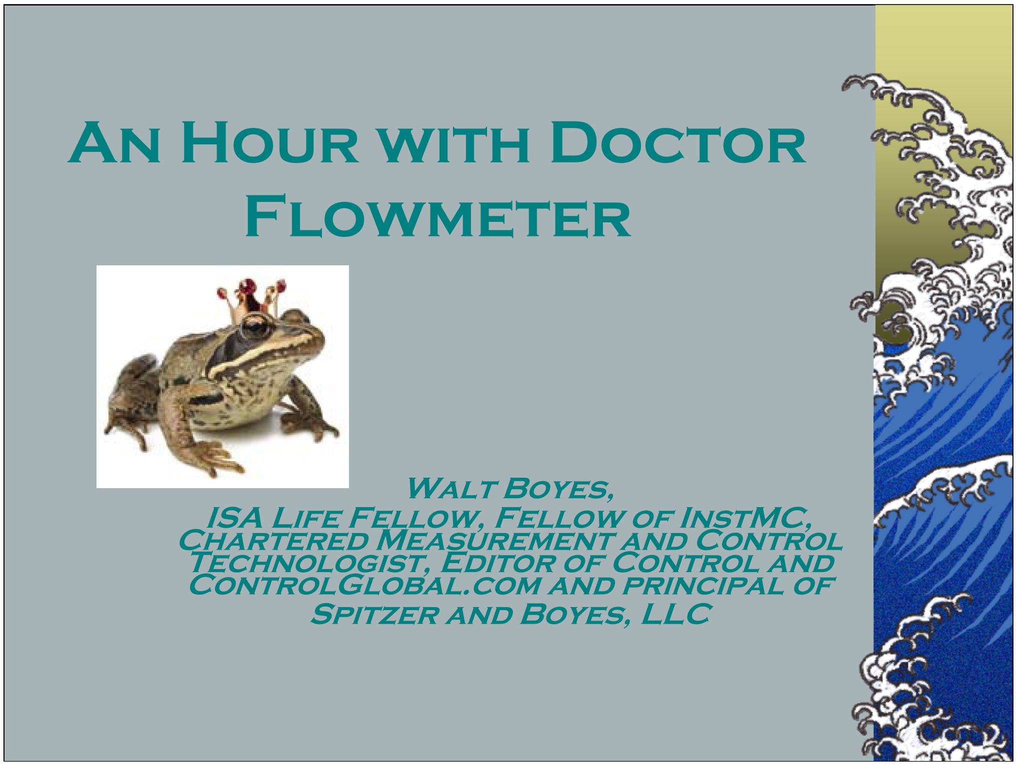
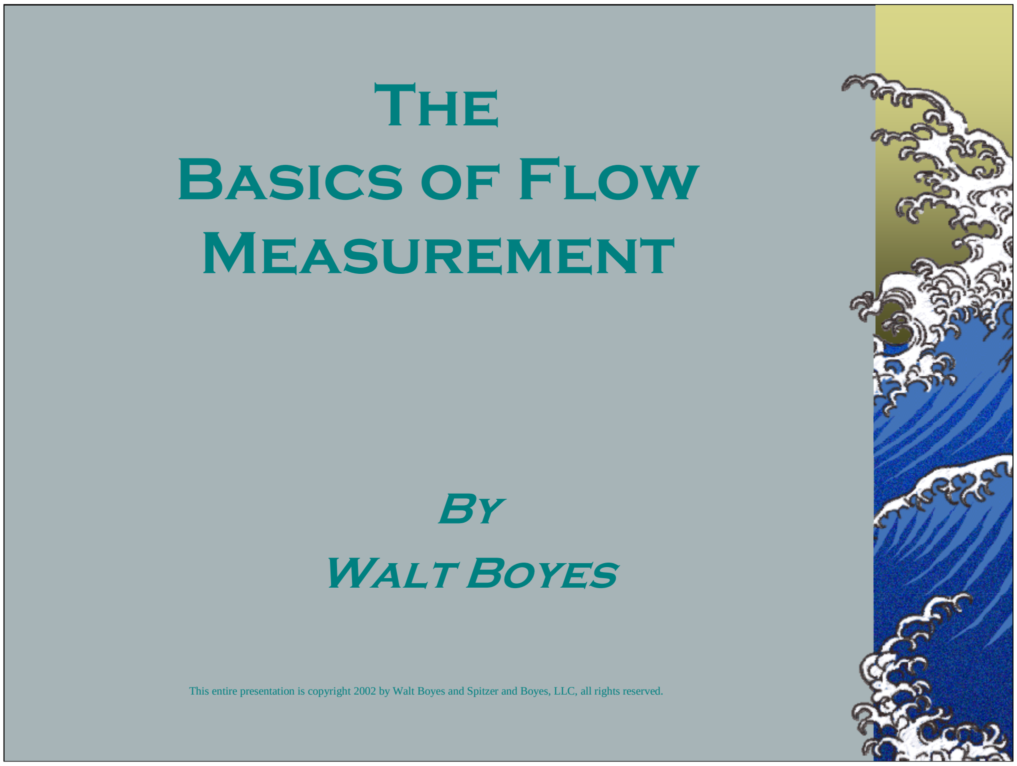



