I. Pipes and Valves

Pipes vs. Tubes

Southland®

https://www.primochill.com/products/copper-tubing-soft-3-8in-id-by-1-2in-od-1-foot
https://www.amazon.com/D-Stainless-Steel-Tubing-Coil/dp/B00ICMEMZ2
http://www.muellerindustries.com/products/plumbing/tube-and-pipe/steel-pipe

Pipe Sizes

A.3 STEEL PIPE DIMENSIONS: CAPACITIES AND WEIGHTS

De Nevers, Fluid Mechanics for Chemical Engineers, 2E

Nominal pipe size, in	Outside diam., in	Schedule no.	Wall thickness, in	Inside diam., in	Cross-sectional area metal, in^2	Inside sectional area, ft^2	Circumference, ft, or surface, ft^2/ft, of length		Capacity at 1 ft/s velocity		Weight of pipe, lb/ft
							Outside	Inside	U.S. gal/min	lb/h water	
$\frac{1}{8}$	0.405	40	0.068	0.269	0.072	0.00040	0.106	0.0705	0.179	89.5	0.25
		80	0.095	0.215	0.093	0.00025	0.106	0.0563	0.112	56.0	0.32
$\frac{1}{4}$	0.540	40	0.088	0.364	0.125	0.00072	0.141	0.0954	0.323	161.5	0.43
		80	0.119	0.302	0.157	0.00050	0.141	0.0792	0.224	112.0	0.54
$\frac{3}{8}$	0.675	40	0.091	0.493	0.167	0.00133	0.177	0.1293	0.596	298.0	0.57
		80	0.126	0.423	0.217	0.00098	0.177	0.1110	0.440	220.0	0.74
$\frac{1}{2}$	0.840	40	0.109	0.622	0.250	0.00211	0.220	0.1630	0.945	472.5	0.85
		80	0.147	0.546	0.320	0.00163	0.220	0.1430	0.730	365.0	1.09
		160	0.187	0.466	0.384	0.00118	0.220	0.1220	0.529	264.5	1.31
$\frac{3}{4}$	1.050	40	0.113	0.824	0.333	0.00371	0.275	0.2158	1.665	832.5	1.13
		80	0.154	0.742	0.433	0.00300	0.275	0.1942	1.345	672.5	1.48
		160	0.218	0.614	0.570	0.00206	0.275	0.1610	0.924	462.0	1.94
1	1.315	40	0.133	1.049	0.494	0.00600	0.344	0.2745	2.690	1,345.0	1.68
		80	0.179	0.957	0.639	0.00499	0.344	0.2505	2.240	1,120.0	2.17
		160	0.250	0.815	0.837	0.00362	0.344	0.2135	1.625	812.5	2.85
$1\frac{1}{4}$	1.660	40	0.140	1.380	0.669	0.01040	0.435	0.362	4.57	2,285.0	2.28
		80	0.191	1.278	0.881	0.00891	0.435	0.335	3.99	1,995.0	3.00
		160	0.250	1.160	1.107	0.00734	0.435	0.304	3.29	1,645.0	3.77
$1\frac{1}{2}$	1.990	40	0.145	1.610	0.799	0.01414	0.498	0.422	6.34	3,170.0	2.72
		80	0.200	1.500	1.068	0.01225	0.498	0.393	5.49	2,745.0	3.64
		160	0.281	1.338	1.429	0.00976	0.498	0.350	4.38	2,190.0	4.86

(*continued*)

Pipe Sizes (Continued)

De Nevers, Fluid Mechanics for Chemical Engineers, 2E

A.3 *(continued)*

Nominal pipe size, in	Outside diam., in	Schedule no.	Wall thickness, in	Inside diam., in	Cross-sectional area metal, in^2	Inside sectional area, ft^2	Circumference, ft, or surface, ft^2/ft, of length		Capacity at 1 ft/s velocity		Weight of pipe, lb/ft
							Outside	Inside	U.S. gal/min	lb/h water	
2	2.375	40	0.154	2.067	1.075	0.02330	0.622	0.542	10.45	5,225.0	3.66
		80	0.218	1.939	1.477	0.02050	0.622	0.508	9.20	4,600.0	5.03
		160	0.343	1.689	2.190	0.01556	0.622	0.442	6.97	3,485.0	7.45
2½	2.875	40	0.203	2.469	1.704	0.3322	0.753	0.647	14.92	7,460.0	5.80
		80	0.276	2.323	2.254	0.02942	0.753	0.609	13.20	6,600.0	7.67
		160	0.375	2.125	2.945	0.02463	0.753	0.557	11.07	5,535.0	10.0
3	3.500	40	0.216	3.068	2.228	0.05130	0.917	0.804	23.00	11,500.0	7.58
		80	0.300	2.900	3.016	0.04587	0.917	0.760	20.55	10,275.0	10.3
		160	0.437	2.626	4.205	0.03761	0.917	0.688	16.90	8,450.0	14.3
3½	4.000	40	0.226	3.548	2.680	0.06870	1.047	0.930	30.80	15,400.0	9.11
		80	0.318	3.364	3.678	0.06170	1.047	0.882	27.70	13,850.0	12.5
4	4.500	40	0.237	4.026	3.173	0.08840	1.178	1.055	39.6	19,800.0	10.8
		80	0.337	3.826	4.407	0.07986	1.178	1.002	35.8	17,900.0	15.0
		120	0.437	3.626	5.578	0.07170	1.178	0.950	32.2	16,100.0	19.0
		160	0.531	3.438	6.621	0.06447	1.178	0.901	28.9	14,450.0	22.6
5	5.563	40	0.258	5.047	4.304	0.1390	1.456	1.322	62.3	31,150.0	14.7
		80	0.375	4.813	6.112	0.1263	1.456	1.263	57.7	28,850.0	20.8
		120	0.500	4.563	7.953	0.1136	1.456	1.197	51.0	25,500.0	27.1
		160	0.625	4.313	9.696	0.1015	1.456	1.132	45.5	22,750.0	33.0
6	6.625	40	0.280	6.065	5.584	0.2006	1.734	1.590	90.0	45,000.0	19.0
		80	0.432	5.761	8.405	0.1810	1.734	1.510	81.1	40,500.0	28.6
		120	0.562	5.501	10.71	0.1650	1.734	1.445	73.9	36,950.0	36.4
		160	0.718	5.189	13.32	0.1469	1.734	1.360	65.8	32,900.0	45.3
8	8.625	20	0.250	8.125	6.570	0.3601	2.258	2.130	161.5	80,750.0	22.4
		30	0.277	8.071	7.260	0.3553	2.258	2.115	159.4	79,700.0	24.7
		40	0.322	7.981	8.396	0.3474	2.258	2.090	155.7	77,850.0	28.6
		60	0.406	7.813	10.48	0.3329	2.258	2.050	149.4	74,700.0	35.7
		80	0.500	7.625	12.76	0.3171	2.258	2.000	142.3	71,150.0	43.4

Tube Sizes (Continued)

