**PERFORMANCE MONITORING WITH UNBIASED METHOD SAVE 10-30% OF THE ENERGY IN REFRIGERATION AND AIR CONDITIONING**

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## INTRODUCTION

Optimising existing systems is the "low hanging fruit" to reduce the energy consumption and climate impact in our industry. Savings of 10-30% are possible at low or no capital investments in most plants. Very few plants have been energy optimised after start-up as installations are done according to specifications where the refrigeration/air conditioning contractor is doing their part while plumbing, ventilation, control and electrical contractors fulfil their specifications. There are in most projects no responsibility and no cost assigned to optimise the overall operation for the loads and climate the plant is exposed to after the hand-over to the owner. The EU requirements on Performance inspections on air conditioning systems above 12 kW are still rarely done with actual measurements. Our experiences correspond to that of many others i.e. the ASHRAE report for commercial and industrial refrigeration (Royal, 2014) which show that "business as usual" for commissioning and maintenance result in that most plants have a significantly higher energy consumption than design.

## 1. SYSTEM EFFICIENCY INDEX – SEI A BENCHMARKING PARAMETER FOR EVALUATION AND OPTIMIZATION

Analyses of system performance in a plant with standard chiller controls and BMS require a lot of engineering work that can be done much more efficiently if performance is available to the expert on Internet.

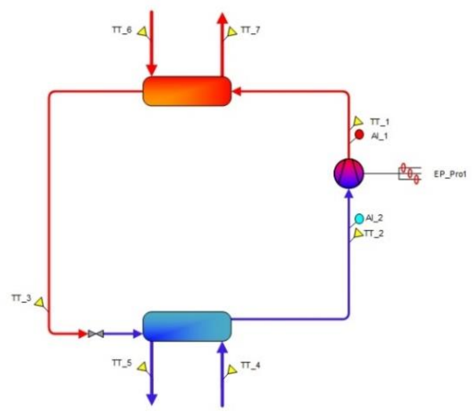



Fig. 1a Ten sensors is required to get all information for a total evaluation of a standard refrigeration process.

Monitoring compressor-, evaporator-, condenser-, cooling tower efficiency, refrigerant charge, expansion valve operation and flows 24/7 reduces the number of failures. Deviations are detected when they first occur instead of when the system fails. As all RAC equipment follows the same thermodynamics, all systems can be monitored with the manufacturer independent and unbiased internal method (with indicators adjusted to the plant). Sensors required to measure performance and capacity of a standard refrigeration process and all relevant parameters is the ten sensors marked in Fig. 1a

SEI has been evaluated in different projects i.e. of Institute of Refrigeration (IoR) in UK and The Mechanical Engineering Industry Association (VDMA) (VDMA, Specification No. 24247 Part 2: "Requirements for system design and components", 2011), (VDMA, Specification No. 24247 “Energy efficiency of refrigeration systems”, 2011) in Germany over the last 10 years. In a project lead by SP Technical Research Institute of Sweden (changed name to RISE).

Field experiences prove SEI to be a powerful tool to benchmark systems and identify weaknesses. It provides owners and operators with an easy to understand visualisation of how their system performs and allows them to identify when performances deteriorate.

The key performance indicator **SEI,** is the efficiency for a refrigeration, air-conditioning or heat pump system compared to a 100 % efficient system (loss free process) at the operating condition it is measured.

### 1.1. Sub efficiencies

The possibility to identify and benchmark weak points on component level as sub efficiencies contributes to making the SEI concept a powerful tool for fault detection and communication.

The most interesting sub efficiencies for most applications are:

- ✓ Cycle efficiency
- ✓ Compressor efficiency
- ✓ Condenser efficiency
- ✓ Evaporator efficiency

As the sub efficiencies and SEI has low variation over operating conditions they are practical analysing and benchmarking parameters than is informative also for none experts Fig. 1b.

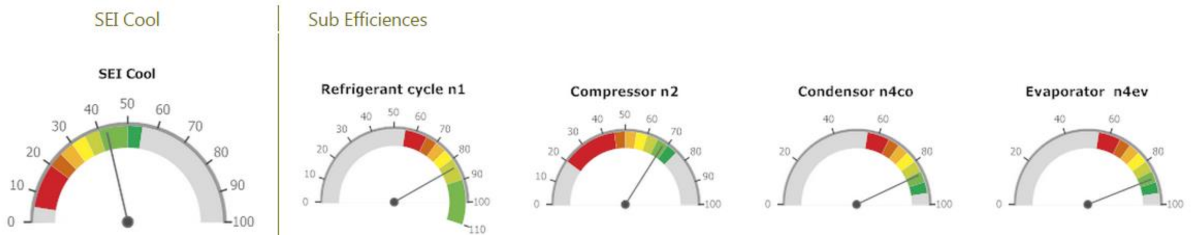



Fig. 1b SEI dashboard showing "normalised” performance for a high efficiency Chiller

## 2. ENERGY SIGNATURES AS A TOOL FOR VALIDATION OF OPTIMISATION

Most equipment owners are mainly interested in costs and reliability and appreciate information converted to kWh, Euro and carbon footprint. In refrigeration and air conditioning systems with varying loads and changing ambient conditions, the energy consumption will change by the hour. Energy signatures becomes a key to create cost effective methods to predict, validate and benchmark efficiency.

