Better Plants
U.S. DEPARTMENT OF ENERGY

Industrial Fan Systems
Virtual INPLT Training & Assessment

Session 7

U.S. DEPARTMENT OF ENERGY

Fan Virtual INPLT Facilitator

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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 <u>MUTE</u> 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 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)

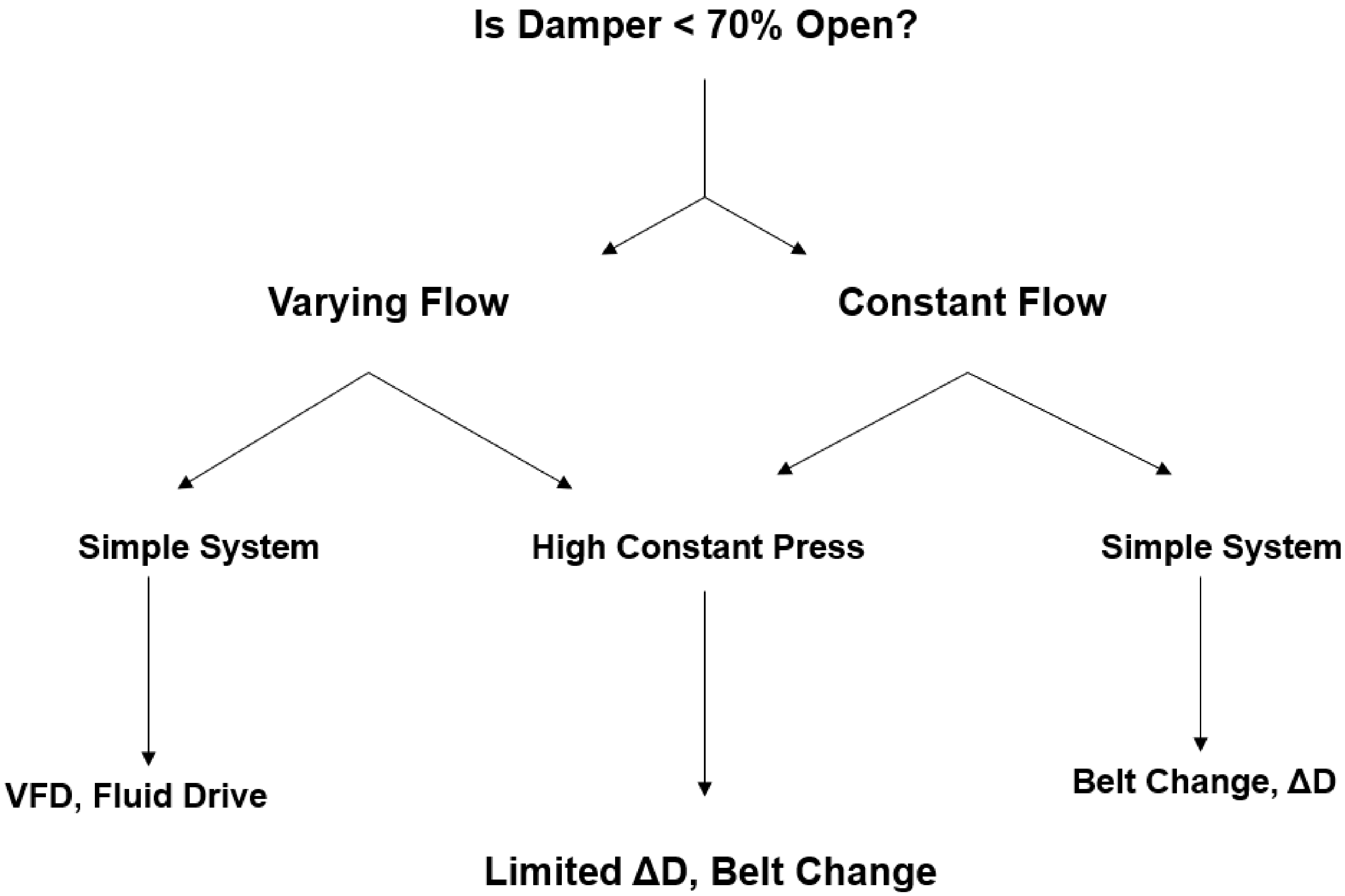
The AMCA website also has loads of pre-recorded webinars you can choose from

Fan optimization techniquess

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

Optimization Techniques for Existing Systems (cont.)

