ADVANTAGES ANALYSIS OF SUPERCRITICAL POWER CO2 CYCLES

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Objectives

•The goal of this study is to analyze critical factors of power cycles with superecritical carbon dioxide

•The short surway of main known advatages is discussed

•The teoretical possibility to built the cycles with high efficiency

•Waste heat (cooling heat) is strongly difeferent at comparison with steam cycle

•Using the supercritical power cycles strongly depend on turbomachineries efficiency

Content

- Today status of power cycles with sCO_2
- Main supposed advatages of these cycles
- Efect of turbomachineries efficiency
- Waste heat
- General effect of flow acceleration
- High efficiency cycle

Today status of power cycles with sCO2

- Just today dont exists experimental or standard device operating with supercritical CO2 at appropriate power (10 MW and more)
- Many cycles calculations was made at different architectures
- Some small experimental devices operated (Sandia, Czech republic etc.)
- Large amount of experiments was made mainly for heat transfer near critical point
- Some projects are at the stage of preparation (power 10 MW and more)
- So it missing the experience similar as is with steam cycle

Supposed advantages

The supposed advantages of the power cycle with supercritical CO_2 are:

- high thermal efficiency of cycles
- lower capital costs (lower dimensions of all turbomachineries, duct etc.)
- optimal thermal input for CO_2 – condensation part of the steam cycle or nuclear reactor heat
- fewer problems with erosion and corrosion – the low-pressure steam part is omitted.

Efect of turbomachineries efficiency

The calculation was made in HeRo EU for optimization the cycles

Efficiency			td	th	pd	ph	
	turbine eff.		50	285,83	7000	20000	
compreso	0,4	0,5	0,6	0,7	0,8	0,9	1
0,4	-67,274	-60,161	-53,048	-45,935	-38,822	-31,709	-24,596
0,5	-40,395	-34,425	-28,455	-22,485	-16,515	-10,545	-4,575
0,6	-26,810	-21,418	-16,026	-10,633	-5,241	0,152	5,544
0,7	-18,613	-13,569	-8,525	-3,481	1,563	6,607	11,650
0,8	-13,128	-8,317	-3,506	1,304	6,115	10,925	15,736
0,9	-9,200	-4,556	0,087	4,731	9,374	14,018	18,661
1	-6,249	-1,731	2,787	7,305	11,823	16,341	20,860

The table shows strong dependence on compressors and turbines efficiency

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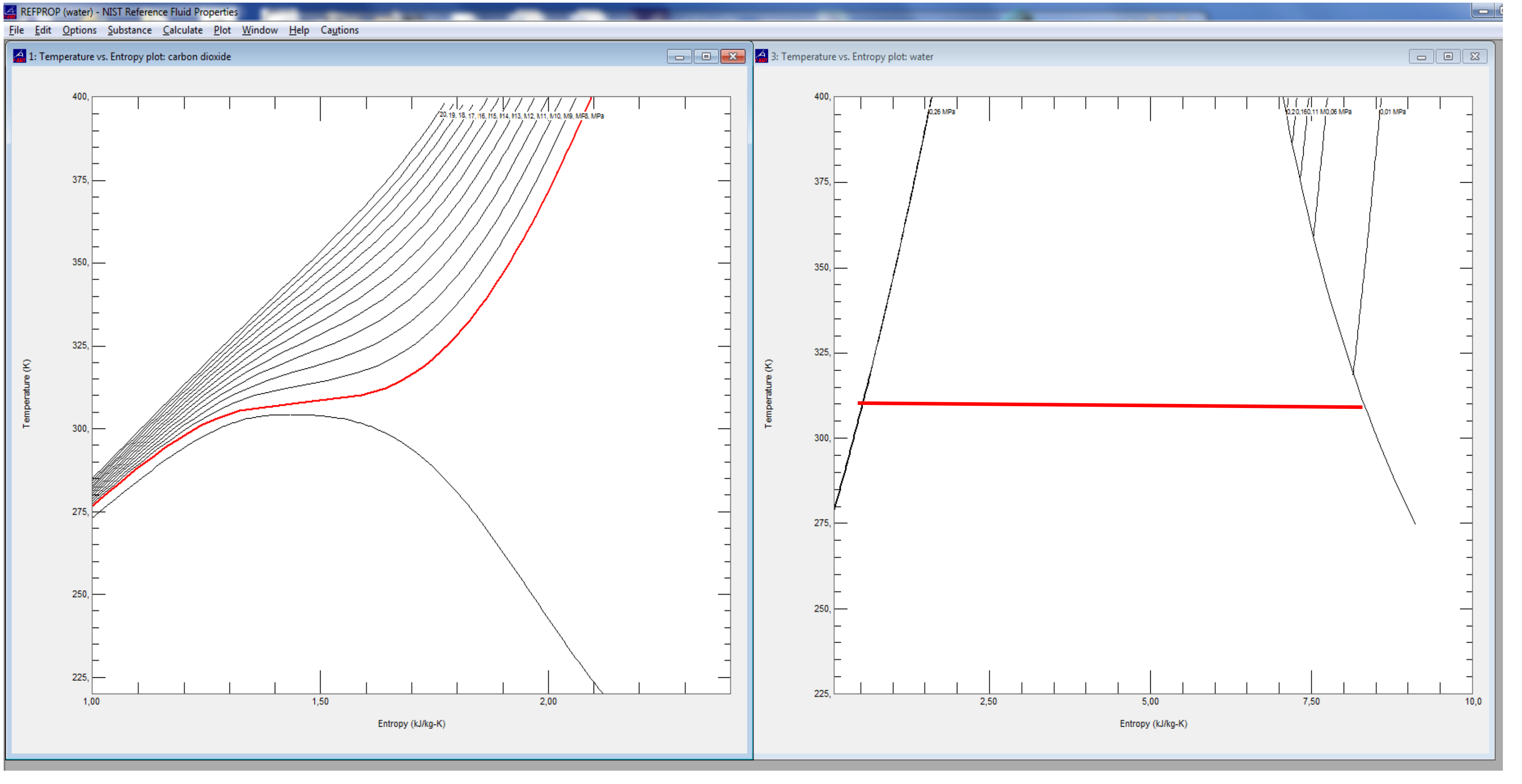
Waste (cooling) heat

