

# Helium Operators Familiarization Program

## Basic Thermodynamic Cycles

Dec 2012 | Vincent HELOIN

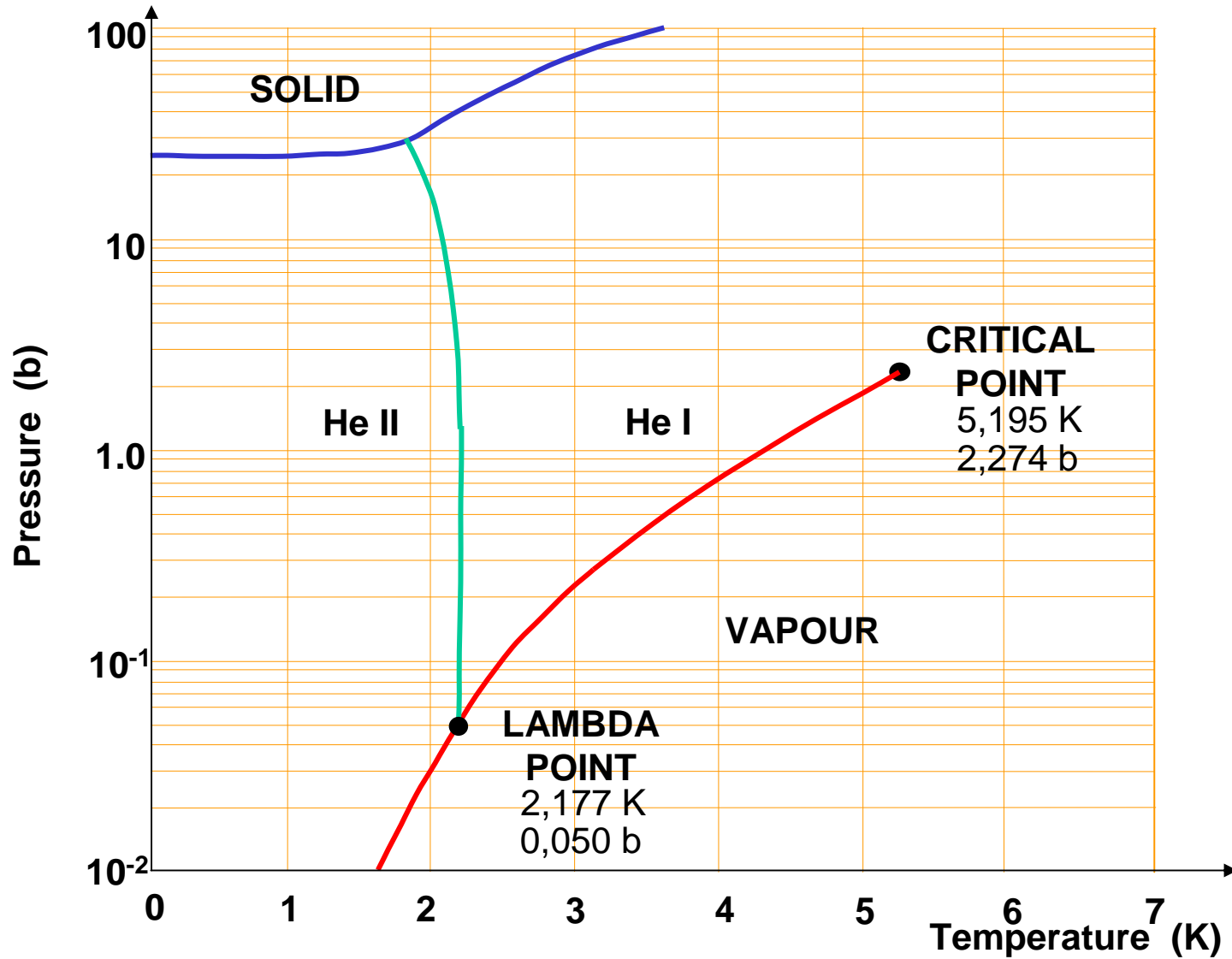


# Fluid properties

	Helium	Nitrogen	Methane	Water
<b>Molar Mass</b>	4,00 g/mol	28,01 g/mol	16,04 g/mol	18,02 g/mol
<b>Boiling Point (1 atm)</b>	4,2K (-269°C)	77,4K (-196°C)	111,6K (-162°C)	373,2K (1 00°C)
<b>Liquid density ( 1 atm)</b>	127 g/L	809 g/L	423 g/L	958 g/L
<b>Saturated vapour density ( 1 atm)</b>	15,9 g/L	4,6 g/L	1,8 g/L	0,6 g/L
<b>Rho Liq / Rho Gas@ sat</b>	8	176	233	1605
<b>Gas density ( 1 atm, 300K)</b>	0,16 g/L	1,14 g/L	0,65 g/L	-
<b>Rho Liq / Rho Gas@300K</b>	784	711	648	-
<b>Triple Point</b>	-	63K (-210°C) 0,12b (1,81Psi)	91K (-182°C) 0,12b (1,7Psi)	273K (0°C) 0,01b (0,09Psi)
<b>Critical Point</b>	5K (-268°C) 2,3b (33Psi)	126K (-147°C) 34b (493Psi)	191K (-83°C) 46b (667Psi)	647K (374°C) 221b (3200Psi)
