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Measuring the flow of liquids is a critical need in many industrial plants. In some operations, the ability to conduct accurate flow measurements is so important that it can make the difference between making a profit or taking a loss. In other cases, inaccurate flow measurements or failure to take measurements can cause serious (or even disastrous) results.

With most liquid flow measurement instruments, the flow rate is determined inferentially by measuring the liquid's velocity or the change in kinetic energy. Velocity depends on the pressure differential that is forcing the liquid through a pipe or conduit. Because the pipe's cross-sectional area is known and remains constant, the average velocity is an indication of the flow rate. The basic relationship for determining the liquid's flow rate in such cases is:

$$Q = V \times A$$

where

Q = liquid flow through the pipe; V = average velocity of the flow; A = cross-sectional area of the pipe.

Other factors that affect liquid flow rate include the liquid's viscosity and density, and the friction of the liquid in contact with the pipe. Direct measurements of liquid flows can be made with positive-displacement flowmeters. These units divide the liquid into specific increments and move it on. The total flow is an accumulation of the measured increments, which can be counted by mechanical or electronic techniques.

**Reynolds Numbers**

The performance of flowmeters is also influenced by a dimensionless unit called the Reynolds Number. It is defined as the ratio of the liquid's inertial forces to its drag forces. The

equation is:

$$R = \frac{3160 \times Q \times Gt}{D \times \mu}$$

where: R = Reynolds number; Q = liquid's flow rate, gpm; Gt = liquid's specific gravity; D = inside pipe diameter, in.; μ = liquid's viscosity, cp.

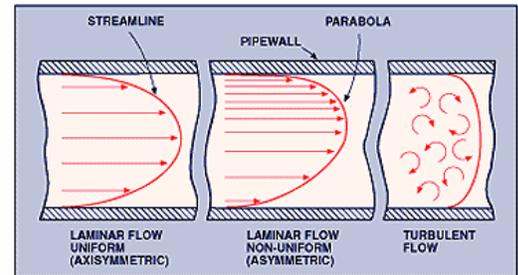


Figure 1: Laminar and turbulent flow are two types normally encountered in liquid flow Measurement operations. Most applications involve turbulent flow, with R values above 3000. Viscous liquids usually exhibit laminar flow, with R values below 2000. The transition zone between the two levels may be either laminar or turbulent.

The flow rate and the specific gravity are inertia forces, and the pipe diameter and viscosity are drag forces. The pipe diameter and the specific gravity remain constant for most liquid applications. At very low velocities or high viscosities, R is low, and the liquid flows in smooth layers with the highest velocity at the center of the pipe and low velocities at the pipe wall where the viscous forces restrain it. This type of flow is called laminar flow. R values are below approximately 2000. A characteristic of laminar flow is the parabolic shape of its velocity profile, Fig. 1.

However, most applications involve turbulent flow, with R values above 3000. Turbulent flow occurs at high velocities or low viscosities. The flow breaks up into turbulent eddies that flow through the pipe with the same average velocity. Fluid velocity is less significant, and the velocity profile is much more uniform in shape. A transition zone exists between turbulent and laminar flows. Depending on the piping configuration and other installation conditions, the flow may be either turbulent or laminar in this zone.

**FLOWMETER TYPES**

Numerous types of flowmeters are available for closed-piping systems. In general, the equipment can be classified as differential pressure, positive displacement, velocity, and mass meters. Differential pressure devices (also known as head meters) include orifices, venturi tubes, flow tubes, flow nozzles, pitot tubes, elbow-tap meters, target meters, and variable-area meters, Fig. 2.

Positive displacement meters include piston, oval-gear, nutating-disk, and rotary-vane types. Velocity meters consist of turbine, vortex shedding, electromagnetic, and sonic designs. Mass meters include Coriolis and thermal types. The measurement of liquid flows in open channels generally involves weirs and flumes.

Space limitations prevent a detailed discussion of all the liquid flowmeters available today.

**Differential Pressure Meters**

The use of differential pressure as an inferred measurement of a liquid's rate of flow is well known. Differential pressure flowmeters are, by far, the most common units in use today. Estimates are that over 50 percent of all liquid flow measurement applications use this type of unit.

The basic operating principle of differential pressure flowmeters is based on the premise that the pressure drop across the meter is proportional to the square of the flow rate. The flow rate is obtained by measuring the pressure differential and extracting the square root.

Differential pressure flowmeters, like most flowmeters, have a primary and secondary element. The primary element causes a change in kinetic energy, which creates the differential pressure in the pipe. The unit must be properly matched to the pipe size, flow conditions, and the liquid's properties. And, the measurement accuracy of the element must be good over a reasonable range. The secondary element measures the differential pressure and provides the signal or read-out that is converted to the actual flow value.

Flokal offers a wide row of pressure measuring units. Amongst them there are a differential pressure meters and gauges. For more information please look appendix 1.

Orifices are the most popular liquid flowmeters in use today. An orifice is simply a flat piece of metal with a specific-sized hole bored in it. Most orifices are of the concentric type, but eccentric, conical (quadrant), and segmental designs are also available. In practice, the orifice plate is installed in the pipe between two flanges. Acting as the primary device, the orifice constricts the flow of liquid to produce a differential pressure across the plate. Pressure taps on either side of the plate are used to detect the difference. Major advantages of orifices are that they have no moving parts and their cost does not increase significantly with pipe size.

Conical and quadrant orifices are relatively new. The units were developed primarily to measure liquids with low Reynolds numbers. Essentially constant flow coefficients can be maintained at R values below 5000. Conical orifice plates have an upstream bevel, the depth and angle of which must be calculated and machined for each application.

The segmental wedge is a variation of the segmental orifice. It is a restriction orifice primarily designed to measure the flow of liquids containing solids. The unit has the ability to measure flows at low Reynolds numbers and still maintain the desired square-root relationship. Its design is simple, and there is only one critical dimension the wedge gap. Pressure drop through the unit is only about half that of conventional orifices.

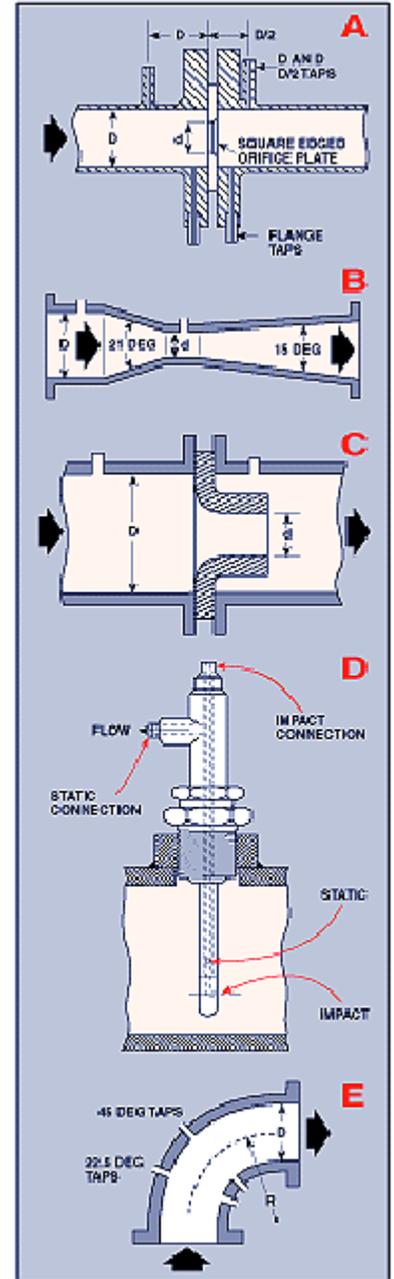


Figure 2: Common differential pressure flowmeters include the orifice (a), venturi tube (b), flow nozzle (c), pitot tube (d), and elbow-tap meter (e). All require secondary elements for measuring the differential pressure and for converting the data to values.

essentially a section of pipe with a tapered entrance and a straight throat. As liquid passes through the throat, its velocity increases, causing a pressure differential between the inlet and outlet regions.

The flowmeters have no moving parts. They can be installed in large diameter pipes using flanged, welded or threaded-end fittings. Four or more pressure taps are usually installed with the unit to average the measured pressure. Venturi tubes can be used with most liquids, including those having a high solids content.

Flow tubes are somewhat similar to venturi tubes except that they do not have the entrance cone. They have a tapered throat, but the exit is elongated and smooth. The distance between the front face and the tip is approximately one-half the pipe diameter. Pressure taps are located about one-half pipe diameter downstream and one pipe diameter upstream.

Flow Nozzles, at high velocities, can handle approximately 60 percent greater liquid flow than orifice plates having the same pressure drop. Liquids with suspended solids can also be metered. However, use of the units is not recommended for highly viscous liquids or those containing large amounts of sticky solids.

Pitot tubes sense two pressures simultaneously, impact and static. The impact unit consists of a tube with one end bent at right angles toward the flow direction. The static tube's end is closed, but a small slot is located in the side of the unit. The tubes can be mounted separately in a pipe or combined in a single casing.

Pitot tubes are generally installed by welding a coupling on a pipe and inserting the probe through the coupling. Use of most pitot tubes is limited to single point measurements. The units are susceptible to plugging by foreign material in the liquid. Advantages of pitot tubes are low cost, absence of moving parts, easy installation, and minimum pressure drop.

Elbow meters operate on the principle that when liquid travels in a circular path, centrifugal force is exerted along the outer edges. Thus, when liquid flows through a pipe elbow, the force on the elbow's interior surface is proportional to the density of the liquid times the square of its velocity. In addition, the force is inversely proportional to the elbow's radius.

Any 90 deg. pipe elbow can serve as a liquid flowmeter. All that is required is the placement of two small holes in the elbow's midpoint (45 deg. point) for piezometer taps. Pressure-sensing lines can be attached to the taps by using any convenient method.

Target meters sense and measure forces caused by liquid impacting on a target or drag-disk suspended in the liquid stream. A direct indication of the liquid flow rate is achieved by measuring the force exerted on the target. In its simplest form, the meter consists only of a hinged, swinging plate that moves outward, along with the liquid stream. In such cases, the device serves as a flow indicator.

A more sophisticated version uses a precision, low-level force transducer sensing element. The force of the target caused by the liquid flow is sensed by a strain gage. The output signal from the gage is indicative of the flow rate. Target meters are useful for measuring flows of dirty or corrosive liquids.

Integral wedge assemblies combine the wedge element and pressure taps into a one-piece pipe coupling bolted to a conventional pressure transmitter. No special piping or fittings are needed to install the device in a pipeline.

Metering accuracy of all orifice flowmeters depends on the installation conditions, the orifice area ratio, and the physical properties of the liquid being measured.

Venturi tubes have the advantage of being able to handle large flow volumes at low pressure drops.

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Variable-area meters, often called rotameters, consist essentially of a tapered tube and a float, Fig. 3. Although classified as differential pressure units, they are, in reality, constant differential pressure devices. Flanged-end fittings provide an easy means for installing them in pipes. When there is no liquid flow, the float rests freely at the bottom of the tube. As liquid enters the bottom of the tube, the float begins to rise. The position of the float varies directly with the flow rate. Its exact position is at the point where the differential pressure between the upper and lower surfaces balance the weight of the float.

Because the flow rate can be read directly on a scale mounted next to the tube, no secondary flow-reading devices are necessary. However, if desired, automatic sensing devices can be used to sense the float's level and transmit a flow signal. Rotameter tubes are manufactured from glass, metal, or plastic. Tube diameters vary from 1/4 to greater than 6 in.