The graphs show great difference between cooling curve of steam and supercritical cycle.



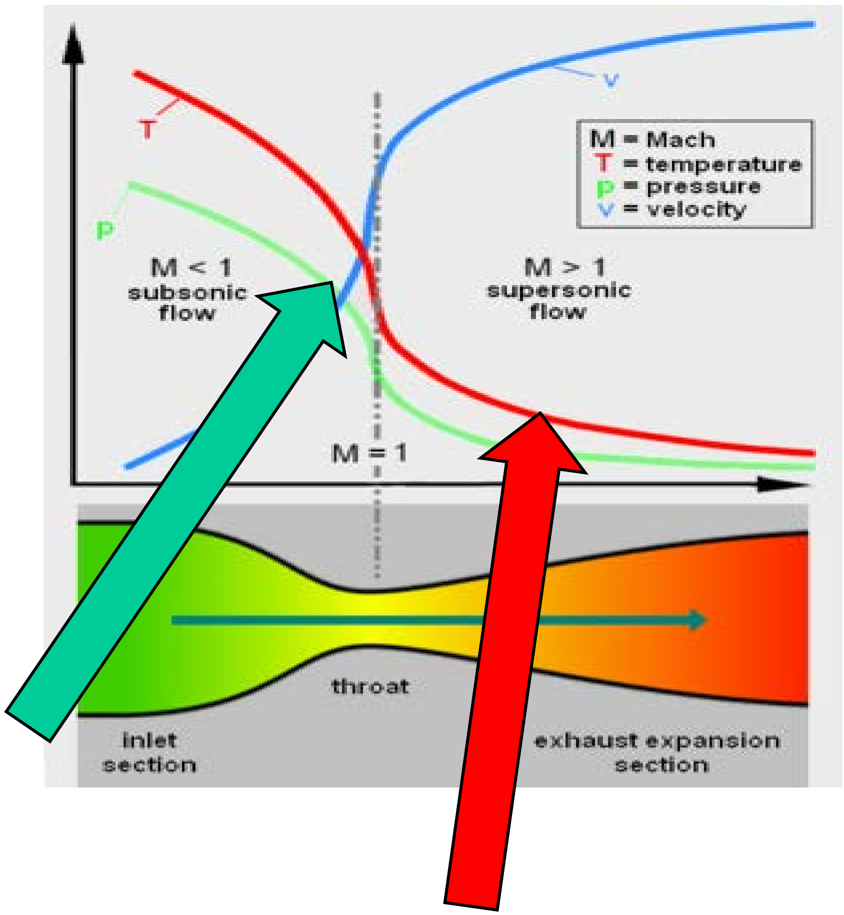
The cooling water, for steam approx. 40°C can go more to 100 °C, more more chance for next utilization.

