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BUILDINGS

TOWARDS DEVELOPMENT OF 1-10 KW PILOT ORC UNITS OPERATING WITH HEXAMETHYLDISILOXANE AND USING ROTARY VANE EXPANDER

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OUTLINE

- Introduction & Motivation.
- Overview of developed units:
 - 1 kW CHP first proof of concept (isopropylbenzene fluid).
 - 1 kW WHR proof of concept (MM fluid).
 - 5 kW WHR unit (MM fluid).
 - 3.5 kW CHP biomass fired unit (MM fluid).
- Sliding vane expander.
- Project aspects of work.
- Conclusion & Future Works.



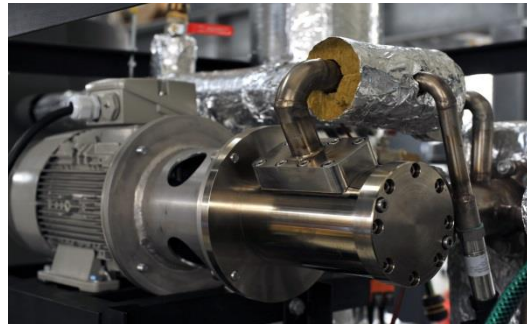
INTRODUCTION

- Potential of 1 – 10 kW el. devices identified.
- Low power ORC is suitable choice.
- Possibility of micro – CHP and micro – WHR applications:
 - Micro-CHP units - farms, warehouses, workshops, hotels and apartment houses use boilers using solid fuels (biomass) not only in central Europe.
 - WHR units - small industries have excess of waste heat at moderate and low temperatures.
- SCALE FACTOR = low efficiency compared to large scale power production, BUT:
 - Possibility of mass production.
 - Reduced complexity.
 - In suitable financing environment possibility of massive installation, advantage of repeatability of business cases.



MOTIVATION

- MOTTO: “Are we able to design, build up and test own low power ORC system? Is there room for business success?”.
- System needs to be simple, robust and reliable.
- Characteristics:
 - Sliding vane expanders.
 - Gear feeding pumps.
 - Round (twisted) tube heat exchangers - evaporators.

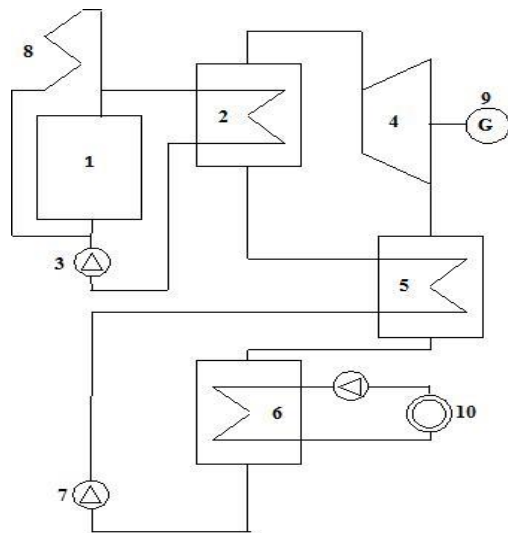




1 KW CHP – LEARNING UNIT

- Built up 2009 – 2012, until end of 2013 in operation.
- Thermo-oil loop integrated (biomass boiler flue gases – thermooil – working fluid – cooling water).
- Isopropylbenzene (cumene) as a working fluid – possibility of high efficiency.
- Specific features of this conceptual unit (safety measures, emergency cooling loop).