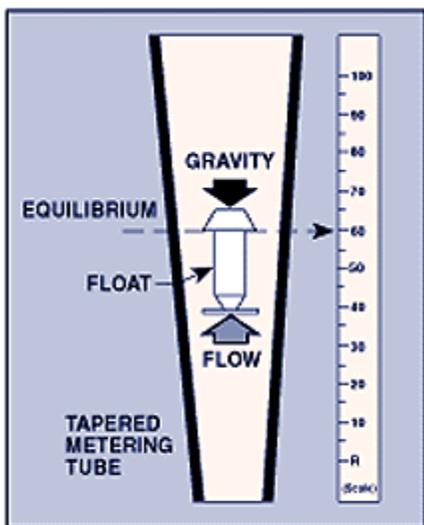


Figure 3: Variable-area flowmeter, also called a rotameter, has a float that moves up or down in a tapered tube. The distance is proportional to the liquid flow rate and the annular area between the float and the tube wall

For familiarization with our product in this direction, please look appendix 2.

## Positive-Displacement Meters

Operation of these units consists of separating liquids into accurately measured increments and moving them on. Each segment is counted by a connecting register. Because every increment represents a discrete volume, positive-displacement units are popular for automatic batching and accounting applications. Positive-displacement meters are good candidates for measuring the flows of viscous liquids or for use where a simple mechanical meter system is needed.

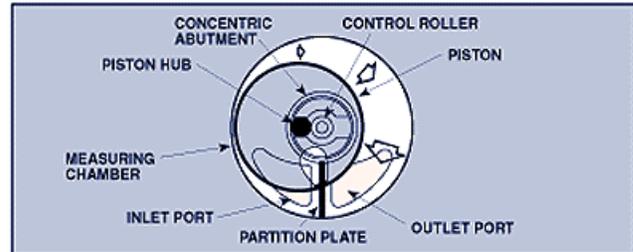


Figure 4: Oscillating-piston meter operates on a magnetic drive principle so that liquid will not come in contact with parts. A partition plate between inlet and outlet ports forces incoming liquid to flow around a cylindrical measuring chamber and through the outlet port. The motion of the oscillating piston in the unit is transferred to a magnetic assembly in the measuring chamber, which is coupled to a follower magnet on the other side of the chamber wall.

Reciprocating piston meters are of the single and multiple-piston types. The specific choice depends on the range of flow rates required in the particular application. Piston meters can be used to handle a wide variety of liquids. A magnetically driven, oscillating piston meter is shown in Fig. 4. Liquid never comes in contact with gears or other parts that might clog or corrode.

Oval-gear meters have two rotating, oval-shaped gears with synchronized, close fitting teeth. A fixed quantity of liquid passes through the meter for each revolution. Shaft rotation can be monitored to obtain specific flow rates.

Nutating-disk meters have a moveable disk mounted on a concentric sphere located in a spherical side-walled chamber. The pressure of the liquid passing through the measuring chamber causes the disk to rock in a circulating path without rotating about its own axis. It is the only moving part in the measuring chamber.

A pin extending perpendicularly from the disk is connected to a mechanical counter that monitors the disk's rocking motions. Each cycle is proportional to a specific quantity of flow. As is true with all positive-displacement meters, viscosity variations below a given threshold will affect measuring accuracies. Many sizes and capacities are available. The units can be made from a wide selection of construction materials.

Rotary-vane meters are available in several designs, but they all operate on the same principle. The basic unit consists of an equally divided, rotating impeller (containing two or more compartments) mounted inside the meter's housing. The impeller is in continuous contact with the casing. A fixed volume of liquid is swept to the meter's outlet from each compartment as the impeller rotates. The revolutions of the impeller are counted and registered in volumetric units.

Helix flowmeters consist of two radically pitched helical rotors geared together, with a small clearance between the rotors and the casing. The two rotors displace liquid axially from one end of the chamber to the other.

**Velocity Meters**

These instruments operate linearly with respect to the volume flow rate. Because there is no square-root relationship (as with differential pressure devices), their rangeability is greater. Velocity meters have minimum sensitivity to viscosity changes when used at Reynolds numbers above 10,000. Most velocity-type meter housings are equipped with flanges or fittings to permit them to be connected directly into pipelines.

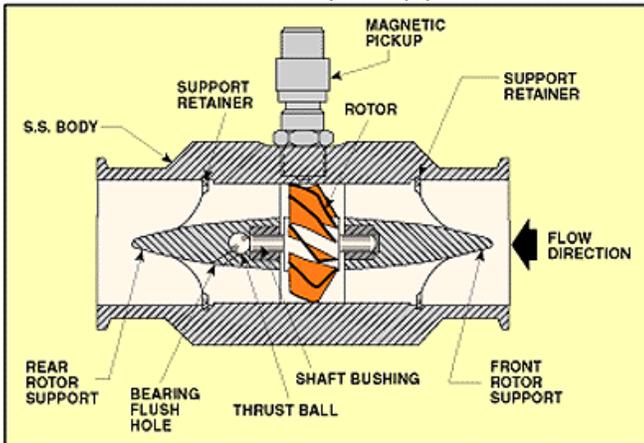


Figure 5: Turbine flowmeter consists of a multiple-bladed, free-spinning, permeable metal rotor housed in a non-magnetic stainless steel body. In operation, the rotating blades generate a frequency signal proportional to the liquid flow rate, which is sensed by the magnetic pickup and transferred to a read-out indicator

Turbine meters have found widespread use for accurate liquid measurement applications. The unit consists of a multiple-bladed rotor mounted with a pipe, perpendicular to the liquid flow. The rotor spins as the liquid passes through the blades. The rotational speed is a direct function of flow rate and can be sensed by magnetic pick-up, photoelectric cell, or gears. Electrical pulses can be counted and totalized, Fig. 5.

The number of electrical pulses counted for a given period of time is directly proportional to flow volume. A tachometer can be added to measure the turbine's rotational speed and to determine the liquid flow rate. Turbine meters, when properly specified and installed, have good accuracy, particularly with low-viscosity liquids. A major concern with turbine meters is bearing wear. A "bearingless" design has been developed to avoid this problem. Liquid entering the meter travels through the spiraling vanes of a stator that imparts rotation to the liquid stream. The stream acts on a sphere, causing it to orbit in the space between the first stator and a similarly spiraled second stator. The orbiting movement of the sphere is detected electronically. The frequency of the resulting pulse output is proportional to flow rate.

Vortex meters make use of a natural phenomenon that occurs when a liquid flows around a bluff object. Eddies or vortices are shed alternately downstream of the object. The frequency of the vortex shedding is directly proportional to the velocity of the liquid flowing through the meter, Fig. 6.

The three major components of the flowmeter are a bluff body strut-mounted across the flowmeter bore, a sensor to detect the presence of the vortex and to generate an electrical impulse, and a signal amplification and conditioning transmitter whose output is proportional to the flow rate, Fig. 7. The meter is equally suitable for flow rate or flow totalization measurements. Use for slurries or high viscosity liquids is not recommended.

Electromagnetic meters can handle most liquids and slurries, providing that the material being metered is electrically conductive. Major components are the flow tube (primary element), Fig. 8.

The flow tube mounts directly in the pipe. Pressure drop across the meter is the same as it is through an equivalent length of pipe because there are no moving parts or obstructions to the flow. The voltmeter can be attached directly to the flow tube or can be mounted remotely and connected to it by a shielded cable.

Electromagnetic flowmeters operate on Faraday's law of electromagnetic induction that states that a voltage will be induced when a conductor moves through a magnetic field. The liquid serves as the conductor; the magnetic field is created by energized coils outside the flow tube, Fig. 9. The amount of voltage produced is directly proportional to the flow rate. Two electrodes mounted in the pipe wall detect the voltage, which is measured by the secondary element.

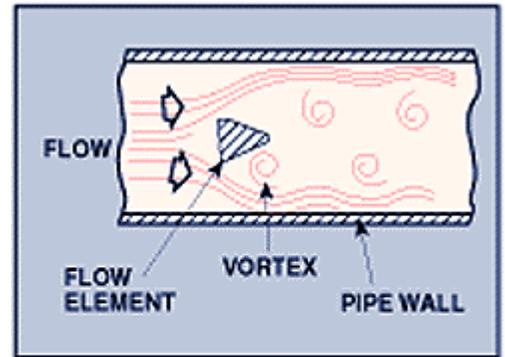


Figure 6: Vortex meters operate on the principle that when a nonstreamlined object is placed in the middle of a flow stream, a series of vortices are shed alternately downstream of the object. The frequency of the vortex shedding is directly proportional to the velocity of the liquid flowing in the pipeline



Figure 7: Vortex Flowmeter is designed to be installed directly into pipelines without the need for special tools or complicated installation procedures. Unit is pre-calibrated and ready for use.

Electromagnetic flowmeters have major advantages: They can measure difficult and corrosive liquids and slurries; and they can measure forward as well as reverse flow with equal accuracy. Disadvantages of earlier designs were high power consumption, and the need to obtain a full pipe and no flow to initially set the meter to zero. Recent improvements have eliminated these problems. Pulse-type excitation techniques have reduced power consumption, because excitation occurs only half the time in the unit. Zero settings are no longer required.



Figure 8: Water-type electromagnetic flowmeter is light weight, compact, and can be easily installed between existing pipe flanges. The no-moving-part instrument has negligible pressure drop and can handle numerous liquids and slurries, provided they are conductive.

Ultrasonic flowmeters can be divided into Doppler meters and time-of-travel (or transit) meters. Doppler meters measure the frequency shifts caused by liquid flow. Two transducers are mounted in a case attached to one side of the pipe. A signal of known frequency is sent into the liquid to be measured. Solids, bubbles, or any discontinuity in the liquid, cause the pulse to be reflected to the receiver element, Fig. 10. Because the liquid causing the reflection is moving, the frequency of the returned pulse is shifted. The frequency shift is proportional to the liquid's velocity.

A portable Doppler meter capable of being operated on AC power or from a rechargeable power pack has recently been developed. The sensing heads are simply clamped to the outside of the pipe, and the instrument is ready to be used. Total weight, including the case, is 22 lb. A set of 4 to 20 millampere output terminals permits the unit to be connected to a strip chart recorder or other remote device. Time-of-travel meters have transducers mounted on each side of the pipe. The configuration is such that the sound waves traveling between the devices are at a 45 deg. angle to the direction of liquid flow. The speed of the signal traveling between the transducers increases or decreases with the direction of transmission and the velocity of the liquid being measured. A time-differential relationship proportional to the flow can be obtained by transmitting the signal alternately in both directions. A limitation of time-of-travel meters is that the liquids being measured must be relatively free of entrained gas or solids to minimize signal scattering and absorption. Mass Flowmeters The continuing need for more accurate flow measurements in mass-related processes (chemical reactions, heat transfer, etc.) has resulted in the development of mass flowmeters.

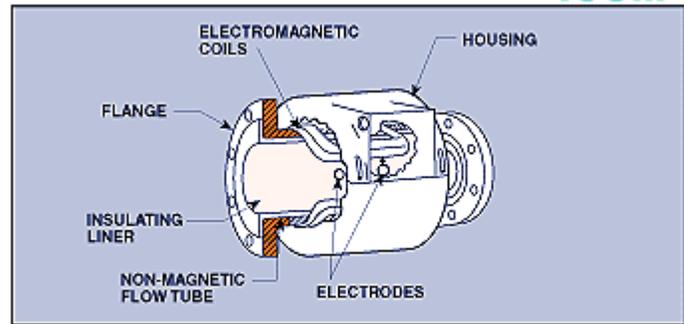


Figure 9: Major components of obstruction-free electromagnetic flowmeter's flow tube include electrodes and coils.

