*Editor's note: Other temperature ranges are available and to be specified to meet application.*]

3.6.1.7. Each flowmeter shall have at least a rated system accuracy within ± 5 % of reading from 150 through 9,000 ft/min. Repeatability shall be within ± 1.0 % of reading. Resolution of any signal conditioning and readout device shall be within ± 0.1 % of reading. The instrument shall be capable of measuring flow within the stated accuracy over the entire range of flow. These requirements are for the end-to-end measurement system including the sensor and any signal conditioning.

3.6.1.8. Each flowmeter shall be individually calibrated at the manufacturer against a volumetric standard accurate to within 0.5 % and traceable to the U.S. National Institute of Standards and Technology (NIST). Flowmeter accuracy shall be within ± 2 % at calibrated typical flow rate. A certificate of calibration shall be provided with each flowmeter.

[*Editor's note: the following is provided as an example of the level of detail required for one measurement device technology, replacing most of what is in 3.6.1.3. – 3.6.1.8.*]

3.6.1.9. Airflow / temperature measurement devices (ATMD)

3.6.1.9.1. Provide airflow/temperature measurement devices (ATMD) where indicated on the plans.

3.6.1.9.2. Fan inlet measurement devices shall not be substituted for duct or plenum measurement devices indicated on the plans.

3.6.1.9.3. Sensor Probes

3.6.1.9.3.1. Each sensor (assembly) shall independently determine the airflow rate and temperature at each measurement point, which are weighted equally for mathematically averaging all of the measurements arrayed in the duct or plenum cross-section prior to output.

3.6.1.9.3.2. Each sensor (assembly) shall be factory or field-calibrated to standards (equipment and methods) that are traceable to the National Institute of Standards and Technology (NIST), at a minimum of 8

airflow rates, including the minimum and maximum flow rate measurement capability of the ATMD, and 3 temperatures.

3.6.1.9.3.3. Each sensor assembly shall be verified by the manufacturer in published materials to possess insignificant drift potential over the life of the product; or, the manufacturer shall include recalibration instructions with a recommended minimum frequency of recalibrations that prevent expected drift from significantly impacting measurement uncertainty (< double the specified system error rate).

3.6.1.9.3.4. Airflow measurement accuracy shall be certified by the manufacturer to perform within +/-2% of Reading (or less) over the entire operating airflow range, in relation to the NIST-traceable reference standards used for calibration, and accounting for all components that affect total accuracy including: repeatability, zero drift, temperature effects, hysteresis, etc. In isolation, repeatability of the device should be no greater than 0.25% of Reading throughout the entire range.

a) Devices whose accuracy is the combined uncertainty in measurement using multiple components must be calibrated as a single system and demonstrate to the satisfaction of the consulting mechanical engineer that the total measurement system accuracy meets the performance requirements of this specification throughout the measurement range.

b) Devices whose accuracy is dependent upon preventative or corrective maintenance must indicate the level, type, any special equipment required and frequency of the maintenance activities needed to ensure that the specified accuracy is available continuously, with degradation in performance of no greater than double the specified error rate, at any time within the maintenance and calibration cycles.

3.6.1.9.3.5. Temperature accuracy shall be 0.15° F (0.1° C) over the entire operating temperature range of -20° F to 160° F (-28.9 to 71.1° C)

3.6.1.9.3.6. The operating humidity range for each sensor probe shall be 0-99% RH (non-condensing).

3.6.1.9.3.7. Each sensor probe shall have an integral, UL-Listed, plenum rated cable and terminal plug for connection to a remotely mounted transmitter.

3.6.1.9.3.8. Each sensor assembly shall not require matching to the transmitter in the field.

3.6.1.9.3.9. A single manufacturer shall provide and be responsible for the performance of both the airflow/temperature measuring probe(s) and transmitter for each measurement location.

3.6.1.9.4. Duct and Plenum Probes

3.6.1.9.4.1. The minimum number of measurement points in a cross-sectional array (individual sensors/sensor assemblies) provided for each location to be averaged shall be as follows:

Duct or Plenum Free Area (ft.^{2})	Duct or Plenum Free Area (M^2)	Min. Total # Sensors / Location
<2	≤ 0.093	4
2 to < 4	>0.093 to < 0.372	6
4 to < 8	0.372 to < 0.743	8
8 to <16	0.743 to < 1.115	12
≥16	1.115 to < 1.486	16

Area (m^2)	**Sensors**		
≤ 0.093	2	≤ 1	2
>0.093 to < 0.372	4	>1 to <4	4
0.372 to < 0.743	6	4 to <8	6
0.743 to < 1.115	8	8 to <12	8
1.115 to < 1.486	12	12 to <16	12
≥ 1.486	16	≥16	16

3.6.1.9.4.2. The operating airflow range shall be 0 to 5,000 ft/min (25.4 m/s) unless otherwise indicated on the plans.

3.6.1.9.5. Transmitters

3.6.1.9.5.1. The transmitter shall have an integral display capable of simultaneously displaying airflow and temperature in either IP or SI units. The display shall be capable of displaying individual airflow and temperature readings of each independent sensor assembly.

3.6.1.9.5.2. The transmitter shall be capable of field configuration and diagnostics using an on-board pushbutton interface and display.

3.6.1.9.5.3. The transmitter shall have a power switch and operate on 24 VAC (isolation not required).

3.6.1.9.5.4. The operating temperature range for the transmitter shall be -20 °F to 120 °F (-28.9 °C to 48.9 °C). The transmitter shall be installed at a location that is protected from weather and water.

3.6.1.9.5.5. The transmitter shall be capable of communicating with other devices using one of the following interface options:

a) Linear analog output signals for airflow and temperature: Field selectable, fuse protected and isolated, 0-10VDC / 4-20mA (4-wire)
b) RS-485
c) 10 Base-T Ethernet
d) LonWorks Free Topology

3.6.1.9.5.6. The transmitter shall be capable of accepting an infra-red interface card for downloading airflow and temperature data or uploading transmitter configuration data using a handheld PDA.

a) Provide PDA upload/download software.
   i. Download software shall be capable of displaying and saving individual sensor airflow rates, the average airflow rate, individual sensor temperatures and the average temperature received from the transmitter.
   ii. Upload software shall be capable of displaying and saving all setup parameters that can be configured using the on-board pushbutton interface and display.
b) Provide a spreadsheet file capable of creating balance reports from PDA data files transferred to a Windows 98 or higher based PC.
c) Provide a spreadsheet file to create configuration data files that can be transferred from a Windows 2000, Windows XP or higher based PC to a PDA for upload to one or more transmitters.

3.6.1.9.6. The ATMD shall be UL-Listed as an entire assembly.

3.6.1.9.7. The manufacturer's authorized representative shall review and approve placement and operating airflow rates for each measurement location indicated on the plans.

3.6.1.9.7.1. A written report of the review shall be submitted to the consulting mechanical engineer if any measurement locations do not meet the manufacturer's placement requirements.

3.6.2. Outside airflow applications

3.6.2.1. Airflow/Temperature Measurement Devices

3.6.2.1.1. Provide airflow/temperature measurement devices (ATMD) where indicated on the plans**.**

3.6.2.1.1.1. Each ATMD shall consist of one or more sensor probes and a single, remotely mounted, microprocessor-based transmitter capable of independently processing up to 16 independently wired sensor assemblies, in accordance with the details in Section 3.6.1.10.

3.6.2.1.1.2. Each ATMD shall be installed at the AHU manufacturer's factory during equipment assembly or in the field before start-up, in accordance with the instructions of the ATMD manufacturer to insure optimal field performance.

3.6.2.1.2. Intake Dampers

3.6.2.1.2.1. Provide outdoor air intake ducts or openings intended for damper installation, sized for a minimum free area velocity of 150 ft/min (0.762 m/s) or greater at the specified design minimum airflow rate.

a) Install a separate minimum intake damper if the specified maximum airflow rate during free cooling (economizer) exceeds the maximum airflow rating of the louver or hood for water carry-over.

3.6.2.1.2.2 All dampers shall be individually actuated and independently controlled. They shall not be mechanically linked.

3.6.2.1.3 Plenum Layout – Louver or Hood Intake Systems

3.6.2.1.3.2 Provide a minimum straight duct (sleeve) length of 18 inches (457 mm) between the trailing edge of the hood or louver, and the leading edge of the fully open intake damper blade to allow for installation of specified airflow measuring devices. (Note: Refer to plan details for schematic representations of these dimensional relationships.)

3.6.2.1.3.3 If a minimum intake damper is required, the sleeve shall be partitioned into two sections, separating the minimum intake damper from the maximum intake damper.

3.6.2.1.3.4 Actual plenum depth should be based on louver or hood performance data and the maximum airflow rate limits necessary to minimize water carry-over into the intake system during all modes of normal operation.

3.6.3 Fan inlets: [*Editor's note: Installing an airflow meter at a fan inlet is not recommended as they require field calibration. Site calibration will require a method suitable for the installation. This will include an approach and field equipment comparable to ratings in Section 4. If necessary use the following.*]

3.6.3.1 Fan inlet air flow station mounted on fan bell. Sensor shall be installed on each inlet of double width fan.

3.6.3.2 Refer to 3.6.1.2 to 3.6.1.8 above as base parameters are the same.

3.7. Power Measurement Devices

3.7.1. Three phase power shall be measured using 3 phase 3 wire or 3 phase 4 wire sensors and signal conditioning that yield true RMS input power based on measured current, voltage and power factor. The power measurement device shall be capable of sensing direct current and fundamental harmonic through the 50th harmonic (odd and even) with no derating in accuracy through the 25th harmonic.

3.7.2. Each power measurement device shall have rated instrument accuracy within ±1.5% of reading. Repeatability shall be within ±1.0 % of reading. Resolution of any signal conditioning and readout device shall be within ±0.1% of reading. The instrument shall be capable of measuring power within the stated accuracy over its entire range. These requirements are for the end-to-end measurement system including the sensor, transmitter and any signal conditioning.

3.7.3. Single watt / watt-hour transmitter or computer bus, gateway or interface output from VSD, providing fuse protected and isolated, 0-10VDC / 4-20mA (4-wire) analog or digital output of electric power. [*Editor's note: power readings provided by VSDs are to be considered suspect; some manufacturers only provide motor output power, which does not take into account VSD efficiency*].

3.7.4. Devices that have programmable outputs and can be networked to suit multiple field applications are preferred.

3.8. Weather Station

3.8.1. Each temperature measurement device shall have a rated instrument accuracy within 0.2 ºF. Repeatability shall be within 0.2 ºF. Resolution of any signal conditioning and readout device shall be within 0.05 ºF. These requirements are for the end-to-end measurement system including the sensor, transmitter and any signal conditioning.

3.8.2. Provide aspirated fan powered sensing chamber.

3.8.3. The weather station should be mounted on a north-facing wall. If solar exposure is possible, it will need to be mounted in a naturally ventilated enclosure that allows access by the operators for maintenance. [*Editor: These devices should note be mounted on or next to high mass walls.*]

3.8.4. Provide 115 Volt AC supply and an area above unit to mount container of distilled water.

3.8.5. Provide three year supply of fresh wicks.

3.8.6. Maintenance will include replenishment of distilled water in the reservoir and fresh wicks every six months and replacement of air filters annually.

3.9. Zone Temperature Measurement Devices

3.9.1. Each temperature measurement device shall have a rated instrument accuracy within 0.5 ºF. Repeatability shall be within 0.5 ºF. Resolution of any signal conditioning and readout device shall be within 0.1 ºF. These requirements are for the end-to-end measurement system including the sensor, transmitter and any signal conditioning.

3.9.2. The device should not be mounted on exterior walls or within 6 feet of windows or doorways.

3.10. Wiring

3.10.1. All wiring shall be provided and installed as required to meet the measurement accuracy goals specified in Section II.D.

3.10.2. All control and interlock wiring shall comply with national, state and local electrical codes.

3.10.3. All NEC Class 1 (line voltage) wiring shall be UL Listed in approved raceway per NEC requirements.

3.10.4. All low-voltage wiring shall meet NEC Class 2 requirements. (Low-voltage power circuits shall be sub-fused when required to meet Class 2 current-limit.) Class 2 wiring shall be installed in UL Listed approved raceway, except where wires are in concealed in accessible locations, approved cables not in raceway may be used, provided that cables are UL Listed for the intended application. For example, cables used in ceiling return plenums shall be UL Listed specifically for that purpose.

3.10.5. Do not install Class 2 wiring in raceway containing Class 1 wiring. Boxes and panels containing high-voltage wiring and equipment may not be used for low-voltage wiring except for the purpose of interfacing the two (e.g., relays and transformers).

3.10.6. Do not install wiring in raceway containing tubing.

3.10.7. Where Class 2 wiring is used without raceway, it shall be supported from or anchored to structural members neatly tied at 10 foot intervals. Cables shall not be supported by or anchored to ductwork, electrical raceways, piping, or ceiling suspension systems and at least 1 foot above ceiling tiles and light fixtures.

3.10.8. All wire-to-device connections shall be made at a terminal block or terminal strip. All wire-to-wire connections shall be at a terminal block.

3.10.9. All field wiring shall be properly labeled at each end, with self-laminating typed labels indicating device address, for easy reference to the identification schematic. All power wiring shall be neatly labeled to indicate service, voltage, and breaker source.

3.10.10. Use coded conductors throughout with different colored conductors.

3.10.11. All wiring within enclosures shall be neatly bundled and anchored to permit access and prevent restriction to devices and terminals.

3.10.12. Maximum allowable voltage for control wiring shall be 120 V. If only higher voltages are available, the Contractor shall provide step-down transformers.

3.10.13. All wiring shall be installed as continuous lengths, with no splices permitted between termination points.

3.10.14. Install plenum wiring in sleeves where it passes through walls and floors. Maintain fire rating at all penetrations.

3.10.15. Size of raceway and size and type of wire shall be the responsibility of the Contractor, in keeping with the manufacturer's recommendation and NEC requirements.

3.10.16. Include one pull string in each raceway 1 inch or larger.

3.10.17. Control and status relays are to be located in designated enclosures only. These enclosures include packaged equipment control panel enclosures unless they also contain Class 1 starters.

3.10.18. Conceal all raceways, except within mechanical, electrical, or service rooms. Install raceway to maintain a minimum clearance of 6” from high-temperature equipment (e.g., steam pipes or flues).

3.10.19. Secure raceways with raceway clamps fastened to the structure and spaced according to code requirements. Raceways and pull boxes may not be hung on flexible duct strap or tie rods. Raceways may not be run on or attached to ductwork.

3.10.20. Install insulated bushings on all raceway ends and openings to enclosures. Seal top end of all vertical raceways.

3.10.21. The installing Contractor shall terminate all control and/or interlock wiring, and shall maintain updated (as-built) wiring diagrams with terminations identified at the job site.

3.10.22. Flexible metal raceways and liquid-tight, flexible metal raceways shall not exceed 3 feet in length and shall be supported at each end. Flexible metal raceway less than ½” electrical trade size shall not be used. In areas exposed to moisture liquid-tight, flexible metal raceways shall be used.

3.10.23. Raceway must be rigidly installed, adequately supported, properly reamed at both ends, and left clean and free of obstructions. Raceway sections shall be joined with couplings (per code). Terminations must be made with fittings at boxes, and ends not terminating in boxes shall have bushings installed.

3.10.24. Electrical service to controls panels and control devices shall be provided by isolated circuits, with no other loads attached to the circuit, clearly marked at its source. The location of the breaker shall be clearly identified in each panel served by it. If a spare breaker is not available within an electrical panel, the installing Contractor shall be responsible for providing any and all equipment and labor necessary to supply an isolated circuit. Controllers controlling only packaged air conditioning equipment may be powered directly from the packaged units control circuit.

3.11. Data Acquisition

3.11.1. The data acquisition system’s analog to digital converter (A/D) shall have a rated instrument full scale accuracy of 0.1%. Repeatability shall be within 0.05% of full scale. The minimum resolution shall be within 0.025% of full scale range and one second for time.

3.11.2. The A/D shall be a factory calibrated monolithic successive approximating A/D or a SAR converter A/D to at least native 10 bit or better with a minimum drift of

30ppm/deg C and minimum resolution of 2.44 mV/bit. 8 bit devices using software or algorithms to achieve 10 bit resolution are not acceptable.

3.11.3. The data acquisition system, including control network and field panels, shall be capable of collecting all point data at a minimum sampling interval of one minute without measurably affecting control performance. Continuous sampling is preferred.

3.11.4. Pulse output devices must provide a pulse value that is less than or equal to 1/256 times full scale (>=8 bit, >= 4.27 Hz) and the smallest scalar resolution possible (0.0001) must be used for the input function.

4. Sensors, Meters, and Calculated Values for Performance Monitoring

4.1. Contractor shall provide all measured, virtual and calculated points listed in 4.4 Table 3.

4.2. Table 3 Legend:

4.2.1. - % of reading unless otherwise noted

4.2.2. Abbreviations:

4.2.3. AI – analog input

4.2.4. DI – digital input

4.2.5. C – calculated value

4.2.6. CB – computer bus, gateway or interface input

4.2.7. P – programmed output

4.2.8. # – unit number

4.2.9. x – denotes more than one value in a group

4.3. Contractor shall develop constants used in calculations except as noted.

4.3.1. C1 – Building Floor Area (ft2): Owner shall provide this value

4.3.2. C2 – constant heating value (Btu/std. ft^3/100,000): Owner shall obtain this value from the local gas utility.

4.3.3. C3 – 0.0293 kW per Btu/hr

4.3.4. C4 – 0.0419 (assumes chilled water at 45 ºF, no glycol)

4.4. Table 3 – Sensors, Meters, and Calculated Values

#	Example Point Name	Point Description and Location if applicable	Input Type	Sensor Type or Calculation Method	Required End-to-end Accuracy *	Display Resolution	Refresh Interval (min)	Trend Interval (min)
S1	OA Temp	Outdoor Air Dry Bulb Temperature	AI	Locate in weather station outside the building in fully shaded location or ventilated enclosure	+/- 0.2 ºF	0.01 ºF	1	10
S2	OA Wb Temp	Outdoor Air Wet Bulb Temperature	AI	Locate in weather station outside the building in fully shaded location or ventilated enclosure	+/- 0.2 ºF	0.01 ºF	1	10
S5	BldgMn Gas Flow or Site Gas Flow	Building Main Gas Meter Flow	AI or DI	Pressure compensated; continuous output	+/- 1.0 % of reading	0.1 scfm	1	1
S7	BldgMn Power or Site Power	Building Main Meter Power	AI or DI	PML 8500 or equal	+/- 1.0 % of reading	0.1 kW	1	1
S9	Rm#Zone Temp	Zone temperatures	AI	10000 Ohm thermistor or 1000 Ohm RTD	+/- 0.5 ºF	0.1 ºF	1	1
S12	Chlr# kW	Chiller # Power	AI, DI or CB	True RMS, Three Phase, integrated equipment, stand alone analog or pulse output or networked power meter; use maximum resolution if pulse output	+/- 1.5 % of reading	0.01 kW	1	1
S13	PriChWP# kW	Primary Chilled Water Pump # Power	AI, DI or CB	True RMS, Three Phase, integrated equipment, stand alone analog or pulse output or networked power meter; use maximum resolution if pulse output	+/- 1.5 % of reading; +/- 3.0 % of reading if from VFD	0.01 kW	1	1
S14	Chlr#CondWP kW	Chiller # Condenser Water Pump Power	AI, DI or CB	True RMS, Three Phase, integrated equipment, stand alone analog or pulse output or networked power meter; use maximum resolution if pulse output	+/- 1.5 % of reading; +/- 3.0 % of reading if from VFD	0.01 kW	1	1

#	Example Point Name	Point Description and Location if applicable	Input Type	Sensor Type or Calculation Method	Required End-to-end Accuracy *	Display Resolution	Refresh Interval (min)	Trend Interval (min)
S15	ClgTF# kW	Cooling Tower Fan # Power	AI, DI or CB	True RMS, Three Phase, integrated equipment, stand alone analog or pulse output or networked power meter; use maximum resolution if pulse output	+/- 1.5 % of reading; +/- 3.0 % of reading if from VFD	0.01 kW	1	1
S16	SecChWP# kW	Secondary Chilled Water Pump # Power	AI, DI or CB	True RMS, Three Phase, integrated equipment, stand alone analog or pulse output or networked power meter; use maximum resolution if pulse output	+/- 1.5 % of reading; +/- 3.0 % of reading if from VFD	0.01 kW	1	1
S20	Plant ChWS Temp	Chilled Water Plant (Loop #) Chilled Water Supply Temperature	AI or CB	10000 Ohm thermistor or 1000 Ohm RTD	+/- 0.1 ºF	0.01 ºF	1	1
S21	Plant ChWR Temp	Chilled Water Plant (Loop #) Chilled Water Return Temperature	AI or CB	10000 Ohm thermistor or 1000 Ohm RTD	+/- 0.1 ºF	0.01 ºF	1	1
S22	Plant ChW Flow	Chilled Water Plant (Loop #) Chilled Water Flowrate	AI or CB	Hot tapped insertion flow meter	+/- 2.0 % of reading	0.1 gpm	1	1
S26	AH#SF Flow	Air Handler # Supply Fan Airflow Rate (penthouse)	AI	Vortex shedding sensor on fan inlet	+/- 5.0 % of reading *	0.1 cfm	1	1
S33	AH#SF kW	Air Handler # Supply Fan Power	AI, DI or CB	True RMS, Three Phase, integrated equipment, stand alone analog or pulse output or networked power meter; use maximum resolution if pulse output	+/- 1.5 % of reading; +/- 3.0 % of reading if from VFD	0.1 kW	1	1
S34	AH#RF kW	Air Handler # Return Fan Power	AI, DI or CB	True RMS, Three Phase, integrated equipment, stand alone analog or pulse output or networked power meter; use maximum resolution if pulse output	+/- 1.5 % of reading; +/- 3.0 % of reading if from VFD	0.1 kW	1	1

#	Example Point Name	Point Description and Location if applicable	Input Type	Sensor Type or Calculation Method	Required End-to-end Accuracy *	Display Resolution	Refresh Interval (min)	Trend Interval (min)
S35	AH#MA Temp	Air Handler # Mixed Air Temperature	AI	Locate in air handler's mixed air section; to minimize effects of stratification use averaging sensor if possible	+/- 0.2 ºF	0.01 ºF	1	10
S36	AH#RA Temp	Air Handler # Return Air Temperature	AI	Locate upstream of air handlers return air damper	+/- 0.2 ºF	0.01 ºF	1	10
S37	AH#SA Temp	Air Handler # Supply Air Temperature	AI	Locate downstream of air handlers coils and supply fan	+/- 0.2 ºF	0.01 ºF	1	10
S39	WB Tot Water Flow	Whole Building Total Water Flowrate	AI or DI	Hot tapped insertion flow meter	+/- 2.0 % of reading	0.1 gpm	1	1
S44	AH#SF Status	Air Handler # Supply Fan Status	AI or DI	Current switch	N/A	N/A	1	10
V1	AH#OA Dmpr%	Air Handler # Outside Air Damper Position (%)	P	Virtual point that commands the damper's position	N/A	0.1 %	1	10
V2	AH#RA Dmpr%	Air Handler # Return Air Damper Position in % of open	P	Virtual point that commands the damper's position	N/A	0.1 %	1	10
V3	AH#ChWVlv%	Air Handler # Chilled Water Valve Position in % of open	P	Virtual point that commands the valve's position	N/A	0.1 %	1	10
V4	AH#Mode	Air Handler # Mode	P	Virtual point(s) that identify which mode the air handler is in (Warm-up, Cool-down, Set-up, Set-down, Occupied)	N/A	N/A	1	10
V5	AH#SA Temp Sp	Air Handler Supply Air Temperature Set-point	P	Virtual point that commands the supply air temp loop	N/A	0.01 ºF	1	10
M1	Bldg Max kW	Whole-Building Maximum Power	C	Maximum of measured value [S7] over a given time interval	+/- 1.5%	0.1 kW	1	10
M4	WB Elec EUI	Whole-Building Area-Normalized Electric Energy Use Intensity	C	Measured value [S7] integrated over a given interval divided by a constant #C1	N/A	0.1 kWh/ft^2	1	10
M5	WB NaGas Heat-rate	Whole Building Natural Gas Heat-rate	C	Measured value [S5] divided by a constant #C2	NA	0.1 therms/min	1	10
M6	WB NaGas EUI	Whole-Building Area-Normalized Gas Energy Use Intensity	C	Measured value [S5] integrated over a given interval divided by a constant #C1	N/A	0.1 kBtu/ft^2	1	10

#	Example Point Name	Point Description and Location if applicable	Input Type	Sensor Type or Calculation Method	Required End-to-end Accuracy *	Display Resolution	Refresh Interval (min)	Trend Interval (min)
M8	Avg Daily OA Temp	Average Daily Outdoor Air Temperature	C	Average of instantaneous measured values [S1]	N/A	0.01 ºF	1	10
M15	ChW Plant ΔT	Chilled Water Plant Delta-T	C	Calculated difference of 2 measured values [S21-S20]; assumes one chilled water loop	0.1 ºF	0.01 ºF	1	10
M16	ChW Plant Power	Chilled Water Plant Power	C	Sum of measured values [S12, S13, S14, S15, S16]	+/- 1.5%	0.1 kW	1	10
M17	Plant ChW tons	Plant Chilled Water (Loop #) Thermal Cooling Output	C	Calculated value [M15] multiplied by measured valued [S22] multiplied by a constant #C4; *assumes one chilled water loop*	+/- 3 %	0.1 tons	1	10
M18	ChWPlant kW/ton	Chilled Water Plant Efficiency	C	Calculated value [M16] divided by calculated value [M17]	+/- 4 %	0.01 kW/ton	1	10
M26	Tot AH kW	Total Air Handler Power	C	Sum of concurrently measured values [S33x+S34x]	+/- 1.5 %	0.1 kW	1	10
M27	Tot AH cfm	Total Air Handler Flow	C	Sum of measured values [S26x]	+/- 5 %	0.1 cfm	1	10
M28	Tot AH SpecPower	Total Air Handler Specific Power	C	Calculated value [M26] divided by a calculated value [M27]	+/- 6 %	0.1 kW/cfm	1	10
M63	AH# OA Temp-Fraction	Air Handler # Outside Air Temperature Fraction	C	Instantaneous difference of two measured values [S35, S1] divided by the difference of two measured values [S36, S35]	NA	0.001	1	1
M64	AH#OA Dmpr - Fraction	Air Handler # Outside Air Damper Fraction	C	Instantaneous quotient of virtual point [V1] divided by the sum of virtual points [V1] and [V2]	NA	0.001	1	1
M70	WB Water EUI	Whole-Building Area-Normalized Water Use Intensity	C	Measured value [S39] integrated over a given interval divided by a constant #C1	N/A	0.1 kgal/ft^2	1	10

4.5 Instrumentation Table Submittal. Contractor shall submit an Instrumentation Table containing the following information**.**

4.5.1 Point name per 4.4 Table 3.

4.5.2 Point description: provide building designation, system type, equipment type, engineering units and functionality; include a description of its physical location

4.5.3 Expected range (upper and lower limit)

4.5.4 Instrumentation (if applicable): manufacturer, model number, range, accuracy specification per section 3.

4.6 Data Point Summary Table Submittal. Contractor shall submit Data Point Summary Table based on Table 3 containing the following information.

4.6.1 Point name

4.6.2 Point description: provide building designation, system type, equipment type, engineering units and functionality; include a description of its physical location

4.6.3 Type

4.6.3.2 AI: analog input

4.6.3.3 DI: digital or binary input

4.6.3.4 CBAI: communication bus analog input

4.6.3.5 CBDI communication bus digital (binary) input

4.6.3.6 P: programmed (e.g. soft or virtual point in control sequence such as a PID input or output)

4.6.3.7 C: calculated value; a soft or virtual point that is specified in section 4.If calculated value, provide formula.

