Case Study summary

IEA-ECBCS Annex 48

Heat Pumping and Reversible Air Conditioning

Belgian Case Study N°1: Laboratory Building in Liège

Université de Liège

Contribution of the University of Liège, Belgium

Introduction

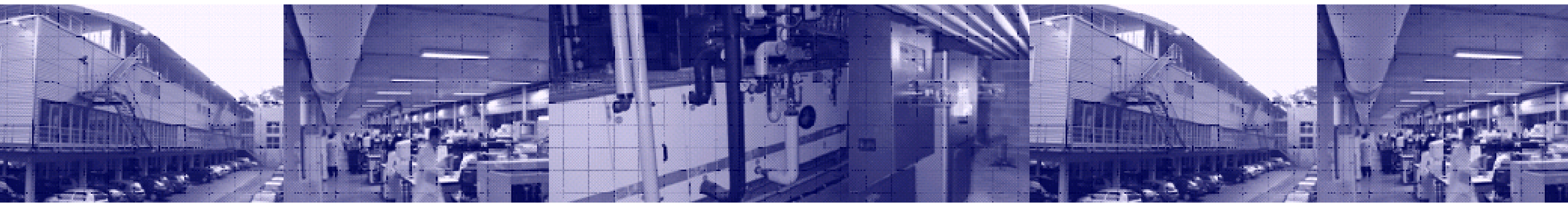
The building considered in this summary was erected in 2003 near Liège (Belgium) is occupied by a pharmaceutical company. The two main building zones are offices (1600 m²) and laboratories (1500 m²).

70 people occupy the office floor from 8 am to 6 pm, 5 days a week. 60 people occupy the laboratories during working hours and 6 people during night. The HVAC system consists mainly of CAV AHUs supplying conditioned air to the different zones through a duct network. Two large CAV AHU supply conditioned air to the laboratories 24h per day. A smaller CAV AHU supplies conditioned air to the offices; 4-pipes fan coil units are installed at the office floor for local temperature control. A building energy management system (BEMS) handles all necessary data and implements the control strategies.

The heating system is composed of 2 condensing gas boilers (300 kW each). A scroll air cooled chiller is used for chilled water production, for a total cooling capacity of 400 kW.

Summary

- Location: Liège, Belgium
- Building sector: office and laboratory
- Gross net area: 6200 m²
- Studied conditioned net area: 3100 m²
- Chiller nominal cooling capacity: 400 kW
- Boiler nominal heating capacity: 600 kW
- U-value external walls: 0,50 W/(m²K)
- U-value windows: 2,9 W/(m²K)



Background

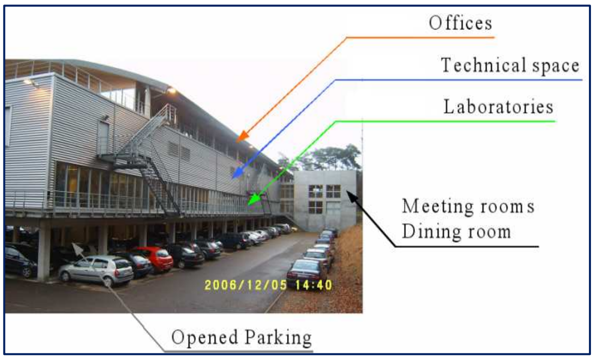
The aim of this study was first to analyze the heat recovery potential of the building. Two heat pumping solutions have been studied and compared in terms of energy savings. Simulation models have been developed and implemented in an equation solver to allow carrying out this study.

Building description

Laboratories (ground floor) are ventilated with 100% fresh air at a constant flow rate of 33000 m³/h by three CAV AHUs, 24h per day and 7 days per week. The three AHUs, called GP/GE 1, 2, 3, ensure the follow-up of the temperature set point (23℃). AHUs are equipped with glycol recovery loops, heating coils, cooling coils and fans. Two of them (GP/GE 2, 3) are equipped with humidification device (electrical steam generator). Their nominal flow rate are of 11500 m³/h and a humidity set point (RH=50%) is imposed in the larger part of the zone (about 70% of the total zone's surface). GP/GE1 is dedicated to the rest of the zone and has a flow rate of about 10000 m³/h. The air is supplied in the zone through some cylindrical porous textile diffusers. There are no other terminal units in the third zone.

