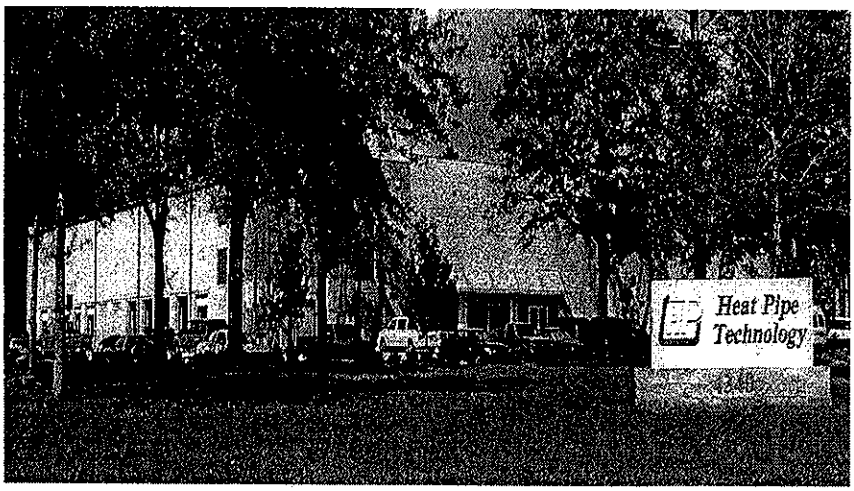
Fundamentals and Applications

Energy Efficient Air Conditioning using Heat Pipes in Custom Air Handlers

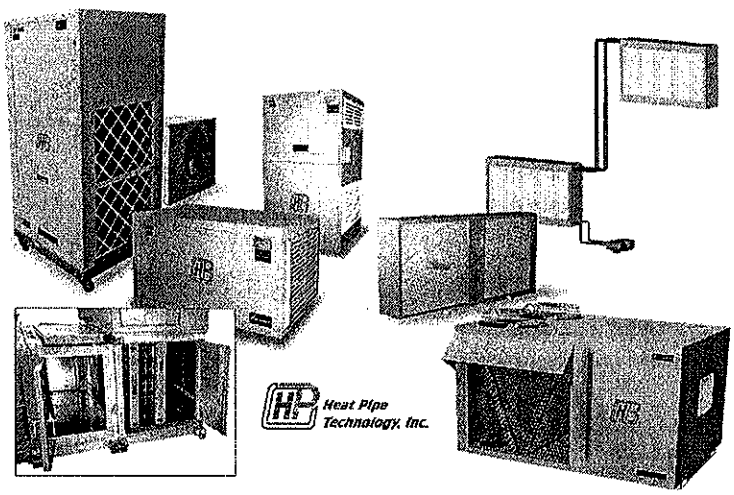
Heat Pipe



Air Enterprises



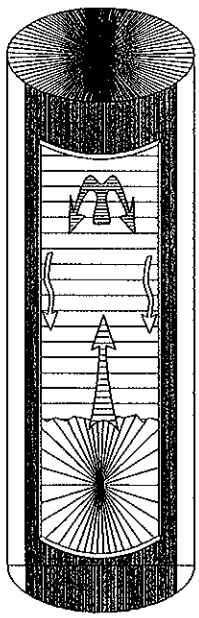
Heat Pipe Products



What Are Heat Pipes?

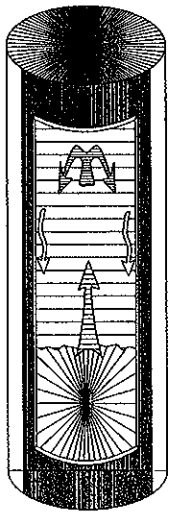
A traditional heat pipe is a hollow cylinder filled with a two-phase fluid.

- **Heat is absorbed at bottom**
- **Liquid evaporates to vapor**
- **Vapor rises to top**
- **Heat is released at top**
- **Vapor condenses to liquid**
- **Liquid drains to bottom**



Heat Pipe Basics

Heat Pipe working fluids have ranged all the way from water to molten metals.

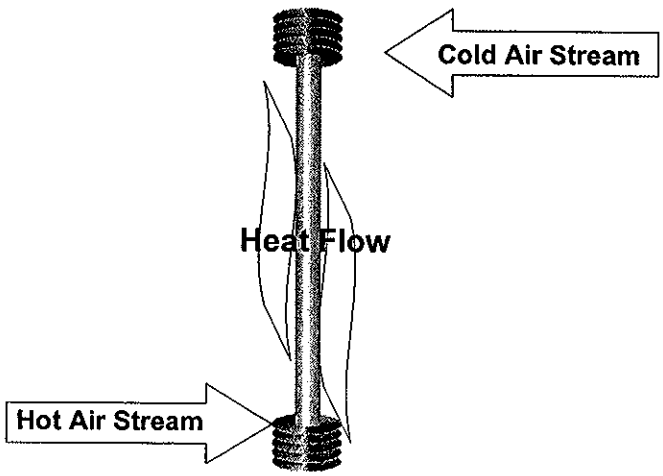


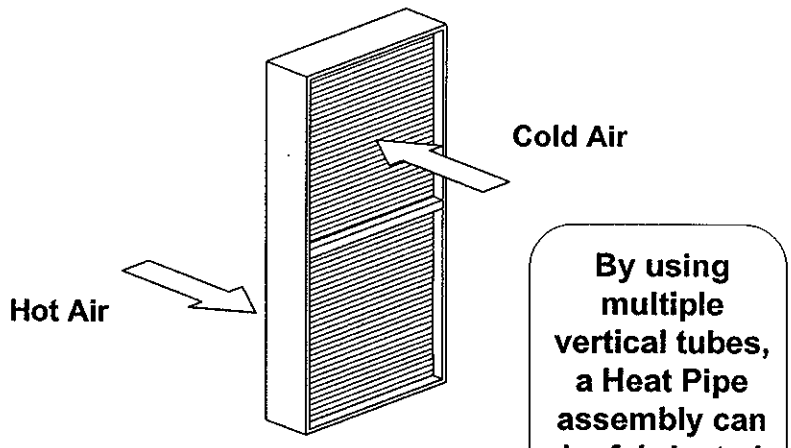
The amount of energy transferred by a basic vertical tube Heat Pipe is many times greater than what can be achieved by natural convection using a single phase fluid .

Why???

Because the Heat Pipe utilizes the latent heat of vaporization & condensation to transport the energy.

Basic Heat Pipe Exchanging Heat Between Two Air Streams





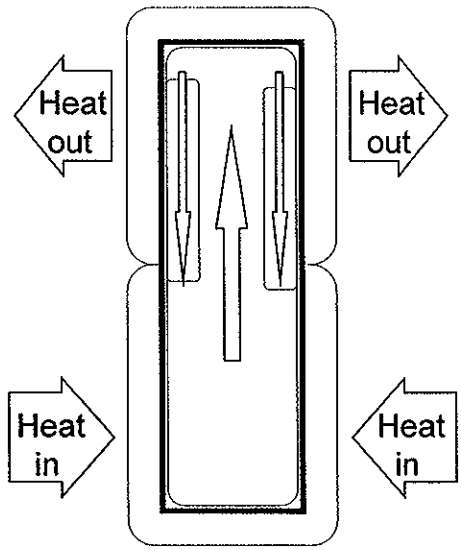
By using multiple vertical tubes, a Heat Pipe assembly can be fabricated similar to an HVAC coil.

Heat Pipes

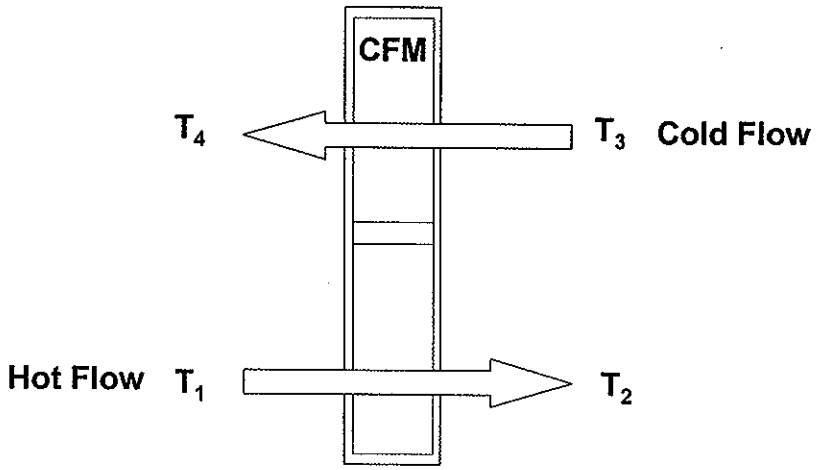
For

Energy Recovery

How it Works

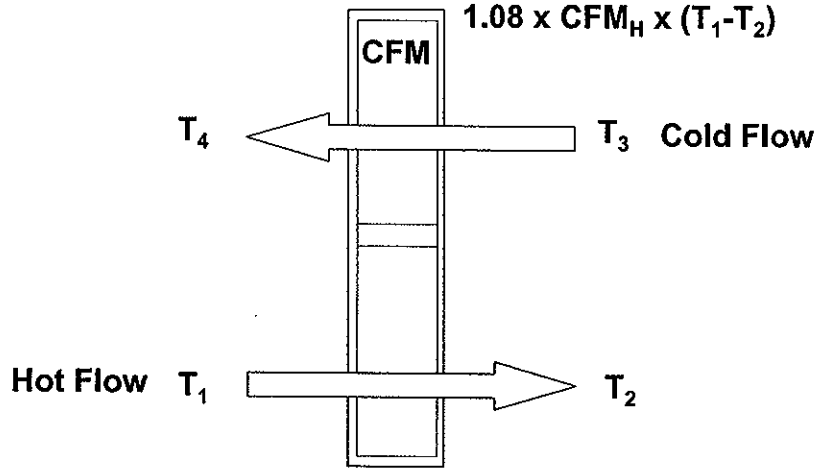


Technical Equations



Energy Transferred

Btuh Heat Transfer Rate = $1.08 \times CFM_c \times (T_4-T_3)$
$1.08 \times CFM_H \times (T_1-T_2)$

