HEAT PUMP BOILERS : TECHNICAL ADVICE PAPER

The application of domestic heat pump boilers, instead of fuel boilers, has recently become very popular. This technical paper has been produced to aid the general understanding of how such systems operate and what the implications / limitations are in respect of swimming pool applications. In essence, the heat pump boiler takes the place of a conventional fuel boiler as the primary heat source.

The Heat Pump Principle :

A heat pump is a comparatively basic refrigeration circuit, comprising of a refrigeration compressor electric motor and heat exchangers.

In essence, a heat pump, like a refrigerator, simply 'moves' heat from one location to another. For example, a domestic refrigerator takes heat from inside it's cabinet and moves this heat outside the cabinet, thereby 'cooling' the inside of the refrigerator cabinet.

Whereas a heat pump takes heat from, for example, outside fresh air and 'moves' this heat inside the dwelling for heating purposes.

The benefit of the heat pump is simple and obvious. The heat absorbed from, in this instance, the outside fresh air is completely free. The customer only has to pay for the energy used through mechanically operating the heat pump (which is, itself, fully utilised), whilst the heat absorbed from the fresh air is completely free.

For every 1 kW of 'paid' electrical energy which the heat pump consumes in it's mechanical operation, a total of 4 kW or more can typically be produced for the customer to use (i.e. 3 kW of free heat is taken from the fresh air). This would frequently be expressed as the 'Coefficient of Performance' or C.O.P. of '4 to 1'.

Effective heat can still be absorbed, even when the temperature is as cold as -20ºC !

Ground Source Heat Pumps & Air Source Heat Pumps :

There are two different types of heat pump boilers in common use : A ground source heat pump, which absorbs heat from the ground via a pipe loop and an air source heat pump, which absorbs heat from the fresh air.

Ground Source Heat Pump Boilers :

THE GROUND SOURCE HEAT PUMP BOILER CONCEPT :

The whole concept of a ground source heat pump is based on the fact that the temperature underground is generally constant at between around 8°C to 13°C in the UK and that this temperature can be up-graded, through the compression effect within a refrigeration heat pump, into a usable temperature for heating purposes.

Therefore, the heat output from a ground source heat pump remains generally the same all year and is unaffected by cold winter weather.

WHAT IS A GROUND SOURCE HEAT PUMP :

A system would typically comprise of three main parts :

1) The heat pump 'box'.
2) The 'central heating pipe circuit' (LPHW or LTHW circuit).
3) The under ground pipe loop.

The Heat pump 'box' :

The heat pump itself is a 'stand alone' box, usually installed within a plant room, primarily containing a refrigeration compressor and two refrigerant-to-water heat exchangers. Through the action of the refrigeration compressor, the first heat exchanger is chilled and absorbs heat from the water circulated through the underground pipe loop. The second heat exchanger becomes hot and gives heat to the water circulated through the central heating pipe loop.

The 'central heating pipe circuit' :

The 'central heating circuit' is identical to that for a conventional fuel boiler. Water is pumped around the central heating pipe circuit, passing through the hot heat exchanger within the heat pump box. Within a domestic house, the central heating circuit could comprise of radiators and a hot water cylinder etc in an identical way to a conventional fuel boiler system, the difference being that the ground heat pump boiler replaces the fuel boiler in the circuit.

With a modern newly designed house, it would be normal to utilise an under floor heating tube circuit, instead of wall mounted radiators.

It is also possible to incorporate a ‘heat store’, which is essentially a hot water storage tank. A heat store can act as buffer between the heat pump and the central heating circuit. A heat store can offer the advantage of taking further heat from other sources, i.e. a conventional fuel boiler or solar panels etc, and also helps maintain a consistent operating condition for the heat pump.

