Cryocoolers

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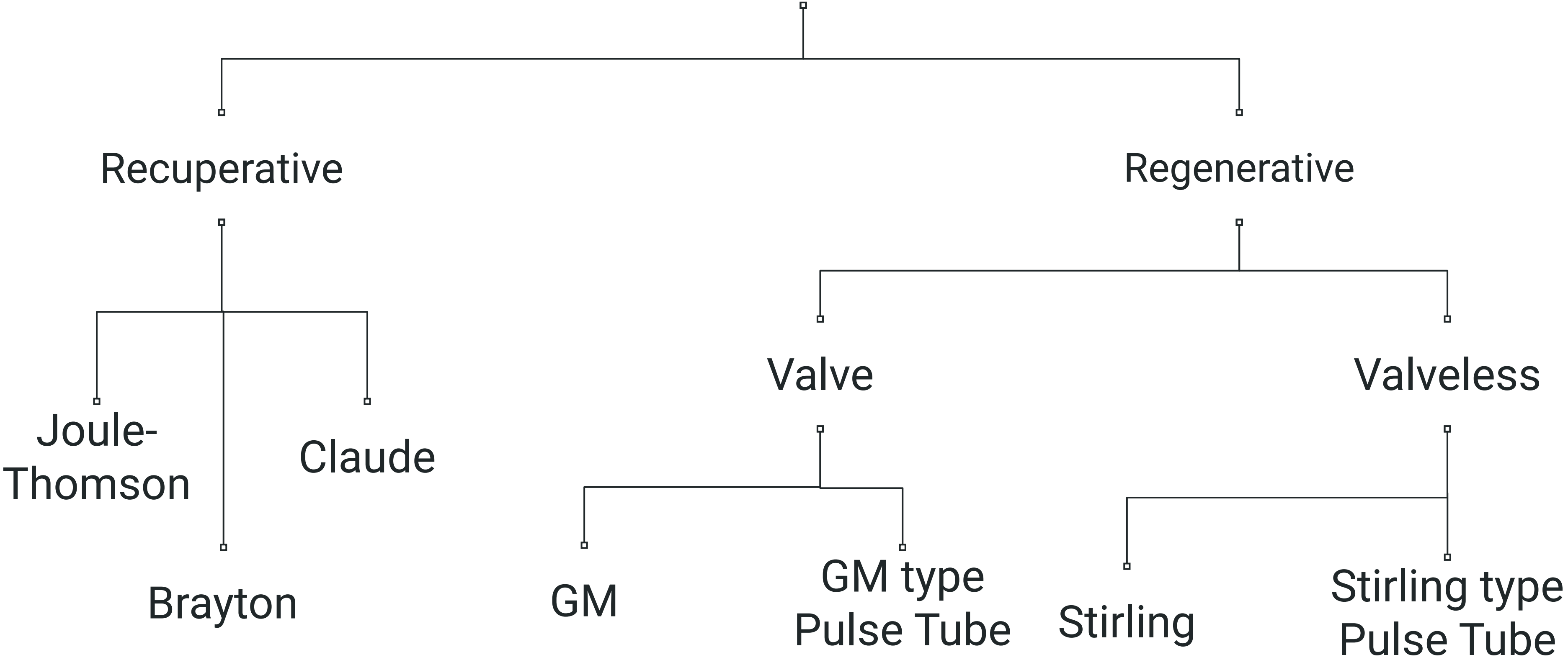
What are Cryocoolers

- Devices which generate low temperature (<123K) due to compression and expansion of fluid
- Components include compressor, heat exchanger, expansion device and evaporator

Need for Cryocoolers

- Can replace the expensive cryogens
- Reliable, maintenance free
- Can be customized for different settings

