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Integration of Heat Recovery and Cooling System in Laundry

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Abstract

The climate change in these few decade have vitally raised the concern about the impact on the environment due to the continue burning of fossil fuel, which emit Green House Gas GHG in the atmosphere that cause the rise in the average temperature of the earth's climate system. The global warming have been being caused by increasing concentration of GHG. The effect of it will cause a rise in sea level due to the melt of ice and the dramatic change in the amount and pattern of precipitation and also a series of natural phenomenon including heat waves, droughts, heavy rainfall, and snowfall. Therefore, energy saving and usage of alternative of energy have been being highly concerned to lower the usage of fossil fuel.

The main emission source of GHG is the usage of electricity in buildings and facilities, which is almost 60% of the source of emission. Moreover, the highest power consumption system in a building is the heating, ventilating, and air conditioning HVAC, which is almost 60-70% of the total. Therefore, to achieve energy saving with high efficiency under the limited resource and minimum impact to human, we have to focus on the improvement of HVAC. This paper presents a real case study of the integration of heat recovery and Air-conditioning system and consideration of it.

Keyword : Heat Recovery, Laundry, Pre-heating, Drying and DDC Control

Integration of Heat Recovery and Cooling System in Laundry

Introduction

The Heating and Cooling Integrated System presented in this paper mainly focus in Hong Kong, where domestic environment is congested with building and also land is the most valuable property in the view of commercial. Under these conditions, renewable energy cannot be applicable in Hong Kong. Because it require a large of space for the installation. Therefore, the technology of it cannot achieve the obvious improvement of generating electricity in Hong Kong.

On the other hand, improvement of electrical and mechanical system inside the building is one of the way figuring out the problem. The system and concept presented in this paper is a real project carried out by a E-saving Company in HK, is also the first step of the laundry industry in Hong Kong.

With the noticeable data about the climate change, a clear goal to achieve reduction of GHG emission was also set by the Hong Kong Special Administration Region HKSAR in 2010-2011, which aim to achieve reduction of carbon intensity by 50-60% in 2020 comparing with that level in 2005. In these few year, the major milestone about the E-saving measure is the establishment of the Code of practice for Energy Efficiency of Building Services installation, 2012, BEC 2012, that mainly emphasis on the advance design criteria in the HVAC, lighting, electrical installation and lift & Escalator Installation. Even though this establishment of BEC has a big impact to the E&M industry, heat-recovery system is not involved.

Implement of measure to the usage of heat recovery system was taken plenty of concern because it involve serval problem including the capital of installation cost, extra space for the installation, the complicated monitoring system and future maintenance. Therefore, this paper will go through the consideration of HVAC heat recovery for HK government and industries as a reference that certainly achieve and energy saving and the reduction of carbon emission in HK.

Background

HVAC heat recovery system can be applied in many industries such as hotel, restaurant, clubhouse and laundry that own the same characteristics that is the same demand of the heating and cooling system "simultaneously". Why emphasis "simultaneously"? It is because the processes of heating and cooling should carry out at the same time during the heat exchange. In the typical saying, heat exchange process is to absorb the heat from a space with higher state temperature and transfer it to another space with lower temperature and released by a medium. So, the demand of the capacity of heat exchange and the time should match each other.

Why laundry? The working operation in a laundry can totally satisfy this condition because its demand of heating and cooling during working hour will maintain in the peak level in 80-90% of time stably. It can total perform the heat exchange process.

Traditionally, the working condition in a laundry is very poor due to the high emission of heat from the washing machine and congested area by it. The laundry owner usually refuse to improve it by installing the Air-conditioning system because of the large operating cost to compensate the large capacity of heat emission by the machine. In case of it, heat recovery will be the best solution figuring out the problem.

In laundry industry, there are nearly **20** laundries with same size, they are all serving the washing process for the hotel, any large organization with uniform and also restaurant. Due to the major development of tourism in HK, there will be 1 multiple of hotel completed in the coming decade. Hotel is the major target for laundry, so it means there will be **30-40%** of new laundries completed to balance the apparent demand of cloth washing. In the view of this, many new project about heating and cooling system will be carried out regarding to the new construction of laundry. At the same time, HK government should implement related measure to support the industry to develop the heat recovery system and establish the policy of control and monitoring the effectiveness of the system.

Project background

The laundry is located in the industrial building. The major equipment related to the heat recovery system are shown below.

