Institute of Fluid-Flow Machinery, Polish Academy of Sciences
Centre of Mechanics of Machines
Department of Turbine Dynamics and Diagnostics

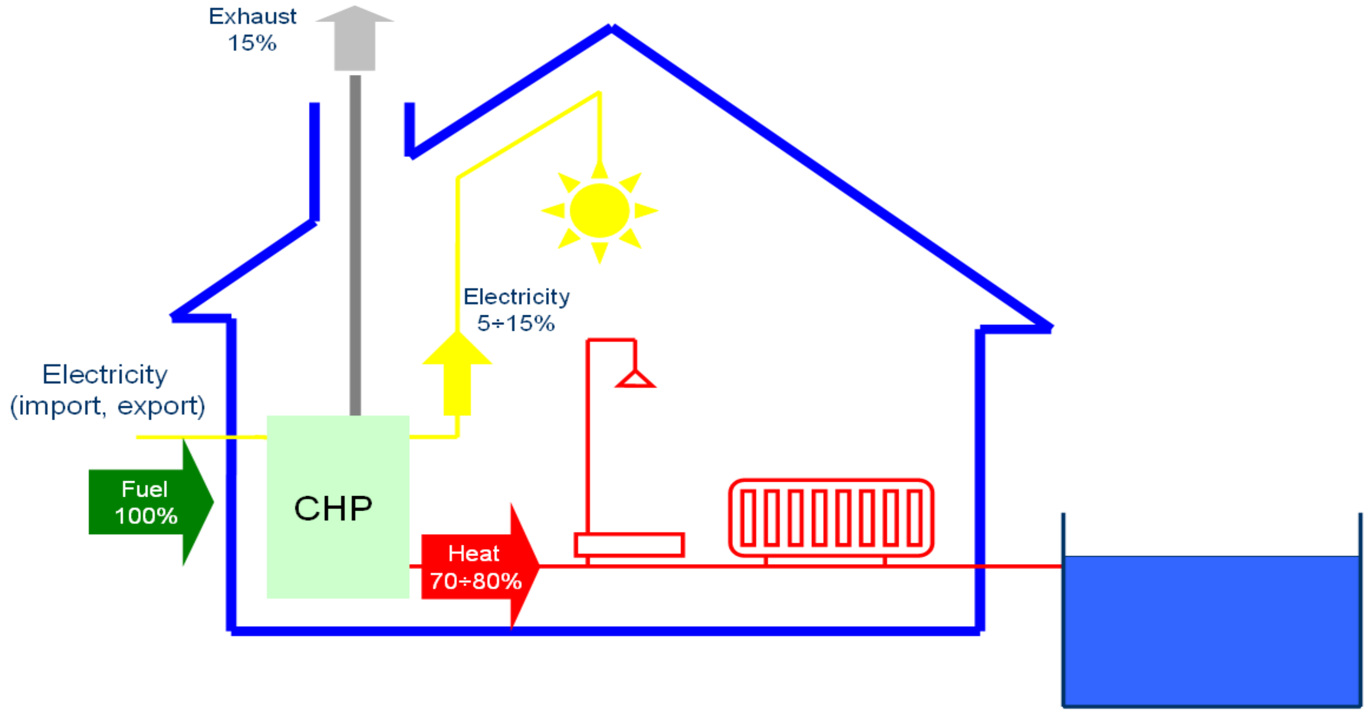
Prototype of the domestic CHP ORC system: construction and experimental research

Grzegorz Zywica, PhD Eng.
Jan Kicinski, Prof. DSc PhD Eng.
Tomasz Kaczmarczyk, PhD Eng.
Eugeniusz Ihnatowicz, PhD Eng.
Tomasz Turzynski, MSc Eng.
Sebastian Bykuc, MSc Eng.

Content of presentation

- Introduction, motivation
- Domestic CHP ORC power plant
  - Working medium and thermodynamic cycle
  - Key components
  - Construction work on the prototype
  - Preliminary tests of the prototype
- Summary and conclusions

