30 Years of Organic Rankine Cycle Development

Author:
Mario Gaia

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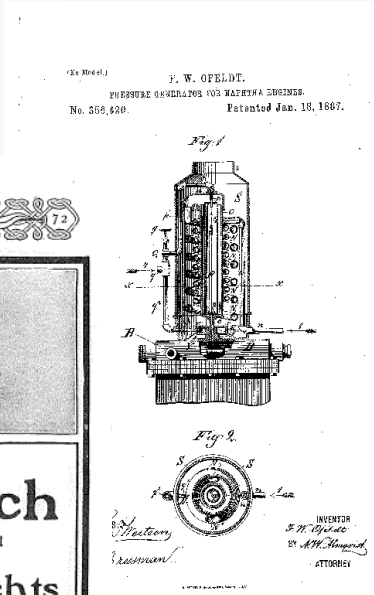
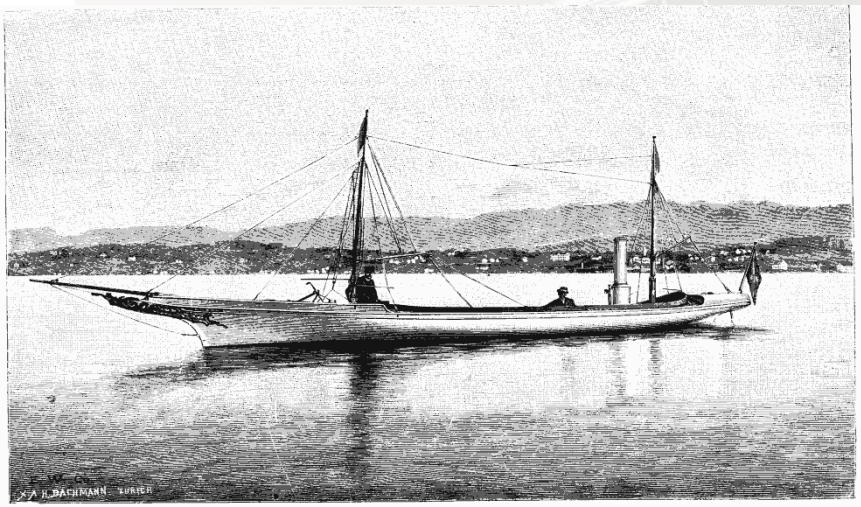
Prof. Gianfranco Angelino,
Politecnico di Milano
during meeting for the Almeria Solar Platform, S.José, California 1978.

- Started Research on ORC in mid sixties

- Envisaged many of the future developments of ORC concept




Aluminium-Yacht „Mignon" des Hr. Nobel (Erfinder des Dynamits).

The first ORC, featuring a reciprocating expander, fed by a hydrocarbon (naphta) vaporizer
Patents of Frank W.Ofeldt, 1886 – 1887
The Alfred Nobel aluminium “Mignon” boat in Zurich 1982

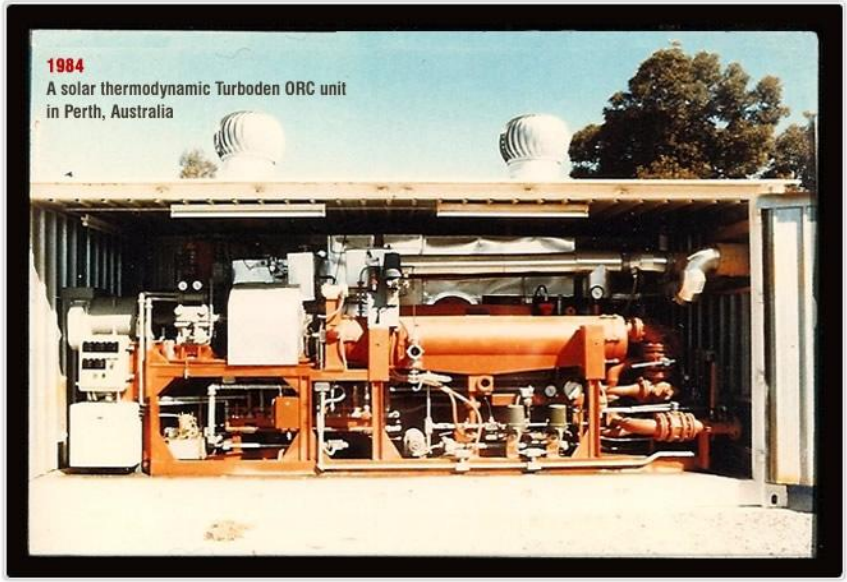
1970 – 80: Angelino Macchi Gaia et al.

Studies on many ORC configurations (for primary generation/ automotive/ heat recovery) and many working fluids, including CO2.
Consultants to Ansaldo, mainly for the Almeria Solar Platform and other solar applications

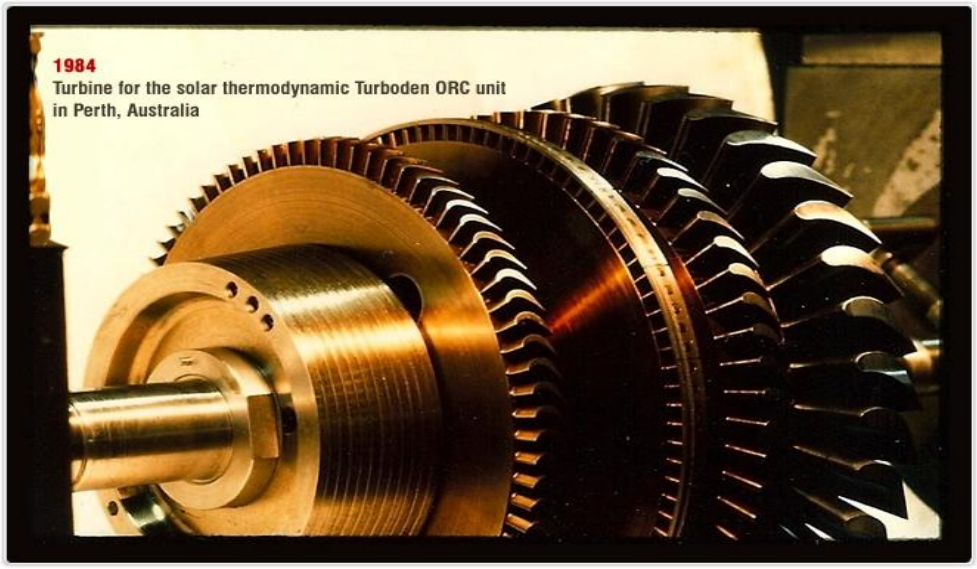
3 kW ORC for flat plate solar collectors field of Ansaldo, Genoa – featuring gravity circulation

3 kW Turbine, single stage

1980 TURBODEN IS FOUNDED by M. Gaia



35 kW Solar,
Perth, Australia
4 stage turbine



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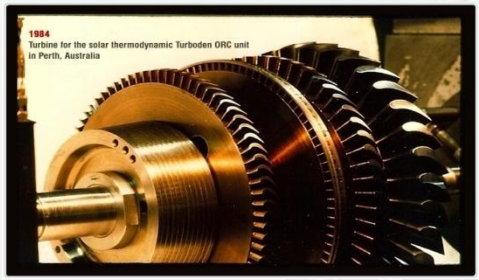
- Working Fluid: C_8F_{16} (Perfluoro-Dimethylcyclohexane)
- Thermal Oil max temperature: 300 °C
- Cycle Efficiency: 0.236



