State of New Mexico
Public School Facilities Authority

Design Guidelines for
HVAC & Controls

For New Construction and Renovation

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DESIGN GUIDELINES
FOR HVAC AND CONTROLS

1.0 *OVERVIEW*

The State of New Mexico Public School Facilities Authority (PSFA) has developed the following Design Guidelines for school districts and design professionals to be used in school construction and renovation projects. The purpose is to provide direction in the design of HVAC and controls systems with regard to:

- Standards of comfort
- Energy efficiency
- Life cycle costs
- Standardization of equipment
- Sustainability
- Suitability/Serviceability
- Maintainability
- Interoperability

The intent of these Design Guidelines is to streamline the design process by providing school districts and design professionals with performance-based rather than prescriptive standards in a framework upon which to work toward the end result of designing HVAC and controls systems that will meet performance criteria.

These Design Guidelines supersede the former Appendix B dated August 16, 2007 of the PSFA *HVAC and Controls Performance Assurance Program Manual*. Because the nature of design guidelines is dynamic, these Design Guidelines may be revised periodically. The most recent revision should be used for the design of school building construction and renovation projects.

2.0 DEFINITIONS & ACRONYMS

Throughout these Design Guidelines there are a number of terms and abbreviations that are commonly used for which the following definitions shall be used.

AHU: Air handling unit.

ANSI: The American National Standards Institute.

ASHRAE: The American Society of Heating, Refrigeration and Air

Conditioning Engineers.

BACnet®: International standard for building automation and controls developed by ASHRAE and ANSI, specified as ISO 16484-5:*year* or ANSI/ASHRAE 135-*year*. NM guideline is now the 2012 version (e.g., ISO 16484-5:2012).

BIM: Building Information Modeling.

BTL: BACnet® Testing Laboratories - established to support compliance testing and interoperability testing activities of the BACnet® conformance certification and listing program.

BMS: *Building Management System* - a computer-based system that controls and monitors building or campus mechanical and electrical equipment consisting of hardware, software and programming, using communication protocols such as BACnet®.

CAD: Computer-aided design.

Contract: Any agreement for the procurement of items of tangible personal property, services or construction.

Contractor: The contractor responsible for constructing the individual project and/or subcontractors working under the Contractor.

Control Systems: All devices and systems (pneumatic, electric, electronic, Direct Digital Control, etc.) associated with control of HVAC equipment and systems from simple unit controls to sophisticated Building Management Systems.

DDC: Direct Digital Control – a system providing the automated control of space condition or equipment operation using a computer and controller(s) with analog and digital inputs for measurement of temperature, humidity, pressure, etc. and analog or digital outputs for control of HVAC equipment.

DOE: The US Department of Energy.

DX: Direct expansion refrigeration using an electric mechanical vapor-compression cycle

Design Professional: The project's architect or engineer.

Design Team: The team selected by the owner responsible for providing professional services for project design and implementation, generally consisting of architects, engineers, and other professionals.

District/Owner: The individual school district involved in a project. This may also include a charter school residing in a particular district, or a charter school that is funded directly by the state of NM. The school district acts as Co-Owner on projects jointly funded through PSFA.

ERU: Energy recovery unit.

GSHP: Ground-source heat pump. Note these systems may also be referred to as ground-coupled heat pump (GCHP).

HVAC: Heating, Ventilating, and Air Conditioning equipment and systems including all major components and auxiliary equipment.

IP: Internet Protocol, as in TCP/IP (Transmission Control Protocol /Internet Protocol): this is the packet protocol used for the Internet and network data worldwide.

LCCA: Life Cycle Cost Analysis.

LEED™ The US Green Building Council's Leadership in Energy and Environmental Design green building certification program.

Lighting Controls: All devices and systems associated with electronic control of lighting systems that may be integrated with a Building Management System.

NMFA: **The State of New Mexico Finance Authority** is the agency that assists qualified governmental entities with affordable financing of capital equipment and infrastructure projects.

Owner: *Owner* means both District/Owner and PSFA, who as Co-Owners are referred to as if singular in number. Each Co-Owner shall designate in writing a representative to act on their behalf on matters covered in this document and in accordance with all applicable project agreements in effect.

PAC: **Performance Assurance Contractor:** The independent third-party agency that holds a price agreement with the PSFA to provide services under the PSFA *HVAC and Controls Performance Assurance Program* including the HVAC and control system testing, adjusting, and balancing required for individual projects.

PSFA: **The State of New Mexico Public School Facilities Authority** is the agency, under the Public School Capital Outlay Council (PSCOC), charged with responsibility for overseeing projects funded by PSCOC and shall serve as Co-Owner on such projects.

PSFA RM: **The Public School Facilities Authority Regional Manager** is the PSFA project representative who administers PSFA design and construction contracts.

RTU: Rooftop HVAC unit, normally using a gas burner for heat and DX cooling.