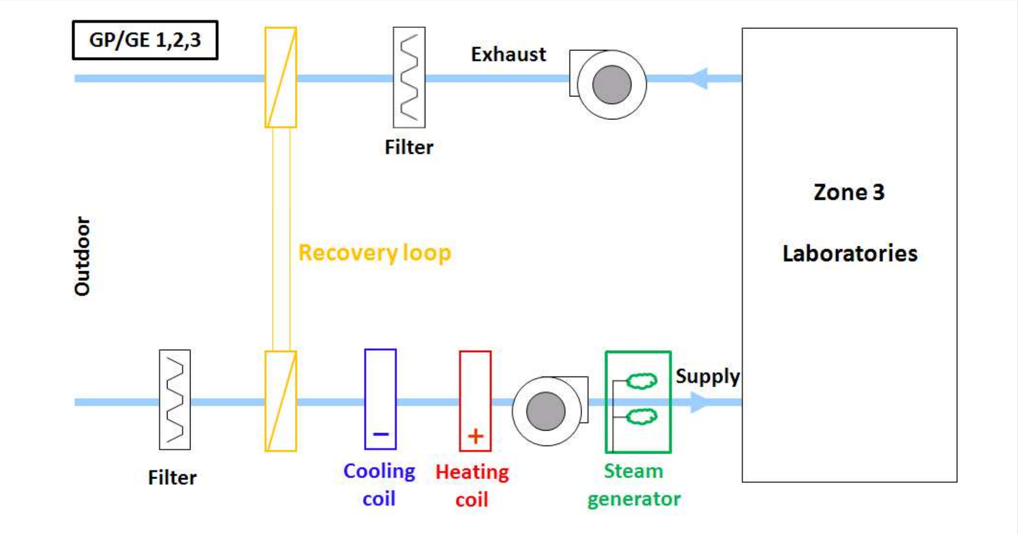
Offices are ventilated with a constant flow rate of 5050 m³/h of 100% fresh air from 6:00 to 20:00. The double flux air handling unit (AHU) dedicated to the offices is denoted GP4/GE4. It is composed of two filters, one glycol-water recovery loop, one heating coil, one cooling coil and two fans. There is no control of humidity in the offices' zone. 4-pipes fan coils units are installed and used to maintain the comfort temperature of about 23℃. Each occupant can contro l this temperature by using the local thermostat.

The others zones (not considered in the present work) include sanitary rooms (heated only by radiators), technical room (non air conditioned), storage hall (including two cold rooms) and restaurant (separated



Building view

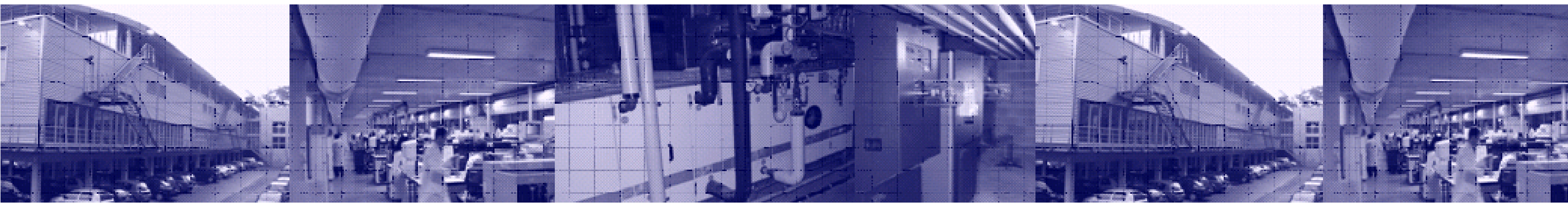
Air Cooled Chiller



Main components of the GP/GE-1/2/3

HVAC plant data

- Total ventilation rate: 33 000 m³/h
- Supply fan: 18 kW
- Exhaust fan: 13 kW
- Hot water loop pumps: 1.1 kW
- Chilled water pumps: 6 kW



Technical concept

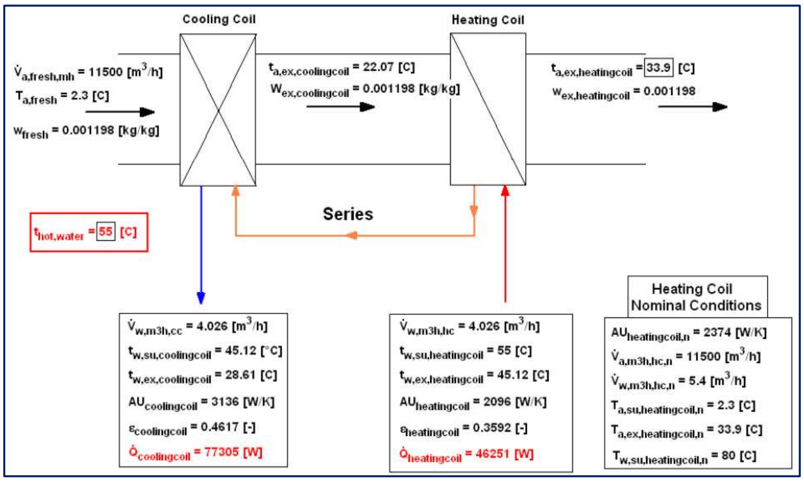
Two retrofit options have been studied. The following configurations have been simulated on a typical year:

1. actual installation;
2. use of a heat recovery system using extracted air as heat source for hot water production;
3. addition or substitution of an “active” (heat pump) recovery to the existing “passive” air-to-air heat recovery system.

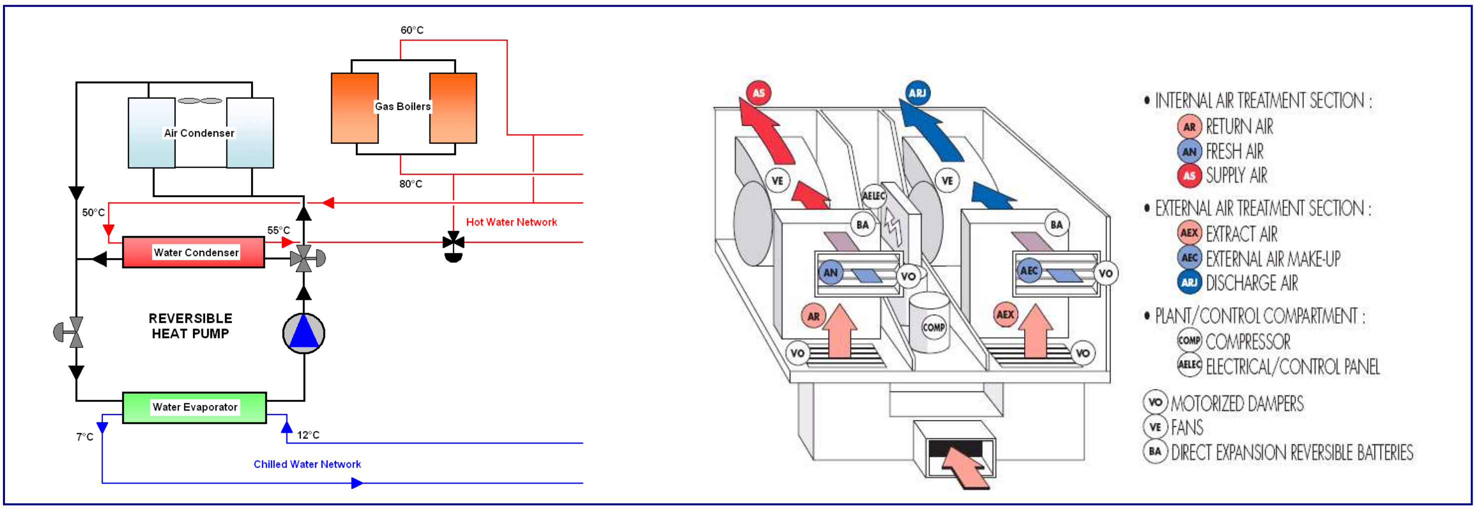
The first retrofit option consists in replacing the existing air-cooled chiller by a dual condenser cooled chiller able to produce hot water at 50℃ with a rating COP of 3.05 (in heating mode). In this case, the vitiated air flow rate extracted from the laboratory zone (33000 m³/h of hot and humid air, 24h/day and 7days/week) would be used as heat source and a water coil would be installed in the return duct. The evaporator network would be connected to the coil in order to recover low temperature heat and produce hot water at a temperature of 50℃ to supply heating coils of air handling and fan coil units. Because fan coil units are oversized, hot water at 50℃ is sufficient to satisfy the d emand in offices. In air handling units, a water change over on the cooling coil (consisting in using the cooling coil for heating, in addition to the existing pre-heating coil sized for 80℃/60℃ water temperature regime) is needed at low outdoor temperature.

The second retrofit option consists in installing a direct-expansion reversible air-to-air heat pump in the air ducts supplying the laboratory zone. In heating mode, such heat pump would directly recover sensible and latent heat from the exhaust air and use it as a heat source for heating. In cooling mode, the exhaust air is used as a heat sink. In case of insufficient capacity of the heat source/sink, outdoor air can be used to increase the capacity. The rating performance of such heat pump are given in the table below.

