

# Filling Magnet Helium Space

## • Pre-cooling

We get the best transfer efficiencies when the transfer lines from the Liquefier to the magnet are sufficiently cold. We have tested two modes (paths) to pre-cool the system: the slow (Figure 1 left) and the fast (Figure 1 right) pre-cooling as well as a combination of these two modes which allows us to reduce the slow pre-cooling time.

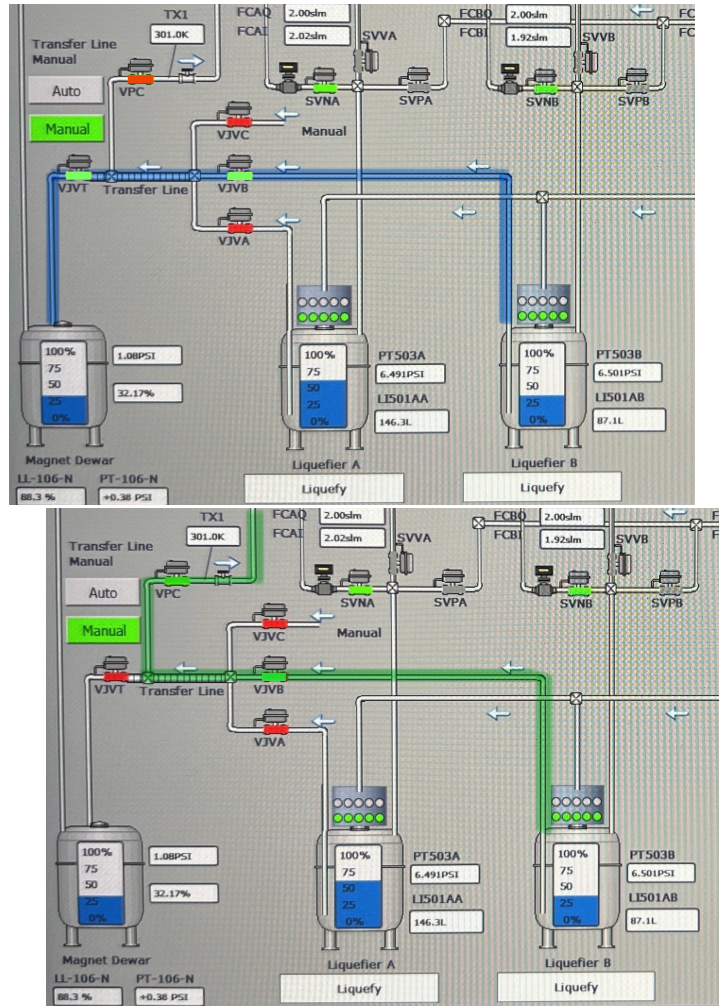


Figure 1: Slow (left) and fast (right) pre-cooling paths illustration for Liquefier B.

The **fast pre-cooling** transfer efficiencies obtained range from 47-49% which does not allow filling the entire magnet volume using only one full Liquefier. Nevertheless, higher efficiencies of about 54% can be obtained with the fast pre-cool if the Liquefier pressure is reduced to 3.5 PSI at the expense of nearly 2 hours (~8L) where the Liquefier is not producing while reaching the set pressure. With the fast pre-cooling the last part of the transfer line is not pre-cooled (see Figure 1). When the GV02 valve is fully open, the fast pre-cooling takes about 4 minutes and consumes 4L. Although the fast pre-cooling has a lower transfer efficiency the procedure could be performed when the magnet needs to be filled immediately and the slow pre-cool hasn't been done because none of the Liquefiers are near full.

The **slow pre-cooling** has consistently given higher transfer efficiencies between 56 and 58% but requires long pre-cooling times (~ 4 to 5 hours) with the potential benefit of a slow filling which is still under study. In this mode, the Liquefier LHe level is maintained constant. During the slow pre-cooling, we can estimate when the system is cold enough through the behavior of the Tank T temperature. Figure 2 (left) shows an example of the Tank T behavior during a slow pre-cooling mode. We can consider the system to be sufficiently cold when the Tank T temperature has decreased after being raised when the slow pre-cooling started. It takes around 4 to 5 hours to decrease (see Figure 2 (left)).

