OPTIMUM CONDITIONS OF A CARBON DIOXIDE TRANSCRITICAL POWER CYCLE FROM LOW TEMPERATURE HEAT SOURCE FOR POWER GENERATION.

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Sept. 22 2011

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CONTENTS

- INTRODUCTION.
- DESCRIPTION OF THE CDTPC.
- MODELLING OF THE PROCESS.
- RESULTS AND DISCUSSION.
- CONCLUSIONS.

Introduction

- Worldwide energy demand is continuously increasing.
- More than 50% of the fuel we use is waste.

But…..

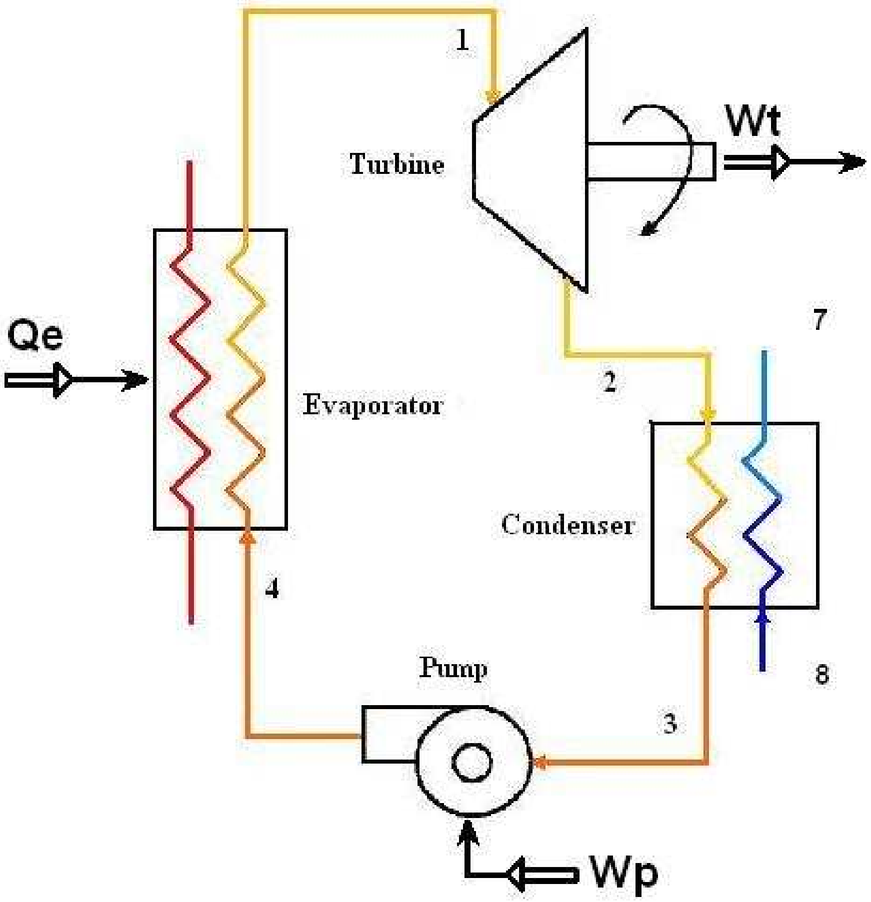
- Conventional steam power cycles cannot give a better performance to recover low-grade waste heat.
- Organic Rankine Cycles show the known pinching problem.

