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RESEARCH ARTICLE

Engineering

Design and Analysis of Different Components of an Air Handling Unit

Diseño y Análisis de Diferentes Componentes de una Unidad de Tratamiento de Aire

Ifrah Asif[1] | Umaid Ghouri[1] | Syed Taha Hussain[1] | Vissam Siddiqui[1] | Syed Ahmed Ghazzal[1] | Syed Jari Naqvi[1]

[1]Department of Mechanical Engineering, NED University of Engineering and Technology, Karachi.

Correspondence
Ifrah Asif
Email: ifrahasif@neduet.edu.pk

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Abstract. AHU (air handling unit) is an imperative component of the HVAC (heating, ventilation and air conditioning) system as it is used to regulate conditioned air into the ducts of this system. AHU deals with the heat change between outdoor air and the air inside the working environment of any building. Designing of an AHU depends upon the specific requirements of temperatures inside the building and the components required achieving those targets. This paper provides a detailed aspect of all kinds of AHU and discusses the considerations taken while designing and choosing the components to be installed inside the AHU. Furthermore it mentions the required calculations necessary for the design of centrifugal blower unit and for the selected heat exchanger coil. Moreover, it contains the design of the components and a two dimensional drawing of the Air Handling Unit. The two dimensional drawing was obtained upon validations of our selected blower unit and heat exchanger coil.

Keywords: AHU System, HVAC System, Blower Unit, Centrifugal fans, Cooling Coil

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Resumen

La UTA (unidad de tratamiento de aire) es un componente imprescindible del sistema CVAA (calefacción, ventilación y aire acondicionado) ya que se utiliza para regular el aire acondicionado en los conductos de este sistema. La UTA se encarga del cambio de calor entre el aire exterior y el aire del interior del entorno de trabajo de cualquier edificio. El diseño de una UTA depende de los requisitos específicos de las temperaturas en el interior del edificio y de los componentes necesarios para alcanzar esos objetivos. Este documento ofrece un aspecto detallado de todos los tipos de UTA y analiza las consideraciones que se tienen en cuenta a la hora de diseñar y elegir los componentes que se instalarán en el interior de la UTA. Asimismo, menciona los cálculos necesarios para el diseño de la unidad soplante centrífuga y para la bobina intercambiadora de calor seleccionada. Además, contiene el diseño de los componentes y un dibujo bidimensional de la unidad de tratamiento de aire. El dibujo bidimensional se obtuvo a partir de las validaciones de la unidad soplante y la bobina intercambiadora de calor seleccionadas.

Palabras clave: Sistema AHU, Sistema HVAC, Unidad de soplado, Ventiladores centrífugos, Batería de refrigeración.

1 | INTRODUCTION

The purpose of installing an heating ventilation and air conditioning (HVAC) system to any specific area is to provide heating or cooling in a specified workplace according to the environmental comfort [1]. What an HVAC system does is, it uses fresh air from outdoor and provides conditioned indoor air. The ventilation in HVAC is the process of replacing or exchanging air within a space. This provides better quality of air indoors, further helps in removal of moisture, smoke, odors, heat, dust, airborne bacteria, carbon dioxide, and other contaminants as well as temperature control and oxygen replenishment [2]. All the core functions, heating, ventilation and air conditioning are interconnected. All these functions are meant for a total control of temperature, moisture content (humidity), supply of outside air for ventilation, filtration of airborne particles, and air movement in the occupied space [3]. An HVAC system consumes 40% of the total energy of any building. Keeping in mind the increased usage of HVAC systems in buildings, the consumption of energy must be stringent and precise [4]. There are different active and passive means to provide the sufficient air conditioning to residential buildings [5]. Many other researchers worked on the solar based air-conditioning and improvement of solar conversion techniques [6, 7, 8]. The main focus of this study will lean more towards how the outside air is cooled or heated after being filtered using Air Handling Unit.

Air Handling Unit (AHU) is an important component of the air conditioning system as it enables large spaces to be cooled simultaneously and also aids in maintaining the Indoor Air Quality (IAQ) [3]. The AHUs are designed in such a way that they meet the desired conditions and ensure that the air is treated in accordance to the standards [9]. The AHU is connected to ducts through which the air is distributed to the building further; these ducts play their part in returning that air back to the AHU for recirculation [10].

An AHU can be either a rooftop unit or an indoor unit. For an indoor unit there larger space is required plus special accessories are installed to control the noise levels of that specific space in order to avoid the increased prescribed sound levels for a human body [11]. An AHU can be either built inside a controlled manufacturing space or on field where it is needed to be installed. But on factory manufacturing of AHU is more efficient with good quality and low manufacturing cost. These can be delivered in shorter time. For the custom and on field manufacturing of AHU, there's more flexibility in structure and arrangement of components can vary as compared to standard AHU structures [12].