Table 1 : Major Equipment Schedule			
No.	Equipment	Quantity	"Heat" Rated Power (kW)
DM-A 1/2/3	Automatic Drying Machine-A	3	NA
DM-B 1/2/3/4	Automatic Drying Machine-B	4	21
CR1/2	30 HP Heat Pump Unit (Outdoor)	2	32kW
ER1/2/3/4	15HP Air-conditioner Unit (Indoor)	4	16kW
EH	Electric Steam Heater 20HP	1	20kW
B	Boiler	1	NA

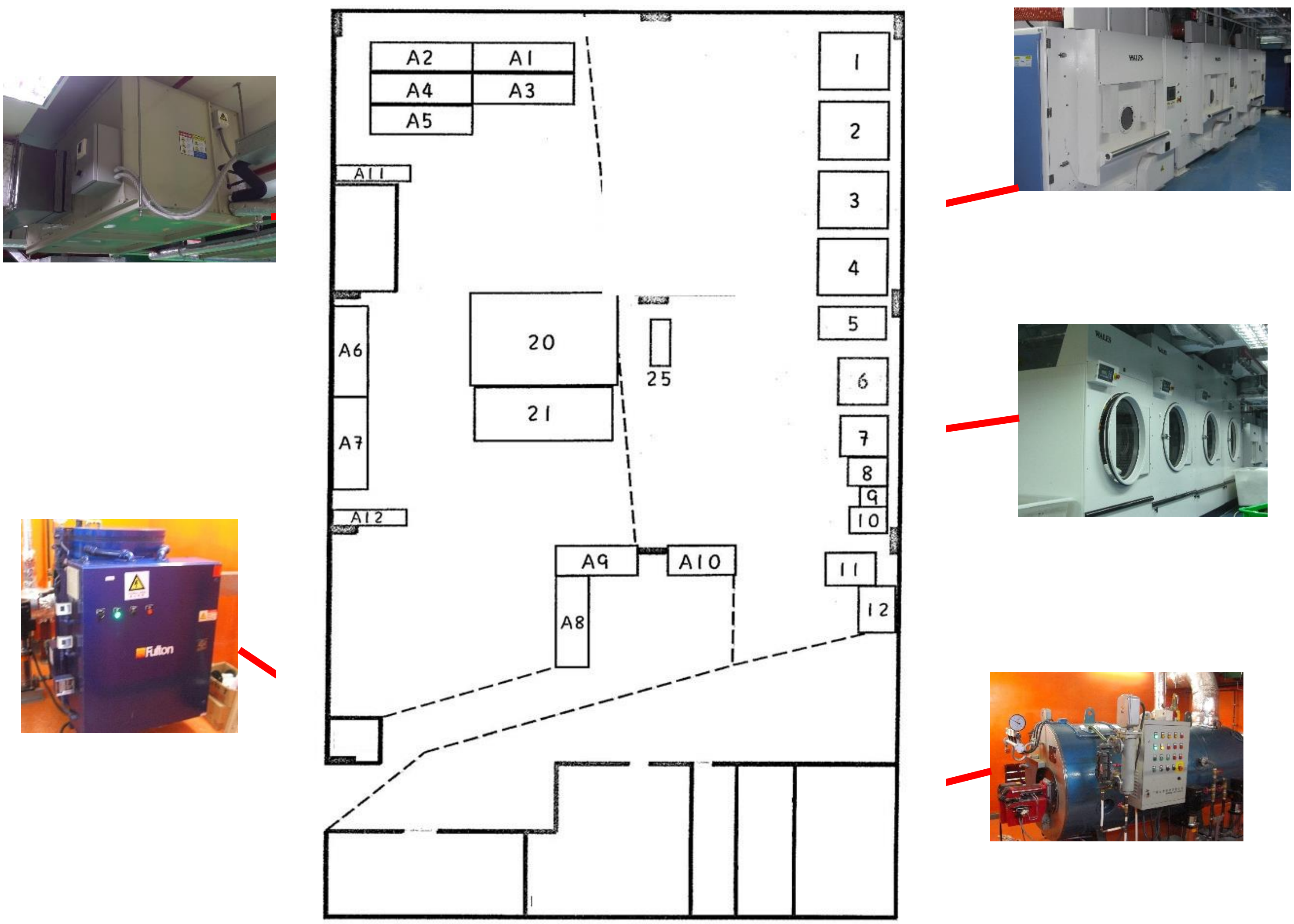

Fig.1: General Arrangement Laundry Layout

System Description

In this project, 4 additional heat pump were installed as HVAC system, which involve 3 technologies with E-saving:

1. Integration of Heat Pump as Pre-heating Process
2. Heat Recovery Air-Conditioning System
3. Heat Recovery by Exhausted Air

1. Integration of Heat Pump as Pre-heating Process

The system use the heat rejected from the heat pump to provide energy for pre-heating air for the drying machine. See the Fig.2 of Heat Pump Pre-heat System Schematic. The outdoor with temperature 30ºC entering to the condenser of heat pump and being pre-heat to 50ºC, and then entering the steam air heater for further heating process from 50 ºC to 85 ºC (design valve).

