ASHRAE GUIDELINE 36

RESEARCH

PAST, PRESENT AND FUTURE

Brandon Gill, PE
Agenda

- **ASHRAE Guideline 36**
  - What is it?
  - How should it be used?

- **Past Research**
  - RP-1455
  - RP-1353
  - RP-1515
  - RP-1547/1747

- **Present Research**
  - RP-1711
  - RP-1661

- **Future Research**
  - RP-1819
  - Work Statement 1865
Guideline 36

- Provides High Performance Sequences for HVAC Systems
- Largely based on RP-1455 Research
- Currently covers:
  - Thermal & Ventilation Zones
  - VAV Terminals
    - Cooling Only
    - Reheat
    - Parallel Fan Powered
    - Series Fan Powered
    - Dual Duct
  - Multiple Zone VAV Air Handlers (with relief and return fan options)
  - Dual Duct VAV Air Handlers
  - Single Zone VAV Air Handlers
- Published in 2018
What issues does GDL36 solve?

- We keep reinventing the wheel!
  - Same application, different sequences
- We don’t keep up with codes!
  - Title 24, ASHRAE 90.1, ASHRAE 62.1...
- We don’t keep up with research
  - ASHRAE RP-980, 1455, 1515, 1547, 1587, 1747, 1711, etc...
- Poor alarms & diagnostics
  - No alarms or too many alarms!
  - No advanced diagnostics
ASHRAE Guideline 36: Desired Implementation

- ASHRAE experts create and maintain advanced sequences
- Manufacturers pre-program, test, and debug all the sequences for their dealers
- Engineers just spec: “Use ASHRAE Guideline 36 sequences”
- Control contractors simply use the preprogrammed sequences
- Commissioning agents use the functional performance tests included with Guideline 36
  - Eventually even forgo FPTs once they are comfortable that manufacturers have programmed them correctly
Guideline 36 Benefits

- **Reduce Cost**
  - Writing sequences, programming, and commissioning

- **Reduce Errors**
  - Unambiguous sequences
  - Algorithms pretested and standardized

- **Ensure Code and Standard Compliance**
  - ASHRAE Standard 90.1 and Title 24 (Energy)
  - ASHRAE Standard 62.1 and Title 24 (Ventilation)
  - ASHRAE Standard 55 (Comfort)

- **Improve Energy Efficiency & IAQ**

- **Improve reliability and ease of operation**
  - Hierarchical alarms
  - Automatic Fault Detection and Diagnostics
RP-1455

• **Title**
  - Advanced Control Sequences for HVAC Systems – Phase I Air Distribution and Terminal Systems

• **Objective**
  - Develop best in class control sequences for airside HVAC equipment.

• **Method**
  - Conduct Background Research
  - Write Plain Language Sequences
  - Implement SOOs in Eikon (functional logic programming tool)
  - Conduct simulation testing in real controllers
    - Loaded in controllers
    - Simulated inputs

• **Completed in 2014**

• **Team**
  - Taylor Engineering, ALC, Paul DuPont, Facility Dynamics Engineering
Title
- Stability and Accuracy of VAV Box Control at Low Flows

Objectives
- Assess the factors impacting terminal unit airflow measurement accuracy at low airflows
- Quantify terminal unit airflow measurement accuracy at low airflows

Methods
- Lab tests of sensor, controller, and system
  - (4) VAV boxes from (3) manufacturers
  - (4) controllers from (4) manufacturers
- Limited field tests
  - (5) controllers

Completed 2012

Team
- Drexel University, Iowa Energy Center
Most tested sensors (flow crosses) achieved $\pm 5\%$ accuracy at 0.003” VP (8” VAV Box, 50 CFM/140 FPM)

Most tested controllers (VAV box transducer, A/D converter, signal processing) achieved $\pm 5\%$ accuracy at 0.003” VP (8” VAV Box, 50 CFM/140 FPM)

Most combine sensor + controller combinations $\pm 10\%$ accuracy at 0.003” VP (8” VAV Box, 50 CFM/140 FPM)

Critical implication
- Turn down on modern VAV box controllers easily allows dual maximum logic with low minimums
Why Not Just Look in the VAV Box Catalog for minimums?

