Speech
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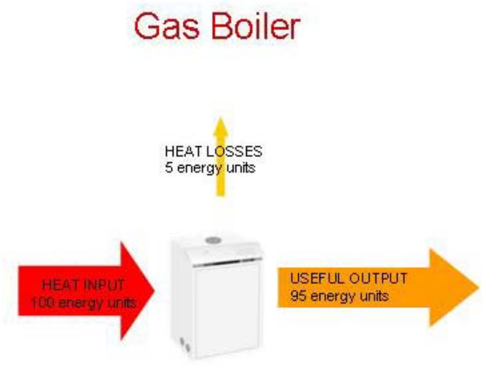
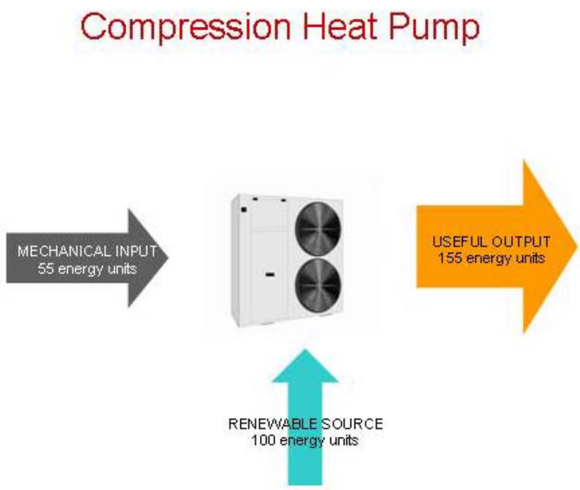
State of Art and Potential of the Gas Absorption Heat Pump Technology

Before entering the presentation of the GAHP technology in the heating applications, let me outline some very basic features of a GAHP versus a regular boiler or versus a regular HP.

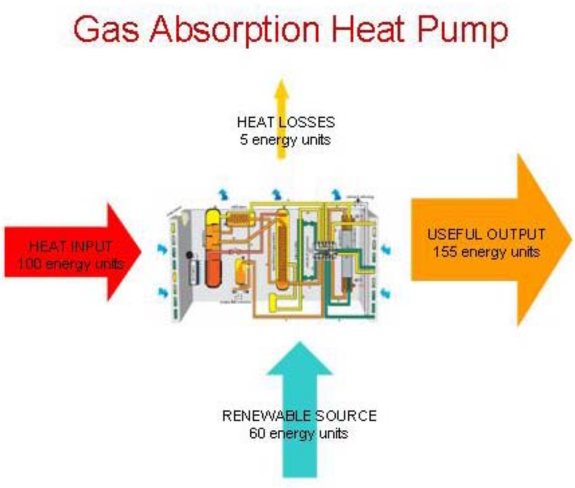
- In a boiler the input is heat (obtained from combustion) and it is released as useful output heat [for example to the water loop of a hydronic heating system]. The amount of output heat is the same amount of the heat input minus the flue losses, and can never exceed the heat input.



- A compression HP is a device in which mechanical energy drives a thermodynamic cycle to “pump” heat from a low temperature source [for example outdoor ambient air] to a higher temperature sink [for example the water loop of a hydronic heating system]. The output heat is the heat pumped from the low temp source plus the mechanical energy input.



- A GAHP (gas absorption heat pump) is a device in which heat drives a thermodynamic cycle to "pump" heat from a low temperature source [for example outdoor ambient air] to a higher temperature sink [for example the water loop of a hydronic heating system]. When applied to an heating system a GAHP device delivers the heat output at an efficiency much higher than a conventional heater, and the useful *output heat* is the sum of the heat input plus the heat pumped from the low temperature source minus the flue losses. The useful *output heat* is higher the *driving input heat* (while in a conventional heater the useful output is always lower than the input).