Various designs are available, but the one most commonly used for liquid flow applications is the Coriolis meter. Its operation is based on the natural phenomenon called the Coriolis force, hence the name.

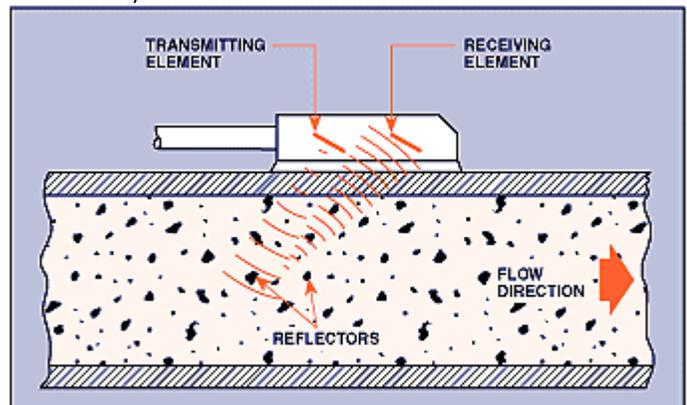


Figure 10: Doppler meters use sound pulse reflection principle to measure liquid flow rates. Solids or bubbles in suspension in the liquid reflect the sound back to the receiving transducer element.

Coriolis meters are true mass meters that measure the mass rate of flow directly as opposed to volumetric flow. Because mass does not change, the meter is linear without having to be adjusted for variations in liquid properties. It also eliminates the need to compensate for changing temperature and pressure conditions. The meter is especially useful for measuring liquids whose viscosity varies with velocity at given temperatures and pressures.

Coriolis meters are also available in various designs. A popular unit consists of a U-shaped flow tube enclosed in a sensor housing connected to an electronics unit. The sensing unit can be installed directly into any process. The electronics unit can be located up to 500 feet from the sensor.

Inside the sensor housing, the U-shaped flow tube is vibrated at its natural frequency by a magnetic device located at the bend of the tube. The vibration is similar to that of a tuning fork, covering less than 0.1 in. and completing a full cycle about 80 times/sec. As the liquid flows through the tube, it is forced to take on the vertical movement of the tube, Fig. 11. When the tube is moving upward during half of its cycle, the liquid flowing into the meter resists being forced up by pushing down on the tube.

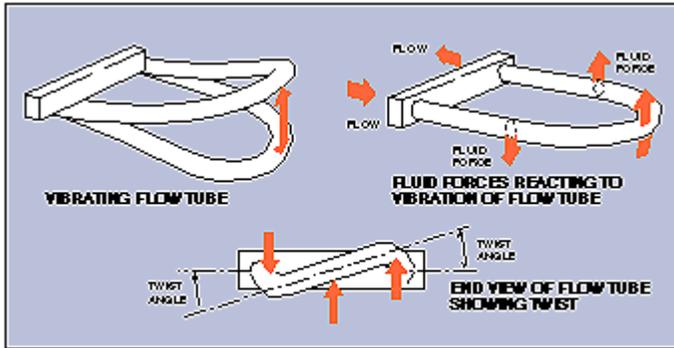


Figure 11: Vibrating, U-shaped flow tube is heart of popular Coriolis mass flowmeter. Tube vibration, coupled with the fluid's force, causes tube deflection that is directly proportional to the mass flow rate

Having been forced upward, the liquid flowing out of the meter resists having its vertical motion decreased by pushing up on the tube. This action causes the tube to twist. When the tube is moving downward during the second half of its vibration cycle, it twists in the opposite direction.

Having been forced upward, the liquid flowing out of the meter resists having its vertical motion decreased by pushing up on the tube. This action causes the tube to twist. When the tube is moving downward during the second half of its vibration cycle, it twists in the opposite direction. The amount of twist is directly proportional to the mass flow rate of the liquid flowing through the tube. Magnetic sensors located on each side of the flow tube measure the tube velocities, which change as the tube twists. The sensors feed this information to the electronics unit, where it is processed and converted to a voltage proportional to mass flow rate. The meter has a wide range of applications from adhesives and coatings to liquid nitrogen.

Thermal-type mass flowmeters have traditionally been used for gas measurements, but designs for liquid flow measurements are available. These mass meters also operate independent of density, pressure, and viscosity. Thermal meters use a heated sensing element isolated from the fluid flow path. The flow stream conducts heat from the sensing element. The conducted heat is directly proportional to the mass flow rate. The sensor never comes into direct contact with the liquid, Fig. 12. The electronics package includes the flow analyzer, temperature compensator, and a signal conditioner that provides a linear output directly proportional to mass flow.

For familiarization with our product in this direction, please look appendix 3.

### Open Channel Meters

The "open channel" refers to any conduit in which liquid flows with a free surface. Included are tunnels, nonpressurized sewers, partially filled pipes, canals, streams, and rivers. Of the many techniques available for monitoring open-channel flows, depth-related methods

are the most common. These techniques presume that the instantaneous flow rate may be determined from a measurement of the water depth, or head. Weirs and flumes are the oldest and most widely used primary devices for measuring open-channel flows.

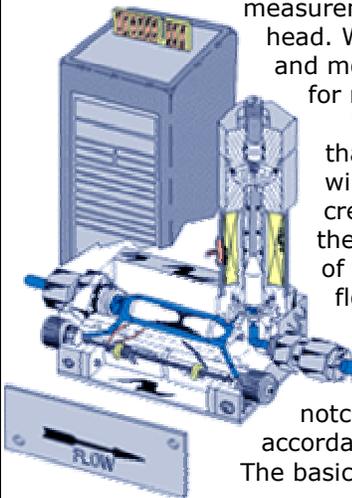


Fig 12: Thermal mass meters utilize a bypass design with RTD sensors to determine the flow rate.

Weirs operate on the principle that an obstruction in a channel will cause water to back up, creating a high level (head) behind the barrier. The head is a function of flow velocity, and, therefore, the flow rate through the device.

Weirs consist of vertical plates with sharp crests. The top of the plate can be straight or notched. Weirs are classified in accordance with the shape of the notch. The basic types are V-notch, rectangular, and trapezoidal.

Flumes are generally used when head loss must be kept to a minimum, or if the flowing liquid contains large amounts of suspended solids. Flumes are to open channels what venturi tubes are to closed pipes. Popular flumes are the Parshall and Palmer-Bowlus designs.

The Parshall flume consists of a converging upstream section, a throat, and a diverging downstream section. Flume walls are vertical and the floor of the throat is inclined downward. Head loss through Parshall flumes is lower than for other types of open-channel flow measuring devices. High flow velocities help make the flume self-cleaning. Flow can be measured accurately under a wide range of conditions.

Palmer-Bowlus flumes have a trapezoidal throat of uniform cross section and a length about equal to the diameter of the pipe in which it is installed. It is comparable to a Parshall flume in accuracy and in ability to pass debris without cleaning. A principal advantage is the comparative ease with which it can be installed in existing circular conduits, because a rectangular approach section is not required.

Discharge through weirs and flumes is a function of level, so level measurement techniques must be used with the equipment to determine flow rates. Staff gages and float-operated units are the simplest devices used for this purpose. Various electronic sensing, totalizing, and recording systems are also available.

A more recent development consists of using ultrasonic pulses to measure liquid levels. Measurements are made by sending sound pulses from a sensor to the surface of the liquid, and timing the echo return. Linearizing circuitry converts the height of the liquid into flow rate. A strip chart recorder logs the flow rate, and a digital totalizer registers the total gallons. Another recently introduced microprocessor-based system uses either ultrasonic or float sensors. A key-pad with an interactive liquid crystal display simplifies programming, control, and calibration tasks.

## SELECTING A FLOWMETER

Experts claim that over 75 percent of the flowmeters installed in industry are not performing satisfactorily. And improper selection accounts for 90 percent of these problems. Obviously, flowmeter selection is no job for amateurs.

The most important requirement is knowing exactly what the instrument is supposed to do. Here are some questions to consider. Is the measurement for process control (where repeatability is the major concern), or for accounting or custody transfer (where high accuracy is important)? Is local indication or a remote signal required? If a remote output is required, is it to be a proportional signal, or a contact closure to start or stop another device? Is the liquid viscous, clean, or a slurry? Is it electrically conductive? What is its specific gravity or density? What flow rates are involved in the application? What are the processes' operating temperatures and pressures? Accuracy (see glossary), range, linearity, repeatability, and piping requirements must also be considered.

It is just as important to know what a flowmeter cannot do as well as what it can do before a final selection is made. Each instrument has advantages and disadvantages, and the degree of performance satisfaction is directly related to how well an instrument's capabilities and shortcomings are matched to the application's requirements. Often, users have expectations of a flowmeter's performance that are not consistent with what the supplier has provided. Most suppliers are anxious to help customers pick the right flowmeter for a particular job. Many provide questionnaires, checklists, and specification sheets designed to obtain the critical information necessary to match the correct flowmeter to the job.

Technological improvements of flowmeters must be considered also. For example, a common mistake is to select a design that was most popular for a given application some years ago and to assume that it is still the best instrument for the job. Many changes and innovations may have occurred in recent years in the development of flowmeters for that particular application, making the choice much broader.

### Calibration

All flowmeters require an initial calibration. Most of the time, the instrument is calibrated by the manufacturer for the specified service conditions. However, if qualified personnel are available in the plant, the user can perform his own calibrations.

The need to recalibrate depends to a great extent on how well the meter fits the application. Some liquids passing through flowmeters tend to be abrasive, erosive, or corrosive. In time, portions of the device will deteriorate sufficiently to affect performance. Some designs are more susceptible to damage than others. For example, wear of individual turbine blades will cause performance changes. If the application is critical, flowmeter accuracy should be checked at frequent intervals. In other cases, recalibration may not be necessary for years because the application is noncritical, or nothing will change the meter's performance. Some flowmeters require special equipment for calibration. Most manufacturers will provide such service in their plant or in the user's facility, where they will bring the equipment for on-site calibration.

### Maintenance

A number of factors influence maintenance requirements and the life expectancy of flowmeters. The major factor, of course, is matching the right instrument to the particular application. Poorly selected devices invariably will cause problems at an early date. Flowmeters with no moving parts usually will require less attention than units with moving parts. But all flowmeters eventually require some kind of maintenance.

Primary elements in differential pressure flowmeters require extensive piping, valves, and fittings when they are connected to their secondary elements, so maintenance may be a recurring effort in such installations. Impulse lines can plug or corrode and have to be cleaned or replaced. And, improper location of the secondary element can result in measurement errors. Relocating the element can be expensive.

Flowmeters with moving parts require periodic internal inspection, especially if the liquid being metered is dirty or viscous. Installing filters ahead of such units will help minimize fouling and wear. Obstructionless instruments, such as ultrasonic or electromagnetic meters, may develop problems with their secondary element's electronic components. Pressure sensors associated with secondary elements should be periodically removed and inspected.

