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Utilization of Heat Compressor in The Air Conditioning of The Ahu Direct Expantion System for Class 100,000 Cleanroom Rooms

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Abstract: Currently, the demand for cleanrooms is quite high. With the growth of the food industry, medical equipment, and hospitals, the need for these spaces has become increasingly important. Cleanroom classifications are regulated in various literature, such as ISO, SNI, NFPA, and others. In ISO 14644-1, cleanroom classification is divided into several categories: Class 100,000 (ISO 8), Class 10,000 (ISO 7), Class 1,000 (ISO 6), and Class 100 (ISO 5). The differences between these classifications lie in temperature, humidity, air changes per hour, particle quality, and airflow distribution.To maintain humidity, electric heaters are generally used as equipment. The energy requirement is quite high, and in an AHU system, this device creates an additional heat load because it generates the full sensible load. In this study, the use of a heat compressor or heat recovery unit could be an option for maintaining humidity in a room conditioned by an HVAC system. The flow rate of the high-temperature, high-pressure refrigerant will be regulated using a solenoid valve triggered by a humidity sensor. A defrost mechanism will be implemented within the heat recovery coil to prevent freezing within the system. The results of this study state that the energy required for a cleanroom AHU system that uses heat recovery for air humidity conditioning is more efficient than using an electric heater.

Keywords: Heat Recovery, Air Conditioning, Humidity, Hot Gas

INTRODUCTION

The use of air conditioning systems at this time is not only used for air conditioning in terms of temperature. In some areas, where a special room is needed for certain activities, air conditioning systems are also designed to be able to condition several air conditioning conditions, including air humidity. An example is in hospitals that require operating rooms with cleanroom classification provisions. The need in Indonesia for cleanrooms is currently quite high, due to the increasing development of hospitals in Indonesia, food and medicine industries, where in every activity in these areas requires sterile rooms.

Rules and standards in design design in Indonesia generally refer to ISO 14644-1 & 2 (related to CPOB and KARS). This ISO standard regulates and explains that sterile rooms must be created based on the classification and needs of the room. In ISO standards, sterile rooms are divided into several classifications based on temperature, humidity, number of air particles, and room pressure, including class 100,000 (ISO 8), class 10,000 (ISO 7), Class 1,000 (ISO 6), Class 100 (ISO 5). For each type of ISO classification of the room, there is a humidity setting that must be achieved. The range of achievement values is at 45% RH – 70% RH. The cleaner or sterile the room classification, the smaller the target air humidity achievement value of the room

At this time, in conditioning the air humidity in the air conditioning system, many methods can be used, including the use of Electric Heater Coil, Dehumifier (desicant whell), Crossflow air mixing circulation. Of the three methods, the use of electric heater coils is the main choice because of its lowest economic value, and it is very easy to use. However, in its implementation, electric heater coils require considerable energy. Because the capacity of the heater's KW is the same as the required electrical KW capacity. In addition, often in the use of eletric heater coil, the cooling capacity of the air conditioning or Air Handling Unit (AHU) is increased because the electric heater coil becomes an additional sensitive load in the cooling system.

In a refrigeration system, there is basically a heat source that can be used. In the PH diagram cycle, we can see that there is a cycle where the refrigrant has a fairly high temperature and high pressure (heat of Compressor) In another cycle in the PH diagram, we also see that there is a condition where the temperature and pressure of the refrigrant must also be lowered (Heat Rejection Condensor). Looking at its potential, the heat rejection condenser can be used as a Hot Gass Recovery method, which utilizes refrigrant heat to replace the heat generated by the electric heater coil. In determining the capacity of the Hot Gass Recovery coil, it must also be taken into account so as not to cause problems with the air conditioning system. Basically, air conditioning systems that use heat recovery will increase their cooling capacity. Therefore, there must be a cooling capacity control in the system to keep freezing somewhat from occurring.

