

Designing HVAC System Of VRV-A in Residential Unit by Cooling Load calculation from DACS-HKGS Software v 2.05 and HAP Software v 4.90

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Abstract - Air Conditioning System is the process of treating the air to simultaneously control temperature, humidity, cleanliness & distribution to meet the requirements of a room, such not only at office buildings, malls, airports but also at residences. Indonesia, with its tropical climate, which has hot, dirty (dusty, smoky) air and erratic winds, needs a way to get comfortable using air conditioning equipment. In this paper, the calculations were carried out, taking into account the ASHRAE standards. For Space references and calculations, the plan is developed by AUTO CAD. Along with the development of Air Conditioning technology and the increasing awareness of climate change, energy consumption, and also more flexible layout of Air Conditioning placement so as to get comfortable, making the use of VRV - A continues to grow not only in office buildings but also in residential areas. This paper will explain how to design an Air Conditioning system of VRV-A by selected indoor unit and an outdoor unit with a connection ratio between 50% - 200%. The cooling load calculation is carried out by using HKGS v 2.05 software and HAP software v 4.90, which is available in the worldwide market. Nowadays, people are estimating the cooling load calculation by approximation method, i.e., by giving dimensions of the building, which the sellers are estimating roughly the cooling capacity.

Keywords - ASHRAE, AUTOCAD, Residences, Tropical, VRV, HKGS Software, HAP Software

I. INTRODUCTION

Residential is housing that functions as a place to live or a residential environment equipped with facilities and infrastructure to accommodate the environment. The ideal housing is housing that is not only assessed from the exterior and interior of the building, its location towards the workplace, education area, shopping area and is easily accessible from the main route but also from the Air Conditioning System. With the selection of a good and reliable Air Conditioning System that will provide

comfort and affect the psychology of the occupants so that every activity can be carried out properly.

Indonesia is a tropical country with a high level of temperature and humidity, and this greatly affects the level of comfort in the room, the standard of comfort in the room against the surrounding air conditions (thermal comfort) is obtained at temperature 62 °F (19,6 °C) – 82 °F (27,9 °C) [2] with relative humidity less than 65% [3].

Air Conditioning system with the latest technology, namely VRV (Variable Refrigerant Volume) or VRF (Variable Refrigerant Flow). The term VRV (Variable Refrigerant Volume) or VRF (Variable Refrigerant Flow) refers to the ability of the Air Conditioning system to control the amount of refrigerant flowing into each evaporator, allowing the use of multiple evaporators of different capacities and configurations, controlling comfort, heating and cooling simultaneously. In different zones and heat recovery from one zone to another [4]. VRV system where one outdoor unit can be used for several indoor units; in other words, the general arrangement of the VRV AC system does not require a large space for many outdoor units, resulting in neatness and beauty in the residential area. Since the release of the first VRV system in 1982, Daikin continuously added new features to meet evolving market demands. From increasing the capacity load to incorporating more recovery technologies, they continue to improve the VRV system to achieve the best in comfort, efficiency, and reliability.

By using the HKGS software v 2.05 and HAP Software v 4.90 to calculate the cooling load requirement for air conditioning (cooling capacity) in a residential by paying attention to heat sources in the room that can increase temperature and air moisture content. Sources of heat can come from outside or inside. Heat sources from outside the room can come from the conduction of heat through roofs, windows, floors, and partition walls. Heat



sources from inside the room can come from humans and room equipment such as cupboards, lights, and others.

II. TECHNOLOGY OVERVIEW

A. VRV-A

VRV-A offers technological improvements over the VRV-IV (previous generation). These technological improvements are to meet various needs while increasing energy savings, ease of installation, and systems with high reliability. The following is a discussion of what the technology improvements are:

- **Energy Savings**
Unlike previous generations of VRV, VRV-A combines advanced Software and Hardware for greater energy savings during system operation. The combination of VRV (Variable Refrigerant Volume), VRT (Variable Refrigerant Temperature), and VAV (Variable Air Volume) technologies can be achieved both in terms of energy-saving and comfortable air conditioning.
- **Automatic Refrigerant Function**
The automatic refrigerant function automatically determines the optimal amount the refrigerant tone charged. This function prevents a capacity shortage or energy loss due to excessive or insufficient refrigerant.
- **High Reliability**
The control functions of inverter technology have been integrated on printed circuit boards. As well as improving reliability, this has reduced the number of parts and enabled downsizing.

B. Indoor Unit VRV-A (FXMQxy-PAVE)

One of the types of VRV-A indoor units is ceiling mounted duct type, or usually, we call it the FXMQ-PAVE type. The following is the description of FXMQxy-PAVE:

- **F** = Unit Category of indoor unit cooled type.
- **X** = Series Category of the inverter.
- **M** = Ceiling Mounted Duct.
- **Q** = Using Refrigerant R410-A.
- **xy** = Capacity Indication from (20(0.8 HP) -140(6 HP)).
- **PAVE** = Power Supply 1 phase, 220 – 240 VAC, 50 – 60 Hz.

This type of indoor unit has adjustable external static pressure from 30 Pa to 100 Pa, and all models of this type have a height of 300 mm. Ceiling mounted duct typed facilitated by separating the drain pipe from a maintenance inspection panel for the drain line and also equipped with silver ion which serves to prevent the growth of mucus, fungi, and bacteria that can blockages and odors smell in the drainage path [4].