7. Eddy Current drives / Magnetic drives
   - + Can be used for larger fan motors greater than 500 kW where a belt drive can't be used
   - + Much less expensive than a medium voltage VFD
   - - Lower part-load efficiency

Best suited to vary the speed on larger motors

Fan system evaluation with MEASUR

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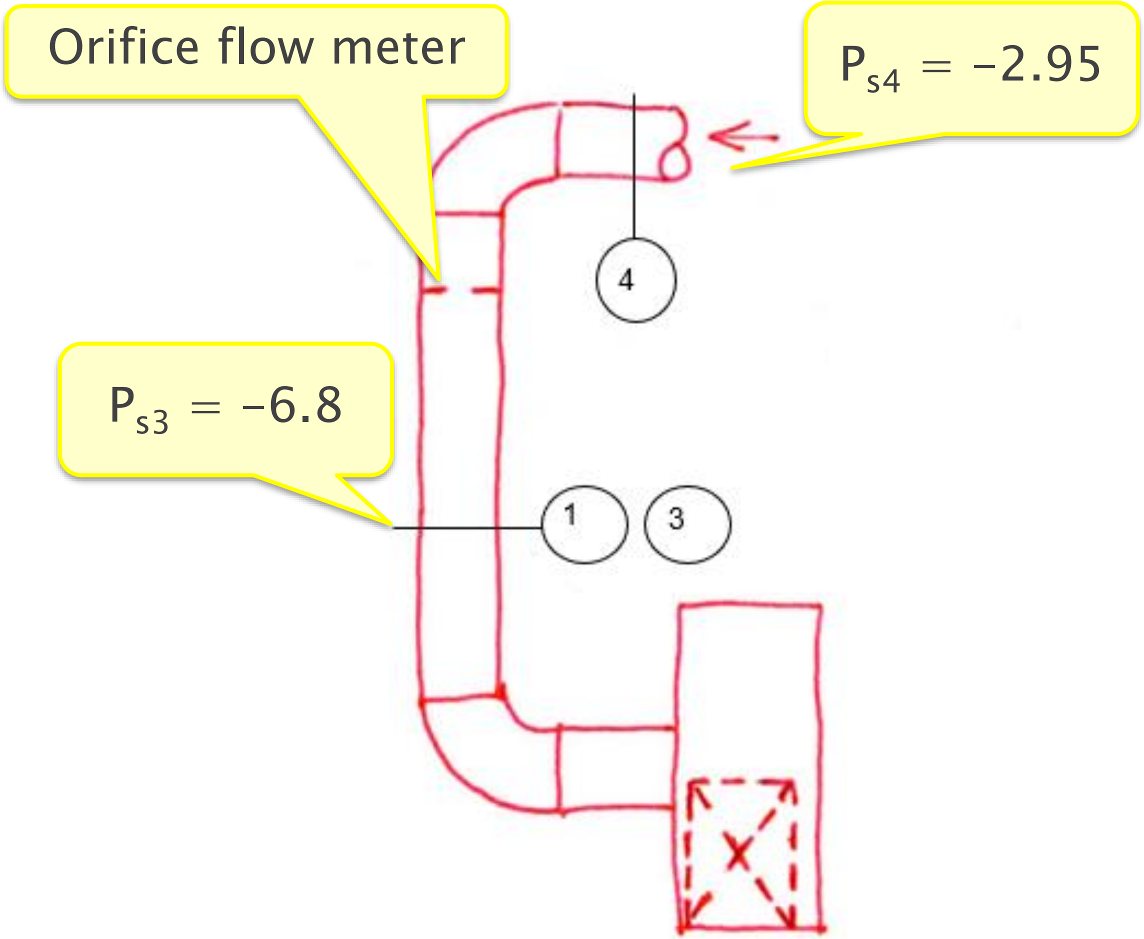
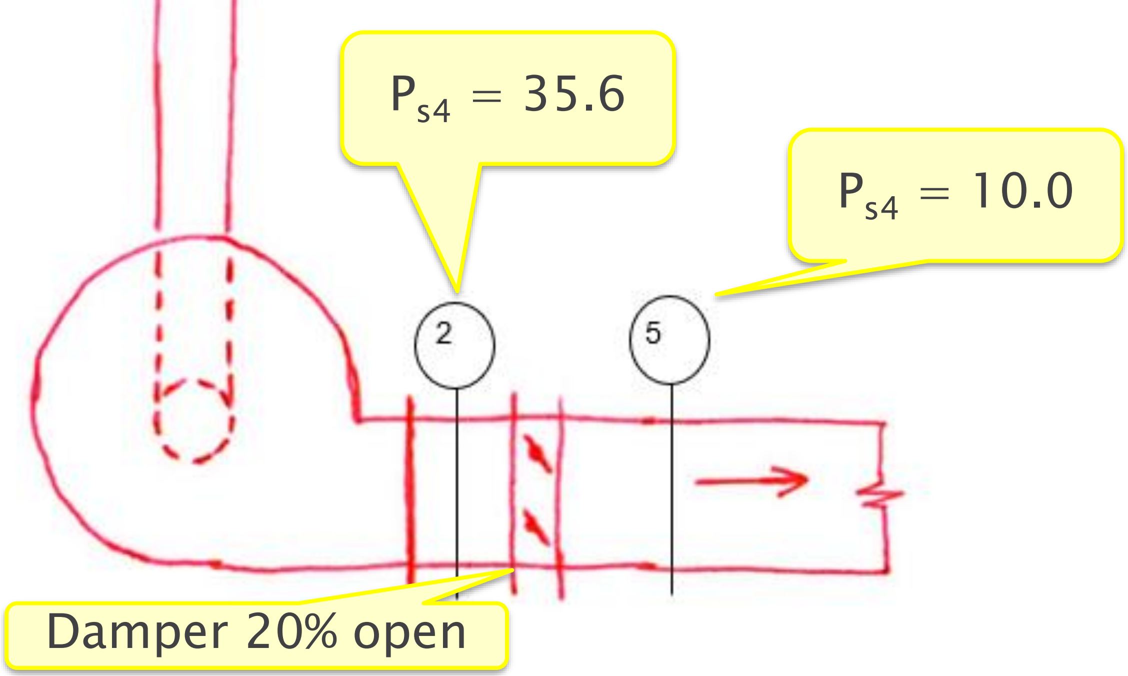
Measurement results for combustion air blower