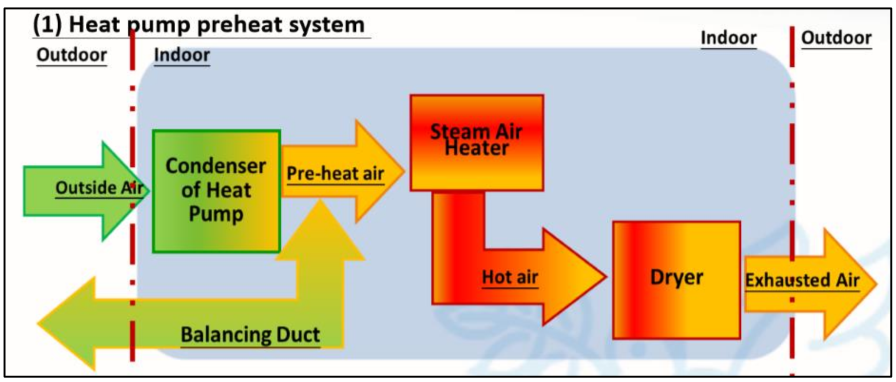

Fig.2 : Heat Pump Pre-heat System Schematic

Calculation of the Energy Saving

Equipment involved in the system are shown below:

3 Nos. of 120kg Drying Machine
- Air Flow Rate = 3.3m^3/s
- In-coil Air Temp. =30ºC
- Off-coil Air Temp. =85ºC

4 sets of 15HP Air-conditioning Unit
- 2 Nos. of Compressor
- Rated Power = 16kW
- Ambient Temp. = 30 ºC
- Condenser off-coil Temp. = 50ºC

Conditions

Equipment	Mode
4 sets of Air-conditioning unit	On
2 sets of Drying Machine	On

Calculation

Traditional (Boiler only)	Integration of Heat Pump	
Boiler	Boiler	Heat pump for pre-heating
Total air flow rate (Mass) for 2 dryers; = 2 x 3.3m3/s x 1.1kg/m3 =7.26kg/s		
Power for heating up the air from 30ºC to 85 ºC = 7.26 x 1.0035 x (85 -30) = 400.2kW For 1 hour, Power consumption for heating up of air : = 400.2 x 1hr / 0.9 (Efficiency of Boiler) = 444.6 kWh Total Cost for heating up of air : =444.6 x $1.1 = $ 489.0	Power for heating up the air from 50 ºC to 85 ºC = 7.26 x 1.0035 x (85 - 50) = 255kW For 1 hour, Cost of energy for heating: = 255kW x 1hr. x $1.1 / 0.9 (Efficiency of Boiler) = $ 311 (Equal to 282kWh)	Power for pre- heating up the air from 30 ºC to 50 ºC by AC System = 7.26 x 1.0035 x (50 -30) = 145.7kW For 1 hour, Cost of energy for pre-heating: = 4Nos. x (25A x 220V x 3) x 1hr x $1.1 = $ 72.6 (Equal to 66kWh)

Total energy saving for 1 hour (kWh) = 444.6 – 66 – 282 = 96.6

Total reduction of Carbon Emission (kg) = 96.6 x 0.54 (Where 0.54kg = 1kWh) = 52.1kg

Total Electricity Fee Saving (HKD) = 489 – 72.6 – 311 = 105.4

Percentage of Energy Saving = 96.6 / 444.6 = 21.7%

2. Heat Recovery Air-Conditioning System

Traditionally, heating and cooling process are separated into 2 system. By integration of heat pump, the evaporators are to absorb and transfer the heat inside the laundry workshop to the heating coil of the drying machine as pre-heating process. Therefore, the workshop was chilled by the pre-heating process simultaneously on the other side (Evaporator) of heat pump. See the Fig.3 - Heat Recovery Air-Conditioning System Schematic details.

Calculation

As the cost of operation for the AC system (4 Nos. of AC units – Evaporator) is totally integrated to the heating side (Condenser). Therefore, the energy saving in the AC system is equal of the full operation cost of the heat pump as pre-heating (66kWh, $72.6) for 1 hour. The percentage of saving is 100%.

