SERIES 15

CPD fundamentals

THE CONTINUING PROFESSIONAL DEVELOPMENT PROGRAMME

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MARK THROWER MANAGING EDITOR

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Heat Pumps – A Low Carbon Solution

By David Hart, director, Energy Intelligent Solutions

Heat pumps are devices that transfer heat from one place to another, and, critically, upgrade the temperature of that heat.

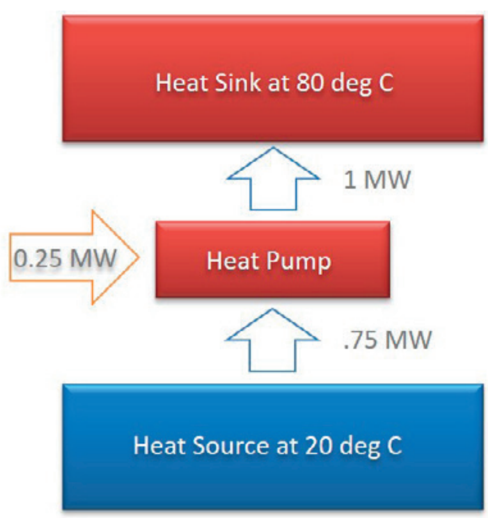
In practical terms, a heat pump is equivalent to a refrigeration system.

A typical heat pump in a commercial space heating application might upgrade heat from outside at ambient temperature to warm air at say 30°C, or to water at 50°C. In an industrial setting, the heat pump might, for example, recover waste heat from a cold process stream at 30°C and upgrade that heat to water at 80°C.

The heat pump process is shown schematically in Figure 1. In this example, 0.75MW of heat is being extracted from the low temperature heat source and upgraded to 1MW of heat at a higher temperature, using 0.25MW of power. Ignoring energy losses, the power into the compressor plus the heat from the source is equal to the heat delivered to the heat sink.

A conventional refrigeration system is such a device, transferring heat from a cooled space and rejecting it, along with the energy from compression of the refrigerant, generally to outside via the condensers. A cold store refrigeration system, for example, might remove heat at -20°C and discharge the energy to outside at 30°C.

Figure 1 - Schematic Diagram of a Heat Pump transferring heat from a low temperature heat source to a higher temperature heat sink, using electricity in the compressor



The refrigeration system can be regarded as a heat pump if the energy rejected is usefully used, which is generally not the case. With refrigeration, the focus is on the 'cold end' of the system, with heat pumps it is on the 'hot end'. Normally, the cooling at the cold end of a heat pump will cool the ambient air rather than anything useful, for example in air source or ground source heat pumps, although in an ideal installation the cooling is useful too.

Recovering waste heat

The opportunity to recover waste heat from refrigeration systems exists in many diverse sectors: in the (petro)chemicals sector where there is concurrent heating and cooling, in food manufacture, in some offices, in data centres where there is adjacent heating demand, and in pubs and restaurants, for example.

In Figure 1, the efficiency of the heat pump, or coefficient of

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performance (COP), can be defined as the heat produced divided by the power used, in this case 1/0.25 = 4. This means that 4 units of useful heat are delivered for every one unit of power used.

Conventional heat comparison

Heat pumps are commonly used to heat office spaces. But how do they compare with more conventional heating? Why are they not more widespread?

A conventional boiler will produce heat at, say, an efficiency overall of 80 per cent. 1MW of heat will require 1.25MW of fuel. This needs to be compared with the 0.25MW of electricity required by the heat pump in the example given.

Figure 2 shows the relative costs of electricity and natural gas in the UK over the last 20 years for larger companies. Currently, a good price for electricity is 9p/kWh, and for gas less than 2p/kWh. The boiler will cost £25 per hour to generate the heat, the heat pump will cost £22.50, much the same. These prices fluctuate.

So, what is the incentive for a heat pump if the running cost is similar? Generally, a like for like conventional heating solution will be cheaper than a heat pump.