Q1 = 8080 cfm
Amps = 104.2
Volts = 460
Hours = 8000
Electric rate = $0.05



Data Analysis of Combustion Air Blower

Fan System Field Data Collection Sheet initial RW test # 1 1 of 3
File 1215

FAN SYSTEM
SURFACE COMBUSTION AIR BLOWER

Customer
OSB

Tester	Test Start Time	Test End Time
RW/FP	9:00 2/19/96	10:10

PROCESS CONDITIONS
Steady 59% Dryer load - Typical

Hours operation 8,000

MOTOR NAME PLATE DATA

Manufacturer	Model/Frame
SIEMENS	HI/EFF / 445T

HP	rpm	Volts	FLA	PF	EFF
125	1785	460	145	89	95.4

Data Analysis of Combustion Air Blower

FAN NAME PLATE DATA	
Manufacturer CHAMPION FAN	Model 385 HPR
Impeller Flat radial	serial 266 V92-1
rpm 2473	Impeller diameter
Notes (age and general condition) Approx 15 years old. good condition	

SYSTEM EFFECT FACTORS Estimate as per Fans and Systems, AMCA Publication 201.
SEF1 N/A
SEF2

AMBIENT CONDITIONS		DB	WB	$P_{Barometric}$
Does $P_{Barometric}$ require altitude correction? NO	pre test	65 °F	50 °F	29.45 in. Hg
Altitude —	post test	67 °F	50 °F	29.45 in. Hg

Data Analysis of Combustion Air Blower

Fan System Field Data Collection Sheet initial RW test # 1 2 of 3
file 1215

FAN AND MOTOR			A	B	C
Motor rpm	1787	Volts	460	458	462
Fan rpm	2473	Amps	104	104.4	104.2
Drive type	BELT	or kW			

TEST PLANES (show on sketch)	DB	WB	Area	P (local)
Plane #1 Fan Inlet BELOW ORIFICE SAME AS #3	°F 127.5	°F 71.7	ft^2 or 2.761	in. H_2O -6.850
Plane #2 Fan Outlet	°F 155	°F	ft^2 or l x w 1.611	in. H_2O 35.60
Plane #3 Traverse SAME AS #1	°F 127.5	°F 71.7	ft^2 or l x w 2.761	in. H_2O -6.850
Plane #4 Upstream	°F 127.5	°F 71.7	ft^2 or l x w 2.761	in. H_2O -2.95
Plane #5 Downstream	°F 155	°F	ft^2 or l x w 2.297	in. H_2O 10.00
Plane #6	°F	°F	ft^2 or l x w	in. H_2O
	°F	°F	ft^2 or l x w	in. H_2O

MEASUR Plane #
Plane 1 & 4
Plane 2 & 5
Plane 3

Average
Volts = 460
Amps = 104.2

Data Analysis of Combustion Air Blower

Traverse Hole Table (Extend #s of Traverse Holes and Insertion Points as Needed)						
Row/Col	Traverse Hole 1	Traverse Hole 2	Traverse Hole 3			
Insertion Point 1	0.2	0.3	0.1			
Insertion Point 2	1.2	1.5	1.9			
Insertion Point 3	1.6	1.9	1.65			
Insertion Point 4	0.7	0.4	0.4			
Insertion Point 5	0.25	0.1	0.25			
Insertion Point 6	-0.05	-0.01	0.25			
Insertion Point 7	-0.04	0.33	0.5			
Insertion Point 8	0.35	0.65	0.7			

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	ρ	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 Worksheete

- 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 Ps 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