AHU can be classified into different types according to their structure, conditioning requirements and location as follows:

- Horizontal or Vertical Unit: In horizontal unit, all the components are installed at same level, where as in vertical unit the fan is not at same level as the filter and coil. The fan is at higher level as compared [6].
- Draw through or Blow through Unit: In draw through unit, the supply fan is positioned downstream to draw the air from coil section. In blow through unit the fan is positioned upstream and the air blows through the coil section [12].
- Outdoor Air AHU or Mixing AHU: Outdoor air AHU uses 100% fresh air to condition it where as in mixing AHU, a ratio of fresh and recirculated air is conditioned [10].
- Single Zone AHU or Multi Zone AHU: Single zone AHU is used to condition the air of one specific zone where as a multi zone AHU is used to condition air of different zones [11]. The design of the cooling coil of an AHU has a significant effect on the performance of the system and the effectiveness of the cooling of the space [12]. A key contributor in cooling coil design is the velocity of the air across the heat transfer surfaces. The higher the velocity, smaller will be the coil and pressure drop is higher. Lower coil velocity has the converse effect. The fan size will depend on the velocity that is chosen, and this will in turn affect the energy usage of the AHU [13].

2 | KEY COMPONENTS

AHU operations not only significantly impact supply air temperature and humidity levels, but also the energy consumed for heating, cooling and ventilation. AHU operations greatly affect the building energy consumption, thermal comfort, and health of occupants. In addition to control building ventilation intake, AHUs connect primary heating and cooling plants with building zones [10]. To perform ventilation functions, various dampers are provided to connect air ducts including return air duct, exhaust air duct, fresh air duct and supply air duct. AHU aims to provide cooling or heating to air streams before supplying to conditioned spaces. AHU also distributes conditioned air to various conditioned spaces in a zone or zones [1]. Key components of AHU include dampers, filters, heating/cooling coils, blower/fans, humidifier, air mixing plenums, vibration isolators.

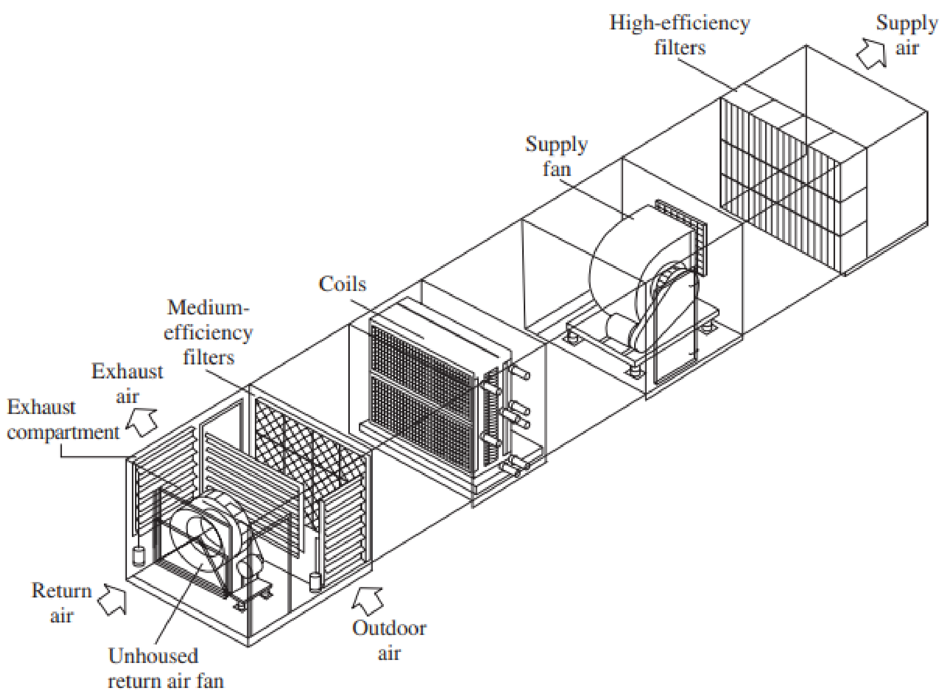

FIG. 1 Typical AHU

Dampers: Damper is a device which uses valves or plates to regulate the flow of air inside an air handling unit [14]. By adjusting the dampers we can increase or decrease the amount of air entering the air handling units. The main component of a damper is the blade which by adjusting its position controls the air. In addition, dampers include frames, linkages, axles, bearings, seals, blade pins, actuating motors, flanging, jackshafts, and sleeves, among other components. Filters: Filters are the first component inside an air handling unit before heating or cooling coils and just after the dampers [6]. In an AHU we typically use two sets of filters, which are called primary and secondary filters. Filters are used in an AHU to clean the air having dust particles and other undesired substances present. The primary filters are typically the panel filters. They are made with a pleated design to increase the surface area to catch more dust particles. They're usually made from a synthetic material with a cardboard outer frame and they're held in shape with a wire mesh. Primary panels are typically used to protect the more expensive secondary panel.

Heating/Cooling Coils: Air Handling Units are typically used for heating, cooling, or both to change the supply air temperature, and humidity level depending on the situation and location. Heat exchanger coils are used for heating and cooling, such coils may be direct or indirect in relation to the medium providing the heating or cooling effect.

