INTRUMENTACIÓN INDUSTRIAL DE PROCESOS

DIPyGI FACET - UNT

TEMA N° 6
Medición de Propiedades de Fluidos

Densidad: escalas, distintos tipos de indicadores y transmisores. Propiedades reológicas de fluidos, medición de viscosidad aparente, aplicaciones. Medición de índice de refracción, de conductividad térmica de gases y de presión de vapor de mezclas. Sistemas de control de densidad. Medición de pH y conductividad específica. Especificación técnica.

PROPIEDADES FÍSICAS DE FLUIDOS
DENSIDAD
CARACTERÍSTICAS REOLÓGICAS **VISCOSIDAD O VISCOSIDAD APARENTE (CONSISTENCIA)**
CONDCUTIVIDAD TÉRMICA DE GASES
ÍNDICE DE REFRACCIÓN
PRESIÓN DE VAPOR

Se trata de una propiedad transportada por el fluido y por lo tanto, la posición en la que se efectúa la medición es un factor clave.

Estas propiedades se miden, entre otras cosas, para:

- Verificación de la calidad de la materia prima
- Para control automático de equipos
- Para control de calidad de producto
- Para gestión de inventario
- otras

MEDICION DE DENSIDAD – PRESION DIFERENCIAL

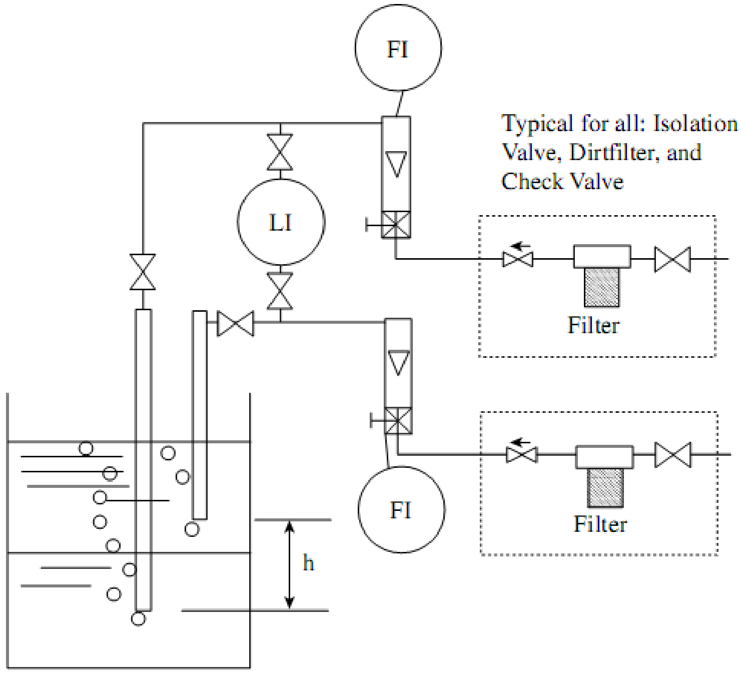


FIG. 6.4c
The measurement of density by using a local d/p indicator in combination with a dual-bubbler system.

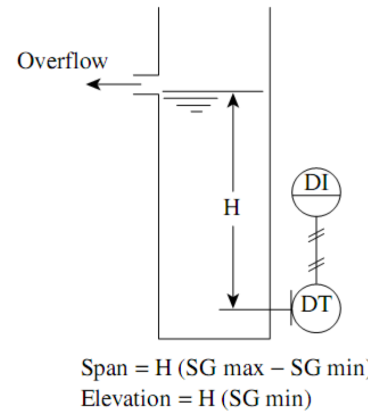


FIG. 6.4e
Density detection in fixed level atmospheric tank.

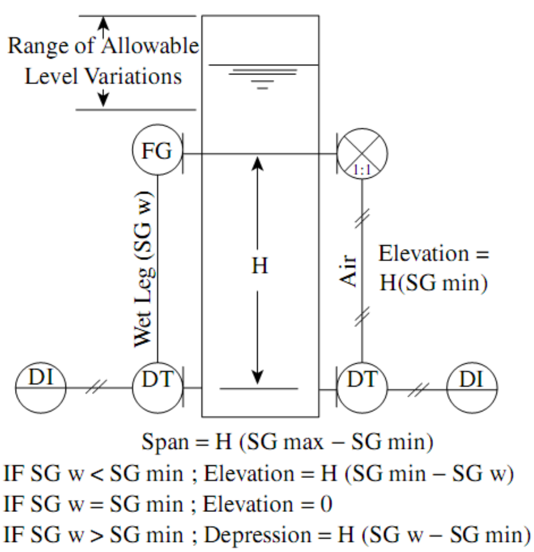
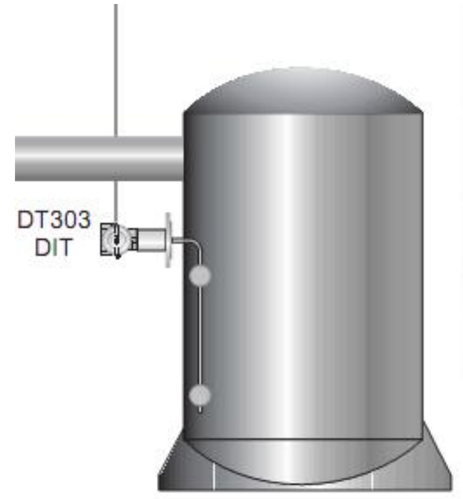
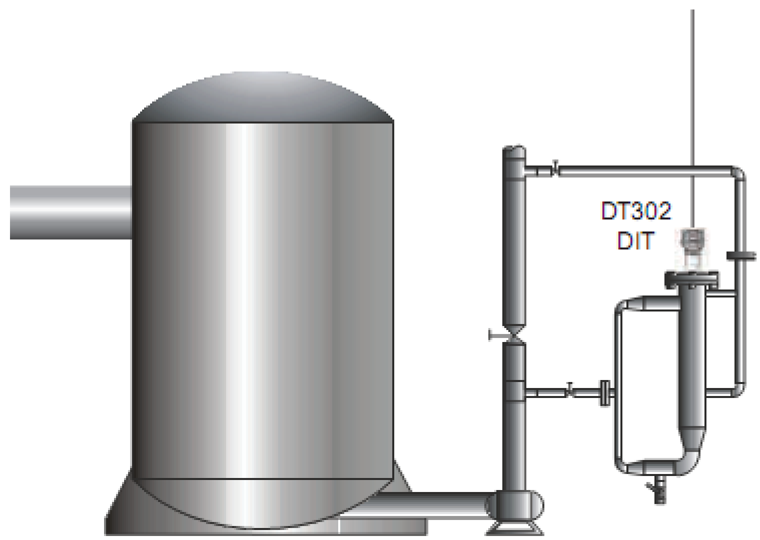
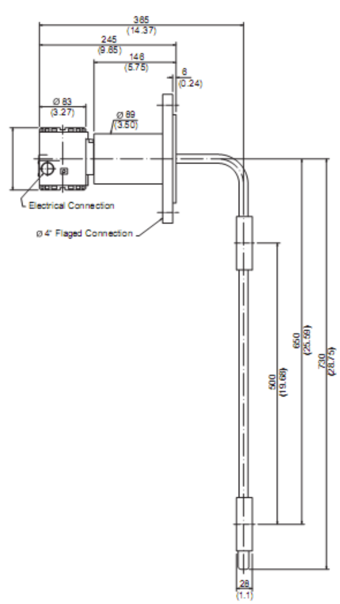


FIG. 6.4f
Density detection in variable level open or pressurized tanks.

