Molbox2 Basics

Topics

- Overview of molbox/molbloc calibration system
- molbox2
- Molbloc-L
- Molbloc-S
- Upgrades
- Molstics
- COMPASS for Flow

Overview

- Molbox/molbloc introduced in ~ 1993 in response to need in semiconductor industry
- Solution to calibrate “low” gas flow instruments
- Core system consists of a molbox2 flow terminal and at least 1 molbloc flow element
- Can include molstic(s) accessory and COMPASS for Flow calibration Software

Common molbloc/molbox user industries

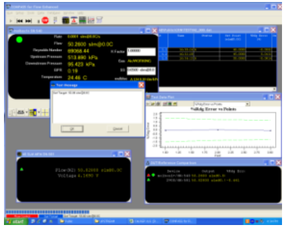
- MFC manufacturers – large user base for manufacturing & service calibrations
- Biopharm & Semiconductor – process MFC calibration
- Environmental & auto emissions- calibrate gas blenders and transfer standards for monitor testing
- Nuclear – Leak rate tester calibration
- Aerospace – military applications and general aviation – many flow devices to support, especially around life support (breathing air) systems.
- Petrochem pilot/research plants – not refineries. They use Brooks MFCs
- Fuel Cell testing – manufacturers or large users of FCs perform testing. Usually higher flows in H2.
- Specialty gas companies – dynamic gas blending
- General metrology – NMI's use molbloc to GFS and successive addition. NIST humidity lab application.

molbloc/molbox system components

FLUKE® Calibration

molbox flow measurement terminal measures pressures and temperatures of **molbloc** elements to calculate flow.

A typical system may have multiple molblocs, accessories and software all working together



COMPASS software

molstics

molbox2

MFC-CB accessory

Typical device under test

molblocs

Molbox2

The molbox2 is a flow computer that calculates flow based on the type of molbloc connected (-L or –S) and flowing conditions of the gas. Using data stored on the molbloc, output of various sensors and thermodynamic details of the flowing gas, flow is calculated within stated uncertainties.

Majority of changes from molbox1 and 1+ are benefits related to use of molbloc-L

- Upgrading to NIST Flow Model and REFPROP 10 allows for stated uncertainties to be available for all gases in molbox2 system
- An accredited measurement uncertainty on a gas for which the molbloc is not calibrated (N_2, Air, He, Ar, H_2, C_3H_8, SF_6, N_2O, CO_2, CH_4)
- Added 7 additional gases for a total of 28, traceable measurements with rest of gasses molbox2 supports
- Room for an additional 36 gases (64 total), including gas mixtures with gases that are included in NIST data.
- Impetus for molbox2 was to allow for customers to use SF_6 with accredited uncertainty, but with Fluke no longer having to use it.

Molbox2

The NIST Flow Model will only be available on molbox2 which has the newest microprocessor and firmware. Older molboxes would have to have the boards replaced

Additional molbox2 features:

- Backward compatible with older molblocs
- Accredited/traceable measurement with other gases only available with molbloc-L-2
- New board allows for a 3.5 x faster response time of 340ms compared to 1.4 seconds. Especially helpful for use with molbloc-S which tend to be less stable.

molbox2

- Flow terminal/computer
  - REFPROP 10 Gas Properties Database
  - User interface to run calibration process
  - Pressure transducers to measure molbloc pressures
  - Resistance circuitry to read PRT and determine temperature
  - Two channels to allow two concurrent molbloc connections
  - Calculates the flow based on temperature and pressure gas properties and NIST Model
  - Optional MFC option

Company Confidential

molbox Flow Terminals

- 4 versions presently available

  - Molbox2-A700K(-MFC) (100 psia)
    (the most common)
  - Molbox2-A350K(-MFC) (50 psia)
  - Molbox2-A2M(-MFC) (300 psia)
  - Molbox2-A1.4M(-MFC) (200 psia)

Legacy versions -

- Molbox1 – Tradeup program or trade in for 15% promo discount
- Molbox1+ – Tradeup program or trade in for 15% promo discount
- Molbox RFM – 15% promo trade in discount

FLUKE® Calibration

molblocs

Physically stable, highly precise flow elements that work in tandem with molbox terminal to accurately calculate mass flow. Laminar and sonic technologies. Transmit pressure and temperature conditions to molbox along with unique calibration coefficients

Calibration chain = customer molblocs calibrated/compared against reference molblocs which trace back to primary standard. (GFS)

molbloc-L (laminar flow elements)

- 10 sccm to 100 slm ranges

molbloc-S (sonic nozzles)

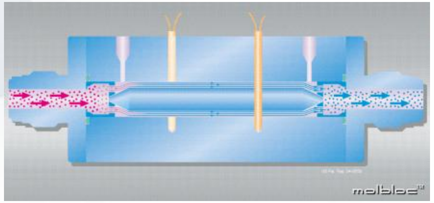
- ranges up to 6000 slm

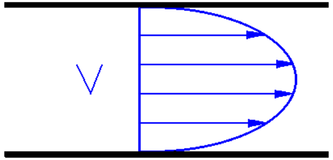
molbloc - L

FLUKE Calibration

P1 P2

P1 P2





molbloc-L (laminar flow elements)

- 10 sccm to 100 slm ranges

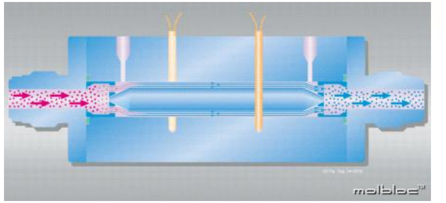
$$qm = \frac{(P_1 - P_2) \bullet \rho_{(P,T)} \bullet \pi \bullet R \bullet h^3}{\eta_{(P,T)} \bullet 6 \bullet L}$$