Heat exchanger cooling coils are used to provide cooling to the building spaces and to maintain the humidity level. These coils use chilled water from the chiller or refrigerant gas to cool the air.

Heat exchanger heating coil is used to heat the air during winter conditions either with hot water system or with electric heaters.

Blower/Fan: Blowers or fans are used to push the air to the building spaces with the help of ventilation system duct work [10]. These fans can either be single speed, dual speed or can be equipped with variable frequency drives in order to control the speed of the fan.

In a large commercial building, AHU can have multiple blowers typically placed at the end of the AHU and before the supply ductwork that's why it is called "supply fan" as shown in Fig. 1.

3 | METHODOLOGY

An Air Handling Unit is designed to supply constant or variable air volume for different levels of air distribution. The equipment mentioned above are all connected inside a box or what can be said Panel. The panel is an aluminum body having dampers at the outer side and filters, coils and fan inside it. The process of the AHU goes like air enters, untreated, the plenum and goes through the filter in order to remove the contaminants which exist in the air. Different types of filters are installed having different grades of filtration. After the air is filtered, it moves on towards the coil section in order for heat transfer to happen. For example if a cooling coil is installed inside the AHU, it means that the air which follows will be cooled down to the certain required temperature. One thing must be made sure that the air which passes through the coil must not have a parallel path particularly in vertical plane systems with double width double inlet fans because these fans then may not completely mix the air which can lead to different temperatures. Poor mixing with high outdoor percentage can result in freezing temperatures at the coils.

The basic method used in this project for cooling the air is by cooling coil with chilled water as the medium for heat transfer. In this method, air passes through an all finned counter flow heat exchanger. Some of the air may pass through it and some amount of it may just bypass without any contact with these fins. The ratio of this bypass air varies from approximately 30% for a 4 row coil and by 2% if the coil has 8 rows. For a coil, a serious problem which should be taken into consideration is coil freezing. Antifreeze solutions or complete coil draining prevents this problem from happening. An easy solution to it is that drain pans should be installed which should be slopped at the drain point of the AHU. This will not allow the water from standing inside the AHU near the coil. Moving forward, after the air attains the certain temperature which needs to be delivered, a supply fan is installed which is connected directly to the duct of the HVAC system. The supply fan which is to be designed is a centrifugal belt driven fan. To avoid losses inside the unit, the distance between the case of the AHU and the fan should be at least equal to the diameter of the fan wheel. Both draw through and blow through AHU are commonly used. Either arrangement is possible for both small and large spaces. The difference between blow through and draw through AHU is that in blow through units the fan is placed before the cooling coil right after the filter section where as in draw through units the blower is installed after the cooling coil. A draw through unit provides more even distribution of air over all parts of the coil however some heat of the fan is added to the airstream which must be taken into account when calculating the desired supply air temperature. On the casing of the AHU, there are pressure gauges installed at inlet point and the outlet point. The purpose of these gauges is to notice if there is any pressure drop across the AHU. A pressure drop indicates that the AHU requires maintenance. This can happen because of any sort of problem occurring at any component of the AHU

4 | FAN SELECTION AND DESIGN

For this analysis, the selection made to design the centrifugal fan is of Backward Inclined Curve blades. These are similar in design and performance to those with Airfoil Blades except for a moderate decline in mechanical efficiency and in the structural strength. The advantages of BI curve are that they are less costly in production as compared to the airfoil and also that they can tolerate somewhat higher temperatures and slightly dustladen gases