How do you pick a flow meter?

Hi, my name is Walt Boyes…and this is… "An Hour with Doctor Flowmeter."

For the next few minutes, we're going to take a very quick introductory tour of the world of flow measurement, and give you some tools to enable you to continue to learn more about flowmeters and their applications.



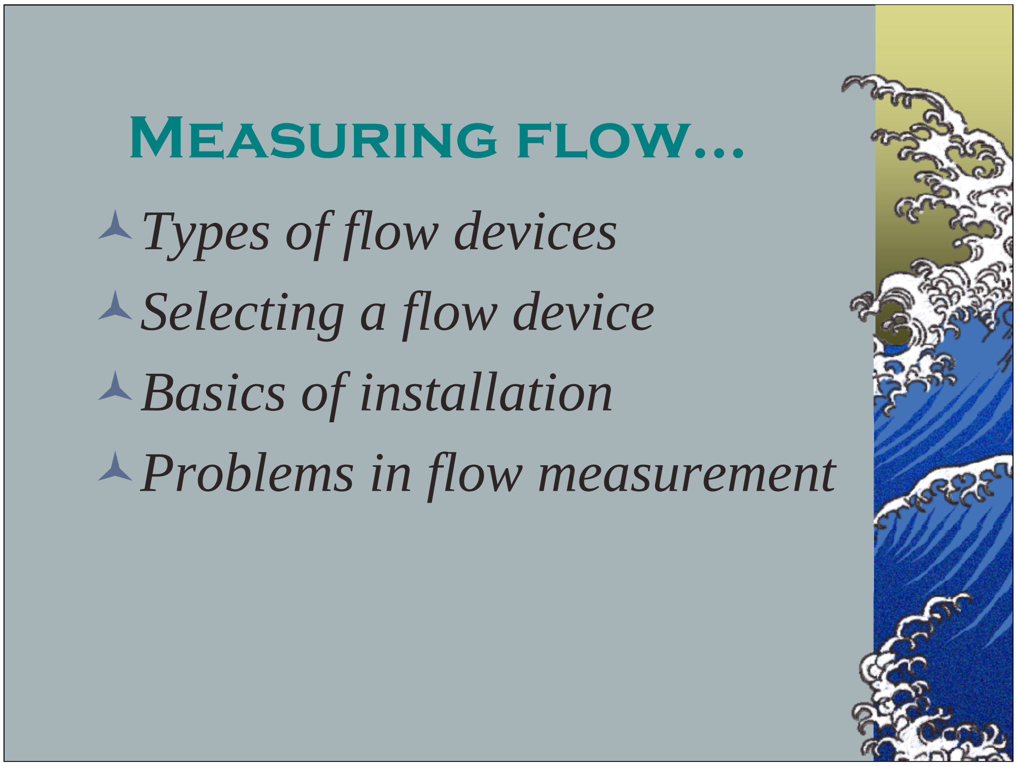

How do you pick a flow meter?

Picking a flow meter takes both knowledge of the kinds of meters available and the kind of empirically derived knowledge that comes from experience.

If you are like most people, you start by thinking about kinds of meters, their features and their hardware and software. You might start to build the meter from the application requirements.

You might make a list of all the types of flow meters in the book, and decide on one to pick.

