ISSUE600 BULLETIN

HEAT PUMPS

August 2016

- Heat pumps provide an energy-efficient means of heating and cooling room air.
- This bulletin focuses on the mechanics, performance and application of air-to-air, split, reversible-cycle heat pumps.
- This bulletin updates and replaces Bulletin 473 of the same name.

1.0 INTRODUCTION

1.0.1 Heat pumps use refrigerants to transfer heat from one location to another. This can include either heating or cooling of indoor air depending on the direction of the heat transfer. There are numerous configurations on the basic system, and a variety of terminology is used (see section 2.0).

1.0.2 This bulletin concentrates on the use of air-to-air, split, reverse-cycle heat pumps, which are commonly referred to as heat pumps. In Australia, cooling is more commonly used, and these units are typically known as reverse-cycle air conditioners. Refrigerant flows in a loop between separate indoor and outdoor units. Indoor air is recirculated by a fan through the coil (heat exchanger) in the indoor unit, where it is either heated or cooled. This conditioned air is mixed with room air to change the room temperature. A corresponding amount of heat is transferred to the outside air through the coil by a fan in the outdoor unit.

1.0.3 Air-to-air, split, reversible-cycle heat pumps are typically used in small to medium-sized building spaces, depending on capacity. They normally condition one room but can do more with different configurations.

1.0.4 This bulletin updates and replaces Bulletin 473 of the same name.

2.0 HEAT PUMP SYSTEMS

2.0.1 Heat pump systems can be differentiated by the heat sources and heat sinks:

- Air-to-air heat pumps transfer heat to/from air outdoors to air indoors. They are the simplest system and most commonly used to control room air temperature.
- Air-to-water heat pumps extract heat from the outdoor air via coils in the outdoor unit and transfer the heat into water that can be stored in a hot water cylinder or circulated through underfloor coils for space heating. Air-to-water heat pumps are discussed in Bulletin 589 *Heat pump water heating*.

2.0.2 Other heat sources and heat sinks can include exhaust air, industrial waste heat, groundwater, swimming pools, rivers, lakes, oceans, geothermal and soil (ground). These are generally used in larger and more sophisticated systems.

2.1 TYPES OF HEAT PUMP SYSTEMS

2.1.1 System configurations are based on unit locations:

- Through the wall – also called room or unitary heat pumps, where indoor and outdoor coils are in the same unit fixed through an external wall of a room. These are less popular as they tend to be noisy.
- Split – also called mini split, where one outdoor unit supplies a separate single indoor unit located in the space being conditioned. The outdoor and indoor units can be separately located for best efficiency (such as unobstructed airflow), but ideally, they should not be too far apart.
- Multi-split – one outdoor unit supplies refrigerant to a number of indoor units in different rooms, separately controlled by room space temperature and refrigerant flow rate and airflow rate.
- Ducted – one indoor unit located in a building void space (for example, above the ceiling) has many conditioned air supply ducts to a number of rooms, separately controlled by airflow rate.

3.0 REFRIGERATION CYCLE

3.0.1 A heat pump uses circulating phase change refrigerant to absorb heat from one space (heat source) and then transfer and release this heat to another separate space (heat sink), either of which can be the room air or outside air.

3.1 REFRIGERATION CYCLE COMPONENTS

3.1.1 The continuous cycle for the refrigerant (Figure 1) is:

- compression at the compressor – refrigerant pressure is increased, which increases its condensing temperature to above the air temperature passing through the condenser coil, and the heat of compression is added
- condensation at the condenser coil – higher temperature refrigerant condenses from gas to liquid as it releases heat to the lower temperature room air (in heating cycle) or outdoor air (in cooling cycle)
- expansion at the expansion device – refrigerant pressure is decreased by throttling it through a valve, which also restricts flow rate to the evaporator coil, while also decreasing its evaporation temperature
- evaporation at the evaporator coil – lower temperature refrigerant evaporates from liquid to gas as it absorbs heat from the higher temperature outdoor air (in heating cycle) or room air (in cooling cycle).

3.1.2 It is the refrigerant changing state between a liquid and a gas in the coils that provides the heating or cooling capacity to give the high energy efficiency of a heat pump. Refrigerant at high pressure condenses to liquid and is subcooled to a lower temperature. Refrigerant at low pressure evaporates to gas and is superheated to a higher temperature.