Split: Refrigerated air and/or heat pump that uses a separate compressor mounted outside.

TAB Agency: The agency performing HVAC and control system testing, adjusting, and balancing required for individual projects. TAB Agency services are provided through the PAC under the *HVAC & Controls Performance Assurance Program*.

VAV: Variable Air Volume multi-zone packaged system using air as the conductive medium to move heat with DX or chilled water for cooling and a boiler or burner for heating.

VFD: Variable Frequency Drive. Electronic device for changing speed of AC motors by varying the AC cycle up or down from 60Hz.

VRF: Variable Refrigerant Flow. A type of distributed heating and/or cooling system that moves heat using compressed refrigerant rather than a hydronic loop.

3.0 GENERAL DESIGN GUIDELINES

Good design for public school facilities supports the vision, educational standards, and performance criteria of public education in New Mexico and provides for the environment that is important to learning for students, educators, staff, parents, and the community at large. Therefore, meeting the Program Statement requirements is basic for a public school construction or renovation project.

In addition to meeting the Program Statement requirements, providing an optimal learning environment encompasses specific considerations with regard to HVAC and control systems. In general, the following guidelines have been established by the PSFA:

- Systems must support the building program.
- Designs must meet adequacy standards.
- Lighting and HVAC controls must be simple and suitable for the classroom environment.
- Each facility shall have no more than one integrated DDC system that is non-proprietary in accordance with *ASHRAE 90.1* and *ANSI/ASHRAE 135-2012* (BACnet®), with all control devices and logic explicitly specified in the design sequence of operations.
- While initial costs for construction are always at the forefront, *life cycle costs* are of great importance to PSFA and the State of New Mexico, and any related analysis must be done using real values such as cost of capital, depreciation, and inflation rates. Equipment and systems that have low initial costs are often the least sustainable and most expensive over time, and as such are not an acceptable use for state capital investment.
- Designs should assure the serviceability of HVAC and controls systems within the capabilities of the maintenance staff in individual school districts and meet all manufacturers recommended clearances for installed equipment.
- Installation and service of mechanical equipment shall not compromise other associated systems (e.g. roof systems).
- Designs of HVAC systems shall be appropriate for local altitude and climate.
- Equipment and materials should be sustainable and sustainably sourced.
- If contractually required, designs may consider the potential application of LEED™ requirements, and the ability to upgrade to the required level of LEED™ certification to the extent that this does not significantly compromise cost, efficiency, or basic functionality of building systems.
- Contract documents prepared by design professionals shall be based upon the most current PSFA guide specifications including those related to Test, Adjust, and Balance, Performance Assurance Contracting for HVAC and Controls, Water Quality, and all Division 01 sections referencing these. The guide specifications along with required Equipment Inventory Data forms which can be found on the PSFA website at www.nmpsfa.org.

In general the learning environment consists of classrooms, activity spaces, resource centers, and labs within a school building. Specialized areas may have different guidelines, and staff offices and other support spaces typically do not require individual zone control but all mechanical equipment must be installed in easily accessible spaces as described under Section 9 'Serviceability' and isolated as necessary so as not to negatively impact acoustical standards. See also acoustical standards and guidelines contained in the *New Mexico State Adequacy Standards* and companion document, the *New Mexico Public School Adequacy Planning Guide*. These are available at www.nmpsfa.org.

The PSFA design model is based on local considerations and actual circumstances rather than historical precedent. Climate zone, energy costs, water quality, and available skills vary across the state. The optimal system type for each school should be appropriate that location, with some parts such as borehole fields or burner types configured according to the given parameters.

The PSFA has established the following guidelines for different types of HVAC systems to serve learning environments. There is no single specification, but the optimal system can be determined in terms of several parameters including:

- The number of classrooms, zones, special areas (e.g., cafeterias, kitchens, and gyms), and total conditioned space.
- Valid water quality results for the site, including pH and dissolved solids.
- Utility rates for gas, electric, water, and propane (if applicable). For future values, contact local energy providers to find out if different rate plans might be available for specific system types (e.g., ice storage for off-peak, subsidies for solar).
- Site-specific issues and qualified experience with the district and availability of local service. Based on district skills and experience any new DDC system must either provide a consistent interface with what is currently in use or it must take precedence and control (per B-AWS specification of *ASHRAE/ANSI 135*) over what is currently in use,

Choices should be based on both efficiency and economics. If gas is substantially cheaper than electricity, then look toward *gas-based systems* such as boilers and gas chillers, but also look at the more efficient equipment of this type. If electricity is substantially cheaper than gas (e.g., with propane), then look first at the most efficient electric systems such as *ground source heat pumps* (GSHP) designed in a centralized or decentralized configuration according to the scale (size) of the school. In either case where the first choice might not work for some reason (ground conditions, local resources, etc.), then look at other similar alternatives. For existing schools, especially in historic buildings, the best or only choice may be some configuration of split, VRF, or mini-split units that can be inserted into small spaces. The basic point is to achieve pragmatic, rational design that suits the local needs, not a boilerplate for all.

