QCLS Routine Tasks
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Several tasks are routinely required for successful operation of the QCLS. These tasks include:

1. Inlet Filter changing
2. LN_2 filling
3. CO_2 Pressure Vessel purging (with Nitrogen)
4. Water Trap purging
5. Calibration Cylinder refilling

Some of these items are included on the Preflight Checklist, but will be outlined here for clarity.

1. Inlet Filter changing

Inlet filters are utilized on the DUAL and CO_2 sample lines to prevent contamination of the instrument, and both should be changed before each flight. While it is unlikely that enough atmospheric aerosols will accumulate on the filters to cause trouble, it is possible for liquid water to be ingested at the inlet and collect in the filter housing. The filter will prevent the liquid water from entering the system, but water will severely reduce the sample flow, and must be removed. Even a damp filter can be troublesome, hence the routine replacement.

To replace the filter elements, it is necessary to remove each of the filter holders from the instrument. On the inlet side, 2 wrenches are required to remove each inlet tube while preventing rotation of the filter holder. After disconnecting the inlet tube, loosen the fitting at the Inlet Calibration Enclosure, and remove the filter holder assembly. Hold the filter holder vertically, and unscrew the retaining ring. Next, lift the upper portion away from the base, and remove the filter element. Sometimes it will stick to the o-ring on the upper portion. Be sure to remove the entire element, and check that the support screen remains in place in the base.

Open the filter element box, and note that as packed, the upper face of the filter element is the inlet side of the membrane. Since you are holding the base of the holder in your hand (outlet side), simply transfer the element to the base, maintaining the same orientation. Ensure that the element is centered in the base, and **does not overlap the o-ring sealing surface.** This is critical, as cabin air will leak into the inlet and ruin the measurement if the edge of the filter element protrudes beyond the o-ring seal. Carefully replace the upper portion of the filter holder, confirm that the element does not protrude, and then tighten the retaining ring until the lines on the holder match. Repeat the procedure for the second filter holder.

After installing the filter elements, reinstall the filter holders and tighten the fittings. Note that lines are drawn on the fittings to indicate how far to tighten them. Synflex tubing is fairly soft, and easily damaged by over tightening, so use the lines to avoid problems. Over time, it may be necessary to tighten slightly past the indicated point, but only a small amount. Because this is a pressurized aircraft, a loose fitting will allow cabin air to contaminate the measurement, so it is also critical to ensure the fittings are tightened enough to prevent leaks.

2. LN_2 filling

Liquid Nitrogen (LN_2) is used to cool the detectors used in the instrument, and **it is very important that the dewars contain LN_2 whenever the instrument is powered**. Prolonged operation with empty dewars will likely destroy the detectors. The hold time of the dewars is at least 24 hours, and it is generally desirable to fill the dewars as late as possible on the day before the next flight. This allows them to thermally stabilize overnight, while still providing sufficient cooling capacity for the duration of the flight. Since LN_2 presents a cold hazard, it is important that proper protective gear (gloves, eye protection) be worn during these operations. Spillage of LN_2 must also be minimized, as it can damage the aircraft floor. Note that a floor mat should be used on the hangar floor beneath the main supply dewar, as spilled LN_2 can cause the epoxy paint on the hangar floor to flake off.

In addition, never completely cap any storage container or dewar, as **nitrogen vapor must be able to vent** or eventually the container will explode. The dewars on board the aircraft are fitted with a mechanical absolute pressure regulation system, which maintains the dewars at a fixed pressure during flight. During filling, this system must be disconnected, and it must be reinstalled properly for safe operation following the filling procedure.

Because the CO_2 Pressure Vessel (PV) must be purged following LN_2 filling, it is usually desirable to fill the CO_2 dewar first. This way, the PV can be purged while the DUAL dewar is filled.

To start, fill a portable 1L dewar with LN_2 from the main supply dewar. Next, remove the 1/4” Swagelok plug from the bottom of the vent plumbing (use a 9/16” wrench), and place an overflow cup beneath the vent port to collect any excess LN_2. Remove the insulation cap from the top of the CO_2 PV, and unscrew the top cover of the PV (1.25” nut). Using an 11/16” socket wrench, remove the 3/8” Swagelok plug from the fill port underneath the cover, and install the tube from the funnel assembly. Tighten the nut **gently** using an 11/16” flare nut tool. Slowly pour about 250mL of LN_2 into the funnel assembly, and allow it to nearly drain from the funnel. This will cool the funnel and associated plumbing, and facilitate more rapid flow of LN_2 into the dewar. When the funnel is almost empty, pour most of the remaining liter of LN_2 into the funnel, and cover the top of the funnel with a rubber glove. This pressurizes the funnel slightly, forcing LN_2 into the rest of the system. Eventually, liquid with begin to emerge from the vent port, into the overflow cup, indicating that the dewar is full. To verify that liquid is not just being forced out due to pressurization of the funnel, remove the glove and observe if liquid continues to emanate from the vent. If unsure, add the remainder of the LN_2 from the portable dewar and observe the vent without pressurization of the funnel. Usually 1L is plenty to complete the fill.

