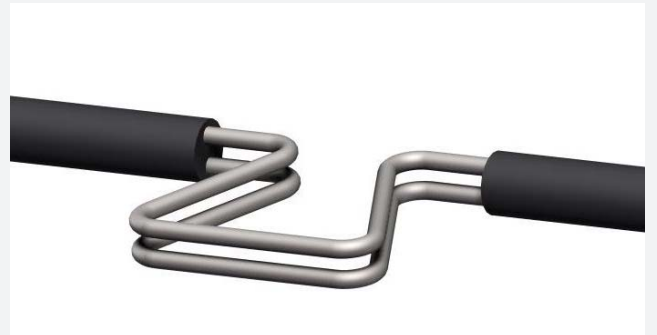
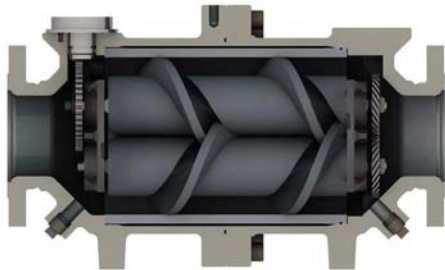


BiRotor Plus vs. Coriolis

In many liquid measurement applications, Coriolis meters have their advantages and are the meters of choice. But what about Custody Transfer applications in the oil industry?

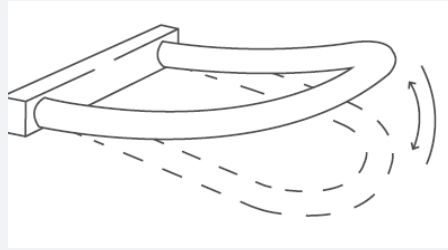
Unlike other Positive Displacement [PD] meters, Brodie's BiRotor Plus meter has major advantages over Coriolis meters when highest accuracy and reliability are required.

This White Paper explains why.

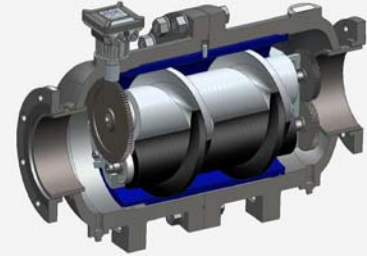


Meter Design

Moving parts



The measurement tubes of a Coriolis meter continuously vibrate at a high frequency, resulting in material fatigue and reduced life expectancy.



The BiRotor Plus has two solid moving parts [the rotors] with no metal to metal contact, except for its hybrid ceramic bearings and timing gears, resulting in a high, field proven life expectancy.

Pulse generation

There is no direct relation between the vibration of the tubes inside the Coriolis Meter and its pulse output - the pulses are calculated and generated by a microprocessor.

This requires complex electronic filtering of the vibration signal and causes a delay between flow and pulse output. It can also cause non uniform pulses that are difficult to use with a proving device.

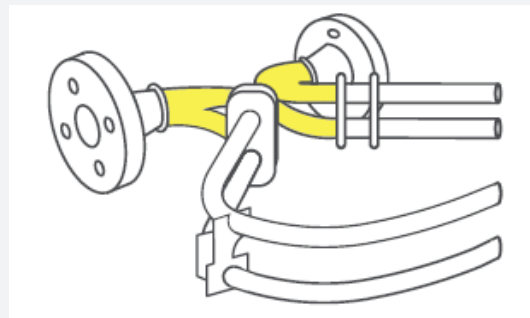
The BiRotor Plus generates real, pulses that originate directly from the rotor rotation. They are "original" and unmanipulated.

The BiRotor Plus pulse output is uniform and works well with all proving methods including Small Volume Provers using pulse interpolation.

Strainer and air elimination requirement

Even if stated otherwise by Coriolis manufacturers, a Coriolis meter requires a strainer and an air eliminator just as a PD meter does. Strainers are inexpensive insurance against foreign material such as weld rods, slag, corrosion coupons that can lodge in the tubes of Coriolis meters. Entrained air can have major effects on accuracy of Coriolis meters. Strainers/Air Eliminators are also required to protect downstream instrumentation like control valves and meter provers.

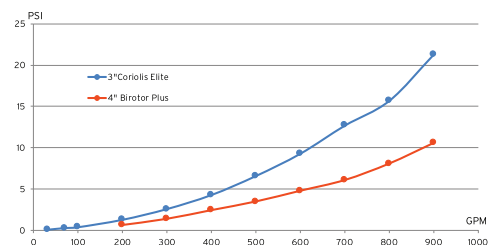
Pressure drop and changes of pressure



Coriolis meters have the highest pressure drop of all metering technologies available. This is due to the splitting of the flow into two smaller vibrating tubes.

Accuracy at higher pressures decreases because of the stiffening of the tubes.

Pressure Drop 3" Coriolis vs 4" BiRotor Plus



Although they handle the same flow rates, the pressure drop across a 4" BiRotor Plus is half the pressure drop across a 3" Coriolis meter [Micromotion Elite].