3.1 Characteristic Parameters

3.1.1 Scale (Size)

The first parameter in system selection is the number of zones or classrooms. The more zones there are in a system, the greater the economies (or diseconomies) of scale. For instance, a very small system with only a few zones might best be served with a distributed system using individual units for each zone, while a very large system with many zones could greatly benefit from having a centralized mechanical plant with relatively fewer individual parts to maintain.

3.1.2 Cost of Energy

Energy is normally split into some mix between electricity and natural gas or propane. Respective tariffs and incentive programs available to schools vary across the state. Given that each system type consumes a relative mix of energy, with boilers and absorption chillers biased for *gas over electricity*, and heat pumps or VRF biased for *electricity over gas*, choosing the right system for the right location is of great importance. Scale is also important, and closely tied to maintenance costs, though some large-scale centralized designs can incorporate *co-generation* to adjust their consumption of energy according to market prices. This option tends to be expensive, so it and should only be considered where the scale of the system and fuel market pricing might warrant it.

3.1.3 Water

Most of New Mexico is arid and available water tends to be hard. For this reason, water testing shall be done at the onset of any project, including pH, corrosively, hardness, and total dissolved solids. Appropriate treatment shall be provided by a New Mexico licensed Water Treatment Contractor, including direction for installation and monitoring for the following:

1. Domestic water
2. Hot water boilers and heating water systems.
3. Chillers and chilled water systems.
4. Glycol systems.
5. Cooling towers and condenser water systems.
6. Steam boilers and steam systems.

Any chemical treatment recommendations must be provided by a Registered New Mexico Professional Engineer that holds a New Mexico Certified Pesticide Applicators License in NMDA Category 11b.

Most domestic hot water use is intermittent in schools, and point-of-use, on-demand heaters are preferred. Where gas is available it should be used for any high demand applications such as kitchens and large showers. For low demand applications such as hand washing sinks, under sink on-demand electric units are preferable. When flow rates for applications (e.g. gang showers) cannot be met with on-demand systems, then other energy efficient systems (e.g., heat pumps) should be considered.

4.0 STANDARDS OF COMFORT

Standards of comfort and air quality shall be an explicit design consideration for all systems in accordance with *ANSI/ASHRAE Standard 55-2010 - Thermal Environmental Conditions for Human Occupancy*, the *New Mexico Public School Adequacy Planning Guide*, and the ASHRAE *Advanced Energy Design Guide for K-12 School Buildings* (ISBN 978-1-936504-13-8).

5.0 ENERGY EFFICIENCY

All school building construction or renovation projects should include the best available technologies to minimize energy use and life cycle costs within the budgets of individual projects. Baseline standards and design considerations can be found in *Advanced Energy Design Guide for K-12 School Buildings* (ISBN 978-1-936504-13-8), which may be considered standard reference on any PSFA school project.

Considering remoteness of New Mexico schools, absolute preference shall be given for long term energy conservation measures that do not require substantial maintenance, most notably energy envelope, insulation, and (minimal) fenestration relative to any mechanical or lighting systems that may wear out and require specialized skills that are unavailable in remote areas. Energy Star component recommendations are accepted as a baseline for consideration, from which any deviations should be explicitly noted and approved.

6.0 MODELING

As energy and budget requirements become ever-more stringent, software models are increasingly used to optimize building designs before construction, helping to avoid potential conflicts between systems, improve use of space and materials, and maximize building efficiency. Just as CAD replaced mechanical drawing 20-30 years ago, 3D BIM (Building Information Modeling) is now replacing 2D CAD in building design, making it possible to use a single model for visualization, mechanical and plumbing, conflict resolution, energy modeling, daylighting, and even for maintenance operations.

Each of these technologies has been developed concurrently in parallel, but they are converging into a single platform standard on BIM (e.g., Revit), such that all functions are performed on the same data set or building model. Common electronic format extends into a full life-cycle model, where design information goes into construction, construction into facility resources, into maintenance, and eventually into resource disposal. PSFA is currently integrating these tools into the design and delivery processes to be the common platform for all design and construction design processes, progressing into maintenance and operations. All energy, lighting, and related analyses will be delivered within this context.

7.0 LIFE CYCLE COSTS

7.1 General

Life Cycle Cost Analysis (LCCA) is a technique to provide comparative cost information for different systems based on net present value (NPV) calculations. It shall be performed in accordance with the guidelines of 10 CFR 436, Subpart A 'Program Rules of the Federal Energy Management Program' as outlined in the National Institute of Standards and Technology (NIST) Handbook 135, and integrated into the design process for school construction and renovation projects involving new or improved existing energy-consuming systems. These are available on-line, with links provided on the nmpsfa.org website.