Domestic micro CHP unit with ORC technology

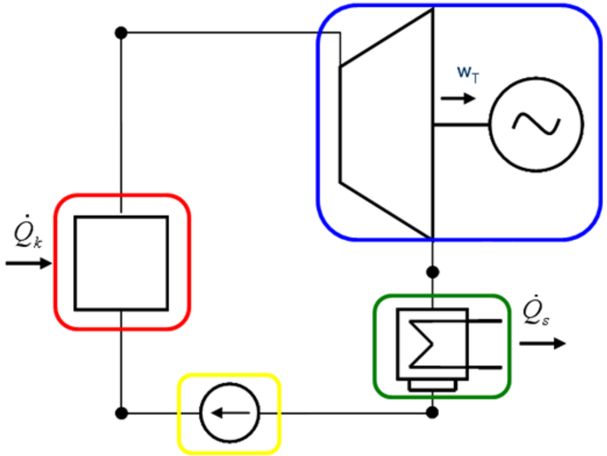


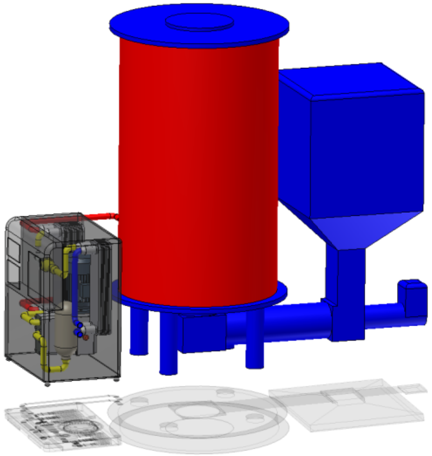
Possible applications:
- detached houses,
- agricultural holdings,
- summer houses, etc.

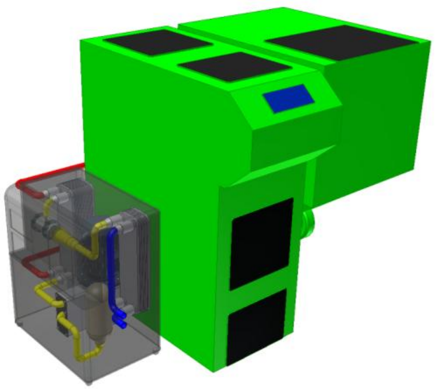
The concept of a micro CHP ORC-based power plant (2008)

Basic assumptions:

- heat output of ca. 20 kW
- electric output of 2 - 3 kW
- multi-fuel boiler (biomass, biogas)
- organic Rankine cycle (ORC)
- steam micro-turbine
- small dimensions

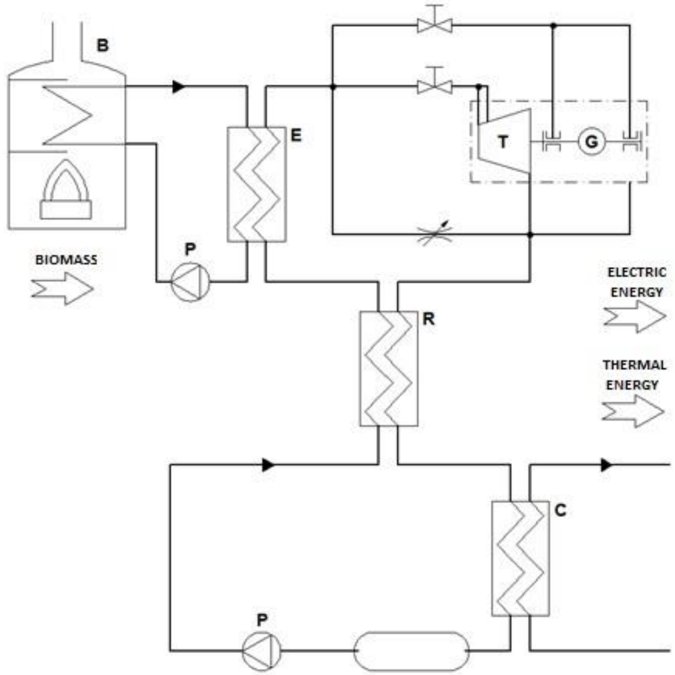




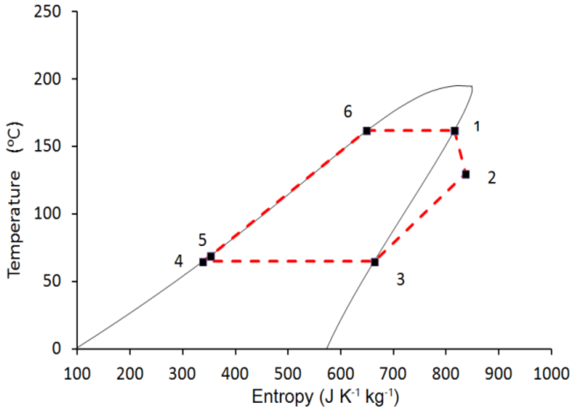


Basic components of the micro power plant

- multi-fuel boiler with a heat exchanger
- heating circuit pump
- circulation pump in the ORC
- heat exchangers
- turbogenerator
- low-boiling medium tank
- a set of valves
- measuring and control system
- working medium: Novec HFE-7100



Properties	Unit	HFE-7100
Boiling point	ºC	61
Melting. point	ºC	-135
Density	g/cm³	1.52
Heat of vaporization	kJ/kg	125
Specific heat	kJ/kg · K	1.17



