Cooling the Superconductors

- Cooling below 2K requires the use of liquid He II
- Lambda point occurs at 2.1768 K
- He II best described with two-fluid model
  - He I (normal liquid)
  - He II (superfluid)
Sub-cooled He II

- Saturated He II leads to normal helium vapor
- He vapor’s poor thermal conductivity results in large local temperature rise
- Best to operate in sub-cooled He II region
- Optimal superconductor coolant
  - Matches required temperature
  - Can absorb heat energy with minimal temperature fluctuations.
Helium Refrigeration Cycle

He I @ 4.2K, 1 atm

He II @ 1.8K, 1 atm

4.2 K Helium Inlet

Vacuum Pump

J-T Valve

Recuperator

He II Heat Exchanger

Superconducting magnet
**Helium Refrigeration Cycle**

- **State 1**
  - $x_1 = 0.0$
  - $P_1 = 1$ atm

- **State 2**
  - $T_2 = T_{\lambda}$
  - $P_2 = P_1 - \delta P_{\text{rec,H}}$

- **State 3**
  - $T_3 = T_{\text{load}} - \delta T_{\text{bath,Hx}}$
  - $h_3 = h_2$

- **State 4**
  - $T_4 = 1.75$ K
  - $x_4 = 1.0$

- **State 5**
  - $P_5 = P_4 - \delta P_{\text{rec,L}}$
  - $h_5 = h_4 + (h_1 - h_2)$
Controlling Refrigeration System

- Recuperator
- Butterfly Control Valve
- 4.2 K Helium Inlet
- J-T Valve
- Pneumatic Actuator
- 1.8K He II
- Vacuum Pump
- Helium Gas Exits to Atmosphere
- He II Heat Exchanger