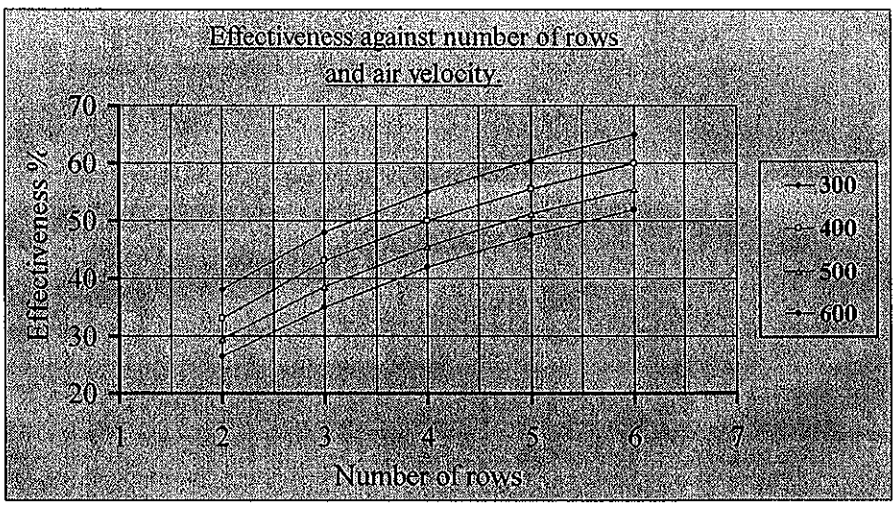


Effectiveness

Temperature Effectiveness =

$$\frac{\text{Change in Temperature of One Air Stream}}{\text{Max. Tem. Diff. Between The Air Streams}}$$

Heat Pipe Effectiveness



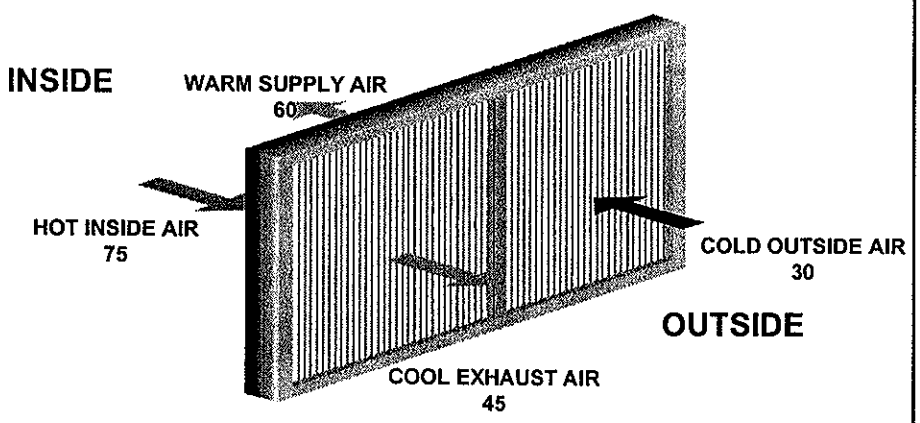
Heat Pipes For Energy Recovery

Recover **HEAT** during the winter

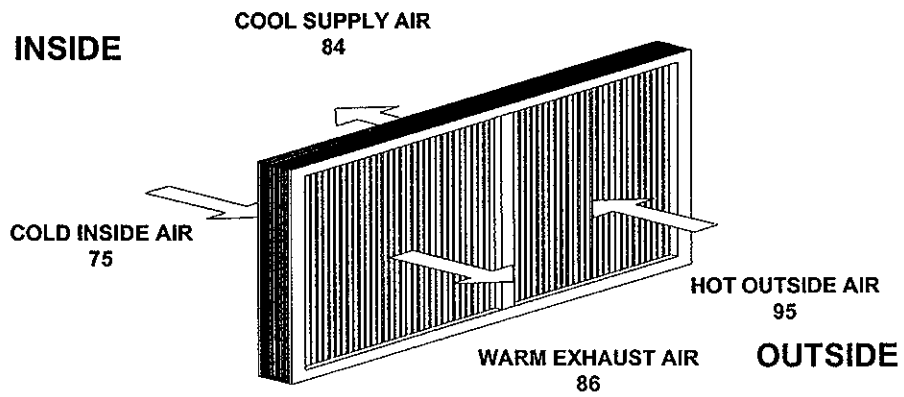
Recover **COOL** during the summer

Recover **HEAT** or **COOL** in process applications

SIDE-BY-SIDE HEAT PIPES
WINTER CONDITION



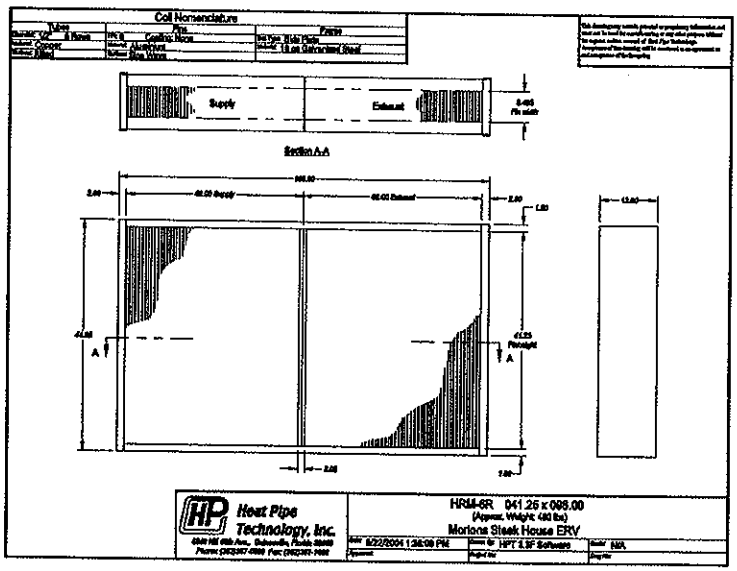
SIDE-BY-SIDE HEAT PIPES
SUMMER CONDITION



Morton's Steakhouse Case Study: Energy Recovery

ERV Energy Recovery Heat Pipes

- Face Velocity 407 FPM
- Total Fin Height: 41.25”
- Total Fin Length: 48” per air stream
- Number of Rows: 6
- Tubes: 1/2” Copper
- Fins: 8 FPI -



SUPPLY SIDE HEAT PIPE					EXHAUST SIDE HEAT PIPE				
SUPPLY IN			SUPPLY OUT		EXHAUST IN			EXHAUST OUT	
SCFM	°FDB	°FWB	°FDB	°FWB	SCFM	°FDB	°FWB	°FDB	°FWB
5600	92.00	77.00	81.91	74.35	5600	72.00	60.00	82.24	63.60
5600	87.00	77.00	79.44	75.03	5600	72.00	60.00	79.69	62.73
5600	82.00	74.00	76.95	72.60	5600	72.00	60.00	77.12	61.83
5600	77.00	72.00	74.48	71.28	5600	72.00	60.00	74.56	60.92
5600	72.00	69.00	72.00	69.00	5600	72.00	60.00	72.00	60.00
5600	67.00	65.00	69.53	65.83	5600	72.00	60.00	69.45	59.06
5600	62.00	60.00	67.08	61.82	5600	72.00	60.00	66.90	58.10

SUPPLY SIDE HEAT PIPE							EXHAUST SIDE HEAT PIPE					
Enter DB (°F)	ΔT (°F)	ΔP (in.H_2O)	Eff. (%)	Conden-sation (lbs/h)	Face Vel. (SFPM)	Energy Transferred (Btu/h)	Enter DB (°F)	ΔT (°F)	ΔP (in.H_2O)	Eff. (%)	Conden-sation (lbs/h)	Face Vel. (SFPM)
92.00	-10.09	0.34	50.4	0.0	407	62894	72.00	10.24	0.33	51.2	0.0	407
87.00	-7.56	0.34	50.4	0.0	407	47205	72.00	7.69	0.33	51.2	0.0	407
82.00	-5.05	0.34	50.5	0.0	407	31441	72.00	5.12	0.33	51.2	0.0	407
77.00	-2.52	0.34	50.5	0.0	407	15715	72.00	2.56	0.33	51.2	0.0	407
72.00	0.00	0.33	100.	0.0	407	0	72.00	0.00	0.33	100.	0.0	407
67.00	2.53	0.33	50.7	0.0	407	15685	72.00	-2.55	0.33	51.1	0.0	407
62.00	5.08	0.33	50.8	0.0	407	31327	72.00	-5.10	0.33	51.0	0.0	407
	41.25				Fin Height (in.)			41.25				
	48				Finned Length (in.)			48				
	13.75				Face Area (SF)			13.75				
	407.27				Face Velocity (SFPM)			407.27				
	6				No. of Rows			6				
	1/2				Tube OD (in.)			1/2				
	8				Fins per inch			8				
	Standard				Fin Type			Standard				

Enter DB (°F)	Out DB (°F)	ΔT (°F)	Power Saved (kw)	Cost Savings ($/hour)	Cost Savings ($/year)	Run hours (/year)
92.00	81.91	-10.09	6.29	$0.63	$1.89	3
87.00	79.44	-7.56	4.72	$0.47	$335.63	711
82.00	76.95	-5.05	3.14	$0.31	$778.47	2476
77.00	74.48	-2.52	1.57	$0.16	$527.56	3357
72.00	72.00	0.00	0.00	$0.00	$0.00	1925
67.00	69.53	2.53	4.60	$0.20	$54.24	273
62.00	67.08	5.08	9.18	$0.40	$3.57	9
					$1,701.36	8754