Laboratory of micro ORC power plant at IFFM PASci

Testing of the heat exchangers and micro-turbine

Testing of the boiler

Developed oil-free turbogenerators

Turbogenerator with a radial-flow supersonic turbine

Design parameters:

rotational speed: 35 000 rpm,

electrical power: 3.26 kW

Turbogenerator with a radial-flow 4-stage turbine

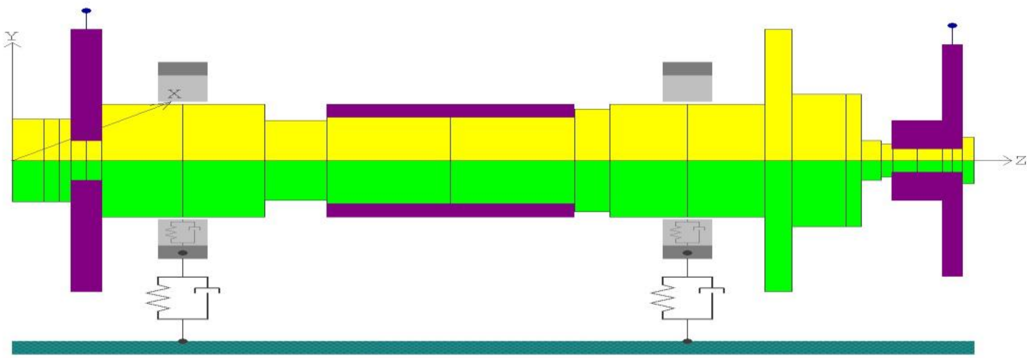
Design parameters:

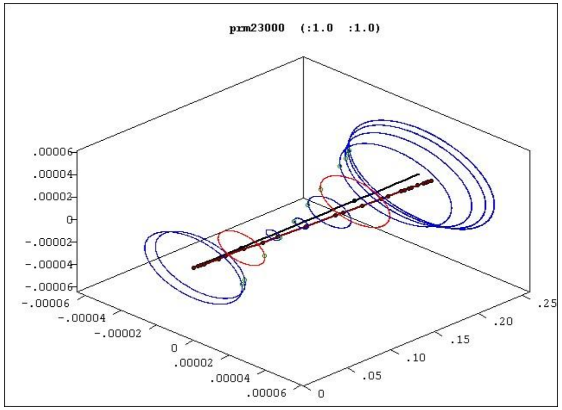
rotational speed: 24 000 rpm,

electrical capacity (nominal): 3 kW

Cooperation with the Lodz University of Technology (Professor Kozanecki's team)

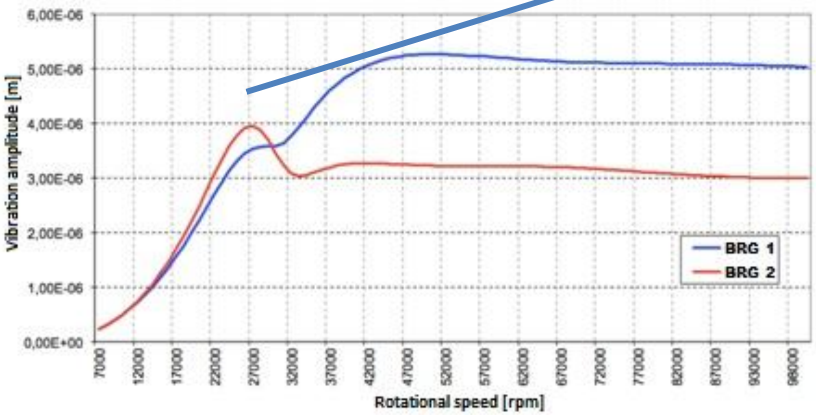
Analysis of the rotor – gas bearings system