4.6.4 Expected range (upper and lower limit)

4.6.5 Input resolution (this is critical for pulse type watt meters; use the smallest resolution possible)

4.6.6 Number of significant digits after decimal point

4.6.7 Data trend interval

4.5.1 Number of samples stored in local controller before transfer to host computer/ server database

4.5.2 Communication protocol information: Ethernet backbone network number, device ID, object ID

4.5.3 Block trend grouping designation

4.5.4 EMCS Controller designation

4.5.5 If time based integrated values are required, provide time periods: minutes, daily, weekly, monthly, and yearly. Also indicate if it is a running average.

4.5.6 Logic diagrams and/or code and any constants for creating the calculated values specified in Table 3 shall be submitted for review and approval

5.0 Data Point Naming Convention

5.1. ***Name Architecture***. Contractor shall use the point naming convention specified below in all documentation and programming.

5.1.1 Format is a four-element string including Location, System, Equipment, and Function. Equipment and function can be interchanged if desired.

5.1.2 Each element in string shall be as long as possible to aid readability without exceeding the overall maximum string length.

5.1.3 Location must include Building, Floor and Room number where applicable.

5.1.4 Names need to be unique. Each of the four elements in a name should include a number if required for uniqueness.

5.1.5 Use agreed upon names if possible. If for some reason a name is too long, an abbreviated string should include a capitalized first letter of each element, or other delimiter as appropriate (e.g., a period). Be as clear as possible, using as much of the original name as possible. Do not omit a word or first letter.

5.1.6 When using uppercase letters as delimiters, do not use uppercase letters other than for the first letter of an element word.

5.1.7 Do not use the same capitalized letter for different meanings, except for an existing site-specific designation or as specified in Table 4 below.

5.1.8 BACnet defined abbreviations shall be used if possible, or use abbreviations in Table 4. [*Editor: This table and the sample point names that follow are provided as examples*.]

Table 4 – Data Point Naming Abbreviations

A	Air
AC	Air-conditioning
AH	Air Handler
Avg	Average
Blr	Boiler
Bldg	Building
cfm	cubic feet per minute
Chlr	Chiller

ChW	Chilled Water
Clg	Cooling
CondW	Condenser Water
CT	Cooling Tower
Dmpr	Damper
DPr	Differential Pressure
E	Entering
Eff	Efficiency
Elec	Electric
EUI	Energy Use Intensity
F	Fan
Flr	Floor
InHdr	Inlet Header
GPr	Gauge Pressure
He	Heat or Heating
Ho	Hot
HVAC	Heating, Ventilation and Air-conditioning
Hz	Hertz
Inst	Instantaneous
kW	kilowatt
L	Leaving
Ltg	Lighting
M	Mixed
Max	Maximum
Mn	Main
Min	Minimum
OA	Outdoor Ambient or Air
P	Pump
Pres	Pressure
Pri	Primary
R	Return
Rm	Room
RTU	Roof-top (packaged) unit
S	Supply
SD	Supply Duct
Sec	Secondary
Stat	Status
Stc	Static
Sys	System
Temp	Temperature
Tot	Total
VFD	Variable Frequency Drive
WB	Whole Building
Wb	Wet-bulb
Z	Zone

Sample point names:

- Bldg01AH02SA Temp = Building 1 Air Handler 2 Supply Air Temp
- Bldg01AH01TempSA = Building 1 Air Handler 2 Supply Air Temp

6.0 Trending

[*Editor: The following specification may be in conflict with an existing specification. It is provided to cover all points that may require trending***.]**

6.1. ***Points to be trended.*** Contractor shall provide trending capability for the following point types:

6.1.1. All specified analog and digital input and output values

6.1.2. All setpoints

6.1.3. All PID loop input and output values

6.1.4. All calculated values

6.1.5. COV. Use of change of value sampling (COV) shall only be used for digital input and output values. [*Editor: Sampling data using COV can be problematic. It can be prohibited here if desired.*]

6.2. ***Group Trends***. Group trend values in trend blocks in a logical way. Identify trend blocks in the Data Point Summary Table specified in Section 4.6.

6.2.1. Group all control loop values together. An example would be an air handling unit discharge air temperature with the analog temperature input, output(s) to the control device(s) and PID control setpoint on the same trend.

6.2.2. Group all data for one "system" together. An example would be chilled water, which has chiller status, chilled water supply temperature, chilled water return temperature, chilled water supply setpoint temperature and outside air temperature together.

6.2.3. If more than one system exists with the same content, provide unique identifier for each system using system name/number.

6.2.4. See Section 8 for other requirements.

7. Archiving data

7.1. ***Trend Data Storage types.*** Three types of data archiving systems will be elaborated upon for trend storage. The type of data will be followed by the general equipment arrangement to satisfy the condition. The conditions may be combined if the system description and hierarchy is submitted for review and approval in advance. The following data storage type guidelines must satisfy the previous section requirements for calculations, aggregation and functionality.

7.1.1. Flat file database integrated or in parallel to the EMCS. Due to the real time need to access data, perform calculations and aggregation, and provide more manageable site data routines, this type of database will not be considered. The system defined in this specification is required to provide real time access data, perform calculations and aggregation, and provide more manageable site data routines.

7.1.2. Stand-alone database integrated or in parallel to the EMCS. This type will be considered.

7.1.3. Formal database integrated or in parallel to the EMCS. This type will be considered.

7.2. Data shall be stored in SQL compliant database format or time series format. Minimum requirements are a SQL server or approved equal.

7.3. The database shall allow other application programs read access to the data with appropriate password protection while the database is running. The database shall not require shutting down in order to access or have data added. Data needed for third party or EMCS routines shall be able to be read from the database without interrupting the continuous storage and calculation of trend data being carried in the EMCS. [*Editor: Web services may be a preferable alternative to direct database access. It's more universal, and provides additional features such as interpolation or "closest sample" for comparing trends with differing sample times. The ASHRAE/BACnet Web services standard provides an excellent format for Web services trend data retrieval.*]

7.4. ***Trend data Interval and Quality***. Trend data shall be archived in a database from field equipment in time intervals no less than once per day. Storage on the field equipment will be reset once data is exported to allow for trending if communication is disrupted. Data will be uploaded once communication is re-established. Blank or null values in the database will be replaced with actual data. Calculations and other metrics will be updated once controller data is uploaded. This overall system update to check for new data should be automated to run once a day.

7.4.1. All data shall be stored in database file format for direct use by third-party application programs. Operation of system shall stay completely online with instantaneous updates during all graphing operations. New data is added to the screens once the database is updated.

7.4.2. Sufficient data storage capacity will be able to store at least two years of data for all data points. In addition, storage capacity will also allow for compression of one year of data for maintenance.

7.5. Time Stamps shall be collected on all data. The timestamp depending on system architecture will be captured at the field controller or system controller and directed to the database archive.

7.5.1. Field Controller including control network and field panels shall be capable of collecting and storing all point data at a uniform sampling interval of one minute without measurably affecting control performance, refresh rates and two way control signaling. Data safeguards for loss of communication will have to be established where up to 24 hours or data will be stored if access to the database is lost. Any other modifications will have to be approved by submittal.

7.5.1.1. Time stamp for the point data shall be assigned at the controller and passed to the storage depository.

7.5.1.2. The storage depository will use the database time index and manage data from multiple fields and systems.

7.5.2. Field Controller to PC / System Controller time stamp will be utilized if field controller does not have storage or an internal clock. Field controller shall send data to System controller or embedded computer for data archiving and then data will be exported once on-board memory is 75% used or transferred at a minimum of once a day to the database. This assumes that a stand alone database will be integrated within the EMCS or linked via ODBC, XML or other protocol for data to be stored. Data safeguards for loss of communication will have to be established where up to 24 hours or data will be stored if access to the database is lost. Any other modifications will have to be approved by submittal.

7.5.2.1. The time stamp will be assigned by the field controller or System Controller / embedded computer depending on system hierarchy, infrastructure and bandwidth. Time will not exceed $1/5^{th}$ of a second between event and time sampling.

7.5.2.2. The storage depository will use the database time index and manage data from multiple fields and systems.

7.5.3. Field Controller to PC / System Controller to Server with database. The point data is stored and sent to a multiple cursor database (*be specific)*. Data in this configuration is sent directly to the database. The data timestamp is used and managed by the database time index. Data safeguards for loss of communication will have to be established where up to 24 hours or data will be stored if access to the database is lost. Any other modifications will have to be approved by submittal.

7.6. User accounts for the terminal, remote and web based clients will be divided as follows. Variances in the user levels can be modified upon approved submittal.

7.6.1. Guest shall be able to view the system and update displays. No controls, programming or administrative tools will be available.

7.6.2. Operator shall be able to operate "Guest" functions and also be able to export data from existing database tables and queries, review control settings and check system status.

7.6.3. Programmer shall be able to operate "Guest" and "Operator" functions and also be able to change database variables, time intervals and start new trends.

7.6.4. Administrator shall be able to change and add new user categories, enable/disable available functions, and create/modify graphic displays. The administrator is the only user that can delete data.

7.7. *Access to Data.*

7.7.1. Data must to be available through the Owner's intranet and/or internet (with appropriate security clearance).

7.7.2. System server shall be capable of periodically gathering performance data stored in real time in the field equipment and automatically archiving these data without operator intervention.

7.7.3. All performance data required to generate the graphic displays listed must be archived.

7.7.4. Archive files must be appended with new data, allowing data to be accumulated.

7.7.5. Systems that write over archived data shall not be allowed unless limited file size is specified and automatic archiving is employed on a scheduled basis to prevent loss of data.

7.7.6. Performance data shall be capable of being displayed in user selectable engineering units including both English and SI units.

7.8. *Trend Data Export for Analysis by Other Software.*

7.8.1. Historical and current data held in temporary memory shall be exportable to following formats for analysis by external software: [*Editor: need must identify their preferred format. See Appendix B for examples.]*

7.8.2. Exported data shall have the following characteristics:

7.8.2.1. Exported data shall contain no duplicate records or duplicate time stamps in output files. Each date/time stamp for a specific point shall be unique. The export query shall be for a specific point or multiple points in a defined group. These groups and / or points will be submitted for approval. Users shall be provided the capability to add, modify or view depending on access level.

7.8.2.2. Date/Time fields shall be in a single column in a format automatically recognized by common spreadsheet or database software tools (*be specific*). The date/time stamp column can be split into two columns as an available user defined output. The date and time identifiers will also be split to maintain the column and row. The single date/time column will be the default condition.

7.8.2.3. The data shall be fully contained in a single file or table for each point. Data shall not span multiple files or database tables. Users can have the option

to modify export file start and end file date span depending on third party program requirements to evaluate the data.

7.8.2.4. Each field of data shall have one and only one unique identifier. The label shall be in the first row of the file. Labels should not be repeated in the stream of data. No unit row is the default. The user shall be able to select if this row is activated in the export.

7.8.2.5. Each table or file shall have a single date/time stamp. Multiple fields that are sampled on the same time stamp can be combined in a single file or table provided that they have the same number of records and are stored in the following default export format:

Date/Time	Field 1	Field2	Field n
DateTimeValue1	Value 11	Value 21	Value n1
…			
DateTimeValuej	Value 1j	Value 2j	Value nj

Example Export Optionally selected by user:

Date	Time	Field 1	Field2	Field n
Date	Time	Unit 11	Unit 21	Unit n1
Date Value	TimeValue	Value 12	Value 22	Value n2
…				
Date Value	TimeValuej	Value 1j	Value 2j	Value nj

7.8.3. Data transfer shall be by OBDC or Web services.

7.9. User with the adequate access level shall be able to change the performance monitoring setup. This includes the meters to be logged, meter pulse value, and the type of energy units to be logged. All points on the system shall be capable of being displayed, archived, and re-displayed from archive.

7.10. Archiving program shall follow password levels requirements for users to delete, modify or change archive parameters. [*Editor: This can be edited to allow admin to be part of the process but not impact the normal operation.*]

8. Graphics Requirements

[*Editor: This section specifies graphic requirements presenting the building's performance results to the user. These requirements are structured by display type (graphic, data table, time series group trend plots, XY group trend plots) and then by building geometry, systems and components, which are defined within an object-oriented structure. All data points are either located within a specific building geometry element (e.g. campus, building, floor, zone, etc), or they are located within a building system or its components (e.g., Chilled Water Plant, Chiller, Heating System, Boiler, Air Handler, Fan, VFD, Electrical System, Lighting, Plug Loads, etc.). Thus, all data points and visualization results can be treated as "child" objects attached to building geometry or building system objects.*]

Each of the subsections below defines specific graphic requirements. Most subsections identify the specific data points, and metrics used to generate the data display, plus the required minimum attributes of the graphic displays of (1) building geometry, (2) building systems and components, and (3) performance monitoring results, whether measured, virtual or calculated.

8.1. Graphical data displays shall be provided for:
- 8.1.1. System and equipment screens
- 8.1.2. Time weighted point screens
- 8.1.3. Tabular multi point data screens
- 8.1.4. Time series group trend plots
- 8.1.5. XY group trend plots

8.2. System and equipment graphic screens shall:
- 8.2.1. Show basic equipment such as filters, coils, valves, dampers, pumps, major equipment and pertinent data
- 8.2.2. Provide visual indication of actual equipment status not just its command
- 8.2.3. Use point-naming convention, as specified in Section 5, for equipment labels and pertinent data Indicate when a manual reset of equipment is required
- 8.2.4. Indicate what point is in override.
- 8.2.5. Sensor locations shall be identified as accurately as possible.
- 8.2.6. Graphic presentations for ancillary equipment such as exhaust fans shall be hot-linked via text links to graphic presentations of related systems and/or building graphics. Specific requirements are listed below.
- 8.2.7. Provide links to related data displays
- 8.2.8. Be viewable by all parties who access the system.
- 8.2.9. Match the actual configuration of the unit or system such that the graphic-screen print-out an operator can visit the unit and visually be able to identify ductwork and devices. A generic flow schematic is not acceptable.
- 8.2.10. Provide the following graphic links as specified include "hot spots" on the screen that shall on a "mouse-over" display the name of a new screen that will be presented if the hot-spot is clicked and if the hot-spot is clicked, display the new screen. [*Editor: For example, if a building graphic shows an isometric of a 3-story building, and if each of the floors is a "hot-spot", then if the user "mouses-over" the second floor portion of the building isometric, the name of the "second floor" display will appear. If the user "clicks" on the second floor portion of the building isometric, then the software program control will display a new "Floor Level" display*.]
- 8.2.11. Provide the following screens and requirements.
  - 8.2.11.1. **Outdoor Air Conditions.**
    - 8.2.11.1.1. Provide a graphic screen with current data for Outdoor Ambient Dry Bulb Temperature (OAT-DB) and Outdoor Ambient Wet Bulb Temperature (OAT-WB).

8.2.11.1.2. Provide a time-series plot showing the current 24 hour data profile for each point.

8.2.11.1.3. Provide a time series plot showing the current 30 day plot of Average Daily Ambient Temperature-DB

8.2.11.1.4. Provide active **text links** for

8.2.11.1.4.1. Campus / Site

8.2.11.1.4.2. Major systems

8.2.11.1.4.3. Summary tables

8.2.11.2. **Floor Level Zone Temperatures**

8.2.11.2.1. The system shall be able to display a graphic for each floor

8.2.11.2.1.1. The type of graphic display requirements listed for floor "#" shall apply to all floors, including basement(s) and penthouse.

8.2.11.2.1.2. Sensor locations will be identified on the floor level graphic, to the nearest space.

8.2.11.2.1.3. Each zone is to be labeled with its room number

8.2.11.2.1.4. A mouse over of the zone shows the terminal box number, which provides a picture link to the **Zone** level graphic**.**

8.2.11.2.1.5. An example graphic is shown below in Figure 8.L.1:

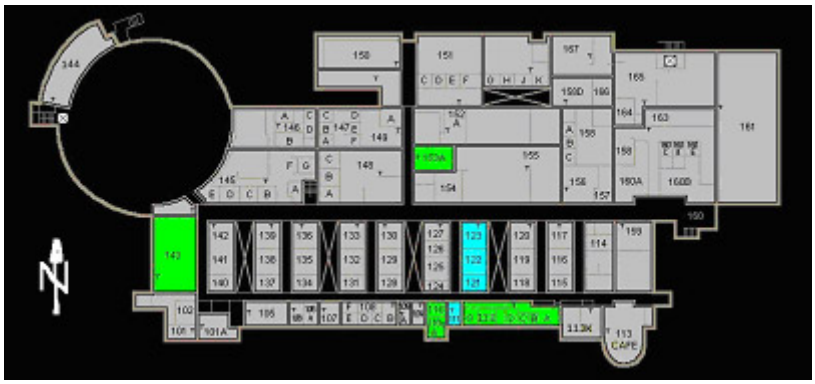


Figure 8.a Example Floor Level graphic

8.2.11.2.1.6. This graphic shall also contain text links to:

8.2.11.2.1.6.1. Campus / Site

8.2.11.2.1.6.2. Building

8.2.11.2.1.6.3. Other floors

8.2.11.2.1.6.4. Building Air Handler # and Boiler #'s

8.2.11.2.1.6.5. Chilled Water Plant

8.2.11.3. **Chilled Water (ChW) Plant**

8.2.11.3.1. If a chilled water plant is present provide an *equipment* graphic that displays an image of the Chilled Water Plant and its major components including:

8.2.11.3.1.1. Chiller(s)

8.2.11.3.1.2. Cooling tower(s)

8.2.11.3.1.3. Pumps

8.2.11.3.1.4. Valves

8.2.11.3.1.5. Sensors

8.2.11.3.1.6. The graphic display shall include related status and performance data, including OAT, OARH, Site Power, Bldg Cooling Load (tons), ChW Plant Power, Chiller kW/ton

8.2.11.3.1.7. Provide indication if the VFD is in "Auto" or "Hand" mode.

8.2.11.3.2. Figure 8.D.1.a shows an example diagram of a Chilled Water Plant with status displays of key components.

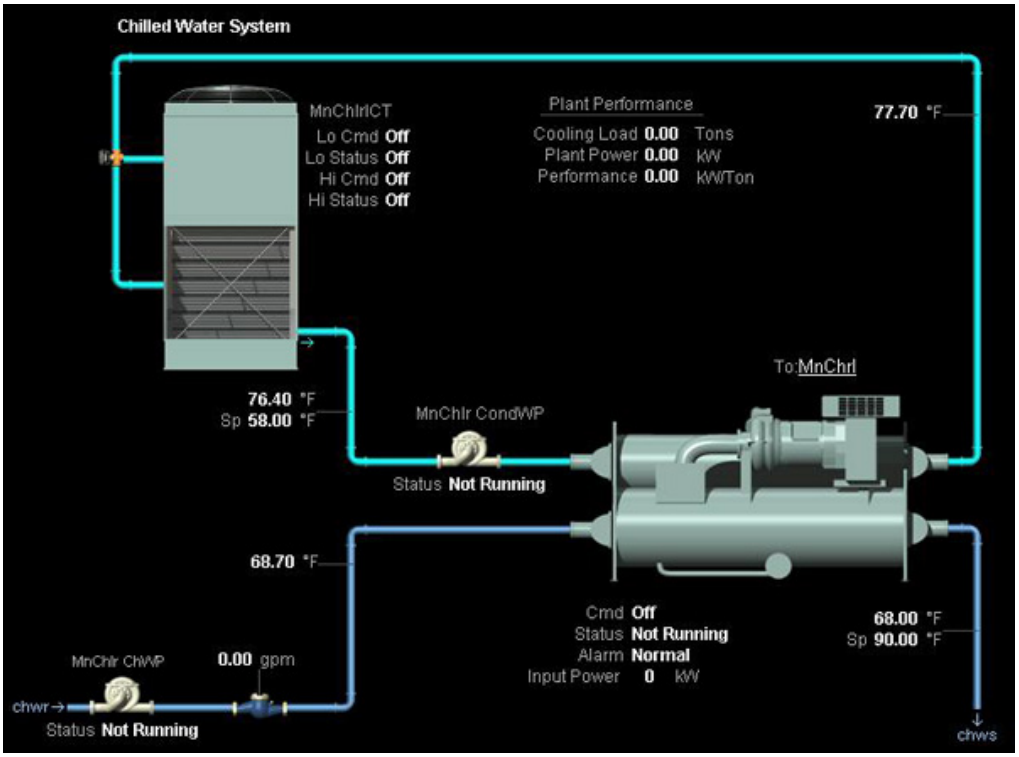


Figure 8.b Example Chilled Water Plant Graphic

8.2.11.3.3. This graphic shall also display text links to:

8.2.11.3.3.1. Campus / Site

8.2.11.3.3.2. Chiller #

8.2.11.3.3.3. Chilled Water Plant Performance

8.2.11.3.3.4. AH# Table

8.2.11.4. **Air Handlers**

8.2.11.4.1. AH #

8.2.11.4.1.1. This *equipment* graphic shall display, for each air handling unit:

8.2.11.4.1.1.1. All basic air handling unit equipment

8.2.11.4.1.1.2. Visual indication of equipment operation

8.2.11.4.1.1.3. Indicate when a manual reset of equipment is required

8.2.11.4.1.2. Figure 8.S.1 shows an example graphic of a typical AH unit with status displays for each component.

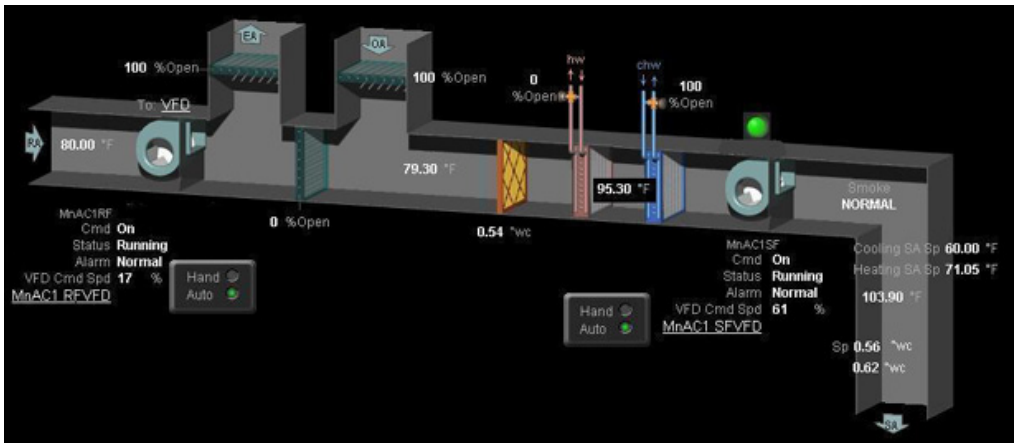


Figure 8.c Example AH# graphic with status indicators

8.2.11.4.1.3. This graphic shall also display active **text links** to:

8.2.11.4.1.3.1. Floor Level(s); It is not a requirement, but a desirable feature, that the text link to Floor Levels from a given AHU# will highlight those floors served by that AHU#. This graphic presentation capability should be provided if possible.

8.2.11.4.1.3.2. Chilled Water Plant

8.2.11.4.1.3.3. Boiler # or Boiler Plant [*which ever is applicable*]

8.2.11.4.1.3.4. AHU Summary Table

8.3. Time weighted point tables screens shall include :

8.3.1. Tabular data with point with integration of point data over the following time periods

8.3.1.1. Today, previous day, week to date, previous week, month to date, previous month, year to date, previous month

8.3.1.2. Example graphics

Figure 8.d Example point total table graphic

8.3.1.3. Provide the following screens and requirements:

8.3.1.3.1. Whole-Building Electric Energy Use (kWh)

8.3.1.3.2. Whole-Building Natural Gas Energy Use (therms)

8.3.1.3.3. Whole-Building Water Use (kgal)

8.3.1.3.4. Whole-Building HVAC Electric-only Energy Use (kWh)

8.3.1.3.5. Chilled Water Plant Electric Energy Use (kWh) and Chilled Water Plant Cooling Energy (tons-hrs)

8.3.1.3.6. Total Air Handler Energy Use (kWh) and Total Air Handler Volume (cf)

8.3.1.3.7. These graphics shall also contain text links to:

8.3.1.3.7.1. Campus / Site

8.3.1.3.7.2. Building

8.3.1.3.7.3. Other floors

8.3.1.3.7.4. Building Air Handler # and Boiler #'s

8.3.1.3.7.5. Chilled Water Plant

8.3.2. Tabular data of maximum point data during the following time periods

8.3.2.1. Today, previous day, week to date, previous week, month to date, previous month, year to date, year month

8.3.2.2. A time series plot of current 24 hour data.

8.3.2.3. Example graphics

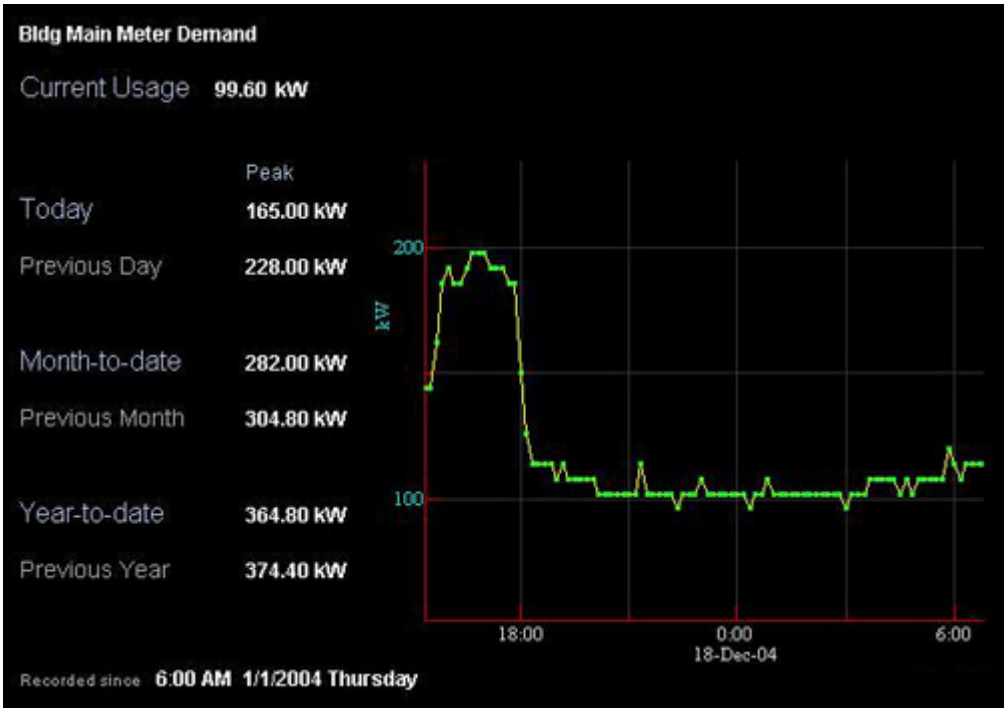


Figure 8.e Example point peak data table graphic

8.3.2.4. Provide the following screens and requirements:

8.3.2.4.1. Whole-Building Electric Power (kW)

8.3.2.4.2. Whole-Building Cooling Load (tons)

8.4. Tabular multi point data screens shall include a:

8.4.1. Title, column headers, and hot links to individual equipment

8.4.2. Provide the following screens and requirements

8.4.2.1. **Air Handler Summary Table: Whole Building # (or Campus)** shall display the AH# plus relevant summary data for the air handling units; if the following AH data points exist in the DDC system, then their status shall be displayed in this graphic:

8.4.2.1.1. Unit Command Status

8.4.2.1.2. Supply Fan Status

8.4.2.1.3. Cold Deck Air Temp (ºF)

8.4.2.1.4. Cooling Setpoint (ºF)

8.4.2.1.5. Chilled Water Valve Position (% open)

8.4.2.1.6. Hot Deck Air Temp (ºF) (if applicable)

8.4.2.1.7. Heating Setpoint (ºF) (if applicable)

8.4.2.1.8. Hot Water Valve Position (% open) (if applicable)

8.4.2.1.9. Supply Fan Command Speed (%)

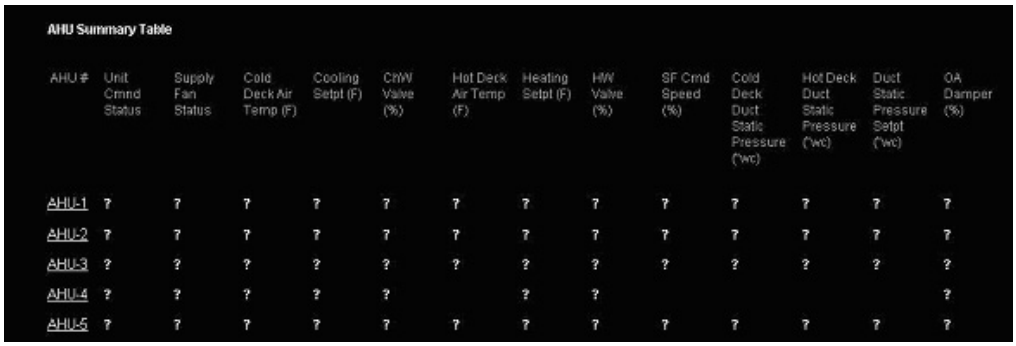
8.4.2.1.10. Cold Deck Duct Static Pressure (iwc)

8.4.2.1.11. Hot Deck Duct Static Pressure (iwc) (if applicable)

8.4.2.1.12. Duct Static Pressure Setpoint (iwc)

8.4.2.1.13. Outside Air Damper PID %

8.4.2.1.14. An example graphic is shown in Figure 8.P.1 below:



AHU Summary Table

AHU #	Unit Cmnd Status	Supply Fan Status	Cold Deck Air Temp (F)	Cooling Setpt (F)	CHW Valve (%)	Hot Deck Air Temp (F)	Heating Setpt (F)	HW Valve (%)	SF Cmd Speed (%)	Cold Deck Duct Static Pressure ("wc)	Hot Deck Duct Static Pressure ("wc)	Duct Static Pressure Setpt ("wc)	OA Damper (%)
AHU-1	?	?	?	?	?	?	?	?	?	?	?	?	?
AHU-2	?	?	?	?	?	?	?	?	?	?	?	?	?
AHU-3	?	?	?	?	?	?	?	?	?	?	?	?	?
AHU-4	?	?	?	?	?		?	?					?
AHU-5	?	?	?	?	?	?	?	?	?	?	?	?	?