The first cuts are obvious: liquid, solid, air, gases…each cut separates out huge numbers of flow meter types. Let's say your flow is liquid. The second cut is obvious here, too: full pipe, not full pipe.




We’re going to review the types of flow devices, and look at selecting a flow device, and the real-world basics of flow meter installation. Then, I hope you’ve brought your favorite flow meter problem, because the Doctor is IN.

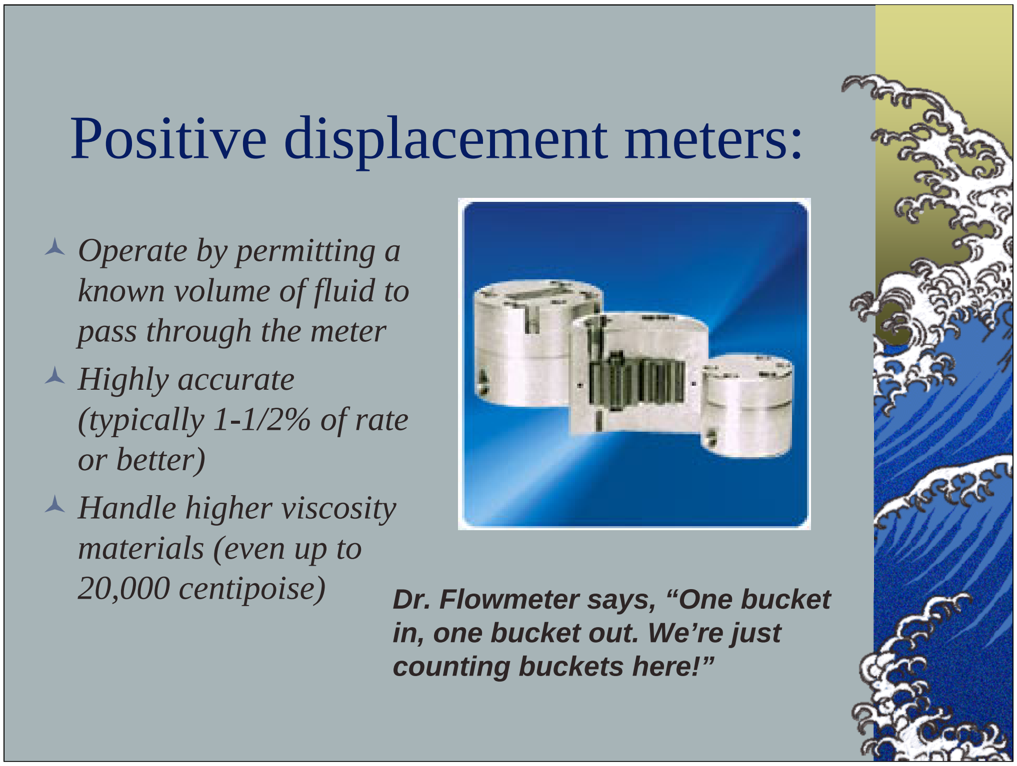
# Types of flow devices

- *Positive displacement*
- *Differential pressure*
- *Mechanical volumetric*
- *Magnetic*
- *Ultrasonic*
- *Thermal*
- *Fluidic*
- *Mass flow*
- *Open Channel*
- *Insertion*

*"You have to kiss a lot of frogs
To find Prince Flowmeter
Charming!"*

*--Dr. Flowmeter*

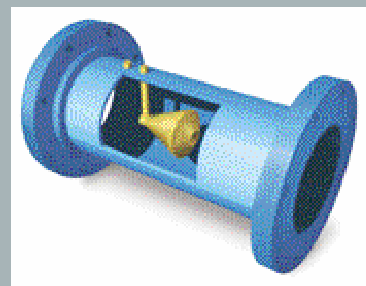
There are lots of flow devices, for both liquids and gases, and closed and open channels. What we'll do here is to look at some of the most common, and try to home in on some simple ways to select and use them. Note that there are at least 10 different types…and they don't all work on all applications.




Positive displacement meters are used for both liquids and gases…and are nearly always highly accurate. They come in a variety of types, such as oval gear, reciprocating piston, nutating disc, rotary piston, and they all work by emulating a bucket. One bucket in, one bucket out.