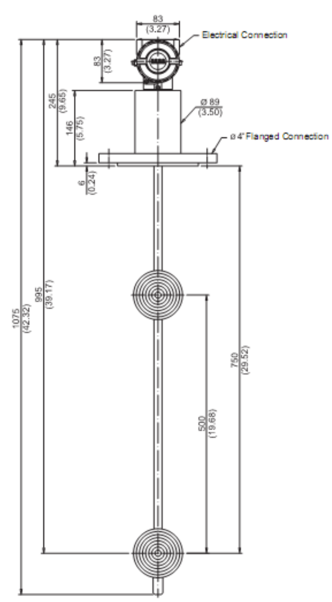
MEDICION DE DENSIDAD – PDT SMAR







Side Mounting Type



Top Mounting Type

MEDICION DE DENSIDAD – DISPOSITIVOS DE DESPLAZAMIENTO

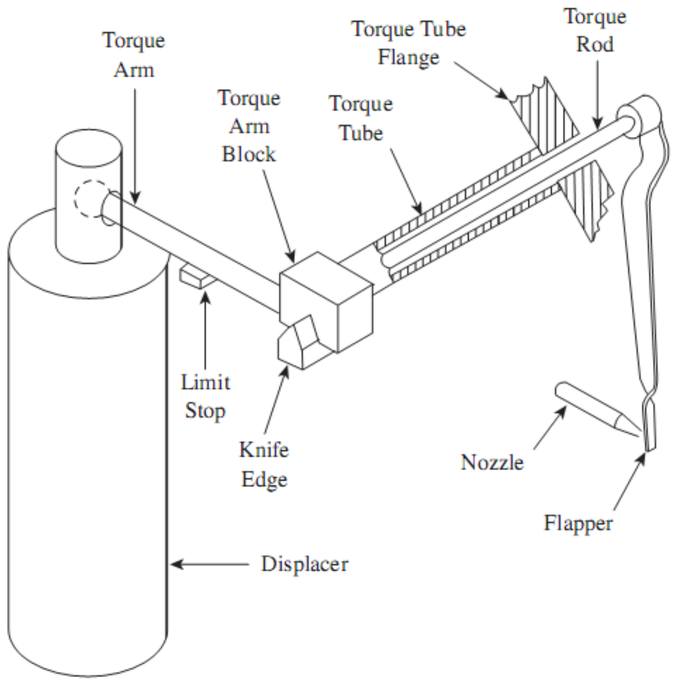
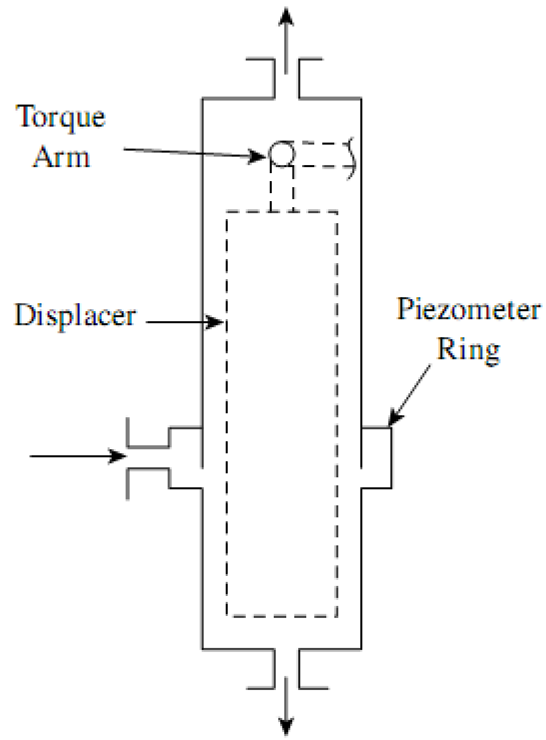


FIG. 6.2a
The buoyant force generated by a suspended displacer can be detected by a torque tube.



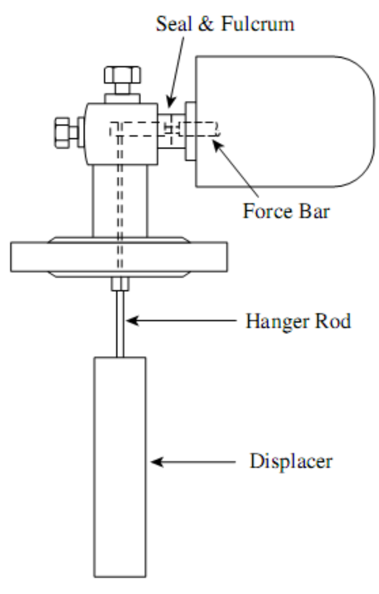


FIG. 6.2d
Diaphragm sealed displacer mounted on top of a flooded tank. (Courtesy of The Foxboro Company, a Division of Invensys.)

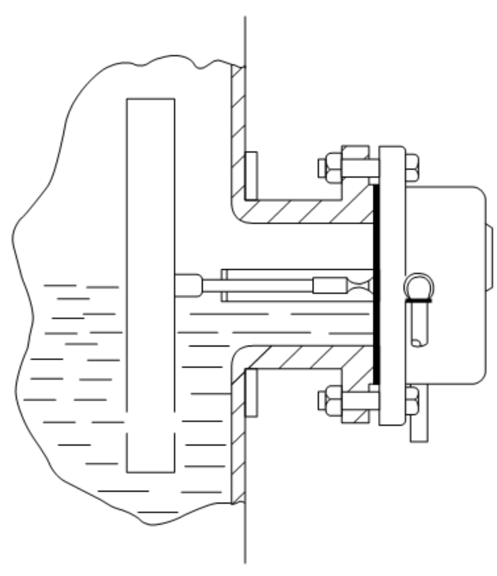


FIG. 6.2c
Displacer mounted on the side of a tank. (Courtesy of Siemens Moore Energy and Automation.)

MEDICION DE DENSIDAD – DENSÍMETROS (HIDRÓMETROS)

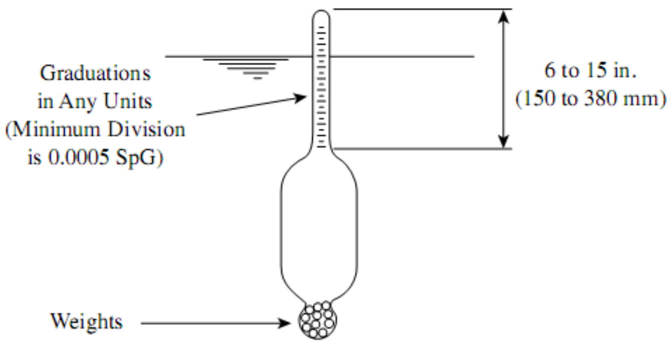


FIG. 6.3a
Hand hydrometer.

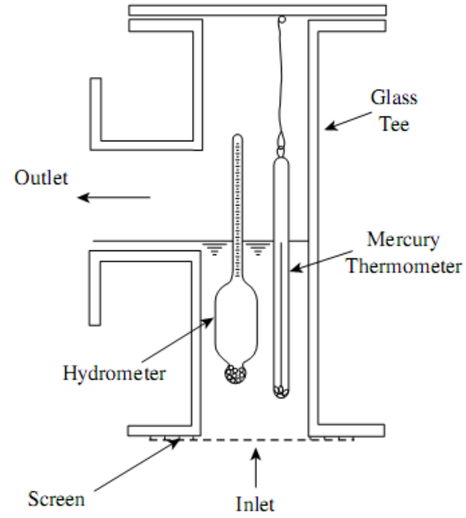


FIG. 6.3b
In-line hydrometer indicator.

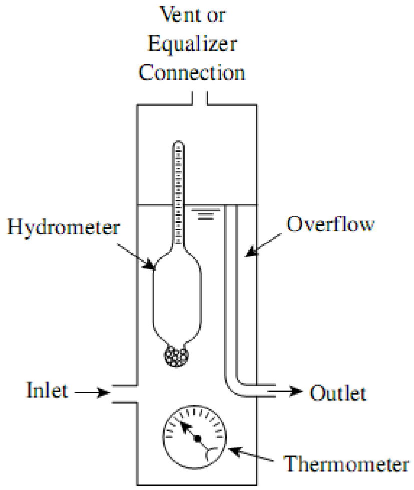


FIG. 6.3c
In-line hydrometer in rotameter housing.

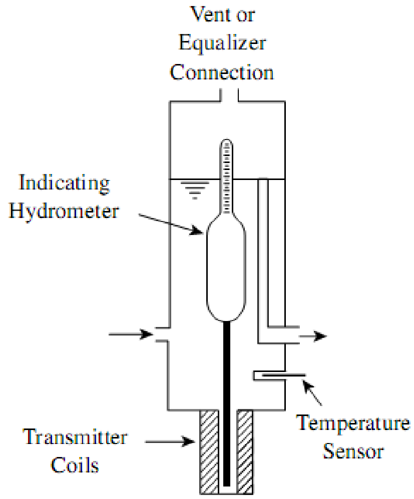


FIG. 6.3d
Hydrometer transmitter in rotameter housing.

MEDICION DE DENSIDAD – VIBRANTE

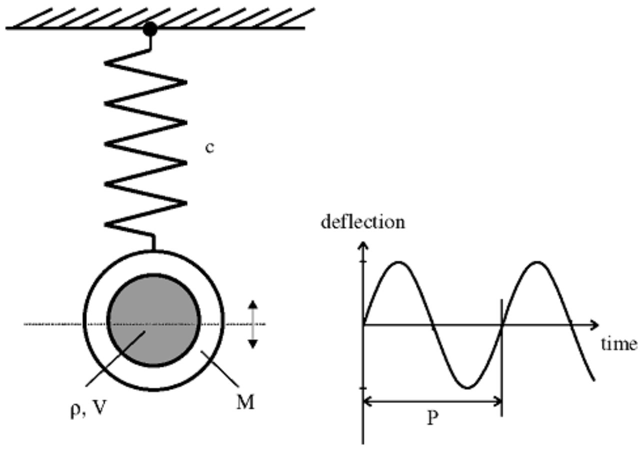


FIG. 6.8a
Mass-spring model of a vibrating densitometer.

$$P = 2\pi\sqrt{\frac{m}{c}} \qquad \textbf{6.8(1)}$$

The oscillating mass of a vibrating densitometer consists of the following: the mass of the vibrating element M and the mass of the fluid participating in the oscillation, being the volume of the participating fluid V times its density ρ.

$$m = M + \rho \times V \qquad \textbf{6.8(2)}$$

Replacing m in Equation 6.8(1) with the right side of Equation 6.8(2) and rearranging leads to:

$$\rho = \frac{c}{4\pi^2 V} \times P^2 - \frac{M}{V} \qquad \textbf{6.8(3)}$$

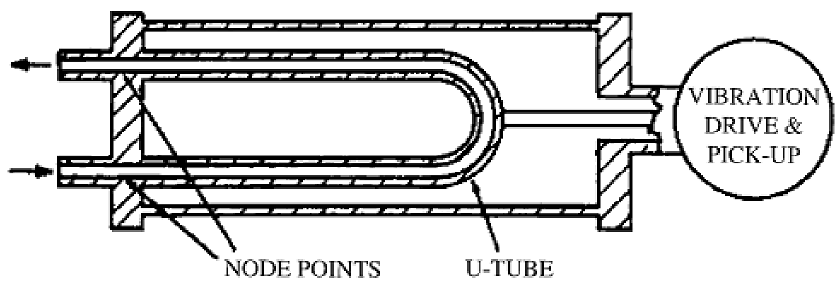
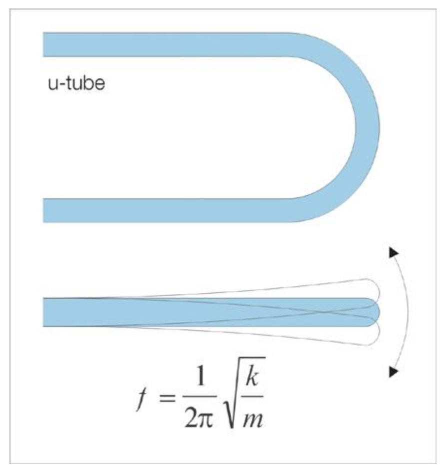


FIG. 6.8c
Vibrating U-tube density detector.