Heat Pipe Installed As: Retrofit
Cooling EER (COP/0.293) 10
Existing Reheat Type: Gas/Fuel
New Cooling Equipment Cost: $0.00/AC Ton
New Reheat Equipment Cost: $0.00/kw

Motor Efficiency: 0.9
Fan Efficiency: 0.7
Burner Efficiency: 0.75
Electric Rate: $0.100/kw-h
Gas or Fuel Rate: $0.95 /therm

Total Running time For Cooling: 8472 hours/year
Savings by Heat Pipe in Cooling mode: $1,644/year
Savings by Heat Pipe in Heating mode: $58/year
Additional cost by fan: $609/year

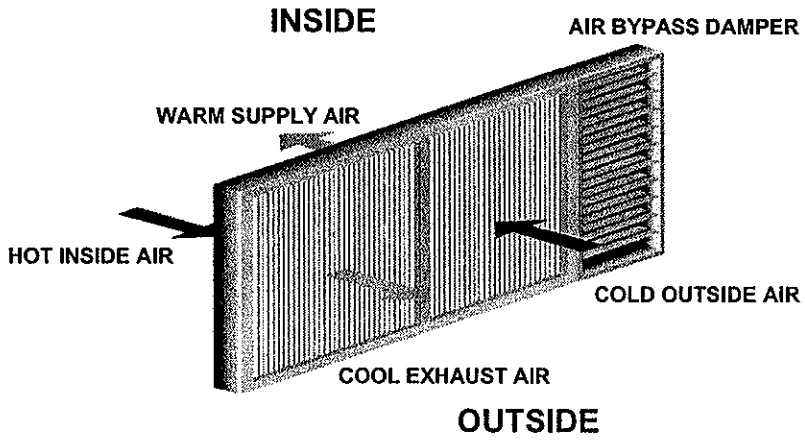
For Heating: 282 hours/year
Net Savings by Heat Pipe: $1,092/year
New Cooling Equip. Savings: n/a
New Heating Equip. Savings: n/a

How can heat pipes be turned off or modulated?

- Face & bypass dampers
- Tilt mechanism

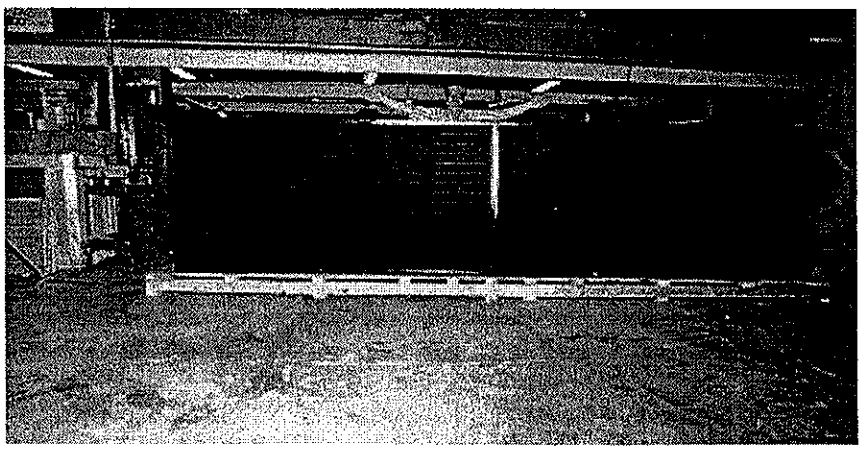
Side-by-side heat pipes with air bypass damper

WINTER CONDITION



Heat Recovery Heat Pipe

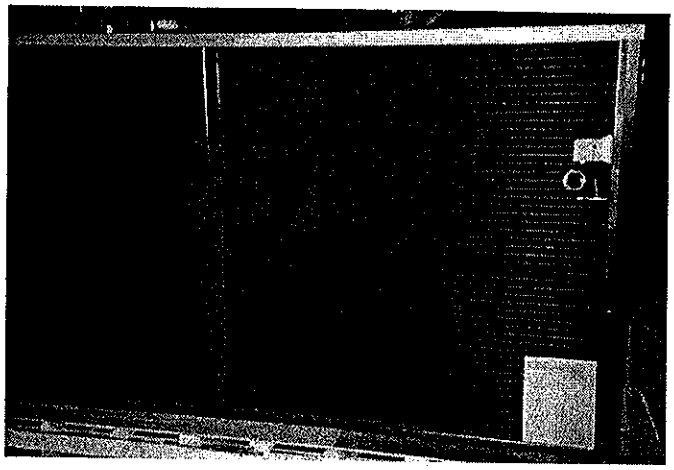
Fairbanks, Alaska – Wastewater Treatment



Heat Pipe size: 45" FH x 200" FL x 6 Rows (2 modules high)

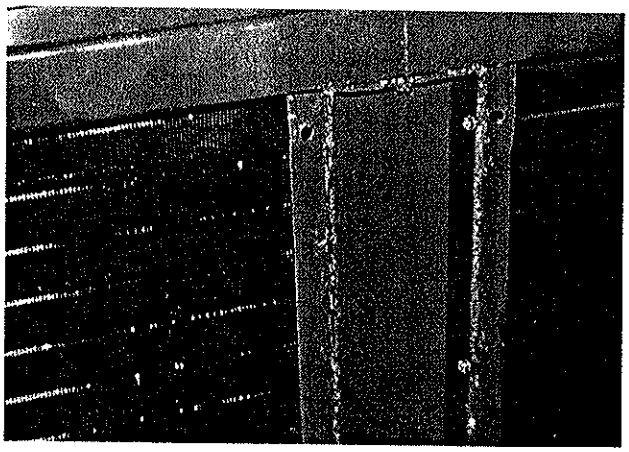
Energy Recovery Heat Pipe

Austin Peay State University – Clarksville, Tennessee, USA

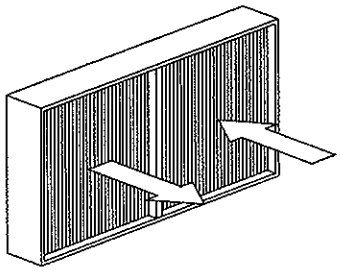


Showing pressure sensor installed

Zero Cross Contamination
4" Partition



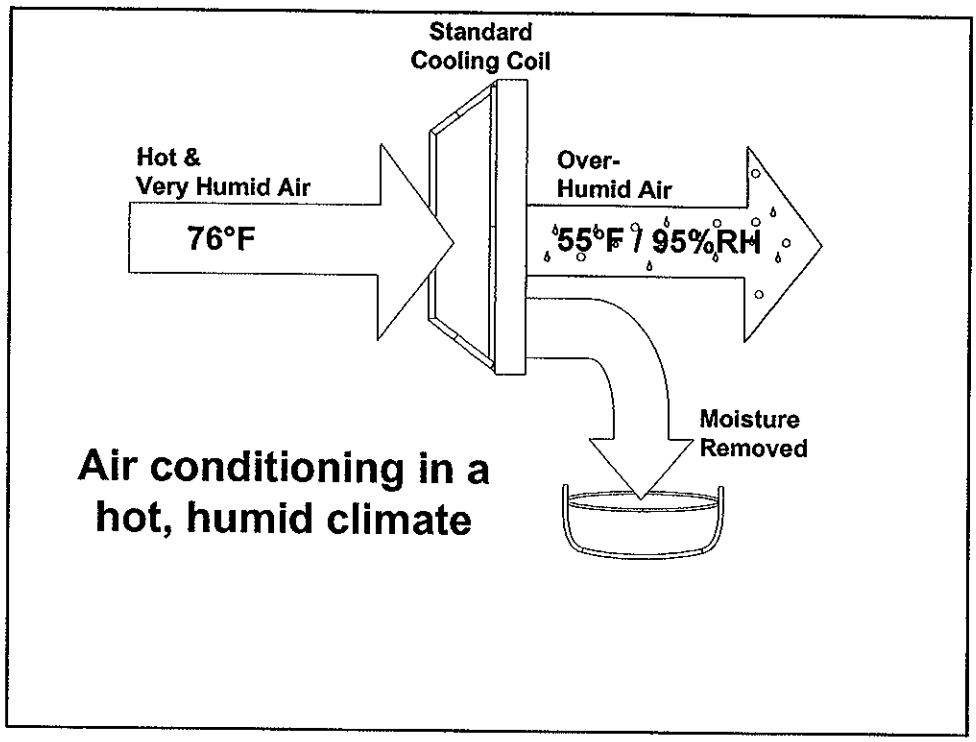
Most common form of Energy Recovery Heat Pipe:

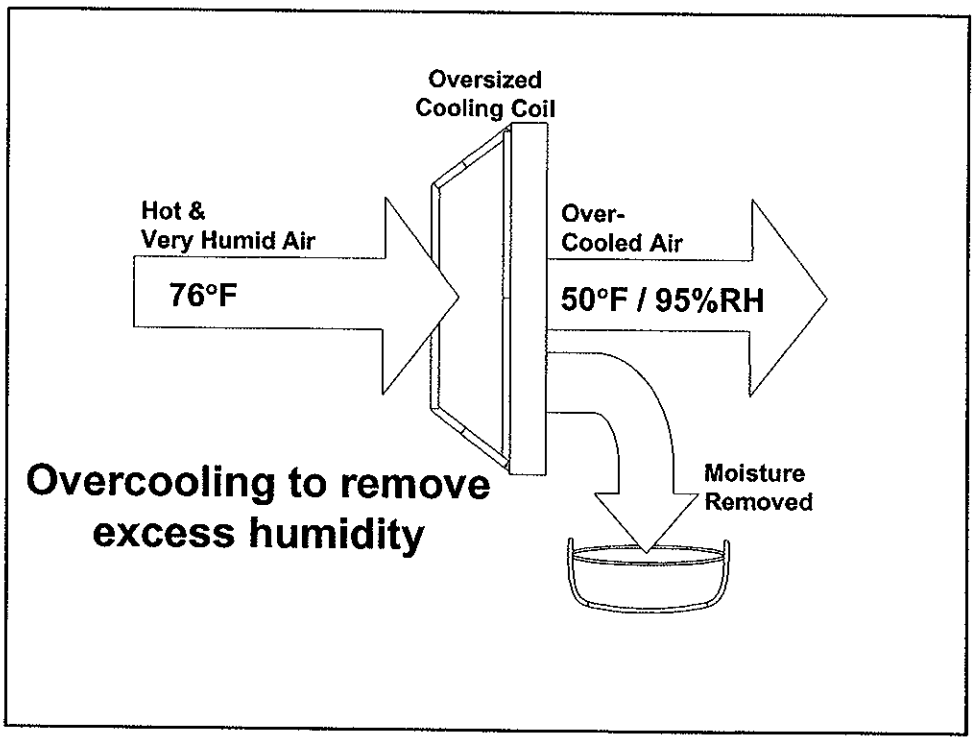


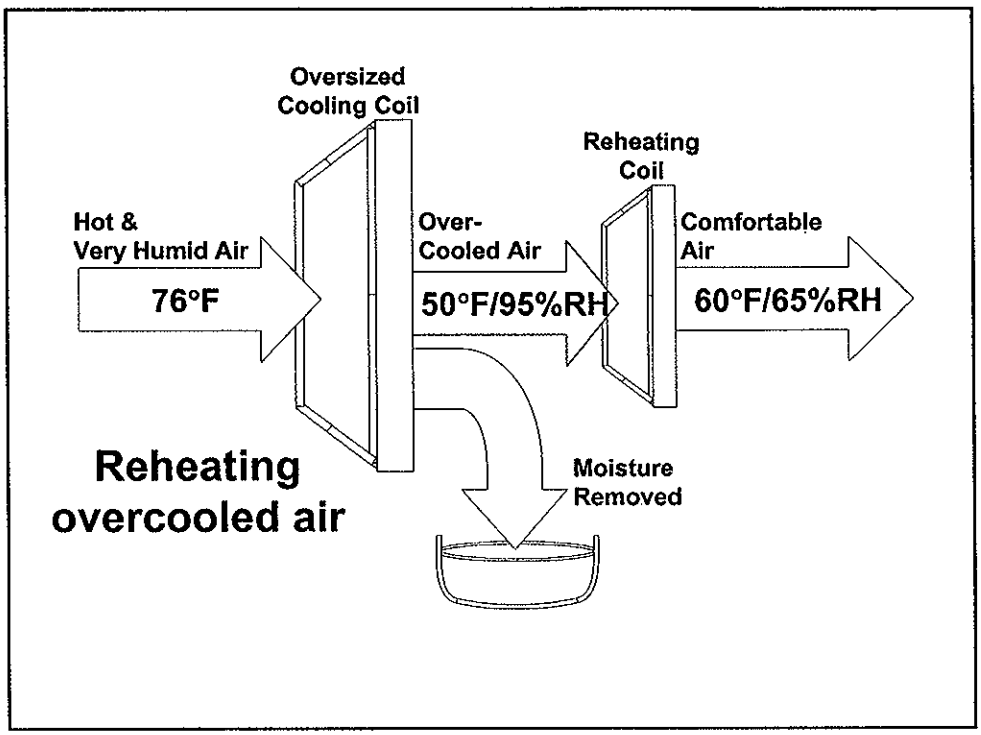
SIDE by SIDE air flows

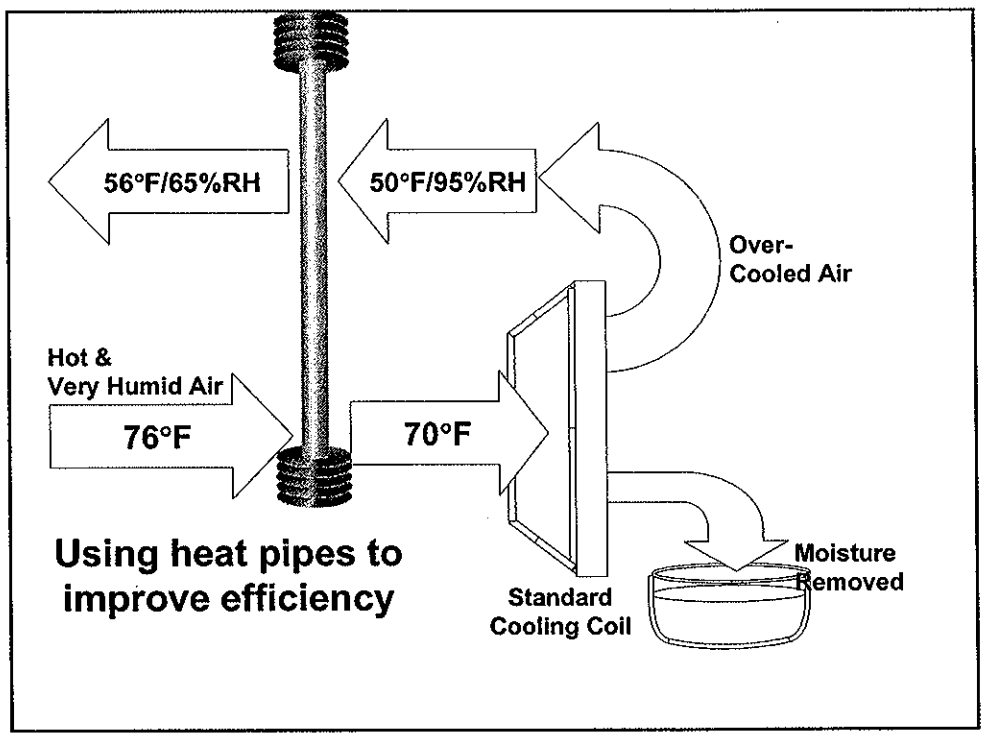
- **HOT flow on one side**
- **COLD flow on the other side**
- **Refrigerant tubes are horizontal**

Heat Pipes For Dehumidification


Standard
Cooling Coil
Hot &
Very Humid Air
76°F
Over-
Humid Air
55°F / 95%RH
Moisture
Removed
Air conditioning in a
hot, humid climate

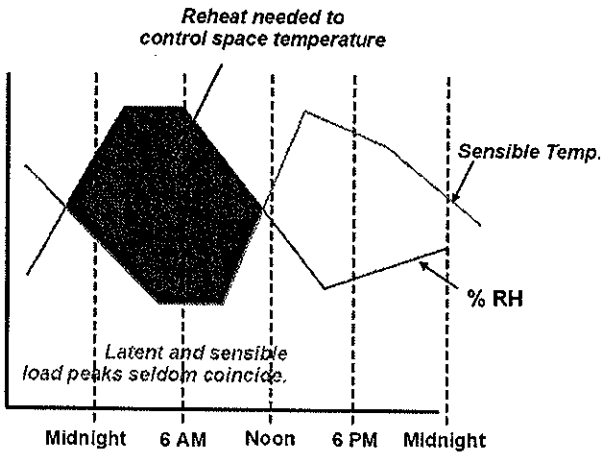

Oversized
Cooling Coil
Hot &
Very Humid Air
76°F
Over-
Cooled Air
50°F / 95%RH
Moisture
Removed
Overcooling to remove
excess humidity


Oversized
Cooling Coil
Reheating
Coil
Hot &
Very Humid Air
76°F
Over-
Cooled Air
50°F/95%RH
Comfortable
Air
60°F/65%RH
Moisture
Removed
Reheating
overcooled air

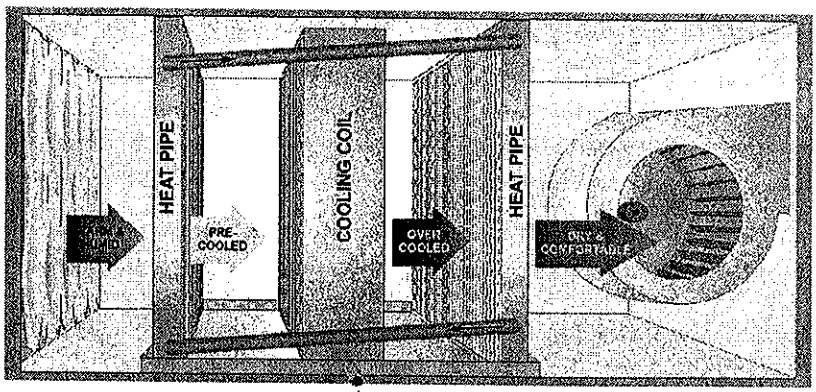

56°F/65%RH
50°F/95%RH
Over-
Cooled Air
Hot &
Very Humid Air
76°F
70°F
Moisture
Removed
Using heat pipes to
improve efficiency
Standard
Cooling Coil