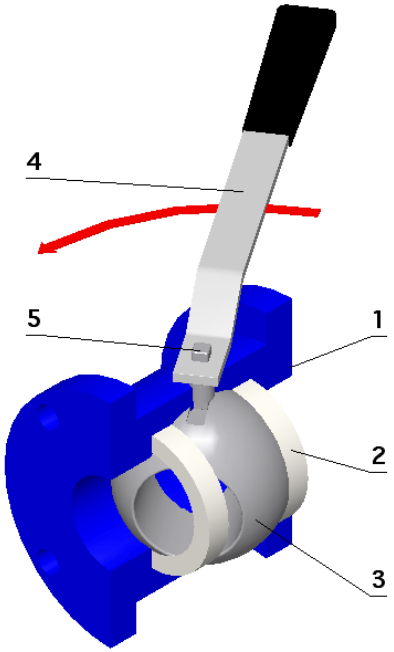
Tube OD in.	Tube Wall in.	Ordering Number	Weight lb/ft	Working Pressure psig
1/8	0.028	SS-T2-S-028-20	0.029	8 500
1/4	0.035	SS-T4-S-035-20	0.080	5 100
	0.049	SS-T4-S-049-20	0.105	7 500
	0.065	SS-T4-S-065-20	0.128	10 200
3/8	0.035	SS-T6-S-035-20	0.127	3 300
	0.049	SS-T6-S-049-20	0.171	4 800
	0.065	SS-T6-S-065-20	0.215	6 500
1/2	0.035①	SS-T8-S-035-20	0.174	2 600
	0.049	SS-T8-S-049-20	0.236	3 700
	0.065	SS-T8-S-065-20	0.302	5 100
5/8	0.065	SS-T10-S-065-20	0.389	4 000
3/4	0.065	SS-T12-S-065-20	0.476	3 300
1	0.083	SS-T16-S-083-20	0.813	3 100
1 1/4	0.095①	SS-T20-S-095-20	1.187	2 800
	0.120	SS-T20-S-120-20	1.473	3 600
1 1/2	0.120①	SS-T24-S-120-20	1.792	3 000
	0.134	SS-T24-S-134-20	1.981	3 400
2	0.134①	SS-T32-S-134-20	2.705	2 500
	0.188	SS-T32-S-188-20	3.686	3 600

① Not recommended for use with Swagelok tube fittings in gas service.

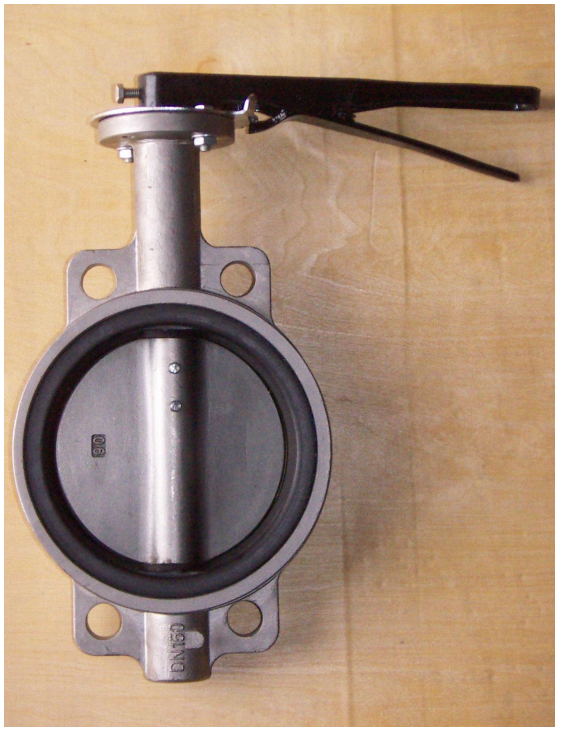
https://www.swagelok.com/downloads/webcatalogs/EN/MS-01-181.PDF

On/Off Valves

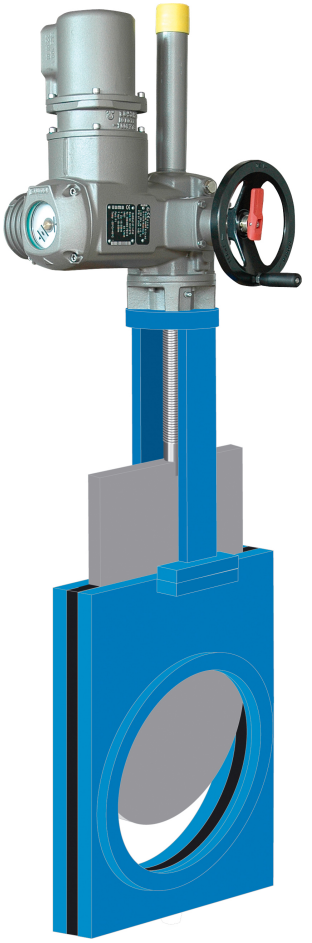
Ball Valve



Butterfly Valve



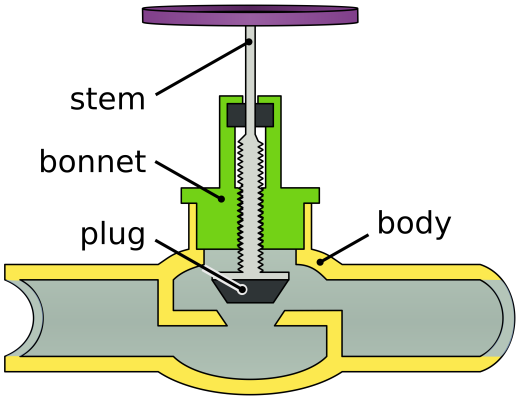
Gate Valve



en.wikipedia.org/wiki/Ball_valve
www.supplyhouse.com/Bluefin-BVT075-NP-3-4-Full-Port-Threaded-Ball-Valve
en.wikipedia.org/wiki/Butterfly_valve
en.wikipedia.org/wiki/Gate_valve

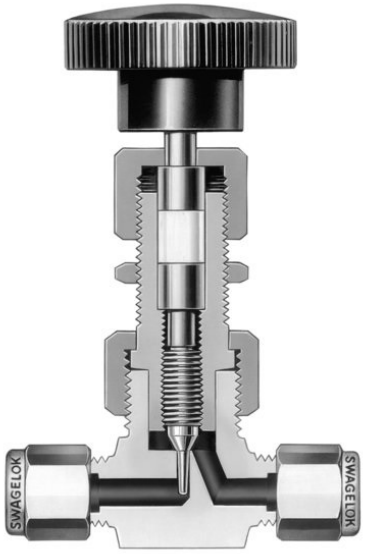
Flow Regulating & Check Valves

Flow Regulating Valves



Globe Valve

Needle Valve

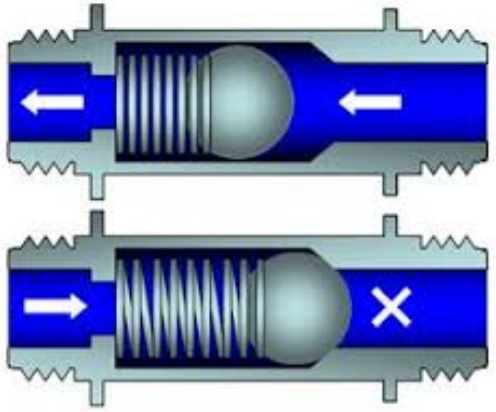


en.wikipedia.org/wiki/Globe_valve
www.hkdivedi.com/2016/05/needle-valve-working-principle-and.html

