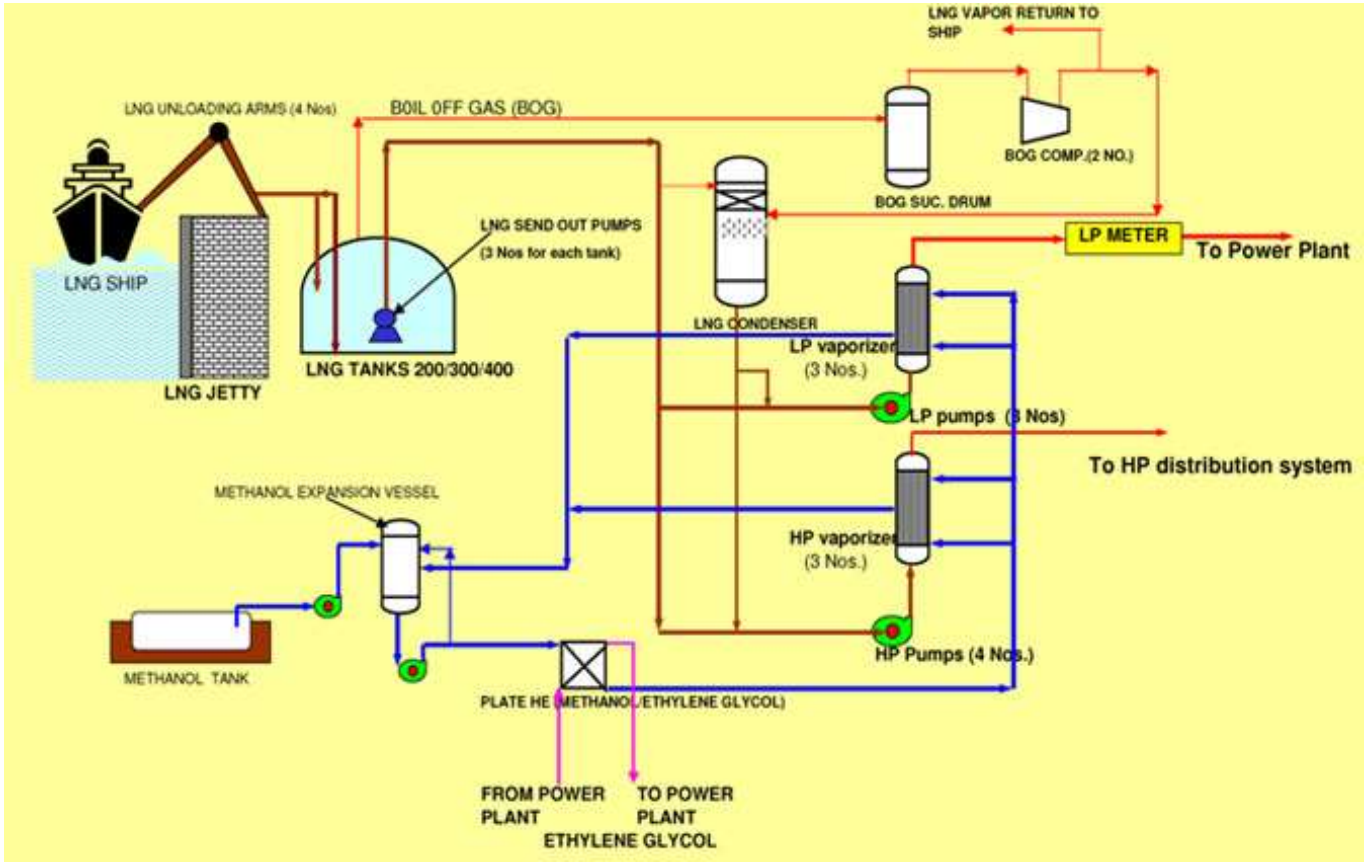
ORC FOR FSRU

Introduction

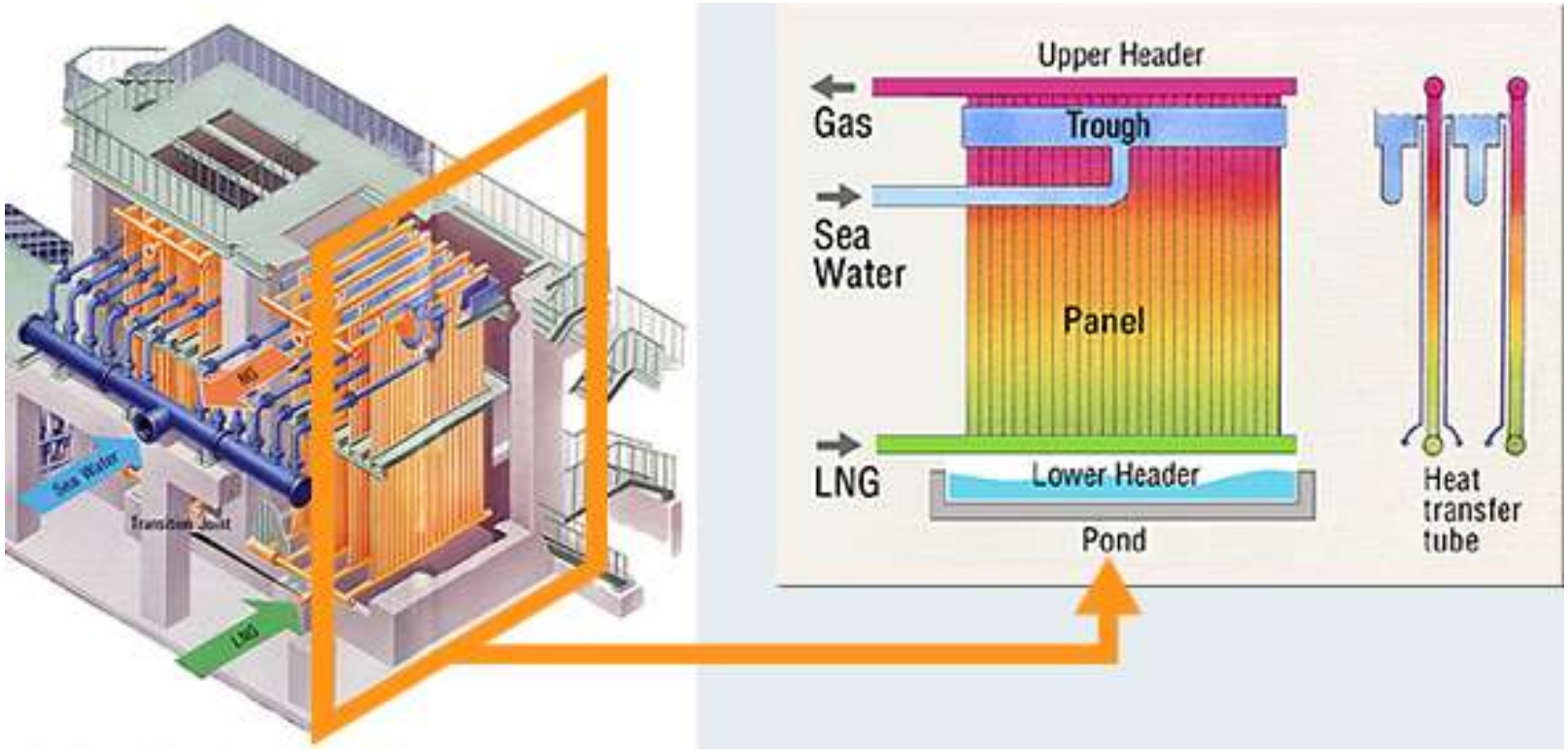
- LNG vaporization process
  - To supply natural gas to consumers, LNG(liquefied natural gas) is vaporized through a vaporizer on the onshore LNG terminal.



http://www.rgppl.com/index.php?option=com_content&view=article&id=65&Itemid=75

Introduction

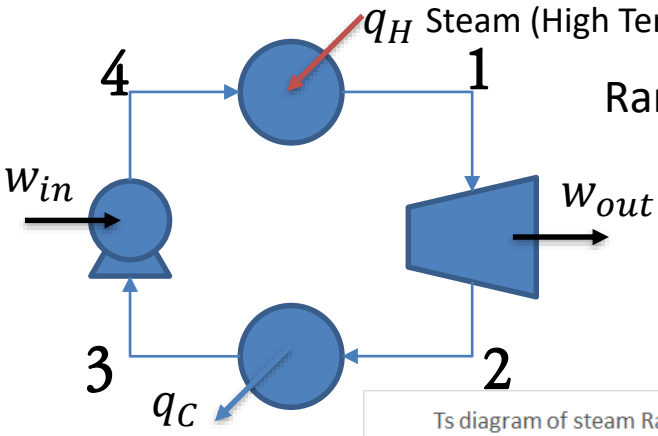
- A vaporizer can use various heating media (ambient sea water, ethylene glycol, waste steam…)