Reheat Requirement

Source: Trane Application Engineering Manual



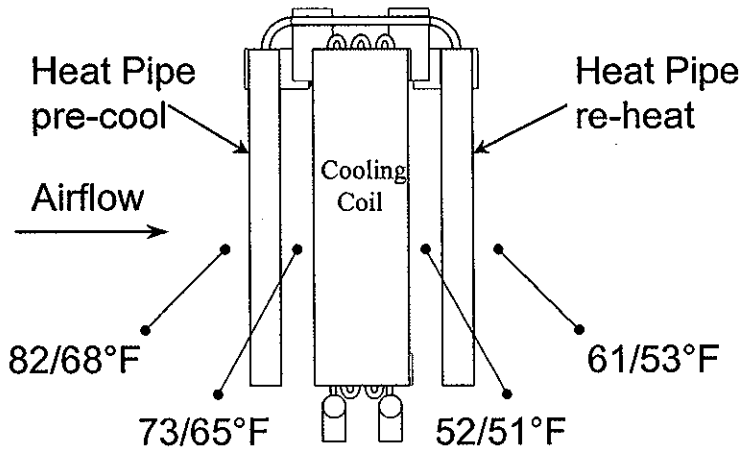
Heat Pipe Dehumidification

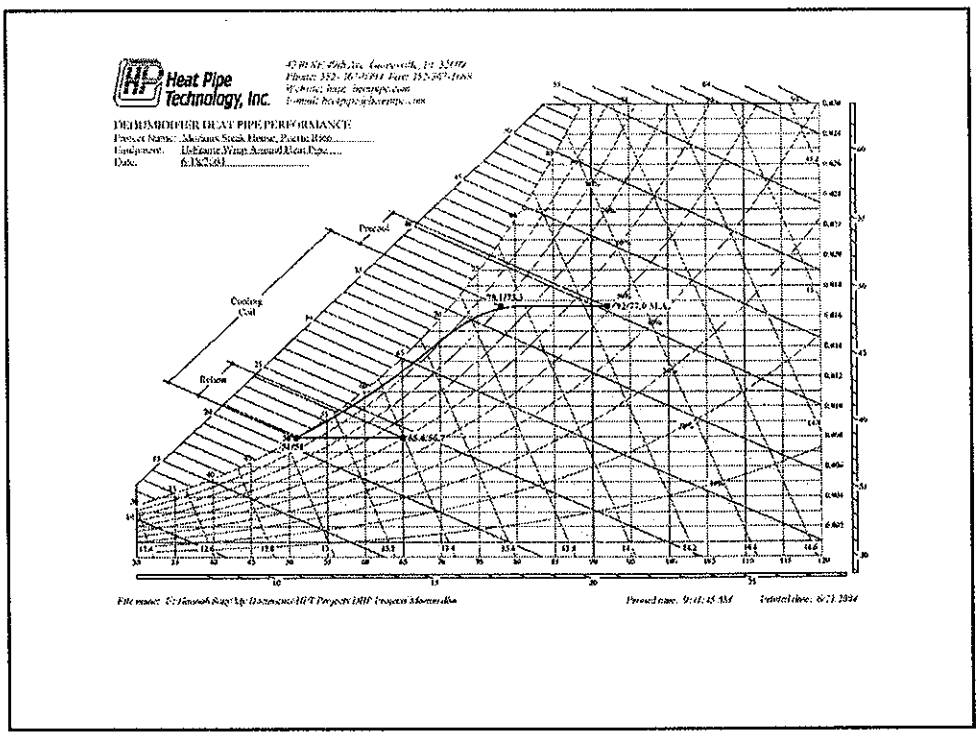


Precool **Reheat**

Increased Condensate

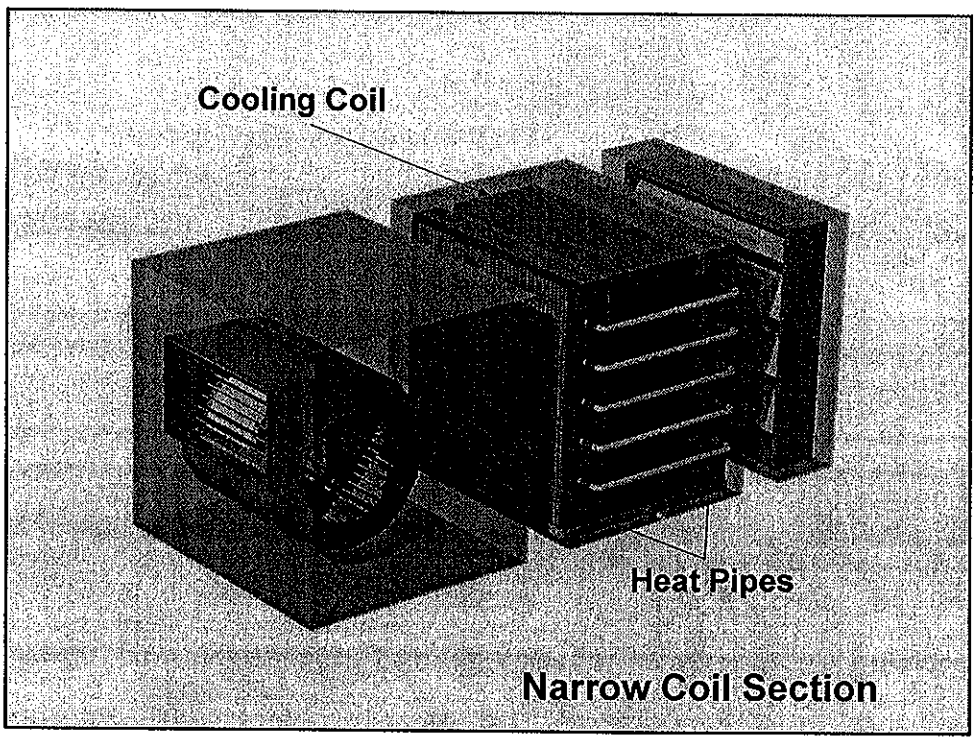
Plan View of Cooling Coil

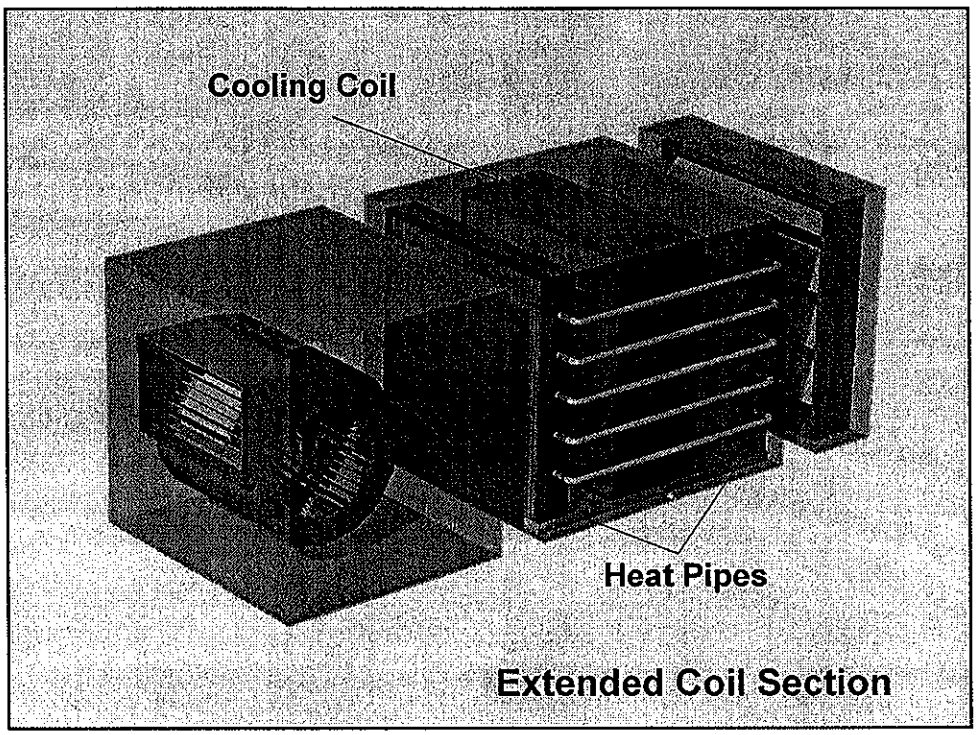


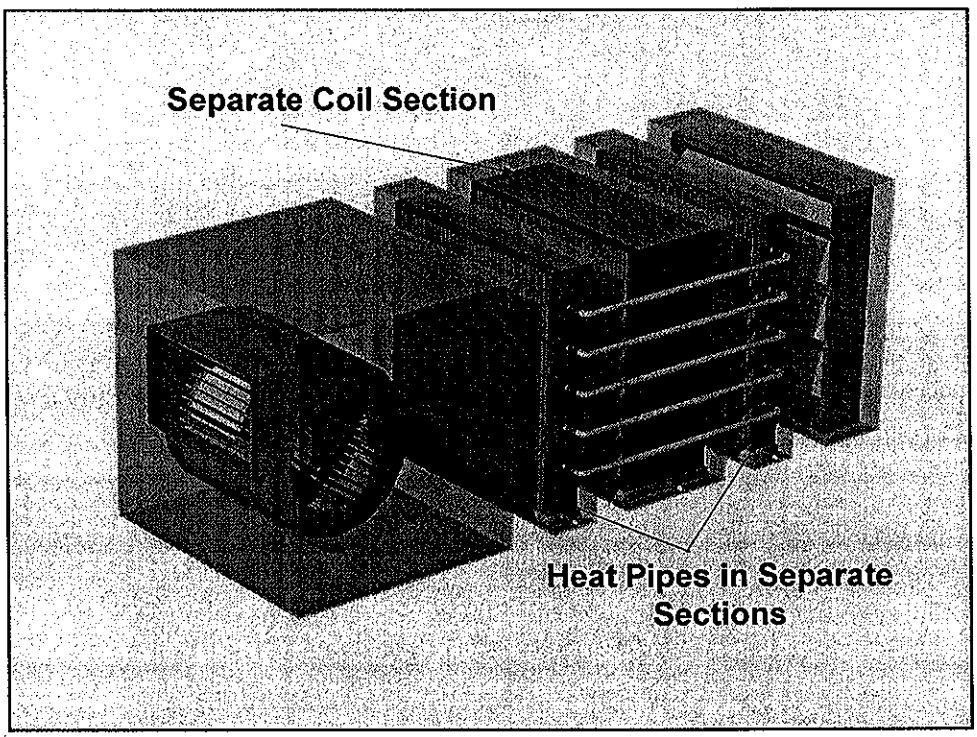


Dehumidifying Heat Pipes

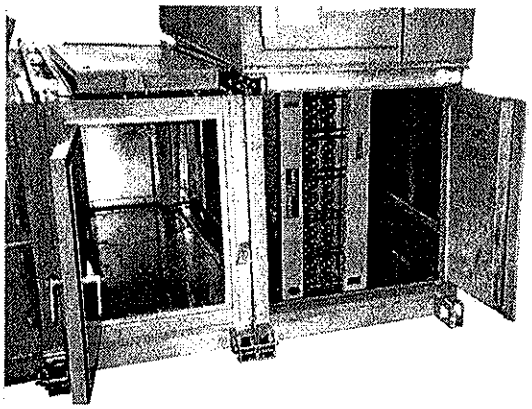
Installation Arrangements




Cooling Coil
Heat Pipes
Extended Coil Section


Separate Coil Section
Heat Pipes in Separate Sections

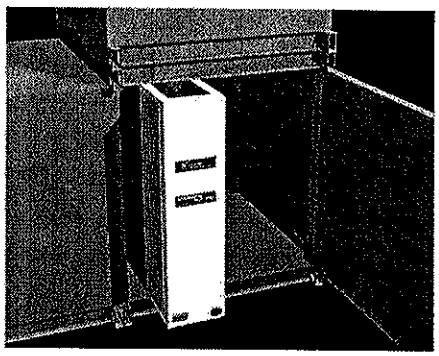
DHP-F
Standard Wrap-Around Heat Pipe Installation