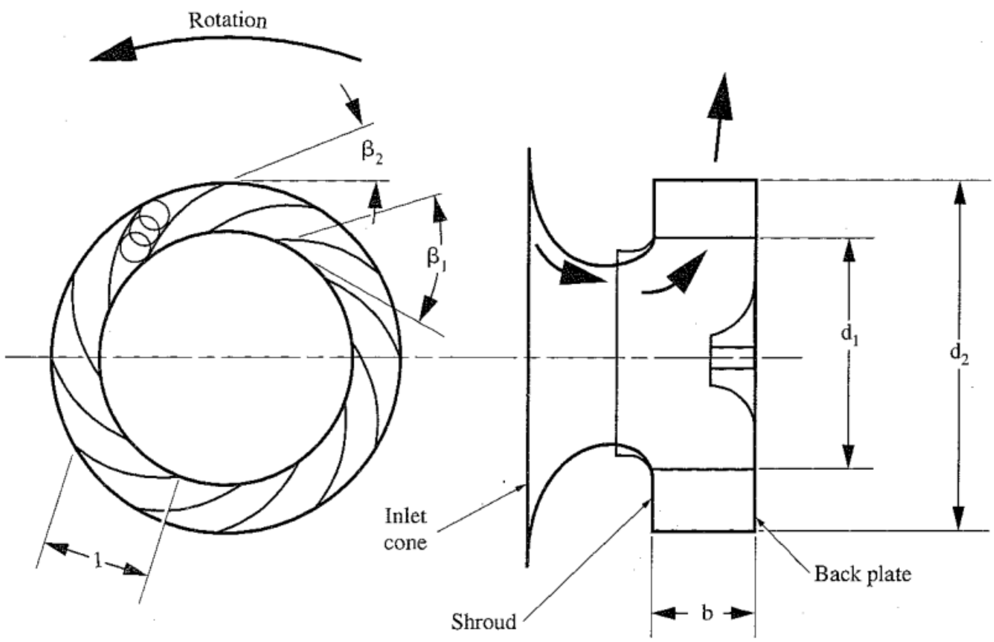

FIG. 2 Typical AHU

Air-handling fans/wheels consist of a plate and a conical shroud. The wheel has a smaller diameter ratio d1/d2, narrower blades and steeper bade angles. The leading edge maybe slanted. These wheels are for handling air, gas, or fumes that are clean or slightly dusty. It usually have 10 BC blades, with blade angles of about 23o at the leading edge and about 57o at the blade tip. Mentioned below are the formulas that we used for the calculations of the basic parameters required to design this impeller

$$b = 0.46d_1 \tag{1}$$

where b is the blade width, and d_1 is the inner diameter of the wheel.

$$\tan\beta = \frac{V_1}{V_2} = 175\frac{\text{cfm}}{(d_1)^2 b \times \text{rpm}} \tag{2}$$

Where, β_1 is angle between tangent of inner circle and the leading edge of blade, V_1 is absolute velocity at the leading edge and V_2 is blade velocity at the leading edge.

$$\cos\beta_1 = (d_1/d_2)\cos\beta_2 \tag{3}$$

Where, d_2 is the out diameter of the wheel, β_2 is angle between tangent of outer circle and the trailing edge of the blade.

To support the selection the values were compared with the Air-handling centrifugal fans with **BI** blades to airfoil centrifugal fans. Below, the figure shows performance comparison between 26 1/8-inch AH unit and 27-inch airfoil centrifugal fan. Both the fans are running at 1160rpm. The following can be noted from the graph • The AH unit has steeper static pressure curve as compared to the airfoil centrifugal fan which results in less air volume but high maximum static pressure. • The maximum mechanical efficiency of AH unit is 79% which is lower than the 88% of airfoil centrifugal fan but still it is a very good efficiency. For design and calculations the Aerovent Industrial Ventilation System catalogue 760 was followed. From the catalogue the values opted were from 122 BIUB fan for design parameters. BIUB denotes that the selection is of a Backward Inclined Belt Driven fan. The options for wheel diameter varied from 10.5 to 60. This category lies under the umbrella of HVAC general fans and can be selected as per the requirement. Our selection features flat blade inclined wheel which can be utilized in applications requiring high CFM at low or medium pressures. Attached below is a screenshot from the 760 catalogue

122 BIUB/BIUBR/BIUBSH

Wheel Dia. = 12.25 inches **Fan Efficiency Grade: FEG80**
Outlet Area = 0.86 ft^2 **Max. BHP = 0.076 (RPM÷1000)^3**

CFM	OV	0.25" SP		0.5" SP		1" SP		1.5" SP		2" SP		3" SP		4" SP		5" SP		6" SP		7" SP		8" SP	
		RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
688	800	869	0.05	1044	0.08	1335	0.17																
860	1000	994	0.07	1152	0.12	1413	0.21	1642	0.31														
1032	1200	1123	0.11	1271	0.16	1512	0.26	1720	0.37	1911	0.49												
1204	1400	1256	0.15	1397	0.21	1622	0.32	1816	0.45	1992	0.58	2317	0.87										
1376	1600	1396	0.20	1525	0.27	1738	0.40	1922	0.54	2088	0.68	2390	0.98	2671	1.33								
1548	1800	1539	0.27	1655	0.34	1861	0.49	2035	0.64	2193	0.79	2480	1.12	2741	1.48	2989	1.87						
1720	2000	1685	0.36	1790	0.43	1988	0.60	2154	0.76	2305	0.93	2578	1.27	2827	1.65	3059	2.05	**3283**	**2.48**	**3500**	**2.94**		
1892	2200	1834	0.46	1929	0.54	2116	0.72	2277	0.90	2421	1.08	2683	1.45	2922	1.84	3144	2.26	**3355**	**2.71**	**3559**	**3.18**	**3758**	**3.67**
2236	2600	2135	0.72	2216	0.81	2377	1.01	2531	1.23	2667	1.44	2909	1.87	3131	2.31	**3337**	**2.77**	**3533**	**3.25**	**3719**	**3.75**	**3898**	**4.27**
2580	3000	2439	1.07	2511	1.17	2650	1.40	2789	1.64	2921	1.89	3151	2.38	**3358**	**2.88**	**3552**	**3.39**	**3735**	**3.90**	**3910**	**4.44**	**4079**	**5.00**
2924	3400	2746	1.52	2810	1.64	2934	1.89	3057	2.15	**3179**	**2.43**	**3402**	**2.99**	**3599**	**3.55**	**3781**	**4.11**	**3955**	**4.69**				
3268	3800	3055	2.09	3112	2.22	**3224**	**2.49**	**3334**	**2.78**	**3444**	**3.08**	**3658**	**3.71**	**3849**	**4.34**	**4023**	**4.96**						