Fig 1. Ceiling Mounted Duct. [4]

These are the specification of indoor units ceiling-mounted duct:

MODEL		FXMQ20PAVE	FXMQ25PAVE	FXMQ32PAVE	FXMQ40PAVE	FXMQ50PAVE
Power supply		1-phase, 220-240 V/220 V, 50/60 Hz				
Cooling capacity	Btu/h	7,500	9,600	12,300	15,400	19,100
	kW	2.2	2.8	3.6	4.5	5.6
Power consumption	kW	0.056**	0.056**	0.060**	0.15**	0.128**
Casing		Galvanized steel plate				
Airflow rate (H/H/L)	m ³ /min	9/7.5/6.5	9/7.5/6.5	9.5/8/7	16/13/11	18/16.5/15
	cfm	318/265/230	318/265/230	335/282/247	565/459/388	635/582/530
External static pressure	Pa	30-100 (50)**	30-100 (50)**	30-100 (50)**	30-160 (100)**	50-200 (100)**
Sound level (H/H/L)	dB(A)	33/31/29	33/31/29	34/32/30	39/37/35	41/39/37
Dimensions (HxWxD)	mm	300x550x700	300x550x700	300x550x700	300x700x700	300x1,000x700
Machine weight	kg	25	25	25	27	35
Piping connections	Liquid (Flare)	φ6.4	φ6.4	φ6.4	φ6.4	φ6.4
	Gas (Flare)	φ12.7	φ12.7	φ12.7	φ12.7	φ12.7
	Drain	VP25 (External Dia, 32/Internal Dia, 25)				
MODEL		FXMQ63PAVE	FXMQ80PAVE	FXMQ100PAVE	FXMQ125PAVE	FXMQ140PAVE
Power supply		1-phase, 220-240 V/220 V, 50/60 Hz				
Cooling capacity	Btu/h	24,200	30,700	38,200	47,800	54,600
	kW	7.1	9.0	11.2	14.0	16.0
Power consumption	kW	0.138**	0.185**	0.215**	0.284**	0.405**
Casing		Galvanized steel plate				
Airflow rate (H/H/L)	m ³ /min	19.5/17.5/16	25/22.5/20	32/27/23	39/33/28	46/39/32
	cfm	688/619/565	888/794/706	1,130/963/812	1,377/1,165/988	1,624/1,377/1,130
External static pressure	Pa	30-200 (100)**	30-200 (100)**	30-200 (100)**	30-200 (100)**	50-140 (100)**
Sound level (H/H/L)	dB(A)	42/40/38	43/41/39	43/41/39	44/42/40	46/45/43
Dimensions (HxWxD)	mm	300x1,000x700	300x1,000x700	300x1,400x700	300x1,400x700	300x1,400x700
Machine weight	kg	35	35	45	45	48
Piping connections	Liquid (Flare)	φ9.5	φ9.5	φ9.5	φ9.5	φ9.5
	Gas (Flare)	φ15.9	φ15.9	φ15.9	φ15.9	φ15.9
	Drain	VP25 (External Dia, 32/Internal Dia, 25)				

Fig 2. Type of indoor units FXMQ-PAVE [4]

C. Outdoor unit VRV-A (RXQxy-AYM)

There are three (3) types for Outdoor unit VRV-A, which are single-unit outdoor, double unit outdoor, and triple unit outdoor. For single-unit outdoor usually, we called it RXQ-xyAYM. The following is the description of RXQ-xyAYM:

- **R** = Unit Category of Outdoor unit for the air-cooled type
- **X** = Series Category of the inverter.
- **Q** = Using Refrigerant R410-A.
- **xy** = Capacity Indication from (6 HP – 20 HP).
- **A** = Single Unit
- **YM** = Power Supply 3 phase, 380 – 415 VAC, 50/60 Hz.

The VRV-A outdoor has low operation sound, between 50 to 60 dB. For areas with stringent restrictions placed on outdoor sound levels, the outdoor unit can be set for low operation sound during the nighttime to meet sound restrictions. The unique 4-sided all-around heat exchanger ensures sufficient surface area for the heat exchanger.

This improves the heat exchanger performance without increasing the footprint [4].

Daikin VRV-A series incorporates a simplified and efficient test operation function that not only greatly accelerates the installation process but also effectively improves the field setting quality like [4]:

- Automatically checks the wiring between outdoor units and indoor units to confirm whether there is defective wiring.
- Automatically check whether the stop valve in each outdoor unit is functioning normally to ensure the smooth operation of the air conditioning system.
- Confirms piping length to optimize operation.

Model	RXQ6AYM	RXQ8AYM	RXQ10AYM	RXQ12AYM	RXQ14AYM		
Combination units	—	—	—	—	—		
Power supply	3 phase 4-wire system, 380-415V/380V, 50Hz/60Hz						
Cooling capacity	Blu/h kW	64,600 16.0	76,400 22.4	95,500 28.0	114,000 33.5	136,000 40.0	
Power consumption	kW	3.38	5.17	6.94	8.70	10.7	
Capacity Control	%	25-100	20-100	13-100	12-100	11-100	
Casing colour	Ivory white (S17.5/1)						
Compressor	Type	Hermetically sealed scroll type					
	Motor Output x Number of Units	kW	2.3x1	3.4x1	4.5x1	5.6x1	6.4x1
Airflow rate	m ³ /min	119	178	191	257		
Dimensions (HxWxD)	mm	1,657x930x765				1,657x1,240x765	
Machine weight	kg	175		185		215	
Sound level	dBA(A)	56		57	59	60	
Operation range	*CDB	10 to 49					
Refrigerant	Type	R-410A					
	Charge	kg	5.9		6.7	6.8	7.4
Piping connections	Liquid	mm	ø9.5 (Brazing)		ø12.7 (Brazing)		
	Gas	mm	ø19.1 (Brazing)		ø22.2 (Brazing)		

Fig 3. Type of single outdoor units. [4]

III. METHODOLOGY

A. Residential House Layout and Location

The objective of this project is to design an HVAC system VRV-A which serves an area of the residential house Mrs.S which is located in Jakarta, Indonesia. The floor plan for this portion of the layout is shown in Figure 5. It is comprised of a Bedroom, WIC (Walk In Closet), and Bathroom on the 2nd floor, but this project only designs an HVAC system for Bedroom and WIC (Walk In Closet). The rooms in this portion will be air-conditioned by one packaged rooftop.

