Overview

- Proposals are approved independently
- Must think holistically and evaluate the interactive effects between all proposals
- TAG should conduct this analysis now, before the SBCC moves these proposals forward to the public comment period

HARGIS

Problem Statement

EM062-2018

- Requires DOAS for Assembly spaces

EM083-2018

- Limits use of HE-VAV section to systems that serve 5 or more zones and greater than 3,000 SF

Outcome:

DOAS becomes the only available system type within Assembly spaces since they're traditionally served by single-zone systems

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Issues

1) DOAS in assembly spaces will **INCREASE** energy consumption (see Hargis' EM062 minority report)
2) DOAS in assembly spaces will **INCREASE** first cost and life cycle costs (see Hargis' EM062 minority report)
3) No available design alternatives – DOAS becomes only option for single-zone spaces

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Solutions

1) Update **proposal EM062** to include the following addition to exception #1 of Section C403.7.1, which will now require DOAS unit to utilize energy recovery and DCV:

> *1) Systems with energy recovery complying with Section ~~403.2.6.2~~ C403.7.7.1. This exception is not available for space types located within the "inclusions" column of A-1 and A-3 occupancy classifications per Table C403.3.5.*

2 & 3)

Update **proposal EM062** to include a new high efficiency single-zone VAV section for assembly spaces (see following text)

And

Update **proposal EM083** requirement #1**,** otherwise there will be a void for systems serving 2-4 zones or less than 3,000 SF in which DOAS becomes the only option:

> *1. Each VAV system must ~~serve a minimum of 3000 square feet and~~ have a minimum of ~~five~~ two VAV zones*.

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Insert the following updates to EM062-2018:

1) Update to Exception #2 of Section C403.3.5:

2. High efficiency variable air volume (VAV) systems complying with Section C403.6.10 for occupancy classifications other than A-1, A-2, and A-3 per Table C403.3.5, and high efficiency variable air volume (VAV) systems complying with Section C403.12 for A-1, A-2, and A-3 occupancy classifications per Table C403.3.5. This exception shall not be used as a substitution for a DOAS per Section C406.6 or as a modification to the requirements for the Standard Reference Design per Section C407

2) Add a new high efficiency single-zone VAV section for systems serving A-1, A-2, or A-3 occupancy classifications:

C403.12 High efficiency single-zone variable air volume (VAV) systems. For HVAC systems subject to the requirements of Section C403.3.5 but utilizing Exception 2 of that section, a high efficiency single-zone VAV system may be provided without a separate parallel DOAS when the system is designed, installed, and configured to comply with all of the following criteria (this exception shall not be used as a substitution for a DOAS per Section C406.6 or as a modification to the requirements for the Standard Reference Design per Section C407):

1. The single-zone VAV system is provided with airside economizer per Section 403.3 without exceptions.
2. A direct-digital control (DDC) system is provided to control the system as a single zone per Section C403.4.11 regardless of sizing thresholds of Table C403.4.11.1.
3. Single-zone VAV systems with a minimum outdoor air requirement of 1,000 cfm (472 L/s) or greater shall be equipped with a device capable of measuring outdoor airflow intake under all load conditions. The system shall be capable of increasing or reducing the outdoor airflow intake based on Section C403.7.1 demand controlled ventilation.
4. Allowable fan motor horsepower shall not exceed 90% of the allowable HVAC *fan system bhp* (Option 2) as defined by Section C403.8.1.1.
5. Minimum fan speed shall not be greater than 30 percent of design airflow required for the greater of heating and cooling operation and ventilation-only operation.
6. Spaces that are larger than 150 square feet (14 m^2) and with an occupant load greater than or equal to 25 people per 1000 square feet (93 m^2) of floor area (as established in Table 403.3.1.1 of the *International Mechanical Code*) shall be provided with all of the following features:
    6.1. Demand control ventilation (DCV) shall be provided that utilizes a carbon dioxide sensor to reset the ventilation setpoint of the single-zone VAV system from the design minimum to design maximum ventilation rate as required by Chapter 4 of the *International Mechanical Code*.
    6.2. Occupancy sensors shall be provided that are configured to reduce the minimum ventilation rate to zero and setback room temperature setpoints by a minimum of 5°F, for both cooling and heating, when the space is unoccupied.
7. Single-zone VAV systems shall comply with one of the following options:
    7.1. Single-zone VAV air handling units with a hydronic heating coil connected to systems with hot water generation equipment limited to the following types of equipment: gas-fired hydronic boilers with a thermal efficiency, Et, of not less than 92 percent, air-to-water heat pumps or heat recovery chillers. Hydronic heating coils shall be sized for a maximum entering hot water temperature of 120°F for peak anticipated heating load conditions.
    7.2. Single-zone VAV air handing units with a chilled water coil connected to systems with chilled water generation equipment with IPLV values more than 25 percent higher than the minimum part load efficiencies listed in Table C403.3.2(7), in the appropriate size category, using the same test procedures. Equipment shall be listed in the appropriate certification program to qualify. The smallest chiller or compressor in the central plant shall not exceed 20% of the total central plant cooling capacity or the chilled water system shall include thermal storage sized for a minimum of 20% of the total central cooling plant capacity.
8. The DDC system shall include a fault detection and diagnostics (FDD) system complying with the following:
    8.1. The following temperature sensors shall be permanently installed to monitor system operation:
        8.1.1. Outside air.
        8.1.2. Supply air.
        8.1.3. Return air.
    8.2. Temperature sensors shall have an accuracy of ±2°F (1.1°C) over the range of 40°F to 80°F (4°C to 26.7°C).
    8.3. The single-zone VAV air handling unit controller shall be configured to provide system status by indicating the following:
        8.3.1. Free cooling available.

