HVAC HESS

PEOPLE

PRACTICES

SYSTEMS

Factsheet

Heat Pump and Heat Recovery Technologies

Heat Pump Cycle

A heat pump cycle, as illustrated in Figure 1, absorbs heat from a source and transfers it to a sink. An evaporator extracts the heat from the source by transferring the heat to a refrigerant. The heat transfer to the refrigerant causes it to change from liquid to gas phase (i.e. evaporate). The evaporated refrigerant gas pressure and temperature is raised utilising a compressor and transferred to the condenser. Heat transfer to the sink causes the high pressure refrigerant gas to condense to a liquid state within the condenser. An expansion valve lowers the pressure of the liquid refrigerant and this expansion process also causes a drop in the liquid refrigerant temperature as the refrigerant enters the evaporator restarting the cycle.

Figure 1: Heat Pump Cycle[1]
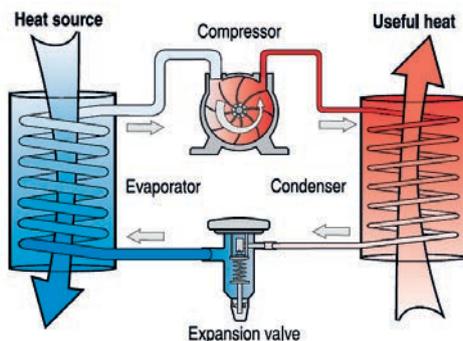
All refrigeration equipment (i.e. air-conditioners, chillers etc.) can be classified as heat pumps. However, in engineering, heat pump terminology is reserved for equipment that produces heat as the usable output as opposed to refrigeration plant that produces cooling as the usable output.

In addition, heat pumps can also incorporate the ability to provide a cooling effect by including appropriate changeover/reversing valves.

Types of Heat Pumps

Heat pumps are typically classified by a number of parameters but the most common classifications utilise the heat source and heating distribution fluid.

The four basic types of heat pumps available are as follows:

1. Air-to-Air Heat Pumps – most common form of heat pump that utilises air as the heat source and air is utilised to distribute heating to the space/process

2. Water-to-Air Heat Pumps – water is utilised as the heat source and air is utilised to distribute heating to the space/process

3. Water-to-Water Heat Pumps – water is utilised as the heat source and water is utilised to distribute heating to the space/ process

4. Ground Source Heat Pumps – ground is utilised as the heat source (i.e. refrigerant circuit is reticulated in the ground). This type is different from a Ground Coupled heat pump that utilises a water loop to reject/absorb heat to/from the ground connected to a water-to-air heat pump.

Heat Pump Performance

The performance efficiency of a heat pump is represented by the Coefficient of Performance (COP) that is defined as:

$$COP_{HP} = \frac{Useful\ Heating\ Capacity\ Output\ [kW]}{Required\ Work\ Input\ [kW]}$$

It is not uncommon to find heat pump COPs of around three for modern equipment (i.e. 1 kW of electricity input provides 3 kW of useful heating output).

Heat Recovery

Heat recovery in a broad sense refers to waste heat and cooling recovery and utilisation. It can range from a simple heat exchanger for energy recovery to utilising a heat pump to translate low grade (low temperature) rejected heat to usable heat in a process.

The primary distinction between a heat pump and heat recovery cycle is that a heat pump cycle will produce only one useful effect (i.e. heating or cooling) at a time whereas a heat recovery cycle will produce both effects simultaneously.

1   Heat Pump Centre (2012), International Energy Agency Heat Pump Program. www.heatpumpcentre.org/en/aboutheatpumps/Sidor/default.aspx

Types of Heat Recovery Systems

Unlike heat pumps, that are typically available as a single package, heat recovery systems are assembled by combining a number of systems to enable heat recovery functionality. Some examples include:

▶ variable refrigerant flow systems that enable recovery of energy between cooling and heating systems

▶ reverse cycle water-to-air heat pumps on a common water loop that allows recovery of energy between units rejecting heat and those requiring heat

▶ heat-reclaim chillers that simultaneously provide heating and cooling

▶ utilising run-around coils or heat-exchangers to recover energy from air exhausted from a building to pre-temper outside-air introduced into the building.

