Lessons Learned in Magnet Slow Cooldown

Target Controls Meeting

2023-Oct-11

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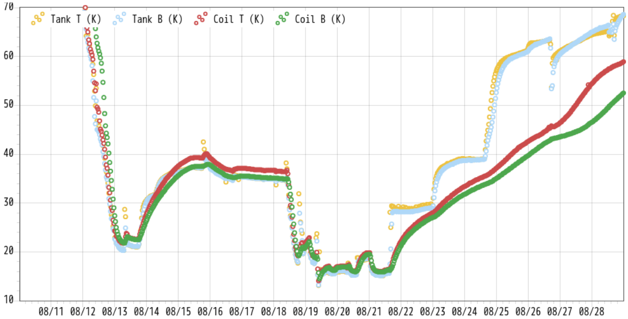
UVA

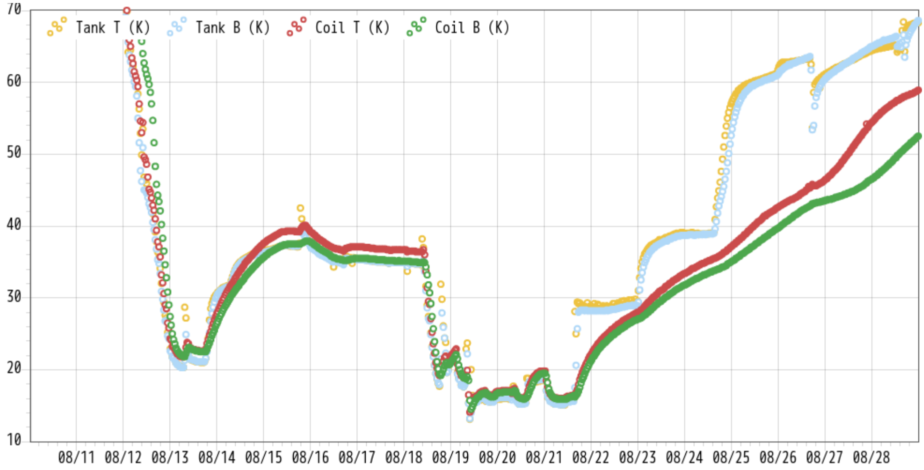
Introduction

- Magnet slow cooldown
  - Started on Aug. 10
  - Disturbed by the LCW problem on Aug. 20-24
  - Ended on Aug. 28, due to the QT stinger & HR3 problems



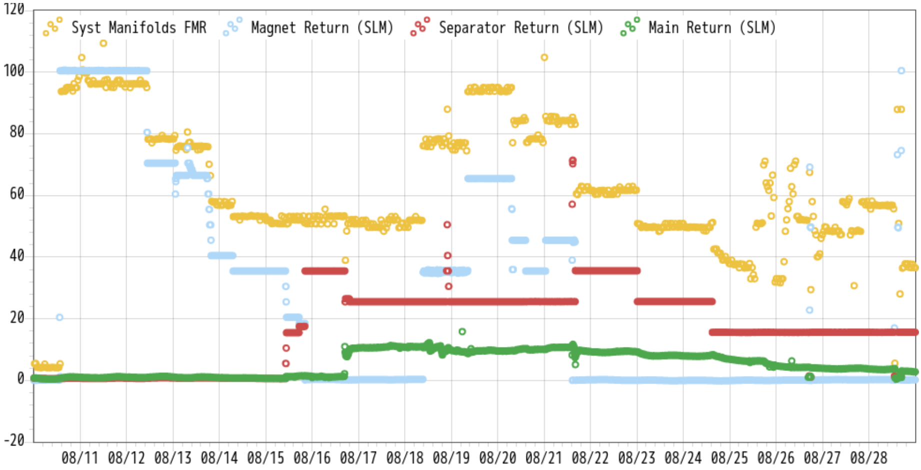
- Elog
  - **Summary:** `http://twist.phys.virginia.edu:8081/General/631`
  - **Work record:** `http://twist.phys.virginia.edu:8081/General/609`
  - Individial records; #609...658