METHOD

The flow framework in research is a process that is carried out from beginning to end containing the process in the implementation of research. The framework of the research flow is as follows:

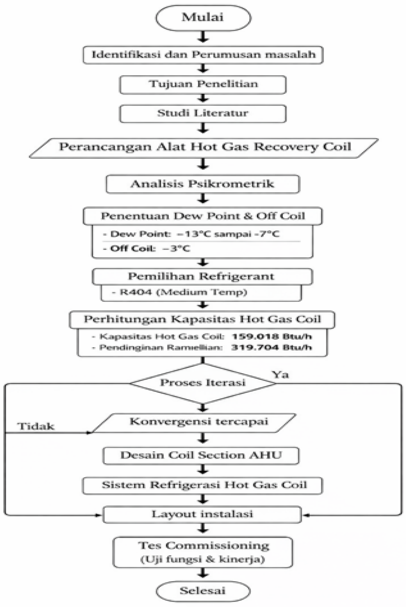


Figure 1. Research Flowchart

Tools and materials

The tools used in this study are psychometric software to determine the air conditions in and out of AHU, including temperature, relative humidity, dew point, and off-coil temperature using the psychometric selection method, Excel to calculate cooling capacity, Hot Gas Recovery Coil capacity, sensitive energy calculation, and data processing from psychometric analysis and AHU units as research objects.

Research procedure

The stages in carrying out the research are in accordance with figure 1. The research stage begins to identify problems, design equipment in the AHU system, conduct psychometer analysis, determine the Temperature Dew point and Off coil that must be achieved by the Air Handling Unit, select refrigerant, analyze the capacity of hot coil gas. The results of the iteration, if appropriate, are immediately made an installation layout and applied in a real form, then a function test is carried out and finished.

RESULT AND DISCUSSION

Hot Gass Recovery Coil tool design

Determination of Temperature Dew point and Off coil that must be achieved by the Air Handling Unit (AHU) using the Psychometric selection method. With a target room temperature of 22-27°C, Air humidity 25-30% RH, total Airflow 6760 m³/h. It can be seen from figures 2 and 3.

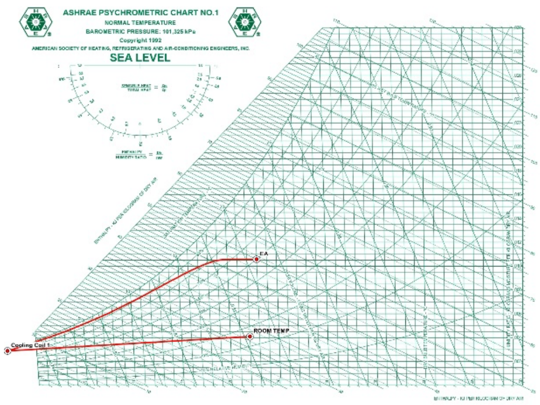


Figure 2 Psychometric Graph

Table 1. ***Selection Table***

1, EA

STATE POINT DATA

Air Flow (Standard) (L/s)	Dry Bulb (°C)	Wet Bulb (°C)	Relative Humidity (%)	Humidity Ratio (g/kg)	Specific Volume (cu.m/kg)	Enthalpy (kJ/kg)	Dew Point (°C)	Density (kg/cu.m)	Vapor Pressure (mm Hg)	Absolute Humidity (g/cu.m)
1.613	23,000	17,731	60,0	10,57	0,853	49,998	14,8269	1,1713	12,6500	12,393

2, Cooling Coil 1

STATE POINT DATA

Air Flow (Standard) (L/s)	Dry Bulb (°C)	Wet Bulb (°C)	Relative Humidity (%)	Humidity Ratio (g/kg)	Specific Volume (cu.m/kg)	Enthalpy (kJ/kg)	Dew Point (°C)	Density (kg/cu.m)	Vapor Pressure (mm Hg)	Absolute Humidity (g/cu.m)
1.613	-3,000	-3,098	98,0	2,89	0,769	4,194	-3,2398	1,2997	3,4993	3,759

Process: Cooling Coil

Start Point Name	Total Cooling (KW)	Total Energy (W)	Sensible Energy (W)	Latent Energy (W)	Dehumidification (kg/hr)	Sensible Heat Ratio	Enthalpy/ Humidity Ratio (kJ/kg / g/kg)
EA	-93,795	-93.795	-50.885	-42.910	-53,6	0,543	5,945

3, ROOM TEMP

STATE POINT DATA

Air Flow (Standard) (L/s)	Dry Bulb (°C)	Wet Bulb (°C)	Relative Humidity (%)	Humidity Ratio (g/kg)	Specific Volume (cu.m/kg)	Enthalpy (kJ/kg)	Dew Point (°C)	Density (kg/cu.m)	Vapor Pressure (mm Hg)	Absolute Humidity (g/cu.m)
1.613	22,000	11,421	25,0	4,10	0,841	32,533	1,0892	1,1874	4,9602	4,876