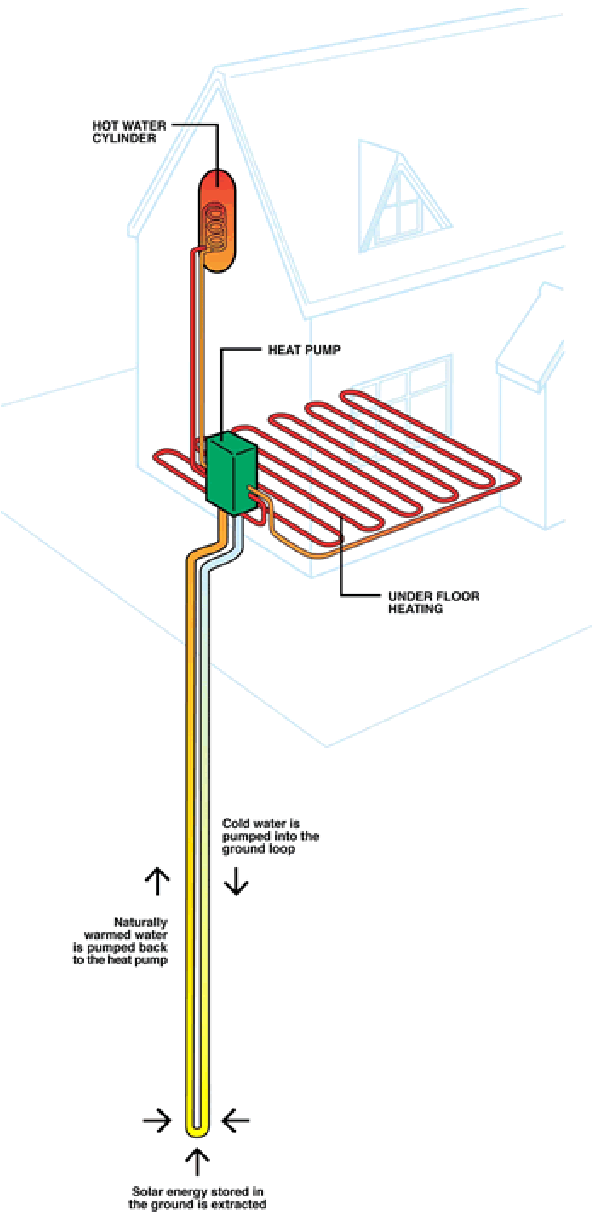
The under ground pipe loop :

A closed loop circuit of polyurethane pipe which would be buried in the ground adjacent to the building. Water, with an anti-freeze agent, is pumped around the pipe loop, passing through the chilled heat exchanger within the heat pump box.

There are two common types of ground pipe loop :

Horizontal slinky : Here the polyurethane pipe is coiled and laid horizontally along a long trench, but only around 1 to 2 metres below the surface.

Bore hole : Here a deep vertical hole (typically 80 to 100m deep) is drilled into the ground and the polyurethane pipe loop is dropped down into the deep hole.



Air Source Heat Pump Boilers :

Air source heat pumps take heat directly from fresh air, so there is no need for any ground loop circuit.

Fresh air is drawn through the heat pump, which is usually installed external to the building, via an integral fan. The fresh air is blown across the cold coil where energy is absorbed.

Unlike a ground source heat pump, the about of heat generated by an air source heating pump will vary in line with the temperature of the fresh air. Basically an air source heat pump would be able to generate more heat during the warmer summer months than during the colder winter months.

The highest demand for heating will invariably occur during cold weather and the heat output rating of the air source heat pump, during colder weather, must relate to the heating demand at that time.

Heat is distributed via a central heating pipe circuit, in exactly the same way as a ground source heat pump system.

Reduced Central Heating Circuit Water Temperature :

A characteristic / limitation of heat pump boilers is that the temperature of the water circulated through the central heating circuit is very much lower than that achieved by a conventional fuel boiler.

In essence, this means that devices used to dissipate the heat from the LPHW pipe circuit into the occupied areas, such as radiators etc, need to be ‘oversized’ in order to compensate for the much lower LPHW circuit temperature.

Whilst a fuel boiler may operate at a flow temperature of 80°C, a heat pump boiler would normally operate at flow temperatures as low as 35 to 45°C. It is not that a heat pump boiler cannot generate hotter circuit temperatures, as they can, the problem is that the efficiency of the heat pump is adversely affected and the coefficient of performance is reduced.

The issue of the reduced water circuit temperature is particularly exaggerated within a swimming pool application. A typical domestic dwelling would be heated to around 22°C, whereas a swimming pool room would require to be heated to a significantly warmer temperature, say 30°C.

