



# Industrial Fan Systems

## Virtual INPLT Training & Assessment

Session 7



# Fan Virtual INPLT Facilitator



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# Acknowledgments

- William (Bill) Hunter, PE, Airclean Systems, Seattle WA
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- William (Bill) W.T. Corey, Corey Consultancy, Surrey England
- US Department of Energy , Advanced Manufacturing Office
- Oak Ridge National Laboratory
- United Nations Industrial Development Organization
- Many industrial clients – both in the US and internationally

# Safety and Housekeeping

- Safety Moment
  - Fans can be dangerous, and caution should be used around fan systems
  - Accidents can be life-threatening
- You are welcome to ask questions at any time during the webinar
- When you are not asking a question, please MUTE your mic and this will provide the best sound quality for all participants
- We will be recording all these webinars and by staying on-line and attending the meeting you are giving your consent to be recorded
  - A link to the recorded webinars will be provided, afterwards



# Fan system Virtual INPLT Agenda

- Week 1 – Industrial Fan Systems Fundamentals and Introduction to MEASUR
- Week 2 – Fan and system curves, Fan types
- Week 3 – Fan affinity laws, Fan system controls
- Week 4 – Creating a fan performance measurement plan & selecting measurement planes
- Week 5 – Pressure considerations, Sizing ducts and estimating losses, Optimization techniques
- Week 6 – Psychrometrics and air density for fan systems, System effect in fan systems
- **Week 7 – Fan system optimization strategies, Fan system evaluation with MEASUR**
- Week 8 – Industrial Fan System VINPLT Wrap-up Presentations



# Session 7 Learning Objectives

## **Class participants will:**

1. List 4 common fan system optimization (FSO) techniques
2. Discuss advantages and disadvantages of common FSO techniques
3. Develop a list of relevant FSO strategies;
4. Describe heat recovery opportunities and strategies;
5. Analyze field data to establish MEASUR inputs;
6. Use MEASUR to analyze the optimization potential of fan systems;

# Other fan application training opportunities

For more in-depth training, go to [AMCA.org](https://www.amca.org) for self-paced, fully interactive courses:

- AC motors in fan systems
- Fan power law
- Psychrometrics for fan systems
- Fan affinity laws – simplified
- Advanced fan affinity laws
- Fan system controls
- In-situ fan measurements (ISO 5802)
- Calculating flow rate
- Heat recovery in fan systems
- Fan energy index (FEI)

The AMCA website also has loads of pre-recorded webinars you can choose from

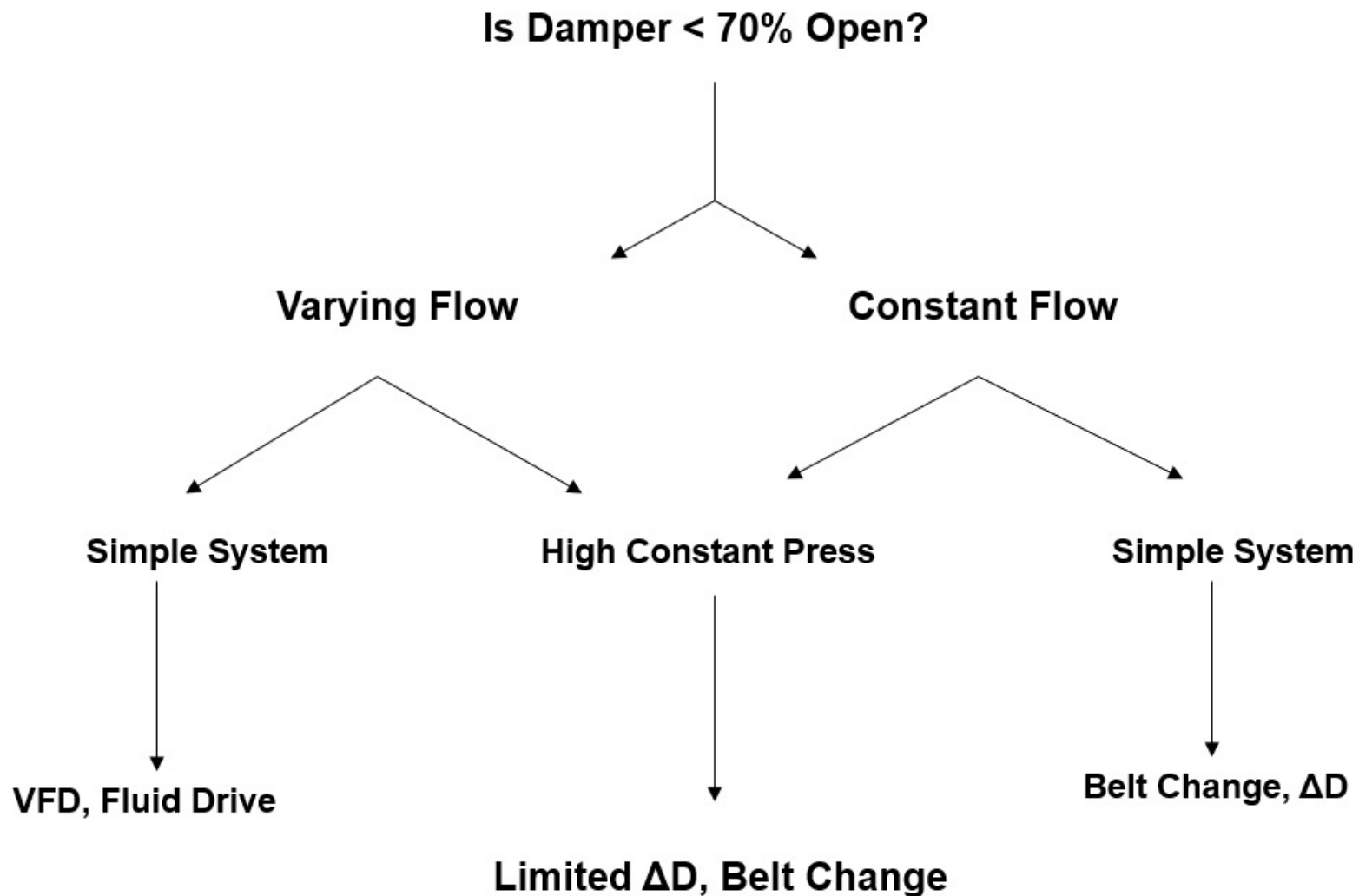
# Fan optimization techniques



# Fan System Optimization

- Overview
- Change Fan Speed (various methods)
  - Affinity Laws
- Modify Impeller (tip/detip)
- Replace Impeller or Fan
- Improve fan control