3.2 REVERSIBLE CYCLE

3.2.1 The coils do not move in a reversible cycle, but simply swap function from being a condenser that releases heat to being an evaporator that absorbs heat and vice versa. The refrigerant flows in the same direction through the same compressor (and sometimes through the same expansion device), but valves switch the inlet and outlet flow from each of the coils.

3.2.2 This means the air in a building can be heated

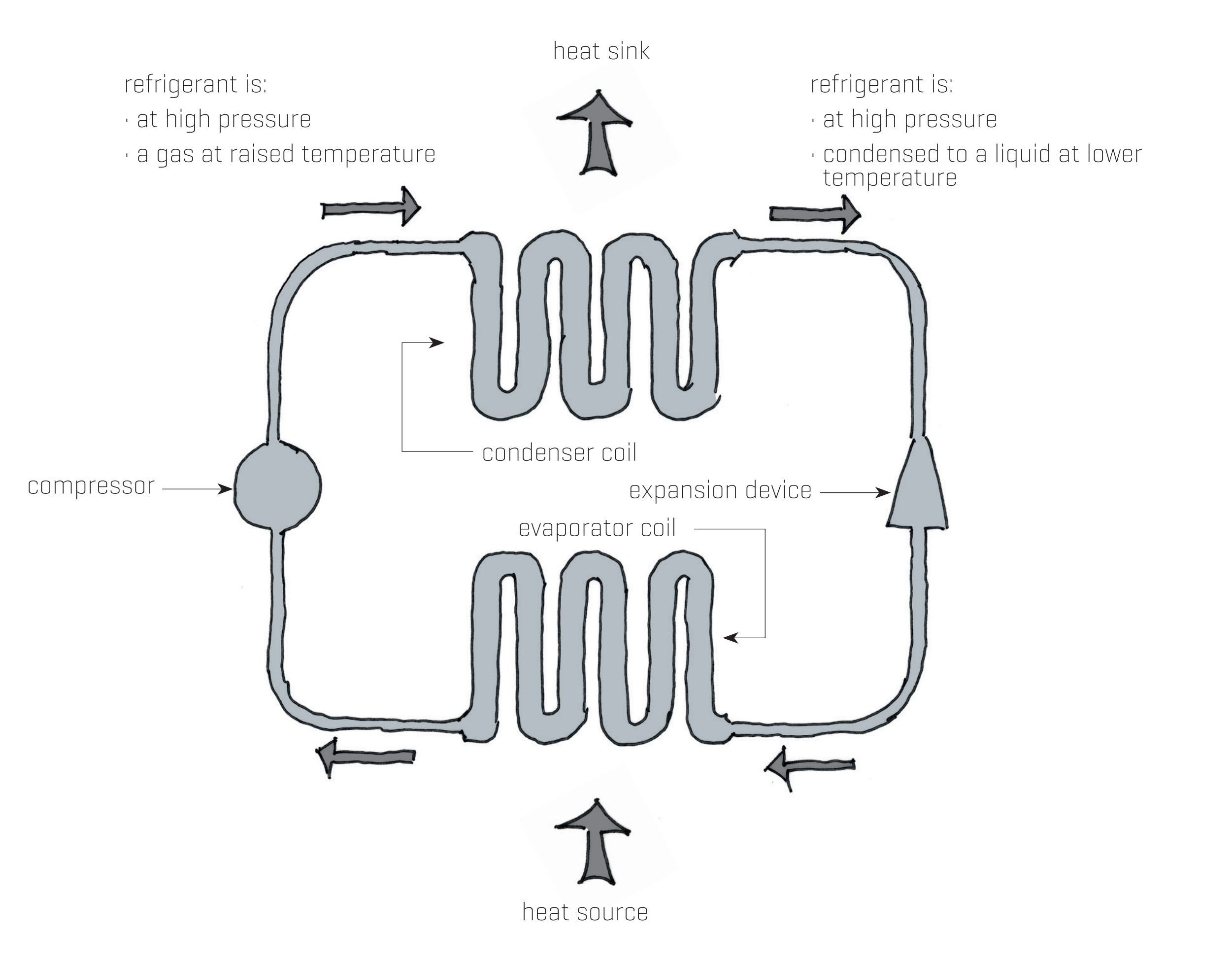

Figure 1. Basic refrigeration cycle for a heat pump.