Check Valves

Swing
Check Valve

Ball
Check Valve

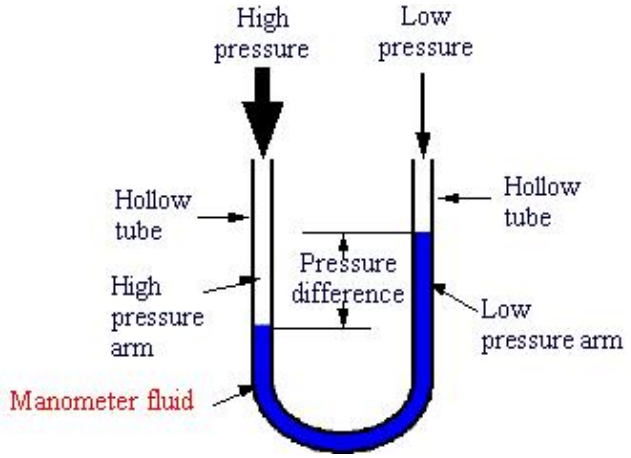


crosscontrols.com/product/walworth-api-602-ball-check-valve/
www.cranecpe.com/chem-energy/products/valves/pacific-csv-cast-steel-valves/pacific-csv-cast-steel-swing-check-valve

II. Pressure and Flow Measurement

A. Pressure

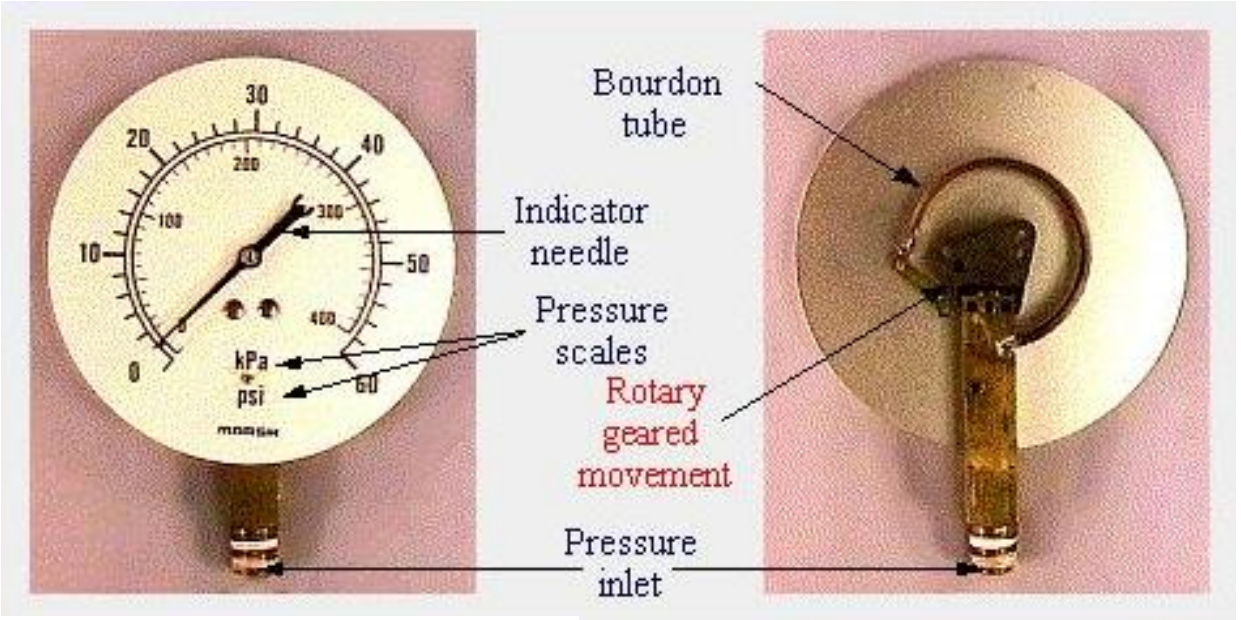
Manometer/Barometer

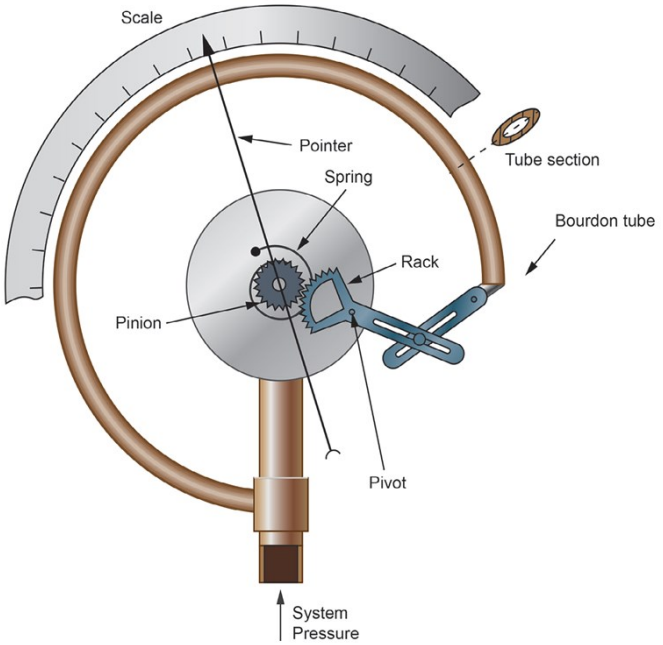


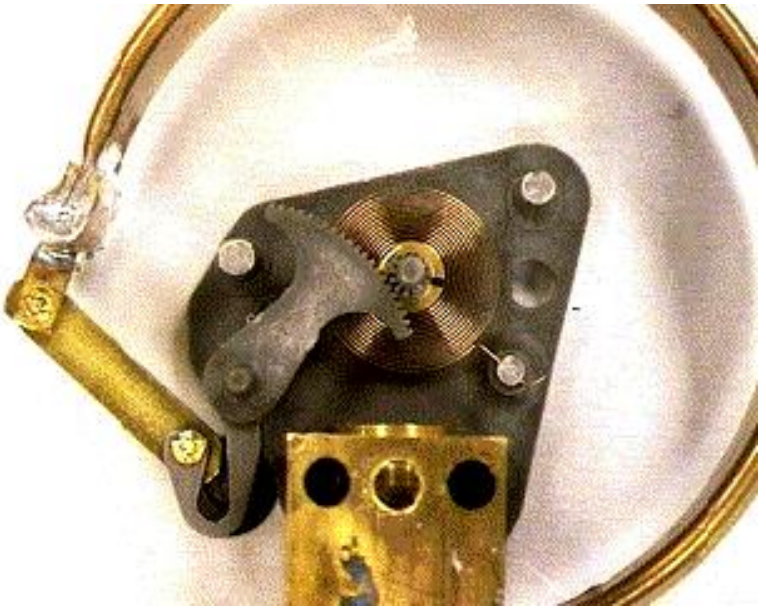
$$\Delta P = \rho g h$$

http://encyclopedia.che.engin.umich.edu/Pages/ProcessParameters/PressureMeasurement/PressureMeasurement.html
https://www.grainger.com/product/GENERAL-Deluxe-Digital-Manometer-3LYE2