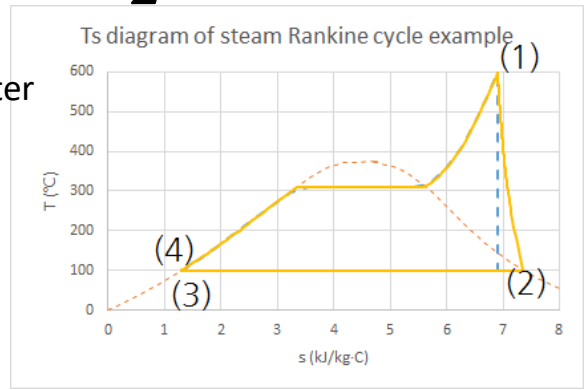
http://www.tokyo-gas.co.jp/lngtech/orv/

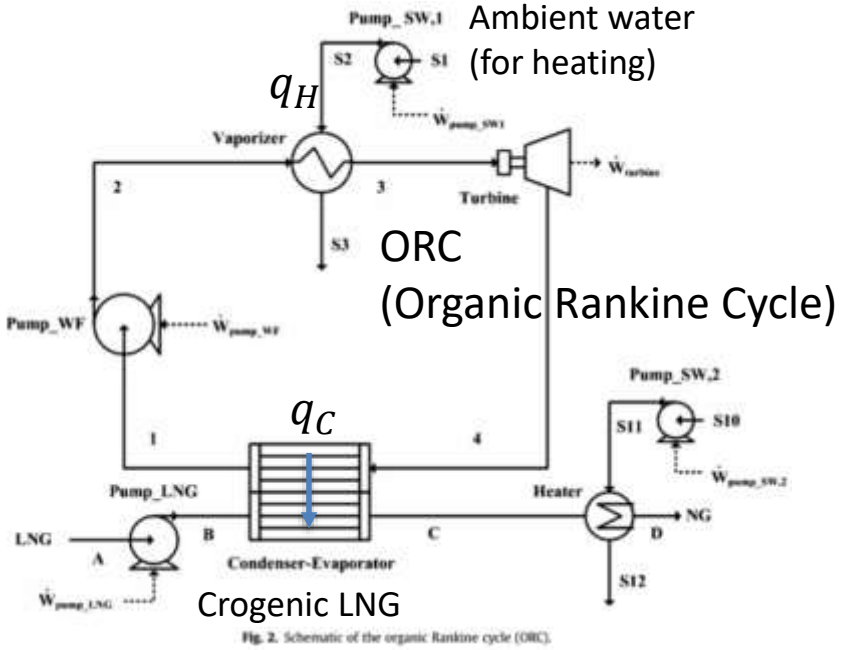
Introduction

- When sea water is used, the cryogenic energy of LNG is lost. If we can recover it, more efficient vaporization process is possible → ORC



Rankine Cycle





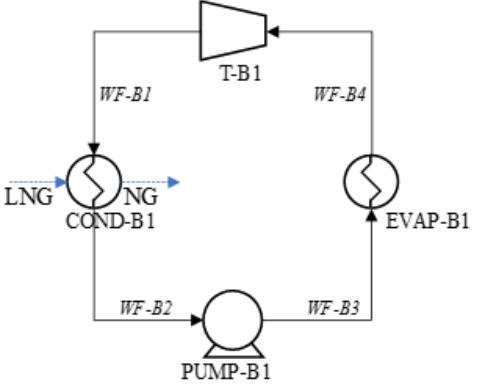
In-Hwan Choi, Sangick Lee, Yutaek Seo, Daejun Chang, Analysis and optimization of cascade Rankine cycle for liquefied natural gas cold energy recovery, Energy, 61(1), 2013

