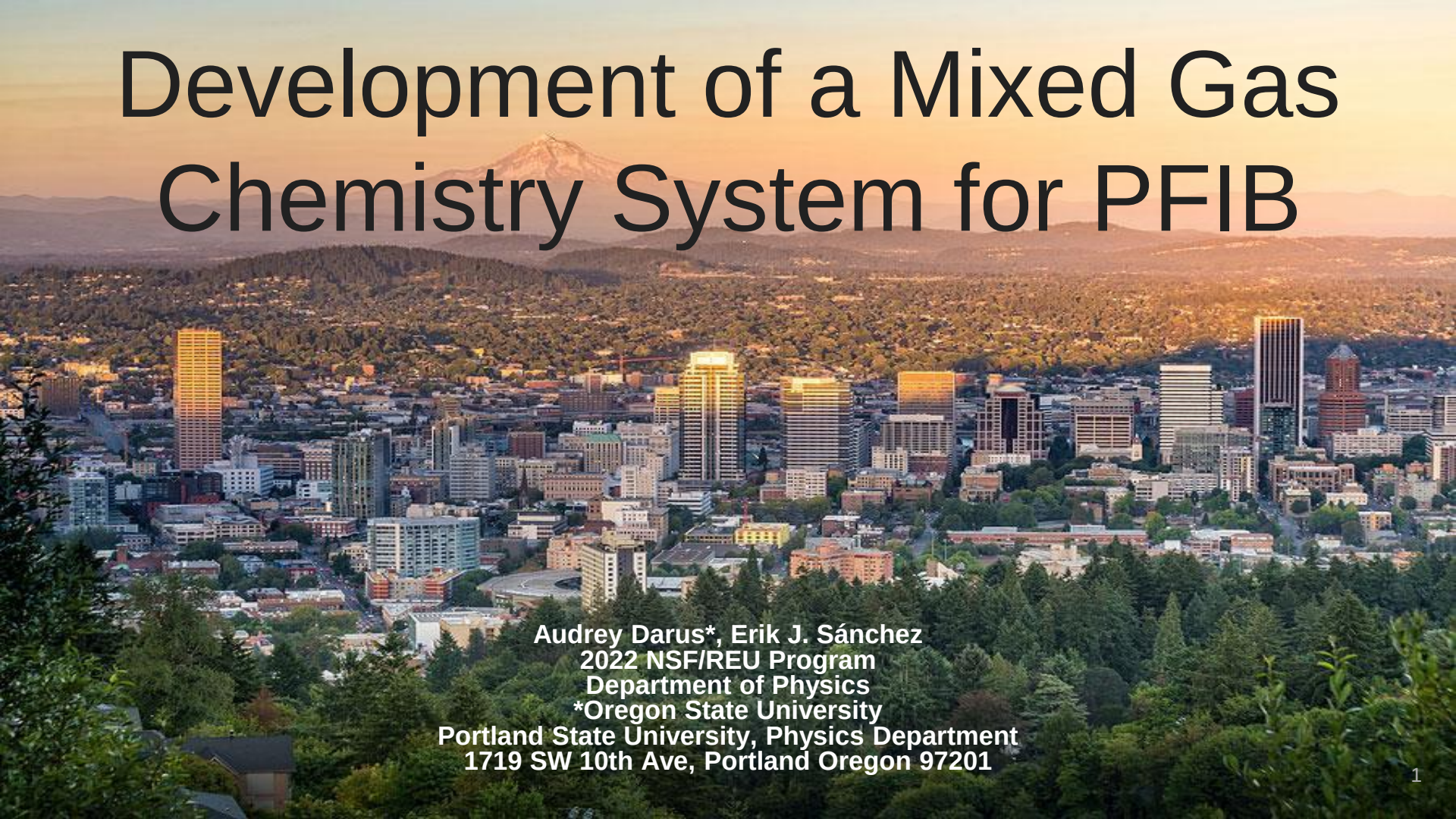
Development of a Mixed Gas Chemistry System for PFIB