General effect of flow acceleration

Well known situation – Laval nozzle

Green line – pressure drop

Red line – temperature drop



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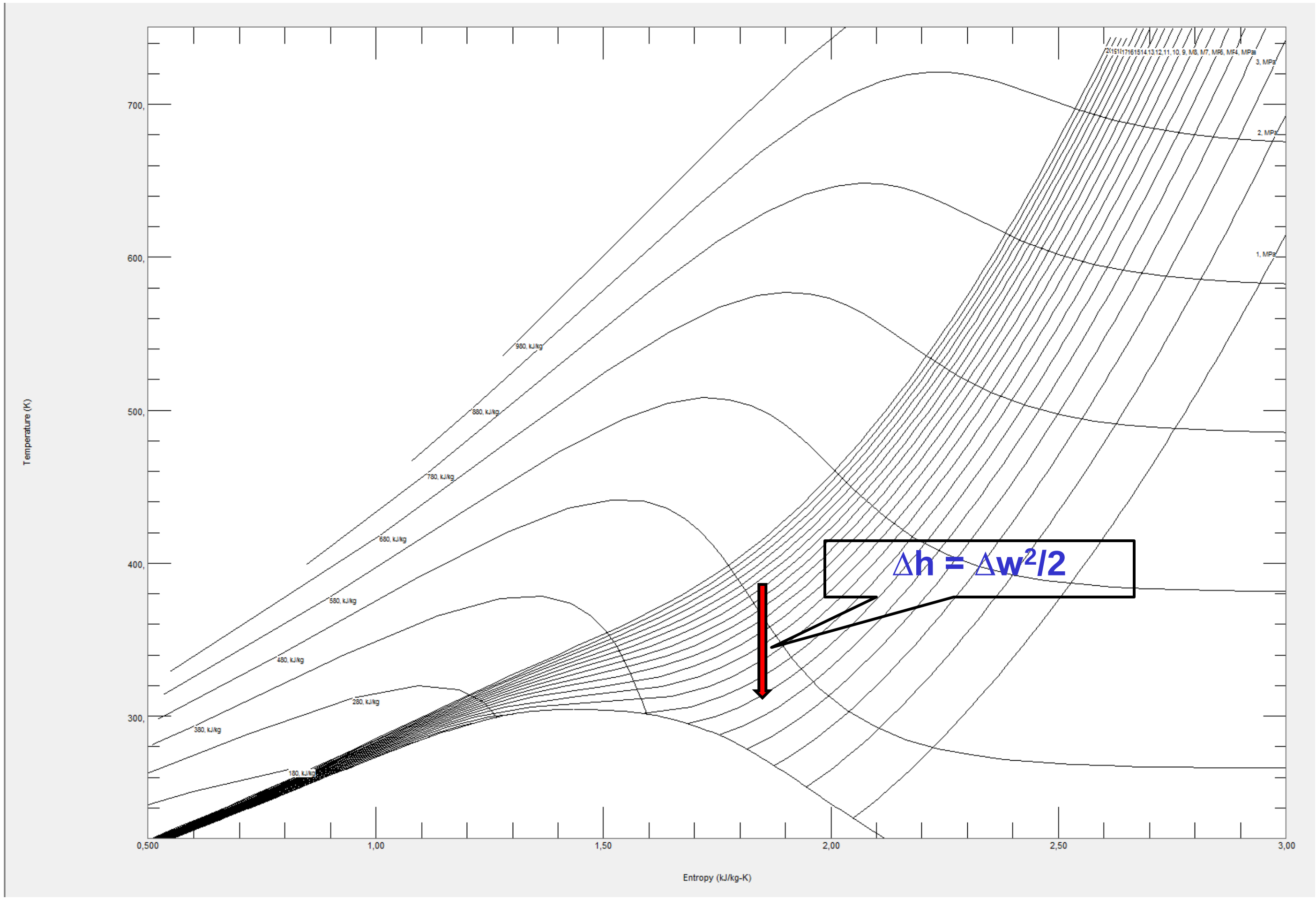
General effect of flow acceleration



The plot shows real pressure and temperature drop of sCO2 (NIST database)

