Energy Recovery – Applied to IAQ

Understanding
IAQ Concept, Energy Recovery Options, HRW Design Parameters and DOAS

By

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Our Presentation Today

- Indoor Air Quality Concept
- Fresh Air Energy Design Dilemma
- Energy Recovery Options
- Heat Recovery Wheel Evaluation Parameters
- Heat Recovery Wheel Applications Green Buildings / Hospitals
- RH Management Concerns
- DOAS Concept & Technology Options
- DOAS Integration with Parallel system / Chilled beams
- Dehumidification Technology for swimming Pools
- Commercial Air & Gas Purification Units
- Cooling Pads Air Conditioning for Dry Places

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What is IAQ?

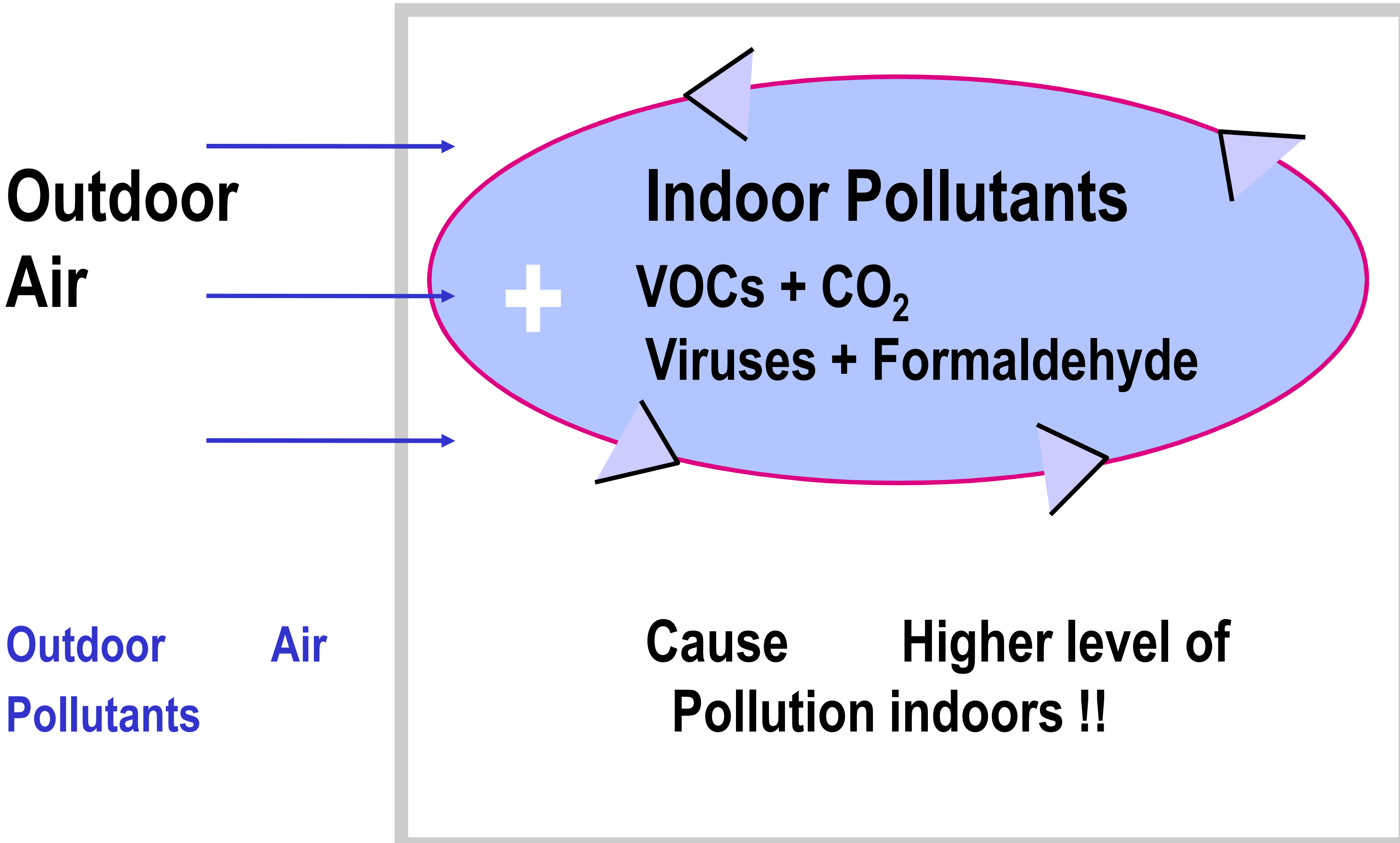
IAQ stands for 'Indoor Air Quality'

Indoor Air Quality (IAQ) refer to the nature of the conditioned (Heat/Cool) Air that circulate throughout space/area where we work and live i.e. the air we breathe during most of our lives.

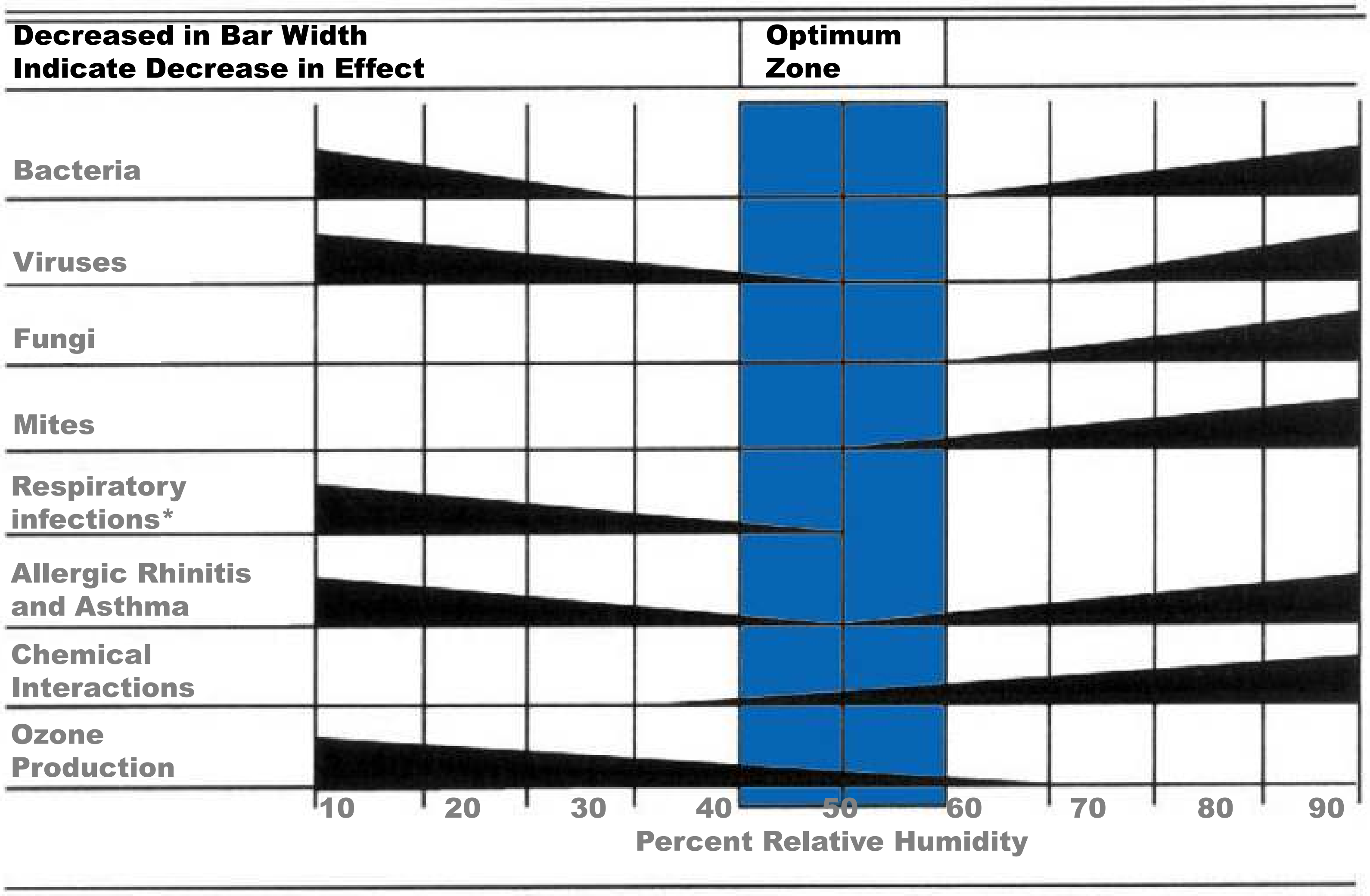
Indoor Air Quality (IAQ)

- Health professionals consistent and persistent concerns on the health hazards caused in workplaces and the increasing number of lawsuits all over the world have prompted the HVAC designer to sit back and think.
- With research clearly indicating that we spend 90 % of our time indoors and the growing scientific evidence that the air indoor is almost 10 to 100 times more polluted than outside, the risk to health is much greater indoors than outdoors.
- Modern techniques and construction have added to the problem, with more and more airtight buildings replacing the leaky buildings of yesteryears.

Conditioned Space



Optimum Humidity Ranges



*Insufficient data above 50% R.H. Source: Sterling: ASHRAE 1985.

Poor IAQ results in

- eye, nose and throat irritation
- headache
- fatigue
- reduced concentration
- irritability
- dry skin and nose bleeds . . . . .

Poor IAQ also results in

- Asthma
- Bronchitis
- Dermatitis
- Flu
- Pneumonia
- Sinusitis

People have varying degrees of sensitivity to humidity, which increases the problem.

INDOOR AIR POLLUTANTS

- Environmental tobacco smoke (ETS)
- Formaldehydes
- Radon
- Asbestos
- VOC from solvents,paints, varnishes, carpets etc.
- Biological organisms like bacteria ,viruses , fungus
- Odours and dust &
- All outdoor pollutants - sulphur, nitrogen dioxide, carbon monoxide, high pollen counts, pesticides, chemicals etc.

Methods to Enhance IAQ

. . . . to reduce Indoor Air Pollution

Control source of pollution

Although, source control is the most effective way of dealing with Indoor Air Quality (IAQ) problem, it is often impractical, expensive and sometimes impossible.

Remove pollutants from air

Air cleaning

- **Not a substitute for fresh outside air**
- **Do not revitalize the air**
- **Cannot rid indoor air of particulate contaminants**
- **Have no effect on concentration of pollutants like formaldehyde, carbon monoxide and other gases**

Increasing ventilation/dilution

Effective Option

Ventilation

Ventilation is the movement of air and it’s contained pollutants to outdoors and flow of fresh air indoors.

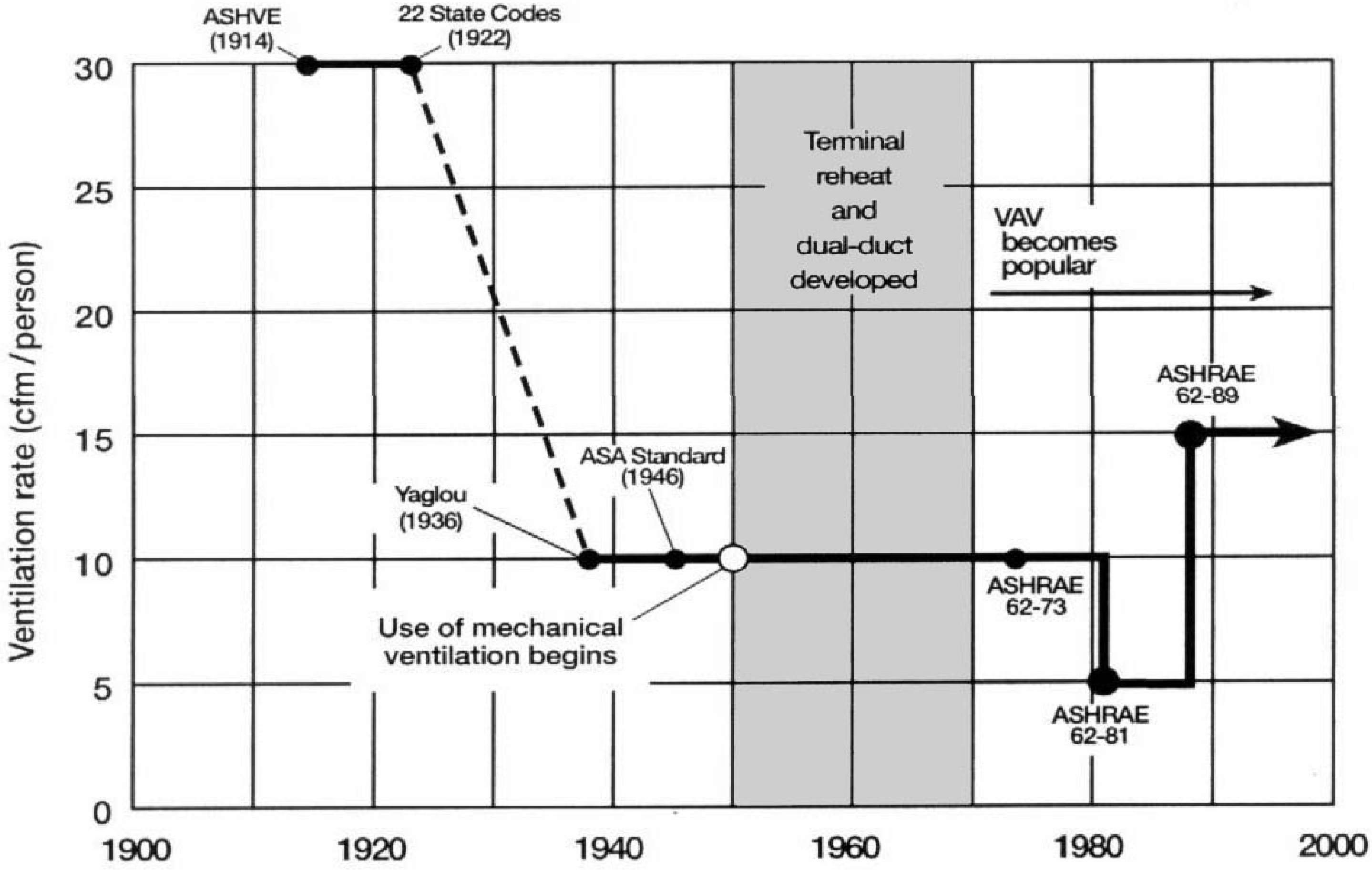
- The flow of fresh air dilutes the concentration of pollutant indoors.
- It is ideal way of keeping indoor air clean.

However, simple mechanical ventilation increases the fresh air

load on conditioning systems resulting increase in tonnage . . .

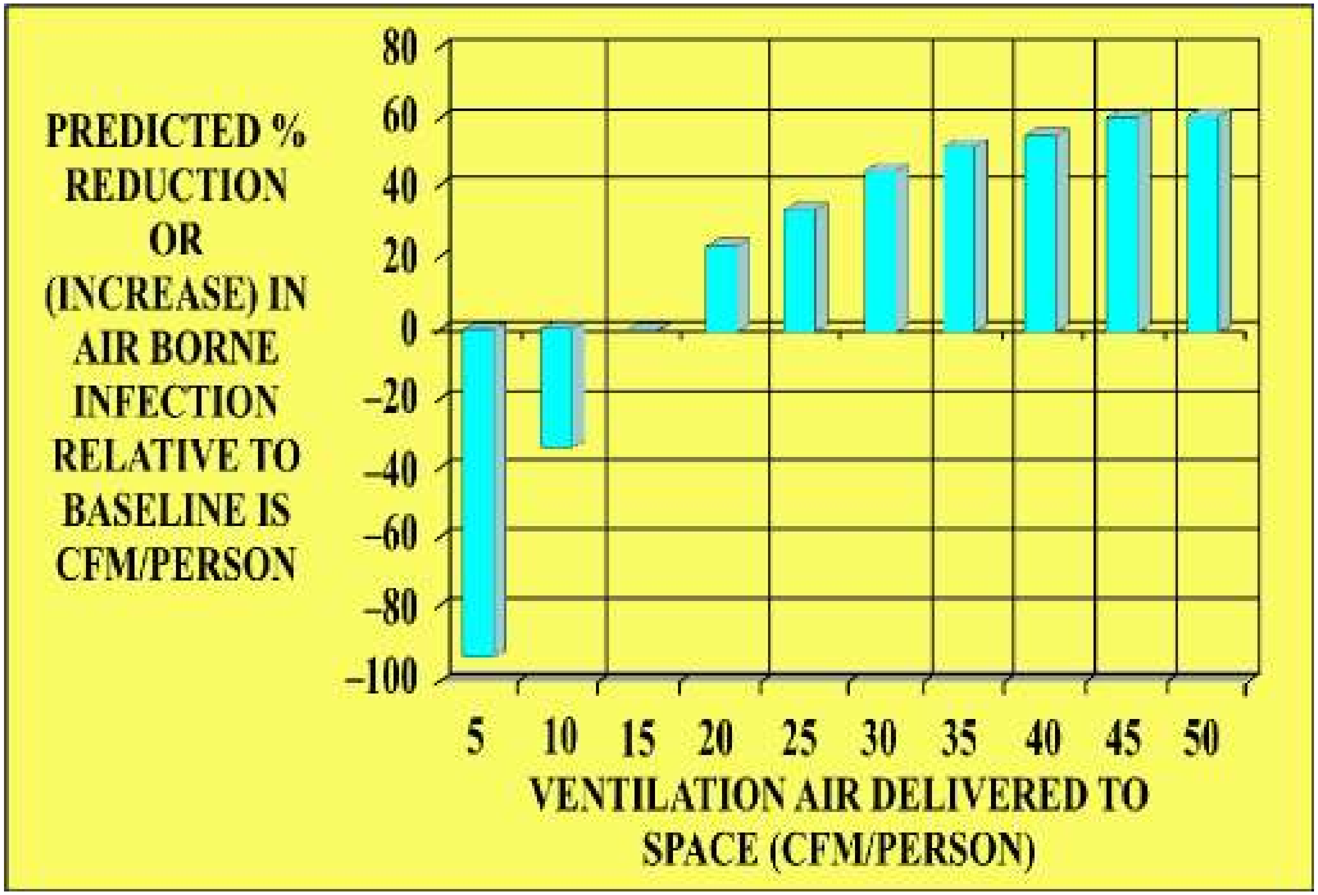
more energy cost.

Indoor Air Quality (IAQ)



Source: Janssen, 127.

