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Controlling Airborne Infection During Covid 19

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ABSTRACT*:* *During the pandemic, nearly every industry faced new challenges and discovered new opportunities. The HVAC industry is no exception. This article aims to find proper solution to mitigate and try to eliminate the airborne infection risk during pandemic such covid 19. In this article am suggesting using heat recovery wheel with the air handling units which are serving Emergency department & public waiting area, despite the normal conditions which are under the traditional rules and standards of HVAC codes in healthcare facilities allowing to return airborne with fresh supply air.*

KEYWORD*:* HVAC; ASHRAE, ACH, AHU, CDC, PANDEMIC, WHO, HEAT WHEEL

INTRODUCTION

During COVID-19 and up to November -2022 a total of 14,122 deaths in Jordan been reported to WHO ,the most seriously in this number that many of those cases are infected on hospitals which is driving us to think more seriously by focuses on the airborne infection risk of COVID-19 in nursing units in inpatient building ,furthermore in my country (Jordan) we had been on unexpected effect—it has made people wary of visiting hospitals over fears of contracting the disease, a consequence of this fear among people, could put further stress on the already strained healthcare system in the country, so the infection control in the hospitals is a vital focus area.

Basically, the first trajectory of any patient is the emergency department, that's why I will focus in this department in term of HVAC.

I will discuss my point of view based on the below table as a sample of ASHRAE Standard 170 Design parameters for clean rooms, Table 1 page 9.2 ASHRAE Handbook—HVAC.

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9.2 2019 ASHRAE Handbook—HVAC Applications

Table 1 Sample of ASHRAE *Standard* 170 Design Parameters

Function of Space	Pressure Relationship to Adjacent Areas	Minimum Outdoor ach*	Minimum Total ach*	All Room Air Exhausted Directly to Outdoors	Air Recirculated by Room Units	Design Relative Humidity,%	Design Temp. °F
Operating room	Positive	4	20	NR*	No	20 to 60	68 to 75
Emergency department public waiting area	Negative	2	12	Yes	NR*	max. 65	70 to 75
All rooms	Negative	2	12	Yes	No	max. 60	70 to 75
Patient room	NR*	2	4	NR*	NR*	max. 60	70 to 75

*ach = air changes per hour, NR = no requirement

Figure -1

For Emergency department public waiting area its clearly ASHRAE is asking for fresh air of 2 air change per hour with minimum total of 12 ACH, however my point here is the table parameters showing no requirements for Air Recirculated by Room Units, based on this allowance all designers are returning the airborne to AHU mixing box which will be mixed with outdoor fresh air passing to cooling coil troughing the treated air again and again to the same department.

Such air treatment in normal conditions might be accepted but definitely its not in pandemic conditions ,however as the latest updated guidance by CDC - Centers for Disease Control - about how Covid spreads emphasizes that the virus can be spread through the air via “very fine droplets and aerosolized particles” from an infected person who is more than 6 feet away, so even the air handlers are equipped with portable high-efficiency particulate air filters (“HEPA”) like MERV 14 , or even air purifiers can help clean the air in areas where lots of people tend to congregate but still in pandemic no chance to venture.

LITRATURE REVIEW

The main point is to avoid airborne return during the pandamic conditions , so let us see the normal conditions then suggest the way of modification, the beolw it’s a double deck hyginic air handler unit using for emergency department waiting public area in one of larger hospitals in Uganda under name of ISHU in the capital (Kampala city) :