Magnet Temperature



https://e906-gat1.fnal.gov/data-summary/e1039/target-all.php?Y0=2023&M0=8&D0=10&h0=0&m0=0&s0=0&Y1=2023&M1=8&D1=29&h1=0&m1=0&s1=0&Cryo+Temperature_Tank+T&Cryo+Temperature_Tank+B&Cryo+Temperature_Coil+T&Cryo+Temperature_Coil+B

Magnet Return Flow



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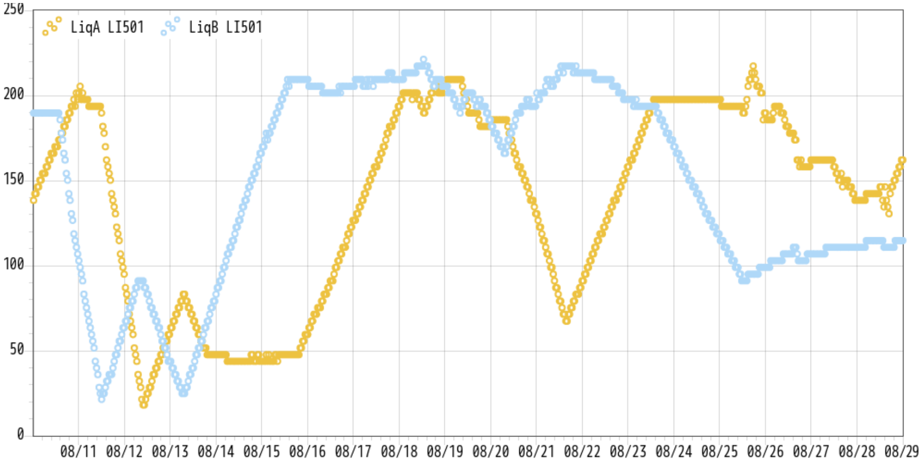
Liquefier Level



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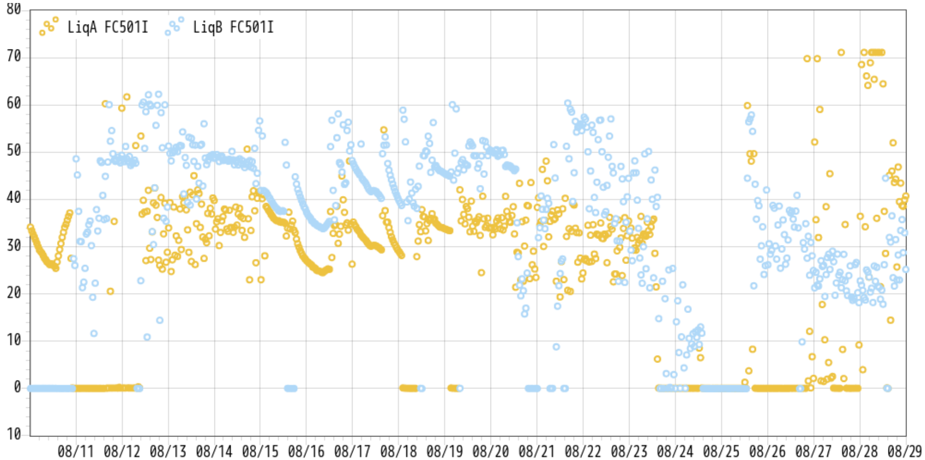
Liquefier Inflow