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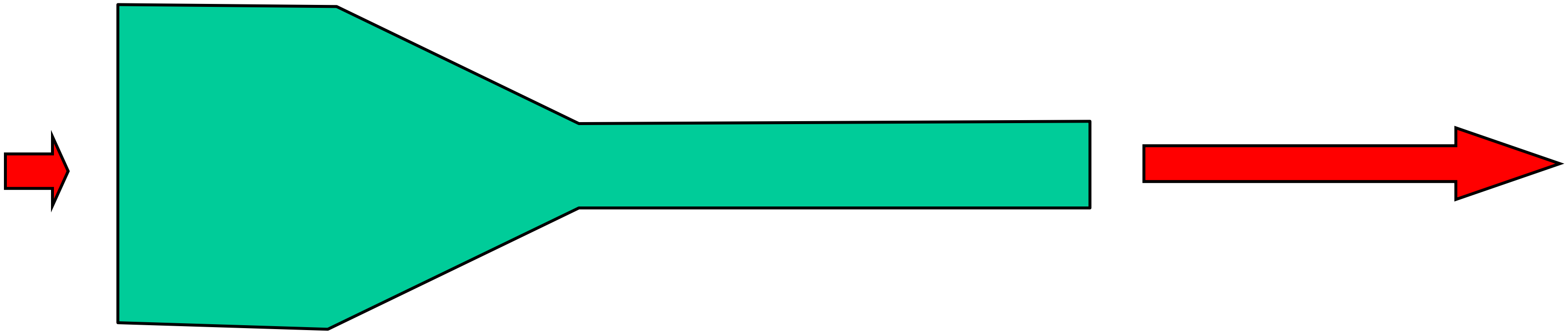
General effect of flow acceleration



Flow acceleration effect

$$\Delta h = \Delta w^2/2$$

Straightforward interpretation of this equation is that a part of thermal energy is changed into kinetic energy.

Kinetic energy is reversible!

This process is connected with **pressure and temperature drop.**

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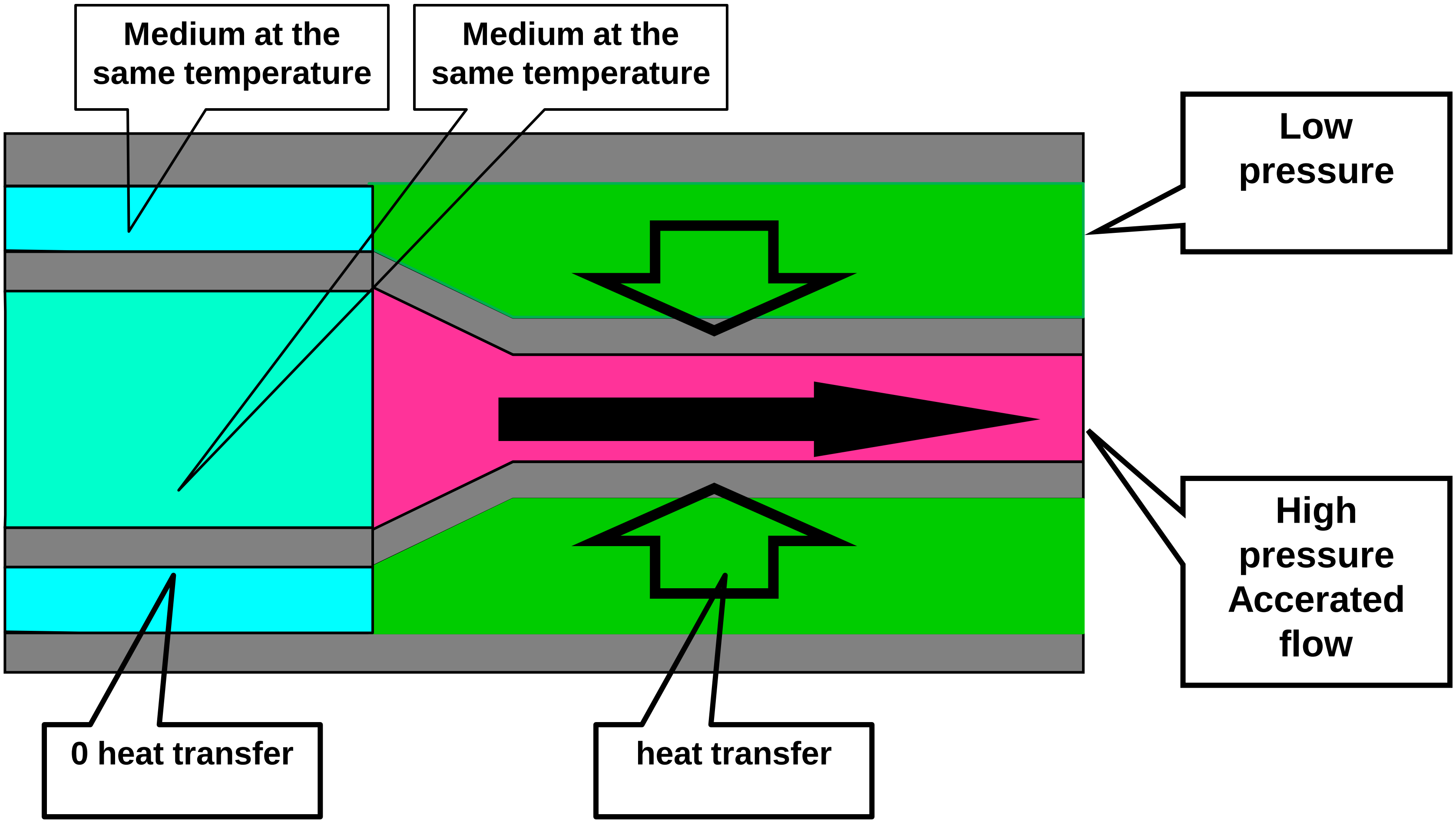
General effect of flow acceleration -the nozzle