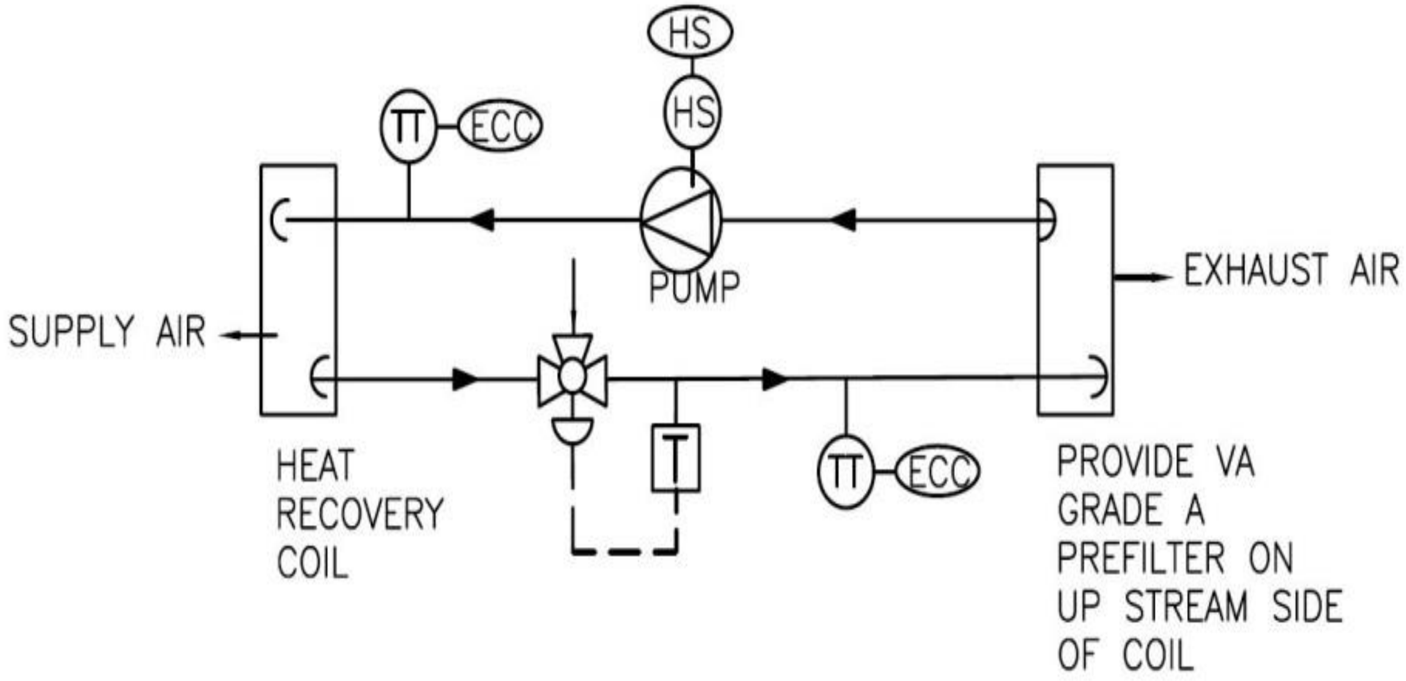
Heat recovery in fan systems

Heat Recovery Strategies

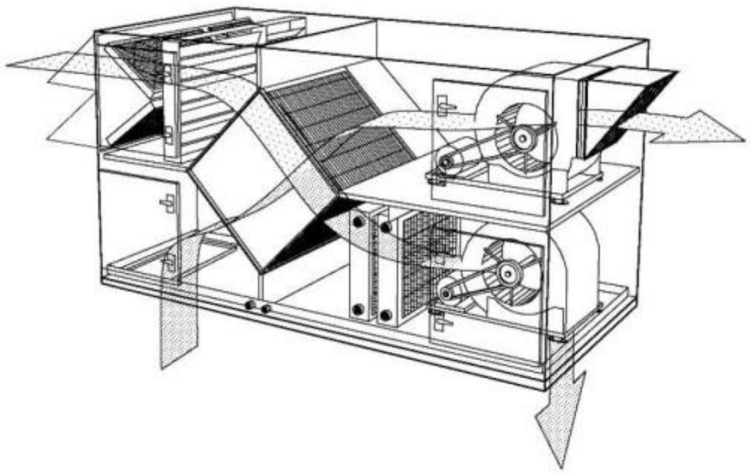
In many fan systems, the thermal energy being carried by the fluid far exceeds the electrical energy driving the fan motor. In all too many cases the energy is dumped to atmosphere or discarded.