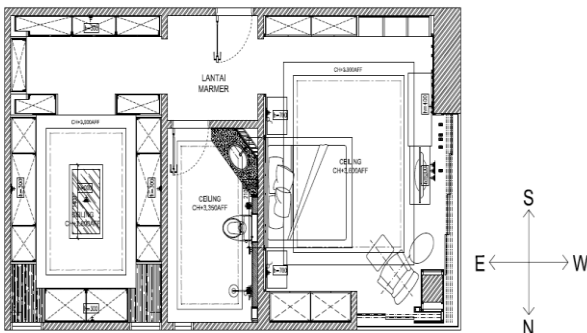


Fig 5. Residential House Layout of Mrs.S

These are the space characteristic of bedroom and WIC:

Table 1: The floor, Ceiling, Wall, and Partition Dimensions

Room Name	Floor Area (m ²)	Ceiling Height (m)	Occupancy (Person)	The outer wall (m)			The inner wall (m)		
				N	E	W	E	S	W
Bedroom	30.2	3.9	2	5.0		6.2	6.2	7.5	
WIC	22.3	3.9	1	3.8	6.2			3.8	6.2

Window name	Width (m)	Height (m)	Quantity	Material	Window (m ²)	
					N	W
Window Bed (N)	2.6	2.7	1	Clear 5mm	7.0	
Window Bed (W)	4.7	2.7	1			12.7
Window WIC (N)	0.8	2.7	2		4.3	

Table 2: The Window Characteristic

Table 3: The U-Value Outer wall

Partition (Inner Walls)	thickness (m)	Conductivity (k), (W/m.K)	1/k, (m.K/W)	R (m ² .K/W)	U (W/m ² .K)
Inside Air				0.11	
Plaster	0.025	0.79	1.27	0.032	
Normal Concrete	0.15	1.4	0.72	0.11	
mortar	0.019	1.5	0.67	0.013	
Plaster	0.006	0.79	1.27	0.008	
Inside Air				0.11	
Total R Value				0.383	
U Value					2.62

Table 4: The U-Value Inner wall

Roof (with Ceiling board)	thickness (m)	Conductivity (k), (W/m.K)	1/k, (m.K/W)	R (m ² .K/W)	U (W/m ² .K)
Gypsum Board	0.012	0.17	5.89	0.08	
Air Gap				0.52	
Total R-Value				0.62	
U Value					1.66

Table 5: The U-Value Roof (With Ceiling Board)

Wall	thickness (m)	Conductivity (k), (W/m.K)	1/k, (m.K/W)	R (m ² .K/W)	U (W/m ² .K)
Inside Air				0,12	
Insulation	0.01	0.19	5.27	0.05	
Normal concrete	0.2	1.4	0.72	0.15	
Mortar	0.02	1.5	0.67	0.013	
Plaster	0.003	0.79	1.27	0.004	
Outside Air				0.03	
Total R-Value				0.367	
U Value					2.725

Table 6: The U-Value of Glass

Window/Glass Type	thickness (mm)	Shading Factor (SC)	U (W/m ² .K)
Clear Glass	5	0.63	4.97



Fig 4. Bedroom Space



Fig 5. WIC Space

B. Cooling Load Calculation

A cooling load calculation determines total sensible cooling load from heat gain through opaque surfaces (walls, floors, ceilings, and doors), through transparent fenestration surfaces (windows, skylights, and glazed doors), caused by infiltration and ventilation, and because of occupancy. The latent portion of the cooling load is evaluated separately. Although the entire structure may

be considered a single zone, equipment selection, and system design should be based on room-by-room calculations. For proper design of the distribution system, the conditioned airflow required by each room must be known [5].

a) Cooling Load Calculation by DACS-HKGSG Software v 2.05.

The DACCS-HKGSG Software ver 2.05 program uses a steady-state load calculation method to compute heat load over a 24-hour period (1 day) on a summer day and a winter day. It also applies effective temperature differences in consideration of the effect of the heat accumulated in the walls since the heat load, which is received from strong sunlight through the outer walls and roofs in summer, is substantial. The program contains the 24-hour weather condition data of major cities in summer and winter (TAC 5%). The standard design data include weather data of 140 countries, which is contributed by the climate data of the British Meteorological Office and Japan Meteorological Agency. The software computes cooling load according to the following flowchart:

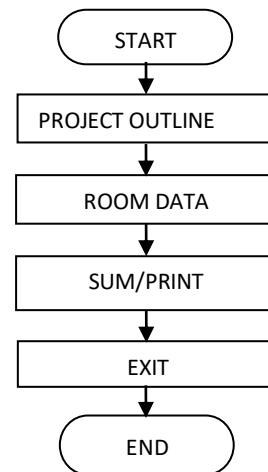


Fig 6. Operational Flowchart DACS-HKGSG Software

These are the cooling load calculation of residential Mrs.S by DACS-HKGSG Software v 2.05:

- Project Outline
Input the project name, country/city names, address, outer wall assembly, wheater data, and design data such as overall heat transfer coefficient.

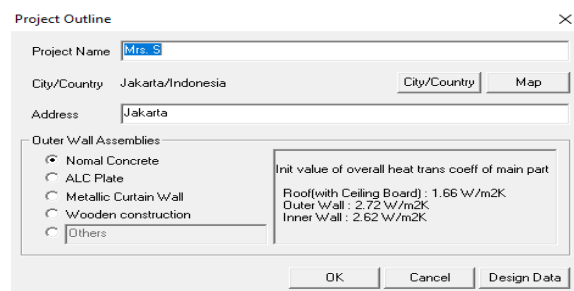


Fig7. Project Outline Mrs.S DACS-HKGSG Software

- Room Data
Determine the room specification of Mrs.S, such as room name, floor number, usage of room, ventilation system, overall heat transfer coefficient, design temperature and humidity, schedule, and so on.

