LOW TEMPERATURE HEAT RECOVERY IN ENGINE COOLANT FOR STATIONARY AND ROAD TRANSPORT APPLICATIONS

PIERRE LEDUC, PASCAL SMAGUE – **IFPEN**

ARTHUR LEROUX, GABRIEL HENRY – **ENOGIA**

4th International Seminar on ORC POWER SYSTEMS

CONTENT

- Objective of the project
- Benefits of “low temperature approach”

  (heat recovery in the engine coolant)
- Case study:
  - Passenger car
  - Long haul truck
- Conclusion

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OBJECTIVE OF THE PROJECT

- TARGET:
  - Joint project of IFPEN and ENOGIA to **develop ORC turbine components** for **heavy truck and passenger car** industry

- CONTEXT:
  - IFPEN: research and innovation center (energy, transport, environment)
  - ENOGIA: “the small turbine ORC company”, ORC manufacturer

- TECHNICAL APPROACH:
  - Waste Heat Recovery (WHR) **in the coolant circuit** of the vehicle

BENEFITS FROM ENGINE COOLANT WHR

In comparison to WHR in the exhaust gas or in the EGR:

- No additional heat to evacuate (from vehicle point of view)
- No contact of the ORC with the exhaust gas
  => No need for material compatible with exhaust corrosive matter
- No parts of the ORC at temperature higher than 100°C (373 K)
  => No costly, high-temperature material
- Evaporator:
  - Integrated into the engine cooling circuit
    => No engine exhaust back pressure
    => No risk of evaporator fouling
  - Hot source in liquid form => compact evaporator
  - No hot spot => no risk of damaging the working fluid
    (Even in the case of a malfunctioning of the ORC pump)
- Stable temperature of the hot source => easier control
  => Safer control of superheating
- In combination with a well-chosen and non-flammable working fluid:
  - ORC running pressure remains low => lightweight sizing of the parts
  - Low-temperature, low-pressure running conditions => safe system

LIGHTWEIGHT

COMPACT

SAFE

LOWER COST

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PASSENGER CAR APPLICATION

- For vehicle speeds from 50 to 90 km/h, heat dissipation in the coolant is about 5 to 10 kWth
- For the future, the advent of efficient thermomanagement strategies will even increase coolant temperature up to 105°C

=> higher grade heat source for WHR

Example of heat loss in the coolant of a passenger car

Vehicle speed (km/h - mph)	Engine power (kW)	Heat flux dissipated at radiator (kW)
30 / 19	1.0	3.7
50 / 31	2.3	5.6
70 / 43	4.8	7.1
90 / 56	8.7	10
120 / 75	18.5	12

Measurements on a Ford Focus EcoBoost 1.0 L at IFPEN chassis dyno

PASSENGER CAR APPLICATION

- Using vehicle measurements as input data, a system simulator has been used to:
  - Identify suitable working fluids
  - Estimate ORC performance

- *Hypothesis for calculation:*
  - *ORC cycle: 85 / 40°C (358 / 313 K)*
  - *Superheating and subcooling = 5 K*
  - *Turbogenerator efficiency = 0.54*
  - *Pump efficiency = 0.15*

Working fluid	Formula	Fluid pressure hp / lp (Mpa)	Fluid mass flow (kg/s)	Turbine Power (W)	Net ORC power (W)	ORC power / engine power (%)
R245fa	$C_3H_3F_5$	0.80 / 0.29	0.03	330	218	4.6 %
HFE 7000	$C_4H_3F_7O$	0.40 / 0.14	0.04	300	233	4.9 %
NOVEC 649	$C_6F_{12}O$	0.27 / 0.09	0.06	280	221	4.6 %

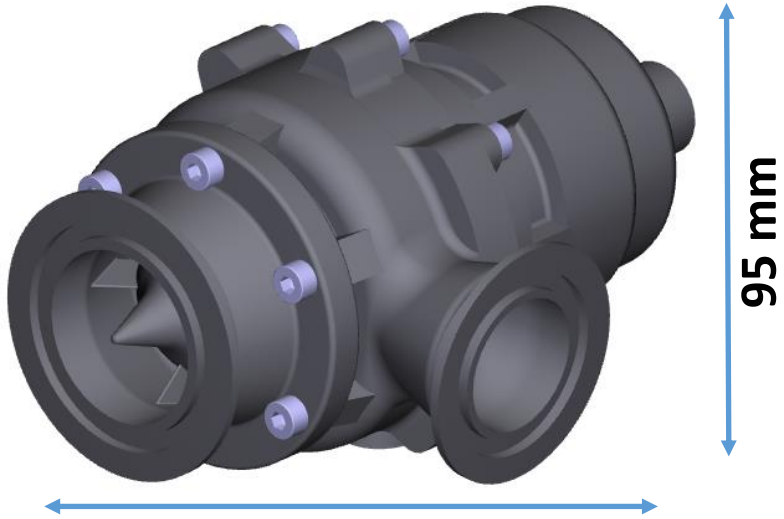
Computed ORC performance for different working fluids