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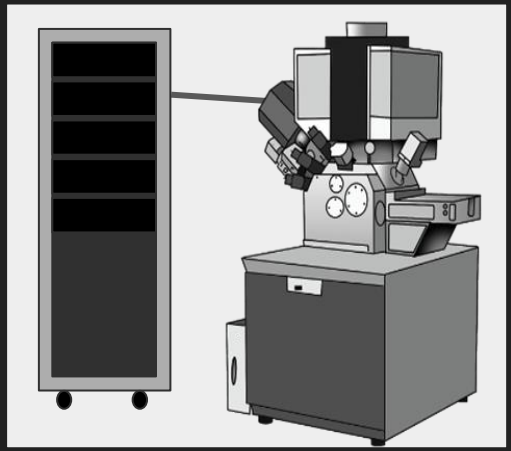
Focused Ion Beam: Gallium to Plasma

- A Focused Ion Beam (FIB) instrument allows a user to mill at micron & nano scale geometries, sputtering material to precise endpoints
    - Historically, the workhorse element has been gallium ion (Ga^+)
- A Plasma Focused Ion Beam (PFIB) has similar use cases to Ga^+ FIB, but uses elements such as Xenon to create an inductively coupled plasma of higher sputtering rates
    - Advantages of using PFIB over Ga^+ FIB include, greater beam currents, increasing throughput by 4x, allowing for greater volumes of material to be removed



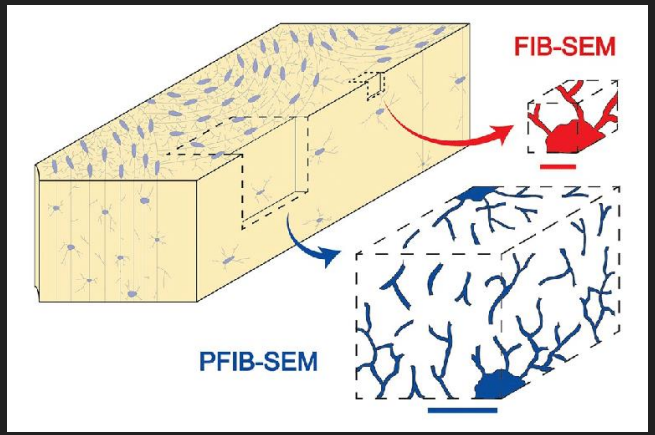


Fig. 1. “PFIB-SEM vs. FIB-SEM”

Fig 1. “PFIB-SEM vs. FIB-SEM”, *Ellipsoidal mesoscale mineralization pattern in human cortical bone revealed in 3D by plasma focused ion beam serial sectioning*, Journal of structural biology. 212. 107615. 10.1016/j.jsb.2020.107615. Binkley, Dakota & Deering, Joseph & Yuan, Hui & Gourrier, Aurelien & Grandfield, Kathryn. (-2020).

Gas Manifold: Where are they used?

- A network for the transportation and mixing gasses through a central supply line
- Advantages are safe and cost-effective alternatives to manually adjusting single gas canisters
- Commonly used in the oil, medical, food processing, and semiconductor industries

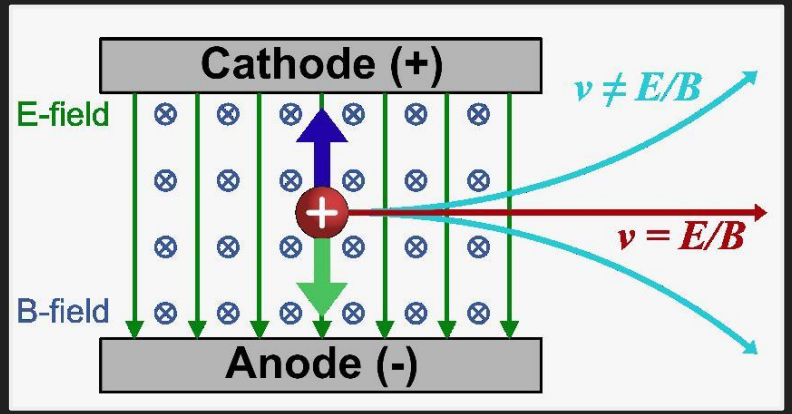
Gas Manifold System

Medical Gas Manifold System

Fig 2. “Gas Manifold” *Sri Venkateshwara Engineering*, https://www.sribalajiind.in/gas_manifold.html
Fig 3. “Medical Gas Manifold Systems” *Schönn Medizintechnik GmbH*, https://schoenn.de/medical-gas-manifold-systems/