Dynamic Type Cryocoolers



Dynamic Type Cryocoolers

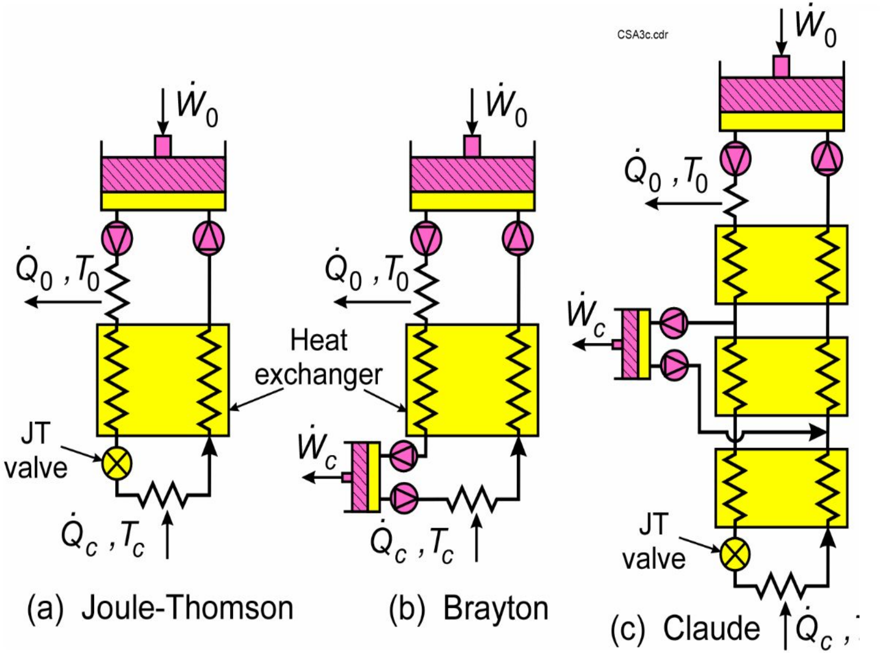


Figure 1. Schematics of the three most common recuperative cycles.

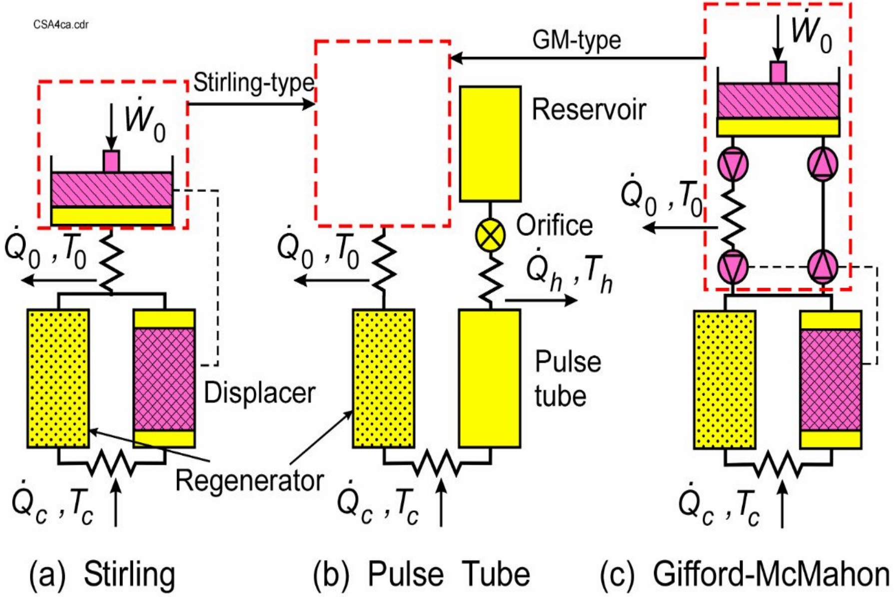


Figure 2. Schematics of the most common regenerative cycles.