Figure 8.f Example Air Handling Unit Summary Data Table graphic

8.4.2.1.15. This graphic shall also display active **text links** to:

8.4.2.1.15.1. Floor Level(s)

8.4.2.1.15.2. Chilled Water Plant

8.4.2.1.15.3. Boiler # or Boiler Plant [*which ever is applicable*]

8.4.2.2. **Performance Monitoring Summary Metric Table: Whole Building #**. Include the following data:

8.4.2.2.1. Site Weather

8.4.2.2.2. Whole-Building Area-Normalized Electric Energy Use Intensity (EUI) (kWh/ft2)

8.4.2.2.3. Whole-Building Area-Normalized Gas Energy Use Intensity (SCFM/ft2)

8.4.2.2.4. Whole-Building Area-Normalized Water Use Intensity (EUI) (kgal/ft2)

8.4.2.2.5. Whole-Building Area-Normalized HVAC Electric-only Energy Use Intensity (EUI) (kWh/ft2)

8.4.2.2.6. Whole-Building Peak Power (kW)

8.4.2.2.7. Chilled Water Plant Efficiency (kW/ton)

8.4.2.2.8. Total Air Handler Specific Power (kW/cfm)

8.4.2.2.9. This graphic screen shall provide text links to the following graphics:

8.4.2.2.9.1. Campus / Site

8.4.2.2.9.2. Chilled Water Plant

8.4.2.2.10. All building AH#

8.4.2.2.11. Boiler # or Boiler Plant [*which ever is applicable*]

8.4.2.2.12. All time weighted displays listed in 8.3.above

8.5. Time series group trend plots shall have the following capabilities:

8.5.1. Individual trended points shall be grouped in groups of up to four points per plot with up to four plots per page.

8.5.2. Multiple Y axes with user selectable ranges

8.5.3. User editable titles, point names and Y axis titles

8.5.4. Group trend time series plots shall have an adjustable time window, default to current and previous day. The user shall be able to select from the following time-series options: (1) a 1-day 24-hour period; (2) a 1-week 7-day period, (3) a 1-month period, with appropriate days for the month selected; or (4) a 1-year period. The user shall be able to select the beginning and ending period for each time series chart, within the time domain of the database being used.

8.5.5. Example

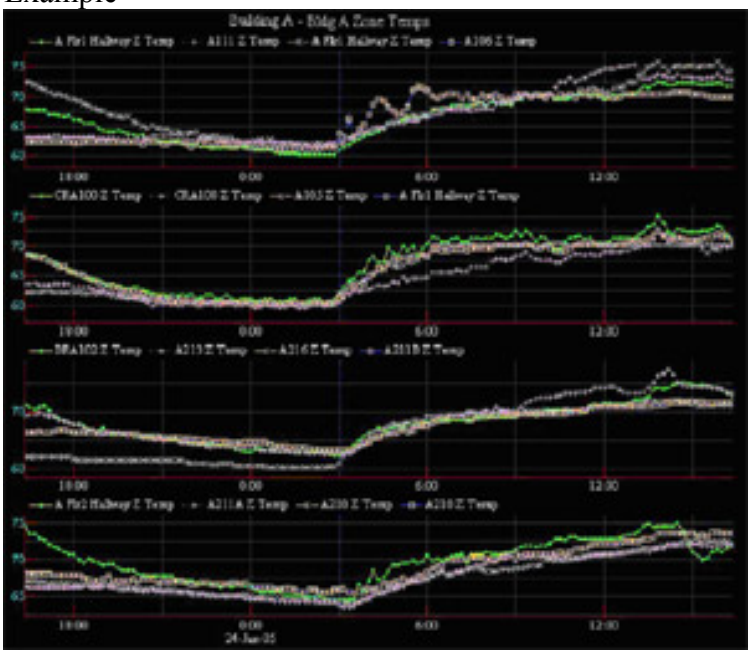


Figure 8.g Example Time-series Group Trend Plot graphic

8.5.6. Provide the following time series group trend plots

8.5.6.1. Zone temperatures group trend plots - select typical and critical zones, grouped by orientation. Example:

8.5.6.1.1. East Zones

8.5.6.1.2. South Zones

8.5.6.1.3. West Zones

8.5.6.1.4. North + Interior Zones

8.5.6.2. Air-handling unit group trend plots (four per AHU)

8.5.6.2.1. Air Handler Mode
8.5.6.2.1.1. Graph 1: Night Setback, Warm-up, Cool-down, Occupied
8.5.6.2.1.2. Graph 2: Heating Requests, Cooling Requests
8.5.6.2.1.3. Graph 3: High Zone Temperature, Low Zone Temperature
8.5.6.2.1.4. Graph 4: Cooling 'OK', Economizer 'OK'
8.5.6.2.2. Supply Air Temp Control
8.5.6.2.2.1. Graph 1: Supply Air Temperature, Supply Air Temperature Cooling Setpoint, Supply Air Heating Temperature Setpoint
8.5.6.2.2.2. Graph 2: Outside Air Temperature, Return Air Temperature, Mixed Air Temperature (if installed)
8.5.6.2.2.3. Graph 3: Outside Air Damper %, Return Air Damper %, Chilled Water Valve %, Supply Air PID,
8.5.6.2.2.4. Graph 4: Heating Water Valve %(if installed), Heating Requests, Cooling Requests, Outside Air Damper Minimum %
8.5.6.2.3. Supply Fan Control
8.5.6.2.3.1. Graph 1: Supply Fan S/S, Supply Fan VFD Status (if available), Supply Fan VFD Alarm (if available), Supply Duct Static Pressure Alarm
8.5.6.2.3.2. Graph 2: Supply Fan Speed (measured and set-point)
8.5.6.2.3.3. Graph 3: Supply Fan Power (calculated from current)
8.5.6.2.3.4. Graph 4: Supply Duct Static Pressure (measured and set-point)
8.5.6.2.4. Return Fan Control
8.5.6.2.4.1. Graph 1: Return Fan S/S, Return Fan VFD Status (if available), Return Fan VFD Alarm (if available)
8.5.6.2.4.2. Graph 2: Return Fan Speed (measured and set-point)
8.5.6.2.4.3. Graph 3: Return Fan Power (calculated from current)
8.5.6.2.4.4. Graph 4: Return Fan controlled variable (building static) (measured and set-point)

8.5.7. Chiller water plant group trend plots
8.5.7.1. Chilled Water Plant Monitor
8.5.7.1.1. Graph 1: Outdoor Ambient Dry-bulb Temperature, Outdoor Ambient Wet-bulb Temperature
8.5.7.1.2. Graph 2: Building Chilled Water Flow Rate (gpm), Building Chilled Water Cooling Load (tons)
8.5.7.1.3. Graph 3: Total Chilled Water Pump Power (sum of all individual pump power readings which have been calculated from current), Total Condenser Water Pump Power (sum of all individual pump power readings which have been calculated from current), Total Cooling Tower Fan Power (sum of all individual tower fan power readings which have been calculated from current), Total Chilled Water Plant Power (sum of all equipment)
8.5.7.1.4. Graph 4: Chilled Water Plant Performance (kW/ton)

8.5.8. Whole building performance group trend plots
8.5.8.1. Whole Building Demand
8.5.8.1.1. Graph 1: Outside air temperature

8.5.8.1.2. Graph 2: Main Meter #1 Power, Main Meter #2 Power; Total Building Power (sum of #1 and #2)

8.5.8.1.3. Graph 3: Total Air Handler Power (sum of all individual air handler power readings which have been calculated from current), Total Chilled Water Plant Power, Total HVAC Power (sum of all HVAC power readings)

8.5.8.1.4. Graph 4: Main Gas Meter Flow

8.5.8.2. Whole Building Performance

8.5.8.2.1. Graph 1: Outside air temperature

8.5.8.2.2. Graph 2: Chilled Water Plant kW/ton

8.5.8.2.3. Graph 3: Air Handler Specific Power (kW/cfm)

8.5.8.2.4. Graph 4: Main Electric Demand per unit area (kW/ft^2), Main Natural Gas Flow per unit area (SCFM/ft^2)

8.6. X-Y group trend plots shall have the following capabilities:

8.6.1. Up to 6 graphs per screen in 2 columns

8.6.2. Multiple X and Y axes with user selectable ranges

8.6.3. User editable titles, point names and X and Y axis titles

8.6.4. User selectable X and Y data points

8.6.5. The user shall be able to select from the following time-period options: (1) a 1-day 24-hour period; (2) a 1-week 7-day period, (3) a 1-month period, with appropriate days for the month selected; or (4) a 1-year period. The user shall be able to select the beginning and ending period for each XY chart, within the time domain of the database being used.

8.6.6. Example

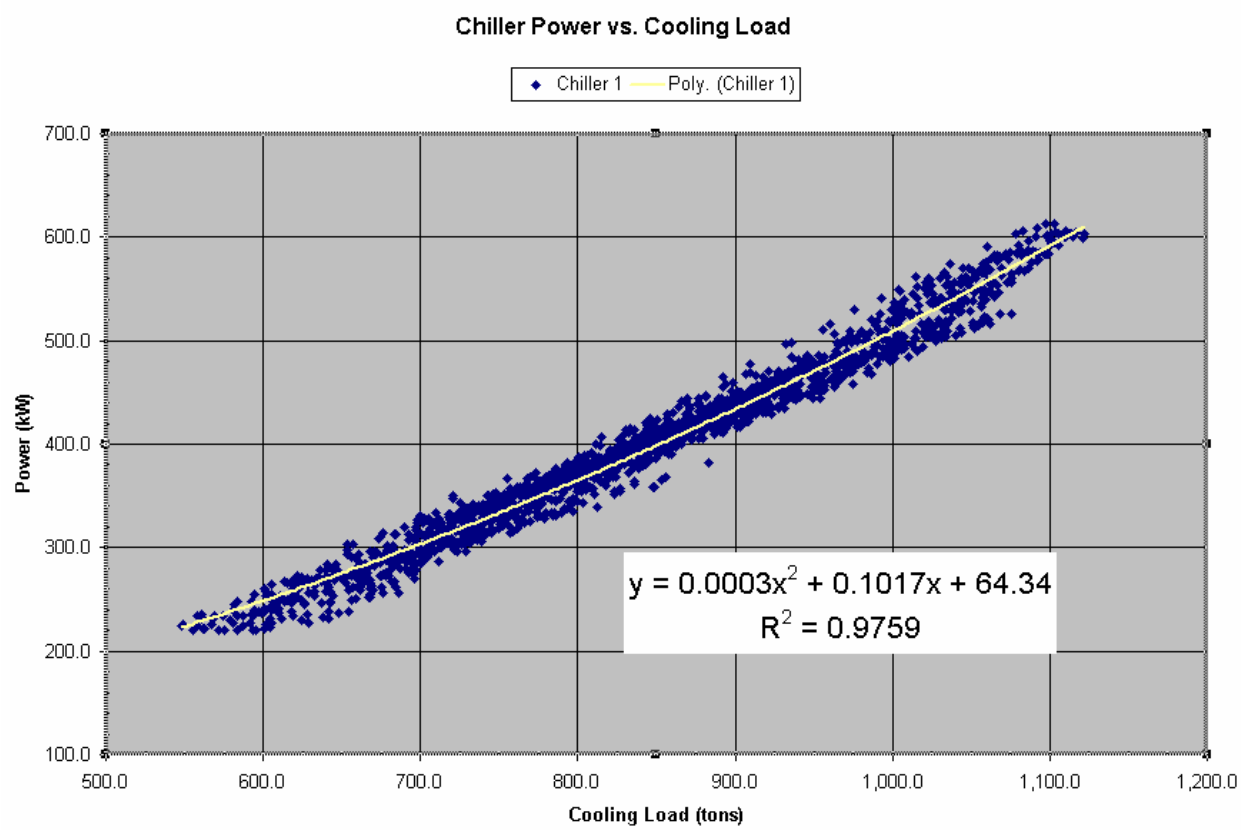


Figure 8.h Example XY Group Trend Plot graphic

8.6.7. Provide the following XY group trend plots:

- 8.6.7.1. ChW Plant Delta-T, ChW Plant tons vs. OA Temp
- 8.6.7.2. ChWPlant kW vs. ChWPlant tons
- 8.6.7.3. ChW Plant kW/ton vs. OA Temp, OA Wb Temp, ChW Plant tons
- 8.6.7.4. HVAC Power vs. OA Temp, OA Wb Temp, ChW Plant tons
- 8.6.7.5. Total Gas Flow vs. OA Temp
- 8.6.7.6. Whole Bldg Electric EUI; Whole Bldg HVAC electric only EUI; Whole Bldg Natural Gas EUI , Whole Bldg Water EUI vs. Avg. Daily OA Temp

9. Commissioning

[*Editor: These requirements apply to the requirements of this specification only, and do not displace commissioning language in any other specification section or contract provision.*]

9.1. Contractor shall submit Submittals as specified in Section 11. They are to be reviewed and approved by the owner's representative prior to hardware, software installation and programming.

9.2. Installation and Set-up: For hardware and each software element, Contractor shall conduct checks and functional tests as necessary to verify that the correct hardware and software has been installed as specified and works properly per this specification.

9.2.1. Sensors: Inspect the installation of all sensors. Verify that all sensors as specified in Section 4 have been installed according to manufacture's installation requirements, are located per contract documents and calibration has been checked per Section 3.

9.2.2. Monitored Points Set-up: Verify that the required monitoring points as specified in Sections 3, 4, and 6 have been programmed including virtual and calculated points. Verify all performance metrics and data points are viewable in the appropriate graphics screen.

9.2.3. Trend Set-up: Assure that each element of Section 6 is functional and reliable.

9.2.4. Archival Database: Assure that each element of Section 7 is functional and reliable. Determine if the data are being sampled at the proper time intervals required and if, how, and where the data is being archived. Determine if the appropriate functionality has been provided. Assure tools are available to access and view archived data.

9.2.5. Visualization and Reporting Software Installation and Set-up: Assure that each element of Section 8 is functional and reliable.

9.2.6. Assure that backup copies of software are available for restoring the system to its original functional setup.

9.3. Sensor Calibration Verification Requirements. Test equipment used for testing calibration of field devices shall be at least twice as accurate as respective installed field devices. The following provides general requirements for verifying DDC sensor calibration in the field.

9.3.1. Temperature: Use a multi-point verification check at various points in the operating range (including minimum, typical, and maximum) utilizing a calibrated thermometer and Dewar flask or a calibrated portable drywell temperature probe calibrator and compare it to the I/O point data at a user interface to field-verify through-system measurement tolerance.

9.3.2. Wet-bulb Temperature: Use a single point calibrator or portable environmental chamber that has been lab calibrated with a NIST traceable dew point monitor and compare it to the I/O point data at a user interface to field-verify through-system measurement tolerance.

9.3.3. Fluid Flow: Use a portable ultrasonic flow meter to spot check flow(s) and compare it to the I/O point data at a user interface to field-verify through-system measurement tolerance. One must be aware that UFM's are velocity dependent devices and are highly vulnerable to variations in flow profile and installation error. They should be considered 5% devices for pipe diameters 12 inches and under. UFM flow profile compensation assumes a fully developed flow profile at the calculated Reynolds number. Even at 10 diameters downstream of an elbow, a significantly altered flow profile will occur. It is suggested that flow profile

compensation be turned off and the acceptable deviation between the measuring flow meter and the UFM be restricted to 5% for applications with less than 10 pipe diameters of straight length pipe upstream of the UFM. If variable flow conditions exist, both flow and the flow profile will need to be evaluated at a range of conditions. See ASHRAE Standard 150-2000 Annex D for a detailed method.

9.3.4. Air Flow: Verification of airflow measurement system calibration in the field is often more difficult than for liquid flow, because of large and complex ductwork. It requires an appropriate and as accurate hand-held device and a capable technician. Field calibration checks can be performed under steady state conditions by using a calibrated pitot tube or propeller anemometer traverses in at least two planes to field-verify through-system measurement accuracy. Where the field conditions vary under normal operation, airflows should be checked over a range of at least five flow rates. It is not recommended that any physical adjustments be made to factory calibrated devices.

9.4. Demonstration/Witness Tests

9.4.1. Contractor shall demonstrate to that satisfaction of the owner that these specifications have been fully implemented. The contractor shall provide those services necessary to support witness testing.

9.4.2. These checks and tests are not intended to replace the contractor's normal and accepted procedures for installing and pre-testing equipment or relieve the contractor of the standard checkout and start-up responsibilities, but to assure the owner that design intent has been met. Any equipment, condition, or software program found not to be in compliance with the acceptance criteria shall be repaired or corrected and then retested until satisfactory results are obtained.

9.4.3. Actual checks and tests will be selected by the owner after the contractor has verified that the installation is complete and operational. These include:

9.4.3.1. Verify that all points have been provided and in the proper location as specified

9.4.3.2. Verify proper use of point naming convention

9.4.3.3. Verify programming of calculated values

9.4.3.4. Verify proper implementation of graphic requirements. Verify that programmed graphic displays (system and equipment graphics, data tables, time series group trend plots, XY group trend plots) are able to display both current and archived data properly and be printed out.

9.4.3.5. Field verify the calibration of a sample of measured points

9.4.3.6. Verify as-built drawings properly document installation including sensor location and point names.

9.4.3.7. Conduct 90 day data loss test. Verify that 99% of data is archived.

9.5. These checks and tests are not intended to replace the contractor's normal and accepted procedures for installing and pre-testing equipment or relieve the contractor of the standard checkout and start-up responsibilities, but to assure the owner that design

intent has been met. Any equipment, condition, or software program found not to be in compliance with the acceptance criteria shall be repaired or corrected and then retested until satisfactory results are obtained.

10. Training

[*Editor: These requirements apply to the requirements of this specification only, and do not displace training language in any other specification section or contract provision.*]

10.1. Hands-on on-site training shall be provided to in-house operating staff. Training shall include a conceptual overview of the purpose of the performance monitoring system, its relationship to the complete building control system, and its overall use, as well as the following detailed aspects of the performance monitoring system.

10.1.1. Instrumentation including sensor maintenance and re-calibration requirements

10.1.2. Data Communications

10.1.3. Performance Metrics Calculations and Data Points

10.1.4. Data Archival Software and Procedures

10.1.5. Data Visualization Software Use. Training shall enable operating personnel to understand the following.

10.1.6. Proper use of the graphic displays for tracking building performance.

10.1.7. How to use each performance monitoring graphic to diagnosis the proper and improper operation and performance of the subject equipment.

10.1.8. What sets of remedial actions might be indicated given values out of range for each performance-monitoring graphic.

10.1.9. Using the data and data displays for ongoing Commissioning

10.2. Assure that in-house staff is familiar with:

10.2.1. All submittals listed in Section X and know their storage location.

10.2.2. Relevant web based resources that could assist in daily operations.

11. Submittals

11.1. Submittals Review Process

11.1.1. Each Submittal Package shall be complete; partial submittals will not be accepted unless Owner's Representative agrees to alternative submittal schedule.

11.1.2. Submit two (2) of Submittal Package to Owner's Representative for review.

11.1.3. Owner's Representative will return one copy with corrections noted.

11.1.4. Contractor shall make corrections and resubmit four (4) clean copies of submittals for final approval. If not all corrections have been made and further resubmittal is required, Contractor will reimburse Owner's Representative for additional review time at normal billing rates.

11.2. Construction Documents. Contractor shall submit the following documents for review and approval by the Owner's representative.

11.2.1. Instrumentation. A complete Instrumentation submittal, as specified in Section IV, shall be provided for approval prior to purchasing and installing any instrumentation. Any instrumentation purchased or installed prior to approval is subject to rejection or revision.

11.2.2. Data Point Summary Table. A complete Data Point Summary Table submittal, as specified in Section IV, shall be provided for approval prior to its implementation. Any installation or programming generated prior to approval is subject to rejection or revision.

11.2.3. Calculation Logic Diagrams. A complete Calculation Logic Diagram submittal, as specified in Section IV, shall be provided for approval prior to any programming. Any programs generated prior to approval are subject to rejection or revision.

11.2.4. Data Archive Procedure. A complete Data Archive Procedure submittal, as specified in Section VII, shall be provided for approval prior to its implementation. Any programming generated prior to approval is subject to rejection or revision.

11.2.5. Block Trend Groupings. A complete Block Trend Grouping submittal, as specified in Section VI, shall be provided for approval prior to any programming. Any graphics generated prior to approval are subject to rejection or revision.

11.2.6. Graphic Diagrams. A complete Graphic Diagram submittal, as specified in Section VIII, shall be provided for approval prior to any graphics generation. Any graphics generated prior to approval is subject to rejection or revision.

11.2.7. Piping and Ductwork Drawings. A complete set of piping and ductwork construction drawings, as specified in ???, shall be provided for approval prior to installation of any sensors.

11.3. Contractor Quality Assurance Documents

11.3.1. Contractor shall prepare forms for documenting that all required hardware and software has been installed, calibrated and are operating properly and submit for approval. Forms shall be tabular in nature and include the following: checks, tests and simulations to be performed; expected outcomes; actual outcome; indication of pass or fail; a space above or below for party performing the activity to sign and indicate actual date of the activity.

11.3.2. Contractor shall submit documentation on approved forms that all required hardware and software has been installed, calibrated and are operating properly prior to the commencement of the activity.

11.4. As-built drawings

11.4.1. Contractor shall submit final as-built documents as listed in Section 11.2 for review and approval by the Owner's representative.

11.5. Training Documents.

11.5.1. Contractor shall prepare training materials in both hard copy and electronic form and submit for approval. Training materials shall include, but not be limited to the following.

11.5.1.1. Project description

11.5.1.2. Facility description

11.5.1.3. Hardware, software and other sensor and materials training guides

11.5.1.4. Performance Monitoring System: A complete description of the system and its use including a discussion of related adjustments, scheduling, sequences, calculations, trending, alarms and approved as-built document products as applicable.

APPENDIX E: OTHER OPTIONS OR ADD ALTERNATES TO CONSIDER

E1. Use Btu meter to calculate real time loads. An example specification follows:

Btu meters. All thermal load calculations shall be provided by Btu Meters.

1. The entire Btu measurement system shall be manufactured by a single manufacturer, and shall consist of a flow meter, two solid state temperature sensors, a BTU meter, thermowells, all required mechanical installation hardware, and color-coded interconnecting cable. The entire system shall be serialized and include NIST traceable factory wet calibration of the complete system.
2. The requirements in Section 3.4. Liquid Flow Meters applies.
3. The requirements in Section3.5. Fluid Temperature Devices applies.
4. Each Btu meter shall provide a solid-state dry contact output for energy total and analog outputs (4-20 mA or 0-10 VDC) for thermal rate, liquid flow rate, supply temperature, and return temperature. As an alternative to the analog outputs, the BTU meter shall provide serial communications compatible with the data acquisition system. Interface meter to data acquisition system providing access to all available data.
5. The analog thermal rate output and dry contact energy output shall have a rated accuracy within ± 2% of reading.
6. The maximum dry contact energy increment shall be no more than 1/10,000 of full scale (1000 tons yields 0.1 ton-hrs per pulse = 10000 pulses per hour = 2.78 Hz).
7. The Btu meter electronics shall be housed in NEMA-13 enclosure and shall include a front panel mounted two-line alphanumeric LCD display for local indication of Thermal Rate, Liquid Flow Rate, and Supply Temperature and Return Temperature. A single 24 VAC or 120VAC connection to the Btu shall provide power to the Btu meter electronics and to the flow meter. Each Btu meter shall be factory programmed for its specific application, and shall be re-programmable by the user using the front panel keypad (no special interface device or computer required).
8. A certificate of calibration shall be provided with each Btu meter.

E2. Use dry bulb and relative humidity probes with wet bulb output in lieu of site based weather instrumentation

E3. Use local NOAA weather station data in lieu of site based weather instrumentation

E4. Add a section on User Security Access Levels

E5. Liquid Flow: Chiller flow can also be measured using and ultrasonic flowmeter with permanently mounted transducers or an accurate DP transducer across the evaporator and square root extraction.

E6. Air Handler # Supply Fan VFD freq (Hz): If a frequency feedback signal is not available from the VFD, replace with control signal that is sent to the VFD in either frequency (Hz) or % of max speed.