Increase in Ventilation Rate Yields Reduction in Airborne Infections



Source : Nunnelly, R.R., Designing for Absolute Moisture, May, 2002.

Ventilation Rates

IAQ generally refers to the quality of the conducted air in an indoor environment. Other terms related to IAQ include **Indoor Environmental Quality (IEQ)** and "**Sick Building Syndrome (SBS)**".

Application	Ventilation Rate/person	Application	Ventilation Rate/person
Office space	20 cfm	**Auditorium**	15cfm
Smoking	60 cfm	**Conference Rooms**	20cfm
Lounge	20 cfm	**Classrooms**	15cfm
Restaurants	25 cfm	**Hospital Rooms**	25cfm
Beauty Salon	30 cfm	**Laboratory**	20cfm
Bars/Cocktail	30 cfm	**Operating Rooms**	30 cfm
Supermarkets	20 cfm		

Problems Related to High Fresh / Ventilation Air

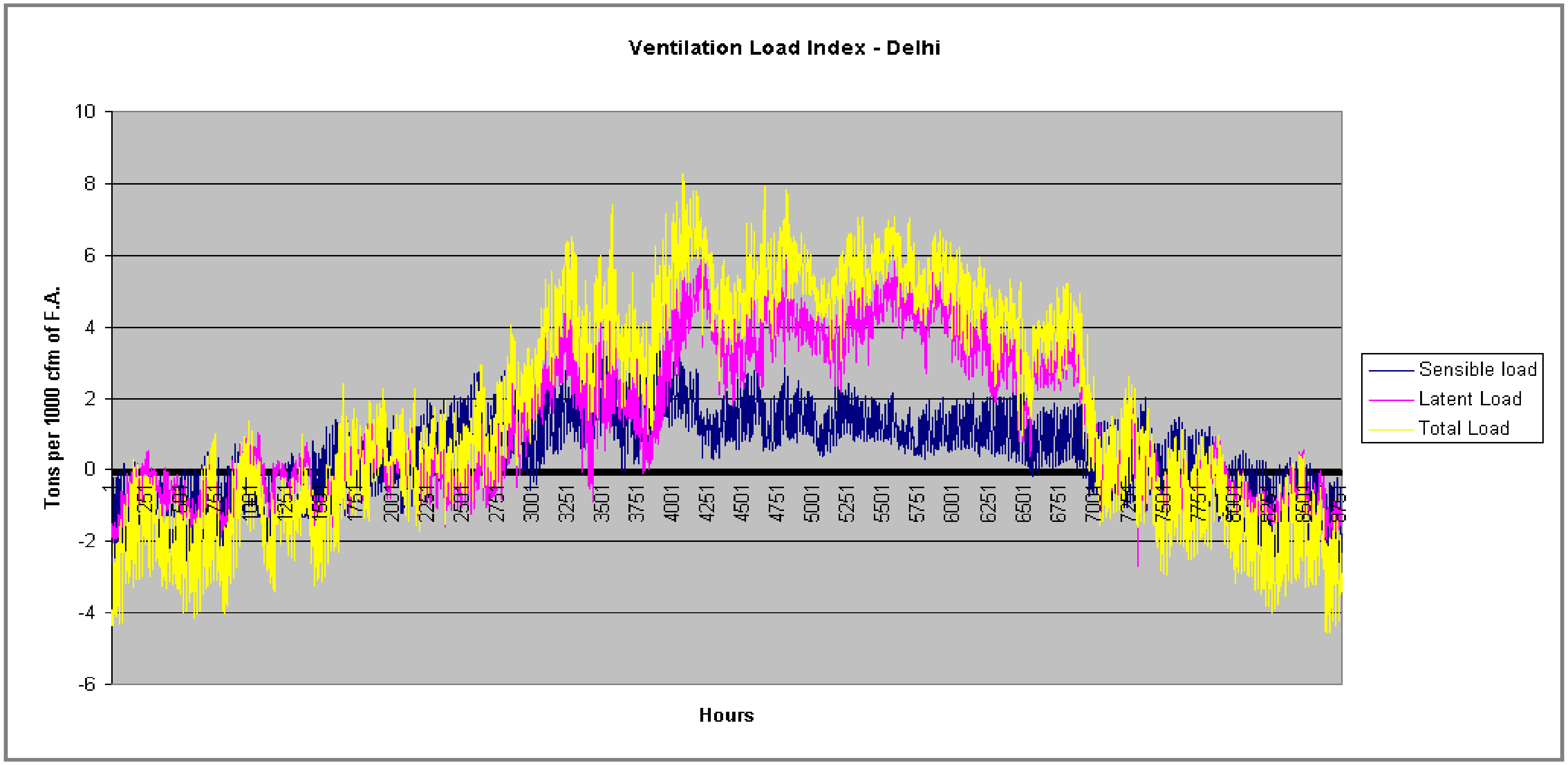
- High fresh air
- ↓
- High moisture flooding with fresh air
- ↓
- Lack of proper or direct moisture control
- ↓

Resultant moisture related problems
Mold, Moldew, Fungus ………

Ventilation Load

The "Ventilation Load Index" or VLI, is a fairly new term that is gaining popularity in our industry. It was introduced to emphasize the difference between the sensible and latent ventilation loads (in ton-hrs/cfm) of outside air introduced inside to a space neutral condition (72 degrees F/55% RH).

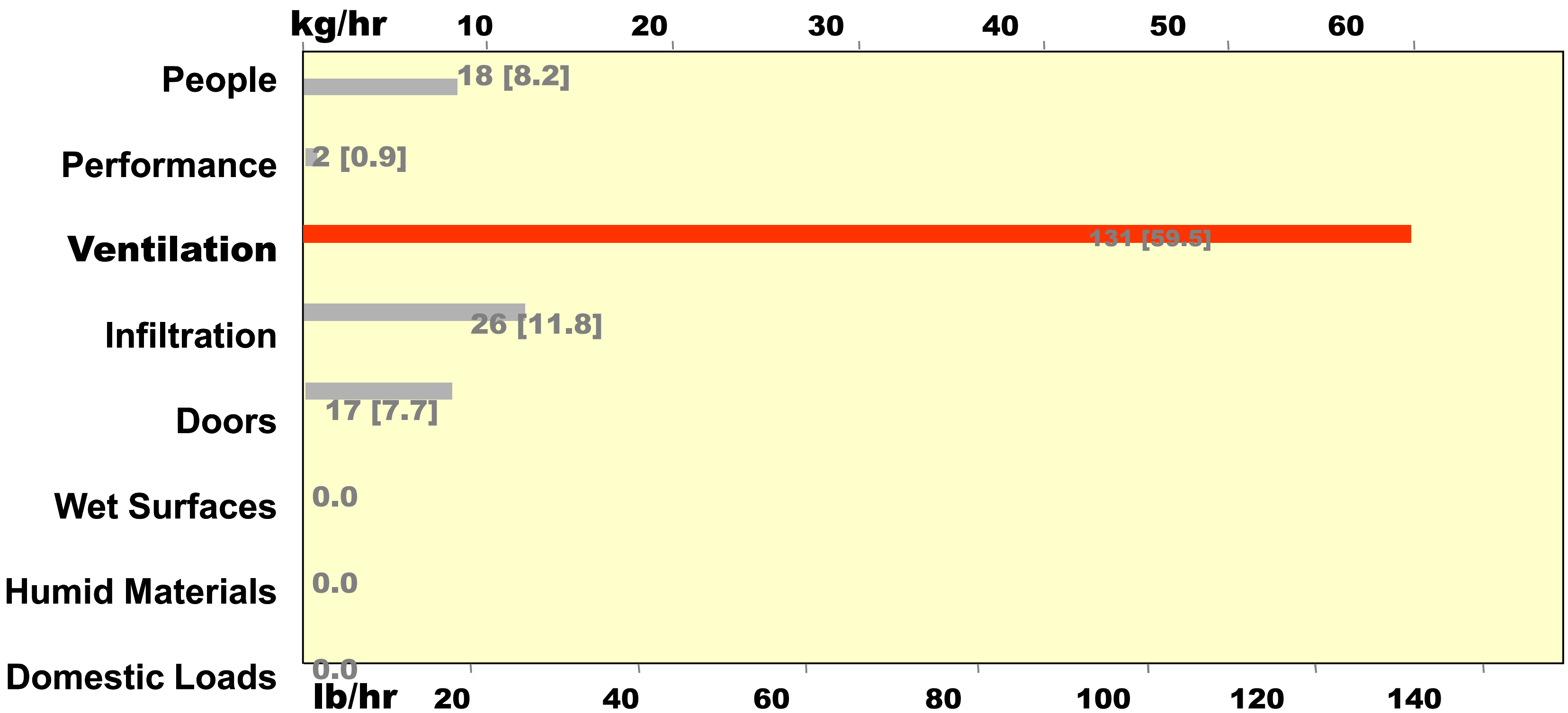
VLI Load Profile



Ventilation Load Index

City	Load per year			Saving with ERV (65% eff. / 1000 cfm) Ton – Hrs / Year		
	Ton - hours / SCFM					
Name	Sensible	Latent	Total			
Ahmedabad	8.78	16.61	25.39	5707	10797	16504
Amritsar	5.58	13.29	18.87	3627	8639	12266
Bangalore	3.35	16.02	19.37	2178	10413	12591
Bhopal	6.13	10.38	16.51	3985	6747	10732
Chennai	8.6	30.14	38.74	5590	19591	25181
Debnigah	3.48	19.55	23.03	2262	12708	14970
Delhi	6.94	14.22	21.16	4511	9243	13754
Guwahati	4.72	23.18	27.9	3068	15067	18135
Hyderabad	7.01	14.58	21.59	4557	9477	14034
Indore	5.74	9.25	14.99	3731	6013	9744
Jaipur	7.49	11.62	19.11	4869	7553	12422
Kolkata	6.85	27.62	34.47	4453	17953	22406
Lucknow	6.42	17.36	23.78	4173	11284	15457
Mangalore	6.64	26.6	33.24	4316	17290	21606
Mumbai	7.38	25.26	32.64	4797	16419	21216
Patna	6.78	20.48	27.26	4407	13312	17719
Pune	4.64	14.84	19.48	3016	9646	12662
Ranchi	4.32	15.66	19.98	2808	10179	12987
Trivandrum	7.68	17.12	24.8	4992	11128	16120
Vizag	7.78	30.72	38.5	5057	19968	25025

Load Characteristics (Typical)



The largest moisture load in most commercial buildings comes from the ventilation air.

Medium sized retail store in : Atlanta
During : 0.4% dewpoint conditions

Source : Lew Harriman

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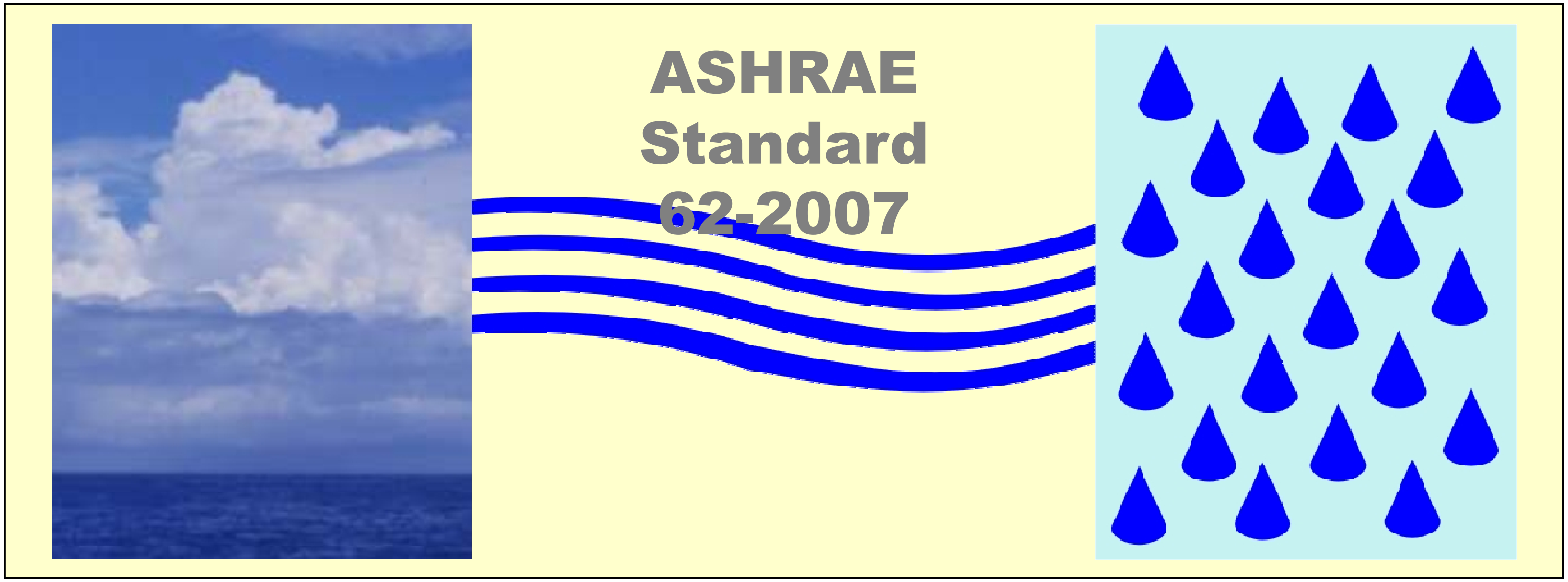
Have we traded one problem for another?

Can the two co-exist?

What are the design options?



- Fresh Air
- Adequate Ventilation Rate
- Good IAQ

- Adequate Fresh Air
- Excess Moisture
- Resultant Problems

Mould, mildew, fungus

The Designer's Dilemma

- *The conventional energy efficient building practices, resulted in construction of 'tighter' building spaces, using re-circulated air for ventilation. Poor design principles were employed to enable energy conservation in air-conditioned spaces, jeopardizing the health of the occupants.*
- *Fresh air ventilation runs contrary to the guidelines being followed by HVAC professionals. Higher fresh air ventilation needs translate into higher outdoor air changes per changes, which leads to more air-conditioning loads necessitating installation of higher capacity plants. This leads to higher initial cost and higher energy bills.*
- *The right humidity levels have to be maintained despite the increased ventilation rates and also to avoid expensive and inefficient solution like re-heat.*
- *New standards and increased awareness of the effect of IAQ on health necessitates the engineers and building designers conceptualize and provide cost effective solution to indoor air quality requirements.*

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Energy Recovery for cost effective IAQ

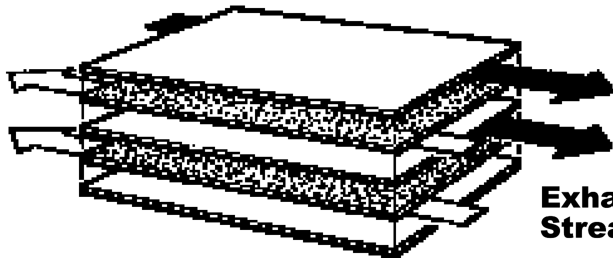
- Increased ventilation for IAQ translates as higher utility bills
- Need for effective management of energy systems
- Integrating energy recovery devices to air conditioning systems becomes imperative for meeting IAQ standards cost -effectively

AIR TO AIR HEAT EXCHANGE DEVICES LISTED ASHRAE EQUIPMENT HB 1988:

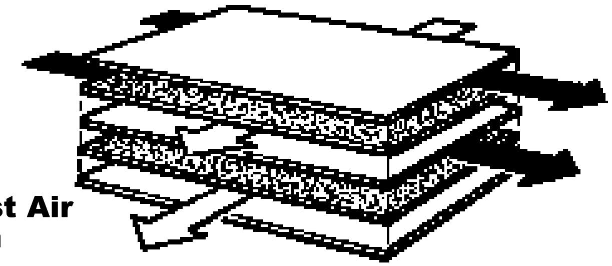
- Rotary Energy Exchangers
- Coil Energy Recovery Loop
- Twin-Tower Enthalpy Recovery Loop
- Heat Pipe Heat Exchangers
- Fixed Plate Exchangers
- Thermo-syphon Heat Exchangers

Heat Recovery Technologies

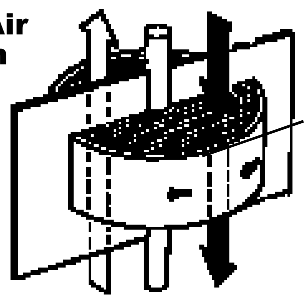
Flat Plate Core (Counter Flow)



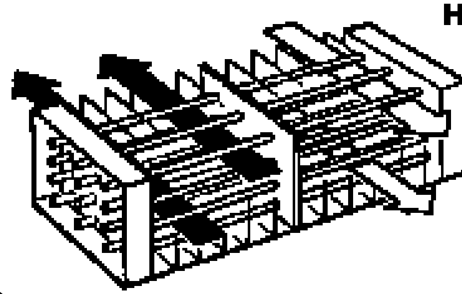
Flat Plate Core (Cross Flow)