Mass flow rate is proportional to differential pressure $P_1 - P_2$

Temperature is also an important parameter, this type of laminar flow element was designed to “force” the gas to take on the temperature of the element

molbloc-L element fundamentals

- High differential pressure relative to traditional LFEs
- Large surface area, low volume flow path for heat exchange (isothermal expansion - gas takes on temperature of molbloc)
- Filter integrated in upstream fitting, and electro-polished flow path surfaces reduce calibration shift caused by contamination
- Mechanically fixed construction defines flow path permanently
- Characterized over range of flows (Re) and line pressures
- Independent calibration for each gas
- Calibration coefficients stored in on-board EEPROM.
- Flow starts from zero
- Maximum flow rate of 100 slm
- Designated as xEx-L-2, e.g. 3E4-L-2
    - Older: xEx-VCR-V-Q e.g.3E4-VCR-V-Q



molbloc-L calibration pressure options

Upstream, low P (standard)

200-325 kPa abs (15-33 psig) upstream of molbloc-L

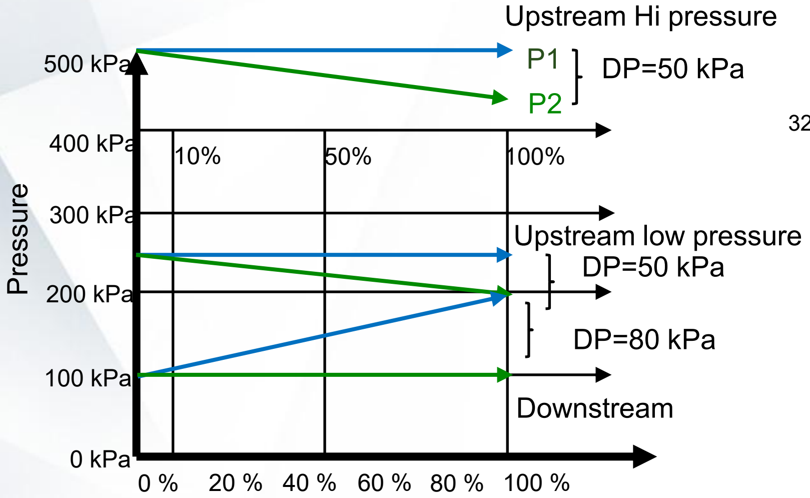
Upstream, high P

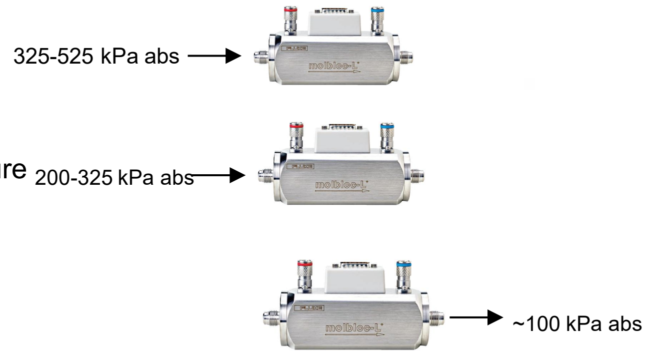
325-525 kPa abs (33-63 psig) upstream of molbloc-L

Downstream

~100 kPa abs downstream of molbloc-L (molbloc outlet vents to atmosphere)

NOTE: Hi Pressure calibrations double the flow range





Remember - Mass flow rate is proportional to differential pressure

molbloc-L Ranges

molbloc-L ranges with low pressure and downstream calibrations

			molbloc size and full scale flow (sccm @ 0 °C)									
			Size									
	Gasses		1E1	5E1	1E2	2E2	5E2	1E3	5E3	1E4	3E4	1E5[3]
Inert	Nitrogen	N_2	10	50	100	200	500	1 000	5 000	10 000	30 000	100 000
Inert	Argon	Ar	10	50	100	200	500	1 000	5 000	10 000	30 000	80 000
Inert	Helium	He	10	50	100	200	500	1 000	5 000	10 000	30 000	100 000
Inert	Sulfur hexafluoride	SF_6	10	50	100	200	500	1 000	**2 000 500**	**6 000 1 000**	**6 000 4 000**	-
Inert	Xenon	Xe	10	40	80	150	400	800	**3 000 500**	8 000	**11 000 3 000**	**30 000 20 000**
Inert	Neon	Ne	10	50	100	100	500	1 000	5 000	10 000	20 000	60 000 6 000
Inert	Krypton	Kr	10	50	100	200	500	1 000	5 000	10 000	20 000	70 000 8 000
Flammable	Butane	C_4H_{10}	20	100	**130 30**	**270 50**	**670 140**	2 300	**2 200 1 400**	**7 000 3 000**	-	-
Flammable	Ethane	C_4H_6	20	100	200	400	1000	2 000	**6 000 1 000**	**18 000 2 000**	**18 000 6 000**	**60 000 50 000**
Flammable	Ethylene	C_4H_4	16	80	160	320	800	1 600	**7 000 1 000**	16 000	**20 000 5 000**	**70 000 40 000**
Flammable	Hydrogen	H_2	20	100	200	400	1 000	2 000	10 000	20 000	60 000	200 000
Flammable	Methane	CH_4	16	80	160	320	800	1 600	8 000	16 000	**40 000 5 000**	**120 000 40 000**
Flammable	Propane	C_3H_8	20	100	200	400	1 000	2 000	**3 000 1 000**	**10 000 2 000**	**10 000 7 000**	-
Flammable	Propylene	C_3H_6	20	100	200	400	1 000	2 000	5 000	10 000 3 000	15 000 8 000	-
Flammable	Acetylene	C_2H_2	20	100	200	400	1 000	2 000	10 000	20 000	25 000 7 000	80 000 20 000
Flammable	IsoButane	iC_4H_{10} (iBtn)	20	100	200	300	700	2 000	3 000 1 000	10 000 3 000	10 000 9 000	-
Flammable	Deuterium	D_2	20	100	200	300	800	2 000	10 000	20 000	50 000	160 000 16 000
Flammable	Natural Gas	NG	20	100	200	400	900	2 000	10 000	20 000	50 000	120 000 18 000
Fluoro-carbons	Carbon tetrafluoride	CF_4	10	50	100	200	500	1 000	**4 000 600**	10 000	**12 000 3 000**	**36 000 25 000**
Fluoro-carbons	Hexafluoroethene	C_2F_6	10	50	100	200	500	1 000	**2 000 600**	**6 000 1 200**	**6 000 4 000**	-
Fluoro-carbons	Trifluoromethane	CHF_3	10	50	100	200	500	1 000	4 000 600	10 000	**12 000 4 000**	**38 000 30 000**
Other	Air	Air	10	50	100	200	500	1 000	5000	10 000	30 000	100 000
Other	Carbon dioxide	CO_2	10	50	100	200	500	1 000	5000	10 000	**20 000 4 000**	**60 000 30 000**
Other	Carbon monoxide	CO	10	50	100	200	500	1 000	5000	10 000	30 000	100 000
Other	Nitrous oxide	N_2O	10	50	100	200	500	1 000	5000	10 000	**20 000 4 000**	**60 000 30 000**
Other	Octafluorocyclobutane[1]	C_4F_8	15	**60 9**	**67 17**	**130 34**	**330 84**	**1 100 175**	**1 050 840**	**3 400 1 700**	-	-
Other	Oxygen	O_2	10	50	100	200	500	1 000	5000	10 000	30 000	80 000

