POLYTECH.MONS

Monitoring methods of domestic heat pumps

Commissioning and Auditing of Buildings and HVAC Systems

Brussels

28 January 2008

Dr. Ir. Eric Dumont

Prof. Marc Frère

Faculty of Engineering, Mons

Why monitor energy-related systems ? (1/4)

- Usually, energy consumption/production of an energy-related system over a given period of time can be evaluated by using manufacturer data/normative methods
- In several cases, the (field-)monitoring of the system is necessary:
- no normative method/manufacturer data
- the monitored system is complex (several simpler sub-systems)
- the field conditions are not reported in manufacturer charts
- the field conditions vary a lot over the monitoring period so that the manufacturer data are not easy to use
- accurate field energy consumption/production is mandatory

Why monitor energy-related systems ? (2/4)

- The kind of energy to be monitored can be:
- energy used by the system, usually:
  * fossil fuels (natural gas, fuel oil, etc.)
  * electricity
- energy produced by the system, usually:
  * heat, for space heating or hot water production
  * cool, for space cooling

Why monitor energy-related systems ? (3/4)

- The results of the monitoring are used to evaluate:

- the energy consumption over a given period of time (1 month, 1 year) in order to obtain the costs related to it
- the energy demand over a given period of time (heating/cooling demand of a building over one heating/cooling season) in order to compare the real demand to the predicted one (insulation effectiveness, etc.)
- the real performance of the energy production system (ratio heat/cool to energy consumed) in order to assess the claimed performance

Why monitor energy-related systems ? (4/4)

- The results of the monitoring are used for:
- energy auditing of systems/buildings
- energy commissioning of systems/buildings
- assessment of new models of energy consumption/production

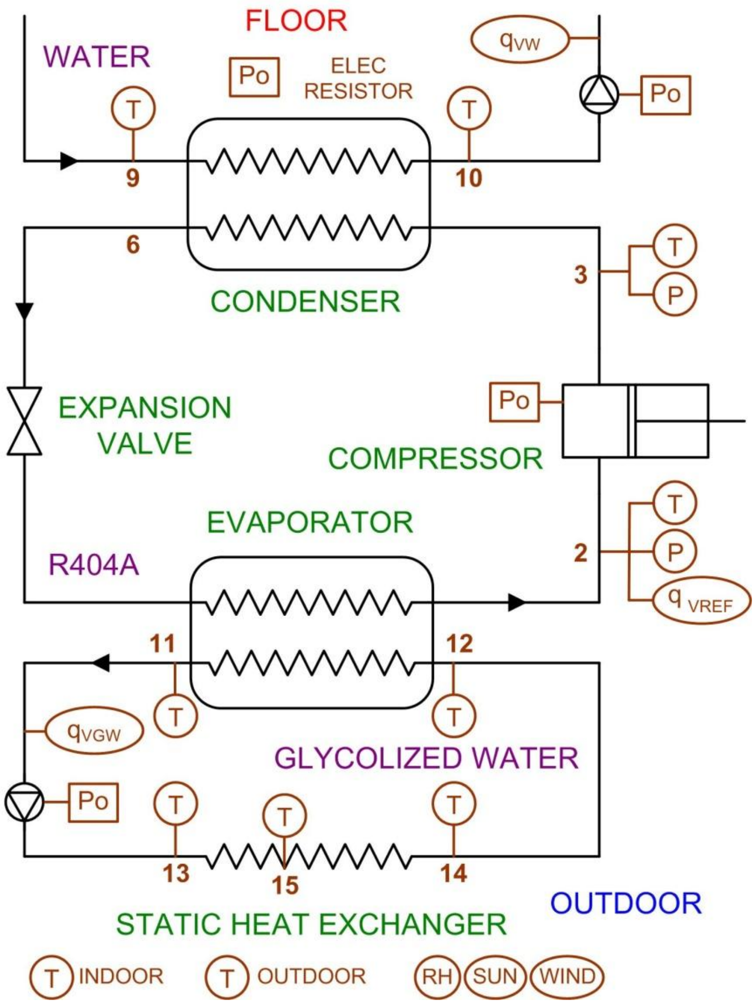
Monitoring of heat pumps (1/4)