Experimental Objective: Ignite Deuterium (D_2) Gas

- Applications used to overcome difficulties igniting D_2 into a plasma
- Using a Wien filter (fig. 1) multiple gasses being supplied to the PFIB will allow for D_2 to ignite and create a plasma
- Allows user to filter ions by mass and energy
- By precisely mixing deuterium with another gas to create a plasma, a Wien filter will allow a user to select only D_2 to travel down the PFIB beam

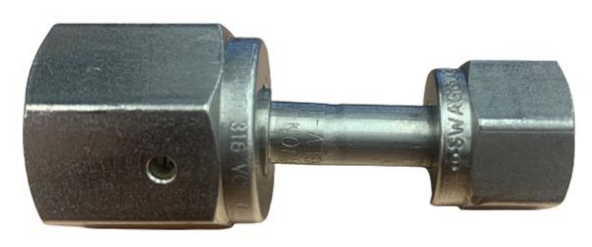


Wien filter Diagram

Fig. 4. “Wien filter”, *IBS Center for Exotic Nuclear Studies*, https://centers.ibs.re.kr/html/cens_en/facilities/infrastructure_0506.html?site_dvs_cd=cens_en&menu_dvs_cd=0506

Design Construction

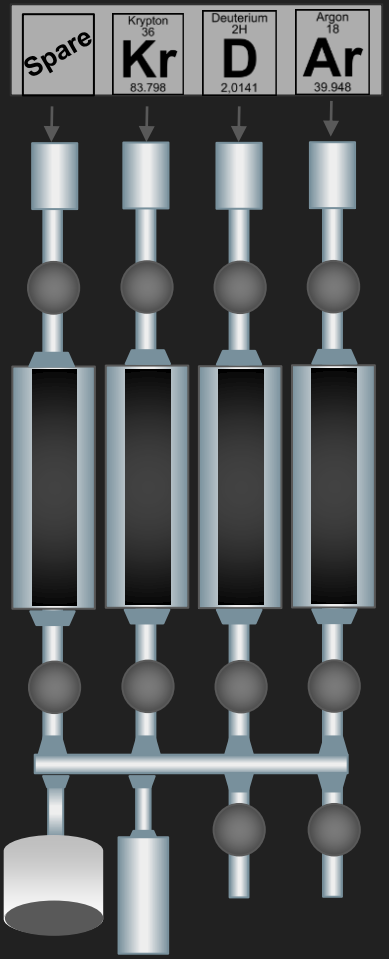
- Hardware was connected using ¼ stainless steel tubing, Swagelok fittings and VCR fittings
- Both fittings ensure a vacuum seal and no leaks

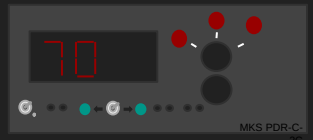


Swagelok Female Tube Fitting Connector

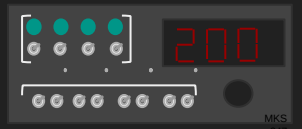
Parts

- Gas filter
  - For removal of trace particles within the gas
- Mass flow controller
  - automatically controls gas flow
- Pneumatic actuator
  - Valves which open and shut to allow flow
- Baratron
  - Measures true pressure of system





MKS PDR-C-2C Power Supply Readout: Displays pressure coming from Baratron



MKS Type 247 4-Channel Readout: User interface to control gas flow rates and mixing ratios

Solenoid valves: direct air into pneumatic actuator to open or close flow

Mass Flow Controller

- A mass flow controller (MFC) uses sensors which detect the flow of gas and contain electronics which analyze flow rates and mix ratio between two or more gasses
- A MFC is important in a gas manifold system because it allows for greater precision of mixing gas with lower risks of leaks