The **fast+slow pre-cooling** allows us to reduce the slow pre-cooling time by initially fast pre-cooling the first part of the transfer line and then transitioning to the slow pre-cooling. Figure 2 (right) shows an example of the Tank T behavior of a slow pre-cooling that followed a fast pre-cooling. It is observed that the Tank T temperature drops significantly faster when a fast pre-cooling is initially performed reducing the slow pre-cooling time to about 1 to 2 hours. The efficiency of this procedure is consistent with the standalone slow pre-cooling efficiency minus 1% given by the initial fast pre-cooling consumption of 4 additional liters of LHe on the Liquefier.

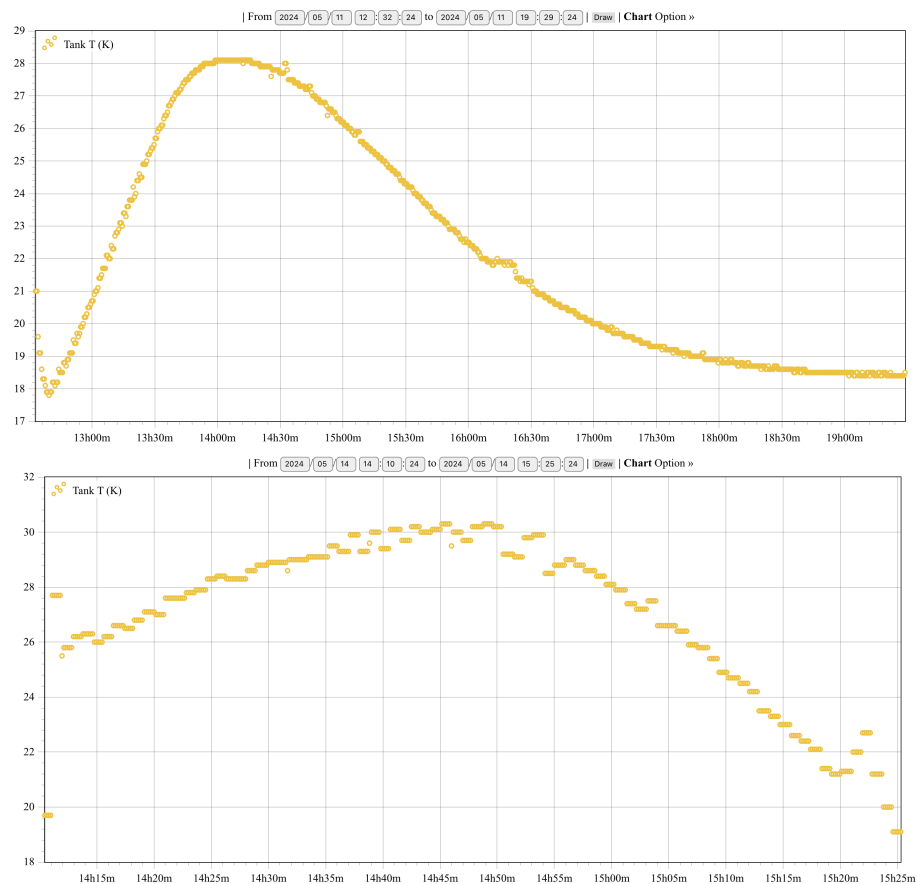


Figure 2: Tank T temperature behavior for *slow* pre-cooling (left) and *fast+slow* precooling (right) procedures.

The reported efficiency values were obtained by performing the magnet fills from the seam to the level probe spike except for the fast pre-cooling where the final level was taken from the level probe since we were not able to fully fill the magnet.

The different pre-cooling procedures are given below. Please confirm with the Target Expert the pre-cooling mode to be conducted.

### ***Slow Pre-cooling:***

1. Enable the Flow PID control of the Magnet Return Bypass at 65 slm.
2. Open VJVA/B, open VJVT and close VPC.

Note: Liquefier A/B should be on *Liquify* mode. If at the time of starting the slow pre-cooling the Liquefier A/B is on *Idle* mode, start the slow pre-cooling and when 4L are consumed on the Liquefier then change it to *Liquify* mode.