(Figure 2) or cooled (Figure 3), depending on the path of the refrigerant flow into the coils.

3.2.3 Some spaces require heating only or cooling only, meaning the heat pump capacity can be optimised and the coils do not change role. For cooling only, the whole system is called an air conditioner.

4.0 INSTALLATION

4.0.1 EECA has produced a guide (*Good practice guide: Heat pump installation*) to installing heat pumps (see 11.3). This guide includes step-by-step instructions and diagrams. The guide also provides checklists to ensure all aspects are covered.

5.0 HEAT PUMP APPLICATIONS

5.0.1 Heat pumps can be used in just about any situation where there is a need for heating and cooling of air in the building. Typical heat pumps with space heating and cooling capacity between 2 kW and 16 kW are suited to:

- a room or connected rooms within a house (2–10 kW)
- one or two office rooms (2–10 kW)
- small halls
- medium-sized lecture or conference rooms (15 kW+)
- hotel rooms (5–10 kW)
- medium-sized shops (15 kW+)
- small gyms (15 kW+)
- small light industrial working areas (10 kW+).

5.1 NATURE OF OPERATION

5.1.1 Heat pumps change the room temperature by providing a heated or cooled air stream from the indoor unit. Heat pumps therefore act more like a convective heater than a radiant heater. This means the nature of their heat output is similar to that of a fan heater rather than a radiant bar heater. It can take some adjustment for people used to sitting in front of a radiant bar heater with its fast radiant heat to experiencing the more enveloping heat from a heat pump.

5.1.2 As a convective type heater, the airflow from a heat pump and around the room needs to be carefully considered. This includes the type and placement of the indoor unit (see section 7.0) as well as how it is operated (see section 10.0).

5.2 NOT A VENTILATION SYSTEM

5.2.1 The majority of heat pump systems do not include a fresh-air supply system – they only recirculate the room air. Consequently, ventilation requirements for the space need to be managed by other means.

5.3 NOT A SUBSTITUTE FOR GOOD THERMAL DESIGN

5.3.1 A BRANZ study of heat pump use (Study Report 329 *Heat pumps in New Zealand*) revealed that good thermal design (including insulation and airtightness) of a building is important in achieving good conditions within the building. The study also found that few of the participants used their heat pump in cooling mode. With a low demand for cooling, overheating may be more effectively managed by good eave and overhang design and appropriate sizing and placement of windows.

6.0 OUTDOOR UNIT

6.0.1 To maximise heat transfer and heat pump capacity, the outdoor coil needs an unrestricted supply of air. Therefore, the inlet air path should be unobstructed, and the outlet air should be directed away from the coil and the air inlet. Typically, the gap from the outdoor unit to any obstruction should be a minimum of 500–1,500 mm on the air outlet and 100 mm to any other face.

6.0.2 Hot and cold air is exhausted from the unit, and this can damage plants, animals or hygroscopic materials in the vicinity. In heating mode, water will usually condense on the outdoor units, so there is a need to provide for this condensate to drain away safely.

6.0.3 Compressors and fans can create nuisance noise. The unit should be positioned to avoid nuisance to people in the building and the surrounds and, in particular, neighbouring properties.

6.0.4 Particles blown or splashed onto the coils, fan and compressor can affect durability and capacity. Rain washing can help if regular washing does not occur.

6.0.5 The outdoor unit should be fixed onto a solid base so that:

- the unit does not fall over in earthquakes, physical contact and high winds
- its weight is supported
- vibrations are damped out
- it is sitting horizontally
- it has clearance so that debris doesn't accumulate under the base.

6.0.6 In general, it's best to avoid placing the outdoor unit on a south-facing wall. Ideally, it should be located on a north-facing wall to ensure it gets the maximum amount of sun during the day. There may need to be compromises in outdoor unit placement to ensure it doesn't end up in a location where it will be exposed to excess moisture or clogged with debris. In addition, it's important to ensure the