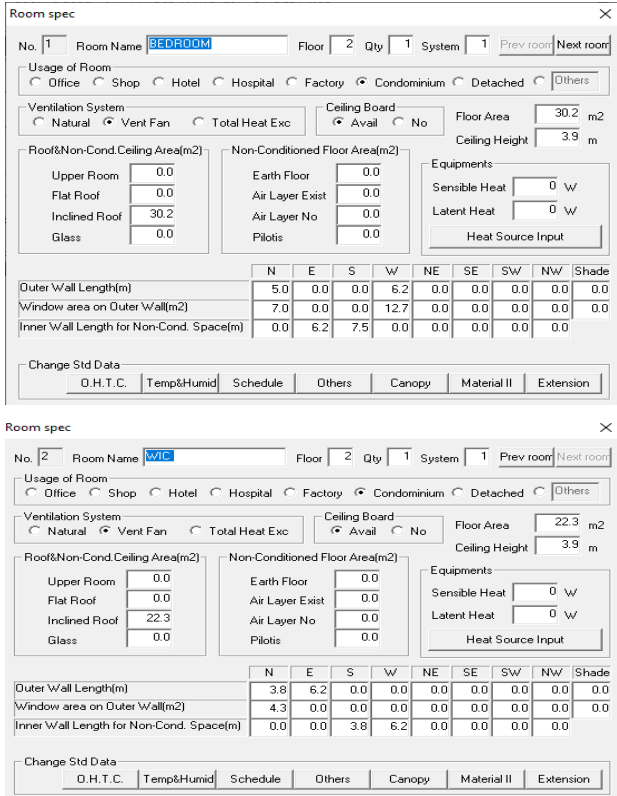


Fig 8. Room data of bedroom and WIC Mrs.S DACS-HKGSG Software

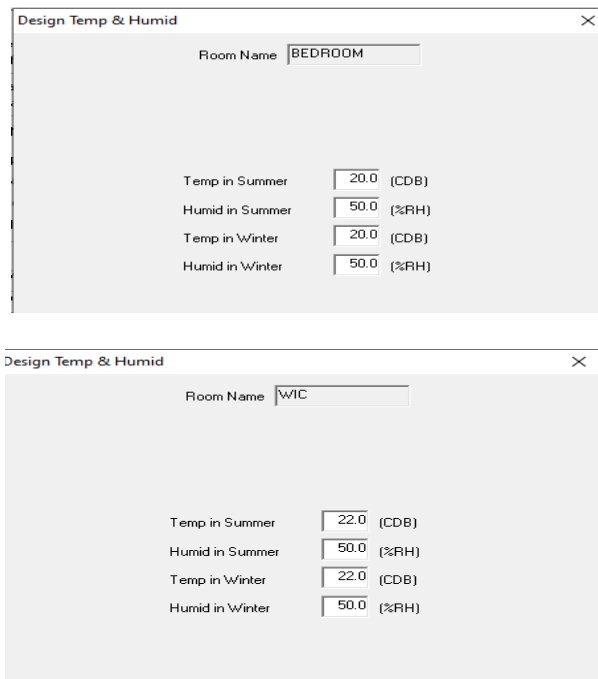


Fig 9. Design Temperature and humidity bedroom and WIC Mrs.S DACS-HKGSG Software

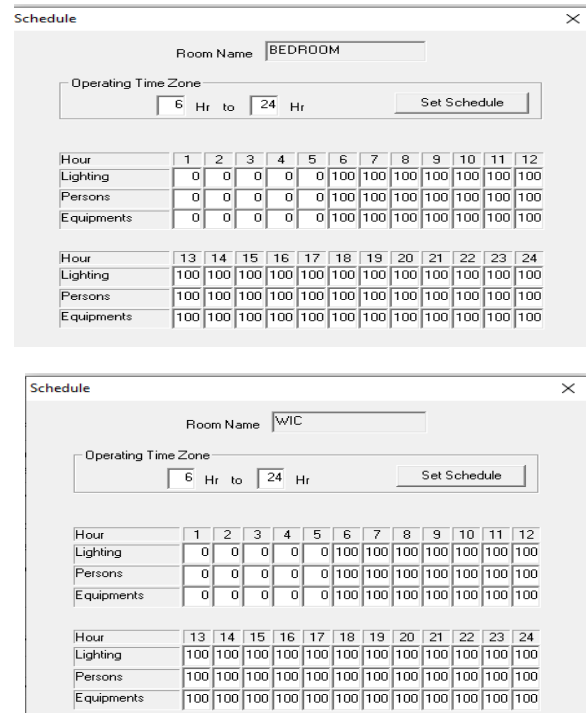


Fig 10. Schedule bedroom and WIC Mrs.S DACS-HKGSG Software

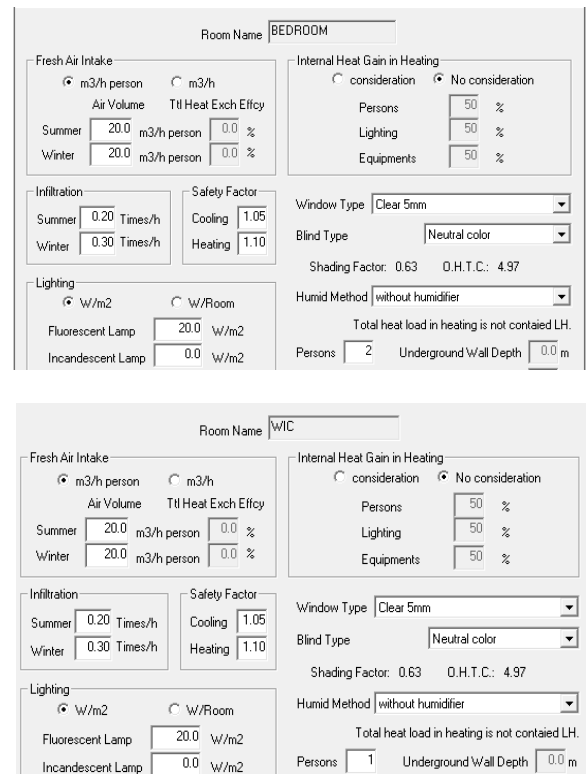


Fig 11. Window Type bedroom and WIC Mrs.S DACS-HKGSG Software

- Sum/Print
Perform calculations and print its results

Heat Load Sum up Table

Floor: All floors

Room Name	Fl.	Sys.	Qty.	Cooling			Heating			Floor Area [m ²]	Heat Load / Area [W]				
				IndoorSH [W]	Total [W]	Selected [W]	Total [W]	Selected [W]	Humid. [kg/h]		Time [Hr]	Cooling [W]	Heating [W]		
BEDROOM	2	1	1	10885	12242	12854	15	0	0	-1.34	6	30.20	425.6	0.0	
WIC	2	1	1	4970	5685	5990	14	61	67	-0.77	6	22.30	268.2	3.0	
Peak Load of Building				2	16817	17897	18752	15	61	67	-2.10	6	52.50	357.9	1.3

Fig 12. Result Calculation cooling load DACS-HKSG Software

- Exit
After all the room, calculate, exit, and save the program.

b) Cooling Load calculation by HAP Software v 4.90

Hourly Analysis Program (HAP) is a computer tool that assists engineers in designing HVAC systems for commercial buildings for estimating loads and designing systems. HAP estimates design cooling and heating loads for commercial buildings in order