HVAC&R Skills Workshop

MODULE 116

UNDERSTANDING RESIDENTIAL AC EFFICIENCY FEATURES

Skills summary

What?
A guide to energy efficiency features in residential air conditioning systems.

Who?
Relevant for anyone involved in the selection, installation, operation, maintenance and assessment of residential air conditioning systems.

In recent years there has been an increasing focus on improving the energy efficiency of household appliances. One effective strategy has been the introduction of consumer-targeted ratings systems.

Manufacturers have responded to this by developing their products to lift their ratings and attract more customers. Modern residential air conditioning units now boast an array of sophisticated features and functions aimed at improving energy efficiency. Some are widely used and understood, while others remain a mystery to end users and technicians alike.

This skills workshop takes a closer look at modern energy efficiency features in residential air conditioning systems and explains how they work and how they can best be used.

PULLOUT

HISTORY AND BACKGROUND

Air conditioning has been around for a long time now, ever since Willis Carrier came up with the principle of air conditioning in 1902. He could never have known that one day his invention would become so large and powerful that people would have to consider how they used it.

Figure 1 shows a breakdown of energy use in an average Australian household. Most of the energy comes from heating and cooling, with water heating costs coming second. Notice how the domestic refrigerator is not a major energy user, and yet this is one of the hardest working appliances in the home.

In 2003 Australia implemented an initiative that had run in 25 other OECD countries to reduce greenhouse emissions by regulating the energy standards of appliances. The Minimum Energy Performance Standards (MEPS) was launched under guidelines set by the National Appliance and Equipment Energy Efficiency Committee (NAEEEC). All appliances – even the humble power transformer in the overhead mains lines in the street – became a focus for improving energy input and consumption. Put simply, appliances had to meet minimum performance standards to be sold or supplied in Australia.

Since then things have evolved. In 2012 the Greenhouse and Energy Minimum Standards (GEMS) act came into effect, and the Equipment Energy Efficiency (E3) program and committee took on the charter of product regulation, licensing and energy star labelling. The E3 program is a government frontline to the consumers, retailers, tradespeople and manufacturers. It is about reducing greenhouse emissions and household expenses, and driving the market to make improvements to produce energy-efficient equipment. More details are available at www.energyrating.gov.au

APPROACHES TO ENERGY EFFICIENCY

Split systems are now designed with more built-in energy efficiency to reduce power input. Neither the customer nor the service technician can control this – an important point.

Some of the changes made by manufacturers include:

- Different refrigerants types used with higher pressure and volumetric efficiency
- Better design of heat exchangers and aerodynamic asymmetrical fan designs
- Wider selection/application of inverter-type air conditioning models
- Use of high-efficiency DC motors indoors and outdoors
- Use of higher field strength permanent magnets
- Reluctance DC motors – PWM/PAM motor drives
- Energy saving features built into the products' logic control
- Factoring higher ambient operation into designs
- Increased indoor heat exchanger surface area and multi-pass design.

Today some air conditioning brands reach "super-efficient" seven-star performance, although this is in heating operation, while cooling is around just over six. That, however, represents a massive shift in economy.

It is not as easy to achieve these star ratings in larger classes of units because the indoor energy

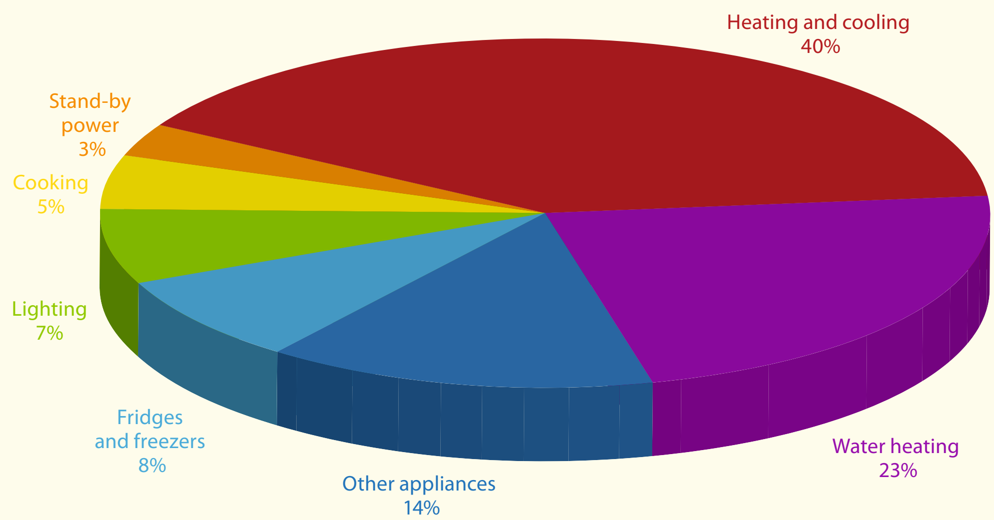

Figure 1: Breakdown of energy consumption for an average household. Source: sa.gov.au

