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Heat Pump Systems in Sweden
- Country Report for IEA HPP
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Summary

This is the Swedish country report for the first part of the IEA Heat Pump Programme Annex 28 “Test procedure and seasonal performance calculation for residential heat pumps with combined space and domestic hot water heating”. It reports on the Swedish heat pump market, background, typical heat pump systems and standards in use. The objective of Annex 28 is to establish a test procedure which delivers the data needed to calculate the overall seasonal performance factor of heat pump systems. The method should keep the testing to a minimum. Also a calculation method for seasonal performance factor should be established.

Since 1995 the heat pump market in Sweden has increased rapidly and the sales for 2002 reached almost 40,000 units. The majority were ground-source heat pumps with a vertical borehole. As number two comes the exhaust-air heat pump, which is a product typical for Sweden. The most used refrigerant is R407C but also R134a, R404A, R417A, R410A and R290 are used.

Ground-source heat pumps are commonly connected directly to a hydronic heating system using floating condensation, i.e. the condensation temperature is allowed to vary with the load. Sanitary hot water is commonly heated via a double-wall tank. Heat pumps used for both space heating and hot water heating often alters the direction of the heating water via a reversing valve such that it flows through the radiator system or through the mantle of the double-wall tank. Exhaust-air heat pumps are very common to install in new fabricated houses with a mechanical ventilation system, due to a regulation stating that heat recovery should be applied to certain types of buildings.

The test methods for heat pumps that are in use in Sweden are the EN 255 part 2 and 3, and SP-method 0029 and 2800. The SP-methods are used for exhaust-air units and the EN standard is used for all other heat pump types.

1 Background

This chapter intends to give relevant background information about the climate, the heating systems and the heat pump market in Sweden.

1.1 Climate

Sweden is a long stretched country with large differences in climate between the northern parts down to the southern parts where the majority of the population lives. To illustrate this the annual mean temperatures for four cities in Sweden are listed in Table 1.1. The location of these cities is marked out in Figure 1.1, and the duration curves are shown in Figure 1.2.



Figure 1.1 The cities in Table 1.1 are marked out on the map.

Table 1.1 Annual mean temperature for different cities in Sweden (Elgestad^[2]).

Place	Temperature (°C)
Lund	+7.3
Stockholm	+5.9
Östersund	+2.4
Gällivare	-0.7

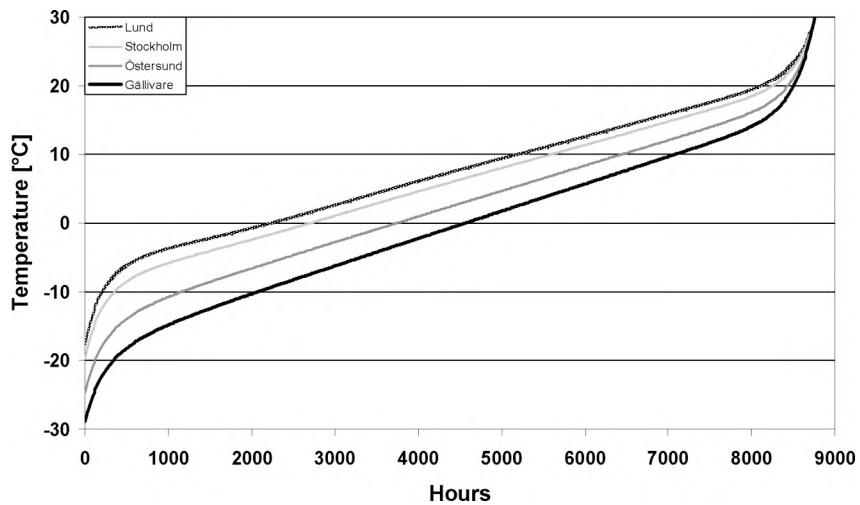


Figure 1.2 Duration curves for the cities in Table 1.1. These curves are calculated from a curve fit equation (Fehrm, et al.^[4]).

For air-source heat pumps the air humidity affects their performance. In Figure 1.3 below, monthly mean values of the relative humidity of the outdoor air in Stockholm is shown. This applies for outdoor air-source heat pumps. For exhaust-air heat pumps the interesting parameter is the humidity of the indoor air. This is also shown in Figure 1.3, where the moisture content of the indoor air have been calculated as the humidity of the outdoor air plus the moisture gained from indoor activities. The figure contains three different curves showing the result for three different moisture loads, 0, 2 and 4 grams of water/m³ air. To exactly predict the actual moisture load is of course difficult but typical values are for normal habitable rooms 3 grams/m³ and for rooms with extra large moisture content, such as bathrooms, the moisture load will typically be 4 grams/m³ (Fahlén^[3]).

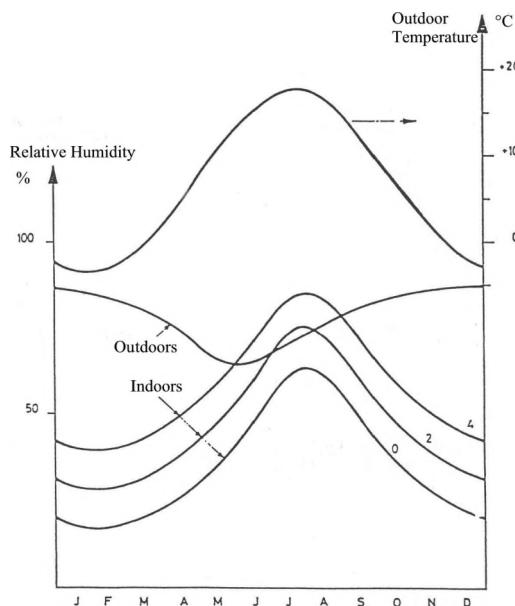


Figure 1.3 Monthly mean values of the outdoor temperature and the relative humidity of the outdoor air for Stockholm as quoted by Fahlén^[3]. The calculated indoor air humidity for different moisture loads is also shown.

1.2 Heating systems

The most common heating systems for domestic use in Sweden are hydronic heating systems and direct-acting electric radiators. Air distributed heat is not common in the domestic sector but is used in office buildings etc. Since heat pumps are mostly used in the domestic sector, this will be the focus in this section.

Before 1980 radiator systems used high temperatures, typically 80/60, which means that the supply temperature was 80 °C and the return temperature 60 °C at the Dimensioning Outdoor Temperature (DOT). In 1984 new building regulations were issued (SBN 1980^[8]) where, in order to decrease the energy use, it was prescribed that hydronic heating systems must be designed such that the supply temperature at the DOT does not exceed 55 °C. Many of the old systems could also be adjusted to these temperature levels because they were oversized. Other actions such as extra insulation of the house etc also helped to decrease the temperature levels. Thus the most common temperature levels today are 55/45 at the DOT.

At present floor heating systems are quite popular in Sweden, probably due to comfort and aesthetical reasons. These systems use low temperatures, such as 35/28 at the DOT. When direct-acting electric heating systems is changed to hydronic systems, a fan-coil system is the most convenient choice. These systems also work with low temperatures and will probably be more common in the future since the Swedish policy is to decrease the use of direct-acting electric heating.

1.3 Development of the Swedish heat pump market

The Swedish heat pump market has had its ups and downs since the early 1980's as illustrated in Figure 1.4. These variations depend on various reasons and the following text will try to explain this.

