



Part-load performance behavior of On-Off and variable capacity heat pumps

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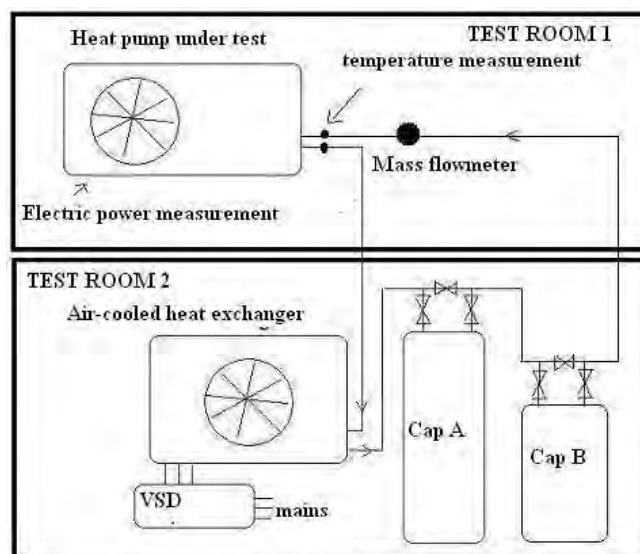
Presentation

- *Testing method for heat pumps (HP)*
- *Data analysis*
- *Inverter HP*
- *Digital scroll HP*
- *Conclusions*

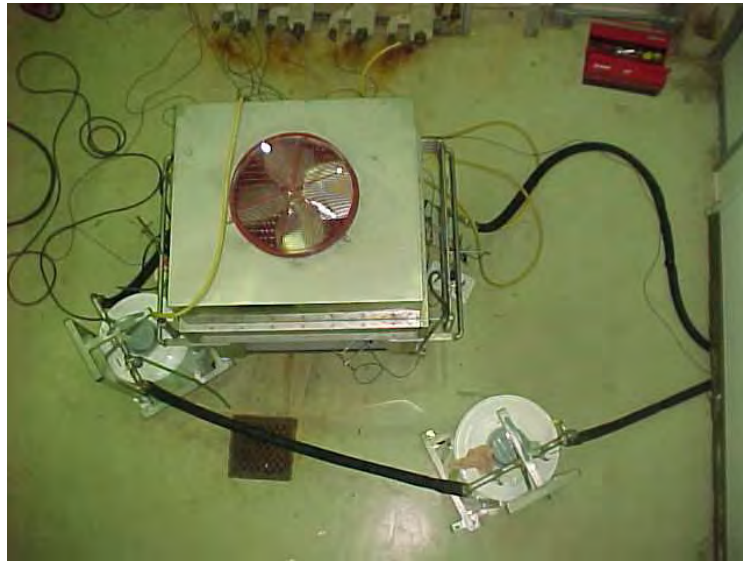
Testing method

- *Same testing facility installation for all types*
- *Steady-state, full load testing*
 - *air 7°C & water 30/35°C => nominal water flow rate*
 - *tests @ at other air temp. with same water flow rate*
- *Part-load testing*
 - *HP connected to water circuit : variable water capacity (2 tanks) and air cooler controlling heating duty - several levers (fan speed, air temperature, louvers, etc)*

Testing Installation



Testing installation



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Testing installation



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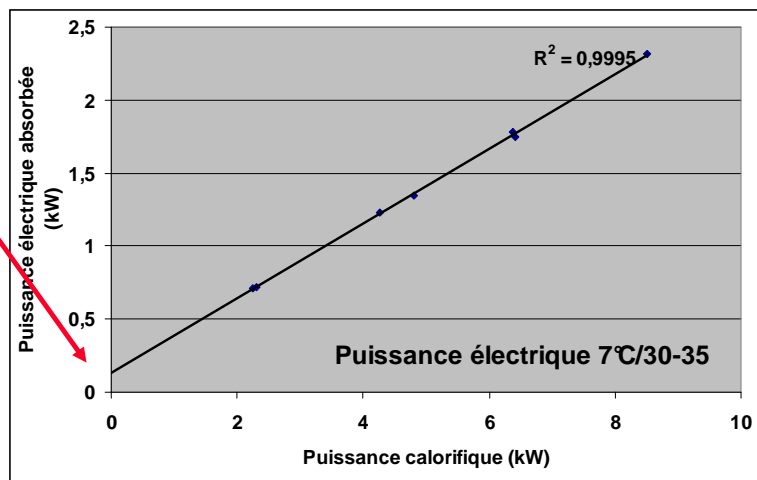
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Test matrix