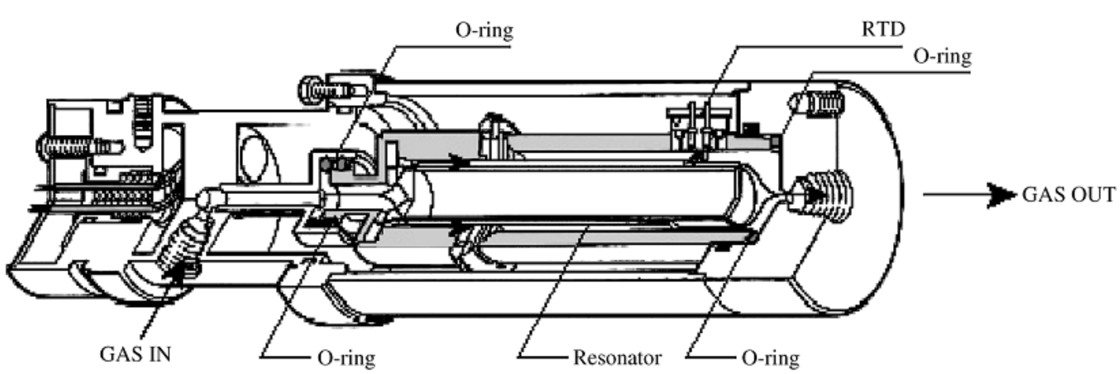


FIG. 6.8d
Gas densitometer using the vibrating cylinder concept. (Courtesy of Yokogawa Corp.)

MEDICION DE DENSIDAD – DE RADIACIÓN

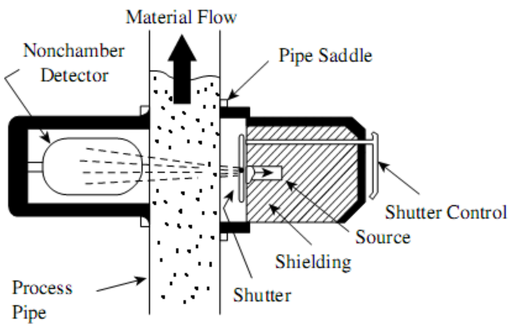


FIG. 6.6e
The gamma source is housed in a lead-shielded holder. When the shutter mechanism is opened, a collimated gamma beam passes through the pipe wall and the process material inside; its intensity at the detector is interpreted into process density.

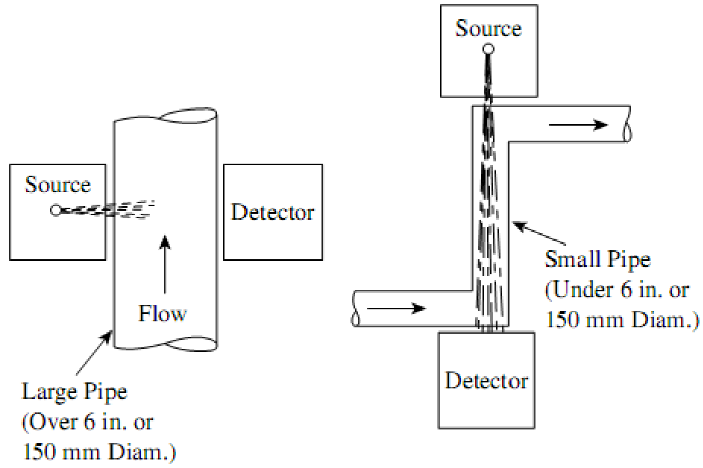


FIG. 6.6f
Radiation density sensors.

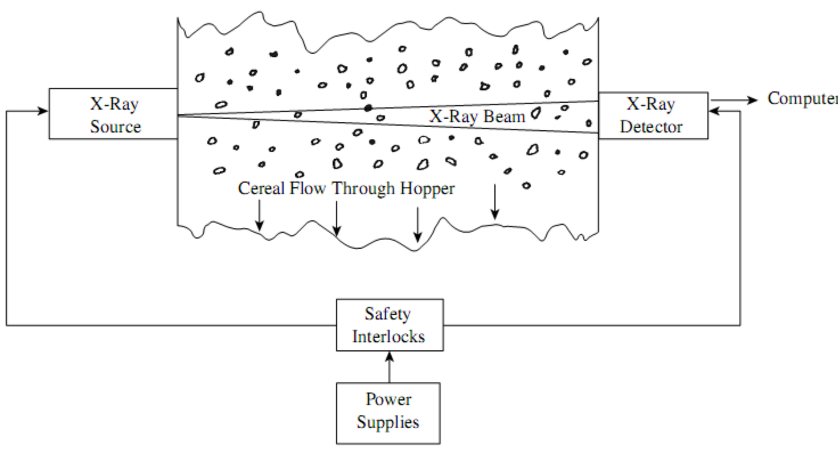


FIG. 6.6h
X-ray densitometer used on cereal hopper contents. (Courtesy of Bedford Control Systems Inc.)

MEDICION DE DENSIDAD – CORIOLIS

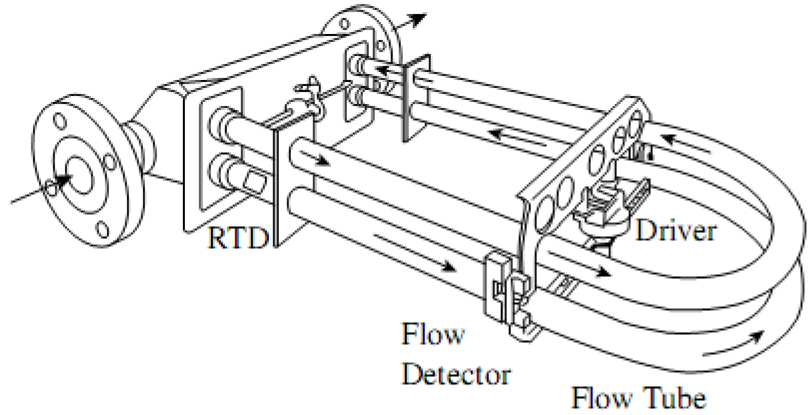


FIG. 6.5b
Design of a typical Coriolis density meter.

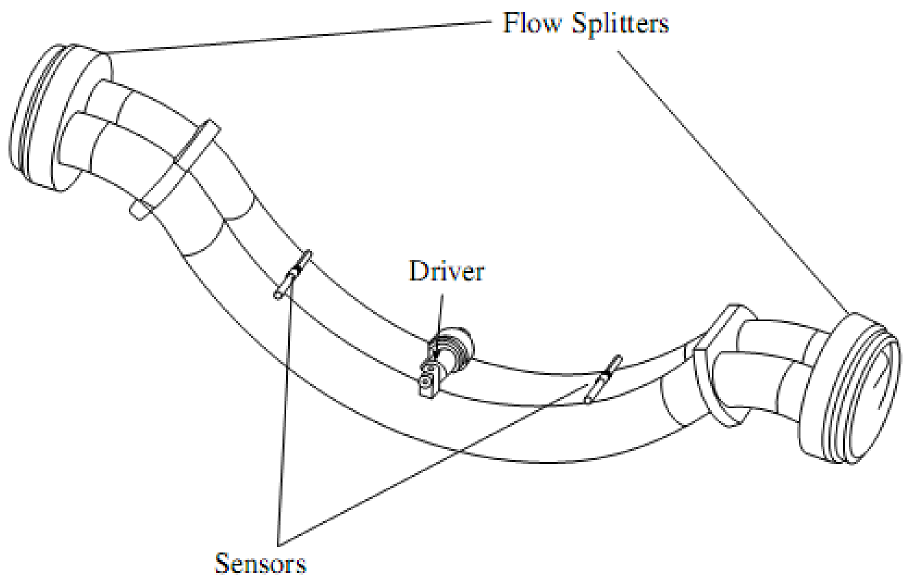


FIG. 6.5a
The components and the tube assembly of a Coriolis meter.