Applications where coatings may occur are also potential problems for obstructionless instruments such as magnetic or ultrasonic units. If the coating is insulating, the operation of magnetic flowmeters will ultimately be impaired if the electrodes are insulated from the liquid. This condition will be prevented by periodic cleaning. With ultrasonic flowmeters, refraction angles may change and the sonic energy absorbed by the coating will cause the meter to become inoperative.

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- ✓ Level measurement & display
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- ✓ Humidity measurement & display
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- ✓ Process Analytical solutions
- ✓ Automation and Software
- ✓ Flow meters

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## APPENDIX 1

### Flokal's differential pressure meters and gauges

#### Differential Pressure Sensor SDP1000 for gases: Low cost & offset-free!

Low cost sensor with differential pressure measurement range from 0.1 Pa to 3500 Pa (0.0004-14 inch water). Ideal for high volume applications due to simple handling and very attractive pricing for OEM applications. Analog voltage output. Fully calibrated and temperature compensated.



#### Differential Pressure Sensor ASP1400: Precise & offset free!

Differential pressure measurement range from 0.001 to 100 Pa. Ideal for very low differential pressures, because it is offset free and without drift. Calibrated and temperature compensated. With digital RS-232 output.



#### OEM Solutions for differential pressure measurement

Starting with the standard products of our leading CMOSens® technology, we develop and customize sensor modules and complete instruments for a wide range of different applications, such as: automatic building control, process control, etc.



#### DPG1000 "Falcon" Series - Digital Pressure Gauge

The base model DPG1000B is a lithium battery operated gauge with 0.25% Full Scale Accuracy. It is an ideal choice as a portable technician's test gauge. Other models include battery powered backlit display, AC/DC or loop powered gauges with transmitting outputs and/or dual relay outputs. The dual relay action allows the gauge to act as an indicating pressure switch with Hi/Low alarm/control levels. All gauges feature 316 SS wetted parts so they are suited for both gas or liquid service. Accuracy levels of  $\pm 0.1\%$  are available as an option, along with NIST test data.



#### 2 Inch Stainless Steel Gauges

The 2 inch gauges were designed and developed for the demanding high-purity applications of the semiconductor industry. With an accuracy of 1% of full scale, the 2 inch gauge offers a reliable and efficient way to monitor pressure locally. This durable measuring device comes in a variety of process corrections, pressure ranges, and socket orientations.



#### 2 Inch Stainless Steel Indicating Pressure Switch

The IPS-122 Stainless Steel Indicating Pressure Switch provides a high-purity, precision pressure gauge and electronic switch with adjustable pressure switch setpoint. This compact 2 inch unit has the ability to operate lights or relays up to a maximum of 12 watts. Available in a variety of pressure ranges and process connections, and cleaned and double bagged in a Class 100 environment, this device provides solid state switching for cleanroom and hazardous applications.



#### 2 Inch Stainless Steel Indicating Pressure Transmitter

With a variety of outputs available, the 2 Inch stainless Steel Indicating Pressure Transmitter (IPT) is a very versatile sending unit. Accurate within 1% of full scale, the IPT can provide 0 - 5 VDC, 1 - 5 VDC or 4 - 20 mA outputs with pressure ranges up to 4,000 psi. The IPT is cleaned and double bagged in a Class 100 environment for ultimate high purity.



#### IDG202 Digital Pressure Gauge

The IDG202 series in-line gauges provide local display of process pressure. Local display of process pressure improves safety and quality control of the gas delivery systems. The IDG202 is battery-powered or can be powered by an external 6 VDC power supply. The IDG202 digital gauge provides accurate, reliable and easy to use pressure measurement and display.



**APPENDIX 2**  
**Flokal's flow meters for process industry**

**BM Series**

BM01 and BM02 are low flow positive displacement oval flowmeters designed for applications requiring the high accuracy measurement of clean liquids with viscosities less than 1000 Cp. Units are available with a pulse output from a Reed switch or solid state Hall effect switch for remote registration and/or totalization.



Models BM04, BM07, BM10, BM40 and BM50 are positive displacement oval gear flowmeters designed for applications requiring high accuracy measurement of clean liquids with viscosity's less than 1000 cP standard, or up to 1 million cP with rotors (gears) cut for high viscosity. All meters are available with a pulse output from a reed switch or solid state Hall effect switch for remote registration and/or totalization. Two optional LCD displays offer rate, resettable total, non-resettable total and the option for simple batch (Deluxe Display). Also offered on sizes BM10 and larger is an option for mechanical totalization. All six meters are available with PPS rotors (gears) as standard. Also available as an option are 316 SS rotors (gears). The Model BM07 is only available with a PPS body, rotors (gears) and optional Hastelloy C® rotor (gear) shafts. The BM07 is specially designed for corrosive liquid service when the optional Hastelloy C shafts are selected. The Model BM10 is available with optional 1 inch Tri-Clover connections in all 316 Stainless Steel construction.

Flow indicator provides a means of indication at lowest cost for noncorrosive flow applications. A standard direct reading scale engraved on the body affords maximum simplicity of installation and operation. Available options include integral needle control valves, as well as flow controllers on the inlet or outlet of single tube meters.



Model 300 two-stage electronic Batch Controller is a microprocessor based panel mounted instrument designed to be used in conjunction with primary flow sensors which have a pulse or contact closure output. The main function of the unit is to provide indication and control of process batch size. The Model 300 factors input pulses into engineering units and provides two control outputs at adjustable set-points. Both local and remote start-stop- reset functions are provided. Selection of counter configurations (reset to zero, set to preset, and inventory totalization), as well as input scaling, preset levels, decimal locations, software selectable debounce settings and special security numbers are all entered on the sealed front key pad by following the displayed instructions.



**Purgemeter Variable Area Sho-Rate™, LFC™ & Brooks-Mite™**

Kynar Sho-Rate series of low flow indicators provides a cost-effective means of accurate flow indication for difficult to handle, corrosive fluids. Available options include the Brooks-Line IVTM or NRSTM integral needle control valves.



LFC series of low flow indicators provides a most cost-effective means of flow indication where the accuracy requirements are not severe. Available options include the Brooks-Line IVTM integral needle control valve.

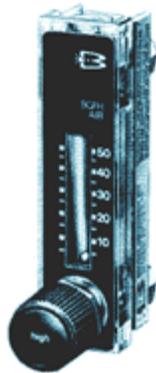


Sho-Rate "50" series of low flow indicators provides a cost effective means of flow indication where the accuracy requirements are not severe. Available options include an integral needle control valve as well as flow controllers piped to the inlet or outlet of the meter.



**APPENDIX 2**  
**Flokal's flow meters for process industry**

Advanced concepts and design at very low cost - Mite "27" Series is a flowmeter of high impact FDA approved polycarbonate. A standart direct reading scale affords maximum simplicity of installation and operation. The unit is designed as a practical approach to low flow rate indication on noncorrosive liquids and gases at lowest possible cost. It is aviable with or without the optional integral control valve.



Model 2700 with Valve



Model 8744

Model 8744 NRS flow controllers accurately adjust and maintain small gas flows. They are designed for constant upstream, variable downstream applications. Model 8744 is supplied with an integral NRS (non-rising stem) control valve. It features an adjustable sliding tapered needle which resists sticking due to foreign matter in the fluid. Suitable for precise control requirements, the valve possesses a high turns-to-lift ratio which provides stable flow for any given stem position.

8601 Pressure Regulators are high precision supply pressure regulators which are direct-acting, non-relieving units that provide bubble-tight shut-off on helium at 100 psi. Compact and economical, these units are assembled in a "clean room" environment and are tested under simulated operating conditions.



Model 8601 Pressure Regulator

**VA Accessories- NRS™ Valves, Flow Controllers & Pressure Regulators**

Flow controllers are designed to maintain a constant differential pressure across an integral manual flow regulating valve. An internal diaphragm-actuated control valve is positioned by the incoming fluid pressure on one side of the diaphragm, and outlet pressure plus spring action on the other side. Variations in the supply and/or discharge pressure disturb the balance of forces on the diaphragm, causing the control valve to open or close, thus maintaining a fixed differential across the manual flow regulating valve. The Series 8800 controllers are designed for all liquid and gas flows with constant downstream pressures; Series 8900 controllers are for all liquid and gas flows with constant upstream pressures.



Model 8944

NRS flow controllers accurately adjust and maintain small gas and liquid flows. Model 8844 is designed for constant downstream, variable upstream applications and Model 8944 is designed for constant upstream, variable downstream applications.

Models 8844 and 8944 are supplied with an integral NRS (non-rising stem) control valve. It features an adjustable sliding tapered needle which resists sticking due to foreign matter in the fluid. Particularly suitable for precise control requirements, this valve possesses a high turnsto-lift ratio which provides stable flow for any given stem position.



Model 8504 Straight Pattern Needle Valve



Model 8513 Angle Pattern Needle Valve with Numerical Handle

NRS (non-rising stem) control valves are designed specifically for extremely low flow gas and liquid applications. Straight and 90° angle pattern models in brass or stainless steel are available. These valves are particularly suitable for precise control requirements and possess a high turns to lift ratio. Six needles with different tapers provide a wide choice of flow ranges. Needles and orifices can be changed without removing the valve body from the line (two different orifices are used, one for needle sizes 1-3, another for sizes 4-6).

## APPENDIX 2

### Flok'al's flow meters for process industry

#### Metal Tube Variable Area Armored Purge, Ar-Met® & Brooksight™

MT 3600, MT 3601 and MT 3602 armored flowmeters are designed to be reliable and economical high flow rate purge meters with 10% accuracy. These meters are especially useful for metering coolants, pump seal fluids, lubricants under pressure, and opaque fluids. The flow rate is measured by the movement of a tapered plug in a fixed orifice. Indication is by an external tubular follower coupled magnetically to an extension of the tapered plug. A certified explosion-proof/ intrinsically safe alarm is optional.



#### Model MT 3810 description

Model MT 3810 Variable Area Flowmeter is a rugged, all metal flowmeter offering 5% full scale accuracy. The MT 3810 is constructed with stainless steel components for measuring a variety of liquid and gas applications. Flow rate indication is provided by means of magnetic coupling where a magnet, encapsulated in the float, is coupled to a rotatable magnet located in the rear of the indicator, thus turning the dial indicator mounted on the meter. Optional accessories available include 4-20 mA output with HART microprocessor transmitter with or without configurable alarms and pulse output for totalization. The microprocessor electronics are based on the proprietary Smart Meter Manager technology utilized as the basis for an array of Brooks Products. Also available are front adjustable inductive alarms.

#### Models MT 3809 & MT 3819 description

Models MT 3809 and MT 3819 Variable Area Flowmeters are rugged, all metal flowmeters offering 2% full scale accuracy. The Model MT 3809 is constructed with stainless steel components for measuring a variety of gas, liquid and steam applications while the Model MT 3819 utilizes a ETFE (Tefzel™) lining for aggressive liquid and gas applications. Flow rate indication is provided by means of magnetic coupling where a magnet, encapsulated in the float, is coupled to a rotatable magnet located in the rear of the indicator, thus turning the dial indicator mounted on the meter. Optional accessories available include 4-20 mA output with HART microprocessor transmitter with or without configurable alarms and pulse output for totalization. The microprocessor electronics are based on the proprietary Smart Meter Manager technology utilized as the basis for an array of Brooks Products. Also available are front adjustable inductive alarms, high temperature or stainless steel indicator housings, valves, sight flows, flow controllers and material certifications.

Ar-Met® Metal Tube Flowmeters are intended for applications where high pressures, temperatures, or corrosive conditions preclude the use of conventional glass or metal tube meters.



