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THE RADIAL OUTFLOW TURBINE TECHNOLOGY

IMPACT ON THE CYCLE, THERMODYNAMICS, MACHINERY FLUID AND ROTOR DYNAMIC FEATURES

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EXERGY
THE RADIAL OUTFLOW TURBINE

ABOUT EXERGY:

EXERGY are the developers, engineers and producers of the Organic Rankine Cycle (ORC) system, with a proprietary and patented technology known as the RADIAL OUTFLOW TURBINE.

Privately owned Italian company, subsidiary of the SECI – Maccaferri Industrial Group within the SECI S.p.A holding

EXERGY – WHAT WE DO:

EXERGY is *the* pioneer of ORC Radial Outflow technology. EXERGY undertake:

- Development and manufacturing of the ORC turbine and plant internally
- Testing
- Engineering
- Project management
- After-sales service

Size range between 0.1 – 10 MW

EXERGY – WHAT WE DO:

A selection of EXERGY ORC units currently in operation:

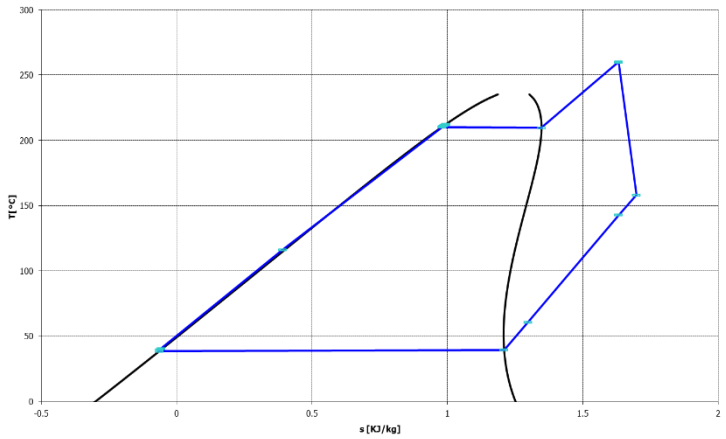
Geothermal
Enel Green Power
Bagnore, Italy

Biomass
Del Tongo
Arezzo, Italy

Biomass
Energia Vulture Alto Bradano
Venosa, Italy

TECHNOLOGY COMPARISON:

A detailed study was conducted of different turbine technology / configurations, and applied to a reference 3MWe heat recovery application. The Cyclopentane (cC5) has been assumed. The main parameters of the cycle were:



Main Cycle Parameters	
P in turbine	30 bar
T in turbine	260° C
P out turbine	0.8 bar
Recuperator terminal DT (vapor out-liquid in)	20° C
Isentropic enthalpy head	186.2 kJ/kg
Volumetric Expansion Ratio	40
Expansion Ratio (Beta)	37.6

COMPETITOR TECHNOLOGIES:

RADIAL INFLOW:

- Single stage or double stage radial inflow
- Integral gearbox
- High speed
- Overhung
- Oil or dry gas sealed
- Sleeve bearings
- Variable inlet geometry

COMPETITOR TECHNOLOGIES:

AXIAL:

- 2/3 stages (disks and diaphragms) axial turbine
- Direct drive
- Overhung
- Oil sealed
- Rolling bearings

EXERGY TECHNOLOGY:

RADIAL OUTFLOW TURBINE:

- Multiple stages (up to 7)
- Radial OUTFLOW with or without last axial stage
- Overhung
- Oil sealed
- Rolling bearings

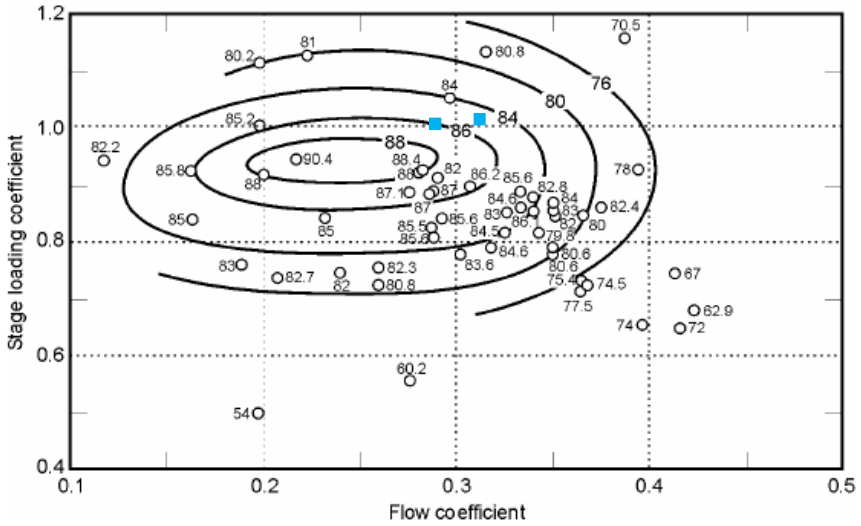
RADIAL INFLOW CONFIGURATION:

Single stage:

- Not suitable due to very high expansion ratio

Double stage:

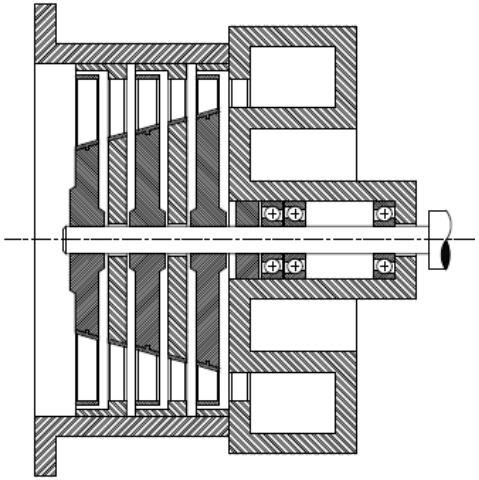
		HP Stage	LP Stage
Rotational speed	RPM	19,000	9,150
Wheel Diameter	mm	300	595
Stage Loading (Dh*is*/U²)	-	1,01	1,03
Flow Coefficient (Cx/U)	-	0,28	0,32
Stage adiabatic efficiency	%	**86%** 1)	**85%** 1)
Efficiency at low speed shaft	%	**84%** 1)	



1)ref. Dr. Nicjolas C. Baines – Radial Turbine – An integrated approach

AXIAL TURBINE CONFIGURATION:

- Many configuration have been studied, varying the number of stages and degree of reaction
- A 3-stage with a low degree of reaction was select as the optimal solution
- Higher number of stages not possible due to rotor-dynamic restrictions

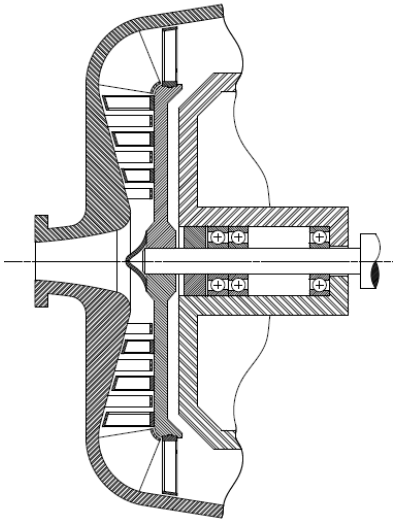


RESULTING OPTIMISED SOLUTION:

Rotational speed	RPM	3,025
Shaft diameter	mm	140
Disks diameters	mm	1030/1050/1100
Rotor blades high		6/24/62
Efficiency	**%**	**79**

RADIAL OUTFLOW CONFIGURATION (EXERGY):

- Many configuration have been studied with a varying number of stages and degrees of reaction
- Due to the SINGLE DISK ARRANGMENT, the EXERGY/OUTFLOW can accommodate a higher number of stages without rotor-dynamic limitation
- A 6 stages, 5 radial outflow + 1 axial has been selected



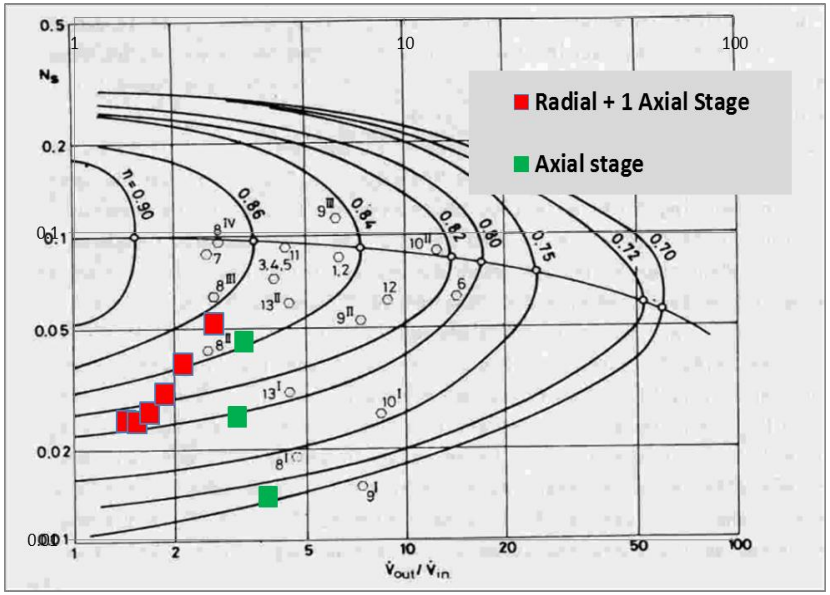
RESULTING OPTIMISED SOLUTION:

Rotational speed	RPM	3,025
Shaft diameter	mm	140
Disks diameters	mm	1.100
Rotor blades high	mm	9/9,5/13/19/32/62
Efficiency	**%**	**84**

EFFICIENCIES COMPARISON:

RESULTING OPTIMISED SOLUTION:

		AXIAL	EXERGY	RADIAL INFLOW
Rotational speed	RPM	3,025	3,025	19,000/ 9,100
Shaft diameter	mm	140	140	-
Disks diameters	mm	1030/1050/1100	1100	300/530
Rotor blades high	mm	6/24/62	9/9,5/13/19/32/62	-
Efficiency	**%**	**79**	**84**	**84**



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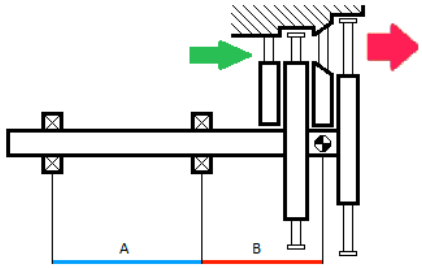
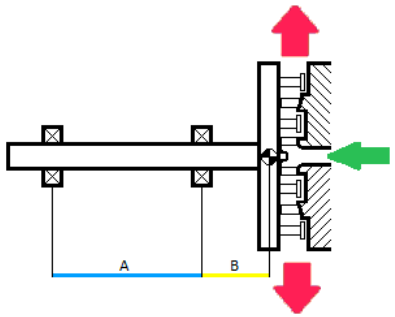
THE RADIAL OUTFLOW TURBINE

ROTOR-DYNAMICS COMPARISON:

RESULTING OPTIMISED SOLUTION:

		AXIAL	EXERGY
Rotational speed	RPM	3,025	3,025
Shaft diameter	mm	140	140
Disks 1 diameters/weight/offset	mm/kg/mm	1030/227/190	1100/280/195
Disks 2 diameters/weight/offset	mm/kg/mm	1050/222/270	n.a.
Disks 3 diameters/weight/offset	mm/kg/mm	1100/212/350	n.a.
First bending mode frequency	**rpm**	**3400**	**4500**





For Radial Inflow turbine the maximum number of stages is not limited by rotrodynamics, since each wheel is installed on a different pinion

EXERGY OUTFLOW CONFIGURATION:

SUMMARY RESULTS:

- EXERGY OUTFLOW & double stage RADIAL INFLOW achieved greater efficiencies than the AXIAL technology
- The EXERGY OUTFLOW proved to be most efficient
- RADIAL INFLOW required complicated 2-wheel configuration due to high volumetric expansion
- EXERGY OUTFLOW configuration can accommodate a higher volumetric expansion cycle with a single disk configuration, thus achieving better efficiencies at a reasonable cost

THANK YOU FOR YOUR ATTENTION

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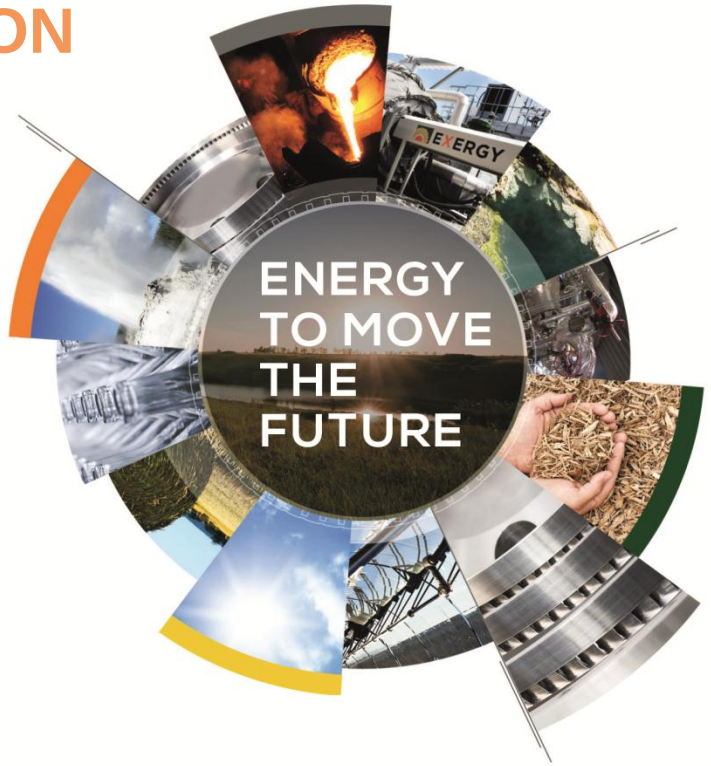

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