MEDICION DE DENSIDAD – SELECCIÓN

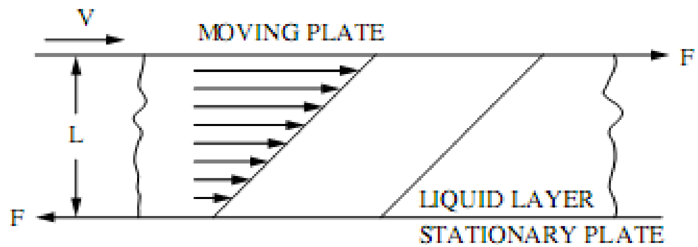
TABLE 6.1a
Orientation Table for Density Sensors

LIQUID Density Sensor Design	*Applicable to*			*Minimum Span Based on Water SG = 1.0*	*Inaccuracy in % of Span or SG Units*	*Design Pressure and Temperature Limitations*		*Temperature Compensation Available*	*Direct Local Indicator*	*Transmitter*
	Clean Process Streams	*Slurry Service*	*Viscous or Polymer Streams*			*PSIG/°F*	*Bars/°C*			
Angular Position Type	✓			0.1	0.5%	1000/500	69/260	N.S.		✓
Ball Type	✓			Digital	0.01 SG	600/160	41/71	N.S.	✓	✓
Capacitance Type	✓	✓	✓	0.1	1%	500/160	34.5/71	✓		✓
Displacement Type										
Buoyant Force Displacer	✓			0.005	1%	1500/850	130/472	N.S.		✓
Chain Balance Float	✓			0.005	1–3%	500/450	34/232	✓	✓	✓
Electromagnetic Suspension	✓			0.01	0.5–1%	200/350	14/177	✓		✓
Hydrometers	✓			0.05	1%	100/200	7/93	✓	✓	✓
Hydrostatic Head Type	✓	✓	✓	0.05	0.2–1%	5000/350	345/177	N.S.	✓	✓
Oscillating Coriolis	✓	✓	✓	0.1	0.02 SG or better	5000/800	345/426	✓		✓
Radiation Type	✓	✓	✓	0.05	1%	Unlimited	Unlimited	✓		✓
Sonic/Ultrasonic	✓	✓	✓	0.2	1–5%	1000/390	69/199	✓		✓
Twin Tube	✓	✓		Digital	0.0001	1440/356	100/180	✓	✓	✓
Vibrating Fork Type	✓	L	L	0.02	0.001 SG	3000/392	207/200	✓		✓
Vibrating Plate Type (also for gases) (currently not manufactured)	✓	L	L	0.1	0.2%	1440/200	100/95			✓
Vibrating Spool Type (also for gases)	✓	L	L	0.3	0.001 SG	725/300	50/149	✓		✓
Vibrating U-Tube Type	✓			0.05	0.00005-0.005 SG	2900/500	200/260	✓		✓
Weight of Fixed Volume Type	✓	✓	✓	0.05	1%	2400/500	165/260	✓	✓	✓

GAS Density Sensor Design	*Minimum Span*		*Inaccuracy in % of Span or in SG Units*	*Design Pressure and Temperature Limitations*		*Manually Operated Indicator*	*Continuous Indicator*	*Transmitter*
	lbm/ft^3	*kg/m*^{3}		*PSIG/°F*	*Bars/°C*			
Sensors Operating at Actual Flowing Conditions								
Centrifugal Type	1.0	16	0.1–0.5%	2000/300	138/49		✓	✓
Displacement Type	1.0	16	0.25%	1500/200	103/93	✓	✓	✓
Fluid Dynamic Type	0.5	8	2%	50/450	3.5/232	✓	✓	✓
Specific Gravity Detectors Operating at Near-Ambient Conditions	Minimum Span Based on Air SG = 1.0							
Electromagnetic Suspension Type	0.01 SG		0.0001 SG	ATM/120	ATM/49			✓
Gas Column Balance Type	0.1 SG		0.001 SG	20/140	1.4/60		✓	✓
Manual Displacement Type Elements	0.1 SG		0.002 SG	ATM/120	ATM/49		✓	
Thermal Type	0.5 SG		0.01 SG	ATM/120	ATM/49	✓		✓
Viscous Drag Type	0.1 SG		0.001–0.002 SG	ATM/120	ATM/49		✓	✓

N.S.: Nonstandard
L: Limited

MEDICION DE VISCOSIDAD



$$\frac{F}{A} = \frac{\mu V}{L} : \mu = \frac{F/A}{V/L}$$

FIG. 8.62a

Viscosity is a fluid property that describes the amount of deformation (V/L) that will result from a particular shear (F/A) that is applied to the fluid.

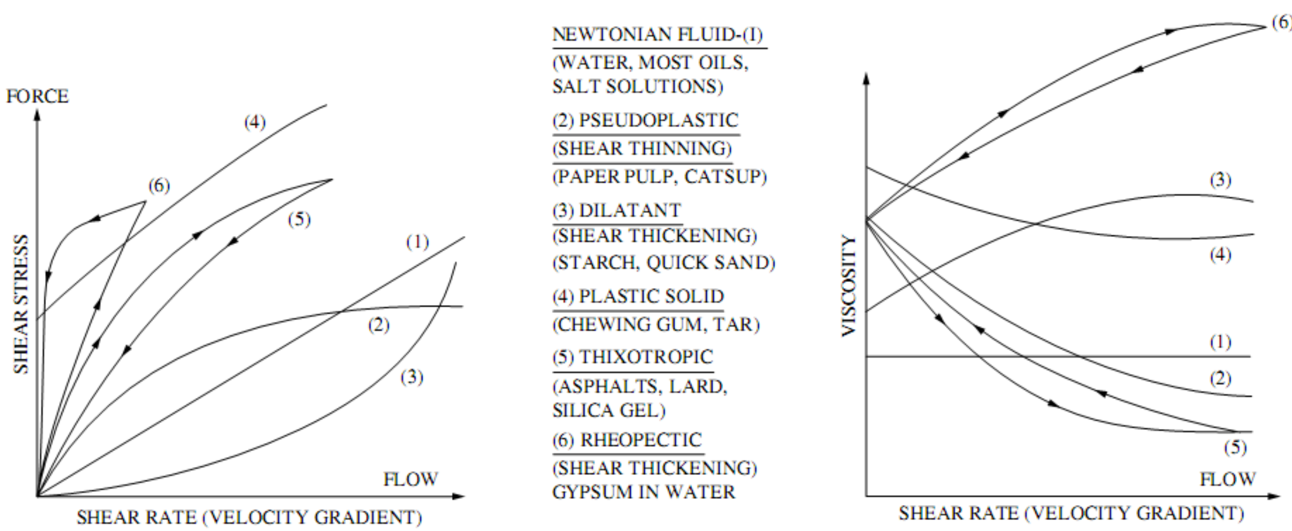


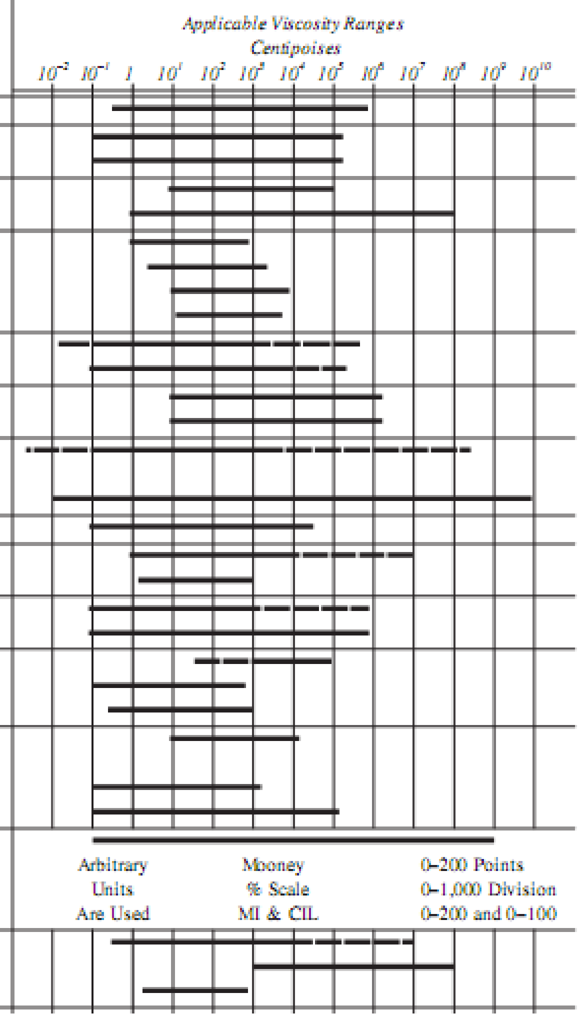
FIG. 8.62c

The viscosity and shear stress of Newtonian and non-Newtonian fluids when these fluids are deformed at various shear rates (velocity gradients).