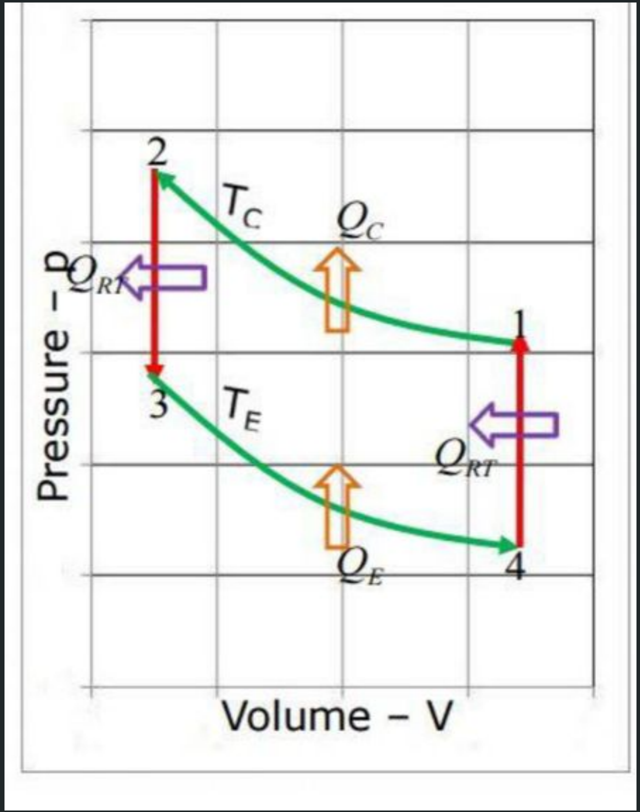
Ideal Stirling Cycle

1-2: Isothermal Compression

2-3: Constant volume heat rejection

3-4: Isothermal Expansion

4-1: Constant volume heat addition



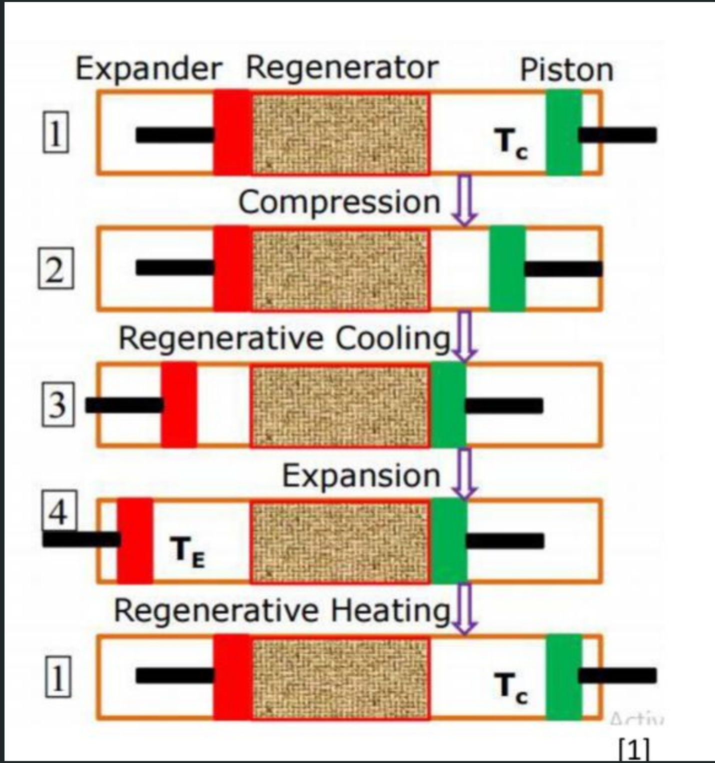
Ideal Stirling Cycle

1-2: Piston moves from BDC, Expander at TDC (compression)

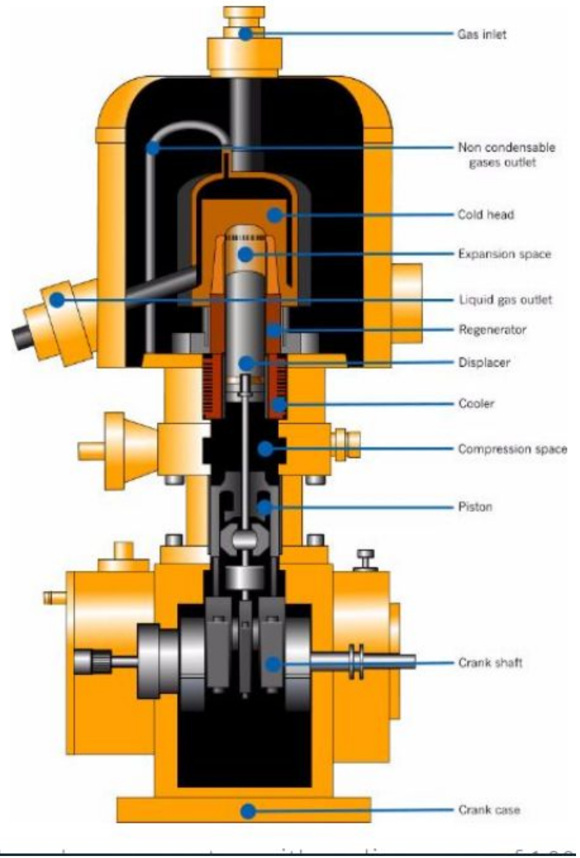
2-3: Piston moves to TDC, Expander moves from TDC (Regenerator matrix absorbs heat)

