Carlos Martinez
Regional Sales Manager
Sigler
COMMERCIAL HVAC DIVISION
The Invention That Changed the World

On July 17, 1902, a young research engineer initiated a set of mechanical drawings designed to solve a production problem at the Sackett & Wilhelms Lithography and Printing Company in Brooklyn, New York. These were not the first drawings that 25-year-old Willis Carrier had prepared on behalf of his new employer, the Buffalo Forge Company. Since graduation from Cornell University a year earlier, this modest but gifted engineer had turned out designs for a heating plant, a lumber dry kiln and a coffee dryer, among others. Such products were the stock-in-trade of Buffalo Forge, a respected supplier of forges, fans and hot blast heaters.

This new design was different—so novel, in fact, that it would not only help to solve a problem that had long plagued printers, but would one day launch a company and create an entire industry essential to global productivity and personal comfort.

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University of Notre Dame

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Kansas State University

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Carrier VRF Division
Commercial Sales Manager
San Diego State University

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Schedule

Sessions will be from 4:30pm - 6:00pm every Wednesday
This includes instruction and work sessions
**No Class Thanksgiving Week

October 11th  Fans in Variable Air Volume Systems
October 18th  Water Piping and Pumps
October 25th  Water-Cooled Chillers
November 1st  Water Source Heat Pumps
November 8th  Controls Level 1: Fundamentals
November 15th Life Cycle Costing for HVAC Systems
November 29th Central Station Air Handlers
December 6th  Variable Refrigerant Flow (VRF)
Housekeeping Items

- Download presentations on Sigler Commercial Website siglercommercial.com > Library > TDP

- Communicate with your monitor any particular requests, questions or concerns.

- Enjoy and send feedback to:
  Carlos Martinez
  cmartinez@siglers.com
SECTION 1

FANS IN VARIABLE AIR VOLUME SYSTEMS

Introduction
Objectives

- Understand the impact of fan regulation
- Identify the types of fans used in VAV
- Discuss previous and current methods of fan volume control
- Utilize fan curves to demonstrate stable fan selections
- Compare fan volume control methods for energy savings
- Discuss fan static pressure control, tracking, and pressurization
Variable Air Volume (VAV) System

System Components:

1. VAV Box with Heating Coil
2. Zone Thermostat
3. Supply Diffuser
4. Return Grille
5. Duct Static Pressure Sensor
6. Supply Fan VFD
7. Air Handler
8. Supply Duct
SECTION 2

FANS IN VARIABLE AIR VOLUME SYSTEMS

Fan Impact
Possible Problems

- Excessive duct pressure
- Excessive duct leakage
- Excessive sound levels
- Erratic VAV terminal control
- Little or no energy savings
- Possible fan instability
SECTION 3

FANS IN VARIABLE AIR VOLUME SYSTEMS

Fan Types Used in VAV Systems
Centrifugal Fans

Air is discharged at a right angle to fan shaft

Scroll or Fan Housing
Plenum Fans

Single-width, single-inlet airfoil impeller design, for mounting inside a cabinet
Axial (In-Line) Fans

Air is discharged parallel to the fan shaft
SECTION 4

FANS IN VARIABLE AIR VOLUME SYSTEMS

Centrifugal Fans
Centrifugal Fan Construction and Terminology

- Double-Width Double-Inlet Wheel (DWDI)
- Backplate
- Hub Disk
- Hubplate
- Webplate
- Housing or Scroll
- Blast Area
- Outlet Discharge
- Inlet Cone
- Inlet Bell
- Inlet Flare
- Inlet Nozzle
- Venturi
- Inlet Collar
- Inlet Sleeve
- Inlet Band
- Bearing Support
- Blades
- Housing Side Sheet
- Outlet Area for Duct Connection
- Impeller Wheel
- Rim
- Shroud
- Wheel Ring
- Wheel Cone
- Inlet Rim
- Wheel Rim

Section 4 – Centrifugal Fans
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Forward-Curved Wheel Design

Characteristics:

- Most commonly used wheel in HVAC
- Light weight – low cost
- Operates at static pressures up to 5 in. wg max
- 24 to 64 blades
- Low rpm (800 to 1200 rpm)
Overloading type fan
- Horsepower will continue to rise with increased cfm and can overload the motor

Dip

Fan Horsepower

Typical Forward-Curved rpm Line
Airfoil Wheel Design

Characteristics:
- Blades are curved away from direction of rotation
- Static pressure up to 10 in. wg
- 8 to 18 blades
- High rpm (1500 to 3000 rpm)
Airfoil Centrifugal Fan Characteristics

