The water vapor pump technologies back in France

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*CIEC is a french company member of the GDF Suez Group. Since 2012, the WVP (water vapor pump) cycle is again among the priorities of CIEC, an eco-responsible company proposing more and more sustainable and green heating solutions to its clients in industrial and district heating. After a large development of the WVP cycle in heating plants during the 1980s and 1990s, this CIEC WVP relaunching brings again to its customers a reference facility in terms of fuel saving and environment protection, especially in case of natural gas heating plant.

If the water vapour pump (WVP) concept has been invented in France in 1978 and quickly recognized by universities and thermal industry as a really advanced concept to save fossil fuels and to protect the environment, the economical approach has often limited the diffusion of the WVP cycle because of a pay-back time often considered as long (about five years)… In spite of that, the WVP cycle has been commercialized in France and in Europe with a special development on direct heating boilers in Canada and more recently on boilers in USA.

The water vapor pump cycle, how does it work?

The water vapor pump cycle is based on a thermodynamic cycle which consists in a wet combustion. This cycle reduces the NOx formation and increases the thermal efficiency of the process.

Here under is a scheme of the WVP cycle:

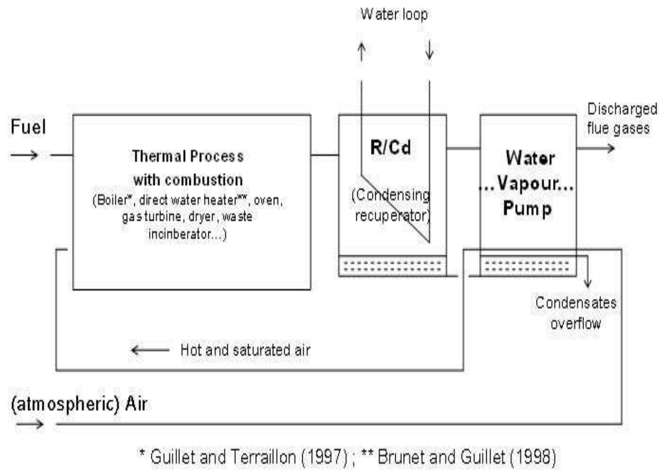

Figure 1: the water vapor pump cycle

Before entering the chimney, the residual combustion products energy is recovered by using the combustion air as additional cold source.

By recycling this residual latent and sensible energy, the combustion air is preheated and, above all, humidified up to its saturation at the said preheated temperature (about 60°C or 140°F).

Of course, the WVP cycle efficiency will be 100% g.c.v. (or 111% n.c.v.) when the exhaust gases temperature at the chimney is the ambient temperature!

The usual dew point of natural gas stoichiometric combustion products is (also) about 60°C (140°F) and then limits the advantages of the condensing boilers to “low temperature” installations. On the contrary and opportunatly, the WVP cycle increases the dew point temperature up to 72°C (162°F) thanks to the combustion air humidification while the recovering of the residual latent and sensible energy (traditionnaly lost) is performed!

The WVP cycle enlarges the field of the water vapor condensation recovery in an additional condenser (which is associated to the main process, when the latter is not designed as a condensing exchanger).

Moreover, in all cases, the WVP cycle brings the guarantee to be the highest efficiency cycle (even if related to traditional condensation systems!).

But the WVP cycle is also a “wet combustion[1, 2]” cycle. In case of natural gas combustion (well-known as a “clean” fossil fuel), another important result is the reduction of NOx production, thanks to a lower adiabatic combustion temperature than in traditional combustion (using directly the atmospheric air).

The WVP exchanger following the double scrubber technology

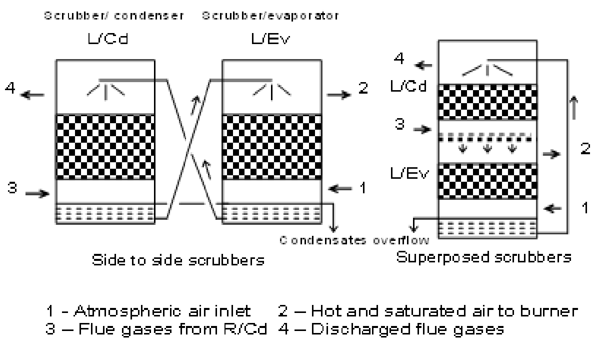

Figure 2: The double scrubber technology

If the double scrubber technology is used (which is the case of the current WVP CIEC design), this latent and sensible heat exchanger is composed of two packed columns with random packing in polypropylene and stainless steel. They are sized and optimized according to the generalized pressure drop correlation (GPDC) and the Eckert[3] correlation for the random packing flooding point.

These two columns can be installed side by side or superposed (fig. 2).