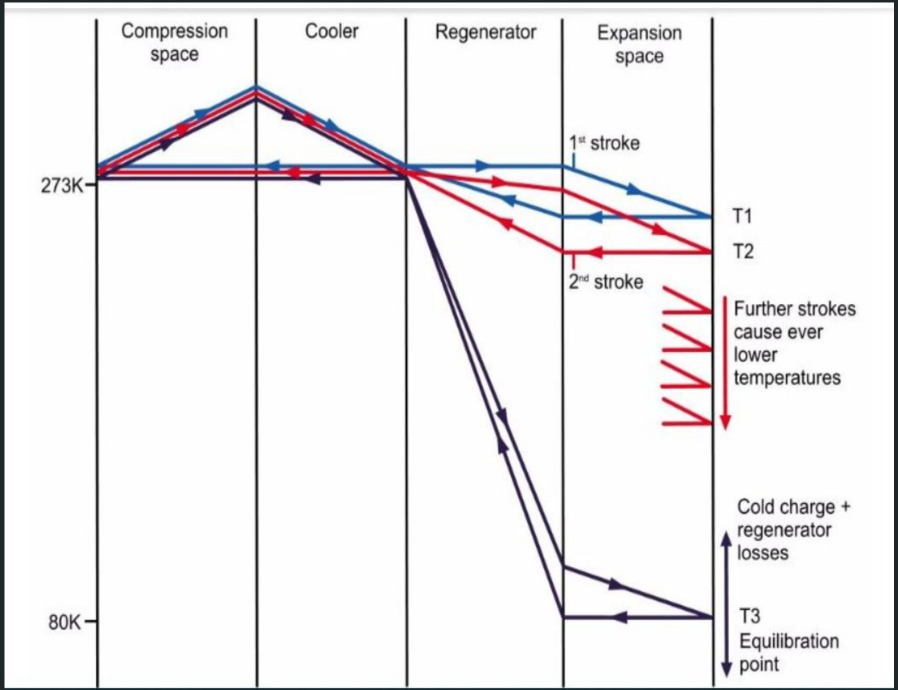
3-4: Piston at TDC, Expander moves to BDC (expansion)

4-1: Back to initial position (Regenerator matrix gives out heat)



Stirling Cryocooler





Efficiency is around 85%
20-150 Hz frequency

G-M Cryocooler

1: Both valves are closed, Displacer at V1,min

1-2: HP valve open, HP gas fills V1 & V2

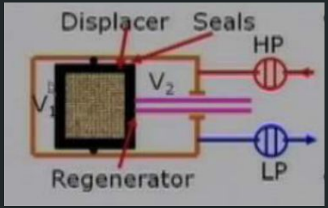
2-3: Dispatcher from V1,min to V1,max, gas flows from V2 to V1 through regenerator

3-4: HP valve closed, LP open, Expansion of gas, Cooling effect at V1

Efficiency is around 25% due to valves
1-2 Hz frequency, Higher Pressure ratio is achieved

V1: cold space
V2: warm space

1.



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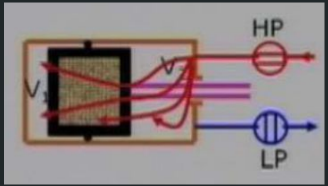

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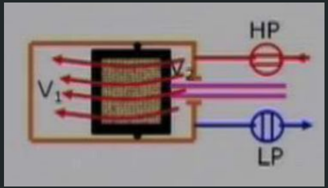