- Non-overloading
  - Horsepower will peak and begin to drop off

![Graph showing Airfoil Centrifugal Fan Characteristics](image)

- Fan Horsepower
- Typical Airfoil rpm Line

Section 4 – Centrifugal Fans
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Plenum Fan Characteristics

Characteristics:

- Single-Width, Single-Inlet (SWSI)
- Operate at static pressures up to 10 in. wg
- Best application with limited space or when multiple duct discharge is desired
Plenum Fans With Cabinets

Inlet Cone

SWSI Plenum Fan Wheel

Fan Cabinet
SECTION 5

FANS IN VARIABLE AIR VOLUME SYSTEMS

Axial Fans
Axial (In-Line) Fans

- Use for high cfm applications
- In-line space savers with no cabinet
- Often used in industrial AC and ventilation applications
- Impeller similar to prop fans but blades are more aerodynamic
- Often used for return fans in AC applications
Axial Impeller Design

- Axial Wheel
  - Air discharged parallel to the shaft
  - Air is often redirected via straightening vanes making the fan a vane axial
SECTION 6

FANS IN VARIABLE
AIR VOLUME SYSTEMS

Fan Volume Control
Fan Volume Control Methods

- Controllable Pitch Axial Fan
- Modudrive®
- Discharge Damper
- System Bypass
- “Riding the Fan Curve”
  - No Volume Control
- Inlet Guide Vanes (IGV)
- Variable Frequency Drive (VFD)
- Eddy Current Coupling
Controllable Pitch Axial Fan

Section 6 – Fan Volume Control
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Modudrive®

- Airfoil or forward-curved fans
- Airflow modulation controlled by pulley adjustment
Dampers are typically mounted close to or right off the fan discharge.

Forward-Curved Fan

Discharge Damper

Remote Duct Static Pressure Sensor
Discharge Damper Characteristics

Legend
- rpm    - bhp
MSE - Max Static Eff.  SC - System Curve  RP - Rated Point = 15,000
rpm = 1010  bhp = 17.8  Class II Max. rpm = 1217
rpms (*100, L to R):  3  4  5  6  7  8  9  10  11  12  13
bhps (L to R):  3  5  7.5  10  15  20  25  30  40

Note: Shaded Area – Recommended Operating Range
MP – Minimum Point (VAV Applications) = 7,500 cfm

Section 6 – Fan Volume Control
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System Bypass

Variable Volume and Temperature System Application

Section 6 – Fan Volume Control
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System Bypass Fan Characteristics

Legend
- rpm
- bhp
MSE - Max Static Eff.
SC - System Curve
RP - Rated Point = 15,000

rpm = 1010  bhp = 17.8  Class II Max. rpm = 1217
rpms (*100, L to R): 3 4 5 6 7 8 9 10 11 12 13
bhps (L to R): 3 5 7.5 10 15 20 25 30 40

Note: Shaded Area – Recommended Operating Range

Section 6 – Fan Volume Control
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Reduced cfm resulting from part load

Design or rated point (RP)

\[ \Delta p \]

\[ \Delta \text{cfm} \]
Riding the Fan Curve Characteristics

“Wasted Static” is absorbed by terminals

Legend

- rpm - bhp  MSE - Max Static Eff.  SC - System Curve  RP - Rated Point = 15,000
rpm = 1010  bhp = 17.8  Class II Max. rpm = 1217
rpms (*100, L to R):  3  4  5  6  7  8  9  10  11  12  13
bhps (L to R):  3  5  7.5  10  15  20  25  30  40
Note: Shaded Area – Recommended Operating Range
MP – Minimum Point (VAV Applications) = 7,500 cfm
## Discharge Dampers and Riding the Fan Curve