Bourdon Tube



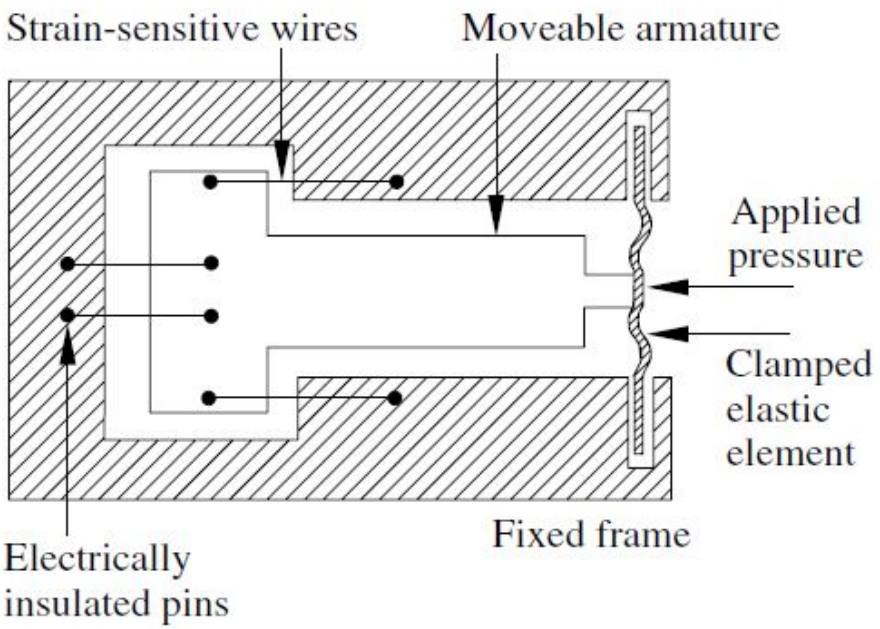




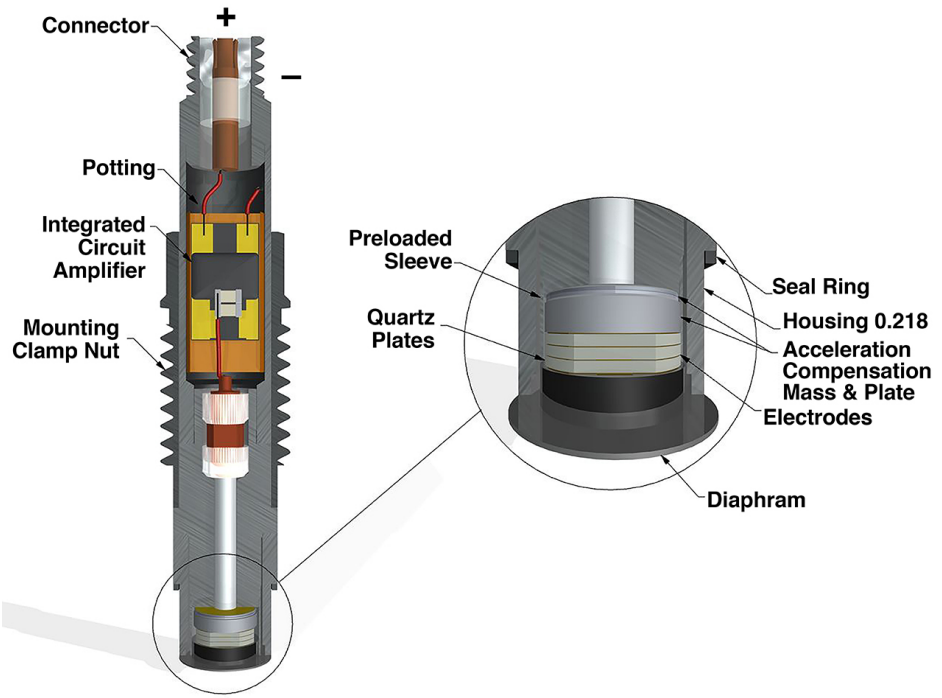
http://encyclopedia.che.engin.umich.edu/Pages/ProcessParameters/PressureMeasurement/PressureMeasurement.html
https://www.flowcontrolnetwork.com/selecting-pressure-gauges-new-advances-old-technology/

Pressure Transducers

Unbonded strain gauge



Piezoelectric sensor



http://encyclopedia.che.engin.umich.edu/Pages/ProcessParameters/PressureMeasurement/PressureMeasurement.html
https://www.omega.com/pptst/PX409_COMP.html

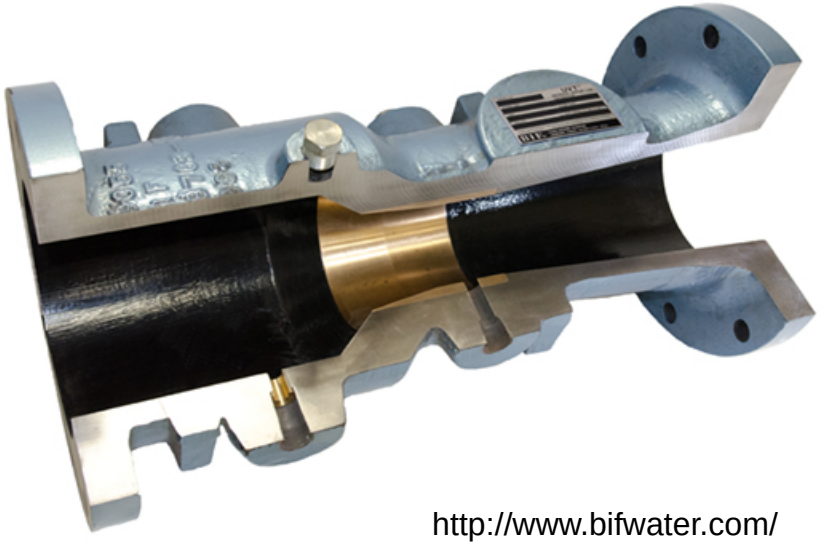
http://www.pcb.com/contentstore/mktgcontent/webimages/resources/techsupport/113B21-1.jpg
http://www.sae.org/dlymagazineimages/web/516/6181_6007.JPG

B. Flow

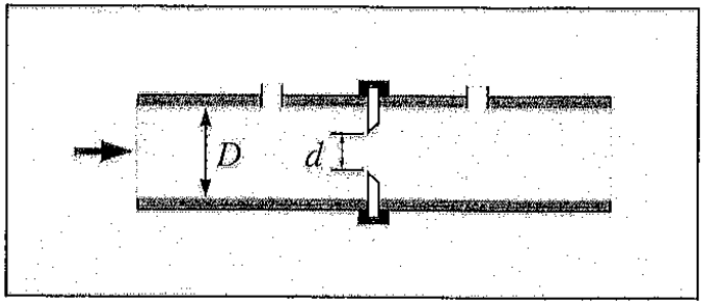
Obstruction Flow Meters

- C_d varies by type of obstruction.
- Cengel and Cimbala give some example relationships.
- Check manufacturer for more details.

