Measurement and Evaluation of Heat Pumps for Air Conditioning in Cooling Mode

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Abstract
This paper aims to determine the methodology for the evaluation of the refrigerating system in air-conditioning. The methodology will then be tested on real device. Social demand for the development of this new methodology from the need to meet regulations and directives of the European Parliament and Council as well as laws and regulations of the Czech Republic.

Keywords
the refrigerating system, the methodology, the legislation, the cooling unit

1. Introduction

It deals with the development and validation of the method of measurement and evaluation of heat pumps in cooling mode for air-conditioning. Social demand for the development of this new methodology from the need to meet regulations and directives of the European Parliament and Council as well as laws and regulations of the Czech Republic. The methodology, its applicability and benefits will be verified during the year on a real refrigerating system. Impulse for choosing this topic is the fact that it has been published about this issue any publications, reports or results.

2. The Legislation

Given the dramatic increase in energy prices and the growing focus on global warming of the Earth, energy efficiency of refrigeration systems and heat pumps is becoming very important issue. Following these reasons were adopted various legal and technical regulations. Specific regulations and directives of the European Parliament, laws and regulations of the Czech Republic are listed below.

2.1 Montreal Protocol

The main objective of this Protocol is to eliminate the production and consumption of controlled substances that deplete the ozone layer. They are:
- fully halogenated chloro-fluorocarbons (CFCs, "hard freons")
- bromo-fluoro-hydrocarbons
- partially halogenated chloro-fluorocarbons (HCFCs "soft freons“)

Controlled substances penetrate into the upper atmosphere where chemical reactions disturb the Earth's ozone layer, which absorbs some UV radiation. Chloro-fluorocarbons are chemically very stable and remain for decades (e.g. CFC-12 102 years old) in the atmosphere.

2.2 Kyoto Protocol

In 1997 was received the Kyoto Protocol, in force since 2005. Its aim is to reduce greenhouse gas emissions by 2012 an average of 5.2% compared to 1990. The initial states of the European Union and the Czech Republic have a limit of 8%. The reduction applies to gases:

- carbon dioxide (CO_2)
- methane (CH_4)
- nitrous oxide (N_2O)

The reduction also applies to gases whose emissions will be compared to either 1990 or 1995:
- partially fluorocarbons (HFCs)
- fully fluorocarbons (PFCs)
- sulfur hexafluoride (SF_6)

HFC refrigerants have been developed to replace ozone-depleting refrigerants harmful CFCs and HCFCs under the Montreal Protocol. HFC refrigerants don't harm the ozone layer, but has an impact on global warming and it is focused on the Kyoto Protocol.

2.3 Regulation (EC) No 2037/2000 of the European Parliament and of the Council of 29 June 2000 on substances that deplete the ozone layer

In this regulation is forbidden to use halogenated hydrocarbons as refrigerant HCFC type:
- since 1.1.2004 in all new facilities
- since 1.1.2010 prohibiting the use of newly manufactured refrigerant for maintaining and servicing existing equipment
- since 1.1.2015 prohibiting the use of equipment with these refrigerants

2.4 Act No. 177/2006 Coll. dated 29 March 2006 amending Act No. 406/2000 Coll. on energy management, as amended

This Act incorporates the relevant regulations of the European Communities (Council Directive 93/76/EEC of 13 September 1993 to limit carbon dioxide emissions by improving energy efficiency and the European Parliament and Council 2002/91/EC of 16 December 2002 energy performance of buildings) and provides:
a) some measures for increasing efficiency of energy use and obligations of natural and legal persons in the management of energy,
b) rules for the creation of National Energy Policy, Regional Energy Policy and the National Program for Economical Energy Management and Use of renewable and secondary sources.
This Act, inter alia:
in § 6, par. 7: "For air-conditioning systems, the owner or operator of a facility with a rated cooling output greater than 12 kW must provide for regular review every 4 years. Method of review and evaluate the results of implementing legislation. "
in § 6, par. 8: "Control of air conditioning systems can be performed only by persons under § 10 of the issues examined by the Ministry of energy use efficiency measures and proposals or a person authorized under a special legal regulation. The scope of the examination of the implementing legislation“. Here is the law mean energy auditors on the list maintained by the Ministry of Industry and Trade and the architects, engineers and technicians authorized under § 5, paragraph 3 letter e) and f) of Act No. 360/1992 on the profession of Certified Architects and the profession of Chartered Engineers and Technicians under construction.