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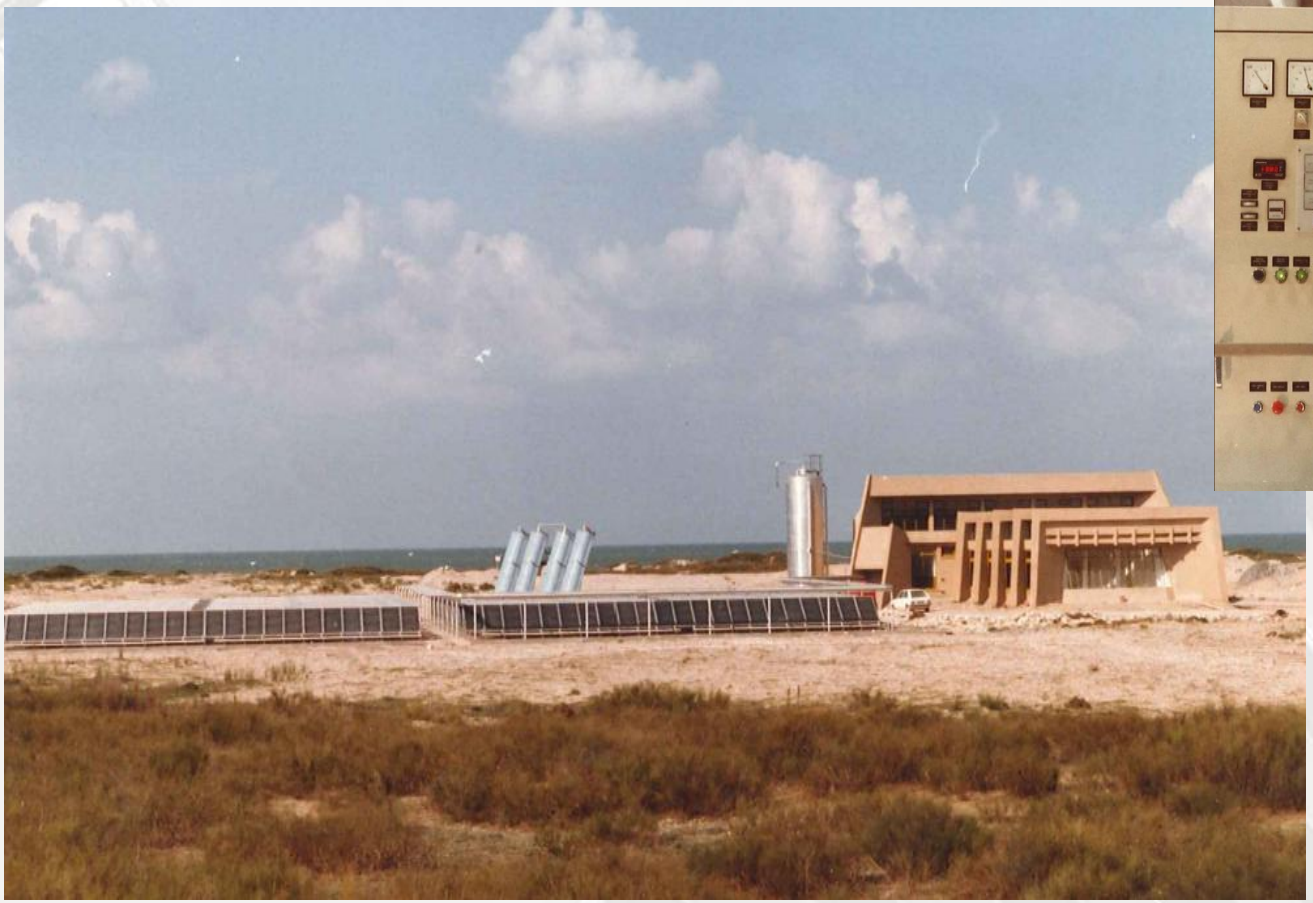
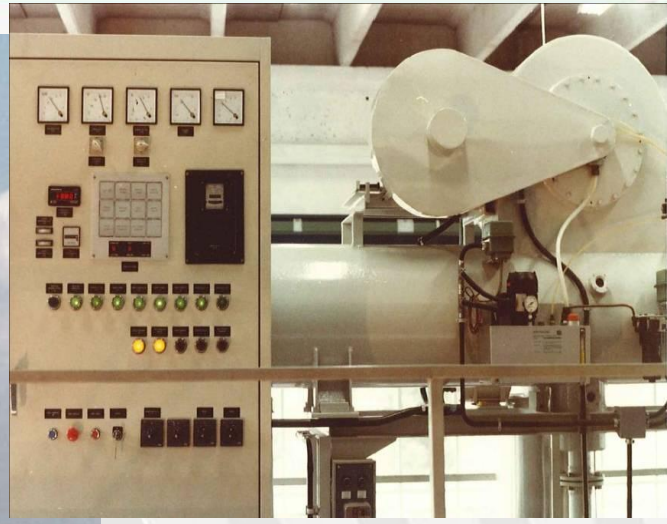
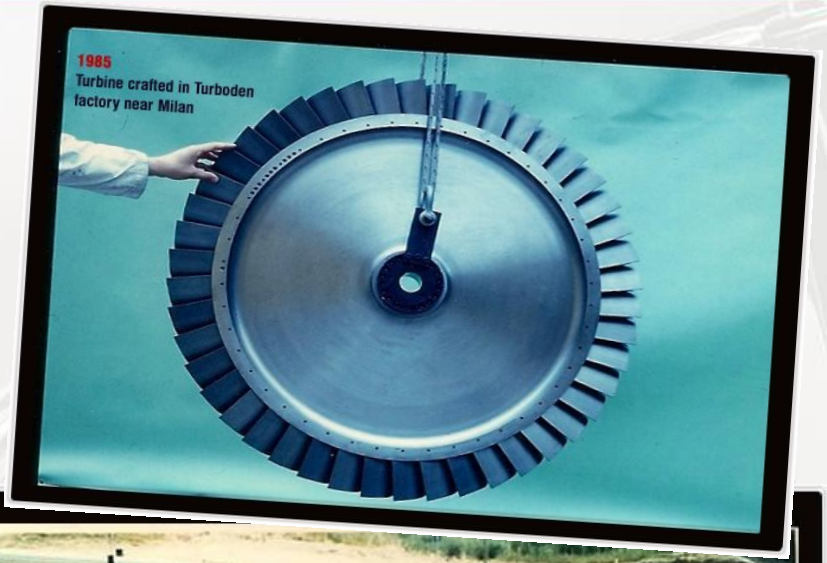


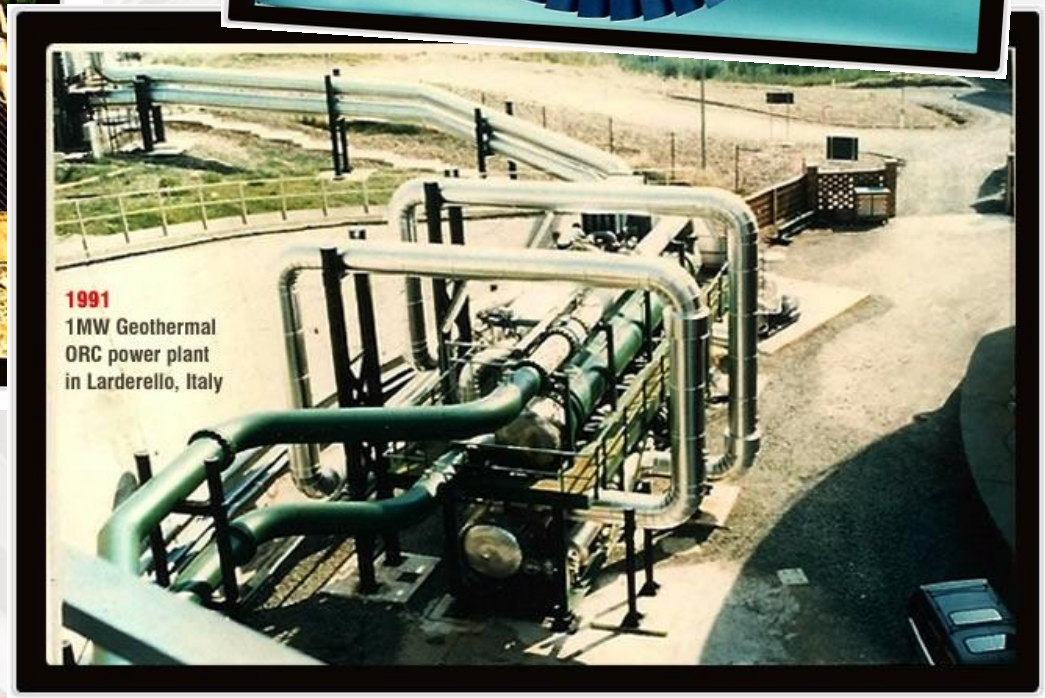


16 kW ORC for the Borj Cedria site in Tunisia, 1982

Heat source: Flat plate solar collector field at 98° C

2 X 100 kW Geothermal KAPISYA – Zambia1988, source liquid water 83°C





1.3 MW Geothermal plant for Enel Castelnuovo V.C. 1991 , source liquid water 114°C

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1996-Heat recovery unit in Torbole, Italy
Source: exhaust gas from a Cupola Furnace.
A cascaded ORC concept with Siloxane and Perfluoropentane working fluids

1997- Biomass unit for the Swiss Army, 300 kW, in Bière, Switzerland, source: 300°C Thermal Oil

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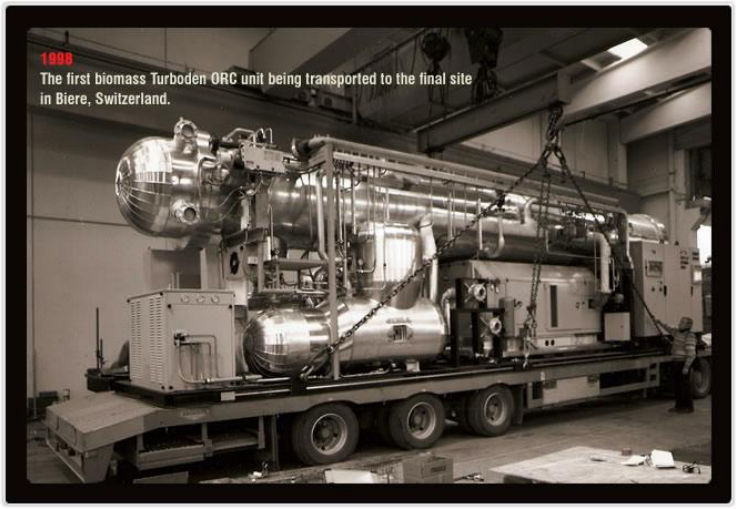

1997- Biomass unit for the Swiss Army

M. *Kurt R. Scheidegger*, ingénieur-conseil, Lausanne, valued the ORC solution and took the risk of adopting a technique yet to be proven.