APPENDIX F: OTHER POTENTIAL MEASUREMENTS, METRICS AND X-Y PLOTS TO CONSIDER

F1. Measurements

(a) Alarms or operator initiated commands.
(b) Conference Room CO_2
(c) Equipment Runtime
(d) RTU Supply Air Temp
(e) Return Air Temp Minimum
(f) Max Zone Temp, Min Zone Temp

F2. Performance Metrics

(a) Sample time based and filtered metrics (1 minute average, 15 minute average, 15 minute running average, 1 hour average, 1 day average)
(b) Metrics that require Return Air Flow to be measured.
(c) Cost based metrics.
(d) Whole Building ton-hrs EUI (ton-hrs/ft^2)
(e) Whole Building kW/ton, Whole Building Total HVAC kW/ton, Whole Building Total Fan kW/ton, Total Primary Chilled Water Pump kW/ton, Total Secondary Chilled Water Pump kW/ton, Total Condenser Water Pump kW/ton, Total Cooling Tower kW/ton

F3. X-Y Plots

(a) Max Building Power, Max HVAC Power vs. Outside Air Temp
(b) Max Zone Temp, Min Zone Temp vs. Outside Air Temp, Outside Air Wb Temp
(c) Average Concurrent System Supply Air Temp vs. Outside Air Temp
(d) Outside Air Temp Fraction Outside Air Damper Fraction vs. Outside Air Flow Fraction
(e) Chiller Efficiency vs. Chilled Water Delta-T, Condenser Water Delta-T, Chilled Water and Condenser Water Temps
(f) ChW Plant kW/ton vs. Total Building Chilled Water Flow
(g) Whole Building kW/ton, Whole Building Total HVAC kW/ton, Whole Building Total Fan kW/ton, ChW Plant kW/ton, Chiller # kW/ton, Total Primary Chilled Water Pump kW/ton, Total Secondary Chilled Water Pump kW/ton, Total Condenser Water Pump kW/ton, Total Cooling Tower kW/ton vs. Outside Air Temp-ChW On
(h) Total Boiler COP vs. Total Building Hot Water Flow
(i) Low Load kW vs. High Load kW (ACEEE 2004)

APPENDIX G: EXAMPLE BASIC LEVEL SPECIFICATION LANGUAGE BASED ON ASHRAE GUIDELINE 13-2000: SPECIFYING DIRECT DIGITAL CONTROLS SYSTEMS

This appendix provides example basic level performance monitoring related specification language for use in DDC system application that replaces or to be adds to example specifications found in ASHRAE Guideline 13-2000: Specifying Direct Digital Controls Systems.

Spec 1.5 Description – [*Editor: add spec content describing PM System including sensor requirements.*]

"D. Performance Monitoring. The system will provide the specified performance monitoring functionality including required monitoring points and performance metrics, improved through system accuracy, data acquisition and data management capabilities, and required graphical and data displays."

"E. Sensors. General sensors requirements as part of this project are as follows:

1. All equipment shall be labeled as described in Table 3.

2. All instrumentation shall be covered by manufacturer's transferable two-year "No Fault" warranty. If manufacturer warranty is not available the installer shall provide the same.

3. All sensors shall be identified including required placement dimensions as specified in this section on pertinent construction drawings, which adhere to the manufacturer's published minimum placement guide and installation instructions.

Spec 1.9 System Performance – [*Editor: revise relevant accuracy requirements in Table 1 and add data calculation capability.*]

"**Table 1: Reporting Accuracy**

Measurement Points and Metrics	Reported Accuracy
Outside air temperature	±0.1°C (±0.2ºF)
Outside air wet bulb temperature	±0.1°C (±0.2ºF)
Space temperature	±0.3°C (±0.5°F)
HVAC electric only energy use (kWh)	2% of reading
Water temperature	±0.05°C (±0.1ºF)
Water delta temperature	±0.08°C (±0.15ºF) or 2% of reading
Water flow	2% of reading with > 20-1 turndown from peak flow
Natural gas flow (std l/s) or (std cfm)	2% of reading with > 10-1 turndown from peak flow and pressure and temperature compensation
Air flow (measuring stations)	5% of reading down to 1/10th of full scale with > 10-1 turndown
Electrical (A, V, kW, *pf*)	1.5% of reading (includes CT error)

Measurement Points and Metrics	Reported Accuracy
Chiller cooling output (kW) or (tons)	3% of reading
Chiller cooling energy (kWh) or (ton-hrs)	3% of reading
Boiler heating output (kW) or (kBtu/hr)	3% of reading
Boiler heating energy (Joule) or (kBtu)	3% of reading
Electric energy use (kWh)	2% of reading
Total HVAC energy use (kWh) (includes air side, water side and natural gas)	3% of reading
Chiller performance (COP) or (kW/ton)	4% of reading
ChW Plant performance (COP) or (kW/ton)	4% of reading
Total boiler performance (COP) or ($kBtu_i/kBtu_o$)	4% of reading
Total air handler specific energy (kW/ l/s) or (kW/cfm)	6% of reading
Net Usable Building floor area (m^2) or (ft^2) #1	2%
Notes: #1 - Floor area is net usable or net rentable space not gross area.	

Spec 1.10 Submittals – [*Editor: add spec subsection and content defining PM System submittal requirements*.]

"A.4. Instrumentation and Data Point Summary Table. Contractor shall submit in table format as specified below. They are to be reviewed and approved by the owner's representative prior to hardware, software installation and programming.

a. Point name per Table 3.
b. Point description: provide building designation, system type, equipment type, engineering units and functionality; include a description of its physical location
c. Expected range (upper and lower limit)
d. Instrumentation (as applicable): manufacturer, model number, range, accuracy specification per section 1.5.E.
e. Type
  i) AI: analog input
  ii) DI: digital or binary input
  iii) CBAI: communication bus analog input
  iv) CBDI communication bus digital (binary) input
  v) P: programmed (e.g. soft or virtual point in control sequence such as a PID input or output)
  vi) C: calculated value; a soft or virtual point that is specified in section 4.If calculated value, provide formula.
f. Expected range (upper and lower limit)
g. Input resolution (this is critical for pulse type watt meters; use the smallest resolution possible)
h. Number of significant digits after decimal point
i. Data trend interval
j. Number of samples stored in local controller before transfer to host computer/ server database

k. Communication protocol information: Ethernet backbone network number, device ID, object ID
l. Block trend grouping designation
m. EMCS Controller designation
n. If time based integrated values are required, provide time periods: minutes, daily, weekly, monthly, and yearly. Also indicate if it is a running average.
o. Logic diagrams and/or code and any constants for creating the calculated values specified in Table 3 shall be submitted for review and approval"

Spec 2.2.E.18 System Applications. Electrical, Gas and Weather Reports - *add spec content describing energy use table and plot requirements*

"e. Provide a graphic display for each point with data table and a current 24 hour trend plot. Include integrated point data for the following time periods ; today, previous day, week to date, previous week, month to date, previous month, year to date, previous month."

Spec 2.3.E.20 System Applications. Group Trends (new) - *add new spec subsection and content describing group trends requirements* [*similar to ALC's*]

"20. Group Trend Time Series Plots.
a. Provide user selectable Y points
b. Provide multiple Y axes with user selectable ranges
c. Provide user editable titles, point names and Y axis titles
d. Individual trended points shall be able to be grouped in groups of up to four points per plot with up to four plots per page.
e. Group trend plots shall have an adjustable time window, default to current and previous day."

Spec 2.3.E.21 System Applications. X-Y Trend Plots (new) – *add new spec subsection and content describing XY plot requirements*

"21. X-Y Trend Plots
a. User selectable X and Y trend inputs
b. Provide multiple X and Y axes with user selectable ranges
c. User editable titles, point names and X and Y axis titles
d. User selectable time-period options: (1) a 1-day 24-hour period; (2) a 1-week 7-day period, (3) a 1-month period, with appropriate days for the month selected; or (4) a 1-year period. The user shall be able to select the beginning and ending period for each X-Y chart, within the time domain of the database being used
e. User selectable display up to 6 plots per screen in 2 columns"

Spec 2.3.H Points List for Performance Monitoring (new). – *add new spec section and content describing performance metrics requirements (Table 3 with introduction)*

"1. Contractor shall provide all measured, virtual and calculated points listed in Table 3.

2. Table 3 Legend:
   a. - % of reading unless otherwise noted
   b. Abbreviations:
      i) AI – analog input
      ii) DI – digital input
      iii) C – calculated value
      iv) CB – computer bus, gateway or interface input
      v) P – programmed output
      vi) # – unit number
      vii) x – denotes more than one value in a group

3. Contractor shall derive constants used in calculations except as noted.
   a. C1 – Building Floor Area (ft^2): Owner shall provide this value
   b. C2 – constant heating value (Joules/L or therms/sft^3): Owner shall obtain this value from the local gas utility.
   c. C3 – 0.0293 kW per Btu/hr
   d. C4 – 0.0419 minutes per gallon per °F [*Editor: This is used to derive* $tons_R$ *- assumes chilled water at 45 ºF, no glycol.*]

Table 3 – Sensors, Meters, and Calculated Values

#	Example Point Name	Point Description and Location if applicable	Input Type	Sensor Type or Calculation Method	Required End-to-end Accuracy	Display Resolution	Refresh Interval (min)	Trend Interval (min)
S1	OA Temp	Outdoor Ambient Dry Bulb Temperature	AI	Locate in weather station in fully shaded location or ventilated enclosure mounted away from thermal mass bodies	+/- 0.2 ºF	0.01 ºF	1	10
S2	OAWb Temp	Outdoor Ambient Wet Bulb Temperature	AI	Locate in weather station in fully shaded location or ventilated enclosure	+/- 0.2 ºF	0.01 ºF	1	10
S5	BldgMn NaGas Flow Or Site NaGas Flow	Building Main Natural Gas Meter	AI or DI	Pressure compensated; continuous output	+/- 1.0 % of reading	0.1 scfm	1	1
S7	BldgMn Power or Site Power	Building Main Meter Power	AI or DI	PML 8500 or equal	+/- 1.0 % of reading	0.1 kW	1	1
S9	Rm#Zone Temp	Zone temperatures	AI	10000 Ohm thermistor or 1000 Ohm RTD	+/- 0.5 ºF	0.1 ºF	1	1
S12	Chlr# kW	Chiller # Power	AI, DI or CB	True RMS, Three Phase, integrated equipment, stand alone analog or pulse output or networked power meter; use maximum resolution if pulse output	+/- 1.5 % of reading	0.01 kW	1	1
S13	PriChWP# kW	Primary Chilled Water Pump # Power	AI, DI or CB	True RMS, Three Phase, integrated equipment, stand alone analog or pulse output or networked power meter; use maximum resolution if pulse output	+/- 1.5 % of reading; +/- 3.0 % of reading if from VFD	0.01 kW	1	1

#	Example Point Name	Point Description and Location if applicable	Input Type	Sensor Type or Calculation Method	Required End-to-end Accuracy	Display Resolution	Refresh Interval (min)	Trend Interval (min)
S14	Chlr#CondWP kW	Chiller # Condenser Water Pump Power	AI, DI or CB	True RMS, Three Phase, integrated equipment, stand alone analog or pulse output or networked power meter; use maximum resolution if pulse output	+/- 1.5 % of reading; +/- 3.0 % of reading if from VFD	0.01 kW	1	1
S15	ClgTF# kW	Cooling Tower Fan # Power	AI, DI or CB	True RMS, Three Phase, integrated equipment, stand alone analog or pulse output or networked power meter; use maximum resolution if pulse output	+/- 1.5 % of reading; +/- 3.0 % of reading if from VFD	0.01 kW	1	1
S16	SecChWP# kW	Secondary Chilled Water Pump # Power	AI, DI or CB	True RMS, Three Phase, integrated equipment, stand alone analog or pulse output or networked power meter; use maximum resolution if pulse output	+/- 1.5 % of reading; +/- 3.0 % of reading if from VFD	0.01 kW	1	1
S20	Plant ChWS Temp	ChW Plant (Loop #) Chilled Water Supply Temperature	AI or CB	10000 Ohm thermistor or 1000 Ohm RTD	+/- 0.1 ºF	0.01 ºF	1	1
S21	Plant ChWR Temp	ChW Plant (Loop #) Chilled Water Return Temperature	AI or CB	10000 Ohm thermistor or 1000 Ohm RTD	+/- 0.1 ºF	0.01 ºF	1	1
S22	Plant ChW Flow	ChW Plant (Loop #) Chilled Water Flowrate	AI or CB	Hot tapped insertion flow meter	+/- 2.0 % of reading	0.1 gpm	1	1
S26	AH#SF Flow	Air Handler # Supply Fan Airflow Rate (penthouse)	AI	Vortex shedding sensor on fan inlet	+/- 5.0 % of reading *	0.1 cfm	1	1
S33	AH#SF kW	Air Handler # Supply Fan Power	AI, DI or CB	True RMS, Three Phase, integrated equipment, stand alone analog or pulse output or networked power meter; use maximum resolution if pulse output	+/- 1.5 % of reading; +/- 3.0 % of reading if from VFD	0.1 kW	1	1

#	Example Point Name	Point Description and Location if applicable	Input Type	Sensor Type or Calculation Method	Required End-to-end Accuracy	Display Resolution	Refresh Interval (min)	Trend Interval (min)
S34	AH#RF kW	Air Handler # Return Fan Power	AI, DI or CB	True RMS, Three Phase, integrated equipment, stand alone analog or pulse output or networked power meter; use maximum resolution if pulse output	+/- 1.5 % of reading; +/- 3.0 % of reading if from VFD	0.1 kW	1	1
S35	AH#MA Temp	Air Handler # Mixed Air Temperature	AI	Locate in air handler's mixed air section; to minimize effects of stratification use averaging sensor if possible	+/- 0.2 ºF	0.01 ºF	1	10
S36	AH#RA Temp	Air Handler # Return Air Temperature	AI	Locate upstream of air handlers return air damper	+/- 0.2 ºF	0.01 ºF	1	10
S37	AH#SA Temp	Air Handler # Supply Air Temperature	AI	Locate upstream of air handlers return air damper	+/- 0.2 ºF	0.01 ºF	1	10
S39	WB Tot Water Flow	Whole-Building Total Water Flowrate	AI or DI	Hot tapped insertion flow meter	+/- 2.0 % of reading	0.1 gpm	1	1
V1	AH#OA Dmpr%	Air Handler # Outside Air Damper Position (% open)	P	Virtual point that commands the dampers position	N/A	0.1 %	1	1
V2	AH#RA Dmpr%	Air Handler # Return Air Damper Position (% open)	P	Virtual point that commands the dampers position	N/A	0.1 %	1	10
M1	Bldg Peak kW	Whole-Building Peak Power	C	Maximum of measured value [S7] over a given time interval	+/- 1.5%	0.1 kW	1	10
M4	WB Elec EUI	Whole-Building Area-Normalized Electric Energy Use Intensity	C	Measured value [S7] integrated over a given interval divided by a constant #C1	N/A	0.1 kWh/ft^2	1	10
M5	WB NaGas Heat-rate	Whole-Building Natural Gas Heat-rate	C	Measured value [S5] divided by a constant #C2	NA	0.1 therms/min	1	10
M6	WB NaGas EUI	Whole-Building Area-Normalized Natural Gas Energy Use Intensity	C	Calculated value [M5] integrated over a given interval divided by a constant #C1	N/A	0.1 therms/ft^2	1	10
M8	Avg Daily OA Temp	Average Daily Outdoor Ambient Temperature	C	Average of instantaneous measured values [S1]	N/A	0.01 ºF	1	10

#	Example Point Name	Point Description and Location if applicable	Input Type	Sensor Type or Calculation Method	Required End-to-end Accuracy	Display Resolution	Refresh Interval (min)	Trend Interval (min)
M15	ChW Plant ΔT	Chilled Water Plant Delta-T	C	Calculated difference of 2 measured values [S21-S20]; assumes one chilled water loop	0.1 ºF	0.01 ºF	1	10
M16	ChW Plant Power	Chilled Water Plant Power	C	Sum of measured values [S12, S13, S14, S15, S16]	+/- 1.5%	0.1 kW	1	10
M17	Plant ChW tons	Plant Chilled Water (Loop #) Thermal Cooling Output	C	Calculated value [M15] multiplied by measured valued [S22] multiplied by a constant #C4; *assumes one chilled water loop*	+/- 3 %	0.1 tons	1	10
M18	ChWPlant kW/ton	Chilled Water Plant Efficiency	C	Calculated value [M16] divided by calculated value [M17]	+/- 4 %	0.01 kW/ton	1	10
M26	Tot AH kW	Total Air Handler Power	C	Sum of calculated values [M24x]	+/- 1.5 %	0.1 kW	1	10
M27	Tot AH cfm	Total Air Handler Flow	C	Sum of measured values [S26x]	+/- 5 %	0.1 cfm	1	10
M28	Tot AH SpecPower	Total Air Handler Specific Power	C	Calculated value [M26] divided by a calculated value [M27]	+/- 6 %	0.1 kW/cfm	1	10
M63	AH# OA Temp-Fraction	Air Handler # Outside Air Temperature Fraction	C	Instantaneous difference of two measured values [S35, S1] divided by the difference of two measured values [S36, S35]	NA	0.001	1	1
M64	AH#OA Dmpr - Fraction	Air Handler # Outside Air Damper Fraction	C	Instantaneous quotient of virtual point [V1] divided by the sum of virtual points [V1] and [V2]	NA	0.001	1	1
M70	WB Water EUI	Whole-Building Area-Normalized Water Use Intensity	C	Measured value [S39] integrated over a given interval divided by a constant #C1	N/A	0.1 kgal/ft^2	1	10

Spec 2.4 Controller Software – [*Editor: data calculation capability.*]

"R. Data calculations. System shall be capable of the following math and data functions:

1. Addition, subtraction, multiplication, division, square root

2. Average, minimum, maximum, total (value integrated over time) and standard deviation of a single input or a calculated value over a predefined time interval (recording interval, hourly, daily, weekly, monthly, yearly)

3. Running average (low pass filter) over a predefined time interval

4. Instantaneous sum and average of a group of inputs and/or calculated values

5. Allow use of predefined constants in calculations

6. Logic triggered data sampling/archive based on any given event

7. Provide means of adjusting the resolution of calculated data

8. Provide a standard means of:
   a. converting line current to 3 phase power
   b. converting natural gas flow (s L/s or scfm) to energy flow (Joules/s or therms/hr)
   c. calculating thermal load (Btu/hr and $tons_R$) and efficiency (COP and kW/ton)
   d. deriving wet bulb temperature from dry bulb temperature and humidity

Spec 2.10 Auxiliary Control Devices – [*Editor: revise existing spec as noted below; renumber as appropriate.*]

A. Main Electric Meter

1. Use existing meter if available. Interface existing meter with the EMCS using the appropriate computer bus, gateway or interface and provide access to all available data from meter.

2. If existing meter is not available or does not have analog or digital outputs, provide a new meter or equivalent per approved submittal. Interface new meter with the EMCS using the appropriate computer bus and provide access to all available data from meter.

B. Main Natural Gas Meters

1. Each flow meter shall have rated instrument accuracy within +/-2.0% of reading, with a minimum of a 10:1 turndown over the range of flow. Repeatability shall be within ±1.0 % of reading. Resolution shall be within ±0.1% of reading. These requirements are for the end-to-end measurement system including the sensor, transmitter and any signal conditioning.

2. Pressure and temperature compensated

3. Continuous data output

4. V-Bar or equivalent per approved submittal

5. Provide analog, digital or pulse output. Provide smallest resolution possible if pulse.

C. Liquid Flow Meters

1. Each flow meter shall have a rated instrument accuracy within ± 1% of reading from 3.0 through 30 ft/s and ± 2% of reading from 0.4 ft/s through 3.0 ft/s velocity. Repeatability shall be within ±1.0 % of reading. Resolution of any signal conditioning and readout device shall be within ±0.1% of reading. The instrument shall be capable of measuring flow within the stated accuracy over the entire range of flow. Flow meter shall be rated for line pressure up to 400 PSI. These requirements are for the end-to-end measurement system including the sensor and any signal conditioning. [*Editor: On an annual basis, most main loop piping is most likely operated well below 6 FPS, so low end accuracy is very important.*]

2. Each flow meter shall be individually wet calibrated against a volumetric standard accurate to within 0.1% and traceable to the U.S. National Institute of Standards and Technology (NIST). Flow meter accuracy shall be within ± 0.5% at calibrated typical flow rate. A certificate of calibration shall be provided with each flow meter.

3. Dual Turbine, Vortex Shedding, or Magnetic Flowmeter per approved submittal. [*Editor: Insertion turbine and vortex shedding meters are not recommended in open cooling tower loops or where dirty water conditions exist.*]

a. Magnetic Full Bore meter (Preferred): Sensor shall be installed in a location clear from obstruction 5 pipe diameters upstream and 2 pipe diameters downstream including pipe elbows, valves and thermowells

b. Insertion Vortex Shedding Meter: Sensor shall be installed in a location clear from obstruction 10 pipe diameters upstream and 5 pipe diameters downstream including pipe elbows, valves and thermowells

c. Dual Turbine Meter. Flow sensing turbine rotors shall be non-metallic and not impaired by magnetic drag. Sensor shall be installed in a location clear from obstruction 10 pipe diameters upstream and 5 pipe diameters downstream including pipe elbows, valves and thermowells.

D. Fluid Temperature Measurement Devices

1. Each temperature measurement device shall have a rated instrument accuracy within 0.1 ºF. Repeatability shall be within 0.1 ºF. Resolution of any signal conditioning and readout device shall be within 0.05 ºF. These requirements are for the end-to-end measurement system including the sensor and any signal conditioning.

2. Temperature measurement devices, which includes any signal conditioning, shall be bath-calibrated (NIST traceable) for the specific temperature range for each application.

3. Temperature measurement devices used in calculating differential temperature shall be documented matched pairs with similar coefficients and calibrated together by the manufacturer. The calculated differential temperature used in the energy calculation shall be accurate to within 2% of the difference (including the error from individual temperature sensors, sensor matching, signal conditioning, and calculations).

4. All piping immersion temperature sensors shall be inserted in newly installed brass or stainless steel wells located downstream of flow meter placement that allows for the removal of the sensor from the well for verifying calibration in the field. The well shall penetrate the pipe at least two inches up to half the pipe diameter. The use of direct immersion sensors is not acceptable.

E. Air Flowmeters

1. Single or multiple point air flow station shall be mounted in air distribution duct or plenum. Flowmeter selection is dependent on application, air parameters, size of duct and length of duct run and manufacturer's published guidelines and recommendations. Measurement devices include volumetric duct-averaging airflow and temperature measurement devices including Airflow / Temperature Measurement Devices, Vortex Shedding and Pitot anemometers per approved submittal. [*Editor's note: velocity pressure-based technologies and non-directional thermal anemometers are more susceptible to errors due to irregular profiles or turbulence. Conditions or duct devices creating turbulence should be avoided. Never place a measurement device downstream of a modulating damper, unvaned elbow, humidifier, wetted coil or sound attenuator.*]

2. Fan inlet measurement devices shall not be substituted for duct or plenum measurement devices indicated on the plans.

3. Airflow measurement accuracy shall be certified by the manufacturer to perform within +/-2% of Reading (or less) over the entire operating airflow range of 150 to 9000 ft/min, in relation to the NIST-traceable reference standards used for calibration, and accounting for all components that affect total accuracy including: repeatability, zero drift, temperature effects, hysteresis, etc. In isolation, repeatability of the device should be no greater than 0.25% of Reading throughout the entire range.

a) Devices whose accuracy is the combined uncertainty in measurement using multiple components must be calibrated as a single system and demonstrate to the satisfaction of the consulting mechanical engineer that the total measurement system accuracy meets the performance requirements of this specification throughout the measurement range.

b) Devices whose accuracy is dependent upon preventative or corrective maintenance must indicate the level, type, any special equipment required and frequency of the maintenance activities needed to ensure that the specified accuracy is available continuously, with degradation in performance of no greater than double the specified error rate, at any time within the maintenance and calibration cycles.

c) These requirements are for the end-to-end measurement system including the sensor(s) and transmitter.

d) A certificate of calibration shall be provided with each flowmeter.

e) Field calibration should only be applied to measurement devices that are not factory calibrated or whose placement is not within the limitations of the manufacturer's minimum placement guidelines or sensor density requirements for field conditions.

4. Flowmeter sensors shall be rated for temperature up to 140 ºF. Flowmeter transmitters shall be rated for temperatures up to 120 ºF.

5. When dictated by disturbances upstream of inlet and short available air flow paths, the flow measurement station shall provide compensation for rotational distortion in the velocity flow profile.

6. Each air flowmeter shall provide isolated linear analog outputs, 4-20 mA (4 wire) or 0-10 VDC, for air flow and temperature. Output shall be selectable from the instrument display or jumper selectable. No other cables, interface devices or software is required. As an alternative to the analog outputs, the air flow meter shall be capable of communicating with other devices using one of the following interface options compatible with the control system: a) RS-485; b) 10 Base-T Ethernet. Interface transmitter to control system providing access to all available data.

7. The air flowmeter transmitter shall be housed in a steel or approved alternate material NEMA rated enclosure and shall include a front panel mounted two-line alphanumeric LCD display for local indication of air flow. NEMA enclosures and display mounting for application will need to be approved by submittal. A single 24 VAC, 24VDC or 120VAC connection to the air flowmeter shall provide power to the meter electronics and to the flowmeter. Each air flowmeter shall be factory programmed for its specific application. The air flowmeter shall be re-programmable by the user using the front panel keypad (no special interface device or computer required) or alternate method approved by submittal.

8. Airflow / temperature measurement devices

a) Provide airflow/temperature measurement devices (ATMD) where indicated on the plans.

b) Sensor Probes

i. Each sensor (assembly) shall independently determine the airflow rate and temperature at each measurement point, which are weighted equally for mathematically averaging all of the measurements arrayed in the duct or plenum cross-section prior to output.

ii. Each sensor (assembly) shall be factory or field-calibrated to standards (equipment and methods) that are traceable to the National Institute of Standards and Technology (NIST), at a minimum of 8 airflow rates, including the minimum and maximum flow rate measurement capability of the ATMD, and 3 temperatures.

iii. Each sensor assembly shall be verified by the manufacturer in published materials to possess insignificant drift potential over the life of the product; or, the manufacturer shall include recalibration instructions with a recommended minimum frequency of recalibrations that prevent expected drift from significantly impacting measurement uncertainty (< double the specified system error rate).

iv. Temperature accuracy shall be 0.15° F (0.1° C) over the entire operating temperature range of -20° F to 160° F (-28.9 to 71.1° C).

v. The operating humidity range for each sensor probe shall be 0-99% RH (non-condensing).

vi. Each sensor probe shall have an integral, UL-Listed, plenum rated cable and terminal plug for connection to a remotely mounted transmitter.

vii Each sensor assembly shall not require matching to the transmitter in the field.

viii. A single manufacturer shall provide and be responsible for the performance of both the airflow/temperature measuring probe(s) and transmitter for each measurement location.

c) Duct and Plenum Probes

i. The minimum number of measurement points in a cross-sectional array (individual sensors/sensor assemblies) provided for each location to be averaged shall be as follows:

Duct or Plenum Free Area ($ft.^2$)	Duct or Plenum Free Area (M^2)	Min. Total # Sensors / Location
<2	≤ 0.093	4
2 to < 4	>0.093 to < 0.372	6
4 to < 8	0.372 to < 0.743	8
8 to <16	0.743 to < 1.115	12
≥16	1.115 to < 1.486	16

Area (m^2)	**Sensors**		
≤ 0.093	2	≤ 1	2
>0.093 to < 0.372	4	>1 to <4	4
0.372 to < 0.743	6	4 to <8	6
0.743 to < 1.115	8	8 to <12	8
1.115 to < 1.486	12	12 to <16	12
≥ 1.486	16	≥16	16

ii. The operating airflow range shall be 0 to 5,000 ft/min (25.4 m/s) unless otherwise indicated on the plans.

d) Transmitters

i. The transmitter shall have an integral display capable of simultaneously displaying airflow and temperature in either IP or SI units. The display shall be capable of displaying individual airflow and temperature readings of each independent sensor assembly.

ii. The transmitter shall be capable of field configuration and diagnostics using an on-board pushbutton interface and display.

iii. The transmitter shall have a power switch and operate on 24 VAC (isolation not required).

iv. The operating temperature range for the transmitter shall be -20 °F to 120 °F (-28.9 °C to 48.9 °C). The transmitter shall be installed at a location that is protected from weather and water.

e) The ATMD shall be UL-Listed as an entire assembly.