8.3.2. Economizer enabled.
8.3.3. Compressor enabled.
8.3.4. Heating enabled.
8.3.5. Mixed air low limit cycle active.
8.3.6. The current value of each sensor.

8.4. The single-zone VAV air handling unit controller shall be capable of manually initiating each operating mode so that the operation of compressors, economizers, fans and the heating system can be independently tested and verified.

8.5. The single-zone VAV air handling unit shall be configured to report faults to a fault management application accessible by day-to-day operating or service personnel or annunciated locally on zone thermostats.

8.6. The FDD system shall be configured to detect the following faults:
8.6.1. Air temperature sensor failure/fault.
8.6.2. Not economizing when the unit should be economizing.
8.6.3. Economizing when the unit should not be economizing.
8.6.4. Outdoor air or return air damper not modulating.
8.6.5. Excess outdoor air.

memo

TO	MVE Committee	**DATE**	September 13, 2018
ATTN.	Eric Vander Mey, PE	**REGARDING**	EM062-2018 – Minority Report
FROM	Michael Baranick, PE Hargis Engineers		

Proposal Status: Passed the WSEC TAG meeting on 7/20/18

Objection: EM062-2018 has improved the language in Section C403.3.5 to better define the occupancy types in which DOAS is required. However, as part of this proposal, assembly spaces (A-1, A-2, and A-3) were added as an occupancy type that now require DOAS, which is a change from the previous version of the WSEC.

Recommendation: Update the change proposal prior to final passage by the SBCC to remove assembly spaces (A-1, A-2, and A-3) as occupancy types that require DOAS.

Reasoning:

1) No available design alternatives. The only available prescriptive option designers have in lieu of DOAS is high-efficiency variable air volume systems (HE-VAV). However, change proposal EM083-2018 that was approved by the TAG committee has limited the use of HE-VAV to systems with 5 or more zones, and since assembly spaces are historically served by single-zone units, DOAS will become the only prescriptive option available.
2) Flawed economic analysis. The economic analysis falsely represents the energy efficiency benefits of using DOAS for assembly spaces as follows:
    a. Only a single project was analyzed. Changes of this magnitude should incorporate a larger sample size, ensuring that the benefits of this change are consistence between all assembly occupancy types (A-1, A-2, and A-3).
    b. The DOAS was paired with energy efficient strategies above and beyond what code requires. Examples include DCV (not required since DOAS has energy recovery) and a VRF system for heating/cooling. These strategies are likely strong contributors to energy benefits portrayed in the analysis, both of which would not be required if the proposal is passed in its current form.
    c. Unsystematic comparison. The analysis compares the DOAS performance to the City of Seattle Benchmarking data, which includes both new and existing assembly buildings. This is not an apples-to-apples comparison. Instead, an energy life-cycle cost analysis (ELCCA) should be completed and compared against a code baseline system per Table C407.5.1(3).
3) Annual energy consumption, energy costs, first costs, maintenance costs, **AND** 50-year life cycle costs will likely **INCREASE** if DOAS is required in assembly spaces. Hargis argues that DOAS is NOT the most cost-effective and energy efficient option, nor does it result in the most attractive life-cycle cost, for most assembly occupancy types. To substantiate this argument, Hargis completed an analysis comparing common system types (including DOAS) that traditionally serve assembly spaces (see following pages).