Applications

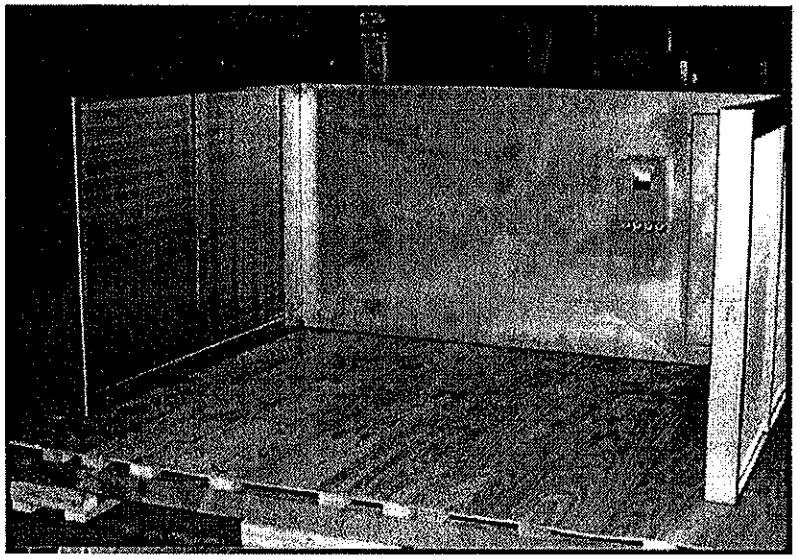
- Most Common Factory or Field Retrofit

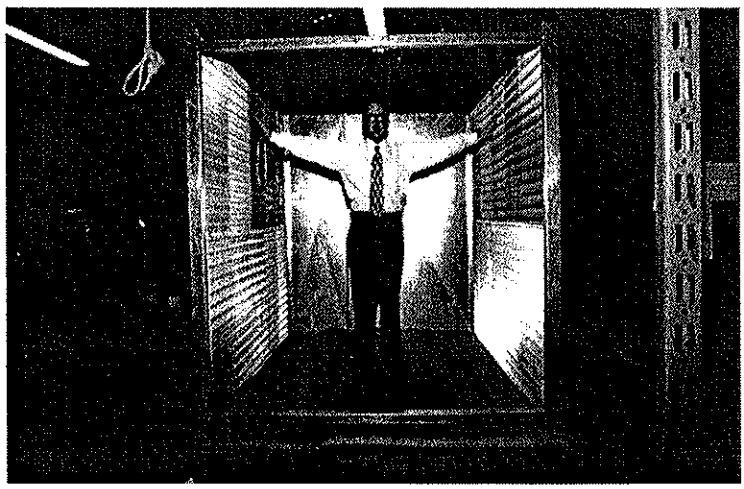
DHP-U
U-Framed Dehumidifier Heat Pipes



Applications

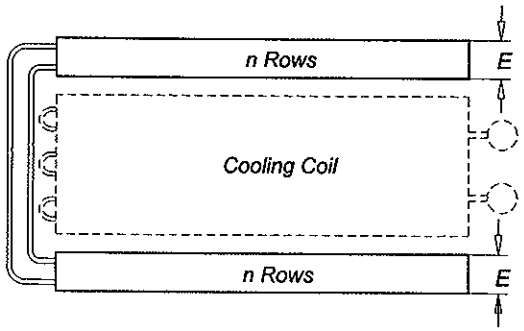
- Custom Built Units
- OEM Applications
- Field Retrofits





Standard Heat Pipe Dimensions (depth, inches)

n Rows	E
1 Row	2.00
2 Rows	2.75
3 Rows	4.00
4 Rows	5.25



Retrofit Types

1.Factory Retrofit:

Contractor/Manufacturer ships Equipment To Heat Pipe Supplier

2. Field Retrofit: Existing systems

Manufacturer's crew travels to job site for the retrofit.

3. U-Frames

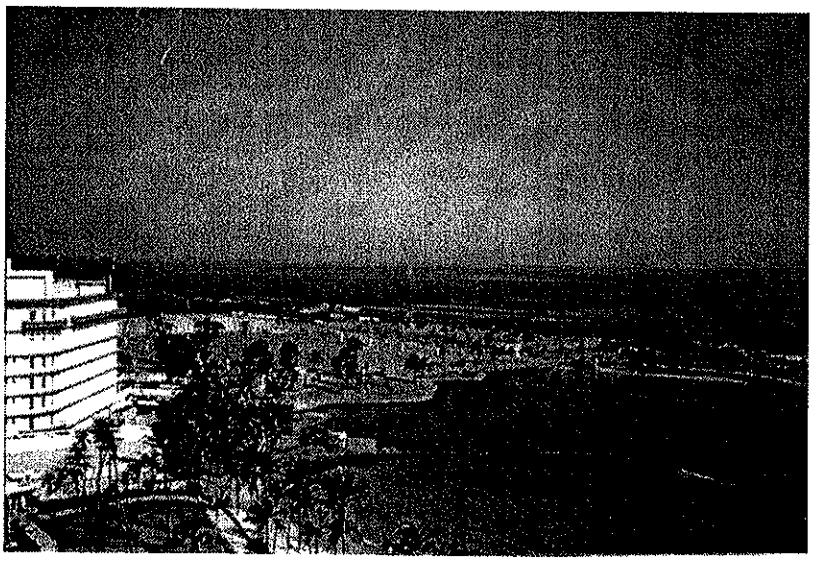
Heat Pipes are sized, Charged and shipped to Manufacturer/Owner for Installation

Morton's Steakhouse Case Study

Case Study

Morton's Steak House
San Juan
Puerto Rico

U-Frame Dehumidifier
Heat Pipe into
Air Enterprises AHU

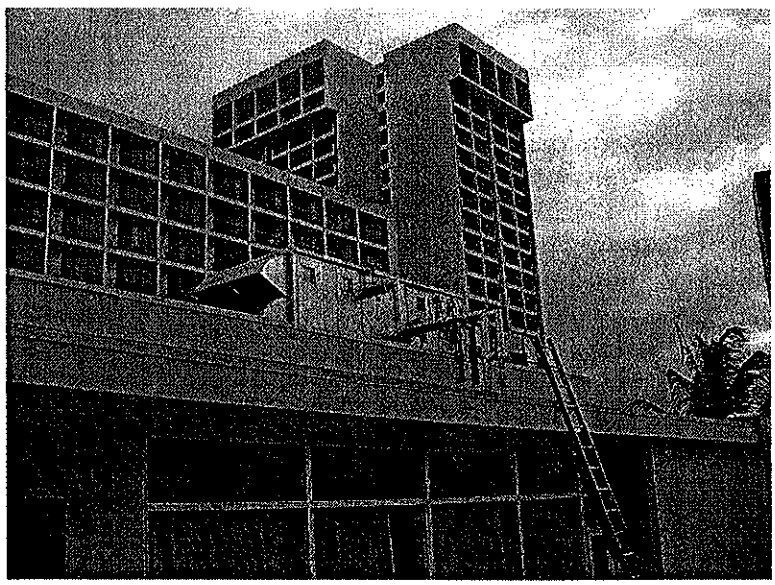


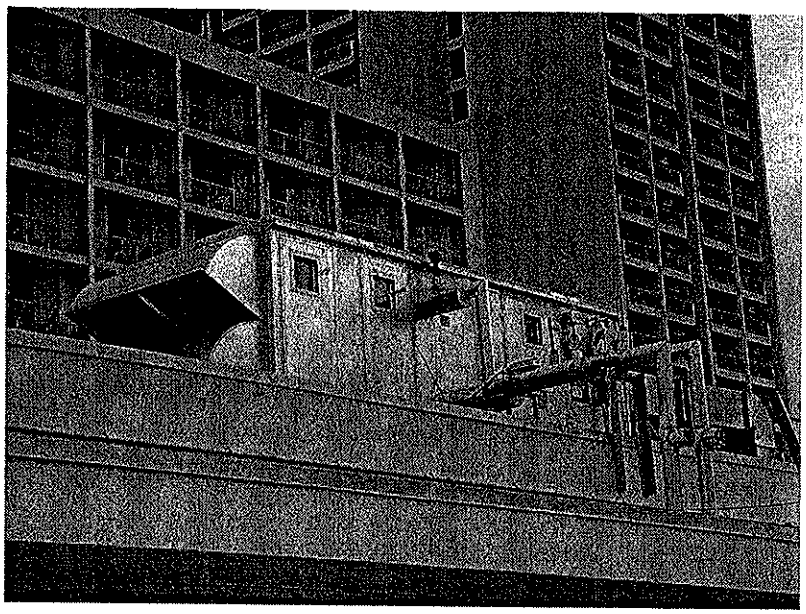
Description:

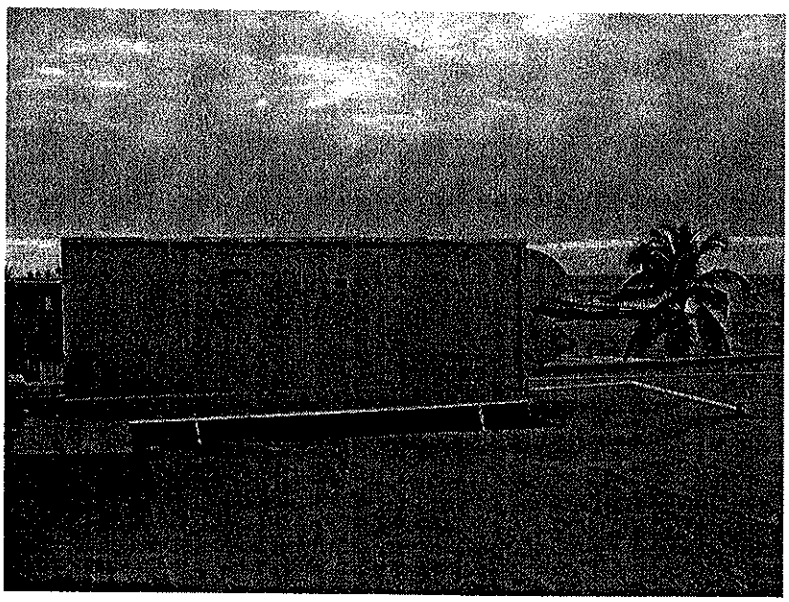
Resort + Restaurant

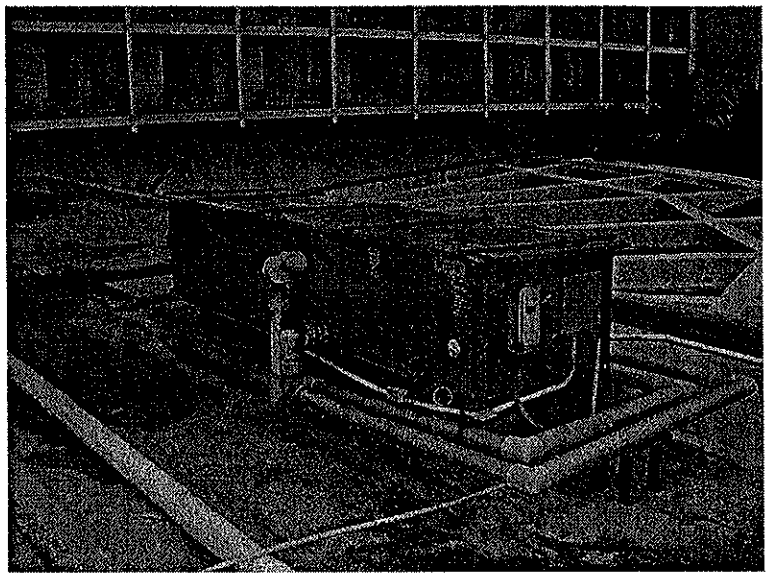
San Juan, Puerto Rico

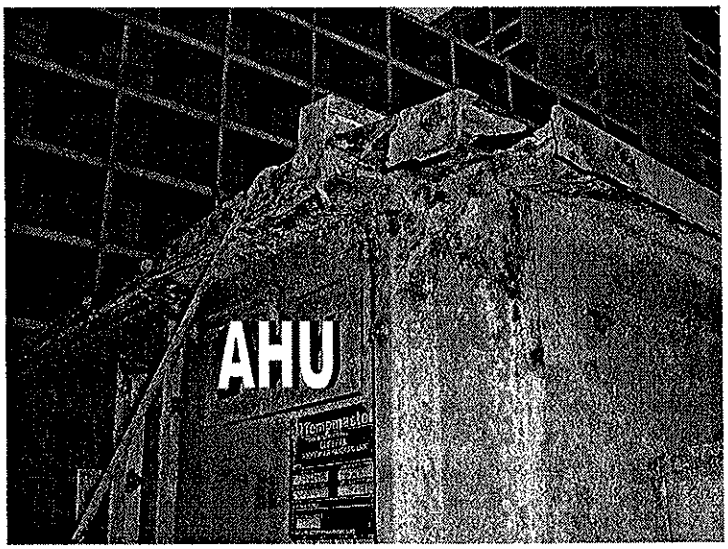
5600 CFM of Outside Air









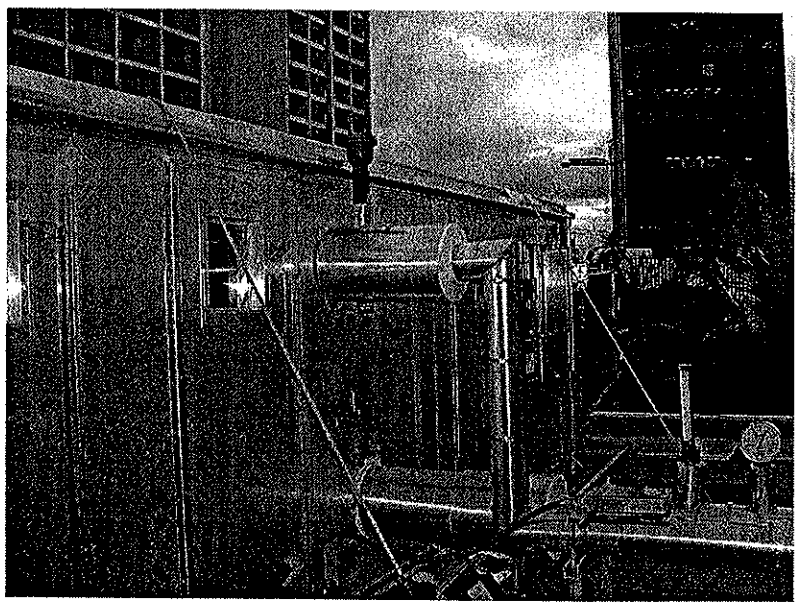

AHU

Design Conditions

Entering Air: Ambient

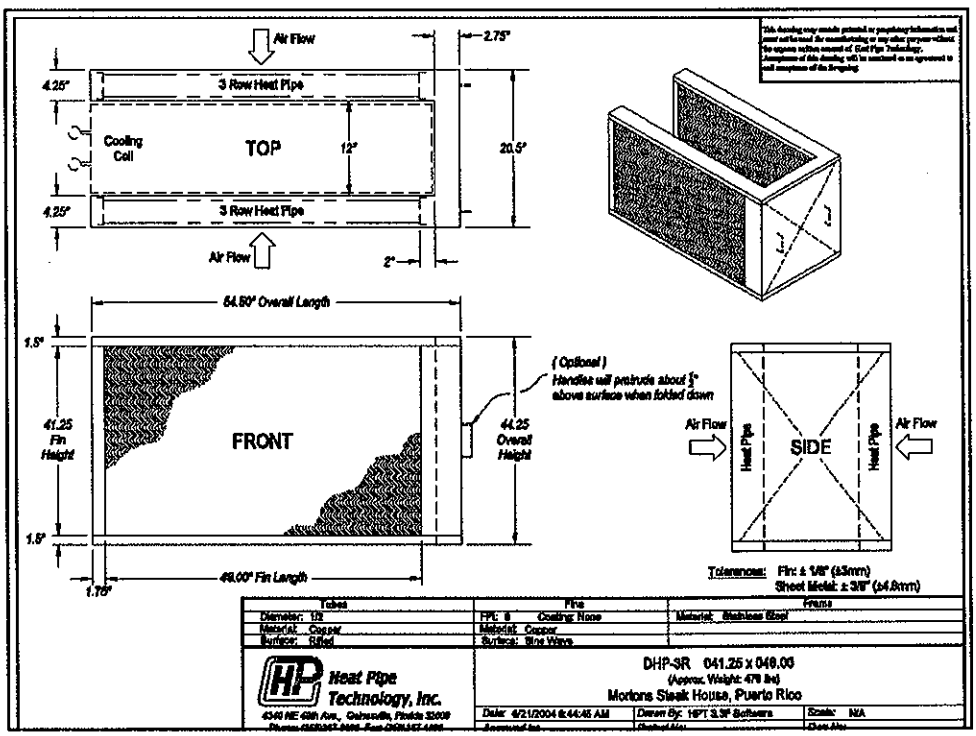
At Design 92/77F DB/WB

Leaving Air from AHU:
65.1F 60% Rh



The Dehumidifying Heat Pipes
Per Air Handler

- Face Velocity 407 FPM
- Total Fin Height: 41.25”
- Total Fin Length: 48”
- Number of Rows: 3 Pre-cool, 3 Reheat
- Tubes: 1/2” Copper
- Fins: 8 FPI Copper
- Type of Retrofit: U-Frame
  Shipped to Air Enterprises Factory



Heat Pipe Performance

Pre-cool 92.0 ⇨ 78.1 13.9F

Reheat 51.0 ⇨ 65.1 14.1F

Energy Transferred:

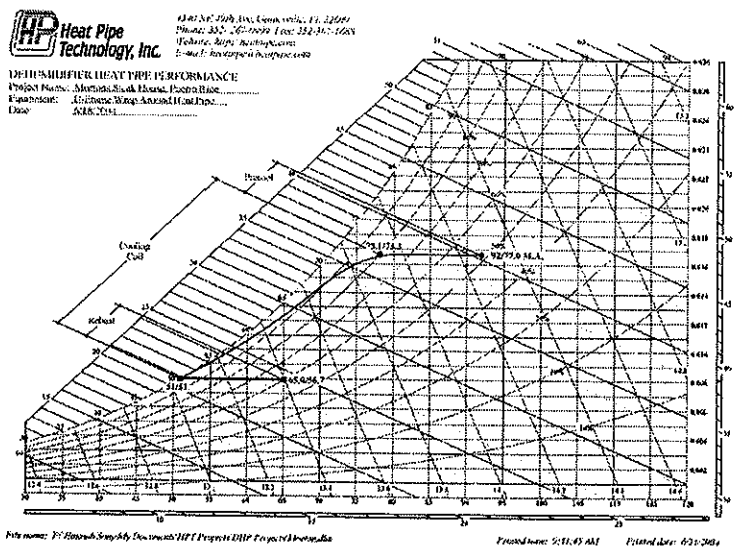
86,414 BTUh = 7.2 ton

Cooling Coil Load:

406,091 BTUh = 33.8 ton

Precool + Cooling Coil:

492,505 BTUh = 41.0 ton



Project Name: Morton's Steak House, Puerto Rico
Equipment: U-Frame Wrap Around Heat Pipe
Bin Data: San Juan
Puerto Rico , U.S.A.

