12th IEA Heat Pump Conference 2017

68% the performance improvement of a thermo-frigo-pump with variable speed compressors to replace a thermo-frigo-pump with piston compressors

José Naveteur[(a)] *, Christian Bruss [(b)]

[a] Senior Engineer, EDF R&D Energy in Buildings and Territories Department. Site des Renardières. Ecuelles, 77818 Moret-sur-Loing, France.

[b] *Head of Service Works Maintenance and Safety, CAF of Rhône, 63 Boulevard Vivier Merle – 69003 Lyon, France*

Abstract

Since 1998, EDF R & D provides energy monitoring of an office building (S = 16633m2) in Lyon and is heating and cooling by a thermo-frigo-pump on groundwater.
In 2014, it was decided to renovate the production of hot and cold and replace:
-The Existing thermo-frigo-pumps (with piston compressors) **by new machines with variable speed compressors.**
-All the water pumps with new variable speed pumps
The measures realized in the year 2014, have shown that
-The building consumption was reduced by 30%
-The consumption of water pumps 41%
-The consumption of thermo-frigo-pump decreased near of 50% and the COP heating + cooling (*) increased by 68%!.
- All of these improvements led to a reduction in CO_2 emissions of 37% (of the building).

© 2017 Stichting HPC 2017.
Selection and/or peer-review under responsibility of the organizers of the 12th IEA Heat Pump Conference 2017.

Keywords: Thermo-frigo-pump, energy efficiency, COP, ground water, variable speed screw compressor and pmps

1. Introduction

Since 1998, EDF R & D realizes monitoring of energy consumption of an office building located in Lyon (area of 16 663m²), which includes offices (627), meeting rooms, and a conference room.
The peculiarity of this building is to be heated and refreshed by a **thermo-frigo-pump** on groundwater that provides:
-The heating in winter
-The air conditioning of the computer room all year and offices, meeting rooms and amphitheater in the summer.

The thermo-frigo-pump realizes the energy transfer between the hot and cold needs by the building which results in excellent performance of the installation, hot or cold surpluses are evacuated by the ground water. It is an ideal solution in terms of energy and costs for buildings which have both cooling and heating needs.

* Corresponding author. Tel.: +33 1 60 73 78 64
E-mail address: jose.naveteur@edf;fr.

2. Technical site characteristics

In October 2013, the building owner decided to improve the energy performance of the building, this one, well maintained, does not justify energy renovation of facades. As regards the PACs, equipped with piston compressors, with over 130 000 hours of operation without major problems, it could be interesting to study their replacement (in advance) by new machines with latest generation screw compressors operating variable speed.
A study by the consultancy ARTELIA (Lyon agency) has highlighted the interest of upgrading the production of hot and cold by thermo-frigo-pump, namely PACs, pumps, regulation, and metrology.

The installation comprises two water/water heat pumps which feed a network of 4-pipe fan coils (630) and Air Handling (5) Units with energy recovery to limit energy consumption.
The hydraulic systems are fitted with variable speed pumps. The well comprises two variable speed-boring pumps with a maximum flow rate per unit of 100 m^3/hr.
Groundwater is at a depth of 5m, drilling units (1 pumping and 1 injection) are at a depth of 20m, and they 316L stainless steel 800 mm diameter.

The two new heat pumps are with screw compressors operating variable speed manufactured by CARRIER type 30XWHV580 (Eurovent Certified), they replace two heat pump with piston compressors (CARRIER 30HG280).

The main characteristics of new heat pumps (data sheet of CARRIER)
Heating mode
Heating capacity (45/50 °C) = 2 *633400W Hot
Power consumption = 2 * 155200 W,
COP in Hot= 4.08
Cooling mode
- Cooling capacity (7/12 °C) = 2 * 618800W Cold
- Power consumption = 2 *96200W
- EER= 6.43, EESER = 7.80

Operating conditions:
– Chilled water is 7-12°C in summer and 10-12°C in winter.
– Hot water is 35°C when it is above 20°C outside and 45°C when it is 0°C outside. The whole installation is managed by a BMS (Building Management System).