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SUPPLEMENTAL INFORMATION – DETAILED ANALYSIS

Analysis Overview:

The analysis below of a large volume high occupancy multipurpose room supports Hargis' concern regarding this proposal. This analysis was conducted using a specific set of conditions and assumptions, but is emblematic of what is seen in current designs. Hargis understands that the results may differ for each unique space and system type; however, this analysis should at minimum encourage the TAG to thoroughly evaluate the potential impacts of this proposal prior to approval in its current form.

Results:

The analysis studied the comparison between energy consumption (EUI), operating costs (energy, annual maintenance, and repair), first costs, and life cycle costs of (3) HVAC system types serving a large volume high occupancy multipurpose room. The three systems types analyzed are listed below.

Option 1: DOAS + RTU
Option 2: VAV-RTU
Option 3: VAV-RTU w/ energy recovery

The table is color-coordinated for visual purposes. For each metric, **green** indicates the best performing system, whereas **red** indicates the worst performing system.

Metric	Option 1	Option 2	Option 3
	DOAS + RTU	VAV-RTU	VAV-RTU w/ Energy Recovery
EUI (kBTU/SF/Yr)	**49.9**	40.3	**37.0**
First Cost	**$64,750**	**$46,200**	$59,350
Energy Cost (year 1)	**$4,290**	$3,442	**$3,244**
Maintenance Cost (year 1)	**$1,741**	**$1,102**	**$1,102**
Life Cycle Cost (50-year)	**$410,271**	**$304,034**	$329,096

The large EUI delta between the two system types is primarily attributed to the fact that DOAS units with energy recovery do NOT require demand controlled ventilation (DCV) per Exception 1 of Section C403.7.1. As the results indicate, eliminating DCV within space types that are frequently loaded at occupancy rates well below peak conditions, such as gyms, multipurpose rooms, auditoriums and large meeting spaces, significantly increases energy consumption even when the DOAS unit contains energy recovery. In simplistic terms, a 50% effective energy recovery device essentially cuts the ventilation rate in half. Assembly spaces (such as gyms, multipurpose rooms, auditoriums, and large meeting spaces) are frequently loaded at occupancy

rates well below peak conditions, and arguably at rates well below 50% on average. Therefore, a non-DOAS HVAC system that includes DCV will outperform a DOAS HVAC system that includes energy recovery anytime the average occupancy rate is below 50%.

Space Information:

Type: Multipurpose room (within a school)
Occupancy: A-3
Size: 6,000 square feet
Height: 30 feet
People: 600 max (100 people per 1000 square feet)
Lighting: 0.98 W/SF
Envelope: prescriptive per Table C402.1.3
Schedule: M-F 8AM-6PM, year-round (except for standard holidays)
Occupancy: assumes 10% (60 people), with 100% occupancy for 1 hour each day

HVAC System Options:

System Features	Option 1	Option 2	Option 3
	DOAS + RTU	VAV-RTU	VAV-RTU w/ Energy Recovery
Cooling	DX Efficiency per Table C403.2.3(1)A	Same as Option 1	Same as Option 1
Heating	80% efficient gas-fired furnace per Table C403.2.3(4)	Same as Option 1	Same as Option 1
Fan Power	RTU & DOAS calculated per Table C403.2.11.1(1) Note: EM094-2018 now requires separate fan power allowance calculations for DOAS	RTU calculated per Table C403.2.11.1(1)	Same as Option 2
Supply Airflow	9,000 CFM (assumes 1.5 CFM/SF)	Same as Option 1	Same as Option 1
Economizer	No	Yes	Yes
Ventilation (Max)	4,860 CFM (7.5 CFM/person, 0.06 CFM/SF)	Same as Option 1	Same as Option 1
Ventilation (Min)	Same as Max	810 CFM (assumes only 60 people)	Same as Option 2
Energy Recovery	Yes (per C403.6.1)	No	Yes
Demand Controlled Ventilation	No (not required per C403.2.6.2 exception 1)	Yes	Yes
Airflow Control	DOAS: constant volume RTU: 2-speed, 50% turndown per C403.2.11.5	VAV (20% minimum turndown)	Same as Option 2
Temperature Setpoints	Heating: 70/60 Cooling: 75/85 (occupied/unoccupied)	Same as Option 1	Same as Option 1

Note: all code references within the table above are based on the 2015 WSEC

Cost Opinion:

2018 RSMeans Mechanical was utilized as the basis for all cost opinions. Cost estimates include rooftop equipment and do not account for ductwork, controls, insulation, commissioning, etc.