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

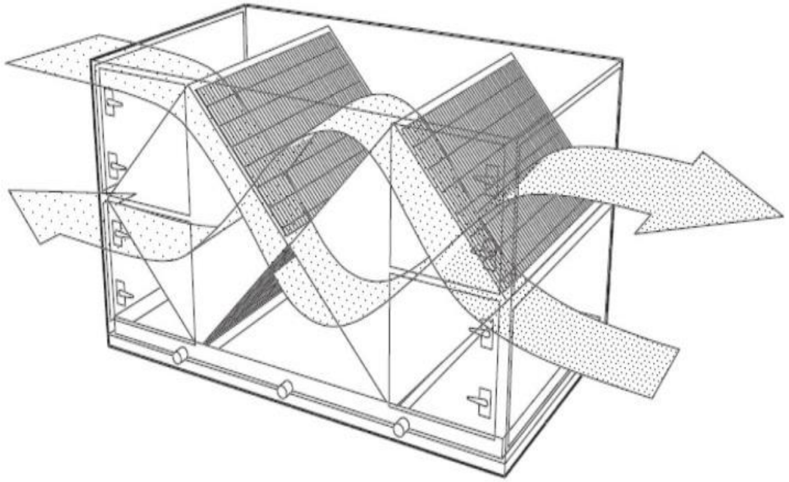
Glycol Run- Around System



Air-to-Air – Flat plate



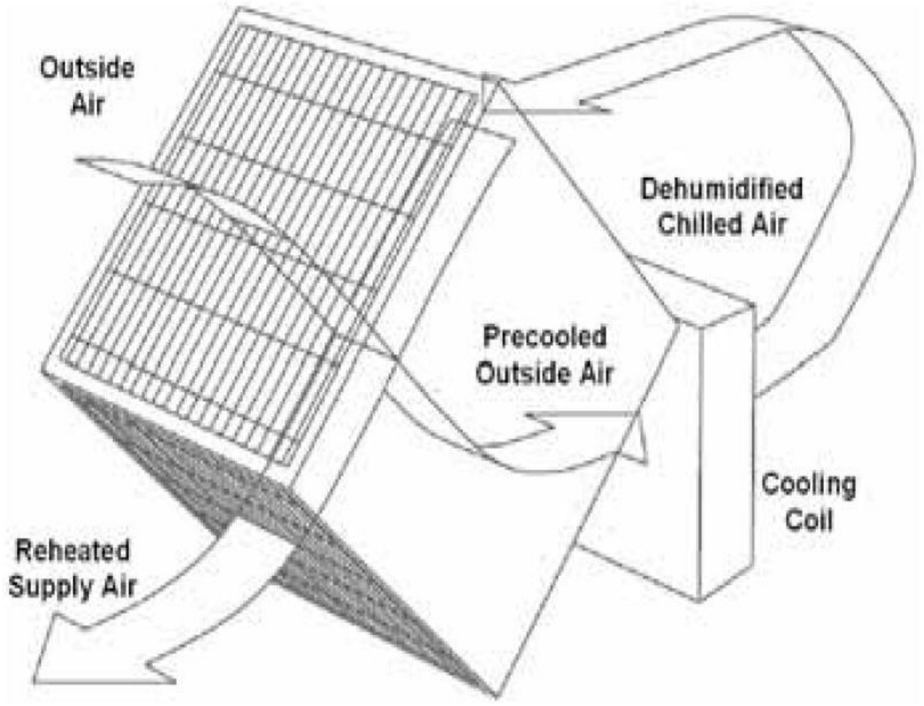
Make-up Air Unit