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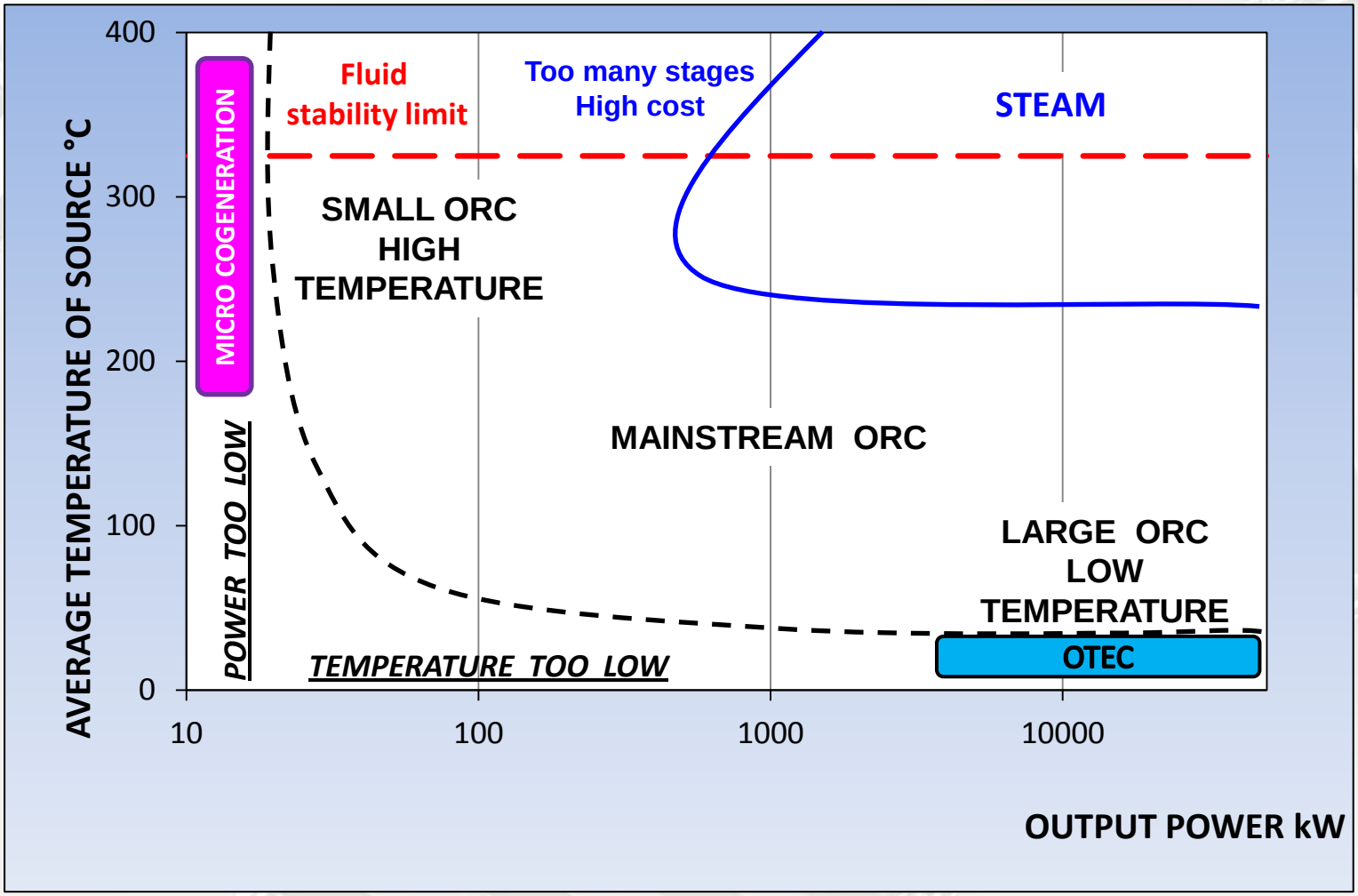
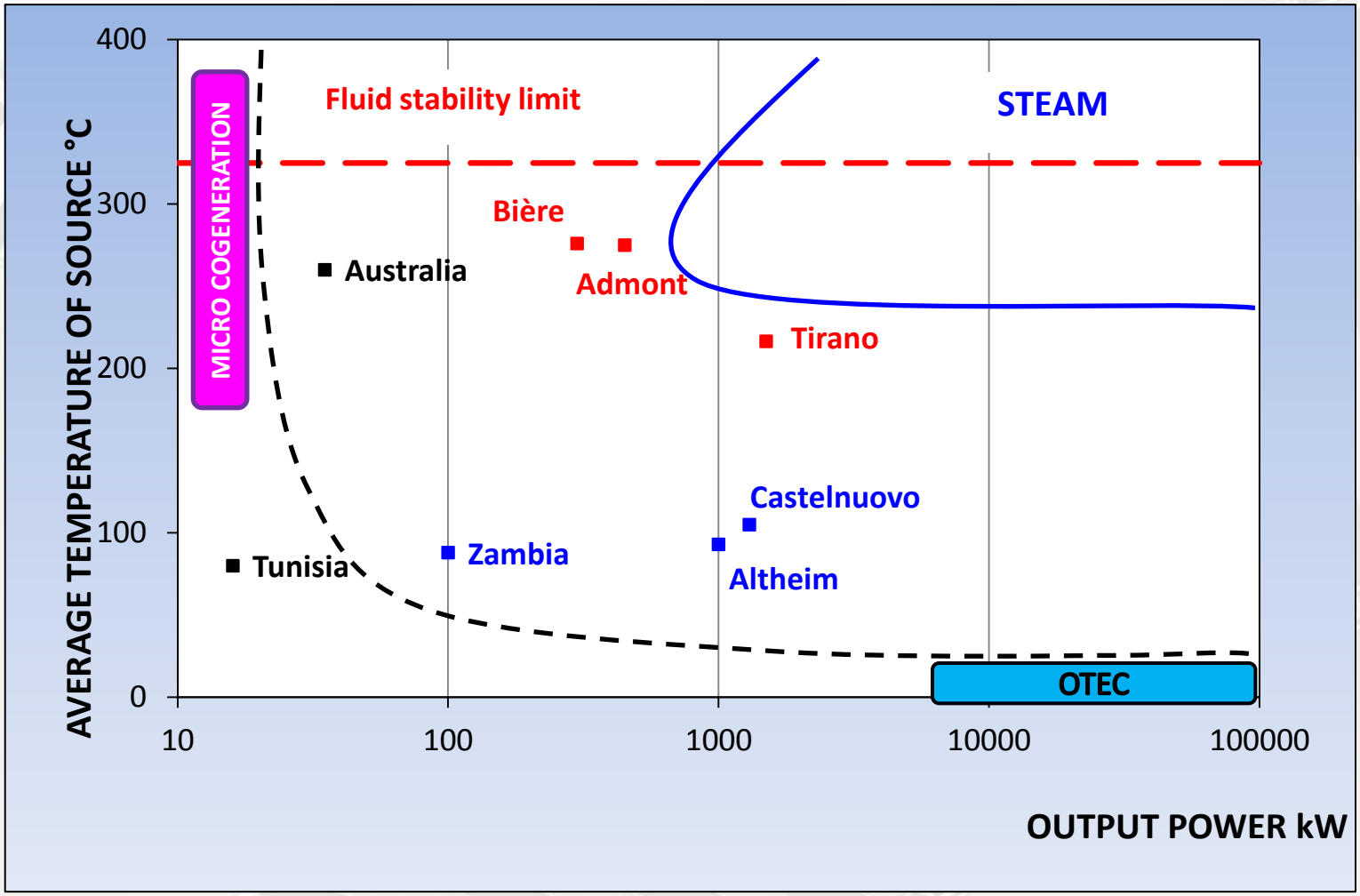
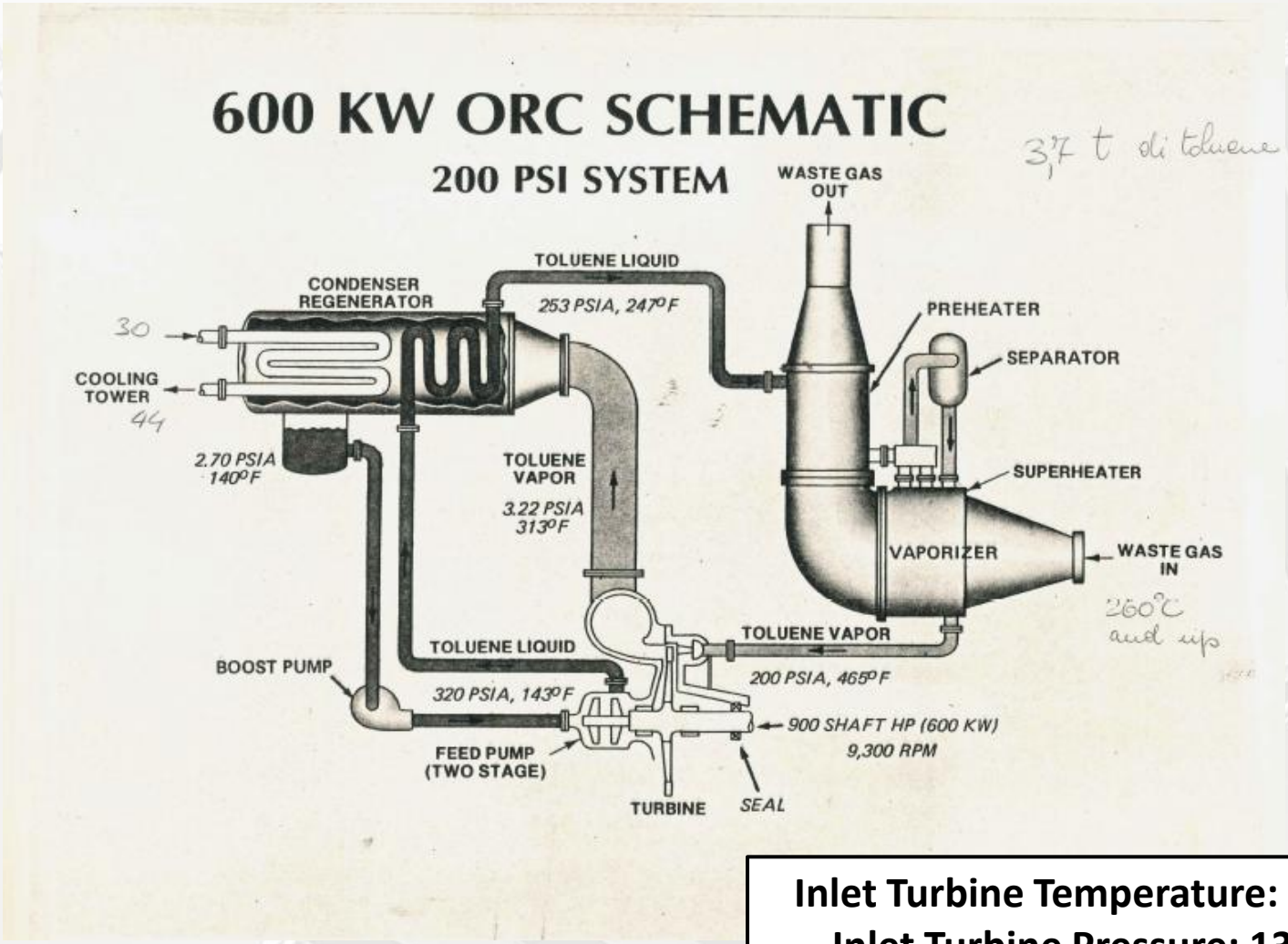