The object of LCCA is to choose the optimal approach from several of the most reasonable alternatives, considering all cost factors, so the least long term cost of ownership is achieved. The choice of which systems to evaluate is not arbitrary, but must be tailored to site information including cost of each utility (and possible demand charges), and shall adequately consider all relevant cost drivers such as weather, water quality, number of mechanical components for each type of system, and accessibility for maintenance implicit in each design. The delivered LCCA shall enumerate all assumptions, all calculations, and all values or constants used with reference information for each source.

The LCCA shall follow evolution of the design from Program Statement through Design Development Phases. Alternatives should be analyzed early in the Schematic Design Phase so a decision can be made and direction can be provided to the design professional for proceeding with design development.

7.2 Specifications

The system selection process shall yield the relative life cycle costs in clear terms, with adequate and complete supporting data. The given metric must include consideration for all relevant costs that would vary from system to system (e.g.

water treatment, maintenance). The Design Team must review their approach and methodology with the PSFA in the first stages of the Schematic Design Phase.

The basic LCCA expected to be performed for HVAC systems considered for the design must fulfill the following requirements:

a. Provide all basis information prior to the initiation of LCCA, and work with the owners to decide which three or four systems might be compared.

b. Perform LCCA early in the Schematic Design Phase of the Project and in accordance with the following:

   - *Utilities Inflation Rate* shall be the average increase in price of grid power over 15 years (e.g., 3.5% simple) or other published and vetted values provided by the authority having jurisdiction (e.g., DOE, or NM PRC).
   - Utilize a *DOE-certified energy model* (e.g. eQuest, EnergyPlus, Trane Trace, Green Building Studio, Ecotech, et al.), that is appropriate for the given process and design with the most recent available weather data. Deliver a copy of the model with the results to the owner.
   - *Cost of capital* is assumed to be the school bond interest rate, or where this rate might substantially deviate from the state bond rate per NMFA (New Mexico Finance Authority), cost of capital shall be averaged by relative participation for a unified rate (e.g., (0.03 x 0.2) + (0.02 x 0.8) = 0.022).
   - Time Length of the Life Cycle Cost Analysis = 30 years.
   - Packaged unit replacement ≤ 15 years.
   - Central plant replacement = building life, with mechanical component refurbishment per ASHRAE.
   - Equipment Replacement Cost per RSMeans plus future price inflation per industry de facto increase of 5% per year.
   - Maintenance Costs per *ASHRAE Related Commercial Resources, Chapter 37, 'Owning and Operating Costs'*. Where New Mexico maintenance costs may not be listed by ASHRAE, use Arizona or Nevada as the direct equivalent, but do not use 'vendor numbers' that are not vetted.

c. Perform analysis in accordance with Executive Order 13123, Guidance on Life-Cycle Cost Analysis (on PSFA website), identifying and accurately evaluating all relevant considerations and cost drivers. Where variable demand charges are given, these must be accurately calculated according to the building use schedule. Provide all inputs, outputs, and actual calculations accurate for the given cost structures (including utility demand charges) and locale.

d. Update *HVAC Options Report* in accordance with Section 5.0 in these Design Guidelines.

Deliver initial HVAC Options Report, including LCCA results early in the Schematic Design Phase, and as agreed to by the owner.

Table 7-1 below provides an example set of input data using current values with their sources. Note that the current cost of capital might change at any time and an update will be provided when the need arises.

	Current Value	Future Value
Utilities Inflation Rate	3.5%	BLCC5 or 10 year average
Cost of Capital	2.37%[1]	Provided by NMFA
Analysis Cycle	30 years	Fixed
Maintenance Costs	per ASHRAE Related Commercial Resources, Chapter 37, 'Owning and Operating Costs'	
Equipment Replacement Cost	RSMeans	Cost per RSMeans plus future price inflation per industry de facto increase of 5% per year
	[1] *or local district bond rate*	

Table 7-1 Example Input Data for LCCA

8.0 SUSTAINABILITY

The concept of sustainability is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."[1] The state's intent in promoting sustainable design is to protect taxpayer investment, lessen operational costs, and maximize funding for the classroom. As a baseline, PSFA follows ASHRAE Advanced Energy Design Guide for K-12 School Buildings (ISBN 978-1-936504-13-8).

9.0 SERVICEABILITY

Many New Mexico schools are remote with limited technical resources, so HVAC and control systems must be designed for simplicity, ease of maintenance, and ready

[1] *Report of the World Commission on Environment and Development: Our Common Future*, United Nations, 1987.

accessibility. All manufacturer's recommended clearances per published 'cutsheets' and/or electronic design models shall be maintained in the design and construction. Systems selected should also optimize staff capabilities and requirements for inventory of maintenance parts and supplies.