- Monitoring of heat pumps are used:
- to measure the real electricity consumption
- to measure the heat released to the building/hot water tank
- to measure the COP of the system
- Monitoring can be performed over different periods of time:
- 1 sec/1 min to obtain instantaneous behavior/performance of the system
- one heating season to obtain average performance (COP over one year = SPF), total energy consumed/heat delivered

Monitoring of heat pumps (2/4)

- Monitored values over one heating season:
- total heat delivered by the heat pump
- total electricity consumption
- Monitored values for instantaneous behavior:
- temperatures
- pressures
- mass/volumetric flow rates
- electrical power

Monitoring of heat pumps (3/4)



- Total electricity consumption
- "power counter" connected to the grid

$W_{PERIOD} = \int_{PERIOD} Po\, dt$

- Total released heat
- "heat counter", need to be placed in the pipe (assuming steady-state)

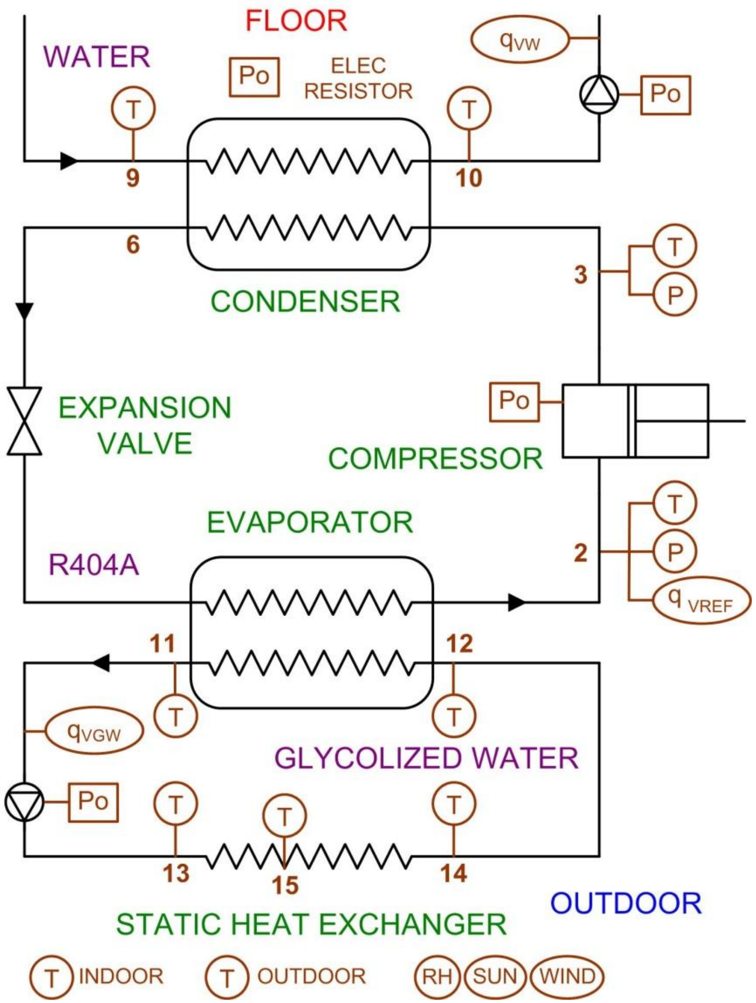
$Q_{PERIOD} = \int_{PERIOD} q_{VW}\, c_{PW}\, (T_{10} - T_9)\, dt$

- SPF

$SPF = Q_{PERIOD} / W_{PERIOD}$

- In case of no water loop, no integral method available

Monitoring of heat pumps (4/4)



- Instantaneous behavior: steady-state assumed

P_{OELEC} : direct measurement

$\Phi = q_{VF}\,\rho_F\,c_{PF}\,(T_{OUT} - T_{IN})$

$\Phi = q_{VR}\,\rho_R(h_3(T_3,P_3) - h_6(T_6,P_3))$

Measurement devices (1/5)