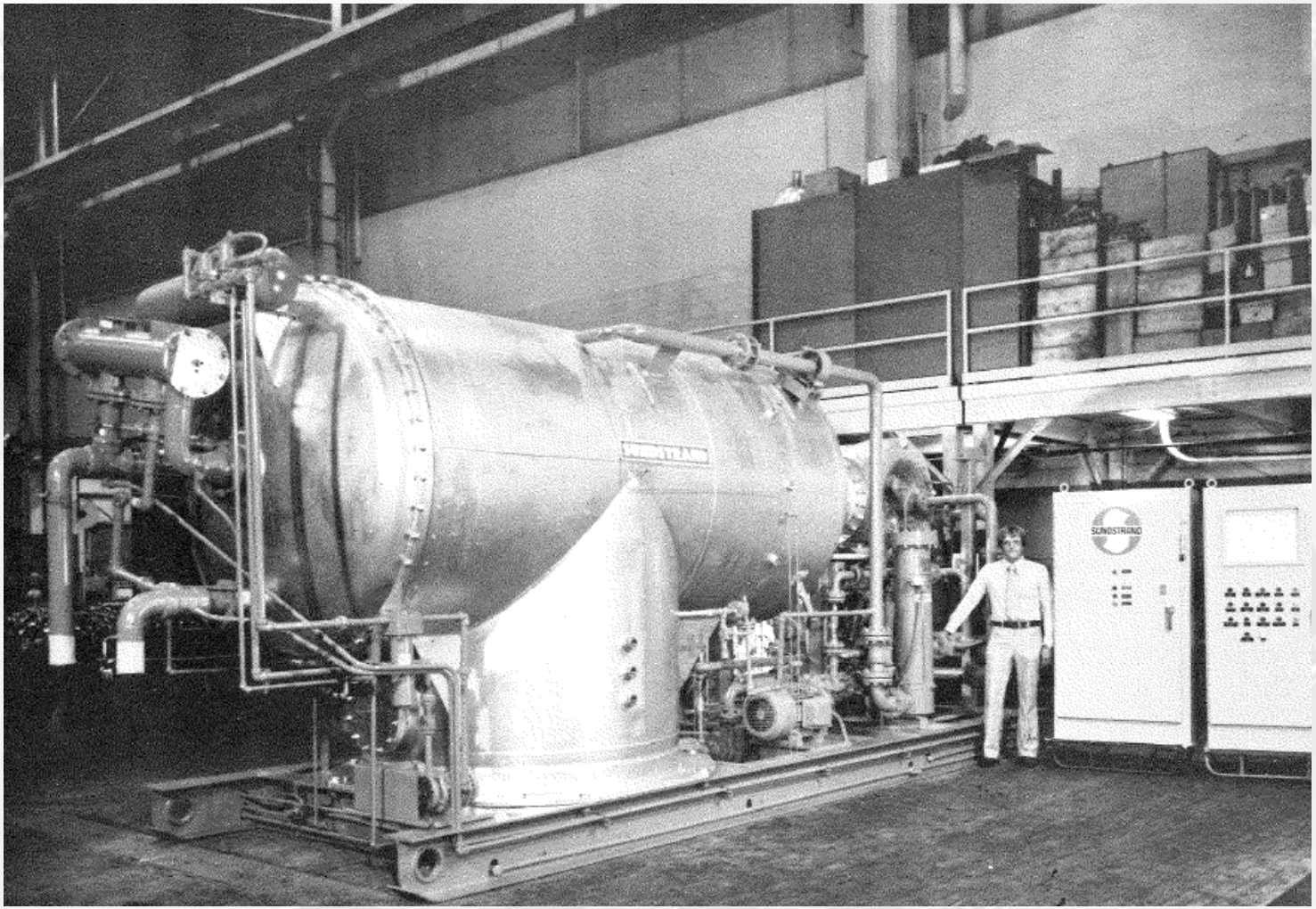


ORC by Sundstrand, 1978



Inlet Turbine Temperature: 240.6 °C
Inlet Turbine Pressure: 13.8 bar
Outlet Turbine Pressure: 0.22 bar

ORC by Sundstrand, 1978



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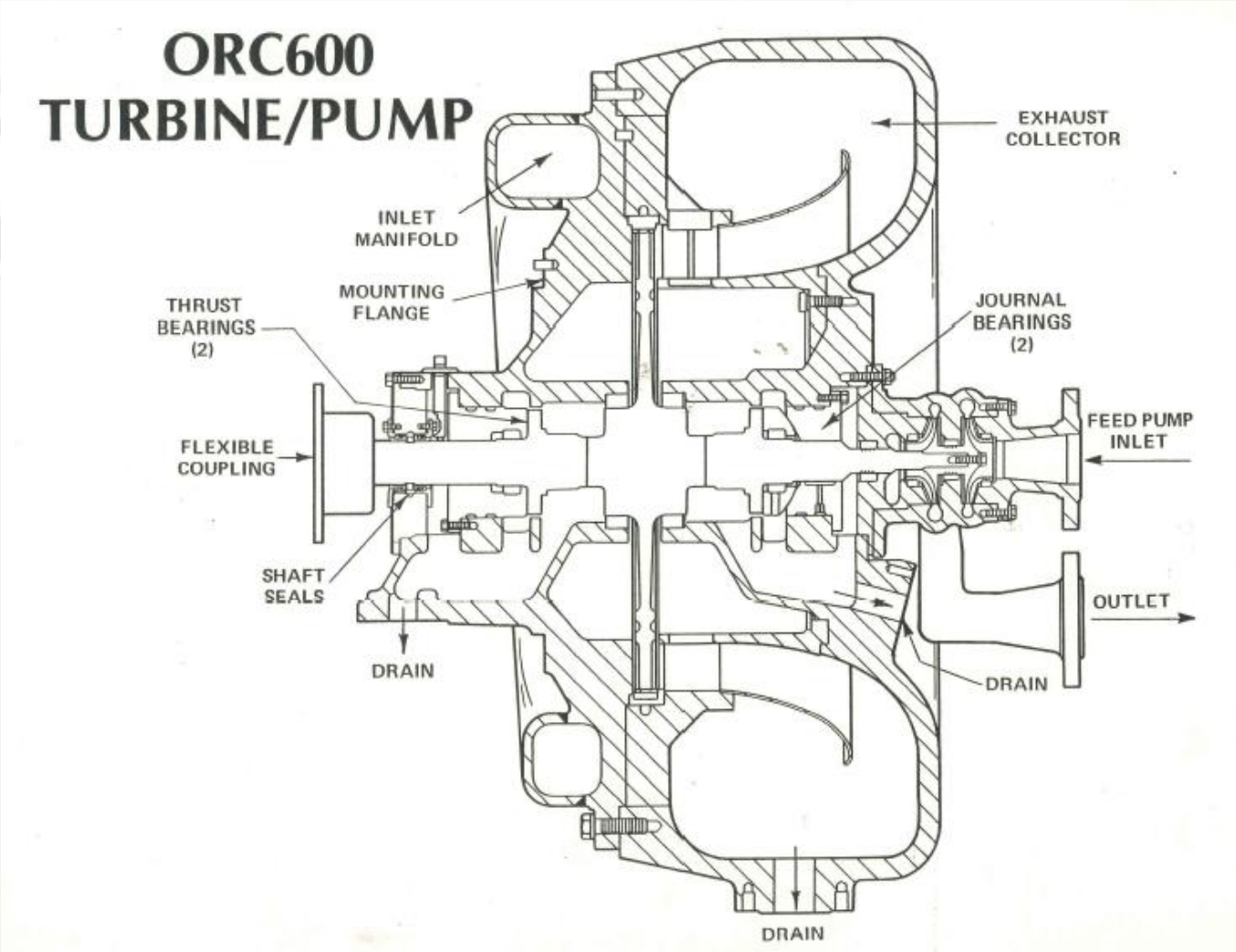