9. The manufacturer's authorized representative shall review and approve placement and operating airflow rates for each measurement location indicated on the plans.

a) A written report of the review shall be submitted to the consulting mechanical engineer if any measurement locations do not meet the manufacturer's placement requirements.

10. Outside airflow applications

a) Provide airflow/temperature measurement devices (ATMD) where indicated on the plans**.**

b) Each ATMD shall consist of one or more sensor probes and a single, remotely mounted, microprocessor-based transmitter capable of independently processing up to 16 independently wired sensor assemblies, in accordance with the details in Section E.8.

c) Each ATMD shall be installed at the AHU manufacturer's factory during equipment assembly or in the field before start-up, in accordance with the instructions of the ATMD manufacturer to insure optimal field performance.

d) Intake Dampers

i. Provide outdoor air intake ducts or openings intended for damper installation, sized for a minimum free area velocity of 150 ft/min (0.762 m/s) or greater at the specified design minimum airflow rate.

ii. Install a separate minimum intake damper if the specified maximum airflow rate during free cooling (economizer) exceeds the maximum airflow rating of the louver or hood for water carry-over

iii. All dampers shall be individually actuated and independently controlled. They shall not be mechanically linked.

e) Plenum Layout – Louver or Hood Intake Systems

i. Provide a minimum straight duct (sleeve) length of 18 inches (457 mm) between the trailing edge of the hood or louver, and the leading edge of the fully open intake damper blade to allow for installation of specified airflow measuring devices. (Note: Refer to plan details for schematic representations of these dimensional relationships.)

ii. If a minimum intake damper is required, the sleeve shall be partitioned into two sections, separating the minimum intake damper from the maximum intake damper.

iii. Actual plenum depth should be based on louver or hood performance data and the maximum airflow rate limits necessary to minimize water carry-over into the intake system during all modes of normal operation.

f) Fan inlets: [Editor's note: Installing an airflow meter at a fan inlet is not recommended as they require field calibration. If necessary use the following.]

i. Fan inlet air flow station mounted on fan bell. Sensor shall be installed on each inlet of double width fan.

ii. Refer to E.1 through E.9 above as base parameters are the same.

F. Power Measurement Devices

1. Three phase power shall be measured using 3 phase 3 wire or 3 phase 4 wire sensors and signal conditioning that yield true RMS input power based on measured current, voltage and power factor. The power measurement device shall be capable of sensing direct current and fundamental harmonics through the 50th harmonic (odd and even) with no derating in accuracy through the 25th harmonic.

2. Each power measurement device shall have rated instrument accuracy within ±1.5% of reading. Repeatability shall be within ±1.0 % of reading. Resolution of any signal conditioning and readout device shall be within ±0.1% of reading. The instrument shall be capable of measuring power within the stated accuracy over its entire range. These requirements are for the end-to-end measurement system including the sensor, transmitter and any signal conditioning.

3. Single watt / watt-hour transmitter or computer bus, gateway or interface output from VSD, providing fuse protected and isolated, 0-10VDC / 4-20mA (4-wire) analog or digital output of electric power. [*Editor's note: power readings provided by VSDs are to be considered suspect; some manufacturers only provide motor output power, which does not take into account VSD efficiency*].

G. Weather Station

1. Provide out door ambient dry-bulb and wet-bulb temperatures.

2. Each temperature measurement device shall have a rated instrument accuracy within 0.2 ºF. Repeatability shall be within 0.2 ºF. Resolution of any signal conditioning and

readout device shall be within 0.05 ºF. These requirements are for the end-to-end measurement system including the sensor, transmitter and any signal conditioning.

3. Provide aspirated fan powered sensing chamber. Filter inlet air.

4. The weather station should be mounted on a north-facing wall. If solar exposure is possible, it will need to be mounted in a naturally ventilated enclosure that allows access by the operators for maintenance. [*Editor: These devices should note be mounted on or next to high mass walls*.]

5. Provide 115 Volt AC supply and an area above unit to mount container of distilled water.

6. Provide three year supply of fresh wicks and filters.

7. Maintenance will include replenishment of distilled water in the reservoir and fresh wicks every six months and replacement of air filters annually.

H. Zone Temperature Measurement Devices

1. Each temperature measurement device shall have a rated instrument accuracy within 0.5 ºF. Repeatability shall be within 0.5 ºF. Resolution of any signal conditioning and readout device shall be within 0.1 ºF. These requirements are for the end-to-end measurement system including the sensor, transmitter and any signal conditioning.

2. The device should not be mounted on exterior walls or within 6 feet of windows or doorways."

Spec 3.11 Installation of sensors – [*Editor: add spec content describing air and hydronic flow sensor installation requirements*.]

"G. ... . The paste shall be rated and keep consistency over the expected temperature range. Allow for at least six pipe diameters upstream and four pipe diameter downstream clear of obstructions.

J. Hydronic flow meters

1. Insertion style flow meters shall be provided with all installation hardware necessary to enable installation and removal of flowmeter without system shutdown. No special tools shall be required for insertion or removal of the meter.

a. Meter shall be installed so the electronics orientate on the three, nine or twelve of clock positions of the pipe on horizontal mounting. On vertical meter mounting, electronics for applications where the medium being sampled is less than dew point shall be covered in removable and replaceable insulation.

b. Strait run pipe requirements will depend on installed control devices, pipe fittings and minimum distances. Such distances require approval by submittal.

2. Inline or flange mounted full bore style flowmeters shall be installed with a bypass assembly and isolation valves to enable installation and removal of the flowmeter without system shutdown. Leave space in mounting to perform maintenance and make connections to the unit.

a. Hot tapable meters require that instructions for isolation and removal be installed at the meter location. Remove handle and place handle with documentation mounted near the meter.

b. provide metal IDs tags on valves and sensor. Provide instructions for proper isolation valve position during isolation and operation modes.

3. When dictated by multiple elbows and other disturbances upstream and short available pipe runs, the flow measurement station shall provide compensation for rotational distortion in the velocity flow profile.

4. Verify that air vents or other air removal equipment exists in the system piping. If none exists, install appropriate air removal equipment upstream of flowmeter. Pipe discharge line to drain.

a. Inline or full bore flowmeters should also have the ground connected and carrier over the flanges to complete the circuit

K. Air flow stations

1. Install airflow measurement devices in accordance with manufacturer's instructions at the locations indicated on the plans. A written report shall be submitted to the consulting mechanical engineer if any discrepancies are found.

2. When dictated by disturbances upstream of inlet and short available air flow paths, the flow measurement station shall provide compensation for rotational distortion in the velocity flow profile.

3. Leave space in mounting of sensor equipment to perform maintenance. Allow space in mounting of electronics to make connections to the unit. Isolate the electronics from vibration inside the enclosure.

4. Duct and plenum airflow measurement devices shall not be adjusted without approval from the consulting mechanical engineer.

Spec 3.17.B Programming. Point naming – [*Editor: replace existing spec with new point naming requirements*.]

"B. Point Naming: Contractor shall use the point naming convention specified below in all documentation and programming.

1. Naming Architecture

a. Format is a four-element string including Location, System, Equipment, and Function. Equipment and function can be interchanged if desired.

b. Each element in string shall be as long as possible to aid readability without exceeding the overall maximum string length.
c. Location must include Building, Floor and Room number where applicable.

2. Naming Rules
a. Names need to be unique. Each of the four elements in a name should include a number if required for uniqueness.
b. Use agreed upon names if possible. If for some reason a name is too long, an abbreviated string should include a capitalized first letter of each element, or other delimiter as appropriate (e.g., a period). Be as clear as possible, using as much of the original name as possible. Do not omit a word or first letter.
c. When using uppercase letters as delimiters, do not use uppercase letters other than for the first letter of an element word.
d. Do not use the same capitalized letter for different meanings, except for an existing site-specific designation or as specified in Table 4 below. [*Editor: This table does not provide a definitive list of names and abbreviations that might be needed for control or other special requirements such as modeling equipment operation. It includes only those names pertinent to the points listed in Table 3. It should be noted that a point may serve multiple requirements*.]
e. Use abbreviations in Table 4 where applicable.

Table 4 – Data Point Naming Abbreviations

A	Air
AC	Air-conditioning
AH	Air Handler
Amps	Amps
Avg	Average
Blr	Boiler
Bldg	Building
cfm	cubic feet per minute
Chlr	Chiller
ChW	Chilled Water
Clg	Cooling
CondW	Condenser Water
COP	Coefficient of Performance
CT	Cooling Tower
Dmpr	Damper
DPr	Differential Pressure
E	Entering
Eff	Efficiency
Elec	Electric
EUI	Energy Use Intensity
F	Fan
Flr	Floor
InHdr	Inlet Header

GPr	Gauge Pressure
He	Heat or Heating
Ho	Hot
HVAC	Heating, Ventilation and Air-conditioning
Hz	Hertz
Inst	Instantaneous
kW	kilowatt
L	Leaving
Ltg	Lighting
M	Mixed
Max	Maximum
Mn	Main
Min	Minimum
Mode	Mode
Na	Natural
OA	Outdoor Ambient or Air
P	Pump
pf	Power factor
Pres	Pressure
Pri	Primary
R	Return
Rm	Room
rpm	Rotations per minute
RTU	Roof-top (packaged) unit
S	Supply
SD	Supply Duct
Sec	Secondary
Sp	Set-point
Spd	Speed
Spec	Specific
Stat	Status
Stc	Static
Sys	System
Temp	Temperature
Tot	Total
VFD	Variable Frequency Drive
Volts	Voltage
WB	Speed
Wb	Wet-bulb
Z	Zone

Spec 3.17.D Operator Interface – [*Editor: add spec content describing animation and navigation requirements; add new spec subsection and content building air handler, performance metric and energy use summary tables*.]

"1. ... . Provide animation or indicator light to indicate equipment is operating. Provide hotlinks to related building, floor and equipment graphics and data displays. Each graphic must match the actual configuration of the unit or system such that the graphic screen print out an operator can visit the unit and visually be able to identify ductwork and devices. A generic flow schematic is not acceptable. In general, standard system and equipment graphics and data displays must:

a. Show basic equipment such as filters, coils, valves, dampers, pumps, major equipment and pertinent data
b. Provide visual indication of actual equipment status not just its command
c. Use point-naming convention, as defined in Section 3.17. B.2, for equipment labels and pertinent data
d. Indicate when a manual reset of equipment is required
e. Indicate what systems are in override.
f. Graphic presentations for ancillary equipment such as exhaust fans must be hot-linked via text links to graphic presentations of related systems and/or building graphics.
g. Sensor locations must be identified on all graphics as installed.
h. Show alarm if measured or calculated value is out of expected range.

4. Show building (or campus) air handler summary information on a graphic summary table display. Provide dynamic information of each point shown. Include hotlink to each air handler. Points include:

a. Unit Command Status
b. Supply Fan Status
c. Cold Deck Air Temp (F)
d. Cooling Setpoint (F)
e. Chilled Water Valve (%)
f. Hot Deck Air Temp (F) (if applicable)
g. Heating Setpoint (F) (if applicable)
h. Hot Water Valve (% open) (if applicable)
i. Supply Fan Command Speed (%)
i. Cold Deck Duct Static Pressure (iwc)
k. Hot Deck Duct Static Pressure (iwc) (if applicable)
l. Duct Static Pressure Setpoint (iwc)
m. Outdoor Ambient Damper PID %

5. Provide the following selectable engineering units:

a. none (blank)
b. %
c. Volts (voltage)
d. Amps (current)
e. kW (power)
f. pf (power factor)
g. Hz (frequency)
h. rpm or rev/s (angular velocity)

i. °F or °C (temperature)
j. iwc, psig, psia, Pa or MPa (pressure)
k. kft^3 or m^3 (volume)
l. ft/min or m/s (linear velocity)
m. gpm or L/s (liquid flow rate)
n. cfm, scfm, or L/s, sL/s (air flow rate)
o. kWh_T, Joules, kBtu, therms or ton-hr (energy use)
p. kBtu/hr, tons or kW_T (thermal load)
q. $kBtu_i$/hr/$kBtu_o$/hr (1/COP), kW/ton or COP (performance)
r. kW/cfm or kW/L/s (specific power)
s. kWh/ft^2, $kBtu/ft^2$ or kWh/m^2 (energy use intensity)

7. Show the following time weighted point table graphic displays:
   a. Whole-Building Electric Energy Use (kWh)
   b. Whole-Building Natural Gas Energy Use (Joules or therms)
   c. Whole-Building Water Use (L or kgal)
   d. Chilled Water Plant Electric Energy Use (kWh) and Chilled Water Plant Cooling Energy (kWh or tons-hrs)
   e. Total Air Handler Energy Use (kWh) and Total Air Handler Volume (L or ft^3)

8. Show a Performance Monitoring Summary Table graphic display for the facility or each building as applicable. Include the following data:
   a. Site Weather
   b. Whole-Building Area-Normalized Electric Energy Use Intensity (EUI) (kWh/ft^2)
   c. Whole-Building Area-Normalized Gas Energy Use Intensity (Joules/ft^2 or therms/ft^2)
   d. Whole-Building Area-Normalized Water Use Intensity (EUI) (L/m^2 or $kgal/ft^2$)
   e. Whole-Building Peak Power (kW)
   f. Chilled Water Plant Efficiency (kW/ kW_T or kW/ton)
   g. Total Air Handler Specific Power (kW/ L/s or kW/cfm)"

Spec 3.17.E Time Series Trends – [*Editor: add new spec section and content describing specific trends requirements.*]

1. Provide trends for the following points:
   a. All specified analog and digital input and output values
   b. All setpoints
   c. All PID loop input and output values
   d. All calculated values
   e. All alarm setpoints

Spec 3.17.F Group Trend Data Displays – [*Editor*: *add new spec section and content describing specific group trend plots.*]

"1. Group trends in trend blocks in a logical way such as grouping all data for one 'system' together or grouping control loop values together. An example would be chilled water, which has chiller status, chilled water supply temperature, chilled water return temperature, chilled water supply setpoint temperature and outside air temperature together. Another example would be an air handling unit discharge air temperature with the analog temperature input, output(s) to the control device(s) and PID control setpoint on the same trend. Required group trend plots include:

2. Zone temperatures group trend plots - select typical and critical zones, grouped by orientation; revise as necessary.
   a. East Zones
   b. South Zones
   c. West Zones
   d. North + Interior Zones

3. Chiller water plant group trend plots
   a. Chilled Water Plant Monitor
      i) Graph 1: Building Chilled Water Flow Rate
      ii) Graph 2: Total Chiller Evaporator tons, Chiller 1 Power, Chiller 2 Power, Total Chiller Power (sum of #1and #2)
      iii) Graph 3: Total Chilled Water Pump Power (sum of all individual pump power readings which have been calculated from current), Total Condenser Water Pump Power (sum of all individual pump power readings which have been calculated from current), Total Cooling Tower Fan Power (sum of all individual tower fan power readings which have been calculated from current), Total Chilled Water Plant Power (sum of all equipment)
      iv) Graph 4: Total Chilled Water Plant kW/ton

4. Whole building performance group trend plots
   a. Whole Building Quantities
      i) Graph 1: PML Meter #1 Power, PML Meter #2 Power; Total Building Power (sum of #1 and #2)
      ii) Graph 2: Total Air Handler Power (sum of all individual air handler power readings), Total Chilled Water Plant Power
      iii) Graph 3: Whole Bldg Natural Gas Flow; Whole Bldg Water Flow
      iv) Graph 4: Outside Ambient Temperature

Spec 3.17.G XY Trend Plot Data Displays – [*Editor: add new spec section and content describing specific XY plot.*]

1. Provide the following XY trend plots:

a. ChW Plant Delta-T, ChW Plant tons vs. OA Temp
b. ChWPlant kW vs. ChWPlant tons
c. ChW Plant kW/ton vs. OA Temp, OA Wb Temp, ChW Plant tons
d. Whole Building Natural Gas Heatrate vs. OA Temp
e. OA Temp Fraction vs. OA Damper Fraction
f. Whole Bldg Electric EUI; Whole Bldg Natural Gas EUI, Whole Bldg Water EUI vs. Avg. Daily OA Temp

Spec 3.18 Control System Checkout and Testing – [*Editor: add spec requirements for check-out and testing of PM System.*]

"0. (new) Installation and Set-up: For hardware and each software element, Contractor shall conduct checks and functional tests as necessary to verify that the correct hardware and software has been installed as specified and works properly per this specification.

3. (revise) Sensors: Inspect installation of all sensors. Verify that all sensors are located per contract documents and installed according to manufacturer's installation requirements. Enable the control systems and verify through system accuracy of all input devices per this section or manufacturer's recommendations. Test equipment shall be at least twice as accurate as the rated accuracy of respective installed field devices. Use the following general requirements for verifying through system accuracy.

a. Temperature: Use a multi-point verification check at various points in the operating range (including minimum, typical, and maximum) utilizing a calibrated thermometer and Dewar flask or a calibrated portable drywell temperature probe calibrator and compare it to the I/O point data at a user interface to field-verify through-system measurement tolerance.

b. Wet-bulb Temperature: Use a single point calibrator or portable environmental chamber that has been lab calibrated with a NIST traceable dew point monitor and compare it to the I/O point data at a user interface to field-verify through-system measurement tolerance.

c. Fluid Flow: Use a portable ultrasonic flow meter to spot check flow(s) and compare it to the I/O point data at a user interface to field-verify through-system measurement tolerance. [*Editor: One must be aware that UFM's are velocity dependent devices and are highly vulnerable to variations in flow profile and installation error. They should be considered 5% devices for pipe diameters 12 inches and under. UFM flow profile compensation assumes a fully developed flow profile at the calculated Reynolds number. Even at 10 diameters downstream of an elbow, a significantly altered flow profile will occur. It is suggested that flow profile compensation be turned off and the acceptable deviation between the measuring flow meter and the UFM be restricted to 5% for applications with less than 10 pipe diameters of straight length pipe upstream of the UFM. If variable flow conditions exist, both flow and the flow profile will need to be evaluated at a range of conditions. See ASHRAE Standard 150-2000 Annex D for a detailed method.*]

d. Air Flow: Verification of airflow measurement system calibration in the field is often more difficult than for liquid flow, because of large and complex ductwork.

Field calibration checks shall be performed under steady state conditions by using a calibrated pitot tube or propeller anemometer traverses in at least two planes to field-verify through-system measurement accuracy. Where the field conditions vary under normal operation, airflows shall be checked over a range of at least three (3) flow rates.

8. (*new*) Programming:
   a. Monitored Point Set-up: Verify that all monitoring points as specified in Section 2.3H have been programmed including virtual and calculated points. Verify all performance metrics and data points are viewable in the appropriate graphics screen.
   b. Trend Set-up: Assure that each element of Sections 3.17.E is functional and reliable.
   c. Archival Database: Assure that each element of Section ?? is functional and reliable. Determine if the data are being sampled at the proper time intervals required and if, how, and where the data is being archived. Determine if the appropriate functionality has been provided. Assure tools are available to access and view archived data.
   d. Data Display and Reporting Software Installation and Set-up: Assure that each element of Section 3.17.F&G is functional and reliable."

Spec 3.19 Control System Demonstration and Testing – [*Editor: revise spec requirements for witness testing of PM System.*]

A. 8. *Replace existing with* "Demonstrate complete operation of operator interface including graphics and data visualization, point definitions, sequences, scheduling, trending, reporting and printing and exporting data."

A. 9.e *Replace* "not more than 10 minutes" *with* "not more than 5 minutes"

Spec 3.21 Training – [*Editor: add spec content describing PM System training requirements.*]

"H. Performance Monitoring. Hands-on on-site training shall be provided to in-house operating staff. Training shall include a conceptual overview of the purpose of the performance monitoring system, its relationship to the complete building control system, and its overall use, as well as the following detailed aspects of the performance monitoring system:

- Instrumentation including sensor maintenance and re-calibration requirements
- Data Communications
- Performance Metrics Calculations and Data Points
- Data Archival Software and Procedures
- Data Display Software Use. Training shall enable operating personnel to understand the following.
  i) Setting up new trends and plots
  ii) Proper use of the graphic displays for tracking building performance.

iii) How to use each performance monitoring graphic to diagnosis the proper and improper operation and performance of the subject equipment.
iv) What sets of remedial actions might be indicated given values out of range for each performance-monitoring graphic.
v) Using the data and data displays for ongoing commissioning.

- Data extraction”

Appendix H: Example Graphic and Data Displays

H1. Outdoor Air Conditions

H1.1 Provide a graphic screen with current data for Outdoor Ambient Dry Bulb Temperature (OAT-DB) and Outdoor Ambient Wet Bulb Temperature (OAT-WB).
H1.2 Provide a time-series plot showing the current 24 hour data profile for each point.
H1.3 Provide a time series plot showing the current 30 day plot of Average Daily Ambient Temperature-DB
H1.4 Provide active **text** links for
- a. Campus / Site
- b. Major systems
- c. Summary tables

H2. Floor Level Zone Temperatures

H2.1 Display a graphic for each floor
H2.2 The type of graphic display requirements listed for floor "#" shall apply to all floors, including basement(s) and penthouse.
H2.3 Identify sensor locations to the nearest space
H2.4 Label each zone with its room number
H2.5 A mouse over of the zone shows the terminal box number, which provides a picture link to the **Zone** level graphic**.**
H2.6 An example graphic is shown below in Figure H1.
H2.7 Provide **text** links to:
- a. Campus / Site
- b. Building
- c. Other floors
- d. Building AH# and Blr#'s
- e. Chilled Water Plant

Figure H.1 Example Floor Level Graphic

H3. Chilled Water (ChW) Plant

H3.1 If a chilled water plant is present, provide an *equipment* graphic that displays an image of the Chilled Water Plant and its major components including: Chiller(s), Cooling tower(s), Pumps, Valves and Sensors.

H3.2 Provide related status and performance data, including OAT, OARH, Site Power, Bldg Cooling Load (tons), ChW Plant Power, Chiller kW/ton

H3.3 Provide indication if the VFD is in "Auto" or "Hand" mode.

H3.4 An example graphic is shown below in Figure F3.

H3.5 Provide **text** links to:

a. Campus / Site
b. Chiller #
c. ChW Plant Performance
d. AH# Table

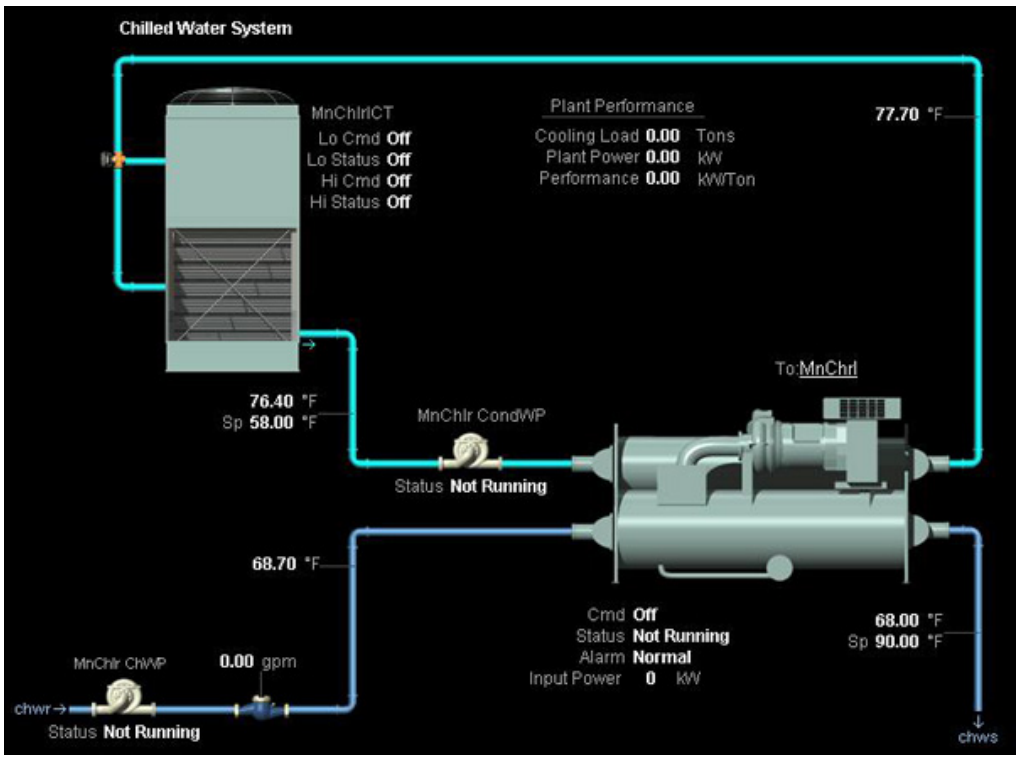


Figure H.2 Example Chilled Water Plant Graphic

H4. Air Handlers - AH #

H4.1 Provide an *equipment* graphic for each air handler that displays an image of all basic air handling unit equipment.

H4.2 Provide visual indication of equipment operation

H4.3 Indicate when a manual reset of equipment is required

H4.4 An example graphic is shown below in Figure F4.

H4.5 Provide **text** links to:

a. Floor Level(s) [*Editor: It is not a requirement, but a desirable feature, that the text link to Floor Levels from a given AHU# will highlight those floors served by that AHU#. This graphic presentation capability should be provided if possible.*]
b. ChW Plant
c. Boiler # or Boiler Plant (*which ever is applicable*)
d. AHU Summary Table

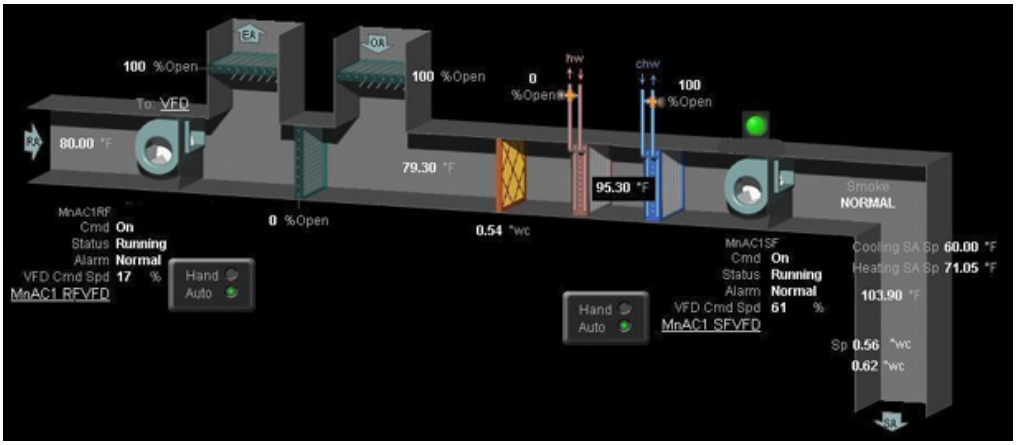


Figure H.3 Example AH# Graphic with status indicators

H5. Time weighted point tables screens

H5.1 Provide integrated and maximum point data over the following time periods: Today, previous day, week to date, previous week, month to date, previous month, year to date, previous month

H5.2 For maximum point tables, include a time series plot of current 24 hour data.

H5.3 An example graphic is shown below in Figure F5 and Figure F6.