(Vehicle running point: 70 km/h - 43 mph)

ORC TURBO-GENERATOR FOR PASSENGER CAR

Design inputs

- Compact, no external lube
- Payback in 60 000 km
- Easy to plug-in and safe working fluid



Weight: 2 kg

Main features

- Heat recovery in the engine coolant
- Electrical output turbine
- NOVEC 649, max 3 bar, 90°C

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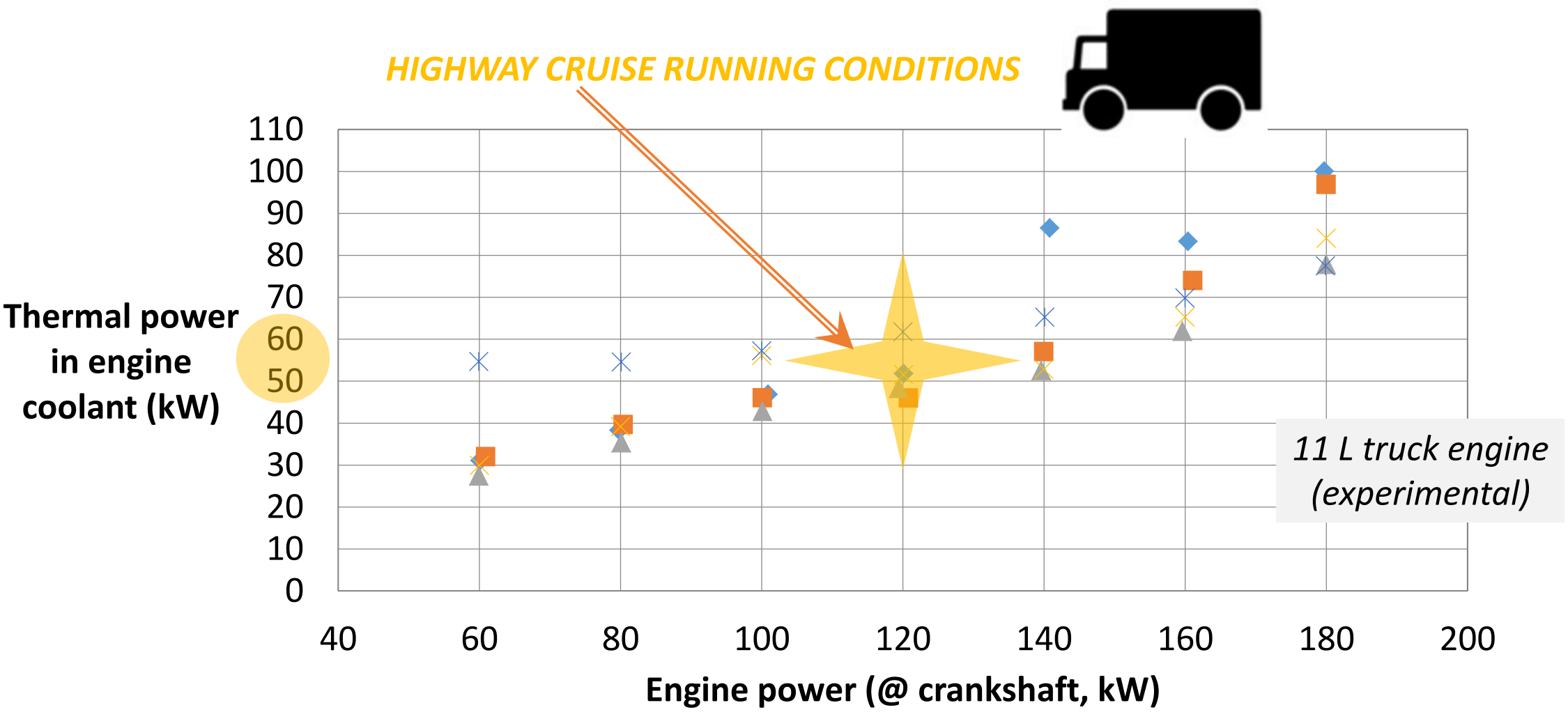
HOT SOURCE POWER AVAILABILITY