to determine the required sizes for HVAC system components. Ultimately, the program provides information needed for selecting and specifying equipment. Specifically, the program performs the following tasks:

- Calculates design cooling and heating loads for spaces, zones, and coils in the HVAC system.
- Determines required airflow rates for spaces, zones, and the system.
- Sizes cooling and heating coils.
- Sizes air circulation fans.
- Sizes chillers and boilers.

The software computes cooling load according to the following flowchart:

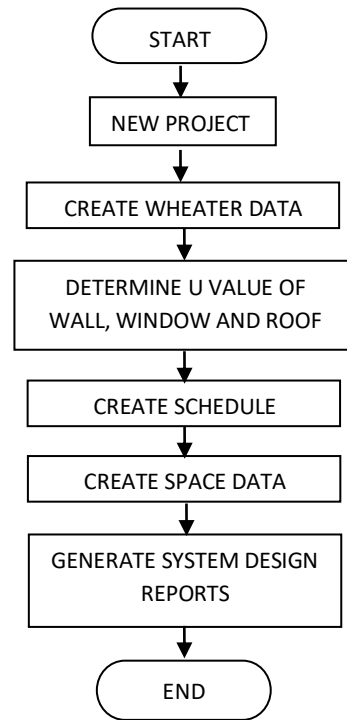


Fig 13. Operational Flowchart HAP Software.

These are the cooling load calculation of residential Mrs.S using Hap Software v 4.90:

- New Project
creates a new project, in this case, create Mrs. S Project. This Function is to hold and save your data.

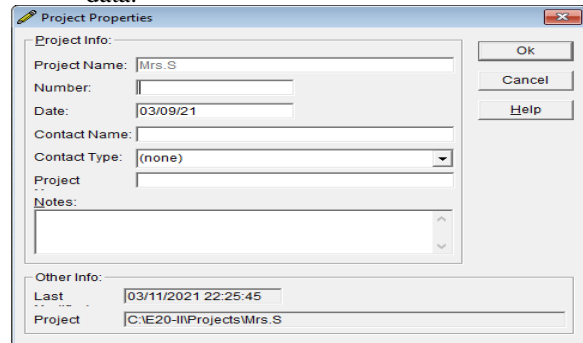


Fig 14. Create Project Mrs.S with HAP Software

- Create Weather Data
Input the weather data Mrs.s

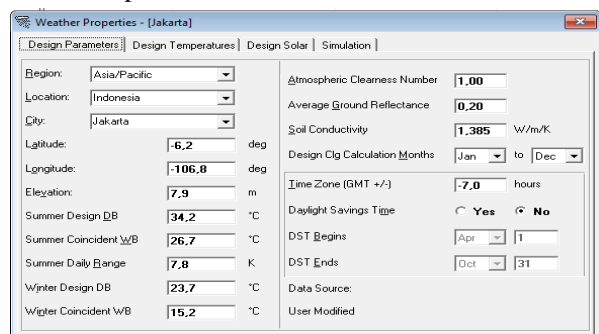


Fig 15. Create weather Data Mrs.S with HAP Software

- Determine U value of wall, window, and roof

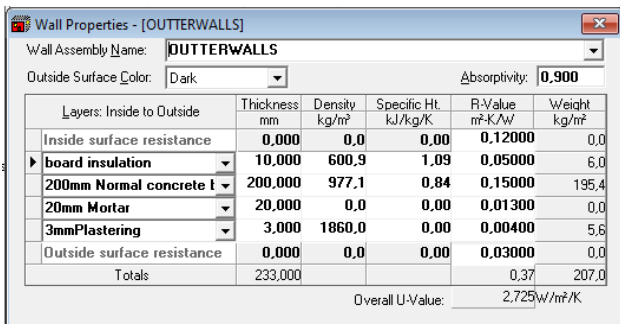


Fig 16. U Value Outerwall Mrs.S with HAP Software.

- Create Schedule

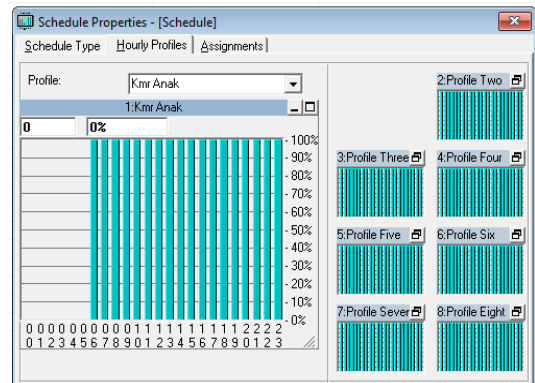
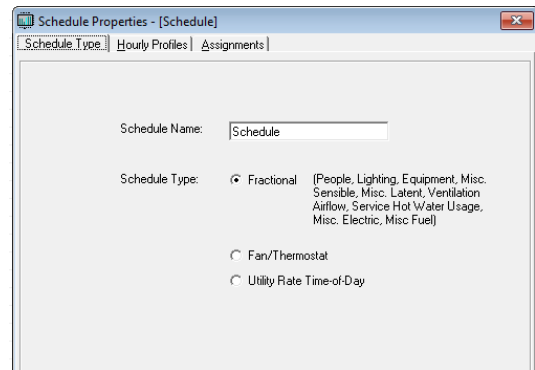


Fig19. Schedule Mrs.S with HAP Software.