FLUKE ® Calibration

molbloc-L Ranges

High pressure calibrations

	Gasses		molbloc size and full scale flow (sccm @ 0 °C)									
			Size									
	Gasses		1E1	5E1	1E2	2E2	5E2	1E3	5E3	1E4	3E4	1E5
Inert	Nitrogen	N_2	20	100	200	400	1 000	2 000	10 000	20 000	**50 000 7 500**	N/A
	Argon	Ar	20	100	200	400	1 000	2 000	10 000	17 000	**45 000 6 000**	N/A
	Helium	He	20	100	200	400	1 000	2 000	10 000	20 000	65 000	N/A
	Sulfur hexafluoride	SF_6	25	**100 15**	**120 30**	**250 50**	**600 150**	**2 000 300**	**2 000 1 400**	**6 200 2 800**	**- -**	N/A
	Xenon	Xe	20	100	150	150	650	1 700	**3 350 950**	**11 000 1 900**	**11 000 5 700**	N/A
	Neon	Ne	10	100	100	100	1 000	1 000	10 000	10 000	40 000	N/A
	Krypton	Kr	20	100	200	200	1 000	2000	**6 000 1 000**	20 000	**20 000 5 000**	N/A
Flammable	Butane	C_4H_{10}	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Ethane	C_4H_6	40	200	**350 50**	**750 100**	**1 800 200**	4 000	**6 000 2 300**	**20 000 4 500**	**20 000 13 000**	N/A
	Ethylene	C_4H_4	40	200	350	700	2 000	4 000	**7 000 1 000**	**2 000 4 000**	**22 000 12 700**	N/A
	Hydrogen	H_2	40	200	400	900	2 000	4 500	22 000	45 000	130 000	N/A
	Methane	CH_4	35	175	350	700	1 700	3 500	**13 000 2 000**	33 000	**42 000 12 000**	N/A
	Propane	C_3H_8	50	**200 25**	**200 50**	**400 100**	**1 000 250**	**3 500 500**	**3 500 2 600**	**11 000 5 400**	**- -**	N/A
	Propylene	C_3H_6		100	200	400	1 000	2 000	5 000	**10 000 3 000**	**15 000 8 000**	- -
	Acetylene	C_2H_2		100	200	400	1 000	2 000	10 000	20 000	**25 000 7 000**	**80 000 20 000**
	IsoButane	iC_4H_{10} (iBtn)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Deuterium	D_2	30	200	300	600	2 000	3 000	20 000	20 000	50 000	**160 000 16 000**
	Natural Gas	NG	20	200	300	700	2 000	3 000	**13 000 2 000**	40 000	**40 000 10 000**	**120 000 18 000**
Fluoro-carbons	Carbon tetrafluoride	CF_4	30	100	200	400	1 000	2 000	**3 700 1 200**	**12 000 2 400**	**12 000 7 300**	N/A
	Hexafluoroethene	C_2F_6	25	**100 15**	**120 30**	**250 50**	**600 150**	**2 000 300**	**1 800 1 500**	**6 000 3 000**	**- -**	N/A
	Trifluoromethane	CHF_3	25	125	**240 30**	**450 60**	**1 200 150**	2 500	**4 000 1 500**	**12 000 3 000**	**12 000 8 800**	N/A
Other	Air	Air	20	100	200	400	1 000	2 000	10 000	20 000	**50 000 7 200**	N/A
	Carbon dioxide	CO_2	25	125	250	500	1 250	2 500	**6 600 1 400**	**20 000 2 500**	**20 000 8 800**	N/A
	Carbon monoxide	CO	20	100	200	400	1 000	2 000	10 000	20 000	40 000 7 500	N/A
	Nitrous oxide	N_2O	25	125	250	500	1 250	2 500	**11 000 1 500**	**20 000 3 000**	**20 000 9 000**	N/A
	Octafluorocyclobutane[1]	C_4F_8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Oxygen	O_2	20	100	200	400	1 000	2 000	10 000	20 000	**40 000 6 500**	80 000

Molbloc-L-2 uncertainty

When used with molbox2, uncertainty is:

- ± 0.2 % of reading or ± 0.02 % FS, whichever is greater (standard calibration), ±0.5% reading/±0.125% FS for 1E5 molbloc

- ± 0.125 % of reading or ± 0.0125 % FS, whichever is greater (premium calibration), Not available on 1E1 and 1E5 molblocs

