PERFORMANCE INSPECTIONS WITH INNOVATIVE ANALYSING EQUIPMENT RESULTS IN SIGNIFICANT ENERGY SAVINGS IN AIR-CONDITIONING AND REFRIGERATION SYSTEMS

Klas Berglöf
ClimaCheck Sweden AB, Sickla Industriväg 6, 131 54 Nacka, Sweden
klas@climacheck.com

ABSTRACT

EU has implemented requirement on "Performance Inspections" on Air-Conditioning system above 12 kW. As 15-20% of the electrical energy in EU is used by refrigeration, air-conditioning and heat pumps units the saving potential is significant.
The paper presents an innovative method for Performance Inspections and practical experiences of optimisation through documentation of performance. The method is used at commissioning, trouble shooting, service and energy optimisation. The "Internal method" for Performance Inspections has proven to be very useful to give detailed documentation of performance which is essential to optimise systems. Experiences from different sectors are presented. The method is cost effective to document COP/ capacity as no costly installations of flow meters or preinstalled sensors are required. The method require 20-30 minutes set up and give capacity with an accuracy of +-7% and COP with +-5% for virtually any compressor driven refrigeration/air-conditioning system.

1. INTRODUCTION

Today's air-conditioning and refrigeration systems are often not operating with the expected efficiency and lifetime that should be expected. To establish the status of refrigeration or air-conditioning systems is a prerequisite for optimisation and to minimize risk of failures as well as to take proper decisions for investments to improve or replace existing equipment. Energy efficiency is on the agenda today but focus is often on rating conditions on new equipment whereas it is often forgotten that optimisation of existing equipment often offers more cost effective saving potential. It is also often that new potentially highly efficient systems are not properly commissioned. Cat effective analysing methods are important as few decision makers will decide on investment in energy optimisations or replacements if no base-line can be established for economical calculations such as pay-off time or Life cycle cost. The problem in relation to the RAC industry is that for two hundred years – since the invention of mechanical cooling in fact – it has not been considered possible to accurately measure the performance of working cooling systems in the field. It has only been possibly in fully equipped climate laboratories, with highly qualified engineers supported by data loggers and computers.

In the low carbon age, it is now critical to deliver high performance, high efficiency cooling. But without being able to cost effectively measure the performance of a plant in operation, engineers and end users are left in the dark.
Now it is possible to cost effectively establish performance of the complete system as well as all its main components. The industry must introduce the new technology and end-user must realise that they can request documentation of performance. Today field equipment allowing cost-effective performance analysing is available see Figure 1.

Figure 1, Field kit for Performance Inspection technology that does not require installation of flow meters to establish the performance and capacity.

2. THE INTERNAL METHOD FOR PERFORMANCE ANALYSIS, FIELD MEASUREMENT METHOD FOR REFRIGERATION AND AIR-CONDITIONING SYSTEMS.

The new performance analyser based on the "Internal Method" is a new technology that has the potential to revolutionise the industry's approach to commissioning, trouble-shooting, service and energy optimisation.

It enables engineers in the field to determine how well operating plant is performing, its actual COP, capacity, and other vital performance parameters without hours of tedious calculations of a highly skilled engineer. The performance can be documented in a un-biased way without inputs of manufacturers of system or components. The method is based purely on fundamental thermodynamic properties and the laws of energy.

It accurately determines a working system's:

- Coefficient of Performance (± 5%)
- Cooling and heating capacity (± 7%)
- Power input (± 2 %)
- Compressor isentropic efficiency

This vital data can be presented dynamically in charts and tables, enabling the engineer and/or end user to gain an immediate picture of the actual performance of the system.

2.1. Innovative approach – how it works

The system uses ten easy to apply sensors that are attached at strategic points around the system. This is 7 temperatures, 2 pressures and active power as shown in Figure 2.

An engineer can hook up the equipment in 20 minutes. From the information gathered the key operating parameters that pinpoint the system's actual performance can be determined independent of any supplier data.

Required measuring points for a standard systems as shown in Figure 2 is:

- Temperature and pressure at entrance of compressor.
- Temperature and pressure at compressor exit.
- Liquid refrigerant before expansion device.
- Active electrical power.

For reference of operating condition and heat exchanger evaluation the temperature of air/liquid entering and exiting condenser and heat exchanger are measured. IN total 10 measurements that are easy to apply to almost all systems in the field.