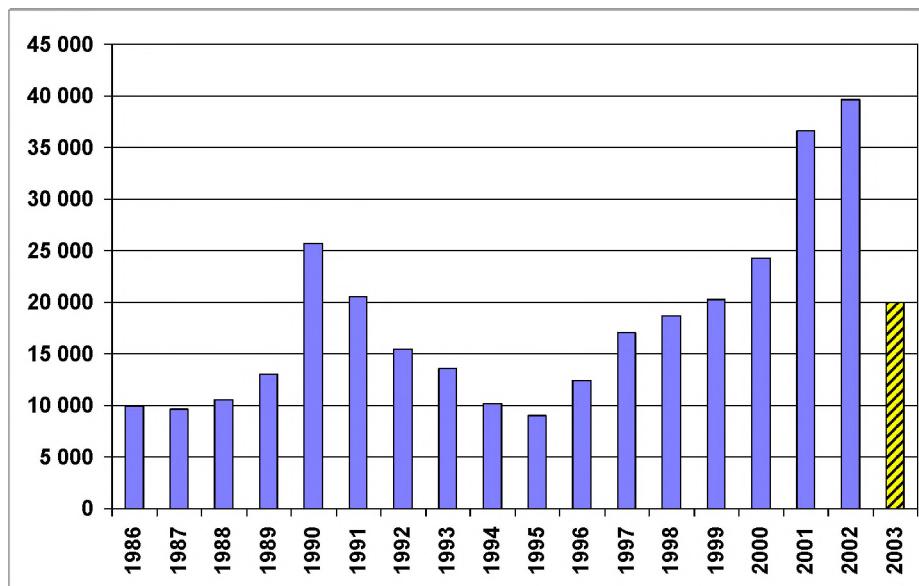


Figure 1.4 The annual sales of heat pumps in Sweden. The data for 2003 includes the sales until June. The data is supplied by SVEP, the Swedish Heat Pump Association.

During the first half of the 1980s horizontal ground-source heat pumps and open-loop systems were quite common. Also outdoor-air-to-water heat pumps and exhaust-air heat pumps were used. During this time the heat pump market was supported by governmental subsidies. The exhaust-air heat pumps increased their market share due to the Swedish

Building Code 1980 (SBN 1980^[8]) stating that buildings with an energy content in the used air exceeding the energy content of the outdoor air by 50 MWh/year during the heating season must install a system for heat recovery. As an example of an acceptable solution was an exhaust-air heat pump heating domestic hot water.

Then, in 1985, the heat pump market experienced a substantial decrease, mainly due to the withdrawal of the governmental subsidies. In the same time the oil price was reduced by 50 %. During the period 1985-1990 the market mainly consisted of ordinary, non-expensive, heat pumps. Direct expansion systems were used for ground-source units. Air-to-water heat pumps were still quite common.

Around the years 1990-1991 the market increased somewhat again, because of an increased sale of air-to-air heat pumps. These were installed in houses with direct-acting electric heating. During these years the debate on the phase out of the nuclear power plants from the Swedish energy system was rather active. The debate then cooled down and the sales went down once again reaching a minimum around the year 1995, with sales below 10,000 units/year.

In 1994-1995 the Swedish National Board for Technical Development (NUTEK) issued a technology procurement on heat pumps. This got quite a lot of attention and the sales started to increase rapidly. There were two winners in this procurement and both were ground-source units. As a consequence these type of heat pump now dominates the market instead of the air-source units, Figure 1.5 illustrates this transition. This transition is due to a major increase in the sales of ground-source units, not a decrease of the air-source units. The sales of air-source units has actually also increased since 1995. The total sales in 2002 were close to 40,000 units, i.e. an increase of more than 400 % in 7 years.

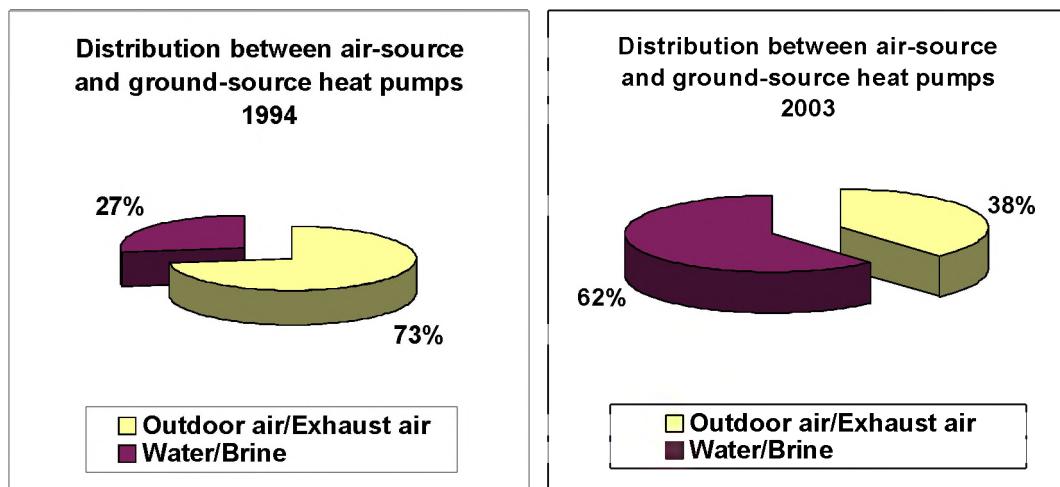


Figure 1.5 The type of heat pumps sold in Sweden has changed from air-source units to ground-source units. The data is supplied by SVEP, the Swedish Heat Pump Association.

1.4 Refrigerants

Sweden are, as many other countries, phasing out the CFC and HCFC refrigerants. The time schedule for this is shown in Table 1.2. In 2001 the Swedish government assigned the Swedish Environmental Protection Agency (SEPA) to investigate possible means for reducing the emissions of fluorinated greenhouse gases. Later the same year the government assigned the SEPA to provide background material for formulation of a regulation aiming towards a reduced use of F-gases (e.g. HFC refrigerants). This

investigation is still undertaken and no regulation has been issued (source: the Swedish Refrigeration Foundation, www.kys.se).

Table 1.2 Time schedule for the phase-out of CFC and HCFC refrigerants in Sweden (source: the Swedish Refrigeration Foundation, www.kys.se).

Refrigerant	Stop for new installations	Refill stop	Stop for use
CFC	1 January 1995	1 January 1998	1 January 2000 *
HCFC	1 January 1998	1 January 2002	Not decided

* For stationary compact (non-split) units with a refrigerant charge less than 900 grams may be used until 31 December 2004.

The phase out of the CFC and HCFC refrigerants led to introductions of new refrigerants on the Swedish market. The most common refrigerant used in heat pumps produced in Sweden today is R407C, but also R404A, R134a and R290 (propane) are used. For air-to-air heat pumps R410A is the most common refrigerant but also R417A is used.

1.5 Electricity supply

The electricity tariffs in Sweden do not vary over the day or night, nor does it exist any special electricity price for heat pumps. Also, no system for planned cutouts exists. This has only been an issue during very cold winter days and then not directed towards heat pumps only.

Problems with heat pumps connected to the electric distribution net are the high currents at start-up and the peak power load caused by the auxiliary electric heaters that are commonly used. Since heat pumps in Sweden are not designed to cover the full load an auxiliary heat source needs to be installed. This is often included in the heat pump when bought and then it is an electric heater, which will be used for only a few hours per year. Since there are many heat pumps installed in Sweden there are also many heaters installed and during cold winter days many of these will operate in the same time causing a high power load to the distribution net. Since it also has a short duration this cause the electric distributors and producers to have equipment designed for this load that may be used for only a short time, and thus it is expensive. This is not a big issue today but it is starting to concern electricity producers and distributors.

