# Performance Inspection saves energy in air-conditioning, refrigeration and heat pump systems.

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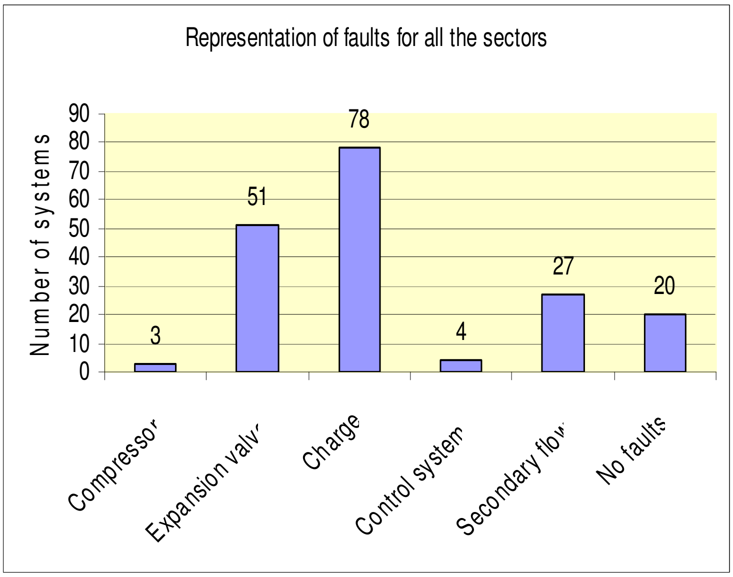
**Refrigeration processes are estimated to use 15-20% of the electrical energy in Europe. This share is increasing as the requirement for comfort is increasing as the economy improves in several new EU member states. The potential to save energy through optimisation of existing refrigeration and air-conditioning systems is significant and the industry is under pressure to take an active role to achieve this. A Master thesis study[1] at the Royal Institute of Technology in Stockholm shows that an average of 10% could be saved in 164 systems where documented "Performance Inspections" were made. If this method was introduced on a European level it would correspond to an energy saving equivalent to all the wind power produced in Europe or the total electrical consumption of Denmark or Portugal. The cost of this type of Performance Inspection would obviously be of a different magnitude than doubling the amount of wind power in Europe. With further focus on reduction of CO2 emissions the refrigeration and air-conditioning industry will have to do everything possible to reduce the energy consumption in our sector.**



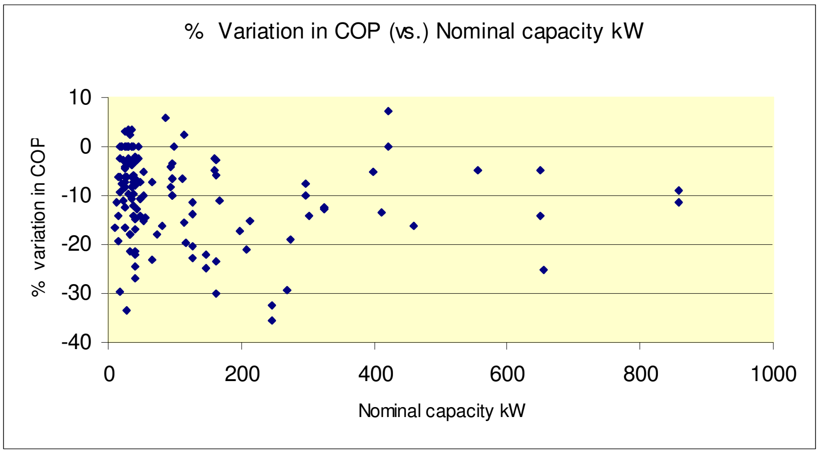

**Fig, 1 Frequency of faults**

The survey based on 164 documented performance inspections on air-conditioning, refrigeration and heat-pump systems showed that only 13% of the systems operated with the specified performance. The inspections were done with the below described "internal performance testing" method in connection to commissioning or warranty inspections or in a few cases scheduled maintenance.

The identified problems in the order of their frequency and example of possibly causes are:

- Wrong refrigerant charge caused by leaks or over-/ undercharging.
- Incorrect operation of expansion devise. This can be caused by improper adjustment or incorrectly selected expansion device.
- Wrong flows of air or liquid over condenser and evaporator. Incorrect design, wrong selection of pumps/fans and blocked filter result in higher system energy consumption.
- Poorly adjusted controls. For example can low pressure cut-out, condenser pressure controls cause significant waste of energy.
- Poor efficiency of compressor. If compressors are exposed to conditions outside envelope, contaminations (moisture, oxides, acids) or high frequency of start or stops compressor components will wear much quicker than what should be expected.