<b>Heat of vaporization</b>	<b>21 J/g</b>	<b>199 J/g</b>	<b>510 J/g</b>	<b>2 257 J/g</b>
<b>Sensible Heat (from BP to 300K)</b>	1 542 J/g	234 J/g	403 J/g	-2 563 J/g
<b>Cp (1,013b ;300K)</b>	5,2 J/g	1,0 J/g	2,2 J/g	4,18 J/g
<b>In case we applied 1 W on a liquid we get :</b>				
<b>Mass vaporized</b>	0,05 g/s	0,01 g/s	0,00 g/s	-
<b>Liquid vaporized</b>	1,36 L/h	0,02 L/h	0,02 L/h	-
<b>Volume of gas generated</b>	1 069,23 L/h	15,93 L/h	10,81 L/h	-
<b>Equivalence of 1g/s</b>				
<b>In Normal Condition : 1b &amp; 273,15 K</b>	20,4 Nm3/h	2,9 Nm3/h	5,1 Nm3/h	-
<b>In Liquid Condition</b>	28,3 L/h	4,4 L/h	8,5 L/h	3,8 L/h

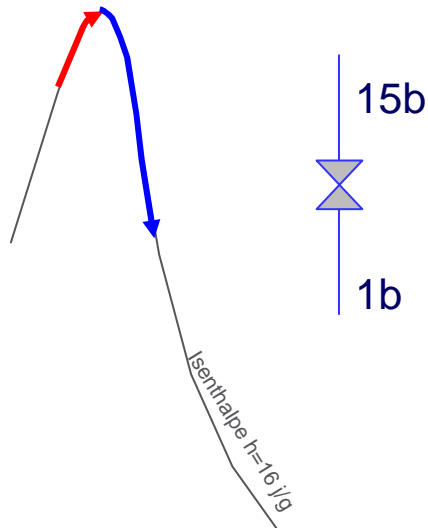
NB : 1 Bar = 14,5 Psi ; 1 Psi = 0,069 bar

# Helium Phase Diagram



# TS Diagram & JT expansion

Isoenthalpic expansion through the valve



At the beginning helium warms up during expansion.