Ground-level locations are preferred for equipment located outside the building. *Roof-mounted equipment* is not acceptable except in certain cases. A penthouse or equipment attic can be used to avoid roof penetrations and provide maintenance accessibility. Where roof placement of equipment is necessary, and with the approval of the PSFA, coordination of structural and roofing systems requirements must be ensured for a leak-free and safe installation. A *roof access hatch* shall be provided with access via a fixed steel ladder installed within a lockable mechanical, storage, or custodial space inside the building.

Equipment not requiring significant mechanical service such as fans and fan/coil units may be ceiling mounted, as long as filters and service points are conveniently accessible, and expedient provision is made for any higher-level maintenance or service that might be required. Adequate and easy access, such as ceiling access panels, doorways for large chase spaces, and so forth shall be provided for service and removal or replacement of equipment. Determining factors include size and quantity of equipment, fixtures, related systems, circulation requirements, and clearances required by codes or maintenance procedures. Code compliance in rooms with mechanical or electrical equipment prohibits general and custodial storage within mechanical rooms and support spaces. Adequate lighting shall be provided in all support spaces.

Additional guidelines for HVAC and control systems are found in other sections of these Design Guidelines.

10.0 INTEGRATION with OTHER BUILDING SYSTEMS and COMPONENTS

On the project level, all control components for the HVAC shall be BACnet® Testing Laboratory (BTL) listed to the current ANSI/ASHRAE 135-2012 standard for integration purposes, with at least one B-AWS listed server connected and available to each system. HVAC and control systems design should be integrated for efficient operation and minimal maintenance. Physical security of system components shall be provided for in the building design, and the control systems shall be integrated with preference for the BACnet® standard. There is generally no separate IP for the Building Management System (BMS) and it will have drops from the building IP system. As a minimum, there must be at least one main Internet drop for the BACnet controls server with an external IP address and two Internet drops for the measurement and verification (M&V) system, one of which has an externally addressable IP, plus any additional network drops specified in the design documents. Communication protocols shall be in accordance with applicable design standards and practices.

The function and operation of the HVAC and control systems shall be designed to work together with, complement, and not compromise other systems and the building structure. Specific levels of integration may include chillers, Variable Frequency Drives (VFD), major air handling units (AHU), Fire Alarm system (secondary monitoring), lighting control systems, occupancy sensors, and others. Service access and compatibility analysis for equipment is considered to be an integral part of designing the building structure.

Designs and specifications for new construction, and especially renovation projects with legacy control system installations, will ensure that new systems will be compatible with existing systems. If the existing control interface is BACnet® (B-AWS) compliant and the district is trained and proficient, then the new system shall follow this same standard and interface. If the existing system is non-compliant or the district is unable to maintain it, then the new BACnet® server must be configured to control existing equipment on the given site, including controllers and/or gateways as required, and it must provide full read, write, and update capabilities for existing and new systems such that there is no loss of features or functionality for the old system in context with the new.

Any new schools or renovation projects that include mechanical systems must include measurement and verification (M&V) in the form of electronic metering, per the design specification defined in UNM GSA 02-24-14 with EMNRD, and shall provide all 47 data points in the format necessary to be connected back to the statewide M&V server at UNM. To this end, lighting and plug loads must be separated for sub-metering (once) at the main electrical closet rather than in individual electrical sub-closets, and the two live Internet drops specified in section 10.0 above, to be provided at the main electrical closet prior to meter installation.

11.0 HEATING, VENTILATING AND AIR CONDITIONING SYSTEMS (HVAC)

The decision of which three systems to evaluate in the LCCA for any given project should follow according to the data collected earlier in the process, but ultimate choice of systems is subjective according to district and state requirements. If one energy source is substantially less expensive than others, then a system optimized to scale and local conditions using this source must be included in the choices evaluated. The other two choices should follow the order of local costs and be appropriate to scale and local conditions.

For information on individual systems, please refer to the ASHRAE publication *Advanced Energy Design Guide for K-12 School Buildings* (ISBN 978-1-936504-13-8) provided by DOE, which serves as a standard basis for ASHRAE, ANSI, AIA, Green Building Council (LEED^{TM}), and PSFA. Table 11-1 below compares the characteristics of some typical systems.

Consideration	GSHP	WSHP	DX	VRF	Direct Evap	Indirect Evap	Condensing Boiler
First Cost	High	Med	Low	Med	Low	High	High
Electricity Consumption	Med	High	High	High	High	High	Low
Gas Consumption	0	Med	Med	0	0	0	Med
Adaptability to Alternative Energy	Low	Low	Low	0	N/A	N/A	N/A
Energy Efficiency	High	Med	Low	Med	High	High	High
Carbon Footprint	Mod	Mod	Mod	Mod	Mod	Mod	Mod
Scale	Med	Med	Low	Med	Med	Med	Med
Maintenance	High	High	High	Low	Med	Med	Low
Ease of Retrofit on Existing Construction	Hard	Hard	Easy	Easy	Med	Med	Med
Wet Weather Performance	N/A	N/A	N/A	N/A	Low	Med	N/A
GSHP = Ground Source Heat Pump; WSHP = Water Source Heat Pump; DX = Direct Expansion							
Refrigeration; VRF = Variable Refrigerant Flow (DX); Direct Evap = Direct Evaporative Cooling;							
Indirect Evap = Indirect Evaporative Cooling; Condensing Boiler = High Efficiency heating system							