Proceed to the filling steps anytime after the transfer lines are cold. The system is sufficiently cold once the Tank T temperature decreases after opening VJVT (about 4 hours).

### ***Fast Pre-cooling:***

1. Open VJVA/B (ensure VPC is already opened).
2. Wait for TX1 temperature to drop below 100K (~ 4 min with GV02 fully opened).
3. Enable the Flow PID control of the Magnet Return Bypass at 65 slm.
4. Open VJVT and wait for magnet pressure to increase to 6 PSI.
5. Close VPC and proceed to the filling steps.

### ***Fast+Slow pre-cooling:***

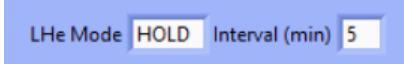
1. Open VJVA/B (ensure VPC is already opened).
2. Wait for TX1 temperature to drop below 100K (~ 4 min with GV02 fully opened).

3. Enable the Flow PID control of the Magnet Return Bypass at 65 slm.
4. Open VJVT and close VPC.

Proceed to the filling steps anytime after the transfer lines are cold. The system is sufficiently cold once the Tank T temperature decreases after opening VJVT (about 1 hour).

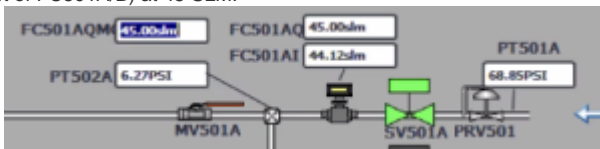
## • Filling

0. Open the "Magnet PS Main" on CCP, and then change the magnet level probe reading option from "HOLD" mode to "CONT" mode.



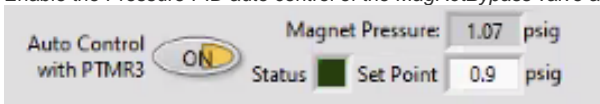
(Click on the field "HOLD", then you will see the two options "HOLD" and "CONT" )

1. Open the *MagRetBypass* valve fully by pressing the "*Full Open*" button on "*MagRetBypass\_Main.vi*" in CCP and wait until you can see it is fully open on the CCP panel. The magnet pressure will start decreasing. The FMR may spike momentarily.
2. After the FMR has stabilized, set the Liquefier A/B to "*Manual + Idle*", open SV501A/B (inlet valve), and set FC501A/BQM (see the box on the left of FC501A/B) at 45 SLM.



Ensure the outlet valve SVNA/B is closed and the cold heads of the Liquefier are *off*.

3. When the magnet level reaches 48%, open VPC, close VJVA/B, close VJVT.
4. Set the Liquefier A/B back to "*Auto+ Liquefy*".
5. Enable the Pressure PID auto control of the *MagRetBypass* valve at 0.9 psi.



## • Post-filling

Monitor the Liquefier A/B pressure until the cold-head temperatures are below 5.5 K ensuring the Liquefier A/B pressure doesn't go above 9 psi:

1. If the Liquefier A/B pressure rises, change the outlet Flow to 60slm on "*Settings*" and wait until the Dewar pressure is between 6-7 psi and the inlet flow is not zero.
2. Repeat step 1 reducing the flow by 10 SLM until reaching 2 SLM. If the pressure increases when the flow is reduced, change it back to the previous value.

Note: Always confirm on the Liquefier screen whether the outlet flow on FCA/B gives what you set it to. If not, press the "*Idle*" button followed by the "*Liquefy*" button immediately after.

