Rapid Building Thermal Diagnosis: Presentation of the QUB Method

Guillaume Pandraud, Saint-Gobain ISOVER

February 6th, 2014

Didier Gossard (SGI) - Florent Alzetto (SGR)

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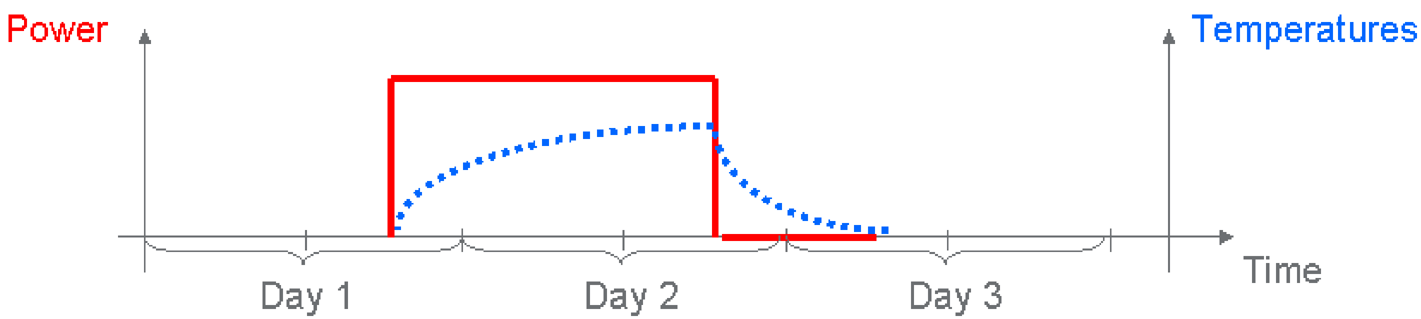
Summary

1. QUB methodology
2. Experimental setup
3. Validation procedure
4. Experimental results
5. Conclusion - Perspectives

1. Methodology

- Objectives
  - "Fast estimation" of the quality of the envelope
  - Fast = Less than 3 days of total experimental time
  - Estimation = Accepted uncertainty of ± 15 %
- Quantitative result: heat loss coefficient K (W/K) (same as in co-heating)

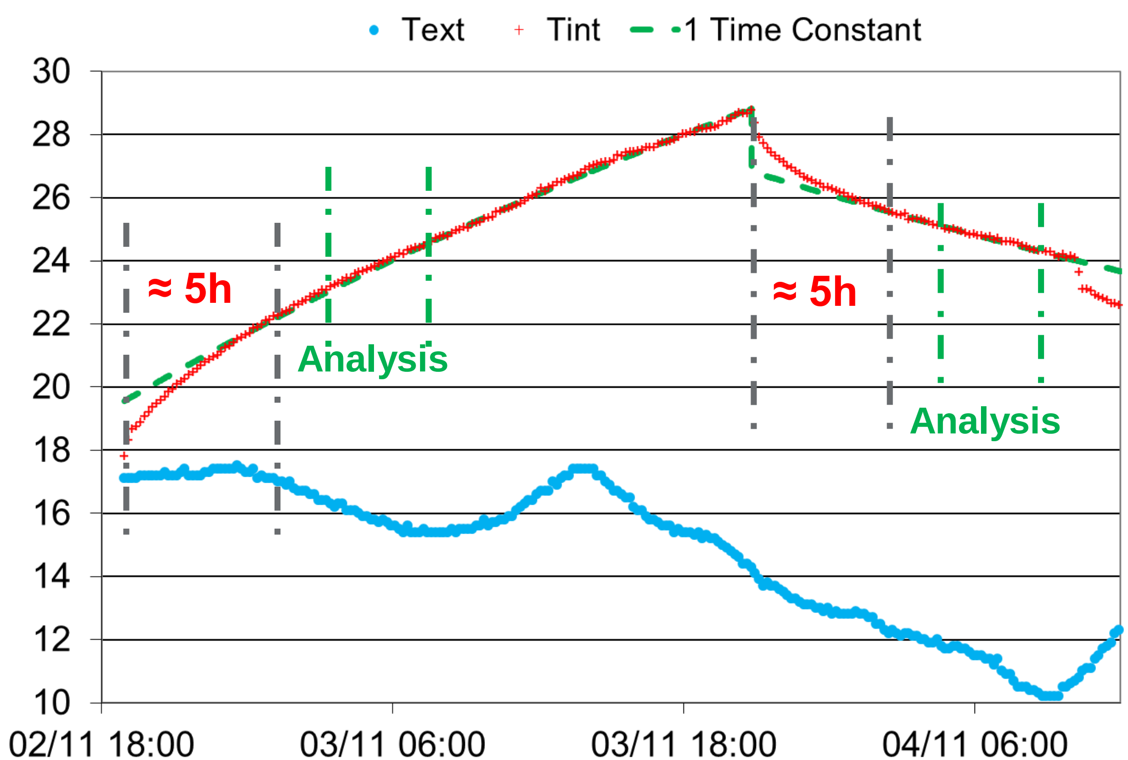
- QUB (Quick U-Value of Buildings): patented dynamic method
  - Building is heated for a few hours, then cooled for a few hours
  - K function of temperatures, temperature slopes and powers (1 equation)
  - Total time for real houses: about 48 hours, including setting up and cleaning



