The novel heat-to-electricity converter

The novel heat-to-electricity converter (generator) is a radically new, thermodynamic heat engine intended to convert heat to mechanical energy and eventually to electricity. The generator has only one moving part and combines most of advantages of the newest external combustion engines (e.g. regeneration) and ability to use any heat sources like waste heat, solar energy, biomass derived products etc. Mechanical energy generated can be converted not only to electricity but can also be used for compression of gases, pumping of liquids, driving of coolers and heat pumps, etc.

The simplest embodiment of the new generator in form of a heat-to-electricity converter is shown in Figure 1.

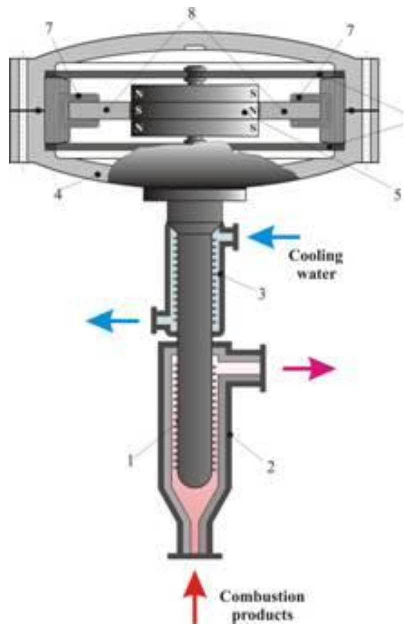

Figure 1. Novel heat-to-electricity converter

The generator includes primer mover 1 consisting of cylinder with well-developed surface (with numerous fins playing at the same time a role of stiffeners) to enhance heat exchange. The lower, hot part of the cylinder is placed inside heater 2 and is heated by available heat source, for example, by natural gas combustion products. The upper, cold part is cooled by water jacket 3.

The primer mover is connected to linear electrical alternator casing 4 operated under high pressure. The reciprocating link of the prime mover is rigidly attached to permanent magnet based rotor 5 of an electrical alternator. The rotor is suspended on linear flexures 6. The alternator also includes electrical coils 7 and laminate core 8.

The generator is self-starting. During the reciprocation the linear alternator generates electricity; the rest of heat rejected goes to hot water storage tank, heat pump, absorption chiller etc.

Therefore the generator proposed combines most advantageous features of Stirling technology and the wide, unique experience in field of high-pressure contactless reciprocating seals, accumulated during the development of the pulsed compression reactors at University of Twente.

The new cycle provides regeneration of heat that makes it possible to increase dramatically thermal efficiency. The regenerator takes up heat from the working fluid during one working stroke, temporarily stores it and subsequently returns it to the working fluid again during the second working stroke. Thus the regenerator may be thought of as an oscillatory thermodynamic sponge, alternately absorbing and releasing heat with complete reversibility and no loss.

The use of noble gases, like helium or argon, as a working fluid prevents corrosion. Volumetric efficiency can be also increased steeply by virtue of using a working fluid under high pressure.

In case the heat is generated by combustion NOx, unburned hydrocarbon and CO emission of the generator is inherently low because of continuous rather then periodic combustion. The use of advanced catalytic burners can additionally decrease emission.

Being an externally combustion engine the generator demonstrates great fuel flexibility.

Both strokes of the piston are working ones in contrary to any other types of piston engines with the only one working stroke.

The generator has a number of advantages compared to state-of-the-art external (Stirling) and internal combustion (IC) engines.

The main advantage is the simplicity. The engine has only one moving part and no gas springs, piston rings, gears or any other rubbing components requiring lubrication. Taking into account that the lifetime of the today's flexures exceeds 50.000 hours the generator can be considered as maintenance-free.

The heat regenerator formed on the side surface of the displacer allows solving the problem of the high-temperature sealing of the displacer typical of all types of Stirling engines. In addition, the design proposed provides an ideal use of the displacer volume minimizing heat loss from an outside gas circuit.

The only seal is located in the cold part of the cylinder in contrary to Stirling and especially IC-engines. It makes it possible to keep an extremely low clearance in between the power piston and the cylinder. As a result the leakage rate in operation can be one-two orders of magnitude as small as that in Stirling engines.

Balancing of the generator is much easy compared to all other types of piston machines because of the only moving part reciprocating on the flexures with almost linear characteristic.

