PG&E

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July 13th, 2006 Workshop Report DDC to the Zone Level Measure 4: Demand Control Ventilation (DCV)

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Overview

Description

This CASE report addresses one of five separate measures that extend the control requirements of the standard. All five of these requirements are possible at a very small cost if the installed control system is direct-digital control (DDC) to the zone level. This initiative does not seek to require installation of DDC to the zone level, rather it extends the current philosophy of the prescriptive requirements such as supply static pressure reset (Section 144(c)2D) that state a functional requirement of the control system if it is designed for DDC to the zone level.

The measures covered by this proposal are as follows:

1. Modification of the existing prescriptive measure 144(d) (Space-conditioning Zone Controls) to allow for "dual maximum" control of VAV boxes

2. A new mandatory measure for global demand shed controls that can automatically reset the temperature set-points of all non-critical zones by 1 to 4°F from a single central command in the building energy management and control system (EMCS).

3. Modification of the existing prescriptive measure 144(j)6 (Hydronic System Measures: Variable Speed Drives) to require demand based reset of the pressure setpoint for pumps serving variable flow systems based on valve demand. This measure is the hydronic analog of the existing prescriptive measure for supply air pressure reset in (Section 144(c)2D).

4. Modification of the existing mandatory demand controlled ventilation (DCV) requirements 121(c)3 (Required Demand Control Ventilation) to include high occupant density zones served by multiple zone systems.

5. Modification of the existing prescriptive measure 144(f) (Supply Air Temperature Reset Controls) for demand based supply air temperature reset for variable air volume (VAV) systems that operate when the system is on 100% free cooling from the air-side economizer.

As each of these measures is simply a matter of programming, the cost for implementing them is quite low. However, as described below each of these measures has a significant potential for energy and demand savings.

This specific report covers the revisions to demand control ventilation (DCV).

Energy Benefits

As described in the Methodology section below this measure was simulated using the eQuest program in each of the 16 California climate zones. The savings are presented in Table 1 below. As can be seen in this table, the TDV savings scaled to a 400 ft2 zone come out to around $1,000/zone. This measure saves both on-peak demand and energy by reducing fan power, reheat and OSA conditioning whenever the densely occupied zones are at less than design occupancy.

Table 1 – TDV Savings for DCV Study

Climate Zone	Basecase TDV Cost	DCV TDV Cost	TDV Cost Savings	TDV Cost Savings per 400sf Zone
CZ01	$ 132,000	$ 114,000	$ 18,000	$ 900
CZ02	$ 150,000	$ 130,000	$ 20,000	$ 1,000
CZ03	$ 139,000	$ 117,000	$ 22,000	$ 1,100
CZ04	$ 153,000	$ 130,000	$ 23,000	$ 1,150
CZ05	$ 138,000	$ 116,000	$ 22,000	$ 1,100
CZ06	$ 153,000	$ 130,000	$ 23,000	$ 1,150
CZ07	$ 128,000	$ 108,000	$ 20,000	$ 1,000
CZ08	$ 158,000	$ 137,000	$ 21,000	$ 1,050
CZ09	$ 172,000	$ 150,000	$ 22,000	$ 1,100
CZ10	$ 171,000	$ 151,000	$ 20,000	$ 1,000
CZ11	$ 162,000	$ 145,000	$ 17,000	$ 850
CZ12	$ 161,000	$ 141,000	$ 20,000	$ 1,000
CZ13	$ 171,000	$ 152,000	$ 19,000	$ 950
CZ14	$ 172,000	$ 156,000	$ 16,000	$ 800
CZ15	$ 204,000	$ 185,000	$ 19,000	$ 950
CZ16	$ 149,000	$ 133,000	$ 16,000	$ 800
			Minimum =>	$ 800
			Maximum =>	$ 1,200
			Average =>	$ 1,000

Non-energy Benefits

This measure reduces the wear and tear on both heating and cooling equipment. An additional benefit of DCV is the ability of occupants and system operators to monitor CO2 concentration in a zone and therefore receive feedback on HVAC system ventilation performance.

Environmental Impact

Beneficial environmental impacts are reduced electricity (energy and demand) and natural gas consumption. When properly tuned, DCV insures that code minimum ventilation rates are maintained at all times. It acts to reduce over-ventilation of spaces when they are not fully occupied.

DCV systems increase the concentration of bioeffluents and building-borne contaminants in the space when partially occupied. However, as documented in the Title 24 2005 DCV study (CEC April 2002), these contaminant levels are maintained at acceptable concentrations based on research, and consensus of code and standard organizations.