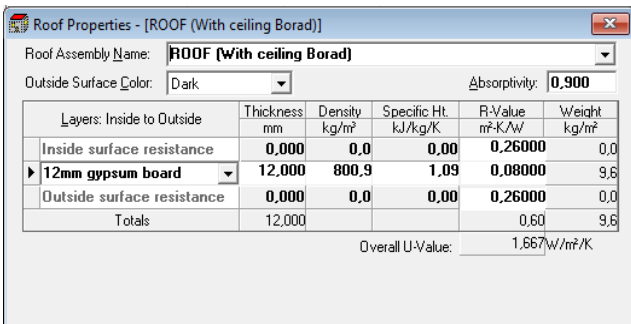


Fig 17. U Value Roof (With Ceiling Board) Mrs.S with HAP Software.

- Create Space Data

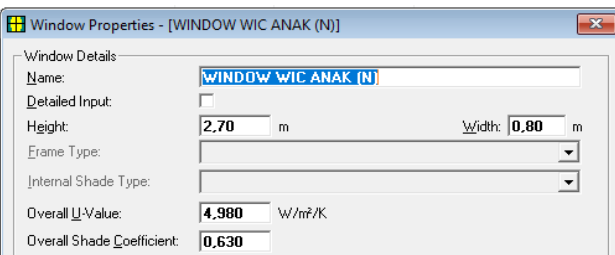
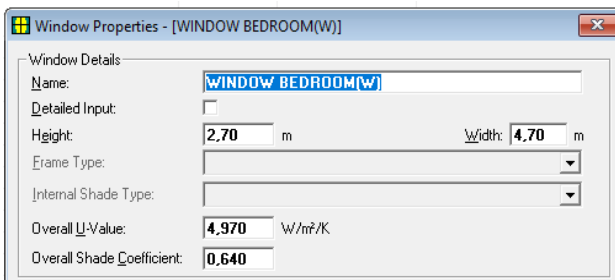
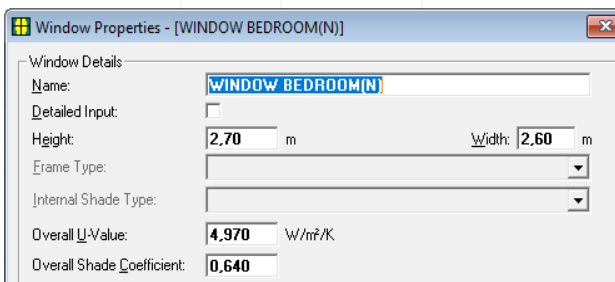
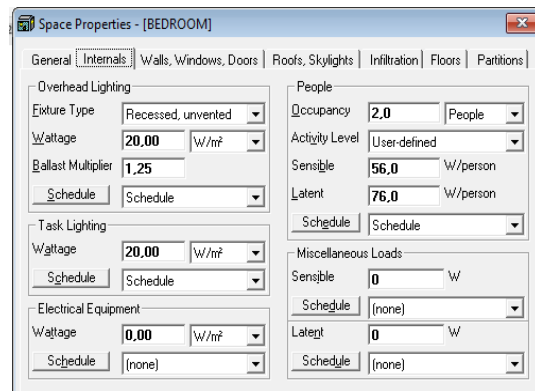
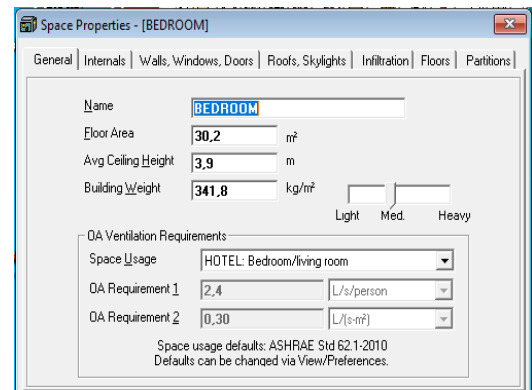


Fig 18. Window Specification Mrs.S with HAP Software.