2 Systems for combined space and domestic hot water heating

The most common systems for combined space heating and domestic hot water heating in the Swedish market are presented below. The chapter is divided into three subheadings where the first two deals with the most common systems, ground-source heat pumps and exhaust-air heat pumps. Outdoor air units is also included in the first section since they very often are installed in the same way as ground source units. In the last part of this chapter interesting but, at this point, uncommon systems are discussed.

2.1 Ground-source and outdoor-air-source heat pumps

The most common type of heat pump in Sweden today is the ground source heat pump, which extracts heat from a borehole, the ground or seawater. Systems using vertical boreholes for the heat extraction are the most common type. In Sweden almost only indirect systems are used. Direct expansion systems are rare today due to negative experiences from a period in the mid 1980s when they were popular. The small amount of direct expansion systems is also the result of a strategy to keep the refrigerant charge to a minimum.

The common way to control the heat pump is by so called curve control where the return temperature from the heating system is correlated to the actual outdoor temperature. Instead of this the indoor temperature can be used as a measure of the heat load. When the heat pump is used for domestic hot water heating this is prioritised. A very common installation of a heat pump of this type is shown in Figure 2.1. Typically the hot water is heated via a double wall tank where the water in the heating system is used for heating the hot water, see Figure 2.2. The heat pump alters between hot water heating and room heating by a reversing valve that shifts the flow such that it flows through the double wall tank only or through the heating system only. This is called “floating condensation” since the condensation temperature follows the changes in heat demand.

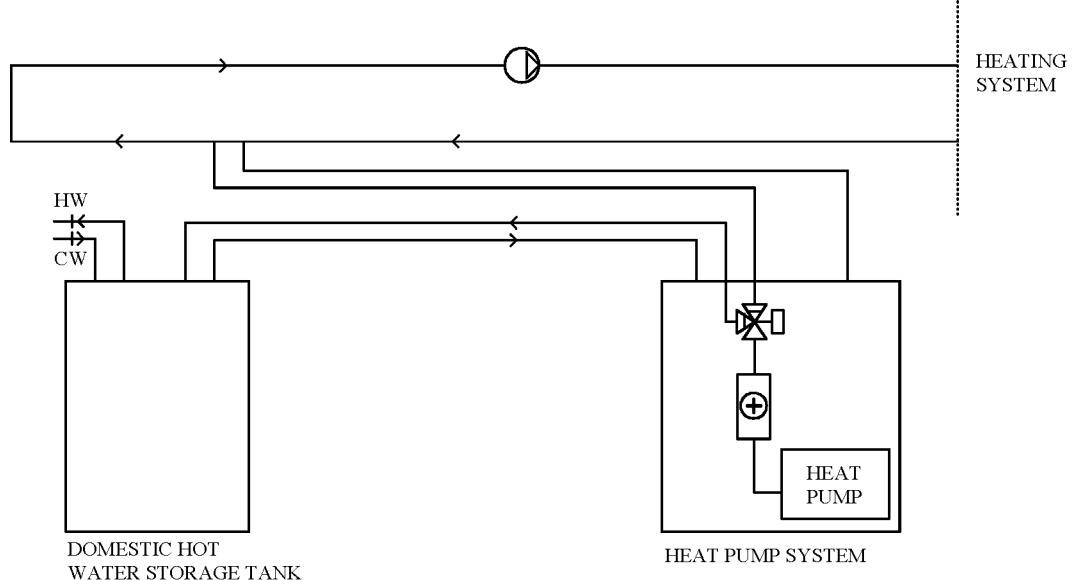


Figure 2.1 Typical configuration of a ground-source heat pump.

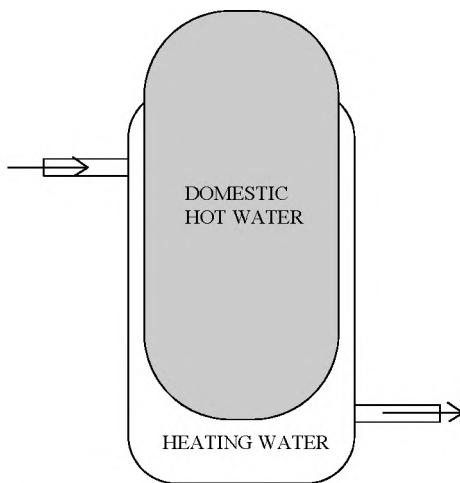


Figure 2.2 Double wall tank.

Another installation is to connect the heat pump to a storage tank as shown in Figure 2.3. In this case the storage tank contains the water for the heating system. This large buffer will reduce the number of on/off cycles for the heat pump. The heating water is also used for heating of the hot water. The hot water may be contained in a storage tank or in one or two coils mounted inside the large storage tank.

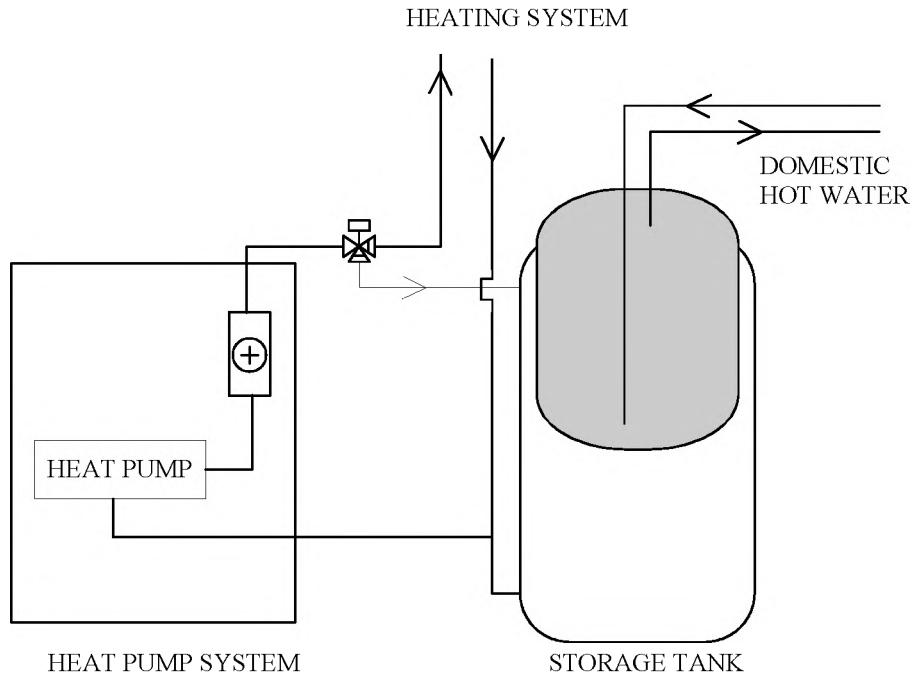


Figure 2.3 Heat pump connected to a storage tank for the heating water with a storage tank for the hot water installed inside.

Another important issue that must be notified is that these systems typically are not designed to cover the maximum heat load. They are sized to cover 55-60 % of the requested heat power at the dimensioning outdoor temperature (DOT). Then they cover approximately 90 % of the annual heat energy demand, as illustrated in Figure 2.4. The remaining part is covered by a supplementary heat source; typically an electric heater but also oil burners and boilers are used. This strategy to dimension the heat pump capacity started around 1985 and is an economic matter. To cover the last 10 % of the annual

energy demand a heat pump with a doubled capacity must be installed, which will be expensive. A heat pump covering the full load will operate with frequent on/off switching during many of its operating hours, which most likely will lead to a reduced life of the heat pump.