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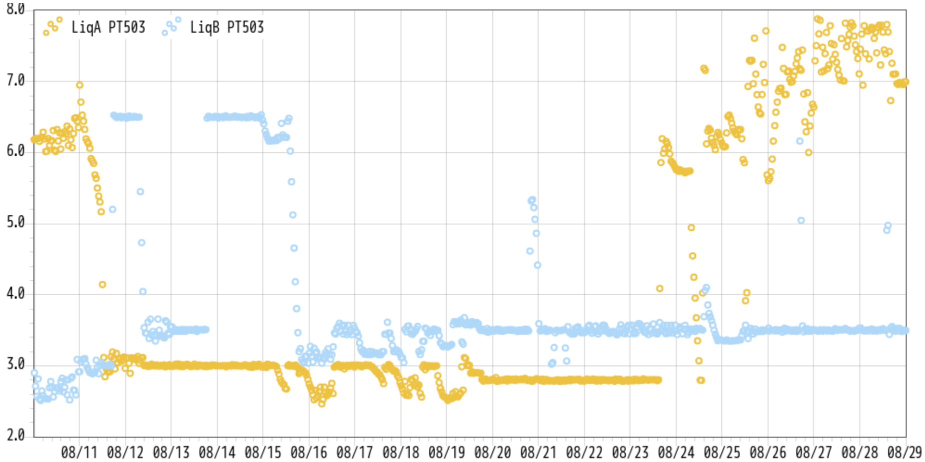
Liquefier Pressure



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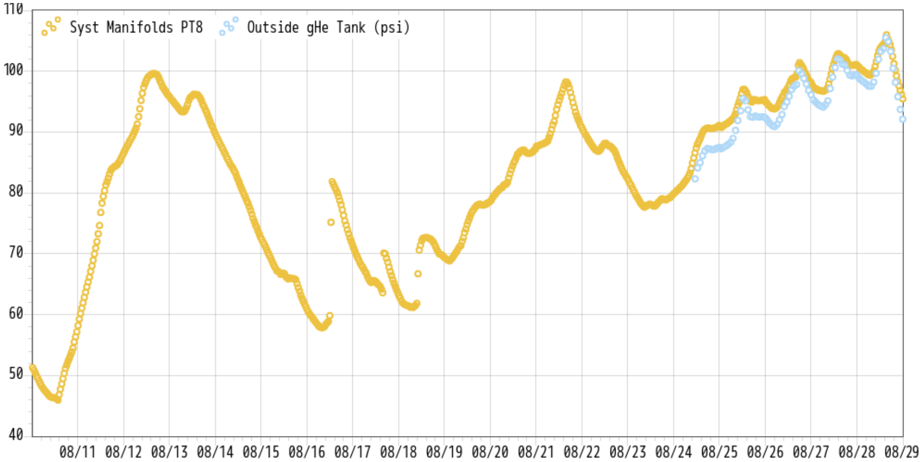
Outside gHe Pressure



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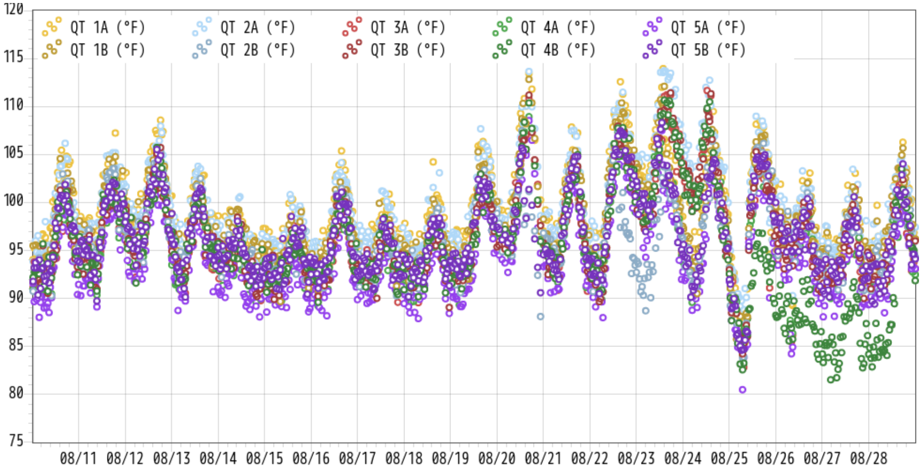
h1=0&m1=0&s1=0&DLSystem0_Helium+Supply+and+Return+Manifolds+PV_PT8&Cryo+Pressure_Outside+gHe+Tank

QT LCW Temperature



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List of Lessons

1. Sustainable flow rate
2. Pressure requirement for outside gHe tank
3. Method of using the two liquefiers seamlessly
4. Equilibrium temperatures at multiple flow rates
5. The lowest temperature with the max flow rate (150-200 SLM)
   - No chance to try this, because of the HR3 problem.

