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Designing HVAC Systems using HRW as an ECM for Energy Efficient Buildings

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Abstract—The importance and want for energy efficiency in buildings is well understood. Also, the contribution of energy needed for HVAC (particularly for cooling in Indian context) in buildings ought to be the foremost important. One among the foremost energy efficient means of providing cooling in building is with the utilization of HRW systems. Despite of being energy efficient and economical; the utilization of HRW system has been minimal in India. However, currently there are few smart examples of such systems and there exists some expertise in designing and operating. Lack of careful understanding of system, lack of design and simulation capabilities, restricted data on integration with the building and remainder of the HVAC system, are a number of the most important barriers in scaling from HRW systems installations in buildings.

Index Terms— AHU, ECM, Energy efficient Buildings, Exhaust Air, Fresh Air, HRW, HVAC, Return Air.

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1 Introduction

This technical paper presents the focus on 'Waste Heat Recovery potential for HVAC systems'. It explains the comparison between two systems Without Heat Recovery Wheel and With Heat Recovery Wheel.

The following assumptions and exceptions have been made during the preparation of this technical paper: (1) This technical paper focuses on Air-to-Air Heat Recovery technologies for HVAC applications in Commercial and Industrial buildings. (2) Recirculation of exhaust air is the cheapest and most efficient form of Heat Recovery. Other forms of Heat Recovery should only be considered after the need for fresh air is minimized, and the use of air recirculation and control strategies to optimize energy consumption at air handling plant have been firstly fully exploited.

2 Nomenclature

AHU - Air Handling Unit, DBT - Dry bulb temperature, HRW – Heat Recovery wheel, HVAC - Heating, Ventilation and Air Conditioning, RH- Relative Humidity, WBT - Wet bulb temperature.

3 Summary

The brief for this technical paper was to carry out a review of the Air-to-Air Heat Recovery technologies available for use in the Commercial and Industrial business sectors.

The research for the technical paper considered a number of commercially available Air-to-Air Heat Recovery Technologies; with particular focus on 'Sensible' heat recovery.

The premise of the technical paper is that where possible the use of air re-circulation is optimized before heat recovery is considered. The technical paper outlines why Heat Recovery should be considered and presents the potential effects on capital and operating costs.

The technical paper presents a worked example using a Rotary Air-to-Air Heat Exchanger.

4 Description

Recirculation of building extract air is the cheapest and most efficient form of Air-to-Air Heat Recovery since it involves little or no energy penalty. However in certain circumstances, e.g. where the exhaust air contains contaminants such as odors, chemicals, dust or corrosives it may not be possible to re-use this air. In these circumstances air-to-air heat recovery devices should be considered in both new and refurbishment projects.

Any time the temperature of the air being discharged from a building is higher than the incoming air to the building there is a potential opportunity for heat recovery. There is great scope for energy conservation if the heat in the exhaust air can be reclaimed and applied as a source of energy to raise the temperature of the incoming outside air. Heat recovery systems use heat energy that would otherwise be rejected as waste to pre-heat the incoming air, resulting in saved energy, lower running costs and potentially reduced plant capacities.

A variety of devices are available which facilitate air-to-air heat exchange, these include:

1) Run-around coils (Water circulation)
2) 'Heat Pipe' Heat Exchangers
3) Air-to-Air Plate Heat Exchangers
4) Rotary Air-to-Air Heat Exchangers

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Two of the above devices deliver direct air-to-air heat exchange and two employ an intermediate circulating medium.

The actual level of heat recovery will depend on the type of heat recovery device selected and the temperature difference between the supply and extract air streams.

All heat recovery devices create a resistance against which a fan has to operate (pressure drop).
This causes the fan to work harder to maintain flow rate, so increasing electricity consumption.
Where an intermediate circulating fluid is used there is the additional consideration of the electrical consumption of the circulating pump and the losses from the interconnecting pipework.

The amount of energy saved by installing a heat recovery device is equal to the energy recovered less the extra energy used in operating pumps, fans, etc.