Type of Change

This measure is proposed as a modification of an existing mandatory requirement. It applies to either new construction or retrofit where all zones have DDC controls. The changes to the Title 24 documents are summarized in the following paragraphs. The complete proposed changes with underlines and strikeouts are in the section Proposed Standard Language below:

Standards

- Revise existing mandatory requirement 121(c)3
- No change is required for 121(c)5 Demand Control Ventilation Acceptance.

ACM

- Modify the language in 2.5.3.11 Zone Ventilation Air
- Modify the existing acceptance test NJ.8. Demand Control Ventilation (DCV) Systems.

Technology Measures

This measure only applies to multiple zone systems with DDC to the zone level. As presented in our industry survey below, this represents between 90% to 95% of the new construction market.

Measure Availability and Cost

EMCS systems with DDC to the zone level are prevalent in the current building market. Our experience and surveys of the major EMCS vendors indicate that all of the major vendors are capable of meeting these proposed requirements. Data on the major market players and the surveys are presented below.

DCV sensors are readily available from a range of manufacturers. Almost all of the large EMCS vendors manufacture or OEM CO_2 sensors. This is in due in part to the Title 24 2005 requirement for DCV on single zone systems.

Useful Life, Persistence and Maintenance

This measure will be tested through the Title 24 acceptance testing requirements. These proposed control sequences (like all controls) will need to be reviewed and the sensors recalibrated as part of the routine maintenance of the EMCS. For this requirement, the sensor calibration is part of both the base case and proposed requirements.

Performance Verification

As documented below the existing Title 24 acceptance requirements will be slightly modified to test this proposed requirement.

Analysis Tools

This measure can be evaluated using either eQuest or EnergyPro. The current ACM procedures (extended to multiple zone systems) will work to capture the savings.

Relationship to Other Measures

This measure is an enhancement of the existing mandatory DCV measure in 121(c).

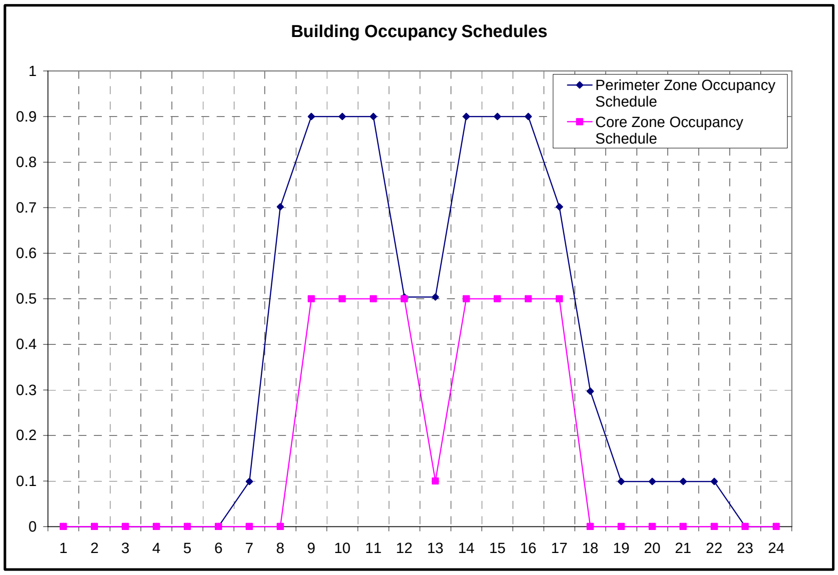
Methodology

Energy Model

This measure was evaluated using the eQuest program. A simple five zone model was used for this analysis with the core zone used for the conference room. The building was served with a packaged VAV system with hot water reheat. The default occupancy schedules from eQuest were used in the model (see Figure 1 below). This model was run in all 16 of the California Climate zones. The TDV energy cost savings are presented in Table 1 above.

The eQuest DCV algorithms were employed. These (as verified by review of the hourly reports) changed both the zone level airflow and OSA minimum position between a floor of 0.15 cfm/ft2 and a demand based airflow rate of 15 cfm per person (derived from the occupancy schedule in Figure 1 below.

Figure 1 – eQuest Occupancy Schedule Used in the Analysis



EMCS Market Share

The authors did a literature search and surveyed the major EMCS vendors to determine the market share of EMCS vendors in the HVAC controls market nationwide. The results follow:

1. Johnson 16%-25%
2. Siemens 15%-17%
3. Trane 6%-15%
4. Honeywell 7%-10%
5. Alerton 5%-10%
6. Automated Logics 7%-10%
7. Andover 7%-10%

8. Invensys 7%

9. All others 10%-20%

Graphical data from one of the market research sources is presented in Figure 2 below.