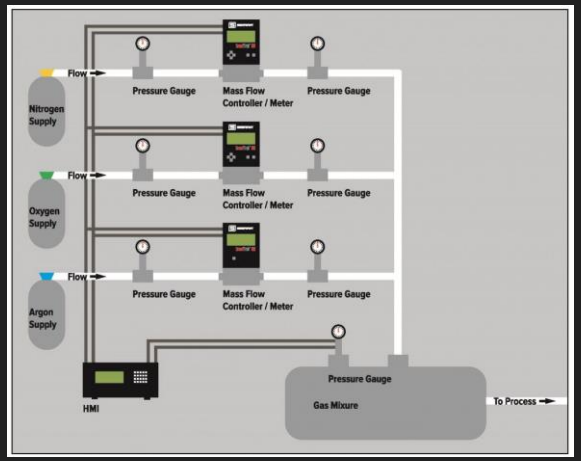
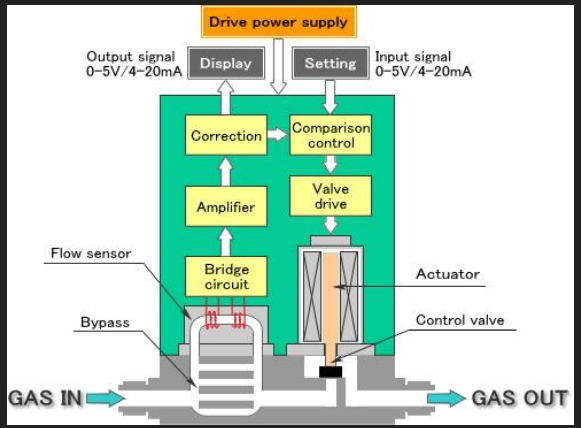


Diagram of Mass Flow System with Mass Flow Controllers



Mass Flow Controller Schematic

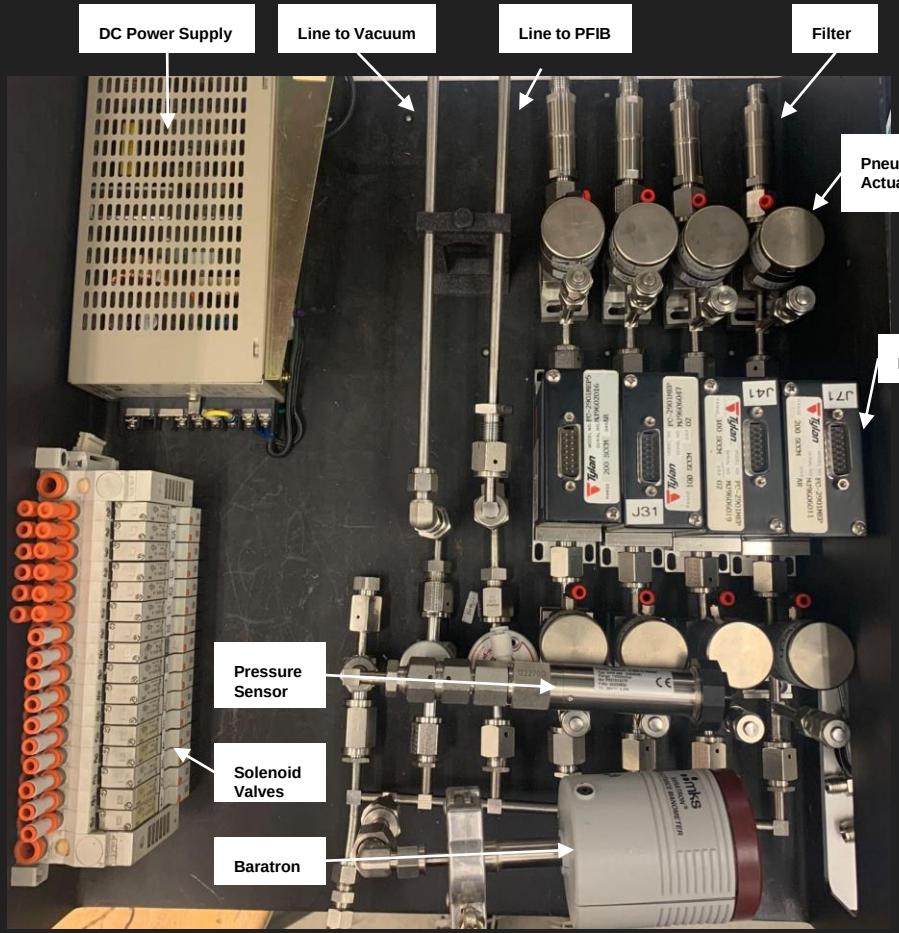
Fig 4. “Mass Flow System with Mass Flow Controllers”, *Complete Guide to Gas Mixing and Blending*, Sierra, 06 February 2019, https://www.sierrainstruments.com/blog/?complete-guide-gas-mixing-blending-sierra-instruments