———— Previous Procedures —————

Use this .docx file (download and edit) to collect data during the fill:

Type	Form
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Filling from a single QT Dewar	<a href="#">Magnet_LHe_Fill_Checklist.docx</a> (updated on 25 Mar 2024 )
Filling from both QT Dewars	<a href="#">Magnet_LHe_Fill_Checklist_filling_from_two_Dewars.docx</a> (updated on 08 Apr 2024 )

Older versions: [Magnet\\_LHe\\_Fill\\_Checklist.docx](#)

## Condition

- The magnet already contains LHe, i.e. the magnet LHe level > 0%.
- You can access and control the QT HMI and the Cryo Control Panel (CCP).
- You can access the strip charts on the data-summary page, particularly these preset pages;
  - Transfer-Line Cool Down: [https://e906-gat1.fnal.gov/data-summary/e1039/target-par-preset/cool\\_down.php](https://e906-gat1.fnal.gov/data-summary/e1039/target-par-preset/cool_down.php)
  - LHe Transfer: <https://e906-gat1.fnal.gov/data-summary/e1039/target-par-preset/transfer.php>

## Procedure for filling from a Single Dewar(alternating each Dewar every other day)

Note: Select the Dewar that you are going to use to fill (Liq should contain at least 193-200 L of Helium).

1. Download [Magnet\\_LHe\\_Fill\\_Checklist.docx](#) file, fill in all the "initial parameters" and get ready to fill the rest of the fields during the fill.

### Precooling (To be Tested on 2024-04-20)

1. Set the Separator flow to 20 slm (or higher) at least 2 hr before the fill. In the operational mode, separator flow should be always 20slm so you can skip this step.
2. If the Liquefier that you are going to use is already in the Idle mode, then please switch it to "Liquefy mode". If the liquid level is having large fluctuations which leads to the liquefier to automatically switching to Idle mode, then you can go to the settings and increase the "Dewar High Level" from 84%(~210L) to 86%(~215L) that way we can keep the Liquefier in the "Liquefy mode" throughout this procedure, and **remember to set it back to 84% once the fill is done**.
3. Read the inlet flow of the liquefier,  $F_{in}$ . Remember  $F_{diff} = F_{in} - 45$ , where 45 SLM is the typical flow rate.
4. Change the set point of the Magnet Bypass Flow PID control to "50 +  $F_{diff}$ " SLM.
5. Enable the Flow PID control of the Magnet Bypass.
6. Open VJVA/B.
7. Wait for 10 seconds, and then close VPC. Move next immediately.
8. Open and close VJVT for 1-2 seconds. Repeat this until the magnet pressure goes up to 6 psi or the Magnet Bypass flow becomes stable around the set point.
9. Open VJVT and keep it opened.
10. Confirm that the liquefier is still in "Liquefy mode". If not, switch to "Liquefy".
  - a. At this time, the liquefier will flow exactly the LHe amount that it is producing, to cool the line.
11. Wait for at least 30 mins. You will see the magnet pressure and Dewar pressure are closer to each other.

### Precooling

1. Set the Separator flow to 20 slm at least 2 hr before the fill. In the operational mode, separator flow should be always 20slm so you can skip this step.
2. If the Liquefier that you are going to use is already in the Idle mode, then please switch it to "Liquefy mode". If the liquid level is having large fluctuations which leads to the liquefier to automatically switching to Idle mode, then you can go to the settings and increase the "Dewar High Level" from 84%(~210L) to 86%(~215L) that way we can keep the Liquefier in the "Liquefy mode" throughout this procedure, and **remember to set it back to 84% once the fill is done**.
3. ~~Then, around 1 hr before the fill, start to cool down the transfer line by opening VJVA/B (ensure VPC is already opened). This is the start time of the transfer.~~
  - a. We skip this step because it should not be necessary, as of 2024-04-19.
4. ~~Wait until TX1 reaches -100 K. While you are waiting, connect to the CCP and get ready to open the Magnet Return Bypass Valve when TX1 is -100 K.~~
  - a. We skip this step because it should not be necessary, as of 2024-04-19.
5. Set Magnet Bypass Pressure PID to 6 psi.
6. Close VPC.
  - a. We might change when we do this step.
7. Quickly open and close VJVT (only for a few seconds) ~~while VPC is open~~ to get the magnet pressure up to 6 psi and then **close VJVT**.  
Note: you may have to open/close VJVT a few times to reach the magnet pressure to 6psi; as you don't want to leave the VJVT open for more than 30 seconds at this stage.
8. Once magnet pressure reaches 6 psi, check the inlet flow to the liquefier that you are going to use (~45 slm).
  - a. Can we finish this check earlier??
9. Set Magnet Bypass Flow PID to 50 slm and switch to Flow PID (this is for balancing with ~45 slm inlet flow to the delivery Dewar).
10. Open VJVT ~~and close VPC~~. Note: The liquefier that you are going to use is still in "Liquefy mode".