H5.4 Provide **text** links to:

a. Campus / Site
b. Building
c. Other floors
d. Building AH# and Blr#'s
e. Chilled Water Plant

Figure H.4 Example Point Table Graphic

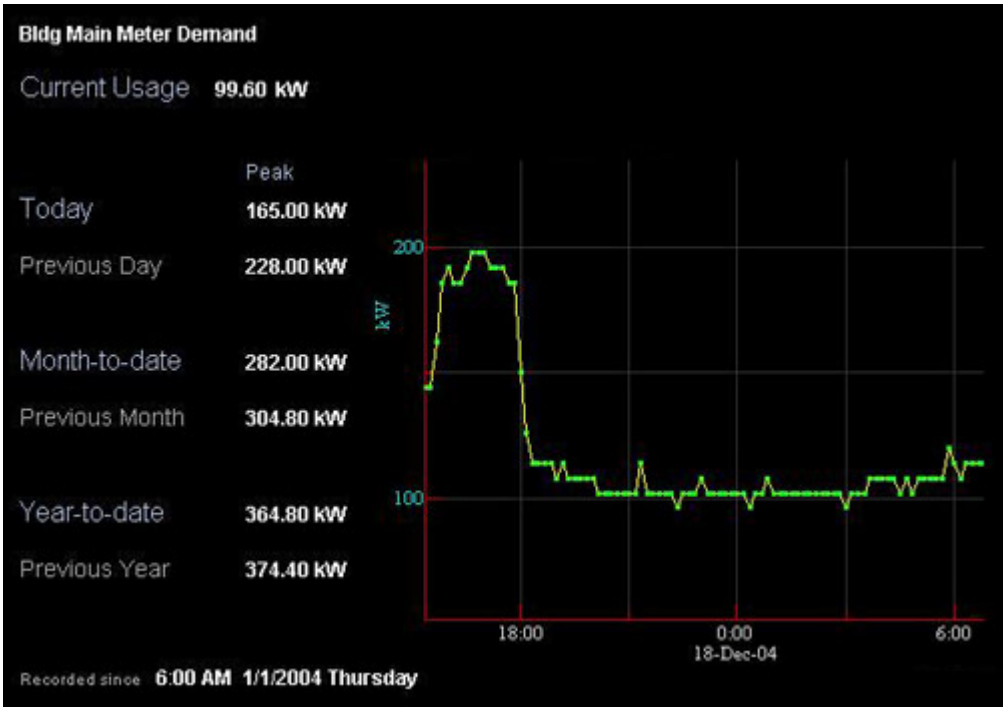


Figure H.5 Example Point Peak Data Table Graphic

H6. Tabular multi point data screens

H6.1 Title, column headers, pertinent data in tabular format and hot links to individual equipment

H6. 2 Example: **Air Handler Summary Table: Whole Building # (or Campus).** Display the AH# plus relevant summary data for the air handling units; if the following AH data points exist in the DDC system, then their status shall be displayed in this graphic:

- Unit command status
- Supply fan status
- Cold deck air temp (F)
- Cooling Setpoint (F)
- ChW Valve (%)
- Hot deck air temp (F) (if applicable)
- Heating Setpoint (F) (if applicable)
- HW Valve (%) (if applicable)
- SF Command Speed (%)
- Cold deck duct static pressure (“wc)
- Hot deck duct static pressure (“wc) (if applicable)
- Duct Static Pressure Setpoint (“wc)
- OA Damper PID %

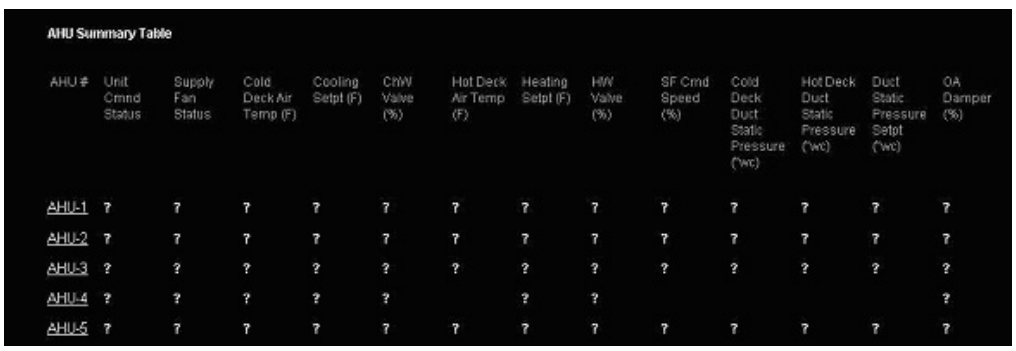
H6.3 An example graphic is shown in Figure F7

H6.4 This graphic shall also display active **text links** to:

a. Floor Level(s)

b. ChW Plant

c. Boiler # or Boiler Plant (*which ever is applicable*)



AHU Summary Table

AHU #	Unit Cmnd Status	Supply Fan Status	Cold Deck Air Temp (F)	Cooling Setpt (F)	ChW Valve (%)	Hot Deck Air Temp (F)	Heating Setpt (F)	HW Valve (%)	SF Cmd Speed (%)	Cold Deck Duct Static Pressure ("wc)	Hot Deck Duct Static Pressure ("wc)	Duct Static Pressure Setpt ("wc)	OA Damper (%)
AHU-1	?	?	?	?	?	?	?	?	?	?	?	?	?
AHU-2	?	?	?	?	?	?	?	?	?	?	?	?	?
AHU-3	?	?	?	?	?	?	?	?	?	?	?	?	?
AHU-4	?	?	?	?	?		?	?					?
AHU-5	?	?	?	?	?	?	?	?	?	?	?	?	?

Figure H.6 Example Air Handling Unit Summary Data Table Graphic

H7. Time series group trend plots

H7.1 Provide user selectable Y points

H7.2 Provide user editable titles, point names and Y axis titles

H7.3 Group Individual trended points in groups of up to four points per plot with up to four plots per page.

H7.4 Provide an adjustable time window, default to current and previous day.

H7.5 An example graphic is shown in Figure F8.

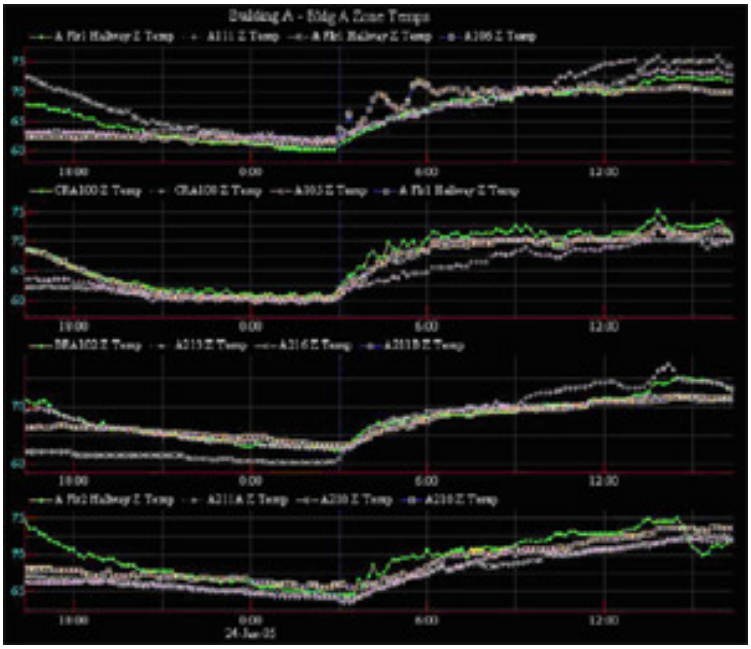


Figure H.7: Example Time-series Group Trend Plot Graphic

H8. X-Y Group Trend Plots

H8.1 Provide user selectable X and Y trend inputs

H8.2 Provide user editable titles, point names and X and Y axis titles

H8.3 Enable the user to select from the following time-period options: (1) a 1-day 24-hour period; (2) a 1-week 7-day period, (3) a 1-month period, with appropriate days for the month selected; or (4) a 1-year period. The user shall be able to select the beginning and ending period for each XY chart, within the time domain of the database being used

H8.4 Enable the user to display up to 6 plots per screen in 2 columns.

H8.5 An example graphic is shown in Figures H.8 and H.9.

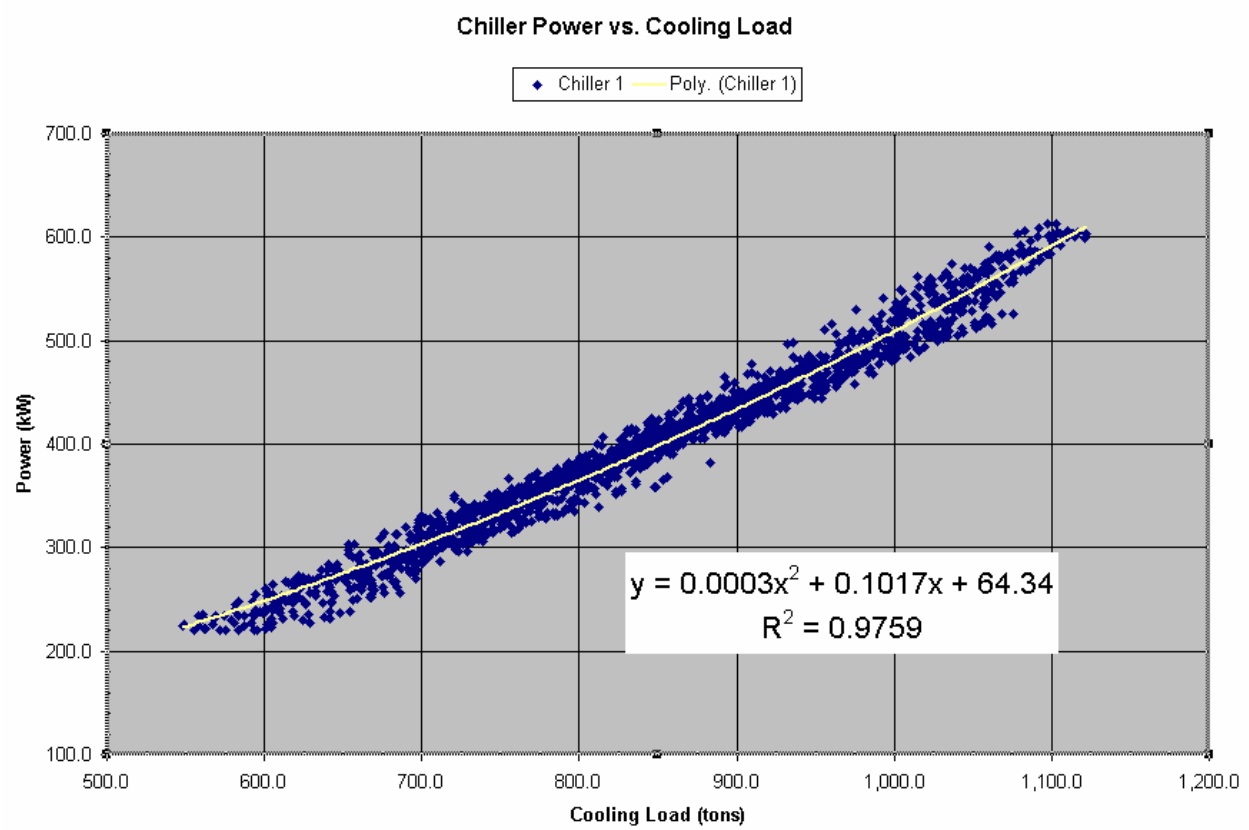


Figure H.8 Example X-Y Group Trend Plot Graphic

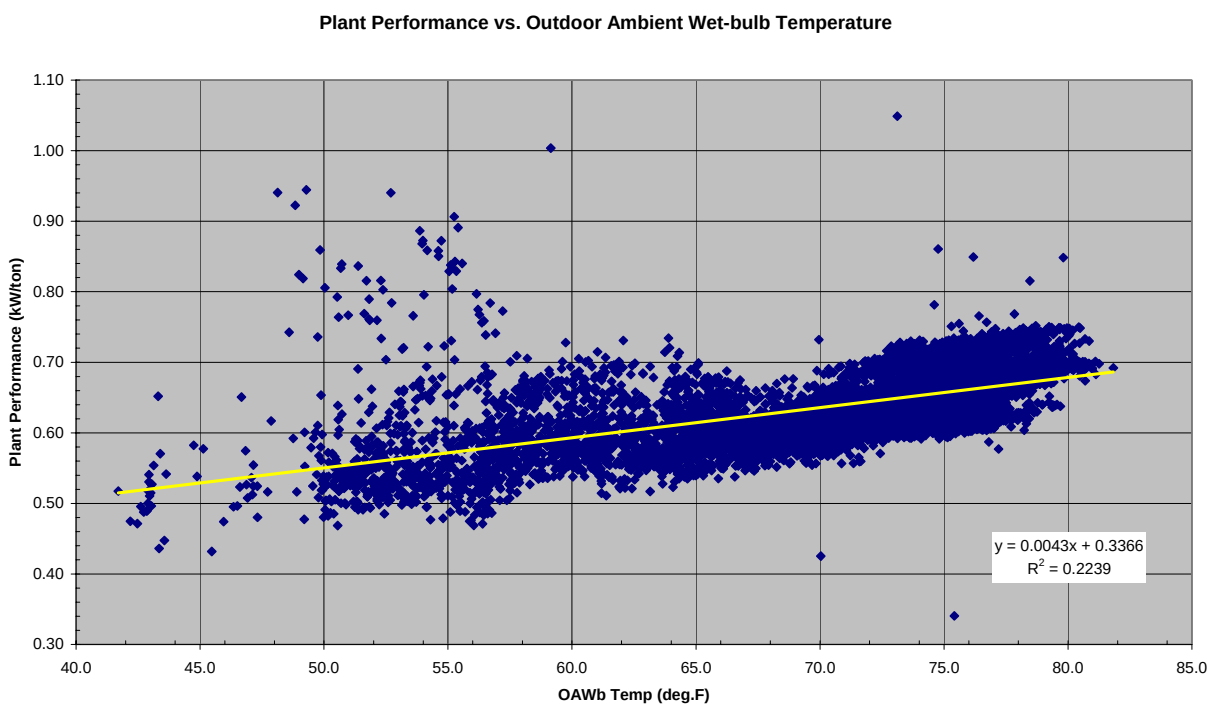


Figure H.9 Example X-Y Group Trend Plot Graphic

APPENDIX I: EXAMPLE POINT NAMING CONVENTIONS

What is provided below should not be considered a complete list; the majority of points listed are hardware points; it does not include all programmed points such as setpoints, events/alarms or trend names.

I1. Example 1

A. Architecture: [location (for examples: Mn, Mt, Wh, MGTF, Ph, L), if applicable] [system name & number, if applicable] [equipment name & number, if applicable] [function]

B. Rules:

1. Naming Architecture
   a. Format is a four-element string including Location, System, Equipment, and Function. Equipment and function can be interchanged if desired.
   b. Each element in string shall be as long as possible to aid readability without exceeding the overall maximum string length.
   c. Location must include Building, Floor and Room number where applicable.

2. Naming Rules
   a. Names need to be unique. Each of the four elements in a name should include a number if required for uniqueness.
   b. Use agreed upon names if possible. If for some reason a name is too long, an abbreviated string should include a capitalized first letter of each element, or other delimiter as appropriate (e.g., a period). Be as clear as possible, using as much of the original name as possible. Do not omit a word or first letter.
   c. When using uppercase letters as delimiters, do not use uppercase letters other than for the first letter of an element word.
   d. Do not use the same capitalized letter for different meanings, except for an existing site-specific designation or as specified in Table I.1 and I.2 below.
   e. If engineering units are used as part of a name they are not capitalized unless the letter is an abbreviation for a proper name. An example is kW for kilowatt.

I2. Example 2

A. **Architecture**: Name string format - If applicable include each of the following in the order presented: [Building/site location ID] [System name & number] [Controller name & number] _[Building interior location]_[Equipment name & number]_[function]_[units]

- Location ID: Building/site, identifies the macro location or building of a campus
- System: Name/number for the HVAC system
- Controller: ID of controller point is wired to

- _Building interior location: Floor and room numbers where sensing/actuating point is located (e.g., Flr1, Rm101, Ph, L). Not necessary if floor and room number is embedded in the equipment ID (e.g., VAV110 refers to first floor room 110). An underscore could be saved if it is not used for this element, see example below.
- _Equipment: ID of equipment such as AHU, VAV, etc. using drawing labels if possible and number if available.
- _Function: Function/purpose of point (see list below) that defines what it does. Use underscore in front to clearly separate it from other string elements.
- _Units: If applicable, include unit descriptor that tells how the data is to be presented

B. Examples: B225Unc1_VAV101_OccCoolSp,
_Ph_AHU1_MATemp or B225Unc2Ph_AHU1_MATemp

C. Rules:

1.Naming Architecture

a. Try to use names and labels consistent with mechanical/architectural drawings
b. Each element in string shall be as long as possible to aid readability without exceeding the overall maximum string length.
c. Location must include Building, Floor and Room number where applicable.

2. Naming Rules

a. Names need to be unique. Each of the elements in a name should include a number if required for uniqueness.
b. Use agreed upon names if possible. If for some reason a name is too long, an abbreviated string should include a capitalized first letter of each element, or other delimiter as appropriate (e.g., a period). Be as clear as possible, using as much of the original name as possible. Do not omit a word or first letter.
c. When using uppercase letters as delimiters, do not use uppercase letters other than for the first letter of an element word.
d. Separate numbers with text string elements
e. Do not use the same capitalized letter for different meanings, except for an existing site-specific designation or as specified in Table I.1 and I.2 below.

I3. Point Name Abbreviations

Table I.1: Abbreviations

#	*include appropriate letter or number as appropriate*
A	Air
Adj	Adjust or Adjustment
Alm	Alarm
Aux	Auxilary
Blr	Boiler
Bldg	Building

Bsmt	Basement
Byp	Bypass
C	Carbon, Coefficient, Coil or Cooling
Cafe	Cafeteria
Ch	Chilled
Chlr	Chiller
Cl	Close
Cmd	Command
Co	Cold
Cool	Cooling Stage
Comp	Compressor
Con	Condensate
Cond	Condenser
CC	Cooling Coil
COP	Coefficient of Performance
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COP	Coefficient of Performance
CT	Cooling Tower
D	Differential, Drive, Dual or Duct
Diff	Differential
Disc	Discharge
Dmpr	Damper (Dr is an alternate)
Do	Domestic
DwPt	Dewpoint
DP	Differential Pressure
DPS	Differential Pressure Switch
E	Entering
East	East
Eff	Efficiency
Elec	Electric
Env	Environmental Chamber
Evap	Evaporator
Ex	Exhaust
EUI	Energy Use Intensity
F	Fan, Frequency or Facility
Fac	Facilities
Flow	Flow
Flr	Floor

Frz	Freeze
G	Gas, Generator or Generation
Gar	Garage
H	Handler
He	Heat or Heating
Heat	Heating Stage
Hi	High
Ho	Hot
Har	Harvester
HVAC	Heating, Ventilation and Air-conditioning
Hum	Humidifier
I	Ice or Integral
In	Inlet
Inst	Instantaneous
Iso	Isolation
J	
K	Kitchen
L	Leaving, Lower Level
Ltg	Lighting
Lo	Low
M	Mixed, Mixing or Modular
Ma	Make-up
Mat	Materials
Max	Maximum
Min	Minimum
Mn	Main
Mt	Metalurgy
N	North
O	Outdoor or ‘of’
NaGas	Natural Gas
Occ	Occupied
Op	Open
Op/Cl	Open/Close
Ovrd	Override
OA	Outdoor Ambient or Air
O_2	Dioxide
P	Pump, Pressure, Performance or Proportional
Perf	Performance
Ph	Penthouse

Pos	Position
Pres	Pressure
Pwr	Power
PID	Proportional Integral Differential
Q	
R	Return
Rh	Reheat coil
Rf	Relief
Rm	Room
Run	Run
RTU	Roof-top (packaged) unit
S	Supply
So	South
Sol	Solenoid
Sp	Set-point
Spd	Speed
Spr	Spray
Stat	Status
Stc	Static
Stg	Stage
Stm	Steam
Suc	Suction
S/S	Start/Stop
T	Tower or Test
Temp	Temperature
Tl	Terminal
U	Unit
Unoc	Unoccupied
V	Variable, Volume or Volts
Vlv	Valve
VAV	Variable Air Volume
VFD	Variable Frequency Drive
W	Water
Wb	Wet-bulb
Wh	Warehouse
WB	Whole Building
Xovr	Changeover
Y	Yard
Z	Zone

Table I2: Engineering Units

%	Percent
Amps	Amperes
cfm	cubic feet per minute
gpm	gallons per minute
Hz	Hertz
iwc	inches water column
kW	kilowatt
kWh	kilowatt hours
pf	power factor
psig	pounds per square inch-gauge pressure
ppm	parts per million
rpm	revolutions per minute
Vac	Volts, AC
Vdc	Volts, DC

I.4 Example Points Names and Group Trend List

A. Point List Table Legend

1. Point name:
2. Point description:
3. Type:
   a) AO: analog output (e.g. 0-1 Vdc, 4-20 mA)
   b) AI: analog input
   c) DO: digital or binary output
   d) DI: digital or binary input
   e) CBAI: communication bus, gateway or interface analog input
   f) CBDI communication bus, gateway or interface digital (binary) input
   g) P: programmed
   h) C: calculated
4. Trend Logging Group

Table I.3: Example Point Names

Point Name	Point Description	Point Type	Trend Group
MnAC1SFVFD S/S	Supply Fan Start/Stop	DO	A1
MnAC1SFVFD CmdV	Supply Fan Speed Command Voltage	AO	A1
MnAC1SFVFD Cmd%	Supply Fan Speed Command in %	Soft	
MnAC1SFVFD CmdHz	Supply Fan Speed Command in Hertz	Soft	A1, AN1a
MnAC1SFVFD Status	Supply Fan Status	MB	A1, AN1a
MnAC1SFVFD Alarm	Supply Fan VFD Alarm	MB	A1, AN1a

Point Name	Point Description	Point Type	Trend Group
MnAC1SFVFD In Local	VFD in local "hand" mode	MB	A1, AN1a
MnAC1SFVFD Hz	VFD output frequency in Hz	MB	A1, AN1a
MnAC1SFVFD Power	VFD output power in kW	MB	AN1a
MnAC1SA StcPres	Supply Duct Static Pressure	AI	A1
MnAC1SFHiStcPres Alarm	Supply Fan - High Static Pressure Alarm	DI	A1
MnAC1RFVFD S/S	Return Fan Start/Stop	DO	B1
MnAC1RFVFD CmdV	Return Fan Speed Command Voltage	AO	B1
MnAC1RFVFD Cmd%	Return Fan Speed Command in %	Soft	
MnAC1RFVFD CmdHz	Return Fan Speed Command in Hertz	Soft	B1, AN1b
MnAC1RFVFD Status	Return Fan Status	MB	B1, AN1b
MnAC1RFVFD Alarm	Return Fan VFD Alarm	MB	B1, AN1b
MnAC1RFVFD In Local	VFD in local "hand" mode	MB	B1, AN1b
MnAC1RFVFD Hz	VFD output in Hz	MB	B1, AN1b
MnAC1RFVFD Power	VFD output power in kW	MB	AN1b
MnAC1 BldgStcPres	Building Static Pressure	AI	B1
MnAC1SA Temp	Supply Air Temperature	AI	C1
MnAC1RA Temp	Return Air Temperature	AI	C1
MnAC1MA Temp	Mixed Air Temperature	AI	C1
MnAC1OADmpr%	Economizer - Outdoor Air Damper Command in %	AO	C1
MnAC1RADmpr%	Economizer - Return Air Damper Command in %	AO	C1
MnAC1ChWVlv%	ChW Valve Command in % open	AO	C1, Rc
MnAC1SA TempSp	Supply Air Temperature Setpoint	Soft	C1
MnAC1SA PID%	Supply Air Cooling PID Output (CPID)	Soft	C1
MnAC1OADmpr Min%	Outside Air Damper Minimum Position	Soft	C1
MnAC1 Occupied	Occupancy Status	Soft	MnAC1 Mode
MnAC1 Run Time Remaining	Run Time Remaining	Soft	MnAC1 Mode
MnAC1 Heat Requests	Heat Requests	Soft	MnAC1 Mode
MnAC1 Cool Requests	Cool Requests	Soft	MnAC1 Mode
MnAC1WrmupMode	Warm-up Mode Status	Soft	MnAC1 Mode
MnAC1ClDwnMode	Cool Down Mode Status	Soft	MnAC1 Mode
MnAC1ZnHighTemp	High Zone Temp	Soft	MnAC1 Mode
MnAC1ZnLowTemp	Low Zone Temp	Soft	MnAC1 Mode
MnAC2SFVFD S/S	Supply Fan Start/Stop	DO	A2
MnAC2SFVFD CmdV	Supply Fan Speed Command Voltage	AO	A2
MnAC2SFVFD Cmd%	Supply Fan Speed Command in %	Soft	
MnAC2SFVFD CmdHz	Supply Fan Speed Command in Hertz	Soft	A2, AN2a
MnAC2SFVFD Status	Supply Fan Status	MB	A2, AN2a
MnAC2SFVFD Alarm	Supply Fan VFD Alarm	MB	A2, AN2a
MnAC2SFVFD In Local	VFD in local "hand" mode	MB	A2, AN2a
MnAC2SFVFD Hz	VFD output in Hz	MB	A2, AN2a
MnAC2SFVFD Power	VFD output power in kW	MB	AN2a
MnAC2SA StcPres	Supply Duct Static Pressure	AI	A2
MnAC2SFHiStcPres Alarm	Supply Fan - High Static Pressure Alarm	DI	A2
MnAC2RFVFD S/S	Return Fan Start/Stop	DO	B2
MnAC2RFVFD CmdV	Return Fan Speed Command Voltage	AO	B2
MnAC2RFVFD Cmd%	Return Fan Speed Command in %	Soft	