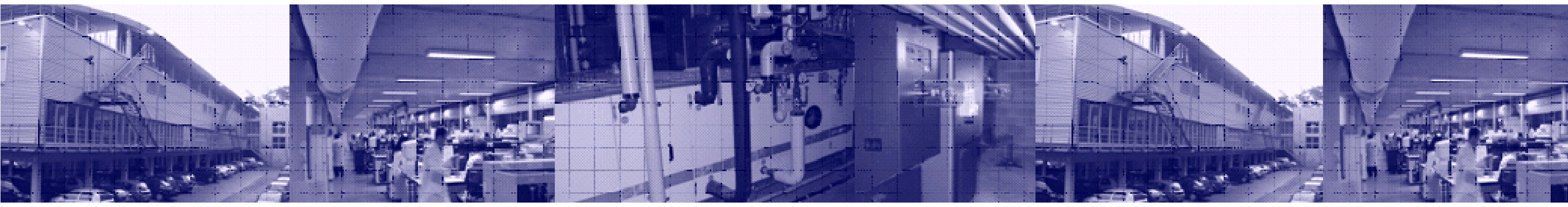
	Conditions	Performances
Heating	IN (DB/WB): 27℃/19℃ OUT (DB/WB): 7℃/6℃	COP (cp): 5.88 COP (cp+fans): 2.25
Cooling	IN (DB/WB): 27℃/19℃ OUT (DB/WB): 35℃/24℃	EER (cp): 4.93 EER (cp+fans): 2.90



AHU coils series change over: the cooling coil is used as a secondary heating coil and allows reaching the temperature setpoint with low temperature hot water (50℃) by increasing the heat transfer area.



Retrofit options 1 (left – dual condenser heat pump) and 2 (right – air-to-air heat pumps)



Conclusion

It appeared that, in the office zone, an adaptation of the re-starting schedule is sufficient to satisfy to the comfort conditions during occupied periods. In the laboratories, a “change over” technique was used on the AHU coils to allow operating with hot water at low temperature (50°C) instead of high temperature (80°C). This technique takes advantage of the already installed and available heat transfer surfaces (as cooling coils) and uses them as additional heating coils. The series assembly of the two coils has to be preferred. The coupling of these two adaptations (modification of re-starting strategy and change over technique) allows the installation to function with low temperature hot water and to meet the comfort conditions. The major cost related to this first retrofit options are due to the modification of the piping work and the replacement of the chiller by a dual-condenser chiller.

While no modification of the water circuit is needed to implement the second retrofit option (direct air-to-air heat pump), this solution requires more important work on the ventilation system and the duct work and cause additional overcosts.

In terms of primary energy, both solutions offer interesting performance and primary energy savings (around 9%).

Simulation results

The simulation of the first retrofit option leads to an over-consumption due to additional pressure drops in the exhaust air ducts and to the heat pump consumption in heating mode. This increase represents about 15% of the initial consumption. The heat pump seems able to satisfy the main part of the heating demand and the natural gas consumption is decreased of about 98%. Combined together, both variations result in a reduction of about 10% of the primary energy consumption.

Change in energy consumption	Variation
Electricity (global) consumption	15.1%
Natural gas consumption	-97.8%
Primary Energy (factor 2.5) consumption	-9.1%

When simulating the second retrofit option, the global electricity consumption is increased of about 15%, because of the over-consumption due to air-to-air heat pump compressors and fans. As expected, the natural gas consumption largely decreased (about 60%), leading to a decrease of the primary energy consumption of about 9%.

Change in energy consumption	Variation
Electricity (global) consumption	15.3%
Natural gas consumption	-60.2%
Primary Energy (factor 2.5) consumption	-8.5%

Further readings

Bertagnolio, S. 2007. Study modeling and analysis of heat pymping solutions in a commercial building. Master Thesis University of Liège.

Bertagnolio, S., Lebrun, J., Aparecida Silva, C., Hannay, J. 2007. Heat pumping and reversible air conditioning: Retrofit opportunities in a laboratory Building. Proceedings of the 5th International Symposium on Heating, Ventilating and Air Conditioning, Beijing, China

Moureau, F. 2008. Energy retrofit potentials in building HVAC. Focus on heat recovery. Master Thesis University of Liège.

Bertagnolio, S., Lebrun, J., Andre, P., Moureau, F. 2008. Heat pumping and reversible air conditioning : how to make the best use of HVAC equipment. 9th IEA Heat Pump Conference, Zurich, Switzerland.

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