Tsa(Tr) / Tee - Tes	-7(-8) / * - 35 °C	2(1) / * - 35 °C	7(6) / 30 - 35 °C	12(8) / * - 35 °C
100	X	X	X	X
75	X	X – capacité 1	X – capacité 1	
75	X	X – capacité 2	X – capacité 2	
50	X	X	X	
25	X	X	X	X

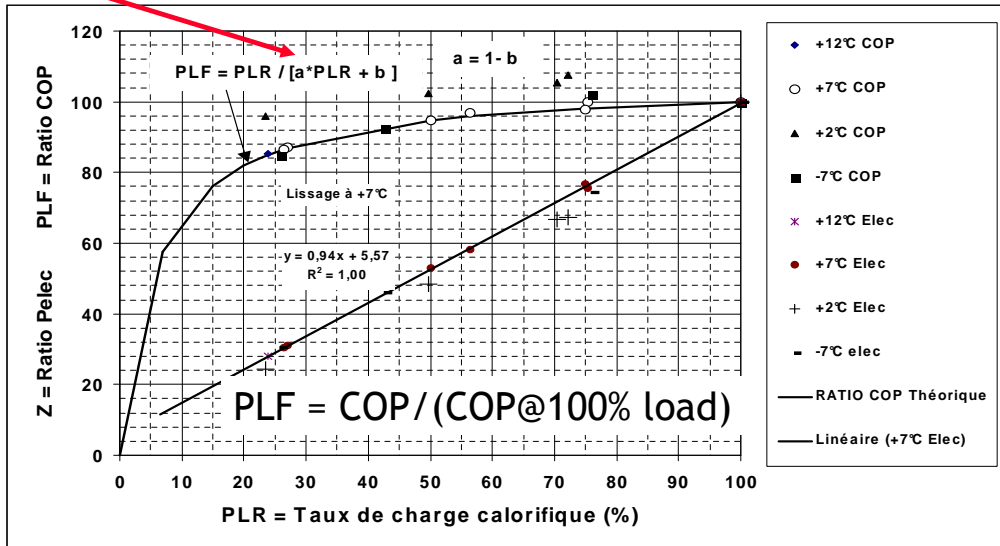
Data analysis

- Observations on On-Off HPs : Pelec vs. Duty is linear
- Important parameter : parasitic electrical consumption



On-Off HP

$b =$ parasitic electrical consumption



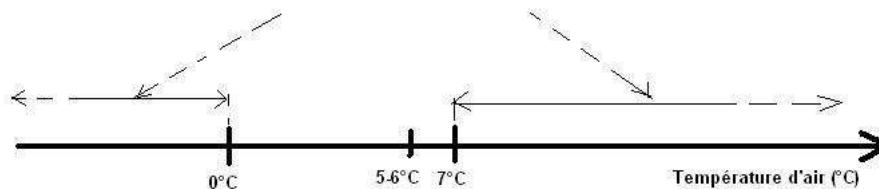
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On-Off Heat Pumps : 3 air temp. zones

Dans ces deux zones, le ratio COP/COP100 peut être calculé à partir du taux de charge. Le COP à taux de charge partielle est toujours inférieur au COP à pleine charge



Dans cette zone, le COP à charge partielle peut être supérieur au COP à pleine charge (taux de charge supérieur à 50%) ou inférieur (taux de charge environ 50%). Plus la température de l'air est élevée, et plus le COP à charge partielle peut augmenter.

Dans cette zone, en charge partielle, la PAC se comporte comme si elle ne givrait pas à pleine charge. Le COP en charge partielle peut être corrélé à un COP hypothétique calculé pour une PAC qui ne givrait pas à pleine charge.

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Inverter HP testing

- *Duty : 10 kW nominal*



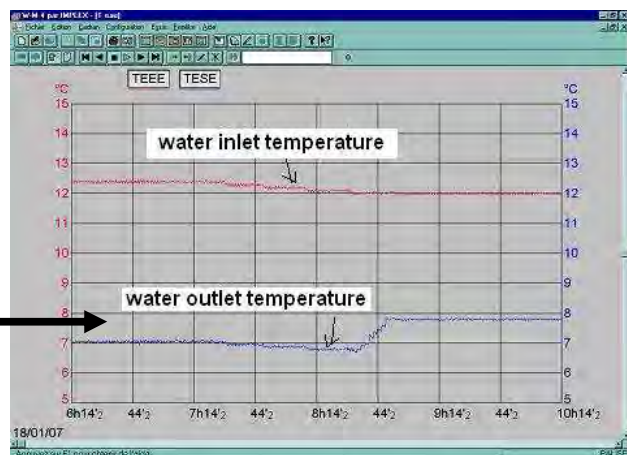
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Inverter HP testing