Rotary Wheel Core



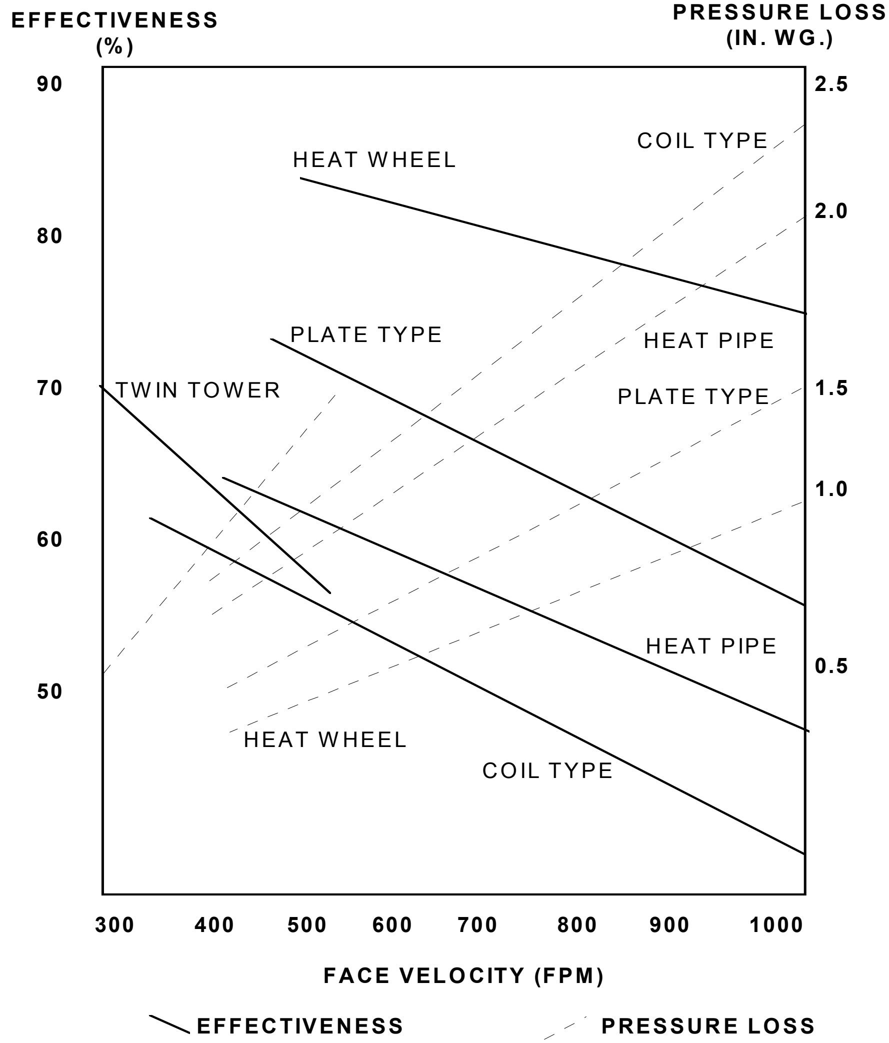
Heat Pipe Core



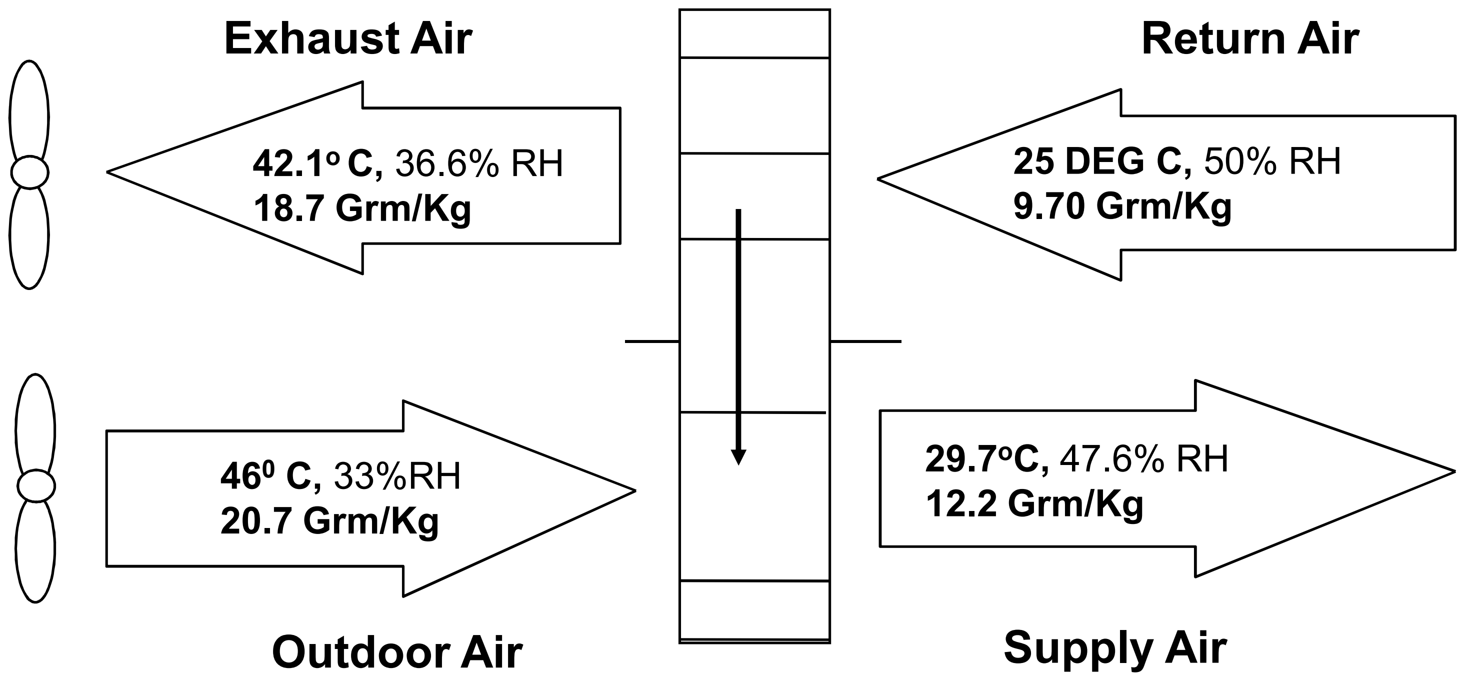
Most Effective Technology for Total Energy Recovery

Enthalpy Wheels - Appropriate choice for energy recovery in comfort ventilation

- The chart compares typical effectiveness and pressure drop data for different recovery device
- The enthalpy wheel has
  - the highest effectiveness
  - least pressure drop at any face velocity



Total Energy Recovery Wheel Principle of Operation



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Evaluation Parameters for Choosing Right Technology

Following are some parameters based on which one can evaluate each option and then test it for ones application. The various parameters important for picking up the right option are

i. Ventilation load profile

ii. Efficiency profile

iii. Substrate type / Desiccant type

iv. Pressure drops

v. Cross contamination

vi. Microbial growth on substrate

vii. Fire Rating

viii. Manufacturing Tolerances

ix. Structural Strength

Efficiency Profile

Total load (VLI)

S.No	Recovery Technology	Sensible Efficiency	Latent Efficiency	Total Efficiency for Mumbai
1	Sensible Rotary heat exchanger	77%	Nil	17%
2	Hygroscopic Rotary heat exchanger	68%	21%	32%
3	Desiccant based rotary heat exchanger	77%	77%	77%
4	Cross flow type	65%	Nil	15%
5	Heat Pipe based	60%	Nil	14%
6	Separated coil based	55%	Nil	13%

Substrate / Desiccant type

	Latent Efficiency	Desiccant Carryover
Etched (oxidized Alumunium)	Low	High
Molecular Sieve 3A^{O}	High	Negligible
Molecular Sieve 4A^{O}	High	Moderate
Silica Gel	High	High

Source : (GTRI report)

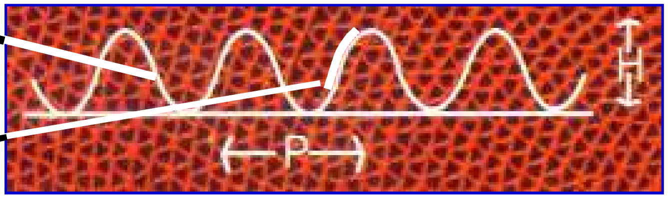
Pressure Drops

Pressure drops across the heat recovery wheel are dependent on following characteristics:

- Pitch Height/Width of Flute
- Substrate Type
- Fouling
- Heat Exchanger Width

Pitch Profile

Substrate
1. Thickness (gsm)
2. Specific Heat
3. Specific Gravity



Flute Geometry
p-pitch
h-height
d-depth

Coating
1. Thickness (gsm)
2. Isotherm
3. Heat of adsorption
4. Heat Capacity

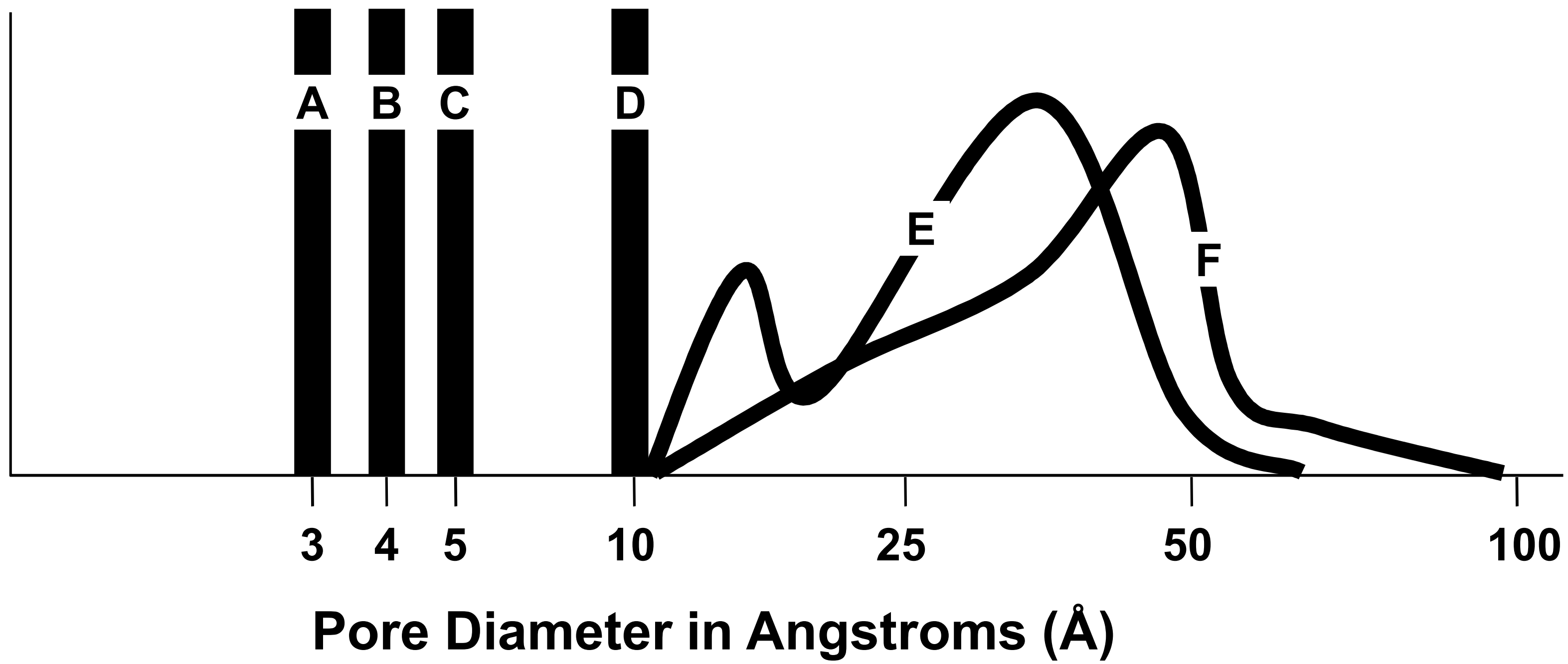
Recommended 0.1” per 100 FPM of Face Velocity

Pressure Drops

	Pressure Drop	Sensible Efficiency	Latent Efficiency
200mm deep etched aluminum substrate HRW	0.51”	68%	21%
270 mm deep desiccant based aluminum substrate HRW	0.76”	78%	76%
100 mm deep synthetic fibre HRW	1.24”	70.6%	66.8%

Cross Contamination

Variations in Pore Diameter among Desiccants



A - 3Å Molecular Sieve
B - 4Å Molecular Sieve
C - 5 Å Molecular Sieve
D - 10Å Molecular Sieve
E - Activated Alumina
F - Silica Gel

Critical Diameters of Various Molecules

All Diameters Expressed in Ångstrom Units

Helium	2.0	Propane, nC_4 to nC_{22}	4.9
Hydrogen, acetylene	2.4	Propylene	5.0
Water, oxygen, carbon monoxide carbon dioxide	2.8	Ethyl-mercaptan, butene 1, butene 2 trans	5.1
Nitrogen	3.0	Diflurochloromethane (R 22)	5.3
Ammonia, hydrogen sulfide	3.6	Iso C_{22}	5.6
Argon	3.8	Cyclohexane	6.1
Methane	4.0	Toluene, paraxylene	6.7
Ethylene, ethylene monoxide	4.2	Benzene	6.8
Ethane, methanol, ethanol	4.4	Carbon tetrachloride	6.9
Methyl-mercaptan	4.5	Methaxylene	7.1
		Tri-ethylamine	8.4

The possibility of adsorption depends not only on the dimension and the shape of the molecules (linear, ramified, cyclic...) but also on their polarity.

If there is no steric hindrance the molecules are preferentially adsorbed when their polarity is well pronounced.

Adsorption Increassing

H_2O
NH_3
CH_3, OH, alcohol, aldehydes, ketones
SO_2
H_2S, mercaptans
Alcynes
CO_2
Alcanes
CH_4
CO

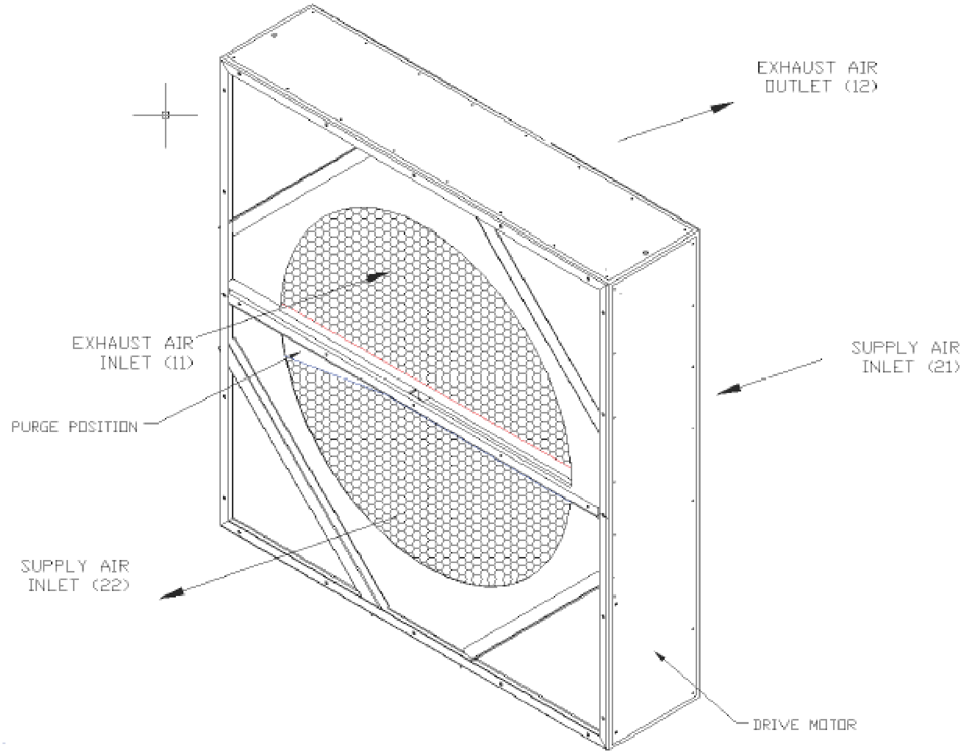
Cross Contamination

Common Pollutants	Molecular sieve $3A^{O}$	Molecular sieve $4A^{O}$	Oxidized Aluminum	Silica Gel
Acetaldehyde	0%	>30%	>50%	>50%
Acetic Acid	0%	30-50%	>50%	>50%
Acetone	0%	<10%	10-30%	10-30%
Amyl Alcohol	0%	0%	30-50%	30-50%
Benzene	0%	0%	10-30%	10-30%
Butanol	0%	10-30%	30-50%	30-50%
Butylacetate	0%	<10%	10-30%	10-30%
Butryic Acid	0%	0%	>50%	>50%
Carbon Dioxide	0%	1%	1-20%	1-20%
Chloroform	0%	0%	30-50%	30-50%
Cyclohexane	0%	0%	<10%	<10%
Dichlorobenzene	0%	0%	<10%	<10%
Dioxane	0%	30-50%	>50%	>50%
Ethanol	0%	30-50%	30-50%	30-50%
Ethyl Acetate	0%	0%	10-30%	10-30%

Desiccant Carryover (source Semco)

SF6 Tracer Gas Test

4.3 Tracer Gas Carry over Test



During the Carry over Test, the Purge was mounted to the shown **Purge Position.**

Purge mounted in Supply Air Leaving Zone

Test 5	qv	qm	t	x	ρ	h	qm2/qm1	n	pBaro	$\Delta p_{22\text{-}11}$	a_{11}	a_{22}	λ_{CO}
Purge Angle 3°	m^3/h	kg/h	°C	g/kg	kg/m^3	kJ/kg	-	-	Pa	Pa	ppm	ppm	%
Exhaust IN 11	3967	4499	19.4	4.7	1.134	31.46	1.00	25	95527	464.3	14.91	0.005	0.03
Exhaust OUT 12	5701	6512	17.3	4.7	1.142	29.33							
Supply IN 21	5842	6515	16.8	4.7	1.144	28.84							
Supply OUT 22	3958	4501	18.6	4.7	1.137	30.62							
Test 6	qv	qm	t	x	ρ	h	qm2/qm1	n	pBaro	$\Delta p_{22\text{-}11}$	a_{11}	a_{22}	λ_{CO}
Purge Angle 5°	m^3/h	kg/h	°C	g/kg	kg/m^3	kJ/kg	-	-	Pa	Pa	ppm	ppm	%
Exhaust IN 11	3967	4998	16.4	5.1	1.140	29.31	1.00	25	95059	251.3	22.20	0.008	0.04
Exhaust OUT 12	5701	6325	13.8	5.1	1.150	26.70							
Supply IN 21	5842	6327	13.1	5.1	1.153	25.93							
Supply OUT 22	3958	5000	15.4	5.1	1.144	28.37							

Microbial growth

TEST RESULTS

Test Methods / Protocol : As per guidelines of **DIN EN ISO 846**

Test Fungi Used :

Aspergillus niger	ATCC 9642
Penicillium funiculosum	ATCC 11797
Aureobasidium pullulans	ATCC 9348
Gliocladium vireus	ATCC 9645
Chaetomium globosum	ATCC 6205

Test Bacteria used :

Pseudomonas aeruginosa ATCC 25668

Incubation Temperature : Fungus : 24 ± 1°C, RH > 95%
Bacteria : 29 ± 1°C, RH > 90%

Incubation Period : 4 weeks

Microbicidal solution used :
Ethanol – water mixture (70 : 30)
o-phenylphenol

Results of the Investigation
(Visual assessment)
The results of the investigations carried out, according to the table no. 4 of reference protocol, are summarized below

Material for investigation	Intensity of the microbial growth	
	Fungus	**Bacteria**
Laminated sheets (coated with ECO Sorb 100) marked as A	0 (No growth apparent under microscope)	0 (No growth apparent under microscope)

Contd. to Report No. 25002 (Page 1 of 3)

18/07/07

AUTHORISED SIGNATORY

NOTE 1. The result listed refer only to the tested sample(s) and applicable parameter(s). Endorsement of products is neither inferred nor implied.