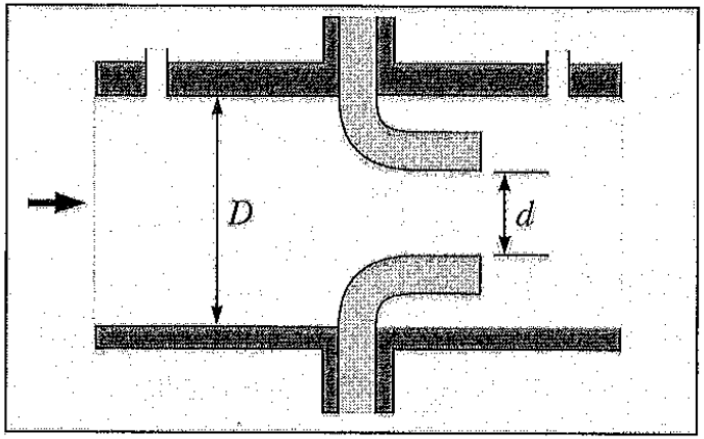
http://www.emerson.com/en-us/catalog/rosemount-3051cfc-conditioning-orifice-plate-flow-meter



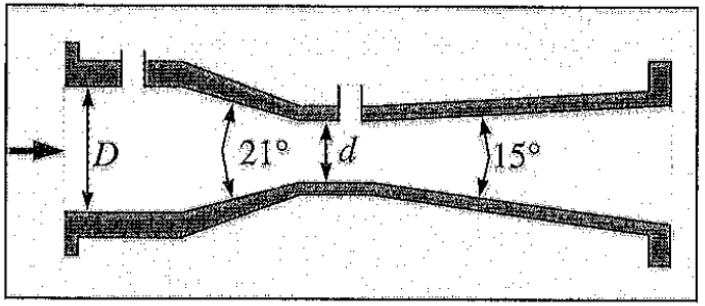
http://www.bifwater.com/



(a) Orifice meter $C_d \approx 0.61$



(b) Flow nozzle $C_d \approx 0.96$

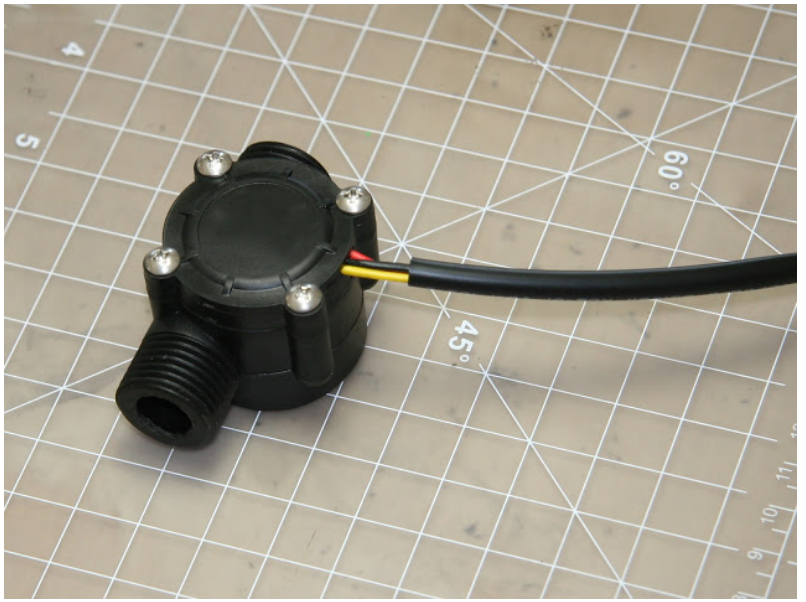


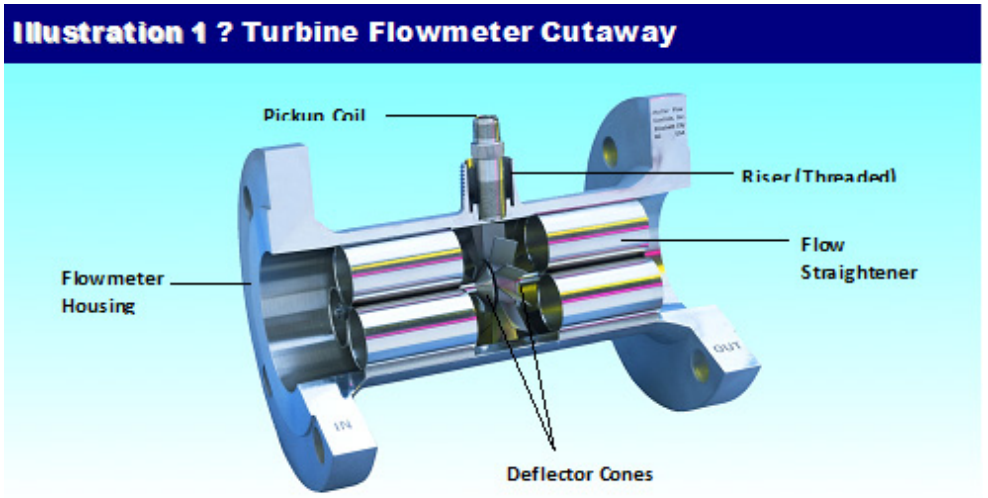
(c) Venturi meter $C_d \approx 0.98$

C_d \$

Cengel and Cimbala. p. 367 Figure 8-56.

Turbine & Paddle-wheel Flow Meters

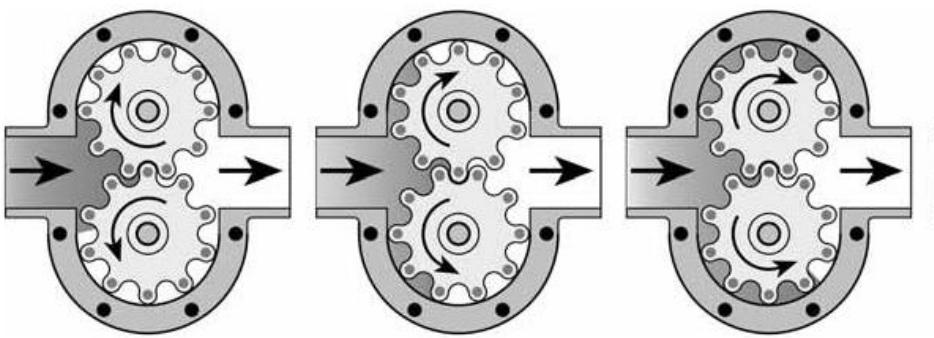




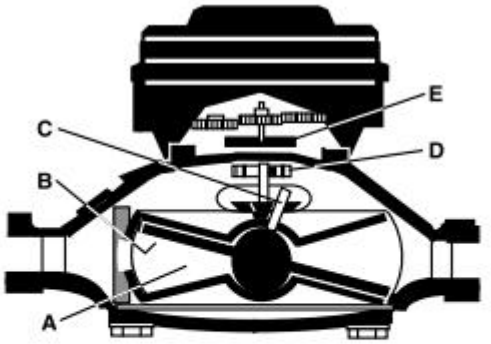
http://encyclopedia.che.engin.umich.edu/Pages/Flowmeters/Velocity/Velocity.html
http://www.hofferflow.com/wp-content/uploads/2017/01/turbine-flowmeter-cutaway.jpg
http://makersconfidential.blogspot.com/2015/06/teardown-of-paddle-wheel-flow-meter.html

