20kW OTEC Turbine Development

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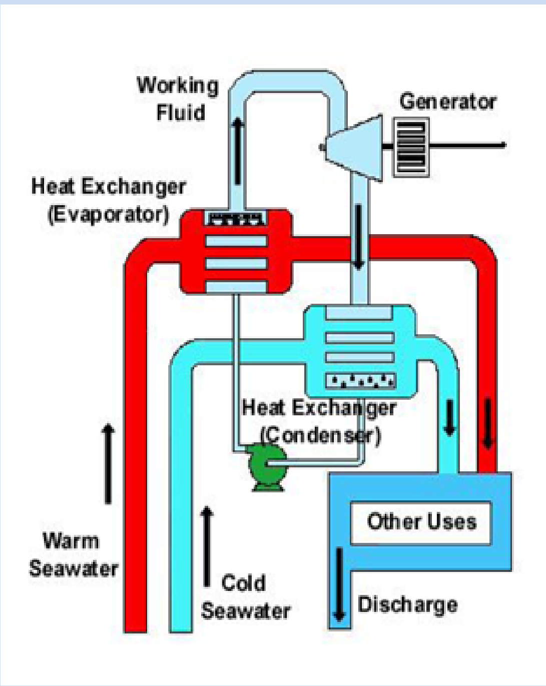
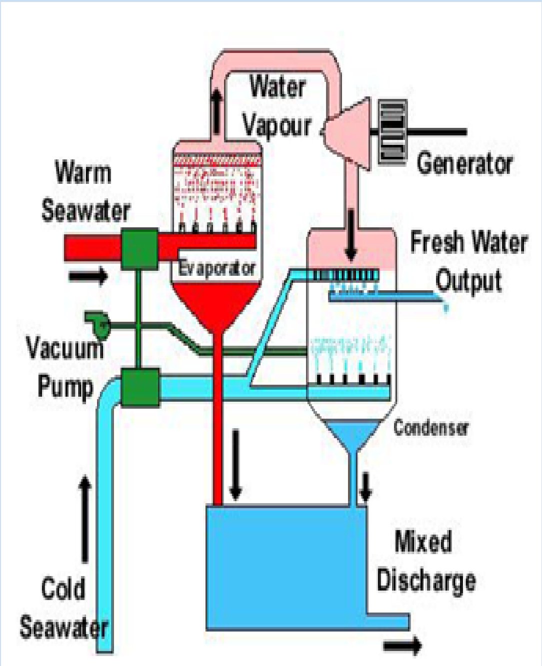
OTEC – Ocean Thermal Energy Conversion

OTEC Concept

- *OTEC power plant uses the temperature difference between deep sea water and surface layer water*
- *CC-OTEC power plant uses Organic Rankine Cycle.*

〈Closed-cycle〉		〈Open-cycle〉
	 *NELHA 210kW OC-OTEC Pilot plant*	

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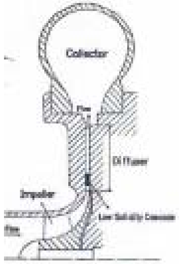
■Design Methods and Tools

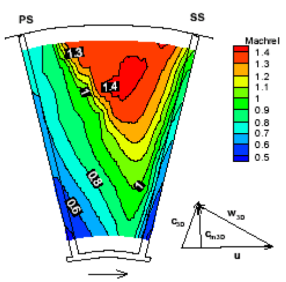


Basic Design

- Rrital - preliminary sizing
- Determine turbine size, nozzle exit angle
- Meridional Performance Analysis