Saturated vapour



Critical point

$T=5.19\text{K}$

$P=2.27\text{ bar}$

Liquid phase

# Inversion Temperature

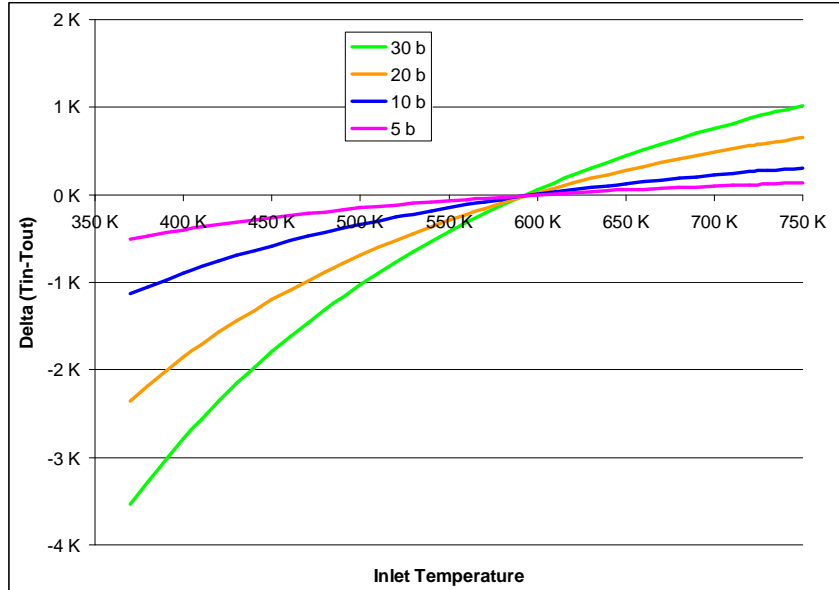
Most of the time a free expansion of a gas through produce cold.

Actually, this is true, when the inlet temperature is below the “inversion point”.

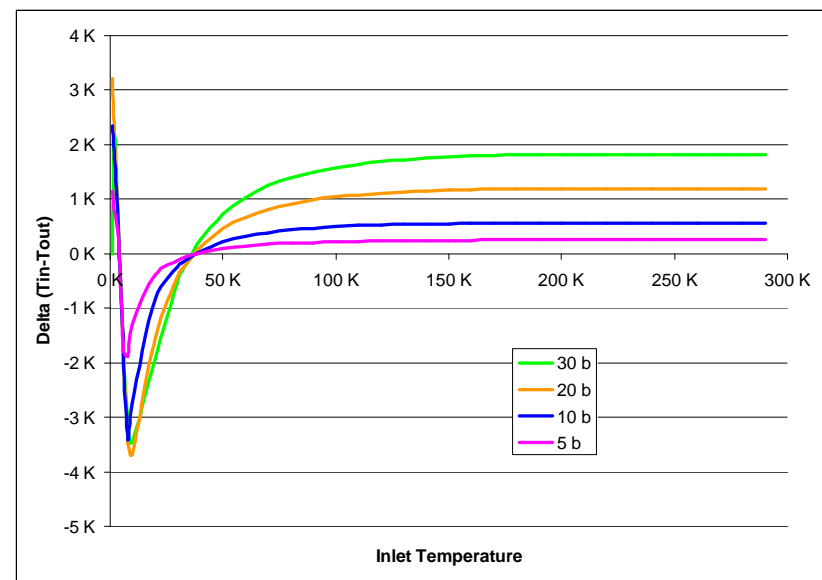
Inversion Temperature of

- Nitrogen 600K (330 °C)
- Helium ~40K (~-230°C)