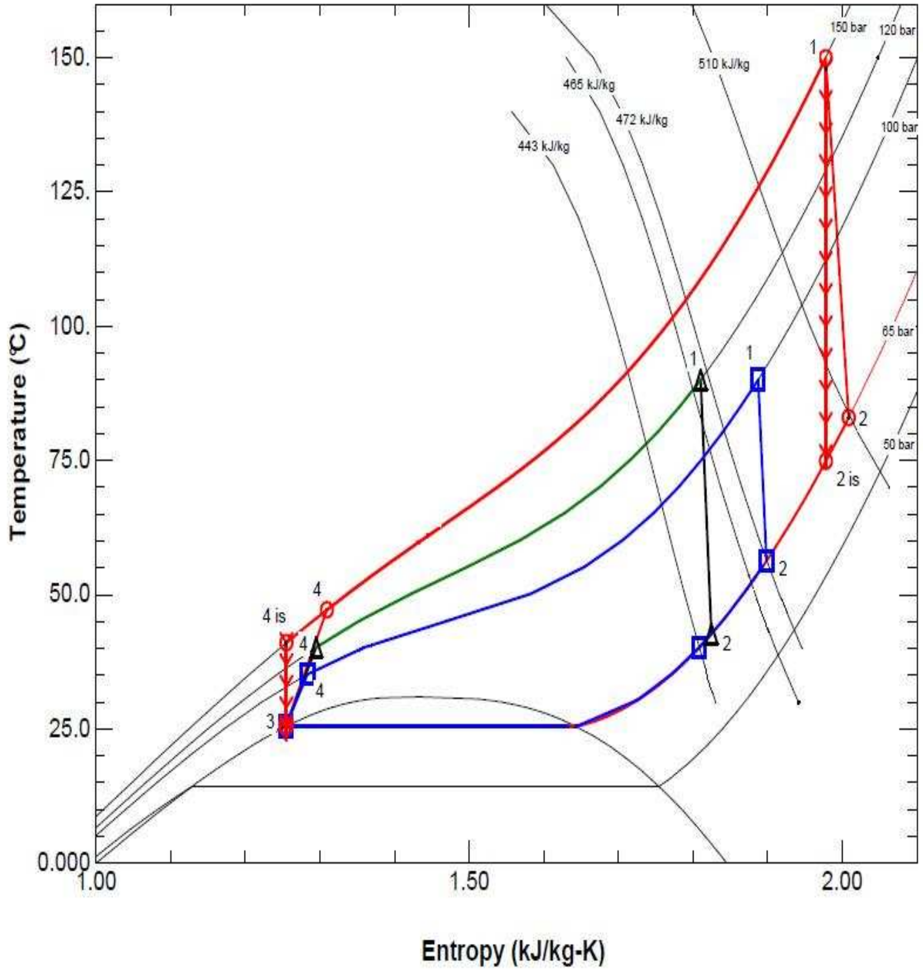
So……

✓ **Use of carbon dioxide in transcritical conditions in a Rankine cycles can solve both problems**.

Description of the CDTPC

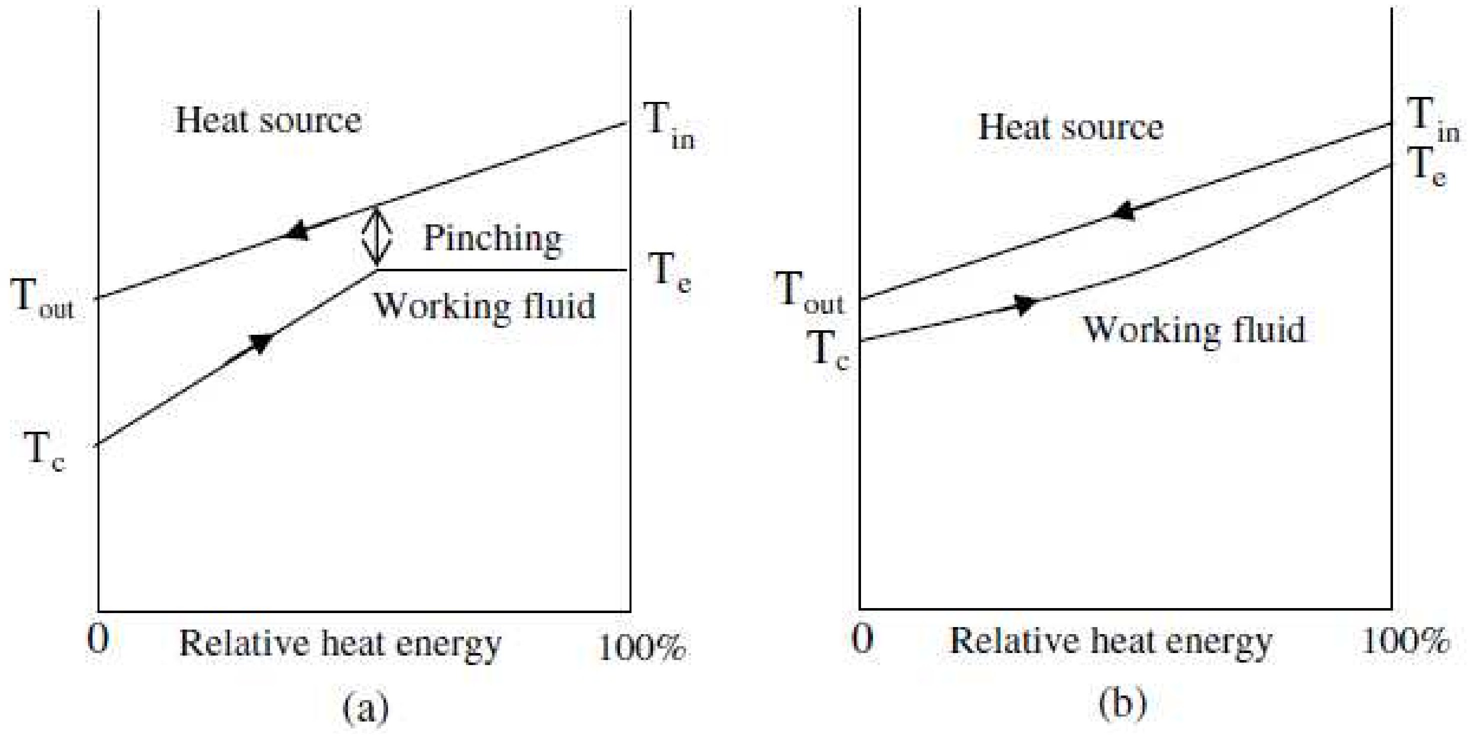
- Rankine cycle where the working fluid (CO_2) goes through both subcritical and supercritical states, "a transcritical cycle".