Microbial growth

TEST RESULTS

Interpretation of Results :

The interpretation of results is carried out according to table no. 5 of the reference protocol

Method	Intensity of Growth	Assessment of test material
A and C	0	The material is not a nutritive medium for microorganisms(it is inert or fungistatic and bacteristatic

Test Procedures :

Method A (Resistance to Fungus)
For determination of resistance of the test pieces against fungi, incomplete agar medium without a carbon source was used.

Arrangement & Identification of specimens

Batch 0
Control specimens, stored under standard temperature and moisture conditions

Batch 1 (inoculated specimens)
Incomplete agar medium was poured into sterile petri plates and after solidification of the medium, specimens were placed onto the surface of agar. Specimens and the media was sprayed with a spore suspension of the test fungi at a concentration of about 10^6 spores / ml

Batch 5 (Sterile specimens)
Specimens were disinfected by dipping them into o-phenylphenol solution and were placed over the surface of incomplete agar medium and stored under standard temperature and moisture conditions

Method C (Resistance to Bacteria)
For determination of resistance of the test pieces against bacteria, mineral salt agar without a carbon source was used.

Contd. to Report No. 25003 (Page 2 of 3)

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Dy. Director/AD Chief
Sr.Scientist/Scientist

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Microbial growth

TEST RESULTS

Arrangement & Identification of specimens

Batch I (Inoculated specimens)
The media was mixed with bacterial cell suspension to achieve approximately 50,000 cells per ml of agar and poured into sterile petri-plates. After the agar has solidified, specimens were placed onto the agar surface and covered with a layer of inoculated agar.

Batch S (Sterile controls)
Uninoculated mineral-salt agar was poured into sterile petri plates.
Specimens were disinfected by dipping them into o-phenylphenol solution and were placed on the solidified agar. The agar was also disinfected with the same solution The specimens were covered with a layer of uninoculated agar.

Each testing was carried out with 10 comparison cases. The test specimens were incubated for a period of 4 weeks for both fungus and bacteria and were examined visually (after 2 and 4 weeks for growth) with naked eye as well as by using a stereo microscope having a magnification of x 50.

Concluding remarks

The material is not a nutritive medium for microorganisms (it is inert or fungistatic and bacteriostatic)

****

D.O.R. – 12.12.2001
D.O.C. – 16.03.2002

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Fire Rating

TEST PROCEDURE

The results of the tests are expressed by indexes which compare the characteristics of the sample under tests relative to that of select grade red oak flooring and asbestos-cement board.

(A) **FLAME SPREAD CLASSIFICATION:**

This index relates to the rate of progression of a flame along a sample in the 25 foot tunnel.

A natural gas flame is applied to the front of the sample at the start of the test and drawn along the sample by a draft kept constant for the duration of the test.

An observer notes the progression of the flame front relative to time. This information is plotted on a graph (flame spread curve).

The test apparatus is calibrated such that the flame spread classification for red oak flooring is 100, and 0 for asbestos-cement board.

CALCULATIONS: **ASTM E84-95**

According to the test standard, the flame spread classification is equal to $\frac{4900}{(195 - A_t)}$ when

A_t is the total area beneath the flame spread curve, if this area exceeds 97.5 minute feet.

If the area beneath the curve is less than or equal to 97.5 minute feet the classification becomes $0.515 \times A_t$.

Fire Rating

TEST RESULTS

FLAME SPREAD

The resultant flame spread classifications are as follows:
(rounded to nearest 5)

Molecular Sieve Desiccant Coated Corrugated Aluminum Foil	Flame Spread	Flame Spread Classification
Run 1	0	0

SMOKE DEVELOPED

TEST PROCEDURE (Continued)

(B) SMOKE DEVELOPED:

A photocell is used to measure the amount of light which is obscured by the smoke passing down the tunnel duct.

When the smoke from a burning sample obscures the light beam, the output from the photocell decreases. This decrease with time is recorded and compared to the results obtained for red oak which is 100.

CALCULATIONS:

$$\frac{10{,}000 - (\text{smoke integrater reading}) \times 100}{3356} = \text{smoke developed}$$

SMOKE DEVELOPED

TEST RESULTS

SMOKE DEVELOPED

The areas beneath the smoke developed curve and the related classifications are as follows: (rounded to nearest 5)

Molecular Sieve Desiccant Coated Corrugated Aluminum Foil	Smoke Developed	Smoked Developed Classification
Run 1	3	5

Manufacturing Tolerances

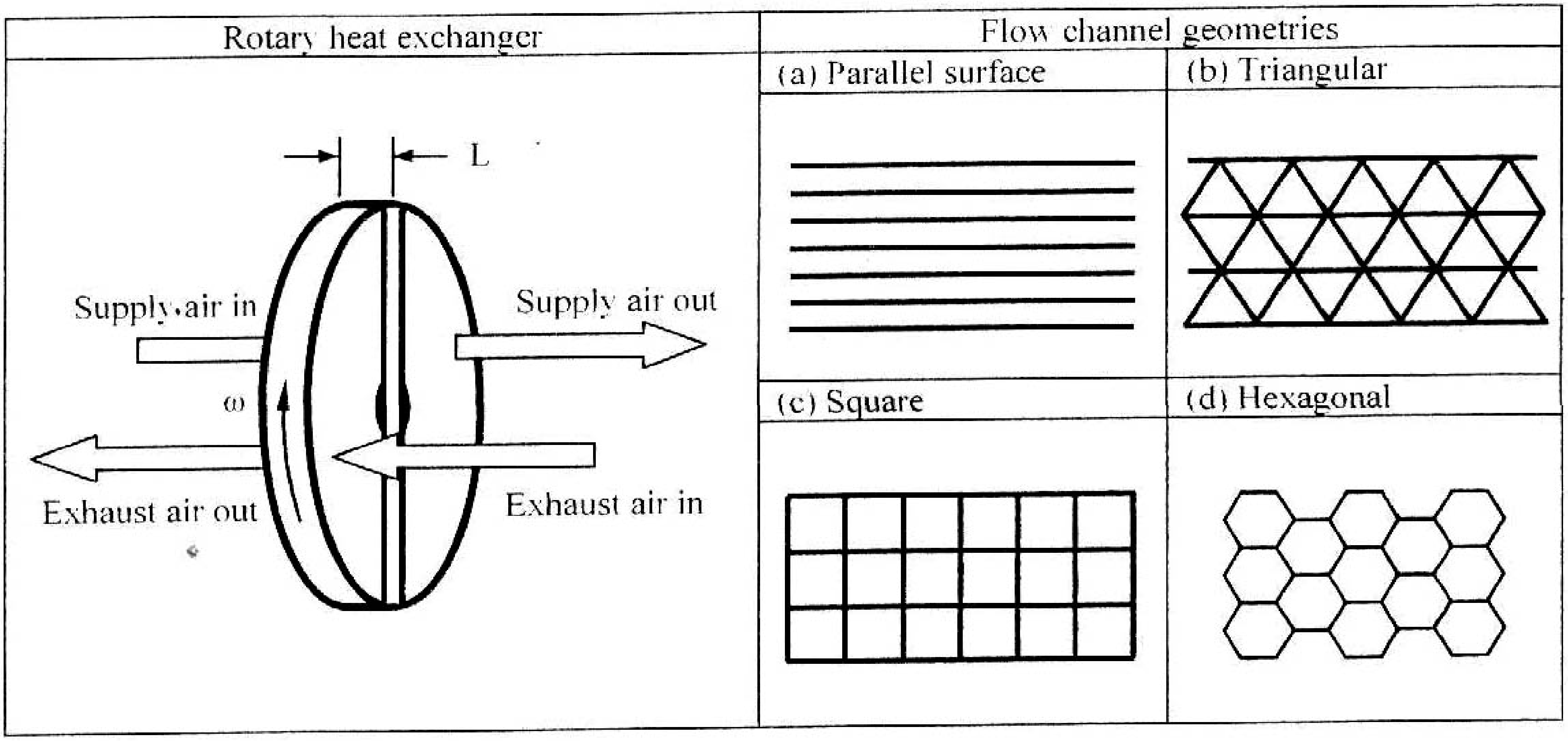
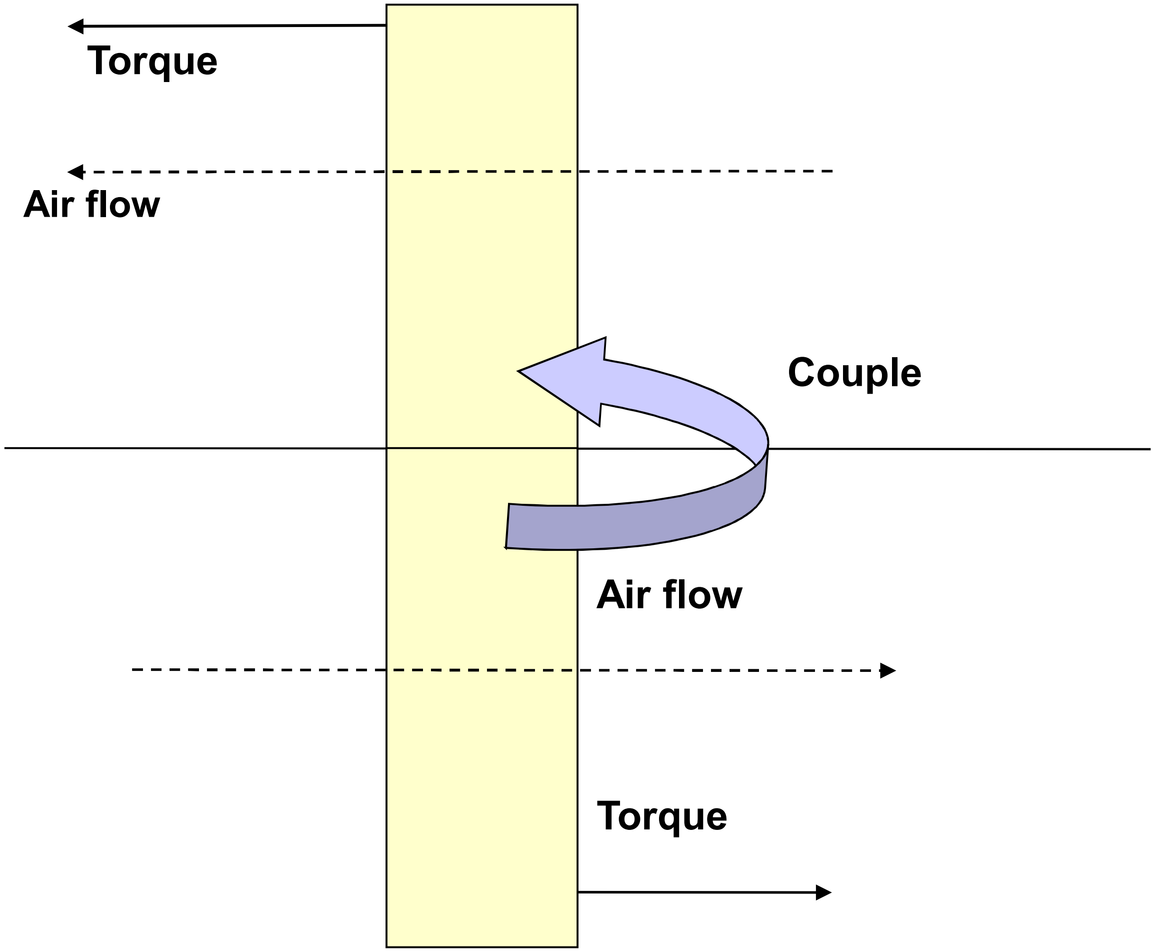


Fig. 1 A typical rotary heat exchanger and four different flow channel geometries

Structural Strength



LCS (Life Cycle Savings)

Wheel Type	Sensible Efficiency	Latent Efficiency	TR Recovery	Annual Energy Savings (A)	Pressure Drop (Pa)	Energy Consumption of TFA/year (B) (with Additional 200 pascal for external/ filters)	Net savings/ Year C= (A-B)	Savings in First cost due to TR Reduction (D)	Savings for Ist Year of operations C+D	*Savings for 15 Years E=15C+ D*
Wheel A	68%	21%	24.8	3,46,000/-	170	1,53,120/-	1,92,880-	6,20,000/-	8,12,880-	35,13,200/-
Wheel B	77%	77%	62.8	8,80,000/-	195	1,63,152/-	7,16,848/-	15,70,000/-	22,86,848/-	1,23,22,720/-
Wheel C	68.7%	64.6%	53.8	7,47,500/-	333	2,11,200/-	5,36,300/-	13,45,000/-	18,81,300/-	93,89,500/-

Outside Conditions = 90DB/86WB

Inside Conditions = 72 DB / 62 WB / 55% RH

Wheel A = 200 mm deep Aluminum substrate Hygroscopic wheel

Wheel B = 270 mm deep Aluminum substrate MS $3A^0$ coated wheel

Wheel C = 100 mm deep synthetic fibre MS $4A^0$ wheel

CFM = 10000 (1800 mm wheel dia)

CITY = KOLKATA

VLI = 34.47 TR-hr/cfm/yr

CALL CENTRE = 16 HR OPERATION

300 days per yr

Power Consumption = 1.1 kw/ TR

Chilled Water System = Rs. 25000/ TR

Qualitative Factors

Wheel Type	Cross Contamination	Microbial growth	Fire Rating	Structural Strength	Manufacturing Tolerances
Wheel A	HIGH	NIL	SUITABLE	MODERATE	MODERATE
Wheel B	NIL	NIL	SUITABLE	HIGH	NEGLIGIBLE
Wheel C	MODERATE	PROBABILITY	RISK	LOW	MODERATE

Wheel A = **200 mm deep Aluminum substrate Hygroscopic wheel**

Wheel B = **270 mm deep Aluminum substrate MS $3A^0$ coated wheel**

Wheel C = **100 mm deep synthetic fibre MS $4A^0$ wheel**

Other Considerations

While finalizing recovery system it is also important that some more aspects be kept in mind while finalizing HVAC design. Some such considerations are

- Balanced/ Unbalanced air flow
- Corrosive Environment
- Redundancy
- Casing leakage Standard
- Space requirements/ Duct adequacies
- Purge

Balanced/Unbalanced Air Flow

Many designers simply use 50 – 70 % of the exhaust air (leave rest for leakage) to recover energy citing the need to keep positive pressure to reduce infiltration. Although the thought is fine but modern building have very low leakage class and a 10%unbalance in the supply air/ exhaust air is sufficient to satisfy that need. Dumping 30-40% exhaust is a waste of energy.

$$\text{Unbalance} = \frac{SA - EA}{SA} \times 100 \quad \%$$

Corrosive Environment

If the internal or external environment is highly corrosive i.e. has a very level of acidic or basic compounds, adequate case should be taken to choose the right substrate. Many manufacturers specify special substrate for highly acidic environments like battery manufacturing etc. Even for mildly corrosive environment like Animal houses special wheels made by manufacturers, are available. Also organic vapours also effect the latent recovery of the wheel and has a masking effect on desiccant. Special filters for such application are advised.

Redundancy

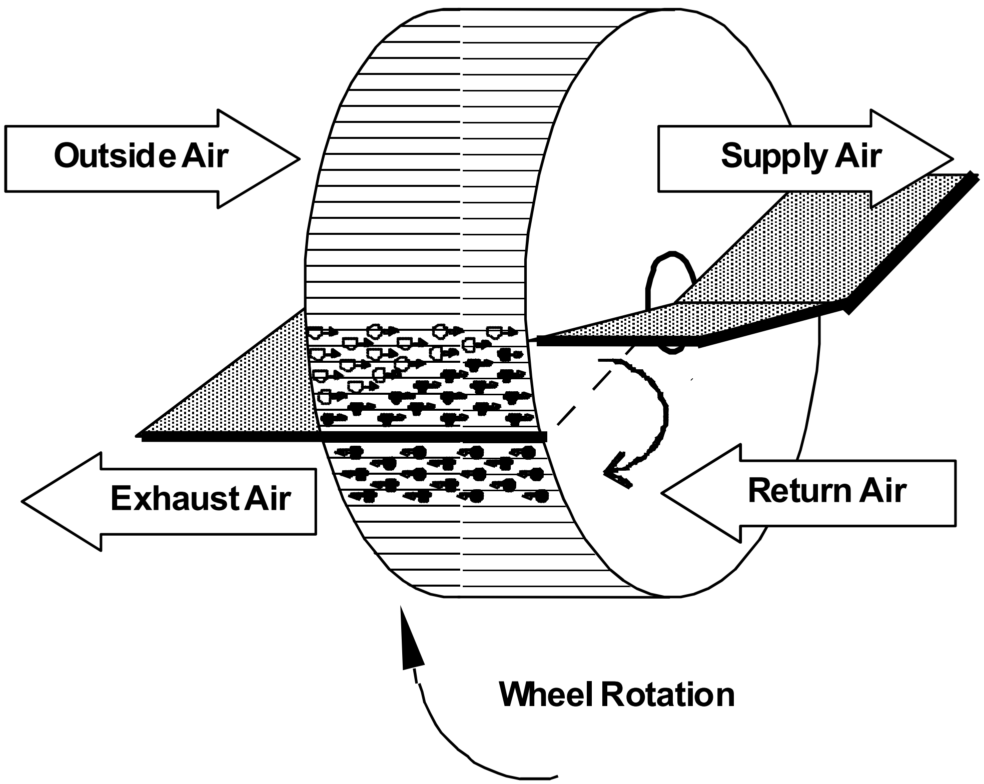
Once a recovery system is put in place, automatically the load requirement reduces. It has been a practice to keep the chiller tonnage as designed (without recovery) and use the recovery device for energy saving only.

Such redundancy not only increases the first cost but also makes the chillers run on partial loads all the time.

This reduces the efficiency of chiller as they are most efficient of full load.