The water vapor pump cycle on heating plant by CIEC in Goussainville

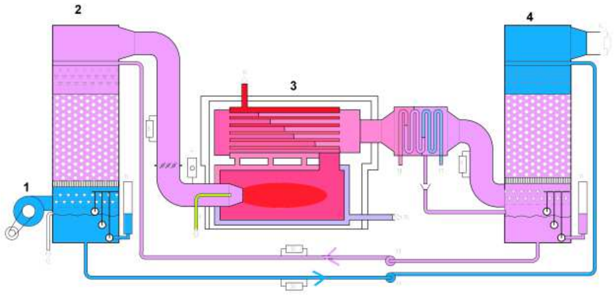

Figure 3: composition of the new Goussainville facility

1 Centrifugal fan; 2 Packed column “evaporator”; 3 Boiler and its associated condensing exchanger; 4 Packed column “condenser”

Nowadays, the WVP cycle is the way to get the most efficient natural gas combustion. For example, when the WVP exchanger efficiency is about 65% and T.Cd = 50°C (water loop temperature back to the condenser), while a classic or traditional (condensing) boiler efficiency is 99% n.c.v., the water vapor pump cycle efficiency reaches 106.5 % n.c.v (see the crossing point between vertical line T.Cd = 50°C and the uppermost limit of the blue area on figure 4).

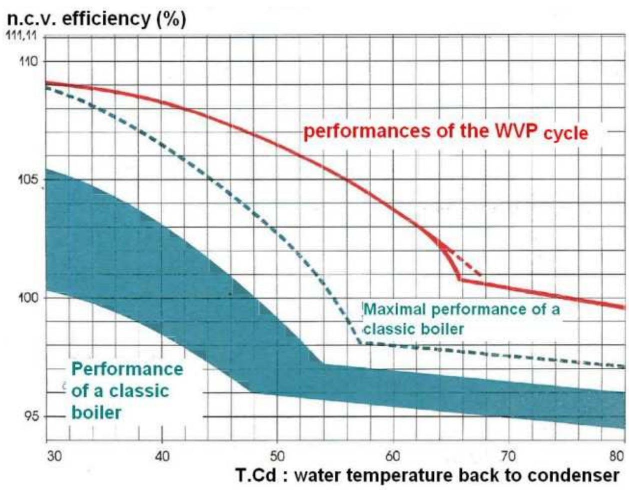

Figure 4: efficiency of a water vapor pump cycle

Besides the energy savings, and always thanks to the wet combustion that the WVP cycle induces, the NOx reduction reinforces the natural gas environmental qualities.

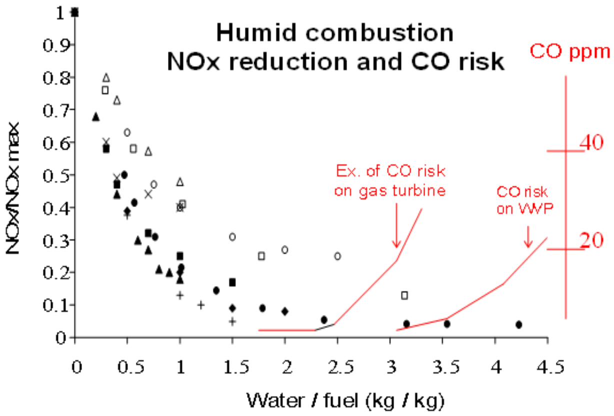

Figure 5: NOx reduction using a wet combustion (as the WVP cycle is…)

For example, when the mass ratio water/fuel is between 1.5 and 2, (which is the WVP cycle average), the NOx formation related to atmospheric combustion decreased to 25% (meanwhile, on the right hand-side of the figure 5, we can observe a risk of CO apparition when the ratio water/fuel is higher than 3; see the continuous curves for a WVP cycle and gas turbine examples).

The water vapor pump cycle in Goussainville

Figure 6: The water vapor pump inauguration in Goussainville, France

7th June 2014, the first water vapor pump cycle of the new CIEC generation was publicly inaugurated in Goussainville, France. Its heating power of 2 MW answers the needs of heating and hot water of the entire residence of 293 households. This water vapor pump is also the first to reach such a high combustion air temperature: 60°C (140°F°).

Other perspectives for the WVP cycle

To get the best with the natural gas combustion, we must consider the WVP cycle advantages!…

Moreover, the water vapor pump cycle can also offer many benefits in case of wood or coal heating plants. For example, when the fumes washing is imposed (for example as in german wood heating plants), the half of the WVP exchanger is already carried out! And the WVP cycle must be studied as a pertinent alternative to a single washer.

In a large development of its use in the world, the wet combustion using the WVP cycle can also be studied as a way to improve the coal combustion… The table here after is an encouragement to experiment wet coal combustion…

	NOx	Particles
bitumen +water (30%)	-20%	-60%
Heavyfuel oil + water (20%)	-15%	-80%

(These values, obtained on reciprocating engines, are extracted from Maruffo and from Diego M.A. presentation at the 17th WEC Congress in Houston) …

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Last but not least, the WVP exchanger is a low temperature exchanger. Its components can be recycled up to more than 80%. The WVP cycle is definitely a good way to move forward to a sustainable world!

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[1] R.Guillet, "Wet way combustion", Elsevier 2000; ISBN 2-84299-180-X

[2] R.Guillet, *"La combustion par voie humide et ses performances"* (Wet way combustion and its performances), thesis, University Nancy 1, 2002

[3] Eckert JS, Foote EH, Walter LF, What affects packing performance, Chem. Eng. Process, vol.62, no.1n p.59/67