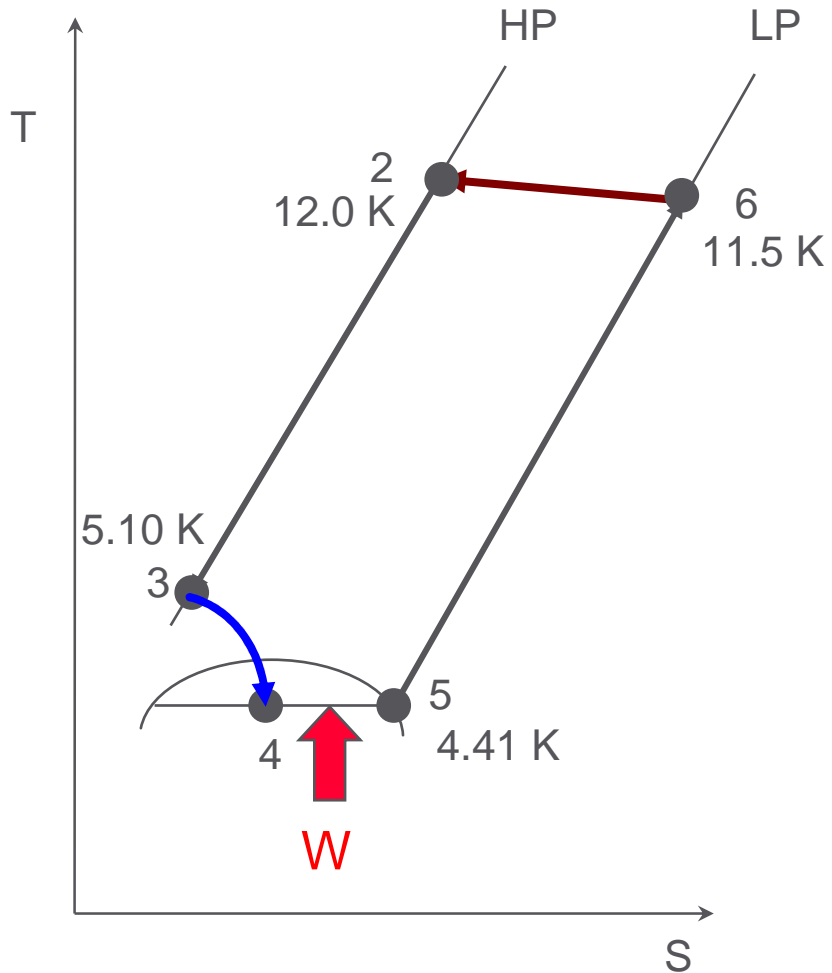
Expansion of **Nitrogen** @ different pressures from 300K to 1b



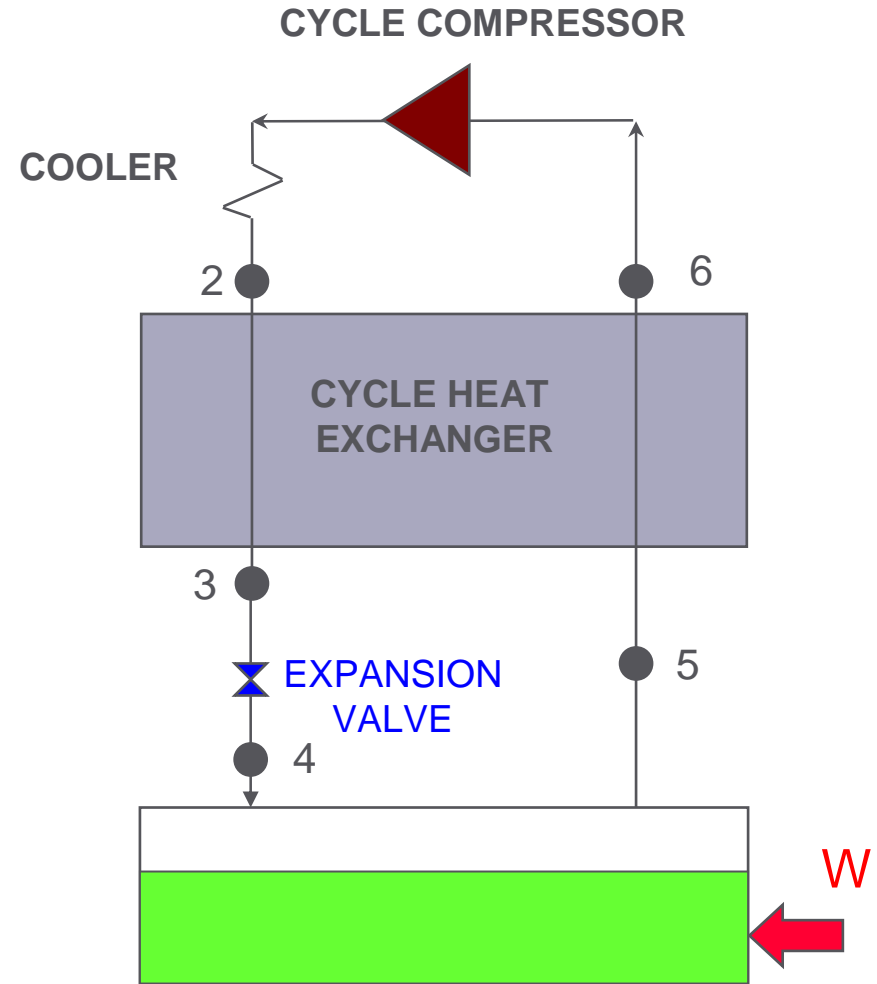
Expansion of **helium** @ different pressures from 300K to 1b