Fig 5. “Structure of Mass Flow Controller”, *What is a Mass Flow Controller? Principle and structure of mass flow controllers,* FCON, http://www.fcon-inc.jp/en/en_MFC/Principle/Principle.html

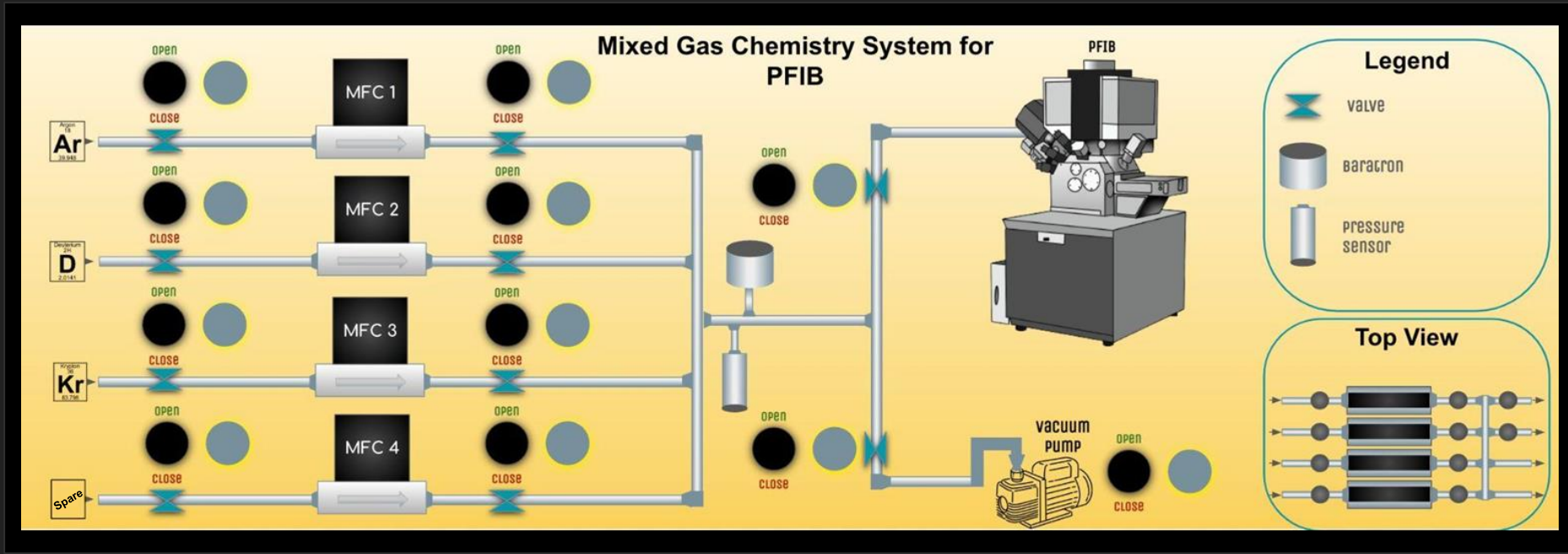
Physical set up

MKS Model 247 4-Channel Readout

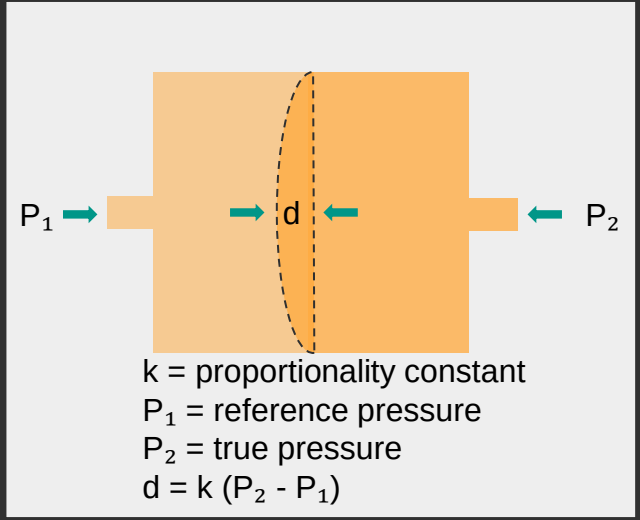
MKS PDR-C-2C Power Supply Readout



Front control panel: for manual operation



MKS Type 622 Baratron Capacitance Manometer

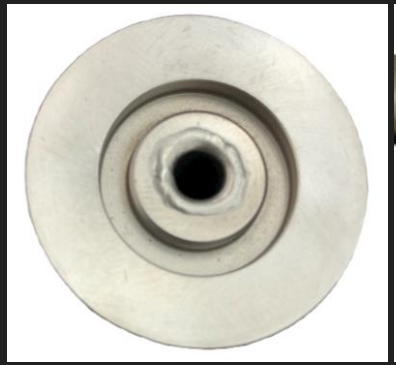


- The Baratron works by comparing a reference pressure against true pressure, by measuring deflection of a thin metal diaphragm