The total energy saving by integration of heat pump for pre-heating and cooling process for 1 hour:

= 96.6 + 66 =162.6kWh (Where equal to electricity fee HKD 178.9)

Annual electricity fee saved

= 178.9 x 12hr x 0.8 (operation ratio a day) x 365 x 0.8 (operational ratio a year)

=HKD 501,400.00

The initial installation cost of additional heat pump integration AC system

= HKD nearly 420,000

The period that the cost recovered by electricity fee saved =420,000.00 / 510,400.00 x 12

=nearly 10 months

Reduction of Carbon emission = 162.6kWh x 0.54kg = 87.804kg

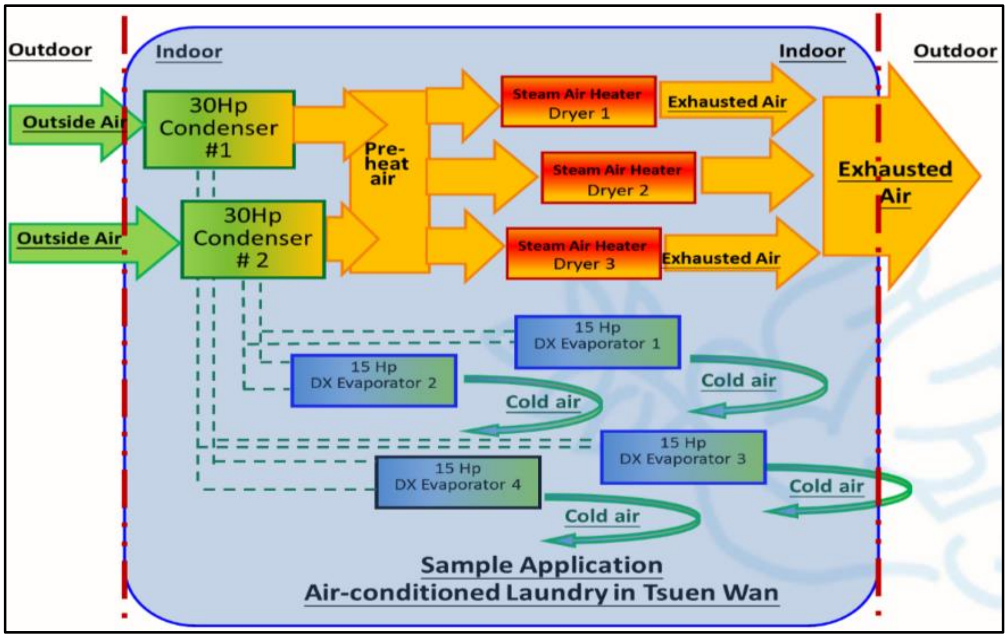

Fig.3 : Heat Recovery Air-Conditioning System Schematic

Operation mode for pre-heating and cooling

The Drying machine and the AC system are integrated into a same system to recover the energy. Theoretically, these 2 type of Machine are operating with same demand of air so that the heat can be transferred to another side at the same time. But, this situation will not maintain for the whole operation due to some factors influenced including:

1. The variation of air intake demand to the drying machine
   Air intake from the condensers side varies under the normal operation of the AC system. Therefore, another way of air intake should be provided, monitored and controlled to satisfy the various demand of it.

2. Risk of failure of any AC units

Another way of air intake should be provided to prevent the failure of delivering heated air under the broken down of any AC units.

Therefore, supplementary system should be added into the system to guarantee the drying process operating in the normal situation under any factors influenced.

Regarding to this issue, a detail **DDC controlling and monitoring system was integrated**, which mainly monitor the pressure level in the suction of the drying machine to control the different dampers and gate valve to ensure to provide sufficient air flow inside the drying machine through the DDC control. The detail can be referred to Fig.3: The Schematic Diagram of the Integration of Heat Pump and Drying Machine.