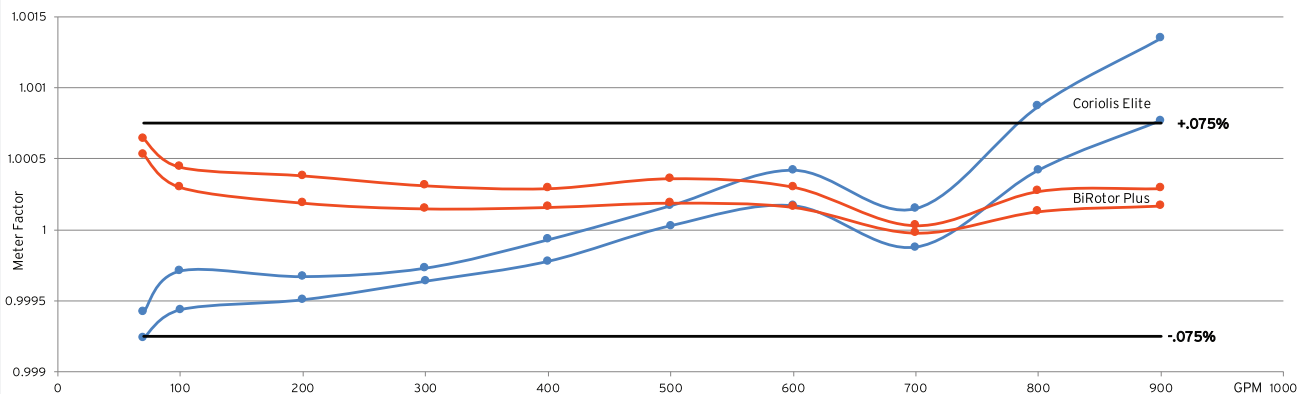
The BiRotor Plus is mostly insensitive to pressure changes.

Meter Performance

Linearity and repeatability

With a published linearity of +/-0.075% and a repeatability of 0.02%, the BiRotor Plus is the most accurate Custody Transfer meter in the industry. Like with other PD meters, the accuracy of the BiRotor Plus improves with increasing viscosity.

Below is a comparison of a 3" Coriolis meter vs. the Brodie 4" BR+ meter.



Test results obtained at Brodie calibration facility in May 2017, comparing a Micro Motion Elite 3" and a Brodie BiRotor Plus 4"

The testing consisted of ten repeatability checks at flowrates from 70 to 900 GPM in 100 gallon increments. The two curves per meter represent the highest and lowest values of the ten repeatability checks at each flowrate.

The linearity curve of the 4" BiRotor Plus meter was nearly flat. The linearity curve of the 3" Coriolis meter was a steady increase. On the meters tested, the linearity of the BR+ meter was +/-0.033% vs +/-0.106% for the Coriolis meter.

The 3" Coriolis repeatability spread constantly increased at flowrates greater than 500 GPM. At 900 GPM, the repeatability spread was over 4 times greater than at 500 GPM.

Every drop counts

Based on the above data, we calculate its implication on cost due to the uncertainties of both meters.

Assumptions

| | |
|--|--------------------------|
| Application: | Truck loading rack |
| Operating flow rate: | 600 GPM [2,270 LPM] |
| Operation of 10 h/day and 365 days/year: | 131,400,000 gallons/year |
| Gasoline cost: | \$ 0.70 |

Uncertainty cost per year

Coriolis: 1.00042 [max meter factor] - 1.00017 [min meter factor] = 0.00025 [uncertainty]
 $131,400,000$ gallons x 0.00025 [uncertainty] = **32,850 gallons/year**

BiRotor Plus: 1.00030 [max meter factor] - 1.00016 [min meter factor] = 0.00014 [uncertainty]
 $131,400,000$ gallons x 0.00014 [uncertainty] = **18,396 gallons/year**

Difference between both meters: 14,454 gallons/year

= \$ 10,118 savings/year if using BiRotor Plus

Meter Operation

Noise and pressure changes

Unlike the BiRotor Plus meter, Coriolis meters are susceptible to noise. The electronics in the Coriolis meter are sensitive to occurrences in the field like noise from the pump, pipe vibration, lightning strikes, power surges and other occurrences. Some Coriolis manufacturers counter this effect by adding complex electronic filters/algorithms to stabilize the signal, however, this does not come cheap and in many cases, adds to the intricacy of operation.

Product pressure also has an effect on the accuracy of Coriolis meters. The higher the pressure, the more the vibrating tubes stiffen, thus, measurement at a higher pressure does not provide the same results as at lower pressure. The bigger the meter the larger this effect. For example, at a 1,000 lb pressure difference, a 2" meter shows an accuracy change of 1/2 percent, while a 6" meter shows 1.5 percent. Coriolis manufacturers offer an electronic correction for this, but it requires additional pressure transmitters which adds further cost. This is an important issue in applications with pressure variations [at 800 - 1000 pound pressure applications].

Coriolis manufacturers test their meters at low pressures and provide software compensations for high viscosity and high pressure to maintain the stated lab accuracies.

The BiRotor Plus does not need any compensations.

Internal product residue

Any residue causes Coriolis tubes to become mechanically unbalanced, which has implications on the accuracy of the Coriolis meter.

Crude oils which contain paraffin wax often coat the inside tubes of the Coriolis meter. Likewise, viscous oil creates an internal layer on the tubes, the "boundary layer". Again, there are correction procedures in the software to correct that, but these need to be monitored and turned on or off. This adds another level of complication because the operator needs to know when he needs it and when he doesn't need it.

The BiRotor Plus meter is self cleaning by design and does not require cleaning of residue.

Maintenance and proving

Coriolis meters require IT-trained personnel to operate as they are set up and maintained using a laptop. The BiRotor Plus does not require any of this.

Coriolis meters need to be taken out and sent to the manufacturer for repair. The tubes can suffer from fatigue caused by its high frequency vibration. Their replacement is costly. With periodic maintenance, BiRotor Plus meters can last for decades and can be repaired on site.

The zero offset (during low or no flow) of a Coriolis meter needs to be checked and verified periodically. Zero error can occur if the tubes become mechanically unbalanced due to coating or erosion. The BiRotor Plus does not require Zero setting.

The complex electronic filtering by a Coriolis meter can cause delays in flow/response measurement. Therefore, a minor change in flow during a proof run can translate to poor repeatability in a Coriolis meter. The pulses of a BiRotor Plus are created in real-time directly from its pulse wheel, without electronic manipulation. This makes proving straightforward and easy.



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