This has a marked impact on the ability of a heat exchange system to transfer heat into the occupied areas.

Therefore, a realistic heating circuit water flow temperature with a heat pump boiler of 55°C is required if meaningful heat exchange for a swimming pool area is to achieved.

For example :

Conventional fuel boiler system :

Heating circuit water flow temperature :	82°C
Heating circuit water Return temperature :	71°C
Mean average in-circuit temperature for heat exchange :	76.5°C

Typical pool room air temperature :	30°C
Temperature difference for heat exchange :	46.5°C (76.5°C – 30°C)
Heat exchange coil performance of rating :	**100%**

Heat pump boiler circuit :

Heating circuit water flow temperature :	55°C	
Heating circuit water Return temperature :	45°C	
Mean average in-circuit temperature for heat exchange :	50°C	
Typical pool room air temperature :	30°C	
Temperature difference for heat exchange :	20°C	(50°C – 30°C)
Heat exchange coil performance of rating :	**43%**	

From the above comparison we can see that, with a heat pump boiler, we are left with less than half of the heat exchange duty previously possible with a fuel boiler.

In respect of pool water heating ability, the scenario can simply be overcome by significantly increasing the selected capacity of pool water heat exchanger to compensate, as the normal flow of pool water from the pool filtration pump would normally still be adequate to transfer the required heat. This is possible because water has a comparatively high specific heat capacity, i.e. it can absorb a lot of energy before any temperature increase becomes apparent.

However, with air heating it is not so easy. To achieve the same heat input to the pool room, the quantity of warm air flow into the pool hall has to be increased to compensate for a lower delivered air temperature on a pro-rata basis.

For example :

Example air heat loss from a typical pool hall :	15kW @ -5°C outside temperature.
Pool hall air temperature :	29°C

Fuel boiler :

Average LPHW in-circuit temperature for heat exchange :	76.5°C
Increase in air temperature through heating coil : (Max.) :	26.6°C
Temperature of air delivered into the pool hall :	55.6°C (26.6°C + 29°C)
Quantity of Air flow through air heating coil necessary to transfer sufficient heat to match room heat loss :	1800 M³/Hr.

Therefore : 1800 M³/Hr. of air, increased by 26.6°C in temperature = 15kW of heat input into the pool hall.

Heat pump boiler :

Average LPHW in-circuit temperature for heat exchange :	50.0°C
Increase in air temperature through heating coil : (Max.) :	12.0°C
Temperature of air delivered into the pool hall :	41.0°C (12.0°C + 29°C)
Quantity of Air flow through air heating coil necessary to transfer sufficient heat to match room heat loss :	4000 M³/Hr.

Therefore : 4000 M³/Hr. of air, increased by 12.0°C in temperature = 15kW of heat input into the pool hall.

Considering that more than half the heat exchange potential has been lost through using the lower circuit temperatures of a ground heat pump, this potentially has a notable affect on equipment selection and air duct work capacity and physical size.

OPERATING COST BENEFITS OF USING A HEAT PUMP BOILER :

The price of electricity within the UK is very high compared to the cost of alternative fuels, such as mains gas or heating oil. Despite the recent notable increases in the respective price of energy, this price relationship still broadly remains the case and the heat pump boiler obviously operates only on electricity.

By comparison :

Typical current price of mains gas :	2.73 p/kWh
Realistic gas boiler efficiency :	85 %
Price of heat produced for customer :	**3.21** p/kWh
Typical current price of heating oil :	3.24 p/kWh
Realistic oil boiler efficiency :	75 %
Price of heat produced for customer :	**4.32** p/kWh
Typical current price of electricity :	7.44 p/kWh
Efficiency of heat pump boiler : (3.5:1 COP) :	350 %
Price of heat produced for customer :	**2.13** p/kWh

In respect of a heat pump boiler, there may be some penalty involved through the need for higher pool hall ventilation rates etc, and so higher electricity consumption fan motors, but generally the operating costs would be less than an alternative fuel fired system, but perhaps not hugely less at today's energy prices.

With an indoor pool, much of the operating costs can relate to the dehumidification, heat recovery and ventilation requirements. By comparison, the actual air heating and water heating costs can be significantly less.

