Performance inspections to pick the low-hanging fruits in existing and new plants

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"To measure is to know" is very true when it comes to energy efficiency in air conditioning and heat pump systems. Optimisation of existing systems is the 'low-hanging fruit' to reduce energy consumption in commercial and industrial buildings. Two-thirds of today existing buildings will still be in use in 2050, and the potential energy savings are enormous. It has been found that few systems operate at an optimal level, or within their original design specifications. The real challenge is to change the 'Don't wake the sleeping dog' attitude; equipment owners need to become aware of their equipment's actual performance through cost-effective performance inspections that are non-invasive, unbiased, and do not require inputs from unit or component manufacturers. When owners request consultants, commissioning agents, or contractors to measure, analyse and optimise their systems, there will be justification to invest in tools and training to service the demand.

Introduction

To measure is to know is a valid statement for air-conditioning and heat pump systems. The savings potential from optimising existing systems is the 'low hanging fruit' to reduce energy consumption in existing buildings. It is estimated that 15-20 % of global electricity is used by vapour compression systems (IIR, 2002). According to the International Energy Agency (IEA, 2012), two-thirds of existing buildings will still be in use in 2050, indicating the importance of optimising energy use in existing buildings and systems. This is resulting in requirements such as those in the EU Energy Performance of Buildings Directive (EPBD, 2010) for performance inspections of air conditioning systems above 12 kW, and incentive programs to re-commission plants in North America. When measured in the field, few systems show the performance that they are designed for. Savings of 10-40 % are often possible at minimal cost (Prakash, 2006). In most cases, the cost of the inspection and optimisation is repaid in a few months. The challenge is to change the 'Don't wake the sleeping dog' attitude when return of investment in measurements cannot be presented in advance. Air conditioning and heat pump systems are looked on as a 'black box' in a ventilation or plumbing system, assuming good performance if the temperature is correct. The Internal Method, based on a thermodynamic analysis of the refrigeration system opens the black box. Performance and all parameters to evaluate the process are measured in 20-40 minutes. There is no requirement for pre-installed meters or inputs from unit or component manufacturers. Capacity can be established with an accuracy of ±7 %, and COP with an accuracy of ±5 %, (Fahlén, 1989) for most compressor-driven heat pump, air-conditioning and refrigeration systems.

Measurement, analysis and optimisation of performance is cost-effective

"If you can't measure it, you can't control it" is another valid statement when it comes to air conditioning, heat pump and refrigeration plants. These systems are often operating with efficiency and lifetime far from their design specifications. A major reason is a lack of established cost-effective methods for measuring performance. As the inefficiencies are not understood, equipment owners, consultants and installers/service companies do not see measurements as necessary, even if cost is low compared to the investment, maintenance and failure costs. The prevailing purchasing process does not deliver the expected efficiency, in spite of investments in advanced controls (CABA, 2013). It is not uncommon for prestigious buildings, marketed as sustainable, to consume 50-200 % more energy than designed for (Roaf, 2013). A major cause is poor coordination between involved contractors/experts, and unclear responsibilities for the building as a whole. Without validation of actual performance under different loads and climate conditions, efficiency cannot be expected

Sub-metering and flow based COP/SPF measurements does not give all answers

It has been rare for electrical consumption of HVAC systems to be measured separately. With an increasing use of sub-metering and installation of flow-based energy meters, the challenges to analyse these data are becoming more pressing.

The first challenge is to measure flows and small temperature differences in real-life systems in operation with sufficient accuracy in the field. Due to the complexity of the systems, variations in loads and climatic conditions mean that any deviations in performance must be significant before a warning is generated. Flow-based Coefficient of Performance (COP) and/or Seasonal Performance Factor (SPF) measurements that do not show the expected performance levels do not give much help to identify the problem in a system with a wide range of operating conditions. Deviations require costly investigations as the data does not contain information for evaluation of the cause.

Building Managements Systems (BMS) are not automatically effective

It is often expected that investment in BMS, EMS and advanced controls replaces the need for validation of performance. In most cases, HVAC systems are treated as a "black box" communicating some measured parameters to the central system. This information normally requires a high level of competence and many hours of analysis to convert into useful information in a dynamic process.

Figure 1. Fixed installed stand-alone Performance analyser with Energy Management capability.

The internal method can be used as stand-alone, Figure 1, to upgrade existing plants, or be integrated in BMS to indicate the system performance at different loads and climate conditions, which is almost a prerequisite for optimising performance. Due to the complexity of BMS and control systems, they can even be counter-productive if they are assumed to ensure efficiency without proper set-up. Based on past experience, it has become apparent to the author that BMS systems that have not been carefully commissioned to provide correct and relevant information can result in repeated failures without alarms, or multiple alarms without faults. Careful commissioning, that includes all sub-systems, is important, as is ensuring that the results are presented in a suitable form for those using the results.

