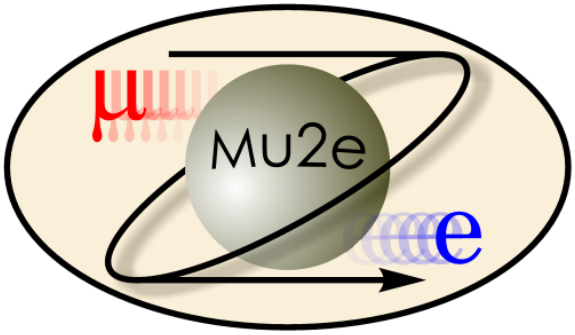

CO_2 Leak Testing of Straws Standard Operating Procedure

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1 Goal

All Mylar straws in the Mu2e electron tracker panels will be inflated with a mix of argon gas and CO_2 during the run of the experiment. Thus, our goal is to determine the leak rate of each straw before panel installation, as well as identify straws that are damaged. We strive to do this in a safe, efficient, and reproducible manner.

2 Equipment Used

- Pallet with Mylar straws
- CO_2 tank with regulator attached
- N_2 tank with regulator attached
- CO_2 pressure gauge and flow meter with hose
- Vacuum grease
- Straw end-piece hose plugs
- Leak test chambers
- Plastic straw loading tubes
- Magnetic grabber
- Arduino Unos connected to leak chambers and computer
- Isopropyl alcohol and paper towels
- Form–fitting nitrile gloves

3 Risks and Dangers

There is an inherent danger when working with pressurized gases. Because the N_2 and CO_2 tanks are pressurized to a maximum of 2500 psi, an uncontrolled discharge of gas from the cylinders would effectively make the cylinders into rockets. This could happen if a cylinder is knocked over and the gas cylinder valve or regulator valve gets damaged. For this reason, compressed gas chambers are harnessed to the wall by a chain. The regulator over the exit valve limits the pressure of gas released from the chamber. To prevent accidental tipping of the cylinders, only a trained supervisor should ever move cylinders or adjust regulator pressure.

High levels of CO_2 in the air can make a person feel dizzy. To CO_2 levels from getting high, the lab has a good ventilation system. Make sure that you can hear the sound of fans from the laboratory ventilation system when working with the CO_2. If you do feel dizzy, close the CO_2 tank valve and step outside for a few minutes. Always close the gas tanks when not in use.

Care must be taken when cleaning with isopropyl alcohol. Contact with skin can cause irritation, so nitrile gloves should be worn at all times. If alcohol gets on skin, it should be washed off with soap and water. If alcohol gets in your eyes, they should be rinsed in the eye wash for several minutes. Then, go to a doctor.

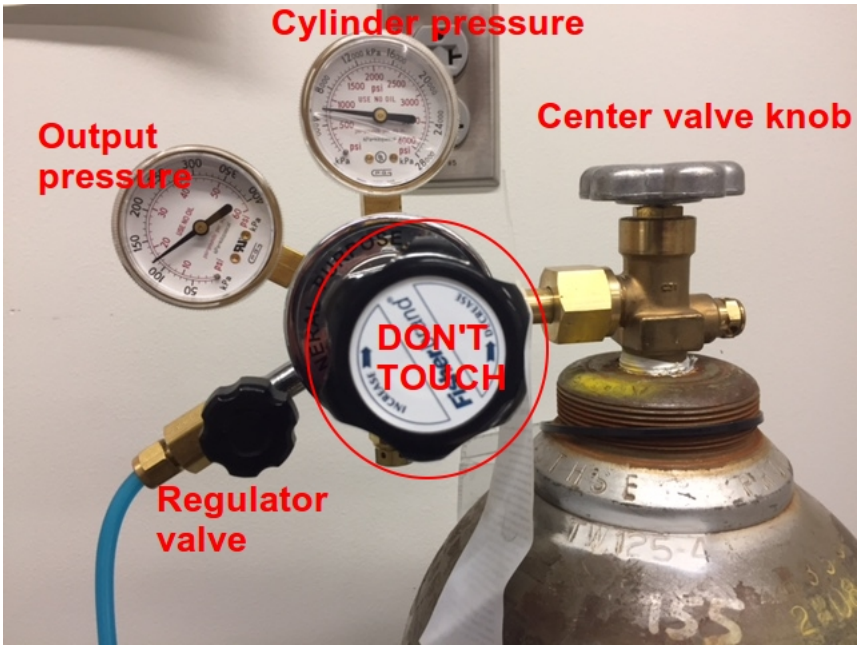

Figure 1: CO_2 tank with regulator attached. The regulator adjustment knob in the center should not be adjusted. The N_2 tank regulator is identical.