Control
This is based on a fundamental principle: *"always satisfy the highest demand."* The BMS must continuously measure the differences in temperature between the two systems (hot and cold). Depending on which system has a higher demand, it determines the operating conditions for the thermo-frigo-pump by prioritising hot or cold operation.
All of the installations are run by a Metaproductique-brand engineering management system.

o How a thermo-frigo-pump works

A thermo frigo pump has five different modes, including:

Heating mode. This mode is used during cold spells. To achieve thermal equilibrium, all the cold produced by the units is discharged into the well.

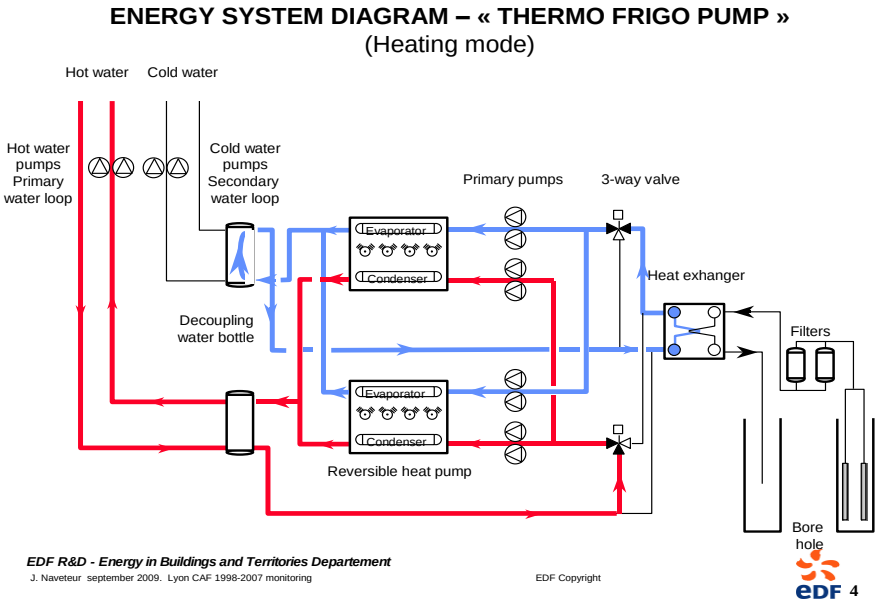


Fig 1: Thermo-frigo-pump in heating mode

Majority heat and minority cold. The building consumes more heat than cold (mid-season and start of winter). Surplus cold is discharged into the well.

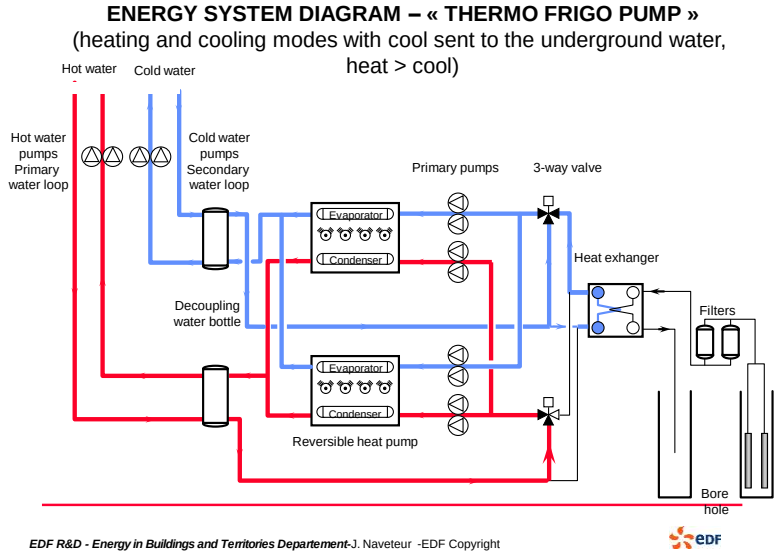


Fig 2: Thermo-frigo-pump with heat > cool

Heat equal to cold. This mode is used when the building consumes all the cold and heat produced. The COP is at its maximum and no energy is discharged into the well.