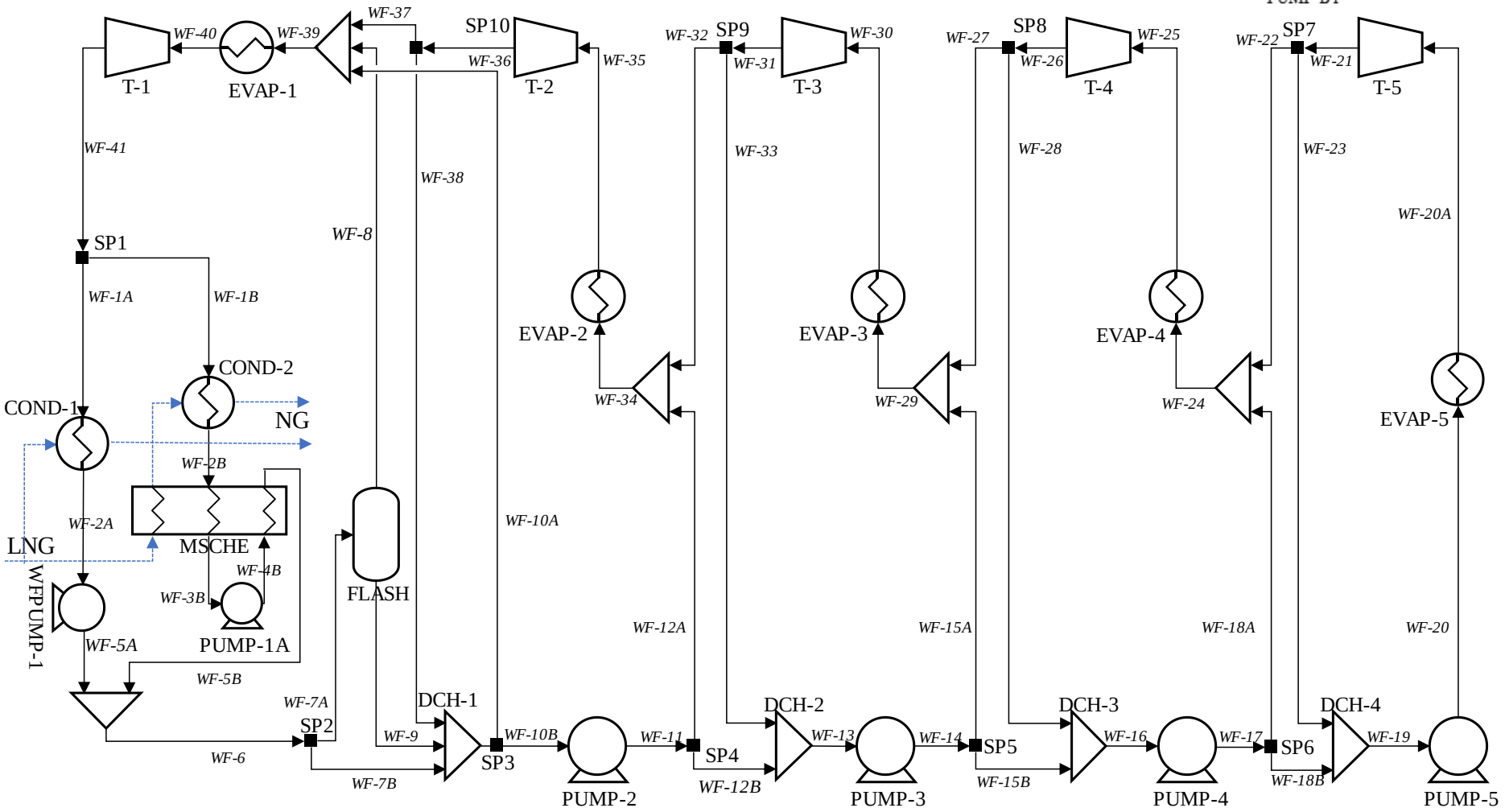
Major issues of the ORC design

- Selection of proper working fluid
  - Several hundreds of researchers studied about the selection of working fluid, but they mainly focused on a pure substance.
    - Multi-component working fluids can make temperature difference smaller than pure substances during condensation.
- Design of the optimal Rankine cycle configuration
  - Separated ideas have been applied
    - Simultaneous optimization of working fluid and process configuration can improve the system.

* U. Lee, J. Jeon, C. Han, Y. Lim, Superstructure based Techno-Economic Optimization of the Organic Rankine Cycle using LNG Cryogenic Energy, Energy, submitted, 2017