Point Name	Point Description	Point Type	Trend Group
MnAC2RFVFD CmdHz	Return Fan Speed Command in Hertz	Soft	B2, AN2b
MnAC2RFVFD Status	Return Fan Status	MB	B2, AN2b
MnAC2RFVFD Alarm	Return Fan VFD Alarm	MB	B2, AN2b
MnAC2RFVFD In Local	VFD in local "hand" mode	MB	B2, AN2b
MnAC2RFVFD Hz	VFD output in Hz	MB	B2, AN2b
MnAC2SFVFD Power	VFD output power in kW	MB	AN2b
MnAC2 BldgStcPres	Building Static Pressure	AI	B2
MnAC2SA Temp	Supply Air Temperature	AI	C2
MnAC2RA Temp	Return Air Temperature	AI	C2
MnAC2MA Temp	Mixed Air Temperature	AI	C2
MnAC2SA TempSp	Supply Air Temperature Setpoint	Soft	C2
MnAC2SA PID%	Supply Air Cooling PID Output (CPID)	Soft	C2
MnAC2OADmpr Min%	Outside Air Damper Minimum Position	Soft	C2
MnAC2OADmpr%	Economizer - Outdoor Air Damper Command in %	AO	C2
MnAC2RADmpr%	Economizer - Return Air Damper Command in %	AO	C2
MnAC2ChWVlv%	ChW Valve Command in % open	AO	C2, Rc
MnAC2 Occupied	Occupancy Status	Soft	MnAC2 Mode
MnAC2 Run Time Remaining	Run Time Remaining	Soft	MnAC2 Mode
MnAC2 Heat Requests	Heat Requests	Soft	MnAC2 Mode
MnAC2 Cool Requests	Cool Requests	Soft	MnAC2 Mode
MnAC2WrmupMode	Warm-up Mode Status	Soft	MnAC2 Mode
MnAC2ClDwnMode	Cool Down Mode Status	Soft	MnAC2 Mode
MnAC2ZnHighTemp	High Zone Temp	Soft	MnAC2 Mode
MnAC2ZnLowTemp	Low Zone Temp	Soft	MnAC2 Mode
MnOA Temp	Outdoor Air Temperature	AI	C1, C2, C5, BC
MnOA %RH	Outdoor Air Relative Humidity	AI	
MnAC3SA Temp	Supply Air Temperature	AI	D, AL
MnAC3OADmpr V	Outdoor Air Damper Command Voltage	AO	D
MnAC3OADmpr%	Outdoor Air Damper Command in %	Soft	D
MnAC3SF Status	Supply Fan Status	DI	D
MnAC3SF S/S	Supply Fan Start/Stop	DO	D
MnAC3ChWVlv V	CHW Valve Command Voltage	AO	D
MnAC3ChWVlv%	CHW Valve Command in % open	Soft	D, Rc
Mn144 Temp	Control Room Temp	LSTAT-AI	AL
Mn144 TempSpAdj	Control Room Temperature Setpoint Adjustment	LSTAT-AI	AL
Mn144 LocalOvrd	Override	LSTAT-AI	AL
Mn144 CoSp	Zone setpoint controller cooling setpoint output in %	Soft	AL
Mn144 HeSp	Zone setpoint controller heating setpoint output in %	Soft	AL
MnAC4SF S/S	Supply Fan Start/Stop	DO	E
MnAC4SF Status	Supply Fan Status	DI	E
MnAC4SA Temp	Supply Air Temperature	AI	F
MnAC4SA TempSp	Supply Air Temperature Setpoint		F
Mn143 Temp	Standards Lab Room Temperature	AI	F, BC

Point Name	Point Description	Point Type	Trend Group
Mn143 Z-TempSp	zone setpoint controller cooling setpoint output in Def.F	Soft	F
Mn143 HeSp	zone setpoint controller heating setpoint output in Deg.F-not used	Soft	
MnAC4ChWVlv V	ChW 3-way Valve Position Command Voltage	AO	
MnAC4ChWVlv%	ChW 3-way Valve Position in % open	Soft	F, K, Rc
MnAC4RA Temp	Return Air Temperature	AI	F, G
MnAC4ChWVlv PID%		Soft	F, G, K
MnAC4HoWVlv PID%		Soft	I
MnAC4HoWVlv V	HW 3-way Valve Position Command Voltage	AO	F
MnAC4HoWVlv%	HW 3-way Valve Position in % open	Soft	F, I
MnAC4CCLA Temp	Cooling Coil Leaving Air Temperature	AI	F, G, K
Mn143 %RH	Standards Lab Room Relative Humidity	AI	G, BC
MnAC4Hum V	Humidifier - Nortec Command Voltage	AO	G
MnAC4Hum %	Humidifier - Nortec Command Output in % open	Soft	G
MnAC4Hum PID%	Humidifier PID Output in %	Soft	G
MnAC4Hum Alarm	Humidifier Alarm Point	DI	G
MnAC4HumCan Alarm	Humidifier Canister Alarm Point	DI	G
Mn143 DewPoint	Standards Lab Dewpoint	Soft	G, BC
MnAC4HoWP1 Status	HW Pump Status	DI	H
MnAC4HoWP1 S/S	HW Pump Start/Stop	DO	H
MnAC4HoWS Temp	HW Supply Temperature	AI	H, I
MnAC4HoWR Temp	HW Return Temperature	AI	H, I
MnAC4Blr Alarm	Boiler Alarm	DI	H
MnAC4Blr Fire	Boiler Fire	DO	H
MnAC4BlrHoWS TempSp	Boiler Hot Water Temperature Setpoint (hwsp)	Soft	H
MnAC4ChWP Status	CHW Pump Status	DI	J
MnAC4ChWP S/S	CHW Pump Start/Stop	DO	J
MnAC4Comp2 Alarm	Chiller Compressor 2 Alarm	DI	BB
MnAC4Comp1 Alarm	Chiller Compressor 1 Alarm	DI	BB
MnAC4Comp1 Amps	Chiller Compressor 1 Amps	AI	BB
MnAC4Comp2 Amps	Chiller Compressor 2 Amps	AI	BB
MnAC4ChWS Temp	CHW Supply Temperature	AI	F, G, K, BB
MnAC4ChWR Temp	CHW Return Temperature	AI	K, BB
MnAC4ChWS Xovr	Chilled Water Supply Changeover Valve Position	DI	J, K, BB
MnAC4ChWR Xovr	Chilled Water Return Changeover Valve Position	DI	J, K, BB
MnAC4HoWS Xovr	Hot Water Supply Changeover Valve Position	DI	I
MnAC4HoWR Xovr	Hot Water Return Changeover Valve Position	DI	I
MnAC5SFVFD S/S	Supply Fan Start/Stop	DO	A5
MnAC5SA StcPres	Supply Duct Static Pressure	AI	A5
MnAC5SA StcPresSp	Supply Duct Static Pressure Setpoint (DPSP)	Soft	A5
MnAC5SAHiStcPres Alarm	Supply Fan - High Static Pressure Alarm	DI	A5
MnAC5SF HiStcReset	Supply Fan Hi Static Alarm Reset	DO	A5
MnAC5SFVFD CmdV	Supply Fan Speed Command Voltage	AO	A5
MnAC5SFVFD Cmd%	Supply Fan Speed Command Output in %	Soft	
MnAC5SFVFD CmdHz	Supply Fan Speed Command Output in Hz	Soft	A5, AN5

Point Name	Point Description	Point Type	Trend Group
MnAC5SFVFD Status	Supply Fan Status	MB	A5, AN5
MnAC5SFVFD Alarm	Supply Fan VFD Alarm	MB	A5, AN5
MnAC5SFVFD In Local	VFD in local "hand" mode	MB	A5, AN5
MnAC5SFVFD Hz		MB	A5, AN5
MnAC5SFVFD Power	VFD output power in kW	MB	AN5
MnAC5SA Temp	Supply Air Temperature	AI	C5
MnAC5RA Temp	Return Air Temperature	AI	C5
MnAC5MA Temp	Mixed Air Temperature	AI	C5
MnAC5OA Temp	Outdoor Air Temperature	AI	C5
MnAC5OADmpr%	Economizer - Outdoor Air Damper Command in %	AO	C5
MnAC5RADmpr%	Economizer - Return Air Damper Command in %	AO	C5
MnAC5ChWVlv%	ChW Valve Command in %	AO	C5
MnAC5ChWP Status	CHW Pump Status	DI	C5
MnAC5ChWP S/S	CHW Pump Start/Stop	DO	C5
MnAC5SA TempSp	Supply Air Temperature Setpoint	Soft	C5
MnAC5SA PID%	Supply Air Cooling PID Output (CPID)	Soft	C5
MnAC5OADmpr Min%	Outside Air Damper Minimum Position	Soft	C5
MnAC5 ManualOvrd	Air handler in manual override	Soft	MnAC5 Mode
MnAC5 Occupied	Occupancy Status	Soft	MnAC5 Mode
MnAC5 Run	Run Command	Soft	MnAC5 Mode
MnAC5 Run Time Remaining	Run Time Remaining	Soft	MnAC5 Mode
MnAC5 Heat Requests	Heat Requests	Soft	MnAC5 Mode
MnAC5 Cool Requests	Cool Requests	Soft	MnAC5 Mode
MnAC5ZnHighTemp	High Zone Temp	Soft	MnAC5 Mode
MnAC5ZnLowTemp	Low Zone Temp	Soft	MnAC5 Mode
MnCT2CondWP Status	CW Pump Status	DI	O
MnCT2Fan Status	Tower Fan Status	AI	O
MnCT2CondWS Temp	CW Supply Temperature	AI	O
MnCT2CondWR Temp	CW Return Temperature	AI	O
MnEnv1Comp Status	Compressor 1 Status	DI	O
MnEnv2Comp Status	Compressor 2 Status	DI	O
MnEnv1 Temp	Zone Temp	AI	AU
MnEnv1 %RH	Zone Humidity	AI	AU
MnEnv2 Temp	Zone Temp	AI	AU
MnEnv2 %RH	Zone Humidity	AI	AU
MnBlr1 Enable	Steam Boiler Enable	DO	T
MnBlr1 Alarm	Steam Boiler Alarm	DI	T
MnBlr1ConRP Status	Condensate Return Pump Status	DI	T
MnBlr1 StmPres	Steam Pressure	AI	T
MnDoHoWP Status	Domestic HW Pump Status	DI	U
MnDoHoWP S/S	Domestic HW Pump Start/Stop	DO	U
MnDoHoWS Temp	Domestic HW Supply Temperature	AI	U
MnDoHoWR Temp	Domestic HW Return Temperature	AI	U
MnDoStmVlv%	Domestic Steam Valve Position	AO	U

Point Name	Point Description	Point Type	Trend Group
MnDoStmVlv PID%	Domestic Hot Water Steam Valve PID Output in % (dhpid)	Soft	U
MnHoWP4 Status	Hydronic HW Pump P4 Status	DI	V
MnHoWP4 S/S	Hydronic HW Pump P4 Start/Stop	DO	V
MnHoWP5 Status	Hydronic HW Pump P5 Status	DI	V
MnHoWP5 S/S	Hydronic HW Pump P5 Start/Stop	DO	V
MnHoWS Temp	Hydronic HW Supply Temperature	AI	V
MnHoWR Temp	Hydronic HW Return Temperature	AI	V
MnStmVlv1/3%	Hydronic Steam Valve1Position	AO	V
MnStmVlv2/3%	Hydronic Steam Valve2 Position	AO	V
MnStmVlv PID%	Hydronic Steam Valve PID Output in % (hpid)	Soft	V
MnBlr ManualOvrd	Steam Boiler Manual Override	Soft	MnBlr Mode
MnBlr Occupied	Occupancy Status	Soft	MnBlr Mode
MnBlr Heat Requests	Heat Requests	Soft	MnBlr Mode
MnBlr Run	Run Command	Soft	MnBlr Mode
MnBlr Run Time Remaining	Run Time Remaining	Soft	MnBlr Mode
MnChlr1 Status	House Chiller Status	DI	Q, Rc, S
MnChlr1 S/S	House Chiller Start/Stop	DO	Q
MnChlr1 Alarm	House Chiller Alarm	DI	Q
MnChlr1ChWP Status	CHW Pump Status	DI	Q
MnChlr1ChWS SpReset	Chiller Temperature Setpoint Reset	AO	Q, Rc
MnChlr1 Tons	Chiller Cooling Load in tons	AI	Q, Rm
MnChlr1 Power	House Chiller Input Power	AI	Q, Rm
MnChWVlv PID%	Chilled Water Valve PID Output in % (cpid)	Soft	Rc
MnChlr1ChWS Temp	CHW Supply Temperature	AI	Rc, Rm
MnChlr1ChWR Temp	CHW Return Temperature	AI	Rc, Rm
MnChlr1ChW Flow	Chiller Entering Water Flow	AI	Rm
MnChWPlant Power	Chiller (measured) + pumps and cooling tower (fixed)	Soft	Rm
MnChWPlant Performance	Plant kW / Chiller tons	Soft	Rm
MnChlr1CondWP Status	CW Pump Status	DI	S
MnChlr1CondWS Temp	CW Supply Temperature	AI	S
MnChlr1CondWR Temp	CW Return Temperature	AI	S
MnChlr1CTF-Lo Status	Cooling Tower Fan Lo Status	DI	S
MnChlr1CTF-Hi Status	Cooling Tower Fan Hi Status	DI	S
MnChlr1CTF-Lo S/S	Cooling Tower Fan Lo Start/Stop	DO	S
MnChlr1CTF-Hi S/S	Cooling Tower Fan Hi Start/Stop	DO	S
MnChlr1 ManualOvrd	House Chiller Manual Override	Soft	MnChlr1 Mode
MnChlr1 Occupied	Occupancy Status	Soft	MnChlr1 Mode
MnChlr1 Cool Requests	Heat Requests	Soft	MnChlr1 Mode
MnChlr1 Run	Run Command	Soft	MnChlr1 Mode
MnChlr1 Run Time Remaining	Run Time Remaining	Soft	MnChlr1 Mode
MnL16 Temp	Basement Comm Room Temperature	AI	
MnElecMeter Power	Electric Meter Pulse Output	DI	
MnEF3 Status	Exhaust Fan 3 Status	DI	

Point Name	Point Description	Point Type	Trend Group
MnEF3 S/S	Exhaust Fan 3 Start/Stop	DO	
MnEF4 Status	Exhaust Fan 4 Status	DI	
MnEF4 S/S	Exhaust Fan 4 Start/Stop	DO	
MnEF5 Status	Exhaust Fan 5 Status	DI	
MnEF5 S/S	Exhaust Fan 5 Start/Stop	DO	
MnEF6 Status	Exhaust Fan 6 Status	DI	
MnEF6 S/S	Exhaust Fan 6 Start/Stop	DO	
MnEF7 Status	Exhaust Fan 7 Status	DI	
MnEF7 S/S	Exhaust Fan 7 Start/Stop	DO	
MnEF8 Status	Exhaust Fan 8 Status	DI	
MnEF8 S/S	Exhaust Fan 8 Start/Stop	DO	
MnEF9 Status	Exhaust Fan 9 Status	DI	
MnEF9 S/S	Exhaust Fan 9 Start/Stop	DO	
MnEF10 Status	Exhaust Fan 10 Status	DI	
MnEF10 S/S	Exhaust Fan 10 Start/Stop	DO	
MnEF11 Status	Exhaust Fan 11 Status	DI	
MnEF11 S/S	Exhaust Fan 11 Start/Stop	DO	
MnEF12 Status	Exhaust Fan 12 Status	DI	
MnEF12 S/S	Exhaust Fan 12 Start/Stop	DO	
MnEF13 Status	Exhaust Fan 13 Status	DI	
MnEF13 S/S	Exhaust Fan 13 Start/Stop	DO	
MnEF14 Status	Exhaust Fan 14 Status	DI	
MnEF14 S/S	Exhaust Fan 14 Start/Stop	DO	
MnEF15 Status	Exhaust Fan 15 Status	DI	
MnEF15 S/S	Exhaust Fan 15 Start/Stop	DO	
MnEF16 Status	Exhaust Fan 16 Status	DI	
MnEF16 S/S	Exhaust Fan 16 Start/Stop	DO	
MnAC7SF S/S	Supply Fan Start/Stop	DO	AP
MnAC7SF Status	Supply Fan Status	DI	AP
MnAC7SA Temp	Supply Air Temperature	AI	AP
Mn113-K Temp	Space Temperature	AI	AP
Mn113-K TempSpAdj	Space Temperature Setpoint Adjustment	AI	AP
Mn113-K LocalOvrd	Local Override	DI	AP
MnAC7Cool1 Run	Cooling Stage 1	DO	AP
MnAC7Cool2 Run	Cooling Stage 2	DO	AP
MnAC7Heat1 Run	Heating Stage 1	DO	AP
Mn113-K CoSp	Zone setpoint controller cooling setpoint output in Deg.F	Soft	AP
Mn113-K HeSp	Zone setpoint controller cooling setpoint output in Deg.F	Soft	AP
MnAC8SF S/S	Supply Fan Start/Stop	DO	AQ
MnAC8SF Status	Supply Fan Status	DI	AQ
MnAC8SA Temp	Supply Air Temperature	AI	AQ
Mn113-Café Temp	Space Temperature	AI	AQ

Point Name	Point Description	Point Type	Trend Group
Mn113-Café TempSpAdj	Space Temperature Setpoint Adjustment	AI	AQ
Mn113-Café LocalOvrd	Local Override	DI	AQ
MnAC8Cool1 Run	Cooling Stage 1	DO	AQ
MnAC8Cool2 Run	Cooling Stage 2	DO	AQ
MnAC8Heat1 Run	Heating Stage 1	DO	AQ
Mn113-Café CoSp	Zone setpoint controller cooling setpoint output in Deg.F	Soft	AQ
Mn113-Café HeSp	Zone setpoint controller cooling setpoint output in Deg.F	Soft	AQ
MnCntRmSF S/S	Supply Fan Start/Stop	DO	AT
MnCntRmSF Status	Supply Fan Status	DI	AT
MnCntRmSA Temp	Supply Air Temperature	AI	AT
MnCntRmCool1 Run	Cooling Stage 1	DO	AT
MnCntRmHeat1 Run	Electric Duct Heater Control	DO	AT
Mn153A Temp	Space Temperature	AI	AT
Mn153A TempSpAdj	Space Temperature Setpoint Adjustment	AI	AT
Mn153A LocalOvrd	AHU Schedule Local Override	DI	AT
Mn153A CoSp	Zone setpoint controller cooling setpoint output in Deg.F	Soft	AT
Mn153A HeSp	Zone setpoint controller cooling setpoint output in Deg.F	Soft	AT
Mn### Temp	Room/Space Temperature	AI	AJ or AL
### is the room number where the stat is located			
Mn### TempSpAdj	Room/Space Temperature Setpoint Adjustment	AI	AJ or AL
Mn### LocalOvrd	AHU Schedule Local Override	DI	AJ or AL
Mn### CoSp	Zone setpoint controller cooling setpoint output in Deg.F	soft	AJ or AL
Mn### HeSp	Zone setpoint controller cooling setpoint output in Deg.F	soft	AJ or AL
Mn???#SA Temp	VAV Discharge Air Temperature	AI	AK or AL
Mn???# SAT Sp	VAV Discharge Air Temperature PID Setpoint	soft	AK
Mn???# CoReset%	zone controller cooling output in %	soft	AK
Mn???# HeReset%	zone controller heating output in %	soft	AK or AL
Mn???#HoWVlv%	Hot Water Valve	AO	AK
Mn???# Flow	airflow controller flow output in cfm	soft	AK
Mn???# FlowSp	airflow controller flow setpoint in cfm	soft	AK
Mn???# Dmpr Cycle Count		soft	AK
MtAC1SF S/S	Supply Fan Start/Stop	DO	AA
MtAC1SF Status	Supply Fan Status	DI	AA
MtEF2 S/S	Exhaust Fan Start/Stop	DO	AA
MtEF2 Status	Exhaust Fan Status	DI	AA
Mt106 Temp	Space Temperature	AI	Z1

Point Name	Point Description	Point Type	Trend Group
Mt106 TempSpAdj	Space Temperature Setpoint Adjustment	AI	Z1
Mt106 LocalOvrd	Local Override	DI	Z1
Mt106 CoSp	Zone setpoint controller cooling setpoint output in Deg.F	Soft	Z1
Mt106 HeSp	Zone setpoint controller cooling setpoint output in Deg.F	Soft	Z1
MtAC1Cool1 Run	Cooling Stage 1	DO	Z1
MtAC1Cool2 Run	Cooling Stage 2	DO	Z1
MtAC1Heat1 Run	Heating Stage 1	DO	Z1
MtAC1SA Temp	Supply Air Temperature	AI	Z1
MtAC2SF S/S	Supply Fan Start/Stop	DO	AB
MtAC2SF Status	Supply Fan Status	DI	AB
Mt105 Temp	Space Temperature	AI	AC
Mt105 TempSpAdj	Space Temperature Setpoint	AI	AC
Mt105 LocalOvrd	Local Override	DI	AC
Mt105 CoSp	Zone setpoint controller cooling setpoint output in Deg.F	Soft	AC
Mt105 HeSp	Zone setpoint controller cooling setpoint output in Deg.F	Soft	AC
MtAC2SA Temp	Supply Air Temperature	AI	AC, AD
MtAC2OADmpr%	Outside Air Damper	AO	AD
MtAC2MA Temp	Mixed Air Temperature	AI	AD
MtAC2Cool1 Run	Cooling Stage 1	DO	AD
MtAC2Cool2 Run	Cooling Stage 2	DO	AD
MtAC2Heat1 Run	Heating Stage 1	DO	AD
MtAC2CTF S/S	Cooling Tower Fan Start/Stop	DO	AE
MtAC2CondWP S/S	Condenser Water Pump Start/Stop	DO	AE
MtAC2CTF Status	Cooling Tower Fan Status	DI	AE
MtAC2CondWP Status	Condenser Water Pump Status	DI	AE
MtAC2CondWS Temp	Condenser Water Supply Temp	AI	AE
MtAC2CondWR Temp	Condenser Water Return Temp	AI	AE
MtAC2WrmupMode	Warm-up Mode Status	Soft	MtAC2 Mode
MtAC2ClDwnMode	Cool Down Mode Status	Soft	MtAC2 Mode
MtAC3CoSF S/S	Cooling Supply Fan Start/Stop	DO	AF
MtAC3CoSF Status	Cooling Supply Fan Status	DI	AF
MtAC3Co StcPres	Cooling Duct Static Pressure	AI	AF
MtAC3HeSF Run	Heating Supply Fan Start/Stop	DO	AF
MtAC3HeSF Status	Heating Supply Fan Status	DI	AF
MtAC3He StcPres	Heating Duct Static Pressure	AI	AF
MtEF7 S/S	Exhaust Fan Start/Stop	AI	AF
MtEF7 Status	Exhaust Fan Status	AI	AF
MtAC3RF S/S	Return Fan Start/Stop	DO	AF
MtAC3RF Status	Return Fan Status	DI	AF
MtAC3Cool1 Run	Cooling Stage 1	DO	AO
MtAC3Cool2 Run	Cooling Stage 2	DO	AO

Point Name	Point Description	Point Type	Trend Group
MtAC3CoBypDmpr%	Cooling Bypass Damper	AO	AO
MtAC3OADmpr%	Outside Air Damper	AO	AO
MtAC3SA-Co PID%	Cooling Supply Air PID in %	Soft	AO
MtAC3CoSA Temp	Cooling Supply Air Temperature	AI	AO
MtAC3MA Temp	Mixed Air Temperature	AI	AG, AO
MtAC3Heat1 Run	Heating Stage 1	DO	AG
MtAC3HeBypDmpr%	Heating Bypass Damper	AO	AG
MtAC3HeSA Temp	Heating Supply Air Temperature	AI	AG
MtAC3SA-He TempSp	Heating Supply Air Temperature Setpoint	Soft	AG
MtAC3 Occupied	Occupancy Status	Soft	MtAC3 Mode
MtAC3 Run Time Remaining	Run Time Remaining	Soft	MtAC3 Mode
MtAC3 Heat Requests	Heat Requests	Soft	MtAC3 Mode
MtAC3 Cool Requests	Cool Requests	Soft	MtAC3 Mode
MtAC3WrmupMode	Warm-up Mode Status	Soft	MtAC3 Mode
MtAC3ClDwnMode	Cool Down Mode Status	Soft	MtAC3 Mode
MtAC3ZnHighTemp	High Zone Temp	Soft	MtAC3 Mode
MtAC3ZnLowTemp	Low Zone Temp	Soft	MtAC3 Mode
MtAC4SF S/S	Supply Fan Start/Stop	DO	AA4
MtAC4SF Status	Supply Fan Status	DI	AA4
MtEF4 S/S	Exhaust Fan Start/Stop	DO	AA4
MtEF4 Status	Exhaust Fan Status	DI	AA4
MtEF5 S/S	Exhaust Fan Start/Stop	DO	AA4
MtEF5 Status	Exhaust Fan Status	DI	AA4
MtAC4SA Temp	Supply Air Temperature	AI	Z4
Mt101 Temp	Space Temperature	AI	Z4
Mt101 TempSpAdj	Space Temperature Setpoint Adjustement	AI	Z4
Mt101 LocalOvrd	Local Override	DI	Z4
Mt101 CoSp	Zone setpoint controller cooling setpoint output in Deg.F	Soft	Z4
Mt101 HeSp	Zone setpoint controller cooling setpoint output in Deg.F	Soft	Z4
MtAC4Cool1 Run	Cooling Stage 1	DO	Z4
MtAC4Cool2 Run	Cooling Stage 2	DO	Z4
MtAC4Heat1 Run	Heating Stage 1	DO	Z4
MtAC5SF S/S	Supply Fan Start/Stop	DO	AA5
MtAC5SF Status	Supply Fan Status	DI	AA5
Mt109 Temp	Space Temperature	AI	Z5
Mt109 TempSpAdj	Space Temperature Setpoint Adjustment	AI	Z5
Mt109 LocalOvrd	Local Override	DI	Z5
Mt109 CoSp	Zone setpoint controller cooling setpoint output in Deg.F	Soft	Z5
Mt109 HeSp	Zone setpoint controller cooling setpoint output in Deg.F	Soft	Z5
MtAC5Cool1 Run	Cooling Stage 1	DO	Z5
MtAC5Cool2 Run	Cooling Stage 2	DO	Z5

Point Name	Point Description	Point Type	Trend Group
MtAC5Heat1 Run	Heating Stage 1	DO	Z5
MtAC5SA Temp	Supply Air Temperature	AI	Z5
Mt### Temp	Room/Space Temperature	AI	AJ
### is the room number where the stat is located			
Mt### TempSpAdj	Room/Space Temperature Setpoint Adjustment	AI	AJ
Mt### LocalOvrd	AHU Schedule Local Override	DI	AJ
### is the terminal box numbering scheme			
Mt### CoSp	zone setpoint controller cooling setpoint output in Deg.F	soft	AJ
Mt### HeSp	zone setpoint controller heating setpoint output in Deg.F	soft	AJ
Mt??-# SA Temp	VAV Discharge Air Temperature	AI	AM
Mt??-# SA TempSp	VAV Discharge Air Temperature PID Setpoint in Deg.F	soft	AM
Mt??-# HoWVlv%	Hot Water Valve Outout in %	AO	AM
Mt??-# CoReset%	zone controller cooling output in %	soft	AM
Mt??-# HeReset%	zone controller heating output in %	soft	AM
Mt??-# CD Flow	cooling airflow controller flow output in cfm	soft	AM
Mt??-# CD FlowSp	cooling airflow controller flow setpoint in cfm	soft	AM
Mt??-# CD Dmpr Cycle Count		soft	AM
MtDD-# HD Flow	heating airflow controller flow output in cfm	soft	AM
MtDD-# HD FlowSp	heating airflow controller flow setpoint in cfm	soft	AM
MtDD-# HD Dmpr Cycle Count		soft	AM
MtDD-# TotFlow	total airflow in cfm	soft	AM
MtDD-# TotFlowSp	total airflow setpoint (sum of cooling and heating) in cfm	soft	AM
WhAC1SF S/S	Supply Fan Start/Stop	DO	AR
WhAC1SF Status	Supply Fan Status	DI	AR
WhAC1Cool1 Run	Cooling Stage 1	DO	AR
WhAC1Heat1 Run	Heating Stage 1	DO	AR
WhAC1SA Temp	Supply Air Temperature	AI	AR
WhFac Temp	Space Temperature	AI	AR
WhFac TempSpAdj	Space Temperature Setpoint Adjustment	AI	AR
WhFac LocalOvrd	Local Override	DI	AR
WhFac CoSp	Zone setpoint controller cooling setpoint output in Deg.F	Soft	AR
WhFac HeSp	Zone setpoint controller cooling setpoint output in Deg.F	Soft	AR
WhAC2SF S/S	Supply Fan Start/Stop	DO	AS
WhAC2SF Status	Supply Fan Status	DI	AS
WhAC2Cool1 Run	Cooling Stage 1	DO	AS
WhAC2Heat1 Run	Heating Stage 1	DO	AS
WhAC2SA Temp	Supply Air Temperature	AI	AS
WhMat Temp	Space Temperature	AI	AS