Heat Recovery Performance

As per the heat pump cycle, COP is used to represent the performance of a heat recovery cycle. However, the COP is modified to accommodate the simultaneous useful heating and cooling effect, and defined as:

$$COP_{HR} = \frac{Heating\ Capacity\ [kW] + Cooling\ Capacity[kW]}{Required\ Work\ Input\ \ [kW]}$$

Heat Recovery systems COPs are dependent on the quality (temperature) of heat output on the condenser side. Typical COPs for Heat Recovery systems would be in excess of 5.
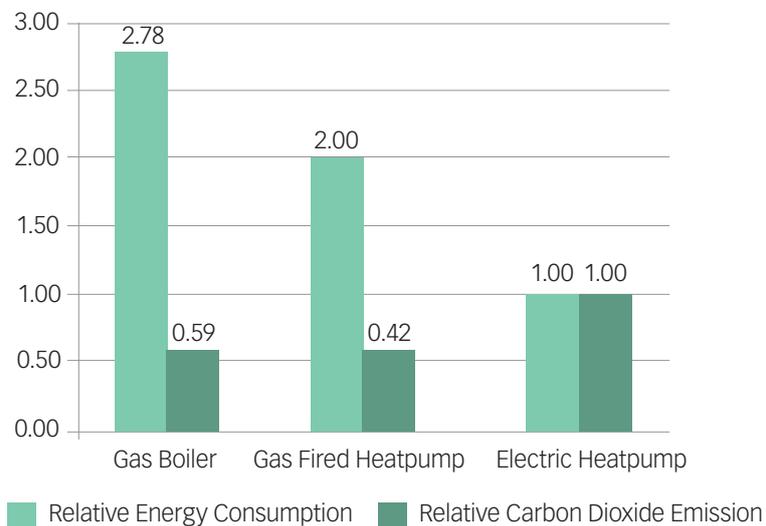
Energy Efficiency Impact

The major energy saving benefit of heat pumps is their ability to improve energy utilisation efficiency. That is, heat pumps typically use less energy input for the same heat output. However, the disadvantage is that the majority of heat pumps utilise electricity as their power input. Energy sourced from the Australian electricity grid incurs an average of four times as much carbon dioxide emission as the same energy sourced from Natural Gas. Future de-carbonisation of the electricity grid would help reduce this difference and further strengthen the case for heat pump utilisation.

The relative energy consumption and carbon dioxide emissions for gas-fired boiler, gas-fired heat pump and electric heat pump are summarised in Figure 2 where the electric heat pump has been assigned a relative value of 1.00. The comparison relates to the Australia market and the following values have been assumed[2]:

▶ Gas-fired boiler COP - 0.9 $\frac{kW_{thermal}}{kW_{gas}}$

▶ Gas-fired heat pump COP - 1.25 $\frac{kW_{thermal}}{kW_{gas}}$

▶ Electric heat pump COP - 2.5 $\frac{kW_{thermal}}{kW_{electricity}}$

▶ Electricity emissions - 1.04 kgCO$_2$-e/kWh

▶ Gas emissions - 0.22 kgCO$_2$-e/kWh.

These values demonstrate that for every kW of energy added, a boiler would only output around 0.9 kW useful heat whereas a gas-fired heat pump would provide 1.25 kW i.e. a boiler will use more energy than a gas-fired heat pump.

Figure 2: Energy Consumption and Carbon Dioxide Emissions Comparison (NDY Management)

A gas-fired heat pump consumes nearly twice as much energy as an electric heat pump but only has 42% of CO$_2$ emissions.

Heat recovery technologies typically provide varying degrees of energy efficiency but do require assessment on a case-by-case basis to ensure a holistic review with regards to energy impact and life cycle costs.

---

2 Department of Climate Change and Energy Efficiency (2012), National Greenhouse Accounts Factors-July 2012, www.climatechange.gov.au

HVAC HESS

The Heating, Ventilation and Air-Conditioning High Efficiency Systems Strategy (HVAC HESS) is a ten year strategy under the National Strategy on Energy Efficiency that aims to drive long term improvements in energy efficiency of HVAC systems Australia wide. Under the Energy Efficiency Working Group, the Buildings Committee manages the implementation of the HVAC HESS. This committee is comprised of representatives from Australian, State and Territory Governments.

The Strategy takes a whole of life perspective in targeting HVAC efficiency improvement, encompassing the design, manufacture, installation, operation and maintenance stages of the HVAC lifecycle. The Strategy consists of a number of complementary measures that fall under three broad initiatives – People, Practices and Systems. This Heat Pump and Heat Recovery Technologies factsheet specifically relates to Systems. It is one of a suite of factsheets developed to provide a quick overview and reference to inform, educate, and encourage energy efficiency in the HVAC industry.

A series of HVAC HESS factsheets can be found at:
http://ee.ret.gov.au/

Acknowledgements