Supercritical CO2 Brayton Cycles: How Pressure Ratio and Turbine Inlet Temperature Drive Performance

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https://infinityturbine.com/supercritical-co2-brayton-cycle-pressure-ratio-and-tit-by-infinity-turbine.html

A deep dive into pressure ratio in supercritical CO2 Brayton cycles. Explains how turbine inlet temperature, compressor conditions, recuperation, and real gas effects set the optimal pressure ratio. Includes a simple text chart of recommended pressure ratio ranges from 40 to 700 deg C.

This webpage QR code

PDF Version of the webpage (maximum 10 pages)

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Introduction

Supercritical CO2 (sCO2) Brayton cycles achieve high power density and efficiency by compressing, heating, expanding, and cooling CO2 while it remains above the critical point. Two levers dominate performance:

1. Pressure ratio across the compressor and turbine.
2. Turbine inlet temperature, often abbreviated TIT.

Unlike ideal gas Brayton cycles, sCO2 behavior near the critical region is strongly non ideal. That means the best pressure ratio is usually moderate and depends on recuperator effectiveness, pressure losses, and the chosen hot and cold end temperatures.

What is pressure ratio

Pressure ratio is the ratio of high side pressure to low side pressure in the loop. In a simple sense, it sets how much the turbine can expand the working fluid and how much the compressor must raise the pressure. In ideal gas Brayton analysis, higher pressure ratio increases thermal efficiency until compressor work and temperature approach limits. In sCO2, the optimum is typically at a moderate ratio because

compressor work rises quickly at high ratio, and
recuperator effectiveness and pinch degrade as ratio grows, reducing internal heat recovery.

Result: most practical recuperated and recompression sCO2 cycles run with an overall pressure ratio of roughly 2 to 4, often near 3 for many designs.

How turbine inlet temperature changes the best pressure ratio

Higher TIT increases turbine specific work. For a given low side temperature and recuperation, you can push to a somewhat higher pressure ratio before compressor work and recuperator pinch overwhelm the gains.
Lower TIT reduces expansion enthalpy drop, so the pressure ratio that maximizes net work shifts downward.

In short, as TIT increases, the preferred pressure ratio moves gently upward, but still remains in a moderate band for most real plants.

The compressor matters as much as the turbine

The compressor sets the low side penalty that the turbine must overcome. Three factors dominate:

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TIT (deg C)    Recommended overall press
40              1.6 – 2.0
100             1.8 – 2.3
200             2.0 – 2.6
300             2.2 – 2.8
400             2.4 – 3.0
500             2.6 – 3.3
600             2.8 – 3.5
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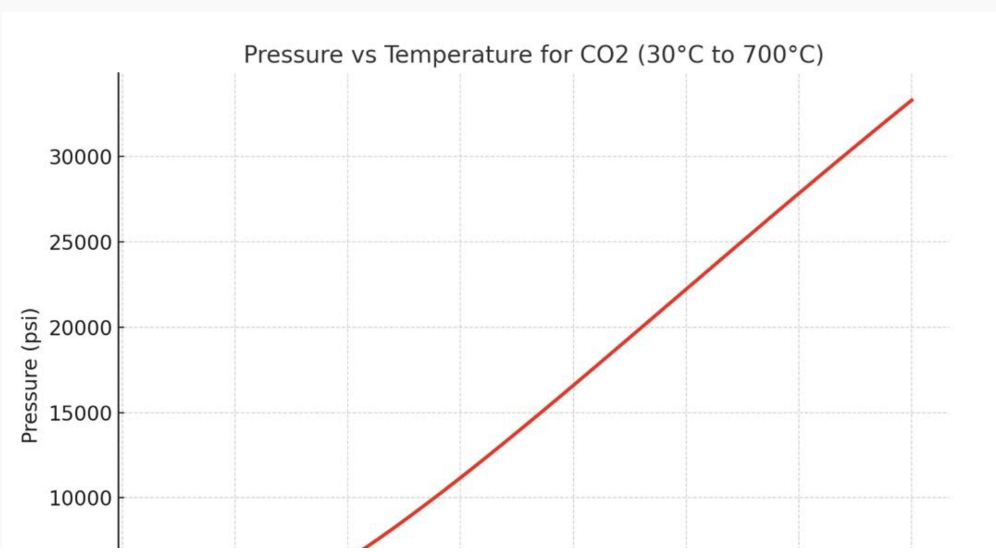
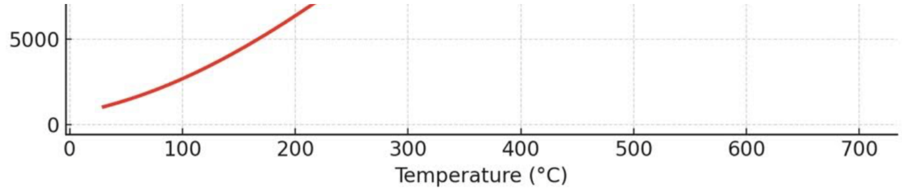
700	3.0 – 3.8


Pressure vs Temperature for CO2 (30°C to 700°C)
Pressure (psi)
30000
25000
20000
15000
10000


5000
0
0
100
200
300
400
500
600
700
Temperature (°C)