Process: Humidification and Heating

Start Point Name	Total Energy (W)	Sensible Energy (W)	Latent Energy (W)	Humidi-fication (kg/hr)	Humidi-fication (L/hr)	Enthalpy/ Humidity Ratio (kJ/kg / g/kg)	Sensible Energy Per Humidification (kJ/kg)
Cooling Coil 1	55.629	49.037	6.592	8,5	8,5	23,342	20.846,2

From the results of data processing in figure 3, to condition the room with a temperature of 22°C, with air humidity at 25%, it is necessary to have an Off Coil temperature at -3°C. The temperature Off Coil is at -3°C, then it can be estimated that the temperature of the dew point on the coil is at a temperature of -13 - -7°C, then the type of refrigrant used is type R404 (medium Temp) refrigrant

AHU Design

Determination of the Coil Section on the AHU system and determination of the capacity of the Hot Gass Coil and the refrigeration system to be used. To obtain the capacity of the Hot Gas Coil, it can be calculated from the potential for increased RH / Humidification as stated in the table of psychometric calculation results.

$$Sensible\ Energy\ Per\ Humidification\ \left(\frac{kj}{kg}\right) \times Flowrate\frac{m^3}{h}\ x\ Density\ \left(\frac{kg}{m^3}\right) = 20{,}7\ \frac{kj}{kg} \times 6760\frac{m^3}{h}\ x\ 1{,}2\frac{kg}{m^3} = 167.918\frac{kj}{h} = 159.018\frac{Btu}{h}$$

From the calculation above, the capacity of the hot gas coil is around 159,018 Btu/h. For cooling capacity, to reach a dew point of -3°C, it takes about 93.7 KW of cooling or around 319,704 Btu/h. From this calculation, the coil section in the Air Handling Unit is determined. can be seen in Figure 3.

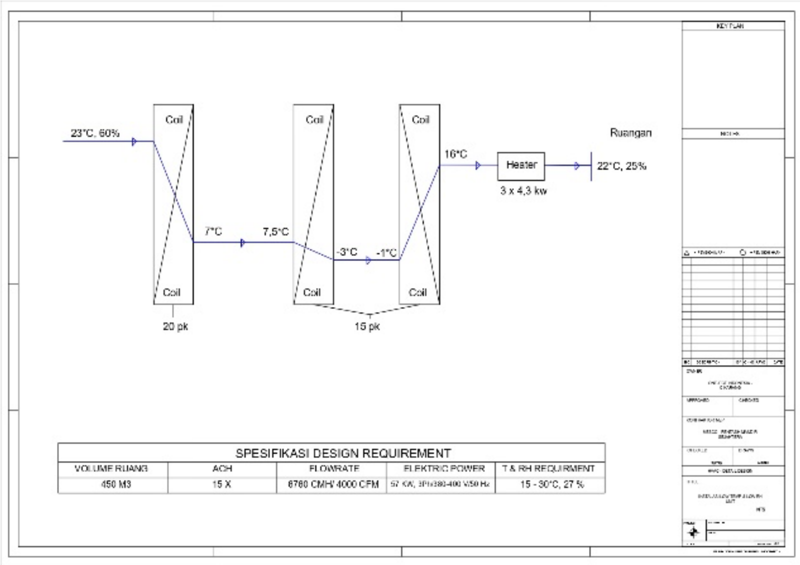


Figure 3. Coil Section AHU

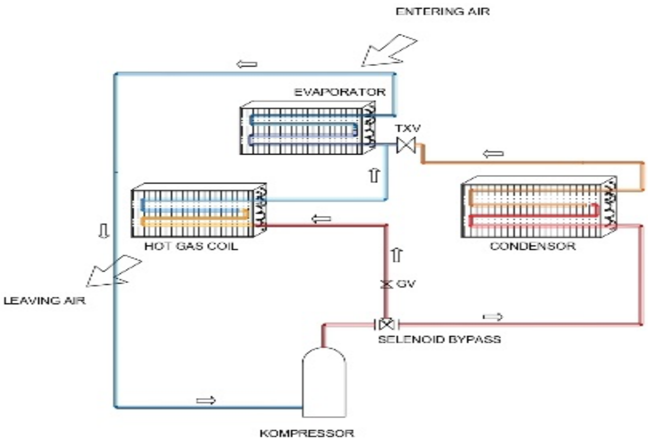


Figure 4. Schematic of Hot Gas Coil Refrigeration System

After the data processing of the cooling capacity needs and hot gas coils has been determined, the next is the determination of the layout or placement of supporting equipment such as the installation of refigrant, electrical, ducting and other supporting equipment. This can be seen in figure 5.