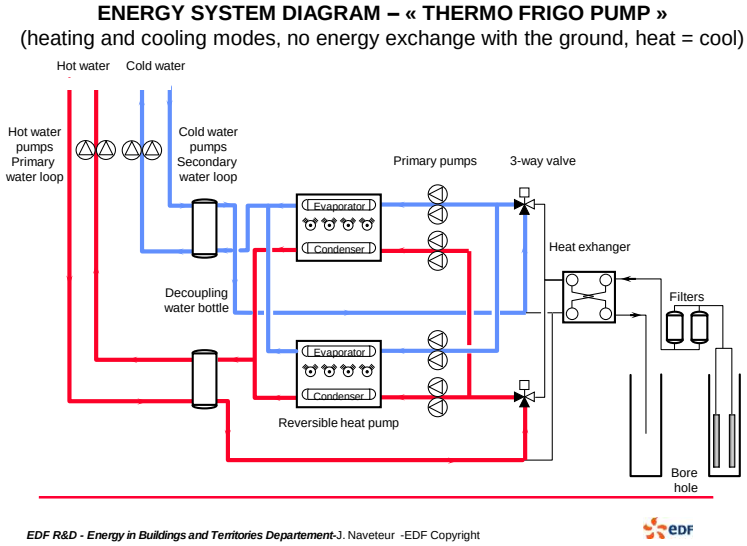


Fig 3: Thermo-frigo-pump with heat = cool

Majority cold and minority heat. The building consumes more cold than heat (mid-season and end of winter). Surplus heat is discharged into the well.

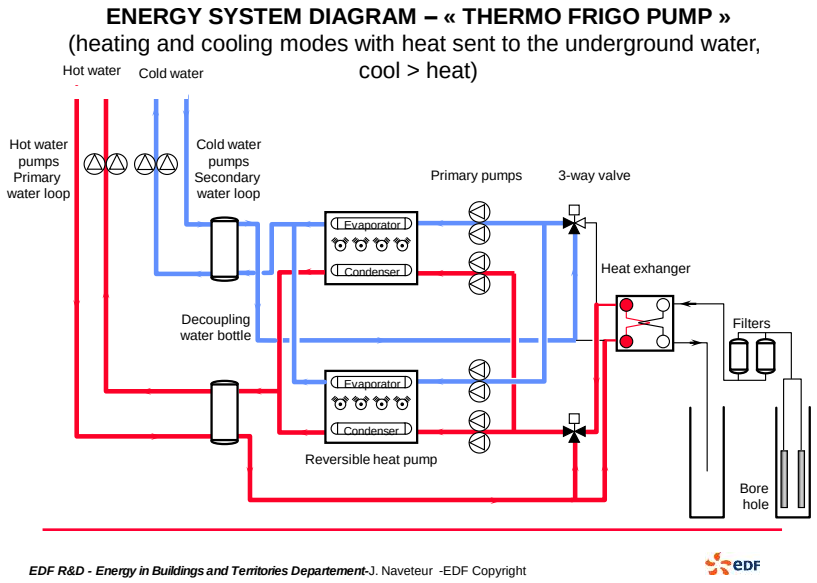


Fig 4: Thermo-frigo-pump with cool > heat

Cooling mode. This mode is used during summer. To achieve thermal equilibrium, all the heat produced by the units is discharged into the well.