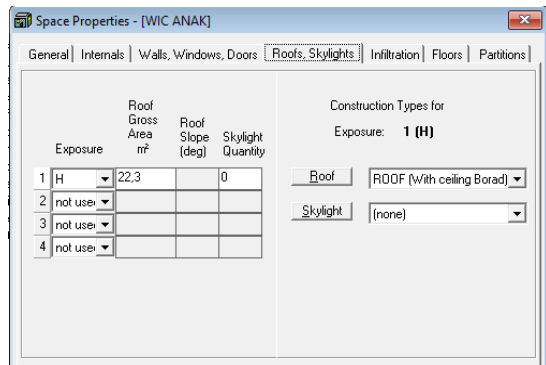
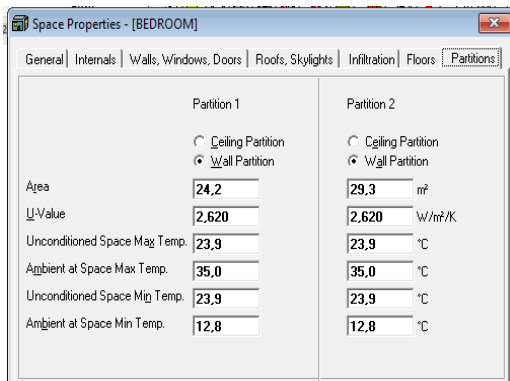
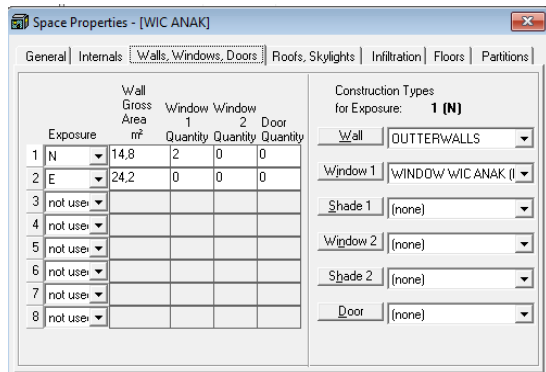
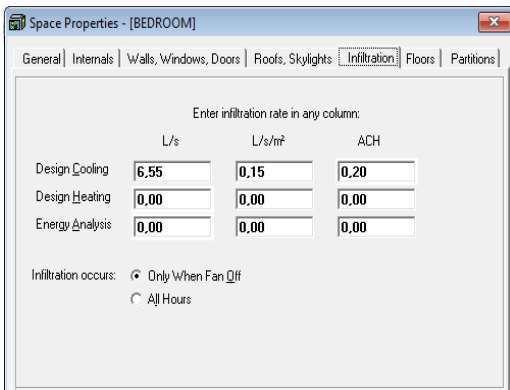
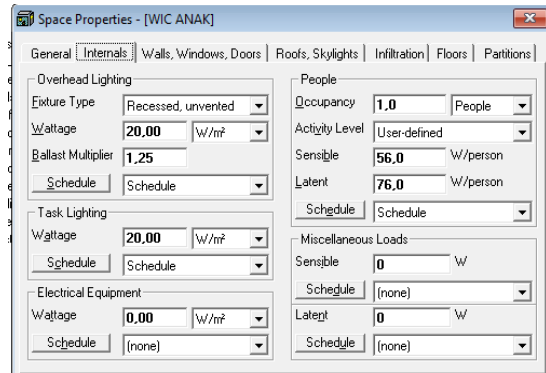
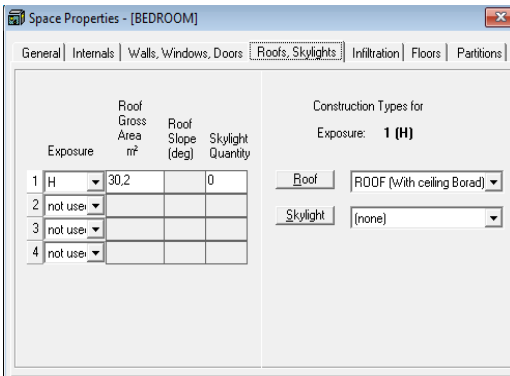
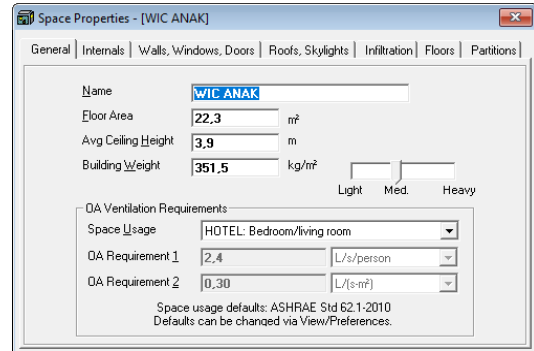
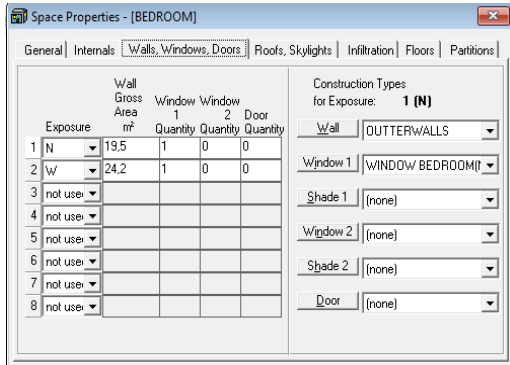


Fig 20. Room Specification Mrs.S for Bedroom with HAP Software.

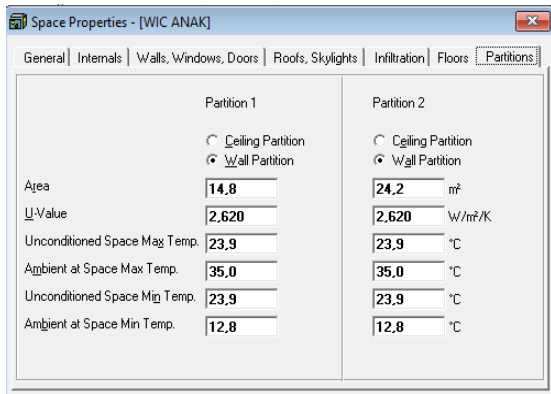


Fig 21. Room Specification Mrs.S for WIC with HAP Software.

- Generate System Design Report

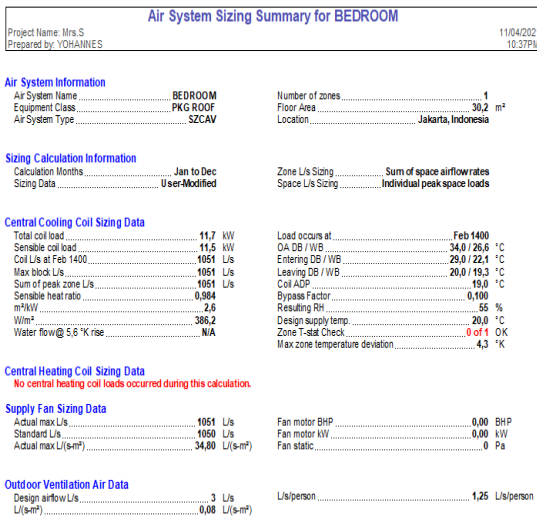


Fig 22. Design Report Mrs.S for Bedroom with HAP Software.