# Optimization Method Flow Chart



# Upgrade / Replace Impeller

- + Improve efficiency
- + Closely match flow and pressure to process requirements
- + Much lower cost than replacing the whole fan
- Specialty item that not all fan vendors can easily supply
- Best done in conjunction with a field performance test

Best suited for over 200 hp and where new impeller design would be more efficient, or have other advantages such as reduced impeller wear

# Tip or De-tip the impeller

Usually used on fans larger than 200 hp

- + Can trim or boost flow to match process requirements
- + Inexpensive compared to replacing the impeller or the fan
- Should be done in coordination with fan supplier
- Before tipping the fan, need to check for adequate space in the housing
- Impeller will need to be re-balanced

# Replace Fan

- + Can be sized to meet the load
- \$\$ New base
- \$\$ Modification
- \$\$ Ductwork may require modification
- Downtime

Best suited for aging or deteriorating fans.

# New belt drive ratio

- + Inexpensive
- + Reversible
- + Ratio can be changed later if needed
- Preparation required
- Performance tests needed

Best suited when there is an existing belt drive, the load is constant\* and the fan is oversized with a damper used as a control mechanism

\* If the load is variable, then you may be able to change the belt ratio and utilize a much smaller VFD



# Convert to belt drive

Best suited:

- when the current fan is oversized and has a direct drive motor operating at 100 hp or less.
- If the load is constant and or if a VFD is too expensive or otherwise unsuitable for the system
  - + Fan speed can be changed
  - + Less costly than a VFD, but still an expensive proposition
  - + Best for steady loads
  - Fan bearings may not withstand the lateral force or belt thrust
  - A new base may be required for the motor or fan
  - Belts require additional maintenance

# Variable Frequency Drive (VFD)

Best suited for systems with variable flow rates

- + Fan output can be exactly matched to process needs
- + No mechanical changes needed
- + Often very cost effective
- + Can easily replace throttle control
- + Can be used to over speed the fan motor
- Costly & slightly less reliable for medium voltage motors
- Can cause problems with electrical systems
- Additional space is needed in the electrical room
- Air conditioning is needed in the electrical room

# Variable Frequency Drive (VFD) (cont.)

- Very sensitive to electrical power quality
- Best to use a specialized cable
- Purchase requires time and expertise
- The VFD vendor needs to know:
  - starting torque of the fan,
  - age and condition of the fan motor, and
  - distance between the fan and electrical room

**DO NOT USE A VFD** with a system already at full capacity, under a steady load, or when there are only minor flow variations

# Optimization Techniques for Existing Systems (cont.)

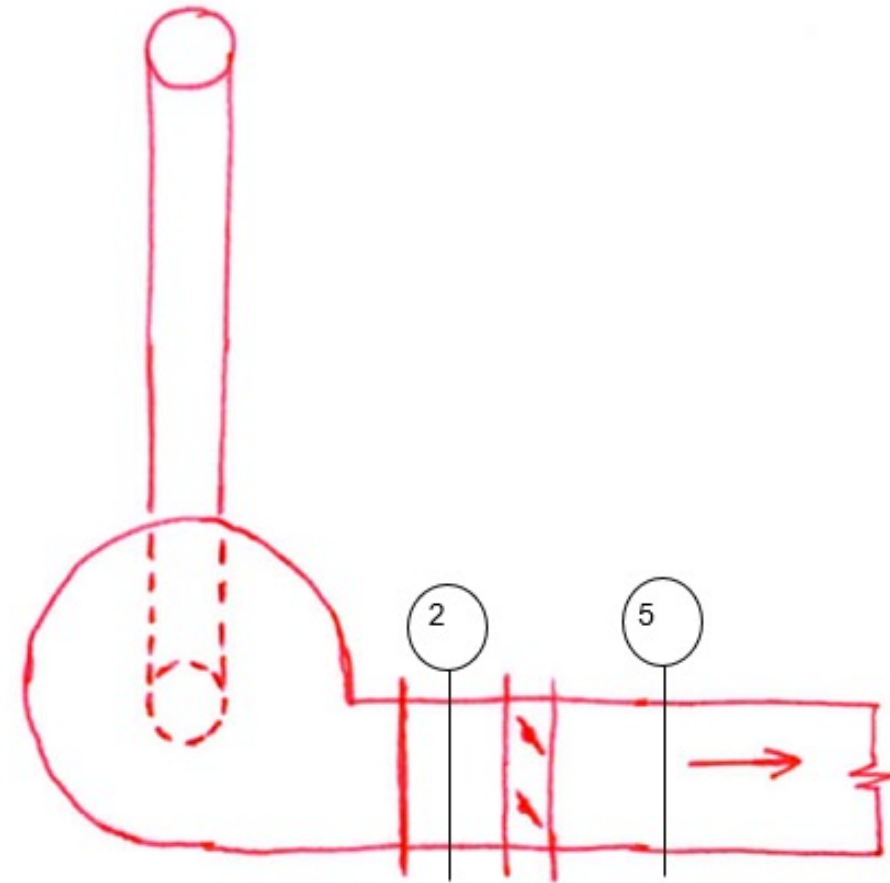
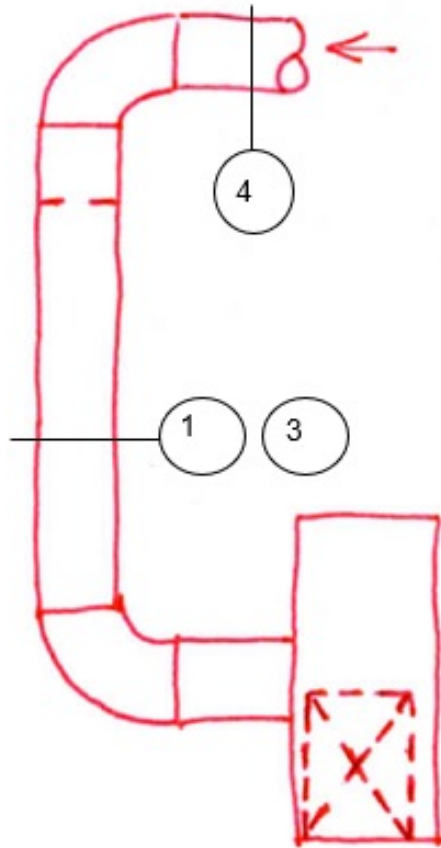
## 6. Fluid Couplings