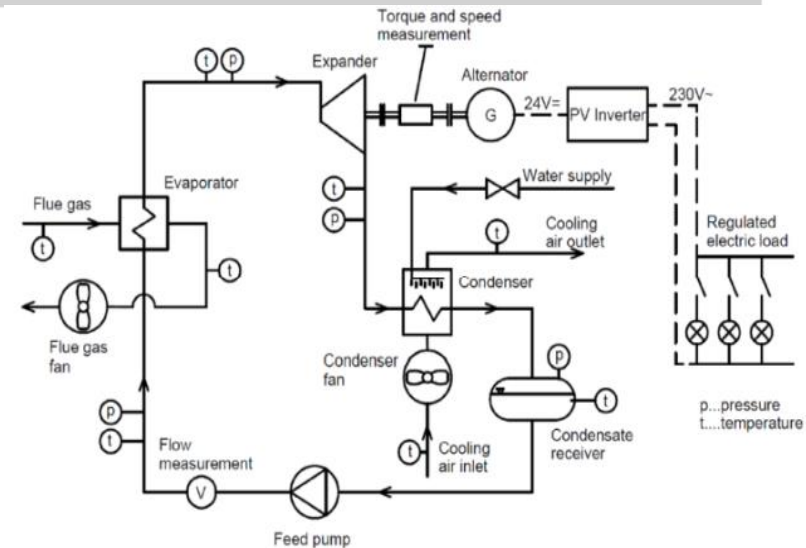
- Achieved performance well below nominal:
 - 0.4 – 0.8 kW expander output;
 - 2.8% gross el. efficiency, large chimney loss, cycle heat input 16-23 kW.





1 KW WHR - PROOF OF CONCEPT

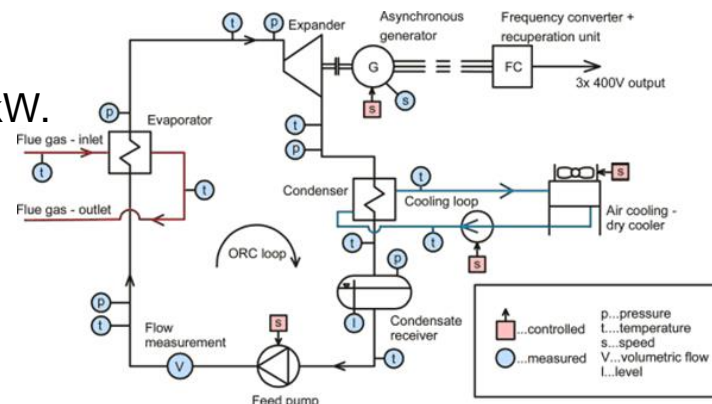
- Built up 2013 – 2014, until spring 2016 in operation.
- Working fluid changed to MM (hexamethyldisiloxane).
- Thermooil loop not installed.
- Regenerator not installed:
 - Small advantage in WHR.
 - Simplification.
- Entering flue gas ~ 280 °C.
- Achieved performance:
 - 0.4 – 0.6 kW expander output (nominal 0.7).
 - 3.5% gross efficiency, net output ~ 0.
 - Cycle heat input 20 - 23 kW.
 - Different modifications of expander tried.





5 KW WHR UNIT

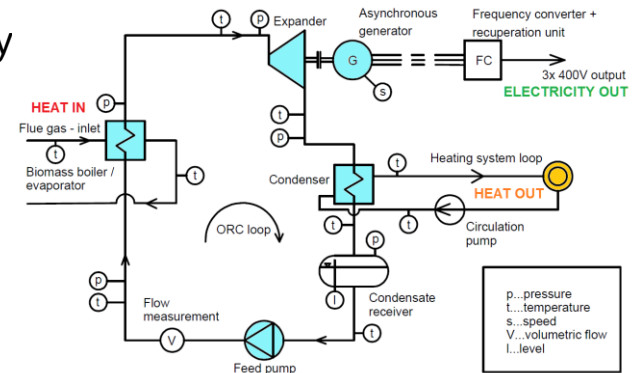
- Built up 2014 -2015, in irregular operation.
- Larger scale of previous proof-of-concept:
 - MM, direct heating by flue gas.
 - Cooling circuit with dry cooler.
 - Flue gas 350 / 110 °C.
 - MM evap ~ 170°C, condensation ~ 80°C.
 - For outdoor environment, pre-pilot unit.
- Achieved performance:
 - Expander output nominal 5 kW, max ~8 kW.
 - Net output ~ 3.5 kW.
 - 6.4% / 3.1% gross/net efficiency.
 - Cycle heat input 60 - 150 kW.
 - Long run tests, especially for expander.