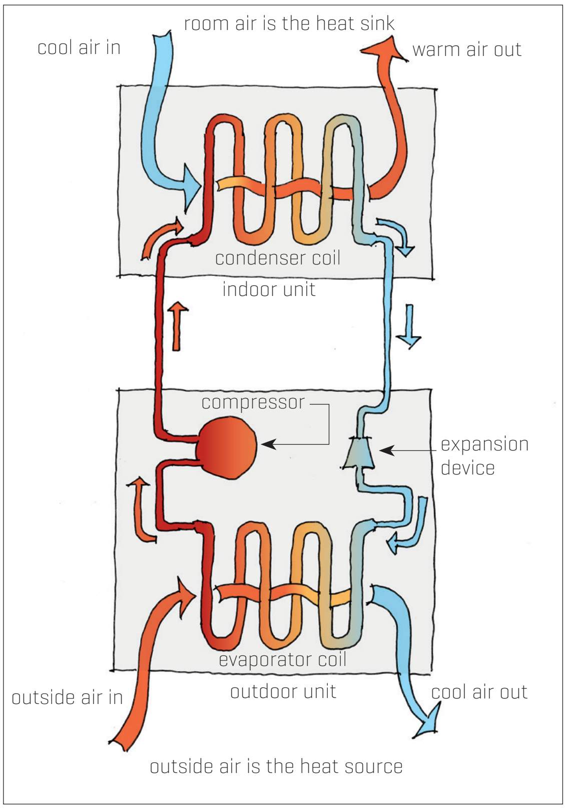

Figure 2. Basic heat pump heating cycle.

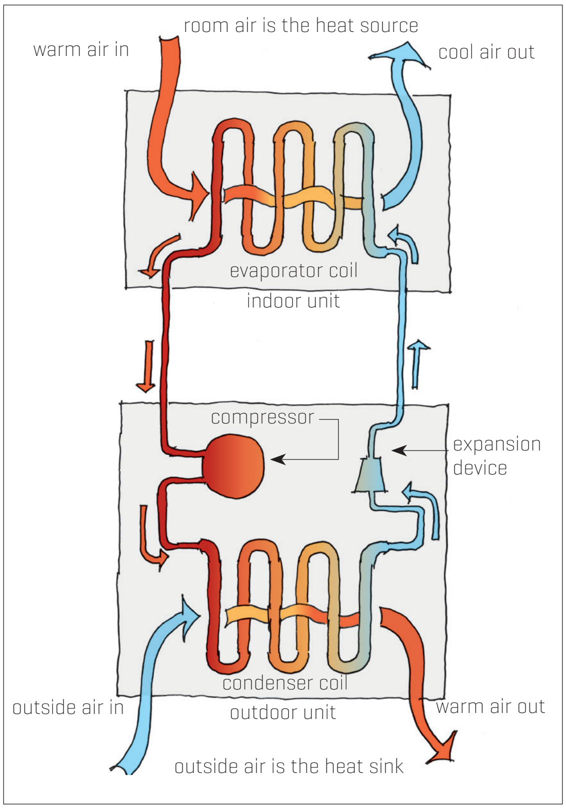

Figure 3. Basic heat pump cooling cycle.

pipe manufacturer's recommended run lengths aren't exceeded in an attempt to place the outdoor unit in an optimal location.

6.0.7 Heat pump coils are more prone to corrosion in coastal areas and areas with high sulphur levels. In these cases, heat pumps with corrosion-resistant coils are recommended. After-market coil coatings are also available.

6.1 DEFROSTING

6.1.1 If the outside air temperature is too low (below approximately 6°C with high relative humidity) in heating mode, the refrigerant can be operating below water freezing point. Ice can form on the coil, reducing airflow through the coil and the rate of heat absorption. Heat pumps are most prone to frosting up between 2°C and 7°C, which is a common winter temperature range in New Zealand's temperate climate.

6.1.2 There are a variety of de-icing mechanisms. All of these have some undesirable outcomes such as increased energy use and temporarily reduced heating output.

6.1.3 Some systems will vary the outdoor fan speed to delay or even prevent freezing, but the heating capacity is reduced. Other systems will de-ice the outdoor coil by switching off the outdoor fan and reversing the refrigerant flow for a short period of time. During this type of defrost cycle, the room may receive some cold air, which may be inconvenient to the occupants.

6.1.4 Some manufacturers provide an H2 rating for their heat pumps, which shows the heat output at 2°C (standard ratings are for 7°C). Energy Star heat pumps are required to demonstrate good performance at 2°C.