2.5 Regulation (EC) No 842/2006 of the European Parliament and of the Council of 17 May 2006 on certain fluorinated greenhouse Gases

The main objective of this regulation is to reduce emissions of fluorinated greenhouse gases covered by Kyoto Protocol.
The duty to put to take measures to prevent leakage of refrigerants and their control

- requires operators to provide a check for leakage by certified personnel:
- at refrigerant charge 3-30 kg (6-30 kg of hermetic devices) the control every 1 year
- at refrigerant charge 30 - 300 kg the control 1x every 6 months
- at refrigerant charge 300 kg requires installation of leak detection system, which controls 1 x every 12 months.
- at refrigerant charge 3 kg stores keep records of the quantity and type of refrigerant
- to reduce greenhouse gas emissions by 8% by 2012
- is obliged Member States by July 4, 2008 establishing the requirements for training and certification.

In this regulation is a list of F-gases. The table shows the refrigerant formula and the value of ODP and GWP. The potential for ozone depletion (ODP), a compound is given as the equivalent of chlorine (one molecule of chlorine ODP = 1). Global Warming Potential (GWP) of certain compounds, measured as CO_2 equivalents (GWP of one molecule CO_2 = 1).

2.6 Decree No. 277/2007 Coll. of 19.10.2007 on the control of air-conditioning systems

This decree provides for the implementation of the method of control and evaluation of results of air-conditioning control systems.
It also provides
- range of examination people to check their implementation
- regular checks of air-conditioners at 12 kW power every 4 years
- regular inspection of air-conditioning system includes an assessment of air-conditioning efficiency and its performance compared to the cooling requirements of buildings
- result of regular inspections of air-conditioning system is a report containing the findings and proposals for action, recommendations and advice on possible improvement or replacement of air-conditioning system and on alternative solutions.

2.7 Commission Regulation (EC) No 1516/2007 of 19 December 2007 establishing, pursuant to Regulation (EC) No 842/2006 of the European Parliament and of the Council, standard leakage checking requirements for stationary refrigerating system, air-conditioning and heat pump equipment containing certain fluorinated greenhouse Gases

This regulation provides
- leakage checking requirements for stationary refrigerating system, air-conditioning and heat pumps, which contain at least 3 kg of fluorinated greenhouse gases
- which places should be pay particular attention to check in the leak
- leak checks are carried out by direct (e.g., soap solution) or indirect (pressure, temperature)
- in case of leakage must be repaired by a person certified

The regulation came into force on September 1, 2008.

2.8 Commission Regulation (EC) No 303/2008 of 2 April 2008 establishing, pursuant to Regulation (EC) No 842/2006 of the European Parliament and of the Council, minimum requirements and the conditions for mutual recognition for the certification of companies and personnel as regards stationary refrigerating system, air-conditioning and heat pump equipment containing certain fluorinated greenhouse Gases

This Regulation applies to workers engaged in the following activities:
- check equipment for leaks with a charge of 3 kg (hermetic device more than 6 kg) of fluorinated greenhouse gases
- recovery
- installation

- maintenance or servicing

Workers engaged in these activities must have a certificate for the corresponding category

- Category I (the highest) – holders can perform all these activities
- Category IV (the lowest) – holders can practice only control equipment for leaks

Regulation specifies minimum requirements for the theoretical knowledge and practical skills needed for certification of the category.

3. Proposed Solution

These laws, regulations and decrees dealing with processes observable external refrigerating system that can be measured and evaluated, but they miss going inside. The subject of my work is finding and tracking dependencies and interactions of outside and internal processes. How is the need to evaluate the refrigerating system and heat pumps, to improve their properties and reduce energy intensity, we find only scientific activities. It focuses in particular on relationships between external and internal manifestations of equipment processes taking place in the refrigeration cycle.

3.1 Measurement methodology

So far no refrigerating system was evaluated as a whole, connecting link between internal and external processes and their impact on reducing energy consumption. It deals with the development and validation of the method of measurement and evaluation of heat pumps in cooling mode for air-conditioning. The methodology is necessary to determine which parameters should be measured and how them measure the cooling device can be properly assessed in terms of annual and long-term operation. Given that several parameters must be evaluated together to interact, it is important to determine the number of measurements, precision and accuracy. Measurement of parameters of the cooling device will be realized in the field, not in laboratory conditions. It is this fact must correspond to the choice of measured quantity, the number and taking into account accuracy. It needs to develop a methodology for measuring, so that breaking into the refrigeration equipment does interfere with its operation and was not feasible in operational terms. Then will be created a model the cooling circuit and measurements will be entered into the characteristics of the cooling device. Based on the above mentioned methodology will be processed by the cooling device.