- Electrical power
- placed on the power source
- connection of voltage (U) and current (I), need a current loop, with optional current transformer
- calculate true and reactive power, power factor, current, voltage
- accuracy: 0.6%

©LOREME

© SOCOMEC

Measurement devices (2/5)

- Temperature sensors
- Pt100 (A class, 3 wires) : accuracy ± 0.15 K
- thermocouple type J,K, etc.: accuracy ± 1.5 K
- Pressure sensors
- capacity sensors (0-40 bar), with optional thermal insulation for high-temperature gasses
- accuracy : 0.2 % full scale (0.1 bar @ 40 bar)

Measurement devices (3/5)

- Flow rate sensors

- Coriolis mass flowmeter

  can be used for any phase (liquid, vapor, mixture)

  accuracy: ± 0.5-1.0%

  expensive

- vortex volumetric flowmeter

  can be used for liquid or vapor phase

  typically for refrigerant

  accuracy: ± 0.75-1.0%

  needs inlet and outlet runs (pipe length)

Measurement devices (4/5)

- Flow rate sensors
- magnetic volumetric flowmeter

  can be used for conductive liquids (water, glycol-water mixtures)

  accuracy: ± 0.5%

  cost-effective

  no pressure drop
- thermal mass flowmeter

  used for air flow rate measurements in air ducts

  accuracy: ± 1.5%

  needs inlet and outlet runs (pipe length)

Measurement devices (5/5)

- Flow rate sensors
  - ultrasonic flowmeter

    can be used on pipes, without insertion

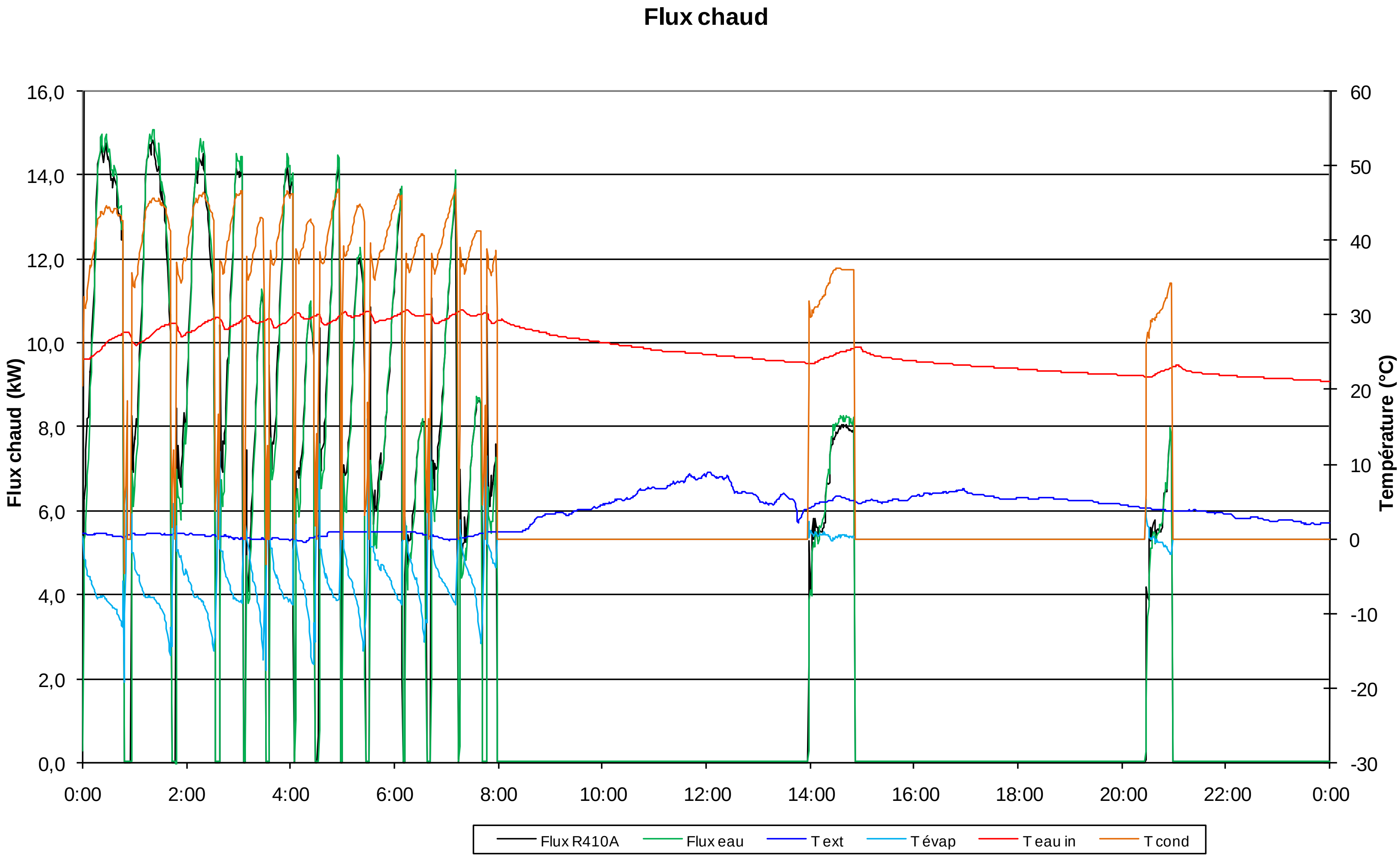
    lower accuracy

    (no experience)

Heat flow rate computation (1/5)

- Air/water or water/water heat pump (and similar)
  $\Phi = q_{VF}\, \rho_F\, c_{PF}\, (T_{OUT} - T_{IN})$ measured on water
- good accuracy (liquid vol. flow rate and 2 temperatures, ρ_F and c_{PF} are accurately known)
- accuracy: 3%
- if glycol-water is used, percentage of glycol must be known precisely
- needs to be calibrated (flow rate without heat release) ($T_{OUT} = T_{IN}$)
- accuracy decreases if temperature difference is low (must be higher than 5 K)

Heat flow rate computation (2/5)



Heat flow rate computation (3/5)

- Direct expansion heat pump (and similar)

  $\Phi = q_{VR} \; \rho_R(T,P) \; (h_{OUT}(T_{OUT},P_{OUT}) - h_{IN}(T_{IN},P_{IN}))$ measured on refrigerant

- average accuracy (gas vol. flow rate, 2 temperatures, 2 pressures, density depend on 1 temperature and 1 pressure measurements)
- needs an EOS (Refprop 7.0, NIST)
- accuracy: 3%
- flowmeter has to be placed before or after the compressor
- best is after (for gas) but some small heat pumps have a very low flow rate; the flowmeter is then placed before the compressor. If no superheating, problem can occur

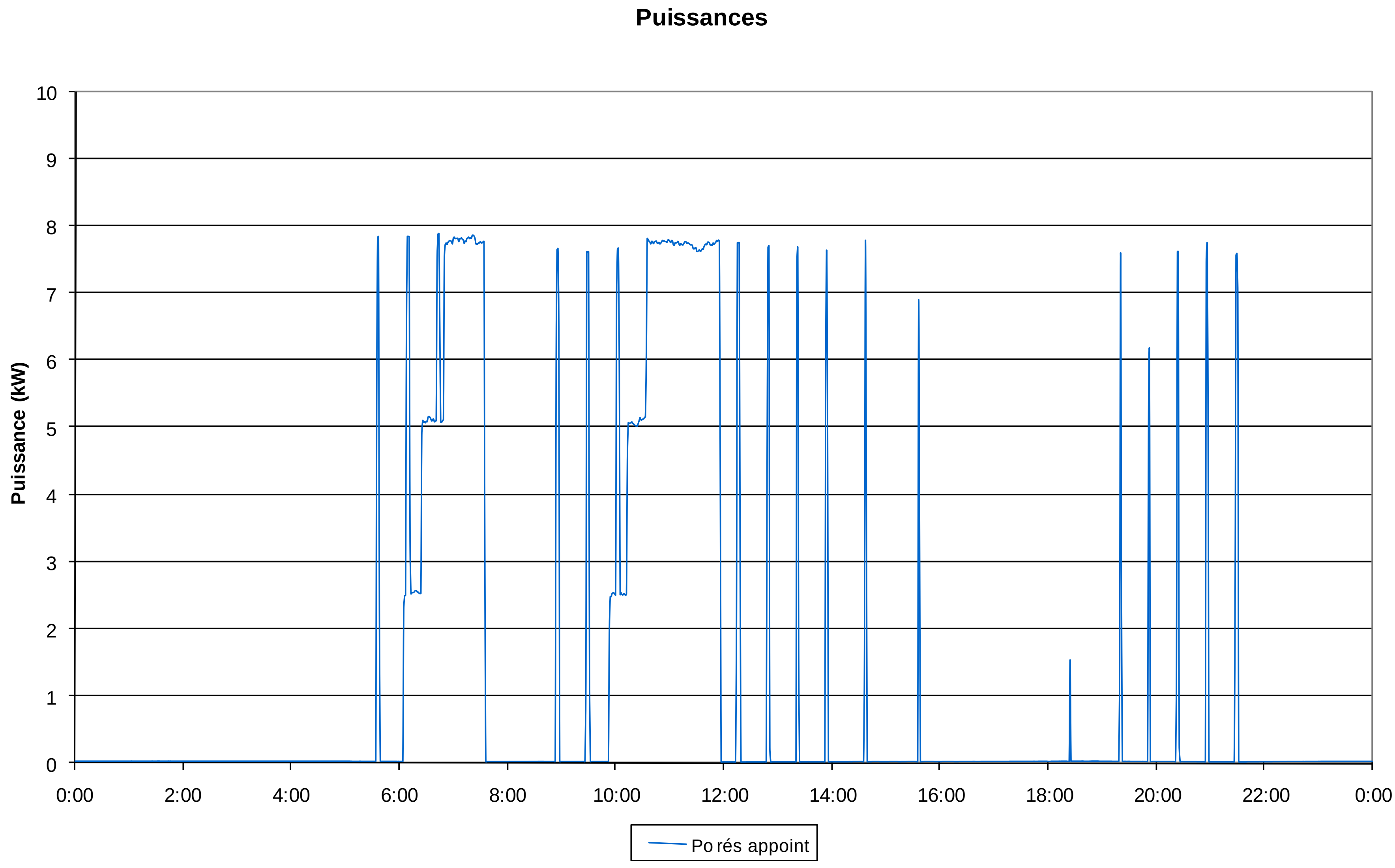
Heat flow rate computation (4/5)

- Water/air or air/air heat pump

  $\Phi = q_{MF}\, c_{PF}\,(T_{OUT} - T_{IN})$ measured on air

- average accuracy due to poor homogeneity of temperature in air ducts
- needs several temperature sensors before and after the heat exchanger if high accuracy needed
- needs to be calibrated (usually with resistor heaters)

Heat flow rate computation (5/5)



Data logging (1/2)

- Measurements recorded:
- If total values are needed (total electrical consumption/heat delivered), a display on the measuring device can be sufficient. One can then check the values regularly.
- If instantaneous values are needed, a data logger must be installed on-site
- Data logger:
- sampling period small enough to keep record of instantaneous behavior (1 sec averaged over 1 min and stored) (steady-state assumption)
- many channels (16 maximum)
- has to restart automatically after electricity shortage
- has to keep recorded values even without electricity

Data logging (2/2)

- Data logger:
- remote download of data possible without complex network (RS-232 modem with analogic phone line)
- big memory to keep record of enough data (2-3 weeks, download once a week)
- closed system to avoid people modifying logger parameters
- resistant to severe conditions (humidity, temperature, etc.)

Conclusions

- Measurements are of “technical quality”. For one heat pump, costs for all measurement devices is about 20 kEur
- Higher accuracy possible but with more expensive devices (“laboratory quality”)
- Use of “technical quality” measurement devices lead to:

- Electrical power: 0.6-1% accuracy
- Heat flow rate: 4-5% accuracy
- COP: 5-6% accuracy

- Need of special calibration, especially for flow rate related measurements