#### Metal Tube Variable Area Flowmeters with Optional Electronics based on Smart Meter Manager™ Technology



#### Models MT 3809 & MT 3819

Broad range of flow capacities; 2% Full scale accuracy; versatile construction for all gas, liquid, steam applications; operable under high temperatures and pressures; flanged or female NPT connections; optional 4-20mA and HART® programmable microprocessor transmitter with or without alarms and pulse output for totalization; electronics designed with either intrinsically safe or explosion proof construction to meet UL, cUL, CENELEC and TIIS certifications and CE requirements.

#### Model MT 3810

Broad range of flow capacities; 5% Full scale accuracy; versatile construction for all gas and liquid applications; no back pressure required for operation; flanged or female NPT connections; optional 4-20 mA and HART® programmable microprocessor transmitter with or without alarms and pulse output for totalization; electronics designed with either intrinsically safe or explosion proof construction to meet UL, cUL, CENELEC and TIIS certifications and CE requirements.

**APPENDIX 2**  
**Flokal's flow meters for process industry**



Ar-Mite™ is a reliable, low flow metal tube flowmeter with 316L stainless steel wetted parts. The magnetically coupled indicator provides a highly reliable method of indication. This model is a practical and economical

approach to low flow rate indication for high pressure and difficult to handle fluids. Optional accessories include 4-20 mA output, Needle Valve, Flow Controllers and Alarms.



Brooksight Model 8000B Sight Flow Indicators provide a quick, reliable and economical way to verify fluid flows through industrial process lines. Brooksight

Model 8000B series is available with four styles of indicators including propeller, bidirectional flapper, bidirectional plain or drip tube.

Full-View High Accuracy Flowmeter is intended for use where the accuracy required is higher than that obtainable with the standard 250mm (10 inch) scale length flowmeter. Each High Accuracy Flowmeter is individually calibrated to a guaranteed  $\pm 1\%$  of rate accuracy. Full-View High Accuracy meters are furnished with the same rigid case construction and other features of the standard Full-View Flowmeter.



Model 1305

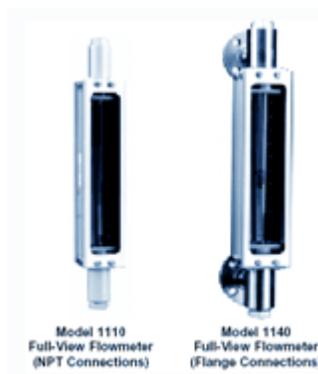
Model 1305 glass tube flowmeters provide a low cost means of flow rate indication and alarm signaling. They are designed for applications where the metering accuracy requirements are not severe. These meters are ideal for purge type service, seal oil systems, bearing lubrication and cooling water indication. Model 1305 is available with vertical inlets and outlets and standard materials of construction only. A general purpose alarm, with flow contacts over the entire flow range, is optional.

**Glass Tube Variable Area GT1000, Full-View® & O-Ring Seal**

GT 1000 combines ruggedness and simplicity in design to provide a versatile glass tube flowmeter suitable for a wide range of applications. The GT 1000 O-ring construction minimizes process downtime by allowing for convenient in-line removal of the glass tube for cleaning and maintenance.



Model GT 1000



Model 1110  
Full-View Flowmeter  
(NPT Connections)

Model 1140  
Full-View Flowmeter  
(Flange Connections)

Full-View® glass tube meters are designed to offer a wide variety of meter configurations to meet a broad range of metering applications. The packing gland seal construction provides for long-term, leak-free, and reliable flow measurement.



Model 1307

Model 1307 O-ring seal flowmeters are economical, accurate indicating flowmeters. They are designed for applications where the industrial features or special materials of construction of Brooks® standard Full-View® or GT 1000 flowmeters are not required.

## APPENDIX 3

### Flokal's mass/liquid flow meters/controllers (from Bronkhorst High-Tech B.V.)

#### EX-FLOW® Mass Flow Meters/Controllers

The flow meters/controllers of the EX-FLOW series are thermal mass flow meters/ controllers in rugged construction for use in hazardous areas. The sensor is PTB or CENELEC tested and approved under number PTB Ex-88.B.2103, protection EEx ib IIC T4. The characteristic properties of Bronkhorst Hi-Tec mass flow meters/controllers are also found in the ex-proof instruments: (no moving parts; short response time; no need for flow computer; temperature and pressure measurement; low pressure drop; pressure ratings up to 400 bar). Lowest range 0,2...10 mln/min. Highest range 220...11.000 mln/min.

#### IN-FLOW® Mass Flow Meters and Controllers for Gases

The instruments of the IN-FLOW series are Thermal Mass Flow Meters/Controllers of rugged design for use in pilot and production plants under industrial operating conditions. The housing of the electronics compartment is IP65 protected.

Lowest range 0,2 ...10 mln/min;

Highest range 220 ...11.000 m<sup>3</sup>n/h.

#### EL-FLOW® Mass Flow Meters for Gases

Instruments of the EL-FLOW series are mass flow meters and controllers in modular construction with an electronics housing suitable for common laboratory type and non-weatherproof industrial type ambient conditions. In order to convert a mass flow meter to a controller, a control valve is used. These series comprise gas flows between the smallest range of 0.06...3 mln/min and the highest range of 25...1250 ln/min. The pressure drop is approx. 35 mbar at maximum flow for the F-110C/ F-111C series and approx. 70 mbar for the F-112AC/F-113AC series.

#### EL-FLOW® Mass Flow Controllers for Gases

EL-FLOW mass flow controllers are the only MFCs on the market that can handle flow ranges between 0...3 mln/min and 0...1250 ln/min and operating pressures between vacuum and 400 bar in one single series of instruments. The control valve design distinguishes itself from competitive designs in its truly modular construction and it can be field replaced or changed by the user without any adjustment. Normally opened valves can also be supplied. Patented constructions enable us to handle high flows and/or pressures at differential pressures up to 400 bar in the EL-FLOW programme, which is unique.



## APPENDIX 3

### Flok'al's mass/liquid flow meters/controllers (from Bronkhorst High-Tech B.V.)

#### EL-FLOW® Digital Mass Flow Meters and Controllers

The digital Mass Flow Meters and Controllers are based on new digital electronics where the analog sensor signal is sent directly to a microprocessor. By doing so, optimum signal stability and accuracy is achieved. An integral alarm function continuously checks the difference between the setpoint- and the measured value. If, for example, the supply pressure of a Mass Flow Controller drops and therefore the flow can no longer be controlled, the instrument gives a warning. In addition the instrument runs a self diagnostics routine, and controller settings can be remotely adjusted with a handterminal or a computer via FLOW-BUS, Bronkhorst Hi-Tec's RS-485 based fieldbus. In these instruments both analog in- and output signals and digital communications are possible at the same time. Thanks to this feature it is very easy to replace analog instruments with digital instruments in an existing installation. The digital features of the new instrument can be selected with a multi-functional switch on the instrument, with a handterminal or a computer via FLOW-BUS.

#### EL-FLOW® Digital Mass Flow Meters and Controllers for Gases "The MFC that speaks your language"

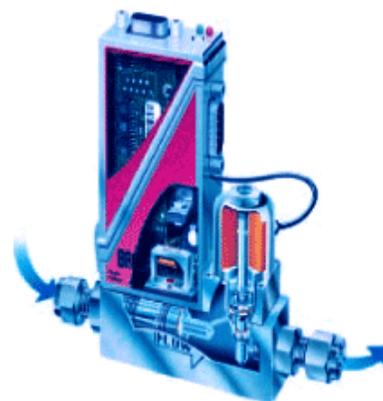
The Mass Flow Meters of the EL-FLOW® Series are compact, modular instruments. They can be combined with control valves, either integrated or separate, in order to measure and control gas flows in ranges starting from 0,06...3 mln/min up to 25...1250 ln/min air-equivalent. Bronkhorst High-Tech B.V. developed their latest digital instruments according to the "multi-bus" principle. The basic pc-board on the instrument contains all of the general functions needed for measurement and control. It has analog I/O-signals and also an RS232 connection as a standard feature. In addition to this there is the possibility of integrating an interface board with DeviceNet™, Profibus-DP® or FLOW-BUS protocol. The last mentioned is a fieldbus based RS485, specifically designed by Bronkhorst High-Tech B.V. for their mass flow metering and control solutions, thanks to which the company already has over ten years of experience with digital communication.

#### EL-FLOW® Digital Mass Flow Controllers for Gases

In some applications there are more requirements for a modern instrument than analog based technology can offer. Examples of these requirements are self diagnostics, alarm and counter functions, digital communication and remotely adjustable control settings. These requirements can only be met with a digital based instrument. Therefore Bronkhorst High-Tech B.V. developed this new instrument that offers you more features than the analog based design.

Lowest range 0,06 ... 3 mln/min.

Highest range 0 ... 1250 ln/min.



## APPENDIX 3

### Flokal's mass/liquid flow meters/controllers (from Bronkhorst High-Tech B.V.)

#### LIQUI-FLOW® Mass Flow Meters and Controllers for Liquids

LIQUI-FLOW® are innovative liquid flow meters/controllers for small flow ranges. The instruments operate on a thermal, thru-flow measuring principle and contains a patented sensor.

Lowest range 0,1 ... 5 g/h H<sub>2</sub>O-equivalent. Highest range 0,4 ... 20 kg/h H<sub>2</sub>O-equivalent.

#### μ-FLOW® Mass Flow Meters and Controllers for Liquids

The μ-FLOW mass flow meter is basically a straight tube of stainless steel 316L without any built-in obstructions, internal diameter approx. 1 mm. In the centre of the tube is the heater/sensor arrangement, based on measuring heat transfer. Flow control is achieved by coupling to the meter a COMBI-FLOW control valve with a purge connection on top of the sleeve, or as an option an on/off valve, so as to eliminate air or gas when starting up the system. The electronic control function forms part of the normal circuitry in the meter.

#### LOW-DP-FLOW® Mass Flow Meters/Controllers for low pressure drop or corrosive gases service

For applications with only little differential pressure Bronkhorst High-Tech developed the LOW-DP-FLOW series mass flow meters and controllers. In these instruments, the flow resistance is minimised by a different sensor and by-pass construction. The design and construction also result in a significantly longer lifetime even when used on corrosive gas service and lower contamination risk, combined with an easy-to-clean procedure.

Lowest range 0,2 ... 10 mln/min.

Highest range 0 ... 1000 m3n/h.



Model F-004AC / F-004BC Control Valves

## APPENDIX 3

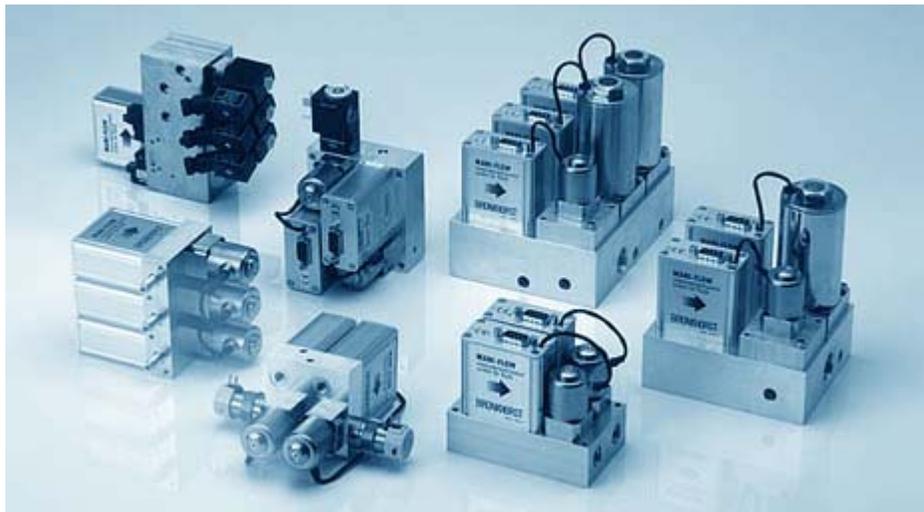
### Flokal's mass/liquid flow meters/controllers (from Bronkhorst High-Tech B.V.)