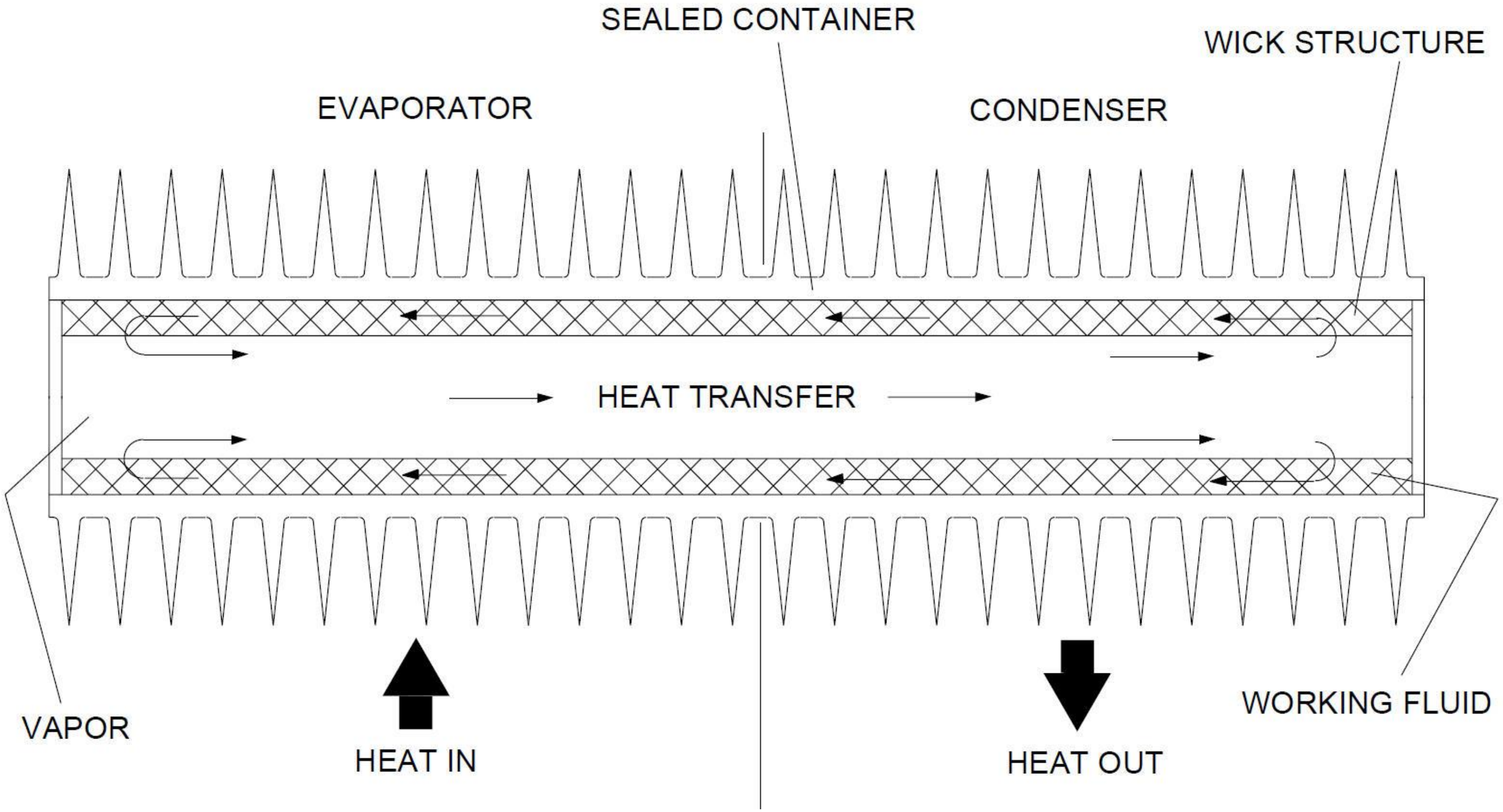
Double Pass Arrangement

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

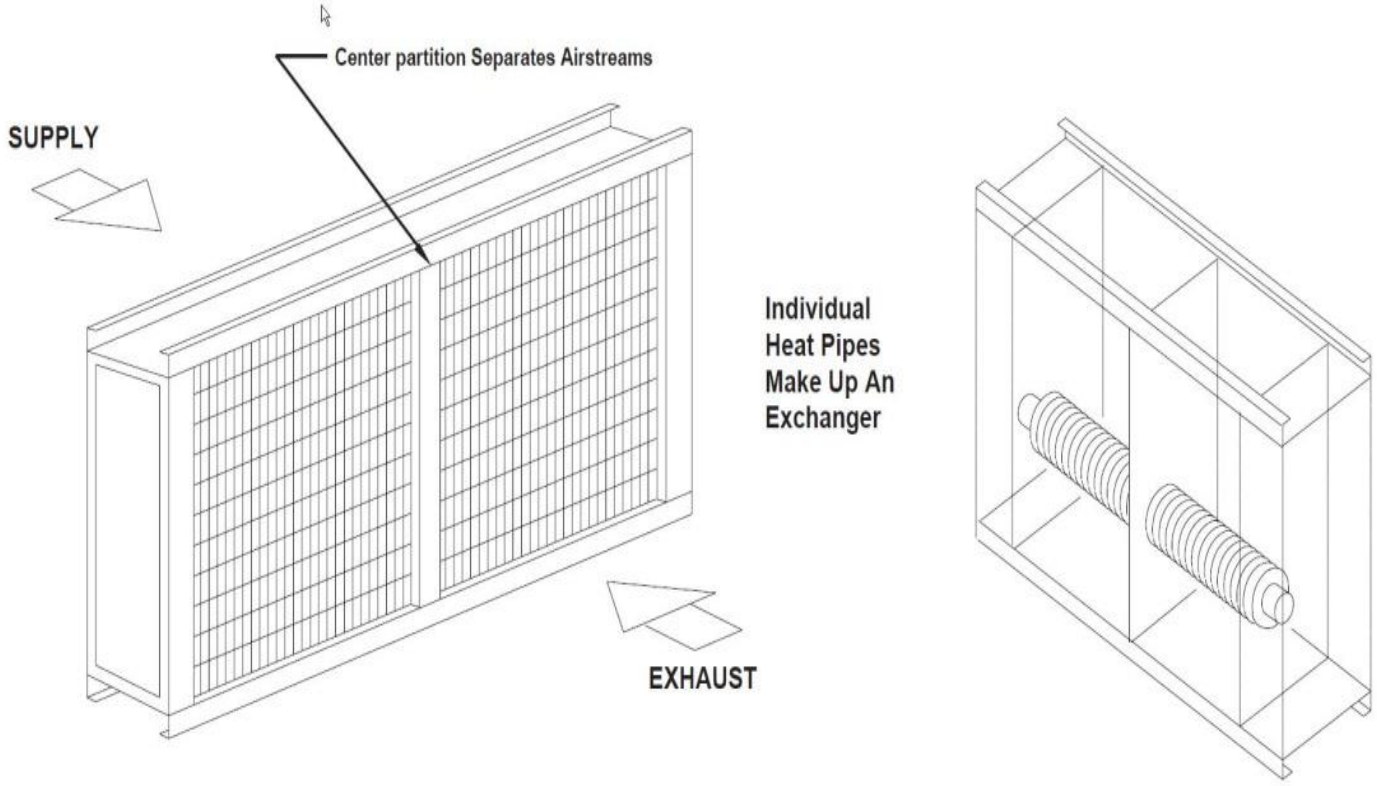
Using Air-to-Air HX to Super-Charge a Dehumidifier