# The Joule Thomson Cycle

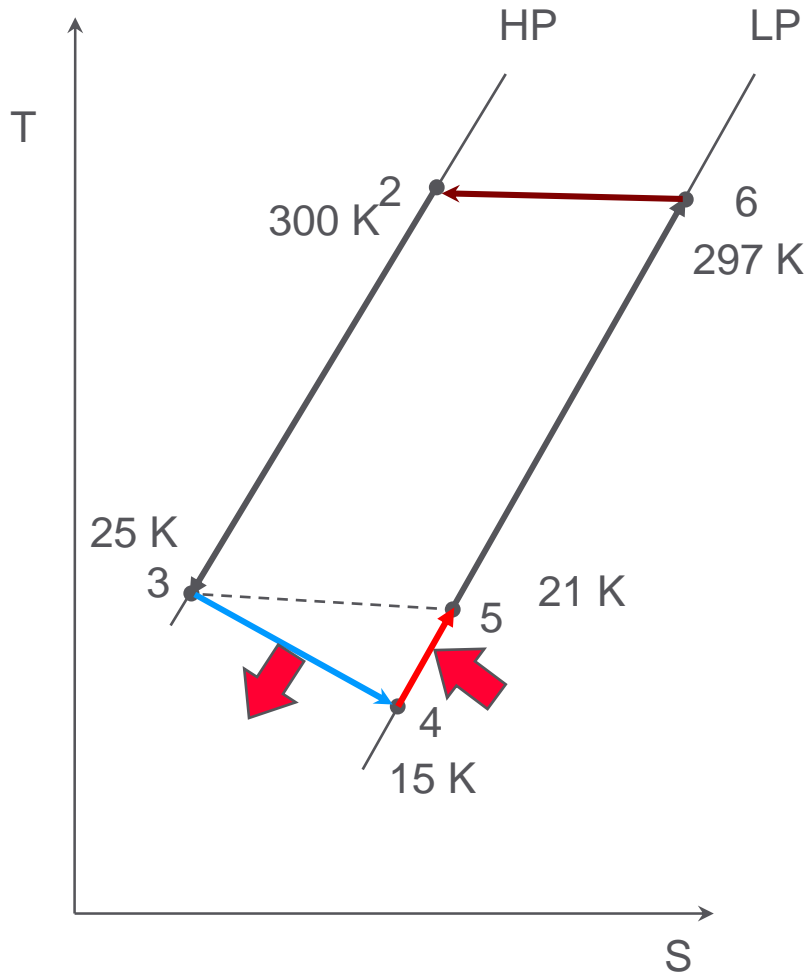


TEMPERATURE/ENTROPY DIAGRAM