- + Can be used for larger fan motors greater than 500 kW where a belt drive can't be used
- \$\$ Can be expensive and inefficient
- Most fluid couplings in service were installed years ago, advances in VFD technology have made fluid couplings almost obsolete

Best suited to vary the speed on larger motors

# Fan system evaluation with MEASUR

# Measurement plan for combustion air blower





# Data Analysis of Combustion Air Blower

<b>Fan System Field Data Collection Sheet</b>						initial <u>RW</u> test # <u>1</u>	1 of 3
<u>File 1215</u>							
FAN SYSTEM <u>SURFACE COMBUSTION AIR BLOWER</u>							
Customer <u>OSB</u>							
Tester <u>RW/FP</u>		Test Start Time <u>9:00 2/19/96</u>		Test End Time <u>10:10</u>			
PROCESS CONDITIONS <u>Steady 59% Dryer load - Typical</u>							
Hours operation <u>8,000</u>							
MOTOR NAME PLATE DATA							
Manufacturer <u>SIEMENS</u>				Model/Frame <u>H1/EFF 1445T</u>			
HP <u>125</u>	rpm <u>1785</u>	Volts <u>460</u>	FLA <u>145</u>	PF <u>89</u>	EFF <u>95.4</u>		

# Data Analysis of Combustion Air Blower

FAN NAME PLATE DATA	
Manufacturer <i>CHAMPION FAN</i>	Model <i>385 HPA</i>
Impeller <i>Flat radial</i>	serial <i>266 V92-1</i>
rpm <i>2473</i>	Impeller diameter
Notes (age and general condition) <i>Approx 15 years old. good condition</i>	
SYSTEM EFFECT FACTORS Estimate as per Fans and Systems, AMCA Publication 201.	
SEF1 <i>N/A</i>	
SEF2	

AMBIENT CONDITIONS		DB	WB	P <sub>Barometric</sub>
Does P <sub>Barometric</sub> require altitude correction?	<i>NO</i>	pre test		in. Hg
		<i>65 °F</i>	<i>50 °F</i>	<i>29.45</i>
Altitude	<i>/</i>	post test		in. Hg
		<i>67 °F</i>	<i>50 °F</i>	<i>29.45</i>

# Data Analysis of Combustion Air Blower

<b>Fan System Field Data Collection Sheet</b>	initial <u>RW</u>	test # <u>1</u>	2 of 3
	<u>file 1215</u>		

FAN AND MOTOR		A	B	C
Motor rpm <u>1787</u>	Volts	<u>460</u>	<u>458</u>	<u>462</u>
Fan rpm <u>2473</u>	Amps	<u>104</u>	<u>104.4</u>	<u>104.2</u>
Drive type <u>BELT</u>	or kW			
TEST PLANES (show on sketch)	DB	WB	Area	P (local)
Plane #1 Fan Inlet <u>SAME AS #3</u> <u>BELOW ORIFICE</u>	<sup>°F</sup> <u>127.5</u>	<sup>°F</sup> <u>71.7</u>	ft <sup>2</sup> or <u>2.761</u>	in. H <sub>2</sub> O <u>-6.850</u>
Plane #2 Fan Outlet	<sup>°F</sup> <u>155</u>	<sup>°F</sup>	ft <sup>2</sup> or l x w <u>1.611</u>	in. H <sub>2</sub> O <u>35.60</u>
Plane #3 Traverse <u>SAME AS #1</u>	<sup>°F</sup> <u>127.5</u>	<sup>°F</sup> <u>71.7</u>	ft <sup>2</sup> or l x w <u>2.761</u>	in. H <sub>2</sub> O <u>-6.850</u>
Plane #4 Upstream	<sup>°F</sup> <u>127.5</u>	<sup>°F</sup> <u>71.7</u>	ft <sup>2</sup> or l x w <u>2.761</u>	in. H <sub>2</sub> O <u>-2.95</u>
Plane #5 Downstream	<sup>°F</sup> <u>155</u>	<sup>°F</sup>	ft <sup>2</sup> or l x w <u>2.297</u>	in. H <sub>2</sub> O <u>10.00</u>
Plane #6	<sup>°F</sup>	<sup>°F</sup>	ft <sup>2</sup> or l x w	in. H <sub>2</sub> O
	<sup>°F</sup>	<sup>°F</sup>	ft <sup>2</sup> or l x w	in. H <sub>2</sub> O

# Data Analysis of Combustion Air Blower

TRAVERSE DATA velocity pressure in. w.g.										
	Points									
Ports	1	2	3	4	5	6	7	8	9	10
1	0.20	1.20	2.50	0.90	0.20	-0.05	-0.04	0.35		
2	0.30	1.50	1.90	0.40	0.10	-0.01	0.03	0.65		
3	0.10	1.90	2.20	0.40	0.20	0.20	0.50	0.70		
4										
5										
6										
7										
8										
9										
10										