Description of the CDTPC

- In the evaporator, it is obtained a better fit with the heat source when the heat is added to the working fluid in supercritical conditions.



Y. Chen et al. / Applied Thermal Engineering 26 (2006) 2142–2147

Modelling of the process

- Constant isentropic efficiencies of 75% are assumed for the pump as well as for the turbine.
- Steady state conditions.
- No pressure drop or heat loss in the evaporator, condenser or the pipes.
- An inlet temperature of the condensation water T_7=15 ºC.
- Working fluid condensation temperature T_3=25 ºC.
- Turbine inlet temperature T_1=150 ºC.
- Turbine inlet pressure P_1, varying from 66 bar until the net work was **around** zero.

Modelling of the process.

- The cycle's total energy efficiency is:

$$\eta = \frac{\dot{W}_t - \dot{W}_p}{\dot{Q}_e}$$

$$\dot{W}_t = \dot{m} \times \eta_t \times (h_1 - h_2) \qquad \dot{W}_p = \dot{m} \times (h_3 - h_4) / \eta_p$$

$$\dot{Q}_e = \dot{m} \times (h_1 - h_4)$$

- The exergy efficiency is defined as:

$$\eta_E = 1 - \left(\frac{\sum_i \dot{I}_i}{\sum_i \dot{E}_{in,i}} \right)$$

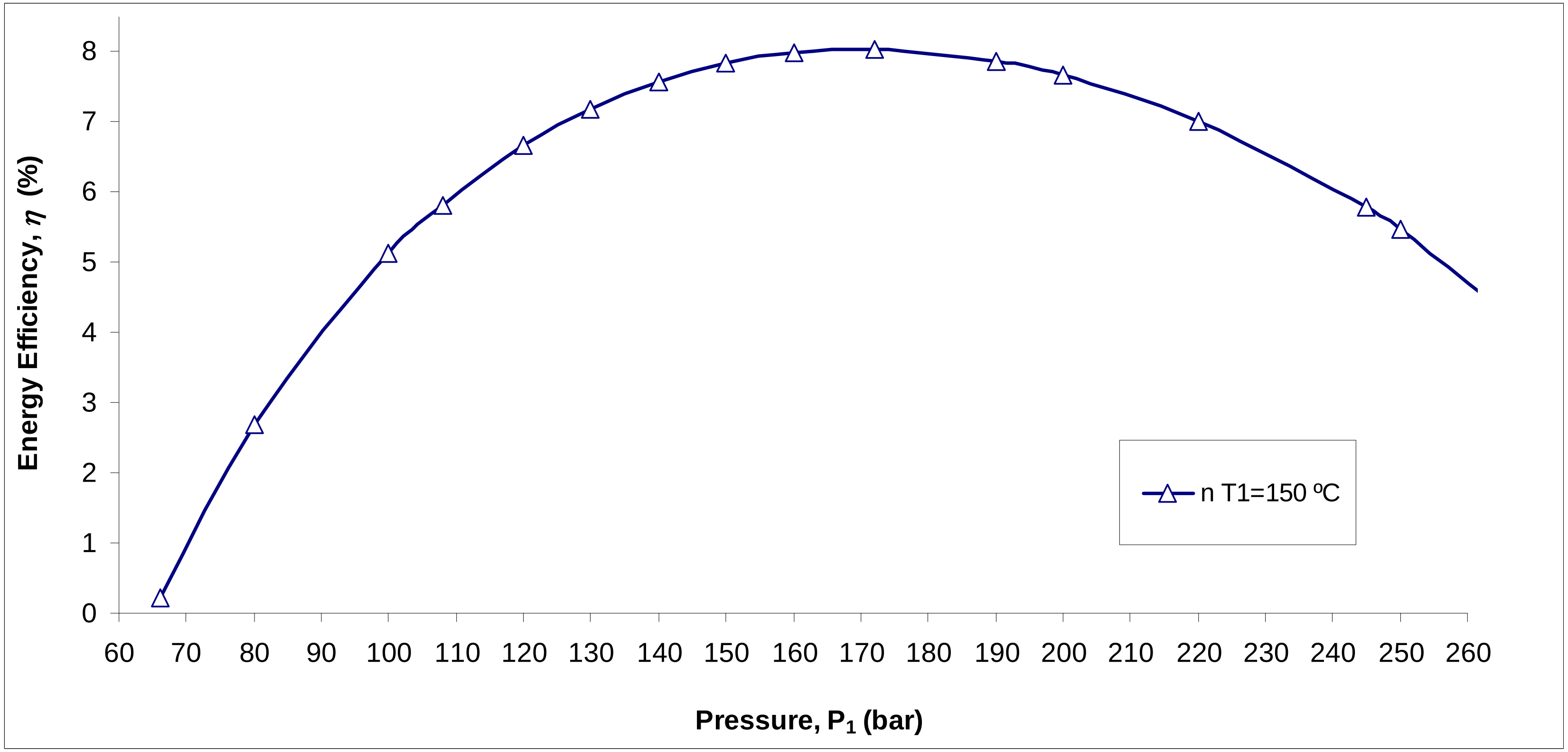
$\dot{I}_i$ is the exergy loss (destruction) of each component i (evaporator, turbine, condenser and pump) that can be found from an exergy balance.

$\dot{E}$ Exergy rate.

Results and discussion

ENERGY ANALYSIS

- Energy efficiency increases as pressure P_1 rises.
- A parabola-like behaviour.