TABLE 8.62f

Orientation Table for Industrial Viscometers

Application	Type of Design	Features	Provides Continuous Signal	In-line Device	Laboratory Device	Local Readout	Remote Readout Trans.	Temp. Compensation	Fluids: Gas	Fluids: Newtonian	Fluids: Non-Newtonian	Maximum Design Pressure, PSIG. (1 Bar = 14.2 PSI)	Maximum Design Temperature, °F (°C = [°F − 32]/1.8)	Inaccuracy (±%) (1) Based on Full Scale (2) Based on Measurement	Minimum sample Size or Flow Rate	Applicable Viscosity Ranges Centipoises
Laboratory	Bubble time	Manual			✓	✓				✓		ATM.	77	2–10(2)	13 CC	
	Capillary tube	Manual timing			✓	✓				✓		ATM.	300	0.35(2)	20 CC	
		Auto timing		✓	✓	✓	✓			✓		ATM.	300	0.01(2)	20 CC	
	Capillary extrusion	Influx efflux			✓	✓				✓	✓	100	300	2.0(2)	0.7 CC	
					✓	✓	✓			✓	✓	5,000	640	2.0(2)	30 CC	
	Efflux cup	Saybolt			✓	✓				✓		ATM.	250	0.1(2)	60 CC	
		Ford cup		✓	✓	✓				✓		ATM.	80	2.0(2)	150 CC	
		Zahn cup			✓	✓				✓		ATM.	80	2.0(2)	44 CC	
		Auto timing			✓	✓	✓			✓	✓	ATM.	80	5.0(2)	—	
	Falling ball	Manual			✓	✓			✓	✓		ATM.	300	0.1–1(2)	30 CC	
		Automatic		✓	✓	✓				✓	✓	15,000	350	0.1–1(2)	70 CC	
	Falling needle	Manual			✓	✓				✓	✓	ATM.	400	0.5–1(2)	2–10 CC	
		Automatic			✓	✓	✓	✓		✓	✓	ATM.	400	0.5–1(2)	2–10 CC	
	Rotational	Coaxial-cylinder			✓	✓	✓			✓	✓	ATM—20,000	80–500	1.0(2)–2.0(1)	1–500 CC	
		Cone and plate			✓	✓	✓			✓	✓	ATM.	750	0.5(2)	0.1 CC	
	Piston	Travel time	✓	✓	✓	✓	✓	✓		✓	✓	10,000	600	2(2)	In-line	
Industrial	Continuous capillary	Differential pressure	✓	✓	✓	✓	✓			✓		670	900	1–2(1)	1–4 GPH	
		Back pressure	✓	✓	✓	✓	✓			✓		500	210	1.0(1)	1 GPH	
	Falling element	Ball or slug		✓	✓	✓	✓	✓		✓	✓	300	350	1.0(1)	—	
		Piston		✓	✓	✓	✓	✓		✓	✓	500	650	1.0(1)	—	
	Float	Single float	✓	✓	✓	✓	✓			✓	✓	650	450	4.0(2)	0.75–2 GPM	
		Two-float	✓	✓	✓	✓				✓		300	450	2–4(2)	0.25–2.5 GPM	
		Concentric	✓	✓	✓	✓	✓	✓		✓	✓	650	450	2–4(2)	2 GPM	
	Oscillating	Blade		✓	✓	✓	✓			✓	✓	375	150	1.0(1)	Up to 6.5 fps (2 m/s)	
		Piston	✓	✓	✓	✓	✓	✓		✓	✓	10,000	600	2.0(2)	—	
		Torsional	✓	✓	✓	✓	✓	✓		✓	✓	5,000	850	2.0(2)	—	
	Plastometer	Cone and plate	✓	✓	✓	✓	✓				✓	100	400	0.5(1)	25 CC	Arbitrary Units Are Used
		Kneader	✓	✓	✓	✓	✓				✓	ATM.	570	1.0(1)	80 CC	Mooney % Scale MI & CIL
		Capillary			✓	✓	✓				✓	5,000	570	2.0(1)	0.6 #/HR	0–200 Points 0–1,000 Division 0–200 and 0–100
	Rotational	Cone disc sphere	✓	✓	✓	✓	✓	✓		✓	✓	1,000	650	1.0(1)	—	
		Agitator power	✓	✓		✓	✓			✓	✓	125	200	−5.0(1)	—	
		Double cylinder	✓	✓			✓			✓	✓	145	300	1.0(1)	—	



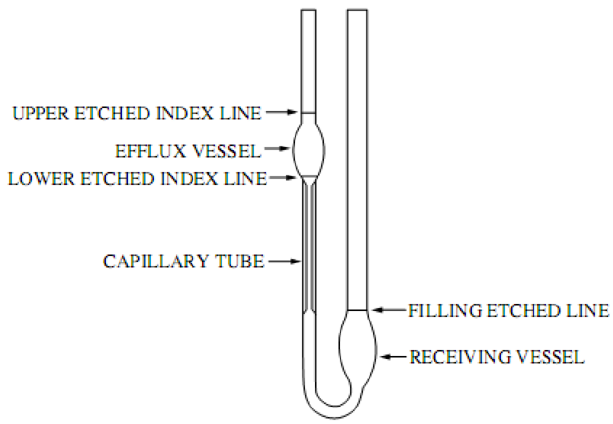
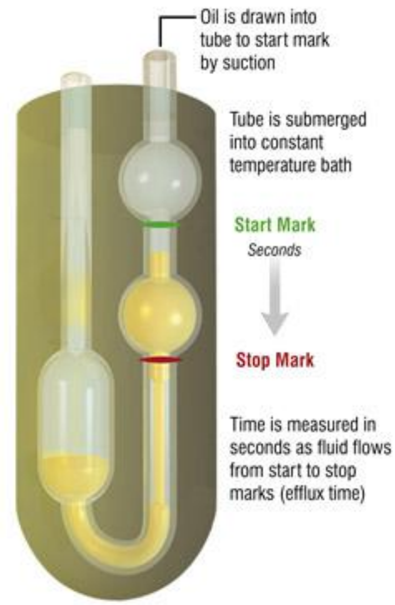
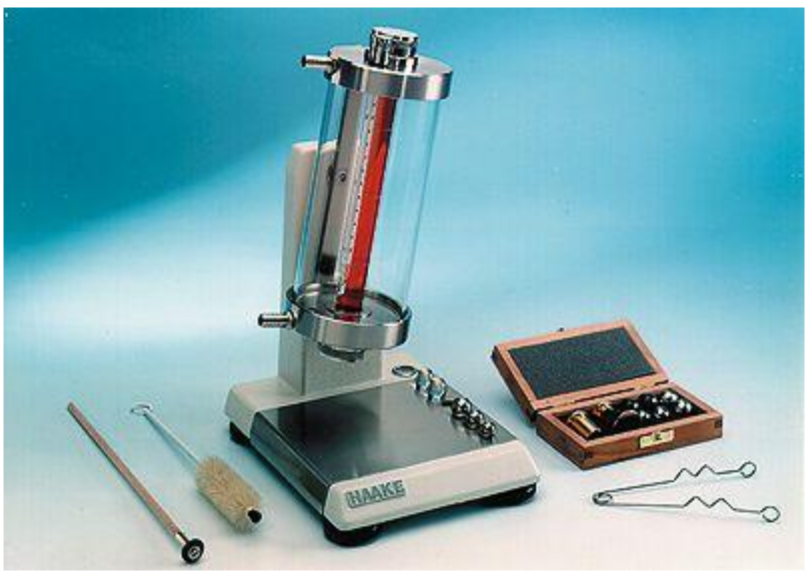


FIG. 8.63b
Ostwald manual capillary viscometer.





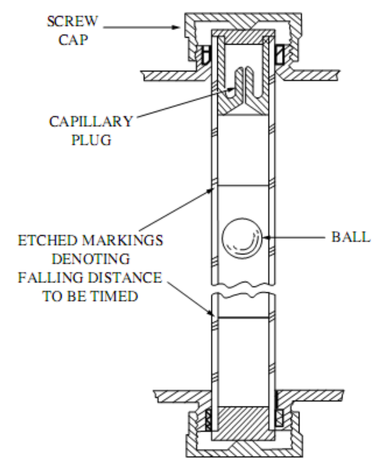


FIG. 8.63n
Falling-ball viscometer.

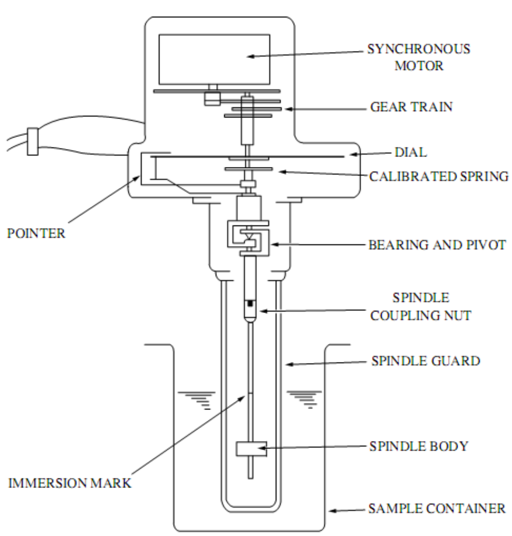
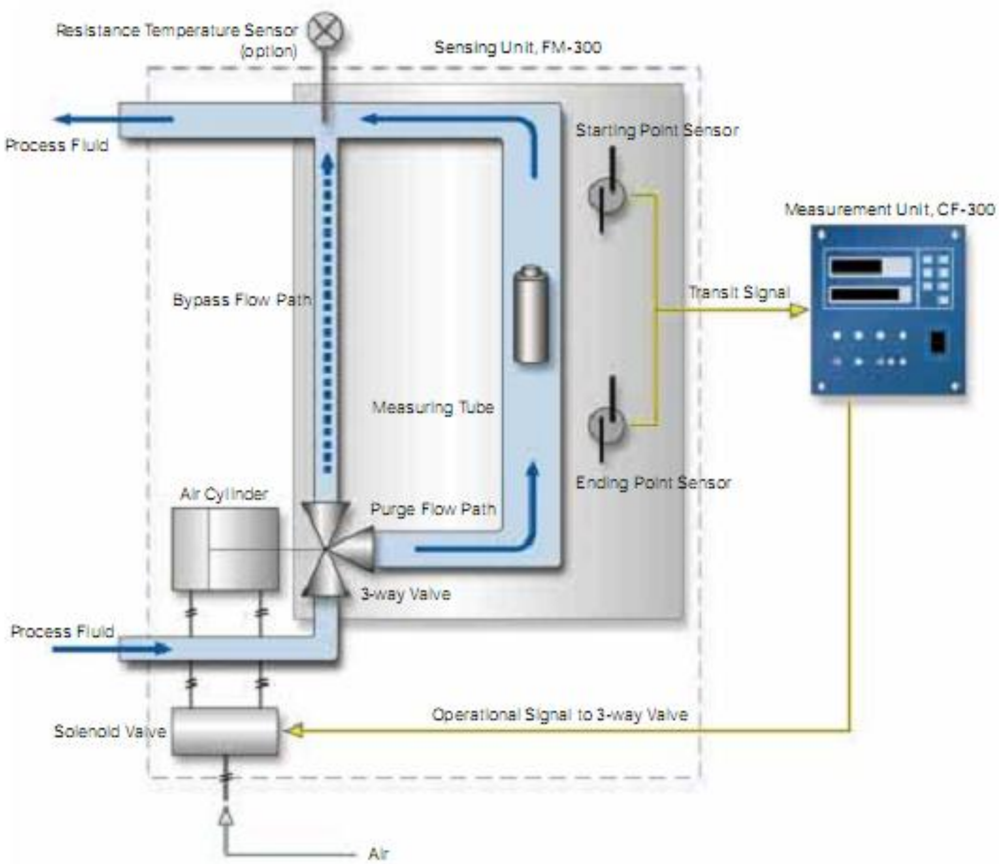