11. At this time, the liquefier will flow exactly the LHe amount that it is producing, to cool the line.
12. Wait for at least 30 mins. You will see the magnet pressure and Dewar pressure are closer to each other.

## Filling

1. After waiting ~30 mins, press the "Full Open" button on "[MagRetBypass\\_Main.vi](#)" in CCP, to open the MagRetBypass valve fully, and wait until you can see it is fully open on CCP panel.  
You will start seeing the magnet pressure start decreasing.
2. Monitor the FMR and make sure the total flow is below 500 slm. If it is above 500slm then wait until it is below 500 slm. Also, ensure the PC 1 is also below 1.5 psi.
3. Monitor the behavior of the magnet pressure, and once the magnet pressure is below 2psi, then Switch the liquefier that you are filling, to "Manual + Idle" mode, and open **SV501** solenoid valve, and after that set **FC501** to 45slm.  
Note: Monitor the FMR and make sure the total flow is below 500slm. If it is above 500slm then use 40slm on **FC501**.
4. Monitor the pressure difference (between magnet and delivery Dewar) using the "LHe Transfer page", and ensure it keeps increasing towards 3.0 psi.  
Ensure the **FMR** value doesn't exceed 500slm (~480slm would be ideal) and if it is increasing above 500slm, then reduce the "FC501" by a couple of 'slm' and continue to monitor.
5. Monitor the parameters using <https://e906-gat1.fnal.gov/data-summary/e1039/target-par-preset/transfer.php>
6. You may need to reduce (increase) it if the pressure difference is increasing-faster (reducing) while monitoring the FMR; but **45 slm** seems the nominal value based on the past fills.
7. Keep monitoring the fill parameters: Magnet level, Delivery Dewar level, Pressure difference, FMR
8. Maintain the pressure differential above 3 psi, by adjusting FC501A/B if necessary (after setting FC501A/B to 40slm is usually smooth until the end of the fill, but pay attention in-case you have to change it)
9. Monitor everything, until the magnet level reaches **50%**, and then observe a level-spike that confirms that you have filled the magnet up to the top level (145 L).  
In case you don't have enough liquid in the delivery dewar, you can stop before seeing the level-spike.
10. Open VPC, Close VJVA/B, Close VJVT.
  - a. This is the **end time** of the transfer. Record the time, the magnet level, and the Liq level.
11. Enable the auto control of the MagRetBypass valve. Change the set point to 0.9 psi.
12. Change the Liq mode to "**Auto+ Liquefy**" mode:
  - a. Change the Dewar Set pressure to 6.5 psi.
  - b. Set the outlet flow is **40 SLM**. Note: **you will need to pay attention to this Liquefier for the next ~1 hr** until you change this to **2 slm** step-by-step while monitoring the Dewar pressure (follow Steps #17, #18).  
If the Dewar pressure is keep increasing beyond the Set pressure (6.5 psi), then you will need to increase this outlet flow to 60slm. When you change this, always confirm on the Liquefier screen's FCA/B whether it's flowing what you set to. If not, you will have to quickly press "Idle" button and then press "Liquefy" button immediately after.
  - c. The Liquefier Compressors' coldhead heaters should be OFF, but it's better to confirm that on the "Helium Compressors" screen.  
If they are ON, please turn them off one-by-one (double tap/click on each button for heaters).
  - d. If you change the mode of the **other** liquefier in step #4, then change it back to **Liquefy mode**.
13. Wait until the Liquefier's Dewar pressure (**PT503**) gets slightly below 6.5 psi, and then check the **actual** inlet flow (FC501 A/B I) to the liquefier is above 40 SLM (FC501 A/B Q will be 60 slm).  
This indicates that you can change the Outlet Flow Set point to a lower value like 30slm (follow the next steps over the next ~40 mins).  
Note: Ensure the Dewar pressure doesn't go above 9 psig. If it is rising, you should change the Outlet Flow Set point to 60slm and wait until the Dewar pressure is between 6-7 psi.
14. Repeat step #17 with outlet flows = 20, 10, 5slm, and and then to 2 SLM when the **cold-head temperatures are below 5.5 K**.
15. Confirm that the Liq pressure stays around the set point (6.5 slm).
16. Calculate the transfer efficiency using initial and final levels in the magnet and the Liquefier Dewar.
17. Post the filled **Magnet LHe Fill Checklist.docx** file on uva-elog including the date of the fill as part of the file name (for example: **Magnet LHe Fill Checklist 03-29-2024.docx** or **.pdf file**)  
If you don't have access to the uva-elog, then please send this file to the Target Expert on shift.