Baratron connection to line: Process

Opening of Baratron incompatible with tube connections

KF 16 blank



¼ “ hole created with mill

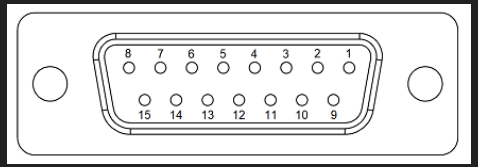
Tubing tungsten inert gas (TIG) welded to milled hole

Swagelok fitting added

Now able to attach to line with O-ring and clamp

Electrical Connections

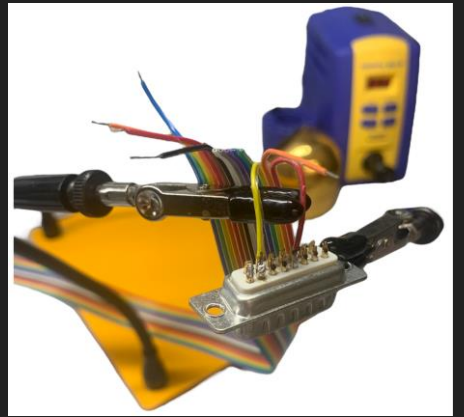
- Device operator manuals contain information regarding compatible pin output configuration
- Physical connections are created by soldering wires to device pins and testing with a multimeter