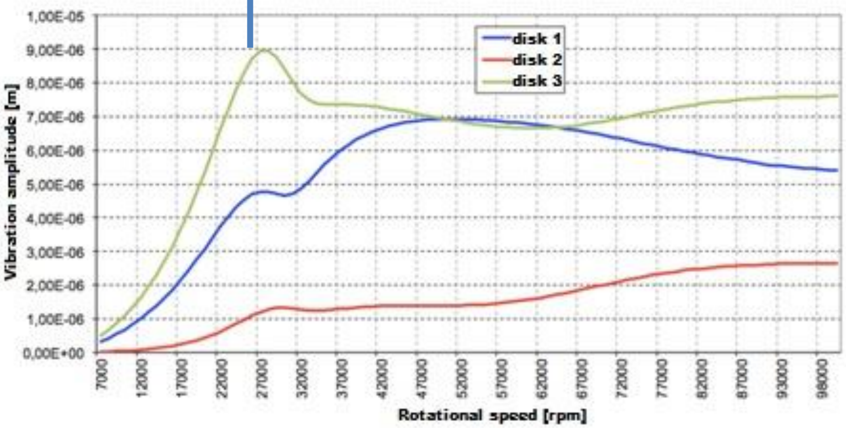




Bearing vibration

Disk vibration

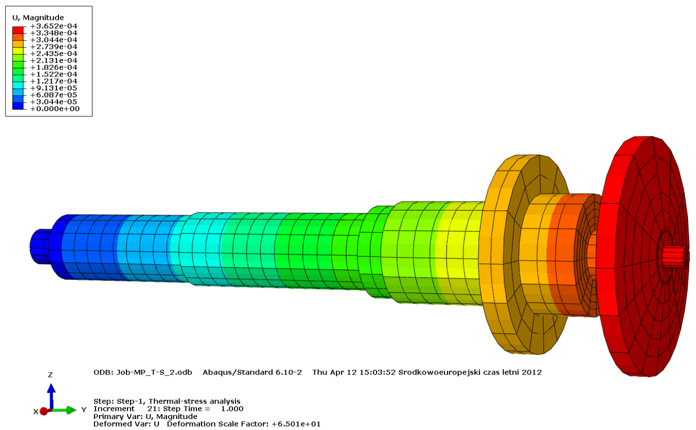


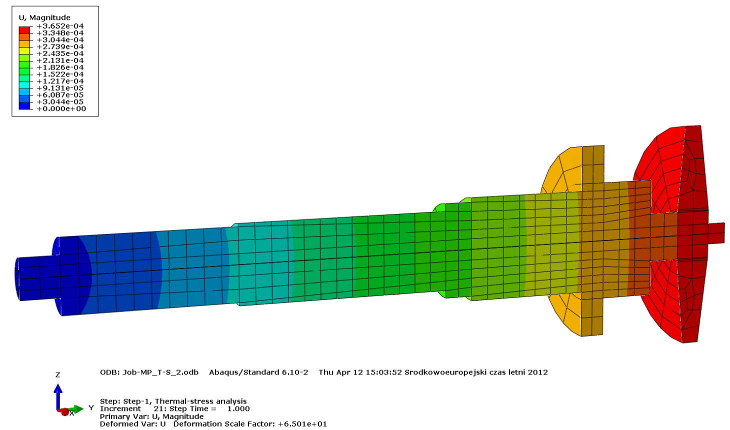


The software called „MESWIR" was used (developed at the IFFM PASci)

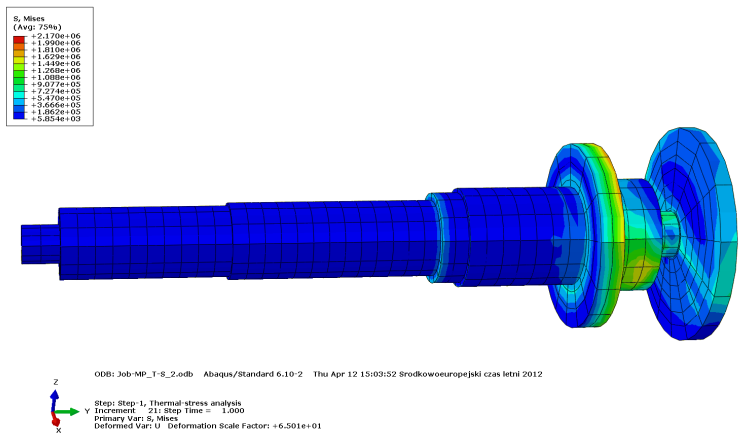
Numerical calculations – analysis of thermal loads

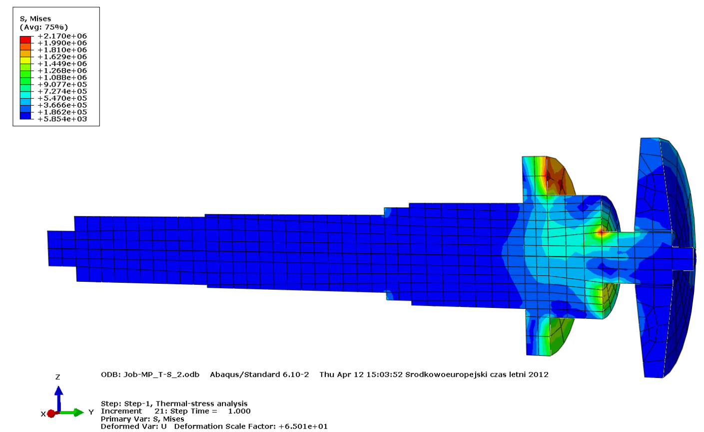
Thermal displacements



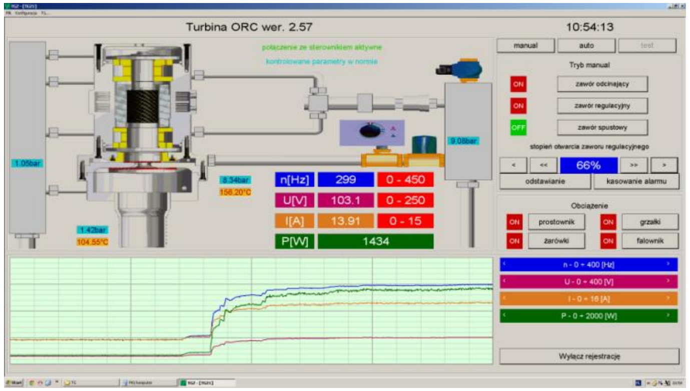


Thermal stress





Start-up of the turbogenerator



October 2012

Testing of the organic Rankine cycle

Test stand for testing heat exchangers

Test stand for testing micro power plant

The most important guiding principles for the design work on domestic ORC-based power plant:

1. The practical layout of elements around the **biggest component** – regenerator

2. The application of the principle: **hot steam at the top**, cold liquid at the bottom (microturbine is the highest and circulating pump is the lowest component above the ground)

3. The use of pipelines of the **highest possible diameter**

4. Avoiding **angle joints** and large changes in the diameter of the pipelines

5. Connecting subassemblies with **flexible fittings**

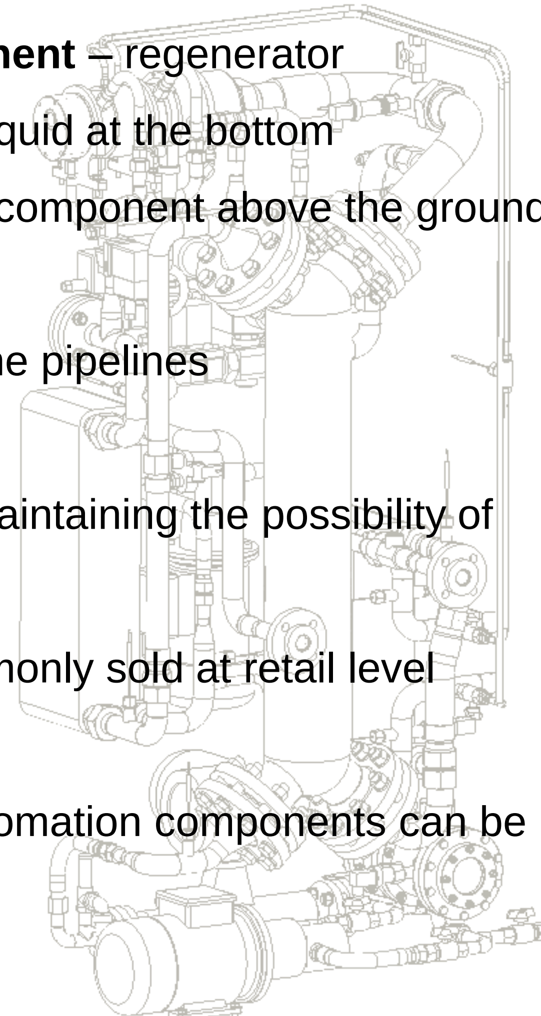
6. Replacement of **detachable joints** by welded joints, while maintaining the possibility of dismantling of each individual part

7. The use of **standard elements and materials** that are commonly sold at retail level (ease of repair or reconstruction)

8. **Continuous circulation of air** so that pump motors and automation components can be cooled effectively

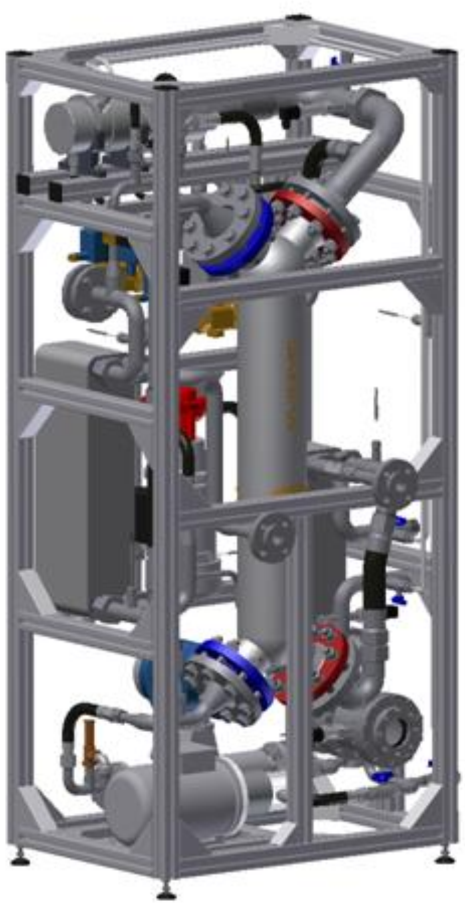
9. Planning the so-called **transparent side**