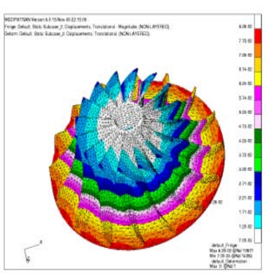
Blade 3D Design

-BladeGen – Generate 3D design
-TurboGrid – assigne mesh to 3D model



CFD Analysis

- ANSYS CFX – full CFD Analysis and Optimization



Stress Analysis

- ANSYS CFX – Stress analysis
- rotor stress analysis

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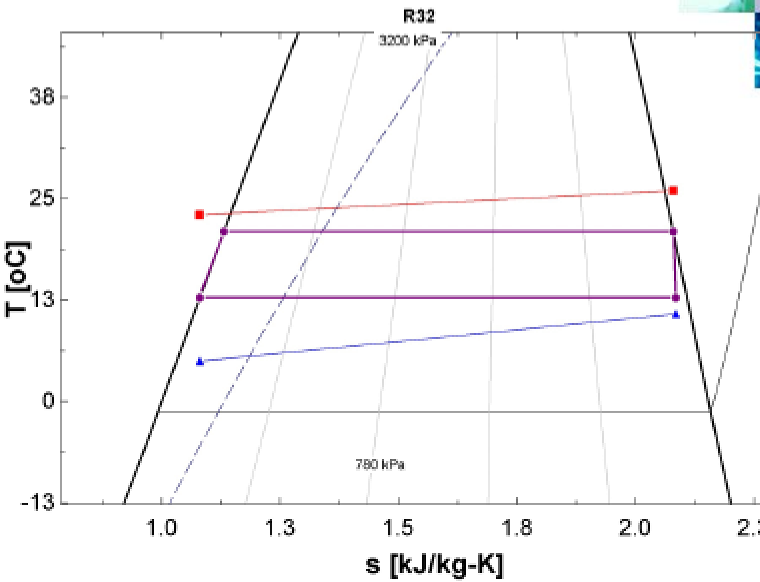
■ Determine Working Fluid

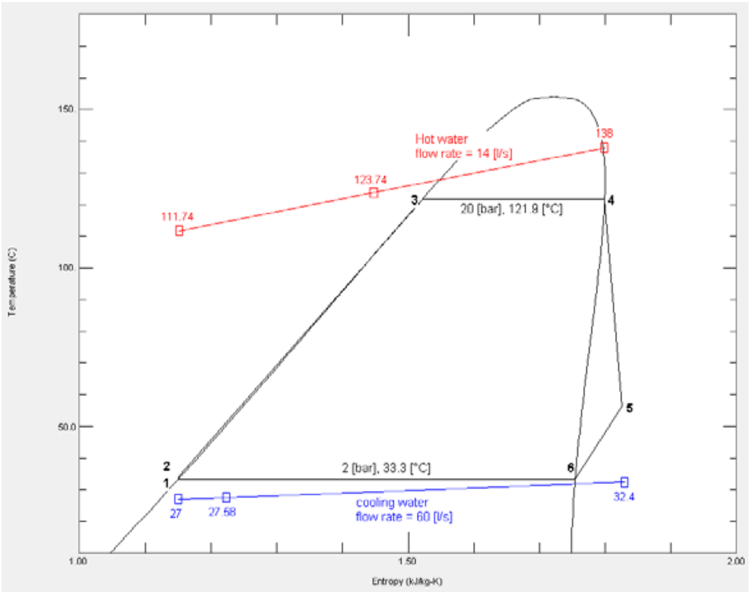
Requirements

- Low-toxic
- Non-flammability
- Low cost and availability
- Good Thermodynamic Properties