If the heat pump is already in place, in other words is a refrigeration system doing useful cooling, then the recovered heat is free. The hierarchy for heating should, in fact, always be to use waste heat first, and using the waste heat from a refrigeration system would be an example of this.

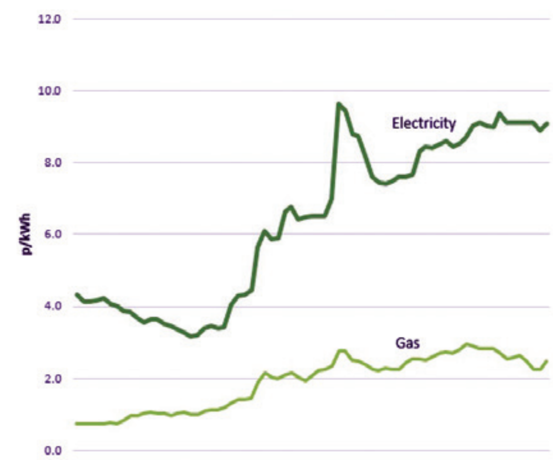
In some cases, the heat pump is equipment that is already available, as in the case of comfort cooling and heating. The device is needed for cooling, and utilising the same device for heating means that capital investment requirements are less.

But what about buying a heat pump instead of a conventional heater? And what about replacing conventional heating with a heat pump – how is the capital investment justified? And how does a heat pump compare with, say, a biomass boiler?

Reducing the use of fossil fuels

UK energy policy is to reduce the use of fossil fuels for heating in the

Figure 2 - Electricity and Natural Gas Prices for Large Users in the UK



medium term, as part of the overall plan to reduce carbon emissions. Traditionally, the carbon dioxide emissions associated with electricity have been high compared to the same amount of energy as gas. Ten years ago, 1kW of delivered electricity would result in carbon dioxide emissions around three times that of natural gas. Nowadays, however, with the decarbonisation of electricity generation due to the wider use of renewable power, the carbon dioxide emissions associated with electricity are lower, and reducing year on year.

The heat pump in the example given would be associated with lower overall carbon dioxide emissions due to its energy use. Carbon dioxide emissions are associated with Global Climate Change, and the value of reduced carbon dioxide emissions can be added to the operating cost benefits of a heat pump.

Generally, carbon emissions have a cost, for example because of the Climate Change Levy, a Climate Change Agreement or the EU Emissions Trading Scheme in the UK.

Current values (2017) for the carbon dioxide emissions from natural gas and electricity in the UK are 0.18416 and 0.35156 kg CO2 per kWh of energy respectively. The 0.25 MW of electricity used in the heat pump compared with 1.25 MW of gas in the boiler will produce carbon dioxide emissions of 88 kg/h compared with 230 kg/h, a reduction of over 60 per cent.

Uptake incentives

Because of the potential role of heat pumps in reducing UK carbon emissions, their use is incentivised in certain cases. In industrial and commercial installations, the Renewable Heat Incentive available for heat pumps is 2.61 p/kWh of heat produced for air source heat pumps, and more for water source and ground source units. Assuming the example in Figure 1 is an air source heat pump, the incentive payments would be £26.10 per hour of full load operation, available for the life of the plant (20 years). These payments are subject to metering requirements being met and the heat being used usefully, and are limited to heat pumps that heat a fluid since this allows the heat output to be accurately measurable. The available incentives mean that heat provided from a heat pump can be free, or even profitable. The incentives are

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also available for the case of waste heat from a refrigeration system, meaning the free heat now becomes heat that makes a profit.

Investment in 'standard' heat pumps for space heating and water heating in industry is further incentivised by Enhanced Capital Allowances. 100 per cent of the capital cost of an installation can be written down against tax in year one, accelerating the return on investment considerably. Asset finance companies are readily available to provide funding for projects for proven solutions, such as heat pumps, especially those that are on the Energy Technology List, the list that means equipment will qualify for the enhanced capital allowances.