DB 15 pin-out diagram

Wire corrected for Baratron connection

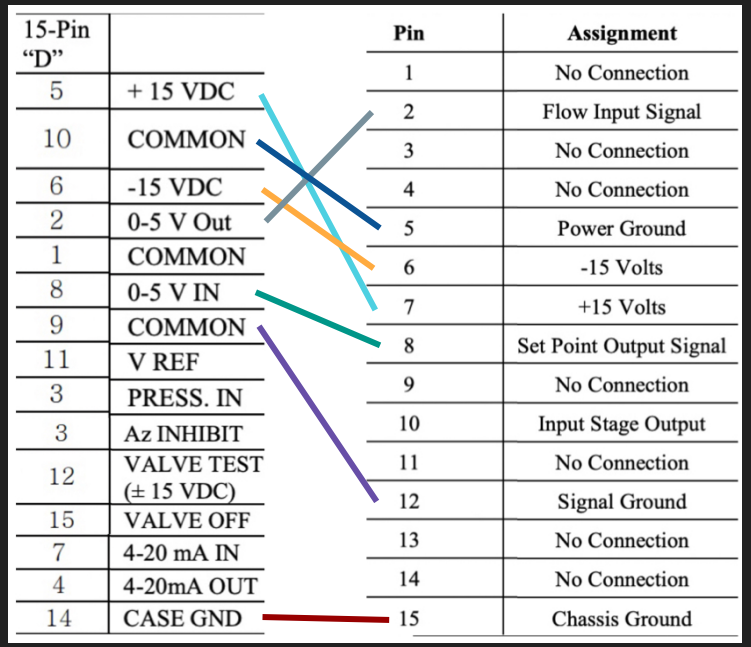
Digital Multimeter



Soldering process

Troubleshooting

- Often connection tables in manuals do not match up, it is up to the user to determine proper connections
- Dangers of connecting wires improperly include electrical shorts, device damage, or malfunctions



15-Pin "D"	
5	+ 15 VDC
10	COMMON
6	-15 VDC
2	0-5 V Out
1	COMMON
8	0-5 V IN
9	COMMON
11	V REF
3	PRESS. IN
3	Az INHIBIT
12	VALVE TEST (± 15 VDC)
15	VALVE OFF
7	4-20 mA IN
4	4-20mA OUT
14	CASE GND

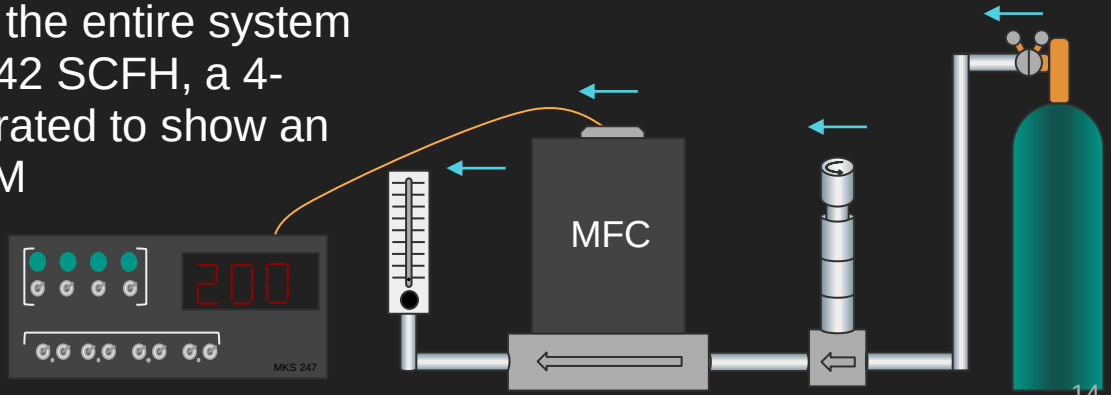
Pin	Assignment
1	No Connection
2	Flow Input Signal
3	No Connection
4	No Connection
5	Power Ground
6	-15 Volts
7	+15 Volts
8	Set Point Output Signal
9	No Connection
10	Input Stage Output
11	No Connection
12	Signal Ground
13	No Connection
14	No Connection
15	Chassis Ground

MFC to 4-Channel Readout Connections

Testing Wires and Readout Calibration

- Tubing from an Argon gas tank led to a needle valve and an MFC with a flow meter following the MFC.
- The flowmeter has a scale of 0.1-1.0 standard cubic feet per hour (SCFH). The maximum flow rate for the MFC is 200 standard cubic centimeters per minute (SCCM)
- Gas flow in series ensures there will be an identical flow rate throughout the entire system
- When the flowmeter reads 0.42 SCFH, a 4-channel readout can be calibrated to show an equivalent value of 200 SCCM

Test setup



Ar gas flowing in series through valve, MFC, and flowmeter

Next steps

- Connect solenoid valves to pneumatic actuators with tubing for testing with a DC power supply
- Test the connection between the Baratron and its PDR-C-2C readout
- Integrate manifold system into 19” rack to connect to vacuum pump and PFIB
- Create a graphical user interface (GUI) to allow for valves to be switched on and off by way of software

Acknowledgment

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Thank you for listening

Questions?