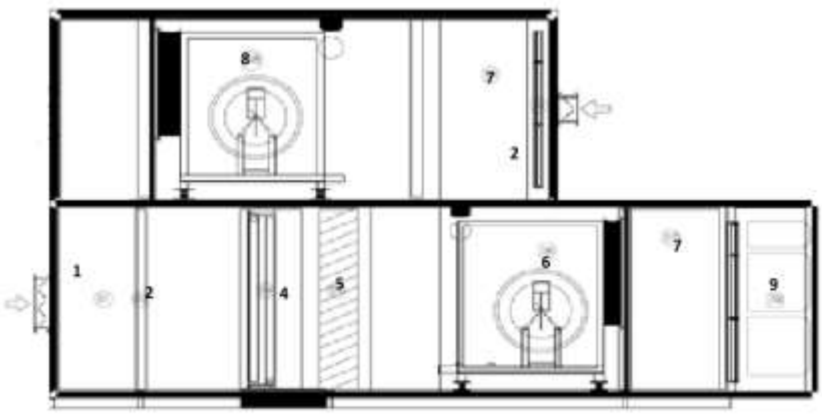

Figure -2

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COLUMN NO.	NAME OF SECTION
1	MIXING BOX
2	FILTER 1 BANK 1
4	COOLING COIL
5	ELEMINATOR
6	SUPPLY FAN
7	SOUND ATTENUATER
8	RETURN FAN
9	FILTER 1 BANK 2

Figure -3

The desiner suggest to have motorized damper in the mixing box which is mix the out door fresh air and the return airborne , what am aiming to say is in the normal conditions as per ASHRAE 170 there is no obligation to mix both air streams neither to exhaust the return, but in case of pandemic conditions such control is required, so if we have a motorized damper in the mixing box which will be normally open in normal conditions and shut off in pandamic outbreak to stop the mixing and exhust the return out of the AHU ,please see the below proposed modification by designer :

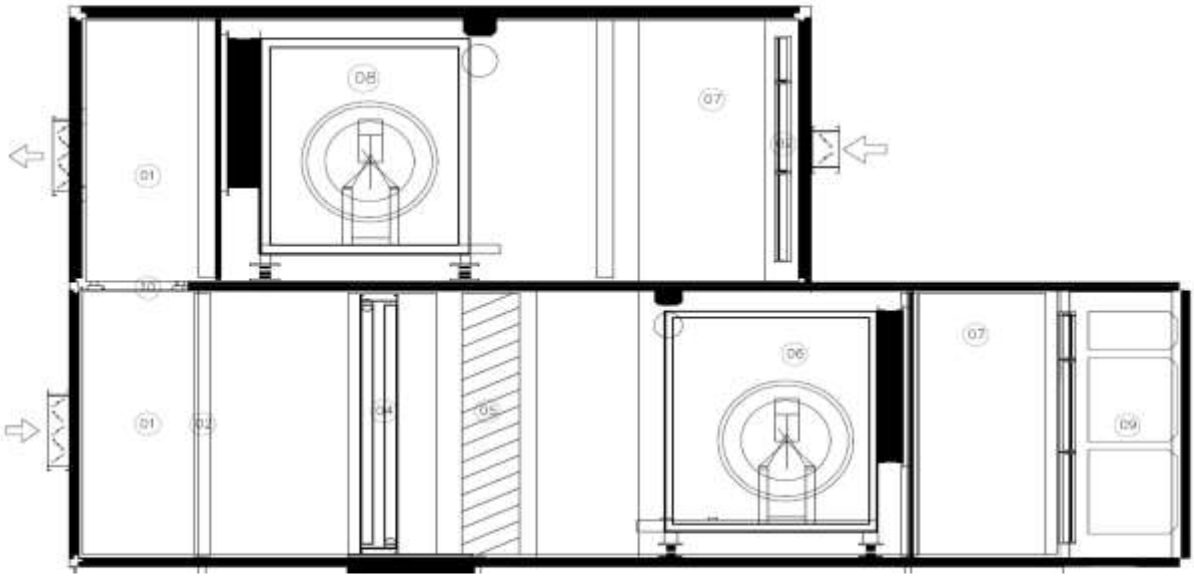

Figure -4

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COLUMN NO.	NAME OF SECTION
1	MIXING BOX
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5	ELEMINATOR
6	SUPPLY FAN
7	SOUND ATTENUATER
8	RETURN FAN
9	FILTER 1 BANK 2
10	DAMPER,NORMALLY OPEN

Figure -5

METHODOLGY

Might somebody will ask what's the affecting of such modification in the cooling coil size capacity, however this is a valid question, therefore am doing this study, so let us take a case study and apply the air thermodynamics theories to get a conclusion whether such suggestion doable or not.The below parameters are a valid case in one of the biggest hospitals in Africa, so we have one air handler unite covering emergency department with area of 1600 square meters, after analytical design information's we got the below details, so let us start our analysis:

Outside air flow rate as per ASHRAE 170 @ 2 ACH and our emergency department has a area of 1600 square meters @ 2.75 m height, so we have OA= 1600 *2.75*2*0.277 so almost we have 2440 l/s as fresh Air requirements.