Still too high

<table>
<thead>
<tr>
<th>UNIT SIZE</th>
<th>400 SERIES (PNEUMATIC) STANDARD CONTROLLER</th>
<th>7000 SERIES ANALOG ELECTRONIC</th>
<th>DDC CONSIGNMENT CONTROLS (See Notes Below)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MIN.</td>
<td>MAX.</td>
<td>MIN.</td>
</tr>
<tr>
<td>4</td>
<td>43</td>
<td>250</td>
<td>35</td>
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<tr>
<td>5</td>
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<td>1545</td>
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<td>340</td>
<td>2250</td>
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<tr>
<td>22</td>
<td>1730</td>
<td>8000</td>
<td>1450</td>
</tr>
</tbody>
</table>

NOTES:
1. Minimum and maximum airflow limits are dependent on the specific DDC controller supplied. Contact the control vendor to obtain the minimum and maximum differential pressure limits (inches W.G.) of the transducer utilized with the DDC controller.
2. Maximum CFM is limited to value shown in General Selection Data.

Good Advice! NEVER use Box manufacturer’s minimums!
Title:
- Thermal and Air Quality Acceptability in Buildings that Reduce Energy by Reducing Minimum Airflow from Overhead Diffusers

Objective
- Measure energy savings & validate simulations
- Identify comfort issues that may occur at low airflow

Method
- Field Study in 7 Buildings
  - Thermal comfort surveys and energy monitoring
- Lab Study
  - Air distribution for various diffuser types

Completed 2012

Team
- UC Berkeley CBE, Taylor Engineering, Price Industries
RP-1515 Measured flow fractions
RP-1515: Measured Loads

Loads are very low!
RP-1515: Total Electricity Usage

![Graph showing Total Electricity Usage vs. Outside Air Temperature]

- Dual Maximum Logic
- Conventional Logic

The graph illustrates the power consumption in kilowatts (kW) on the y-axis and the outside air temperature in degrees Fahrenheit (°F) on the x-axis. The data points are color-coded to differentiate between Dual Maximum Logic and Conventional Logic systems.
“How satisfied are you with the temperature in your workspace?”

- 800 Ferry Building
- Yahoo! Cool season
- Yahoo! Warm season

% dissatisfied of people

HIGH min flow rate
LOW min flow rate
RP-1747

- **Objective**
  - Develop and field test real world sequences implementing ASHRAE 62.1 DCV based on RP-1547 findings.
  - Test energy/ventilation performance with simulation

- **Addresses 62.1 challenges**
  - Complicated and poorly understood
  - Indeterminate – infinite solutions
  - When applied incorrectly to VAV systems yields high energy use
  - 90.1 requires DCV but 62.1 provides no clear path

- **Benefits**
  - Simplify ventilation design process
  - All Ventilation Rate Procedure logic is in BAS
  - Dynamic ventilation control based on occupancy & CO2 sensors

- **Completed 2017**

- **Team**
  - University of Alabama, Iowa Energy Center, Taylor Engineering
## RP-1747 DCV – VAV Schedule

### WITHOUT DCV

<table>
<thead>
<tr>
<th>TAG</th>
<th>AIRFLOW SETPOINTS</th>
</tr>
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<tr>
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<td>COOLING</td>
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<tr>
<td>VAV-1</td>
<td>385</td>
</tr>
<tr>
<td>VAV-2</td>
<td>770</td>
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<tr>
<td>VAV-3</td>
<td>295</td>
</tr>
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</table>

### WITH DCV

<table>
<thead>
<tr>
<th>TAG</th>
<th>AIRFLOW SETPOINTS</th>
<th>VENTILATION PARAMETERS</th>
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<tr>
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<td>HEATING</td>
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<tr>
<td>VAV-1</td>
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<td>265</td>
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<tr>
<td>VAV-2</td>
<td>770</td>
<td>340</td>
</tr>
<tr>
<td>VAV-3</td>
<td>295</td>
<td>95</td>
</tr>
</tbody>
</table>

*NOTE: NO MINIMUM COLUMN!*
RP-1747 DCV Required Sensors

OUTDOOR AIR

RETURN AIR

AFMS

SUPPLY AIR CO2

VFD

CO2

T

DENSELY OCCUPIED SPACES

T

CO2

OCC

ALL OTHER SPACES
 RP-1711

- **Research Objectives**
  - Develop “Best in Class” Sequences for Hydronic Systems
    - Hot, Chilled, and Condenser Water Distribution
    - Boilers
    - Chillers
    - Heat Rejection Systems
  - Program sequences into a BACnet controller
    - Use a graphical language
    - Thoroughly test programs to eliminate bugs
    - Verify viability of SOOs on common controls hardware
  - Submit Sequences for inclusion in ASHRAE Guideline 36

- **Ongoing, Q4 2019 Completion**

- **Research Team**
  - Taylor Engineering, Automated Logic, Facility Dynamics, P2S, Integral Group
Task I: Background Literature Search