Positive Displacement Flow Meters

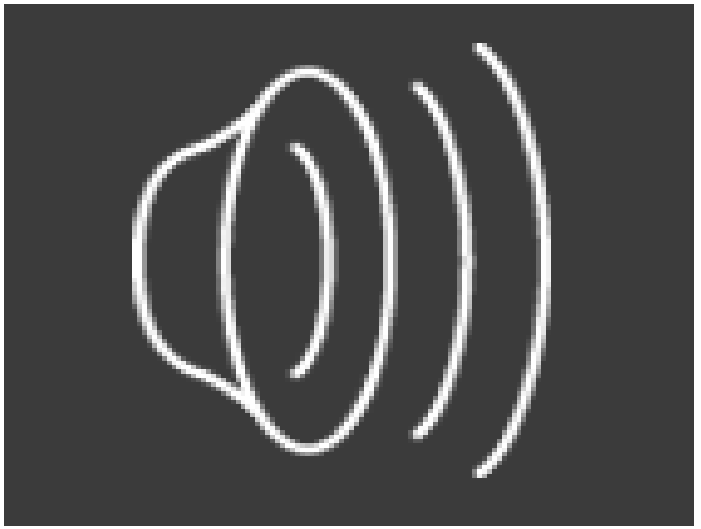
Impeller



Nutating disk

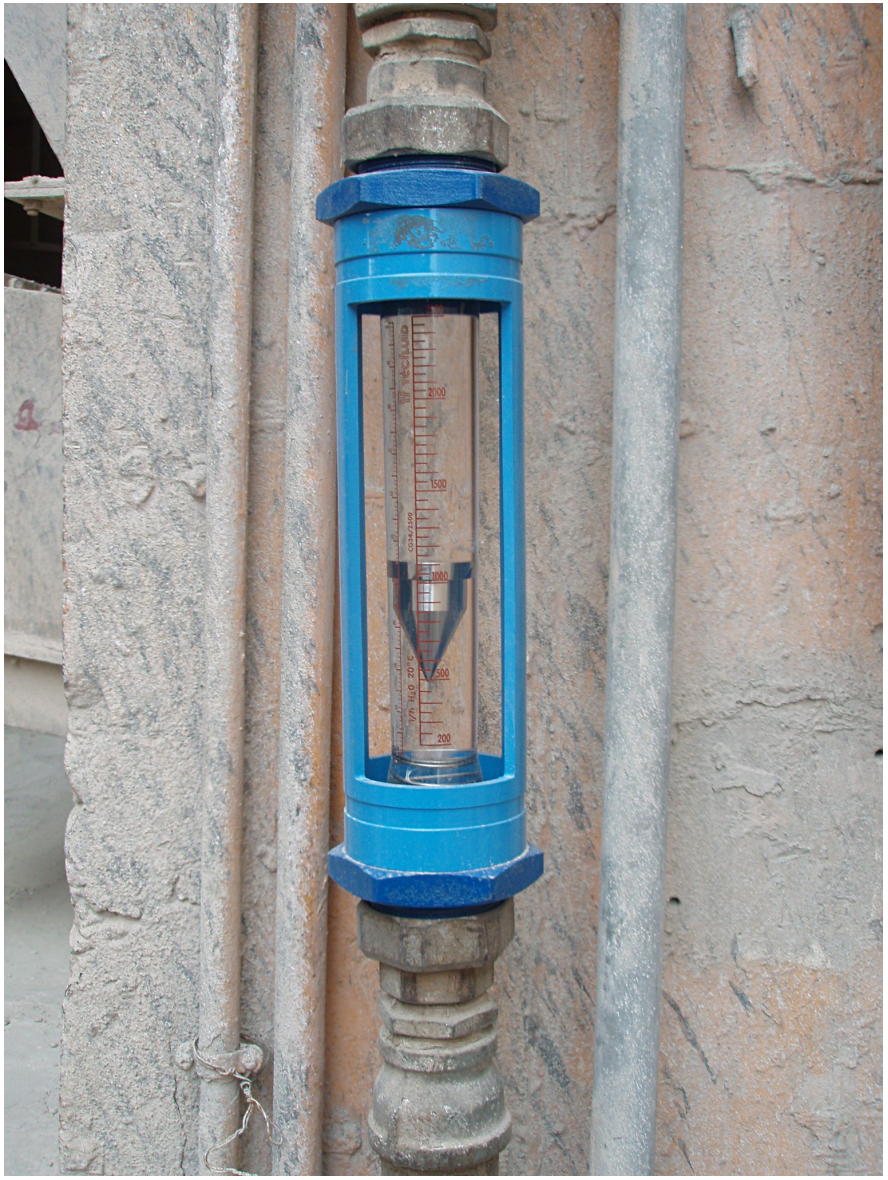


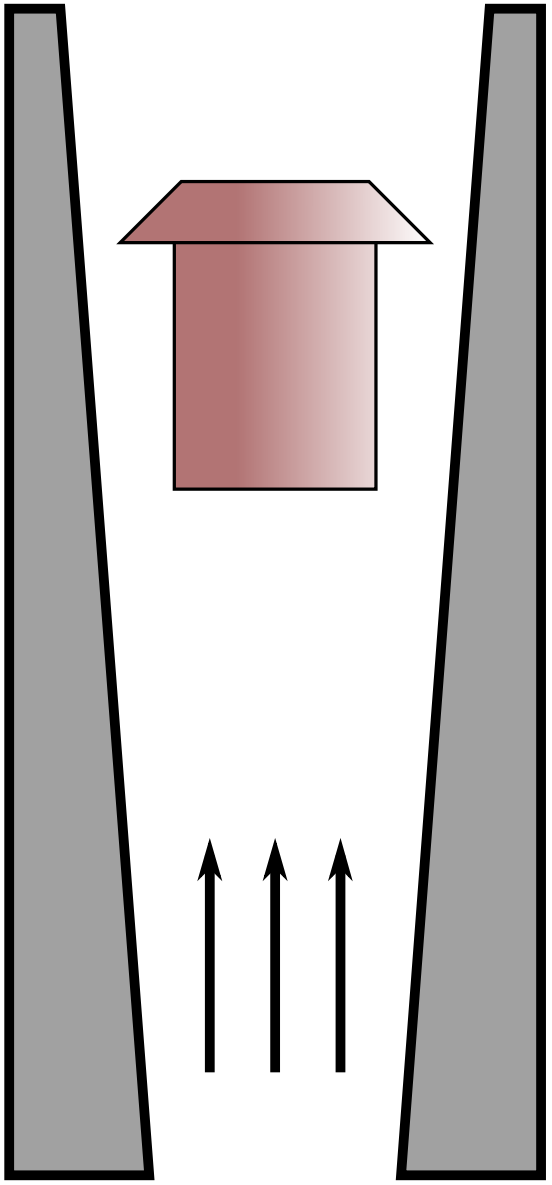
Liquid flowing through the meter chamber (A) causes a disc (B) to nutate or wobble. This motion, in turn, results in the rotation of a spindle (C) and drive magnet (D). Rotation is transmitted through the wall of the meter to a second magnet (E) which operates the transmitter.



http://encyclopedia.che.engin.umich.edu/Pages/Flowmeters/PositiveDisplacement/PositiveDisplacement.html
https://www.youtube.com/watch?v=ioId2PV0wZM

Rotameters (Variable-Area Flow Meters)