FIG. 8.63o
Rotational viscometer.



Process Falling Piston Viscometer

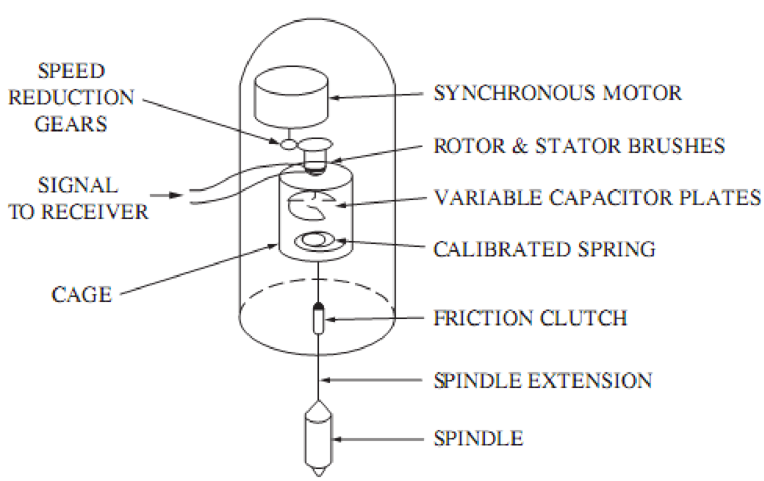


FIG. 8.64v

The operation of the rotating-spindle-type industrial viscometer.

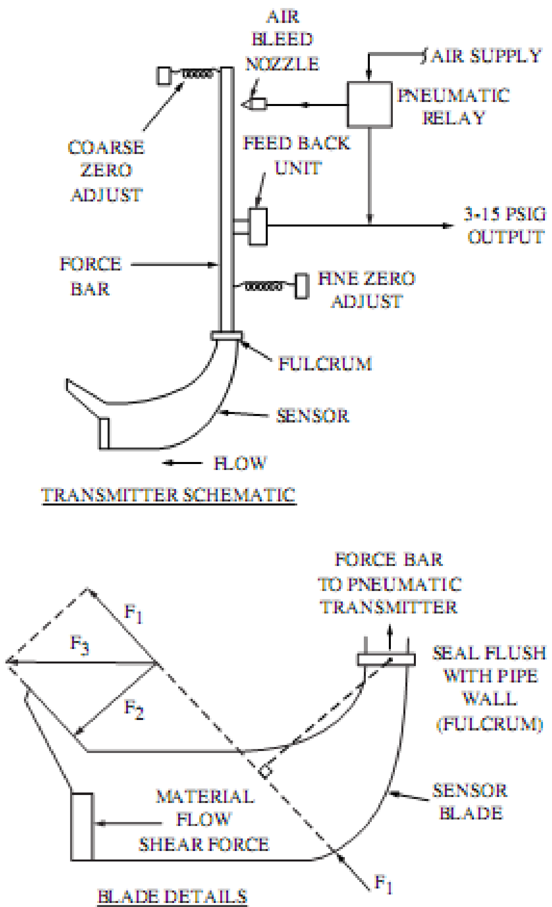


FIG. 8.18b
Stationary blade sensor and transmitter schematic. (Courtesy of Invensys Process Systems/Foxboro.)

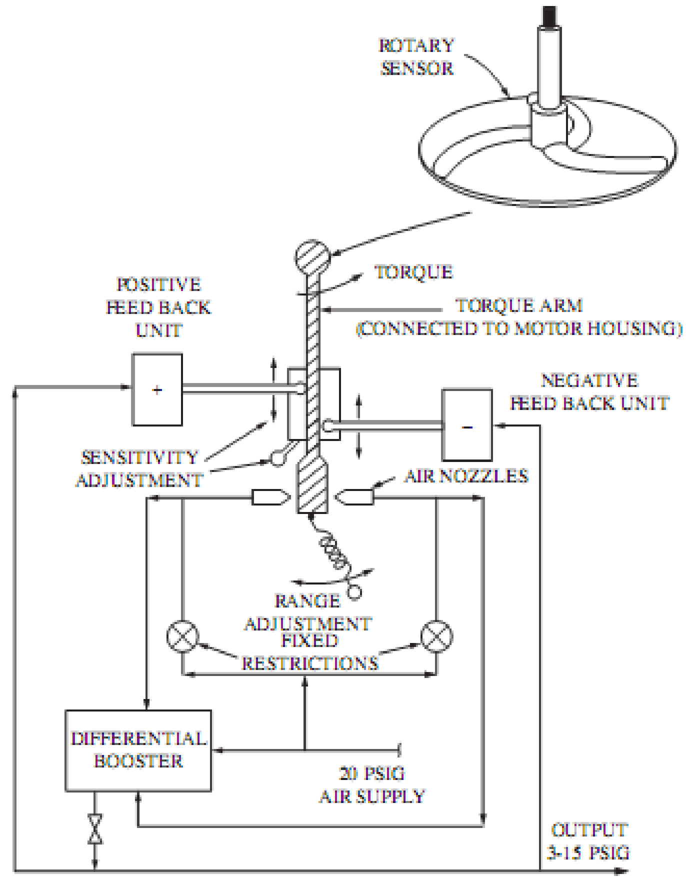
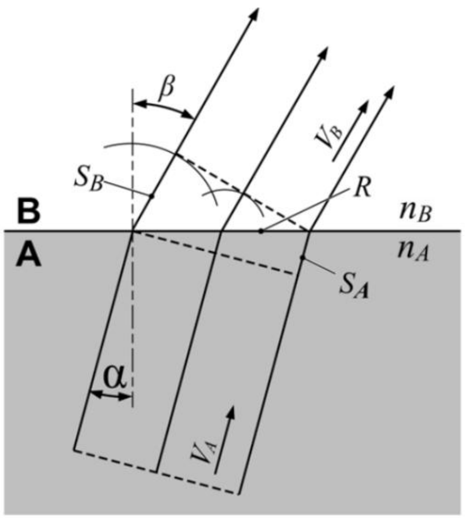


FIG. 8.18c
Air schematic of rotating sensor.