10. Additional connections specially designed to make **servicing simple and convenient**



CHP module – the basic part of micro power plant

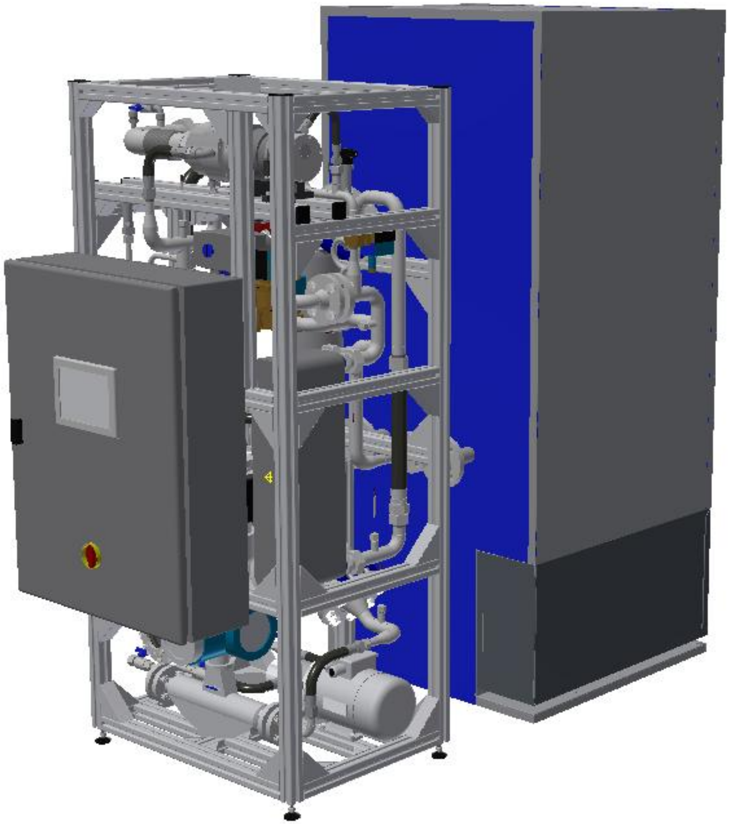
CAD model



Assembly operations

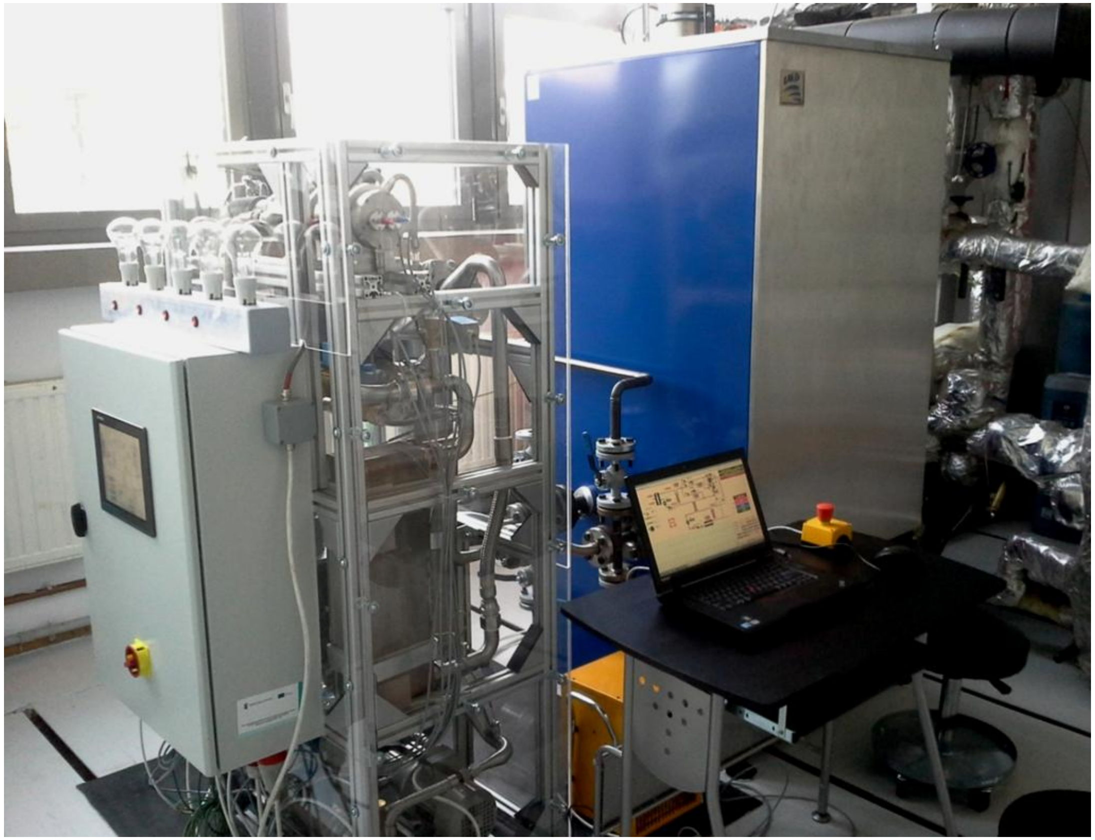
CHP ORC-based micro power plant (boiler with the CHP module)