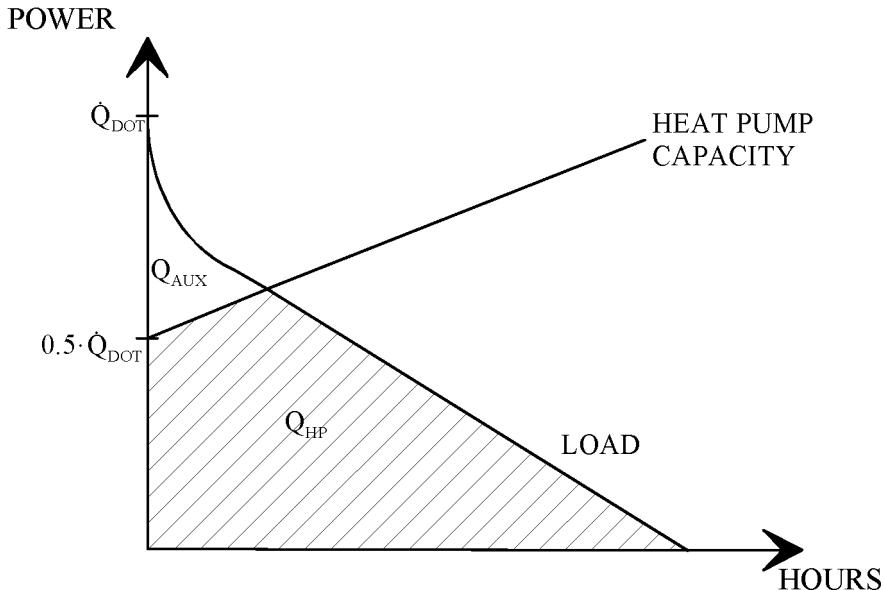


Figure 2.4 Covering 50 % of the power load means that approximately 85-90 % of the energy load is covered. The hatched area illustrates the energy supplied by the heat pump (Q_{HP}) and the area designated Q_{AUX} illustrates the energy supplied by the auxiliary heater.

Outdoor air units are installed in the same manner as the ground source units. They can be made both as single units, with the whole heat pump installed outdoors, or as split units where the condenser is installed indoors and the rest outdoors. Ducted units have been available on the market but are very rare now. These units also need a supplementary heat source that is able to cover the maximum heat load since they are shut off at low outdoor temperatures. These systems must be defrosted under certain conditions and almost always they use hot gas defrost by reversing the refrigerant flow via a four-way valve.

2.2 Exhaust-air heat pumps

The second most common heat pump in Sweden is the exhaust-air heat pump. This heat pump is used in houses with active ventilation system, mainly in small buildings. Exhaust-air heat pumps for apartment buildings or office buildings exist but hardly any new units are built. The heat pump withdraws heat from the exhaust-air and rejects the heat to domestic hot water, a hydronic heating system, to the supply air or a combination of these. The two first mentioned types or combinations of these are the most common. No exhaust-air heat pumps used for heating of the supply air have been sold since 1998. Typical solutions are shown in Figure 2.5 to Figure 2.8. The capacity of an exhaust-air heat pump is limited by the exhaust-air flow and can thus not be sized as the ground source units described in the previous section. The airflow is determined by the demands on ventilation, which is prescribed in the Swedish Building Regulations (BBR^[1]). This together with the size of the house determines the minimum airflow. Increasing this flow will, of course, increase the ventilation but also increase the inflow of outdoor air and thus increase the heating demand. Because of the limitation in capacity a supplementary heat source must always be available, in most cases it is an electric heater. When the exhaust-air heat pump is used for heating of both hot water and heating water the control

system often prioritise the heating system and if there is a simultaneous need for heating of hot water the supplementary heater provides the necessary capacity.

As shown in the figures below there exists different solutions for the heat release to the hot water. In Figure 2.5 and Figure 2.7 the refrigerant heat exchanges directly to the hot water. In Figure 2.5 a coil is placed inside the storage tank. In Figure 2.7 there is a small coil placed inside the storage tank for hot water where the refrigerant is desuperheated. A larger coil is placed inside the mantle of the storage tank and it heats both the hot water and the heating water. The system in this figure also use the most common solution for controlling the temperature fed to the heating system, the supply flow is mixed with the return flow via a shunt.

The solution showed in Figure 2.6 was more used a couple of years ago. The control is performed as in ground source heat pumps, if there is no need for heating of hot water the heating water is bypassed the storage tank. If there is a need for hot water heating the heating water pass through the coil situated inside the storage tank. A reversing valve controls the direction of the heating water flow. The heat pumps connected to the heating system use curve control as described in section 2.1 for capacity control.

To avoid problems with freezing on the evaporator and thus need for defrosting the compressor is often controlled such that no freezing occurs. This is common but there exist systems that allow freezing and then the evaporator is defrosted by means of stop defrosting, i.e. the compressor is turned off and the exhaust-air defrosts the evaporator.

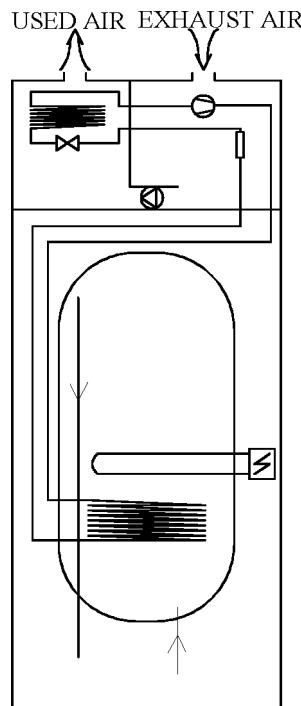


Figure 2.5 Exhaust-air heat pump for heating of hot water only.

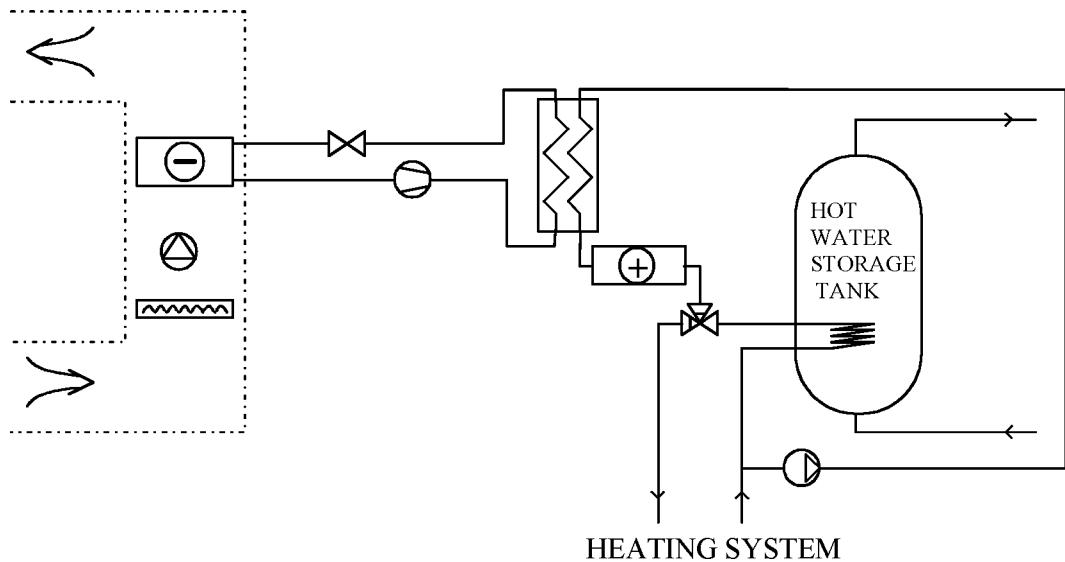


Figure 2.6 Exhaust-air heat pump for heating of both hot water and heating water. The heat pump switches between heating of hot water and heating system.