When certain that liquid is coming out of the vent, wait until the funnel is empty and then remove the tube from the fill port using the 11/16” flare nut tool. When cold, it can be significantly more difficult to loosen the nut, and care must be used not to burn your hand on the frigid fitting. Once removed, wipe the fill port dry and replace the 3/8” Swagelok plug. Tighten it by hand to be sure it is not cross-threaded, and then secure it with the 11/16” socket wrench. Note that this fitting is located on top of the detector dewar, and aggressive tightening could

cause optical misalignment, so just tighten it slightly past hand tight. Refer to Step 3 below to start purging of the CO_2 PV.

Once purging of the CO_2 PV is underway, begin filling the DUAL dewar. First, refill the portable 1L dewar with LN_2 from the main supply. Next, remove the 3/8" Swagelok cap on the top of the dewar assembly, similar to the CO_2 configuration. Install the tube from the funnel assembly, and gently tighten the nut. Repeat the filling procedure used above, first adding about 250mL to cool the funnel, then using the pressurization technique to hasten the filling process. Similar to CO_2, watch for fluid flow at the vent port, and confirm that the dewar is really full by rechecking for fluid without pressurization. The DUAL dewar has the same capacity as the one in the CO_2 instrument, so 1L should be adequate to completely fill it.

Once the funnel is empty, remove the tube from the fill port, dry the fitting, and then replace the 3/8" Swagelok plug. Similar to CO_2, tighten the fitting gently to avoid optical alignment issues. Using a paper towel, wipe off as much frost as possible from the vent plumbing, and reinstall the 1/4" Swagelok plug on the vent port. Secure it with a 9/16" wrench. Check on the status of the PV purging, and refer to Step 3 below to complete the procedure.

3. CO_2 Pressure Vessel purging (with Nitrogen)

The laser, detector, cell, and optics of the CO_2 instrument are contained in a sealed pressure vessel (PV) to ensure that the optical path is stable and free of large concentrations of CO_2. Whenever the PV has been opened and exposed to outside air, such as when filling the detector dewar, it is necessary to purge the PV using an external cylinder of high-purity nitrogen. Typically, a purge flow of 2L/min for 30 minutes has been sufficient to thoroughly clean the PV, regardless of past exposure.

To start, secure the external N_2 cylinder under the seat in front of the QCLS instrument, and install the purge regulator. Next, connect the purge tube from the regulator to the PV purge fitting (a 1/8" Swagelok tee near the front of the PV). Note that the purge tube has a flow-regulating frit inline, rated for 1L/min @ 30 psi. Verify that the top cover (1.25" nut) of the PV is loosened about 1 turn, exposing a multitude of small vent holes. Open the external cylinder's main valve, and set the regulator to 60 psig. Open the regulator outlet valve, and note the time.

After approximately 30 minutes, close the regulator's outlet valve and quickly close the top cover of the PV. Gently tighten the top cover with a 1.25" wrench (a flare nut-type crow's foot wrench, turned by hand, is sufficient.) Reinstall the PV's insulation cap. Close the main valve on the external N2 cylinder, disconnect the vent tube from the PV, and quickly reinstall the 1/8" Swagelok plug on the PV's purge fitting. Tighten gently with a 7/16" wrench.

Remove the purge tube from the regulator, caps both ends, vent the remaining pressure from the regulator, and pack everything up.

4. Water Trap purging

Water vapor is removed from the sample flows of the DUAL and CO_2 instruments using a pair of a Nafion pre-driers and subsequent dry ice cooled u-tubes, mounted in a stainless steel dewar. The Nafion units remove the bulk of the incoming water vapor, but they don't dry the sample flows to a low enough dew point, so the u-tubes are provided to finish the task. After approximately every 3 flights, the tubes need to be removed from the dewar, warmed up, and purged of liquid water. It should be noted that if the dewar is allowed to warm up between flights, and the tubes not purged, there is a risk that the melted water previously distributed along the tube as frost will refreeze in the bottom of the tube, potentially plugging the line. As long as the dewar is kept cold, this will not be an issue.

To purge the tubes, disconnect all of the sample lines to the dewar, and install caps and plugs on all of them to keep them clean. Loosen the two hose clamps that retain the dewar, and remove it from the aircraft. Remove the kapton tape around the top of the dewar, and undo the two slotted screws that hold the top in place. To remove the mounting tabs, first rotate the top assembly about 15 degrees, then push down on the tabs and gently work them out of the side brackets.