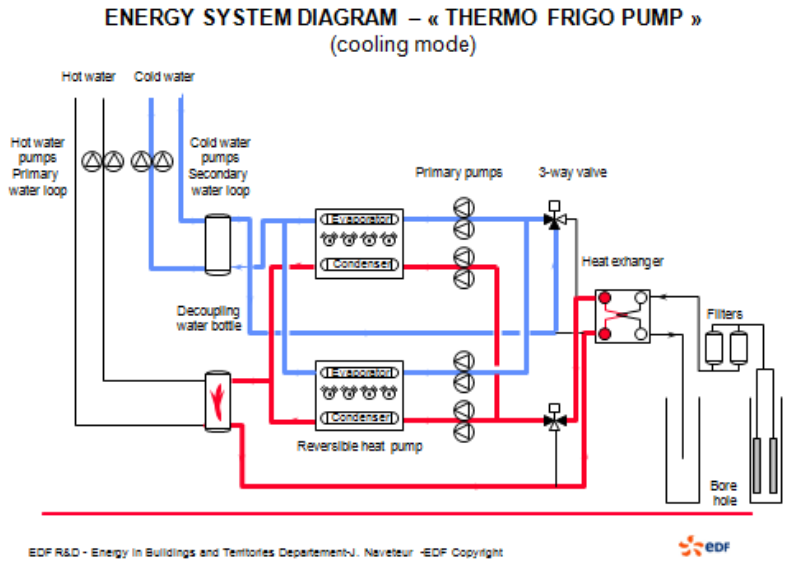


Fig 5: Thermo-frigo-pump cooling mode

3. Measurement results: Average 1998-2013 compare at 2015

The site has been monitored for energy performance since 1998 with monitoring installation carried out by EDF R&D using 9 electricity meters (6 of which having remote reading capabilities), 1 heating meter, 1 cooling meter and 1 BMS remote investigation and monitoring system.

The building consumption decreased by 33%, and near 50% for the heat Pumps. It should be noted that all consumption are down which shows the involvement of all in the good management of the site.

Table 1: Average 1998-2013 compare at 2015

	Average 1998 2013		**2015 compared to the average from 1998 to 2013**	**Consumptions 2015**	**Area=16633m2**
Total consumption	2608226kWh	157kWh/m²	**-33,25%**	1741036kWh	**105kWh/m²**
Consumption of Heat pumps	614901kWh	37kWh/m²	**-49,27%**	311913kWh	19kWh/m²
Consumption of water Pumps	302067kWh	18kWh/m²	**-41,15%**	177754kWh	11kWh/m²
Consumption of Air Handling Units	195449kWh	12kWh/m²	**-30,57%**	135693kWh	8kWh/m²
Consumption of other uses	1471379kWh	90kWh/m²	**-25,41%**	1115676kWh	67kWh/m²
Heating Degree Days	2187		**-8,73%**	1996	
kWh heating/Degree Days comsumption by the building	515kWh/Dju		**-8,80%**	470kWh/Dju	
Heating consumption	1 126 157kWh Heating	68kWh Heating/m²	**-16,77%**	937 332kWh Heating	56kWh Heating/m²
Cooling consumption	1 345 206kWh Cooling	81kWh Cooling/m²	**1,05%**	1 359 310kWh Cooling	82kWh Cooling/m²

The COP in heating +cooling increased by 68%!