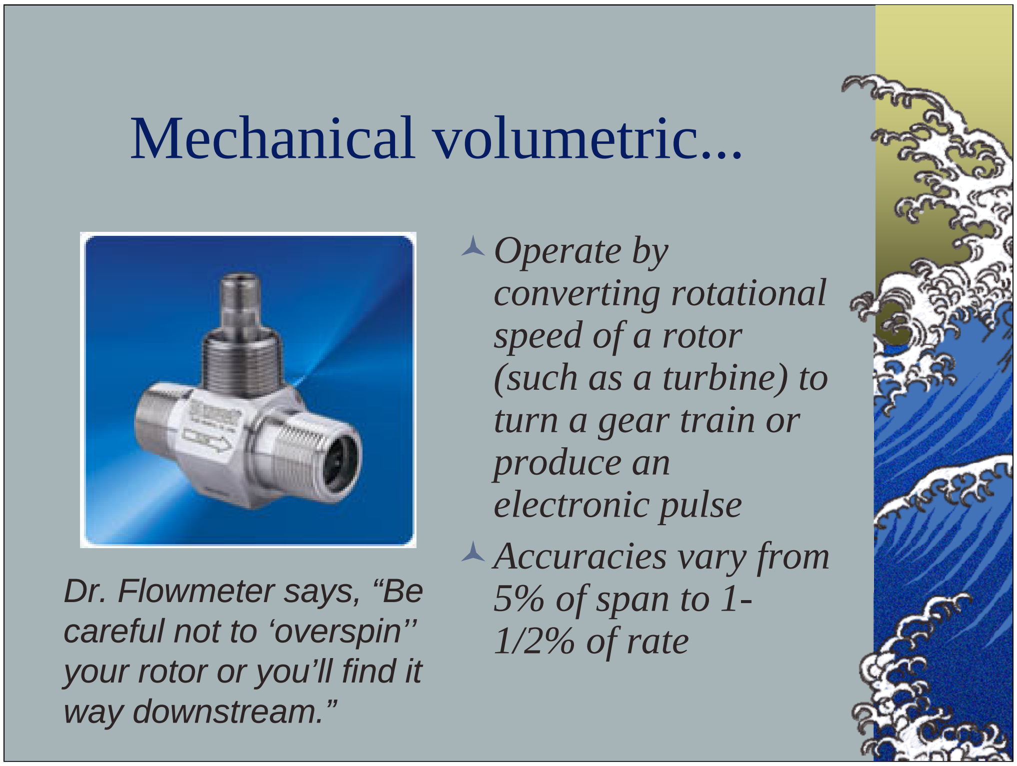
# Differential pressure...

- *Operate by sensing the differential across an orifice or flow restriction…the flow rate is proportional to the square root of the differential. This is an example of an advanced differential pressure meter.*



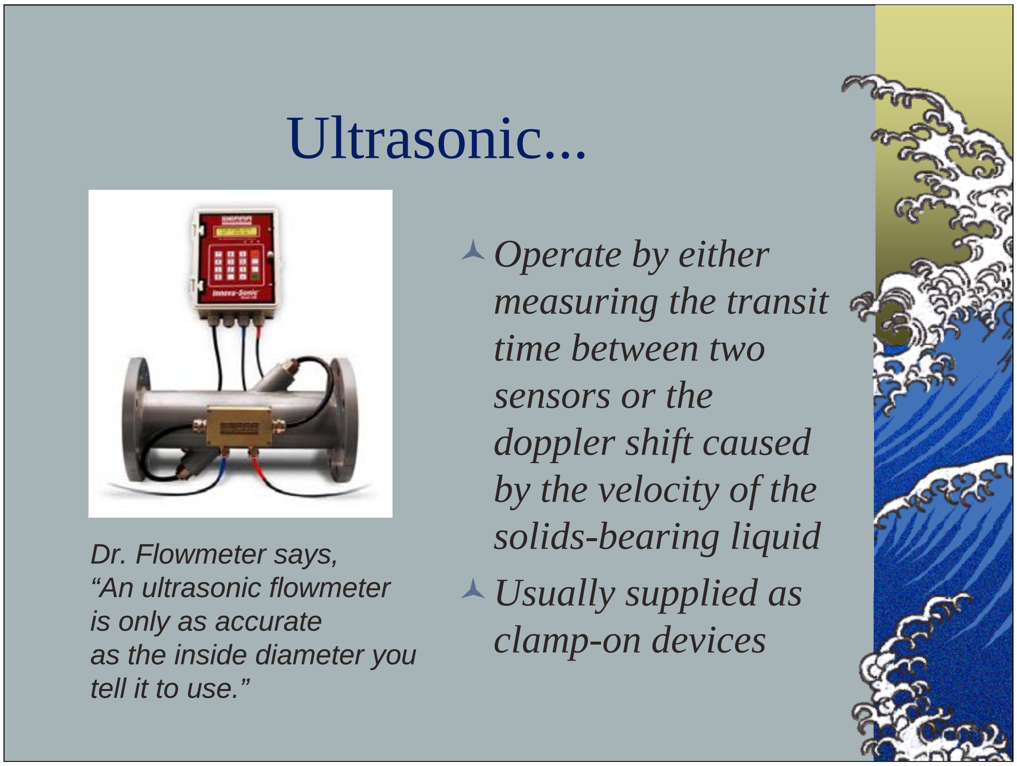
*"Take an orifice plate and rip it inside out, and this is what you get!" --Dr. Flowmeter*