For gases in which we calibrate the molbloc

Molbloc-L-2 uncertainty

When used with molbox2, uncertainty is:

- ± 0.5 % of reading or ± 0.05 % FS, whichever is greater when flowing accredited and traceable gas for without a molbloc calibration in that gas.
- >± 0.5 % of reading or >± 0.05 % FS, when flowing traceable gases that molbox supports.

molbloc-L Uncertainty

Uncertainty when flowing gas for which molbloc was not calibrated

Uncertainty with NIST REFPROP10 + Actual N_2 gas calibration

Gas library		% Uncertainty using NIST REFPROP10 + actual N_2 gas calibration	A2LA Accredited + Traceable	Traceable
nitrogen*	N_2	0.2 or 0.125	X	
helium*	He	0.5	X	
argon*	Ar	0.5	X	
hydrogen*	H_2	0.5	X	
oxygen	O_2	2		X
methane*	CH_4	0.5	X	
ethylene	C_2H_4	5		X
air*	Air	0.5	X	
R116 Hexafluoroethane	C_2F_6	5		X
nitrous oxide*	N_2O	0.5	X	
R14 Carbon Tetrafluoride	CF_4	1.3		X
sulfur hexafluoride	SF_6	0.5	X	
R143a Triflouromethane	CHF_3	10		X
carbon dioxide*	CO_2	0.5	X	
propylene	C_3H_6	3.7		X
propane*	C_3H_8	0.5	X	
ethane	C_2H_6	0.5		X
carbon monoxide	CO	1.1		X
butane	C_4H_{10}	1.5		X
xenon	Xe	1		X
acetylene	C_2H_2	20		X
RC318 Octofluorocyclobutane	C_4F_8	1.9		X
neon	Ne	3		X
krypton	Kr	3		X
isoButane	iC_4H_{10}	0.5		X
deuterium	D_2	5		X
NG	Natural Gas	0.5		X
HeOx	HeliOx 79/21	2		X

*Actual gas calibrations available at ±0.2% rdg uncertainty (standard) or ±0.125% rdg uncertainty (premium)

Molbloc-L-2 vs molboc-L

- Any legacy molbloc can be used with molbox2
- To take advantage of the new gas features customer must use molbloc-L-2
- Molbloc-L-2 cannot be used with legacy molbox1/1+
- If customer is adding a molbloc to an existing molbox1 system and not upgrading to molbox2, we should offer legacy molbloc xEx-VCR-V-Q.

E.g 1E2-VCR-V-Q 3069627 1E2 LAMINAR MOLBLOC FLOW ELEMENT

vs.

1E2-L-2 6084583 1E2 LAMINAR MOLBLOC FLOW ELEMENT

molbloc-L gas calibration

FLUKE® Calibration

- The default gas calibration for a molbloc-L is standard in upstream, Lo P N2.
  - Can substitute upstream, hi P or downstream
  - Can substitute premium calibration with price adder
- Need to specify other gases in which to calibrate each molbloc, both uncertainty type and pressure condition
- To operate in other gases with standard or premium uncertainty, molbloc must be calibrated in that gas.

e.g. 3E4 molbloc

Default Calibration, low P N2, Std

3E4-L-2	6084605	3E4 LAMINAR MOLBLOC FLOW ELEMENT
MOL-L GAS CAL	3534520	FULL MOD, LO P, >5E1, PREM AIR

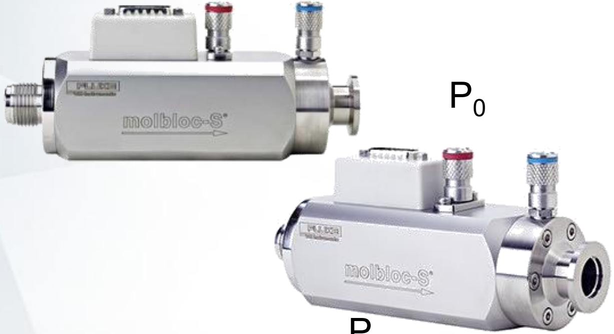
Adding Premium Air Calibration, Hi P

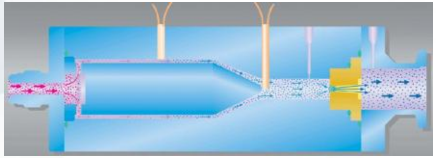
molbloc-S-2

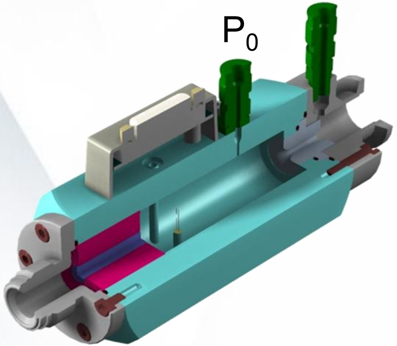
- Introduced in 2002. Extends molbloc high flow capability above 100 slm to greater than 20000 slm (Phoenix is accredited to 6000 slm)
- Same “transfer standard” approach as molbloc-L
  - Solid metrological implementation of an appropriate existing technology - providing usable system to user
- Compatible with same molbox2
- Same specifications as laminar molblocs
  - ±0.2% of reading uncertainty with molbox1+ (standard)
  - ±0.125% of reading uncertainty with molbox1+ (premium)
- No specifications for flowing gases for which the molbloc is not calibrated

molbloc - S

FLUKE ® Calibration







molbloc-S (sonic nozzles)