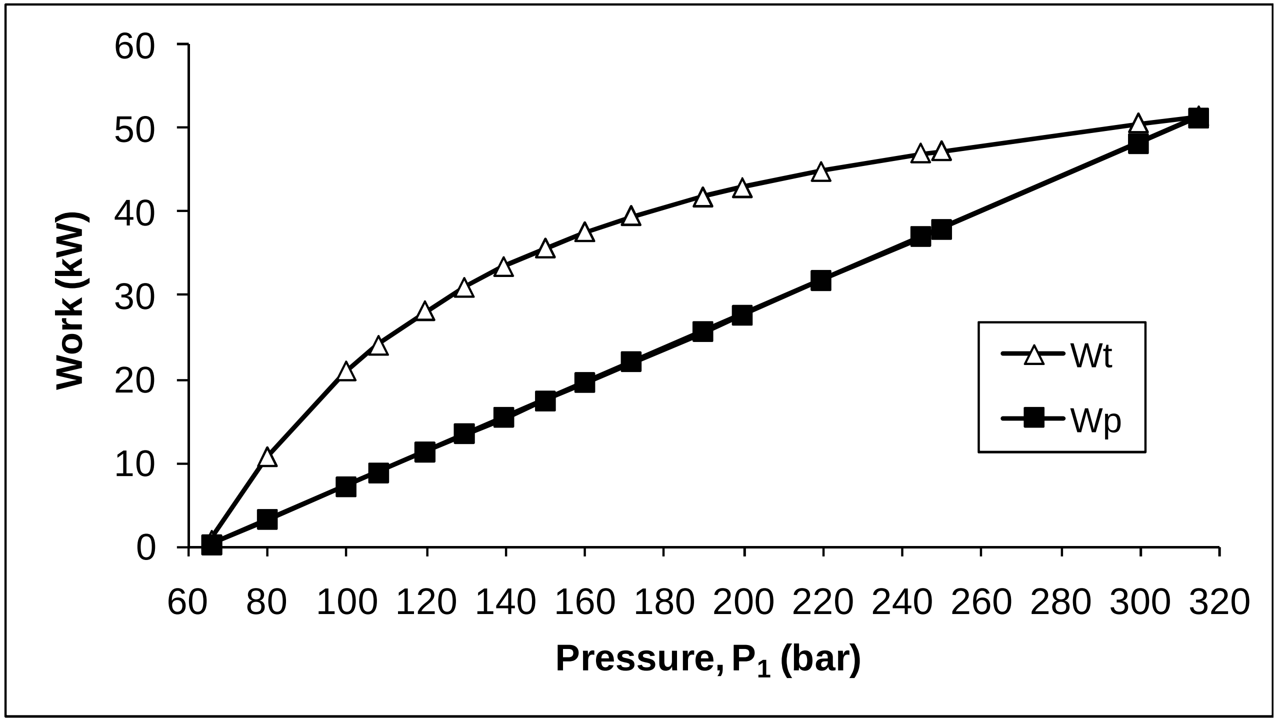


Energy efficiency vs Pressure P_1 with an inlet temperature to the turbine at 150 ºC.

Results and discussion

ENERGY ANALYSIS

- Energy.