4 Leak Testing Procedure

4.1 Setup

1. Put on nitrile gloves that fit snuggly. These must be worn at all times when handling straws.

2. Check that the regulator is attached to CO_2 tank. Do not touch center regulator knob. Open both the gas cylinder and regulator exit valve completely. (Figure 1) If these are only partially opened, gas may leak from the valve.

3. Check cylinder pressure. If below 200 psi, stop using cylinder immediately. If below 500 psi, have Dan order a new cylinder.

4. Adjust flow meter on near pressure gauge to 10 scfh. Cover end of CO_2 nozzle with finger and confirm that the pressure on near pressure gauge reads 15.0±0.1 psi. If not, consult a supervisor.

4.2 Loading Straws

1. On N_2 tank, open center and regulator valves by a full turn. Make sure N_2 valve is closed on each leak chamber.

2. Insert nozzle into straw end-piece hose and let flush for 10 seconds. Meanwhile, apply a dab of vacuum grease to a hose plug, and plug hose on side opposite to CO_2 nozzle.

3. Apply dab of vacuum grease to another plug. On CO_2 hose side of straw, pinch end-piece hose with pliers and remove CO_2 hose. While continuing to pinch hose, insert plug into straw hose.

4. If testing entire pallet, inflate all straws and then carry loaded pallet over to loading station. For individual straws, slide inflated straw into a tube and skip to step 6.

5. Carefully lift each straw from one end and push it into a tube about 5 inches. Then pull the tube over the straw so that each straw is inside a tube and still on the pallet.

6. Make sure leak chambers are empty before sliding in tubes. Load desired straws into chambers.

7. With straw in chamber and the chamber open, open black N_2 valve lever on chamber so it will flush. Flush chamber for about 30 seconds. Flush only one chamber at a time.

8. After flushing, close black N_2 valve and seal chamber by turning the white lever to the left.

4.3 Measuring Leak Rate

1. Open the leak test GUI, titled "Leak Test GUI Launcher.py". It is located on the desktop. A picture of the right-half of the GUI is shown in figure 2.

2. Before loading or unloading straws, log into the worker portal. Do this by clicking the "log in" button at the top of the GUI and entering your worker ID.

3. Make sure straws have been properly loaded into the chambers, following section 4.2. Nitrogen supply should be cut off and the white lever should be closed.

4. To start taking data on a specific row, click the "Start Data" button below the desired chamber row. When a chamber row is active the square in which the number resides will turn green.

5. To load each straw, click "Load Straw", enter the straw ID, and click ok.

6. Straws take 60-90 minutes to test. A plot of the measured data can be viewed for each straw by clicking the "Plot" icon below each straw. This can be used to make sure straw leak rates are being measured correctly. A proper plot will have a strong linear trend.

4.4 Emptying Leak Chamber

1. When a straw is done testing it will light up either red or green. Green straws meet the minimum leak rate requirement, but red ones have failed.

2. Before physically removing finished straws, click "Unload", and make sure the straw name disappears from the GUI.

3. Open the white lever and use the magnetic grabber to gently remove the tube. Slide the straw out of the tube. Pick up straw by gently pulling straw hoses taut. Put straw back into spot on pallet. Pull hose plugs out of straw.