Internal method for performance analysis

Cost-effective establishment of the baseline performance of an HVAC System is a prerequisite for optimisation of energy consumption and minimisation of the risk of failures.

Figure 2. Performance Inspections give full information after 20 minutes.

The 'Internal Method' offers this option with portable equipment in 20-30 minutes, providing information ranging from high-level findings for overall system performance down to detailed information at component level. See Figure 2. Continuous analysis using a fixed installation is also possible, delivering continuous real-time data via an on-line portal. The method is well-proven, with 25 years of experience. Hundreds of thousands of analyses have been performed in manufacturers' test rigs as well as in the field. The method is described in more detail in several published papers; e.g. (Berglöf, 2011), and does not require pre-installed sensors or inputs from unit or component suppliers. Performance analyses can often be done without even stopping the compressors. When systems are permanently monitored, early-warning alarms at component level can be generated, reducing the risk of failure. There is a close relationship between efficient and reliable operation. Optimisation of existing equipment is the low-hanging fruit to reduce energy costs. In order to pick these fruits, equipment owners must first realise the benefits of performance analysis, and industry as a whole must increase its skills in measuring, analysing and optimising dynamic systems.

Measurements required for an unbiased performance inspection

The Internal Method is based on the well-defined thermodynamic properties of the refrigerants, and offers an accuracy that can hardly be achieved by conventional methods in the field. All relevant data for validation of performance, optimisation and trouble-shooting can be presented dynamically in real time, i.e.:

- Coefficient of performance (± 5 %)
- Cooling and heating capacity (± 7 %)
- Power input (± 2 %)
- Compressor isentropic efficiency at full and part load
- Evaporator heat transfer
- Condenser heat transfer
- Indicators for refrigerant charge for early detection of leaks
- Superheat

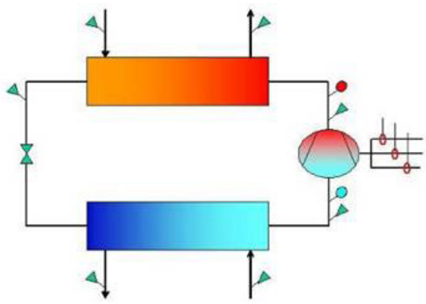

Figure 3. Sensors required and their location to establish performance of a standard refrigeration System.

A basic system requires ten easy-to-apply sensors that are attached at strategic points around the system, as shown in Figure 3:

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

The temperature of air/liquid entering and exiting the condenser and heat exchanger are measured for reference information on ambient conditions.

Well proven method

The method and technology was first developed in Sweden in 1986, and validated by SP in 1989 (Fahlén, 1989).

Figure 4. Field kit for Performance Analyser that does not require installation of flow meters to establish the performance and capacity.

Today, performance analysers, Figure 4, are used by many manufacturers and by 600 contractors/consultants in more than 20 countries. They are used in development and production tests rigs, for validation of prototypes in the field, and to improve the efficiency of existing systems. Many systems are monitored 24/7 over the internet, facilitating monitoring of system performance. Warnings are generated in response to faults or problems long before the symptoms are noticed by the users. Equipment owners have access to energy reports with energy profiles which, in combination with underlying information on the efficiency of various components, enable systems to be optimised. World-leading companies in the industry have validated and use the performance analysers to document the efficiency of products in test rigs as well as in the field. Over 20 universities and training centres around the world use performance analysers in education and research work to document and display performance.

Example – Heat pump working within manufacturing specification

Figure 5 shows a measurement of a heat pump validated to perform within manufacturer's specification, both regarding COP, capacity and all internal parameters such as, e.g. charge, superheat, heat transfer, flows and compressor performance.

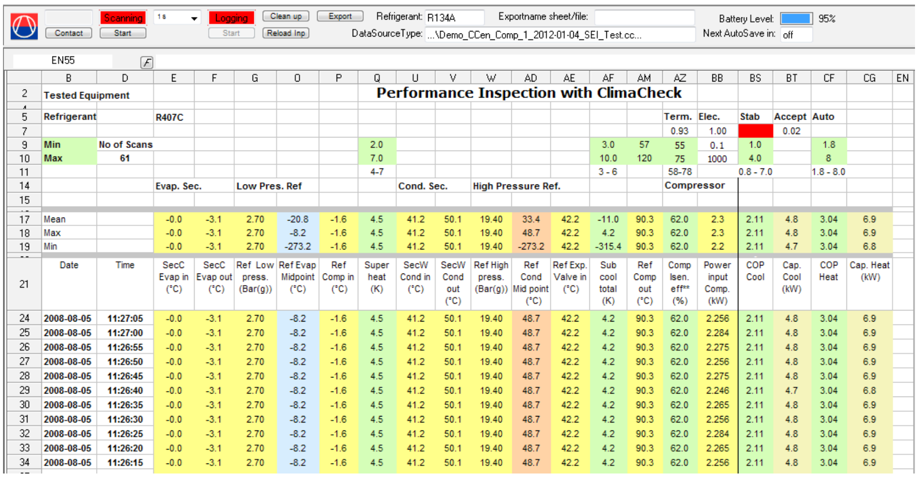

Figure 5. Validation of performance of a heat pump operating within specification.