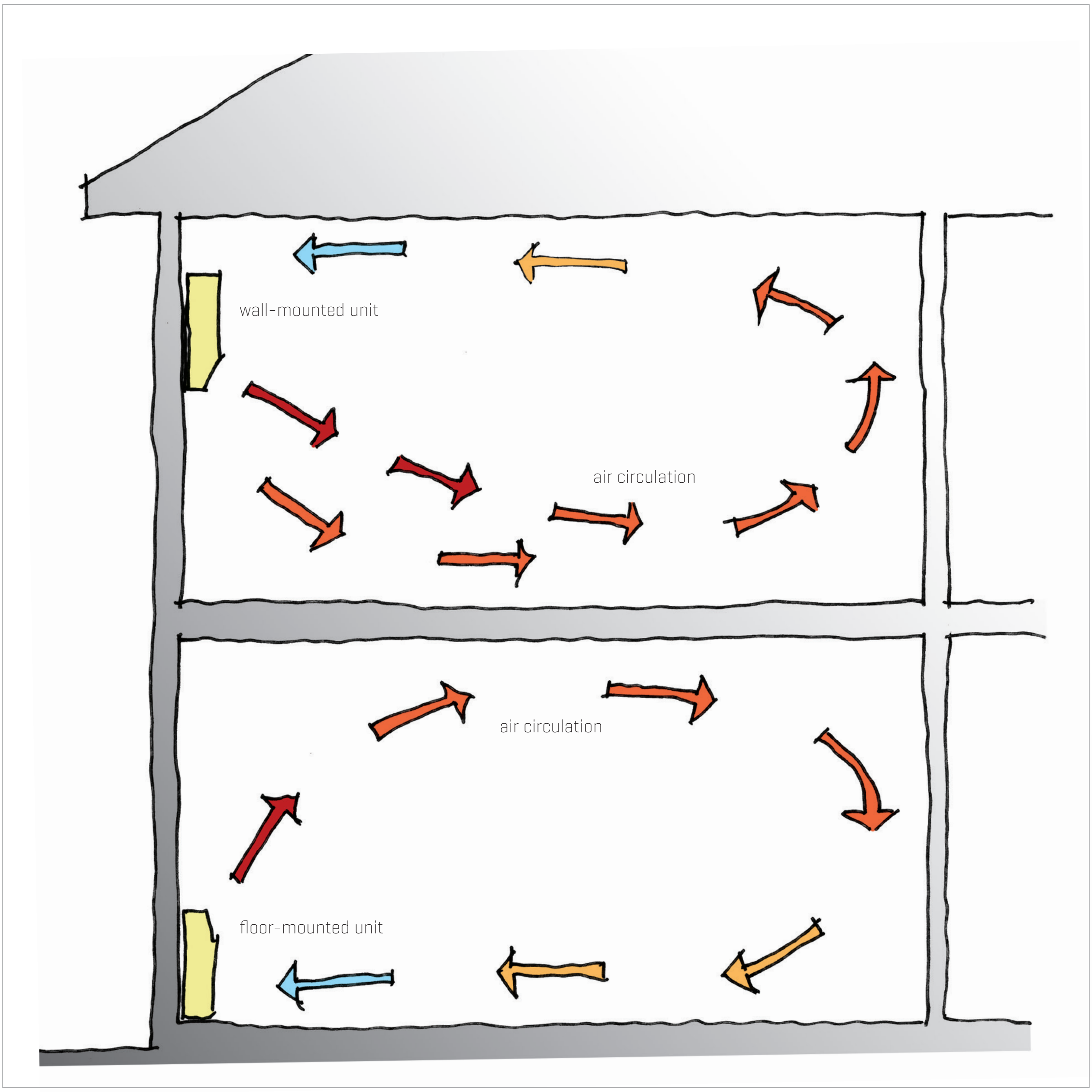

Figure 4. Indoor unit positions in a room.

7.0 INDOOR UNIT

7.0.1 The indoor unit heats, cools and circulates the room air. In dry and cooling modes, it dries the room air. It usually contains a coil, fan, air filter, air vanes and condensate drain.

7.0.2 An indoor unit is named by its position in a room (Figure 4):
- Wall or high wall – mounted high on a wall, it brings air in from below or above and directs air horizontally outwards into the room.
- Under ceiling – mounted on the underside of a ceiling, near to a wall, it brings air in from below or the wall side and directs air across the room at ceiling level.
- Ceiling cassette – mounted within ceiling panels, it brings air in from below at its centre and directs air out from each of the four edges at ceiling level.
- Floor – mounted on or just above a floor and against a wall, it brings air in from below or from floor level and directs air up the wall.
- Ducted – mounted in the space above the ceiling.

