ANALYSIS OF TRANSCRITICAL AND SUPERCRITICAL CO_2 POWER CYCLE FOR APPLICABILITY IN WASTE HEAT RECOVERY

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BACKGROUND

- Introduction
- Working fluid comparison
- Why co_2 used as a working fluid
- Supercritcal and Transcritical co_2 power cycle
- Result and Discussions
- Conclusions

INTRODUCTION

❑ What is waste heat?

✓ Waste heat is heat, which is generated in a process by way of fuel combustion or chemical reaction, and then "dumped" into the environment even though it could still be reused for some useful and economic purpose. The essential quality of heat is not the amount but rather its "value". The strategy of how to recover this heat depends in part on the temperature of the waste heat gases and the economics involved.

❑ Waste heat classification

High temperature heat recovery (650^{o}C to 1400^{o}C)
(Ex. Ni, Al, Zn refining furnaces, Hydrogen plants, Glass melting furnace etc.)

Medium temperature heat recovery (230^{o}C to 650^{o}C)
(Ex. Steam boiler, Gas turbine, Reciprocating engine exhaust, Drying and backing ovens)

Low temperature heat recovery (70^{o}C to 230^{o}C)
(Ex. Annealing furnaces, Forming dies, Liquid still condenser, Hot processed liquids and solid)

WORKING FLUID COMPARISON

- **The following Thermo physical properties should be considered when selecting the working fluid:**

✓The critical temperature and critical pressure will indicate whether cycle run as transcritical or subcritical CO_2 cycle.

✓Specific heat(c_p) value influence the shape of temperature profile in the system of heat exchanger.

✓The specific volume and specific power density will indicate the sizes of the system components.

✓The value of (dS/dT) will indicate the possibility of moisture content at the turbine outlet.

✓Environment aspects namely GWP and ODP, safety availability and cost.

WHY WE ARE NOT USING ORGANIC RANKINE CYCLE?

WORKING FLUID COMPARISON (Continue..)

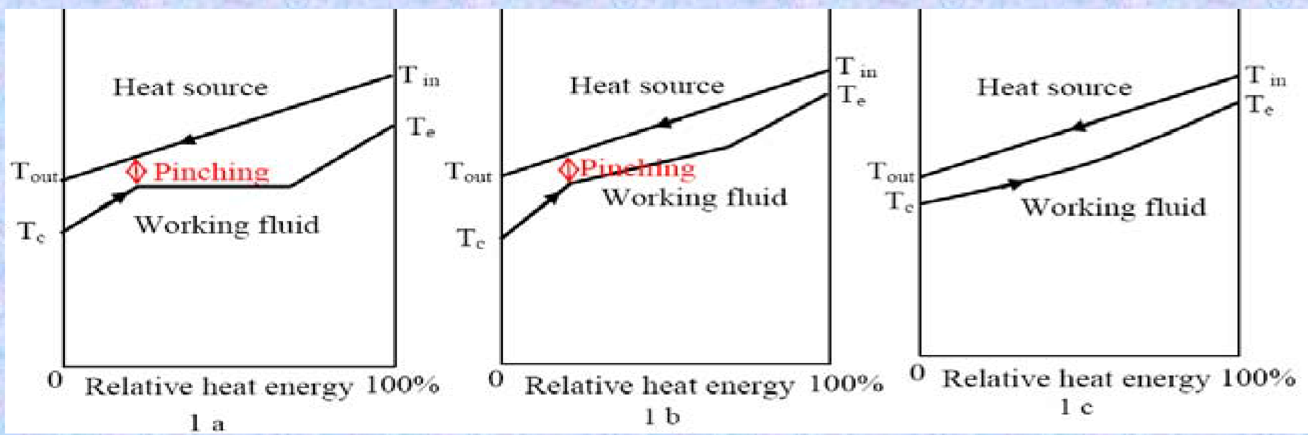
Fluid Name	ASHRAE No.	Critical Temperature (°C)	Critical Pressure (Bar)	ASHRAE Level for safety	ODP	GWP 100yr	dS/dT
Trifluoromethane	R23	26.29	48.3	A1	0	11700	-6.49
Difluoromethane	R32	78.26	57.8	A2	0	580	-4.33
2.2-Dichloro-1.1.1-trifluoroethane	R123	183.83	36.6	B1	0.02	93	0.26
Pentafluoroethane	R125	66.17	36.2	A1	0	2800	-1.08
Hydroflorocarbon	R134a	101.1	40.7	A1	0	1300	-0.39
1.1.1-Trifluoroethane	R143a	72.86	37.6	A2	0	3900	-1.49
1.1-Difluoroethane	R152a	113.41	45.2	A2	0	140	-1.14
Octafluoropropane	R218	72.02	26.4	A1	0	7000	0.45
Propane mixture	R290	369.8	42.47	A3	0	<10	-0.79
Zeotropic mixture	R407C	87.3	48.2	A1	0	1525	?
Azeotropic	R500	102.1	41.7	A1	0.74	6310	?
Butane	R600	152	37.9	A3	0	<10	1.03
Isobutane	R600a	134.7	36.4	A3	0	<10	1.03
Ammonia	R717	132.89	112.8	B2	0	0	-10.48
Water	R718	373.89	221.5	A1	0	0	-17.78
Carbon dioxide	R744	30.98	73.8	A1	0	1	-8.27
Propylene	R1270	92.57	46.6	A3	0	0	-1.77