Differential pressure based flow measurement is still the widest used technique throughout the process industries. Why? It is simple, inexpensive, and is accomplished with the use of pressure transmitters, which the plant usually has for other measurements (pressure and level) anyway.




Turbines, paddlewheels, impellers, propellers…there are a wide variety of types and styles of volumetric mechanical meters, but they all work by converting the speed of a rotor to a volumetric flow value. They can be highly accurate (1% of reading) or only approximate (5% of span). They can be spool piece style, barstock style like the one shown, or insertion devices. They range from very inexpensive to medium priced, with some fairly expensive models available with high precision and special materials.


Because they measure the average velocity in the fluid directly, spool piece magmeters are the most accurate volumetric metering technique there. The only other flow technologies that can rival a magmeter for installed accuracy are correlation-type ultrasonics with calibrated spool pieces, and of course, coriolis mass flow meters. Note, however, that a point-velocity, or insertion magmeter is only about as accurate as a paddlewheel meter, since it is only seeing approximately the same cross sectional area of velocity that a paddlewheel meter sees.



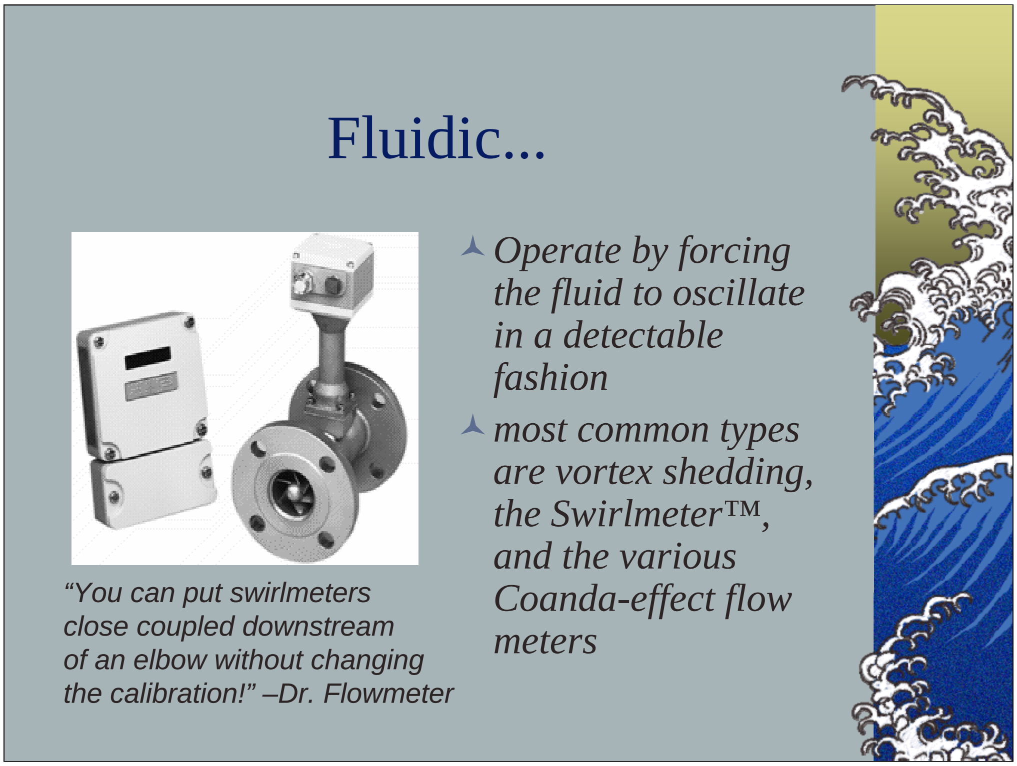

Ultrasonic flow meters are the most misapplied flow meters around… when they were first introduced, they were supposed to replace all other types. But what happened is that they, too, found their niche. The “Prince Charming” of flow meters has not yet come.

# Thermal...

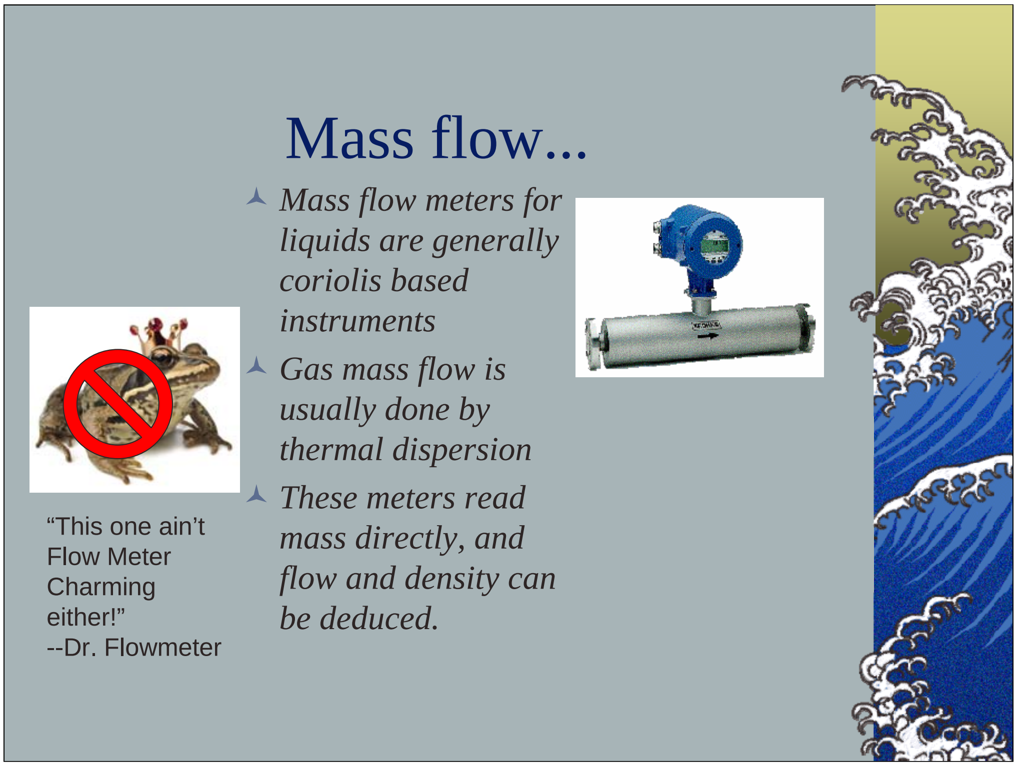
- *Operates by measuring the thermal dispersion caused by a moving fluid flowing past a heated temperature sensor*
- *Excellent for use as a flow switch, usually about 5% accuracy*