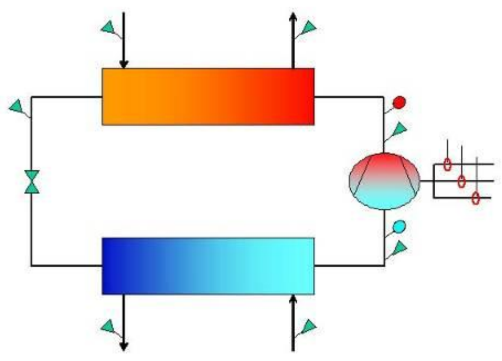
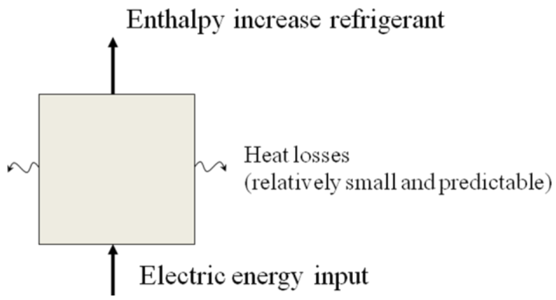


Figure 2, Sensors required and their location to establish performance of a standard refrigeration system.

At the heart of the performance analyser is the energy balance over the compressor and a series of algorithms, based on the thermodynamic properties and operating characteristics of the refrigerant in use.

The heat losses are low relative the total input power limiting the impact of variation as documented by (Asercom, 2003) and (Naumburg, 1987). So equation (1) will give a good accuracy of mass flow of refrigerant.

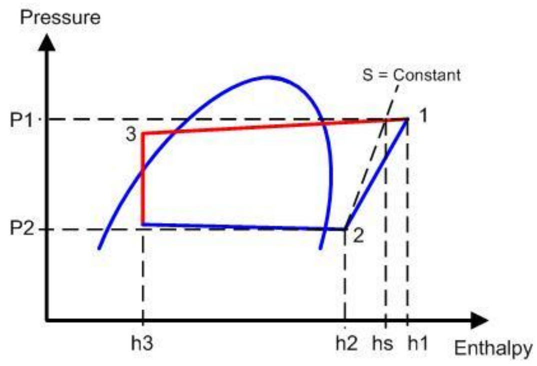
The losses varied in documentation and tests between three and ten percent in hermetic and semi-hermetic compressors without external cooling representing the vast majority of compressors on the market. For open drive and compressors with cooling the same methodology can be used by adding a model of the amount of energy not introduced in the refrigerant flow. When the net energy to the refrigerant flow calculated as the measured electrical power – heat losses are known the massflow is also known through equation (1).



Mass flow = $\frac{\text{(electrical input-heat losses)}}{\text{Enthalpy difference}}$ (1)

From the above described energy balance and these enthalpies all data required can be derived including COP, Capacities, and the compressors total isentropic efficiency. Method described in more detail by i.e. (Berglof, 2004), (Berglof, 2005), and (Fahlén, 2004).

Figure 3, *The energy balance with consideration of heat losses over the compressor allows calculation of mass flow.*



Cooling Capacity = Mass flow * (h2 – h3) (2)

Heating Capacity = Mass flow * (h1 – h3) (3)

Isentropic Effic = $\frac{(hs - h2) * (1 - \text{rel. heat loss})}{(h1 - h2)}$ (4)

Figure 4, Pressure – enthalpy graph of "standard" refrigeration process.

2.2. Well proven method

The method and technology was first developed in Sweden 1986 and validated by SP the national Swedish testing institute (Fahlén, 1989). More than 40 manufacturers and 300 contractors in 20 countries have introduced the "Internal Method" as a tool to improve their development, production and aftermarket activities. Examples of world leading companies in the industry that has validated and use the Internal Method to document the performance of their products and optimise the systems are Carrier, Trane, Johnson Control, Copeland, Bitzer, Gea, Danfoss Heat pumps and DuPont.

2.3. Practical benefits

All data required for a full evaluation of the system are available as soon as sensors are connected - most of the time without requirement to stop the system. With the information provided, engineers can identify plant performance problems, including among many others:

- refrigerant shortage or over-charge
- incorrect superheat setting
- compressor damage or wear
- fouling of heat exchangers
- oil logging in the condenser/evaporator
- fan/pumps underperformance, Flow problems on secondary medias (air/water/brine)
- control problems

The system identifies irregularities in compressor, component performance that could result in future impairment of performance – or even plant breakdown, enabling pre-emptive maintenance and energy optimisation.

