Claude cycle for Nitrogen Liquefaction

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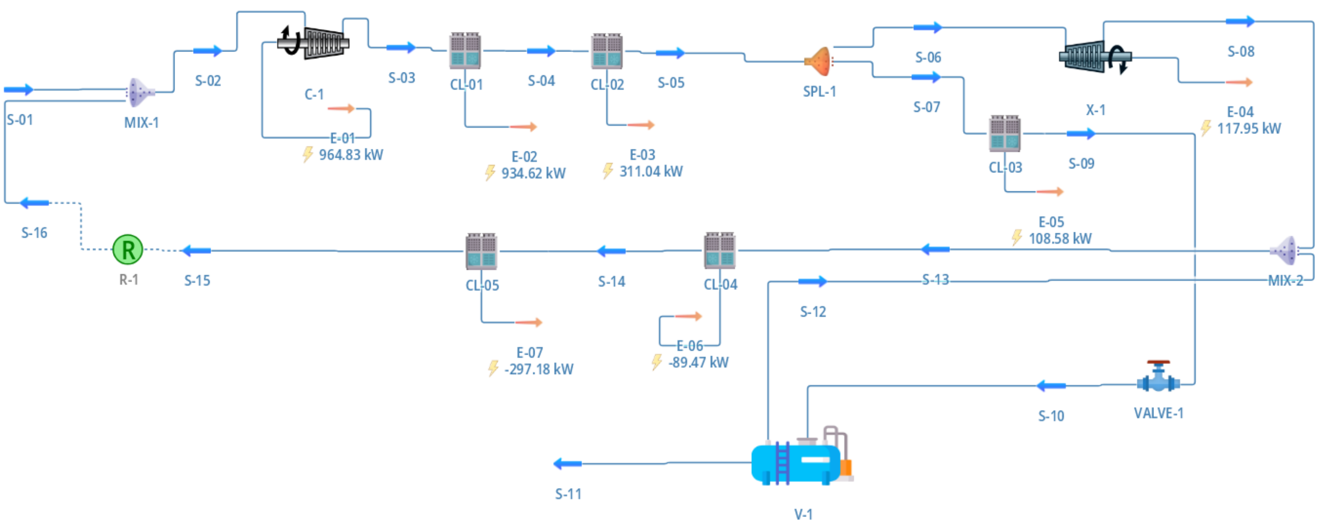
Background & Description:

Claude introduced a novel cycle featuring a turbine and an expansion valve, characterized by the use of a single fluid compressed at a single pressure level within the system, as depicted in the accompanying figure. This cycle, known as the Claude cycle, has been widely applied in air liquefaction plants. One notable advantage of this cycle is its ability to achieve significantly lower compression ratios compared to the Linde cycle. However, a challenge arises from the inefficiency of the expansion machinery when the fluid remains in the vapor zone or maintains a high quality.

The innovative aspect of the Claude cycle is its integration of isentropic expansion within the turbine and isenthalpic expansion specifically during the expansion phase leading to gas liquefaction.

The cycle initiates similarly to the Linde cycle: gas compression for liquefaction, followed by cooling to approximately room temperature. Subsequently, the gas traverses a regenerator that facilitates cooling to around -105°C. The gas flow then divides, with around 15% undergoing expansion through a turbine. The main gas flow passes through a second regenerator and is subsequently released at a very low temperature. It then experiences isenthalpic expansion, leading to the extraction of the liquid phase. The vapor is combined with the flow exiting the turbine and serves as a coolant in the second regenerator and subsequently in the first.This vapor is later recycled by mixing with the gas entering the cycle.

Flowsheet:



Claude process

Thermodynamic Package: Cool Prop

Results:

Master Property Table																	
Object	S-01	S-02	S-03	S-04	S-05	S-06	S-07	S-08	S-09	S-10	S-11	S-12	S-13	S-14	S-15	S-16	
Temperature	26.85	9.66919	462.34	30	-105	-105	-105	-195.907	-149.534	-195.907	-195.907	-195.907	-195.907	-158.24	6.89	6.89	C
Pressure	1	1	30	30	30	30	30	1	30	1	1	1	1	1	1	1	bar
Mass Flow	0.27848	2	2	2	2	1.3	0.7	1.3	0.7	0.7	0.27848	0.42152	1.72152	1.72152	1.72152	1.72152	kg/s
Molar Flow	9.94096	71.3944	71.3944	71.3944	71.3944	46.4064	24.988	46.4064	24.988	24.988	9.94094	15.0471	61.4535	61.4535	61.4535	61.4534	mol/s
Volumetric Flow	0.247917	1.67826	0.147327	0.0598211	0.0292101	0.0189865	0.0102235	1.13402	0.00151034	0.397739	0.000345255	0.397394	1.53142	0.579505	1.43034	1.43034	m3/s
Molar Enthalpy (Mixture)	8717.67	8216.49	21730.6	8639.68	4283.06	4283.06	4283.06	1741.34	-62.2492	-62.2492	-3424.55	2159.07	1843.62	3299.48	8135.42	8135.42	kJ/kmol
Molar Entropy (Mixture)	191.77	190.05	190.05	163.265	144.079	144.079	144.079	146.191	111.26	122.841	79.3127	151.599	147.515	163.646	189.762	189.762	kJ/[kmol.K]
Molar Fraction (Vapor)	1	1	1	1	1	1	1	0.925186	0	0.602172	0	1	0.943504	1	1	1	
Phases	V	V	V	V	V	V	V	V+L	L	V+L	L	V	V+L	V	V	V	
Energy Flow	86.662	586.611	1551.45	616.825	305.787	198.761	107.025	80.8092	-1.55549	-1.55549	-34.0433	32.4878	113.297	202.765	499.949	499.949	kW

Master Property Table						
Object	CL-01	CL-02	CL-03	CL-04	CL-05	
Flow Conductance	1	1	1	1	1	[kg/s]/[Pa^0.5]
Volume	1	1	1	1	1	m3
Minimum Pressure	1.01325	1.01325	1.01325	1.01325	1.01325	bar
Initialize using Inlet Stream	-1	-1	-1	-1	-1	
Reset Content	0	0	0	0	0	
Pressure Drop	0	0	0	0	0	Pa
Efficiency	100	100	100	100	100	
Outlet Temperature	30	-105	-149.54	-158.24	6.89	C
Heat Removed	934.621	311.038	108.581	-89.4676	-297.185	kW
Outlet Molar Vapor Fraction	1	1	0	1	1	
Temperature Difference	-432.34	-135	-44.54	37.6665	165.13	K.

Master Property Table		
Object	V-1	
Vessel Orientation	0	
Operating Pressure	0	bar
Liquid Level	0	m
Volume	1	m3
Height	2	m
Minimum Pressure	1.01325	bar
Initialize using Inlet Stream	-1	
Reset Content	0	
Separation Temperature (if overriden)	25	C
Separation Pressure (if overriden)	1.01325	bar

Conclusion:

Finally, we got a 0.27848 kg/s of liquid nitrogen and 0.42152 kg/s of gaseous nitrogen separated in a gas-liquid separator. With final on addition with mixer we got 1.72152 kg/s of gaseous nitrogen for 2 kg/s of feed.