needs might rise yet the required performance for comfort remains the same, all while power input is rising to cope with capacity and closing the gap on energy efficiency ratio (EER) and coefficient of performance (COP).

ENERGY-SAVING TECHNOLOGY

Explaining energy saving to a customer is not always easy. Although the technology and cleverness of it all may impress those in the field, the customer needs to know how it affects their bottom line and why they should use it. Some of it is autonomous, such as inverter technology shedding loads to demand. Other times it is a selectable option.

This skills workshop looks at some of the features that come with split systems. It will focus on the first-time buyer and the introductory system market such as high wall-type energy-saving features. Other features can be found on ducted systems.

Figure 2: Daikin BRC1E61 controller, which does not hide the fact that energy saving features are accessible to the consumer. Source: Dennis Kenworthy

TEMPERATURE SHIFTING

Of all the energy saving features, this is perhaps the most misunderstood by customers. Human comfort is based on 23.5°C at 50 per cent relative humidity on average. As we raise the setpoint temperature in cooling mode, the system becomes increasingly efficient in terms of refrigerant flow and heat absorption. It uses less energy, but more importantly it makes it easier to manage sensible heat and room thermal mass. When we think about temperature swings, shifting back to desired temperature is easier from 2K than 10K, and uses less energy.

All the customer must do is raise the setpoint on their remote when they go out. That may be easier said than done, but with a passive infra-red detector (PIR) the work is done for them. Many will be familiar with the intelligent eye on Daikin units, but Fujitsu has its own version too: the Human Sensor control.

Figure 3: A PIR sensor used for energy saving on a Daikin split system indoor unit. Source: Dennis Kenworthy

The PIR detects infra-red heat in the room and splits a signal within the field emitted into a positive and a negative half. The field can be from 90 to 110 degrees wide, depending on the sensor design. But what really makes this more effective is the sensing optics, which are in the form of an attached front cover lens. The plastic convex cover is a Fresnel lens, which divides the signal more evenly to a wider area. When the field is even on both positive and negative sides, the room is radiantly stable. If an object with differing heat crosses the positive or negative area, this creates an imbalance and an output is generated to a junction field effect transistor (JFET).

The manufacturers use this technology to detect no movement in a room for 20 minutes and then automatically shift setpoint by 2K up for cooling and down for heating. This is a good use of technology that saves money for people who forget to change the setpoint when they go out. Of course, they must turn the function on too!

Another instance of detection can be found in Mitsubishi Electric's split system. It uses a radius angle to check floor temperatures in heating and cooling. Using floor level is a clever idea since the floor radiates heat at a more constant level, whereas air at the midpoint height of a room is in flux, mixing at higher energy within itself. The system uses detected conditions to reduce energy consumption.

DEMAND OPERATION

Many domestic-class units have now been equipped to operate with demand control, typically in the form of optional extras. Demand is current or power control. Here the control is over current consumption rather than any other underlying mode. The internal current transformers (CT) in the split-system circuit board are used.

It is possible to change the percentages for current demand all the way down to "no operation" or "compressor off" for full ventilation modes. Typically, inverter systems are easier to regulate, but this feature can also switch constant-speed compressors off to meet demand needs.

Note that this does not change the surrounding heat load equation and running a system in lesser capacity may not make sense, but it is sometimes necessary.

Power companies in some countries send demand settings to air conditioners to load shed off the grid. This is especially the case for high-density housing and lower power input per household.

Households equipped with lesser mains breaker sizes need to off shed current to run other appliances at times, such as a clothes dryer. Typically, this is seen in other countries or locations that are off grid power and run independent generation.

Larger buildings using demand curve control for maintaining a power index and carbon footprint can off shed when needed.

It is also a great way to force economy cycles for full ventilations when conditions are right.