<table>
<thead>
<tr>
<th>% Air flow</th>
<th>Airflow (cfm)</th>
<th>Fan Static Pressure*</th>
<th>System Static Pressure**</th>
<th>Fan Static Pressure minus System Static Pressure</th>
<th>bhp***</th>
<th>% bhp****</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>15,000</td>
<td>4.0</td>
<td>4.0</td>
<td>0</td>
<td>17.8</td>
<td>100%</td>
</tr>
<tr>
<td>90%</td>
<td>13,500</td>
<td>4.15</td>
<td>3.24</td>
<td>0.91</td>
<td>15.7</td>
<td>88%</td>
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<tr>
<td>80%</td>
<td>12,000</td>
<td>4.25</td>
<td>2.56</td>
<td>1.96</td>
<td>13.3</td>
<td>75%</td>
</tr>
<tr>
<td>70%</td>
<td>10,500</td>
<td>4.3</td>
<td>1.96</td>
<td>2.34</td>
<td>12.0</td>
<td>67%</td>
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<tr>
<td>60%</td>
<td>9,000</td>
<td>4.25</td>
<td>1.44</td>
<td>2.81</td>
<td>9.81</td>
<td>55%</td>
</tr>
<tr>
<td>50%</td>
<td>7,500</td>
<td>4.15</td>
<td>1.0</td>
<td>3.15</td>
<td>8.0</td>
<td>45%</td>
</tr>
</tbody>
</table>

* Fan static pressure is from the fan curve
** System static is determined using the second fan law
*** bhp is from the fan curve
**** % bhp is the percent as compared to the maximum bhp
### Discharge Dampers and Riding the Fan Curve

#### Section 6 – Fan Volume Control

<table>
<thead>
<tr>
<th>% Air flow</th>
<th>Airflow (cfm)</th>
<th>bhp</th>
<th>% bhp</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>15,000</td>
<td>17.8</td>
<td>100%</td>
</tr>
<tr>
<td>90%</td>
<td>13,500</td>
<td>15.7</td>
<td>88%</td>
</tr>
<tr>
<td>80%</td>
<td>12,000</td>
<td>13.3</td>
<td>75%</td>
</tr>
<tr>
<td>70%</td>
<td>10,500</td>
<td>12.0</td>
<td>67%</td>
</tr>
<tr>
<td>60%</td>
<td>9,000</td>
<td>9.81</td>
<td>55%</td>
</tr>
<tr>
<td>50%</td>
<td>7,500</td>
<td>8.0</td>
<td>45%</td>
</tr>
</tbody>
</table>
Section 6 – Fan Volume Control

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Inlet Guide Vanes Configuration

- Inlet Vanes
- Lube Line for Bearing
- Actuator Shaft (actuator not shown)
- Fan Bearing
Inlet Guide Vanes bhp Chart

Effect of Inlet Guide Vane Position on bhp

Airfoil Centrifugal Fan Horizontal Draw-Thru

Brake Horsepower (Percent of Max)

% Vane Opening

0% 25% 40% 50% 60% 70% 80% 90% 100%

cfm (x 1000)

Section 6 – Fan Volume Control
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Effect of Inlet Guide Vane on Static Pressure

Airfoil Centrifugal Fan Horizontal Draw-Thru

Static Pressure (Percent of Max) vs. cfm (x 1000)

% Vane Opening

SC

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Variable Frequency Drive

USER INTERFACE
Eddy Current Coupling

1. Eddy Current Coupling
2. Fan Motor
3. Special Cabinet Extension (as required to accommodate eddy current coupling)
Legend
- rpm - bhp  MSE - Max. Static Eff.  SC -System Curve  RP - Rated Point
rpm = 2210  bhp = 18.8  Class II Max. rpm = 2442
rpms (*100, L to R):  8  10  12  14  16  18  20  24  26
bhps (L to R):  3  5  7.5  10  15  20  25  30  40
Note: Shaded Area – Recommended Operating Range
MP – Minimum Point (VAV Applications) = 7500 cfm
## Fan Modulation Methods

<table>
<thead>
<tr>
<th>% Air flow</th>
<th>Airflow (cfm)</th>
<th>System Static Pressure*</th>
<th>Fan rpm VFD</th>
<th>bhp** VFD</th>
<th>% bhp*** VFD</th>
<th>% bhp Discharge Dampers and Riding the Fan Curve</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>15,000</td>
<td>4.0</td>
<td>2210</td>
<td>18.8</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>90%</td>
<td>13,500</td>
<td>3.525</td>
<td>2000</td>
<td>14.1</td>
<td>75%</td>
<td>88%</td>
</tr>
<tr>
<td>80%</td>
<td>12,000</td>
<td>3.1</td>
<td>1810</td>
<td>10.8</td>
<td>57%</td>
<td>75%</td>
</tr>
<tr>
<td>70%</td>
<td>10,500</td>
<td>2.725</td>
<td>1625</td>
<td>7.6</td>
<td>40%</td>
<td>67%</td>
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<tr>
<td>60%</td>
<td>9,000</td>
<td>2.4</td>
<td>1475</td>
<td>5.9</td>
<td>31%</td>
<td>55%</td>
</tr>
<tr>
<td>50%</td>
<td>7,500</td>
<td>2.125</td>
<td>1300</td>
<td>4.1</td>
<td>22%</td>
<td>45%</td>
</tr>
</tbody>
</table>