1. Methodology

➤ Main hypothesis

- **After a few hours, the temperatures vary as if the building only had 1 time constant**
- **If true, temperatures follow a single exponential function of t (variables: K and C)**
- **➔ CdT = (P – KΔT) can be applied for both heating and cooling periods**
- **Direct consequence: $K = (T'_1P_2 - T'_2P_1) / (T'_1\Delta T_2 - T'_2\,\Delta T_1)$**



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2. Experimental setup

➤ Knowledge of the inputs

- **Temperatures inside and outside the house: easy**
- **Power: more difficult**

➤ Measurement of electric heating

- **Possible with other source of power, but less accurate (conversion factors)**
- **Estimations with nominal consumption of sources can have a large uncertainty**
- **Network tension is ± 10% → Measurement of I and U is needed**

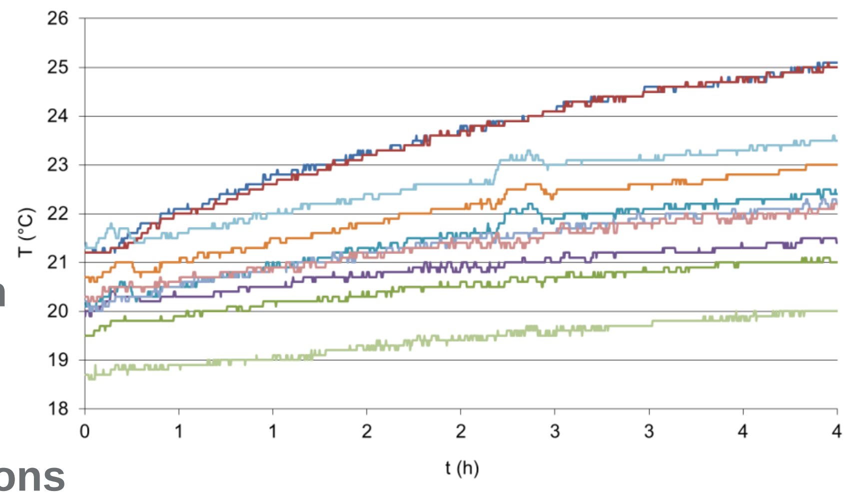
➤ Reduction of unknown power sources

- **Only the night periods are used for analysis**
- **Empty building**
- **Measurement of all electricity sources that cannot be stopped (e.g. fridge)**
- **Ventilation: air vents closed (as in an air pressurization test)**

2. Experimental setup

➤ Dynamic method

- Constant powers, no temperature regulation
- ➔ High temperature differences possible
- Temperatures have to be averaged
- Can lead to errors due to the sensors positions



➤ Solution: homogeneous heating

- Sometimes possible: homogeneous volume (HVAC) or surface (underfloor) heating
- Easier: high number of low power sources
  - Low radiation to heat the air rather than the walls
  - Conductive heating to keep internal convection low