TEMPERATURE LIMITING AND RESETTING

A temperature limit is more an adult way of preventing others from interfering with design settings or going outside of normal parameters. It has its place, but an effective design only needs one setpoint based on human comfort level. Temperature resetting allows for the setpoint to be changed, but it will reset to the design temperature condition after an elapsed time.

There is a psychological aspect to this as well, giving people the ability to change conditions with some overriding control over the standard setting. People are different in makeup and metabolic function, so it does suggest that not everyone is pleased with a single setpoint or room condition.

STAND-BY POWER REDUCTION

Electrical energy for the home is delivered as apparent power (the total energy from the supplier). Products that consume this power hopefully use the sum of their total rating without any wastage. Unfortunately, magnetic fields in electronics and switched mode power supplies have the side effect of using the apparent power but delivering no real work (real power usage) in the process. This energy consumed with no work done is known as reactive power and is consumed both during normal operation and in stand-by mode.

Power factor and efficiency is based on the comparison of apparent power to real power used, offset by reactive energy losses. Typically, it is not easy to remove this from a system design where printed circuit boards contain many components that consume reactive power. But it can be abated or minimised when equipment is not being used.

Stand-by power adds to the carbon dioxide emitted from the power generation plants into the atmosphere, which not only contributes to global warming but also requires additional baseload and energy consumption to deal with losses in apparent power.

The E3 committee set a 2007 requirement to reduce passive stand-by power (when a system is off) to less than 1W and active standby to less than 2W.

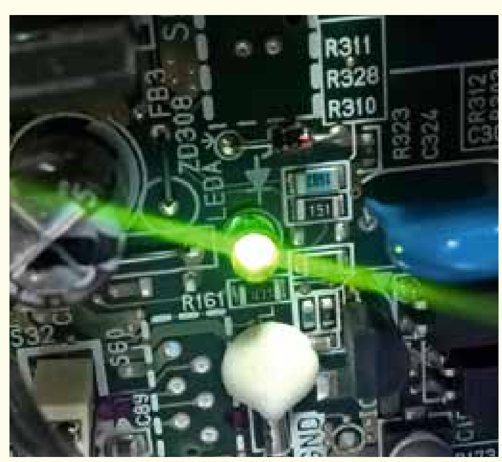

Figure 4: A printed circuit board monitor light flashes to indicate status and health of a CPU, but this may turn off when the unit is in passive standby mode. Source: Dennis Kenworthy

In 2012 it then tightened the requirements to keep passive stand-by for air conditioners below 0.3W and active standby below 1W. Heating mode was excluded from this equation, although the energy of the reversing valve when in locked stand-by operation would add to the total consumption, given we energise a reversing valve to heat in this country.

As a result, redundancy methods have been embedded into logic control. Flashing monitor LEDs turn off in passive mode, effectively going to sleep when not required. Many technicians confuse this with a fault as typically monitor or status LEDs flash constantly. It does, however, show the lengths that manufacturers go to in complying with energy efficiency rules.

TEMPERATURE OVERRIDES

Ask the average person how to save energy and they will likely say turn the appliance off. It's a sensible thought, but also counterproductive.

If we let an occupied space suffer no control, it may exceed desired thermal limits, putting stress on the refrigeration system later, and deteriorate sensitive furniture in the room. Most commercial units and some domestic ones come equipped with overrides that bring the air conditioning system online to take care of low and high temperature swings. It is designed to allow a system that is redundant in operation to come on briefly to abate excessive temperature swings in an occupancy.

Not only does this take care of load swings in unoccupied rooms, it reduces wear and tear on wood furniture and carpets. Usually this mode only deals with temperature limits above 32°C or below 16°C, but it can be adjusted.

REVERSING VALVE CHANGEOVER AND COIL OPERATION

This may seem a small fact, but in consideration much has changed with heat pump or reverse cycle operation. Mode control for heat to cool and vice versa allow no call for reversing valve changeover until called for by the thermostat. Here a reversing valve is not turned on/off until a heating temperature call is made, and it will not release until a cooling call is made.

This is to abate noise from changeover, which can be considerable in larger systems when a unit is turned off or awaiting a mode call. Another interesting fact is that a reversing valve's coil may be aligned with heating or cooling mode depending on country or region.