The final decision on installing heat recovery systems depends on economic viability. As the cost of electricity is greater than the cost of fossil fuels, the heat recovery device will need to recover enough energy to economically justify its inclusion, while delivering a reasonable Payback Period

The following TABLE: 1 outlines the potential effects on Capital and Operating costs associated with the Installation of a Heat Recovery system

	Expenditure	**Savings**
Capital Costs	- Design Costs - Supply and Installation costs of the completed assembly - Modifications to existing plant and services to accommodate the new equipment - Additional plant-room Space - Controls	- Reduction in Central plant size - Reduction in distribution pipework
Running Costs	-Additional operating costs due to increased fan power. -Pump operating costs where runa-round coils are employed - Increased maintenance	-Net reduction in operating costs due to heat recovery - Reduced Carbon emissions

TABLE 1: Potential effects on Capital & Running cost associated with the installation of HRW

Technical items to be considered (at design stage and when considering a retro-fit)

5. POTENTIAL EFFECTS ON CAPITAL AND OPERATING COSTS

The following technical items should be considered when selecting an Air-to-Air Heat Recovery device:

a. Space accommodation requirements of the Heat Recovery System.

b. Distance between the supply and extract air streams.

c. Type of Energy recovery required ('Sensible' only or 'Total' Energy (Sensible and Latent))

d. Supply and Extract air quantities (mass flowrates) to be accommodated.

e. 'Effectiveness' of the Heat Recovery device.

f. Quality and condition requirements of the Supply Air stream (Is cross-contamination acceptable? – consider the risk of cross contamination between exhaust air streams and supply air streams due to Carry-over or Leakage).

g. Quality and condition of the Exhaust Air stream (Corrosive, dust laden, High temperature, High static pressure), leading to additional costs for anti-corrosion coatings, additional filtration, robust construction, etc.

h. Construction materials – consider corrosion, location, differential pressures, contaminants, etc.

i. Additional operating energy and service requirements for the Heat Recovery system, e.g. electrical supplies and condensate drains.

j. Modification requirements to existing plant and service routes to accommodate the new equipment.

k. Move-in space provision, i.e. consider the move-in path for a large item of equipment.

l. Construction costs.

m. Disruption to existing occupied areas, e.g. downtime.

n. Additional maintenance costs – filtration, cleaning, motor drives, etc.

o. Impact on the performance of existing air handling equipment, e.g. additional pressure drop resistance on existing fans.

p. Control method (also, additional controls and upgrading of existing BMS systems).

q. Condensation formation and frosting on the exhaust air side of the heat exchanger.
r. Maximum allowable pressure drop through the unit (particularly when the unit is being retrofitted to an existing system).

s. Air flow arrangements (Plate Heat Exchangers – Cross-flow or Counter-flow)

t. Face velocities at the Heat Exchanger.

Rotary Air-to-Air Heat Exchanger

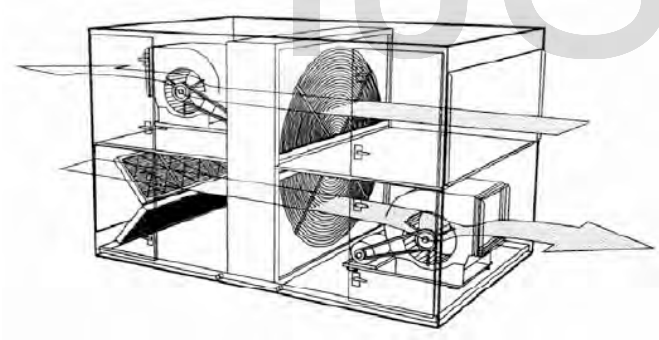

Figure 1: Rotary Air-to-Air Heat Exchanger

A rotary air-to-air heat exchanger has a revolving wheel filled with an air-permeable medium having large internal surface area. The wheel is mounted in a supporting structure, and the motor driven at up to approximately 20 revolutions per minute. Adjacent supply and exhaust air streams each flow through half of the wheel in a counter-flow pattern.