WHY CO_2 USED AS THE WORKING FLUID

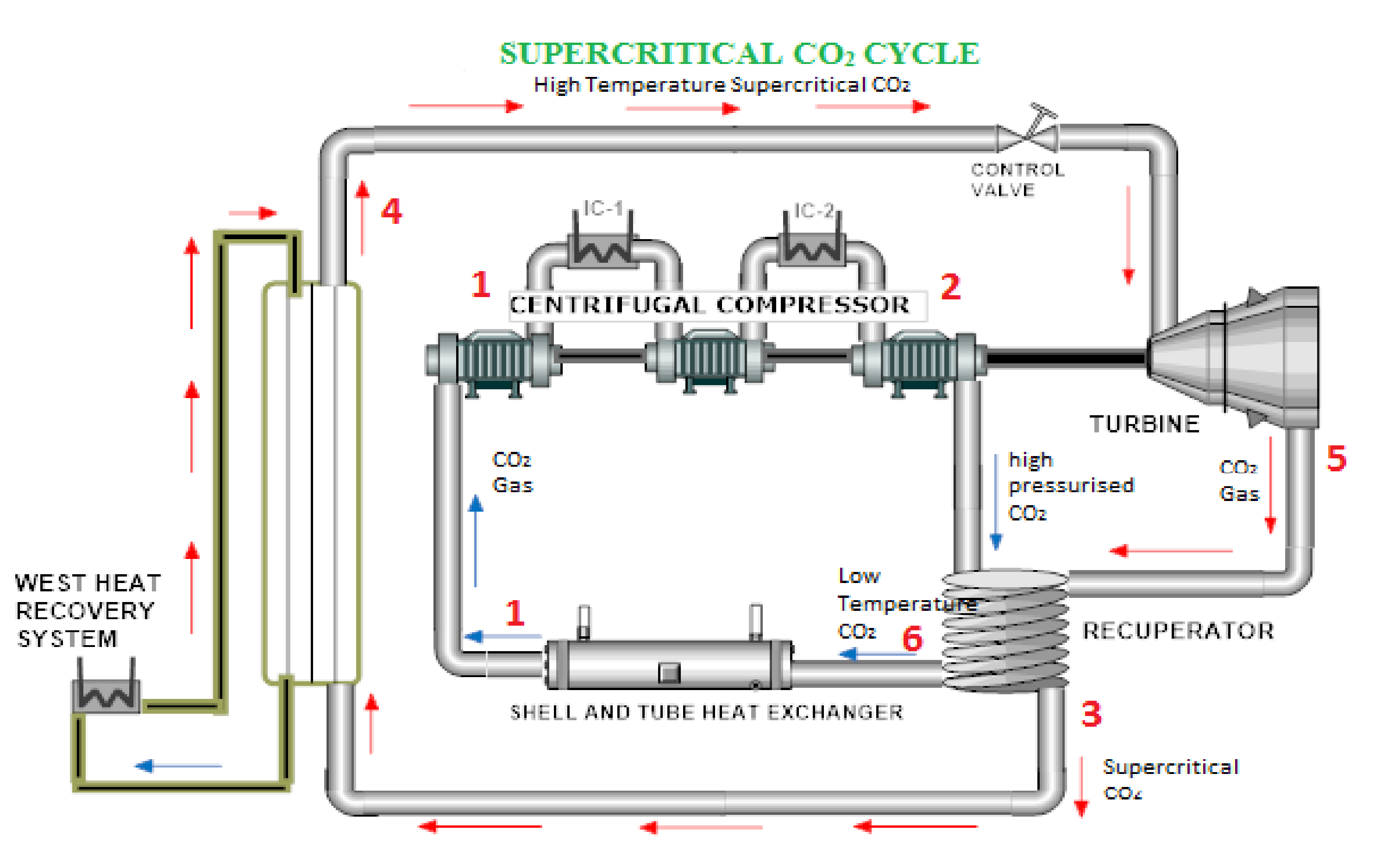
•There is no pinching problem occurred because better temperature profile match with heat source and it is single phase in supercritical region.