MEDICION DE ÍNDICE DE REFRACCIÓN



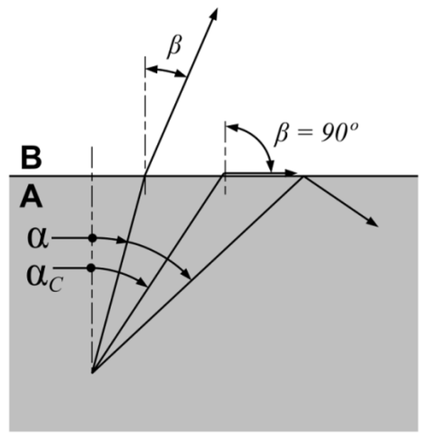
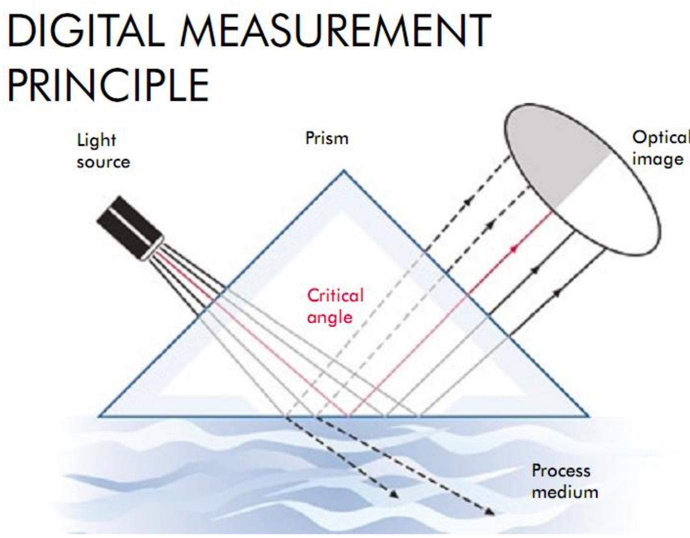
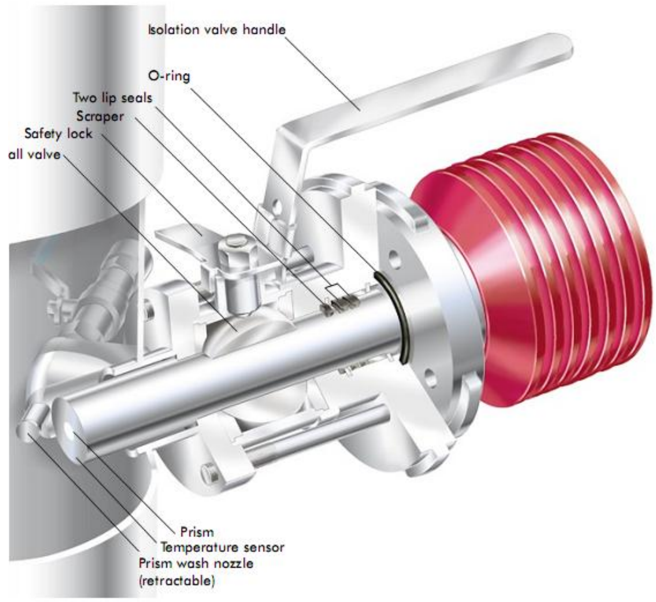
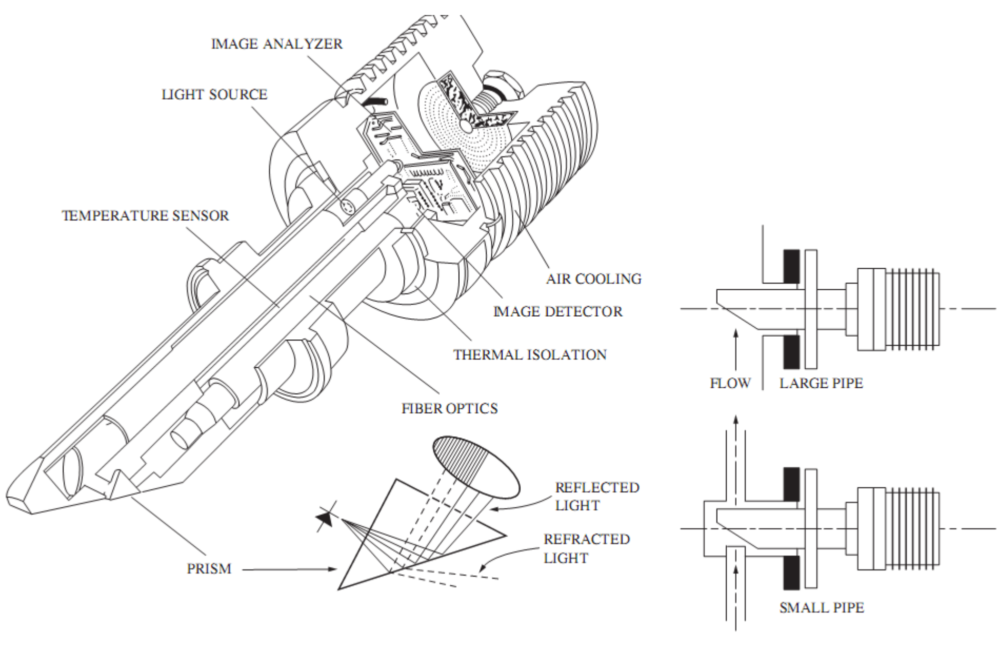


Figure 2. Ray at the critical angle







CONDUCTIVIDAD TÉRMICA DE GASES

Permiten medir la composición de mezclas binarias con moderada sensibilidad.
Aplicado en columnas de destilación

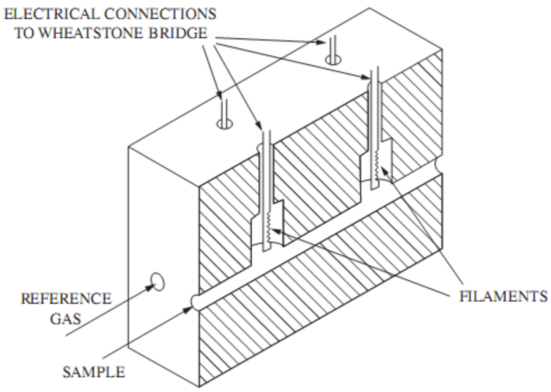


FIG. 8.57d
Four-element thermal conductivity cell.

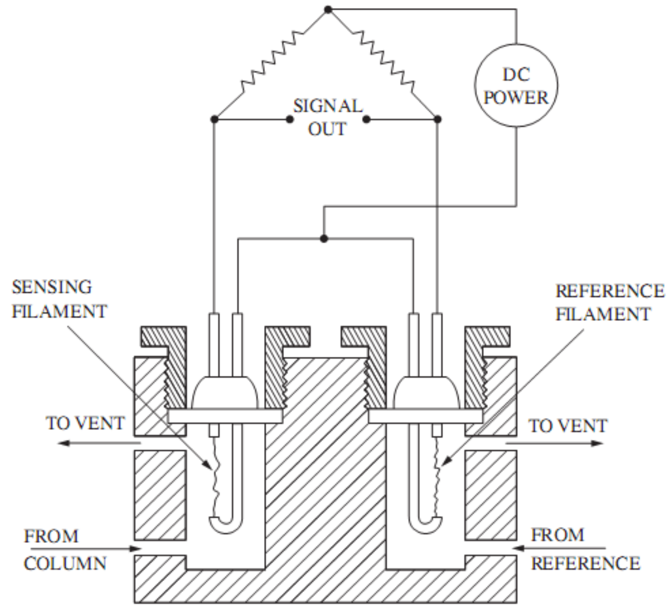
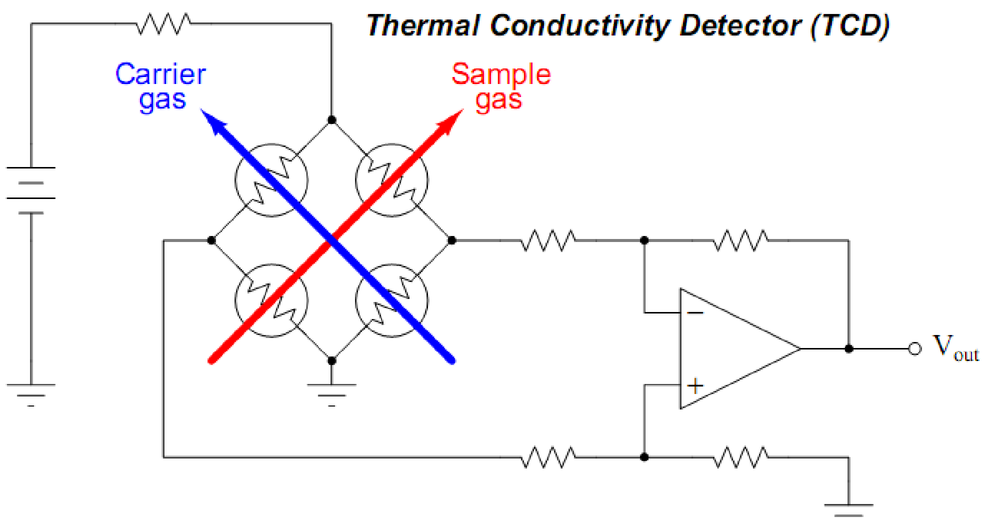


FIG. 8.57c
The design of a two-element, flow-through TCD cell.



MEDICIÓN DE COMPOSICIÓN EN LÍNEA

APLICACIONES:

- Chequeo de materia prima
- Calidad del producto
- Control automático de procesos
- Para gestión de inventario
- Para seguridad y protección
- Investigación y Desarrollo

CONSIDERACIONES PRÁCTICAS

- La muestra debe ser representativa
- El estado físico de la muestra es fundamental
- Especificidad del método

MUESTREO (Sampling)

Operación mediante la cual se toman porciones del fluido a analizar y se lo transporta hasta el punto donde de analiza la composición. Proceso crítico por la precisión y fuente de problemas de mantenimiento.