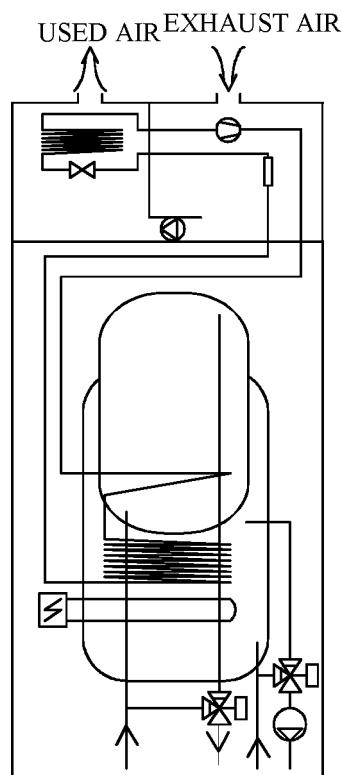


Figure 2.7 Exhaust-air heat pump for heating of both hot water and heating water. The heat pump does not switch between heating of hot water and heating system. This is the most common solution today.

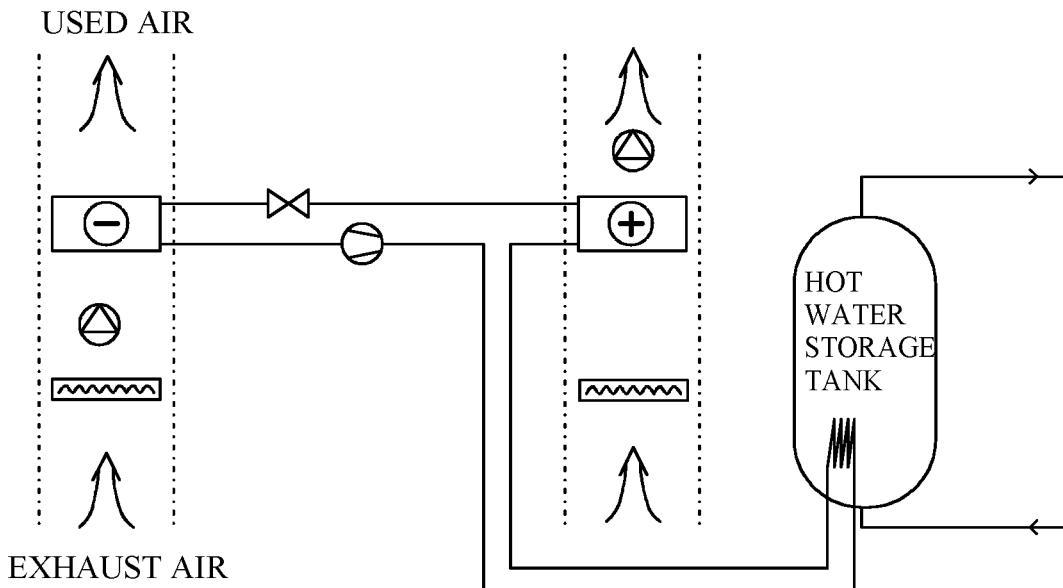


Figure 2.8 Exhaust-air heat pump for heating of both hot water and supply air.

2.3 Other units

In section 2.1 and 2.2 it have been assumed that the heat pumps adjusts their capacity to the load by using on/off control and curve control. Just recently one Swedish manufacturer released an outdoor air source heat pump containing a compressor with the possibility for capacity control in two stages, i.e. the compressor volume can be changed in two levels. In the future it is likely that heat pumps with continuous capacity control by means of variable-speed control will be available on the market.

Another interesting new solution is the combination of an exhaust-air heat pump and a ground source heat pump as shown in Figure 2.9. In this system the exhaust-air heats the brine flow, which increase in temperature and thus may increase the COP. If the heat pump is not in operation the energy from the exhaust-air is used for raising the temperature in the borehole.

Another hybrid heat pump involving exhaust-air is a heat pump using both outside-air and exhaust-air for the heat extraction. The airflows are mixed and the heat pump can then be used in the same manner as other exhaust-air units.

Ground-source heat pumps may also be used for providing cooling during the summer. This is achieved by using the cool liquid in the borehole and heat exchanging it to the water of the fan-coil system. In this way the house is cooled down and the temperature of the borehole is increased which may lead to increased efficiency of the heat pump system.

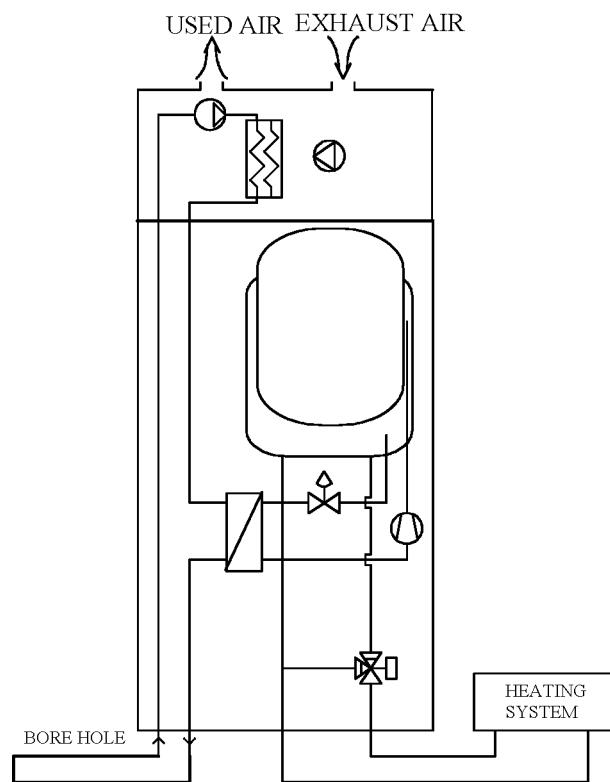


Figure 2.9 A combined exhaust-air and ground source heat pump.

3 Parameters to be measured

This chapter give suggestions to which parameters that should be measured in order to characterise the heat pump systems described in chapter 2.

3.1 Ground-source and outdoor-air-source heat pumps

For these heat pumps the parameters described in SS-EN 255-2^[13] and SS-EN 255-3^[14] is sufficient in order to characterise the system. Even though the two systems in Figure 2.1 and Figure 2.3 are somewhat different they should be tested according to these standards. The difference in operation can then be handled by a calculation method. In this way the test procedure can be the same for all systems. Another argument for this approach is that no heat pump is manufactured for just one special heating system; instead the same heat pump can be used in various systems. Thus the parameters that should be measured (as a minimum) is as follows:

Ground-source units:

- Temperature of the brine flowing in to the evaporator
- Temperature of the water flowing in and out of the condenser
- Water flow
- Brine flow
- Electric power

Outside-air-source units:

- Temperature of the air flowing in to the evaporator
- The humidity of the air flowing in to the evaporator
- Temperature of the water flowing in and out of the condenser
- Water flow
- Electric power

Both these types of heat pumps can be used for hot water heating and thus tests according to SS-EN 255-3^[14] can be used in order to characterise their performance. When the standby power input (P_{es}), the maximum quantity of usable hot water (V_{max}), the coefficient of performance (COP) and the reheating energy input (W_{et}) are determined, the characteristic of the heat pump while heating hot water is determined.