The space load sensible and latent load based on HAP program calculations obtained based on civile parameters available in the design stage are sensible load 60.8 with latent load of 30 kw.

Since ASHRAE 170 asking for 12 ACH as a total air supply for emergency department, then for emergency department has a area of 1600 square meters @ 2.75 m height, so we have
SA= 1600 *2.75*12*0.277 so almost we have 14626 l/s as total supply Air requirements.

Return air flow rate = supply air flow rate – outside fresh air flow rate =14626 -2440 = 12180 l/s

So, in order to have the total cooling load we have to get the below (a & b) details:

a. Space loads (sensible and latent) = [Q roof + Q walls + Q windows + Q people + Q lights + Q appliances] (It does not include ventilation load). --------- [This is also called Room Total Load].

b. Total loads = Space Loads + Ventilation Load-------- [This is also called Gross Total Load].

We have space loads = 60.8+30 = 90.8 kw

For ventilation load:

So will start analyse tow options, the first is the normal way of mixing outside fresh air with return air (i.e. airborne return from emergency and public waiting area waiting) and the second option which designer suggesting to use the motorized damper to stop the mixing and exhaust the return airborne then we will study the affecting on the cooling coil capacity whether doable or not.

Option 1: (Mixing airborne with outside fresh air -Normal conditions)

From Psychrometric Chart (Sea Level):

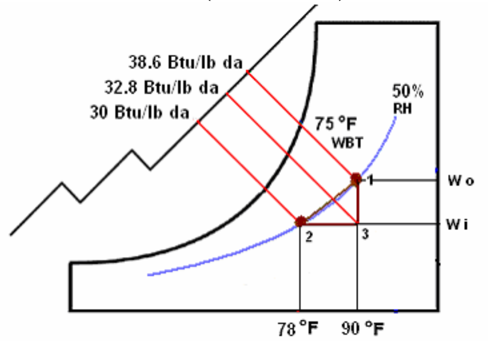

Figure 6

Sensible Heat
Q Sensible = 60 * CFM * ρ * CP * ΔT
Q Sensible = 60 hr/min * CFM (ft³/min) * (0.075) Ibm/ft³ * (0.24) Btu/Ibm-°F * ΔT (°F)
Q Sensible = 1.08 * CFM * ΔT
ρ = Air density (0.075 Ibm/ft3)
Cp = Specific heat of air (0.24 Btu/Ib F)
Recommended ventilation is 14626 l/s (this will ensure conservative analysis), therefore,
CFM (Air flow rate) = 30,990 ft³/min
Now
Q Sensible = 1.08 * CFM * ΔT
ΔT = Indoor minus Outdoor temperature difference (To - Ti) since both streams are mixed so we have To = 90 °F, Ti = 78 °F, Tmix = 80 °F based on percentage mixing of air steams (2440 /14626 =17 %) & (12180/14626 = 83%) so we have (90 *17 %) + (78 * 83%) =T mix = 80 °F
Therefore
Q Sensible = 1.08 * 30,990 * (80- 78)
Q Sensible = 33,469 Btu/hr almost 10 kw

Latent Heat
Q Latent = 4840 * CFM * ΔW
Where:

ΔW = Humidity ratio of indoor air minus humidity ratio of outdoor air, (Wo - Wi) in lbm water/ lbm dry air however here we have new mixing properties of W mix @ T mix = 80 °F
From Psychometric chart:
Indoor - For 78° F dry bulb temperature (DBT) at 50% Relative Humidity:
W i = 0.0102 Ibm water/Ibm dry air
Outdoor - For 90 ° F dry bulb temperature (DBT) at 50% Relative Humidity:
Wo = 0.0152 Ibm water/Ibm dry air, however W mix @ 80 °F is =0.0112 Ibm water/Ibm
ΔW = (Wmix - Wi) = 0.0112 - 0.0102 = 0.001 Ibm water/Ibm dry air
Therefore
Q Latent = 4840 * 30,990 * 0.001 =150,000 Btu/hr almost 44 kw
Gross Total Load = (space loads 60.8+30) +Fresh air sensible and latent (10+44) = 145 kw so we have cooling coil capacity of 42 tons.