Armed with this vital information, engineers can address the issues identified, optimising system performance. The result is huge potential savings in power consumption and carbon emissions over a plant's lifetime.

Without an effective method and an efficient tool, these problems normally go unrealised, with the plant continuing to perform inefficiently – or eventually breaking down with potentially catastrophic consequences for refrigerant loss and stock damage.

Whenever required a modem can be connected to the data collection unit and information in real time transferred to an Internet server where calculations are done and made available to any expert in the world who is given access through user name and password for validation and advice on best actions to take.

2.4. Significant energy savings achieved in large survey

Refrigeration and air conditioning plant was already in 2002 estimated to use between 15 to 20 per cent of the electrical energy in Europe according to (IIR, 2002). The use in in this sector is increasing as the requirement for comfort increases as well as the use of heat pumps to decrease energy consumption. EU legislation such as the Directive 2002/91 on Energy Performance in Building require "Performance analysing" of all air-conditioning systems above 12 kW and standards (CEN, 2007) for these are being implemented.

There is enormous potential to save energy by optimising existing refrigeration and air conditioning systems and the pressure on the industry to take action is increasing.

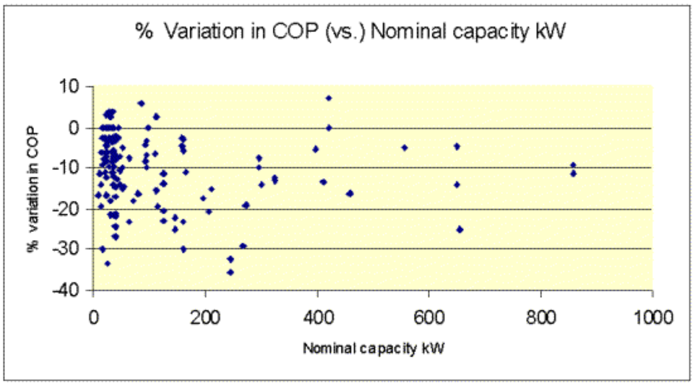


Figure 5, Variation of COP in 164 analysed systems (Prakash, 2006)

In a master thesis at the Royal Institute of Technology in Stockholm, (Prakash, 2006) did a survey on 164 performance inspections on air conditioning, refrigeration and heat-pump systems showed that only 13 per cent of the systems operated within the specified performance criteria. That means that some 87 per cent did not perform to specification. The graph in Figure 5 show the deviation of the performance in the 164 plants. The average "over-consumption" of electrical energy was approximately 10% in some cases over 30%.

The most common problems identified, with examples of possible causes, were:

- **Incorrect sub-cool - refrigerant charge** caused by leaks or over-/ undercharging.
- **Incorrect superheat - operation of expansion device**. This can be caused by improper adjustment, malfunction or an incorrectly selected device.
- **Incorrect air or liquid flow over condenser / evaporator** due to incorrect design, wrong selection of fans / pumps and/or blocked filters resulting in higher system energy consumption.
- **Poorly adjusted controls.** For example, low pressure cut-out or condenser pressure controls causing significant waste of energy.
- **Poor efficiency of compressor** due to wear or damage to compressor**.**

If the identified savings was extrapolated to the total European market, the potential savings would be dramatic. The power saved would correspond to the equivalent of all the electricity produced by wind power in Europe or the total electrical consumption of Denmark or Portugal.

2.5. Experience from supermarket, hotel and industrial applications show that "Performance Analysing" improves performance and reduce failures.

The method is used to validate performance of all types of systems in connection with commissioning as well as in energy optimisation projects i.e. to define the cost effectiveness of retrofit/upgrade or replacement. Without a baseline of the performance of the plant it is almost impossible to do give the equipment owner a calculation on saving and cost-effectiveness of measures.

Supermarket operators such as Tesco, Carrefour, Sainsbury, Metro use the technology to check the performance and efficiency of conventional as well as developmental CO2 systems. Access to detailed information is essential to evaluate and optimise the efficiency of dynamic systems under real life application before adopting new systems.
The method is suitable to document performance of any compressor driven refrigeration system and is used besides supermarket and industrial plants in for example air-conditioning of hotels and offices as well as heat pump applications from 5 kW to 25 MW. By documenting the process in detail the actual behaviour over varying loads can be defined and potential savings by optimisation efforts can be calculated and after measures are implemented the result can be validated.