3.2 Exhaust-air heat pumps

The same parameters valid for outside-air-source heat pumps are also valid for exhaust-air heat pumps. They can also be used in air distributed heating systems and thus it is not always water that flows through the condenser. The parameters to be measured are:

- Temperature of the exhaust-air flowing in to the evaporator
- The humidity of the exhaust-air flowing in to the evaporator
- The exhaust-air flow
- Temperature of the water or air flowing in and out of the condenser
- Water or airflow through the condenser
- Electric power

Also for these units the SS-EN 255-3^[14] standard can be used for characterizing the system while heating hot water. For exhaust-air heat pumps the internal and external air leakage must also be measured. How and why are explained in chapter 5.

4 Temperature levels and draw-off profiles

Temperature levels, hot flows and draw-off profiles in regulations and standards used in Sweden are described in this chapter. Hot flows and profiles used for some other heating equipment is also included since they were considered valid also for heat pump systems.

4.1 Demands on temperature level for domestic hot water

In the Swedish Building Regulations (BBR^[1]), issued by the Swedish National Board of Housing, Building and Planning, paragraph 6:612 it is specified that, “Installations for hot water shall be designed such that the temperature at the hot water outlet is not less than 50 °C”. To avoid problems with microorganisms an advice in the regulations says that the water temperature, in applications where the hot water is stationary e.g. a storage tank, should exceed 60 °C.

In paragraph 8:42 it is specified that, “The temperature of hot water outlets for household use and personal hygiene shall not exceed 65 °C”. This paragraph is stated to avoid injuries due to burns.

4.2 Design guidelines and draw-off profiles

The following advice in the Swedish Building Regulations (BBR^[1]) is stated in order to provide a sufficient hot water flow and temperature level; “A water heater *without* storage in a single-occupancy house should have a heating capacity which provides a flow rate of 0.35 dm³/s of mixed cold and hot water of the temperature 40 °C. A water heater *with* storage in a single-occupancy house should be dimensioned such that it can heat cold water of 10 °C during a period not exceeding six hours such that it is possible to, within one hour, draw-off two volumes of 140 dm³ each of mixed hot and cold water with the temperature 40 °C. The flow rate should be not less than 0.2 dm³/s.”

This advice was formulated for single-occupancy houses. For apartment buildings, Svensk Fjärrvärme (the Swedish district heating association) has issued a piece of advice regarding the dimensioning hot water flow (FVF F:101^[5]). The following diagram concludes these, where the dimensioning hot water flow is plotted as a function of the number of apartments.

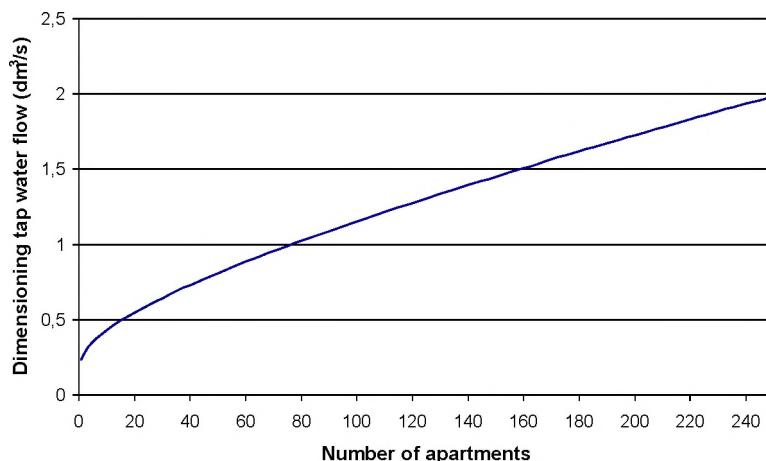


Figure 4.1 Dimensioning hot water flow as a function of the number of apartments (FVF F:101^[5]).

Standards for laboratory tests of heat pumps heating domestic hot water that is in use, or has been used, in Sweden quite recently is SS-EN 255-3^[14], SS 2095^[12], SP method 0029^[9] and SP method 2800^[10]. These will be further discussed in chapter 5 below. The draw-off profile and flows of SS-EN 255-3 should be well known and thus only SS 2095 and SP-method 0029 will be briefly discussed here (SP-method 2800 use the same pattern as SS-EN 255-3).

In the standard SS 2095 and the test method SP 0029 the hot water tests are performed as:

- Heating up period and stabilisation
- Standby power input
- Draw-off program to determine the COP
- Maximum quantity of usable hot water

The draw-off program consists of 5 draw-offs according to Table 4.1. The hot water draw-off starts at the specified hours and the draw-off continues until the hot water temperature falls below 40 °C or the specified maximum energy content is reached, whichever comes first. The water flow shall be 0.1 dm³/s. The fifth draw-off is used as a check, it should not deviate more than 10 % from the first draw-off. If it does the whole draw-off cycle must be repeated until the deviation is smaller than 10 %. The temperature of the cold water shall be +10 °C.

Table 4.1 Start hours and maximum energy content of the hot-water draw offs (SS 2095^[12]).

Start (h)	Maximum energy content (kWh)
1. 0.00	4.5
2. 6.00	0.9
3. 12.00	1.8
4. 16.00	3.6
5. 24.00	4.5

After this draw-off program follows a six-hour stabilisation period, and then a hot-water draw-off down to the outgoing temperature +40 °C is made. The flow is 0.2 dm³/s. The energy content in the draw-off is shown as equivalent amount of 40 °C water.

5 Existing standards and test methods

Below will standards and test methods for exhaust-air heat pump be described since this is a type of heat pump that is typical for Sweden and that is not well covered by any European or international standard. For other heat pump types as described in chapter 2 the EN 255 standard is used in Sweden.

5.1 SP-method 0029

This method is not a Swedish standard but is a test method that has been in use for many years. The whole heat pump system is tested, i.e. the heat pump plus the supplementary heater. The tests are made both for space heating only, and during space heating with a simultaneous hot water withdrawal and thus hot water heating. The test method is developed for Swedish circumstances. The test points, i.e. flows and temperatures are chosen based on the Swedish climate and the Swedish Building Regulations, BBR^[1].

Before the performance tests the heat pump unit is checked for external and, if applicable, internal leakage. All exhaust-air heat pumps are checked for external leakage according to NT-VVS 021^[6]. Exhaust-air heat pumps with two air-handling systems are checked for internal leakage, i.e. leakage between the two systems, NT-VVS 022^[7]. The leakage must be lower than 6 % of the nominal flow. If the leakage flow is larger than this the unit must be sealed. These tests are made for accuracy reasons; if the leakage between the surrounding and the heat pump is large there is no point of having an accurate measurement of the temperatures since there is no control of the flow.