* System static is determined using the second fan law
** bhp is from the fan curve
*** % bhp is the percent as compared to the maximum bhp
Fan Modulation Methods

Section 6 – Fan Volume Control
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SECTION 7

FANS IN VARIABLE
AIR VOLUME SYSTEMS

Fan Stability
Typical VAV VFD Fan Characteristics

**Legend**

- rpm
- bhp

**MSE** - Max. Static Eff.
**SC** - System Curve
**RP** - Rated Point

- rpm = 2210
- bhp = 18.8
- Class II Max. rpm = 2442

- rpms (*100, L to R): 8 10 12 14 16 18 20 24 26
- bhps (L to R): 3 5 7.5 10 15 20 25 30 40

*Note: Shaded Area – Recommended Operating Range*

**MP** – Minimum Point (VAV Applications) = 7500 cfm

Full cfm = 15,000 (RP)
Min. cfm = 7500 (MP)

Section 7 – Fan Stability
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### Input Screen VAV Fan

**Unit Size:** 30

**Orientation:** HORIZONTAL

**Application:** DRAWTHRU

| Design Airflow | 15000.0 CFM |
| Altitude       | 0.0 ft      |
| Upstream External Static | 0.000 in wg |
| Downstream External Static | 2.71 in wg |
| Cooling Coil Static | 0.89 in wg |
| Heating Coil Static | 0.19 in wg |
| Other Losses   | 0.00 in wg  |
| Total Accessory Losses | 0.21 in wg |

**Total Static Losses** | 4.00 in wg |

**VAV Appl.** | Min CFM 7500 | Min S.P. 1.50 |

**Accessories**

1. Filter Mixing Box 2” Throw [0.07]
2. Mixing or Exhaust Box [0.14]

---

Section 7 – Fan Stability

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Manual Plot of System Curve

System Cooling Design: 15,000 cfm
System Static Pressure: 4 in. wg
Minimum Airflow: 7,500 cfm
Minimum Static Pressure Set Point: 1.5 in. wg

<table>
<thead>
<tr>
<th>% cfm</th>
<th>cfm</th>
<th>System and Fan Static Pressure (in. wg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>15,000</td>
<td>4.0</td>
</tr>
<tr>
<td>90</td>
<td>13,500</td>
<td>3.525</td>
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<td>80</td>
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<td>2.4</td>
</tr>
<tr>
<td>50</td>
<td>7,500</td>
<td>2.125</td>
</tr>
</tbody>
</table>
SECTION 8

FANS IN VARIABLE
AIR VOLUME SYSTEMS

VFD Energy Savings in VAV Systems
VFD Energy Savings

The three fan laws state:

- Airflow varies directly with the fan speed
- Static pressure varies as the square of the fan speed
- Horsepower varies as the cube of the fan speed
SECTION 9

FANS IN VARIABLE AIR VOLUME SYSTEMS

VAV Fan Control, Tracking, and Pressurization
VAV Fan Control

1/2 to 2/3 Duct Length
Constant airflow differential is maintained between supply and return fans.
The inside space pressure sensor, controls the exhaust fan to maintain slight positive pressure.
FANS IN VARIABLE AIR VOLUME SYSTEMS

Summary
Summary

- Explained the impact of fan regulation
- Identified the types of fans used in VAV
- Examined previous and current methods of fan volume control
- Utilized fan curves to demonstrate stable fan selections
- Compared fan volume control methods for energy savings
- Examined fan static pressure control, tracking, and pressurization
FANS IN VAV SYSTEMS

Work Session

1. True or False? The drive losses in an eddy current coupling are less than that in a VFD.
   ______________________

2. Which fan type is best for VAV applications and why?
   ___________________________________________________________
   ___________________________________________________________

3. True or False? VAV systems have the ability to track changes in building loads.
   ______________________

4. Which method of volume control is the most cost effective and efficient?
   ______________________

5. Discharge dampers are used with which type of fan?
Thank You

This completes the presentation.

TDP-613  Fans in Variable Air Volume Systems

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