Option 2 : (Total outside fresh air without mixing -Emergency conditions at pandemic outbreak)
From Psychrometric Chart (Sea Level):

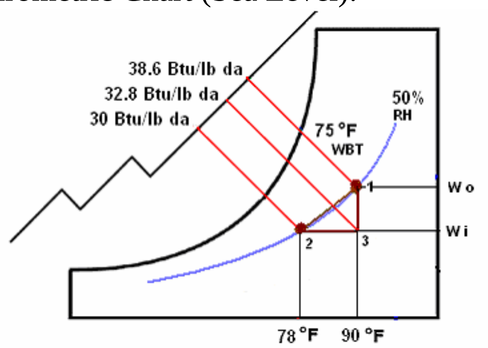

Figure 7

Sensible Heat
Q Sensible = 60 * CFM * ρ * CP * ΔT
Q Sensible = 60 hr/min * CFM (ft³/min) * (0.075) Ibm/ft³ * (0.24) Btu/Ibm-°F * ΔT (°F)
Q Sensible = 1.08 * CFM * ΔT
ρ = Air density (0.075 Ibm/ft3)
Cp = Specific heat of air (0.24 Btu/Ib F)
Recommended ventilation is 14626 l/s (this will ensure conservative analysis), therefore,
CFM (Air flow rate) = 30,990 ft³/min
Now
Q Sensible = 1.08 * CFM * ΔT
ΔT = Indoor minus Outdoor temperature difference (To - Ti) since both streams are mixed so we have To = 90 °F, Ti = 78 °F
Therefore
Q Sensible = 1.08 * 30,990 * (90- 78)
Q Sensible = 401,603 Btu/hr almost 118 kw

Latent Heat
Q Latent = 4840 * CFM * ΔW
Where:

ΔW = Humidity ratio of indoor air minus humidity ratio of outdoor air, (Wo - Wi) in lbm water/ lbm dry air .
From Psychometric chart:
Indoor - For 78° F dry bulb temperature (DBT) at 50% Relative Humidity:
W i = 0.0102 Ibm water/Ibm dry air
Outdoor - For 90 ° F dry bulb temperature (DBT) at 50% Relative Humidity:
Wo = 0.0152 Ibm water/Ibm dry air
ΔW = (Wmix - Wi) = 0.0152 - 0.0102 = 0.005 Ibm water/Ibm dry air
Therefore
Q Latent = 4840 * 30,990 * 0.005 =749,958 Btu/hr almost 220 kw
Gross Total Load = (space loads 60.8+30) +Fresh air sensible and latent (118+220) = 429 kw so we have cooling coil capacity of 122 ton.
Let us wrap both options by one conclusion:
If we use the second option of motorized damper in emergency case and we still using the same cooling coil of first option then,
Q Sensible = 1.08 * CFM * ΔT
33,469 Btu/hr =1.08 x 30,990 cfm x (90- Ti)
Ti =90-1=89 °F
That's mean such cooling coil super under size will not be suitable for such application, moreover the larger size of the second option will drive us to move away from both methodologies by finding another way compromising by healthy requirements with economical side.

DISCUSSIONS AND IDEAS

Based on the previous analytical information's we discover the big difference in term of tonnage capacities between mixing the return airborne with fresh supply air methodology versus the totally fresh supply air using motorized damper , however such large difference should not stop us to use another efficient way which can reduce the energy consumption and reduce the cooling coil size furthermore the most important is to stop mixing the return airborne with fresh supply air in emergency and public waiting area.

The below figure self-explanatory of heat recovery wheel idea, the most important is such method is eliminating the return of airborne and extracting the energy of the return air.