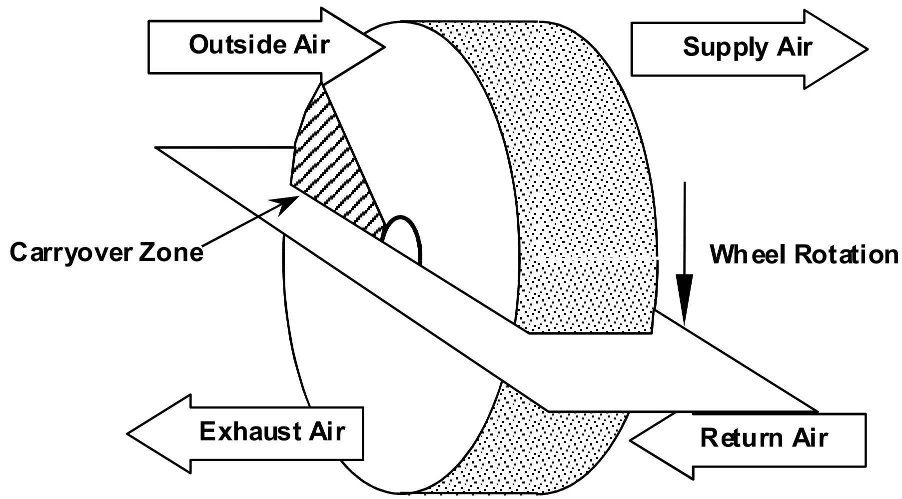
Illustration of Wheel Purge Section

Theory of Operation - A specific volume of air is allowed to bypass into exhaust air stream, minimizing carryover of contaminants from return air.



Purge angle is a function of air velocity, and purge volume is a function of wheel volume and rotation speed.

Media Carry Over



Due to the fixed volume of air being transferred as the wheel rotates, cross contamination of the air streams occurs.

CHECK LIST

Efficiency	:	S.E. > 75% L.E. > 75%
Pressure Drop	:	less than 0.1" per 100 FPM
Substrate	:	Aluminum
Desiccant	:	Desiccant MS $3A^0$
Microbial Growth	:	Tested for 0% growth of fungi / Bacteria as per DIN EN ISO 846.
Fire Rating	:	Should be 0% Flame spread 0-5 class for smoke developed
Manufacturing Tolerance	:	Minimum deviation from mean hydraulic diameter vertical winding
Structural Strength	:	Suggested 200 mm deep or higher
Purge	:	Must
Balance	:	10% unbalance
Corrosive Environment	:	Right substrate
Redundancy	:	Remove extra chiller capacity
Casing	:	Class B of Eurovent Standard

Our Presentation Today

- Indoor Air Quality Concept
- Fresh Air Energy Design Dilemma
- Energy Recovery Options
- Heat Recovery Wheel Evaluation Parameters
- **Heat Recovery Wheel Applications Green Buildings / Hospitals**
- RH Management Concerns
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- DOAS Integration with Parallel system / Chilled beams
- Dehumidification Technology for swimming Pools
- Commercial Air & Gas Purification Units
- Cooling Pads Air Conditioning for Dry Places

Green Building

A green building is an environmentally sustainable building-designed, constructed and operated to minimize the total environmental impacts.

The main strategy to achieve a green building status includes:

- **Reduced energy consumption**
- **Better IEQ (Indoor Environmental Quality)**
- **Water conservation**
- **Recycling waste**

LEED

- LEED (Leadership in Energy & Environmental design) is a “Green Building Rating System” which attempts to certify and push the advancement of a global implementation of green buildings and development standards.

- Under LEED extra points can be gained by increasing the Fresh Air Quantity by at least 30% above the minimum rates required by ASHRAE standard 62% 2007 as determined by EQ-requisite 1.

Outdoor Air Requirements for Ventilation of Air Conditioned Spaces

The LEED standard states “Increase breathing zone outdoor air ventilation rates to all occupied spaces by at least 30% above the minimum rates required by ASHRAE Standard 62.1-2007 as determined by EQ Prerequisite 1”.

This increased amount of ventilation has definitely solved IAQ related problems, but the inability to maintain the right humidity by our HVAC systems has lead us to other problems.

Mold & Mildew are serious dilemma in itself, which are caused by lack of humidity control. The question is “Have we Traded one problem with the other”.

Olympia Tech. Park - Chennai, India

Fresh Air Facts

- Internal room comfort at 730 F +_ 2 and RH not exceeding 60% as against a prevailing norm of 730 F +_ 2 and RH not exceeding 65 %.
- Installation of **carbon dioxide sensors** to monitor indoor air quality and replace stale CO_2 laden air with a fresh in-draft whenever C02 exceeds a certain level.
- Planned indoor **fresh air quality at 20 CFM per person** (ASHRAE Standards) as against the prevailing norm of 15 CFM.
- **Air replacement cycle** adapted to the number of people present in the indoor area; when the number of people declined, the sensors monitor this accordingly and slow down the air replacement frequency from five per hour to two per hour and vice versa.
- 102 no.'s of Treated Fresh Air Units model FLE-150 with **Heat Recovery Wheels** Model HRW-950, each handles 2400 cfm of fresh air.

Why do you need to Treat Fresh Air in

Special Areas

- Operation Theaters
- Nurseries
- Burn Wards
- ICUs
- Labs
- Isolation Wards (TB, HIV, etc.)

To

- Avoid infection from spreading
- Maintain IAQ
- Keep Utility/Air conditioning Bills down

Hospital Vs. General Building Airconditioning

- To restrict air movement in and between various depts.
- For ventilation and filtration ….
  - ➲ To dilute and remove contamination--
  - ➲ odour, airborne micro-organisms, viruses, hazardous chemical and radioactive substances.
- Varying temperature and humidity requirements.
- Design sophistication needed…
  - ➲ For accurate control of environmental conditions

APPENDIX E
VENTILATION RATES FOR HEALTH CARE FACILITIES, RESIDENTIAL BUILDINGS, AND VEHICLES

TABLE E-1*
Outdoor Air Requirements for Ventilation of Health Care Facilities (Hospitals, Nursing and Convalescent Homes)

Application	Estimated Maximum** Occupancy P/1000 ft^2 or 100 m^2	Outdoor Air Requirements cfm/ person	L/s · person	cfm/ft^2	$L/s \cdot m^2$	Comments
Patient rooms	10	25	13			Special requirements or codes and pressure relationships may determine minimum ventilation rates and filter efficiency. Procedures generating contaminants may require higher rates.
Medical procedure	20	15	8			
Operating rooms	20	30	15			
Recovery and ICU	20	15	8			
Autopsy rooms	20			0.50	2.50	Air shall not be recirculated into other spaces.
Physical therapy	20	15	8			

* Table E-1 prescribes supply rates of acceptable outdoor air required for acceptable indoor air quality. These values have been chosen to dilute human bioeffluents and other contaminants with an adequate margin of safety and to account for health variations among people and varied activity levels.

** Net occupiable space.

Source: ASHRAE STANDARD 62.1

Medicity Hospital, India

Good IAQ and high energy efficiency in Medicity are maintained through properly designed HVAC systems. DRI has installed 24 units of Treated Fresh Air Units (TFAs) to ensure considerable reduction in installed tonnage, reduction in utility bills for entire life cycle, enhanced IAQ and productivity and reduced health risks.

- Total Fresh Air provided by DRI TFA's = 1,19,300 cfm
- Air Conditioning tonnage reduction = 526 TR

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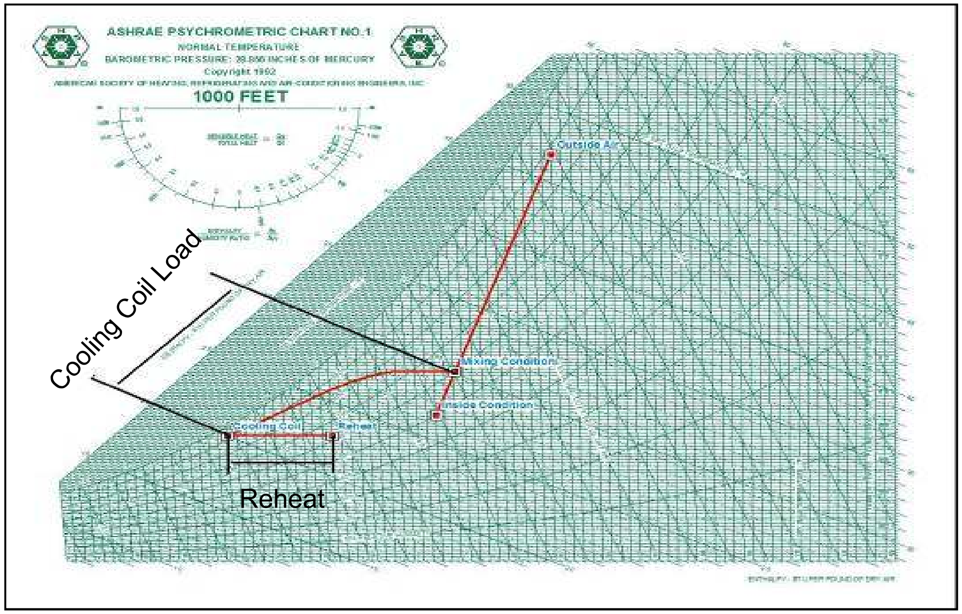
Control Strategies



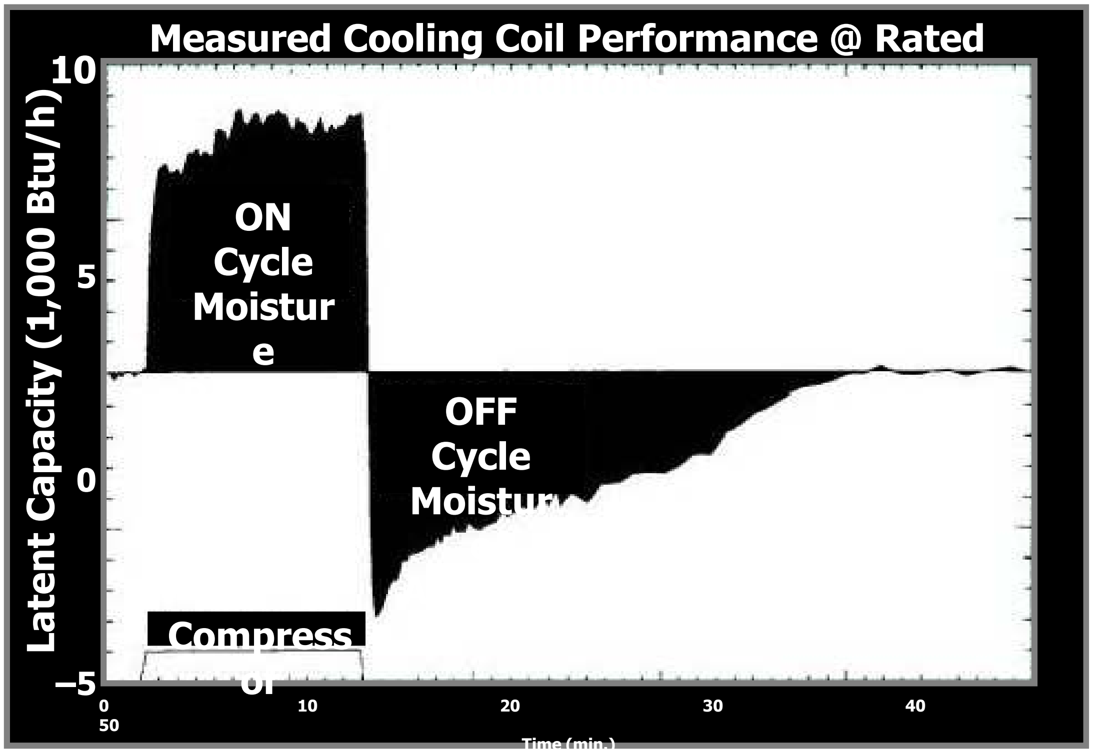
Baseline system with Reheat

Traditionally one would immediately talk about a system with low ADP. i.e., having low chilled water temperature, high row deeps (8 row or deeper) and reheat with active energy.

Such systems do help but are highly inefficient and drain lot of energy. The fact that one has to first sub-cool and then add active reheat wasting energy twice.

An example of passive Humidity/Moisture control in a 3 ton unit

This is what happens in conventional air-conditioning units handling high moisture loads with little sensible loads.



Moisture removal by a conventional cooling unit is small or negligible unless the run time is in excess of 40 to 50%.

Research by Hensender

After the compressor shuts off, moisture condensed on the cooling coil re-evaporates

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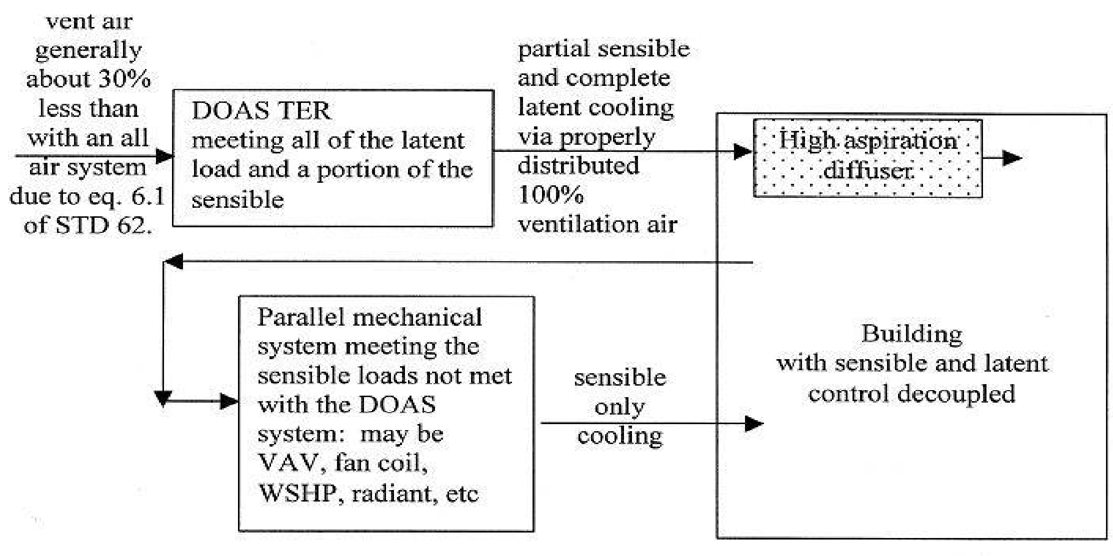
DOAS Approach



- Divide the load into the two components i.e. Sensible & Latent.
- Approach commonly referred to as the "Divide and Conquer".
- All the latent load brought by outside air is removed at the source & also air is supplied at a low dew point to take care of internal latent load.
- The parallel internal cooling devices are then limited to take care of sensible cooling load.

Consider a two storied Call Center in Mumbai with the following load profile

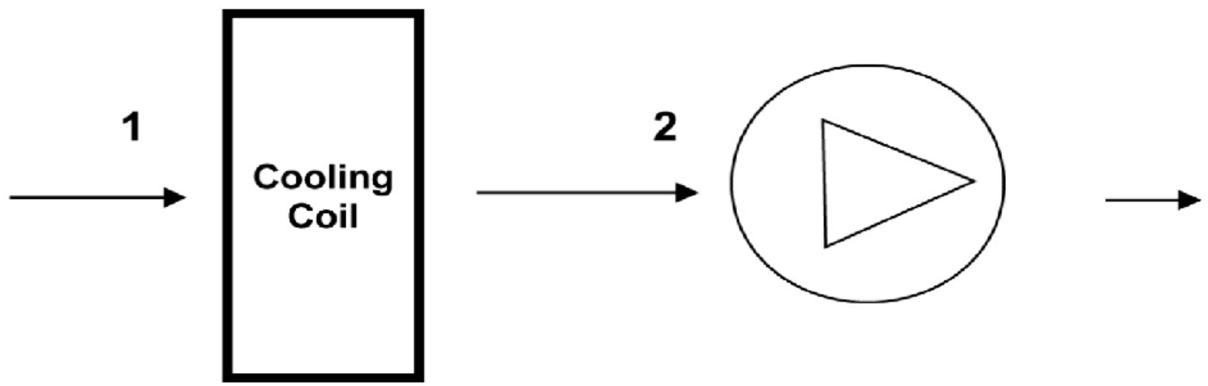
1) Peak Wet Bulb temperature with mean coincidental dry bulb (0.4%) (peak enthalpy)	=	93^{O}F DB/82^{O} FWB/149 gr/lb
2) Inside condition	=	72^{O}F DB/55% RH/65gr/lb
3) Inside Load pattern		
GROUND FLOOR (GF)		
Effective room Sensible Heat	=	451680 Btu/hr
Effective room Latent Heat	=	98000 Btu/hr
Occupancy	=	300 Persons
FIRST FLOOR (FF)		
Effective room Sensible Heat	=	515832 Btu/hr
Effective room Latent Heat	=	101000 Btu/hr
Occupancy	=	325 Persons
4) Outdoor Air Flows		
GROUND FLOOR (GF)	=	300 x 20 = 6000 cfm with 20 cfm per person
FIRST FLOOR (FF)	=	325 x 20 = 6500 cfm
5) Humidity Ratio rise for DOAS to maintain 65 gr/lb inside		
GROUND FLOOR (GF)		
Effective room Latent Heat	=	98000 Btu/hr
Bypassed OA Latent Heat (6000 x (149-65) x0.68x0.12)	=	41126 Btu/hr
1.2 - Bypass Factor Internal Latent Loads W/o OA load	=	56874 Btu/hr
Humidity Rise ΔWGF	=	$\frac{56874}{0.68 \times 6000}$ = 13.9gr/lb
FIRST FLOOR (FF)		
Effective room Latent Heat	=	101000 Btu/hr
Bypassed OA Latent Heat (6500 x (149-65) x0.68x0.12)	=	44554 Btu/hr
Internal Latent Loads W/o OA load	=	56446 Btu/hr
Humidity Rise ΔWFF	=	$\frac{56446}{0.68 \times 6500}$ = 12.8gr/lb
Hence we choose ΔW Selected	=	13.9gr/lb
6) Supply air dew point (DOAS)		
W **supply**	=	W **Inside** – ΔW Selected = 65 – 13.9 = 51.1 gr/lb
T **supply**	=	49^{O}F Dew point
7) Supply air Temperature (DOAS)	=	70^{O}F

Hence one can design a Dedicated Outside Air System with 70^{O}F DB/ 49^{O} F DP as supply air condition and internal AHU's will work as sensible cooling devices only.