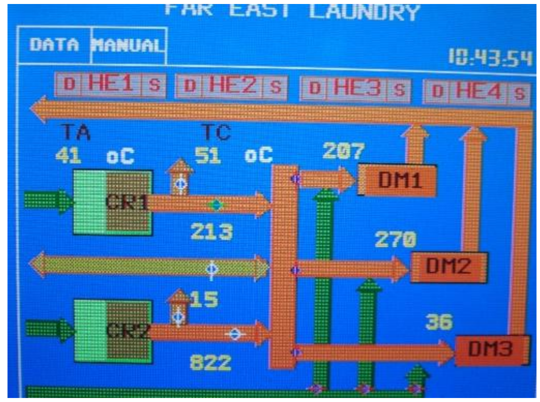

Fig.4 : DDC Controlling and Monitoring System

Drying Machine Mode Study

There are several modes for the drying machine to be studied shown below:

Table 2 : Drying Machine Mode Schedule

	Mode	Status of Equipment	
		Drying Machine	AC System
1.	AC mode	Off	On (Chilled Cooling)
2.	Drying Mode	On (Drying)	On (Chilled Cooling)
3.	Cooling Mode	On (Natural Cooling)	On (Chilled Cooling)

1. AC mode
In the AC mode, the AC system remain processing without drying process. The heat absorbed from the laundry workshop is removed to the outdoor through air flow from the fresh air intake of the condensers. The status of equipment are shown below.

Sequence	Equipment	Status	Action
1	CR1 / CR2	ON	Condensers operating
1	CD1 / CD2 / CD3	OFF	No fresh air input to the drying machine
1	HD1 / HD2 / HD3	OFF	No pre-heat air input to the drying machine
2	GV1 / GV2	Position A	Off coil air flow from condenser exhausted to outdoor

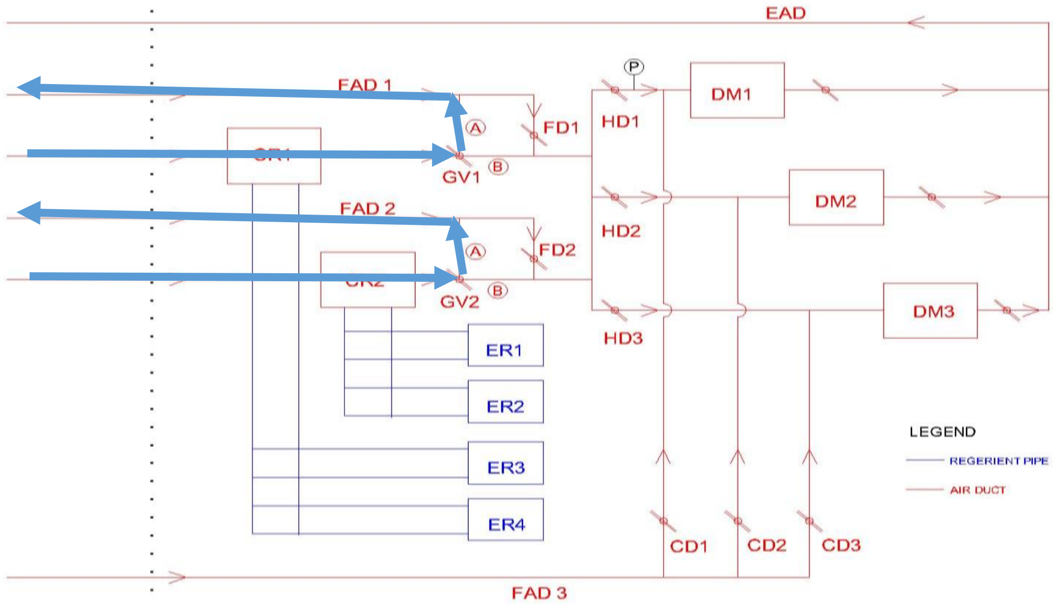

Fig.5 : AC Mode of the Integration of Heat Pump System

2. Drying Mode
   In the Drying Mode, the drying machine DM and AC system CR&ER are operating at the same time. The pressure gate at the suction of the dry machine detect the level of pressure and control different damper (OPEN/CLOSE) through the DDC controller. Due to the demand variation of the flow of the intake air to the drying machine with remaining normal operation of the AC units, the ratio of openness of the dampers FD are adjusted in different level to satisfy the various demand of air intake to the drying machine. **Sequence 4** shows three level of in-take air demand by the adjustment of the dampers FD1 / FD2. The status of equipment are shown below:

Sequence	Equipment	Status	Action
1	DM1 / DM2 / DM3	ON	Drying Machine operating
1	CR1 / CR2 / ER1 / ER2 / ER3 / ER4	ON	AC system operating
2	Pressure gate P1	Activated	The pressure meter detected the negative pressure due to open of the suction of drying machines and deliver the signal to the controller
3	GV1 / GV2	Position B	The dampers activated by the signal form the controller and open. Pre-heated air flow from the condenser to the drying machine
3	HD1 / HD2 / HD3	OPEN	The dampers activated by the signal from the controller and open. Air flow from the condensers units.