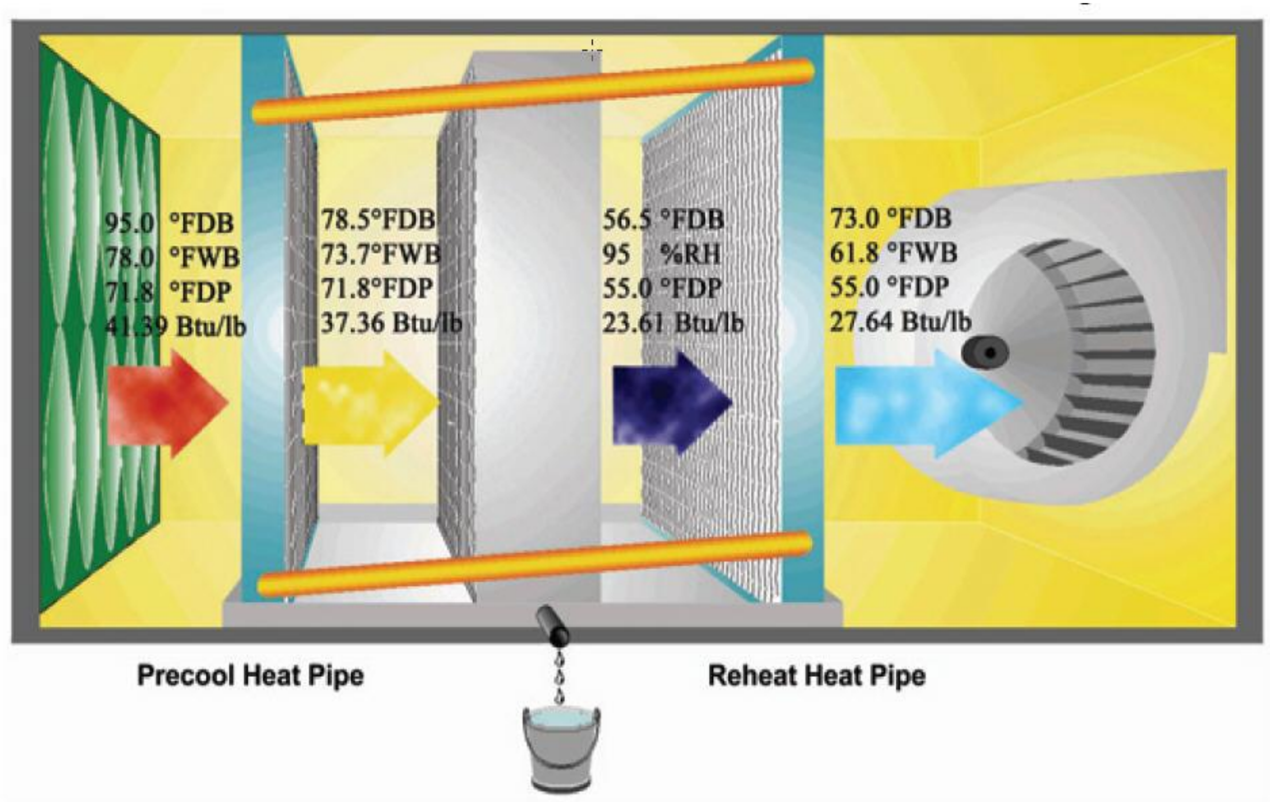
Heat Pipe Inner Workings



Heat Pipes in Side-by-Side Heat Recovery Arrangement

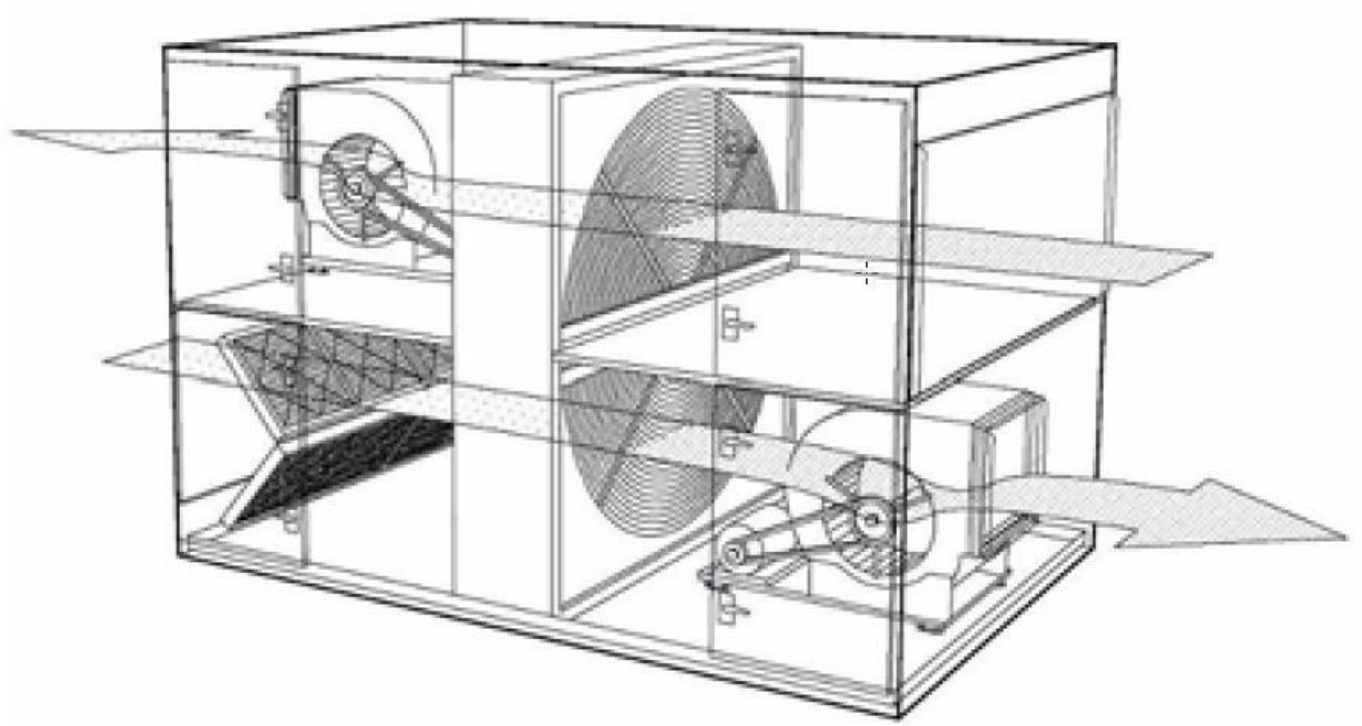


Heat Pipes used to supercharge dehumidification



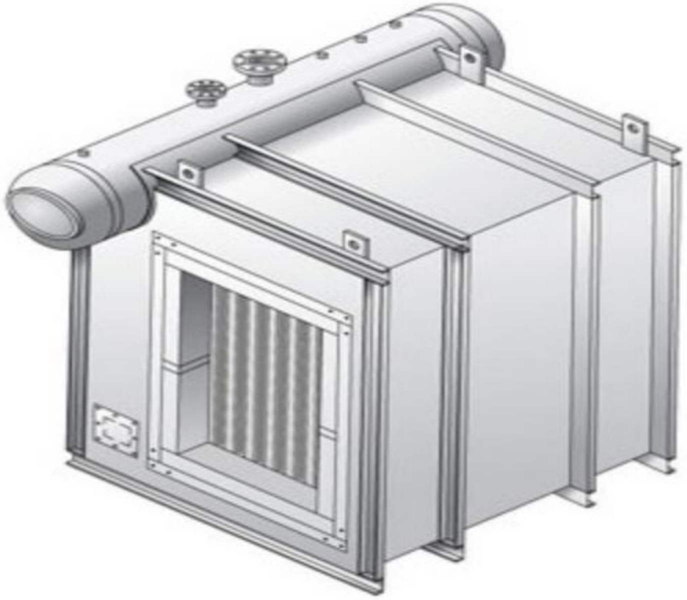
Heat Wheel Make-Up Air Heat Recovery Unit