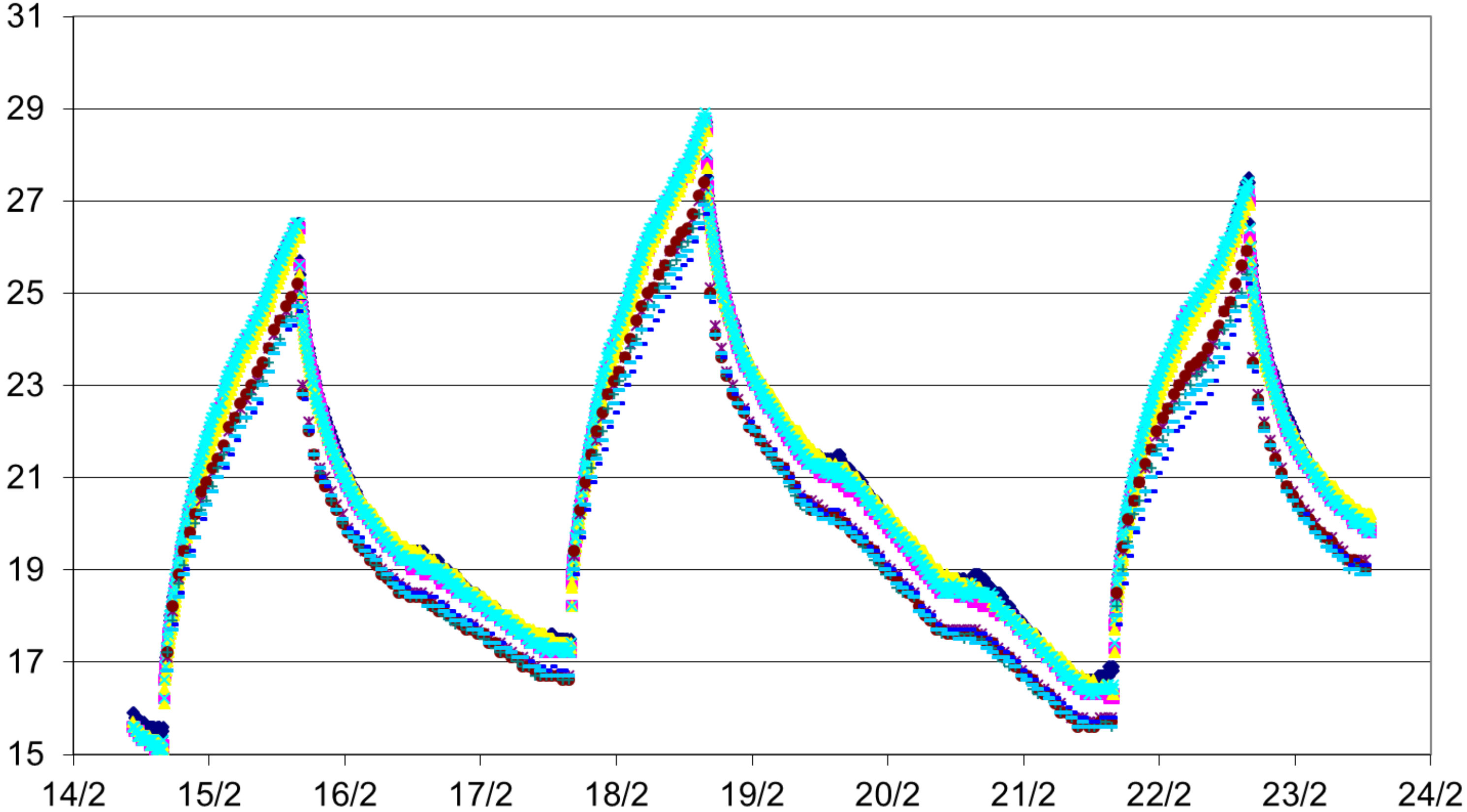
➤ SG solution: heating mats, placed vertically

- Led to significant improvement of method reliability and reproducibility

2. Experimental setup

➤ Example of homogeneity with vertical mats

- **3 tests over 10 days**
- **9 temperatures over 2 floors**



3. Validation procedure

Principle

- **Comparison of result with a reference value**
  - Must be based on actual in situ performance
  - Not estimated or calculated
  - Not occupant-dependent
- **Difficulties to get reference value in a standard building: requires specific measurements and no occupation**