- *Capacity control by frequency change*
- *Testing problem : several nominal « steady state » points*
- *See exemple in cooling* →
- *Control differential and resolution do not enable fine tuning of water temperature*



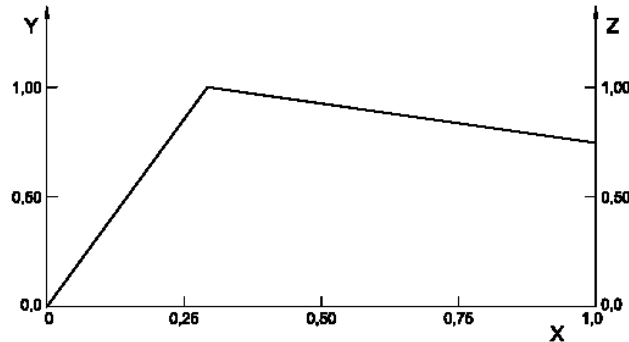
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Inverter HP testing

- *Italian Standard UNI 10963 : recommends a test at full load and a test at maximum COP (...?? Does not say how to find it ?)*

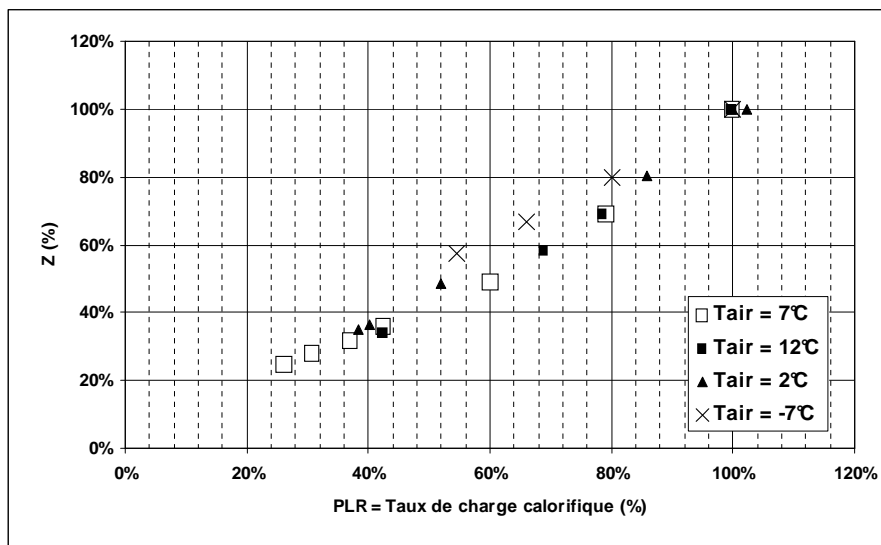


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Electric consumption vs. duty : quadratic profile

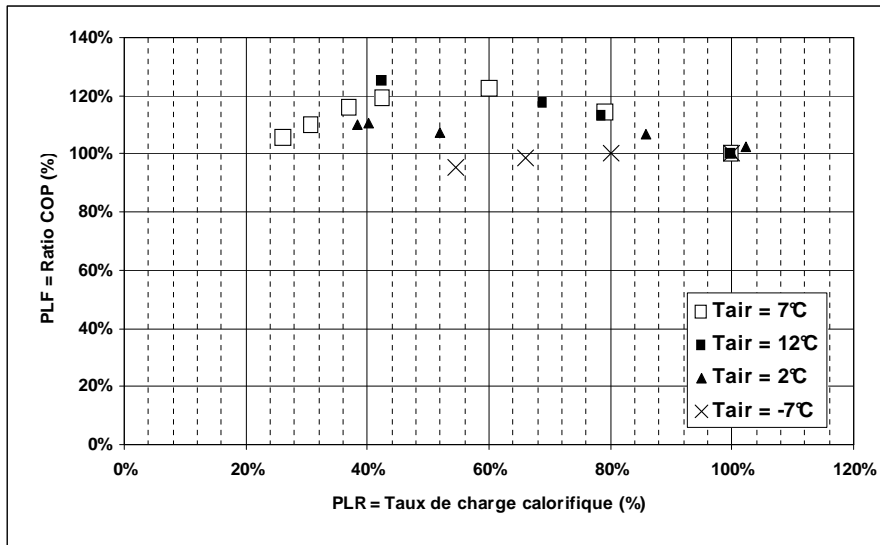


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Part-load COP : increases with decreasing load