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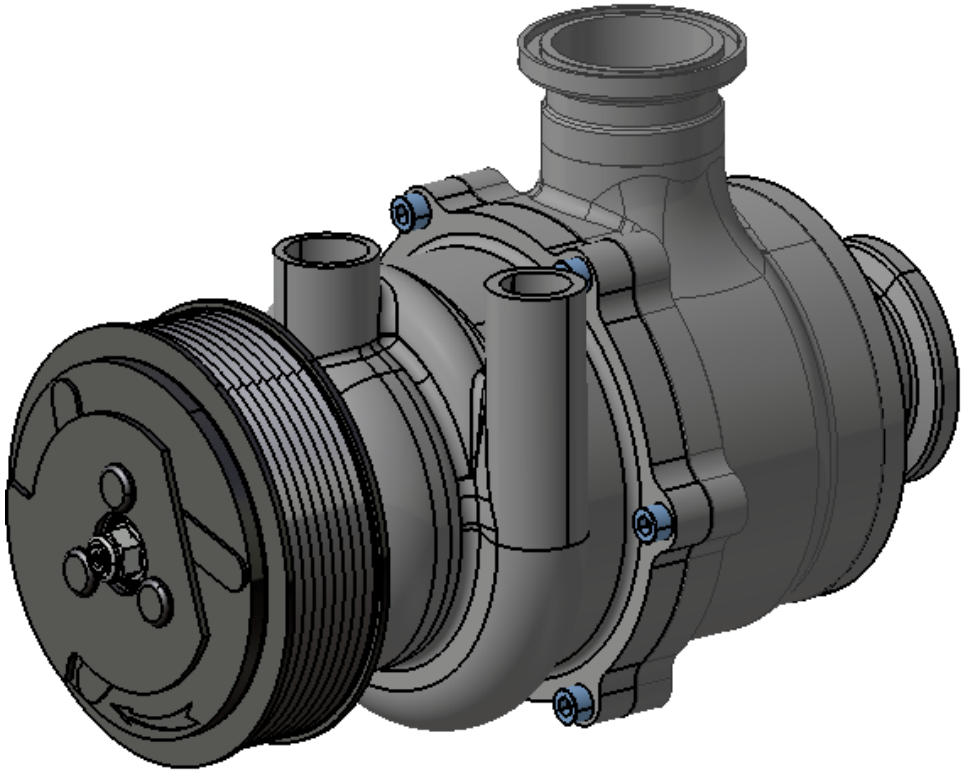
ORC TURBO-PUMP FOR HEAVY TRUCK

Design inputs

- 2 years payback
- Safe working fluid
- Compact, no external lube
- Upgradable to electrified solution



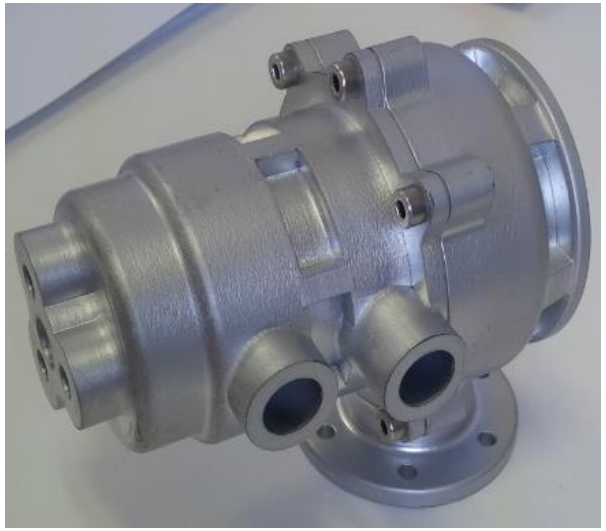
8 kg, length = 290 mm, diam. = 150 mm

Main features

- Heat recovery in the engine coolant
- Purely-mechanical ORC turbo-pump
- Up to 3% fuel eco on highway cruise
- NOVEC 649, max 3 bar, 90°C

CONCLUSION

- IFPEN innovates for transport for 70 years…
- …and ENOGIA is a specialist of small scale ORCs, especially at low temperature
  - 40 references, in 13 countries around the world
- Low temperature (90°C) ORC turbines are being developed, for the road transport industry
- Prototypes have been realized:
  - Purely mechanical, ORC turbo-pump for truck (belt driven)
  - Electric ORC turbo-generator for passenger car
  - … *Testing should start soon*
- Heat recovery in engine coolant:
  - is lighter, cheaper and safer than in exhaust gas
  - should reduce fuel consumption by up to 3%
  - in the long term, could be combined with WHR in the exhaust to realize a kind of "*ultimate waste heat recovery*"



See the turbogenerator for passenger car at ENOGIA's booth!

Thanks for your attention!

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Find us on:

www.ifpenergiesnouvelles.com

@IFPENinnovation

pierre.leduc@ifpen.fr
arthur.leroux@enogia.com