	Outside Air		Precool Air		Leaving C/C Air		Reheat Air		
CFM	DB	WB	DB	WB	DB	WB	DB	WB	RH
5600	92.0	77.0	78.1	73.3	51.0	51.0	65.1	56.8	60.3
5600	87.0	77.0	74.8	73.8	51.0	51.0	63.4	56.1	64.0
5600	82.0	74.0	71.5	71.0	51.0	51.0	61.6	55.4	68.0
5600	77.0	72.0	69.3	69.3	51.0	51.0	60.2	54.9	71.6
5600	72.0	69.0	66.6	66.6	51.0	51.0	58.7	54.3	75.4
5600	67.0	65.0	63.0	63.0	51.0	51.0	56.9	53.5	80.5
5600	62.0	60.0	58.6	58.6	51.0	51.0	54.8	52.6	86.8

Precool Heat Pipe			Cooling Coil		Reheat Heat Pipe		
ΔT (°F)	ΔP (in.H_2O)	Condensate (lbs/h)	Heat Transferred (Btu/h)	Condensate (lbs/h)	ΔT (°F)	ΔP (in.H_2O)	Heat Transferred (Btu/h)
13.86	0.18	0.0	406091	218.6	14.08	0.17	86414
12.15	0.18	0.0	417911	248.2	12.37	0.17	75924
10.48	0.17	0.0	355942	210.5	10.64	0.17	65326
7.66	0.18	8.4	319157	189.3	9.22	0.17	56570
5.38	0.18	13.3	263470	153.7	7.74	0.17	47474
3.98	0.18	11.2	194625	111.0	5.94	0.16	36477
3.42	0.17	2.4	117087	64.9	3.84	0.16	23589

Fan Efficiency:	0.7	Reheat Type:	Gas/Fuel
Motor Efficiency:	0.9	Electric Rate:	$0.100 /kw-h
Burner Efficiency:	0.75	Gas or Fuel Rate:	$0.95 /therm
Cooling EER (COP/0.293):	10		

Precool Heat Pipe			Reheat Heat Pipe	
Cost Saving ($/hour)	Cost Saving ($/year)	Run Time (hours/year)	Cost Saving ($/hour)	Cost Saving ($/year)
$0.86	$2.59	3	$1.09	$3.28
$0.76	$539.82	711	$0.96	$683.77
$0.65	$1,617.46	2476	$0.83	$2,048.79
$0.57	$1,899.04	3357	$0.72	$2,405.45
$0.47	$913.88	1925	$0.60	$1,157.58
$0.36	$99.58	273	$0.46	$126.14
$0.24	$2.12	9	$0.30	$2.69
	$5,074.50			$6,427.70

Additional Energy Cost by Fan: $314/year

Net Operating Savings : $11,189/year

The Savings

Per AHU

- **88 Tons of Cooling**
- **220 GPM of Chilled Water**
- **310 KWh of Free Reheat**

For 4 AHU's

- **352 Tons cooling**
- **880 GPM Chilled Water**
- **1,240 KWh Free Reheat**

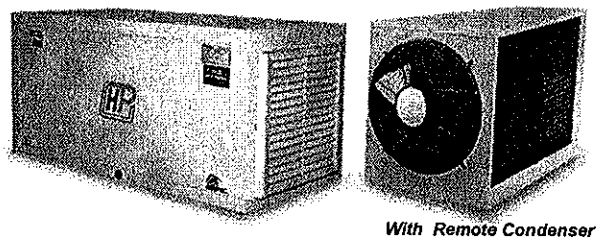


BKP & BKP-AC Dehumidifiers

Incorporating Heat Pipes

BKP 250, 350, 450

Advanced Heat Pipe Dehumidifier



With Remote Condenser

Features

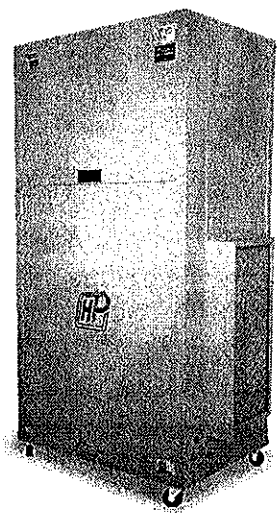
- Dehumidifier heat pipe enhancement
- Heavy duty painted metal cabinet
- Long life Copeland® scroll compressor
- Time delay relay for compressor protection
- Remote dehumidistat control
- Built-in filter dryer
- Easy access for servicing
- Squirrel cage high static/low noise blower
- Duct flanges

BKP 750-1000

Advanced Heat Pipe Dehumidifiers

Features

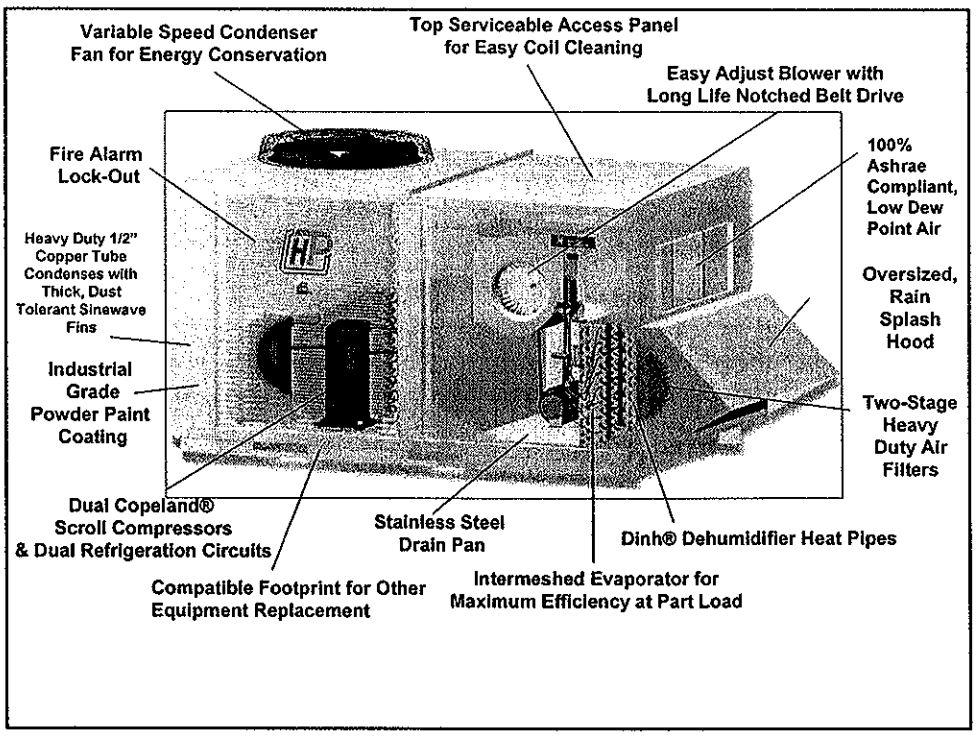
- Dehumidifier heat pipe enhancement
- Heavy duty painted metal cabinet
- Long life Copeland® scroll compressor
- Time delay relay for compressor protection
- Installed condensate pump
- Remote dehumidistat control
- Built-in filter dryer
- Easy access for servicing
- Squirrel cage high static/low noise blower
- Casters for portability
- Duct flanges



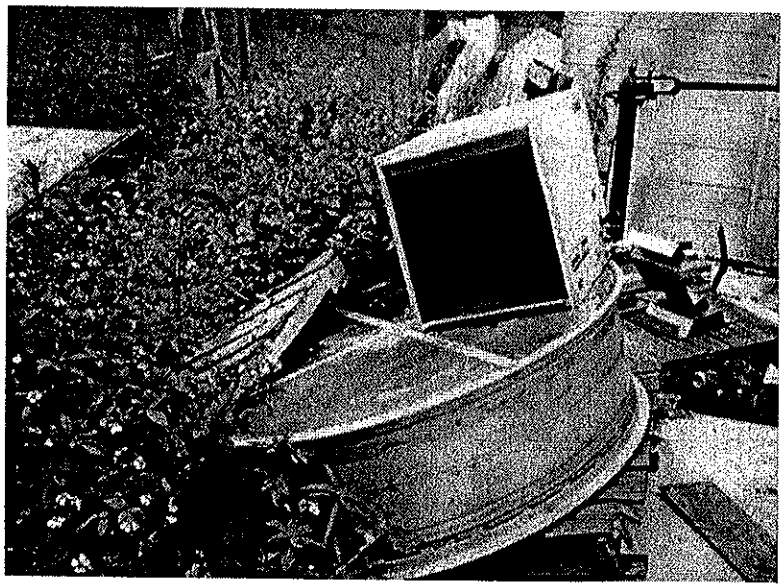
With Internal water cooled AC Condenser for AC Mode

Introducing . . .

The Fresh Air Machine (FAM Series)







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koh@airenterprises.com