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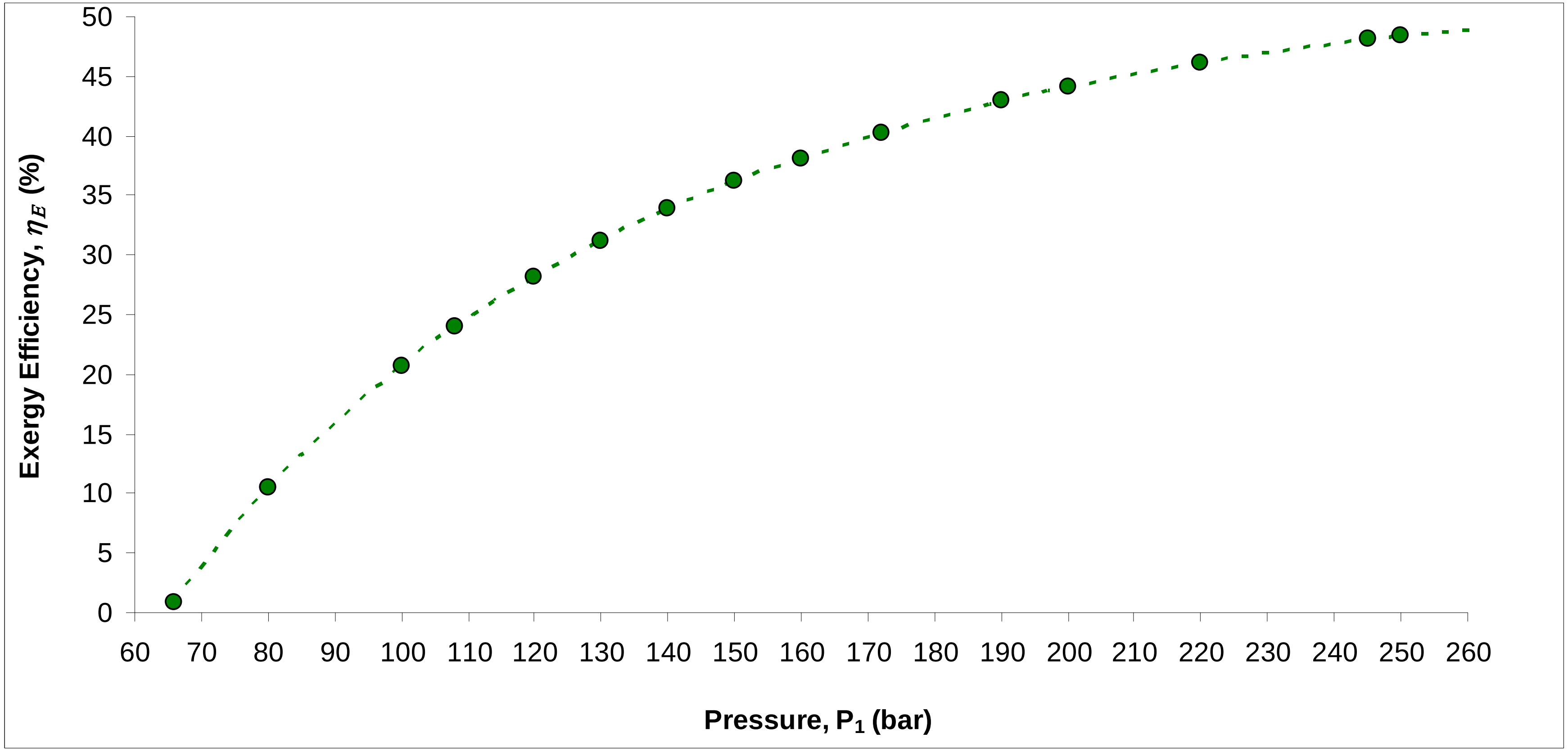
Work produced and consumed by the turbine and the pump, respectively vs Pressure P_1 with an inlet temperature to the turbine at 150 ºC.