Point Name	Point Description	Point Type	Trend Group
WhMat TempSpAdj	Space Temperature Setpoint Adjustment	AI	AS
WhMat LocalOvrd	Local Override	DI	AS
WhMat CoSp	Zone setpoint controller cooling setpoint output in Deg.F	Soft	AS
WhMat HeSp	Zone setpoint controller cooling setpoint output in Deg.F	Soft	AS
MGTF Office Temp	Space Temperature	AI	

Table I.4: Example Group Trends Referenced in Table I.3

Trend Report Title	Notes	# used in Table I.3
????? Mode	Used on air handlers and other major equipment	????? Mode
Supply Fan Control	MnAC1; add VFD loop output	A1
Return Fan Control	AC1; add bldg static pressure setpoint loop output	B1
SAT Control	AC1; add economizer loop output if different from economizer damper; add SAT setpoint loop output	C1
Supply Fan Control	MnAC2; add VFD loop output	A2
Return Fan Control	AC2; add bldg static pressure setpoint loop output	B2
SAT Control	AC2; add economizer loop output if different from economizer damper; add SAT setpoint loop output	C2
Supply Fan and SAT Control	MnAC3; Add Clg loop output if different from cooling valve	D
Supply Fan Control	MnAC4	E
Standards Lab Temp Control	MnAC4; Add zone cooling setpoint, SAT setpoint loop output, coil leaving air temp and RAT	F
Stds. Lab Humidity Control	MnAC4; add humidifier loop output, voltage and percent open; add zone dewpoint temp	G
Local Boiler HoW Pump Control	MnAC4;	H
Local Boiler Monitor	MnAC4; new	BA
HoW Temp Control	MnAC4; add HoW valve loop output and % open (opposite); add S&R crossover valve status; add hot water coil leaving temp	I
Local Chiller ChW Pump Control	MnAC4;	J
Local Chiller Monitor	MnAC4; new - includes run condition, S&R cross over valve status, comp1 & 2 amps, S&R temps, and alarms 1 &2	BB
ChW Temp Control	MnAC4; Add ChW valve loop output and % open (opposite); add S&R crossover valve status; add ChWR temp and coil leaving air temp	K
Standards Lab Monitor	MNAC4; new - includes zone temp, RH, dewpoint and OAT	BC
Supply Fan Control	MnAC5; Add VFD loop output	L
Env Chamber CW Monitor	Add loop output if used	O

Trend Report Title	Notes	# used in Table I.3
(Bldg) Rm #-# Exhaust Hood Monitor	Typical	P
Main ChW Pump/Chiller Control		Q
Main ChW Supply Temp Control	Add ChW Supply Temp loop output	Rc
Main Chiller-1 Monitor		Rm
Main Chiller-1 CW Temp Control	Add loop output if used	S
Main Boiler Control		T
Main Domestic HW Temp Control	Add loop output if used	U
Main Hydronic HW Temp Control	Add loop output if used	V
Main ChW Plant Power	Includes Chiller-1 kW, ChW Pump kW, CW Pump kW, CT kW and ChW Plant kW; see 3.02 K. 6.	X
Met AC# Fan Controls		Y
Met AC# Zone # Temp Control	Typical for Met AC-1, 4 & 5	Z
Met AC# SAT Control	Typical for Met AC-1, 4 & 5; add heating and cooling setpoint loop outputs; add SAT setpoint loop output if used	AA
Met AC2 Fan Controls		AB
Met AC2 Zone # Temp Control		AC
Met AC2 SAT Control	Add heating and cooling setpoint loop outputs; add SAT setpoint loop output if used	AD
Met AC2 CW Control		AE
Met AC3 Cooling SAT Control	Add economizer and cooling setpoint loop outputs	AO
Met AC3 Cooling Fan Control		AF
Met AC3 Heating SAT Control	Add heating setpoint loop output	AG
Met AC3 Heating Fan Control	Add heating setpoint and duct pressure setpoint loop outputs	AH
Met AC3 Return and Exhaust Fan Control		AI
M?### Zone Temp Control	Typical for single duct VAVRH, DDVAV and COVAV zones; add cooling and heating setpoint outputs,	AJ
VAV Reheat or COVAV SAT Control	Typical for VAVRH and COVAV zones; add hot water valve loop output if aplicable, add cooling and heating setpoint outputs, add flow, sp and damper count, add CO2 if applicable	AK
Mn### Contant Volume Reheat or Mn### Reheat Only Temp Control	Typical for CVRH or Reheat only zones; add heating setpoint output and hot water valve loop output	AL
DDVAV SAT Control	Typical for DDVAV zones; add cooling and heating setpoint outputs, add flows, sp and damper count for both ducts, add CO2 if applicable	AM
(Bldg) VFD # Speed Control	Typical	AN

APPENDIX J: DEMONSTRATION SITE CASE STUDIES

The research project's short duration did not allow sufficient time to fully evaluate the costs and benefits of implementing a performance monitoring system at participating sites. This would require a project of 3 to 5 years duration. The project team focused primarily on engaging interested owners and developing site specific specifications, which required a number of iterations. Overall, the project team interfaced with facility personal from 9 sites including state and federal facilities, university campuses and a private building. Additional effort was given to developing general specification language and obtaining review and feedback from a competent group of specifying engineers, manufacturers and building owners and operators and the subsequent development of the guide. Many sites have instrumentation only recently installed instrumentation or are yet to install them. Provided below is brief summary of activities at a few sites.

Government Office Building, Santa Rosa: the project team prepared a comprehensive set of performance monitoring capabilities that was integrated into the overall controls specification; new instrumentation will be installed once the expansion project construction phase of the new chilled water plant starts.

Government Office Building, Sacramento: the project team prepared a comprehensive set of performance monitoring capabilities that has been reviewed by staff and integrated into their overall retrofit project controls specification in preparation for a request for bids.

Commercial Office Building, West Sacramento: the project team prepared an initial and updated set of performance monitoring specifications; a series of bids were then solicited in order to obtain one that was most reasonable. It is hoped that the new monitoring capabilities will be installed soon as the Chief Engineer is anxious to use the new system to resolve an ongoing comfort issue.

APPENDIX K: TREND DATA EXTRACTION TOOL USING XML

C:\data\ALC WebCTRL3_0 Data M

Many ALC control systems maintain trend data in a Microsoft Access database located on the WebCTRL Server that is accessible over the internet. An Excel workbook has been developed that automates the process of acquiring data from an ALC controls system that is furnished with the Web enabled front-end called "WebCTRL". This appendix provides instructions for utilizing these spreadsheets. The workbook, ALC WebCTRL3_0 Data Macro Demo.XLS, can be found at http://cbs.lbl.gov/performance-monitoring/specifications/.

Typically one or more spreadsheets would be setup for each project such that each spreadsheet can be readily reused to download the data pertaining to one or more specific systems to be monitored and analyzed. Utilizing this form of access is much faster that copying trend data from ALC trends.

One must have a user name and password to logon to WebCTRL and have privileges set for Remote Data Access. Contact the controls installer or other with Administrator access to provide Remote Data Access privileges assigned to your access level. The VBA code embedded within the Excel workbook requires Microsoft SOAP Toolkit 3.0 (Simple Object Access Protocol) to be loaded on the computer. You can download SOAP Toolkit 3.0 at http://www.microsoft.com/downloads/details.aspx?familyid=C943C0DD-CEEC-4088-9753-86F052EC8450&displaylang=en.

In the "Configuration" sheet, in the "Geo Reference Name/Sourcepath" column cells, the comment reads "Enter the sourcepath for the trend in this column (as seen in trends.mdb, METADATA table). What needs to be entered is each trend point's global reference name including its path. An example of a global path / global reference name could possibly look like this (#hp-401_rm_264/lstat/zone_temp/trend_log). "/trend_log" should be removed from the name, though it has no impact other than the point name will properly show in the "Equipment Summary" sheet of the workbook. What should be apparent is that the WebCTRL trend database will only contain trended points. Trends for each point must be previously setup.

There are three ways to acquire the point global path / global reference names; (1) access the WebCTRL server trend database at the site, (2) access the WebCTRL trend database across the web or (3) piece the global path / global reference names by reviewing the individual points on WebCTRL. The last way is cumbersome and tedious and not discussed here as one is much better just down loading data from the WebCTRL trend pages accessible through Internet Explorer. The second method requires remote access to the computer running "WebCTRL" via PC Anywhere or PC Duo. In the first and second methods access the WebCTRL Server. On drive C: (named WebCTRL3.0 at CSUB), the Access Database was found at: c: WebCTRL3.0/webroot/"site_name"/Trends.mdb. Open Trends.mdb in MS Access and then

open the database table METADATA. This table contains the global path / global reference names in the column labeled "'SOURCEPATH_". Export this table to MS Excel.

The WebCTRL server that I was working with had PC Duo on the machine. This is works very much like PC Anywhere. This made it possible to get the information needed from the METADATA table without going to the site or having some locally access the database and forwarding it to you. This software will be a good tool to have available for future projects as it is reasonably priced.

The original VBA Code was written for WebCTRL 2.5. Later versions of WebCTRL require the VBA code to be modified from **http://** to **https://.** The VBA code has been modified in two locations. The additional "s" is required because later versions of WebCTRL use Secure Sockets Layer protocol.

Of note-worthy reading is the help file found in WebCTRL under Advanced topics and features - Using Web services to retrieve or change data.

Do not begin your password with a zero (0) as the leading 0 was removed by Excel (Excel doesn't think there should be a zero in front of a number unless the cell is formatted as text) and thus the logon was not accepted when the VBA code executed.

APPENDIX L: VIZTOOL

Overview

VizTool is a desktop application for graphing building performance information from different data sources. VizTool can present data in a number of charting formats, including time-series, X-Y scatter plots, carpet plots, and 3D surface plots. A user can interactively identify data outliers within a plot, and the outlier flags are stored in the data base, so that the outlier flags will appear in other plots or views of the data.

VizTool is intended to be an open-source toolkit that might raise the level of visualization techniques that are widely available for monitoring the performance of buildings and for diagnosing the operation of building systems, especially HVAC systems and their controls. Key initial objectives were to be able to display data on a PC that might be located at a building operator's station in a building, including:

- Data collected at one-minute intervals or more for up to one full year duration.
- Up to 10 variables extracted from a database and displayed simultaneously.
- Display of both static historical data as well as dynamic current data.
- Display of data within a variety of formats
- Ability to flag outlier or faulty data
- Allow user to focus in on specific times with data set

VizTool is written in Python and uses wxPython (for windows widgets) and matplotlib (for plotting functions and display) as core libraries. It is delivered as an installable application on Windows machines.

The October 2006 version of VizTool is an Alpha demonstration prototype application. It demonstrates functionality but is not yet a complete application. A user must “get under the hood” when adapting VizTool to their specific data set and use case. Specifically, a user must write their own .xml file describing data points and perhaps alter a portion of the VizTool python code to read from their database. Furthermore, some bugs may exist in the current implementation especially on more experimental features. A current copy of VizTool is available for free download at: http://www.viztool.org.

Research Context for Software Development

The October 2006 version VizTool product was developed within the context of several related research efforts. Thus, programming development priorities were driven by emerging research priorities during the software development cycle. As the basic features of VizTool were under development, a high priority was placed upon developing the ability to flag "outlier" data. Once the basic outlier capability was developed, high priority then was placed upon permitting VizTool to be called from a semi-automated diagnosis program - FDD - that was under development. One consequence of these priorities was that the development of other functionality was placed at lower priority.

Thus, VizTool functional capabilities have typically been developed incrementally. A new capability (e.g. outliers, chart types, etc) would be developed for a single set of data variables and chart type. Once the new capability was successfully tested for a single data set/ chart combination, then if it had sufficient priority, then it could be generalized to become a capability available throughout some or the entire VizTool program. Due to resource limits and research priorities, some capabilities have been well generalized, while others are still only partially generalized, and yet still others are only functional within the initial limited situation. For example, the plotting formats and features developed for use with the FDD application have interesting features, but there has been no chance to date to generalize these features to be available elsewhere within the VizTool.

VizTool Status

The current VizTool implementation is an alpha version work in progress. Some capabilities are reasonably well implemented; other capabilities are currently implemented either in prototype or proof-of-concept form or are only partly implemented, thus serving as placeholders or to capture ideas for consideration and future development. The following status report summarizes the state of VizTool, what works now. See "Next Steps" for a discussion of what might be done to extend or to enhance the current demonstration prototype application.

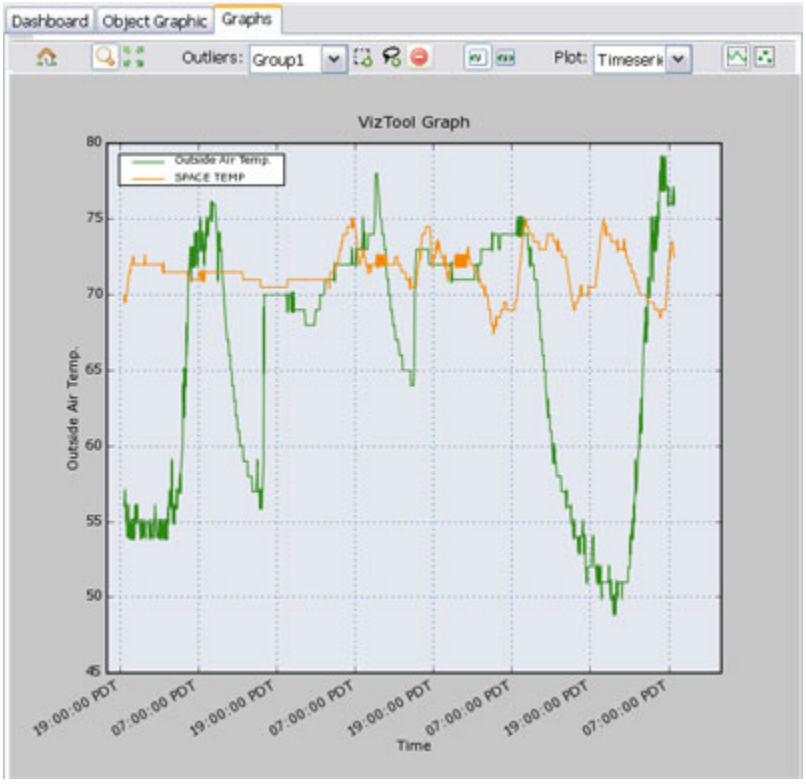
The following features are currently implemented.

1. Graph Types

The following graph types are now implemented. For details of how to use each graph type see the "Documentation" section of this website.

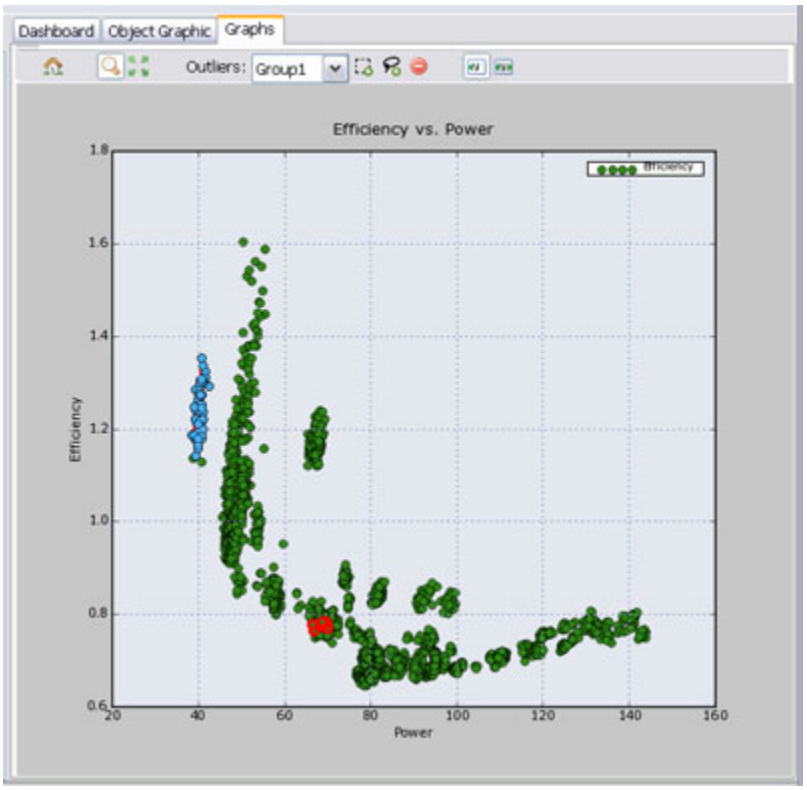
Time-series

This displays one or more variables along the Y-Axis, with Time displayed along the X-Axis.



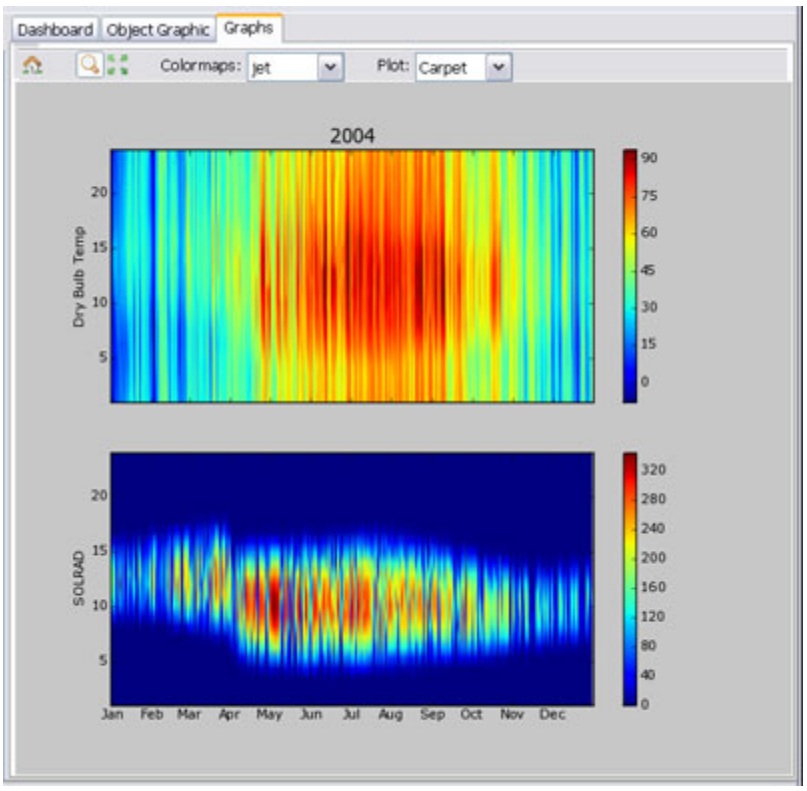
X-Y Scatter Plot

This plot displays the relationships of 2 or more variables. One variable is scaled along the X-Axis. One or two variables can be scaled along the Y-Axis.



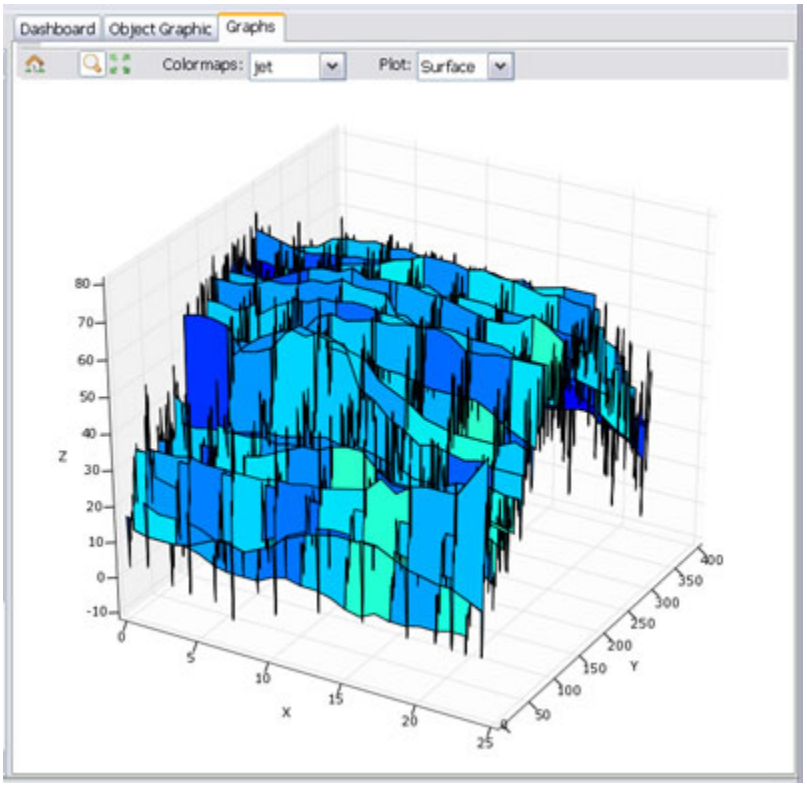
Carpet plot

This plot "wraps" time-series data into 24-hour chunks. Each vertical line represents a day. In the plot below weather for an entire year in Chicago is shown with dry bulb temperature on the top and solar radiation on the bottom.



3D Surface Plot

A prototype 3D surface plot is working within VizTool.



2. XML structure for data points

An XML structure was created to situate data points and graphs within a tree of building system components – an actual schema for this XML document needs to be created. Right now, the schema is implicitly suggested by the structure of the example XML docs. VizTool reads in this XML structure and uses it to produce navigation for the user as well as to store meta-data about data points, graphs, building components and object graphics (for more on object graphics see above). An XML structure must be created for each data source (e.g. Chiller data stored in flat file, or data for a government small office building stored in MySQL file).

3. Data Sources

VizTool does not yet read from generic data resources. Rather, a few sample resources have been set up.

- MySQL source: VizTool currently reads Chiller2 data from MySQL
- FlatFile source: A simple flat file from ePrimer has been converted to CSV and can be read by VizTool
- FDD source: VizTool can run in a special mode where it displays information from the FDD tool (mode is invoked with command line option... more information will be included in this document in the future)

- A MySQL structure has been developed for information from a government office building in California.
    - A point naming structure and abbreviations have been developed using the CA Performance Monitoring project Guide Spec as a source. Several revisions have been made to this structure.
    - This structure has been applied to the Government office building.
        - Data available in MS Access is being converted to MySQL
        - A logical structure for creating MySQL data tables has been implemented.

4. Graphing Window

- The graphing window is functional and correctly displays pre-configured graphs as well as graphs for individual data points
- ***Drag and Drop:*** A drag-and-drop feature is working that permits adding data points to the graphic window. is working (needs testing on for multiple dropped data points)
- ***Zoom in:*** A zoom in feature within graphs is functional
- ***Zoom out:*** Zoom out feature within graphs was working in previous versions but currently is not working. It is logged as a bug and is on our action list.
- ***Pan:*** A feature to pan the graph area is functional
- ***Double Y axis:***
    - Double-Y axis works for simple graphs of two variables
    - Double-Y axis works on complex graphs (e.g. Efficiency vs. Power) but needs testing
- ***Toggling between Single and Double Y-Axis:*** Selecting between single and double Y axis is functional

5. Outliers

Outliers and Faults: Problematic data can be flagged either prior to data entering VizTool or interactively form within VizTool. Data flagged prior to entering VizTool is referred to as "faults." Date that is identified interactively by a user from within VizTool is referred to as "outliers." Such data can be encircled by the user by means of either a rectangular tool or a free-form lasso tool. In either case, the information about the outlier or fault status is stored in the database along with the data, so that the outlier or fault status can be presented in other plots or other views of the data.

- ***Outlier function:*** This function is working but only in the context of the specific example data structures created for VizTool.
- In other words, it's currently “hard-coded”
- We are now working to better generalize this function.
- ***Outlier Groups:*** Outliers can be placed into three different groups
- ***Lasso-tool:*** Outliers can be selected with either a rectangular tool or a free-form lasso tool. Both types of selection tool are functional within VizTool, and menu items have been added to the toolbar to permit selection of either the lasso or rectangle tool.

6. Graphics of building objects

(such as chillers, boilers, pumps, etc.):

- An "Object Graphic" area has been created within the VizTool Graphic User Interface (GUI), but is only partly functional.
    - We have successfully embedded Flash.swf animations within this area for proof-of-concept
    - We would need to write a Python-to-Flash bridge if we want to dynamically display current data from VizTool within a Flash visualization

7. Dashboards

- A dashboard area has been created as part of the GUI
- This is intended to present the user with a summary of charting results for the current building system or "object"
- However, this feature is not yet functional.

Getting VizTool to Read Your Data

The main mechanism for the configuration of user data within VizTool resides in an .xml document that describes the entire list of data points, graphs and their parent components. This .xml document is read in and used to populate the navigation menu, as well as to inform VizTool about each data point's specific properties. So, in order to get VizTool to graph data, one must create an .xml document with the structure used by VizTool that describes the data points to be graphed.

Next Steps

Actions Needed to Produce a Beta Version

The following steps are needed to transition this alpha demonstration prototype into a beta version that would be ready for field-testing or other type of independent, unguided public review:

- Group review and validation of Schema document to make sure it covers the different structure documents that may be created
- Creation of any required template graphs outside of existing set (i.e. Time series, X-Y Plot, X-Y TS Duo, Carpet, 3D Surface)
- Integration of a dynamic time-series plotting capability. This is under development by J.D. Hunter but is not yet completed.
- Intensive Testing
    - Whole application
    - This includes testing of Carpet and 3D plots, which are still very raw
    - Testing of calling VizTool from FDD
- Validation of current features by group and identification of missing functionality.

Refine Outlier Function

The outlier function now works well under specific conditions. The following extensions would increase its applicability:

- Extend the *Outlier* capability to work in all chart types. Even though the outlier information is stored within the VizTool databases, outliers are currently displayed only in time-series and in X-Y scatter plot type charts.
- Extend *Outlier* capability to function with data variables in different database tables; the functionality currently works only for variables within a single database table.
- Extend outlier capability to work with multiple Y-Axis on a chart (.ie., select axis, or chart layer, and then perform outlier operations)

Graphic Display Area

- Add ability to handle imbedded Flash movies, with communication to background simulations (ala HVAC ePrimer) to display in the Object Graphic display.

Additional Chart Types

The development of a robust set of chart types took second priority to other development objectives (e.g., outlier function, Calling from FDD). Thus, several chart types of interest have not yet been developed within VizTool. These include:

- Operational profile charts for key HVAC elements (e.g., economizer, coils, fan, etc). These are types of graphic displays being explored by the German researcher Oliver Baumann and others.
- Matrices of plots providing systematic system overview. This is another type of graphic display concept developed by Oliver Baumann.
- "Jello mold" semi-transparent 3D plots of building zone data in which zone geometry is on X and Y axes and time is on the Z-axis.

Extend Functionality of Existing Chart Types

- Time-series charts
  - Complete dynamic charting capability
  - Add ability to stack 2 or more charts. Reasonable objective is 4 stacked charts, each with 4 to 6 variables showing.

- XY scatter
  - Provide button on tool bar to permit calling X-Y scatter chart type, without requiring manual insertion of XML
  - Provide dynamic charting capability

- Time-series and X-Y scatter
  - Add ability to have multiple Y-axes
  - First allow stacked chart with same X-axis that each have 2 Y-axis. If 3 stacks, this is total of 6 Y-axis.

- 3D Surface
  - Provide ability to control view point angel and height
  - Provide ability to show multiple variables on one plot
  - Allow 3D surface to intersect with planer values.
  - Control transparency of 3D surface

- All charts
  - Provide ability to de-select one of more data variables shown on the chart without closing the chart and re-starting.
  - Add templates for key output displays defined for California

User Interface

- Enable access to databases more directly from the menu.
- Enable new chart formats and combination formats to be built from the menu.