7.0.3 Many of the participants in the BRANZ study of heat pump use (Study Report 329) reported that positioning of the indoor unit and the airflows from the indoor units were of concern in terms of draughts.

7.0.4 In many retrofit situations, standard back-to-back installation is used when the indoor unit and outdoor unit are positioned on opposite sides of the same external wall. While this reduces pipe runs, the two units may not be best placed in terms of airflow.

7.0.5 In new construction, there may be more opportunity to locate the indoor unit at a better location within the room (a more central internal wall) to allow for better airflows, including reducing draughts.

7.0.6 For air to freely enter the indoor unit, there should be clearances (typically 50 mm) between the unit and any airflow obstructions.

7.0.7 The hot or cold air blown out of the indoor unit needs to mix with room air and get close to comfortable temperature levels before it reaches the occupants within the room.

7.0.8 For reverse-cycle heat pumps, this is normally best accomplished with the unit at or near ceiling level. The air should be blown along the underside of the ceiling, where it is forced to mix with room air before reaching the occupants. Draughts can occur when cold air is blown at low velocity from the unit and drops to floor level very quickly.

7.0.9 To improve the mixing of air due to passive air circulation, where warmer air rises and colder air falls, heating-only heat pumps are often floor mounted and cooling-only heat pumps are mounted in or on ceilings or walls.

7.0.10 It is important to limit uncontrolled airflow into the room being heated with the heat pump. Positioning the unit over doors or under windows that are regularly open will decrease the effectiveness of room air conditioning. Positioning a heat pump within a hallway in which all of the doors are closed will not be effective in heating the rooms off the hallway.

7.0.11 The indoor units of ducted systems are normally located in the ceiling void, with room supply and return air ducts to grilles in separate ceiling panels spaced apart. On occasions, ducted systems are located underfloor and have ducts leading to grilles in the floor or in walls.

7.0.12 There has to be adequate structural support for the size and weight of the indoor unit. Brackets that fix into wall framing are normally supplied with wall-mounted units. Ceiling-mounted units often need to be fixed back to a structural roof or floor member and probably seismically restrained.

8.0 SIZING

8.0.1 The output from a heat pump is given in kilowatts (kW) and is measured at standard indoor and outdoor temperature conditions specified in AS/NZS 3823.1 *Performance of electrical appliances – Air conditoners and heat pumps*. Two outputs are measured:
- Heating capacity – the rate of heat released to the room air during the heating cycle.
- Cooling capacity – the rate of heat absorbed from the room air during the cooling cycle.

8.0.2 Heat pump heating capacity is typically about 2–16 kW for domestic systems and 10–30 kW for larger commercial systems. Cooling capacity is generally about 10–20% less than heating capacity.

8.0.3 It is critically important to size a heat pump correctly.

8.0.4 An undersized heat pump may:
- not heat the space sufficiently
- require greater defrost frequency
- work too hard, lowering its energy efficiency
- cause undue wear and tear.

8.0.5 An oversized heat pump may:
- create too much air movement, causing nuisance draughts even at low fan speed
- operate at a higher noise level
- short cycle with many stop/starts that stresses the compressor unnecessarily
- have a higher initial capital cost.

8.0.6 The size of the heat pump should take account of the heating requirements for the space being heated as well as the lowest ambient temperature of the climate in which it is installed.

8.0.7 The heating output of a heat pump will vary with outdoor temperature so it is important to ensure that the selected heat pump is able to supply the required level of heating at an appropriate lowest temperature for the climate.

8.0.8 The EECA *Good practice guide: Heat pump installation* gives guidance on how to make these calculations (see 11.3).

8.0.9 A rough rule of thumb to determine the heating requirements for rooms is for:

- non-insulated older houses – use 65 W/m^3 room volume
- well insulated houses – use 50–55 W/m^3 room volume.

9.0 ENERGY EFFICIENCY AND ENERGY USE

9.0.1 Energy efficiency for heat pumps is the ratio of the heating or cooling capacity (in kW) to the electrical power input (in kW) to run the heat pump in a laboratory at a particular temperature. The two measures are called:

- coefficient of performance (COP) – in heating mode
- energy efficiency ratio (EER) – in cooling mode.