Figure 2 – EMCS Market by Company in 2001 (BCS 2002)

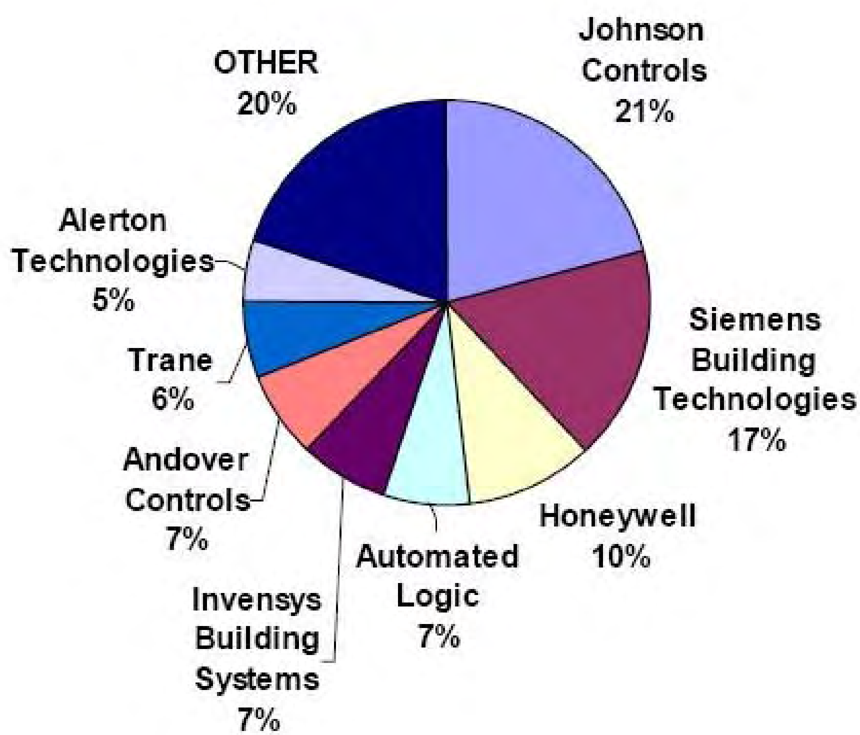
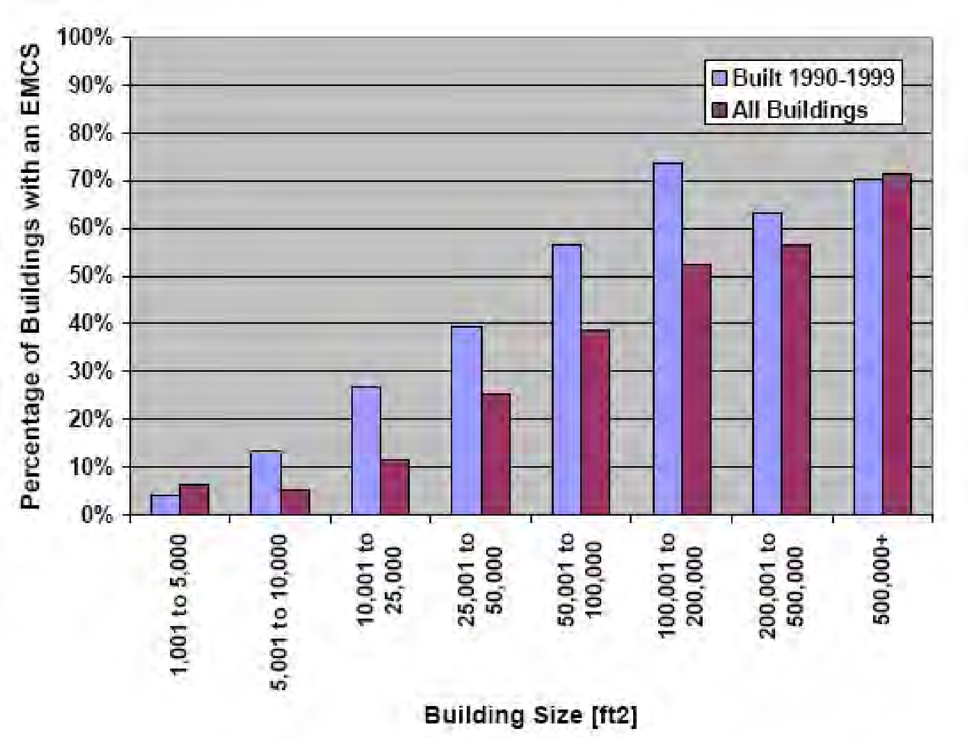