# Fan System Field Data Analysis Worksheet

**Directions:** There are four steps in analyzing fan system field data:

1. Calculate or establish the density at the measurement planes.
2. Estimate the average air velocity and calculate flow rate at the traverse plane.
3. Translate the flow rate to other measurement planes and calculate velocity pressures at the other measurement planes.
4. Once the velocity pressures are known :

# Fan System Field Data Analysis Worksheet

	$P_v$	$P_s$	$P_t$	$\rho$	$V$	$A$	$Q$
Plane 1							
Plane 2							
Plane 3							
Plane 4							
Plane 5							
Plane 6							



# Fan System Field Data Analysis Worksheet

- Estimate the average air velocity and calculate flow rate at the traverse plane:
- Calculate the root mean square of velocity pressure

$$P_{v3} = \left( \frac{\sum_{i=1}^n \sqrt{P_{v3i}}}{n} \right)^2$$

# Fan System Field Data Analysis Worksheet

- A table like this can be used to sum up the square of the velocity pressure readings

Ports	1	2	3	4	5	6	7	8	9	10
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
Total										
grand total										

# Fan System Field Data Analysis Worksheet

- After finding the velocity pressure at plane 3, calculate the velocity at plane 3 and the flow rate.

$$V_3 = 1096 \sqrt{\frac{P_{v3}}{\rho_3}}$$

$$Q_3 = V_3 A_3$$

# Fan System Field Data Analysis Worksheet

- Translate the flow rate to other measurement planes and calculate total pressure at other measurement planes:
  - Calculate the flow rate at the other planes.

$$Q_x = Q_3 \left( \frac{\rho_3}{\rho_x} \right)$$

# Fan System Field Data Analysis Worksheet

- Step 3 continued
  - Calculate the velocity at the other planes

$$V_x = \frac{Q_x}{A_x}$$

# Fan System Field Data Analysis Worksheet

- Step 3 continued
  - Calculate the velocity pressure and the total pressure at other planes

$$P_{vx} = \frac{V_x^2 \times \rho_x}{1096}$$

$$P_{tx} = P_{vx} + P_{sx}$$



# Fan System Field Data Analysis Worksheet

- Calculate the MEASUR inputs:
  - Calculate  $P_s$  the fan static pressure

$$P_s = P_{s2} - P_{s1} - P_{v1}$$

- Calculate the pressure required by the process
- Calculate the average amps and volts

# Combustion Air Blower Performance: MEASUR Input

1. Complete the Data Collection Worksheet
2. Input flow traverse, pressure, and power findings into MEASUR
3. Use MEASUR to analyze the fan efficiency
4. Analyze optimization improvements