Sequence	Equipment	Status	Action
4	FD1 / FD2	OPEN (Fully)	The dampers activated by the signal from the controller and fully open due to the pressure gate sense the low pressure level. Fresh air will flow from outdoor through the fresh air duct to off coil of the condenser
4	FD1 / FD2	OPEN (partially)	The dampers activated by the signal from the controller and partially open due to the pressure gate sense the high pressure level. Air flow from outdoor through the fresh air duct to off coil of the condenser is reduced.
4	FD1 / FD2	CLOSE	The dampers activated by the signal from the controller and close due to the pressure gate sense the very high pressure level. No air flow from the outdoor to compensate the insufficient of the air supply to the drying machine

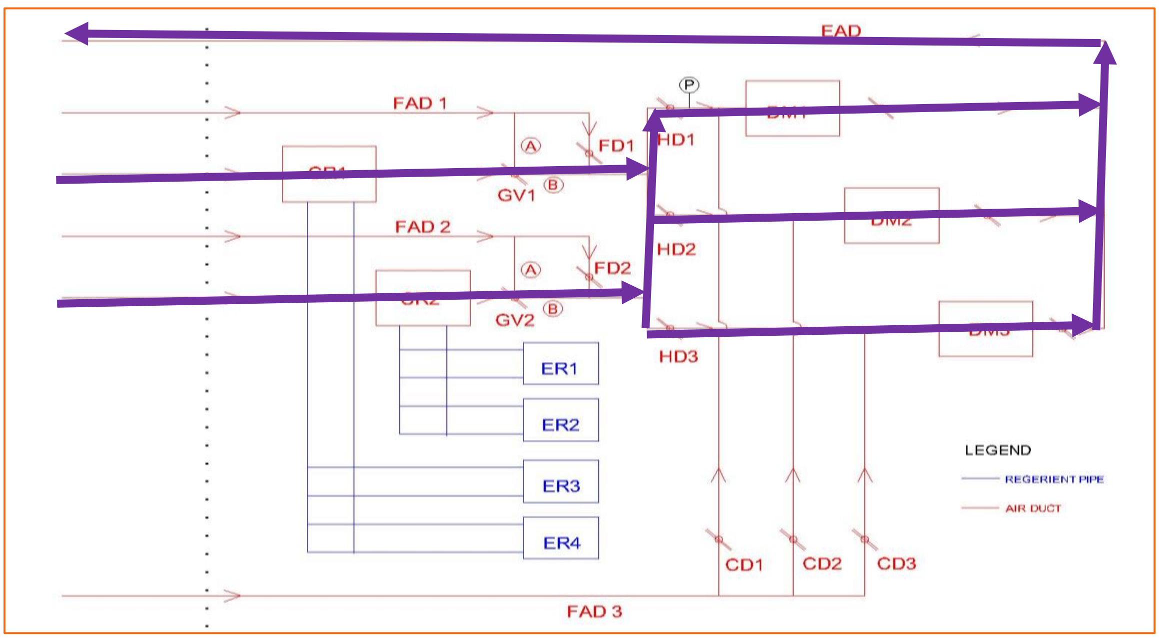

Fig.6 : Drying Mode of the Integration of Heat Pump System

3. Cooling Mode
   In the cooling mode (after the drying mode), the purpose of natural is to cool the cloth heated by the drying machine with high temperature (nearly 85ºC). During the process, the dampers HD& FD are CLOSE and terminated the heat air flow intake from the condensers. The heated air flow to the outdoor through EAD 1&2. To provide fresh air for natural cooling, the dampers CDs are OPEN for the intake of the fresh air flowing through the FAD3 to the drying machine. After the

cooling mode, the system will return to the initial drying mode condition and ready for the next drying mode.

Sequence	Equipment	Status	Action
1	DM1 / DM2 /DM3	ON (Cooling)	Drying machine start the natural cooling mode to cool the cloth
2	HD1 / HD2 / HD3	CLOSE	The dampers are activated and Close by the signal form the controller. No air flow from the off-coil of the condenser to the drying machine
2	FD1 / FD2	CLOSE	The dampers are activated and close by the signal from controller. No air flow from the off-coil of the condenser to the drying machine
2	CD1 / CD2 / CD3	OPEN	The dampers are activated and open by the signal from the controller. Fresh air from outdoor flow through the FAD3 to the drying machine for natural cooling process.