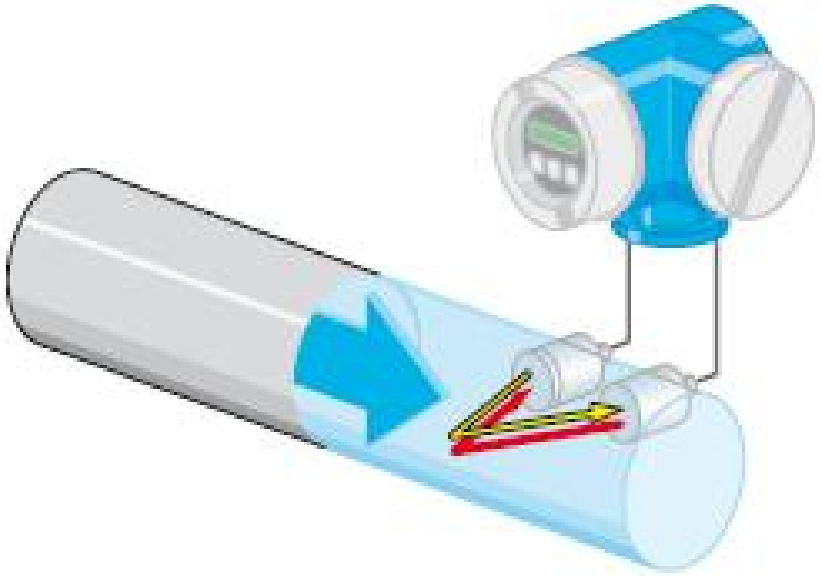




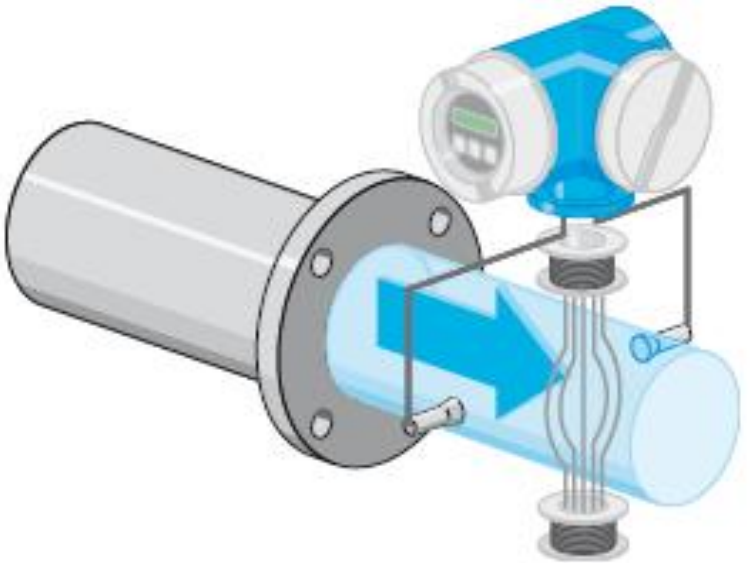
https://upload.wikimedia.org/wikipedia/commons/0/07/Techfluid-CG34-2500.jpg
https://commons.wikimedia.org/wiki/File:Rotameter_(schematic).svg

Other flow meters

Ultrasonic/Doppler

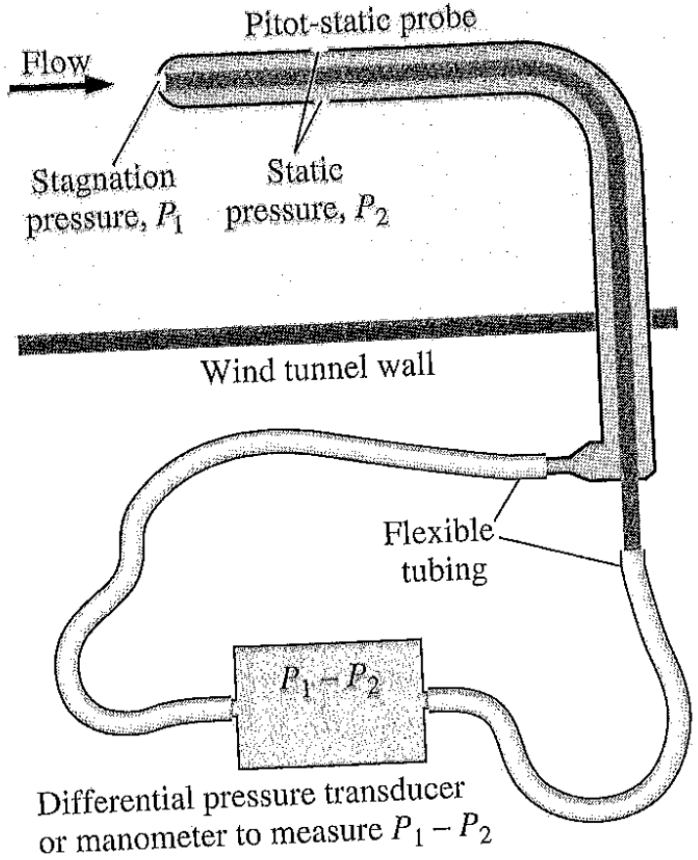


Electromagnetic

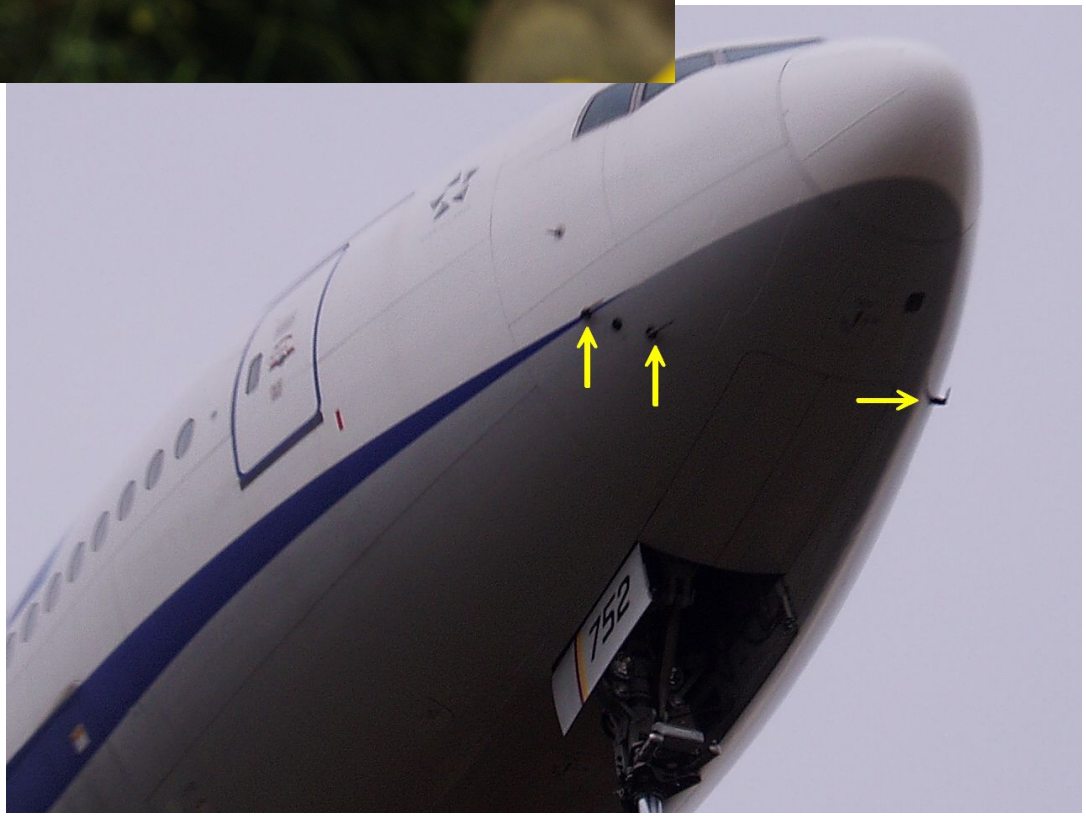


http://encyclopedia.che.engin.umich.edu/Pages/Flowmeters/Velocity/Velocity.html
http://img.directindustry.com/images_di/photo-g/5863-8061684.jpg
https://www.coleparmer.com/i/krohne-cp-vb14-1-vn31-enviromag-2000-magnetic-flowmeter-1-2-3-93-3-gpm/3316867

Pitot Tube



Cengel and Cimbala. p. 366 Figure 8-53.