Cheaper and cost effective

On a like for like basis, heat pumps can be much cheaper and more cost effective than biomass solutions, and give a much quicker return. Air source heat pumps are more cost effective and easier to install than ground source solutions in general. Specific circumstances always need to be considered, however.

The COP, or efficiency, of a heat pump may not be 4.0 as quoted in the example above. In fact, the COP will depend on a number of factors, but most significantly on:

- the temperatures of the heat source and sink; and
- the heat pump equipment and controls.

The theoretical maximum COP of a heat pump operating between two temperatures, TH and TC, where TH is the temperature of the heat sink (the hot end) and TC is the temperature of the heat source is given by:

COP = TH/(TH-TC)

The temperatures must be in Kelvin, which is equivalent to Celsius + 273.

For example, an air source heat pump operating with a heat source at 0°C and a heat sink at 25°C has a maximum theoretical COP of 298/25=11.92. In practice, this COP might only be 60 per cent of this value at best, or in this case around 7. This is better than the example we have analysed in this article so far. The higher the COP, the better the savings and return on investment.

For comparison, consider an industrial plant where the heat source is at 20°C and the heat sink is at 90°C. The expected best practical COP will be 0.6*363/70 =3.1, much lower than the example above.

Advances in technology have resulted in heat pumps that achieve higher performance levels than previously were possible. Variable speed compressor control, for example, allows the part load performance to be very high, and the use of modern expansion valves eliminates the need for head pressure control which impairs overall performance in some cases. High performance heat exchangers allow a close approach between the refrigerant temperatures and the fluids being heated and cooled, thereby effectively raising TC and lowering TH.

Figure 3 Global warming potential of some common refrigerants

HFC	GWP
404A	3,922
410A	2,088
407C	1,824
32	675

Dealing with refrigerants

One issue with heat pumps, as with refrigeration systems in general, is that of the refrigerant. Over the years, the harmful effects of certain refrigerants, the working fluid of the heat pump, have become apparent. These include not only issues of toxicity and flammability, but ozone depletion which was associated with the now banned CFC refrigerants, and more recently the Global Warming effects of modern HFC refrigerants.

Some of the most common refrigerants in use have very high Global Warming Potentials – 1 tonne of R404A released into the atmosphere, for example, has the equivalent effect to 3,992 tonnes of carbon dioxide released.

The F Gas Regulations came into force in 2014 and from 2015 a phase down of HFCs started in this country. By 2030, the amount of HFCs available will have reduced to 20 per cent of the levels accepted between 2009 to 2012. The first significant drop in availability has already happened.

Purchasers of heat pumps and refrigeration systems need to be aware of these issues and ensure that systems purchased have the lower GWP refrigerants, have smallest possible refrigerant volumes and have minimal opportunity for leakage.

Eliminate use of fossil fuels

Heat pumps can be important because they make low temperature waste heat usable. They represent a significant opportunity to eliminate the use of fossil fuels for heating in the longer term, providing a cost-effective retrofit opportunity in many cases, on a par and often better than combined heat and power and biomass heating.

Government incentives make the economics very attractive for some installations at present, and finance is readily available for many projects. Heat pump technology is well proven and long established. The issue with refrigerants represents a challenge, but one which the industry has to handle, and is considered not to be a major barrier to their more widespread use.

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ENTRY FORM

HEAT PUMPS

Please mark your answers on the sheet below by placing a cross in the box next to the correct answer. Only mark one box for each question. You may find it helpful to mark the answers in pencil first before filling in the final answers in ink. Once you have completed the answer sheet in ink, return it to the address below. Photocopies are acceptable.

QUESTIONS

1. How is the performance of a heat pump defined?

- ☐ Energy into the compressor divided by useful energy output
- ☐ Useful energy output divided by total energy input to the system
- ☐ Useful heat delivered divided by power used by the system

2. How much power would an air source heat pump require, approximately, to deliver 100 kW of heat at 30 OC when the ambient temperature is 10 OC?