3.2 Cooling System

Measurements will be made on the cooling unit, which is used for cooling water for air conditioning units (VZT). A source of cold is the cooling unit system with a liquid-cooled condenser. For cooling the condenser of cooling unit is designed water cooler with axial fans. This is called indirect cooling system, where is water used for cooling (not directly refrigerant). A system in which the measurement will be carried out, the water-water. The block diagram (Fig. 1) shows its principle. Water from the cooling unit at a temperature of 6°C is transported to the air handling units. From here is transported at temperature 12°C back to the evaporator cooling unit where it is cooled to 6°C. Condenser cooling unit is cooled with water. Water at 45°C flows into the water cooler, where it is cooled to 40°C and flows back into the condenser cooling unit. The recurring demand for the supply of cold. The cooling unit is in machine room in the 2nd sublevel and water cooler is placed on the roof of the building (9th floor). Refrigerating capacity is 131kW, condensing capacity of water cooler is 174kW. The refrigeration unit works with ecological refrigerant R 407C.

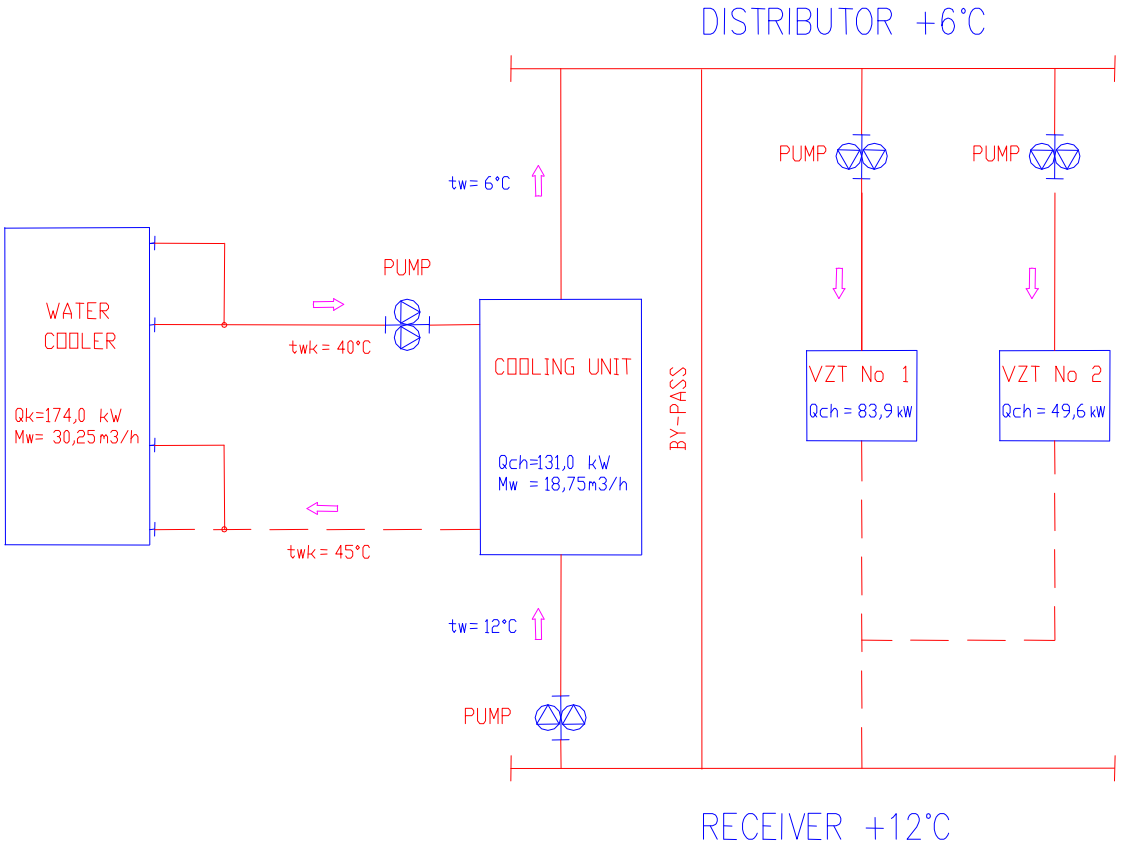

***Fig.1**. Block Diagram of Refrigerating system*

3.3 Measured Parameters

In order to correctly evaluate the cooling device, it is necessary to scan at a time a number of parameters in several different places. Among the measured parameters include the temperature of refrigerant in the suction of the compressors and then in the discharge of compressors. There will also be measured refrigerant pressure. Other points are the measured temperature and pressure refrigerant before throttling valves and the refrigerant entering the evaporator. From Fig. 2 is clear that other points are measured temperatures of water entering and leaving the evaporator and condenser. Finally, it is necessary to measure water flow on both the condenser and the evaporator side. Given that the refrigeration unit has two compressors (Scroll type), it is necessary to scan the value of inputs from both of these machines. All these parameters will be scan in machine room. The last place is the roof of the building, where will be measured the ambient temperature. The above mentioned values will be recorded in data loggers. For those measurements will be used for resistance thermometers, ultrasonic flowmeters, pressure sensors and electrical power sensors. Evaluation of measurement must be done simultaneously with the measurement to the possible erroneous measurement was excluded and can be immediately repeated. The measurement is dependent on immediate weather conditions.