Inverter HP : learnings

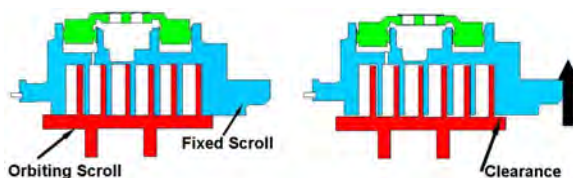
- *The testing laboratory must be provided with the means to control the frequency in order to fix the load.*
- *In addition to the heating nominal test points, either :*
 - ◆ *carry out two runs at partial load @ each air temperature*
 - ◆ *or assimilate all part-load results to the same curve hence carry out two part-load tests at any air temperature and find the quadratic eqn. Parameters. Then determine $PLF = f(PLR)$ relationship*

Digital Scroll HP

WARNING : the tested HP is a prototype , especially built for the PERSAPAC project. The conclusions listed herein need further testing to be fully confirmed.

- HP under testing : Nominal duty circa 14 kW @ (71(6)°C - 30/35°C
- digital scroll compressor, control scheme designed and built by the OEM partner.

Digital Scroll HP

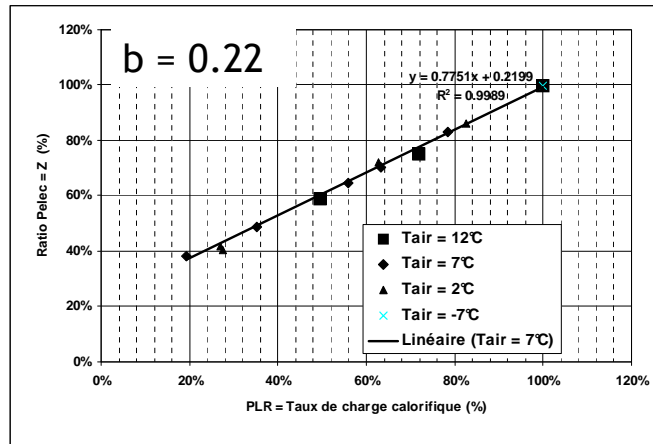


Note : very fine water temperature tuning



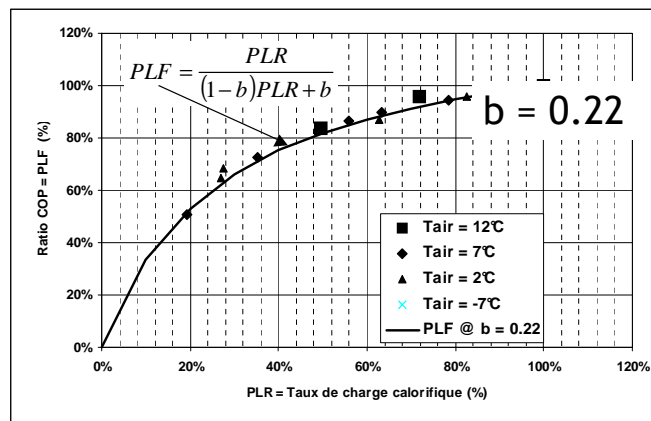
Digital Scroll HP testing

- *Electrical consumption vs Duty : linear relationship*



Digital Scroll HP testing : COP under part-load

- *Evolution similar to that of an On-Off HP*
- *Tested down to 20% part-load with no problem*



Digital Scroll HP

- *Part load performance requires :*
 - *full load tests @ all the recommended air temp.*
 - *One part-load test (e.g. 30%) and find parameter « b » as the intercept*

TAKE HOME MESSAGE

- *When designing the system, pay careful attention to the parasitic electrical consumption :*
 - *Pumps*
 - *Fans*
 - *Controls etc.*
- *If possible, modulate electrical consumption with required duty*
- *Careful design of capacity control scheme (e.g. variable speed pumps)*

Conclusions : same installation for all HP types

■ Inverter HP :

- *As PLR decreases, COP shows a max value, then decreases*
- *Cycling occurs under threshold PLR*
- *Elec. Power = $f(PLR)$: Quadratic equation*
- *requires HP control scheme bypass to fix the frequency : Testing Lab must be provided with means and information/data to perform it.*
- *needs at least 2 tests in addition to full load test, for each air temperature, unless approximation is made*

Conclusions

■ Digital scroll

- *showed fine tuning of water temperature*
- *COP decreases with decreasing PLR*
- *tested down to 20% without cycling*
- *Elec. Power vs Duty : linear relationship*
- *measured b factor = 0.22*
- *ESCOP determination requires full load testing at recommended temperatures and only one part-load.*

« The little I know, I owe to my ignorance »

Sacha Guitry