Table 11-1 Comparisons of Typical Systems

11.1 Energy Recovery Units (ERU)

CO_2 modulated variable rate ventilation with ERU (sometimes called *Energy Recovery Ventilation)* is the baseline standard for public schools in New Mexico, in lieu of recirculating stale air or dumping conditioned air except where outside air meets the conditioning requirements (i.e., economizer mode). *Energy recovery units* transfer energy from outgoing exhaust air to incoming ventilation air. Sensible heat recovery units are simply heat exchangers run by fans, while latent heat recovery units employ a desiccant wheel to transfer both heat and moisture between two air streams.

11.2 Guidelines for Specialized Areas

Requirements for special *electrical rooms* for heat generating equipment such as computers, servers, telephone equipment, etc. shall be calculated into the energy model by the Design Professional to assure adequate conditioning and temperature control for these spaces. Attention shall be paid to equipment specifications and manufacturers published recommendations such that equipment should not be over or under cooled.

Electronic computer equipment such as servers, routers, and HVAC controllers is very temperature sensitive. Spaces for this equipment may need to operate well *below* the temperature of normal occupied spaces and will likely require mechanical refrigeration. Common practice is to provide a mini-split secondary system for each server room in addition to space conditioning.

Transformers and switching equipment produce a very large amount of heat, but operate above the range between occupied spaces and outside air, requiring ventilation to prevent dangerous heat build-up. Typically this equipment should be cooled by ventilation or exhaust air rather than mechanical refrigeration.

Considering that these two major types of electrical equipment have temperature requirements on opposite ends of the range established in the *Adequacy Standards* for occupied spaces, combining these different types of equipment into a single space is not allowed.

11.3 Air Filtration

Local conditions for school buildings may present problems with airborne dust. Each project must be evaluated to take dust impacts on air filtration into account and appropriate filtration materials, efficiencies, and replacement frequencies must be specified based upon local conditions relative to dust. Where dust storms are common, ventilation system shall be centralized for maintenance with a coarser pre-filter to remove sand before the main filter. This may be centrifugal or a static-charged metal grid and shall be maintainable and replaceable.

11.4 System Start-up

All components and devices of systems shall have startup logs completed per individual system requirements. This shall be performed as part of the preparation of Construction Checklists per the requirements of the HVAC and Controls Performance Assurance Program. Logs must be diagnostic data for troubleshooting analysis.

11.5 Requirements for Equipment Inventory Data

Equipment data collection forms (from the PSFA website) to be completed by the Contractor shall be included by the Design Professional within the Contract Documents for the Project. All inventory information shall be provided in both written and electronic spreadsheet form.

12.0 BUILDING MANAGEMENT AND CONTROL SYSTEMS

12.1 General Requirements

All building control systems shall be compliant with *ANSI/ASHRAE Standard 135-2012* and *ISO 16484-2012*, with all devices and controllers being BACnet® Testing Laboratory (BTL) listed. At least one B-AWS server in a secure (conditioned) location with all hardware and software components or packages licenses, or keys necessary for efficient operation per PSFA standards shall be provided in each system with at least an operator console (Internet access and B-OWS or secure Web interface with at OWS functionality) available at each site or school. The capability of local school district maintenance staff shall be taken into consideration and additional *training* needs shall be addressed in the Project Manual. All systems must also provide secure Web access to the DDC for monitoring, and remote electronic notification through Short Messaging Service (SMS) for any alarms or faults. All event data and log files shall be maintained in the system for at least 365 days. Server capacity requirements such as number of simultaneous users, quantity of connected DDC controllers, etc. shall be specified by the Design Professional.

	B-AWS	B-OWS	B-OD	Web Interface	SMS Notification	BTL Listing
Each BACnet LAN	*connected*			√	√	
Each Campus	√					
Each School	Operational Capability					
Each Component						√

Table 12-1 BACnet® Workstation Requirements

12.1.1 Individual Zone Control

Per New Mexico Public School Adequacy Planning Guide each classroom or learning space shall have individual temperature control. Offices and other support spaces may be zoned in blocks according to ASHRAE 90.1, or individual zone controls may be installed at district expense. Where very high *zone density* is demanded in these spaces, such as individual zones for each administrative office, the PSFA may not participate. PSFA participation may also be curtailed where zone density affects the over-all system design (e.g. where administration is given preference over student learning environments).