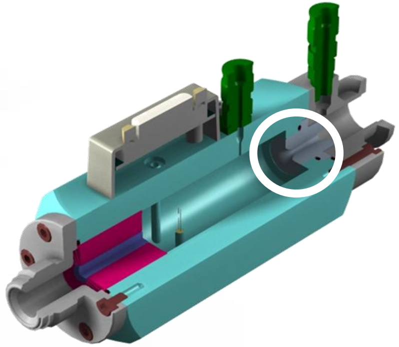
- ranges up to 6000 slm

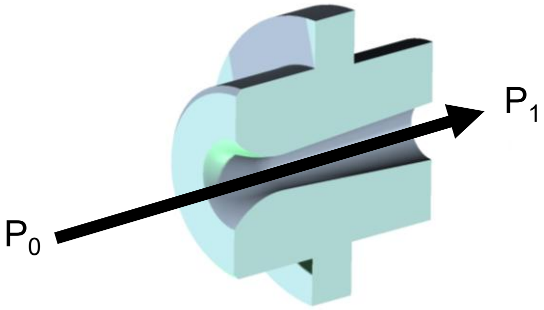
$$q_m = \frac{A^* \times C \times C_R \times P_0}{\sqrt{(R/M)T_0}}$$

Mass flow rate is proportional to absolute pressure P_0 once the nozzle is choked, meaning the BPR remains below the critical value.

How does it work?

Gas enters the nozzle at P0, is compressed and speeds up. Maximum speed is at smallest diameter of nozzle. Maximum velocity will be the speed of sound if P1 is about ½ of P0.





Flow will be amount of gas that can pass through the throat diameter @ the density of the gas @ the speed of sound

Ensuring critical flow in molbloc-S

- In practice the molbloc-S technology requires that the ratio of the outlet to inlet absolute pressure **(known as the back pressure ratio, or BPR)** be less than a pre-defined critical value. This ensures flow is critical and molbloc-S flow calculation is valid
- The BPR value is dependent on molbloc-S size and is empirically determined by Fluke Calibration.
- molbox terminal monitors BPR and indicates to the user when reliable measurements can (and cannot) be made.
- Mass flow rate is proportional to absolute pressure P_0
- Can use a vacuum pump downstream of molbloc to lower P1 and therefore extend the range of a molbloc-S

molbloc-S element fundamentals

- Integrated flow conditioner and heat exchanger
- Redundant integrated temperature probes
- Redundant absolute inlet pressure measurement by molbox
- Real time calculated output with sonic nozzle, updates every 340 ms
- Use of nozzle over wide pressure (and Re) range
- Independent calibration for each gas
- Calibration coefficients stored in on-board EEPROM.
- Gas speed defined by physical laws - speed of sound
- Extremely linear, stable and insensitive to contamination
- Designated as xEx-S-2, e.g 5E2-S-2
    - Old xEx-S, e.g. 5E2-S

molbloc-S-2 calibration pressure options

Standard Pressure (SP) calibration range:

- 50 to 600 kPaa Upstream Pressure

Low Pressure (LP) calibration range:

- 20 to 200 kPaa Upstream Pressure

High Pressure (HP) calibration range*:

- 200 to 2000 kPaa Upstream Pressure *requires higher pressure molbox1+

P?

Remember - Mass flow rate is proportional to inlet pressure assuming critical BPR is met

molboc-S mass flow rate (slm @ 0 ° C) when molboc-S upstream pressure is: 1,2										
Designator	KF (sccm/kPa)	20 kPa (3 psia)	50 kPa (7 psia)	100 kPa (15 psia)	Minimum without vacuum3	200 kPa (30 psia)	600 kPa (87 psia)	800 kPa (116 psia) (typ. compressor)	1.2 MPa (174 psia)	2 MPa (290 psia)
1E1-S	10	0.2	0.5	1	1.8	2	6	8	12	20
2E1-S	20	0.4	1	2	3.2	4	12	16	24	40
5E1-S	50	1	2.5	5	7.7	10	30	40	60	100
1E2-S	100	2	5	10	15	20	60	80	120	200
2E2-S	200	4	10	20	28	40	120	160	240	400
5E2-S	500	10	25	50	67	100	300	400	600	1000
1E3-S	1000	20	50	100	129	200	600	800	1200	2000
2E3-S	2000	40	100	200	248	400	1200	1600	2400	4000
5E3-S	5000	100	250	500	596	1000	3000	4000	6000	10000

Molbloc-S Range Chart

molbloc-S ranges with high pressure, standard pressure and low pressure calibrations