# MEASUR Demo

- Switch to live demo of MEASUR software

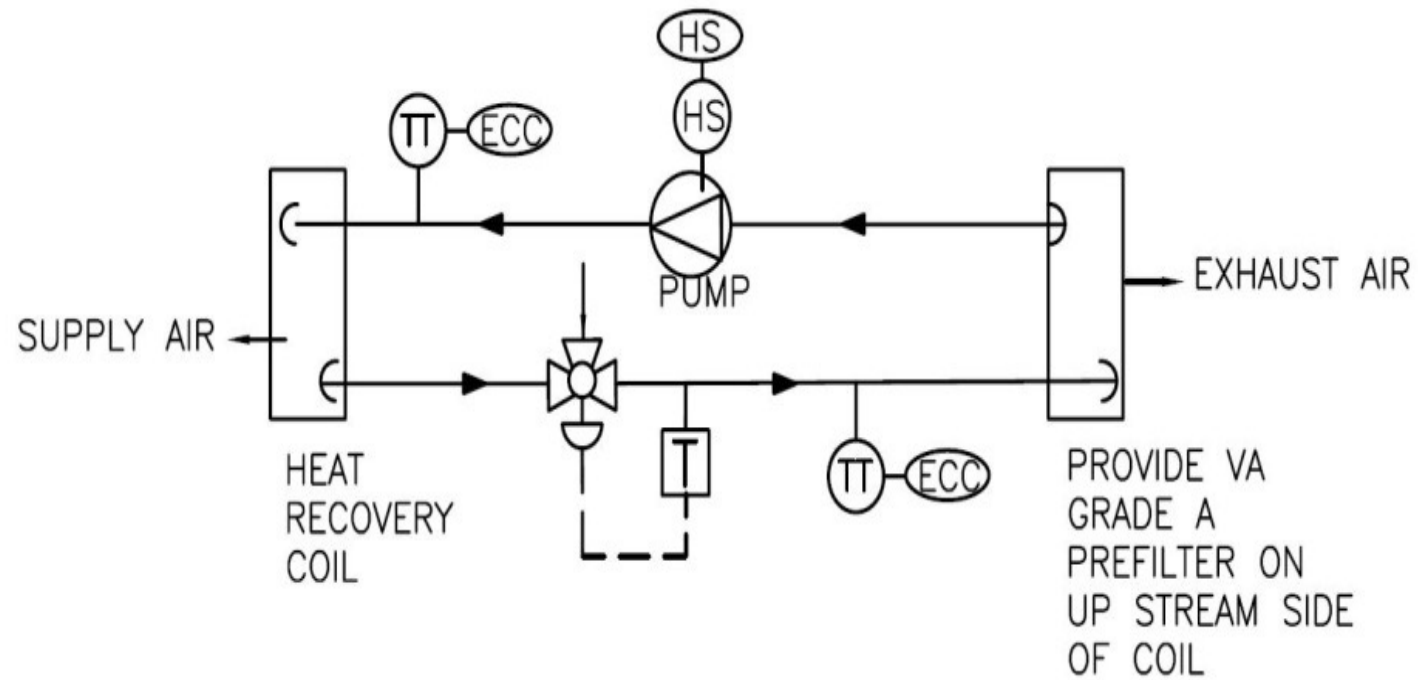
# Heat recovery in fan systems

# Heat Recovery Strategies

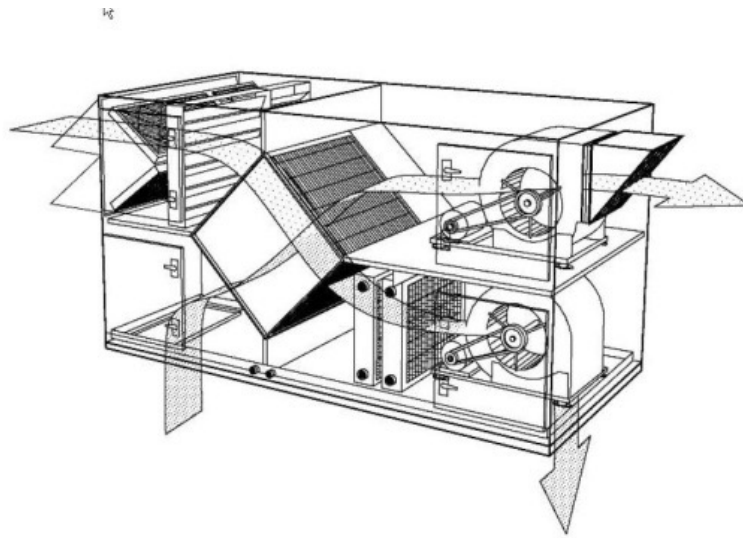
In many fan systems, the thermal energy being carried by the fluid far exceeds the electrical energy driving the fan motor. In all too many cases the energy is dumped to atmosphere or discarded.

- Glycol Run-Around System
- Air-to-Air
  - Flat plate
  - Heat Pipes
  - Heat Wheel
- Air to Water
- Water to Air