The heat transfer medium and the form of heat transfer surface varies between manufacturers and can be selected to pick up 'Sensible' heat only or 'Total' heat (sensible and latent heat). Sensible heat is absorbed at the warm room exhaust section (exhaust air) and released into the cold outside air section (supply air).

Because rotary exchangers are compact, counter-flow devices with small flow passages they can achieve high heat transfer effectiveness. Air contamination, exhaust air temperature and supply air properties influence the selection of materials for the casing, rotor structure and heat transfer medium for the heat exchanger.

The exchanger media are fabricated from metal, mineral or synthetic materials and provide either random or directionally orientated flow through their structures.

Cross-leakage, cross-contamination or mixing between supply and exhaust air streams can occur in all rotary heat exchangers by two mechanisms – Carry-over and Seal Leakage. Carry-over occurs when air from the exhaust air stream is carried into the supply air stream. This happens each time a portion of the matrix passes the seals dividing the supply and exhaust air sections. It can be prevented by installing a purge section on the heat exchanger. The introduction of a purge section can reduce the level of carry over to reasonable limits, e.g. 0.1%, but cannot completely eliminate it.

Cross-leakage occurs due to pressure differentials between air streams. Air leakage is driven from the region of high pressure to the region of low pressure. This can be minimized by avoiding large pressure differentials, providing an effective seal, and placing the fans to promote leakage into the exhaust air stream.

In many HVAC applications carry-over or cross-contamination is not a concern, however in critical applications such as Laboratories, Cleanrooms or Operating theatres stringent control of carry-over is required.

Two methods are commonly used to control the operation of a rotary heat exchanger – Supply air by-pass control (outside air) and speed control of the rotating wheel.
In supply air by-pass control a by-pass damper controlled by a supply air temperature sensor regulates the volume of outside air allowed to pass through the rotating wheel and therefore controls the temperature of the supply air.

The second method regulates the rate of heat recovery by controlling the speed of the rotary wheel using a variable speed drive. Heat recovery increases with wheel speed, but so does carry-over.
Wheel speed is ultimately limited by carry-over.
Maintenance requirements need to be taken into consideration since the rotary wheel is difficult to clean.

Wheels are available in sizes up to 5.5m diameter to handle air quantities in the range of 25 l/s to 35,000 l/s.

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6. Main Features:

Materials of construction:

- Casing material: Aluminum, Steel and Polymer.
- Rotor material: Aluminum, Steel and Polymer.
- Exchanger Media: Aluminum, Stainless Steel, Copper or Monel

Performance:

- Effectiveness: 50 - 85% (Sensible)
- Resistance to air flow: Approx. 150 Pa at a face velocity of 3 m/s.

Typical Applications:

- General HVAC systems in Commercial or Industrial applications where 'sensible' heat recovery is required. This technology (using a suitable media) may also be used for Total heat transfer (sensible and latent).

- Not suitable in applications where cross-contamination may be an issue.

7. Specific Numbers

Heat Recovery Efficiency

The heat recovery efficiency or 'Effectiveness' of a device is normally defined as follows:

Effectiveness = Actual Heat Transfer / Maximum possible heat transfer

Exit properties of two air streams can be estimated by knowing the flowrates and the effectiveness of the two air streams. The effectiveness of a heat recovery device can be used as a measure of the heat recovered.

8. Worked Example

Below is a worked example based on the use of a Rotary Air-to-Air Heat Exchanger device.

The resultant heat energy savings, running cost savings and payback period are based on the following input data,

1. Weather Data – Hyderabad. The Outside Summer Dry Bulb temperatures is 106℉ and Wet Bulb temperature is 78℉.
2. 24 hour operation of the air handling system and heat recovery device.
3. The extract air temperature is 76℉.
4. The Fresh Air Temperature is 106℉.
5. Space Used as Classroom.
6. Floor Area 1627.0 sq.ft

Comparison between two cases

1. Case 1 Without Heat Recovery Wheel
2. Case 2 With Heat Recovery Wheel

CASE 1: Without Heat Recovery Wheel

In this case the positive pressure 848 CFM which is created in class room is directly removed from exhaust fan as shown in Figure 3.

