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Technical Note

EHPA Quality Label

Model Range Definition

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Background and Overview

The purpose of this technical note is to explain and to demonstrate how the model range is defined, the reasoning behind this definition and the procedure taken to review a model.

A model range according to the EHPA definition consists of a set of largely identical heat pumps that comply with a set of strict criteria and conditions[1], The EHPA model range approach follows the reasoning, that all heat pumps within a model range have a similar, very close to identical performance.

Section A of this document outlines the structure and definition of the EHPA Quality Label Model Range, Section B explains the logic behind the definition and to this end draws on both technical and practical examples.

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1. EHPA Regulations for granting the International Quality Label for Electrically Driven Heat Pumps, Version 1.31, Release 07.10.2009, European Heat Pump Association, Brussels.

Section A

A heat pump **Model Range** is comprised of a number of **Individual Models**. Qualification as a model range involves conforming to a number of strict conditions and criteria as outlined later in this section.

If this model range definition is adhered to and hence the model range is uniform, the performance of the individual models within the range will also be uniform.

Each **individual model** is referred to as being 'identical in design' to the **reference model** in the model range if its main components are similar to the main components of the reference model, within a strictly defined framework (described later). This ensures that the most important output data, performance coefficients and refrigerant mass of individual models are uniform in their relationship to the reference model. Components that play an insignificant part in heat output, performance coefficients, or noise level are not covered by the term "identical design".

1. Technical Conditions for Model Range Qualification

The first step is ensuring that individual models actually qualify as a model range. For this to be the case all models within the range must meet the following criteria:

- The same refrigeration process.
- The same refrigerant.
- The same number and same compressor series resp. compression principle (piston, scroll, …)
- The same expansion valve design.
- The same evaporator design.
- The same condenser design.
- The same defrosting principle.
- The same principle of capacity control.
- The same construction of hot water storage tank incl. insulation (domestic hot water heat pumps)
- The variable characteristics follow a regular pattern (theoretical piston displacement, heat exchanger surfaces, charge quantities).
- The same version of control software/algorithms
- Circulation pump/s.

2. Uniformity in Design for Model Range Qualification

Secondly, a standard assessment procedure is utilised to ensure uniformity across the individual models in the range. The following table shows the format in which data must be presented to ensure compliance with model range uniformity.

Individual Models Within the Model Range		Model 1	Model 2	Model 3	Model 4
Technical data (from manufacturer, standard conditions)					
Nominal effect/ heating capacity	[kW]				
Condenser, heat exchanger surface	[m^2]				
Evaporator, heat exchanger surface	[m^2]				
Refrigerant	[kg]				
Specific data (calculated)					
Compressor, theoretical piston displacement	[m^3/(kWh]				
Condenser, heat exchange surface/heating capacity	[m^2/kW]				
Evaporator, heat exchange surface/ heating capacity	[m^2/kW]				
Refrigerant quantity/ heating capacity	[kg/kW]				

Table 1: Standard Assessment Procedure to ensure compliance with uniformity across model range.

3. Reference Unit Testing Procedure

The model range definition states that a minimum number of models within the range must be tested according to EN 14511 by an accredited third party Test Institute. These are termed 'reference models' and must undergo full and complete EN 14511 testing, by independent parties accredited to the respective test method. The following table outlines the number of reference models that must be examined from each model range.

n_{HP} serie	Ratio Q_{max}/ Q_{min}	Q_{max}-Q_{min}	
		≤ 30 kW	>30 kW
≤ 4	-	1	2
> 4	≤ 3.0	2	2
> 4	> 3.0	2	3

Table 2: Number of individual model(s) to be tested (space heating) within the model range as described above:

n_{HP} serie indicates the number of individual models in a model range
Q_{max} is the maximum heat output within the model range, at full load (largest individual)
Q_{min} is the minimum heat output within the model range, at full load (smallest individual)

Assuming the individual models have met the model range qualification criteria, the certification process dictates that the test institute/centre should then randomly select the required number of reference model heat pump(s) for testing.

Section B

4. Heat Pump Systems

The objective of a development engineer is always to achieve the optimum balance between the efficiency of a heat pump system (Coefficient of Performance, COP) and minimum investment and production costs.

Components

Every component supplier (e.g. compressor) has its own individual component model ranges. These are designed for applications with defined conditions (e.g. air as heat source medium, refrigerant, capacity, range of pressure). This means, that all models within the component model range have very similar characteristics at various capacity points (e.g. 5 kW, 10 kW, 15kW, etc.)

System

The heat pump manufacturer has the task to identify the best possible combination of components available on the market, so that comparable behaviour and performance of the heat pump units is achieved across the model range. This is a challenge as it involves choosing standard components from a variety of suppliers, the result being that the final product ultimately represents a compromise in achieving the original design goal.

Figure 1 shows a simplified schematic diagram of a compression heat pump with its main components, connected via the refrigerant circuit. The influence of these main components on the performance of the heat pump will be explained in the next section.

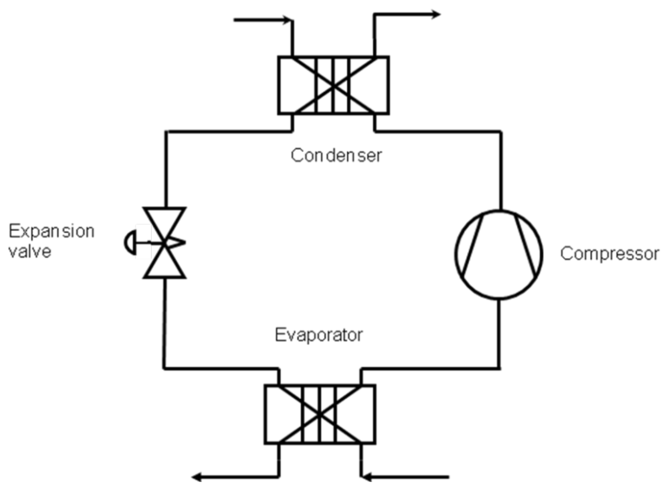

Fig. 1: Compression Heat Pump Schematic

5. System configuration and Performance

5.1 Refrigerant Circuit and Refrigerant

The operation characteristics of a compression heat pump are defined by the refrigerant circuit and the refrigerant used (= working fluid). The basic circuit consists of four main components as shown in figure 1. The operating conditions e.g. heating capacity, temperature range of hot water and the minimum usable heat source temperature define the number of compressors, the type of circuit (single-stage or two-stage) and also the refrigerant used.

The selection of a suitable refrigerant for a specific field of application is always a compromise between the demands of a number of elements namely: fluid properties, chemistry, economics, and environmental protection.

In the EHPA model range definition, identical refrigerant and similar refrigeration circuits are used which ensures that the key factors which potentially cause variances in performance are eliminated.

5.2 Compressor

Designing a heat pump starts with defining the compressor model. The type of compressor used (reciprocating compressor versus scroll compressor) will influence the COP of the heat pump as can be observed by different efficiency curves in both cases. The lubrication systems of the compressor models are also different, and so the cooling management also varies. The internal compression process is also completely different; in the first case it is piston-based compression, whereas in the second case the compression takes place during the orbital movement of one spiral. If it is assumed that the evaporation pressure and the condensing pressure of the heat pumps under comparison are kept constant then the outlet temperature of the compressed refrigerant is dependent on a number of factors such as the refrigerant, the compressor model itself, and the efficiency of the compressor. In addition, another influencing factor is the volumetric efficiency which is caused by design differences in the various compressor models.

The EHPA model range definition however eliminates all of the key compressor related factors which may cause variances in performance – so the compressors used will exhibit very similar performance characteristics.

5.3 Evaporator

Depending on the type of heat source (air, water, ground) used, heat pumps utilise different models of evaporator. Air to water heat pumps cool down the incoming air usually with finned-tube evaporators. Water and ground source heat pumps insert brazed plate heat exchangers.

The refrigerant gas-liquid mixture enters at the bottom side and gas leaves at the top side of the evaporator. The evaporation in a plate heat exchanger is dependent on a number of design characteristics. Important are the flow distribution of the refrigerant, the space distance between any two plates, the corrugation pattern of the plates, the flow regime, the operating pressure in the evaporator, and pressure drop in the channels. Another influencing factor includes the presence and quantity of refrigerant oil mixed with the refrigerant as it flows through the evaporator.

If air is the heat source medium, the design is more complicated, because these evaporators are very sensitive to the flow distribution of the outside air. The geometry and the number of fins per square meter of heat transfer area have to be optimized based on a number of factors including heat transfer, air volume flow rate, and pressure drop.

The channels formed between the corrugated plates are arranged so that the two fluids flow through alternate channels and always in opposite directions. The two phase refrigerant (vapour and liquid) enters the evaporator with a vapour quality depending on the operating condition of the heat pump. Evaporation of the liquid phase takes place inside the channels and some degrees of superheat are always requested, which is the reason why the process is called "dry evaporation". If a zeotropic mixture (e.g. R 407 C) is used as refrigerant the temperature increases during the evaporation process and therefore the operation points of the heat pump are different compared with a single-component refrigerant (e.g. R 134a).

As the evaporators used within the EHPA model range definition are from a strictly defined series, these factors that could cause a performance variance are mostly eliminated – so the evaporators used will exhibit very similar performance characteristics.

5.4 Condenser

In small heat pumps for heating and hot water production brazed plate condensers are used. The task of the condenser is to transport heat from the refrigerant to the water side of the heat exchanger. The heat transfer process inside a condenser is divided into three steps: release of superheat, release of condensation heat and release of supercooling. The refrigerant gas enters at the top side and condensate leaves at the bottom side of the condenser. Important design criteria are the flow distribution and the flow velocity of the refrigerant, the space distance between two plates, the corrugation pattern of the plates, the condensate discharge and pressure drop in the channels. If a zeotropic mixture (e.g. R 407 C) is used as refrigerant the temperature decreases during the condensation process and therefore the operation points of the heat pump are different compared with a single-component refrigerant (e.g. R 134a).

As the condensers used within the EHPA model range definition are from a strictly defined series, these factors that could cause a performance variance are mostly eliminated – so the condensers used will exhibit very similar performance characteristics.

5.5 Expansion valve

The function of the expansion valve is to reduce the pressure from the high pressure side to the low pressure side of the heat pump and to control the refrigerant mass flow rate in the circuit. In heat pumps thermostatic expansion valves (TEV) or electrical expansion valves (EEV) are used. The design of an expansion valve is dependent on the refrigerant and the mass flow rate in the refrigerant circuit. A TEV is a device designed to maintain a constant value of superheat independent of the evaporation temperature of the heat pump. The superheat is desired as low as possible with the purpose of operating the evaporator at a high heat transfer capacity.

As the expansion valve design remains identical across the entire model range it can be expected that all expansion valves will exhibit similar performance characteristics.

5.6 Example

In this section an example is used to highlight the working of a model range, demonstrating how using different components from a strictly defined series will actually result in near identical performance in practice.

A model range of an air to water heat pump with R 404A as refrigerant is designed with a finned-tube evaporator, a scroll compressor, a brazed plate heat exchanger as condenser and a thermostatic expansion valve (TEV), respectively.

The design temperatures for all heat pumps in the model range are: air inlet-temperature of +5 °C and hot water outlet-temperature of +35 °C. The design evaporation temperature is for example -8°C and design condensing temperature +37 °C. As a TEV is used the outlet-temperature of the refrigerant at the evaporator is approximately -3 °C.

With the pre-condition, that the over-sizing of all heat pump components within the models range and the efficiency of the scroll compressors are similar, the operating conditions are independent of the size of the heat pumps and therefore independent on the heat output capacity of the condenser. The COP for all heat pumps is approximately 3.5 within the model range.

If the air-inlet temperature is reduced from +5 °C to -5 °C and the hot water outlet-temperature is still +35 °C the condensing temperature will not change but the evaporation temperature is reduced to -18 °C and therefore the outlet-temperature of the refrigerant at the evaporator is decreased to -13 °C. The COP of all heat pumps is reduced from approximately 3.5 to approximately 2.9 within the model range.

If the hot water outlet temperature is increased from +35 °C to +50 °C and the air-inlet temperature is still +5 °C the evaporating temperature will not change but the condensing temperature is increased to +52 °C. The outlet-temperature of the refrigerant at the evaporator is still -3 °C. The COP of all heat pumps is approximately 2.8 within the model range.

If the scroll compressor is replaced with a reciprocating compressor in one of the heat pumps within the model range and the efficiency of the reciprocating compressor is lower than from the scroll compressor the result is, that the COP is reduced for this heat pump model. The discharge temperature of the refrigerant gas is higher than for the other heat pumps with scroll compressor.

If a heat pump model range is build only with reciprocating compressors then the COPs of all the heat pumps within the model range are lower than for a heat pump model range with scroll compressors.

This example demonstrates firstly how in practice, the performance of a number of heat pumps in a strictly defined model range will be similar, and secondly that altering a number of variables such as air inlet temperature or the hot water outlet temperature leads to a similar impact on all of the models within the model range.

6. Summary

This study has considered the main components in the refrigeration cycle that may impact on performance. There are other secondary components and processes such as the control system, the defrosting principle, the capacity control etc. For these however, the same logic applies, in that as they are either identical or from a strictly defined component model range they will exhibit very similar performance characteristics.

As all components are connected via the refrigerant piping to a closed thermodynamic circuit any changes in operating conditions will have a similar and consistent effect on performance across the entire model range.

It should however be noted that there could be minor performance variances between the models in the range due to differences in the ratio of volume to surface area of the components. This could impact on heat loss and efficiency, and is a normal consequence as a model range is scaled from lower to higher capacity product variants.

7. Conclusion

The technical description above shows, that one typical heat pump model range with exactly defined components, under similar operating conditions, will exhibit similar performance characteristics for all products within the model range.

The model range definition of the EHPA takes account of the primary and secondary components and additional processes associated with the functioning of the complete heat pump system. It envisages a system designed with a high degree of technical uniformity and consistency, according to similar physical principles.

It is logical to conclude that the approach of measuring a number of products within the strictly defined model range, obviates the need for complete testing of all the units in the family as very similar performance values can be expected across the entire range.

It should also be noted that apart from this technical explanation, many years of observed evidence, both in laboratories and in the field have proved this hypothesis to be the case in practice.