9.0.2 The technology in heat pumps is continually improving. Newer heat pumps tend to have better energy COP and EER performance values than older models.

9.0.3 The energy use in actual operating conditions will differ from that obtained by multiplying the COP or EER by the input energy. This is because the operating conditions in actual use (such as the outside temperature) will vary from those in the laboratory test.

9.0.4 BRANZ Study Report 329 found that heat pumps in actual use may use between 1.5 to 3 times less energy than a standard electric heater. Standards testing suggests that new models of heat pumps will provide a higher level of performance.

9.0.5 The COP and EER values for heat pumps provide a useful guide to the relative performance of the heat pumps. The COP and EER values are used to determine the Energy Star rating (see 9.3) for a particular heat pump.

9.0.6 In general, heating COP falls off quite rapidly with temperatures between 7°C and 2°C. This reduction continues but is less dramatic as the temperature reduces below 2°C and past 0°C.

9.0.7 On average, heating COP reduces as heating kW output increases, which can skew consumer choice when looking for the best heat pump. The most important thing is finding a heat pump of the correct capacity, then looking for the most efficient heat pump of that size.

9.1 MINIMUM ENERGY PERFORMANCE STANDARD

9.1.1 Heat pumps come under the requirements of the Energy Efficiency (Energy Using Products) Regulations 2002. Heat pumps for sale in New Zealand must meet the minimum energy performance standards (MEPS) given in AS/NZS 3823.2:2013 *Performance of electrical appliances – Air conditioners and heat pumps – Part 2: Energy labelling and minimum energy performance standards (MEPS) requirements*.

9.2 ENERGY RATING LABEL

9.2.1 An energy rating label must be fixed to the heat pump. It indicates performance criteria for that particular model and provides two labels side by side. The left label is for cooling and shows blue stars. The label on the right is for heating and shows red stars.

9.2.2 The stars range from 1 to 6. The more stars, the more energy efficient the heat pump.

9.2.3 Where a heat pump is super-efficient, additional stars may be displayed above the standard stars (up to a total of 10 stars).

9.2.4 With heat pumps improving all the time, the energy labels can change over time. An older heat pump label that uses a different scale involves one label that has two colour bands above it (blue for cooling and red for heating). The newer label has two labels side by side, one for heating and one for cooling. It is important when comparing products that ratings are considered only when the labels are of the same type.

9.3 ENERGY STAR

9.3.1 The blue Energy Star label is displayed on heat pumps that meet higher performance standards.

9.3.2 Energy Star heat pumps are also tested for performance at 2°C, the temperature range at which many heat pumps struggle and are prone to frosting up.

10.0 USING A HEAT PUMP

10.0.1 Almost a third of the participants in the BRANZ field study of heat pump use (Study Report 329) did not receive information on how to use and maintain their heat pump or found the information too difficult to understand.

10.0.2 The Eco Design Advisor service has produced a guide on to how to operate a heat pump effectively (see 11.3). This factsheet includes photographs of actual heat pump controls, making it easier to understand how to use them.

10.0.3 The energy use of a heat pump depends on many factors, including how cold it is outside, how cold it may be inside when started as well as how the heat pump is operated.

10.0.4 The heat pump remote control typically groups buttons into four sections: operating mode, temperature setting, fan speed and other functions.

10.1 OPERATING MODE

10.1.1 Generally, these are operating modes of a heat pump:

- Heating – shown as ‘heat’ or a sun symbol. Provides heating when room air is below set point temperature. Many units switch off the fan in heating mode when the set point temperature has been reached to avoid draughts that can have a cooling effect.
- Cooling – shown as ‘cool’ or a snowflake symbol. Provides cooling when room air is above set point temperature.
- Automatic – shown as ‘auto’ or commonly a circle with a dot or A in the centre. Provides heating when room air is below a particular temperature, cooling when it is above.
- Drying – shown as ‘dry’ or a water drop symbol. Provides a reduction in air relative humidity by cooling air to below dew point to extract moisture as condensate and then reheating the drier air. The airflow is also reduced during this cycle.
- Fan – shown as ‘fan’ or a fan symbol. Circulates room air through the indoor unit without providing any heating or cooling.