12.1.2 Access and Licensing

The system manufacturer's service tool software, keys, and other proprietary tools for DDC systems installed shall be provided. In addition, the District/Owner shall be granted a perpetual, irrevocable royalty-free license for any and all software or other intellectual property rights necessary for the continued operation, maintenance, and repair of the DDC systems installed, as well as for any additional software, gateways, or components used. Access to all DDC controllers and workstation/servers shall be open to the District/Owner at the highest user-level, and the District/Owner shall be free to assign this access to any Contractor of their choosing. No DDC products with *closed licensing* shall be allowed.

12.1.3 Integrated Control Sequence

All *control sequences* used within the system shall be specified by the design professional in the system design. If an individual unit or subsystem includes its own control sequence, that sequence shall also be explicitly specified, and must be smoothly integrated into the main DDC sequence specified in the design drawings such that no operational conflicts arise between any embedded control sequences for equipment and the main system control sequence as defined in the design.

An important challenge for many projects is the integration of equipment manufacturer-provided controls with the Building Management System (BMS), such that these controls can participate in the required overall sequence of operation needed for the building. Some equipment such as packaged air handling units, require the addition of a separate controller to properly execute sequences such as optimal start/stop, morning warm-up, day/night scheduling, demand ventilation, smoke control, and so on.

Equipment manufacturer-provided controls shall be BTL-listed at the system level. Where subsystem components such as VRF require a separate integration, this subsystem shall have the ability to communicate via a BTL-listed BACnet® controller for integration into the main DDC system. Metering that does not have a logical control element (i.e., only providing data, not control) may use other protocols (e.g., pulse gas meters) through a BTL-listed controller or gateway. The design professional is responsible for researching these two exceptions and providing for it in the specifications.

It is also the design professional's responsibility to research the *sequence of operation* capabilities of any manufacturer's equipment-provided controls and to develop the BMS sequences to properly complete and/or supervise this control. Unless the design professional and manufacturer of the HVAC equipment that is the basis of design can determine that the factory controls will properly participate in the required overall sequence of operation, and all *embedded manufacturer sequences* are explicitly specified within the design sequence of operations, controls for HVAC equipment should be installed in the field by the controls contractor.

12.1.4 Lighting Controls

When *automated lighting control systems* are included in the design, the controller shall be BTL listed and able to communicate with the BMS per *ANSI/ASHRAE Standard 135-2012* for full system integration. *Occupancy sensors* shall be accessible via BACnet® to enable integration of environmental control when desired.

12.1.5 Remote Monitoring Capability

Web-based remote monitoring capability of the building controls shall be included, as also shall remote notification capability via electronic messaging (SMS) including information on the specific alarm event sent to at least three different numbers or addresses defined by the user. This remote monitoring capability shall not supersede the requirement for local control of building/campus DDC systems. The Design Professional shall be responsible for designing and implementing a system to ensure security of the remote connection so that it cannot be compromised maliciously or by external means.

12.2 Guidelines and Requirements for Documentation

The design professional shall produce sufficient documentation to allow competitive bidding of the control systems work. This documentation will include at a minimum:

- Points list for every sequence or unit using owner approved point names.
- Floor plans showing locations of all devices including thermostats or sensors that are part of or connected to the system;
- Sequences of operation, including set-points and alarm limits.
- A control diagram with sensors and point configuration.
- Control diagrams/flow diagrams for non-DDC controllers and/or thermostats (e. g. for unit heaters, etc.).
- All dedicated power wiring shall be provided in conduit and shown on the electrical series Drawings. In general controls communication (i.e. MS/TP) will be shown on controls submittals and as-built drawings.

- IP wiring will be shown on electrical drawings if the electrical engineer is laying out the IP. A dedicated IP is typically not used for the BMS by PSFA, however there are dedicated drops. A dedicated VPN and standardized VPN communication is needed so PSFA can access the system remotely and for security from outside intrusion.

- Mounting heights for *thermostats* shall be in conformance with both ADA and manufacturer's recommendations. *Temperature sensors* however shall be installed strictly per Manufacturer's recommendations.

12.3 Guidelines for System Installation and Performance

12.3.1 General

a. The District/Owner Controls Specialist and HVAC and Controls Performance Assurance Contractor (PAC) will review the scope document prepared by the design professional prior to bidding. The design professional shall participate in bid review meetings.

b. Hardware and software shall include point database, graphical system display and network interface to a central supervisory control system. Controllers shall have the capacity for all of the points including any used for operation and trending. Required spare capacity should reflect the forecasted growth for the school. In general, a minimum of 20% spare capacity for software shall be included.

c. In consultation with the Owner the Contractor shall develop a point naming convention that is acceptable to the Owner and shall program all sequences of operation into the control system.

d. Tracking and trending shall be from actual control points and results shall come from that point and not be software-generated.

e. All hydronic control valves, including those on VAV units and fan coils, shall be protected from system flush with a separate by-pass flushing valve.

f. All HVAC equipment shall have Δp and Δt sensors and capability for reading motor current (i.e. from a Variable Frequency Drive) for airflow diagnostics.