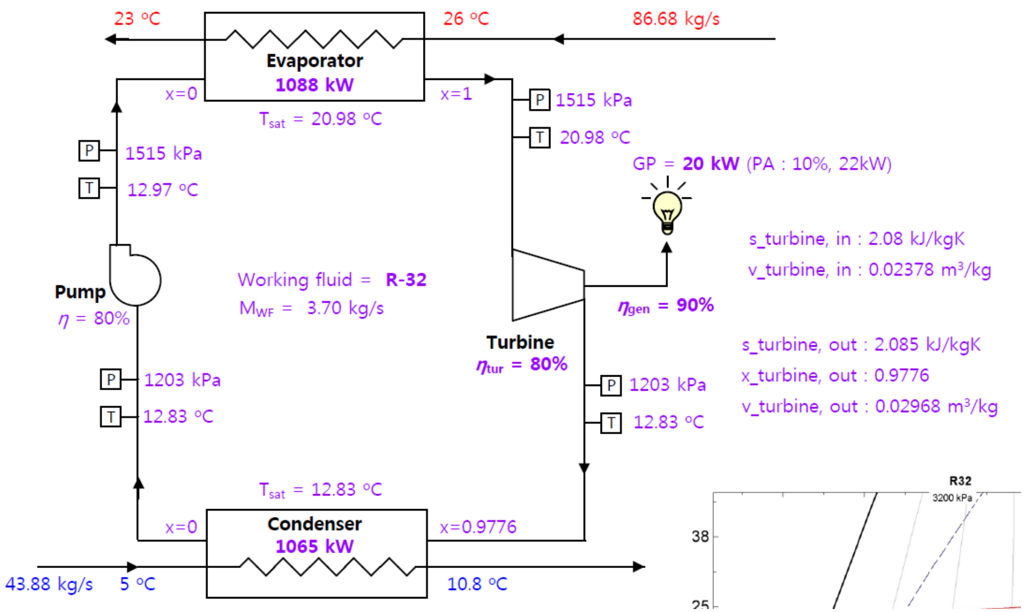
Candidate

- R22 – Low saturation pressure, negative gradient in T-S plot, bigger system
- R32 – High saturation pressure, small system, negative gradient in T-S plot <- determined
- R245fa – Low saturation pressure, High cost, bigger system



■ OTEC Cycle And Turbine Specification

20kW OTEC Cycle Analysis



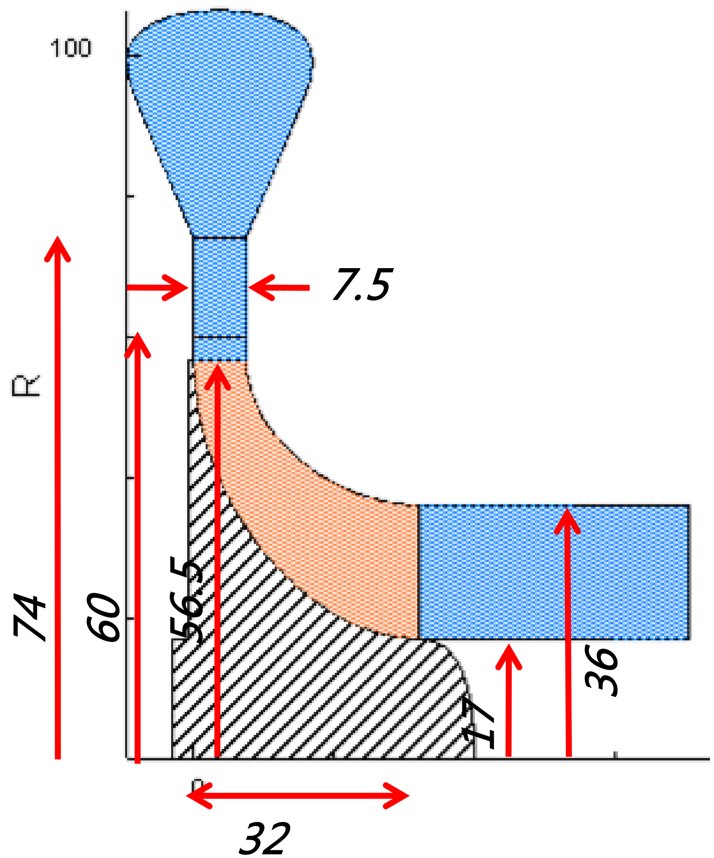
- ***20kW Turbine with R-32 working fluid***