#### CORI-FLOW® Mass Flow Meters and Controllers for Gases and Liquids

Bronkhorst High-Tech BV, designed a new series, CORI-FLOW, mass flow metering instruments to provide high accuracy ( up to  $\pm 0,1$  % FS plus  $\pm 0,2\%$  of Reading). CORI-FLOW utilizes a patented, advanced Coriolis type mass flow sensor to achieve unsurpassed performance, even with changing operation conditions in pressure, temperature, density, conductivity and viscosity. CORI-FLOW is offered with or without integral control valve and analog and digital communication, RS-232 with Profibus-DP or Devicenet.



#### MANI-FLOW Customized Manifold Solutions for Mass Flow and Pressure



The MANI-FLOW Series originate from the demand of some customers to design an economical solution that combines various functions into one compact device. Since 1996 a large variety of solutions has been designed and manufactured. On a compact manifold one or more mass flow or pressure sensor modules can be combined with control valves, two- or three-way valves, shut-off valves, filters or any other functional module as per customer's request. The specifications are open for discussion. Depending on the application the customer may prefer an aluminum or stainless steel manifold, with female threads for gas connections to specification. On request, the system will be assembled, tested and packaged in a clean room. Because of the infinite number of possible solutions, we recommend you to contact our nearest distributor to discuss your application.

### FLOKAL B.V.

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## APPENDIX 3

### Flokal's mass/liquid flow meters/controllers (from Brooks Instruments)

#### Smart Gas Mass Flow Meters and Controllers

Brooks Instrument expands the capability and functionality of their successful Smart Mass Flow Products. Along with analogue and digital communication interfaces, these highly accurate instruments are also available with PROFIBUS-DP. The superior design makes these Brooks Smart Mass Flow Products virtually insensitive (fit-and-forget) to process interference's. All Smart Flow Controllers are provided with adaptive control algorithm to ensure unrivalled performance and fast control even under varying process conditions.

#### Smart Metal Sealed/Ultra High Purity Digital Mass Flow Meter and Controller

Brooks Instrument expands the capability and functionality of their successful Smart Mass Flow Products to include a metal sealed, UltraHigh Purity instrument. This new breed of mass flow controller is available with analog, digital, RS-232, RS-485 or PROFIBUS-DP communication interface protocols. Brooks Proprietary Adaptive Valve Control makes these Smart Mass Flow Products virtually insensitive to process interference. The Adaptive Valve Control algorithm ensure sunrivalled performance and fast control, under varying process conditions. Brooks' commitment to continuous improvement in safety standards and application flexibility, has resulted in a product that offers industry leading performance. Brooks Instrument continues to excel in performance, features, reliability, serviceability and quality.

#### High Performance Metal Sealed Mass Flow Controllers

The Brooks ® Model 5964 Metal Sealed Mass Flow Controller offers state of the art performance in gas flow measurement and control. It combines the outstanding leak integrity of metal seals, ultraclean internal surface finish (5 Ra) for particulate-free delivery and enhanced response for rapid process applications. A leader in its class, the Brooks Model 5900 Series MFC's redefine Ultra Clean Performance by providing molecular contamination levels which are less than half the industry standard. The superior design also allows for very rapid gas changeover.

#### High Performance Metal Seal High Flow Mass Flow Controllers

The Brooks ® Model 5965 Mass Flow Controller offers state of the art performance in high flow gas measurement and control. It combines the outstanding leak integrity of metal seals, ultraclean internal surface finish (7 Ra) for particulate-free delivery and enhanced response for rapid process applications. A leader in its class, the Brooks Model 5900 Series MFC's redefine Ultra Clean Performance by providing molecular contamination levels which are less than half the industry standard. The superior design also allows for very rapid gas changeover. All of this makes the Model 5965 the best solution for even the most challenging application.



## APPENDIX 3

### Flokal's mass/liquid flow meters/controllers (from Brooks Instruments)

#### Delta Class Gass Mass Flow Meters and Controllers (EL Series)

Brooks Instrument Delta Class elastomer seal thermal mass flow measurement and control product line offers unparalleled flexibility and performance. Latest EL Series combine the benefits of superior accuracy with Brooks' proprietary Adaptive Valve Control algorithm. The MFC/M's microprocessor uses a multi-point calibration curve, to deal with residual sensor non-linearity, yielding a highly accurate process signal. The microprocessor then executes Brooks' proprietary Adaptive Valve Control algorithm to rapidly adjust the valve actuation to match setpoint. Process data and commands are available as traditional 0-5 volt analog I/O or digital DeviceNet communications. Measurement and control performance are the same! Delta Class Products take advantage of modular design in both mechanical and electrical construction. The Delta Class EL Series controllers and meters can directly replace existing analog Products providing greatly improved accuracy. Analog and digital applications will see settling time improvements and improved stability to varying process conditions, due to Brooks' proprietary Adaptive Valve Control algorithm.

#### QUANTIM® Precision Mass Flow Measurement and Control

##### Brooks QUANTIM® IP40/NEMA 1 & Brooks QUANTIM® NEMA 4X/IP65 Precision Mass, Multivariable Flow Measurement and Control

Brooks® QUANTIM® offers unsurpassed accuracy and unmatched zero stability in demanding low flow liquid applications. QUANTIM® provides Precision Mass Flow Measurement and Integral Control, On-line Density and Temperature Measurement all in one compact package. The heart of the device is a patented and revolutionary Coriolis sensor design, which measures low flow, independent of the fluid type or process variables. This provides you with unsurpassed performance in even the most challenging operating environments. The QUANTIM sensor features no moving parts or obstructions in the flow path. There are no special mounting or flow conditioning requirements. Most critical processes require control as well as measurement, therefore the QUANTIM series offers an optional integrally mounted, in-line control valve.

#### Flomega™ Liquid Mass Flow Controllers/Meters

##### Liquid Mass Flow Controller/Meter Model 5881/5891 (100 gram/hr. max.)

The Brooks ® Flomega thru-flow liquid mass flow sensor is the heart of the Models 5881 and 5891. Both models are self-contained with signal conditioning electronics and housed in weather-tight enclosures. The Flomega Model 5881 Liquid Controller includes an integrally mounted control valve and control electronics. The Flomega Model 5891 Liquid Mass Flowmeter and Model 5881 Liquid Mass Flow Controller accurately measure extremely low flows of liquid.

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## APPENDIX 3

### Flokal's mass/liquid flow meters/controllers (from Brooks Instruments)

#### E-Series Mass Flow Controllers (Models 5850E, 5850EM)

The Brooks® Model 5850E Mass Flow Controller accurately measures and controls gas flows. The heart of the system is the removable flow sensor which produces an electrical output signal linear with flow rate used for indicating, recording, and/or control purposes. It eliminates the need for continuous monitoring and readjustment of gas pressures to provide a stable gas flow.

#### E-Series Mass Flow Controllers&Meters (Models 5853E, 5863E)

The Brooks® Models 5853E/5863E Mass Flow Controller and Meter accurately measure and control gas flow (5863E Meter only). The heart of the system is its removable, attitude- insensitive sensor which produces an electrical output signal linear with flow rate used for indicating, recording, and/or control purposes. It eliminates the need for continuous monitoring and readjustment of gas pressures to provide a stable gas flow.

#### E-Series Mass Flow Meters (Models 5860E, 5861E)

The Brooks® Model 5860E, 5861 E Mass Flowmeter accurately measures gas flow. The heart of the system is the flow sensor which produces an electrical output signal linear with mass flow rate. This signal is used for indicating and/or recording. Many options are offered to provide a versatile system of mass flow measurement.

#### E-Series High Flow Mass Flow Controllers (Model 5851E)

The Brooks® Model 5851E Mass Flow Controller accurately measures and controls gas flow. The heart of the system is the removable flow sensor which produces an electrical output signal linear with flow rate used for indicating, recording, and/or control purposes. It eliminates the need for continuous monitoring and readjustment of gas pressures to provide a stable gas flow.



Model 5850E  
with Card Edge Connector



Model 5850E  
with "D" Type Connector



Model 5853E  
with D-Type Connector  
and Compression Fittings



Model 5863E  
with D-Type Connector  
and Flange Fittings



Model 5861E



Model 5860E  
Mass Flowmeter



Model 5851E  
with Card Edge Connector



Model 5851E  
with "D" Type Connector

## APPENDIX 3

### Flokal's mass/liquid flow meters/controllers (from Brooks Instruments)

#### E-Series Metal Seal High Flow Mass Flow Controller (Model 5851EM)

The Brooks® Model 5851EM Metal Seal Mass Flow Controller offers state of the art performance in high flow gas measurement and control. It combines the outstanding leak integrity of metal seals with a variety of options which allow maximum application flexibility. The heart of the Model 5851EM is the highly stable sensor which provides an electrical output signal linear with flow rate. This signal is used for indicating, recording and/or control purposes without the need for an auto-zero circuit.

#### E-Series Mass Flow Meters and Controllers (Model 5850 TR)

The Brooks model 5850TR flow controller accurately measures and controls gas flows. It is an economical solution to various metering and control processes, or for installation in (OEM) analytical and environmental equipment. It provides simple and direct mass flow measurement and stable control.

#### E-Series Elastomer or Metal Seal Remote Transducer Pressure Controller/FlowMeter (Model 5866 RT)

The Brooks® Model 5866RT Pressure Controller/Flow-meter controls pressure while also measuring flow rate. The Model 5866RT receives a remote pressure transducer signal, and using adjustable integral PID control electronics and control valve, will Maintain a desired set pressure. In addition to the pressure control function, the Model 5866RT provides a 0-5 V signal which is linear with mass flow rate. The Model 5866RT can also be configured as a mass flow controller for calibration or test purposes.

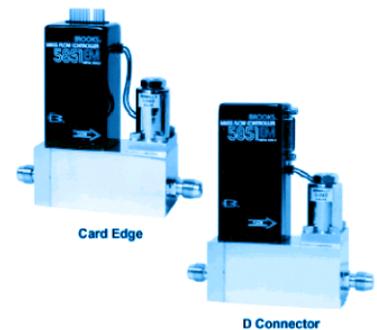
#### i-Series High Flow Industrial Mass Flow Controller&Meter (Models 5853i/5863i)

The Brooks® Models 5853i and 5863i industrial mass controller and meter accurately measure and control high gas flow. The heart of the system is its removable, attitude- insensitive sensor which produces an electrical output signal linear with flow rate used for indicating, recording, and/or control purposes. It eliminates the need for continuous monitoring and readjustment of gas pressures to provide a stable gas flow.