DOAS Evaluation

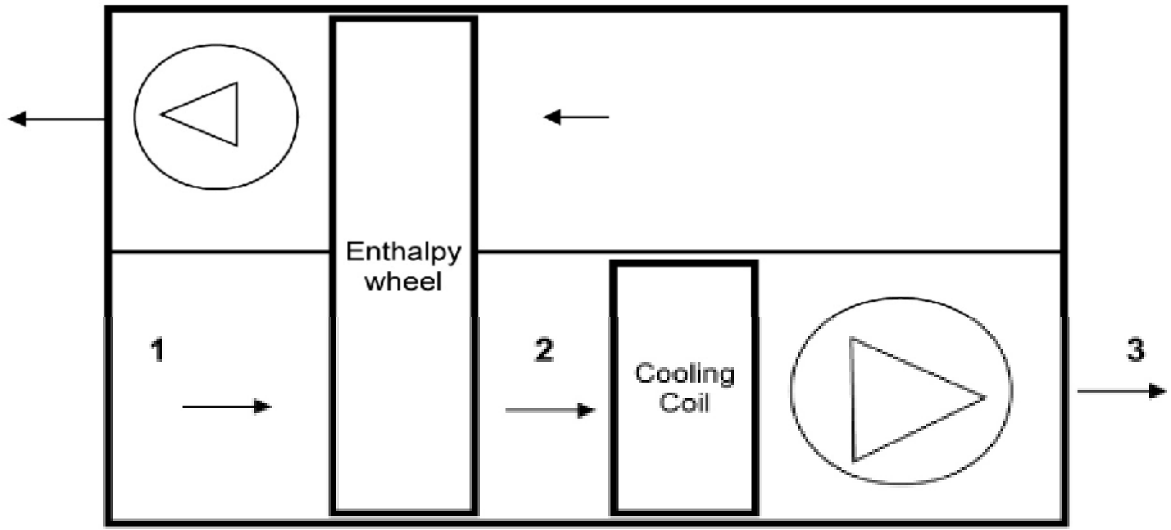
- **OPTION I** : Baseline system with dehumidification coil only (CC)
- **OPTION II** : Rotary passive desiccant air-to-air heat exchanger coupled with dehumidification coil. (EW+CC)
- **OPTION III** : Rotary passive desiccant air-to-air heat exchanger coupled with dehumidification coil and sensible air to air heat exchanger. (EW+CC+SW)
- **OPTION IV** : Active desiccant dehumidification wheel (with condenser heat reactivation) coupled with DX Cooling coil. (CC+ADESW)
- **OPTION V** : Rotary passive desiccant air-to-air heat exchanger coupled with dehumidification coil and passive desiccant dehumidification wheel. (EW+CC+PDHC)

Schedule of DOAS System with Cooling Coil



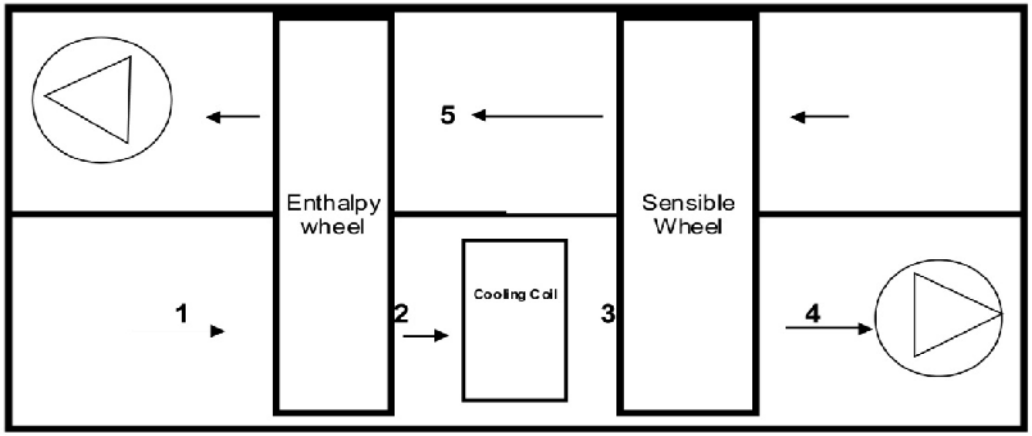
S.No.	1				2		
	Outdoor Air Conditions				Supply Air Conditions		
	cfm	DBT °F	grs/lb	Btu/lb	DBT °F	grs/lb	Btu/lb
1	1000	95	152.98	46.93	48.75	51.1	19.6
2	1000	85	162.27	45.88	48.75	51.1	19.6

Schedule of DOAS with Enthalpy Wheel and Cooling Coil



S.No.	1				2			3		
	Outdoor Air Conditions				Off Wheel Conditions			Off Coil Conditions		
	cfm	DBT °F	grs/lb	Btu/lb	DBT °F	grs/lb	Btu/lb	DBT °F	grs/lb	Btu/lb
1	1000	95	152.98	46.93	80	91.89	33.6	48.75	51.1	19.6
2	1000	85	162.27	45.88	77.5	94.21	33.35	48.75	51.1	19.6

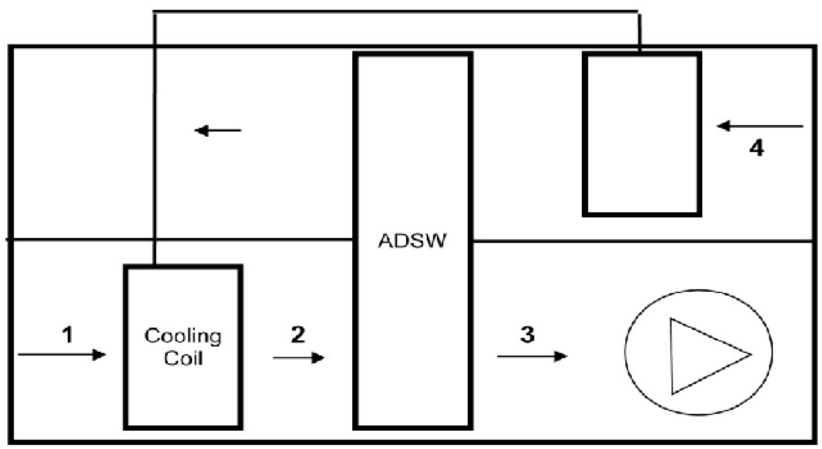
Schedule of DOAS with Enthalpy Wheel, Cooling Coil and Sensible Wheel



S.No.	1				2			3			4			5		
	Outdoor Air Conditions				Off Wheel Conditions			Off Coil Conditions			Supply Air Conditions			Return Air on EN Wheel		
	cfm	DBT °F	grs/lb	Btu/lb	DBT °F	grs/lb	Btu/lb	DBT °F	grs/lb	Btu/lb	DBT °F	grs/lb	Btu/lb	DBT °F	grs/lb	Btu/lb
1	1000	95	152.98	46.93	68.19	91.89	30.69	48.75	51.1	19.6	64.5	51.1	23.43	59.25	71.52	25.33
2	1000	85	162.27	45.88	65.89	94.21	30.44	48.75	51.1	19.6	64.5	51.1	23.43	59.25	71.52	25.33

Schedule of DOAS with Cooling Coil and Active Desiccant Wheel

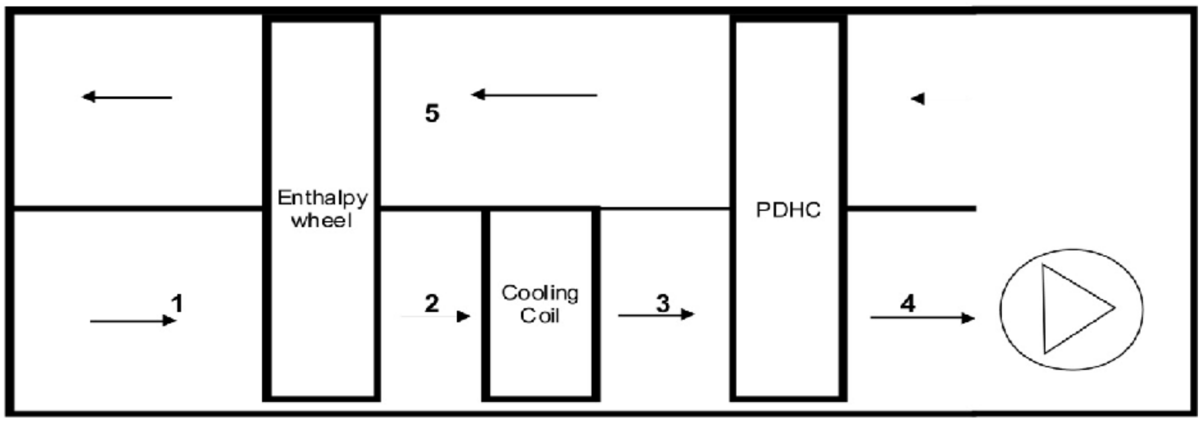
(React with Condenser Heat at 120°F)



S.No.	1 & 4				2			3		
	Outdoor Air Conditions				Off Coil Conditions			Off Wheel Conditions		
	cfm	DBT °F	grs/lb	Btu/lb	DBT °F	grs/lb	Btu/lb	DBT °F	grs/lb	Btu/lb
1	1000	95	152.98	46.93	55.64	66.1	23.6	75.64	51.10	26.15
2	1000	85	162.27	45.88	55.64	66.1	23.6	75.64	51.10	26.15

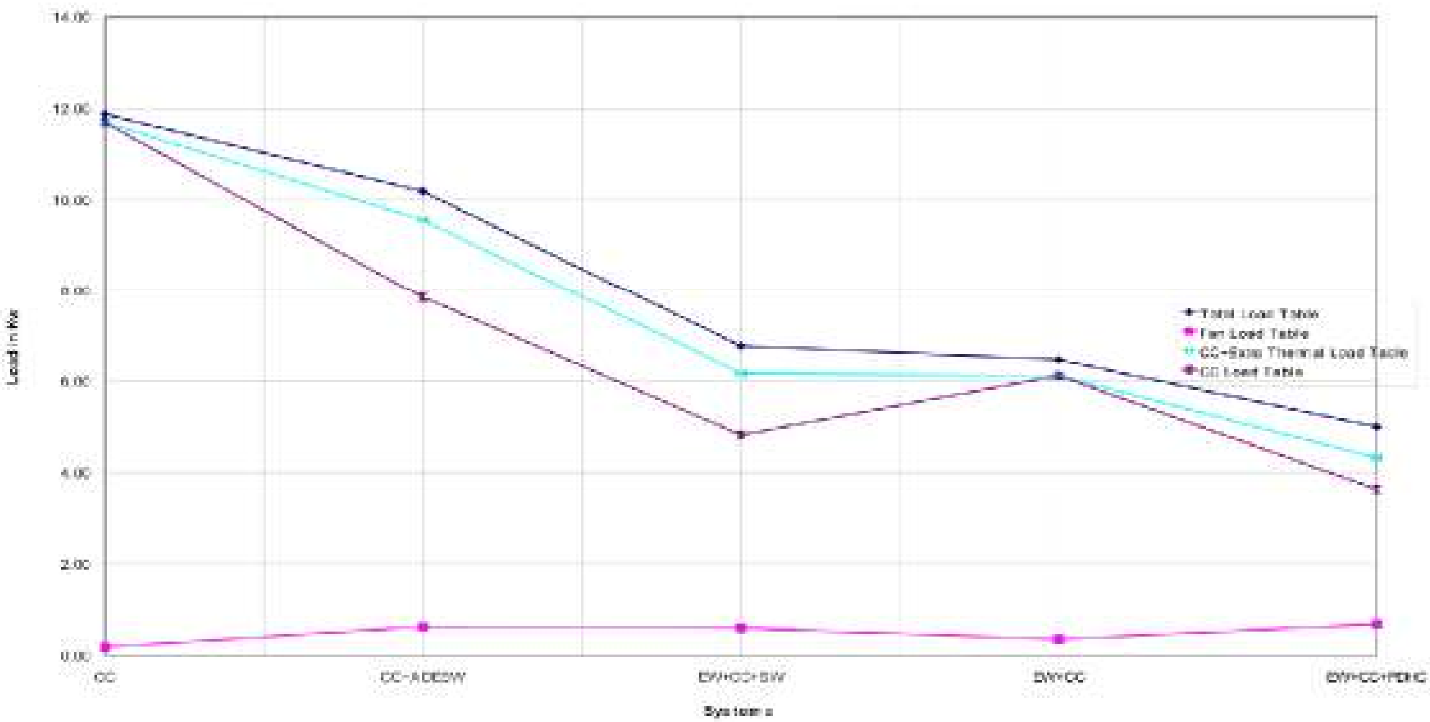
Schedule of DOAS with Enthalpy Wheel, Cooling Coil

and Passive Desiccant Wheel

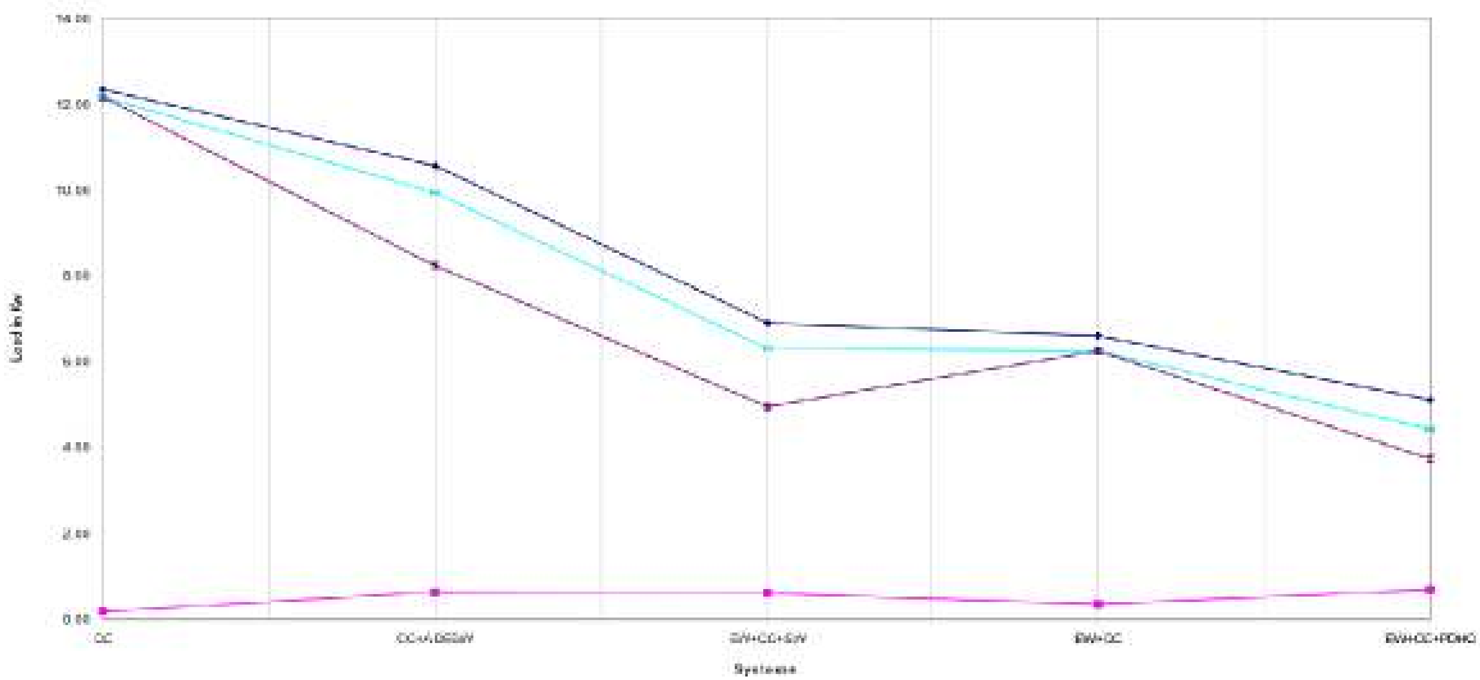


S.No.	1				2			3			4			5		
	Outdoor Air Conditions				Off Wheel Conditions			Off Coil Conditions			Supply Air Conditions			Return Air on EN Wheel		
	cfm	DBT °F	grs/lb	Btu/lb	DBT °F	grs/lb	Btu/lb	DBT °F	grs/lb	Btu/lb	DBT °F	grs/lb	Btu/lb	DBT °F	grs/lb	Btu/lb
1	1000	95	152.98	46.93	73.96	101.64	33.64	54.79	64.1	23.08	62.88	51.1	23.04	66.94	84.52	29.24
2	1000	85	162.27	45.88	71.46	103.96	33.38	54.79	64.1	23.08	62.88	51.1	23.04	66.94	84.52	29.24