CAD 3D model



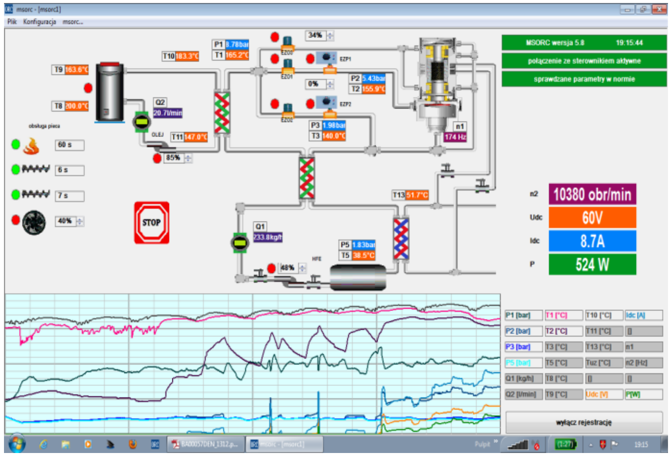
Complete prototype in the lab

Prototype of domestic CHP ORC power plant

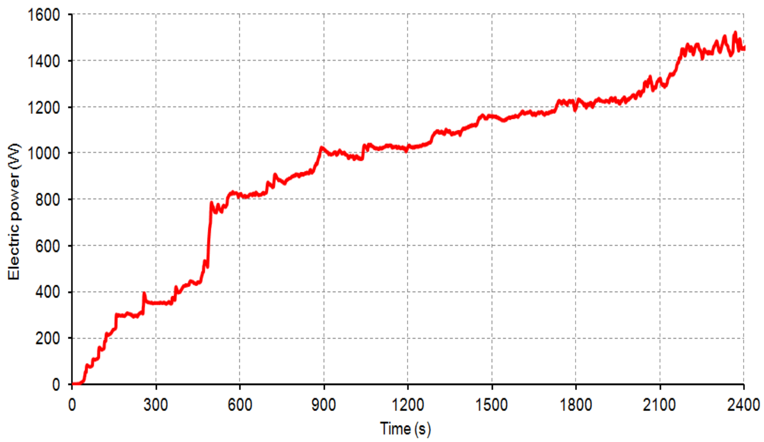


Technical data:

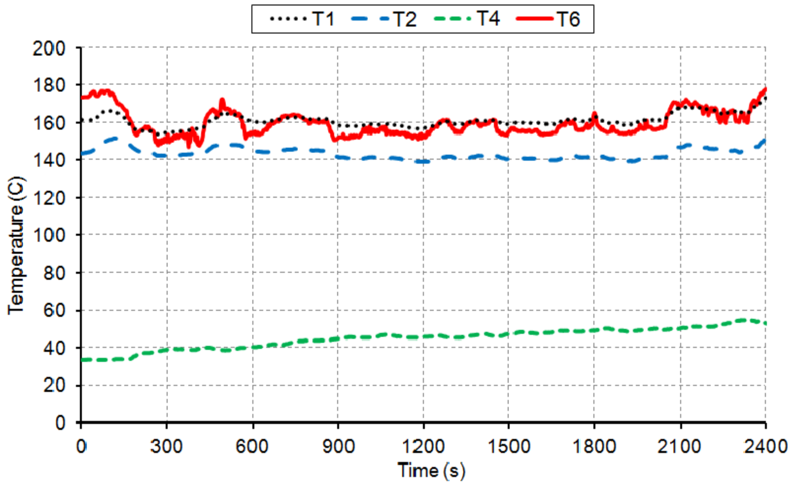
Dim 160x74x74(175) cm
Heat output: ~25 kW
Electrical power: ~2.5 kW
Output voltage: 230V AC 50Hz
Fuel: biomass (pellets)