## Tentative procedure for filling from two Dewars

1. Download **Magnet LHe Fill Checklist filling from two Dewars.docx** file, fill in all the "initial parameters" and get ready to fill the rest of the fields during the fill.
2. You will see an alarm when Tank B at 4.6 K, at that time ensure that the Dewar B pressure at 3psi and the Dewar A pressure at 5.5 psi.  
**This step needs some time estimate depending on how long each Dewar takes to reach the set pressure.**
3. Monitor the magnet level reaching the seam (when Tank B is around ~4.8 K)
4. Switch the Magnet level probe to "CONT".
5. At right before the fill, open the run valve to 2 turns for 3 mins and put it back to 0.8 turns.
6. Start pre-cooling by opening VJVA first (this is to pre-cool the line A assuming that the line A is relatively colder then we switch filling from BA; we will have to pre-cool line B in the next step).
7. When TX1 reaches ~100 K, then pre-cool line B by opening VJVB and close VJVA.
8. Ensure TX1 ~100 K or below, then open Mag return bypass fully, open VJVT, and close VPC.
9. Switch the Dewar B to Manual mode and set FC501 B to 45slm, and monitor FMR.
10. Monitor until the Dewar B level reaches 12 L, and then open VJVA to pre-cool until it reaches 9 L.
11. Close VJVB. Now you are filling from A. Magnet Pressure may have a pressure spike. After the pressure spike set Dewar A to Manual mode and set FC501A to 45slm.
12. Switch LQ-B to Auto + Liquefy mode, and set the Dewar pressure back to 6.5 psi.
13. Adjust the flow FC501A to keep FMR below 480slm, PC1 below 1.1 psi, and magnet pressure below 2.5 psi.
14. At the end of the fill, Open VPC, Close VJVA, and VJVT. Also, ensure VJVB is closed.
15. Switch LQ-A to Auto + Liquefy mode, and set the Dewar pressure back to 6.5 psi.
16. Set the Magnet Bypass to pressure PID to 0.9 psi.
17. Switch the Magnet level probe back to "HOLD" mode.

# Procedure for filling from a Single Dewar(Since 03/29/2024)

Note: Select the Dewar that you are going to use to fill (Liq should contain at least 200 L of Helium), and then change Dewar Set pressure to 3 psi **at least 3 hours** before the fill.