Option 1: DOAS+ RTU

Component	Cost	Reference
DOAS	$14,800 $13,150	Page 392: 12.5 ton single-zone RTU w/ DX & gas heat (assumes 400 CFM/ton) Page 390: Air-to-air heat wheel, 5000 CFM
RTU	$36,800	Page 392: 20 ton single-zone RTU w/ DX & gas heat (assumes 400 CFM/ton)
Total	**$64,750**	

Option 2: VAV-RTU

Component	Cost	Reference
DOAS	-	
RTU	$46,200	Page 393: 25 ton single-zone RTU w/ DX, gas heat, & VAV (assumes 400 CFM/ton)
Total	**$46,200**	

Option 3: VAV-RTU w/ Energy Recovery

Component	Cost	Reference
DOAS	-	
RTU	$46,200 $13,150	Page 393: 25 ton single-zone RTU w/ DX, gas heat, & VAV (assumes 400 CFM/ton) Page 390: Air-to-air heat wheel, 5000 CFM
Total	**$59,350**	

Maintenance Estimates:

The Whitestone Building Maintenance and Repair Cost Reference was utilized as the basis for all maintenance estimates.

Option 1: DOAS+ RTU

Component	Annual Maintenance	Repair Costs	Repair Frequency	Annualized Cost
DOAS	$392	$2,994	10 years	$691
RTU	$725	$3,252	10 years	$1,050
			Total	**$1,741**

Option 2: VAV-RTU

Component	Annual Maintenance	Repair Costs	Repair Frequency	Annualized Cost
DOAS	-	-	-	-
RTU	$761	$3,414	10 years	$1,102
			Total	**$1,102**

Option 3: VAV-RTU w/ Energy Recovery

Component	Annual Maintenance	Repair Costs	Repair Frequency	Annualized Cost
DOAS	-	-	-	-
RTU	$761	$3,414	10 years	$1,102
			Total	**$1,102**

Energy Modeling:

A simple shoe-box model was developed for each HVAC option based on the inputs described above. 2018 IES-VE was utilized as the energy modeling software.

Appendix:

1) 50-year ELCCA
2) DOAS+RTU One-Line Diagram
3) Single-zone RTU One-Line Diagram

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H A R G I S

DOAS WITH ROOFTOP UNIT (RTU)

NOTES:

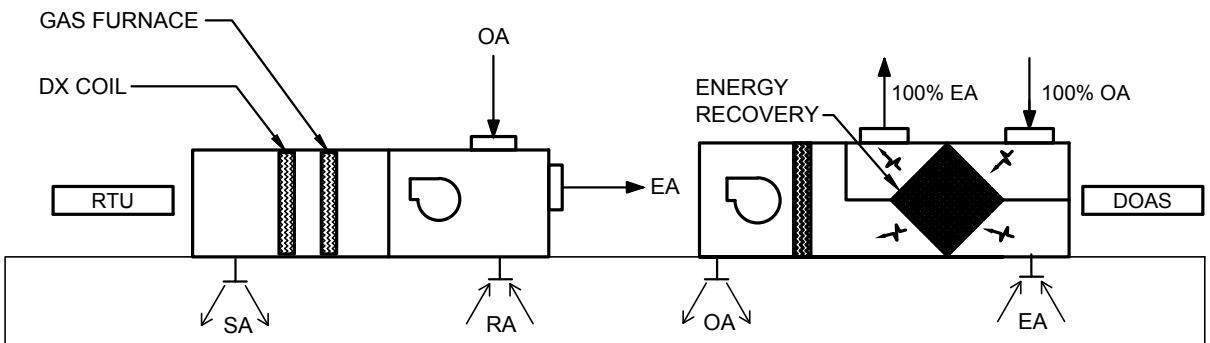
1) ALL CODE REFERENCES PER 2015 WSEC.
2) ASSUMES MULTIPURPOSE ROOM IS OPERATED YEAR-ROUND FROM 8AM-6PM WITH TYPICAL HOLIDAYS.
3) HEATING SETPOINT = 70°F (60°F). COOLING SETPOINT = 75°F (85°F).
4) ASSUMES 25% OCCUPIED ON AVERAGE (60 PEOPLE) WITH 100% OCCUPANCY FOR 1 HOUR EVERYDAY.
5) PUMP ENERGY IGNORED (RELATES TO SINGLE-ZONE VAV SYSTEM ONLY).