2 validation methods used

- **“Standard” buildings: co-heating tests**
  - Saint-Gobain bungalows
- **“Specific” buildings: steady-state conditions (all variables are stabilized)**
  - Numerical validation with TRNSYS: all QUB results have an error < 15%
  - Energy House, University of Salford

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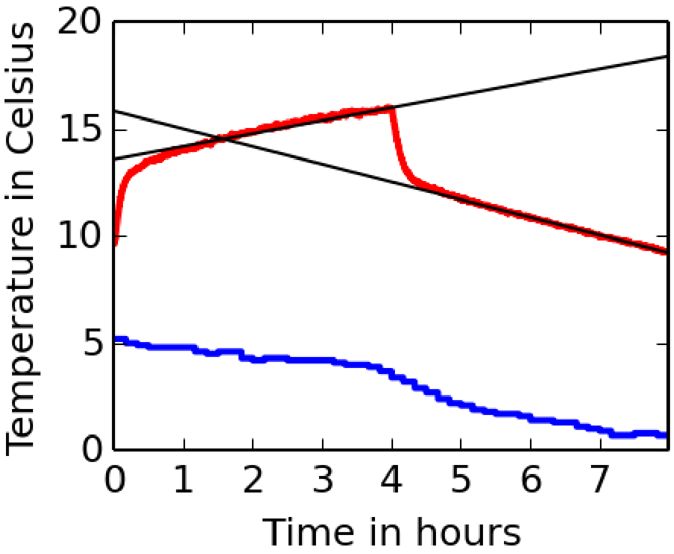
4. Experimental results

- Saint-Gobain bungalows
  - **Situated near Paris, FR**
  - **Reference: 2 x 2 weeks co-heating at 2 T_{int}**
    - $K_{25\,°C}$ = (34.6 ± 6.6) W/K
    - $K_{35\,°C}$ = (29.3 ± 5.2) W/K
    - Difference can be explained by very variable wind speed
    - Average (at 4 m/s): K_{ref} = 32.7 ± 0.9 W/K



- QUB tests
  - **Very light building → tests in one night**
    - 4 h heating – 4 h cooling
  - **25 tests done**
  - **Reproducibility: K_{QUB} = (32.7 ± 2.6) W/K**
  - **Extremes: 28.5 W/K < K_{QUB} < 38.5 W/K**

- Comparison shows very close results and no real outliers

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4. Experimental results

- The Energy House, University of Salford
  - **Typical 1910 terraced property from the UK**
    - But which has been through reasonable modifications
  - **In a well insulated concrete chamber**
  - **Built on a solid concrete base**

- Chamber cooled by condenser units
  - **Heating provided by a heat pump**
  - **Controlled with a 0.5 °C accuracy**
  - **Temperature ranges from -14 °C to 30 °C**

- Possibility to reach steady-state
  - **Stable temperatures and fluxes**
  - **Perfect reference**
  - **Only such place in the world we are aware of**