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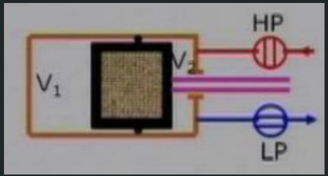
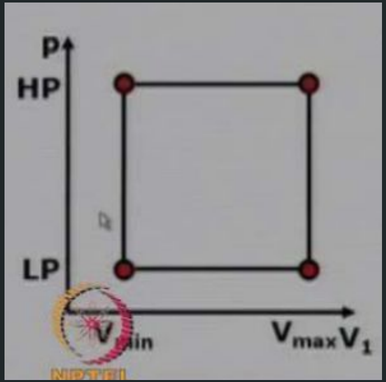
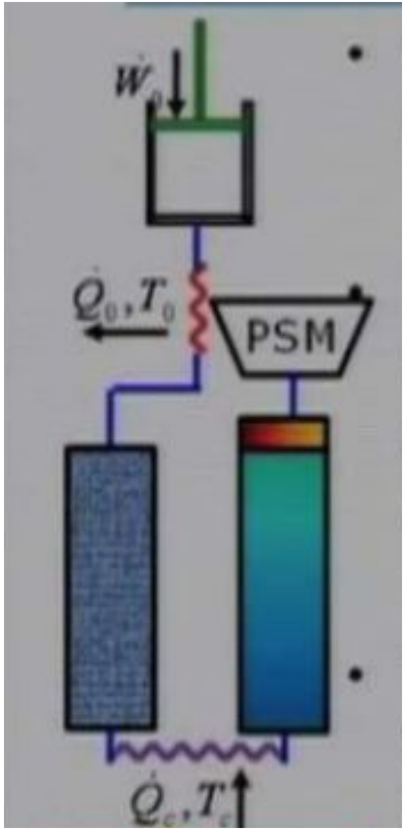




Pulse Tube Cryocooler

- Mechanical expander-displacer is replaced by a thin walled gas column known as pulse tube
- Oscillating gas flow produces cooling effect
- Components: compressor, heat exchanger, regenerator, pulse tube, phase shift mechanism
- Since there is no mechanical displacer- Efficiency improves, vibration reduces
- The PT cryocooler can be of Stirling Type and GM type