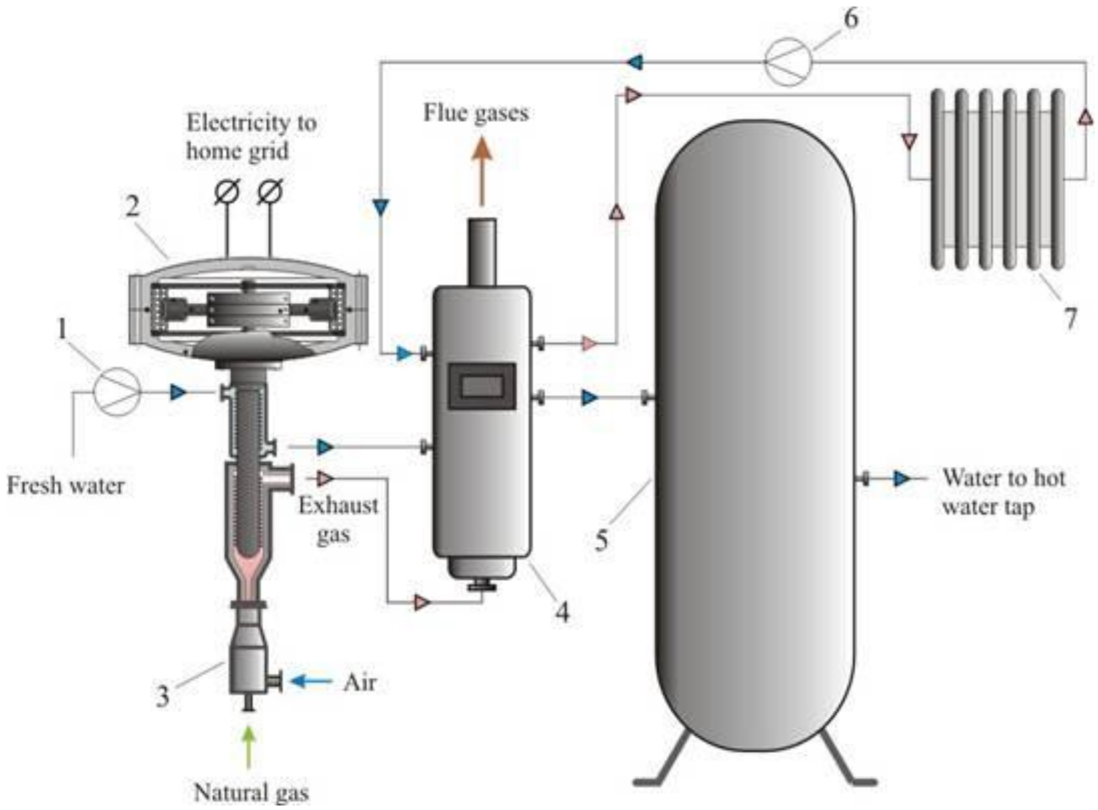

Figure 2. Possible domestic micro-CHP installations

The generator is expected to be used as a hermetically sealed prime mover for a domestic microcogeneration installations, standby generators, unmanned small-scale remote areas generators for telecommunications and control equipment on unattended offshore gas platforms, for pipeline cathodic protection and remote gate valves actuation, for telecommunications, SCADA, repeater station, spacecraft and weapons power supply systems etc.

One of the possible, simplest domestic micro-CHP installations based on natural gas is shown in Figure 2.

Water pump 1 supplies fresh cold water to the cold, upper part of generator 2; heat is provided by burner 3 fuelled with natural gas. The preheated water from the generator goes to waste heat boiler 4 heated by exhaust combustion products after the generator. The hot water produced goes to heat insulated hot water storage tank 5 and then to hot water taps. The boiler also has an additional heat coil to produce hot water for home heating. Water circulates by means of centrifugal pump 5 through the closed loop including the boiler heating coil and a set of heat radiators 7.

More complicated case can include an absorption or compression type heat pump, conditioner etc.

Instead of natural gas, any kind of heat sources can be used – coal, wood chips, biogas, solar radiation etc.

In practice the generator will be combined with burner and heat recovery boiler resulted in a final hermetic, fully integrated, noiseless, safe, reliable and maintenance-free wall-mounted unit.

Such installations can provide electricity generation and all home heating needs for decades. The heat produced can be used not only for space and water heating but also for cooling (trigeneration); excess of electricity can be fed into the grid. Such a technology can offer energy savings ranging between 15-40%, improvements of the reliability of the power supply, reducing the cost of electricity, and lower emissions of air pollutants (Robert W. Shaw, Jr., Microgeneration Technology: Shaping Energy Markets; Preprint of an article published in "The Bridge", National Academy of Engineering, Summer 2003).

A demand for such systems is expected to be tremendous. In case of microcogeneration, for example, only in the Netherlands more than 6 million houses have gas central heating appliances, and 400,000 gas boilers are sold each year. In Germany there are some 21 million households with gas central heating, and annually some 1.5 million boilers are replaced. There are approximately 17 million gas-fired heating systems in Great Britain and approximately 1.3 million gas boilers are sold a year, indicating a large potential market for micro-CHP. Across the whole of the current European Union there is a potential for up to 50 million installations with the key markets being the UK, the Netherlands, Germany, France, Italy, Belgium, Demark and Ireland (Micro-CHP needs specific treatment in the European Directive on Cogeneration, www.cogen.org). An conservative estimates of the market potential within the existing market for the whole of Europe for shown about 5 million units per year by 2020, displacing 20% of domestic electricity consumption (N. Constantinescu, District heating across Europe; trends from East to West; Cogeneration and On-Site power production, Volume 4, Issue 5, September-October 2003).