				molbloc-S size, KF (sccm/kPa), and full scale flow (slm @ 0 °C)										
				Size	1E1-S	2E1-S	5E1-S	1E2-S	2E2-S	5E2-S	1E3-S	2E3-S	5E3-S	1E4-S
				KF (sccm/kPa)	10	20	50	100	200	500	1000	2000	5000	10000
Gases			Ratio	Cal type										
Inert	Nitrogen	N_2	1.000	HP	20.00	40.00	100.0	200.0	400.0	1000.0	2000	4000	10000	20000
				SP	6.00	12.00	30.0	60.0	120.0	300.0	600	1200	3000	6000
				LP	2.00	4.00	10.0	20.0	40.0	100.0	200	400	1000	2000
				minimum w/o vac	2.00	3.50	7.7	15.0	28.0	67.0	129	248	596	1173
	Argon	Ar	0.837	HP	16.74	33.49	83.7	167.4	334.9	837.2	1674	3349	8372	16744
				SP	5.03	10.0	25.1	50.3	100	251	503	1004	2512	5023
				LP	1.67	3.35	8.4	16.7	33.5	83.7	167	335	837	1674
				minimum w/o vac	1.70	3.00	6.5	12.9	23.3	57.1	108	208	498	996
	Helium	He	2.647	HP	52.94	105.87	264.7	529.4	1058.7	2646.8	5294	10587	26468	52936
				SP	15.9	31.8	79.4	159	318	794	1588	3176	7940	15881
				LP	5.29	10.59	26.5	52.9	105.9	264.7	529	1059	2647	5294
				minimum w/o vac	9.40	13.10	25.7	51.4	91.5	199.4	399	695	1738	3281
	Sulfur hexafluoride	SF_6	0.435	HP	8.70	17.39	43.5	87.0	173.9	434.8	870	1739	4348	8695
				SP	2.6	5.2	13.1	26	52	130	260	522	1304	2609
				LP	0.87	1.74	4.3	8.7	17.4	43.5	87	174	435	870
				minimum w/o vac	0.80	1.40	3.1	5.9	11.4	26.9	54	100	250	500
	Xenon	Xe	0.460	HP	9.21	18.42	46.0	92.1	184.2	460.4	921	1842	4604	9209
				SP	2.8	5.5	13.8	28	55	138	276	552	1381	2762
				LP	0.92	1.84	4.6	9.2	18.4	46.0	92	184	460	921
				minimum w/o vac	0.80	1.40	3.6	6.5	12.9	29.7	59	110	267	529
Flammable	Ethane	C_2H_6	0.960	HP	19.21	38.42	96.0	192.1	384.2	960.4	1921	3842	9604	19208
				SP	5.8	11.5	28.8	58	115	288	576	1152	2881	5762
				LP	1.92	3.84	9.6	19.2	38.4	96.0	192	384	960	1921
				minimum w/o vac	1.50	3.00	6.7	13.4	25.2	61.9	119	229	552	1104
	Ethylene	C_2H_4	0.996	HP	19.92	39.83	99.6	199.2	398.3	995.8	1992	3983	9958	19916
				SP	6.0	12.0	29.9	60	120	299	598	1195	2987	5975
				LP	1.99	3.98	10.0	19.9	39.8	99.6	199	398	996	1992
				minimum w/o vac	1.70	3.10	7.5	13.9	27.7	64.2	128	237	572	1144
	Hydrogen	H_2	3.730	HP	74.60	149.19	373.0	746.0	1491.9	3729.8	7460	14919	37298	74596
				SP	22.4	44.8	112	224	448	1119	2238	4476	11189	22379
				LP	7.46	14.92	37.3	74.6	149.2	373.0	746	1492	3730	7460
				minimum w/o vac	8.30	14.50	36.2	62.5	114.5	280.9	509	980	2312	4623
	Methane	CH_4	1.320	HP	26.40	52.81	132.0	264.0	528.1	1320.2	2640	5281	13202	26403
				SP	7.92	15.8	39.6	79.2	158	396	792	1584	3960	7921
				LP	2.64	5.28	13.2	26.4	52.8	132.0	264	528	1320	2640
				minimum w/o vac	2.60	4.40	10.2	20.1	36.7	88.2	170	327	786	1517
	Propane	C_3H_8	0.789	HP	15.77	31.55	78.9	157.7	315.5	788.7	1577	3155	7887	15774
				SP	4.73	9.47	23.6	47.3	95	237	473	947	2366	4733
				LP	1.58	3.15	7.9	15.8	31.5	78.9	158	315	789	1577
				minimum w/o vac	1.30	2.30	5.5	10.5	20.8	48.8	98	181	453	907
Fluoro-carbons	Carbon tetrafluoride	CF_4	0.563	HP	11.26	22.51	56.3	112.6	225.1	562.9	1126	2251	5629	11257
				SP	3.37	6.76	16.9	33.7	67.7	169	337	676	1688	3377
				LP	1.13	2.25	5.6	11.3	22.5	56.3	113	225	563	1126
				minimum w/o vac	0.90	1.80	4.1	7.9	15.7	36.3	70	134	323	647
	Hexafluoro-ethene	C_2F_6	0.447	HP	8.95	17.89	44.7	89.5	178.9	447.3	895	1789	4473	8947
				SP	2.69	5.36	13.4	26.9	53.6	134	269	536	1342	2684
				LP	0.89	1.79	4.5	8.9	17.9	44.7	89	179	447	895
				minimum w/o vac	0.80	1.30	3.2	5.9	11.8	27.6	55	103	257	514
	Trifluoro methane	CHF_3	0.629	HP	12.59	25.18	62.9	125.9	251.8	629.4	1259	2518	6294	12588
				SP	3.78	7.55	18.8	37.8	75.5	189	378	755	1888	3776
				LP	1.26	2.52	6.3	12.6	25.2	62.9	126	252	629	1259
				minimum w/o vac	1.00	2.00	4.4	8.8	17.2	40.6	78	150	362	723
Other	Air	Air	0.983	HP	19.67	39.34	98.3	196.7	393.4	983.5	1967	3934	9835	19670
				SP	5.90	11.8	29.5	59.0	118	295	590	1180	2951	5900
				LP	1.97	3.93	9.8	19.7	39.3	98.3	197	393	983	1967
				minimum w/o vac	2.00	3.40	7.6	15.2	27.4	67.1	127	244	585	1170
	Carbon dioxide	CO_2	0.795	HP	15.91	31.81	79.5	159.1	318.1	795.3	1591	3181	7953	15906
				SP	4.78	9.54	23.9	47.8	95.4	239	478	954	2386	4772
				LP	1.59	3.18	8.0	15.9	31.8	79.5	159	318	795	1591
				minimum w/o vac	1.40	2.50	6.2	11.1	22.1	51.2	102	189	473	914
	Carbon monoxide	CO	1.000	HP	20.00	40.00	100.0	200.0	400.0	1000.0	2000	4000	10000	19999
				SP	6.00	12.0	30.0	60.0	120	300	600	1200	3000	6000
				LP	2.00	4.00	10.0	20.0	40.0	100.0	200	400	1000	2000
				minimum w/o vac	2.00	3.50	7.7	15.4	27.8	68.3	129	248	595	1190
	Nitrous oxide	N_2O	0.795	HP	15.90	31.80	79.5	159.0	318.0	795.1	1590	3180	7951	15902
				SP	4.78	9.54	23.9	47.8	95.4	239	478	954	2386	4771
				LP	1.59	3.18	8.0	15.9	31.8	79.5	159	318	795	1590
				minimum w/o vac	1.40	2.50	6.2	11.1	22.1	51.2	102	189	473	914
	Octafluorocyclobutane[1]	C_4F_8	0.367	LP	0.73	1.47	3.7	7.3	14.7	36.7	73	147	367	733
				minimum w/o vac	0.60	1.10	2.4	4.8	9.2	22.7	44	84	211	421
	Oxygen	O_2	0.935	HP	18.71	37.42	93.5	187.1	374.2	935.4	1871	3742	9354	18708
				SP	5.62	11.2	28.1	56,2	112	281	562	1122	2807	5612
				LP	1.87	3.74	9.4	18.7	37.4	93.5	187	374	935	1871
				minimum w/o vac	1.90	3.40	7.3	14.4	26.4	63.8	120	232	557	1113

1 The vapor pressure of Octafluorocyclobutane is 238 kPa absolute, Only LP operation is possible. Downstream vacuum is recommended.