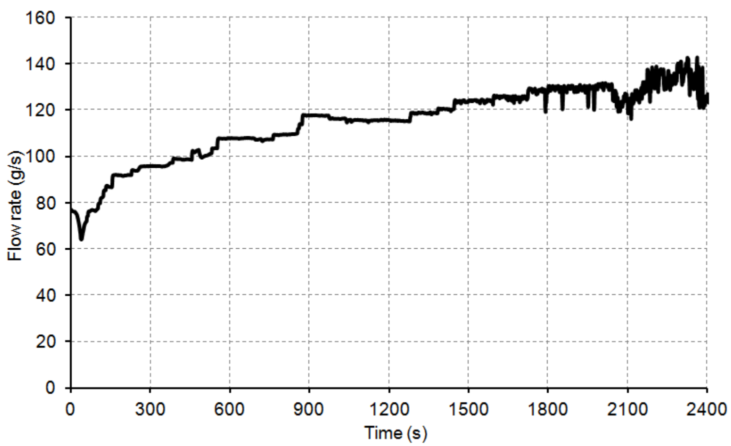
Selected results of investigation



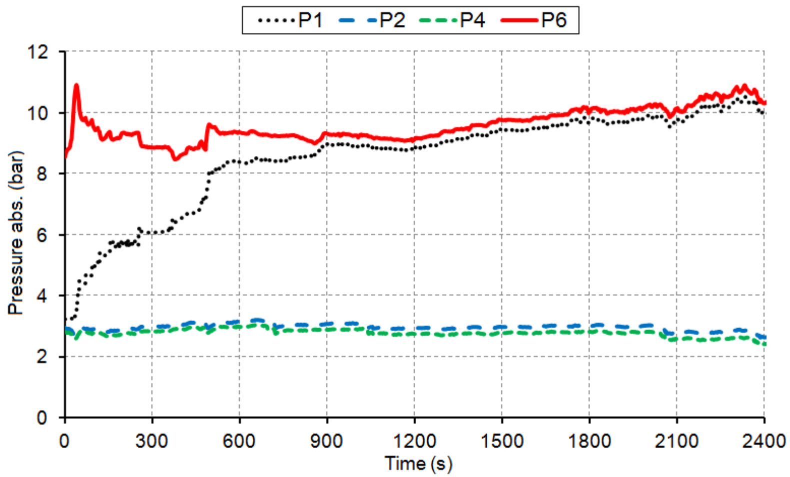
Electric power produced by the turbo-generator during preliminary tests of the CHP ORC energy system



The temperature of the working medium HFE-7100 during test (T1 – temperature before the micro-turbine, T2 – temperature after the micro-turbine, T4 – temperature in the tank, T6 – temperature after the evaporator).

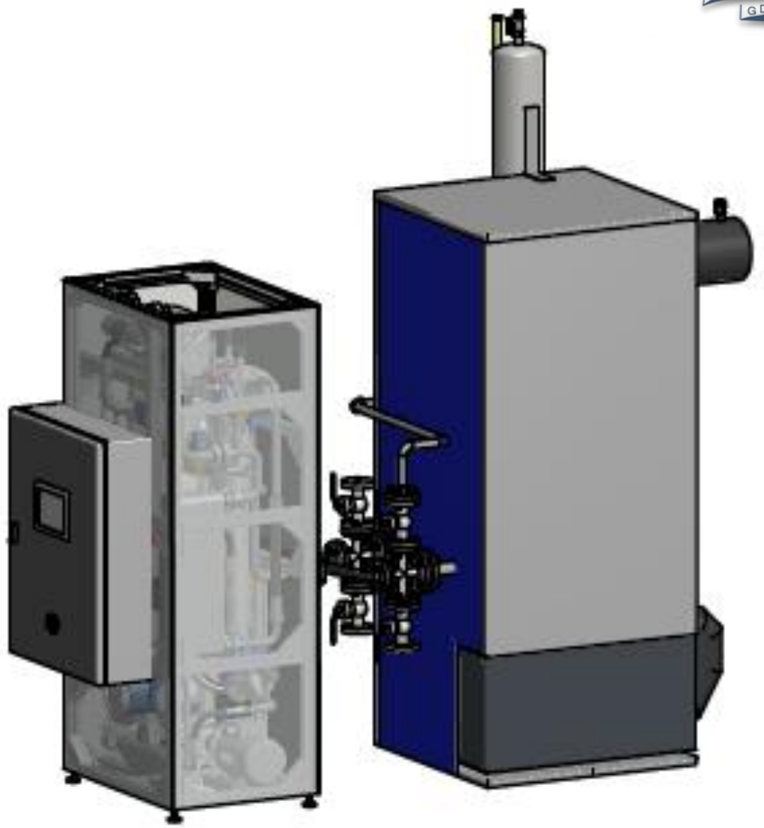


The mass flow rate of the working medium HFE-7100 during test



The pressure of the working medium HFE-7100 during test (P1 – pressure before the micro-turbine, P2 – pressure after the micro-turbine, P4 – pressure in the tank, P6 – pressure after the evaporator,).

Summary and conclusions



Potential application areas:

- single-family homes
- agricultural holdings
- public buildings
- holiday homes

Main advantages:

- better fuel exploitation
- electricity and heat produced from RES
- larger share of RES in the energy balance
- increased energy security
- efficient use of local resources
- easy adjustment of reserved capacity to actual needs
- possibility to sell an energy excess

Contact :

Institute of Fluid-Flow Machinery, Polish Academy of Sciences

www.imp.gda.pl

www.pkagro.imp.gda.pl

gzywica@imp.gda.pl

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modelowe kompleksy agroenergetyczne

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Research Task No. 4

DEVELOPMENT OF INTEGRATED TECHNOLOGY OF FUELS AND ENERGY FROM BIOMASS, AGRICULTURAL WASTE AND OTHER