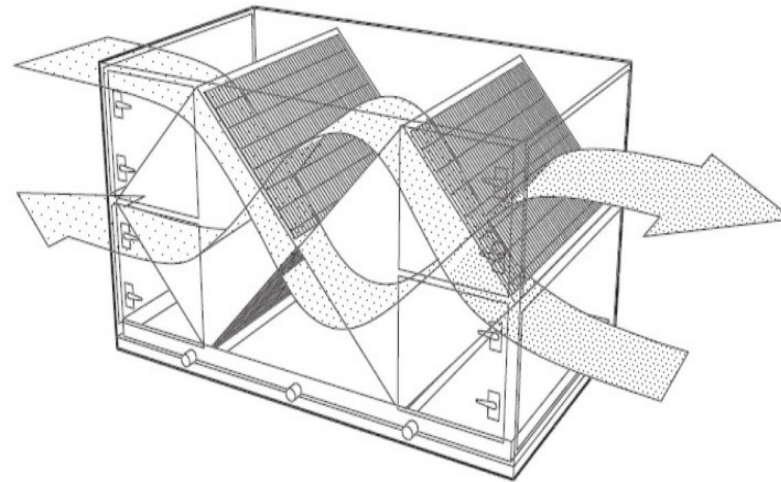
# Glycol Run-Around System



# Air-to-Air – Flat plate



Make-up Air Unit



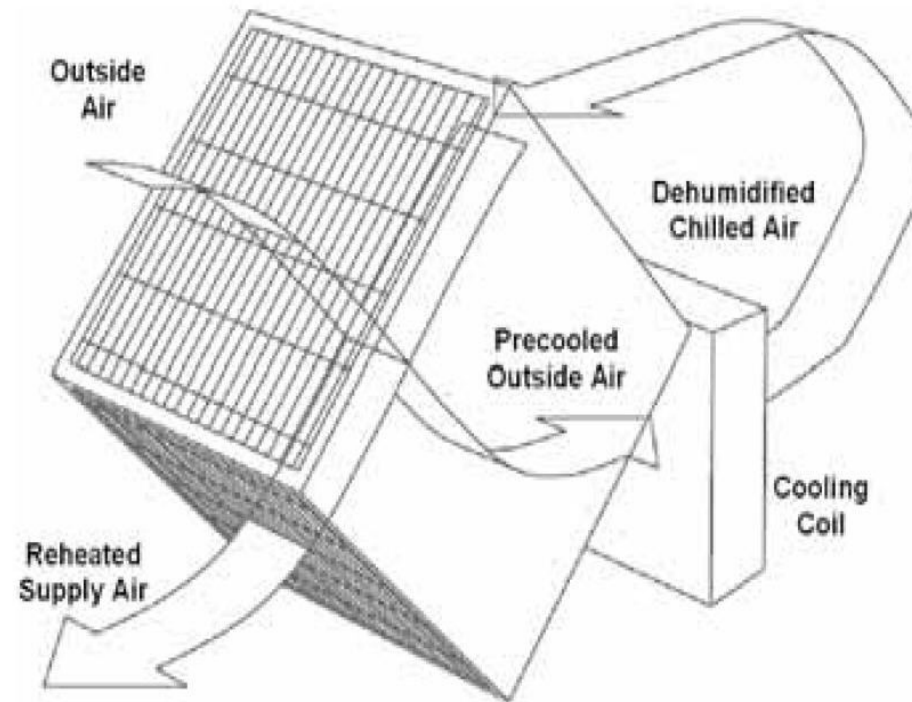
Double Pass Arrangement

# Industrial Grade Air-to-Air 2 Pass HX with Steel Construction

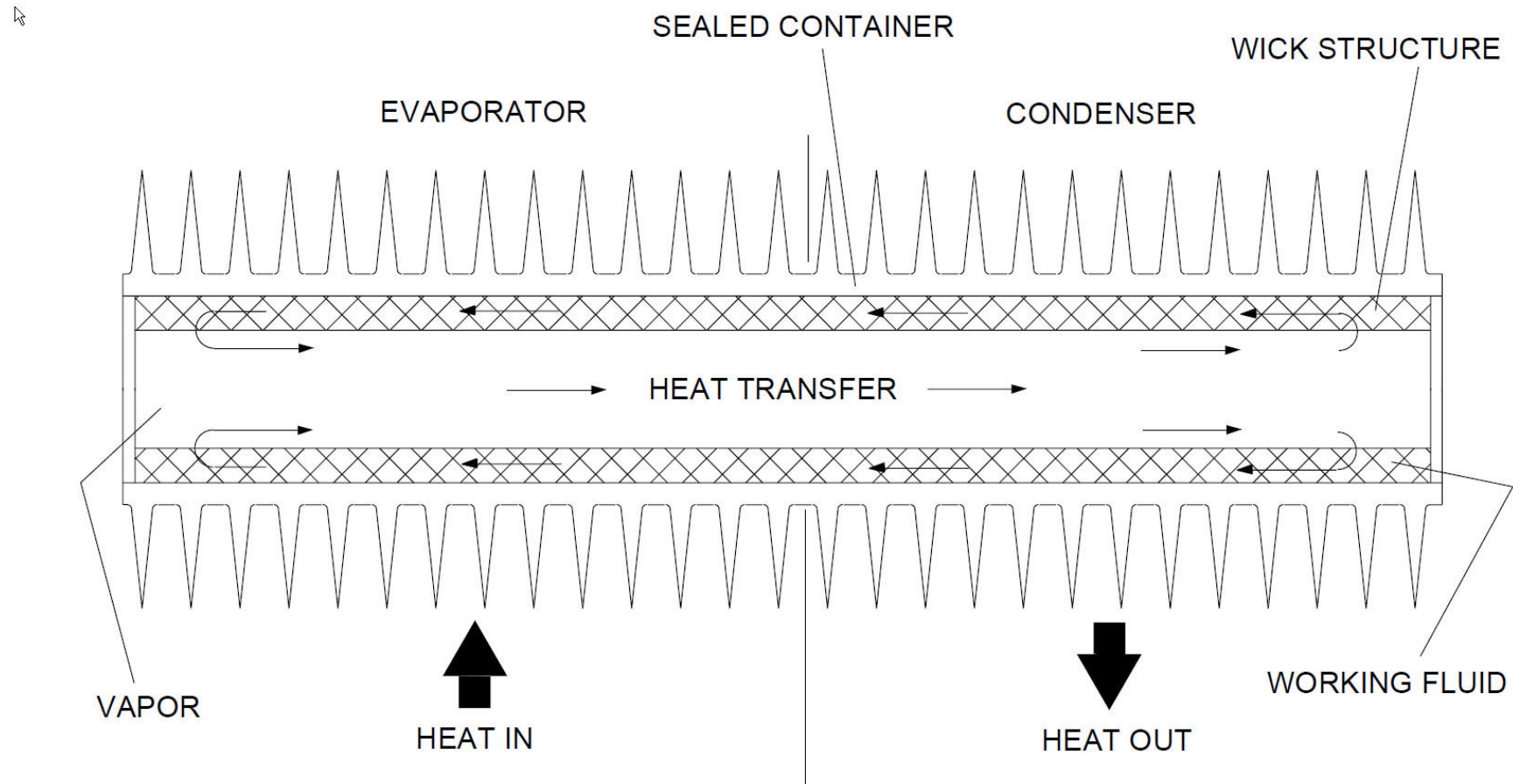




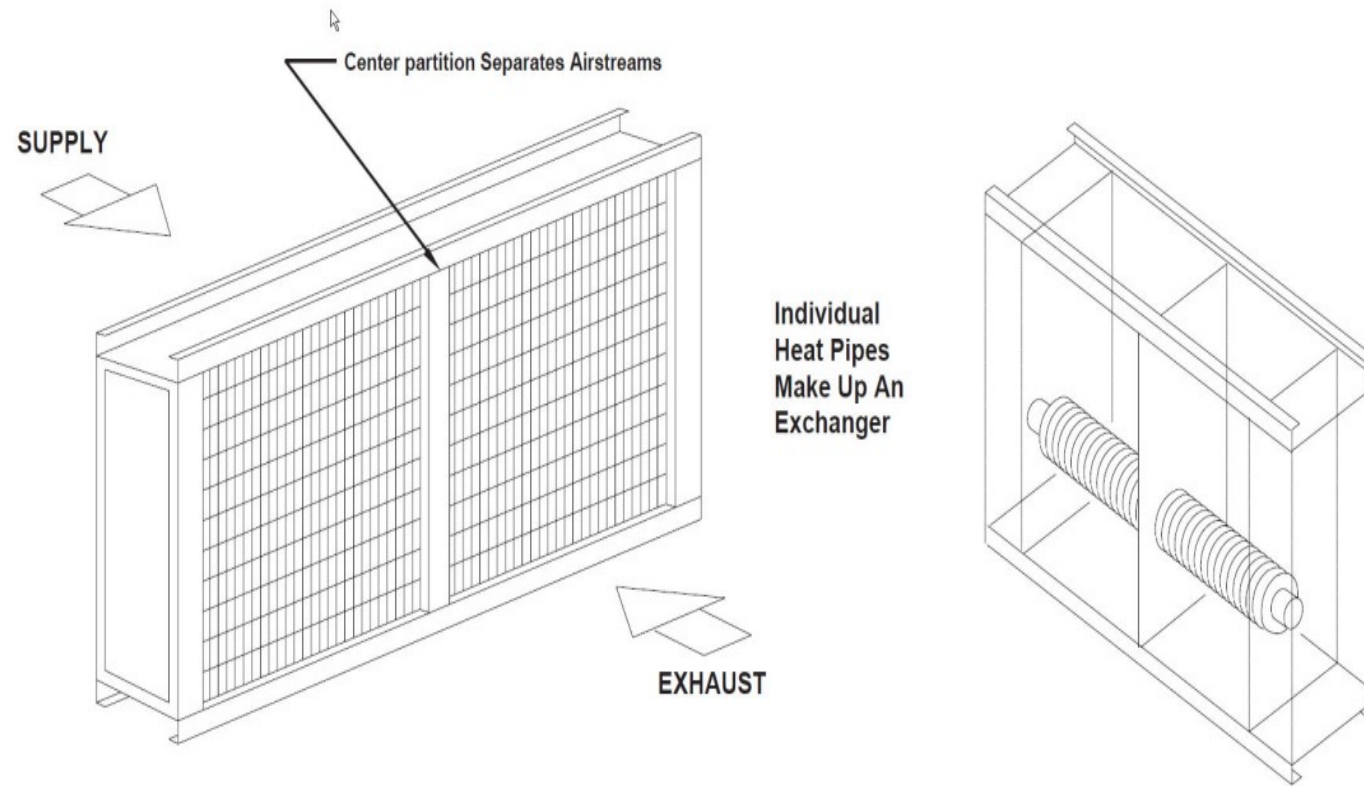
# Using Air-to-Air HX to Super-Charge a Dehumidifier