Ratio = Inverse square root density ratio of the indicated gas to that of nitrogen. Also the ratio of mass flow rates in each gas for a given molbloc-S element.

KF = Pressure to flow conversion ratio, sccm/kPa

To estimate a flow in a given gas at a given pressure: Flow(slm) = KF * pressure in kPa absolute / 1000 * gas ratio

All flows are approximate; in gases other than nitrogen and air, flows may vary up to 10% due to differences in nozzle characteristics and manufacturing

Cal Types: HP = High Pressure calibration 200 kPa to 2 Mpa absolute; table shows flow @ 2 Mpa, minimum flow is 10 % of value shown
SP = Standard Pressure calibration 50 kPa to 600 kPa absolute; minimum flow with vacuum is ~8.4 % of value shown (flow at ~50 kPa)
LP = Low Pressure calibration 20 kPa to 200 kPa absolute; table shows flow @ 200 kPa, minimum flow with vacuum is 10 % of value shown

Molbloc-S Gas Calibrations

- Default gas calibration for molbloc-S is SP STD in Air but we can substitute N2 if preferable for application and can sub HP or LP and/or Prem.
- In order to achieve manufacturer's uncertainty, the molbloc must be calibrated in the specific gas.
- We cannot calibrate in all the gases that are on chart and can refer to Gas Calibration Availability Matrix (GCAM) to check on availability of gas calibration for specific molblocs. Currently we can calibrate molbloc-S in Air, N2, AR, CO2 and He.
- E.g 2E2-S-2 with SP STD Cal in Air and SP Prem in AR

2E2-S-2	6084475	2E2-S SONIC MOLBLOC FLOW ELEMENT
MOL-S GAS CAL	3534708	SP, PREM, AR

Upgrades

- No physical changes to the molbloc-L to newer molblocs, minor EEPROM data change that doesn’t interfere with the original structure. Very old molblocs (SNs < 6000 or with no “+” in SN) require hardware upgrade to be molbloc-L-2 compatible
- Any molbloc-S can be upgraded to molbloc-S-2
- Molbox1 and molbox1+ trade up to molbox2: Customer sends us existing molbox and Fluke uses some components to build molbox2 About 50% of cost of new molbox.

Molbloc/molbox upgrades

Noun	Description	Item Number
1E1-L V6.0+MBX2 UPGD	UPGRADE 1E1 LAMINAR MOLBLOC V5.4 TO V6.0 + MOLBOX2 FORMAT	6095192
5E1-L V6.0+MBX2 UPGD	UPGRADE 5E1 LAMINAR MOLBLOC V5.4 TO V6.0 + MOLBOX2 FORMAT	6095267
1E2-L V6.0+MBX2 UPGD	UPGRADE 1E2 LAMINAR MOLBLOC V5.4 TO V6.0 + MOLBOX2 FORMAT	6095251
2E2-L V6.0+MBX2 UPGD	UPGRADE 2E2 LAMINAR MOLBLOC V5.4 TO V6.0 + MOLBOX2 FORMAT	6095246
5E2-L V6.0+MBX2 UPGD	UPGRADE 5E2 LAMINAR MOLBLOC V5.4 TO V6.0 + MOLBOX2 FORMAT	6095233
1E3-L V6.0+MBX2 UPGD	UPGRADE 1E3 LAMINAR MOLBLOC V5.4 TO V6.0 + MOLBOX2 FORMAT	6095185
5E3-L V6.0+MBX2 UPGD	UPGRADE 5E3 LAMINAR MOLBLOC V5.4 TO V6.0 + MOLBOX2 FORMAT	6095171
1E4-L V6.0+MBX2 UPGD	UPGRADE 1E4 LAMINAR MOLBLOC V5.4 TO V6.0 + MOLBOX2 FORMAT	6095163
3E4-L V6.0+MBX2 UPGD	UPGRADE 3E4 LAMINAR MOLBLOC V5.4 TO V6.0 + MOLBOX2 FORMAT	6095159
1E5-L V6.0+MBX2 UPGD	UPGRADE 1E5 LAMINAR MOLBLOC V5.4 TO V6.0 + MOLBOX2 FORMAT	6095222
SONIC V6.0+MBX2 UPGD	UPGRADE SONIC MOLBLOC V5.4, ANY RANGE, TO V6.0+ MBX2 FORMAT	6095205
V6.0/V6.0+MBX2 UPGD	UPGRADE ANY MOLBLOC, ANY RANGE, FROM V6.0 TO V6.0+ MBX2 FORMAT	6095214

MOLBOX2-TRADEUP	MOLBOX2 TRADEUP, TRADE IN MOLBOX1 FOR MOLBOX2 MASS FLOW TERM	6074841
MOLBOX2-TRADEUP1+	MOLBOX2 TRADEUP, TRADE IN MOLBOX1+ FOR MOLBOX2 MASSFLOW TERM	6074856

Molbox/molbloc calibration

- Molblocs must be calibrated at Fluke against reference molblocs. There is no US calibration lab that has the capability to calibrate molblocs to manufacturer’s specifications.
- Molbox2 calibration requires calibration of pressure transducers and verification of standard resistors. High end calibration labs with a piston gauge and sufficient resistance standards can calibrate
- Molbox2 and molbloc are independent of each other and therefore can be calibrated separately, not as a system. Any mobloc operates with molbox2