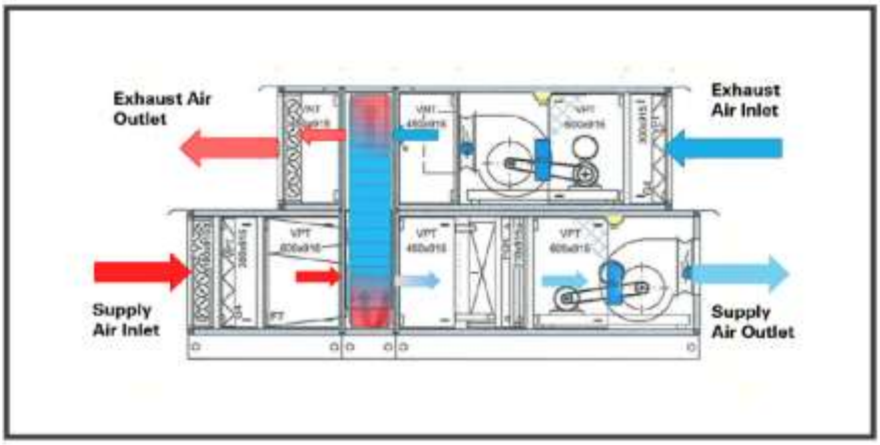

Figure 8

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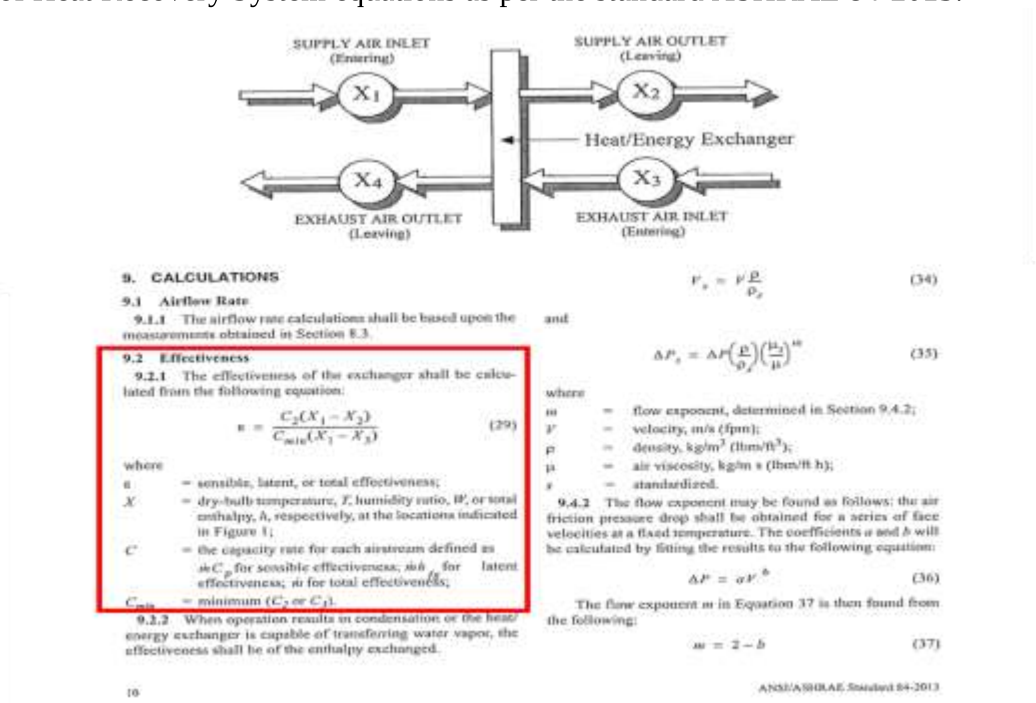
The below are several points why we have to think in using such methodology in hospitals:

- In general terms it is a type of energy recovery heat exchanger between two streams of air.
- Buildings use mechanical ventilation to supply fresh air and extract contaminated air from buildings.
- The fresh air must be either heated or cooled to acceptable temperature and relative humidity. The heating or cooling of fresh air consumes significant energy and on the other hand already conditioned air is being exhausted out.
- Heat Recovery wheel rotates between the air streams and transfers energy between fresh air and exhaust air. Hence precool or preheat the fresh air hence reducing the cooling or heating energy.