#### Nema 4X and IP65 Mass Flow Controllers and Meters

The Brooks® Mfx Series mass flow controllers and flowmeters are specifically designed to be used in hazardous locations. These devices are Listed and Recognized by Underwriter Laboratories, Inc. and found to be suitable for Class I Division 2, Groups A,B,C,D and Class II Division 2, Groups F,G and Class III. These controllers and meters offer high accuracy, control and measurement of industrial gases. The heart of the controller and meter is the thermal flow sensor which produces an electrical output signal linear with mass flow rate. This output can be used for indicating, recording and/or control purposes.

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## APPENDIX 3

### Flokal's mass/liquid flow meters/controllers (from Brooks Instruments)

#### i-Series Industrial Mass FlowMeter (Models 5860i/5861i)

The Brooks® Model 5861i Mass Flowmeter accurately measures gas flow. The heart of the system is the flow sensor which produces an electrical output signal linear with mass flow rate used for indicating and/or recording. Both 0-5 Vdc and 4-20 mA or 0-20 mA linear output signals are available for flexibility in interfacing with readout equipment. Many options are offered to provide a versatile system of mass flow measurement.

#### i-Series Industrial Mass Flow Controller (Models 5850i/5860i)

The Brooks® Model 5850i Mass Flow Controller accurately measures and controls gas flows. The heart of the system is the removable flow sensor which produces an electrical output signal linear with flow rate used for indicating, recording, and/or control purposes. It eliminates the need for continuous monitoring and readjustment of gas pressures to provide a stable gas flow.

#### MassRate™ Electronic Flow Meters

The Brooks® MassRate 5700 is a gas flow meter specially designed to satisfy the needs of purge gas, process analysis and analytical flow measurement applications. The MassRate 5700 utilizes a proven thermal mass flow sensor which provides excellent repeatability, wide turn down and an electrical output signal. It has a rugged all stainless steel construction and no moving parts providing superior corrosion resistance and long-term reliability. The MassRate 5700 is an economical meter with an electrical output signal making it ideal for replacing turbine meters, variable area meters and other volumetric devices.

#### Delta Class Mf Series Mass Flow Meters/Controllers (Mf Series) (Models SLMf50/51/53 and SLMf60/61/63)

Brooks Instrument Delta Class thermal mass flow measurement and control product line offers unparalleled flexibility and performance. Latest Mf Series combine the benefits of superior accuracy with Brooks' proprietary Adaptive Valve Control algorithm. Brooks now offers DeviceNet™ high-speed (up to 500k baud) digital communications. Brooks' communications capabilities and device-profile have been certified by ODVA (Open DeviceNet Vendors™ Association). The MFC micro-processor uses a multi-point calibration curve to deal with residual sensor non-linearity, yielding a highly accurate process signal. The microprocessor then executes Brooks™ proprietary Adaptive Valve Control algorithm to rapidly adjust the valve actuation to match setpoint. Process data and commands are available via digital I/O DeviceNet communications. Delta Class Products take advantage of modular design in both mechanical and electrical construction. This modularity allows for simplified customer ordering and factory configuration, enabling Brooks to more easily meet the ever changing needs of our global customers. Brooks' production flexibility translates into reduced lead times for our customers. The Delta Class Mf Series greatly improve accuracy. Applications will see settling time improvements and improved stability to varying process conditions, due to Brooks' proprietary Adaptive Valve Control algorithm.



MassRate 5700



## APPENDIX 3

### Flokal's mass/liquid flow meters/controllers (from Qualiflow)

#### Mass Flow Controller AFC 202 & Meter AFM 302

This series is the best solution for high flow from 30slm to 400slm.

#### Digital Mass Flow Controller AFC 202 D & Meter AFM 302 D

The best solutions for high flow from 30slm to 400slm.

#### Mass Flow Controller AFC 260 & Meter AFM 360

Target applications that require great process stability and reliability using flow rates from 10sccm to 5slm.

#### Liquid Vapor Controller LVC 414

This Liquid Vapor Controller is designed to measure and control the mass flow rate of doping materials by varying the flow of carrier gas through a bubbler containing the source material.

#### Mass Flow Controller AFC 261 & Meter AFM 361

Based on the same technology than as the 260 and 360 series, they each can handle flow rates from 10slm to 20slm.

#### Digital Mass Flow Controller AFC310 MD

Built to answer the most demanding 300mm applications: Piezo-electric valve, conical bypass and all metal design.



### APPENDIX 3

#### Flokal's mass/liquid flow meters/controllers (from Qualiflow)

##### Mass Flow controller AFC 50 & Meter AFM 55

Are suitable for flow rates from 10sccm to 30slm, featuring a unique reliable horizontal electromagnetic valve.

##### Digital Mass Flow Controller AFC 50 D & Meter AFM 55 D

Suitable for high performance from 10sccm to 30slm with elastomeric seals in standard.

##### Digital Mass Flow Controller AFC 80 MD & Meter AFM 85 MD

Are dedicated to systems using reactive gas from 10sccm to 30slm. All metal seals, ultra clean finish and no particle generation.

##### Mass Flow Meter AFM 10& AFM 11

Is a cost-saving flow meter used in vacuum control systems. Flow rate from 60slm to 120slm. Compact housing made of brass.

##### Digital Mass Flow Controller INFLUX

This mass flow meter is designed to replace rotameters whenever a signal of the flow is required. Flow rate from 2slm and 60slm. Made in brass material, the AFM10 has a small footprint and is used for vacuum control.



## APPENDIX 3

### Flokal's mass/liquid flow meters/controllers (from Mykrolis corporation)

#### Tylan® FC2900 and FM3900 Mass Flow Control and Flowmeters

Designed to meet the exacting requirements of the semiconductor processes and equipment, the Tylan FC2900 and Tylan FM3900 models are premium quality elastomer-sealed mass flow controllers and meters. These MFCs combine proven components and techniques with innovative concepts in both mechanical and electrical design.

#### Tylan® FC2979M/FM3979M Mass Flow Controllers and Flowmeters

Mykrolis's Tylan FC2979M is designed to meet the rigorous demands of ultra-clean weldless gas delivery systems required in today's most advanced semiconductor processes.

#### Tylan® IntelliFlow® Digital Flow Controller

IntelliFlow II is an advanced digital mass flow controller, expanding the attributes of the first generation IntelliFlow product line. Key enhancements for IntelliFlow II include: user configurability; extension of flow range to 100 slpm (N<sub>2</sub> equivalent); advanced electronic, mechanical and software designs.

#### Tylan® FC2925 and FM3925 Mass Flow Controllers and Flowmeters

Low cost mass flow controllers that provides reliable measurement and control up to 1000 slpm.

#### Tylan® FC2900 and FM3900 Mass Flow Control and Flowmeters

Premium quality metal-sealed mass flow controller for use with toxic gases in semiconductor applications.



### APPENDIX 3

#### Flokal's mass/liquid flow meters/controllers (from Mykrolis corporation)

##### Tylan® FC260/FM360 Mass Flow Controllers and Flowmeters

Low cost mass flow controllers with long-term repeatability and performance.

##### Tylan® VC4900/VC4900M Vapor Controllers

Mykrolis's Tylan VC4900 and Tylan VC4900M vapor controllers are designed specifically to meet the exacting requirements of today's semiconductor and industrial processes. The Tylan VC4900 vapor enable the delivery of organometallics such as tetraethoxsilane (TEOS), trimethylphosphate (TMP) and trimethylborate (TMB) with pressure drops as low as 6.7 kPa (50 Torr).

##### Tylan® FC2920 and FM3920 Mass Flow Controllers and Flowmeters

Low cost mass flow controllers that provides reliable measurement and control up to 200 slpm.



## APPENDIX 3

### Flokal's mass/liquid flow meters/controllers (from Sensirion)

#### ASF1430 bidirectional Mass Flow Meters

The ASF1430 Mass Flow Meter enables extremely accurate bidirectional measurement of fast changing gas flow over four orders of magnitude. Its leading performance is based on SENSIRION's unsurpassed CMOSens<sup>®</sup> sensor technology which combines a high precision sensor element with the amplification and A/D converter circuit on one single CMOS chip. This results in superior resolution, fast response time and large dynamic range at lowest power consumption. All measurement data is fully calibrated and temperature compensated by means of an internal microcontroller. Mounted in rugged, chemically inert PBT housing the ASF1430 is suitable for a wide range of applications. Such include mass flow metering for process control, medical applications, heating ventilation and air conditioning (HVAC) solutions, as well as gas flow metrology. The sensor housing provides two inlets for measuring the gas flow and withstands overpressures of 2 bar (29 psi). The ASF1430 requires a supply voltage of 7...18Vdc and provides an RS-232 and SPI compliant electrical interface.

#### ASF1400 bidirectional Mass Flow Meters

The ASF1400 Mass Flow Meter enables extremely accurate bidirectional measurement of gas flow over four orders of magnitude. Its leading performance is based on SENSIRION's unsurpassed CMOSens<sup>®</sup> sensor technology. With CMOSens<sup>®</sup>, the on-chip sensor element forms an integrated whole with the amplification and A/D converter circuit. This results in superior resolution, fast response time and large dynamic range at lowest power consumption. All measurement data is fully calibrated and temperature compensated by means of an internal microcontroller. Mounted in rugged, chemically inert PBT housing the ASF1400 is suitable for a wide range of applications. Such include mass flow metering for process control, medical applications, heating ventilation and air conditioning (HVAC) solutions, as well as gas flow metrology. The sensor housing provides two inlets for measuring the gas flow and withstands overpressures of 2 bar (29 psi). The ASF1400 requires a supply voltage of 7...18Vdc and provides an RS-232 and SPI compliant electrical interface.

#### SLG1430 Liquid Mass Flow Meters

The SLG1430 Liquid Micro Mass Flow Meter enables extremely sensitive and fast measurement of ultra low liquid mass flows. This particularly small and light device operates with high pressure resistant total media isolation and hardly any dead volume. Its leading performance is based on SENSIRION's unsurpassed CMOSens<sup>®</sup> sensor technology which combines a high precision sensor element with the amplification and A/D converter circuit on one single CMOS chip. This results in superior resolution, fast response time and large dynamic range at lowest power consumption. Excellent chemical resistance and bio-compatibility is ensured. The medium only gets in contact with the internal fused silica capillary and PEEK<sup>™</sup> screw fittings. Typical applications for this sensor include precise mass flow and volume measurement for HPLC, Lab-on-a-chip systems and medical devices. The sensor flow path provides two inlets for measuring the liquid flow and withstands fluid overpressures of 100 bar (1500 psi) and more during operation. The SLG1430 requires a supply voltage of 7...18 VDC and provides an RS-232 compliant electrical interface.



## APPENDIX 3

### Flokal's mass/liquid flow meters/controllers (from Sensirion)

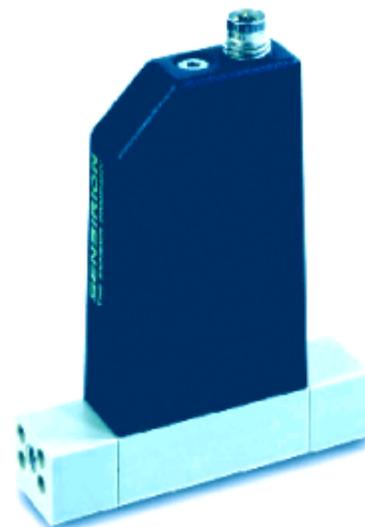
#### CMOsens® PerformanceLine Mass Flow Controllers for Gases

The CMOsens PerformanceLine Mass Flow Controller enables very fast and accurate control of gas flows over a very wide range. Its leading performance is based on Sensirion™'s unsurpassed CMOsens ® sensor technology which combines a high precision sensor element with the amplification and A/D converter circuit on one single CMOS chip. The digital calibrated and temperature compensated sensor signal is converted directly on the CMOsens chip into a PWM signal which is used in a fast analog controlling circuit to control the valve. This results in very high accuracy, fast settling time and large dynamic range. The CMOsens sensor is packed in a vacuum tight stainless steel package which is mounted on a rugged aluminium housing. This makes the PerformanceLine MFC the best choice for a wide range of applications, such as mass flow controlling for process control, medical applications, fuel cells, as well as gas flow metrology. The PerformanceLine MFC provides analog electrical interfaces for input and output signals (0 - 5 V) and requires a standard supply voltage of 15VDC. It can be operated at input pressures of up to 10 bar (145 psi).