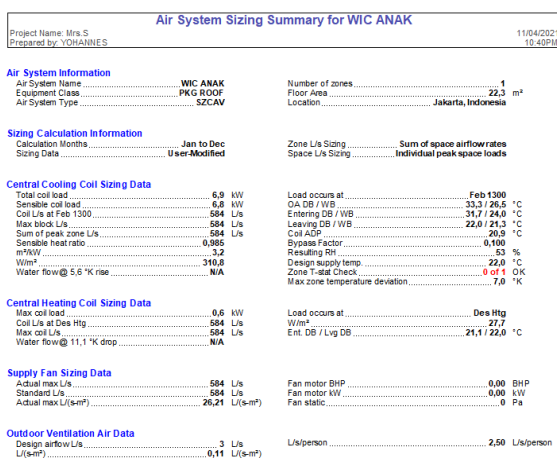


Fig 22. Design Report Mrs.S for WIC with HAP Software.

IV. RESULT AND DISCUSSION

Fig 11. shows the calculation cooling load result using DACS-HKGSG Software v 2.05 for the bedroom was 12.85 kW and for WIC was 5.98 kW. And Fig 21. shows the calculation cooling load result using HAP Software v 4.90 for the bedroom was 11.7 kW and figure 22 shows the calculation cooling load result using HAP Software v 4.90 for WIC was 6.9 kW.

Based on the result cooling load of both software, the suitable indoor unit for the bedroom is FXMQ125PAV, and the indoor unit for WIC is FXMQ63PAV. With a connection ratio of 94%, the suitable outdoor unit is RXQ8AYM.

Table 7: Selection Units

NO	LOCATION	TEMP (°C)	TYPE	CAPACITY	MODEL	SYSTEM	
1	OUTDOOR UNIT						8 HP
							RXQ-8AYM
2	Bedroom	20	FXMQ	125	5 HP	Ceiling Mounted Duct	
3	WIC	22	FXMQ	63	2.5 HP	Ceiling Mounted Duct	
TOTAL INDEKS LOAD						188	
CONNECTION RATIO						94%	

The defined selection units for the VRV system are tested using Multi-Use USB Temp & RH Data Logger – Temp U03 from Tzone.

Table 8: Temp U03 Specifications[9]

Temperature Scale	°C or °F
Accuracy	± 3 % RH; 0.5 °C (-20 °C ~ +40 °C), ± 1.0 °C (kisaran)
Resolution	0.1 °C atau 0.1 °F; 0.1% RH
Communication	USB
Measuring Range	Temp: -30 °C ~ 60 °C; Humidity: 0% RH – 100% RH

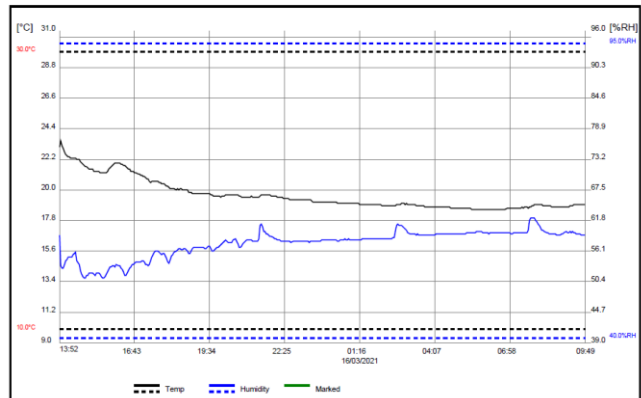


Figure 23. Relative Humidity and Temperature of Bedroom[9]

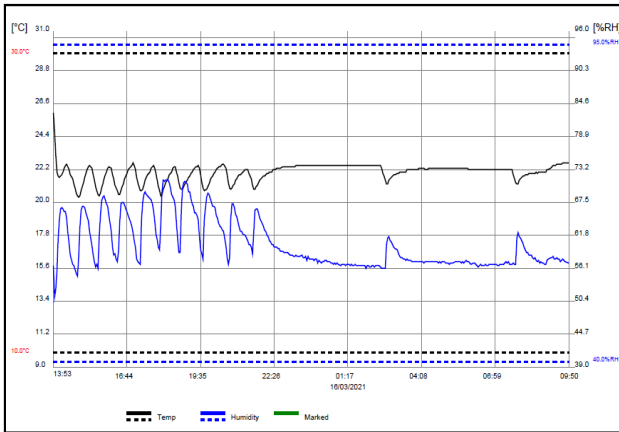


Figure 24. Relative Humidity and Temperature of WIC [9]

In figure 23, the average relative humidity and temperature of the bedroom is 57.6 % (RH), 19.6 °C. On figure 24, the average relative humidity and temperature of the bedroom is 60.1 % (RH), 22.0 °C. The result from Temp U03 shows that all the rooms are in thermal comfort conditions.

V. CONCLUSIONS

In this paper, both software is designed to find the cooling load estimation. To design the VRV system with a standard thermal comfort zone by ASHARE. The design for indoor type unit using approximation method of cooling load form HAP Software v 4.90 and DACS – HKGSG Software v 2.05.

Table 9: Summary cooling load

NO	SOFTWARE	LOCATION	COOLIG LOAD (kW)	INDOOR TYPE
1	HAP SOFTWARE 4.90	Bedroom	11.7	FXMQ125
		WIC	6.9	FXMQ63
2	DACs - HKGSG SOFTWARE 2.05	Bedroom	12.8	FXMQ125
		WIC	5.9	FXMQ63

As per the tabulated summary sheet (Table 9) following conclusions have been made.

- Base on the result of cooling load from both software by using approximation method, the designing of indoor type for VRV system is same.
- Figure 23 and figure 24 shows that the designing of VRV system corresponding with ASHRAE standard.

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