Anemometers

Cup anemometer

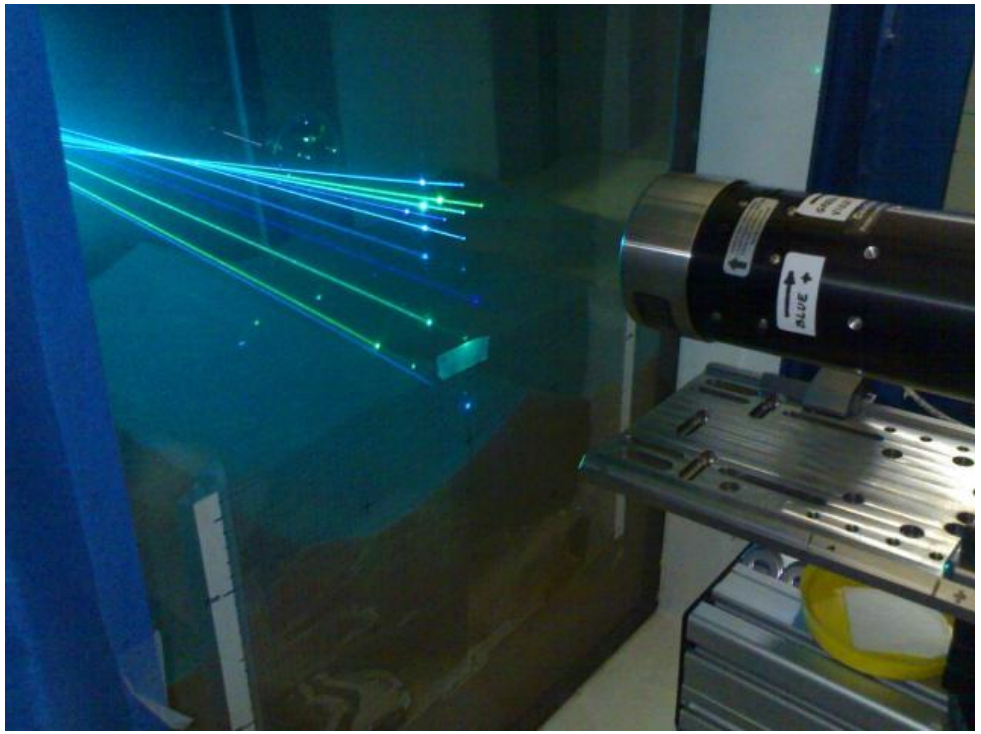
THE ROBINSON ANEMOMETER.

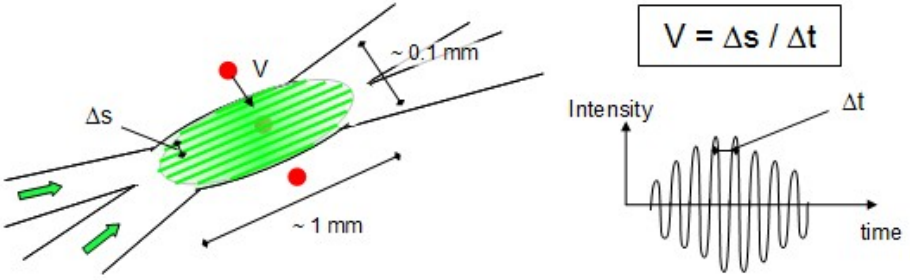
Hot wire anemometer

https://en.wikipedia.org/wiki/Anemometer#/media/File:Wea00920.jpg
https://www.dantecdynamics.com/images/content/products-and-services/fluid-mechanics/cta/CTAprobe2014.jpg

Velocimetry (LDV and PIV)

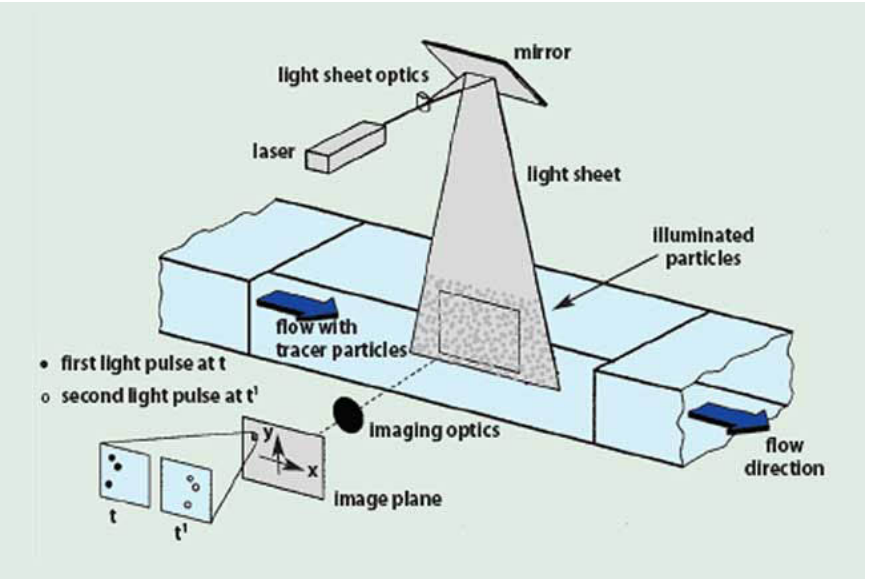
Laser Doppler Velocimetry

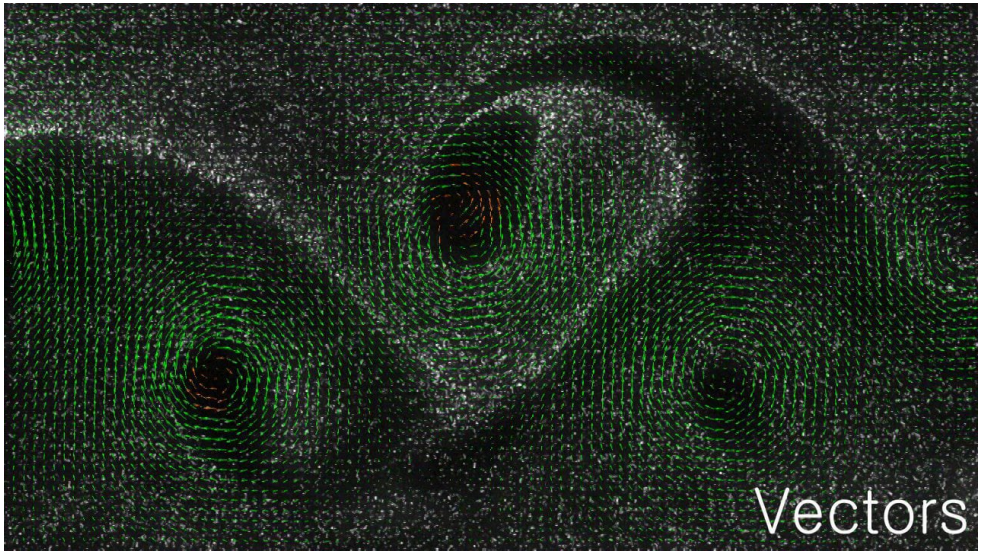




http://vtchl.illinois.edu/facilities/experimental-facilities/3-d-laser-doppler-velocimetry-ldv-system/

Particle Image Velocimetry





https://www.photonics.com/a25121/Particle_Image_Velocimetry_Basics_Developments
https://vimeo.com/62169075