*"Beware of abrupt changes in temperature of the fluid!"*
*--Dr. Flowmeter*

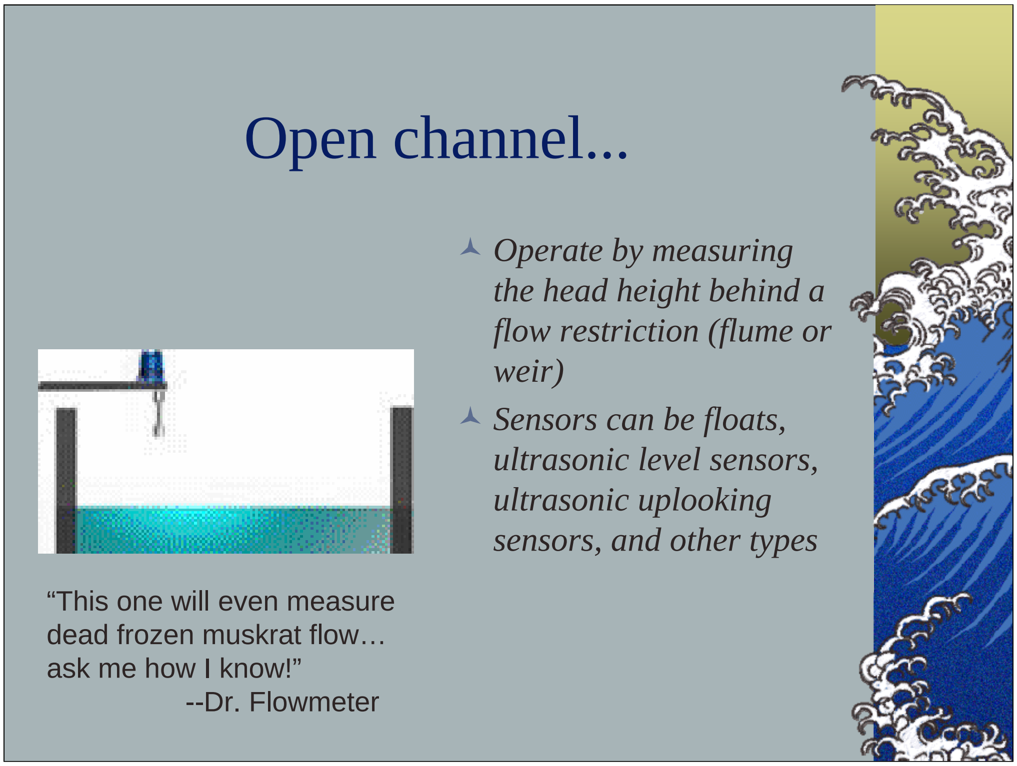
Thermal dispersion is also used for very highly accurate flow meters in very low flow applications, and can even be used for mass flow of gases. Considerable care, though, needs to be taken for applications like these.