Figure 3 – Buildings with EMCS (EIA 1999)



Survey of EMCS Manufacturers on the Proposed Requirements

An email survey was sent to EMCS vendors to get their reaction to the proposed requirements. The survey was sent to Trane, Honeywell, Invensys, Alerton, Johnson, Automatic Logic Corporation and Siemens. At the time of this report, responses were received from Alerton, Automated Logic Corporation and Siemens. The survey that was sent follows:

Dear [Insert Name],

We are working on the development of the 2008 update of California's building energy code, Title 24. We are preparing for a workshop on July 13th and would appreciate your response by July 1st if possible. One of the issues we are researching relates to DDC controls. We are investigating a code change to specify control requirements on systems that have DDC to the zone level. In order to determine the feasibility of these ideas, we are surveying vendors and contractors for their opinions on the viability of these proposed measures and the make-up of the BMS market in California. To assist our deliberations, we would like you to answer the following questions:

1. *In your opinion, for new construction in commercial buildings what percentage of the controls marketplace (based on $ spent by owners) belongs to the following classes of control products:*

    a) *Fully DDC (including the zone controls)?*

    b) *Hybrid DDC and pneumatic systems?*

    c) *Fully pneumatic?*

    d) *Other (please elaborate)?*

In considering your answer to this question exclude the single zone units that are controlled by programmable thermostats

2. *In your experience what are the most important (top 3 to 5) factors that drive a customer to purchase DDC controls? Consider the following list but feel free to list other major factors:*

    a) *First cost*

    b) *Energy savings*

    c) *Alarming*

    d) *Improved comfort and control*

    e) *Trending*

    f) *Tenant submetering*

    g) *Tenant after hours management*

    h) *Facility management*

    i) *Web based access*

    j) *Other factors (please list)*

3. *What are the relative installed costs of DDC and pneumatic systems for typical office and retail buildings?*

    a) *On a $/sf basis (or relative % cost basis) if you have the data*

    b) *Qualitatively, are they about the same or is one significantly more expensive?*

4. *Do you have any data on comparative maintenance costs for DDC and pneumatic systems?*

5. *Would you support a code change requiring DDC controls to the zone level for new control systems serving multiple zone systems and equipment?*

    a) *What are some questions or concerns you might have about such a code change?*

    b) *Are there systems or applications where this would not be appropriate?*

6. *The following are specific control requirements that we are considering. Please provide feedback (positive or negative about each). For each control requirement please address the following issues:*

    - *whether your existing systems (hardware and software) will be able to support these requirements*
    - *what exceptions should be included*
    - *the added effort to program and tune these control algorithms*

    Here are the proposed new control requirements

a) *Hydronic pump pressure reset by demand (either directly by valve demand or through a " trim and respond " algorithm)*

b) *Ability to globally reset cooling set points on zone thermostats on " non critical " zones by 1 to 4°F for central demand shed.*

c) *Supply air temperature reset on VAV systems that is only enabled when the system is on 100% economizer cooling*

d) *Demand controlled ventilation for multiple zone units serving one or more densely occupied zones. The control logic is likely to cascade with the first step controlling the zone box minimum and the second step controlling the minimum OSA damper position.*

Please contact us if you need any clarifications on the above questions. We thank you in advance for your time and we welcome your comments and feedback.

A summary of the survey results follow:

Question 1, EMCS market place: All three respondents indicated that DDC to the zone level was between 90% to 95% of the new construction market.

Question 2, Top Factors for DDC Purchases:

- Facility Management - 3 Votes
- Improved Comfort and Controls – 3 Votes
- Tenant After Hours Management – 2 Votes
- Alarming – 2 Votes
- Energy Savings – 2 Votes
- First Cost – 2 Votes
- Web Based Access – 1 Vote

Question 3, Relative First Cost of DDC and Pneumatic Controls: The consensus of the respondents is that pneumatic controls generally have a slightly smaller first cost. This cost depends on the number of points in the system as the pneumatic control system incurs a large first cost penalty for the compressor and associated equipment (like air dryers and filters). For small control systems DDC is actually less expensive. For medium and large control systems DDC is likely to be a slight cost premium.

Question 4, Relative Maintenance Cost of DDC and Pneumatic Controls: The consensus of the respondents is that pneumatic controls have a significantly higher maintenance cost (on the order of 20%-40%).

Question 5, Support for the Proposed Requirements: All respondents support the proposed requirements.

Results

The results of our investigations indicate that this measure is both cost effective and would be embraced by the industry.