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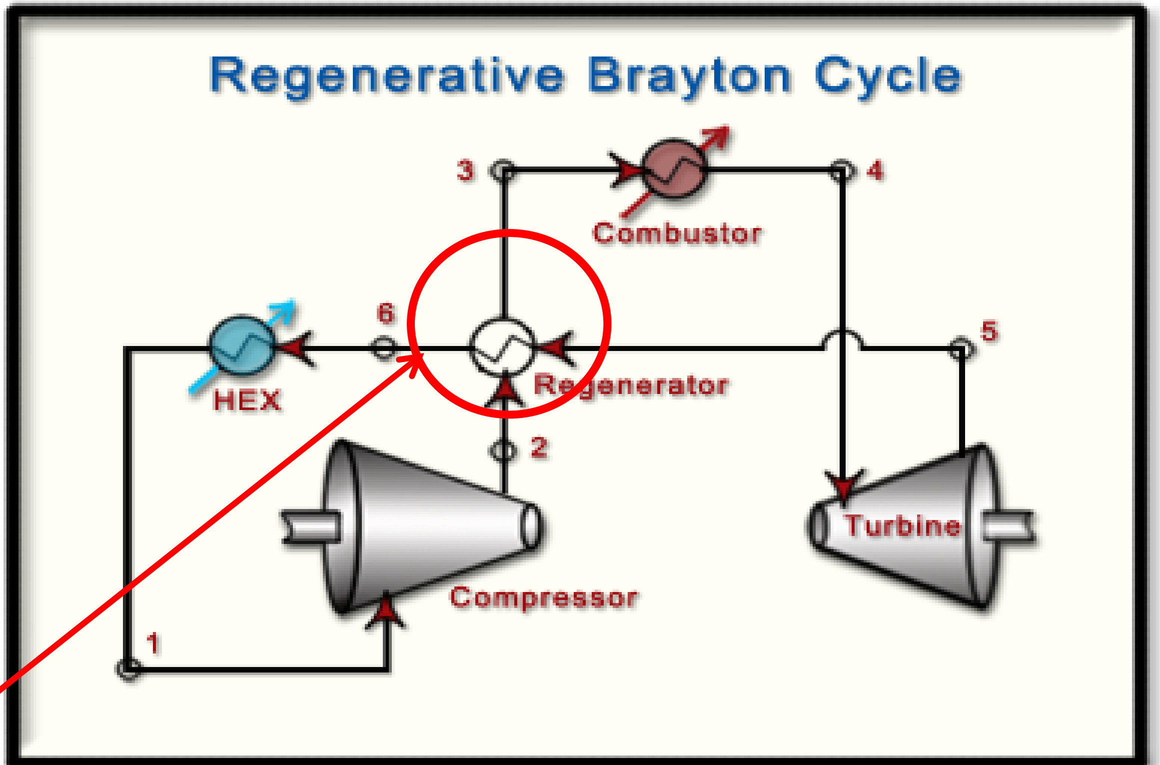
Brayton cycle with regeneration