FIG. 3 Aerovent Catalogue snapshot

From this table it was decided to go with 1204 cfm, 1400 outlet velocity at 1 wg static pressure which gives 1622 rpm and 0.32 bhp. The outer wheel diameter is mentioned at the top as wheel dia which is 12.25 inches. It was required to check for which value of inner diameter we get better mechanical efficiency. So the best way out was to apply hit and trial method to find out the best efficiency. For this we had to calculate the static pressure, velocity pressure, total pressure, air horsepower and mechanical efficiency at different diameters.

Inner Diameter (in)	Static Pressure (Pa)	Velocity Pressure (Pa)	Total Pressure (Pa)	Air Horsepower	Mechanical Efficiency
5	0.200	0.122	0.322	0.069	18.75%
6	0.300	0.122	0.422	0.078	24.50%
7	0.400	0.122	0.522	0.098	30.77%
8	0.519	0.122	0.641	0.121	37.98%
9	0.657	0.122	0.779	0.147	49.15%

FIG. 4 Results of calculations at different inner diameter

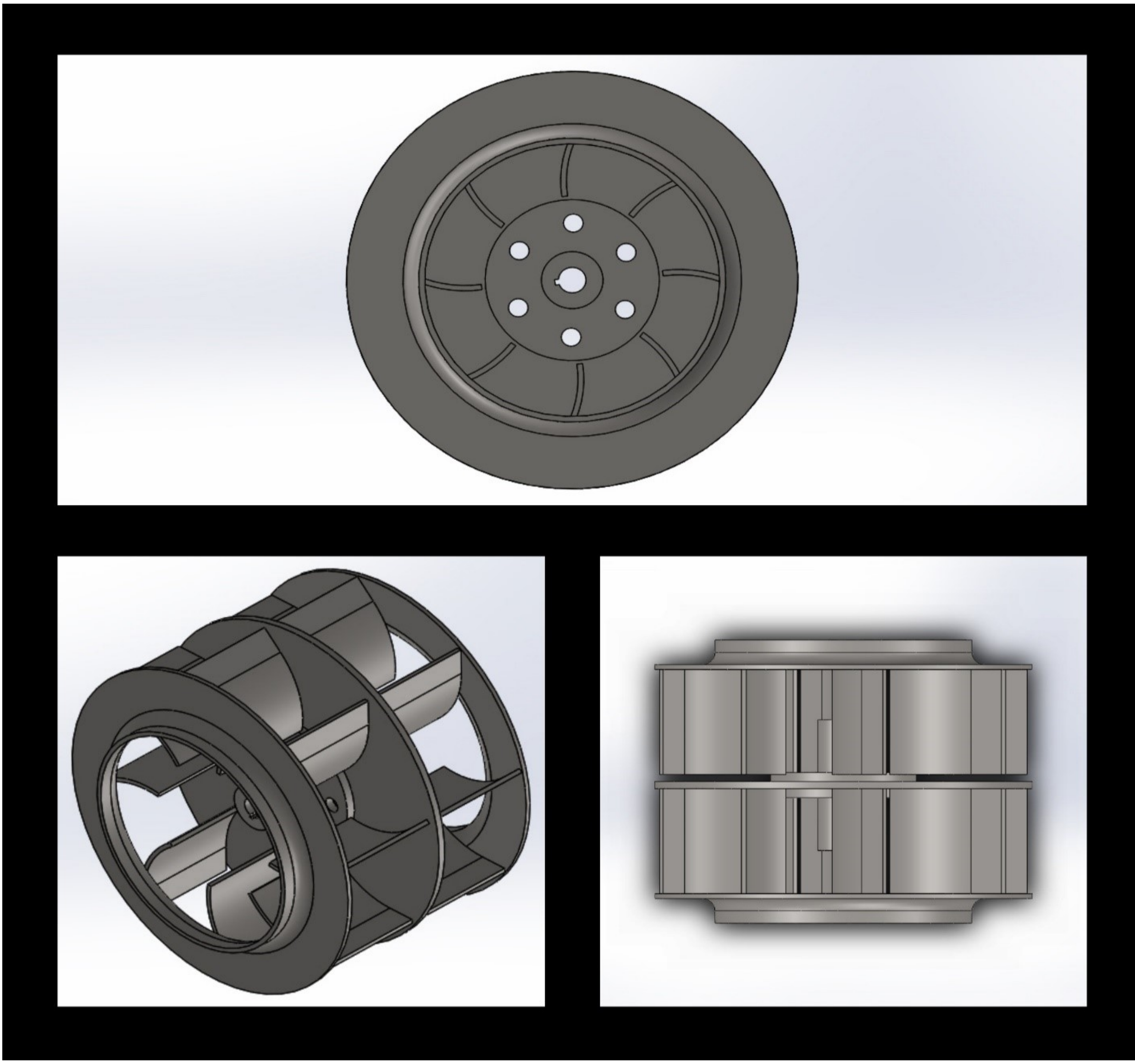

FIG. 5 Double width double inlet Impeller

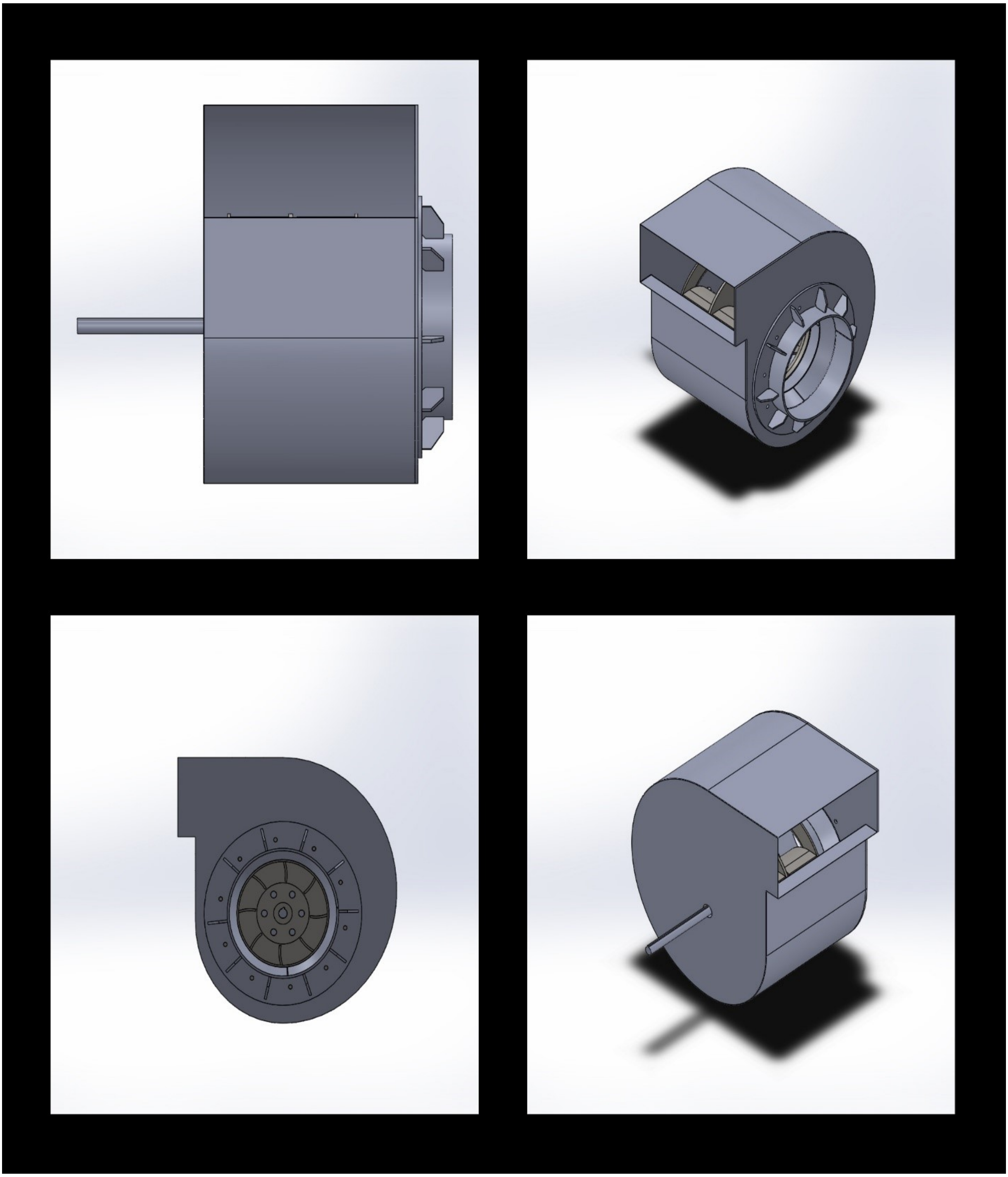

FIG. 6 Blower Design

5 | COIL SELECTION AND DESIGN

In finned coils, the external surface of the tubes is primary, and the fin surface is secondary. The primary surface generally consists of rows of round tubes or pipes that may be staggered or placed in line with respect to the airflow. Flattened tubes or tubes with other non-round internal passageways are sometimes used. The inside surface of the tubes is usually smooth and plain, but some coil designs have various forms of internal fins or turbulence promoters either fabricated or extruded to enhance performance. The tubes are interconnected by return bends to form a serpentine arrangement (circuits). Cooling coils are made of aluminium fins and copper tubes. Common core tube outside diameters are 5/16, 3/8, 1/2, 5/8, 3/4, and 1 in., with fins spaced 4 to 18 per inch. Tube spacing ranges from 0.6 to 3.0 in. on equilateral (staggered) or rectangular (in-line) centers, depending on the width of individual fins and on other performance considerations. Fins should be spaced according to the job to be performed, with special attention given to air friction. The primary surface that is the copper tube is mechanically expanded into the fin collars of the secondary surface. The mechanical expansion provides a permanent metal-to-metal bond for efficient heat transfer. Tubes are staggered in the direction of airflow The secondary surface which are the fins of the coil are corrugated plate type fins.