System load at Mumbai Monsoon Condition

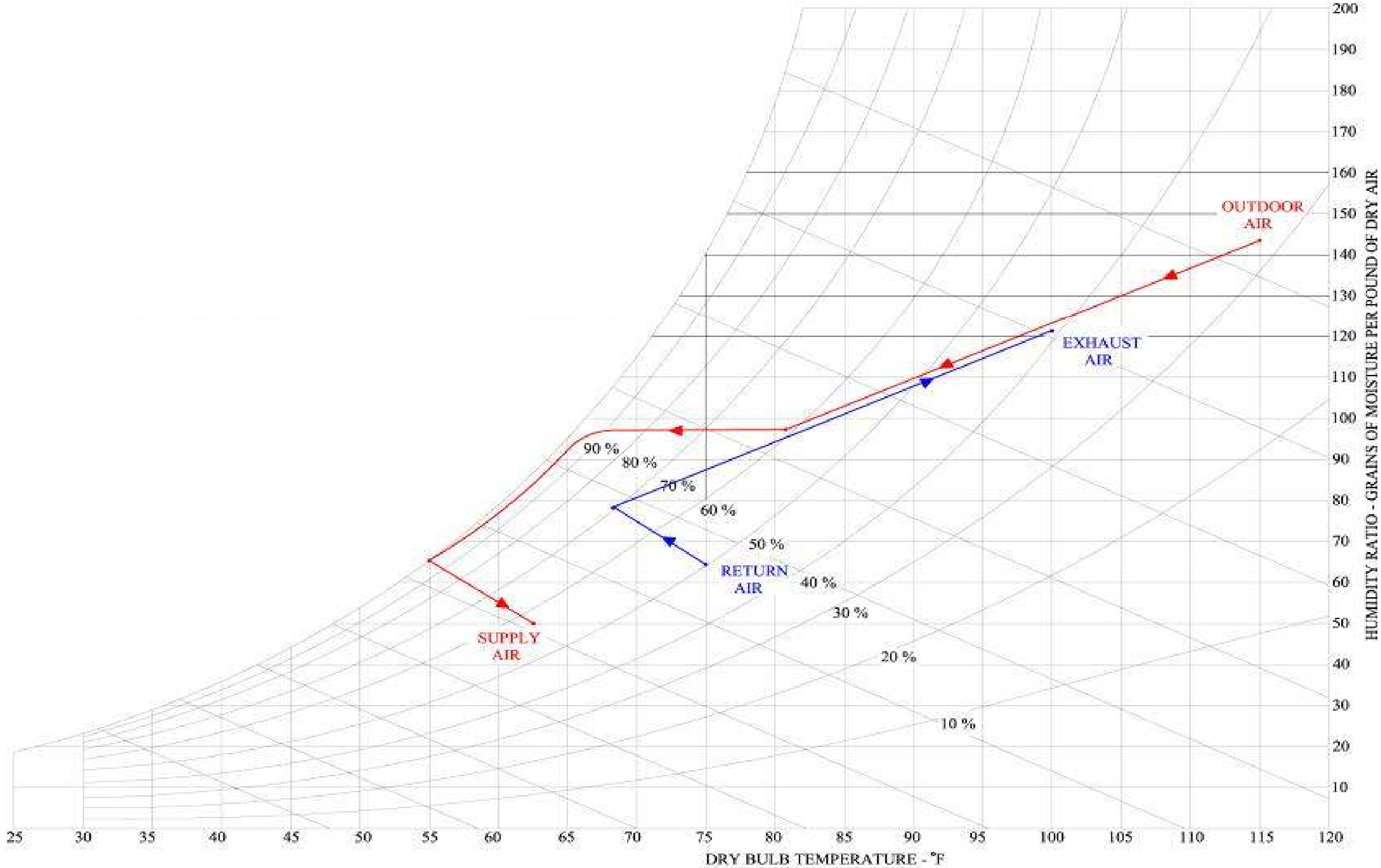


System load at Mumbai Summer Condition

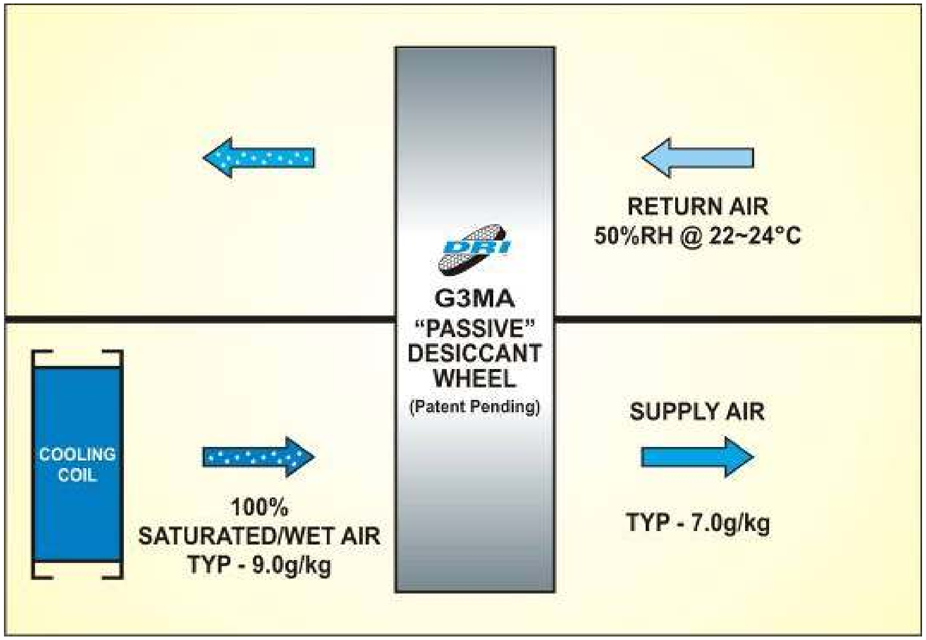


The Ultimate Fresh Air HVAC System

Psychometric Process



Working Principle of Passive Desiccant Wheel



The unique passive desiccant wheel (Patent Pending) has the ability to be regenerated with the 50% RH room return air allowing for substantial moisture removal through dehumidification of the saturated (100% RH) Fresh Air being supplied to the room. This is intelligently controlled by the DRISmart EMS (Energy Management System) to regulate speed optimization for different load conditions and different outside conditions.

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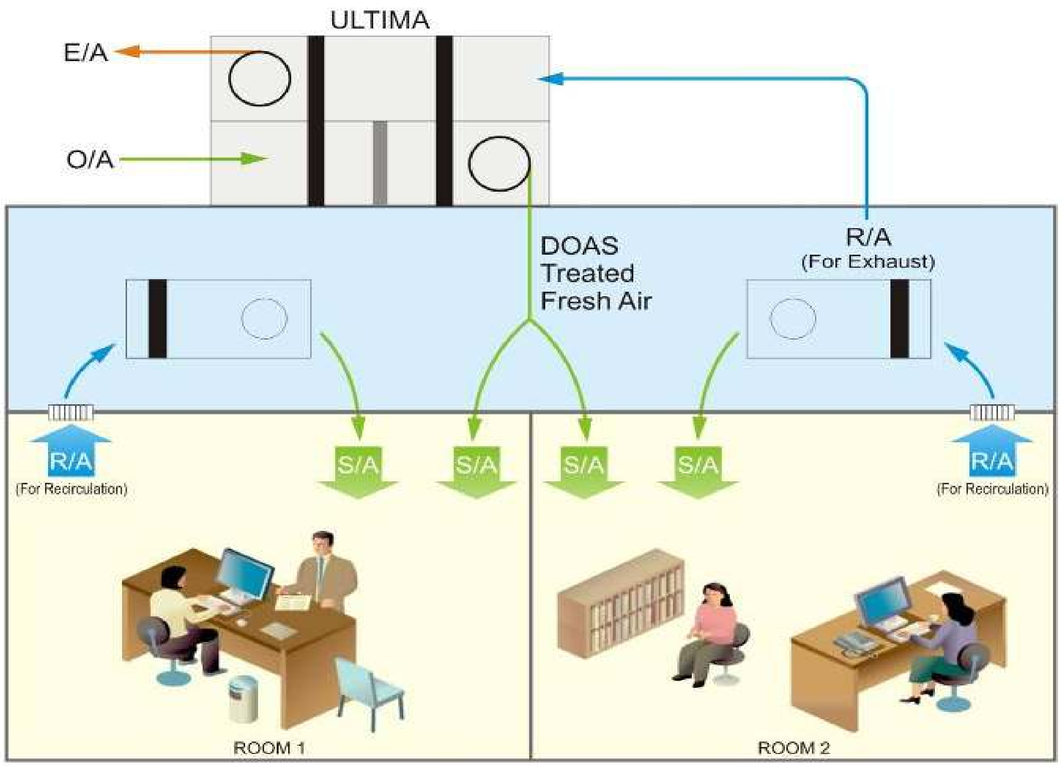
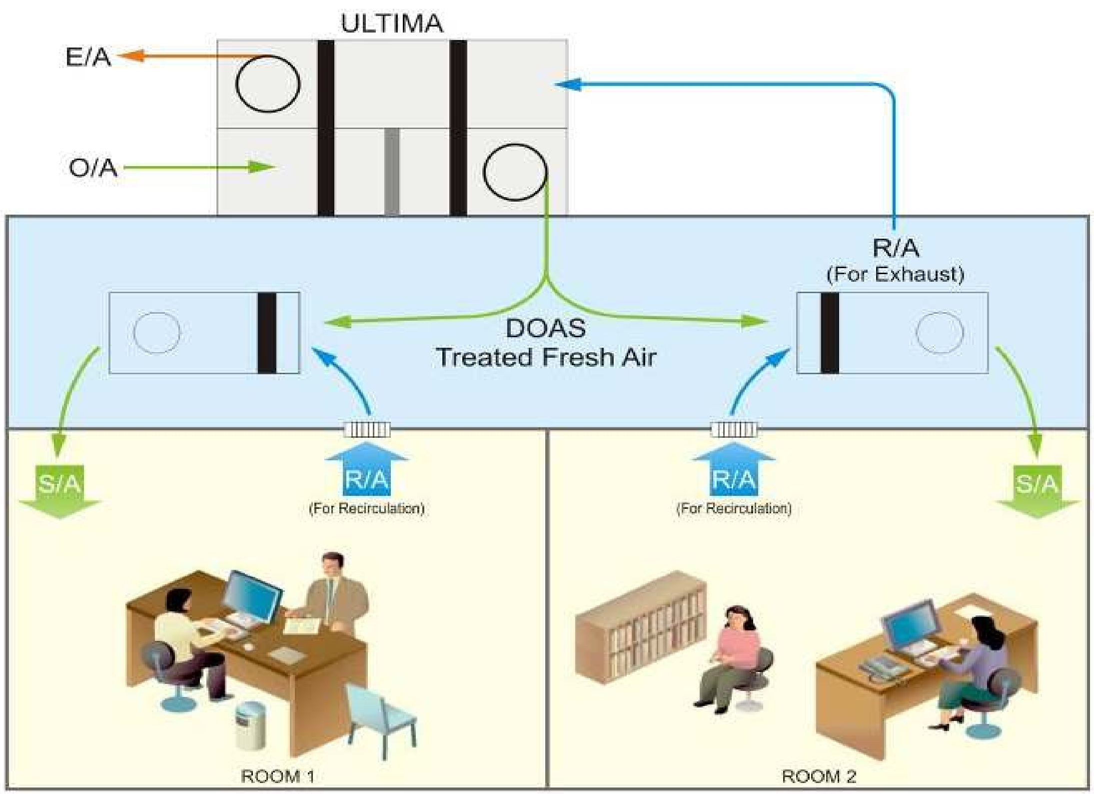
Installation Options

DOAS in Parallel with Terminal Equipment



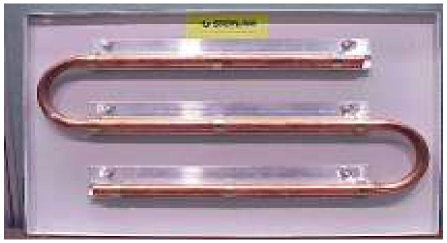
Installation Options

DOAS in Series with Terminal Equipment



Parallel Sensible Cooling Options

When using the DOAS approach the internal cooling devices work only as sensible cooling devices. The options available for internal cooling / heating are:

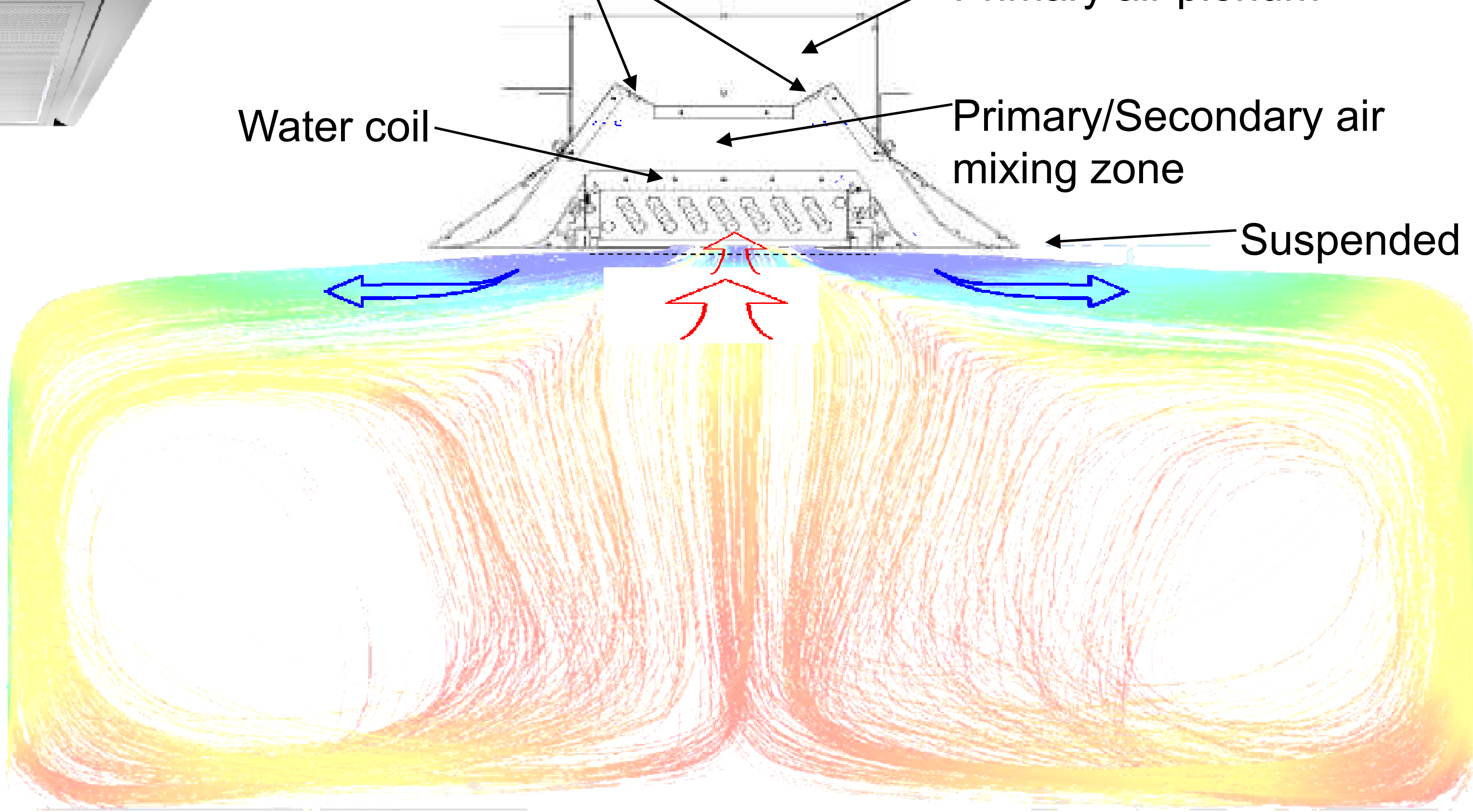


Radiant Cooling Panels

Fan Coil Units

Unitary ACs

Active Chilled Beams



Chilled Beams

Out of the four options the chilled beam is coming out to be a winner with distinct advantages on Energy. Also the problem of condensation is resolved by the use of DOAS.

- Utilizes a constant volume of primary air providing the full ventilation air required and humidity control at all times and at all sensible load conditions.
- Has less potential for objectionable drafts during cooling as the discharge air temperatures are much more temperate.
- Can significantly reduce fan energy consumption as the primary airflow is much lower than other conventional HVAC systems, particularly “all air” systems by about 60-70%.
- Offers very low noise levels when designed at typical unit inlet static pressures of 0.5”w.c (typically NC -30 or less)
- Reduces maintenance requirements as the active chilled beams have no moving parts requiring regular maintenance, and use simple, low cost controls.

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Typical problems in Indoor Swimming Pools

- Uncomfortably humid in the pool area when in normal clothes
- Strong and persistent smell of chlorine
- Foggy windows
- All metal objects, including doors and light fixtures, are subject to chlorine induced corrosion.
- Condensation on the glass panels / AC grills
- Many Pools /Spas uses costly wood interiors and high humidity causes the Wood Decay and Rot.
- Chlorine laden water vapor permeates the walls of your pool room, it will start to deteriorate cement blocks, mortar joints and bricks.
- When air leakage carries water vapor into walls and ceilings, it is called *Interstitial condensation*.

Case Study to calculate the Evaporation Load from Pool Surface

Project :- Defence Swimming Pool
Pool Description / Type :- Recreational Pool
Pool Water Surface Area :- 3470 Sq Ft
Pool Water Temperature :- 80.6 Deg F or 27 Deg C
Pool Room Air Conditions :- 77 Deg F or 25 Deg C and 55% Relative Humidity

Evaporation Rate (Grains/Lb)
= 650 X (1 + V/230) X (VL – VA) X Water Surface Area (Sq. Ft.) X Activity Factor

Where,
V= Velocity of Air over the water surface in FPM (17- 23 FPM Assumed)
VL= Vapor Pressure equivalent to the temperature of surface water - inches of Hg.
VA= Vapor Pressure equivalent to the Dew Point Temperature of the air over pool surface - inches of Hg.

Activity Factor = There are standard activity factors depending on the type of pool provided by ASHRAE. In general, it is the water surface movement of the pool.

CASE STUDY CONTINUATION

Therefore (from the vapor pressure tables & ASHRAE standards)
VL= 1.05372 at pool Water Temperature of 80.6 Deg F
VA= 0.51527 at Dew Point Temperature of Room Air that is 59.6 Deg F
Activity Factor = 0.65 for Recreational

Now Substituting the Values in the formula
VL- VA = 1.05372 – 0.51527 = 0.53845 inches of Hg

Evaporation Rate (Grains/Lb)

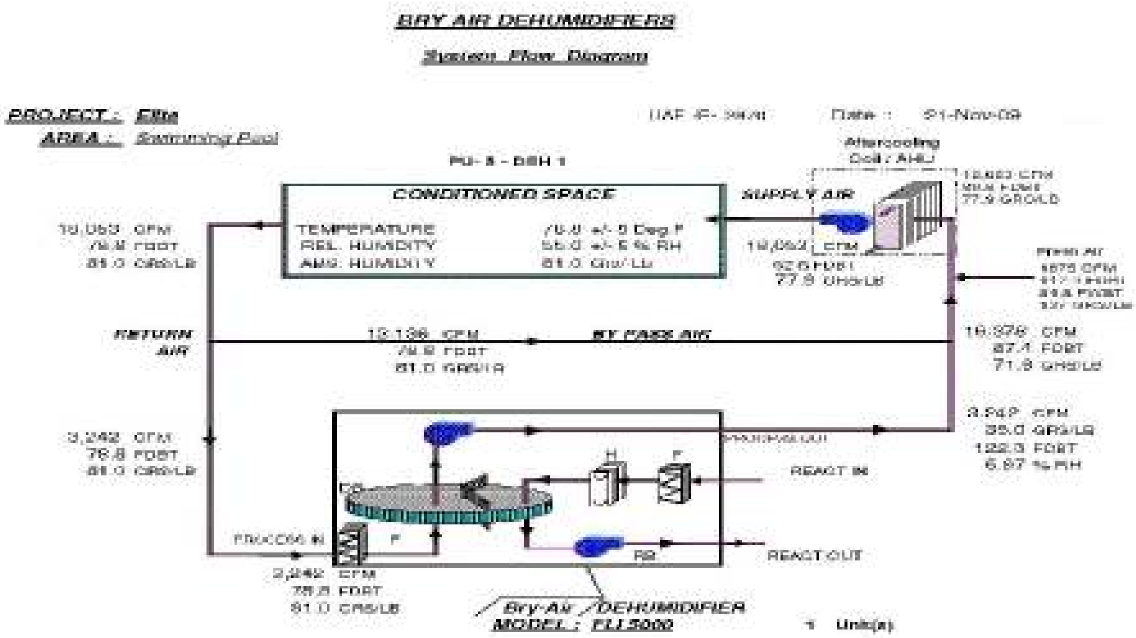
= 650 X (1 + V/230) X (VL – VA) X Water Surface Area (Sq. Ft.) X Activity Factor

= 650 X (1 + 23/230) X (0.53845) X 3470 (Sq. Ft.) X 0.65

Evaporation Rate = 885795 Grains/ Hr OR 57.5 Kg/ Hr

Note:- Always keep pool water temperature is kept 1 Deg C or 2 Deg F lower than the Room temperature to avoid chilling effect on the human body.