ORC Superstructure





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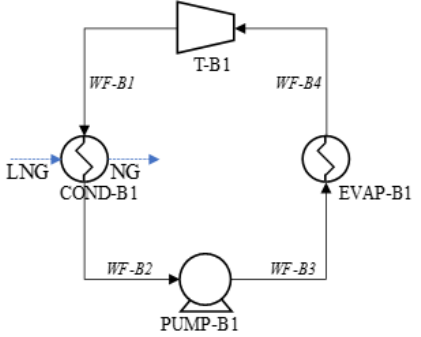
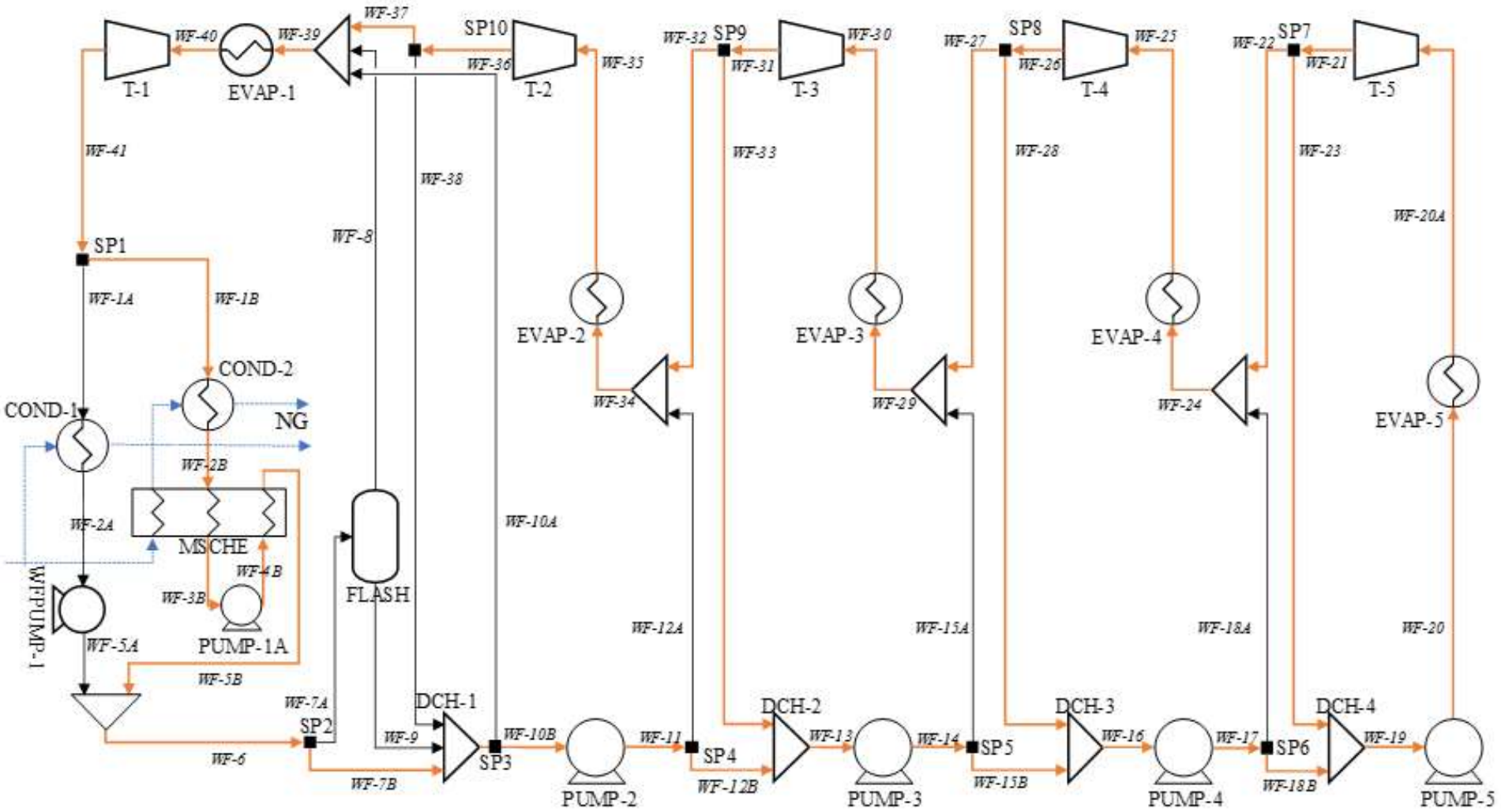
Optimization results





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Cycle efficiency

	Base case		Opt. results	
Required Heat for evaporation (MW)	$Q_{EVAP-1B}$	493.7	Q_{EVAP-5}	306.0
			Q_{EVAP-4}	54.0
			Q_{EVAP-3}	49.3
			Q_{EVAP-2}	13.2
			Q_{EVAP-1}	34.1
		493.7		456.6
Required power for pumps (MW)	$W_{PUMP-B1}$	4.3	$W_{PUMP-1A}$	2.0
			W_{PUMP-2}	2.0
			W_{PUMP-3}	0.9
			W_{PUMP-4}	4.3
			W_{PUMP-5}	5.6
		4.3		14.9
Produced power from turbines (MW)	W_{T-B1}	94.5	W_{T-5}	11.6
			W_{T-4}	16.3
			W_{T-3}	6.0
			W_{T-2}	19.0
			W_{T-1}	81.6
		94.5		134.5
Efficiency		18.3		26.2

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Future works

- For a FSRU, additional limitation is required.
  - Limited heat source: waste steam may not exist on FSRU.
  - Limited weight and foot print: multi-expansion turbine may not be practical on FSRU due to the limitation of hull.
  - Fire and Explosion Risk: Offshore people are reluctant to use flammable components as working fluid.
- What's the optimal ORC design for a FSRU?
  - Ongoing research