Only regenerator will be changed, the rest of the cycle is the same

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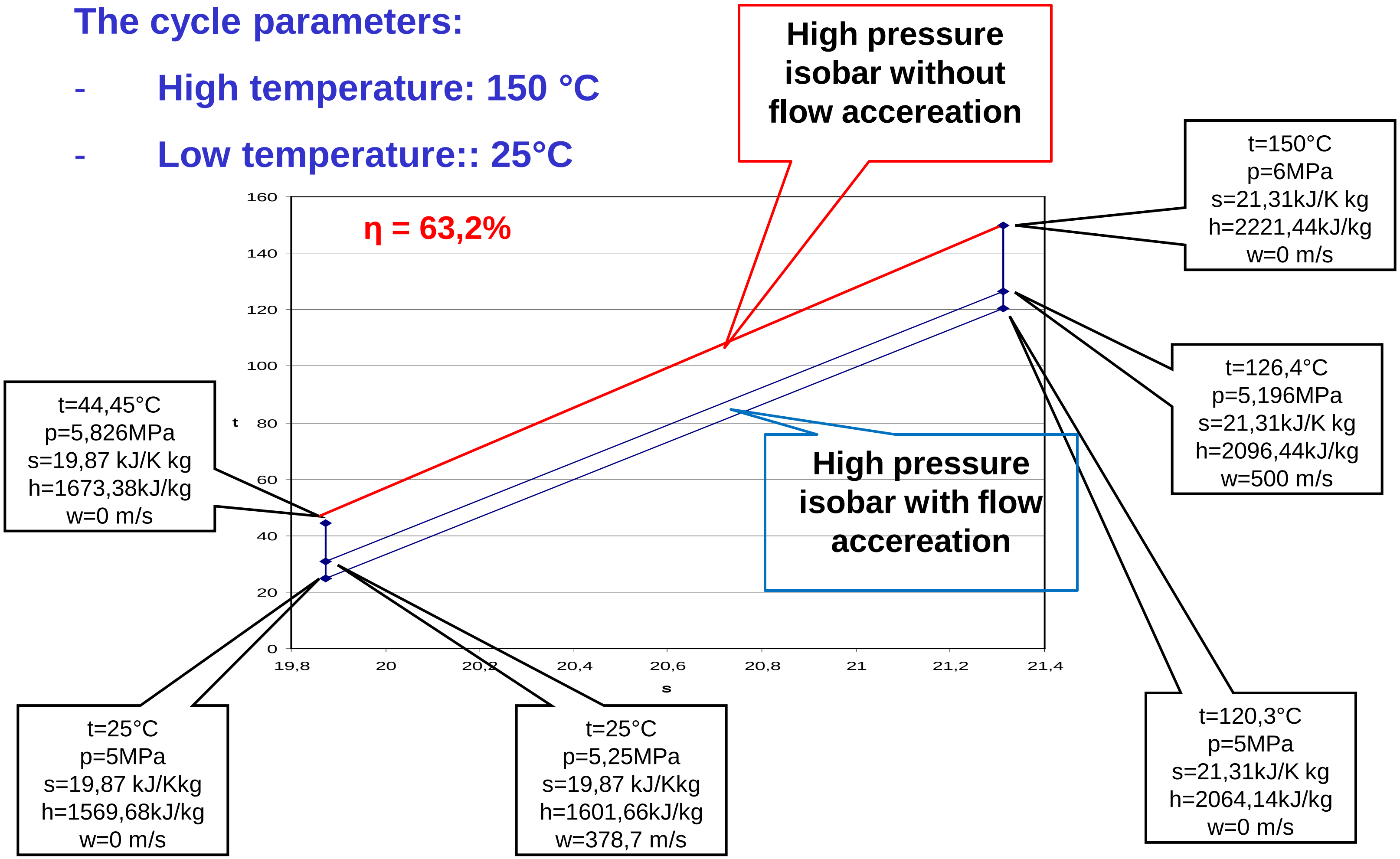
Regenerative Brayton cycle with flow acceleration

The cycle parameters:

- High temperature: 150 °C
- Low temperature:: 25°C



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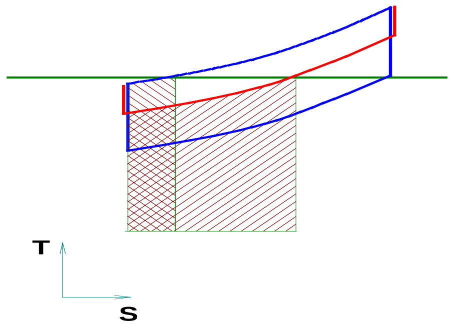
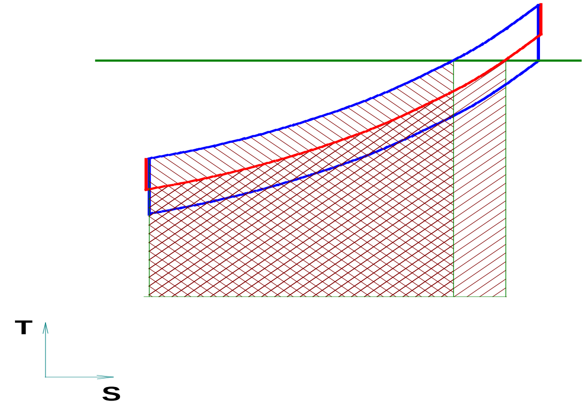
Regenerative Brayton cycle with flow acceleration
High Temperature Effect