- Canvased ASHRAE TCs for SOOs
  - 1.4 – Control Theory and Application
  - 6.1 – Hydronic and Steam Equipment and Systems
  - 9.1 – Large Building Air Conditioning Systems
- Mined Project Team Member Archives
- Reached out to Controls Contractors
Ultimately reviewed SOOs from…
Task 2: Plain Language SOO Development

- Analyze provided SOOs from Task 1
- Pick best parts from each
- Develop “Best in Class” SOOs for selected systems
- Report in structure consistent with GDL36 for future adoption

This style (bold) provides direction to the editor of these sequences so that they are properly implemented, e.g., identifying mutually exclusive options.

This style (italics) is intended to provide guidance or additional information about specific sequences.
Task 2: Covered Systems - CHW

- **Chilled Water Distribution**
  - Variable Primary
  - Constant Primary
  - Constant Primary – Variable Secondary
  - Variable Primary – Variable Secondary
  - Primary-Distributed Secondary

- **Chiller Configuration**
  - Parallel
  - Series

- **Chiller Types**
  - Positive displacement (screw/scroll)
  - Variable speed centrifugal
  - Constant speed centrifugal

- **Waterside Economizers**

- **Pump Configurations**
  - Dedicated
  - Headered

- **Heat Rejection**
  - Cooling Towers
  - Air Cooled
Task 2: Covered CHW Topics – Lots!

- Plant Run Conditions
- WSE Enable/Disable & Control
- Chiller Staging
- CHW Loop CHWST & DP Resets
- Primary CHWP Staging & Speed Control
  - Constant Flow
  - Single DP sensor
  - Multiple DP sensor
  - Cascading DP sensors
  - Secondary Flow Matching
- Secondary CHWP Staging & Speed Control
  - Single, Multiple, or Cascading DP
  - Coil Pumps
- Min Flow Bypass Control
- Condenser Water Pump Staging & Speed Control
- Head Pressure Control
- Cooling Tower Staging & Speed Control
- CWRT or CWST Reset
  - CWRT vs. Load Reset
  - CWST Self-tuning method
- Water Treatment CW Loop Override
- Tower MUW Control
- Chiller EPO
- Freeze Protection
  - Tower Bypass
  - Basin Heaters
- Performance Monitoring
- Alarming
- AFDD
Task 2: Covered Systems - HW

- **Hot Water Distribution**
  - Variable Primary
  - Constant Primary - Variable Secondary
  - Variable Primary – Variable Secondary

- **Boiler Plant Types**
  - Condensing
  - Non-Condensing
  - Hybrid

- **Primary Pump Configuration**
  - Dedicated
  - Headered
Task 2: Covered HW Topics – Lots!

- Plant Run Conditions
- Boiler Staging
- HWST Setpoint Reset
- Primary HWP Staging & Speed Control
  - Single DP sensor
  - Multiple DP sensor
  - Cascading DP sensors
  - Secondary Flow Matching
- Secondary HWP Staging & Speed Control
  - Single, Multiple, or Cascading DP
- Min Flow Bypass Control
- Performance Monitoring
- Alarming
- AFDD
Tasks 3 & 4 - Programming and Functional Testing
Title:
- Development of Near-Optimal Control Sequence for Chiller Plants with Water Side Economizer using Dynamic Models

Objective
- Evaluate state of the art water side economizer control sequences and develop a near-optimal sequence

Method
- Literature review
- Dynamic CHW plant model development
- Evaluation of waterside economizer sequencing strategies and optimal sequence development

Team
- University of Colorado, Boulder
Future Research

- **RP-1819 – CO2 Demand Controlled Ventilation in Multiple Zone VAV Systems with Multiple Recirculation Paths**
  - September 2018 – May 2020
  - Sponsored by TC4.3

- **WS-1865 – Optimizing Supply Air Temperature Control for Dedicated Outdoor Air Systems**
  - Just approved by ASHRAE TC 1.4
  - Cosponsored by TC 8.10

\[
E_{\nu} = (F_a + X_r \times F_h - Z_{nr} \times E_n \times F_r) / F_o \quad (A1.2.2-1)
\]

\[
F_a = E_p + (1 - E_r) \times E_r \quad (A1.2.2-2)
\]

\[
F_b = E_p \quad (A1.2.2-3)
\]

\[
F_c = (1 - (l - E_z) \times (1 - E_r) \times (1 - E_p) \quad (A1.2.2-4)
\]
Questions?

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