RTU INFO:

- 9,000 CFM SUPPLY (1.5 CFM/SF)
- 100% AIRSIDE ECONOMIZER PER EM080-2018
- 50% MIN TURNDOWN (4,500 CFM) PER C403.2.11.5
- DX COOLING EFFICIENCY PER TABLE C403.2.3(1)A
- ASSUMES 80% EFFICIENT GAS FURNACE PER TABLE C403.2.3(4)
- FAN POWER PER TABLE C403.2.11.1(1)

DOAS INFO:

- 4,860 CFM OA (7.5 CFM/PERSON, 0.06 CFM/SF)
- NO TURNDOWN (CONSTANT VOLUME)
- ENERGY RECOVERY PER C403.5
- FAN POWER PER TABLE C403.2.11.1(1) (PER EM094-2018)



MULTIPURPOSE ROOM (WITHIN A SCHOOL)
- 6,000 SF
- 30'-0" TALL
- 600 PEOPLE MAX (100 PEOPLE/1000 SF)
- 0.98 W/SF LIGHTING

CODE MIN ENVELOPE PER TABLE C402.1.3

S OS

PER C403.2.6.3

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SKETCH NUMBER

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SINGLE-ZONE HIGH EFFICIENCY VAV

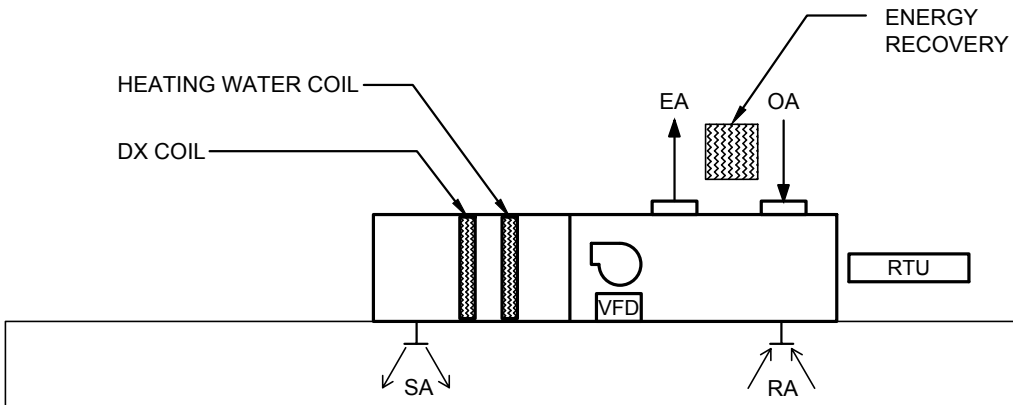
NOTES:

1) ALL CODE REFERENCES PER 2015 WSEC.
2) ASSUMES MULTIPURPOSE ROOM IS OPERATED YEAR-ROUND FROM 8AM-6PM WITH TYPICAL HOLIDAYS.
3) HEATING SETPOINT = 70°F (60°F). COOLING SETPOINT = 75°F (85°F).
4) ASSUMES 25% OCCUPIED ON AVERAGE (60 PEOPLE) WITH 100% OCCUPANCY FOR 1 HOUR EVERYDAY.
5) PUMP ENERGY IGNORED (RELATES TO SINGLE-ZONE VAV SYSTEM ONLY).

RTU INFO:

- 9,000 CFM SUPPLY (1.5 CFM/SF)
- 4,860 CFM OA (7.5 CFM/PERSON, 0.06 CFM/SF)
- 100% AIRSIDE ECONOMIZER
- 20% MIN TURNDOWN (1,800 CFM)
- DEMAND CONTROLLED VENTILATION
- DX COOLING EFFICIENCY PER TABLE C403.2.3(1)A
- UNIT SERVED BY 90% EFFICIENT GAS-FIRED BOILER PER SECTION C403.7.15.1
- FAN POWER PER TABLE C403.2.11.1(1)

ENERGY RECOVER PER C403.5



MULTIPURPOSE ROOM (WITHIN A SCHOOL)
- 6,000 SF
- 30'-0" TALL
- 600 PEOPLE MAX (100 PEOPLE/1000 SF)
- 0.98 W/SF LIGHTING

CODE MIN ENVELOPE PER TABLE C402.1.3

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PER C403.7.13

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