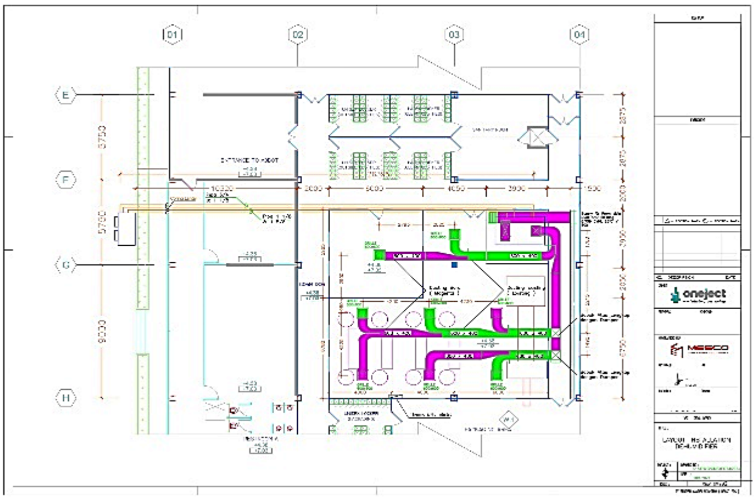


Figure 5. Installation Layout

Comitioning Test

After all installations are installed, the next process is to carry out a Test and Comitioning process to test the performance of the hot gas coil system. In the initial test, there was freezing in the system because the amount of the refrigrant mass flow value that entered the Hot Gas Coil system was too much, so adjustments were made by opening

Figure 6. Freezing on gas lines

Figure 7. Freezing disappears after adjustment of the refrigrant mass flow rate with globe valve

After the repair, the test was carried out using a data logger method that was spread across several points of the room based on the ISO standard used. The following is the data on the distribution of logger tool points in the testing process

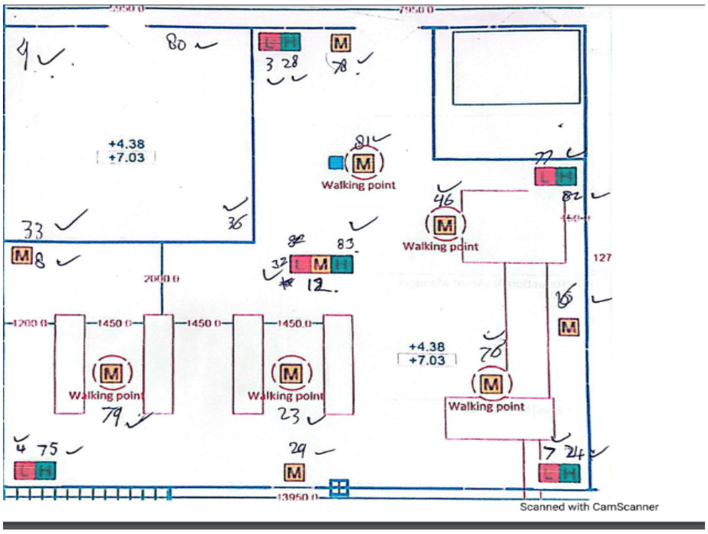


Figure 8. Data logger point

The test was carried out for 2 x 24 hours, and from the test the following data was obtained:

Table 2. Function Test Results Data

Result of Temperature & RH Checking

IVD Area

No	Data Logger	Temperature Min	Temperature Max	Temperature Avg	Humidity Min	Humidity Max	Humidity Avg
1	THD 16	21,0	28,9	25,094	23,6	44,00	28,451
2	THD 82	21,0	29,8	25,200	22,6	42,20	27,185
3	THD 81	19,2	29,0	24,268	23,6	44,50	28,971
4	THD 28	16,9	28,8	23,134	26,0	50,40	32,127
5	THD 24	23,5	32,8	28,259	20,4	37,30	24,539
6	THD 78	17,3	29,4	23,581	24,5	49,60	30,584
7	THD 32	21,1	26,3	24,470	25,2	45,10	30,244
8	THD 29	21,2	27,6	24,661	24,2	44,10	28,921
9	THD 8	21,2	27,6	24,661	25,0	45,70	29,987
10	THD 4	21,0	27,1	24,372	25,3	46,80	30,668
11	THD 76	19,2	29,9	24,570	23,0	46,10	28,712
12	THD 46	21,2	28,7	24,626	24,9	45,20	30,036
13	THD 7	20,5	29,8	25,512	22,9	44,50	28,506
14	THD 23	20,8	28,5	24,812	23,0	43,50	28,715
15	THD 3	17,3	28,7	23,095	26,3	51,10	32,748
16	THD 79	23,5	26,8	25,396	22,7	42,60	27,688
17	THD 12	20,8	26,7	24,426	24,4	62,00	30,917
18	THD 83	20,9	26,6	24,532	23,4	44,70	29,136
19	THD 77	21,3	27,5	24,514	23,9	45,10	29,245
No	Data Logger	Temperature Min	Temperature Max	Temperature Avg	Humidity Min	Humidity Max	Humidity Avg
20	THD 80	22,9	25,8	24,377	27,5	41,80	31,404
21	THD 33	23,1	25,7	24,477	28,3	41,80	31,885
22	THD 9	23,3	25,7	24,502	28,6	42,50	32,446
23	THD 36	22,6	25,8	24,185	28,1	42,40	32,049

Notes:
Acceptance Criteri Temperature: 15 - 30 ° C
Humidity: < 30% Rh

Number 1-19 located on IVD assembly area
Nomber 20-23 located on storage room

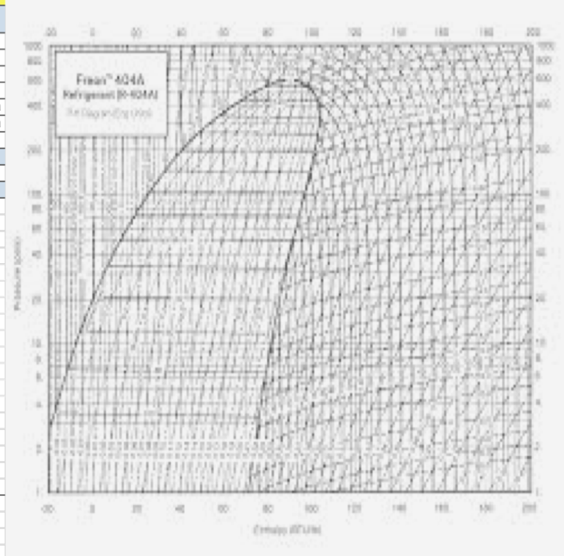
From the data, it can be seen that the range of achievement values at temperature is only 1 pint which does not enter the target range of achievement value, namely at the THD 24 point, with a value of 32.8 ºC. And for the range of air humidity values, at all THD points / looger data do not reach the maximum limit value of air humidity, which is 30% RH. From the results of raw data analysis from each logger, it was found that there were several indications that an increase in air humidity occurred due to changes in the outside air temperature. The changes that occur in the outside air greatly affect the refrigeration system that occurs in the Hot gas Coil system. During the day, when the ambient temperature is quite high, the capacitor decreases, and the capacity of the evaporator increases, while at night when the ambient temperature decreases, the capacitance of the condenser coil increases, while the capacity of the evaporator coil decreases. In this condition, the system freezes and is unable to maintain the humidity of the air in the room, because refrigeration is problematic. This phenomenon can be measured using the calculation method of the refractive cycle on the PH diagram, using several data, namely: High pressure and low pressure refrigerant (liquid and gas line, heat compressore temperature (T3), gas line temperature T4, compressor current load, temperature after coil condenser (T2 and T1). Details of the calculation can be seen in the figure 9 below.