2.6. Global access to on-line expertise through Internet open new ways to ensure best performance.

As all relevant parameters are logged and analysed and available on the Internet in-house support staff, manufacturers and suppliers as well as independent experts can be consulted and see reel life operation of the system including performance of all components in the system to give on site personal guidance on what can be done to trouble shoot and optimise systems. This makes it possible to in an extremely cost effective way access the best experts in the world.

2.7. Energy optimisation in Italian supermarkets save 15 to 30% and early detection of problems reduce maintenance cost.

A leading refrigeration contractor in Italy initiated a test with on-line monitoring with the described method on two Metro and six Carrefour Hypermarkets in Italy. Logging equipment was installed and connected to a web based service presenting detailed analyses of the refrigeration systems in real time. Based on the information the systems where optimised to minimise energy consumption. In Figure 6 it is shown how after one day of logging the system controls where reset with a drastic improvement of COP with 27%. The total electrical consumption of the stores under the test period was reported to have been reduced with 7 to 13% as the refrigeration system use approximately 50% of the total electricity the saving from optimisation and correction of problems resulted in energy savings of 15 -30% on the refrigeration system. The investment was more than compensated by early detection of compressor problems which resulted in that repair at limited cost could be performed instead of costly failures.

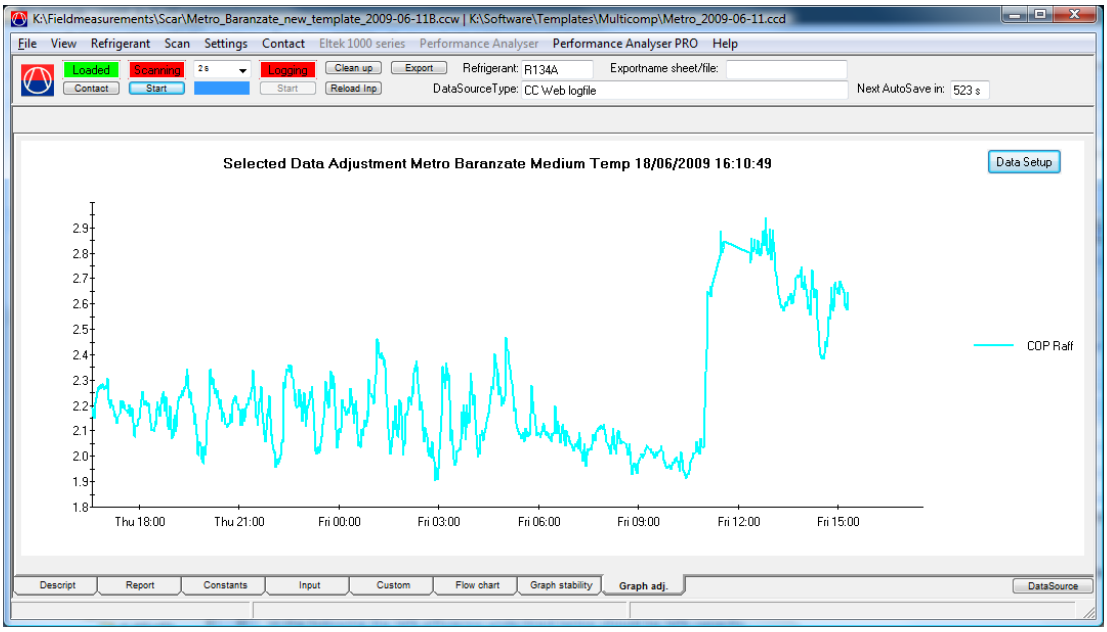


Figure 6, Change in COP when controls where adjusted in Italian hyper market.

Maintenance costs can also be reduced through early detection of problems and the possibility to define what action that need to be taken before the technician is sent to the site.

In an evaluation of the six Carrefour hypermarkets the savings of the total electrical consumption in the stores showed a saving of between 7 and 13 % which correspond to between 7% and 13% of the total consumption of the store which corresponds to a energy savings of the refrigeration process of 15% to almost 30%.

2.8. Energy profiles and bench marking

With the technical data on the process the technicians and engineers can optimise the system and locate problems before they affect the reliability of the plant. For the equipment owner the documentation of the energy consumption and operating cost are relevant information. By using fixed installed monitoring equipment the technicians as well as equipment owners can get the information they require. Energy statistics and Energy profiles are important to visualise the performance and cost as well as a tool to get the bases for decisions on optimisation and their saving potential. With access to both detailed technical data and the economic information the proper decisions can be taken.