SYSTEM FLOW DIAGRAM



Enthalpy	Deh.Inlet	Deh.Outlet	Delta E	
(Btu/Lb)	31.59	35.22	3.63	
Heat Addition by Dehumidifier(s)		50,470 BTUH		

LEGEND

DB	DESSICANT BED
H	HEATER BANK
F	FILTER
PB	PROCESS BLOWER
RB	REACTIVATION BLOWER

WHY REQUIRE DESICCANT BASED DEHUMIDIFIER ?

- The pool dehumidifying equipment not only needs to remove the evaporated moisture, but also the moisture from the Fresh Air and the People. The problems in an indoor pool humidity control arises, when there is a single system to control temperature and humidity.
- Once the temperature is maintained, the cooling coil would stop the cooling as the system is driven by thermostat.
- This would stop the condensation taking place at the cooling coil (i.e. it stops the moisture removal from the swimming pool air)
- However, there is a constant evaporation from the pool surface, causing the humidity to shoot up, and leading to various problems described earlier.

Solution

- The best way to tackle / address to the humidity problem in an indoor pool is to

DIVIDE & CONQUER

- Separate the Temperature Control and the Humidity Control
- Temperature is controlled by the Cooling Coils and Thermostat
- Humidity is controlled by the Desiccant Dehumidifier and Humidistat

SUMMARY & CONCLUSION

Major benefits realized through humidity control in Indoor Swimming Pools using sorbtion technologies are:

- Reduced injuries due to avoidance of slipping and falling accidents due to wet floor.
- Reduction in annual maintenance costs.
- No fogging, condensation, rusting and rotting .
- Independent temperature and humidity control.
- Year round Comfort conditions for humans.
- No Molds & Mildew on the wall / duct surfaces
- Improved sanitation in indoor pool area through elimination of overhead grill condensation.

Our Presentation Today

- Indoor Air Quality Concept
- Fresh Air Energy Design Dilemma
- Energy Recovery Options
- Heat Recovery Wheel Evaluation Parameters
- Heat Recovery Wheel Applications Green Buildings / Hospitals
- RH Management Concerns
- DOAS Concept & Technology Options
- DOAS Integration with Parallel system / Chilled beams
- Dehumidification Technology for swimming Pools
- **Commercial Air & Gas Purification Units**
- Cooling Pads Air Conditioning for Dry Places

Why do you need a Air & Gas Purification?

- to prevent CORROSION of process computers and delicate electronic equipment in industries such as oil refineries, pulp & paper mills, chemical plants etc., caused by acid gases (hydrogen sulphide, sulphur dioxide, nitrogen oxides), mercaptans and chlorides.
- to control ODOUR problems in municipal waste water treatment plants located near / in crowded urban areas.
- to maintain acceptable IAQ levels in enclosed air conditioned places.

The SOLUTION to corrosion and odour problems lies in GASEOUS FILTRATION, which involves passing the contaminated air stream through a bed of dry media placed in a properly designed housing.

Air & Gas Purification is necessary

Heavy Industry

- Protect electronic equipment
- Remove acid gases
- Control air pollution

Light Industry and Municipal Facilities

- Control odor
- Control air pollution
- Eliminate hydrocarbons
- Remove acid gases

Commercial and Institutional

- Enhance indoor air quality
- Improve personal comfort
- Reduce volatile organic compounds
- Control environmental Tobacco smoke
- Reduce corrosion

Methods of Control

There are three methods of control for gas contaminants :

- **Source control : Removal of source [s] of the contaminants – not possible always.**
- **Ventilation control : Introduce clean air into the spaces to dilute the level of the contaminants within acceptable limits.**
- **Removal control : Control contaminants by either physical or chemical means.**

THIS IS WHAT WE DO.

"To achieve an acceptable level of contaminant control, economically, a combined strategy of dilution and removal control may be required ".

Air & Gas Purification

The Bry-Air Air & Gas Purification helps to filter gaseous contaminants like SO_2, H_2S etc. from air

1

Recommended Room Environmental Standards

- Relative Humidity : <60% at <6% change per hour

- Temperature : 17-24°C ± 3°C change

- Room pressure; 12.5 - 25 pa

- Corrosion rates:

Copper	<10 angstroms/24 hours <300 angstroms/Month
Silver	<10 angstrom/24hours <300 angstrom/Month

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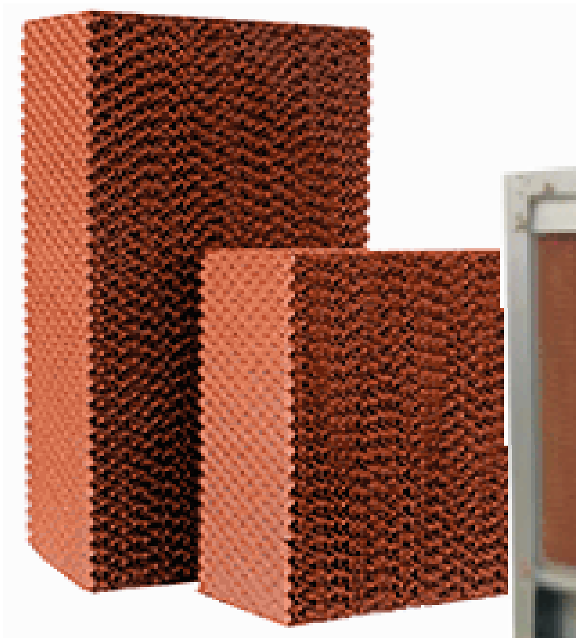
Evaporative Cooling Pad / Coolers



Evaporative Cooling Process

- Psychrometrically referred as Adiabatic Saturation Process
- Adding water in vapor form to the air cools the air
- Evaporation process is used to cool the air passing through a wetted cooling media.

<u>TECHNICAL PARAMETERS</u>

- Wet Bulb Depression : is the difference between Dry bulb and Wet bulb temperatures
- Evaporation rate : The rate at which water is absorbed into the air passing through the cooling media , measured in gallons of water per minute.
- Cooling Efficiency : The percent of temperature drop across the cooling media compared to the wet bulb Depression .Also termed Saturation Efficiency as it refers to amount of moisture packed in the air

Methods of Cooling

- Fogging Systems/ Spray Type Systems
- Evaporative Cooling Pads

EVAPORATIVE COOLING PADS

Evaporative Cooing Pads are called so because water gets evaporated when it comes in contact with the air. It withdraws the Sensible heat of air as the heat of evaporation. This process in turn brings down the temperature of air. The air temperature thus approaches the WBT of the incoming air.

The functioning of Evaporative Pad is very simple. The air is allowed to pass through the pad and at the same time water is added at the top through distributor.

Advantages of Evaporative Cooling :

- Low Pay back period
- Low Operational costs
- Low Maintenance costs

Fluted Rigid Media Evaporative Pads

- The latest type of Evaporative Cooling Pads use the cellulose media with wetting agents and rigidifying saturants ,constructed into alternating ,transverse flutes of 45 /45 degrees.
- The 45 degree flutes carry the water (introduced over the top of the media) to the front of the media where the oncoming air forces it back into the media assisting in thorough wetting of the media.
- The air flows through the transverse 45 degree flutes. Water flows down the flutes in a thin moving film over the whole surface of the media due to its wetting properties.
- This in turn provides maximum air to water contact surface area ,enhancing the rate of evaporation.

Basic Construction Types

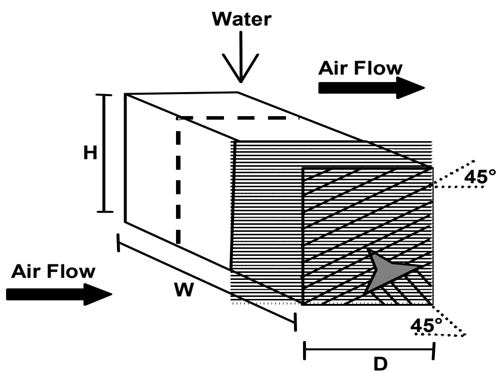
The unique air-to-liquid contact media consisting of corrugated sheets of wettable, strong cellulose material impregnated specially with decay – resisting chemicals. The impregnation also makes the materials stiff enough to make it Self-supporting and protects the media against decomposition caused by water and air very effectively.

FLUTE HEIGHT

- Due to corrugation each sheet of the pad looks like sinusoidal wave, almost semi circular in nature double the radius of each semicircle is called Flute Height.
- Types – Cooling pad is broadly classified into two types on the basis of Flute Height. Generally two types of flute height are available in the market e.g. 5MM & 7MM. These pads are further subdivided on the basis of flute angles.

Basic Construction Types … contd.

45/45



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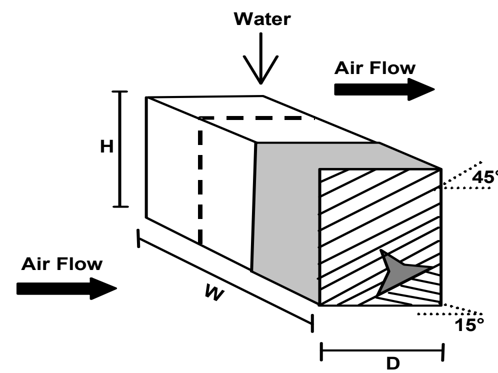

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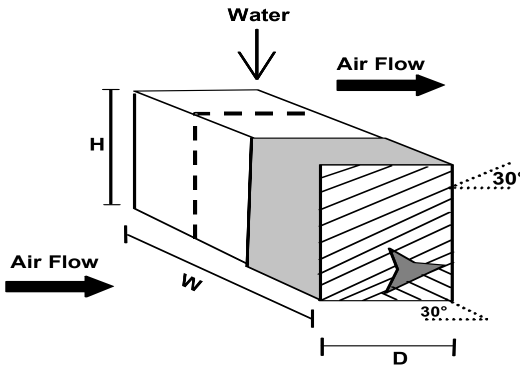
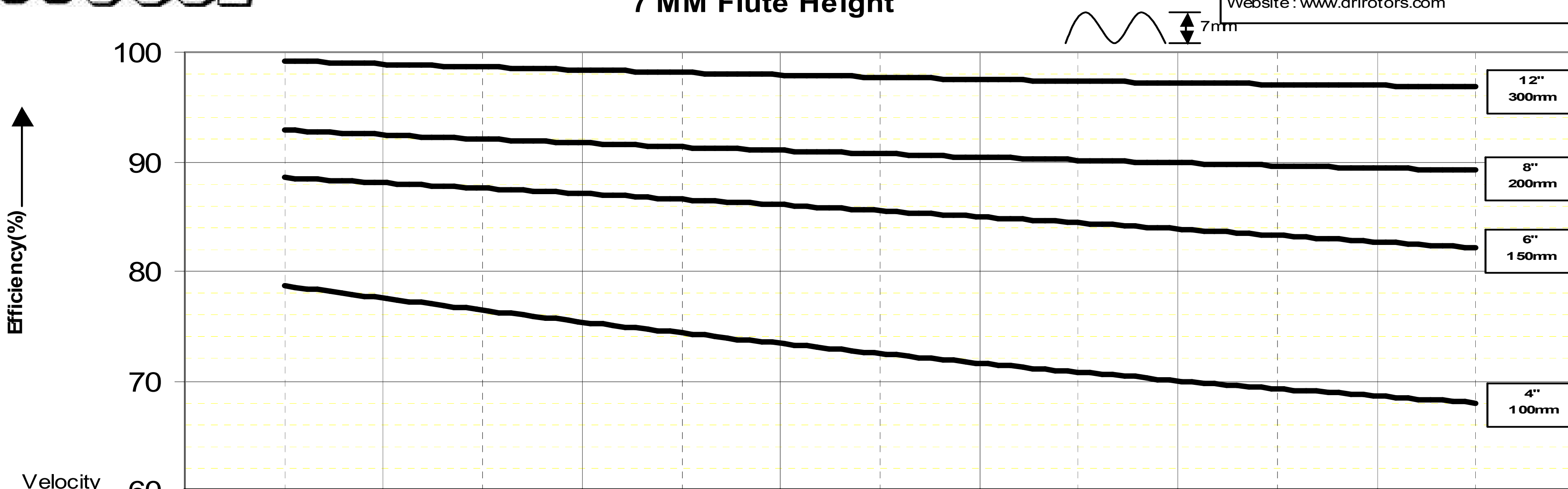


Performance Graph

20, Rajpur Road, Delhi-110054 (India)
Phone : 91-11-3912800 Fax: 91-11-3915127
E-Mail : enquire@pahwa.com
Website : www.drirotors.com

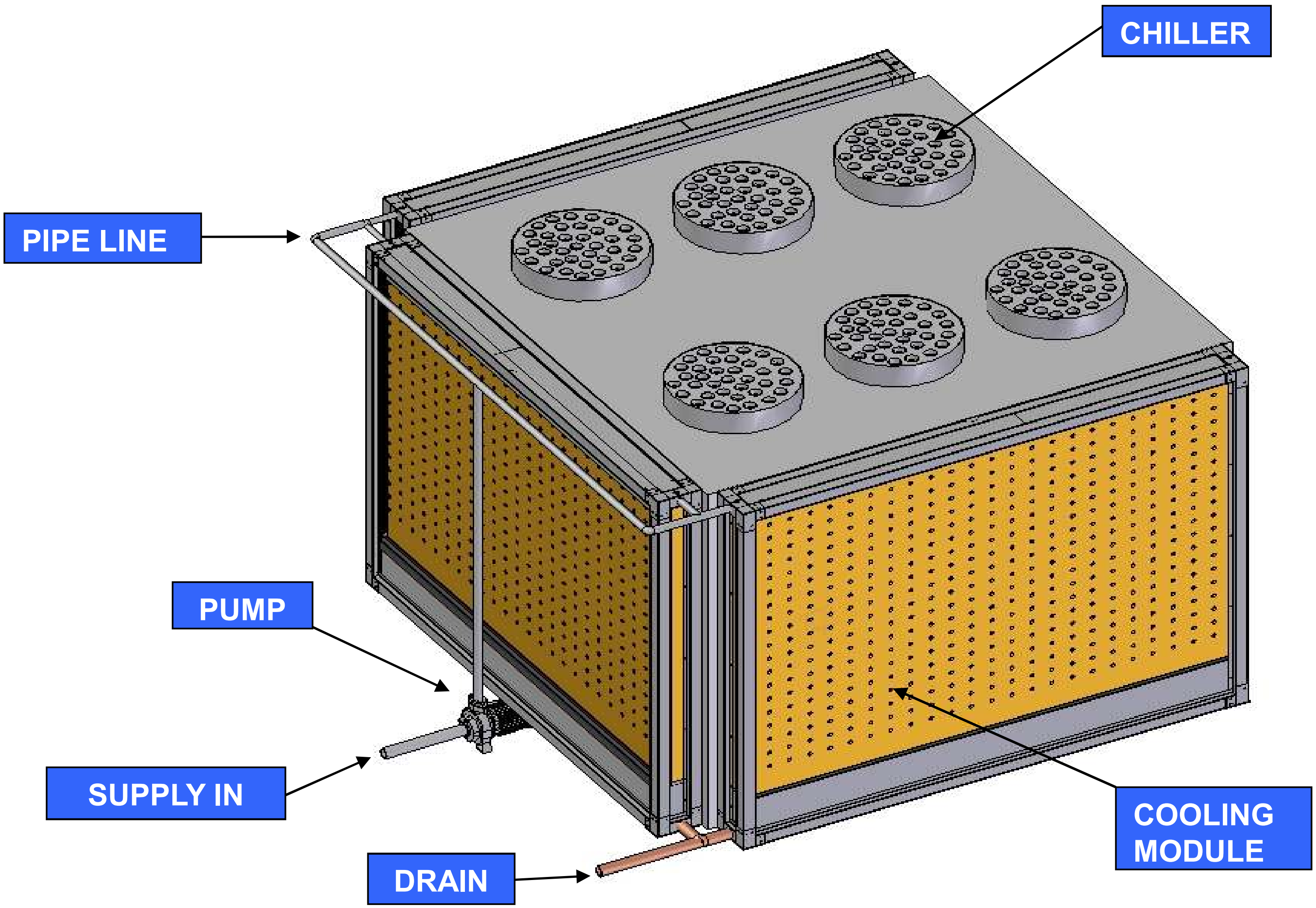
Typical Saturation Efficiency (45/45)
7 MM Flute Height



Velocity							
FPM	200	250	300	350	400	450	500
M/S	1	1.25	1.5	1.75	2	2.25	2.5
Pad Thickness: 4" / 100 mm	79	76	74	73	71	69	68
6" / 150 mm	89	87	86	86	85	83	82
8" / 200 mm	93	92	91	91	90	90	89
12" / 300 mm	99	99	98	98	97	97	97

Date: 05.04.2000 - ECP-2000-303-F

Cooling Module



COOLING

MODULE

MOUNTING

To further explore existing and upcoming Desiccant Technologies in HVAC Systems

please visit our websites

www.drirotors.com

www.bryair.com

Thank You !