Field monitoring of domestic heat pumps in Belgium: 7 years experience

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Background (1/4)

- Experience of 7 years (2000-2007) in monitoring energy consumption and performance of 15 heat pumps installed in single family dwellings
- ELECTRABEL research program (2000-2003): two-year monitoring of 6 heat pumps for space heating of single-family dwellings
  - devoted to performance measurement only (COP-SPF)
- ELECTRABEL-Intermixt-ALE research program (2003-2006): two-year monitoring of 5 heat pumps, 3 for space heating and 2 for domestic hot water production in single-family dwellings
  - devoted to performance measurement (COP-SPF) and heat pump behavior analysis
Background (2/4)

- FPMs research program, funded by manufacturer (2005-): two-year monitoring of 2 prototype heat pumps for space heating of single-family dwellings
  - devoted to heat pump behavior analysis, performance measurement and improvement of heat pump operational parameters (SPF maximization)
- BEPAC (Minergibat research program) (2006-): two-year monitoring of 2 prototype heat pumps, 1 for space heating, 1 for domestic hot water production in single-family dwellings
  - devoted to heat pump behavior analysis, performance measurement and improvement of heat exchangers design (energy/economical performance maximization)
Background (3/4)

- Heat pumps for space heating monitored:
  - Dynamic air/air: 3
  - Dynamic air/water: 3 (1 with variable speed compressor)
  - Static air/water: 3 (2 with variable speed compressor)
  - Ground/floor (DX): 2
  - Ground/water: 1 with variable speed compressor

- Heat pumps for DHW production monitored:
  - Ground/water: 2
  - Static air/water: 1
Background (4/4)

- Evolution of fluids:
  - R22 (2000)
  - R410A (2007)
  - Propane (2007)

- Evolution of type of compressor:
  - reciprocating compressors (2000)
  - fixed speed scroll compressors (2003-2004)
  - variable speed scroll compressors (2004-)
Measurements (1/5)

- All heat pumps have been equipped to analyze instantaneous behavior
- Values to be monitored can be:
  - temperatures
  - pressures
  - mass/volumetric flow rates
  - electrical power
Measurements (2/5)

- From pressure and temperature measurements:
  - \( h = f(T,P) \)
  - \( \rho = f(T,P) \)
  - \( T_{EVAP}, T_{COND} \)
  - pressure drop

- From power measurements:
  - \( P_{O\,COMP} \)
  - \( P_{O\,FAN} \)
  - \( P_{O\,PUMP} \)
  - \( P_{O\,RES} \)
- From flow rate measurements:
  - $\Phi_H = q_{VF1} \rho_{F1} c_{PF1} (T_{OUT F1} - T_{IN F1}) = q_{VR} \rho_R (h_3 - h_2)$
  - $\Phi_C = q_{VF2} \rho_{F2} c_{PF2} (T_{OUT F2} - T_{IN F2}) = q_{VR} \rho_R (h_1 - h_4)$
  - $P_{MEC} = q_{VR} \rho_R (h_2 - h_1)$
Measurements (4/5)

- Other interesting quantities:
  - COP = $\Phi_H / (P_{O\text{ COMP}} + P_{O\ldots})$
  - $\eta_{\text{ELEC}} = P_{O\text{ MEC}} / P_{O\text{ COMP}}$
  - $\eta_{\text{ISOS}} = (h_{2\text{ ISOS}} - h_1) / (h_2 - h_1)$
  - $UA_{\text{COND}} = \Phi_H / LMTD_{\text{COND}}$
  - $UA_{\text{EVAP}} = \Phi_C / LMTD_{\text{EVAP}}$
Measurements (5/5)
Field experience - manufacturer data (1/16)

- Manufacturer data <= measurements:
Field experience - malfunctioning (2/16)

- Heat flow rate too low:

![Graph showing heat flow rate and temperature over time.](image)
Field experience - malfunctioning (3/16)

- Resistor heaters too often used:

![Puissance Graph]

- Puissance (kW)
- Puissances
- Po rés appoint
Field experience - heat pump behavior (4/16)

- Evaporator superheating:

![Graph showing temperature variations at the evaporator (R404A)]
Field experience - heat pump behavior (5/16)

- Condenser subcooling:

![Graph showing condenser subcooling temperatures](image)

- Condenser subcooling temperatures in °C.
Field experience - heat pump behavior (6/16)

- Compressor efficiencies:

![Graph showing compressor efficiencies over time]
Field experience - air source behavior (7/16)

- Bad defrosting:

![Temperature graph](image)

**Températures : 2/01/2002**

- $T_{sor\ cond}$
- $T_{amb\ int}$
- $T_{ent\ cond}$
- $T_{amb\ ext}$
- $T_{evap}$
- $T_{sor\ appt}$
Field experience - air source behavior (8/16)

- Good defrosting:

![Graph showing temperature changes](image-url)
Field experience - ground source behavior (9/16)

- Influence of heat pump on ground temperature:

**Ground temperature at 60 cm depth**

![Graph showing ground temperature variations with and without heat pump over time.](image-url)
Field experience - ground source behavior (10/16)

- **Ground behavior:**

![Diagram showing ground behavior with temperature values from September 2001 to June 2002.](chart)
Field experience - floor behavior (11/16)

- Condensation temperature:

Influence du type de plancher

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Field experience - optimization (12/16)

- Condenser pump running time:

![Diagram showing power consumption and temperature over time]
Field experience - optimization (13/16)

- Variable speed compressor:

![Graph showing temperature variations from January 2004 to November 2006 with temperature ranges from -15°C to 20°C. The graph compares evaporation temperature (Tevap) and soil temperature (Tsol) for different periods. The legend includes lines for Tevap, Tsol, and Série2.]
Field experience - optimization (14/16)

- Variable speed compressor:

![Graph showing temperature variations](image-url)

**Evaporateur**

**Novembre 2005 - Janvier 2008**

- Text
- T évap bulle
- T évap rosée
Field experience - optimization (15/16)

- Variable speed compressor:

COP
Novembre 2005 - Janvier 2008
Field experience - model development (16/16)
Conclusions

- Monitoring gives many interesting results about the real behavior of heat pumps:
  - comparison between real measurements and manufacturer data
  - misfunctioning of heat pump
  - source/sink behavior
- Measurements can be used:
  - to maximize the performance of the machine
  - to develop assessed theoretical models