- 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



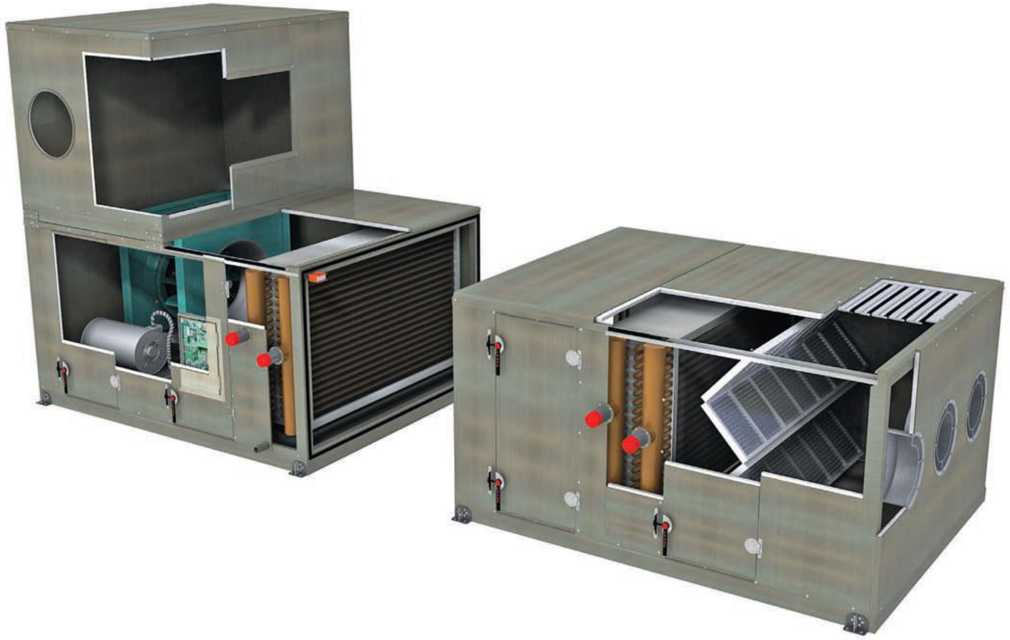
Air to Water

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 #1

- 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 next week

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

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