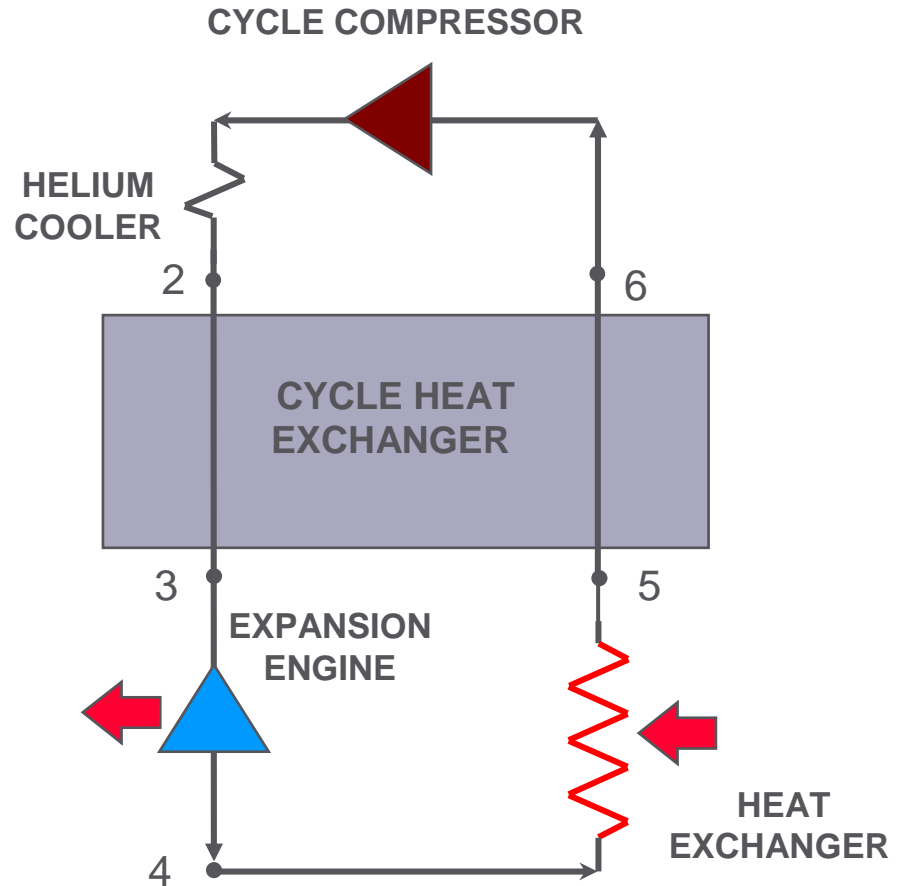


FLOW DIAGRAM

# The Brayton Cycle