5.1.1 Stationary tests

Stationary tests are performed at the test points specified in Table 5.1. During these tests any supplementary heater is switched off. Measurements at test points without frosting are performed during 30 minutes after a preceding period of 30 minutes of stable operation. For heat pumps with a built-in storage tank the tests are performed with an empty tank if not otherwise stated by the manufacturer. If the tank cannot be emptied the test period is lengthened to 24 hours consisting of a 12-hour stabilisation period followed by a 12-hour measurement period. During frosting conditions, i.e. the evaporating temperature is below zero degrees Celsius, the measurements are made for a whole number of cycles. A cycle is defined as the period between a defrost initiation to the next initiation of a defrost. If this period is shorter than 8 hours then measurements shall be performed during three complete cycles. If the period is between 8 and 12 hours measurements are made for two cycles, and if the period is longer than 12 hours the measurements are continued for maximum 24 hours. The temperature of the high-temperature heat transfer media entering the heat pump shall be kept at the specified value during these frosting and defrosting cycles.

Table 5.1 Test points for stationary tests.

Heat source (temperatures and flows to the heat pump)		Heat sink (temperatures and flows to the heat pump)					
Exhaust-air		Heating water		Supply air		Circulated air	
Temp (°C)	Flow (m ³ /h)	Temp (°C)	Flow (m ³ /h)	Temp (°C)	Flow (m ³ /h)	Temp (°C)	Flow (m ³ /h)
1. 20(13)	150	33.1	0.408	2	150	10	q_n
2. 20(11)*	150	33.1	0.408	2	150	20	q_n
3. 20(15)*	150	33.1	0.408	2	140	20	q_n
4. 20(13)	100*	33.1	0.408	2	100*	20	q_n
5. 20(13)	150	33.1	0.303*	2	100*	20	q_n
6. 20(13)	200*	33.1	0.408	2	150	20	q_n
7. 20(13)	150	33.1	0.510*	2	200*	20	q_n
8. 20(13)	150	42.6*	0.408	-15*	150	20	q_n
9. 20(13)	150	33.1	0.408	2	25*	25*	q_n
10. 20(13)	150	33.1	0.408	2	150	20	0.5 q_n *

- Temperatures within parenthesis are the wet bulb temperature.
 - q_n is the nominal circulated flow.
 - Conditions marked with a * indicates that the condition is changed from the nominal test point.

5.1.2 Testing of the heat pump system

The whole heat pump system (heat pump plus supplementary heater) is tested during hot water heating and combined hot water heating and space heating. The following parameters can be determined from these tests:

- The heating-up time
- The stand-by power input
- The coefficient of performance for the system
- The maximum usable quantity of hot water

The test points are stated in Table 5.2. Points 1-5 are so called summer draw-offs and are valid for heat pumps that heats hot water only. Points 6-10 are valid for heat pump used for both hot water heating and space heating.

The summer draw-offs consists of four tests:

- Heating-up and stabilisation
- Standby power input
- Draw-off program
- Continuous draw-off

Heating-up and stabilisation begins when the heat pump starts to operate. The hot water storage is filled with water of 10 °C. The heating-up period is the time between the start of the heat pump to the first shut-off. Then the stabilisation phase begins and it ends at the first compressor stop after 12 hours. The standby power is then measured for at least 12 hours and ends at the first compressor stop after that. During the standby test no hot water is drawn off. The standby power input is defined as the ratio between the electric energy

fed to the heat pump system and the time for the test. The following draw-off program is specified in Table 5.3. It is used for determining the COP for the system. The fifth draw-off is a control, the energy content of this must not deviate more than 10 % from the first draw-off. The hot water flow shall be 0.1 dm³/s. Each draw-off is continued until the hot water temperature goes below +40 °C, but not longer than specified by the maximum energy content in Table 5.3. The COP for the system is then defined as the ratio between the total energy content of the draw-offs and the total electric energy supplied to the heat pump. After the draw-off program a 6-hour stabilisation period follows and then a continuous draw-off starts at the next compressor stop. The hot water flow shall be 0.2 dm³/s and the draw-off continues until the hot water out of the storage tank goes below +40 °C.

For the winter case, the tests include a draw-off program as described for the summer case with a simultaneous space heating demand. The measurements lasts for 24 hours, determined by the draw-off program in Table 5.3.

Table 5.2 Test points for testing of the entire heat pump system. All points are measured during 24 hours with draw-offs according to Table 5.3.

Heat source (temperatures and flows to the heat pump)		Heat sink (temperatures and flows to the heat pump)					
Exhaust-air		Heating water		Supply air		Circulated air	
Temp (°C)	Flow (m ³ /h)	Temp (°C)	Flow (m ³ /h)	Temp (°C)	Flow (m ³ /h)	Temp (°C)	Flow (m ³ /h)
1. 20(13)	100	-*	-*	-*	150	-*	q _n *
2. 20(13)	200	-*	-*	-*	150	-*	q _n *
3. 20(11)	150	-*	-*	-*	150	-*	q _n *
4. 20(13)	150	-*	-*	-*	150	-*	q _n *
5. 20(15)	150	-*	-*	-*	150*	-*	q _n *
6. 20(14)	150	29.8	0.408	7	150	20	q _n
7. 20(13)	150	33.1	0.408	2	150	20	q _n
8. 20(13)	100	33.1	0.408	2	100	20	q _n
9. 20(12)	150	38.4	0.408	-7	150	20	q _n
10. 20(11)	150	42.6	0.408	-15	150	20	q _n

- The temperature within parenthesis is the wet bulb temperature.
 - q_n is the nominal circulated flow.
 - * At this so-called summer draw-off no heat load is present. Supply air fans operate continuously. Radiator pumps and circulation air fans operate only if the control system demands it. The test points 1-4 are valid only for heat pumps heating hot water only.

Table 5.3 Times and maximum energy content for draw-offs.

Draw-off (No.)	Start of draw-off (h)	Energy content (kWh)	Approximate water volume (dm ³)
1	0.00	4.5	111
2	6.00	0.9	22
3	12.00	1.8	44
4	16.00	3.6	88
(5)	(24.00)	(4.5)	(111)

5.1.3 Comparison to EN 255

From the description above it is quite obvious that there are a number of differences between the SP-method 0029 and EN 255. The test conditions in the SP-method are based on typical Swedish circumstances, such as climate and regulations. This method also describes how to measure the performance during a simultaneous need for space and hot water heating, which is the objective of the IEA HPP Annex 28. The testing of hot water heating performance differs from the EN 255-3 but it is mainly a difference in which order the different tests are performed. The major difference is the cold water temperature which is +10 °C in SP-method 0029 and + 15 °C in EN 255. One other major, and very important, difference is that the EN 255 does not prescribe the necessity of the tests for internal and external leakage. These tests are important to perform; otherwise nothing can be said about the accuracy of the tests. EN 255 contains test point for exhaust-air heat pumps but only a few test points are included. Also, no exhaust-air flow is prescribed, which is the case in the SP-method. A flow should be prescribed since this is linked to the regulations concerned with ventilation and indoor climate and it also affects the COP.

5.2 SP-method 2800

This method is also concerned with exhaust-air heat pumps. The method is based on the SP-method 0029 with the aim to adapt that method to EN 255. Because of that the tests for hot water heating and space heating is separated and performed according to EN 255. The test points for the space heating are shown in Table 5.4. The wet bulb temperatures have also been changed from the values in SP-method 0029 in order to adapt to EN 255. Neither is the heating water flow specified due to the same reason.

Table 5.4 Test points for exhaust-air heat pumps according to SP-method 2800.