Operating costs and energy usage, whilst associated, are not the same thing and the heat pump boiler will invariably consume far less energy and be far less damaging to the environment than fuel fired alternatives. This obviously may be an important consideration for some customers.

In the foreseeable future, i.e. in 10 to 15 years time, the energy market and prices may be very different from today. It is probable that, for environmental and political reasons, the use of renewable energy solutions will continue to be heavily promoted through both incentive and penalty and the availability and price of fossil fuel alternatives may continue to grow as issues.

In the long term, be it from nuclear or renewable sources, the method of energy distribution will invariably be through electricity.

Therefore, a system that utilises electrical energy over fossil fuel alternatives, looks a good long term bet today.

CAPITAL COST OF HEAT PUMP BOILERS :

The capital cost of a heat pump boiler installation, as opposed to a conventional fuel fired boiler system, is invariably much higher, certainly on a like for like heat output basis.

Therefore the 'pay back period' is a consideration. The 'pay back period' is the period of time it would take for the end client to recuperate the extra capital cost of the heat pump through lower operating costs.

Accordingly, at today's fuel prices, the 'pay-back' period may still be many years and may not be that attractive to the end client. However, as previously indicated, this is not the only consideration involved.

With a ground source heat pump, the ground pipes themselves should have a life-span of at least 50 years and probably much longer, so there will be plenty of opportunity in the future to utilise this part of the installation works / cost.

There are also various grants already available, although some of these are means tested.

HEAT OUTPUTS AVAILABLE FROM HEAT PUMP BOILERS :

The actual heat outputs available / achievable from a heat pump boiler are generally significantly less than for a conventional fuel boiler. This is generally because of the high capital cost of the heat pump equipment / installation per kW output and other practicalities such as electrical supply loadings and physical space issues.

There is not the luxury / flexibility of the comparatively very high heat outputs that would be associated with fuel boilers.

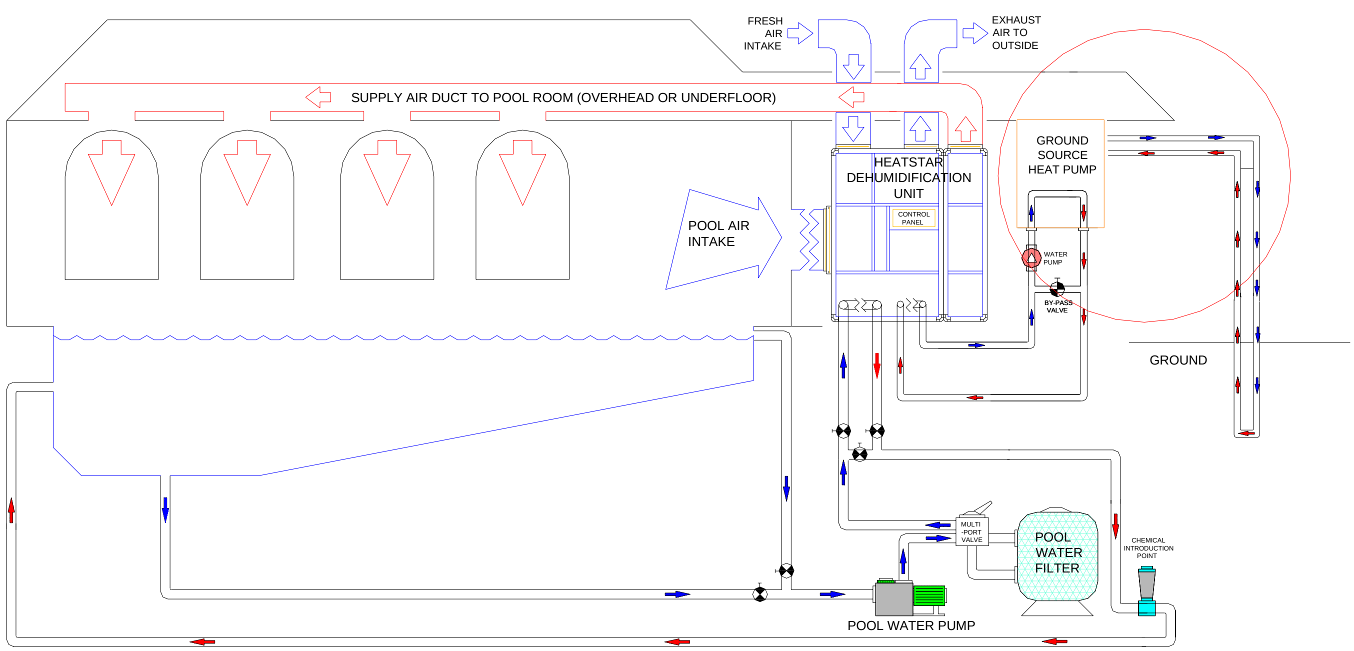
Accordingly, there may be some limitations on the overall effect of the heat pump boiler, particularly in terms of a long initial warm-up period of the pool water from cold and the ability of the system to maintain the exact correct temperatures during cold weather.