10.2 SETTING TEMPERATURE

10.2.1 The set point is the desired temperature for the room return air at the indoor unit set at the controls by the user. Depending on the operating mode, heating is required when the room air temperature is below the set point, and cooling is required when it is above. For automatic mode, a deadband is needed between a lower set point for onset of heating and a higher set point for cooling. Otherwise, the heat pump will continually swap between heating and cooling. Some controls have two separate set points for this, whereas those with only one entered set point normally have a temperature differential and time delay.

10.2.2 The set point temperature should be the desired temperature within the room. The set point temperature will not be reached faster if the temperature is turned up for heating or down for cooling.

10.2.3 The set point temperature may need to be adjusted up or down if the comfort temperature within the room differs from that measured by the heat pump (for example, if there is poor air circulation between the heat pump and the part of the room occupied).

10.3 FAN SPEED

10.3.1 An automatic setting for fan speed (shown as ‘auto’) means the heat pump automatically reduces fan speed when the rate of heating or cooling needed reduces.

10.3.2 Manually setting the fan speed (high, medium or low) means the airflow remains constant irrespective of the required heating or cooling rate. The room occupant may notice that, with a higher fan speed, there is a greater:
- rate of room air circulation and therefore heat exchange with the room
- rate of airflow over the skin – chilly in cold conditions or cooling in hot conditions
- increased background noise.

10.3.3 Manually setting the fan setting to ‘low’ or ‘quiet’ may restrict the heat output of the heat pump.

10.4 OTHER CONTROLS

10.4.1 Most heat pumps have timer controls. Using timers well can reduce the operation of the heat pump at the coldest time of day (when the heat pump is operating at a lower level of efficiency) as well as providing a greater level of comfort.

10.4.2 New heat pumps may also be connected to the internet so that they can be controlled remotely from a web browser or a smartphone Wi-Fi app.

11.0 FURTHER INFORMATION

11.1 STANDARDS

11.1.1 There has been extensive updating of standards covering heat pumps in recent years. This has included the adoption of many international standards with modifications for New Zealand conditions.

11.1.2 These standards are collected together under the Australia/New Zealand number AS/NZS 3823 *Performance of electrical appliances – Air conditioners and heat pumps*.

11.1.3 Part 1 of this standard, AS/NZS 3823.1, concerns the testing and rating of performance for a number of different types of heat pump systems:
- AS/NZS 3823.1.1:2012 covers non-ducted air conditioners and heat pumps.
- AS/NZS 3823.1.2:2012 covers ducted air conditioners and air-to-air heat pumps.
- AS/NZS 3823.1.3:2005 covers water-source heat pumps – water-to-air and brine-to-air heat pumps.
- AS/NZS 3823.1.4:2012 covers multiple split-system airconditioners and air-to-air heat pumps.
- AS/NZS 3823.1.5:2015 covers non-ducted portable air-cooled airconditioners and air-to-air heat pumps having a single exhaust duct.

11.1.4 Part 2, AS/NZS 3823.2:2013, and Part 3, AS/NZ 3823.3:2002, are concerned with the calculation of performance for minimum energy performance standards (MEPS) requirements as well as requirements for energy labelling.

11.1.5 Part 4, AS/NZS 3823.4, is concerned with testing and calculation methods for seasonal performance factors, separately considered in:
- AS/NZS 3823:4.1:2014 for calculation of cooling seasonal performance factors
- AS/NZS 3823:4.2:2014 for calculation of heating seasonal performance factors
- AS/NZS 3823:4.3:2014 for calculation of annual seasonal performance factors.

11.2 BRANZ

Bulletin 589 *Heat pump water heating*

Burrough, L., Saville-Smith, K. & Pollard, A. (2015). *Heat pumps in New Zealand*. BRANZ Study Report SR329. Judgeford, New ZEaland: BRANZ Ltd.

Level Sustainable Building Series *Heating and Ventilation*.

Level Sustainable Building website: www.level.org.nz/energy/space-heating/heat-pumps/

11.3 OTHER RESOURCES

Consumer website: www.consumer.org.nz

Eco Design Advisor. (2015). *Heat pumps – how to run them effectively.* Factsheet 11. www.ecodesignadvisor.org.nz/assets/Uploads/Heatpump-Factsheet-no-11.pdf

Energy Efficiency and Conservation Authority (EECA). (2009). *Good practice guide: Heat pump installation.* www.eeca.govt.nz/assets/Resources-EECA/heat-pump-installation-guide-2013.pdf

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ISSN 1170-8395