An energy signature show how kWh/h consumption depends on ambient temperature for each location. In spite of the differences they can still be compared for all overlapping temperatures and normalised to desired indicator of size (i.e. kWh/m$^2$, meter display case or installed load). Energy signatures are a key component to predict and validate how energy consumption change versus design and/or with planned measures.

In real life, the model becomes slightly more complex as the load pattern in a supermarket or commercial property varies depending on whether the store/office is open or closed. To create separate signatures for open and closed hours make energy signatures adapted to changes in utilisation and loads the key to evaluate Energy statistics as shown in Fig. 2.

Energy saving for store 29% approx. 45,000 kWh per year

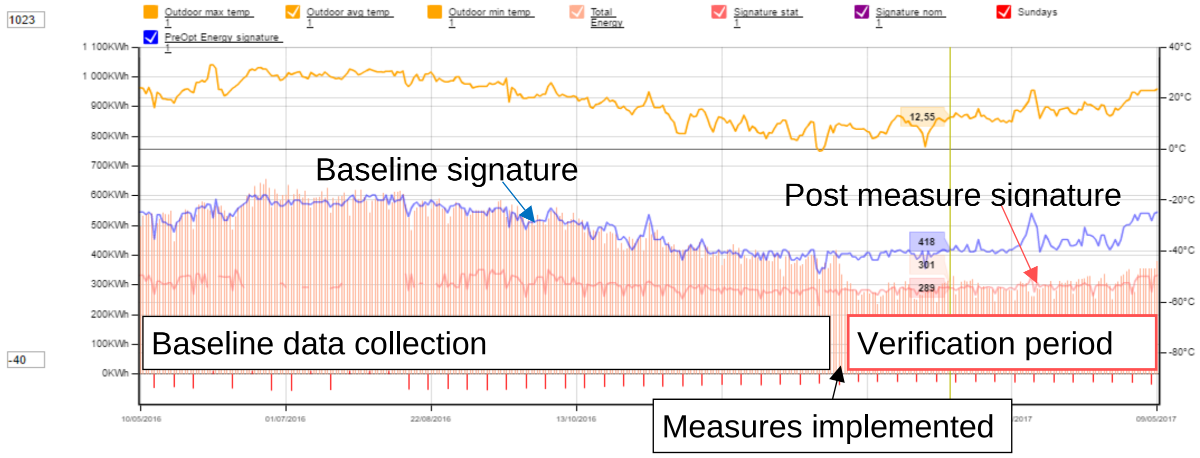



Fig. 2 Energy statistics with energy signature pre- and post-measures for supermarket optimisation project

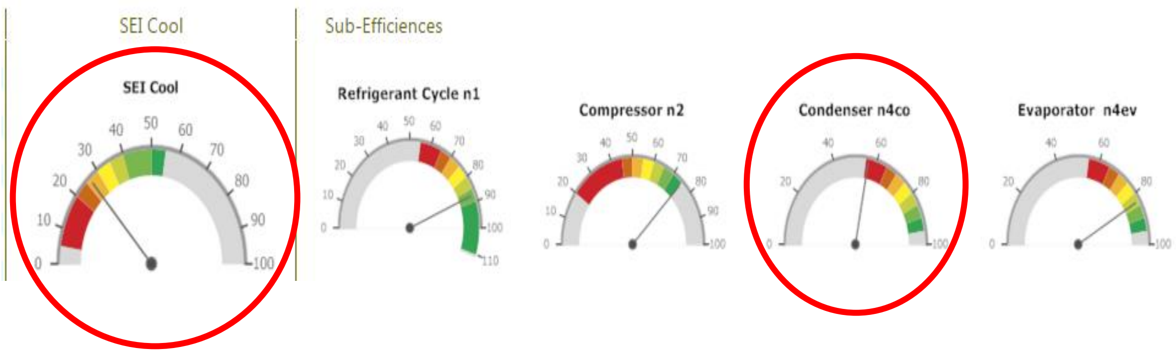
## 3. SNAPSHOTS OF AUDITS AND OPTIMISATION FROM AROUND THE WORLD

### 3.1. Air cooled chiller - USA

SEI dashboard in Fig. 3 below show low SEI caused by poor condenser efficiency. An IR picture visualise the higher subcooling and higher discharge temperature of incoming tube.