In Australia, the most common use for air conditioning is cooling, so we energise the coil in heating mode. This saves energy during peak summer when the power grid is loaded. Although the energy needs of a coil may only be reduced by 30W, when multiplied across all domestic systems it adds up. Countries with very low ambient and a greater need for heating may do the opposite with changeover.

PULLOUT

PMV CONTROL (Predicted Mean Vote)

Have you got your hard hats on? PMV control has been embedded into some air conditioning systems and is really very hard to explain. To do so requires a brief history. The full background and theory are too wide and complicated to cover here.

In the 1960s, Danish professor Povl Ole Fanger studied thermal comfort with college-aged students to assess invariant thermal conditions in air conditioned buildings. The effects of building temperature and climatic conditions were either supported or criticised in a mean average vote.

Fanger's thermal comfort model looked at satisfaction, wellbeing and performance with air conditioning. His calculations allowed engineers to predict optimum temperature for a large group of people to be satisfied in thermal comfort, given their activity and clothing worn.

The thermal comfort model incorporated a human metabolic (M- Met) rate that considered:

- The clothing index or Clo
- Air velocity in metres/second
- Mean radiant temperature in Celsius
- Ambient air temperature in Celsius
- Vapour pressure of water in ambient air in pascals.

Clo is an insulation factor of clothing. A factor of 1 Clo = 0.155W/m^{2}K is based on a person sitting in a room at 21°C with 0.1m/sec airflow and with a surrounding humidity of 50 per cent. This person would be typically wearing a business suit or perhaps long shirt, long pants and a jacket (0 Clo = an undressed person).

Fanger's equation for PMV was based on the formula:

$$PMV = (0.303e\ {-0.036M} + 0.028)\ L$$

Where M = metabolic rate and L = thermal load, defined as the difference between the internal heat production and heat loss to the actual environment for a person hypothetically kept at comfort values of skin temperature and evaporative heat lost by sweating at the activity level. Defining the thermal load can be quite complex with numerous other factors and formulae applied.

From this a PMV value is generated and has been applied with ASHRAE standard 55 and ISO 7730.

The Fanger seven-point scale ranges from -3 (cold) to +3 (hot) and reflects the thermal sensation of a person based on the ASHRAE standard 55. The air conditioning industry aims to keep conditions between -2 and +2, and as close to zero as possible. With these figures it was possible to predict the percentage of people dissatisfied or (PPD) and yes there is another formula for that one too. It goes without saying that more people will be unhappy when the temperature drifts more.

The Predicted Mean Vote (PMV) is an average response of happy versus unhappy for many people. In some buildings the mean average setpoint is based on the type of clothing and activity in the building. Heavier and more abundant clothing requires a much lower setpoint, whereas wearing less could mean a higher setpoint. Green building initiatives take this matter quite seriously.

Manufacturers can embed these formulas in program logic and use temperature sensors in the system to control thermal comfort. It has seen its way into controls for larger systems and is used with automatic temperature mode functions. Of course, it cannot establish an individual's metabolic rate at a given time or their clothing or activity. It can, however, use indoor and outdoor temperatures to calculate mean average setpoints for automatic operation.

Inverter technology can now control rate of change better because we can reduce net refrigerating effect and mass flow as indoor demand reduces. Human comfort has a much wider selection than before with lesser temperature drifts. The fact that manufacturers go to this extent to keep people happy is not just based on a standard but also a way to minimise discomfort and lower energy input. It is nothing short of amazing, yet try explaining this one to customers!

If you are interested in learning more check out the Centre for the Built Environment (CBE) thermal comfort tool. This uses ASHRAE Standard 55 and shows relationships for PMV plotted to a psychrometric chart.

CUSTOMERS

Customers are spoilt for choice now with never-before-seen technology and convenience – everything from wi-fi control to an indoor unit that looks like a painting.

The warranties for domestic units are generous. Try getting a five-year parts and labour arrangement for a washing machine or car.

Modern air conditioning systems are closed-loop control operating to performance without adjustment other than standard user control functions.

A lot has changed since the first room air conditioner that rattled in the wall and only had two settings: off and on. A combination of government regulation, industry standards and even simple common sense has added value to the equation of human comfort. ■

MORE INFORMATION

This month's Skills Workshop was provided by Dennis Kenworthy, Affil.AIRAH, of South Metropolitan TAFE, Western Australia.

More information can be found at his website www.whatwoulddennisdo.com

Next month: Calibration and use of instruments.