Coil Options

Rows	Fin Height	Fin Length	Fin Spacing	Fin Thickness ALUMINUM	Fin Thickness COPPER	Tube O.D.Tube Thickness	Tube Spacing Face x Row	Casing	Max. Std. Operating Conditions
1,2, 3,4,5, 6,8, 10,12	6" to 60"	12" to 240"	1/2" 8 to 14 fins per inch 5/8" 6 to 14 fins per inch	1/2" 0.006" 5/8" 0.008" 0.010"	1/2" 0.006" 5/8" 0.006" 0.008" 0.010"	1/2" 0.017" 0.025" 5/8" 0.020" 0.025" 0.035" 0.049"	1/2" 1.25"x1.083" 5/8" 1.50"x1.299"	16 or 14 GA Galvanized Steel 304, 316 Stainless Steel	250 PSIG 300° F

FIG. 7 Coil Options for design

FIG. 8 Parts used to design the cross flow heat exchanger of AHU

FIG. 9 Design of Cross Flow Heat Exchanger

6 | AHU DESIGN

For the validation of the design, consultations were made with Coolmax International. All the calculations and results were provided to them which also consisted of all the selections and designs. The calculations were approved by their professionals. They then generated, by using their professional software a two dimensional design of an AHU. Fig 10 shows a design with different color bands representing the components inside the casing of the AHU