Heat source (temperatures and flows to the heat pump)		Heat sink (temperatures and flows to the heat pump except for the heating water where the temperature fed from the heat pump is given)					
Exhaust-air		Heating water	Supply air		Circulated air		
Temp (°C)	Flow (m ³ /h)	Temp (°C)	Temp (°C)	Flow (m ³ /h)	Temp (°C)	Flow (m ³ /h)	
1. 20(10)	150	35	2	150	20	q_n	
2. 20(12)	150	35	2	150	20	q_n	
3. 20(15)	150	35	2	150	20	q_n	
4. 20(10)	150	50	2	150	20	q_n	
5. 20(12)	150	50	2	150	20	q_n	
6. 20(15)	150	50	2	150	20	q_n	
7. 20(12)	100	35	2	100	20	q_n	
8. 20(12)	100	50	2	100	20	q_n	
9. 20(12)	200	35	2	200	20	q_n	
10. 20(12)	200	50	2	200	20	q_n	

- The temperature within parenthesis is the wet bulb temperature.
 - q_n is the nominal circulated flow.

5.3 NT-VVS 086

This standard is directed towards laboratory testing of large exhaust-air heat pumps used in apartment buildings etc. The tests are divided into stationary performance tests and sanitary hot water tests. The performance tests are executed at the climatic conditions stated in Table 5.5 and Table 5.6.

For test points without frost formation the measurements should last for 30 minutes after a preceding 30 minutes where the heat pump has been in stable operation. For test points with frost formation the measurements should contain 3 complete cycles if the time for one cycle is less than 8 hours. If the cycle time is between 8 and 12 hours two cycles should be measured. If the cycle time exceeds 12 hours the measurements should last for a maximum of 24 hours.

Table 5.5 Test points for heat pumps for installation indoors.

Test point	Ambient temperature °C	Exhaust-air temperature (incoming) °C	Heating water temperature (outgoing) °C	Supply air temperature (incoming) °C	Circulated air temperature (incoming) °C	Exhaust-air flow (% of nominal flow rate)
1	+20	+20(12)	65*	-15	20	100
2	+20	+20(12)	50	-15	20	100
3	+20	+20(12)	35	+2	20	100
4	+20	+20(15)	50	-15	20	100
5	+20	+20(12)	50	-15	20	80**
6	+20	+20(12)	50	-15	20	120
7	+20	+15(10)**	50	-15	20	100

* Or highest temperature as recommended by the manufacturer

** Or lowest flow or temperature as recommended by the manufacturer

Table 5.6 Test points for heat pumps for installation outdoors.

Test point	Ambient temperature °C	Exhaust-air temperature (incoming) °C	Heating water temperature (outgoing) °C	Supply air temperature (incoming) °C	Circulated air temperature (incoming) °C	Exhaust-air flow (% of nominal flow rate)
1	+2	+20(12)	65*	-15	20	100
2	+2	+20(12)	50	-15	20	100
3	+2	+20(12)	35	+2	20	100
4	-15	+20(15)	50	-15	20	100
5	+2	+20(12)	50	-15	20	80**
6	+2	+20(12)	50	-15	20	120
7	+2	+15(10)**	50	-15	20	100

* Or highest temperature as recommended by the manufacturer

** Or lowest flow or temperature as recommended by the manufacturer

If the heat pump is intended for domestic hot water heating this should be tested. This test is performed as the hot water test in SP-method 0029. The differences are in the two last points, the draw-off program and the continuous draw-off. The draw-off program is shown in Table 5.7, where the last draw-off is only a check the energy content of this draw-off should not differ more than 10 % from the first draw-off.

The flow rates and energy contents in the table are valid for one apartment. If the heat pump is intended for apartment buildings the following correction should be done. The energy content should be corrected as:

$$Q_{1vvi} = Q_{0vvi} \cdot \text{number of apartments}$$

where:

Q_{1vvi} = Energy quantity

Q_{0vvi} = Energy quantity for each draw-off according to Table 5.7.

The hot water flow should be determined as:

$$q_{vvv} = q_{mvvl} \cdot \lambda$$

where:

q_{vvv} = Flow rate

q_{mvvl} = Flow rate according to Table 5.7

λ = Conversion factor obtained from Table 5.8. Obtain values of λ for draw-offs 1, 4 and 5 from column 2, and for draw-offs 2 and 3 from column 1.

Table 5.7 Times and maximum draw-off energy quantities and flow rates for one apartment.

Start hours	Maximum energy quantity drawn off (kWh)	Flow (dm ³ /s)
0.00	3.4	0.1
6.00	0.7	0.1
12.00	1.4	0.1
16.00	2.7	0.1
24.00	4.5	0.1

Table 5.8 Conversion factors for standard apartments with allowance for diversity, suitable for correction of flow rates and heating power.

Number of apartments	1	2
1	1	1
2	1.07	1.25
3	1.13	1.43
4	1.18	1.59
5	1.22	1.74
10	1.40	2.32
20	1.67	3.23
30	1.91	4.00
40	2.12	4.69
50	2.31	5.34
60	2.50	5.95
70	2.68	6.54
80	2.85	7.11
90	3.02	7.66
100	3.18	8.20

For the continuous draw off the flow should be corrected for the number of apartments as:

$$q_{mvv} = 0.2 \cdot \lambda$$

where:

λ = Conversion factor obtained from Table 5.8, column 2.

The draw-off continues until the hot water temperature has dropped below + 45 °C.

The comments on this standard when compared to the EN 255 standard is similar to the comments of SP-method 0029 and thus no further comments are made here.

5.4 Energy and quality labels

There are two marking systems in Sweden today, the **P**-mark, which is a quality marking and the Swan that is an eco-label.

5.4.1 The **P**-mark

The **P**-mark (SPCR 130^[11]) is a quality marking that has been developed by the SP Swedish National Testing and Research Institute together with Swedish heat pump associations and manufacturers. To receive the marking the product must fulfil:

- Efficiency demands (COP at certain operating points)
- Efficiency demands when heating domestic hot water (if applicable)
- The Swedish Refrigeration Code
- The Swedish Building Regulations
- Noise levels according to the Swedish Building Regulations
- Demands for CE-marking, both for electricity and pressure vessels
- Demands on the information in the manuals and installation instructions
- Demands on the quality of the manufacturing. This is controlled by surveillance inspections

For further information about the **P**-mark visit SP's homepage at www.sp.se.

5.4.2 The Swan

The Swan is a Nordic eco-label introduced by the Nordic Council of Ministers. The marking put demands on:

- Noise
- The refrigerant
- The secondary refrigerant
- Plastic details
- Surface treatments
- Packaging material
- Efficiency
- The information material

The refrigerants allowed must not have an ODP>0 and/or a GWP>1900 (time perspective 100 years). The secondary refrigerant and/or additives must not be considered as harmful for the environment. Plastic details, surface treatments and packaging material must not contain certain compounds, such as lead or cadmium.

The COP must, for water/water, brine/water and outside air/water heat pumps, be larger than 25 % of the thermodynamic possible. For air/air heat pumps this must be above 9 %.

$$COP_{\min} = 0.25 \cdot \frac{T_k}{T_s - T_k} + 1; COP_{\min} = 0.09 \cdot \frac{T_k}{T_s - T_k} + 1$$

T_s = The temperature of the heat transfer media out of the condenser

T_k = The temperature of the heat transfer media entering the evaporator

More information about the swan can be found at www.svanen.nu.

6 References

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- 14 SS-EN 255-3, 1997, Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors - Heating mode - Part 3: Testing and requirements for marking for sanitary hot water units. (CEN.) Brussels, Belgium.

7 Literature

The list below contains reports, articles etc that should be interesting to this IEA Heat Pump Programme Annex 28.

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