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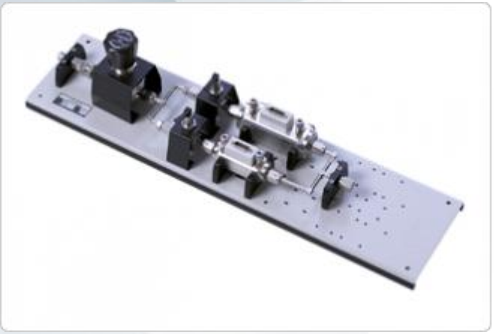
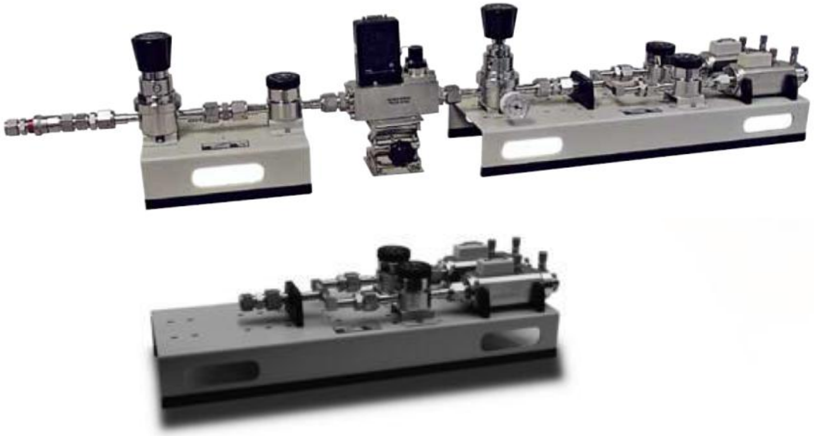
molstics

- Optional mounting platforms with valves, regulators, filters and interconnecting hardware to facilitate a more turn-key solution



molstic-L

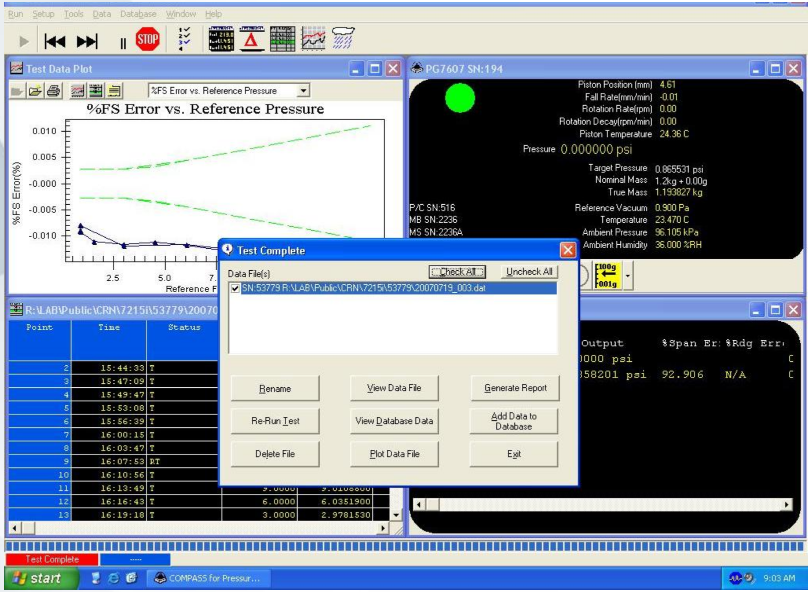


molstic-S

COMPASS for Flow software

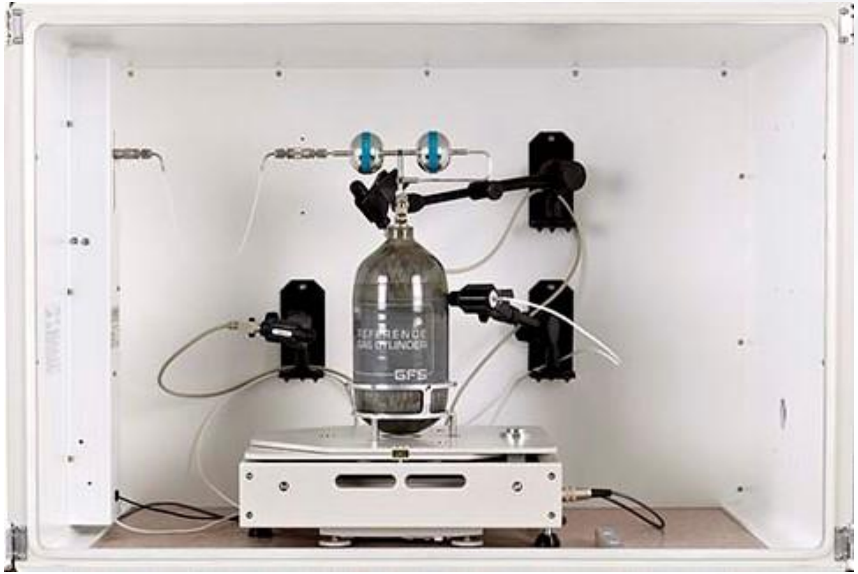
FLUKE® Calibration

Fully/partially automate flow calibrations including control and reading of DUTs, density corrections (when applicable), reporting, etc.



Primary Standard

- Our own Primary dynamic gravimetric flow system GFS-2102
- As low as ~ 0.02% expanded uncertainty
- Featured on the cover of CalLab Magazine in 2007
- Flow in the fundamental SI units of kg per second, mass vs. time
- Used to calibrate Fluke Calibration’s reference molblocs



Molbloc/molbox

Questions?