1. Change the liquefier mode to "Auto+Idle" mode, if it is not.
2. Download [Magnet LHe Fill Checklist.docx](#) file, fill in all the "initial parameters" and get ready to fill the rest of the fields during the fill.
3. Start to cool down the transfer line by opening VJVA/B (ensure VPC is already opened). This is the **start time** of the transfer.
4. Wait until TX1 reaches ~100 K. While you are waiting, connect to the CCP and get ready to open the Magnet Return Bypass Valve when TX1 is ~100 K.  
Also note that you will have to perform Steps 5, 6, 7 relatively quickly.  
Meanwhile, ensure the mode of the **other liquefier** is on "Auto+Idle". If not, set it to "Aut+Idle" mode. \*\*
5. When TX1 is ~100 K, then press the "Full Open" button on "[MagRetBypass\\_Main.vi](#)" in CCP, to open the MagRetBypass valve fully, and wait until you can see it is fully open on CCP panel.
6. Open VJVT and close VPC.
7. Switch the liquefier that you are filling, to "Manual + Idle" mode, and open SV501 solenoid valve, and after that set FC501 to 45slm.
8. Monitor the pressure difference (between magnet and delivery Dewar) using the "LHe Transfer page", and ensure it keeps increasing towards 3.0 psi.  
Ensure the FMR value doesn't exceed 480slm (~470slm would be ideal) and if it is increasing above 500slm, then reduce the "FC501" by a couple of 'slm' and continue to monitor.
9. Once the pressure difference reaches ~3.0 psi, then reduce the flow on FC501 to 40slm, and continue to monitor using <https://e906-gat1.fnal.gov/data-summary/e1039/target-par-preset/transfer.php>
10. You may need to reduce (increase) it if the pressure difference is increasing-faster (reducing) while monitoring the FMR.
11. Keep monitoring the fill parameters: Magnet level, Delivery Dewar level, Pressure difference, FMR
12. Maintain the pressure differential above 3 psi and below 3.3 psi, by adjusting FC501A/B if necessary (after setting FC501A/B to 40slm is usually smooth until the end of the fill, but pay attention in-case you have to change it)
13. Monitor everything, until the magnet level reaches 50%, and then observe a level-spike that confirms that you have filled the magnet up to the top level (145 L).  
In case you don't have enough liquid in the delivery dewar, you can stop before seeing the level-spike.
14. Open VPC, Close VJVA/B, Close VJVT.
  - a. This is the **end time** of the transfer. Record the time, the magnet level, and the Liq level.
15. Enable the auto control of the MagRetBypass valve. Change the set point to 0.9 psi.
16. Change the Liq mode to "**Auto+ Liquefy**" mode:
  - a. Change the Dewar Set pressure to 6.5 psi.
  - b. Set the outlet flow is **40 SLM**. Note: **you will need to pay attention to this Liquefier for the next ~1 hr** until you change this to **2 slm** step-by-step while monitoring the Dewar pressure (follow Steps #17, #18).  
If the Dewar pressure is keep increasing beyond the Set pressure (6.5 psi), then you will need to increase this outlet flow to 60slm. When you change this, always confirm on the Liquefier screen's FCA/B whether it's flowing what you set to. If not, you will have to quickly press "Idle" button and then press "Liquefy" button immediately after.
  - c. The Liquefier Compressors' coldhead heaters should be OFF, but it's better to confirm that on the "Helium Compressors" screen.  
If they are ON, please turn them off one-by-one (double tap/click on each button for heaters).
  - d. If you change the mode of the **other** liquefier in step #4, then change it back to **Liquefy mode**.
17. Wait until the Liquefier's Dewar pressure (PT503) gets slightly below 6.5 psi, and then check the **actual** inlet flow (FC501 A/B I) to the liquefier is above 40 SLM (FC501 A/B Q will be 60 slm).  
This indicates that you can change the Outlet Flow Set point to a lower value like 30slm (follow the next steps over the next ~40 mins).  
Note: Ensure the Dewar pressure doesn't go above 9 psig. If it is rising, you should change the Outlet Flow Set point to 60slm and wait until the Dewar pressure is between 6-7 psi.
18. Repeat step #17 with outlet flows = 20, 10, 5slm, and then to 2 SLM when the **cold-head temperatures are below 5.5 K**.
19. Confirm that the Liq pressure stays around the set point (6.5 slm).
20. Calculate the transfer efficiency using initial and final levels in the magnet and the Liquefier Dewar.
21. Post the filled [Magnet LHe Fill Checklist.docx](#) file on uva-elog including the date of the fill as part of the file name (for example: [Magnet LHe Fill Checklist 03-29-2024.docx](#) or [.pdf file](#))  
If you don't have access to the uva-elog, then please send this file to the Target Expert on shift.