The temperature of exhaust air is 76℉ which is directly wasted outside.

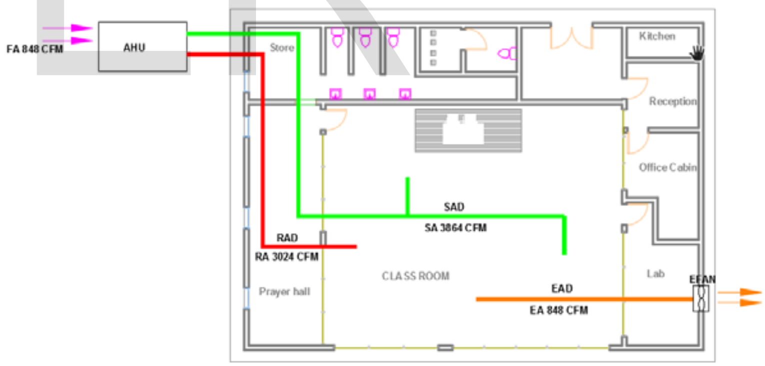

Figure 2: Layout without Heat Recovery Wheel

After Cooling load calculation for this classroom the total cooling capacity is 11.6 TONS.

CASE 2: With Heat Recovery Wheel

In this case the positive pressure 848 CFM which is created in class room is moved towards AHU coupled with HRW from room as shown in Figure 3. So the energy is recovered.

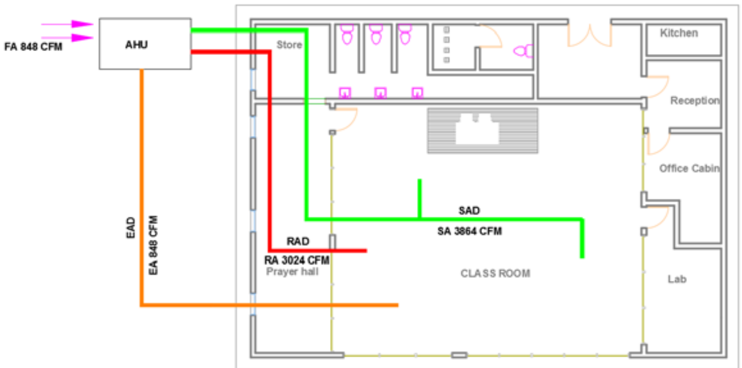

Figure 3: Layout with Heat Recovery Wheel

After Cooling load calculation for this classroom the total cooling capacity is 9.9 TONS.

9. Conclusion

After using AHU with Heat recovery wheel the energy reduction is 15% from **11.6 TONS to 9.9 TONS.**

10. References

[1] Eurovent 10/1 (1986) – 'Heat Recovery Devices – Specifications, Terminology, Classification and Functional Characteristics'.
[2] Eurovent 10/3 (1989)– 'Heat Recovery / Energy Conservation – Some Typical Methods'.
[3] Besant R.W., C.J. Simonson, Wei Shang – 'Design for Air-to-Air Heat and Moisture Exchange in HVAC Applications'
[4] ASHRAE Handbook (2007) - 'Heating, Ventilating and Air-Conditioning – Applications'.
[5] BSRIA TN 11/86 (1986) – 'Selection of Air-to-Air
[6] Article – Bureau of Energy Efficiency 'Waste Heat Recovery'.
[7] BSEN 13053 (2001) 'Ventilation for buildings- Air Handling Units – Ratings and performance for units, components and sections'.
[8] BG2/2009 – 'Illustrated Guide to Ventilation', BSRIA.
[9] CIBSE Guide B – 'Heating, ventilating, air conditioning and refrigeration' Chartered Institution of Building Services Engineer