Once the mounting tabs are removed, lift the entire tube assembly out of the dewar, and brush off the bulk of the remaining dry ice. Set the assembly aside to warm up, with one precaution: **it is very important to keep liquid water out of the internal filters**, so orient the assembly such that as things melt, the collected water will not flow down into these filters.

While waiting for the u-tubes to warm up, dump out any remaining dry ice from the dewar, and wipe the interior clean. After the dewar is warm, wipe it out a final time to eliminate any liquid water. Next, wipe off the u-tubes, and prepare to purge them. First, remove the caps from the u-tube fittings and dump any collected water **out the inlet side** (away from the internal filter.) Retrieve the nitrogen used to purge the CO_2 PV, and connect the purge regulator. Attach the adaptor fittings to the regulator and to the **outlet side** of one of the u-tubes, and flow nitrogen through the u-tube to flush out any remaining liquid water. It is helpful to periodically plug the inlet side with your finger and then release it, to create a pulsed flow. Once clean, repeat for the other u-tube and replace the fitting caps. Check that the nomex insulation is dry, and if necessary, use a paper towel to help wick water out of the insulation.

Reinstall the tube assembly in the dewar, install the mounting tabs and screws (note the need to rotate the assembly to accomplish this), retape back portion of the nomex insulation, and reinstall the dewar in the aircraft. Connect all of the sample tubes before tightening the retaining hose clamps, and ensure that the electrical cables behind the dewar are not pinched. When tightening the sample fittings, note that all of them have lines indicating how far to tighten, similar to the inlet fittings. A loose fitting here will allow cabin air in, and will ruin the measurement, so use care to make sure all are properly tightened.

5. Calibration Cylinder refilling

One of the most critical routine tasks is determining when to refill the various calibration cylinders, and then completing the task without contaminating either the source tank or the on board cylinder. In general, cylinders should not be allowed to go below 500 psig before refilling, as changes in delivered concentration have been observed as the pressure drops below this point. One exception is the DUAL ZERO cylinder, which contains specially purified nitrogen, and can be operated to 200 psig. When refilling a cylinder in one of the Gas Decks, the following components are required:

high pressure regulator (usually CGA590)
fill tube (1/8” 316 stainless steel)
7/16 (2), 1 1/8" wrenches
9/16” socket and driver
cylinder wrench (for main valve)

The basic procedure is to flush the regulator and fill tube 3 times to remove water and to condition the system with the appropriate gas, to dump the existing gas in the Gas Deck cylinder, and to refill the cylinder with uncontaminated calibration gas.

1. Install the regulator onto the fill tank, and attach to fill tube to the regulator. Check that the regulator valve is closed.

2. Crack open, and then quickly close, the fill tank. Open the regulator valve, and crack open the fitting on the end of the fill tube. Bleed a little flow out of the tube, and then close the fitting and the regulator valve. Let them sit for several minutes.

3. Open the regulator valve, and crack open the fitting on the fill tube again. Bleed the pressure out of the regulator. As soon as the regulator is empty, close the fitting and regulator valve.

4. Repeat steps 2, 3.

5. Open the fill tank about a quarter turn. Open the regulator valve, and crack open the fitting on the end of the fill tube. Bleed a little flow out of the tube, and then close the fitting and the regulator valve.

6. Remove the plug on the fill port of the appropriate cylinder. Using the 9/16” socket/driver, open the fill valve of that cylinder, and gradually drain the existing gas until it is almost completely gone. Close the fill valve.

7. Immediately open the regulator valve, and crack the fill tube fitting. Adjust the regulator delivery pressure and regulator valve to give a small flow out of the fill tube. Be careful not to set it too high – aim for as low a setting as possible that still gives detectable flow. Remove the fitting and flush the fill port by holding the tube directly in front of it.

8. Connect the fill tube to the Gas Deck fill port, and tighten the fitting. Open the fill valve, then open the regulator valve more, about a half turn. Gradually turn in the regulator setting to fill the Gas Deck cylinder to the desired pressure. Go slowly, to minimize the temperature changes.

9. When the regulator stops increasing at the desired pressure, immediately close the fill valve and regulator valve. Close the main fill tank valve. Back out the regulator adjustment somewhat (not quite all the way).

10. Crack open the fill tube fitting at the regulator end. Slowly open the regulator valve to bleed out the high pressure in the regulator. When empty, close the valve, then remove and cap both ends of the fill tube. Plug the Gas Deck fill port. Double check that the Gas Deck fill valve is closed tightly. Remove the regulator from the fill tank.