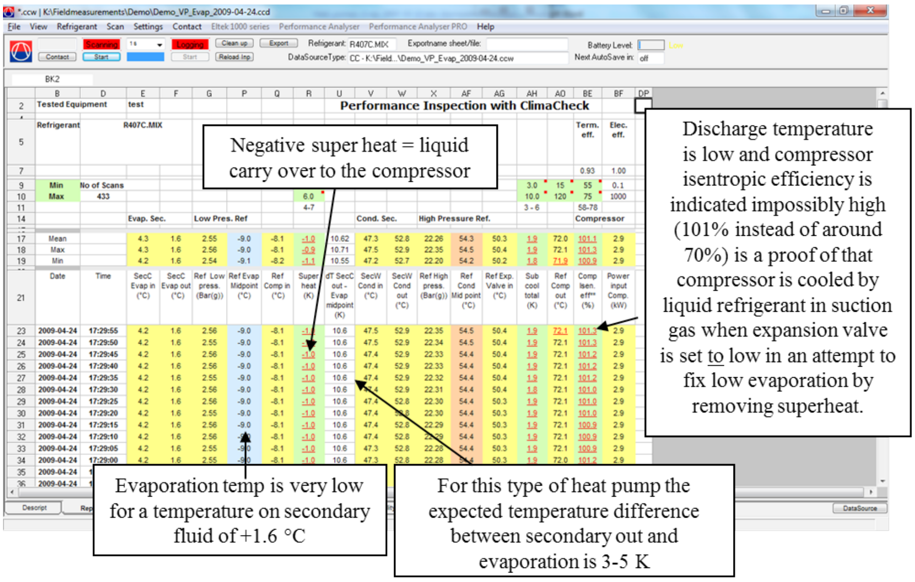

Figure 6. Validation of performance of a heat pump with problems.

These data allow any expert to fully evaluate the systems performance versus manufacturer's specificationss, as well as benchmarking the systems performance

Example – Heat pumps with problems

The internal method was developed in the booming Swedish ground-source heat pump market 25 years ago to solve the much too frequent problems. Portable and fixed equipment is now used widely to optimise systems in all applications of heat pumps, air conditioning and refrigeration. The information contains all the information that a competent person needs to evaluate the plant without having to go there. Figure 6 shows documentation that was used to resolve a two-year-long dispute. A heat pump owner was not satisfied with the performance and repeated stops due to low pressure. The contractor had spent many hours on trouble-shooting and modifying the system with a larger circulation pump for the ground collector, resetting safety limits, and adjusting the expansion valve, all without achieving reliable operation. Just before the case was due to go to court, the house owner's insurance company requested an unbiased inspection.

A performance inspection documented all the parameters of the heat pump in less than two hours. The complete information pin-pointed the problem to poor heat transfer caused by the secondary fluid

in the ground source loop. Poorly handled secondary fluid resulted in fouling of the evaporator, resulting in turn in poor evaporation and in frequent tripping on low pressure when changing from domestic hot water to radiator mode. The contractor had tried to fix the poor evaporation by increasing the flow with a larger pump and, when that did not help, had decreased superheat to increase the evaporation, causing refrigerant liquid to enter the compressor, decreasing its life expectancy. After two years of frustrating battle and many hours of work for the contractor, the performance inspection resulted in a quick decision to change the secondary fluid and clean the evaporator. Court action was avoided, and the investigation and changes cost significantly less than the original claim, to replace the heat pump, which would not have solved the problem. With hindsight it is easy to say that the contractor's and manufacturer's representatives who had visited the plant several times should have solved the problem, but without proper tools and documentation it often turns out to be difficult to identify the problem.
To measure is to know.

Conclusions

The heat pump, air conditioning and refrigeration industry is facing a new market situation, with increased focus on actual operating efficiency. Experience shows that improvements of 10-40 % can be achieved for low investment costs if plants are operating as intended. Increased quality and documentation of commissioning, maintenance and trouble-shooting with state-of-the-art performance analysers decreases energy cost and carbon footprint. Decreased repair costs, reduced down-time and minimised loss of goodwill from failures are key driving forces for new analysis methods. The biggest challenge to introducing performance inspections is the need to change the business-as-usual attitude in a conservative industry where equipment owners concentrate on initial price. The result is that failed components have to be replaced, and many contractors' survival is at stake when price levels on contracts are pushed too low.

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