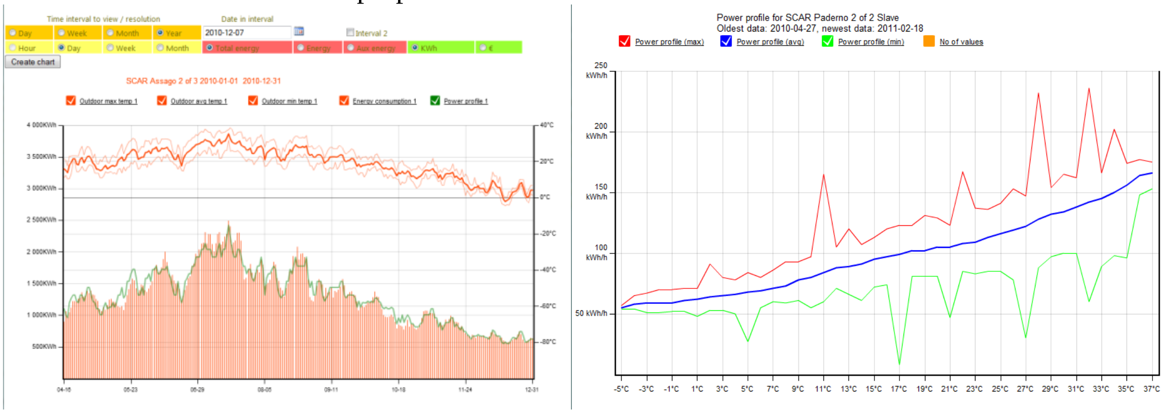


Figure 7, Energy statistics and Energy profiles versus ambient temperatures are important in optimisation work.

3. CONCLUSIONS

The air-conditioning and refrigeration industry is phasing a new surrounding when suddenly energy efficiency becomes an important parameter and just keeping temperature is not the only challenge. Experience show that in many plants savings of 20-40% that can be realised at low investments just by ensuring that the plant is operating as intended. Work on supermarkets in Italy showed savings in the refrigeration process between 15 and 30% and many surveys from different markets show that savings of 10-40% are possible low investment. Significant decrease in energy cost and carbon footprint can be achieved by increased quality of commissioning and service. Benefits such as decreased repair cost and minimized bad-will from failures are also key driving forces to implement improved methods to document performance and functionality.

4. REFERENCES

Asercom. 2003. Definition of Total Heat Rejection Rate for Compressors. *www.Asercom.org.* [Online] 2003. http://www.asercom.org/files/Heat_Reject_270503.pdf .

Berglof. 2005. *Methods and Potential for on-site Performance Validation of Air Conditioning.* Las Vegas : IEA, 2005.

—. 2004. *Methods and Potential for Performance Validation of Air Conditioning, Refrigeration and Heat Pump Systems.* London : IOR, 2004.

CEN. 2007. *Ventilation for Building - Energy Perfromance of Buildings - Guidelines for Inspections of air-conditioning systems.* s.l. : CEN, 2007. EN 15240.

Directive 2002/91 on Energy Performance in Building. **EU. 2002.** s.l. : EU, 2002.

Fahlén, P. 1989. *Capacity measurements on heat pumps - A simplified measuring method.* s.l. : Swedish Counsil for Building Research, 1989. R4:1989.

—. 2004. *Methods for commisioning and performance checking heat pumps and refrigeration equipment.* Papiernicka : IIR, 2004.

IIR. 2002. *Refrigeration Report 2002.* Paris : IIR, 2002.

Naumburg, P-H. 1987. *Experience of Performance tests on medium size hermetic compressors,.* s.l. : Scan Ref, 1987.

Nordtest. 1997. *Refrigerant and Heat pump equipment: General conditions of filed testing and presentation of performance.* Esbo : Nordtest, 1997. VVS115.

—. 1997. *Refrigeration and Heat pump equipment: Check-ups and performance data inferred from measurements under field conitions in the refrigerant system.* Esbo : Nordtest, 1997. VVS116.

Prakash, John Arul Mike. 2006. *Energy Optimisation Potential through IMproved Onsite Analysing Methods in Refrigeration.* Stockholm : KTH , 2006.