The energy use could, as a direct result of the inspections, be decreased by an average of more than 9%. The total potential of improved optimisation methods could be expected to be significantly larger as the above 9% was based on direct improvements in the refrigeration system and did not include the potential through improved control strategies or modifications relative the original design. Such needs for improvements often become obvious when systems are analysed.




**Fig, 2 Deviation of COP in Performance inspected systems**

Besides the significant energy aspect of the underperformance it should be noted that it causes increased wear on the system and increased failure rate with loss of goods and services as a consequence. It is clear to the initiated that that service cost is drastically increased when systems are operated outside their envelope and run until they fail rather than when problems are located through inspection prior to the failures. As an example it cost only a fraction of the cost to replace the valve of a semi hermetic compressor versus running it till burn out. Even with a hermetic compressor there are huge cost savings by replacing a compressor before a burn out creates acids. These often shorten the life time of the system even if costly measures with burn-out filters, oil changes and/or flushing is done according to recommendations. The experience is that few systems are evaluated for performance or reliability as long as the desired temperature is kept and no “cut out” occur.

As the inspection reported in the above mentioned survey were mainly done on quite new systems in connection with Inspections at commissioning or end of warranty the contractor can be expected to have “pre checked” a significant number of and corrected some problems thus it is more likely that the average improvement potential of all systems will be rather higher than lower than in this survey. It can also be noted that these installations were in Sweden where there are long established requirements on competency and licensing of companies in the servicing sector. A conclusion that seems to be clear is that competency requirements without relevant requirements on Performance Inspection and follow up by trained and independent “inspectors” will not result in energy efficient installations.

The survey show that the requirement for “Performance Inspections” of all air-conditioning systems with a capacity above 12 kW, required in the Energy Performance in Building Directive (EPBD)[2], are well motivated. The potential saving only on energy consumption is significant as well as the potential to decrease failure rates, repair cost and down times. Obviously the savings will only be realised if the methods used for these inspections give relevant information for evaluation. A proposal for “Performance Inspections” is now being specified in the prEN 15240[3] standard “Guidelines for inspection of air-conditioning systems”. So far there seems to be a preference from many stakeholders to push for a standard without requirement for any measurements. This appears to be an “optimistic” approach as there can be no meaningful evaluation of refrigeration system performance without well specified measurement methods.

### The “Internal Method” for Performance Analysing

The Internal method is based on the measurements of temperature and pressures in the refrigerant circuit as shown in Fig, 3 Connection of sensors to standard process. The recommended accuracy of the measurements is: Pressures ± 1%, temperatures ± 0.5 K, power Input ± 2% This allows for the above total measurement accuracy after taken temperature errors caused by using external temperature sensors into account. The enthalpies of the refrigerant in the key points can then be calculated and the main performance parameters such as COP and Capacity

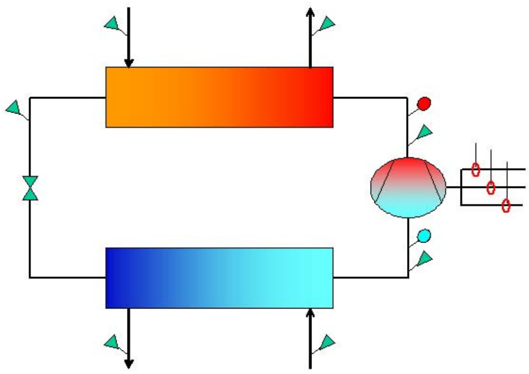
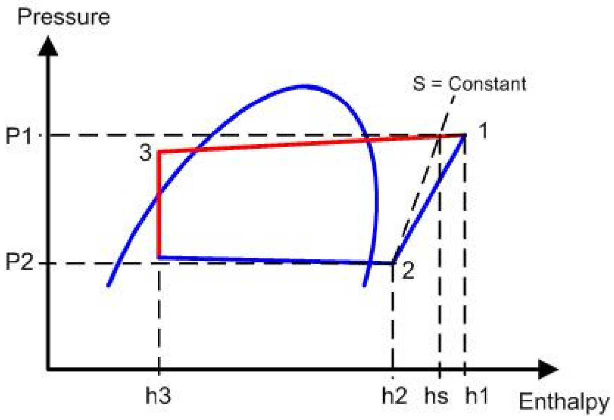