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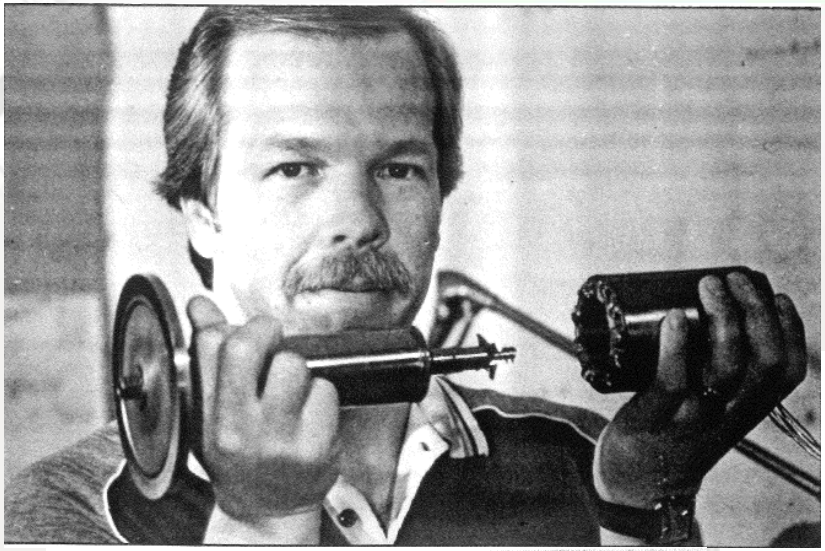
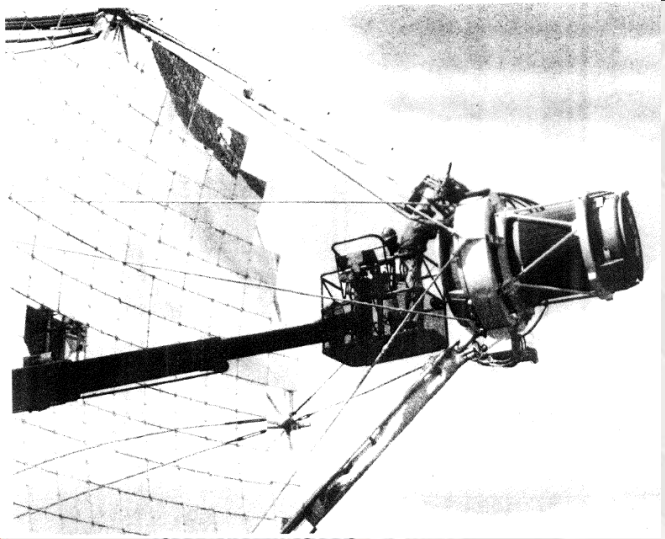
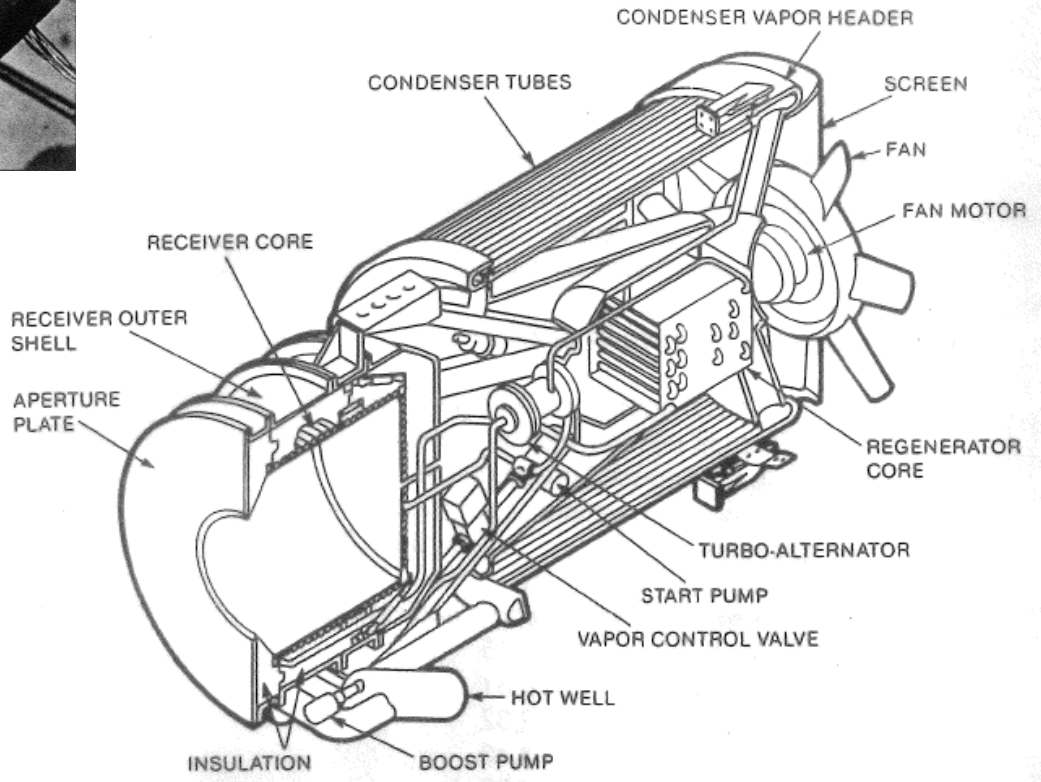
First International Seminar on ORC Power Systems