•Due to in single phase process, there is no latent heat is required and continuously temperature is increase and due to that there is no irreversibility produce.

•It is non toxic, non flammable ,thermally stable at very high temperature and inexpensive fluid. It has low Global Warming Potential (GWP=1) and no Ozone depletion Potential.

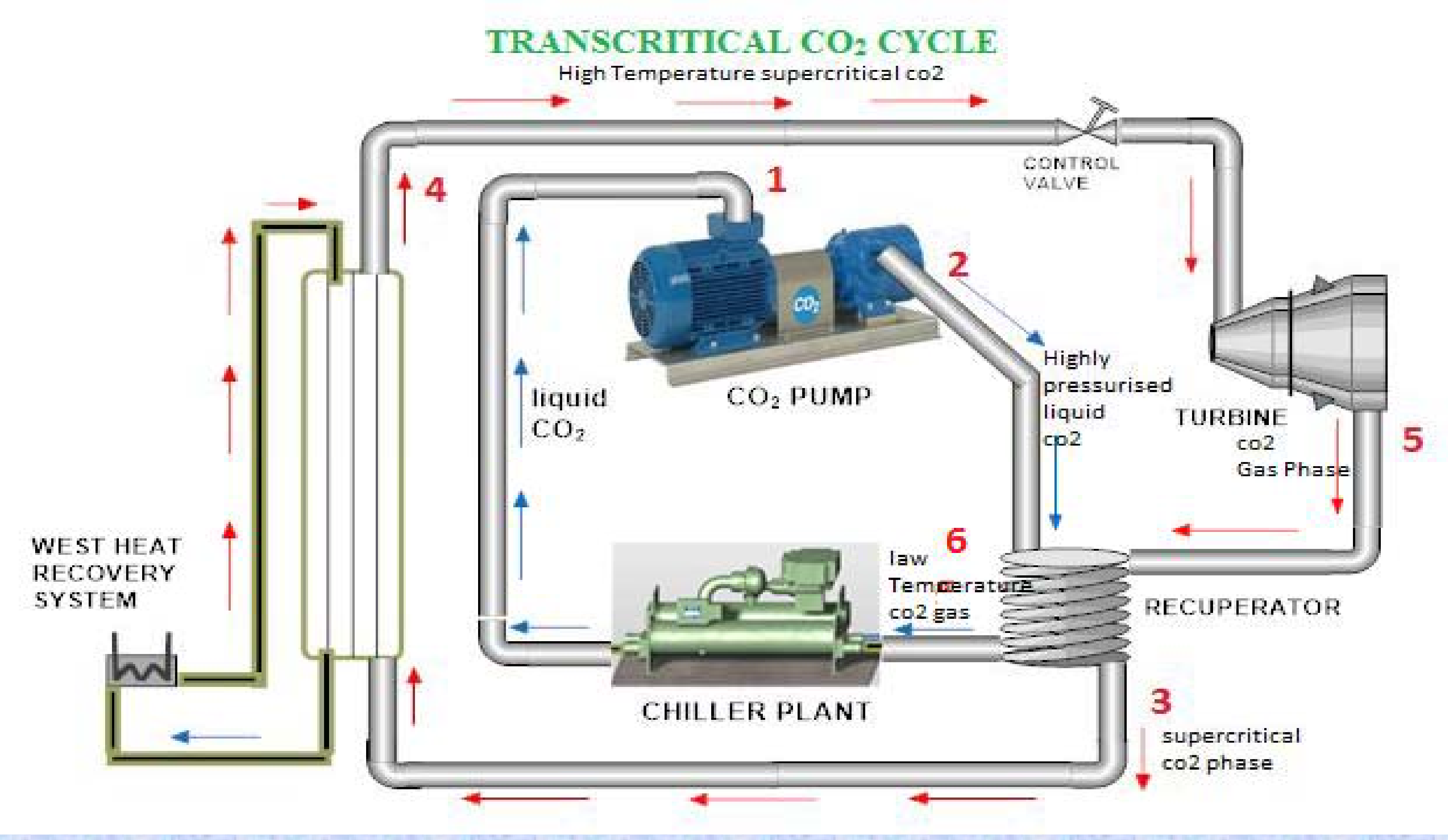


SUPERCRITICAL CO_2 POWER CYCLE



SCHEMATIC LAYOUT OF S-CO_2 POWER CYCLE

TRANSCRITICAL CO_2 POWER CYCLE



SCHEMATIC LAYOUT OF T-CO_2 POWER CYCLE

ASSUMPTIONS