Poor condenser efficiency can be the result of:

- Fouling of condenser
- Too much refrigerant charge
- Insufficient air flow – often caused by default = high setting of condenser fan control



IR picture shows:

A. Higher discharge temperature due to higher pressure
B. Low temperature in bottom of condenser in spite of higher condensing e.g. sub cool is higher and in larger part of condenser. This reduces surface for condensing.

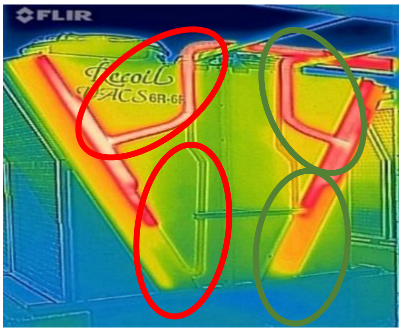



Fig. 3 Air cooled chiller with build-up of refrigerant in condenser resulting in low performance

### 3.2. Optimisation of large chiller plant saves millions - China

A good example of what is achievable through a well-executed M&V based optimisation project is the work done at Sands Casinos in Macau that was presented in the ASHRAE Technology Award Case study (Abuel, 2018). The impressive annual saving of 29,361,145 kWh achieved with an ROI of 1.54 years by implementation of a comprehensive optimisation strategy. One of the components to identify deviations, evaluate impact of measures and maintain optimised operation was to implement a “Refrigerant Performance Analysing tool” showing COP and SEI in real time for each chiller.

### 3.3. Control issues in chiller with oil free variable speed compressors – Canada

This example in Fig. 4 from a chiller plant with variable speed oil free compressors show how lack of commissioning result in continuous fluctuations of capacity. Here with increases of 60% and sometimes more causing not only issues in chiller but also affecting controls in the whole plant when capacity is pulsating. The rpm changes increase wear and it has been seen in many systems with compressor reliability problems. There is also an obvious risk of liquid carry over. Lack of understanding of time constants in systems is a major cause of erratic operation in chiller and heat pump plants.

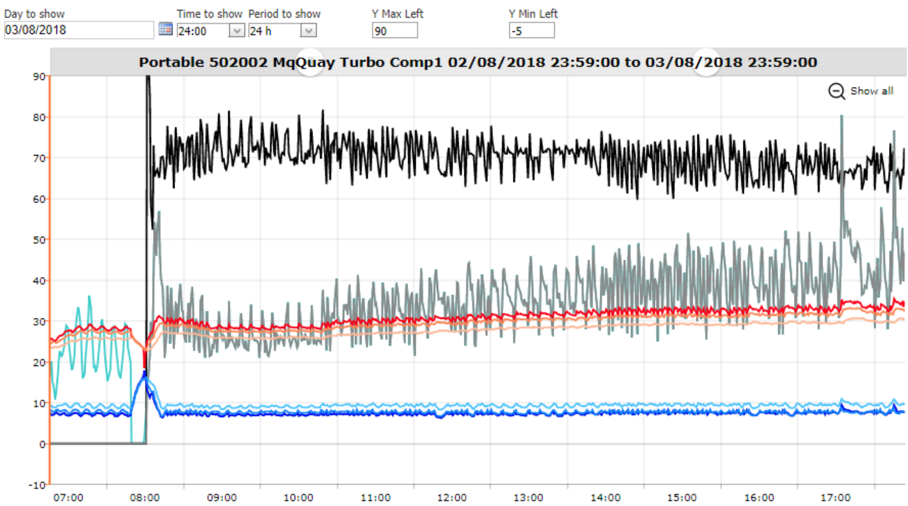



Fig. 4 Poorly commissioned capacity control causing erratic operation (grey line is power) with continuous increase - decrease of rpm on variable speed compressor

### 3.4. $CO_2$ Rack before and after optimisation of control – USA

Control issues are common also on new plants where advanced solutions are used to achieve high efficiency. Transcritical $CO_2$ systems are introducing a higher degree of complexity, but it is still common that commissioning is neglected. As long as temperature is maintained, and no alarms occur, erratic control with many starts/stops is not considered an issue. The graphs in Fig. 5 shows before and after – in spite of recommendations corrections were not done until compressor failed.