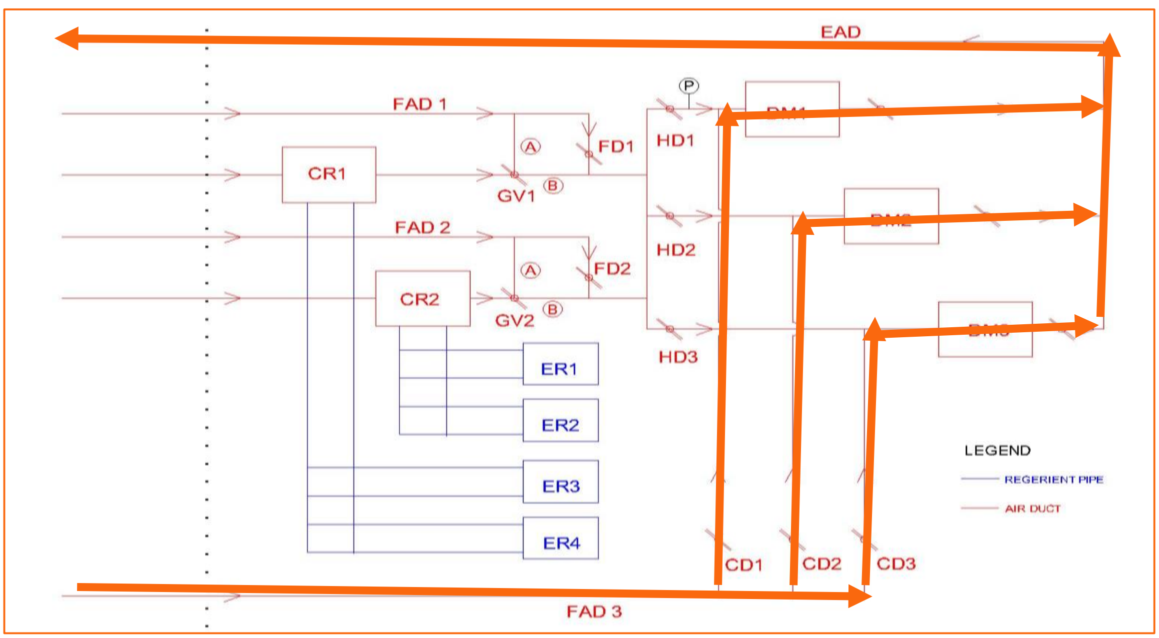

Fig.7 : Cooling Mode of the Integration of Heat Pump System

3. Heat Recovery by Exhausted Air

In the view of the exhausted air from the drying machine with high temperature around 50-60°C, the air can be recovered to for 2 functions:

1. Enhancement of the **COP** of Heat Pump in the **Winter Mode**

Referring to Fig.8: P-H Diagram of R410A and Fig.9 : The Effectiveness of Heat Pump Performance Diagram Against the Ambient Temperature. In winder mode, low ambient temperature cause the reduction of COP of the heat pump, the incoming temperature to the heat pump is usually 8-13°C in HK.