COMMISSIONING

Informasi Klien		Kontraktor	
Building Name :		Name :	
Address :		Address :	
Phone ; -		Phone	
Contact Person		Contact Person	

DATA UNIT DEHUM

No.	Description	Actual Pengukuran	Satuan	Konversi	Satuan	Keterangan
1	T.out Condensor (T1)	45	˚C	265	KJ/Kg	PH Diagram
2	T.in TXV (T2)	45	˚C	265	KJ/Kg	PH Diagram
3	T.in Compressor (T3)	25	˚C	425	KJ/Kg	PH Diagram
4	T.out Compressor (T4)	92	˚C	475	KJ/Kg	PH Diagram
5	Low Pressure Refrigerant	60	Psi	0,414	Bar	1Psi = 0,00689476 Mpa
6	High Pressure Refrigerant	340	Psi	2,344	Bar	1Psi = 0,00689476 Mpa
7	Ampere Rata-Rata	15,27	Ampere			
No.	**Description**	**Data Sheet**	**Satuan**	**Konversi**	**Satuan**	
8	Spesific Volume Refrigerant	0,058	m^3/kg	0,934	ft^3/lb	1m3/kg = 16,0185 ft3/lb
No.	**Description**	**Calculation**			**Satuan**	
9	FLow Rate Compressor (Flow Mass. Refri. x Specific Volume Refri.)	**Daya Kompressor (Watt) (KJ/H)=**	**Flow Mass Refri. (Kg/H) x T4-T3 (KJ/Kg)**			
		Daya Kompressor =	Ampere	x Voltatge x Cos Phi x 1.73		
		=	15,27	x 380 x 0,8 x 1,73		
		=	8029,045333		Watt	
		Flow Mass. Refri. =	Daya Kompressor / T4-T3			
		=	8029,05 / 50		Watt / KJ/Kg	
		=	28904,56 / 50		KJ/H / KJ/Kg	1 watt = 3,6KJ/H
		=	578,091264		Kg/H	
		Flow Rate =	Flow. Mass. Refri. x Specific. Vol. Refri.			
		=		33,70272069	m3/H	
				19,83667994	ft^3/min	1 m3/h = 0,58ft3/min
10	Refrigerant Effect (RE)	T3	-	T2		
		425	-	265	KJ/Kg	
		160			KJ/Kg	
		68,788			BTU/lb	
11	Heat Of Compressor (HC)	T4	-	T3		
		475	-	425	KJ/Kg	
		50			KJ/Kg	
		21,496			BTU/lb	
11	Heat Rejection Condensor (HR)	T4	-	T1		
		475	-	265	KJ/Kg	
		210			KJ/Kg	
		90,284			BTU/lb	



		0,93	ft^3/lb	(COP)	50	KJ/Kg
	=	**21,241**	lb/min	=	**3,200**	KJ/Kg

EVAPORATOR CAPACITY						CONDENSOR CAPACITY					
Capacity	MFR		*	RE		Capacity	MFR		*	HR	
	21,241	lb/min	*	68,788	BTU/lb		21,241	lb/min	*	90,284	BTU/lb
	1461,131				BTU/min		**1917,735**				BTU/min
	87667,879				BTU/H		**115064,091**				BTU/H

Figure 9. PH diagram calculation

The final result of the performance test of this unit was determined that the Hot Gas Coil unit did not function properly and optimally 100%, because there was still an achievement of the air humidity value above the requirement. From the results of the unit's function test, it was decided that the room operation will be used at 09:00 – 17:00.

CONCLUSION

From the results of designing, installing, and testing the function of the use of heat compressor utilization for the use of Hot gas coil recovery in the air conditioning system of the AHU Direct Expantion Air Handling Unit for cleanroom air conditioning class 100,000, with a temperature of 22-27ºC, and RH 25-30%, it can be concluded that the unit does not succeed in 100% keeping the humidity in the range of 25-30% under uncontrolled conditions (weather, outside air temperature and factors affecting the refrigeration system). AHU Direct expantion which uses a Hot gas coil system, the performance of the refrigeration system is greatly affected by the ambient weather conditions, this can be seen from the PH cycle diagram when the capacity of the unit becomes changing. This system is quite good if the target of achieving the air humidity of the room is in the range of 45 - 55°C. With a temperature of 18-22ºC This is based on the results of the function test data that has been carried out.

In addition, the Hot gas coil system has also succeeded in eliminating the use of electric heaters that have been commonly used for air humidity conditioning. So this system can result in savings in energy use because the heat used in the conditioing water system uses the heat energy of the system itself Heat recovery, i.e. from the heat compressor or Heat of Compressor

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