High temperature of the cycle

≅ 100°C

heat transfer elevation ≅ 350%

High temperature of the cycle

≅ 180°C

heat transfer elevation ≅ 11%

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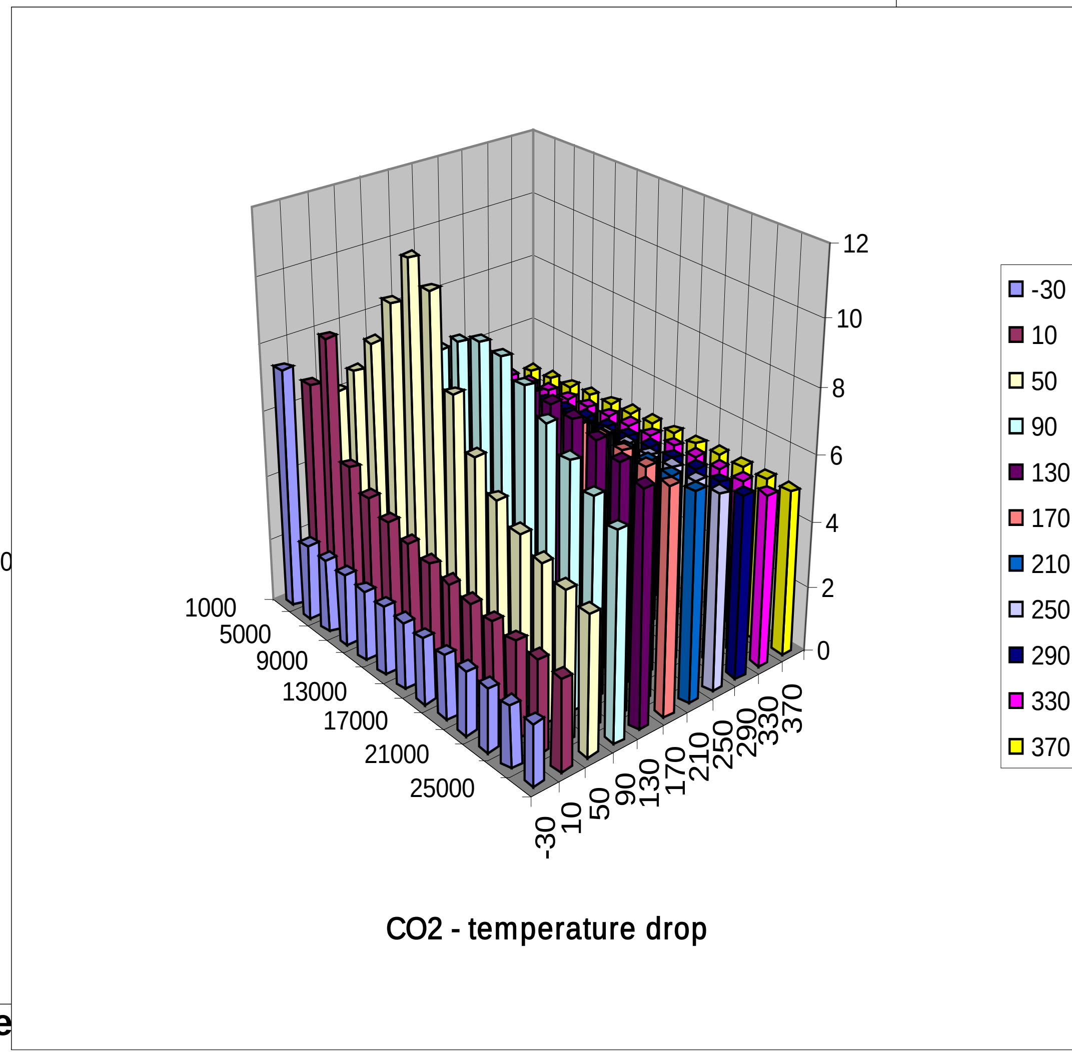
Media

It is neces... flow acceleratio...

- In nearly id...
- In water – t... ;
- In CO_2, coola...