		Value
Working Fluid		R-32
Inlet Total Temperature	℃	20.98
Inlet Total Pressure	kPa	1515
Outlet Total Temperature	℃	12.83
Outlet Total Pressure	kPa	1203
Mass Flow rate	kg/s	3.7
Expansion ratio (TT based)		1.26

■ 20kW Turbine Meridional Design

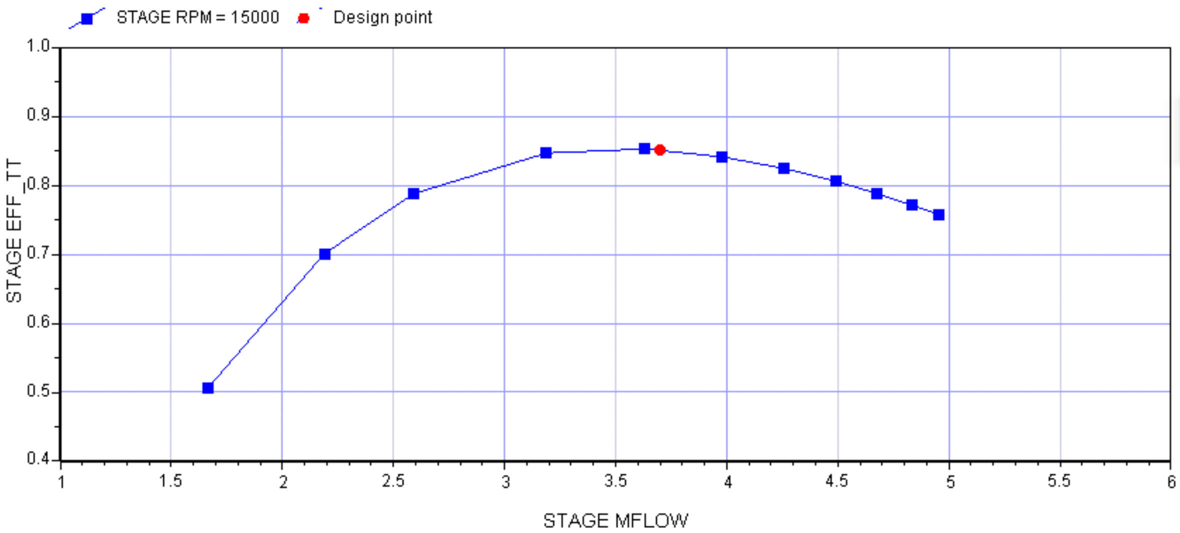
Meridional Design

NREC Rital and NIST property are used



NOZZLE	
r2(mm)	74
b2(mm)	7.5
r3(mm)	60
b3(mm)	7.5
ROTOR	
r4(mm)	56.5
z1(mm)	0
r4(mm)	56.5
z2(b4)(mm)	7.5
r5s(mm)	36
z5(Ax_Len)(mm)	32
r5h(mm)	17
z5(Ax_Len)(mm)	32
Performance	
Power(kW)	25.7
Stage RPM	15000
Specific speed	0.61
Efficiency TS	0.79