In the previous speech we have seen that several new European initiatives (ErP Final Report, RHC platform, Ecolabel, 7th Frame program) have already recognized in the various heat pumps technology, and specifically in GAHP the potential to address a significant reduction in energy consumption.

New heat pump heating systems (used in new buildings or in buildings that have undergone major renovation), are capable of achieving energy saving up to 50%. Most European countries already consider Heat Pumps as the "next step" after the condensing boiler in achieving higher efficiencies in new buildings.

The scenario is extremely favourable, but a number of technological and non-technological issues need to be addressed carefully to make the HPs a viable product for the market. In this speech I will focus primarily on the technological issues.

When dealing with heating and DHW in Europe it is important to highlight that the residential market is roughly 90% of total sales. In this large share roughly 95% is a retrofit/replacement market, which basically means hydronic systems based on radiators and with heating water temperatures in excess of 70°C; this is the legacy of the existing European building stock resulting from decades of application of gas boilers.

In the retrofit applications, that is where the highest demand for improvement exist, we found significant challenges for the various Heat Pump technologies. I would like to list you some of the most demanding challenges, in particular for the residential applications.

1. Access to a low temperature source: there are several options, outdoor air, geothermal heat, winter solar panel, ground water, and combinations of the above.
2. Radiators impose water temperatures in excess of 70°C (especially when outside is -20°C) Use of existing venting system to avoid expensive building renovation.

3. Modulation of heating capacity: typical residential boilers maximum capacities are around 20kW, which can be modulated down to 4kW in the best design condensing boilers. The maximum output is normally delivered only during those very few hours per years when the outdoor temperature reaches its lower level.
4. Availability of DHW: the system must be able to provide DHW as a complementary service, like a regular boiler does.
5. Ease of installation: the average installer must be able to correctly install and service the product. The location of the device should either exactly replace an existing boiler or fit within given typical appliance dimensions. Outdoor installation could be an advantage, but it is not always available/possible.
6. Low noise level: boilers have already established in the mind of consumers a very high expectation for quietness of the heating function.
7. high efficiency operation: efficient performances must be assured with a simple system control and even simpler user interface, no sophisticated controls will be accepted by the installer and end user.
8. Reduced amount of direct and indirect emissions in particular in urban areas (CO2, NOx and PM)
9. Availability of technology at a price level that will encourage end users to upgrade either because of short payback time (against regular boilers) or because lower required investment than alternative renewable heating solutions

Let’s now review how today’s HP heating technology can address these challenges.

For a residential retrofit application the only viable renewable source choice is outdoor air with possible support of solar heat. Drilling geothermal wells or using ground water is possible for new buildings, but only in “corner case conditions” for existing buildings. The geothermal installation itself will raise the cost of a heat pump system far above any other alternative.

Current status of Heat Pump technology implies that temperature in excess of 70°C can be reached only by means of water-ammonia absorption, CO2 or two stages compression systems with a possible choice of alternative refrigerants [R290(Propane, R600(Butane), R245fa (Pentafluorpropane), etc].

Combination of high temperature heating water with low air source temperatures, while providing full capacity is possible with absorption technology, or with compression HP plus back-up boiler combination. Modulating capacity also is a mandatory feature and it is already available in GAHP. In our opinion the back-up boiler is a simple concept, but it adds cost, and especially big complexity to the control system [making the efficiency of the heat pump rely on the boiler switch-off/switch-on settings].

Installation and size is a common challenge for most heat pump systems. Very difficult to be exactly fitted within the typical boiler location and dimension; by the way new HP design are available allowing more compact and lower weight units (the target of achieving less than 10kg per kW of output power is indeed conceivable).

Noise and auxiliary energy consumption of future HP could take advantage of the latest developments in acoustic insulation, fan blades geometry, high efficiency inverters for fan and water circulators.

Installation cost of HPs (in general) will be higher than a plain boiler, but the potential for a significant difference reduction is in large volume manufacturing.

Let me focus on specific considerations about GAHP heating technology for heating application.