#### ASL1430 Media Isolated Liquid Mass Flow Meter

The ASL1430 Mass Flow Meter enables extremely fast and accurate measurement of ultra low liquid mass flows. This particularly small and light device operates with total media isolation and hardly any dead volume. Its leading performance is based on SENSIRION's unsurpassed CMOsens ® sensor technology which combines a high precision sensor element with the amplification and A/D converter circuit on one single CMOS chip. This results in superior resolution, fast response time and large dynamic range at lowest power consumption. All measurement data is fully calibrated and temperature compensated by means of an internal microcontroller. Excellent chemical resistance and bio-compatibility is ensured. The medium only gets in contact with PEEK. Typical applications for this sensor include precise mass flow and volume measurement for analytical instruments, medical devices, process control, as well as liquid handling applications. The sensor flow path provides two inlets for measuring the liquid flow and withstands fluid overpressures of 5 bar (72 psi) during operation. The ASL1430 requires a supply voltage of 7...18 VDC and provides an RS-232 compliant electrical interface.



**APPENDIX 3**

**Flokal's mass/liquid flow meters/controllers  
(from Sevenstar Huachuang Electronic Co Ltd)**

**MFC-D07-16 Metal-Sealed Gas Mass Flow Controller with Maximum Operating Pressure: 10MPa**

**MFC-D07-12A Mass Flow Controller with High Accuracy and Quick Response Available**

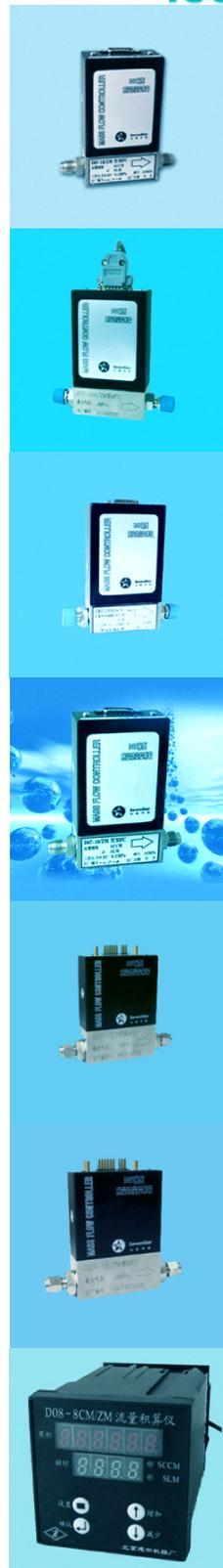
**MFC-D07-11A IS-Approved Mass Flow Controller in Weight of 1.2 kg**

**MFC-D07-50 Intelligent Gas Mass Flow Controller with High-Speed Reaction**

**MFC-D07-15 High-Stability Gas Mass Flow Controller with Maximum Pressure of 3MPa**

**MFC-D07-18 Accurate Gas Mass Flow Controller with Maximum Pressure of 3MPa**

**D07-8CM 220V Gas Meter with Automatic Review Function and Two Indicators**



## APPENDIX 3

### Flokal's mass/liquid flow meters/controllers (from Lintec Co., LTD.)

#### DeviceNet 1.125 inch MFC MC-5000

**Features:** DeviceNet (ODVA) digital interface; High performance (metal seal, piezo valve, high accuracy, multi gas); +24V single power operation; Surface mount interface; Patented ambient temperature compensated flow sensor (U.S. and Japan).

#### High performance digital MFC MC-4000

**Features:** High performance 1.125 inch digital MFC.(metal seal, piezo valve, high accuracy and digital controlled); Compatible to analog MFC; Software compatible with MC-2000,3000 series; RS232C and RS485 digital interface (on-board jumper selection); Surface mounting option available (SEMI STD.).

#### Digital Mass Flow Controller MC-3100E/3200<sup>E</sup>

**Features:** The MC-3000E series is divided into the MC-3100E and MC-3200E according to differences in full scale ranges. They respectively have normally open or normally closed valve actuators.

#### Liquid Mass Flow Meter LM-2100A

**Features:** The LM-2100A liquid mass flow meter measures various liquid material flow rates with high precision; LINTEC's patented original thermal mass flow sensor is incorporated for measuring flow rate. Digital circuitry provides high-speed reliable flow rate measurement; Combined with the flow rate control valve CV series, high precision liquid flow rate control is possible; In addition, combination with LINTEC's original vaporizer VU series makes high precision and high speed vaporization possible.



### APPENDIX 3

#### Flokal's mass/liquid flow meters/controllers (from HoribaStec)

##### SEC-G100 Series (Semi configuration)

Smallest MFC (39mm square).

Response Time within 1 sec.

Inside Volume Reduced by 80%.

Supports IGS Gas Panel Fittings.

Available with 1/4" VCR.

##### SEC-G100 Series (NeSSI configuration)

Smallest MFC (39mm square).

Supports NeSSI Surface Mount Sticks.

Designed for ANSI/ISA 76.00-02 2002 Standard.

Inside Volume Reduced 80% (compared to standard MFC).

##### SEC/SEF-4000 Series

Wide Range MFC / SEC-4400SR.

Free Mounting Orientation MFC / SEC-4400MF. 4500MF Applicable Gas:  $C_2F_6$ ,  $C_3F_8$ ,  $C_4F_8$ ,  $SF_6$ ,  $SiF_8$ , etc.

##### SEC/SEF-4001 Series

Most Reliable Mass Flow Controller.

Fastest Analog Mass Flow Controller.

Fastest Analog MFC-Less Than 1 sec. Response Time.

High Reliability-New Precision Sensor Circuit.

Optional "Mount Free" Sensor-Eliminates. Thermal Syphoning.



## APPENDIX 3

### Flokal's mass/liquid flow meters/controllers (from HoribaStec)

#### SEC-E40 Series

Mass Flow Controller (Solenoid Control Valve).

General Purpose.

Auto Zero Function.

Up to 500 slm.

#### SEC-6470-6480 Series

High Flow Mass Flow Controller.

Capable to flow from 200 SLM ~ 1000 SLM (N<sub>2</sub>). This model is equipped with the combination of pneumatic metal diaphragm valve and solenoid actuator valve. The fitting in this model employs all stainless configuration (M Type).

#### SEC/SEF-7300 Series

Mass Flow Controller (Piezo Control Valve).

Reliable, Accurate Zero Point / New Type Sensor.

Fast Response / New Type PC Board.

Compact Size Model / Surface Dimension: 106mm: 1SCCM~30SLM(N<sub>2</sub>).

#### SEC/SEF-300/400/500/600 Series

Thermal Mass Flow Controller.

(Thermal Control Valve).

Compact Size / SEC-310 .

High Accuracy Model / SEC-405.

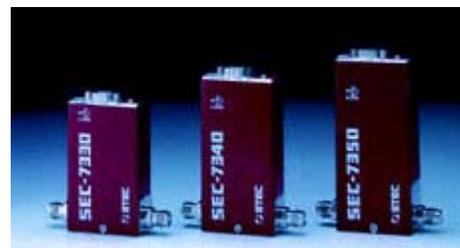
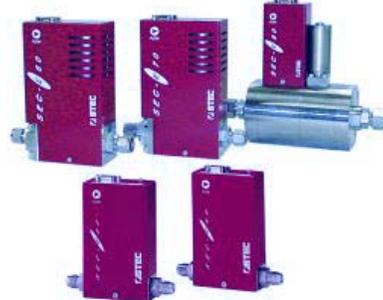
#### SEC/SEF-8000/2000 Series

Mass Flow Controller For High Temperature.

Piezo Actuator / SEC-8000 series.

Thermal Actuator / SEC-2000 series.

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### APPENDIX 3

#### Flokal's mass/liquid flow meters/controllers (from HoribaStec)

##### SEC-7340LD Series

Low Differential Pressure MFC.

Specifically Designed for SDS® Safe Delivery Source.

Applicable Gases-AsH<sub>3</sub>, BF<sub>3</sub>, PH<sub>3</sub>, Sif<sub>4</sub>, GeF<sub>4</sub>.

##### SEC-F700 Series

Piezo Control Valve.

Up to Five Separate Calibration Curves.

Fast Response for All Flow Ranges / Digital PID.

Diagnose MFC Problems by Various Alarm Functions / flow rate setting, output signal, valve, valve clearance, sensor, power, temperature of PC board.

IGS or Standard Fittings.

RS-485, RS-422.

##### SEC-V100 Series

Digital/Analog · Compact · Low Cost · Solenoid Valve.

RS-422 Serial Bus Communication.

RJ-11 Daisy Chain.

10 sccm to 50 slm Same Footprint.

IGS or Standard Fittings.

##### SEC-Z Digital Series

First 300mm Standard.

DeviceNet™ Controlled MFC.

Compact Mass Flow Controller.

Fastest Response - All Ranges / Piezo Actuator / Latest Technology Sensor.

Ultra Clean / 5 Ra Standard / Minimized Welding Points.

Standard DeviceNet™ Interface / ODVA Certified.

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## APPENDIX 3

### Flokal's mass/liquid flow meters/controllers (from HoribaStec)

#### LF-LV Series

The LF Series Mass Flow Meters are designed to measure liquid flow rates from 0.02 to 100 ccm. Its unique cooling method sensor (patent pending) developed by STEC is the first of its kind in the world. The cooling method allows us to measure ultra low flow rates of liquids with extreme accuracy and high stability, even in the case of low boiling point liquids. Any liquid can contain dissolved gases that can cause cavitation and bubble generation when passed through a conventional, heated sensor tube, but with the STEC cooling element, these problems are eliminated. The LV series liquid Mass Flow Controller employs the cooling method sensor and the high performance STEC, piezo actuated, metal diaphragm control valve. The field proven piezo valve is also an excellent component for use with low boiling point liquids because there is virtually no heat generation, especially when compared to solenoid valves. Both the LF and LV are designed with minimized surface area, straight flow through (no bypass), and no dead volume for ultra clean liquid delivery.

#### VC Series

Compact Liquid Source Vaporization System.

Compact-1/5 the Size of Previous Models.

Fast, Complete Vaporization.

Installation Flexibility.

Suitable for Semiconductor Films Such as LPCVD, MCVD, TEOS, TMPO, TMOA, TiCl<sub>4</sub>, etc.

Suitable for the Next Generation of Semiconductor Materials Such as Thin Ferroelectric Films, Ba, Ta, Ti, and more.

#### LK-P

#### KARMAN'S VORTEX SYSTEM LIQUID FLOW METER.

All PFA Construction.

No Particle Generation / No Moving Parts.

No Dead Space.

Attitude Insensitive.