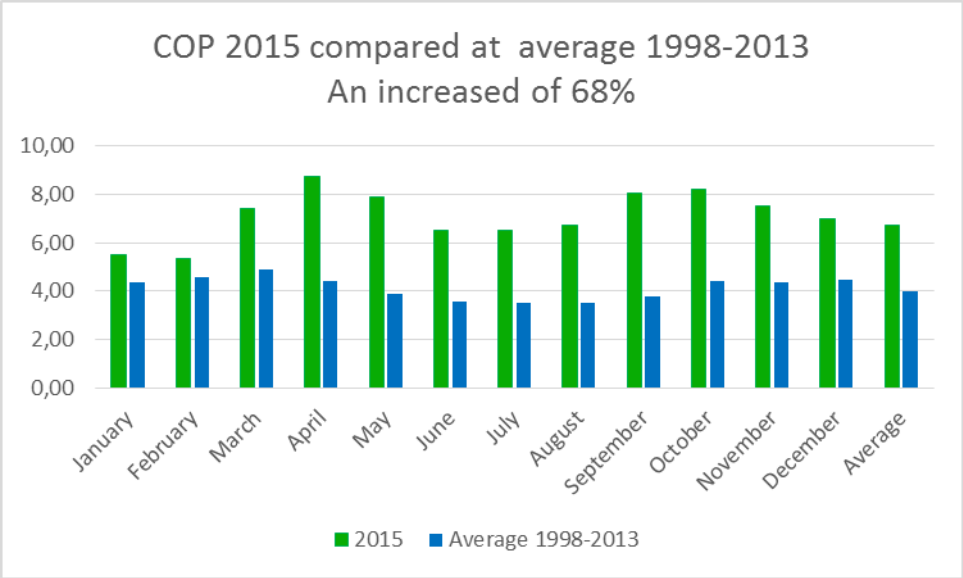


Fig 5: COP: 2015 compare at average 1998-2015

-The CO_2 emissions are also reduced by **37%** compared to older the heat pumps. Compared to a gas boiler and

*COP = Hot and cold consumption by the building / Electrical energy consumed by the thermo frigo pumps + the well pumps.

The cost of consumption has decreased of **4.82 € HT / m²**, of **1.65 € HT / m²** for the heat pumps and that of 0.70 € HT / m² for the all the pumps.

The average cost of producing kWh of heat/cold is **€0.014/kWh** in decrease of 45%
The cost of renovation of the thermo-frigo-pump (Heat pumps, pumps, management system,) is 34900€ HT or 25 € HT / m². **The payback time (IRR) is 11 years!**

(Nb) All cost in this article exclude taxes

4. Know-how transfer

Given the experience gained during this monitoring, we then carried out other site monitoring at other buildings equipped with geothermal heat pumps such as a shopping center (2), a town hall (3), a museum (4), a swimming pool and an auditorium which is equipped with a heat pump pile foundations.
We have written many articles (5, 6) and conferences (7) presenting the results of these facilities and we participated in drafting technical guide (8).
We also work in courses organized by the National Agency for Energy Management and universities where we train interns and students to achieve this type of facility.
EDF R&D is recognized as one of the actors of this type of installation in France.

5. Conclusion

Replacing thermo-frigo-pump has resulted to:
-Reduced 50% of consumption.
-Reduced 37% of CO2 emissions.
-Reduce by 45% of the cost of MWh cold hot product.
The time to return on investment of 11 years is satisfactory.

Note that for this successful renovation of the Rhône CAF obtained, in 2015, the price of innovation and sustainable development of social security.

References

(1) JC.Léonard, J.Naveteur. Electronic variation speed, a good means of carrying out energy saving review Qualita N°60 (June 2000).

(2) S.Barrois, J.Naveteur. Cora Colmar, commercial center equipped with a geothermal heat pump Assessment 10 years. Review CVC (is like ASHRAE journal in France) 864-(June /2010)

(3) S.Barrois, D.Bulle, J.Naveteur. Experience feedback on a building HQE the Town hall of Mureaux. Review CVC 846 (July 2007)

(4) J.Naveteur, A.Rousset, V.Foray. Energy performance and sustainable development of the National Center of Costume Scene (NCCS) in Moulins (France) -Average 2007-2011.Congress Climamed 2013-Istanbul-Turkey

(5) J.Naveteur, C.Bruss. A solution of geothermal heat pump on ground water. Revue Qualita N°66- 03/2003

(6) J.Naveteur, C.Bruss. CAF of Lyon: 9 years assessment of operation. Review CVC 846 (March 2007)

(7) J.Naveteur, C.Bruss. CAF de Lyon : A geothermal thermo frigo-pump for ten years. REHVA Congress (Europeen ASHRAE congress) –Antalaya-Turkey (May 2010)

(8) J.Naveteur, C.Bruss. CAF de Lyon : A geothermal thermo frigo-pump for 15 years. 11th IEA Heat Pump Conference - Montreal (May 2014)

Member (since 2015) of Board of Directors of AICVF (French association of engineers in heating and air conditioning)

Member of the editorial board of guides (2008):

-The geothermal heat pumps from drilling aquifer: Manual for the design and implementation. Edited by l'ADEME (French agency for energy) and The BRGM (Bureau of Geological and Mining Research).

Member (since 2003) of the drafting committee of the revue heating, ventilation en an air conditioning. This is the revue of AICVF (French association of engineers in heating and air conditioning)