These elements contribute to make *water ammonia air source modulating gas fired heat pump* as one of the most promising technologies for the next steps in energy efficiency improvement.

- Existing GAHPs already provide among the highest efficiencies available in heating system.
- The technology is based on natural refrigerant Water + Ammonia: ODPO=0, GDP=0. Direct and indirect emissions: according to the latest data published by the European Commissions, when taking in consideration all emission factors (CO2, NOx and PM), GAHP already outstands as the “cleanest” solution for heating application.
- GAHPs are gas fired, can be air source (and yet maintain its high efficiency) and deliver high water temperatures. This makes the application of the GAHPs very similar to regular boilers, from capacity, temperature and controls point of view.
- The thermodynamic cycle is hermetically sealed and substantially static (a solution pump, which reduces to two check-valves and a membrane are the only mechanic moving parts), for long life and maintenance free operation required in heating applications.
- GAHPs are already industrially manufactured and benefit from the long experience of the absorption chillers industry.
- The cycle components are (mandatory) steel made (versus the copper made compression component). This requires specifically developed component design and manufacturing process, which is a technology barrier. Once developed there is a high potential of manufacturing cost reduction, the steel base material ranging from 1/5 to 1/8 of the copper base material cost.
- GAHPs are gas fired, so do not add load to the electrical grid and therefore impose neither the creation of smart grids to manage the incremental loads nor the upgrade of the generation and transmission systems to deliver the extra capacity.
- The principle of Absorption thermodynamics has been known since late 1800. But the potential for new developments on Gas absorption heat pump technology is huge. Only few manufacturers and university/research labs have recently investigated on this technology. What would happen if even a small portion of the effort has been devoted to boilers or compressors R&D would be addressed to this technology?
- The GAHP technology has already reached a GUE of 160% (at rating conditions EN12309). Potential efficiency increase up to 190% and more are already possible with advanced cycle design (there is already a large number of novel advanced absorption cycle theory available. Lot of them never really fully simulated and experimentally developed).
- The skills required for the GAHP technology range from thermodynamic systems to chemistry, to heat and mass exchanger simulation, to fluid dynamics, to metallurgy, etc. The jobs created for such development are high education, training and expertise requiring. They will form a core competence team that will add value to the entire organization investing in them.

In conclusion, we have just reviewed the key challenges of the retrofitting and the “key” and “unique” benefits that GAHP technology can bring to address these issues.

Finally, let me add some considerations about further potential of the water ammonia absorption cycles as “fall out” of the technology in other field of application.

- The water ammonia absorption technology is the base for new multistage cycles that can be driven by low temperature waste heat to deliver free A/C or refrigeration. I am personally following the development of an air cooled refrigerating prototype (for demonstration purpose only) using a pure water and ammonia dual lift absorption cycle driven by hot water from 70°C to 95°C. This innovative absorption development concept could offer several new opportunities including:

    - automotive A/C o truck refrigeration (when used in combination with engine cooling water),
    - air conditioning applications (without cooling towers) driven by low temp thermal solar systems (flat panels) or biomass boilers
    - air conditioning applications (without cooling towers) based on district heating networks,
    - trigeneration applications for growing market of high efficiency Combined Heat and Power
- The water ammonia absorption technology is the base for the Kalina family power cycles, the most efficient alternative to the Rankine cycle up to date (60+% of world power generation today).

In conclusion, the research and development in GAHPs technology offer the heating industry a unique opportunity for:

- providing significant energy saving in the European heating and DHW market (35% of final energy use)
- providing a range of high efficiency products (GUE=160%) fitting into the “real” and most demanding marketplace: the retrofit/replacement with its own related constrains.
- to help shifting the excess manufacturing capacity of the heating industry toward a high tech industrial environment.
- to create highly qualified jobs and new proprietary core competence teams.
- to explore other significant possibilities offered by the same core base absorption technology.