The results of our simulation indicate an average TDV cost savings of $1000 for a 400 ft2 zone. As established in the Title 24 2005 report for the single zone DCV measures (CEC April 2002) the installed costs per zone for DCV controls are conservatively $575 per zone. This is only 60% of the calculated TDV savings.

Statewide Energy Savings

[To be developed later]

Recommendations

Proposed Standards Language

Modification of Existing Prescriptive Requirement 121(c)3 Required Demand Control Ventilation

121(c)3. **Required Demand Control Ventilation**. HVAC ~~single zone~~ systems with the following characteristics shall have demand ventilation controls complying with 121 (c) 4:

A. They have an outdoor air economizer; and

B. They serve a space with a design occupant density, or a maximum occupant load factor for egress purposes in the CBC, greater than or equal to 25 people per 1000 ft2 (40 square foot per person)~~.~~; and

C. They are either:

i. Single zone systems with any controls; or

ii. Multiple zone systems with DDC controls to the zone level.

EXCEPTION 1 to Section 121 (c) 3 B: Classrooms are not required to have demand control ventilation.

EXCEPTION 2 to Section 121 (c) 3 B: Where space exhaust is greater than the design ventilation rate specified in 121 (b) 2 B minus 0.2 cfm per ft2 of conditioned area.

EXCEPTION 3 to Section 121 (c) 3 B: Spaces that have processes or operations that generate dusts, fumes, mists, vapors, or gases and are not provided with local exhaust ventilation (such as indoor operation of internal combustion engines or areas designated for unvented food service preparation).

Alternate Calculation Manual

Modifications to 2.5.3.11 Zone Ventilation Air

2.5.3.11 Zone Ventilation Air

…

Modeling Rules for Standard Design (All): The reference method determines the standard design zone ventilation rate as follows:

1. If no tailored ventilation rate has been entered, the ACM shall use values from Table N2-2 or Table N2-3for the applicable occupancy as the zone ventilation rate for the standard design.

2. If a tailored ventilation rate has been entered, the ACM shall assume the tailored value as the zone ventilation rate for the standard design.

3. If the zone is served by either a single-zone system or a multiple zone system with DDC to the zone level (in the proposed design) that has an air-side economizer and has a design occupant density greater than or equal to 25 people per 1000 ft2 (40 ft2 per person) from Table N2-2 or Table N2-3, unless space exhaust is greater than the design ventilation rate specified in 121 (b) 2 B minus 0.2 cfm per ft2 of conditioned area, the ACM shall output on compliance forms that DEMAND CONTROL VENTILATION IS REQUIRED FOR THIS ZONE PER SECTION 121 and the ACM shall use the larger of the following as the zone ventilation rate for the standard design:

a) half of the value from Table N2-2 or Table N2-3.

b) the minimum rate.

c) half of the user defined amount, if the zone ventilation rate has been entered by the user.

Modifications to NJ.8. Demand Control Ventilation (DCV) Systems

NJ.8. Demand Control Ventilation (DCV) Systems

~~Demand control ventilation is tested on package systems per Standards Section 121 (c)3.~~

All DCV sensors and controls shall be tested.

~~NJ.8.1 Packaged Systems DCV Acceptance~~

NJ.8.1~~.1~~ Construction Inspection

Prior to Performance Testing, verify and document the following:

- ~~C~~All carbon dioxide (CO_2) control sensors are ~~is~~ factory calibrated (proof required) or field-calibrated with an accuracy of no less than 75 ppm.
- The sensor is located in the room between 1ft and 6 ft above the floor.
- System controls are wired correctly to ensure proper control of outdoor air damper system.
- There is one CO_2 sensor for each densely occupied space per Standard section 121(c)4A.

NJ.8.1.2 Equipment Testing

For each zone with a CO_2 sensor verify the following:

Step 1: Simulate a high CO_2~~CO2~~ load ~~and enable the demand control ventilation by adjusting the demand control ventilation controller setpoint below ambient CO2 levels~~. Verify and document the following:

- Either the zone air damper or the o~~O~~utdoor air damper modulates open~~s per Standards to maximum position~~ to satisfy ~~outdoor air~~ ventilation requirements specified in Standard Section 121(c).

Step 2: Continue from Step 1 and Simulate a low CO_2 load ~~disable demand control ventilation by adjusting the demand control ventilation controller setpoint above ambient CO2CO2 levels~~. Verify and document the following:

- Either the zone air damper or the o~~O~~utdoor air damper closes ~~to minimum position~~to satisfy minimum ventilation requirements specified in Standard Table 121-A.

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Appendices

None.