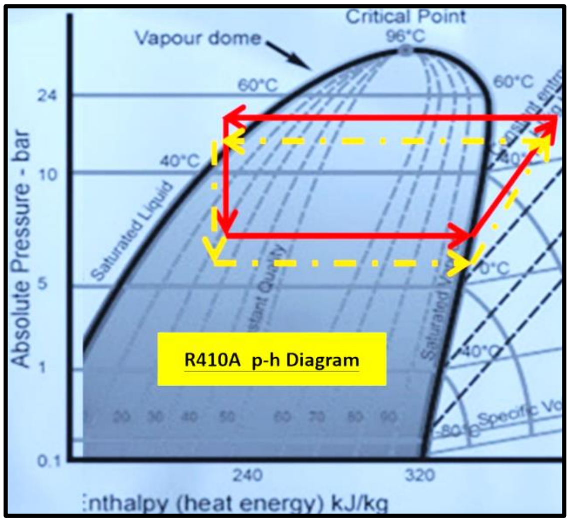

Fig.8 : P-H Diagram of R410A

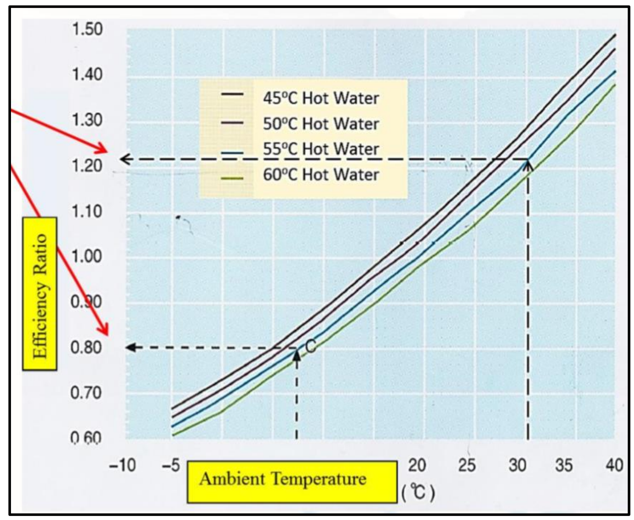

Fig.9: The Effectiveness of Heat Pump Performance Diagram Against the Ambient Temperature.

Therefore, in order to rise the ambient temperature in the laundry, the exhausted air from those 3 Drying Machine **DM-A1, 2&3** are designed to be transferred back to the evaporator to recover the heat energy in the air. Regarding to the measure, the COP of the integration of heat pump can be increased in the winter mode.

2. Heat recovery for pre-heating process

As mentioned before, the temperature of the exhausted air is still remaining at high level, which can be transferred for pre-heating process. With a view to increasing the percentage of energy saving in the laundry, the exhausted air is designed to be transferred to the **Counter Flow of Air to Air flow Exchanger**. The heat air exhausted is transferred to the incoming air of those 4 drying machine DM-B1, 2, 3&4 for pre-heating. Therefore, part of energy for the heating process can be saved by replacing the boiler part by exhausted air for pre-heating. The details can be referred to the Fig.10 Heat Recovery Air-Conditioning System Schematic

In the recovery of exhausted air, a self-cleaning air filter is applied to avoid the containment entering the laundry.

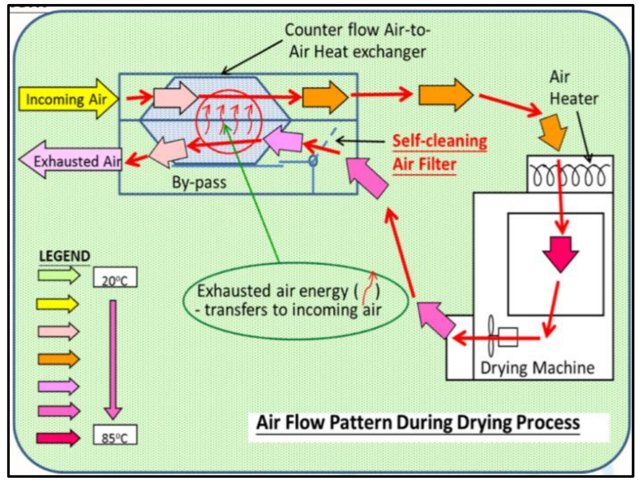

Fig.10 : Heat Recovery Air-Conditioning System Schematic

Conclusion

This paper presents and illustrates the integration of heat pump and air-conditioning system for pre-heating and cooling process that can combine the traditional heating system and cooling system. 1 kWh of power now can be multi-function in the laundry. Overall percentage of energy saving can be achieved **32%** at the peak level. In this case, the air-conditioning part is totally **100 % free of charge**. Reduction of carbon emission is also achieved to a dramatic enhancement. In the view of the owner, in spite of extra additional cost and space for the system, it was found that the initial cost can be recovered by a very short period (10 months) that is an attractive value for them to select it rather them traditional system. Not only do energy saving can be achieved, but also the traditional poor working condition could be improved well. The workers can achieve the thermal comfort during working.

Also, the factors influenced the normal operation of the drying machine and AC system are considered and figured out by the **DDC Controlling and Monitoring System** to the air flow control.

Besides, the exhausted air from the drying machine is also recovered to the laundry for enhancement of the COP of heat pump and pre-heating for drying. Heat energy is recovered “again” for E-saving.

In the view of laundry owner, integration of heat pump technology to the air-conditioning system is proved as a **valuable** measure in the aspects of energy saving, financial, user-friendly and health. Also, as we mentioned the trend of the demand of laundry will become a high level due to the rapid development of tourism industry in HK in the future. That means many **new** laundries will be completed within these 10 years to satisfy the rise of demand of the laundry. In regards of these situation, HK government should shoulder the responsibility to lead the laundry, hotel, catering trade or others related to heating and cooling system to develop the integration of heat recovery and Air-conditioning system to achieve effective energy saving.

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Figure Captions

Table Captions