However, the end customer must appreciate that there may be some compromise in taking a 'green' approach to the heating of their swimming pool.

It is also possible to supplement the heat generated by the heat pump boiler with more conventional means, by installing direct electric in-line heaters or even fuel boilers as part of the central heating circuit. However, the central heating circuit temperature should still not be allowed to exceed the optimum temperature for the heat pump operation – otherwise the heat pump may not be able to operate correctly.

POOL HALL BUILDING DESIGN :

The architectural design of the pool hall is an important factor in the successful application of a heat pump boiler on a swimming pool. If the pool hall design is generally of comparatively high structural heat loss, with extensive use of glazing, then it may not be at all practical to use a heat pump boiler as the heat source. However, if the pool hall is very well insulated with minimum use of glazing, then the implications of using a heat pump boiler would be easy to overcome.



installation schematic

RETROSPECTIVE INSTALLATION :

It is not easy to retrospectively install a heat pump boiler onto an existing project which was designed around a conventional fuel boiler. The original environmental control unit and the air distribution ducting would unlikely to be adequately sized to compensate for the much reduced heating circuit temperatures. Such a system may struggle to maintain conditions through the winter months.

OUTDOOR POOLS :

For a typical summer use outdoor pool, a ground source heat pump boiler is not the most obvious approach.

This is simply because, during the summer months, the ambient fresh air temperature is warmer than the ground temperature. Therefore, a conventional air source swimming pool heat pump, like the Heatstar Aquarius model, placing heat directly into the swimming pool water through a titanium heat water condenser coil, would offer superior efficiency during this period.

An outdoor pool which is used during the winter may gain some benefit from a ground source heat pump, but the heat pump is unlikely to offer much contribution towards the very high heat losses from the pool during such periods.

Obviously, with a dwelling within the UK, generally all the domestic air heating requirements for the winter season will, in contrast, occur when the ambient fresh air temperature is less than the temperature underground.

SPA WATER HEATING :

The low temperature of the water circulated through the central heating circuit with a heat pump boiler is an issue for heating spa water.

If the spa water is to be heated up to a temperature of, say, 40°C, there is only minimum temperature difference available to achieve meaningful heat exchange.

It is not theoretically impossible to heat the spa, given a huge heat exchanger, but a more practical approach would be to omit the spa heat exchanger and use a direct electric heater instead.

HOUSE AIR CONDITIONING :

Some more complex heat pump boiler installations have the ability to operate on a ‘reverse cycle’ principle during the summer months, whereby they provide cooling in the house and transfer the excess heat back into the ground via the ground pipe loop or dissipate it to outside air. During the winter months, when heating is required, some of this energy can be re-absorbed from the ground and utilised. It is unlikely such a facility can be utilised practically within a swimming pool application.

SUMMARY :

The use of heat pump boilers, instead of fuel boilers, will invariably continue to expand and, in the long term, may become a standard approach.

Heatstar have embraced the concept of operating their swimming pool climate control systems in conjunction with heat pump boilers and have developed a special range of products designed specifically to overcome the characteristics involved.

Heatstar have also already developed the necessary software to predict the genuine operating cost benefit involved in using a heat pump boiler on any given indoor pool application and to confirm the necessary flow rates involved etc to the specialist heat pump boiler installers.

For more information, please contact Heatstar, Tel : 0044 (0)1983 521465 or e-mail info@heatstar.com