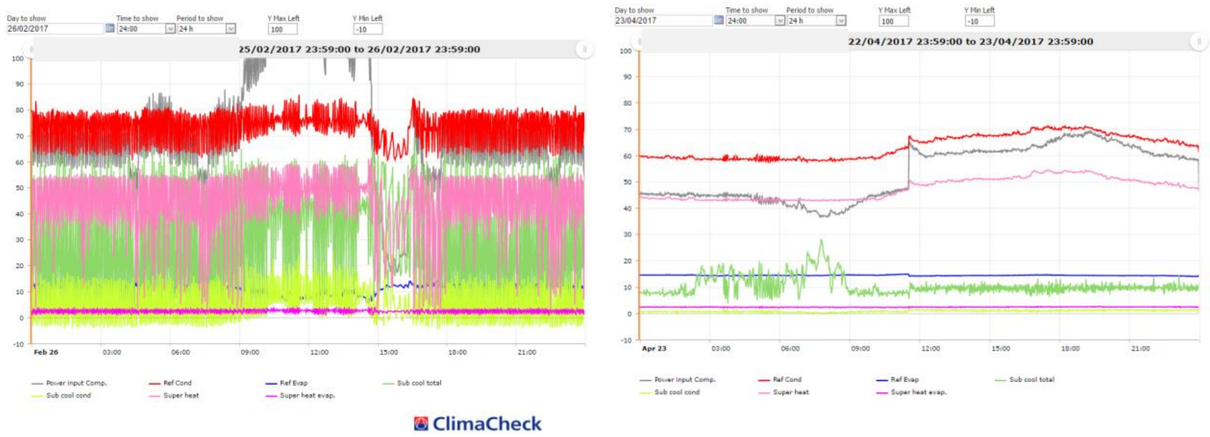



Fig. 5 New CO2 rack that was operating with erratic capacity at many load conditions in spite of one compressor with VSD.

### 3.5. Indirect leak detection in supermarket

Refrigerant leaks can be detected as deviation from operating parameters, but also as changes in energy signature before the leak caused the system to trip as in Fig. 6. As soon as vapor starts passing out of the receiver, energy consumption is affected as the gas is pumped without generating cooling capacity. In Europe the legally required intervals between manual leak detections can be doubled if the system is monitored with an automatic system that detects leaks.

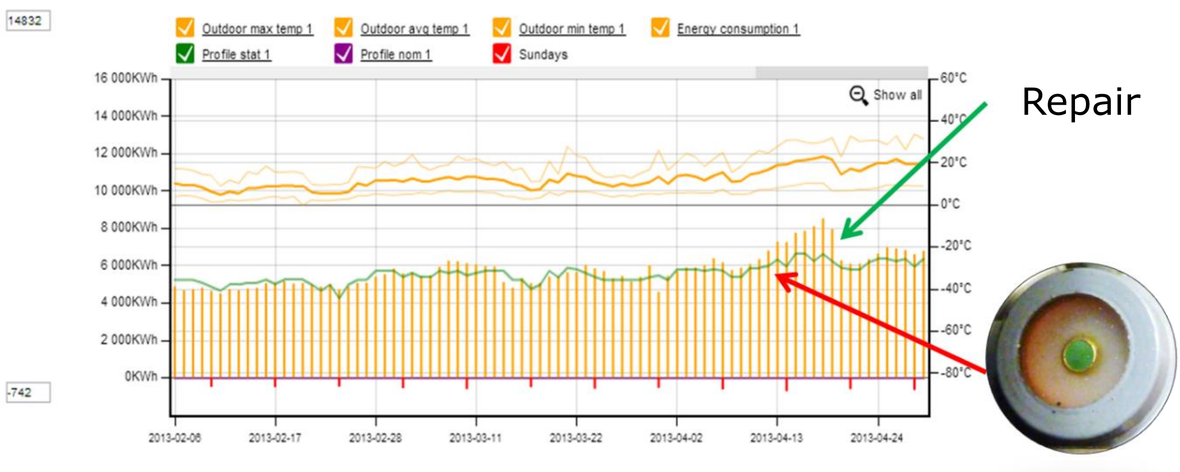



Fig. 6 Energy signature identifying refrigerant leak in Supermarket.

## CONCLUSIONS

It is a necessity to minimise energy consumption of air conditioning and refrigeration systems for environmental and cost reasons. This is a business opportunity in an industry using 20% of the global electricity. Historically the focus has been to maintain a temperature and efficiency has been assumed. This frequently results in excess capacity being installed and that 10-30% of energy consumed is wasted. The continuous variation of COP with operating conditions and challenges with traditional flow-based measuring technologies explain the lack of understanding and focus on efficiency. The introduction of the “Internal method” for performance analysis has reduced the time and cost to measure COP and capacity under field conditions. The unbiased method makes detailed information on performance available at lower cost.

System Efficiency Index, SEI, is a powerful performance indicator used to benchmark performance with low dependence of operating conditions. This overcomes the challenge with COP/EER and chiller efficiency in kW/RT that continuously change with operating conditions. Sub efficiencies for condenser – evaporator and compressor facilitate trouble shooting and improves communication with decision makers and operational staff.

Experience from more than 1500 measuring systems on the global market show that 10-30% energy savings are achievable through low cost optimisation measures. More than 1,000 MW cooling is monitored 24/7 in the cloud and over 100,000 temporary performance inspections highlight the importance of upgrading preventive maintenance and optimisation skills in the RAC industry.

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