However, to proof analytically the effectiveness of such methodology we can follow the effectiveness of Heat Recovery System equations as per the standard ASHRAE 84-2013:



9. CALCULATIONS

9.1 Airflow Rate

9.1.1 The airflow rate calculations shall be based upon the measurements obtained in Section 8.3.

9.2 Effectiveness

9.2.1 The effectiveness of the exchanger shall be calculated from the following equation:

$$\varepsilon = \frac{C_2(X_1 - X_2)}{C_{min}(X_1 - X_3)} \quad (29)$$

where

ε = sensible, latent, or total effectiveness;
X = dry-bulb temperature, T, humidity ratio, W, or total enthalpy, h, respectively, at the locations indicated in Figure 1;
C = the capacity rate for each airstream defined as $\dot{m}C_p$ for sensible effectiveness; $\dot{m}h_{fg}$ for latent effectiveness; $\dot{m}$ for total effectiveness;
C_{min} = minimum (C_2 or C_3).

9.2.2 When operation results in condensation or the heat/energy exchanger is capable of transferring water vapor, the effectiveness shall be of the enthalpy exchanged.

10

$$V_s = V\frac{\rho}{\rho_s} \quad (34)$$

and

$$\Delta P_s = \Delta P\left(\frac{\rho}{\rho_s}\right)\left(\frac{\mu_s}{\mu}\right)^m \quad (35)$$

where

m = flow exponent, determined in Section 9.4.2;
V = velocity, m/s (fpm);
ρ = density, kg/m³ (lbm/ft³);
μ = air viscosity, kg/m s (lbm/ft h);
s = standardized.

9.4.2 The flow exponent may be found as follows: the air friction pressure drop shall be obtained for a series of face velocities at a fixed temperature. The coefficients a and b will be calculated by fitting the results to the following equation:

$$\Delta P = aV^b \quad (36)$$

The flow exponent m in Equation 37 is then found from the following:

$$m = 2 - b \quad (37)$$

ANSI/ASHRAE Standard 84-2013

Figure 9

Therefore, based on the above ASHRAE guidance for heat recovery system which where the two air streams are not close enough then It generally delivers a maximum efficiency of around 35% to 50% which is still better option instead of have a large cooling coil with adding motorized damper suggestion neither mixing of return airborne with fresh supply air.

CONCLUSION

- Covid 19 virus can spread in poorly ventilated and/or crowded indoor settings, where people tend to spend longer periods of time such emergency department public waiting areas, This is because aerosols can remain suspended in the air or travel farther than conversational distance (this is often called long-range aerosol or long-range airborne transmission, that why we have to stop mixing return airborne with fresh supply air inside the air handling units.

- The utilizing of motorized dampers Inside the fresh air handler units is totally wastage of energy and wastage of money consequently hence the cooling coil will be larger than the normal minimum of 60% .
- The concept of heat recovery wheel .
- s more efficient healthy wise and more economically.

Suggestions

The Heat recovery wheel is one of the major issues for the sustainable energy industry, creating more efficient cooling systems, therefore, to use such systems in healthcare facilities not only economical solution but its more efficient healthy solution keeping a secured environment for nursing teams aside from the patients during of outbreak pandemic days.

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HTM (HTM 03-01) Specialised ventilation for healthcare buildings
NHS National Standards of Healthcare Cleanliness 2021

<u>APPENDIX</u>

Figure -1: ASHRAE Standard 170 Design Pparameters for clean rooms, Table 1 page 9.2 ASHRAE Handbook—HVAC.
Figure -2: Double deck hyginic air handler unit using for emergency department waiting public area.
Figure -3: Air handler sectional part details
Figure -4: Double deck hyginic air handler unit using for emergency department waiting public
Figure -5: Modified Air handler sectional part details

Figure -6 & 7: Psychrometric Chart (Sea Level) showing design parameters

Figure -8: Heat recovery wheel with air handler unit.

Figure -9: Heat Recovery System equations as per the standard ASHRAE 84-2013: