Independent testing of heat pumps is needed for reliable COP

Heat pumps offer a high potential to rapidly increase the proportion of renewable energy share within total heating energy consumption. Due to their built in multiplication effect, by using environmental heat sources the supplied energy is transformed into more thermal energy. This factor is called the Coefficient of Performance or COP. How is this factor determined? What has to be considered when comparing performance ratings? Can a high rate of performance always be trusted? This article illustrates how various factors have to be included in testing and how the testing has to be performed to get reliable results.

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The basis for comparison

The determination of performance rates for heat pumps is largely standardised throughout Europe on the basis of the EN 14511. This defines standardised conditions for testing electric heat pumps and determining their COP using a test rig. This involves using steady state and virtual steady state measuring points, which form the basis for the comparison of individual devices, as well as the dimensioning and design of whole systems. EN 14511 was revised in 2011 and has, for a number of years, replaced EN 255-1+2.

Environmental heat sources which can be exploited include outside air, exhaust air, ground or surface water and ground heat (brine). The heat source side is described in the standard as the external heat exchanger, which corresponds to the evaporator of the refrigeration circuit in heating case. The transfer of usable energy can be via air or water. The usable heat side is described as the internal heat exchanger. In heating case this corresponds to the condenser.

The standard defines so called nominal standard and nominal working conditions for each category of device. A device using brine as heat source and water as heat transfer for example is called a brine/water heat pump. In the case of brine/water heat pumps, the nominal standard conditions at low temperature are for brine at 0°C (B0, B = brine) and a heating water temperature of 35°C (W35, W = water). This boundary condition is abbreviated to B0W35.

If the heat transfer is via water, the temperature of the heating circuit influences the efficiency of overall heat generation. The lower this temperature level is, the higher the efficiency of the heat pump. EN 14511 specifies four temperature levels at which devices can be tested. These are distinguished according to their outlet temperatures and are defined as follows: low temperature (35°C, W35), medium temperature (45°C, W45), high temperature (55°C, W55) and very high temperature (65°C, W65). The efficiency of the heat pump however, depends on the mean condensation temperature. Therefore the input temperature which depends on the mass flow rate of the water must also be specified. These are set at the nominal standard point, where the mass flow rate set to produce a 5 K temperature difference on the heating side.

If the heat transfer is via air, a uniform input air temperature of 20°C (A20, A = air) in the condenser is used. The air output is governed by the volume flow rate, which in turn is determined by the internal fan.

A further important influence on the efficiency of heat pumps is the temperature of the heat source. The higher this temperature level is, the higher the efficiency of the heat pump. In this case the standard also offers a variety of temperature levels, categorised by the input temperature at the evaporator. Seasonal variations are minimised using ground or water heat sources. For brine there are three temperature categories: –5°C (B-5), 0°C (B0), and +5°C (B5). For water as the heat source, two categories are defined: 10°C (W10) and 15°C (W15). The largest temperature span is available when using outside air as a heat source, where 12°C (A12), 7°C (A7), 2°C (A2), –7°C (A-7), and –15°C (A-15) are defined as source

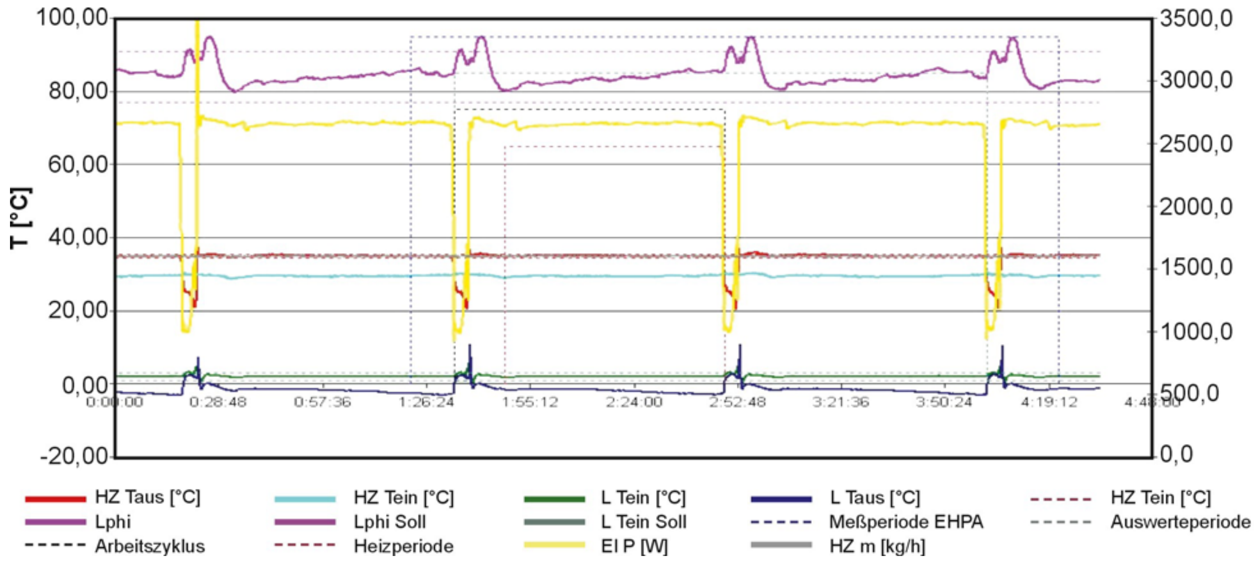

Figure 1. Diagramme of an air/water heat pump with defrosting cycles.

Figure 2. Ice build-up on an evaporator.

temperatures. If exhaust air is the heat source, a standardised temperature of 20°C (A20) is used.

As a matter of principle, the lower the difference in temperatures between the heat source and the output side is, the higher the COP of the device in question. So naturally, the COP of an air/water heat pump at A7W35 is much higher than at A-7W55 and care must be taken to ensure COP ratings are compared under the same border conditions!

Icing of Air/Water heat pumps

The evaporators on heat pumps using air as a heat source can freeze at low source temperatures depending on the humidity of the air. These devices therefore have to provide periodic defrost cycles in order to free the evaporator of ice. These usually work with a reversal of the normal process, temporarily delivering heat for defrosting from the heating circuit. The energy required for this process is taken into account when determining the COP and results in a reduced rating. During testing according to the standard, the device operates over a four hour period, and depending on the number of defrosting cycles completed in this time, the COP is calculated across one or more cycles. As the ice build-up and the number of defrost cycles are heavily dependent on the humidity of the air, this parameter has also been specified for each temperature level. Typically freezing occurs at testing points below A7 and devices can normally be run ice free above A7. The COP rating reduction through defrosting cycles is in the region of 0.3…1.0 depending on the efficiency of the defrosting algorithm employed (**Figure 1**, **Figure 2**).

Correction for the pumps and fans

A further aspect to be considered when determining the COP is the power consumption of circulation pumps and fans. Some devices have hydraulic circulation pumps integrated into their design, whilst others are delivered without a pump. If this was disregarded, devices with integral pumps would be at a disadvantage due to their higher consumption of electrical energy. In order to allow for this the standard includes a correction for the pump. The basis for this is the assumption that only the capacity necessary to overcome the device's internal pressure loss should be ascribed to the device itself. The correction is based on the measurement of the hydraulic capacity and on its conversion, using a virtual pump or fan efficiency factor, into an equivalent electrical input. This is then either added to the electrical energy consumption value, or subtracted from it. Correction for the pump and fans affects the COP up to 0.3.

Additional standards

Other than EN 14511, further standards can be applied in the testing of heat pumps. EN 12102, for example, specifies conditions for sound measurements, and describes the relevant geometric boundary conditions supplementary to the working points laid out in EN 14511.

EN 15879 describes the boundary conditions for the testing of direct evaporation heat pumps. The cooling medium evaporates directly in a pipe buried beneath the ground. During testing this evaporator pipe lies in a brine tank at specified temperatures.

EN 14825 describes the determination of a seasonal coefficient of performance (SCOP) for brine/water, water/water, air/water and air/air heat pumps. Based on a linear relationship of heating load, supply temperature and outside temperature, the standard defines per cent loads and supply temperatures for different outside temperatures. To determine the SCOP, the standard, apart from allowing the selection of a temperature level, provides a choice of three climate zones: cold (c, T_{design} = –22°C), medium (m, T_{design} = –10°C), and warm (m, T_{design} = 2°C). Furthermore a bivalence point must be defined up to which the unaided heat pump must cover the heating load. According to the chosen boundary conditions the device is now tested on the basis of EN 14511 at different per cent loads. This standard is particularly significant for testing devices using outside air as their heat source, as in this case the heating requirements of a building at diminishing heat source temperatures increase, while both the efficiency and capacity of the heat pump decrease.

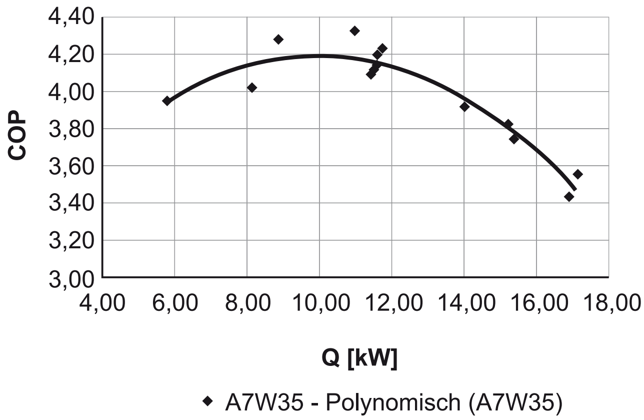

Figure 3. COP of a modulation air/water heat pump at A7W35 plotted against heat output.

Also the advantages of output-regulated devices become more apparent. When regulating their capacity according to per cent load conditions, their efficiency usually increases (**Figure 3**).

Domestic hot water heating

EN 16147 describes the determination of performance ratings for the heating of domestic hot water, and replaces EN 255-3. The boundary conditions on the heat source side are adopted from EN 14511. On the output side daily hot water tapping profiles are used to determine the COP. These daily tapping profiles specify water withdrawal in varying quantities spread over a day, ranging from profile S (2.1 kWh/d) up to profile XXL (24.53 kWh/d). Normally the COP increases with the quantity of water used, as in this case the storage losses, which are fully incorporated in the determination of the COP, remain relatively low. For this reason the test is usually undertaken using the largest possible water usage profile, and this at the same time, makes a statement about the heat pump's performance. The cold water temperature is specified at 10°C, and for every withdrawal a minimum achieved water temperature is stipulated. If this temperature cannot be reached by the device, a direct electrical heater cuts in. The challenge is to define suitable initial test conditions, so to ensure that the energy content in the storage is the same at both the beginning and the end of the test. In opposition to the old EN 255-3 the storage losses over a 24 hour period are incorporated in the calculation of the COP, so the measured COP ratings are, in comparison, much lower. With environmental air as a heat source (A15) COP ratings are typically in the region of 2.3…2.7.

Figure 4. Test rig at the HLK test centre.

Gas powered heat pumps

EN 12309 describes the testing of gas powered absorption and adsorption heat pumps. Along with the tests on the gas side of the device, part 2 specifies the conditions for the determination of its efficiency. There are differences to EN 14511 for the test conditions in heating mode. For example testing is conducted using the volume flow rates specified by the manufacturer. On the heat usage side, there is, additional to the low temperature level of 35°C (W35), a high temperature level of 50°C (W50) specified. The ratio of extracted heating energy to the combustion energy expended provides the resulting performance rating. Typical values for an air/water heat pump operating at A7W50 are in the region of 1.5. However, here the consumption of auxiliary electrical energy, which can be extensive, is not taken into consideration.

Independent testing

The measurement of these specified values on a test rig make exacting demands on the test surroundings and on the measuring apparatus. Not all manufacturers can, or choose, to provide the necessary laboratories. Also there is often an absence of verification for distributers' claims for their products. Confidence in the accuracy of declared ratings is achieved through tests carried out at an independent testing centre, which has access to appropriate laboratories and has the necessary experience to arrive at reliable results.

The Prüfstelle HLK test centre of the Institute for Building Energy (IGE) at the University of Stuttgart has, as an independent test centre accredited according to ISO 17025, all the necessary competence to determine specified ratings under the above mentioned conditions. Electrically or gas powered brine/water, water/water or air/water heat pumps up to 70 kW heating capacity can be tested. Also domestic hot water heat pumps for all cycles can be tested (**Figure 4**).

Certification

On the basis of an independent test a certification of specific ratings is possible. The EHPA Quality Label for electrically powered heat pumps, awarded by the European Heat Pump Association is widespread. One criteria for the award of this label are performance and sound tests carried out at an independent testing centre where a minimum COP rating has to be achieved. The minimum COP for air/water heat pumps hereby is 3.1 at A2W35. The minimum COP for brine/water heat pumps is 4.3 at B0W35, for water/water heat pumps it is 5.1 at W10W35 and for direct evaporation heat pumps it is 4.3 at E4W35. Apart from the performance requirement, the device has to be delivered with a documentation in the language of the country of sale, and the availability of a service network.

Experience shows that through unreliable declarations of performance ratings, both the consumer and the image of heat pumps are repeatedly harmed when the promises of the planning phase are not fulfilled after the system is installed. One building block towards reliability is to only trust in certified performance ratings determined by independent testing centres. In this way a reliable foundation can be laid, so that together with competent system planning, the full potential of environmental heat sources can be realised.