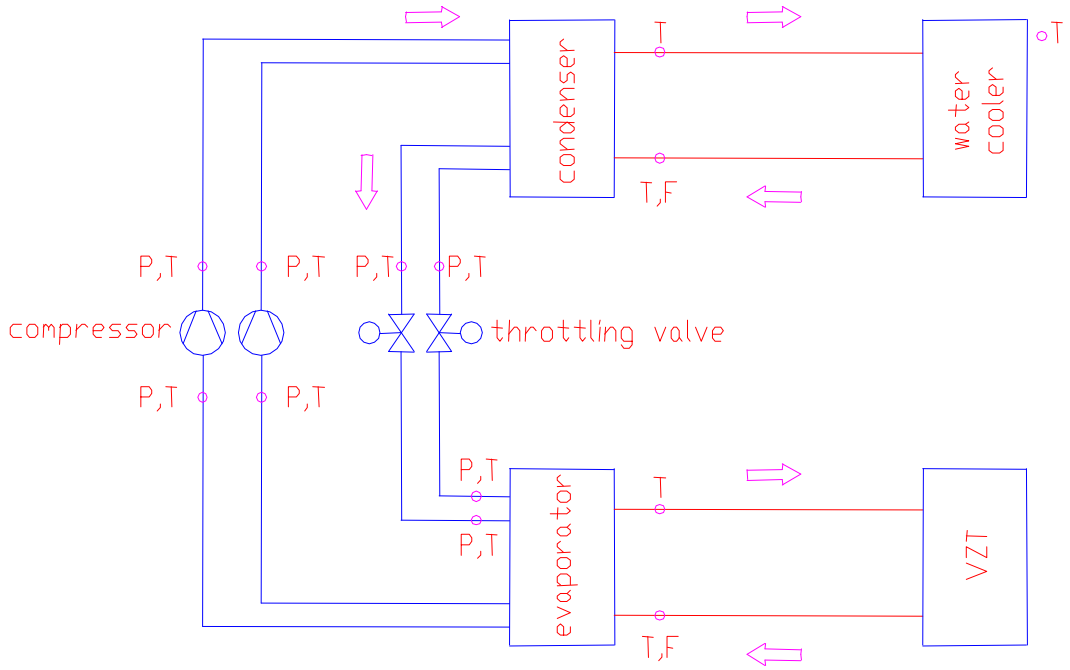

***Fig.2**. Measured points*

4. Conclusions

So far, no refrigerating system measured in the system and no one was examining the functions and structure of internal and external processes running in it. These decrees and regulations set leakage checking of the refrigeration, air conditioning control equipment or certification. They focus only on their appearances. This is not a qualitative approach and examines whether and how to decrease their energy efficiency. Given the above, it is evident that this solution evaluation and reduction of energy intensity has deficiencies. It is to be completed proper scientific studies. The aim of this thesis is to establish a methodology for evaluating refrigeration and air conditioning and verify this methodology on a real device. Then will be published recommendations for modification of refrigerating systems from the viewpoint of continuous monitoring and evaluation of their performance and of input parameters.

List of Abbreviations

T	Temperature	[°C]
P	Pressure	[kPa]
F	Flow	[m^3/h]
Q_k	Condensing capacity	[kW]
Q_{ch}	Cooling capacity	[kW]
M_w	Water quantity	[m^3/h]
t_w	Water temperature	[°C]
t_{wk}	Water temperature	[°C]

References

[1] Regulation (EC) No 2037/2000 on substances that deplete the ozone layer. Brussels: The European Parliament and of the Council, 2000.

[2] Zákon č.177/2006 Sb., kterým se mění zákon č. 406/200 Sb., o hospodaření energií, ve znění pozdějších předpisů. Parlament České republiky, 2006.

[3] Regulation (EC) No 842/2006 on certain fluorinated greenhouse Gases. Brussels: The European Parliament and of the Council, 2006.

[4] Vyhláška č. 277/2007 Sb. o kontrole klimatizačních systémů.

[5] Commission Regulation (EC) No 1516/2007 establishing pursuant to Regulation (EC) No 842/2006, standard leakage checking requirements for stationary refrigerating system, air-conditioning and heat pump equipment containing certain fluorinated greenhouse Gases. The European Parliament and of the Council, 2007.

[6] Commission Regulation (EC) No 303/2008 establishing pursuant to Regulation (EC) No 842/2006, minimum requirements and the conditions for mutual recognition for the certification of companies and personnel as regards stationary refrigerating system, air-conditioning and heat pump equipment containing certain fluorinated greenhouse Gases. The European Parliament and of the Council, 2008