Results and discussion

EXERGY ANALYSIS

- Exergy.

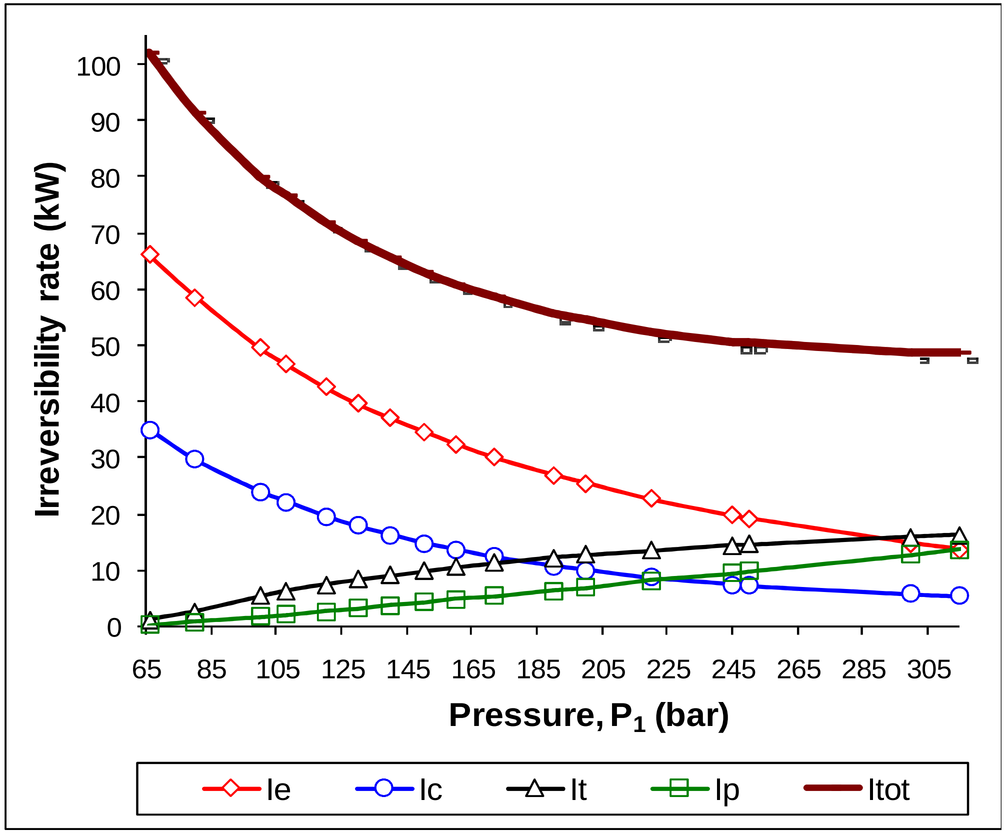


Exergy efficiency vs Pressure P_1 with an inlet temperature to the turbine at 150 ºC.