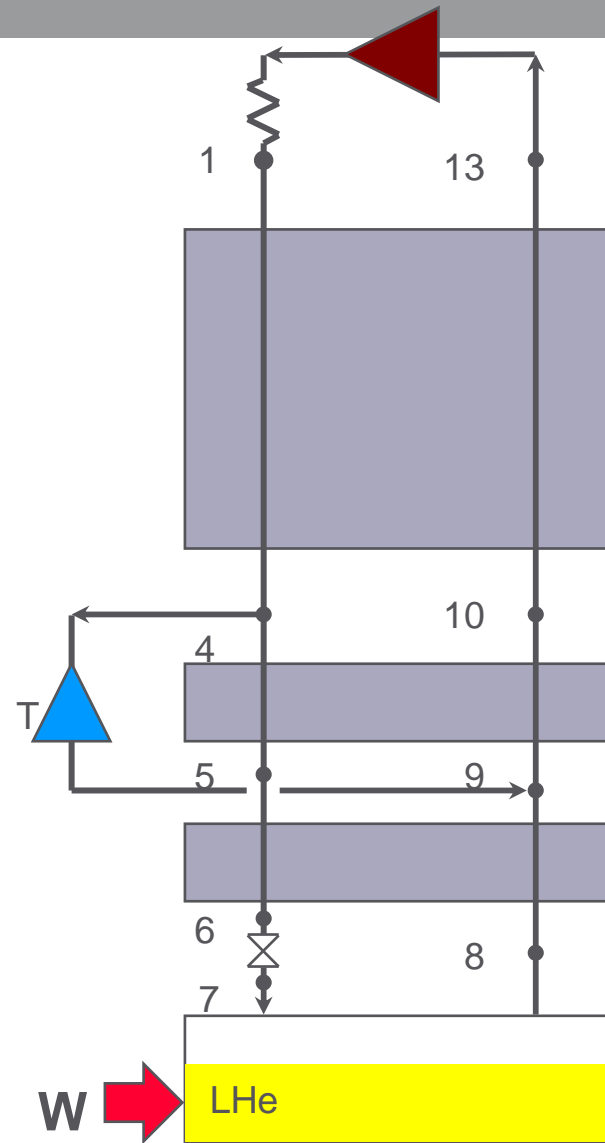
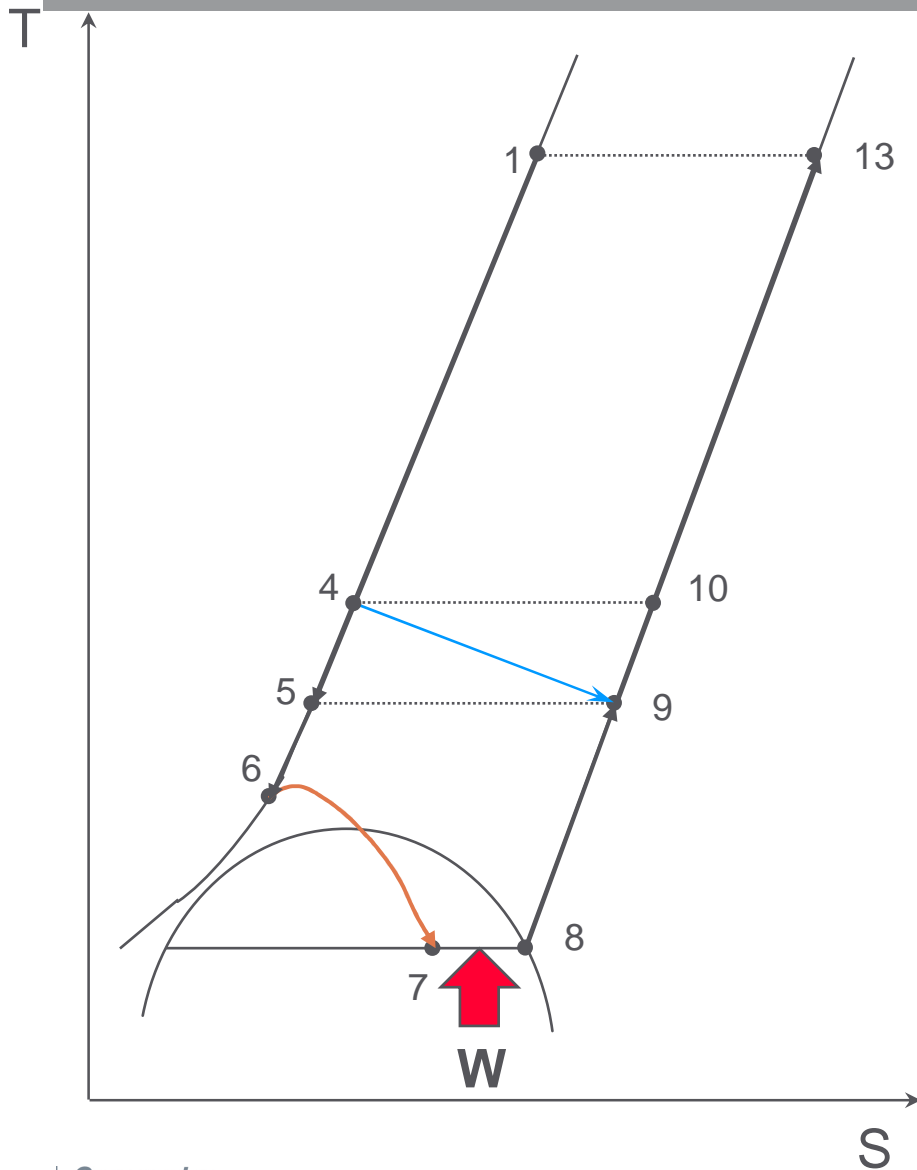