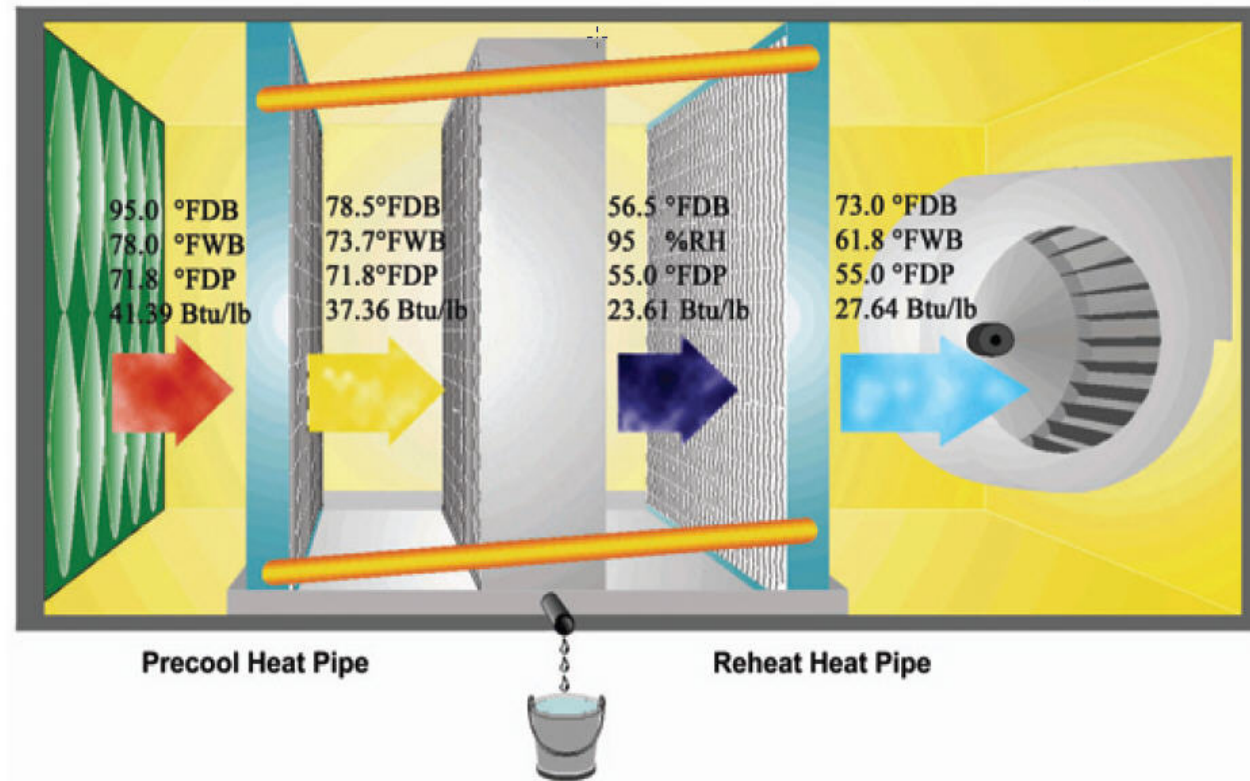
# Heat Pipe Inner Workings



# Heat Pipes in Side-by-Side Heat Recovery Arrangement

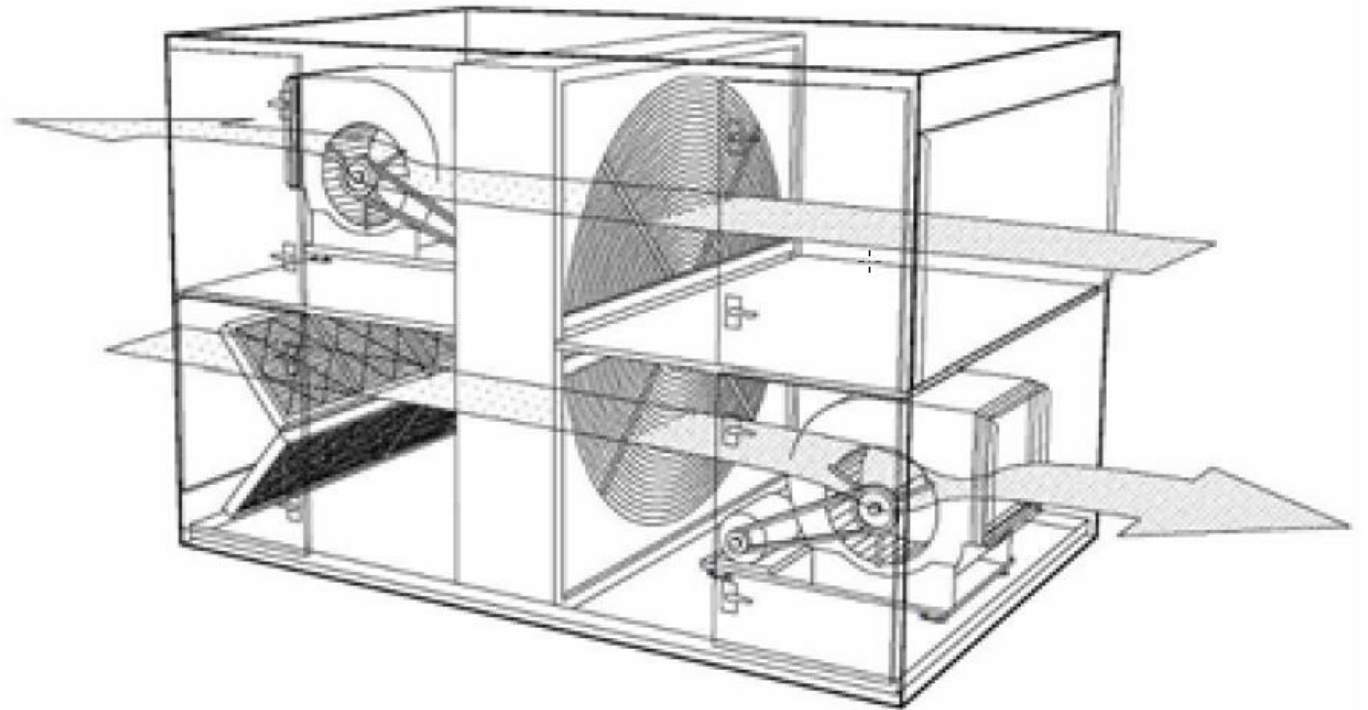


# Heat Pipes used to supercharge dehumidification



# Heat Wheel Make-Up Air Heat Recovery Unit

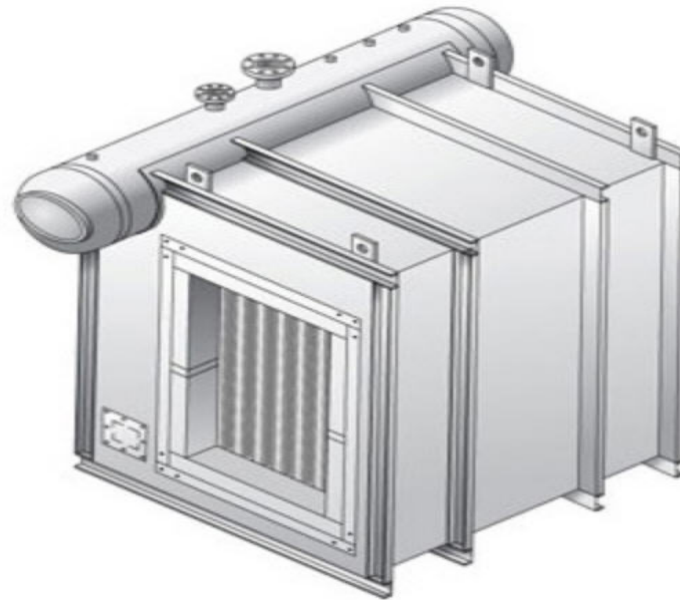
- Wheel can be made of porous material to recover latent heat
- Wheels made of
  - Fibrous paperboard
  - Silica gel
- Large silica gel wheels can be very heavy



# Air to Water



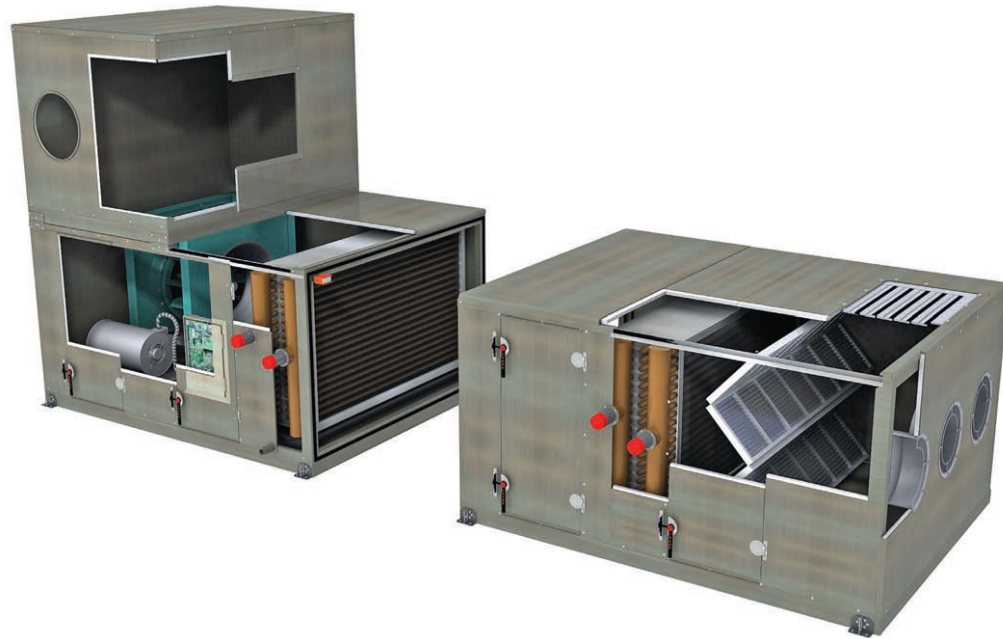
Flue Gas Heat  
Recovery Tube Bundle



Heat Recovery  
Steam Generator



# Water to Air



- Easiest heat recovery id when there is hot water already available from a process, such as water-cooled ductwork, furnace jacket water, etc.

# Key Points / Action Items



1. *Based on the situation analyze suitable optimization opportunities, i.e. new fan, VFD, belt ration change, etc.*
2. *Look at thermal opportunities for heat recovery*
3. *Once gaps are identified, delve into more detail using the other US DOE's tools and resources*
4. *Quantify, prioritize, implement and continue to monitor*





# Homework #7

- Use the MEASUR tool to analyze the data for one of your fans, or the cement kiln ID fan data that was provided a few weeks ago.
- Develop optimization opportunities as appropriate for the system
  - Reduce wasteful pressure loss
  - Reduce unnecessary flow (i.e. leaks)
  - Use a more efficient control method for the fan
  - Use a more efficient configuration of the fan, i.e. new belts and pulleys, tip/de-tip, replacement fan, replacement impeller

**Thank You all for attending today's webinar.**

**See you all on next Thursday –**

**If you have specific questions, please stay online and  
we will try and answer them.**

**Alternately, you can email questions to me at  
[ron@productiveenergy.com](mailto:ron@productiveenergy.com)**