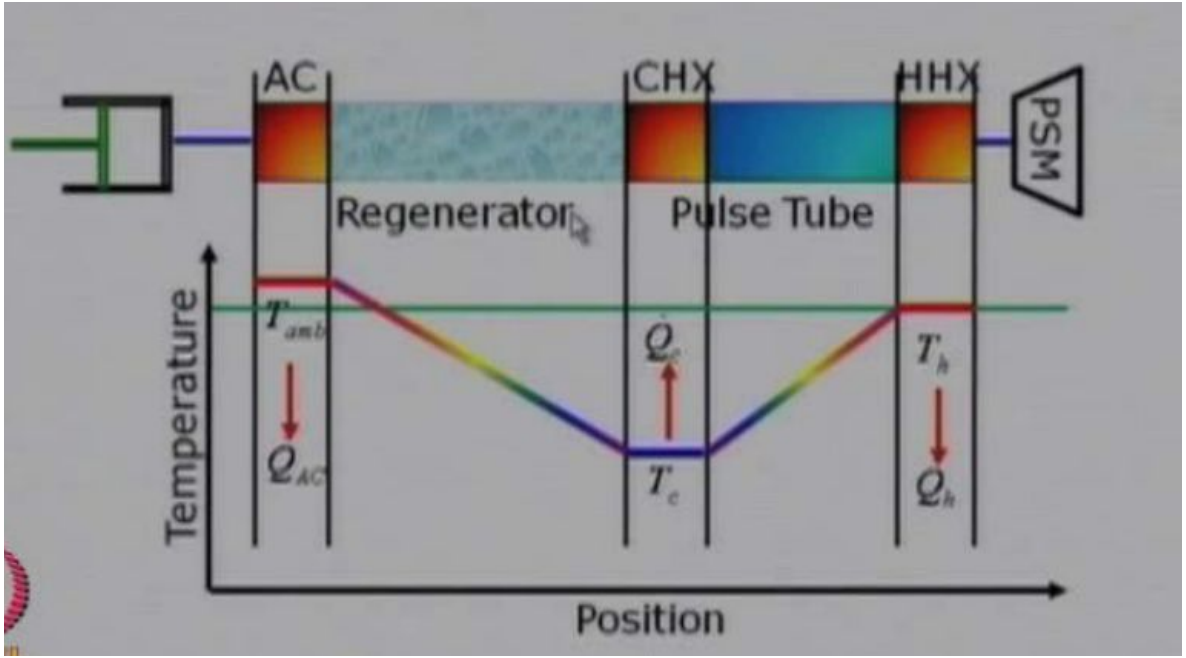
Working of Pulse Tube Cryocooler



Stirling type PT

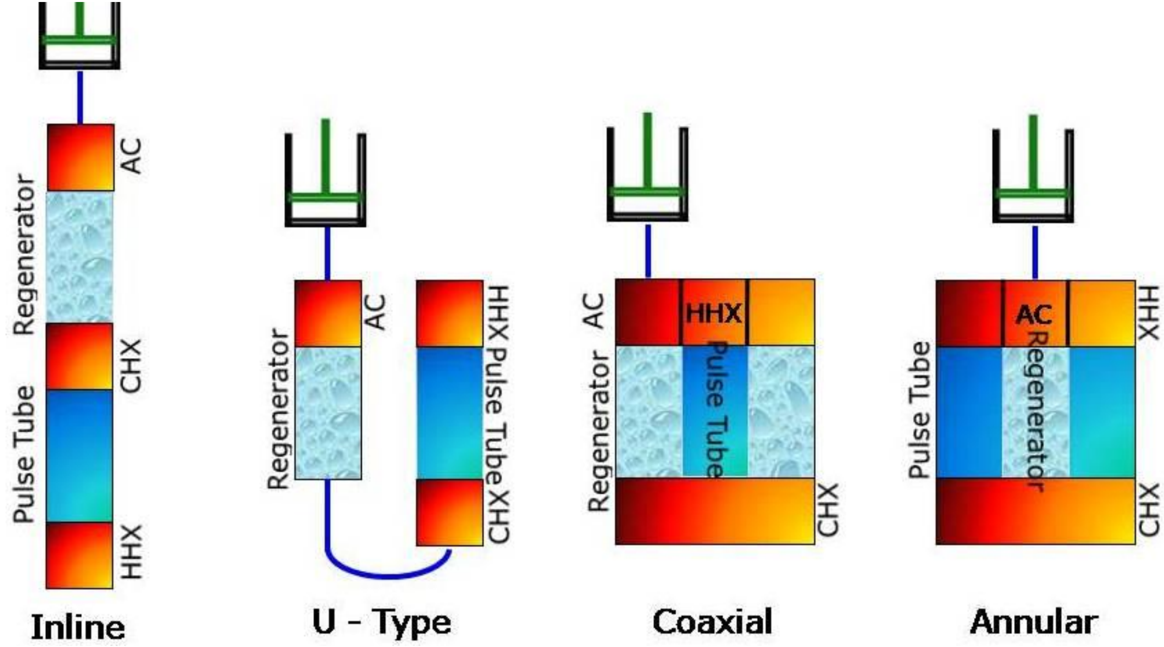
1. Piston moves down- compression- HP gas flow through the aftercooler which takes the heat of compression
2. This gas flows across the regenerator, getting precooled (giving heat to the regenerator matrix)
3. This enters the PT and compresses the gas present towards the top end (The phase between the piston and gas pressurization-depressurization is controlled by the Phase Shift Mechanism)
4. The compression causes a rise in temperature, which is greater at the top end (Top end is maintained at ambient temp.- HHX)
5. Piston moves back- depressurization- Gas expands in the pulse tube
6. This expansion causes a decrease in temperature across the PT, lowest temp will be achieved at the bottom end (CHX)
7. As the LP gas moves back through the regenerator, absorbs heat from the regenerator

Pulse Tube Cryocooler



Inline Type Pulse Tube Cryocooler

PT Cryocoolers based on geometry



The Stirling type cryocoolers can also be classified on the basis of **Frequency**:

1. Low
2. High
3. Very High

Types of Cryocoolers

- Open Cycle
  - Stored Gas
  - Stored Container
- Closed Cycle
  - Static
    - Sorption
    - Magnetic/ Laser
    - Radiator
  - Dynamic
    - (On the next slide)