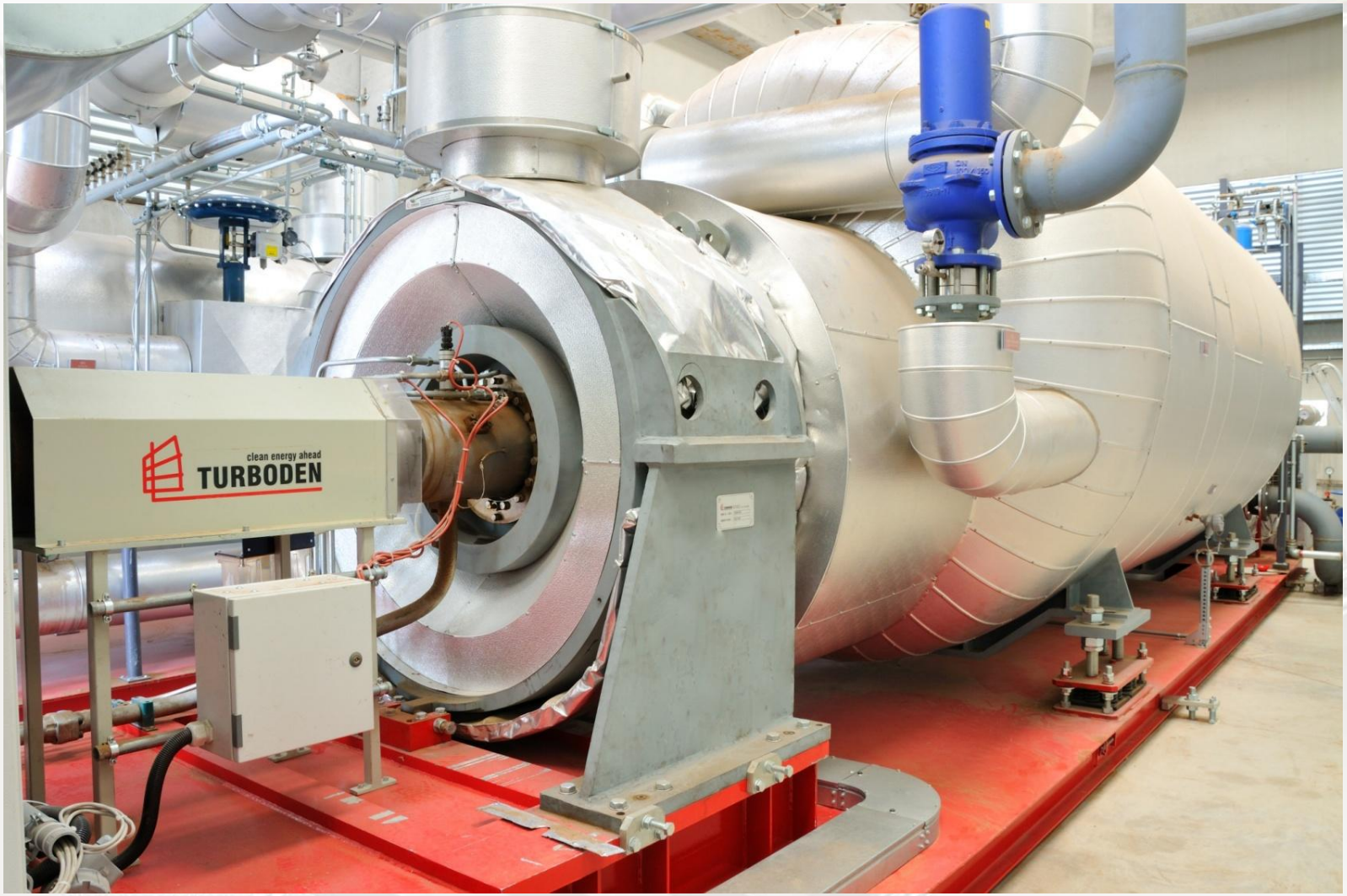
30 Years of Organic Rankine Cycle Development





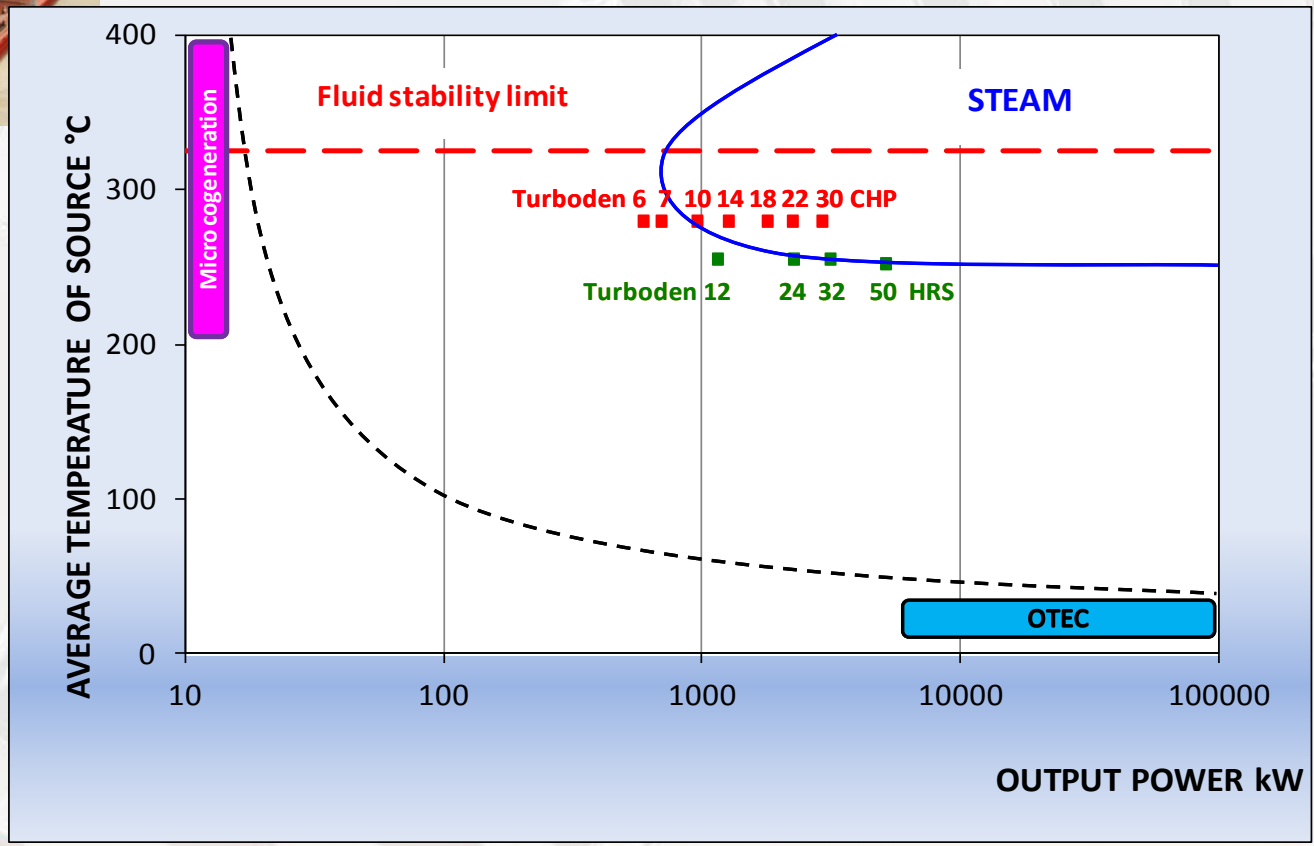
Barber and Nichols, Colorado, USA
High speed generator: 60000 rpm
Electric Power: 25 kW
Working Fluid: Toluene
Efficiency: in excess of 20%





Turboden biomass units

#14 Frames from 400 kW to 5 MW
Energy source: thermal oil 310/240 and 240/130 °C



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Heat Recovery – Reference Case study

Example of **Turboden** tailor-made ORC plant for heat recovery from hot water: **3 MW** installation in Roeselare (B)

Plant type:
Heat recovery from pressurized water boiler in waste incinerator

Customer :
MIROM (Roeselare-Belgium)

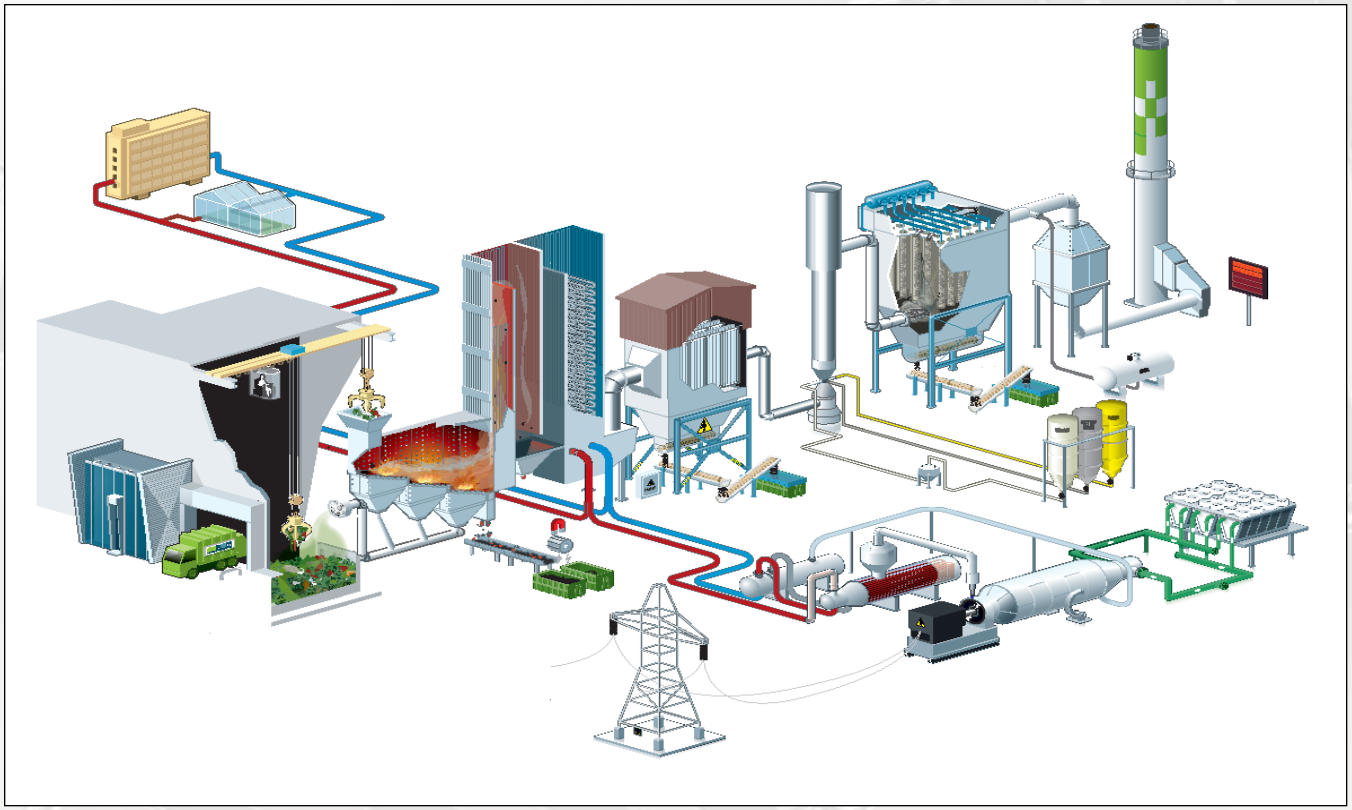
In operation since:
2nd quarter 2008

Heat source:
hot water at 180 C (back 140 C)