- **The following assumptions required for comparison of thermal efficiency for S-CO_2 and T-CO_2 cycle for same heat source temperature at one particular inlet temperature and pressure of turbine:**

✓The system is at steady state, the kinetic and potential energies as well as the heat loss are negligible.

✓There is no pressure drop in the waste heat exchanger and cooler/condenser. Assume as the constant pressure process.

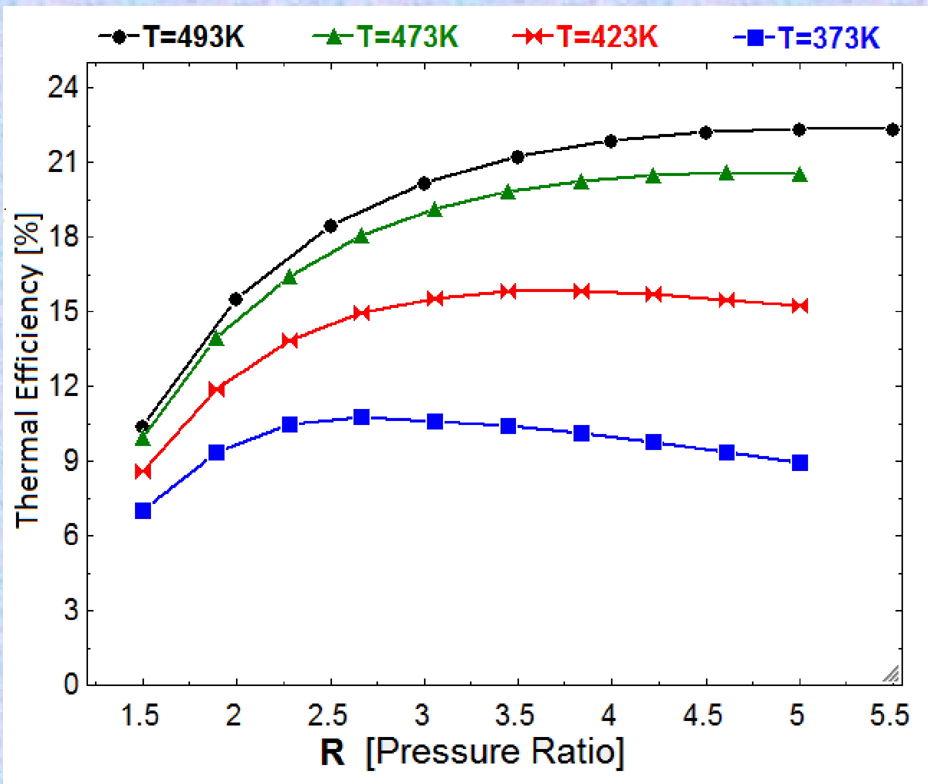
✓The Turbine and Pump / Compressor isentropic efficiencies are assumed to be 90%.