Results and discussion

EXERGY ANALYSIS

- Irreversibilities of the process in each device.



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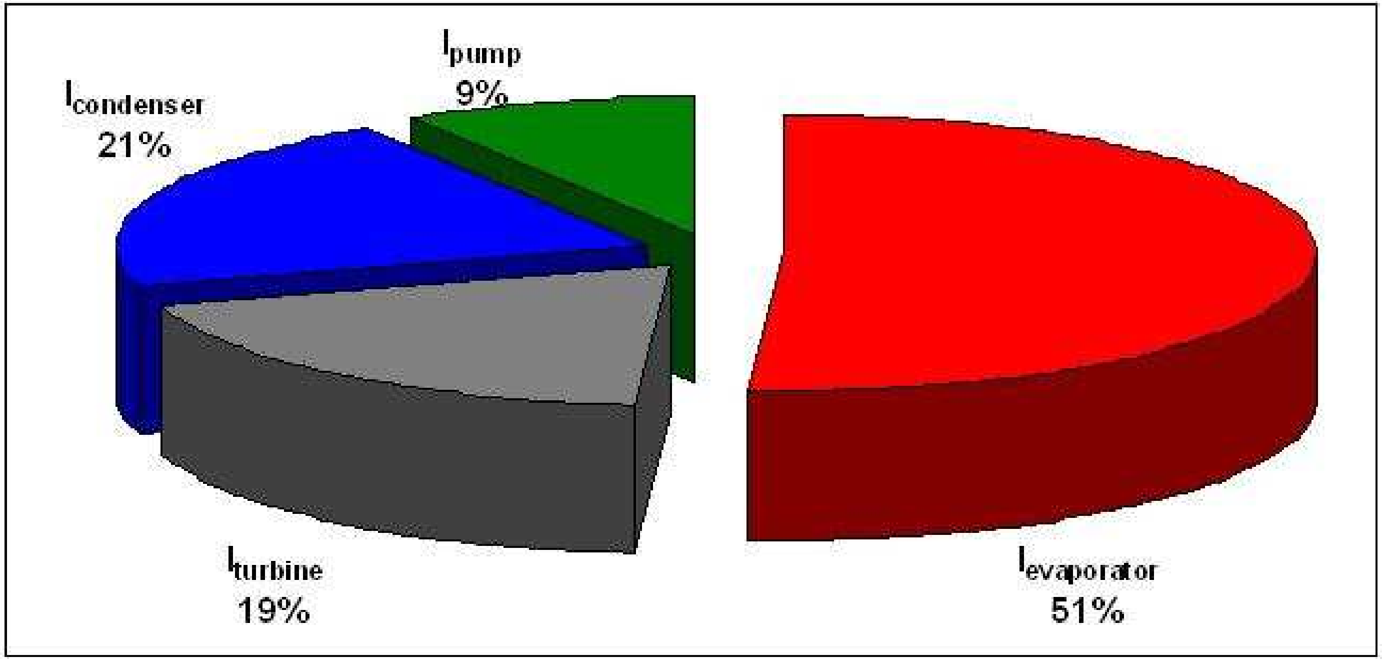
- **Effect of the inlet pressure to the turbine over the irreversibilities of the process with an inlet temperature to the turbine at 150 ºC.**

Results and discussion

EXERGY ANALYSIS

- Irreversibilities of the process in each device at optimum conditions.



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Irreversibilities of the process in optimum conditions with an inlet temperature to the turbine at 150 ºC.

Conclusions

Optimum conditions of design at T_1=150ºC.

Parameter			
Pressure (bar)	η (%)	η_E (%)	*wne* (kJ/kg)
172.0	8.0	40	17.5

- ✓ **CDTPC is suitable for the production of useful energy utilising low enthalpy heat.**
- ✓ **It is possible to operate with a CDTPC in relatively low temperature ranges.**
- ✓ **Maximun point in the energy efficiency of the process is found.**

Low temperature heat source for power generation:

Exhaustive analysis of a carbon dioxide transcritical power cycle

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THANK YOU FOR YOU ATTENTION.

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