10



Calculated temperature

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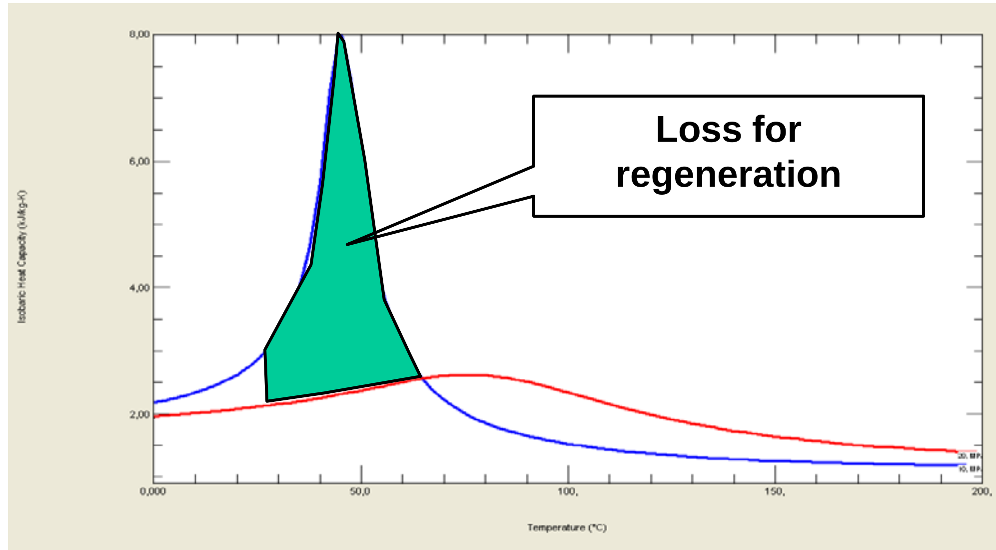
CO2 cycles losses

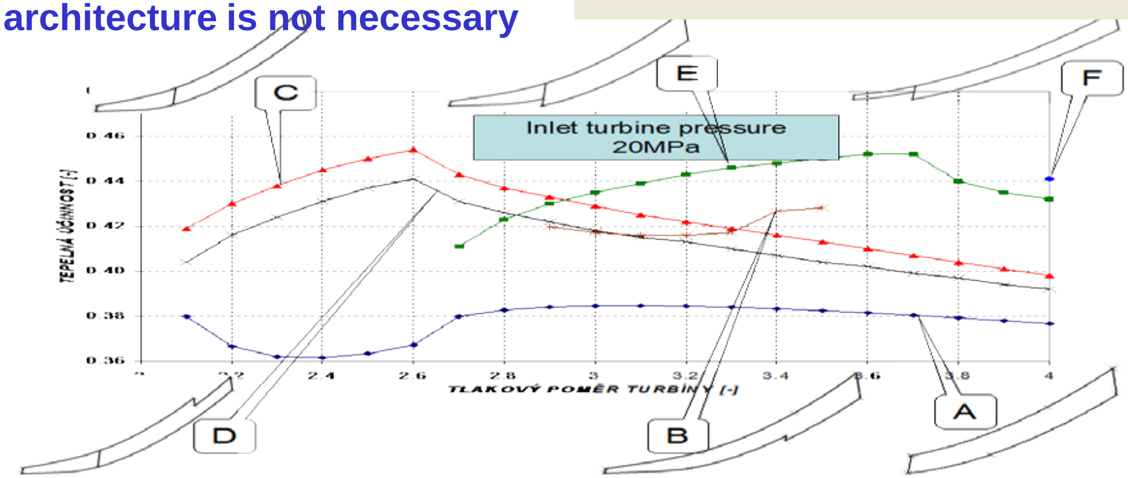
The principle:

Loss of low temperature heat, at low pressure isobar

From these reason is necessary to change the architecture of the cycles

Flow acceleration transfer the curve of high pressure isobar to low pressure, change of architecture is not necessary





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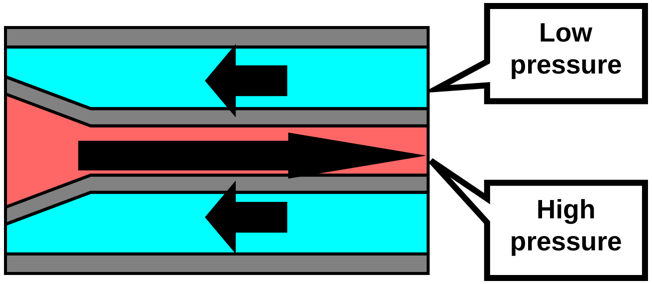
General effect of flow acceleration
Ideal cycles
SUMMARY



- The goal – to find a theoretical cycle with higher efficiency, using some parts with high flow rate – was accomplished.
- Brayton cycle with flow acceleration is near to technical realization than Carnot cycle
- For nearly ideal gases, the real temperature drop is small, so it cannot be exploited.
- Calculated flow rates are very high , special solutions are necessary

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Conclusions

- **The effect of turbomachineries efficiency if important, more that at steam cycle**
- **Cooling heat of supercritical cycle is more useful, mainly for comercial heating**
- **The Carnot cycle has the maximum efficiency but only at quasistatic processes**
- **For ideal medias can be suggested cycle with higher efficiency, the main factor is dynamic processes using flow acceleration**

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