Ventilation and Humidity Control in Army Barracks Using DOAS for Better Indoor Air Quality and Energy Conservation

Author: John Vavrin, PE    Presenter: Dale Herron
Then

What a difference !!

Now
Introduction

- U.S. Military barracks range from the wooden World War II-era buildings to the college-dorm-type dwellings of today and are located in all climatic zones.
- U.S. Army has been steadily building and renovating barracks under different long-term programs.
- The Barracks Upgrade Program (BUP), Training Barracks Improvement Program (TBIP), Barracks Improvement Program (BIP), and Flagship Programs are focused on improvement of conditions in permanent-party barracks and include:
  - mold and mildew removal;
  - repairing or replacing damaged heating or air conditioning systems;
  - fixing water leaks; and ensuring all toilets, showers and plumbing are in working condition;
  - painting of buildings and repair of doors and windows.
- These 4 programs address needs of 26 CONUS Army installations + installations in Europe and Korea with a total cost of ~$484M.
Scope of Measures

- Building Envelope
  - Roofing
  - Wall Insulation
  - Air Leakage Reduction
  - Window Shading
  - Basement Water Leakage Reduction
- Separate Ventilation and Temperature Control (A/C) System
- Outdoor Air Dehumidification
- Demand-Side Management
  - Lighting
  - Occupancy Control Systems
General Problems with Humidity in Barracks, Major Concern in SE United States
Moisture Control

Strategies for dealing with moisture in buildings include:

- Keeping water out,
- Avoiding (or managing) plumbing leaks,
- Avoiding condensation inside the building or within the building envelope,
- Controlling the entry of humid outside air,
- Controlling indoor sources of humidity (i.e. moisture coming from insufficiently ventilated showers),
- Providing adequate mechanical ventilation/dehumidification.
Dedicated Outside Air System

Use DOAS to pressurize apartments, provide humidity control and make-up air for mechanical exhausts (separate room temperature control system):

• **Dehumidification Only**
  - dehumidifies and tempers summer outside air
  - uses one air-air heat exchanger
  - is not an air-to-air energy recovery device

• **Dehumidification with Energy Recovery**
  - dehumidifies and tempers summer outside air
  - tempers winter O/A
  - uses two air-air heat exchangers
  - performs energy recovery using building exhaust air
Reasons Engineers Are Choosing Dedicated OA Systems

• Ventilation Air Distribution In All Air VAV Systems. Engineers cannot be sure where the ventilation air, in all air systems, is distributed once brought into the building and mixed with return air at the air-handling unit.

• Excess OA Flow And Conditioning Required For All Air VAV Systems.

• VAV Box Minimum Settings Must Be Surprisingly High.

• Inability Of Most All Air VAV Systems, As Currently Designed, To Decouple The Space Sensible And Latent Loads.
Problems of All-Air VAV

- Multiple spaces equation (ASHRAE Std. 62)
  - Does not guarantee that individual space will always receive the intended OA quantity
- Conditioning and transporting air
  - Consumes large quantities of energy
- Part load humidity problem
  - Space humidity is passively controlled
DOAS Systems

20-70% less OA than VAV

DOAS Unit W/ Energy Recovery

Cool/Dry Supply

Parallel Sensible Cooling System

Building With Sensible and Latent cooling decoupled

High Induction Diffuser
Why decouple sensible and latent space loads with DOAS?

Tight humidity control minimizes the potential for IAQ problems and related sick-building illnesses, and improves thermal comfort and productivity.

*Which are caused largely by biological contaminants breeding in damp ducts, ceiling tiles, insulation behind shear barriers and carpet.*
Potential Health & Productivity Related Economic Benefits of DOAS

The significance of DOAS is illustrated by estimates that US companies lose as much as $48 Billion annually to cover medical expenses and $160 Billion annually in lost productivity as a result of sick-building illnesses.

Source: ASHRAE Literature
VAV problems solved with DOAS plus Radiant or Chilled Beam

- Poor air distribution.
- Poor humidity control.
- Poor acoustical properties.
- Poor use of plenum and mechanical shaft space.
- Serious control problems, particularly with tracking return fan systems.
- Poor energy transport medium, air.
- Poor resistance to the threat of biological and chemical terrorism, and
- Poor and unpredictable ventilation performance.
Additional Benefits of DOAS

Beside solving problems that have gone unsolved for over 30 years with conventional VAV systems, note the following benefits:

• Greater than 50% reduction in mechanical system operating cost compared to VAV.
• Equal or lower first cost.
• Simpler controls.
• Generates up to 80% of points needed for basic LEED certification.
Conclusions

• Significant energy saving potential – over 40%
  – Small SA quantity $\rightarrow$ Fan energy reduction
  – Total energy recovery $\rightarrow$ Equipment size reduction

• Increased pumping energy
  – Offset by reduced fan & chiller energy consumption
Sample DOAS pitfalls?

- Wrong supply air temperature
- Wrong controls for the enthalpy wheel
- Wrong controls for the heating coil
- Wrong controls for the cooling coil
- Wrong location for the heating coil
Questions or Comments??