3.5 KW CHP – WAVE UNIT

- Built up 2015 – 2016, in operation.
- Back to original CHP idea with better technology
 - In-house developed biomass boiler.
 - MM, direct heating by flue gas.
 - Heat rejection to utility hot water (60/80°C).
 - MM evap ~ 170°C, condensation ~ 90°C.
- Performance:
 - Expander output 2.0 kW (nominal 2.7 kW).
 - Net output ~ 1 kW, 4.2%/1.5% gross/net efficiency.
 - Possibilities in minimizing of parasitic load.
 - Fuel input 65 kW, utility heat output 50 kW.
 - WAVE - biomass boiler providing electricity for own consumption + little extra.





3.5 KW CHP – WAVE UNIT II

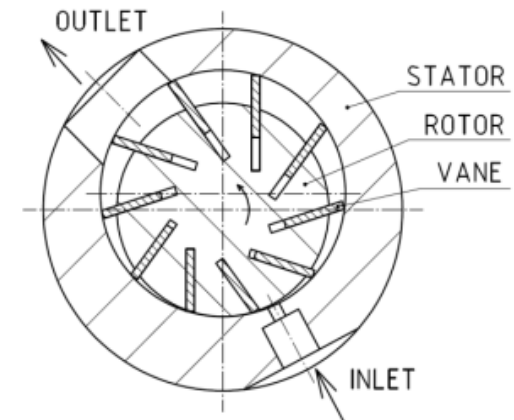
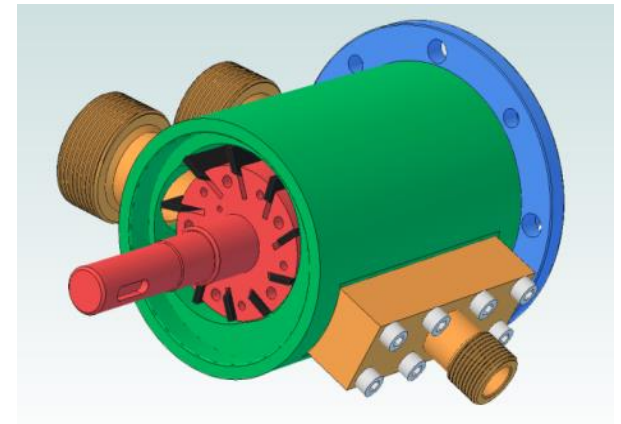
- 2017
- Evaporator design modified – automatic cleaning.
- Condensation detecting system applied.
- Electrostatic solid pollutant separator applied.
- Possibility to scale up power (150 – 200 kW heat output), up to 10 kW electricity production.
- Island energy system with PV and battery storage is being designed.
- Attractive solution for business.





SLIDING VANE EXPANDERS

- Potentially cost-efficient solution:
 - For small series manufacturing.
 - Compared to scroll or screw simple machining, achievable tolerances.
- Vanes are inserted in grooves in the eccentrically placed rotor, creating expanding chambers.
- Slightly lower efficiency potential due to balance between friction loss (vane-wall) and leakages (between vane and wall).
- Summary of performance in manuscript.
- Separate paper – Mr. Václav Vodička.





PROJECT HIGHLIGHTS AND PLANS

- 2015 – E.ON Energy Globe Award CZ winner in „IDEA“ category – „Micro-power plant WAVE“.
- 2016 – official „baptism“ of WAVE prototype with Czech vice prime minister Mr. Bělobrádek and CEO of E.ON Czech Mr. Michael Fehn.
- Successful know-how transfer to SPV.
- Plans: 5 pilot plants in 2018:
 - Signed – 1 x WAVE + 3 x WHR – pre-commerce grants.
 - Not signed - WAVE - 1 purely commercial.





CONCLUSION AND FUTURE

- Development of ORC from proof-of-concept to pre-pilot plants.
- Pilot installations under preparation.
- Major and unique component:
 - **Round tube evaporators.**
 - **Sliding vane expander - efficiency up to 60%, separate paper.**
 - **Gear pumps – up to 60% efficiency, separate poster.**
- Major space for improvement:
 - Optimization of the rotary vane expander.
 - Optimization of parasitic load.
 - Manufacturing chain optimization.
 - Project - business models creation and verification, strategic partnership.



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