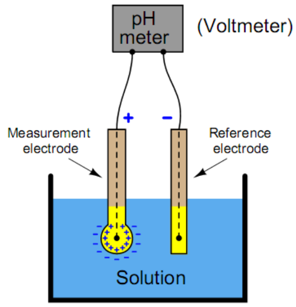
Los tipo de muestreo son:

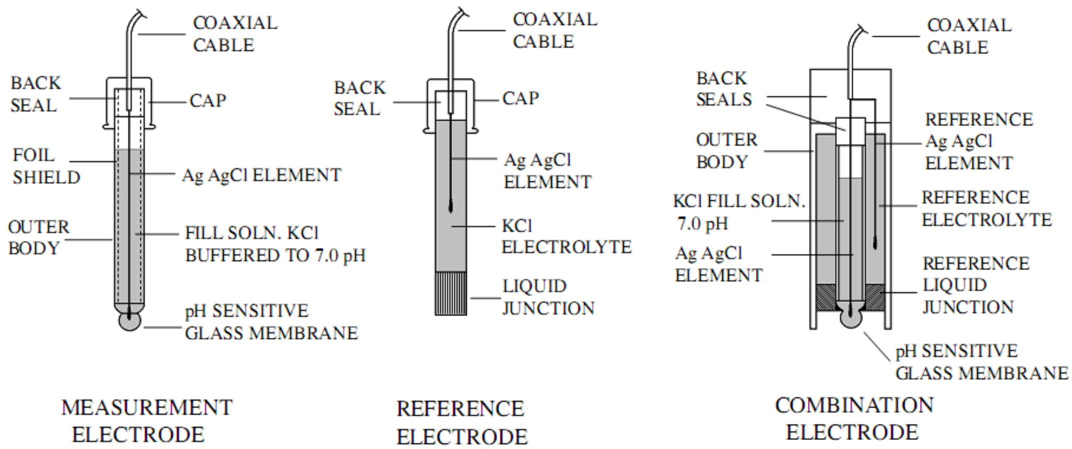
- In situ (on line)
- Ex situ (extractivo)
- Discreto

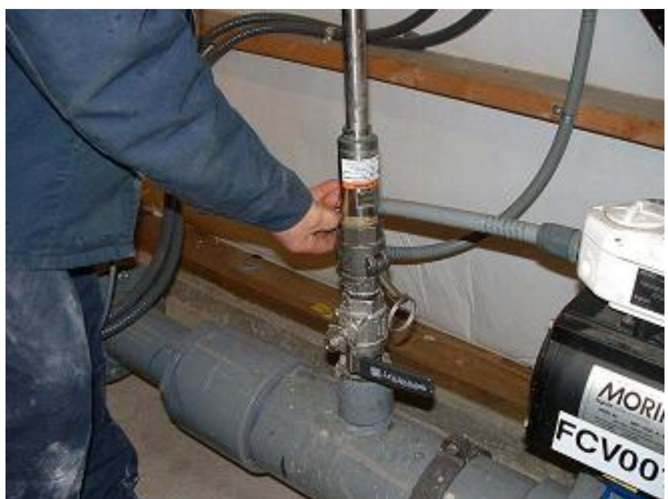
CLASIFICACIÓN DE LOS ANALIZADORES

GENERALES	Se aplican a un gran número de sustancias y para cada caso debe calibrarse con patrones. Se los puede categorizar en: • Cromatográficos • Espectrométricos • Electroquímicos
ESPECÍFICOS	Sirven para una sustancia determinada y corresponden a componentes muy difundidos y/o importantes. Ejemplos: humedad, oxigeno, etc.

MEDICIÓN DE pH EN LÍNEA







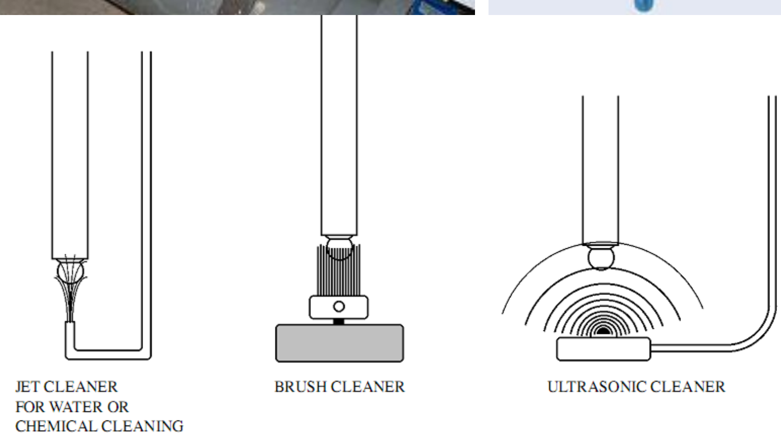
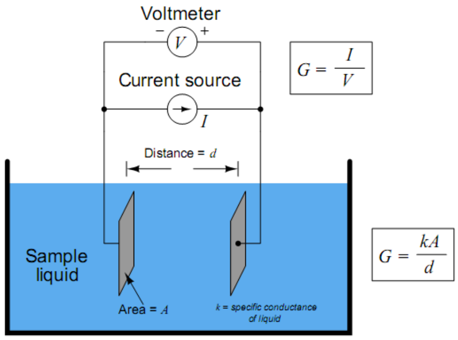
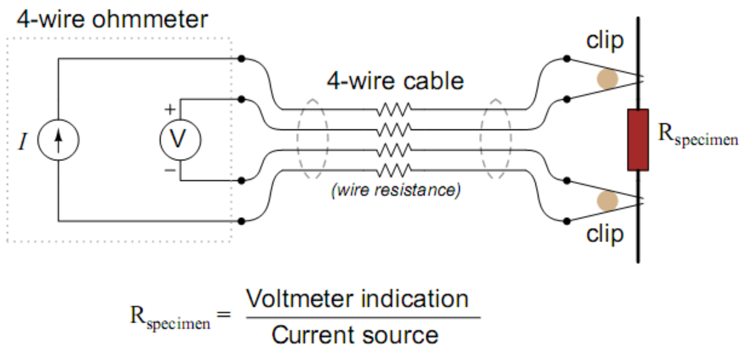
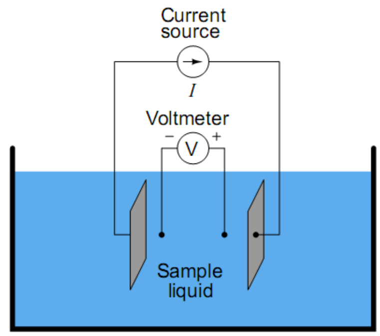


FIG. 8.48u
Design variations of on-line electrode cleaners.

MEDICIÓN DE CONDUCTIVIDAD







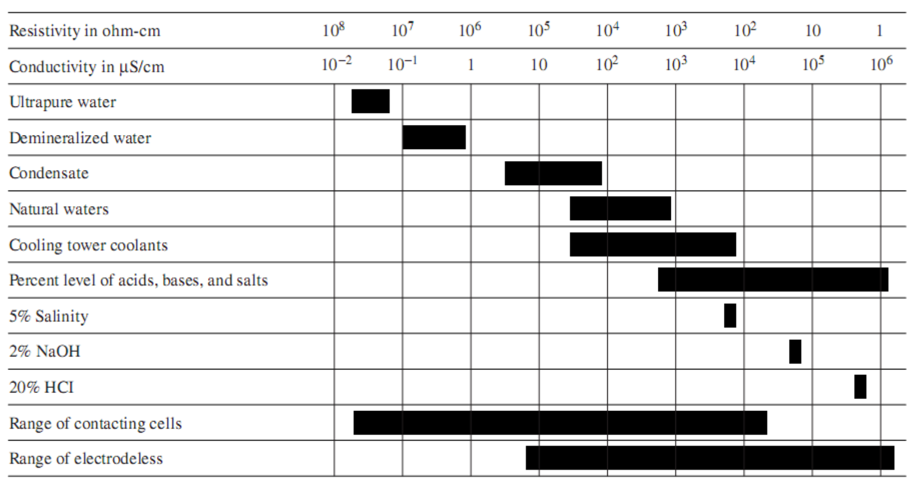
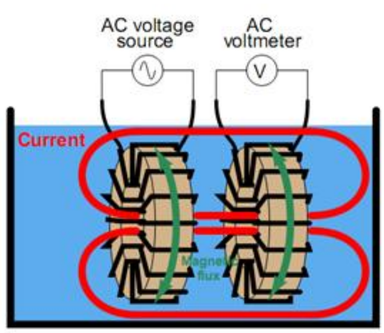
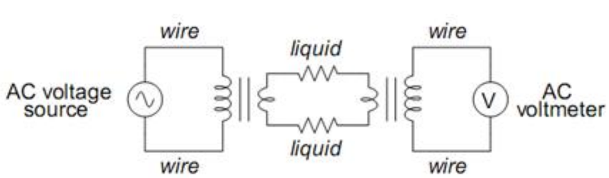


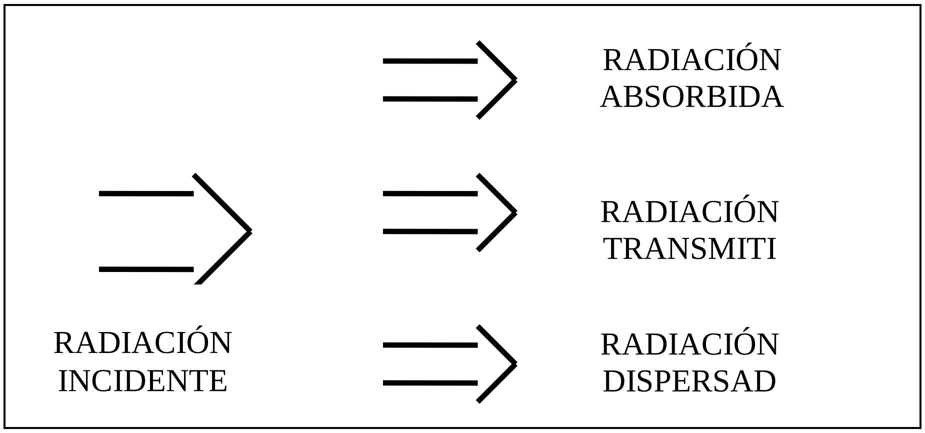
FIG. 8.17d
Resistivity/conductivity spectrum of aqueous electrolytes. (From Light, T. S., Chemtech, August 1990, pp. 4960–4501.)





ANALIZADORES ESPECTRÓMETRICOS

PRINCIPIO DE FUNCOINAMIENTO



TIPOS

- Analizadores Infrarrojos no dispersivo (NDIR)
- Analizadores fotométricos
- Analizadores Ultravioletas
- Analizadores de Rayos X
- Espectrómetros de masa (variante)
- Combinación de los anteriores