4. If a row has no straws being tested, click "Stop Data" to turn it off.

5. Repeat x21000

4.5 Cleanup

1. Make sure that N_2 and CO_2 cylinder and regulator valves are closed.

2. Put any extra straw end-piece hose plugs back into their container.

3. Wipe and clean any vacuum grease off of work surface with alcohol and paper towel.

4. Throw away gloves—they likely have vacuum grease on them.

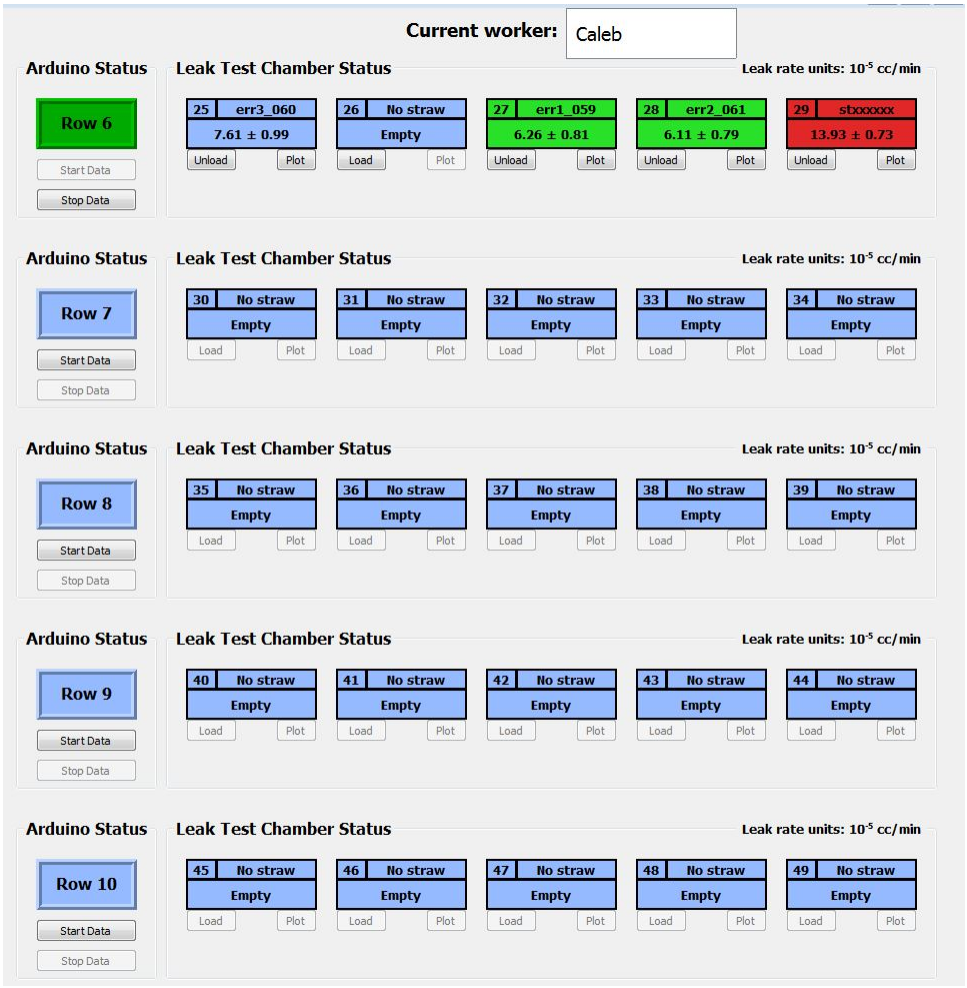

Figure 2: Right-half of the Leak Test GUI. Row 6 is the only row running. The straws with green backgrounds pass, the red one has failed, and the blue ones are either empty or still testing.

5 Troubleshooting

- **Problem:** One of the chambers isn't taking data.

  Solution: Make sure that the sensor cable is attached to the chamber, and is plugged securely into its Arduino port. If this doesn't work, sometimes the CO_2 level offset can be initially to low in the chamber. Open the straw loading valve and exhale for about half a second into chamber, then close valve. If this does not help, unplug Arduino from power supply for a minute. Then replug and try again. If the problem persists, ask for help.

- **Problem:** A straw is stuck in the chamber.

  Solution: Unplug sensor cable from chamber, and slide entire chamber off of rack. With the straw loading valve open and hold over valve, tip chamber upside down and try to shake straw out. If this doesn't work, try to grab onto the straw with claw grabber. If this doesn't work, consult manager.

- **Problem:** Starting a row causes the GUI to crash

  Solution: Likely an arduino error. Make sure the sensor cable is securely connected to the arduino port. If it is, unplug the arduino for 30 seconds and plug it back in.

- **Problem:** The straw I entered disappeared from the GUI

  Solution: The program is likely still collecting data, but the straw information is not showing up. Click "Load" and enter the straw ID again. The straw information should return right away. If not, ask a manager for help.

- **Problem:** I accidentally entered the wrong straw for a chamber.

  Solution: Empty the chamber in the program. Ask a manager to delete the incorrectly named file. Re-enter the correct straw in the leak test program.

- **Problem:** A straw is epoxied at the end-piece to the pallet, so I can't remove it.

  Solution: Carefully try to peel stuck end off of plastic. If it looks okay, leak test it as usual. If it is obviously damaged, cut damaged end off of straw and give to epoxy station to re-epoxy and end-piece in.

- **Problem:** A straw is stuck in the chamber.

  Solution: Unplug sensor cable from chamber, and slide entire chamber off of rack. With the straw loading valve open and hold over valve, tip chamber upside down and try to shake straw out. If this doesn't work, try to grab onto the straw with claw grabber. If this doesn't work, consult manager.