Cooling source:
water/air

Total electric power:
3 MW_{el}

Net electric efficiency: 16,5%



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United Technologies Corporation

A *Fortune 50* corporation
$ 54.3 bn turnover 2010
operating in 195 nations
210.000 employees

United Technologies


UTC Power

UTC Fire & Security

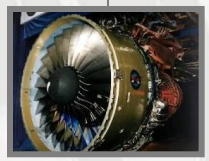

Hamilton Sundstrand


Carrier


Research Center


Sikorsky


Otis


Pratt & Whitney
A United Technologies Company


EPC Service


Large Engines


After market


Marine


Mobile Power


Wind Power


ORC Technology

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The PureCycle® Power System

- 280 kW Gross Power
- Renewable baseload power generation
- 195°F – 300°F resource range
- Modular for larger plants
- Short lead times
- 24/7/365 remote monitoring
- High availability

PureCycle®

* 91ºC – 149ºC

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Turboden ORC plants in the world

BIOMASS	HEAT RECOVERY	GEOTHERMAL	SOLAR	TOTAL PLANTS
in operation 124	in operation 8	in operation 3	in operation	in operation 135
under construction 54	under construction 13	under construction 3	under construction 1	under construction 71
TOTAL 178	TOTAL 21	TOTAL 6	TOTAL 1	TOTAL 206

CZECH REP 3		DANMARK 1		FINLAND 2		FRANCE 2		GERMANY 75	
biomass	3	biomass	1	biomass	1	biomass	2	biomass	69
heat recovery		heat recovery		heat recovery	1	heat recovery		heat recovery	3
geothermal		geothermal		geothermal		geothermal	1	geothermal	3

ITALY 54		LATVIA 7		MOROCCO 1		NETHERLANDS 1		POLAND 4	
biomass	45	biomass	7	biomass		biomass	1	biomass	4
heat recovery	8	heat recovery		heat recovery	1	heat recovery		heat recovery	
geothermal	1	geothermal		geothermal		geothermal		geothermal	

ROMANIA 2		RUSSIA 1		SPAIN 4		SWEDEN 1		SWITZERLAND 4	
biomass	1	biomass		biomass	4	biomass	1	biomass	4
heat recovery	1	heat recovery	1	heat recovery		heat recovery		heat recovery	
geothermal		geothermal		geothermal		geothermal		geothermal	

TURKEY 1		UNITED KINGDOM 3		UNITED STATES 2	
biomass	1	biomass	3	biomass	
heat recovery		heat recovery		heat recovery	1
geothermal		geothermal		geothermal	
				solar thermal power	1

BIOMASS	HEAT RECOVERY	GEOTHERMAL	SOLAR	TOTAL PLANTS
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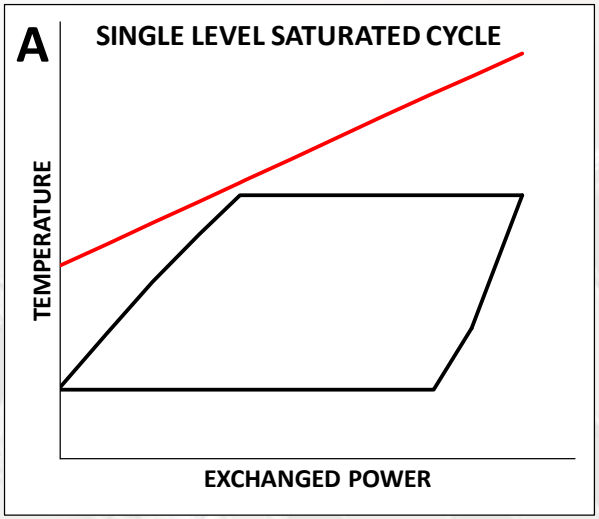
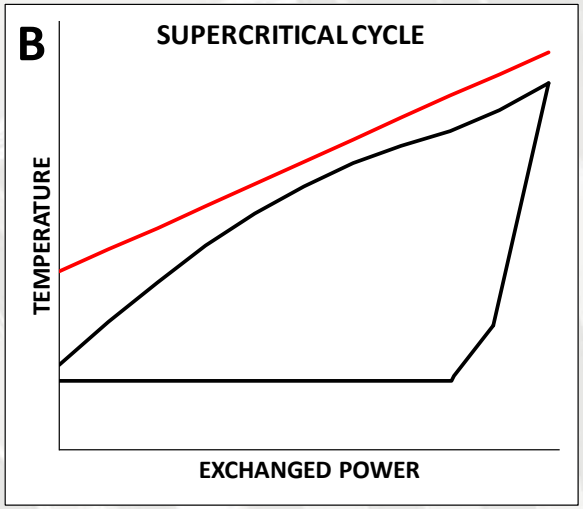
Update September 2011

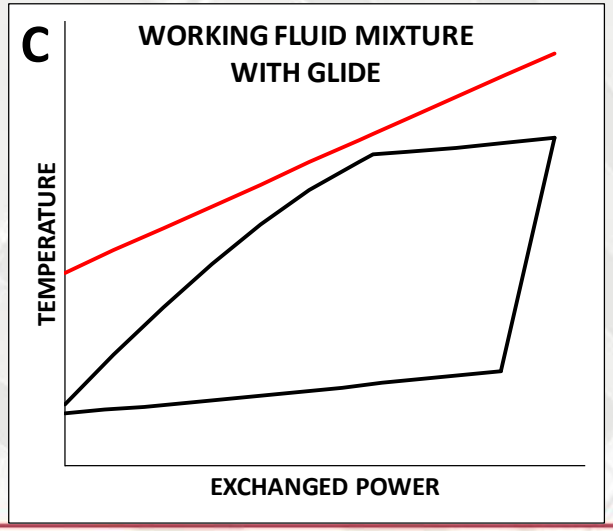
Turboden together with Pratt & Whitney Power Systems currently has more than 280 ORC units all over the world.

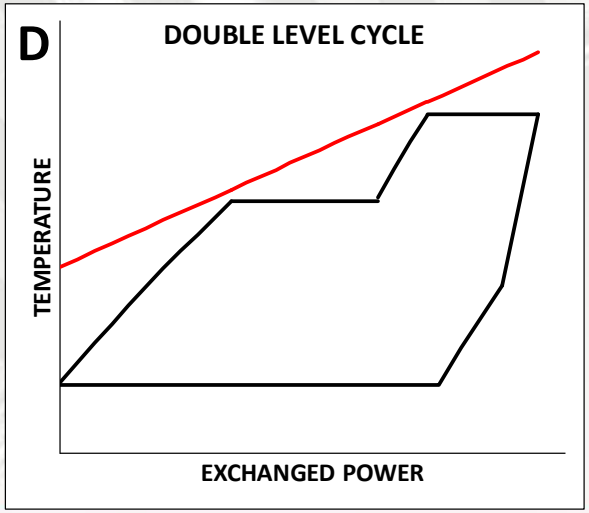
SOLUTIONS FOR VARIABLE TEMPERATURE HEAT SOURCES

- LIQUID GEOTHERMAL FLUID
- HEAT RECOVERY
- .....