Contact Information
Mr. John Vavrin PE
http://www.cecer.army.mil
US Army Corps of Engineers
Engineer Research and Development Center
ERDC –CERL (Energy Branch)
john.vavrin@erdc.usace.army.mil
(217) 373-5856
BACKUP SLIDES

DOAS System Psychometrics and Case Studies
Other regions?
Next slide
EW control for various OA conditions

- EW on when OA h > RA h
- EW off
- EW to modulate or duty cycle to hold SAT SP when OA < SAT SP
Example of an incorrect EW control logic

EW on

Cleaning cycle when off!
Frost protection when cold outside!

EW on

EW off

EW on

EW off

Humidity ratio (grains/lb)

.028
.024
.020
.016
.012
.008
.004

Humidity ratio (Lbv/Lba)

28
140
168
196
112
84
56
28
Reheat adds 2.8 tons of cooling load, plus the heating energy wasted in the 1,710 cfm OA sys.

Neutral temperature a huge energy waste!

> 3 ton cooling lost with wheel off

CC Control based upon maintaining a SA DPT, what happens if the OA is hot and dry?

EW off, huge control error when it could significantly reduce the CC load if operating.

CC load ~ 10 ton
EW Duty cycle defined

When EW off (40F) SAT = OAT

When EW on

SAT = OAT + (RAT - OAT) * EWeff (65.6F)

By adjusting the EW ON time (54.7% or 8.2 min) in 1 period (15 min) can get an avg. temperature equal to the desired SAT (54F). Duty cycle changes to 100% ON at 40F OAT to avoid tripping freeze stats. NOTE: HC must be off since when EW off, DAT < DATSP and the CC must be off when the EW on!
EW operation when OA below 54F

- No duty cycle SAT
- OPP duty cycle SAT
- Revised duty cycle SAT
- VFD EW SAT

Heating Coil begins modulation at -18F to maintain 54F SAT
Findings from Case Study @ Ft. Stewart

- Chilled water temperature rise in the distribution system between the CEP to barracks by 8 °F
  - 50°F CWS can’t dehumidify properly
  - CWS should be 45°F or less
- Many rooftop MUA units not operational
- Portable space dehumidifiers require daily emptying and add to room cooling load
- Condensation drips and negative room pressure lead to mold growth
- At least $1 Million annually for mold cleanup
- Potential man-hours lost due to building related illness (BRI)
Example of Dehumidification Project for Barracks
Scope, Costs and Savings for Ft. Stewart

- **Scope**
  - 31 modular barracks
  - 2460 rooms
  - 1,160,000 ft$^2$ conditioned space

- **Costs**
  - Estimate Total Cost Installed - $2.8 Million

- **Savings (Energy and Ancillary)**
  - $715K

- **Payback**
  - 3.9 Years
Flow Schematic: Typical Unit
Dehumidification with Energy Recovery

Exhaust air
Energy Recovery Heat Exchanger

Precool/Reheat Heat Exchanger

Dehumidification coil

Outside air

95/76F

Energy Recovery Heat Exchanger

83/72F

55/55F

68/68F

50/75F

Return air

52/73F

Tempered supply air
Other Findings: Supply Air Ducts in Barracks and Mold in Barracks Rooms

Not Changed (Clean Only) During Renovation
1. Mold and Mildew
2. Rust

Clean thoroughly with bleach-type cleaner and paint or replace all grills

1. Dehumidify Air
2. Ensure supply air units operating
3. Blower door tests to ensure room tightness
4. Install insulation on exposed cold piping
5. Clear condensate drain panels
6. Replace wall partitions
Pilot "Proof Of Concept"
DOAS/CRCP (Ceiling Radiant Cooling Panel) System

- Penn State University
- Space Conditions
  - 3200 ft² studio (43’ X 74’)
  - 14’ ceiling height with 8 rows of pendent illumination at the 9-ft plane
  - 40 students
  - Office equipments (desk lamps, personal computers)
Chiller Energy Reduction

• Chiller Size
  – VAV system: 14 ton
  – DOAS/CRCP pilot system: 10 ton

• Annual Chiller Energy Consumption
  – VAV system: 10.6 MWh/y (3.7 seasonal COP)
  – DOAS/CRCP pilot system: 7.9 MWh/y (4.5 seasonal COP)
Fan and Pumping Energy

- **Fan Energy Reduction**
  - Design SA quantity: DOAS – 1200 scfm
    VAV – 3220 scfm
  - Annual Fan energy: DOAS – 2.33 MWh/y
    VAV – 7.97 MWh/y

- **Pumping Energy**
  - But, DOAS/CRCP system consumes nearly twice as much pumping energy
  - Counterbalanced by the greatly reduced fan and chiller energy

37% of VAV
71% Reduced
Total Energy Consumption

42% Reduced!

11 MWh

19 MWh

Energy Consumption [MWh]

DOAS/CRCP

VAV

Fan

Pump

Chiller