TEMPERATURE/ENTROPY DIAGRAM

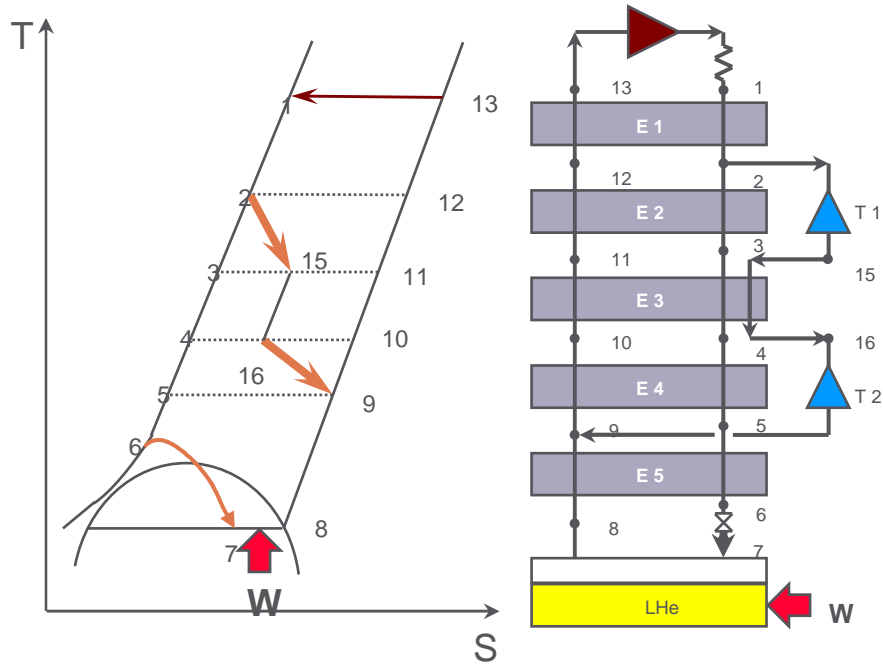


FLOW DIAGRAM

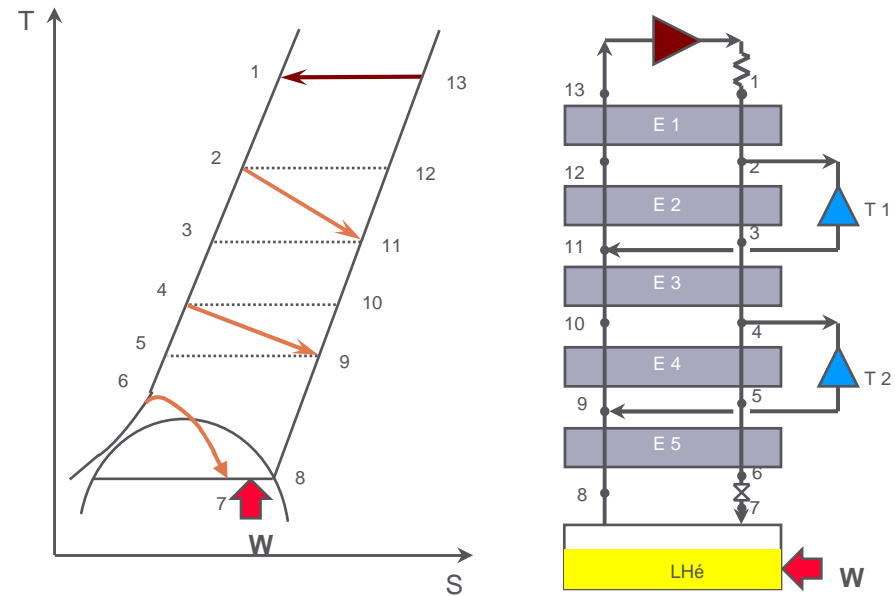
# The Claude Cycle



# Arrangement of typical small Liquefiers



Turbines in series



Turbines in parallel