12.3.2 Utility Metering

Utility (sub) metering shall be in accordance with the standards and requirements of Statewide M&V as described in UNM GSA Share No. 14-521-0300-0122.

12.3.3 Training

Training requirements shall include specified hours for each type of training session to be provided. This shall include a minimum of eight (8) hours for each DDC panel installed. At a minimum, training shall be provided in two separate training sessions for two separate groups to allow onsite training of one group while the other group remains available to respond to normal work requests. A written sequence of operations shall be provided to each attendee at training sessions.

12.3.4 Typical Components - HVAC Controls

The control system is a building control and automation system that is able to manage an entire district facility or campus. It performs control and monitoring through its components and by integrating to HVAC equipment to improve their operational efficiencies. Through integration, building systems that previously acted as stand-alone entities function as a single system for monitoring and control. At a minimum, the system designed shall have the following capabilities.

a. Historical Data Collection – Standard data collection capabilities applicable to all data points (DDC logging).

b. Information Reporting –Trending capabilities that allow data to be transferred to MS Excel and the PSFA Facility Information Management System.

c. Alarming Monitoring – Notification to operators of an out-of-normal condition via operator interface screen and printers. Alarms shall be capable of having different priorities assigned and of directing messages to different locations depending on the severity of the alarm to allowing early warning notification for out-of-normal conditions.

d. Preventive Maintenance – Collection of equipment runtime to allow maintenance to be performed on a predictive basis to avoid incurring unnecessary and preventable costs due to a machine breakdown. The Owner will define what equipment gets runtime collection and what alarm thresholds are. The controls contractor shall then create each point (runtime + alarm) using the alarming capability in (c) above. Alarming functions to notify the appropriate maintenance crew when service is requested shall be considered in the system design. As a minimum, three levels of alarm notification/escalation will be provided with at least SMS notification.

e. Equipment Scheduling – To program normal operating hours and to program special events ahead of time so that an operator need not be on-site to turn on equipment and adjust set points for planned events. Any occupancy sensors when used shall be programmed into the DDC to allow automatic recognition of occupied/unoccupied modes according to a set schema. For example, 20 minutes of sensor activity outside of occupancy hours occupies that zone for one hour as an 'after-hours event', while no sensor activity 30 minutes into occupancy hours turns the zone unoccupied as a 'holiday'.

12.4 Requirements for Control System Testing

12.4.1 Pre-Functional Test

A Pre-Functional Test shall be conducted with a letter submitted by the Contractor certifying all systems were tested and operational. This shall be performed as part of the preparation of Construction Checklists per the requirements of the *HVAC and Controls Performance Assurance Program*. Trend reports that show the system is completely operational shall be included.

12.4.2 Functional Performance Test

A Functional Performance Test (FPT) with a sequence of operation check shall be developed by the Performance Assurance Contractor (PAC) and the Contractor shall be responsible for providing this testing with the PAC including testing all equipment and sensing points. Systems may be tested incrementally by system using the PAC's FPT checklist and the sequence of operation provided by Design Professional and Contractor.

13.0 DOCUMENTATION AND REPORTS

All designs developed in BIM shall use Revit 2013 or higher to a level of detail sufficient for collision and energy analysis. All other documents shall be in AutoCAD 2000 or higher. In all cases the Design Professional shall be responsible for checking the accuracy of as-built drawings prepared. The Design Professional shall schedule and attend meetings with the Contractor and Owner personnel, at regular intervals during the construction process, to review progress and to assure that the Contractor is keeping accurate records of system installation.

Standard PSFA requirements for as-builts, shop drawings, submittals, training, reports and project closeout materials are outlined in the *General Conditions of the Contract for Construction,* and Divisions 01 and 23 guide specifications.

The Contractor shall provide a printed copy of each specified report to demonstrate the reported data is accurate and complete. The Contractor shall provide an as-built document in each DDC panel showing each system controlled by that panel, control conduit runs, boxes and devices with numbers, and HVAC control schematic drawings.

REFERENCES AND SOURCE MATERIAL

NMAC 6.27.30 New Mexico State Adequacy Standards, New Mexico Public Schools Capital Outlay Council

New Mexico Public School Adequacy Planning Guide, New Mexico Public Schools Capital Outlay Council

Request for Approval of School Construction, State of New Mexico

Report of the World Commission on Environment and Development: Our Common Future, United Nations, 1987

'Advanced Energy Design Guide for K-12 School Buildings' (ISBN 978-1-936504-13-8), ASHRAE, AIA, et al., 2011.

ANSI/ASHRAE Standard 135-2012 and ISO 16484

ANSI/ASHRAE Standard 55-2010 - Thermal Environmental Conditions for Human Occupancy

National Institute of Standards and Technology (NIST) Handbook 135: 10 CFR 436, Subpart A *'Program Rules of the Federal Energy Management Program'*

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