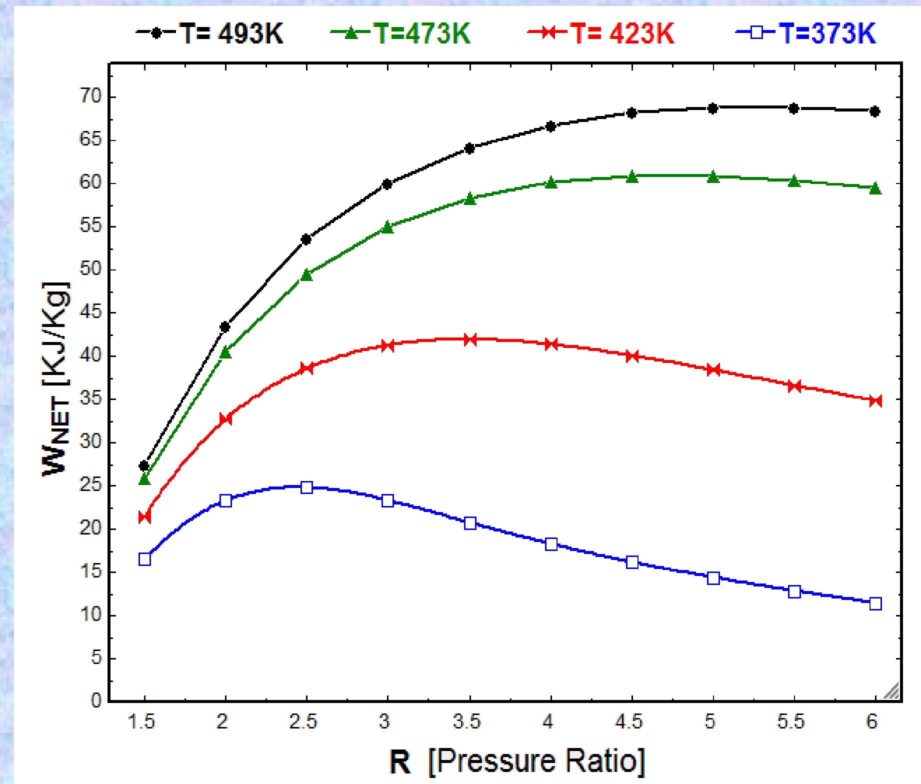
✓Recuperator effectiveness is assumed to be 90%.

RESULTS AND DISCUSSIONS

- The results obtained from the EES software and analyze the maximum thermal efficiency and net work output:

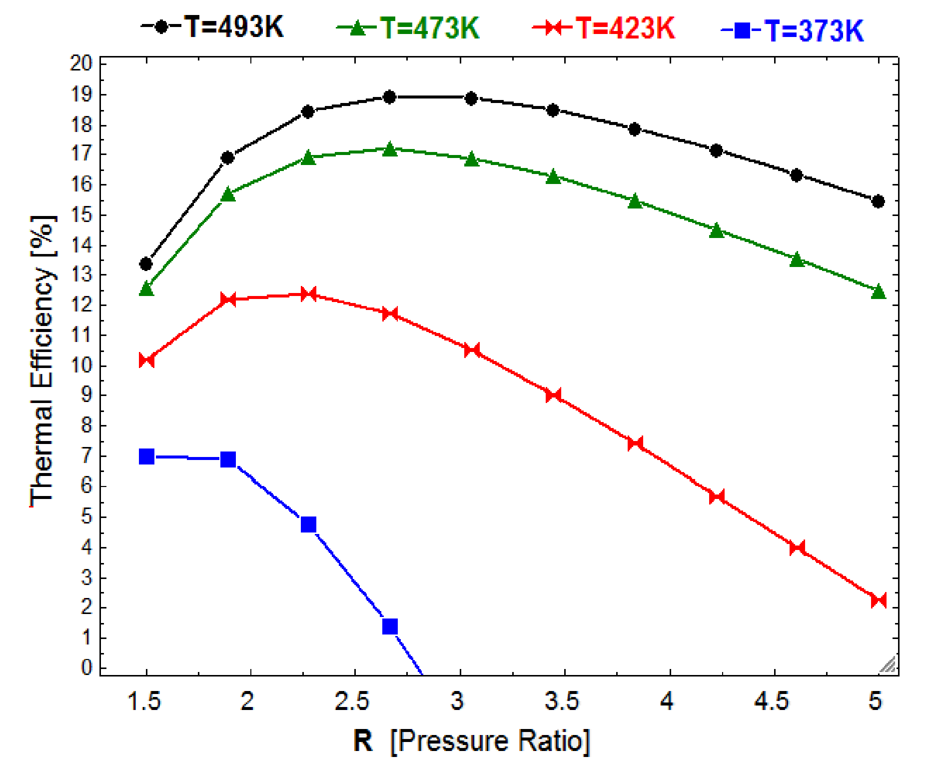
T-CO_2 CYCLE

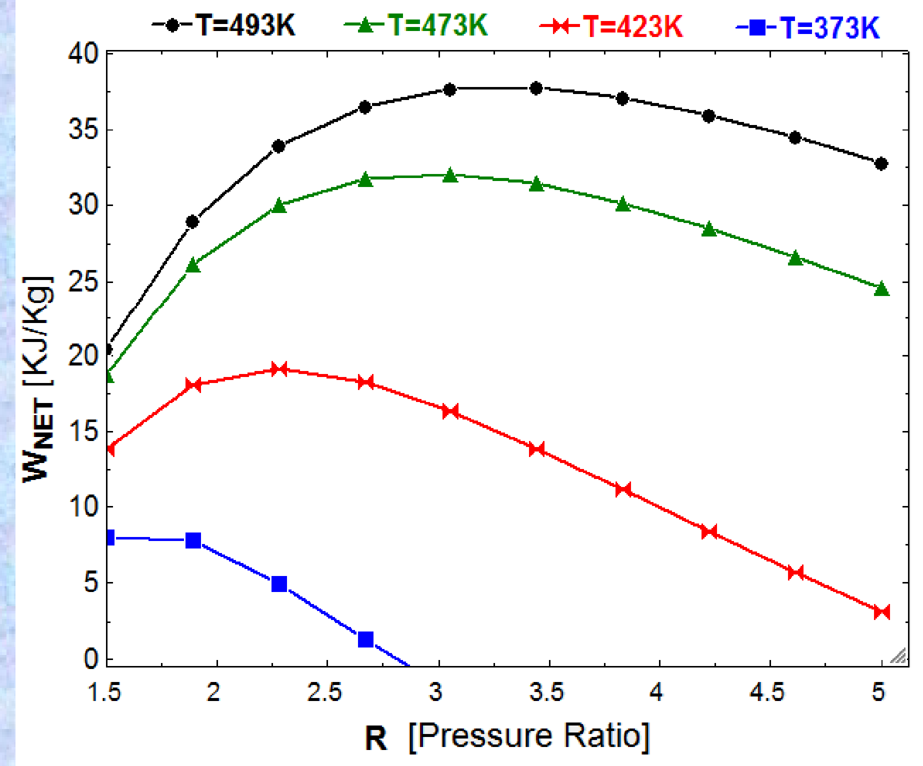




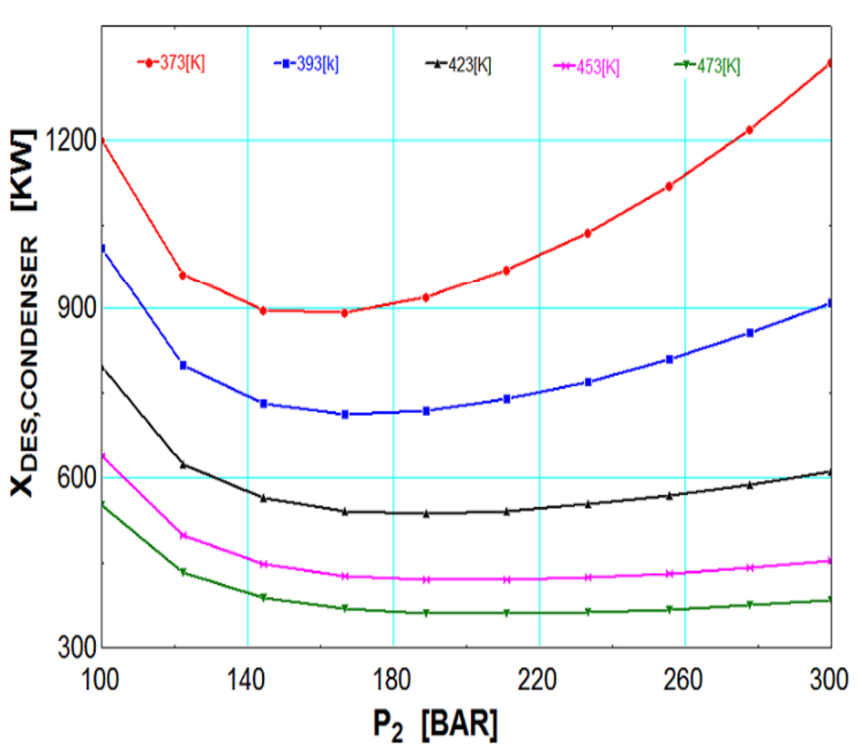
RESULTS AND DISCUSSIONS (Continue..)