Sustainable Flow Rate

- Flow rate = liquefaction rate
- Found to be 70 SLM in total from Liq A & B
- Expected to be 100 SLM
  - Correspoinding to 4 L/h $\times$ 2 liquefiers
  - But the liq. rate was lower at lower pressure, as the pressure had to be as low as the magnet pressure ($\sim$3 psi)
- Remaining question
  - If we can quickly change the pressure of one liquefier that is not sending out LHe, the flow rate should be 50+35 SLM at max
    - Should be possible once the outlet flow controller of Liq A is replaced

Pressure Requirement for Outside gHe Tank

- What is the reasonable pressure when both Liq A & B are full (200+200 L)?
- For conservation of He
  - 400 L of LHe in Liq A+B $\Longrightarrow$ 100 psi when fully evaporated
  - The tank pressure should be $<$20 psi, so as to capture all evaporated He
- For liquefaction rate
  - The Liq inlet pressures (PT501A/B) drop by 30-40 psi when both Liq A & B are liquefying
  - The tank pressure should be 50-60 psi, so that PT501A/B are high enough to maintain the inflows
- We will be able to keep track of these relation by using the new pressure sensor next to the tank

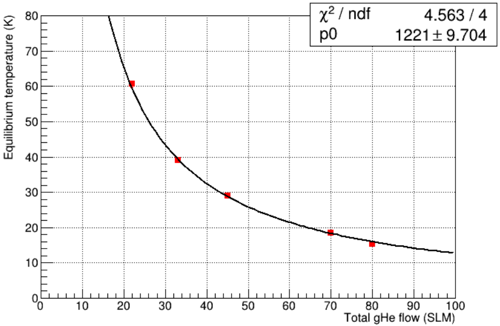
Method of Using Two Liquefiers Seamlessly

- Using the two in parallel (simultaneously)
  - Found to be too complicated to operate — elog 635
  - One liquefier loses LHe and the other gains LHe, even when the flow rate was adjusted to keep the total level constant
  - The magnet temperature was not reproducible, namely it varied time-to-time even under the same flow rate
- Using the two in series
  - When switching from Liq A to B for example;
Open VPC $\Longrightarrow$ Open VJVB $\Longrightarrow$ Close VJVA $\Longrightarrow$ Close VPC
  - How long do we wait at each step, to minimize the temperature raise?
  - How much do we consume extra LHe?
  - We didn't have a chance to quantify these, because of the HR3 problem

Equilibrium Temperatures at Multiple Flow Rates

- Model & formula — elog 630
  - $T = 4 + (H/(F/700 * \rho_{LHe}) - L_{LHe})/S_{gHe}$ — Eq. (1)
    - T: Equilibrium temperature
    - H: Total heat load (or influx), including the transfer line and the magnet
    - F: Magnet flow rate
    - $\rho_{LHe} = 0.125$ kg/L: Density of LHe
    - $L_{LHe} = 2.3\text{e}4$ J/kg: Latent heat of LHe
    - $S_{gHe} = 5.2\text{e}3$ J/kg/K: Specific heat capacity of gHe
- Measurements — elog 639 & 656
  - The eq. temperature was reproducible (i.e. one-to-one relation to flow rate) when the flow came from one liquefier (not two in parallel)
  - The eq. temperatures were measured at 22, 33, 45, 70 and 80 SLM

- **Model fitting — elog 657**
  - The measured data were fitted with Eq. (1), with H the only fit parameter



  - Result; $H = 1220.6 \pm 9.7$ J/m.
    It is close to the one given in doc5753 (1126 J/m = 18.7741 W).
  - Using the fit result of H, the minimum flow to bring the magnet to 4 K is expected to be 300 SLM
    - $F = H * 700/0.125/2.3e4 = 297$ SLM
    - It might be different now, since we evacuate the transfer line/stinger