- ☐ 120kW
- ☐ 11kW
- ☐ 75kW

3. What features of a modern space heating heat pump system improve the energy efficiency?

- ☐ Large evaporator, large condenser, good heat transfer, high efficiency compressors, variable speed drives on compressors, modern expansion valves, digital controls
- ☐ Small evaporator, large condenser, good heat transfer, high efficiency compressors, variable speed drives on compressors, modern expansion valves, digital controls
- ☐ Large evaporator, small condenser, good heat transfer, high efficiency compressors, variable speed drives on compressors, modern expansion valves, digital controls

4. How does a heat pump contribute to Global Warming?

- ☐ Loss of refrigerant
- ☐ Energy used by condenser
- ☐ Electricity used and loss of refrigerant

5. Why is a heat pump a preferred heat source to fossil fuels in some circumstances?

- ☐ Incentives
- ☐ Lower carbon emissions
- ☐ Lower energy costs

6. When is a heat pump not suitable?

- ☐ Low grade heating required
- ☐ High grade heating required
- ☐ Low temperature heat source available

7. What is the difference between a heat pump and a refrigeration system?

- ☐ No difference
- ☐ Different working fluids
- ☐ Uses more power

8. Put these in order of the most efficient use of energy to produce heat: gas boiler, heat recovery, biomass boiler, heat pump, direct electric heating?

- ☐ Heat recovery, heat pump, gas boiler, biomass boiler, direct electric heating.
- ☐ Biomass boiler, heat recovery, heat pump, gas boiler, , direct electric heating.
- ☐ Heat pump, heat recovery, gas boiler, biomass boiler, direct electric heating

9. Why are heat pumps a key part of UK energy policy?

- ☐ Use electricity which is more efficient than using gas
- ☐ Proven technology that can deliver low grade heat with lower carbon emissions compared with fossil fuels.
- ☐ New technology that can deliver low grade heat with lower carbon emissions compared with fossil fuels.

10. What incentives are available for heat pumps in non-domestic circumstances?

- ☐ Reduced carbon costs (CCL, CCA and EU ETS)
- ☐ Renewable Heat Incentives
- ☐ Enhanced Capital Allowances.

Please complete your details below in block capitals

Name .... (Mr. Mrs, Ms) ....

Business ....

Business Address ....

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.... Post Code ....

email address ....

Tel No. ....

Completed answers should be mailed to:

The Education Department, Energy in Buildings & Industry, P.O. Box 825, GUILDFORD, GU4 8WQ. Or scan and e-mail to editor@eibi.co.uk

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How to obtain a CPD accreditation from the Energy Institute

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This is the tenth and final module in the fifteenth series and focuses on **heat pumps**. It is accompanied by a set of multiple-choice questions.

To qualify for a CPD certificate readers must submit at least eight of the ten sets of questions from this series of modules to EiBI for the Energy Institute to mark. Anyone achieving at least eight out of ten correct answers on eight separate articles qualifies for an Energy Institute CPD certificate. This can be obtained, on successful completion of the course and notification by the Energy Institute, **free of charge** for both Energy Institute members and non-members.

The articles, written by a qualified member of the Energy Institute, will appeal to those new to energy management and those with more experience of the subject.

Modules from the past 14 series can be obtained free of charge. Send your request to editor@eibi.co.uk. Alternatively, they can be downloaded from the EiBI website: www.energyzine.co.uk

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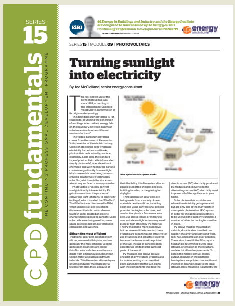

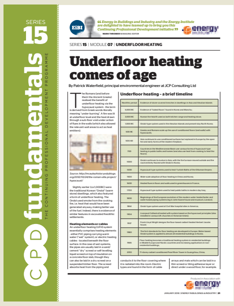

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