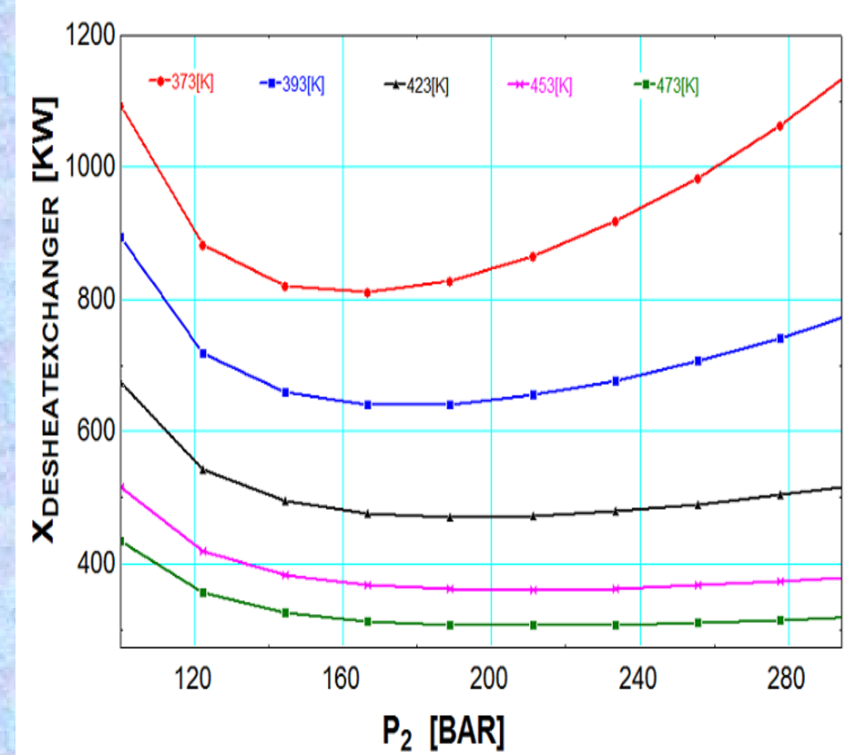
S-CO_2 CYCLE



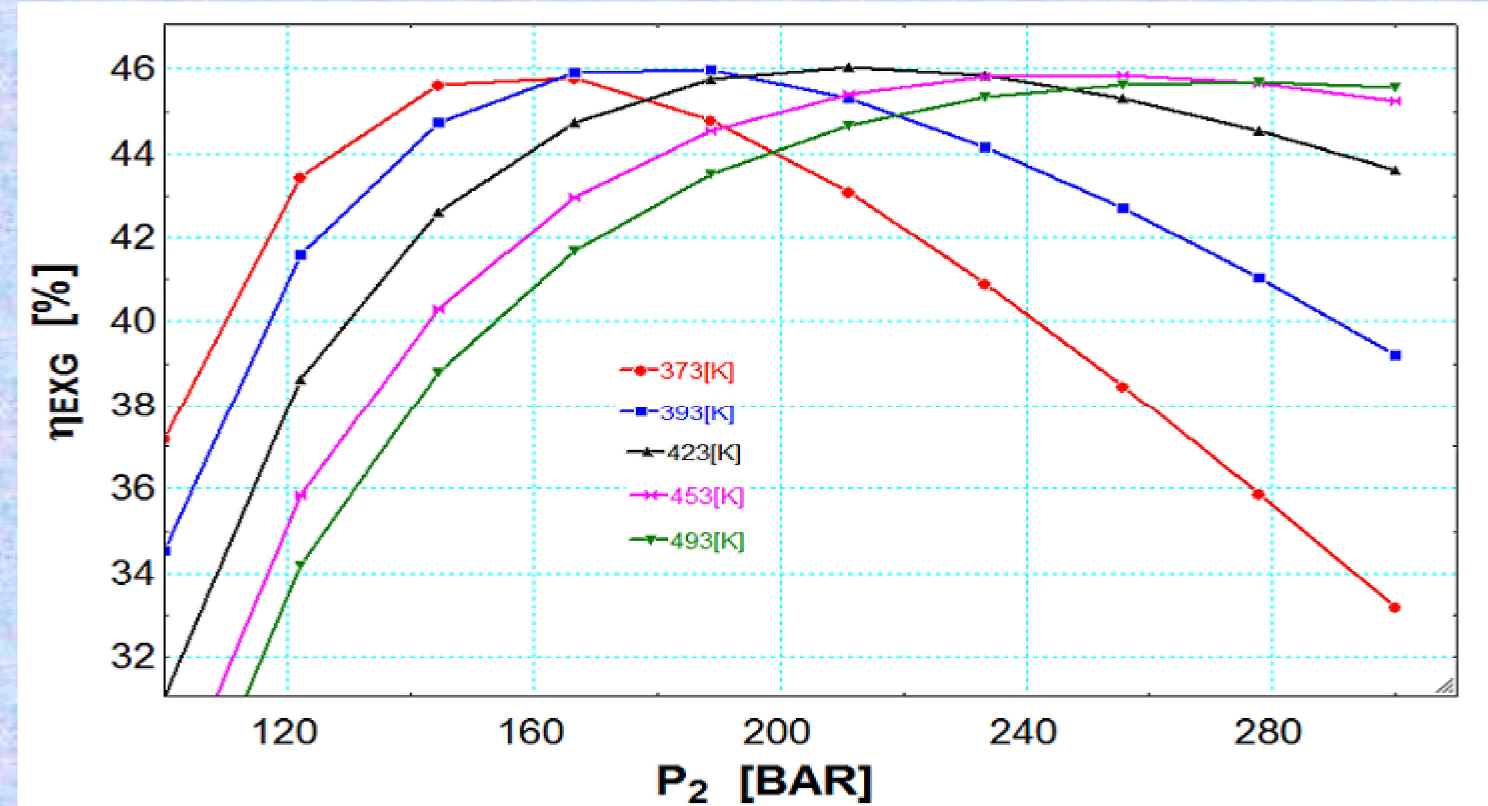


EXERGY ANALYSIS OF $T\text{-}CO_2$





EXERGY ANALYSIS OF T-CO_2



CONCLUSION

- In the present study, investigation of carbon dioxide transcritical and supercritical power cycles performance driven by low temperature flue gases waste as heat source was carried out based on parametric analysis.
- The cycles utilize flue gases exhaust temperature in the range of 373K-500K as a heat source which can be obtained from a gas turbine exhaust gas.
- Based on the first law analysis at given conditions T-CO2 cycle produces higher thermal efficiency and network output compared to S-CO2 cycle.
- The optimum turbine inlet pressure that gives the highest thermal efficiency is found to increase as the turbine inlet temperature increases. This study generates clearer overview on the use of carbon dioxide cycles for the conversion of medium temperature heat source into power.

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PLEASE
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QUESTIONS?

THANK YOU
FOR
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