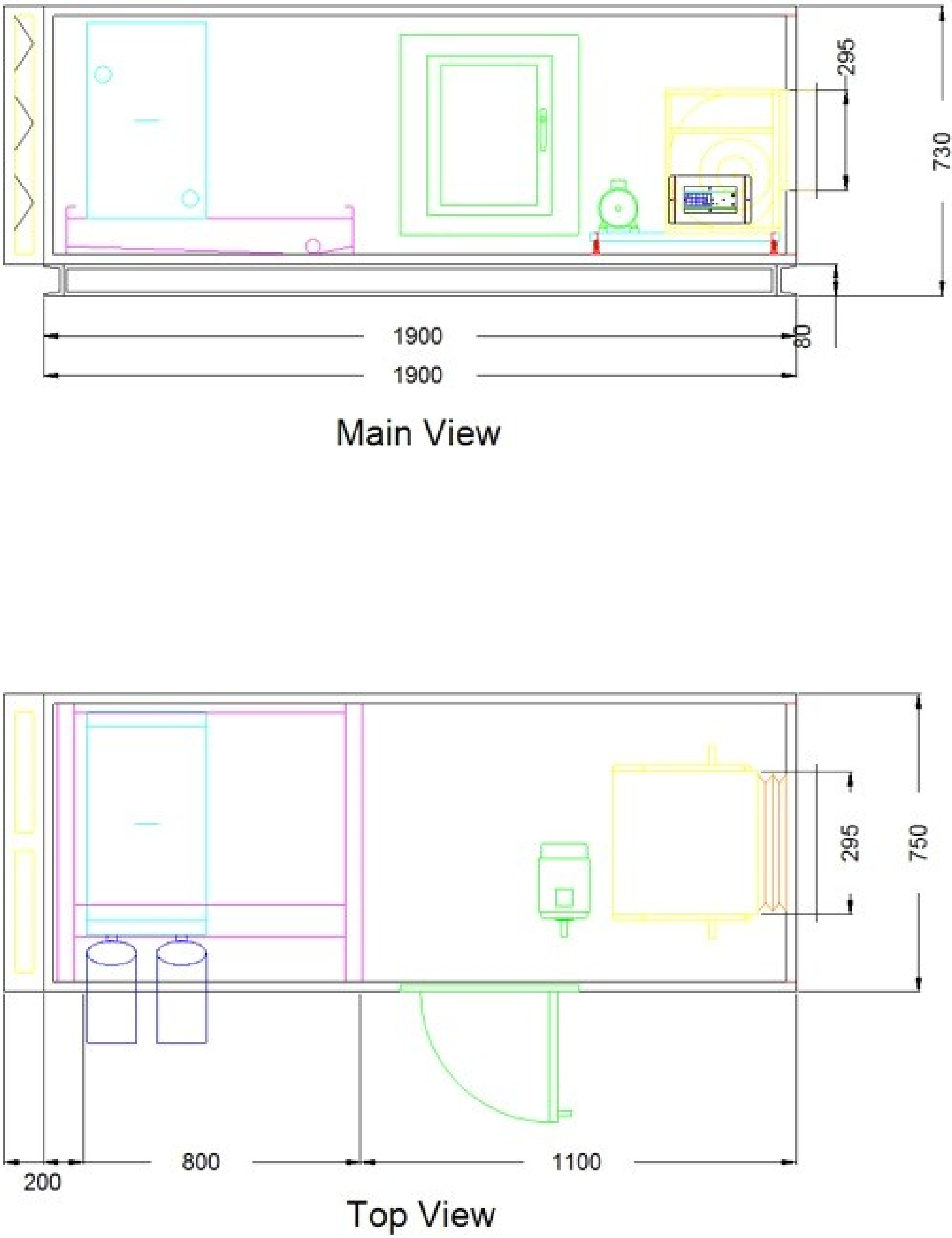

FIG. 10 2D design of AHU

The following color band represent different components of an AHU • The initial yellow color represent the filters. From the main view, the black lines inside the filter section represents the dampers. • The cyan color represents the heat exchanger with the blue color cylinders from the top view being the water links connected to an AHU • The purple color represents the PU Insulations • The Green color represents two things. The is the panel door and the other thing is the motor which is connected with the fan via a belt • The yellow color which follows represents the blower of the AHU

New Air Vol	1204	CFM	Motor Type	TEFC-IP55	
Blower Brand	Yilida		Motor Pwr-Pole	0.55-4	kW-Pole
Blower Type	Backward Curved		Motor Brand	BeiDe	
Blower Model	SYQ225R		Motor Supply	380V/3Ph/50Hz	
Shaft Brand	Standard		Mtr Shaft Brand	Standard	
Supply Dir.	FT		Motor Hz Type	Single Speed	
Supply Air Vel	6.85	m/s	Motor Eff	Nomal Efficiency	
Blower Spd	2727	RPM	Motor Loc	Rear Motor	
Max Spd	4500	RPM	Terminal Box	Motor Power Less Than or Equal to 7.5KW	
			Air Velocity	1.35	m/s
TSP	456	Pa	(Unit Section, Vclass)		
Blower OP	0.49	kW	Wiring Loc	Left	
Total Eff	56.2	%	Door Type	Hinged	
Motor Power Input	0.73	kW	Door Loc	Left	
Outlet Type	Flange		Section Depth	1100	mm
SFP int	314.3	W/(m³/s)	ISP	455	Pa

Note1 : The fan system effects are taken into account in the fan performance.

Note2 : Air density is set at 1.2kg/m³.

FIG. 11 AHU Specifications

7 | CONCLUSION

In order to attain more efficiency with these selections, we can add further more components like an energy wheel for the heat recovery process. The requirement of HVAC systems will only keep on increasing and keeping in mind the energy consumption of this system we need to further work on the optimization of every component of it. Work should be done via mathematical modelling and by making this system smart. Smart in sense that we install IoT systems which keeps on monitoring such complicated equipment.

References

[1] R. Howell, W. Coad, and H. Sauer, "Principles of heating ventilating and air conditioning, ashrae handbook—fundamentals."

[2] R. Miller and M. Miller, "Air conditioning and refrigeration, mcgraw hill professional."

[3] L. Sun, Y. Li, H. Jia, and Y. Ying, "Research on fault detection method for air handling units system," *IFAC-PapersOnLine*, vol. 52, no. 3, p. 79–84.

[4] N. A, "Solutions, chilled or hot water coil type wc."

[5] A. Shazad and M. Uzair, "Utilization of solar energy for cooling applications," *Memoria Investigaciones en Ingeniería*, vol. 24, p. 69–91.

[6] N. Rehman and M. Uzair, "The proper interpretation of analytical sky view factors for isotropic diffuse solar irradiance on tilted planes," *Journal of Renewable and Sustainable Energy*, vol. 9, no. 5.

[7] M. Uzair and N. Rehman, “Intercept factor for a beam-down parabolic trough collector,” *Journal of Solar Energy Engineering*, vol. 143, no. 6, p. 061002.

[8] A. Naqvi, T. Nadeem, A. Ahmed, M. Uzair, and S. Zaidi, “Techno-economic design of a grid-tied photovoltaic system for a residential building,” *Adv Energy Res*, vol. 8, p. 59–71.

[9] S. Wang, “Handbook of air conditioning and refrigeration,” in *McGraw Hill ISBN: 9780070681675*, 2nd ed.

[10] D. Torre Vázquez, “Validation exercise for facility gmp hvac system,” *Manufacturing Engineering*.

[11] M. Zaki and D. Mishra, “Overview of hvac system: operational significance of hvac provision for pharmaceutical facilities,” *International Journal on Recent and Innovation Trends in Computing and Communication*, vol. 3, no. 3, p. 1261–7.

[12] L. Nilsson, “Air-handling energy efficiency and design practices,” *Energy and Buildings*, vol. 22, no. 1, p. 1–13.

[13] Y. Lun and S. Tung, “Air handling unit,” in *Heat Pumps for Sustainable Heating and Cooling*, Cham: Green Energy and Technology. Springer.

[14] F. Bleier, “Fan handbook: selection, application, and design.”