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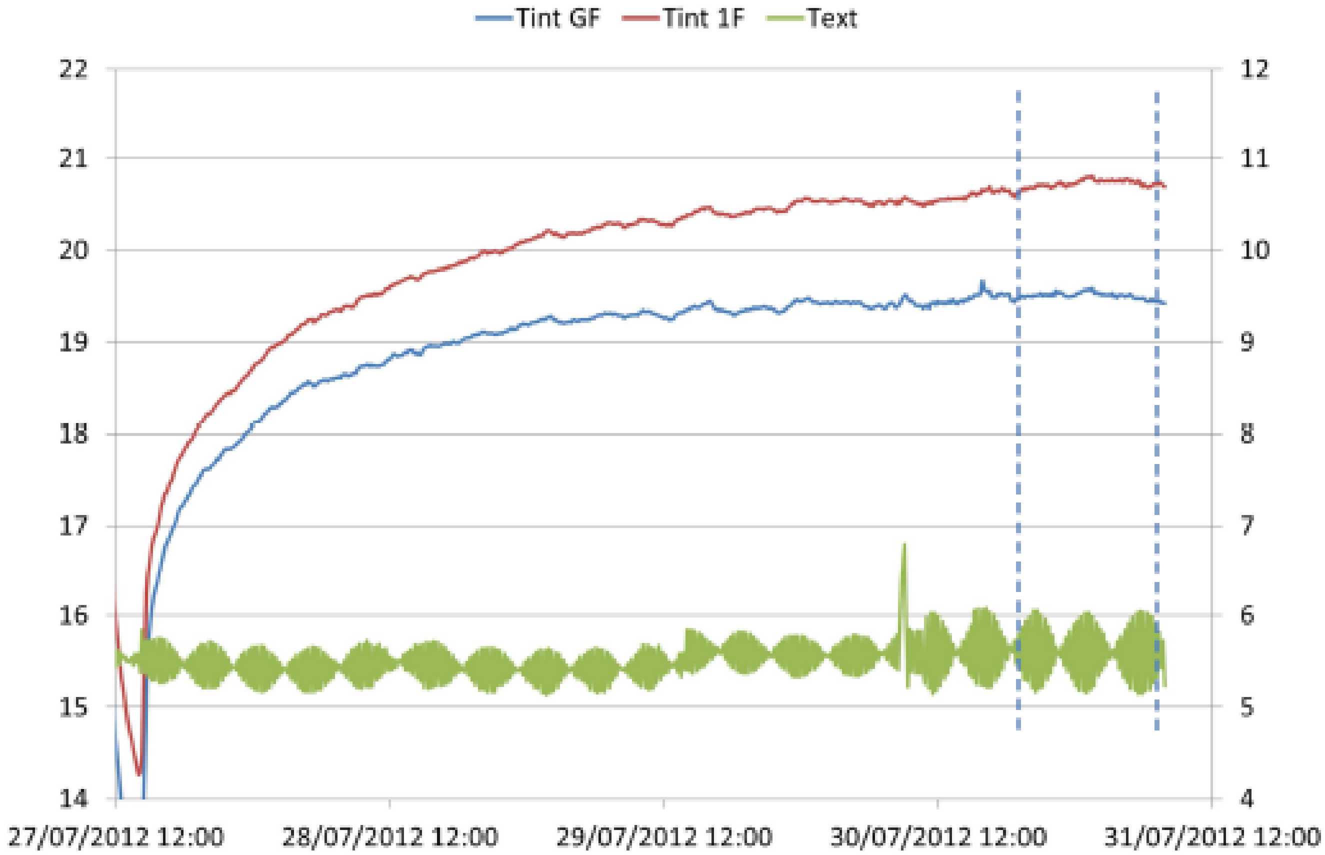
4. Experimental results

➤ Example of a steady-state test



4. Experimental results

- Comparison of QUB tests with reference
  - **2 cases: with and without insulation in the attic, over the ceiling**

Case	No roof insulation		Insulated roof
Test Number	1	2	3
Steady-state (W/K)	262.7		215.4
QUB (W/K)	274.5	263.8	229.8

Maximum difference between QUB and steady-state values: 7%

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4. Experimental results

- Influence of other parameters checked experimentally and numerically
  - **Insulation level**
    - Results OK in non-insulated to quasi passive houses
  - **Climatic conditions**
    - Linked to reproducibility: usually about ± 10%
    - Houses with lower insulation / higher infiltrations are more sensitive to climatic conditions
  - **Seasonal influence**
    - Low difference between summer and winter results
  - **Type of wall structure**
    - QUB can be applied on external and internal insulations, although more easily with internal
  - **Infiltration / ventilation rate**
    - QUB measurement is an accurate estimation of TOTAL losses (infiltration + transmission)
    - By itself, it cannot differentiate these two types of losses
    - If only transmission losses are wanted, separate estimation of infiltration losses are necessary

5. Conclusion - Perspectives

- QUB method: fast and reliable building energy diagnosis method
  - **Experimental setup and data processing are very easy**
  - **Requires specific material to be done in an optimal way**
  - **Gives the value of the total heat losses (infiltration + transmission)**
  - **Patented by Saint-Gobain Isover**

- Method validated in very different conditions

- Next steps
  - **Method acceleration**
    - Tests in one night only are possible
    - Results as good as two night results, but with more experimental constraints
    - Validation process is almost finished
  - **Use on collective housing**
    - Adaptation should be possible, best experimental method not determined yet
    - Lack of experimental reference cases

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