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Advantages of ORC Turboden Turbogenerators

Solar ORC (medium temperature applications) perform well with

- **Low cost** solar collectors, efficient at moderate temperature
- L**ow cost** thermal oils
- **Non toxic**, non harmful thermal oils (according to 67/548/CEE and 1999/45/CE)
- **Simple plant configuration**, thermal oil used both as heat transfer fluid and as thermal storage medium

Reference plant

5.5 MW solar plant under construction

Plant type: Solar thermal power plant with thermal oil storage

Developer: Sopogy

Location: Honolulu, Hawaii

Commissioning expected: 2012

Net solar collector surface: about 75.000 m^2

Heat transfer fluid: mineral oil at 270 C nominal

Heat rejection: wet cooling tower

Thermal storage: single-tank storage with thermal oil

Total gross electric power: 6 MW

Gross electric efficiency: 20.5%

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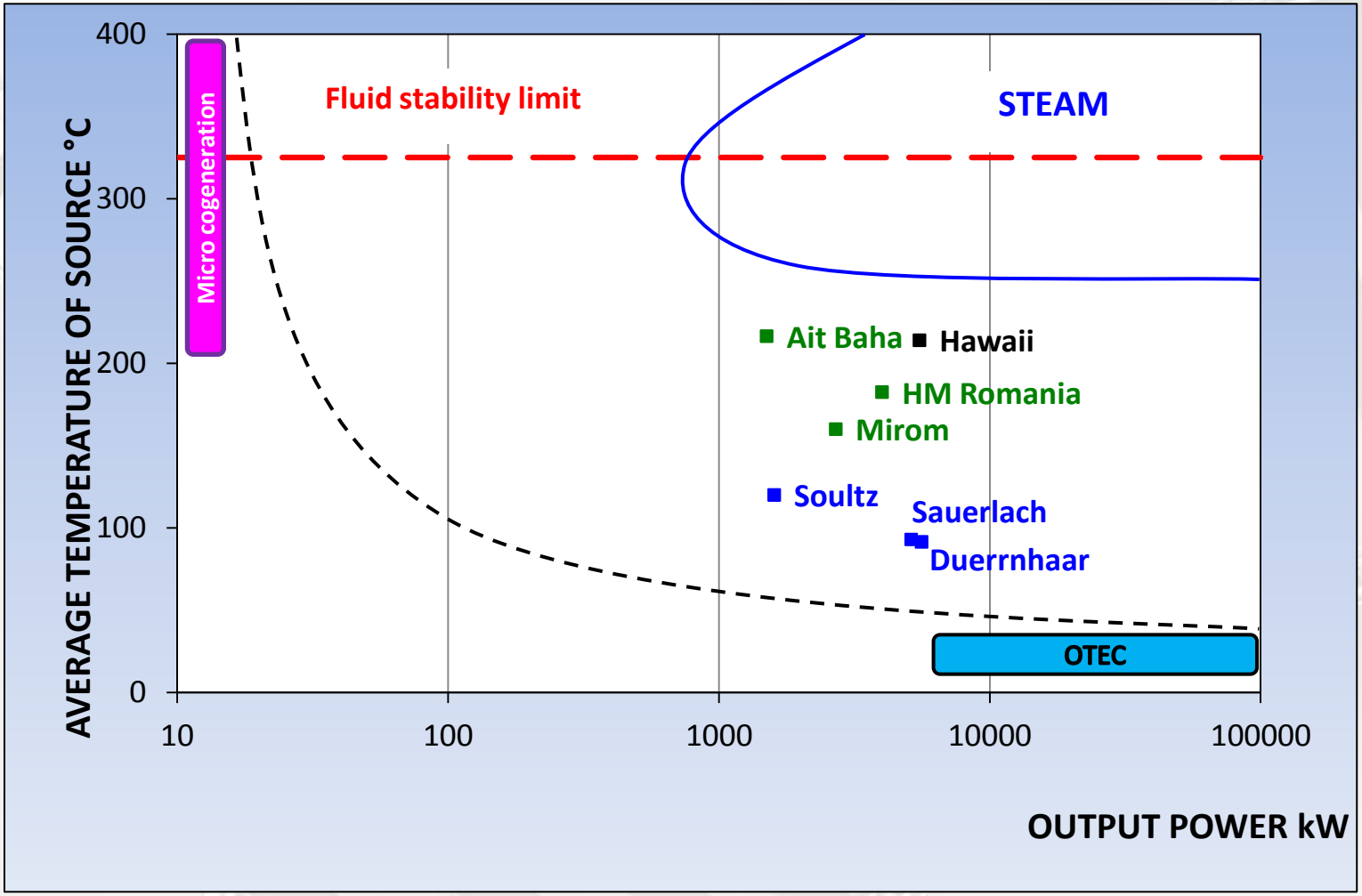


ORC: LARGE GROWTH POTENTIAL

A few companies believed in ORC
Now many follow the track.

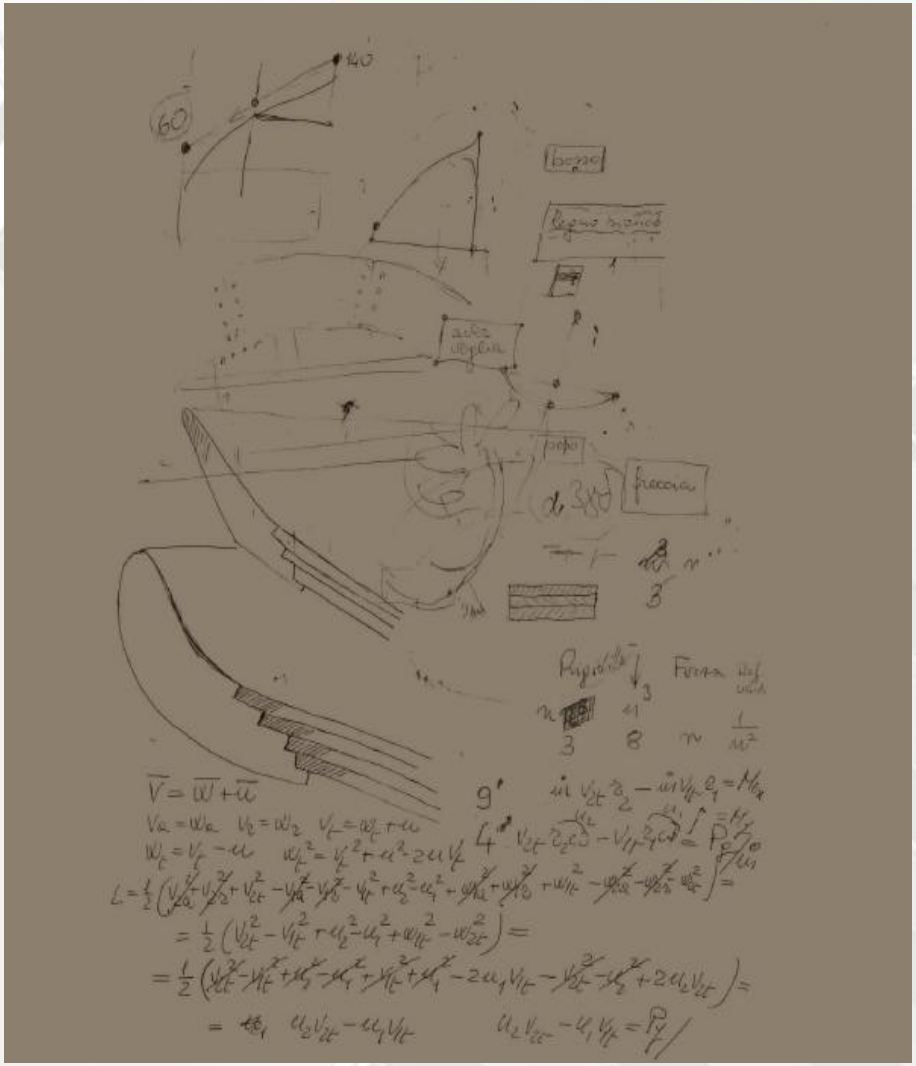
We are proud to be among the pioneers

Primary Generation & Cogeneration
Domestic Cogen (few kW range)
Biomass (Residual & Energy Crops)
Difficult Fuels (Syngas, Flare gas etc)
Solar thermodynamic (CSP)

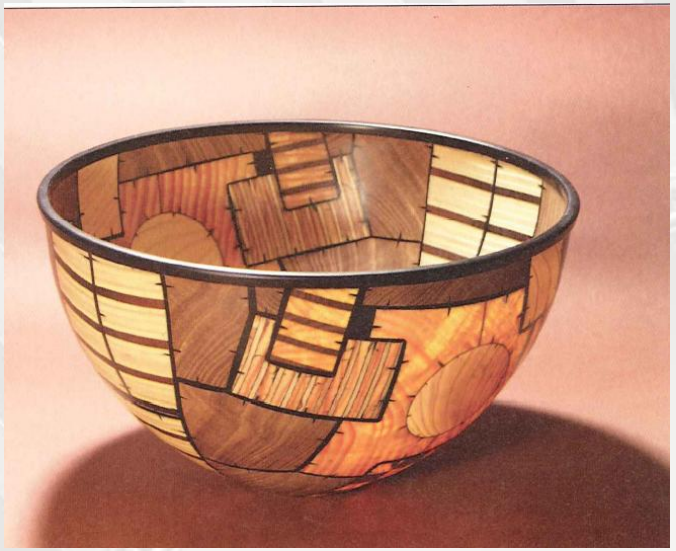
Heat Recovery
Industrial Process
Gas Turbines
Reciprocating Engines
Glass, Steel, Cement
Automotive & Marine
Cryogenics

Geothermal

Otec



Prof. Angelino, a Scientist,
a Guide and a wood Artist



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Thank you for your attention

and thanks to the many persons

within and outside Turboden which made development possible

Turboden s.r.l.
Via Cernaia, 10 - 25124 Brescia, Italia
tel +390303552001 - fax +390303552011
info@turboden.it www.turboden.it

C.F./P.I. IT02582620981
capitale sociale €1.800.000 i.v.
R.I.: C.C.I.A.A. di Brescia 02582620981
REA 461817