■ Performance Analysis

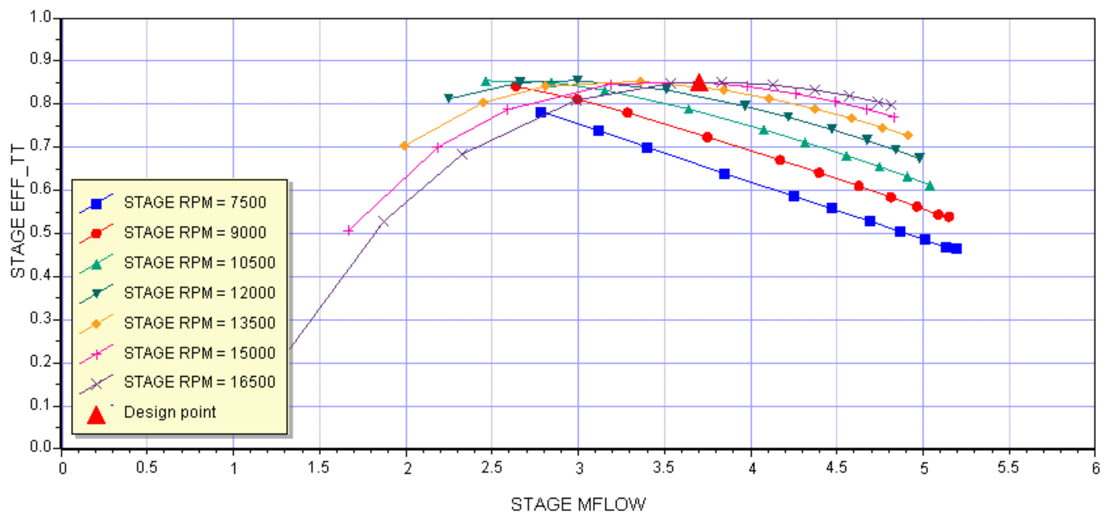


Design Performance

Maximum efficiency at 3.5kg/s flow rate -> Design point

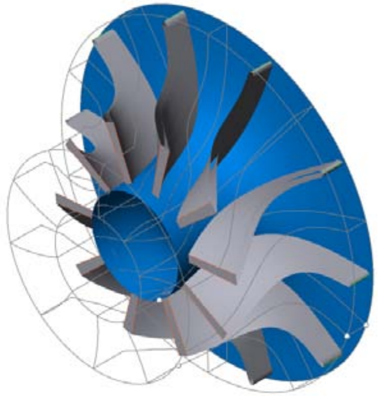
Off-Design performance

With 50, 60, 70 ,80 ,90, 100, 110% rpm, good efficiency is obtained



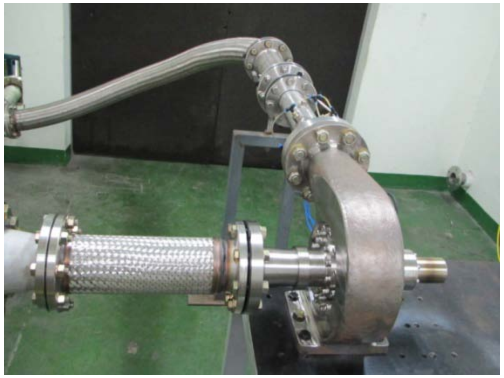
■ 3D Model Design / 20kW OTEC Turbine Prototype

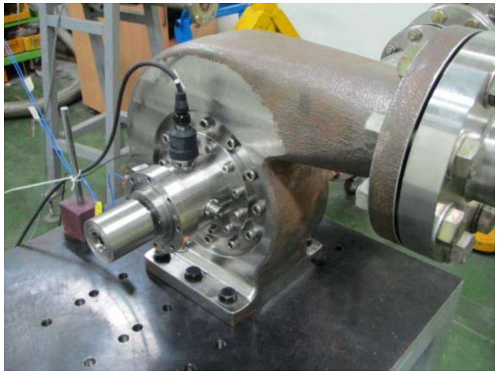
Nozzle shape



Rotor shape

- Determine the number of rotor/nozzle, rotor beta angle
- Finally, find the optimized shape to obtain high efficiency





- **Cold test with air to check the initial design without loading**

■ Conclusion

- Meridional Design
  - Choose the design without chocking in nozze and rotor.

- 3D Full CFD
  - Change the number of nozzle/rotor blade -> obtain high efficiency
  - Change the beta angle of Rotor blade -> obtain high efficiency
  - Too many blades are not allowed due to space limitation and complexity

- Stress analysis
  - Because OTEC turbine runs in low temperature, stress analysis is not a issue.