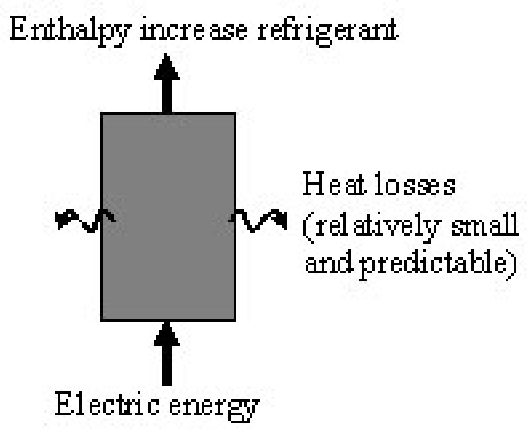
**Fig. 3 Connection of sensors to standard process**




**Fig, 4 Performance calculated with ref. properties**

can be established as shown in Fig, 4. The results can be illustrated in a Pressure-Enthalpy diagram of the respective refrigerant. The actual performance of the system can then calculated as the refrigerant massflow of the system can be established through an energy balance over the compressor by considering it as a Black Box as shown in Fig, 5. For hermetic and semi hermetic suction gas cooled compressors the heat losses are predictable. The heat losses are found by extensive analyses of calorimetric data validated by compressor manufacturers to be between 3-10% (7% is used for standard processes). The error introduced by the variation of the heat losses is small. If the method is used on open compressors or those with external cooling of some type the cooling must be known or established to give accurate results.

The performance based on the internal method tends to be more accurate than for traditional flow based measurements as they are generally much less sensitive to measurement errors and have only an uncertainty around 5% on COP and 7% on capacity. The advantage of this method is that it not only pinpoints the deviation in performance but also provides information on reason for the deviation.




**Fig, 5 Black box analysis**

**The "Internal Method" for Performance Testing is well proven**

The "internal method" for performance testing was developed 1985-86 during the "first heat pump boom" in Sweden. The method was evaluated in a report[4] by the SP The Swedish Testing and Research Institute. A Nordtest standard VVS115[5] and VVS116[6] was developed and published as a result of this. More than 200 units of a first generation "Performance Analyser" was sold mainly in Sweden but also on some other markets between 1985 and 1995. After a period without further development of the "Internal method", a new generation of "automatic" Performance Analysers has been introduced on the market during the last 3 years and more than 400 systems are in use in over 15 countries.

The applications range from manufacturers test and production rigs over field inspections to fixed installations with continuous Web “supervision”. With state of the art hard- and software the new generation of Performance Analysers offers new possibilities to cost effective field analyses of almost any refrigeration process with an accuracy of 7% on cooling capacity. The Performance Analyser can be applied in less than 30 minutes after which performance information is continuously presented and recorded. As the method requires no pre-installed equipment it offers a cost effective option for performance analyses. Based on the measurements of two pressures, seven temperatures and active power input to the system it is possible to establish all relevant operating parameters in the system including:

- Cooling/heating capacity
- COP
- Compressor efficiency
- Superheat
- Sub-cooling

The innovative approach is to use an energy balance of the compressor to achieve mass flow of the refrigerant.

***Reference list***

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[1] Energy Optimisation Potential through Improved Onsite Analysing Methods in Refrigeration, Master Thesis by John Arul Mike Prakash, Department of Energy Technology Royal Institute of Technology (KTH), Stockholm, Sweden.

[2] DIRECTIVE 2002/91/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 December 2002, on the energy performance of buildings

[3] DRAFT prEN 15240, Ventilation for buildings - Energy performance of buildings - Guidelines for inspection of air-conditioning systems

[4] Fahlén P., Johansson K. 1989, Effektmätning på Värmepumpar, Förenklad mätmetod, Byggforskningsrådet R4:1989. (Only available in Swedish but resulted in the methods proposed in the reference 5 and 6 below)

[5] REFRIGERATION AND HEAT PUMP EQUIPMENT: VVS 115, GENERAL CONDITIONS FOR FIELD TESTING AND PRESENTATION OF PERFORMANCE

[6] REFRIGATOR AND HEAT PUMP EQUIPMENT: VVS 116, CHECK-UPS AND PERFORMANCE DATA INFERRED FROM MEASUREMENTS UNDER FIELD CONDITIONS IN THE REFRIGERANT SYSTEM