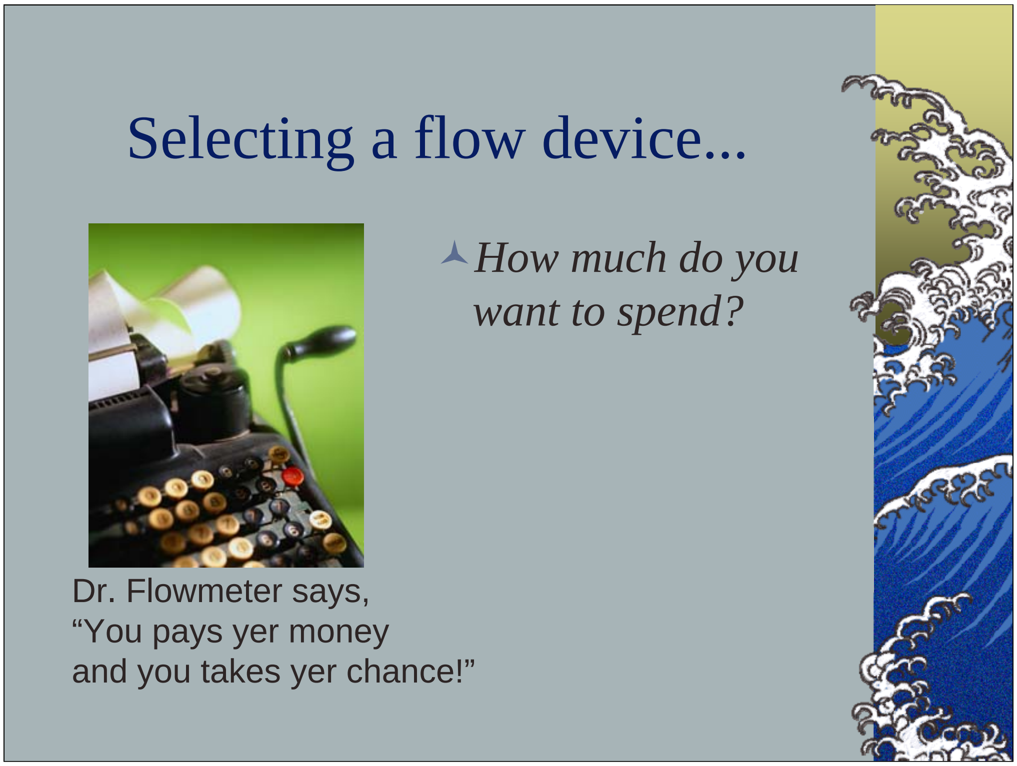

Vortex shedding meters and other fluidic types have no moving parts and use the fluid itself the way a turbine uses its rotor.  A traditional vortex shedding meter uses a bluff body (often called a shedder bar) to produce the repeatable oscillation.  A Swirlmeter uses a stationary "rotor-like" device to twist the flow and a restriction to contain and make the oscillation repeat.  The Coanda-effect meter uses hydraulic feedback to force the fluid to oscillate in proportion to velocity.




If I were told that I had to pick two types of flow meters to use, forever, and only two; and that I would be judged based solely on the accuracy of the measurement, I'd surely pick a coriolis mass flow meter as one of the two. A spool piece style magmeter would probably be the other one.



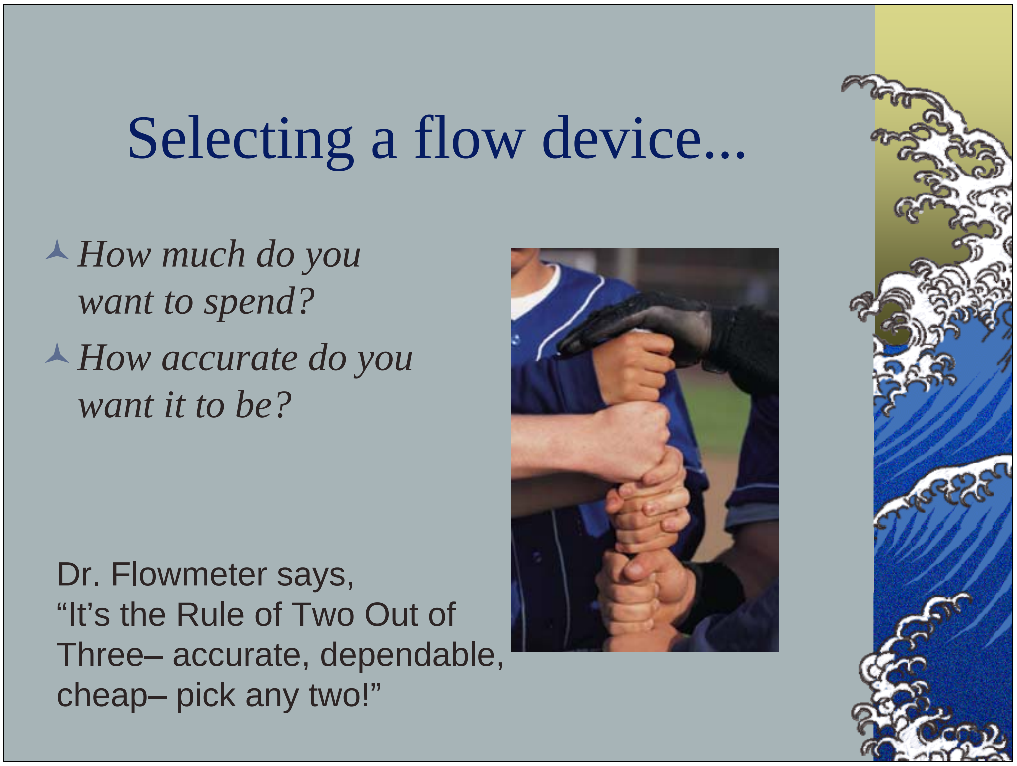

In an open channel application, the "flow meter" is the flow restriction itself: the flume or weir. The instrument is only the level sensor used to automate the meter reading. You can use a yardstick and be quite accurate.



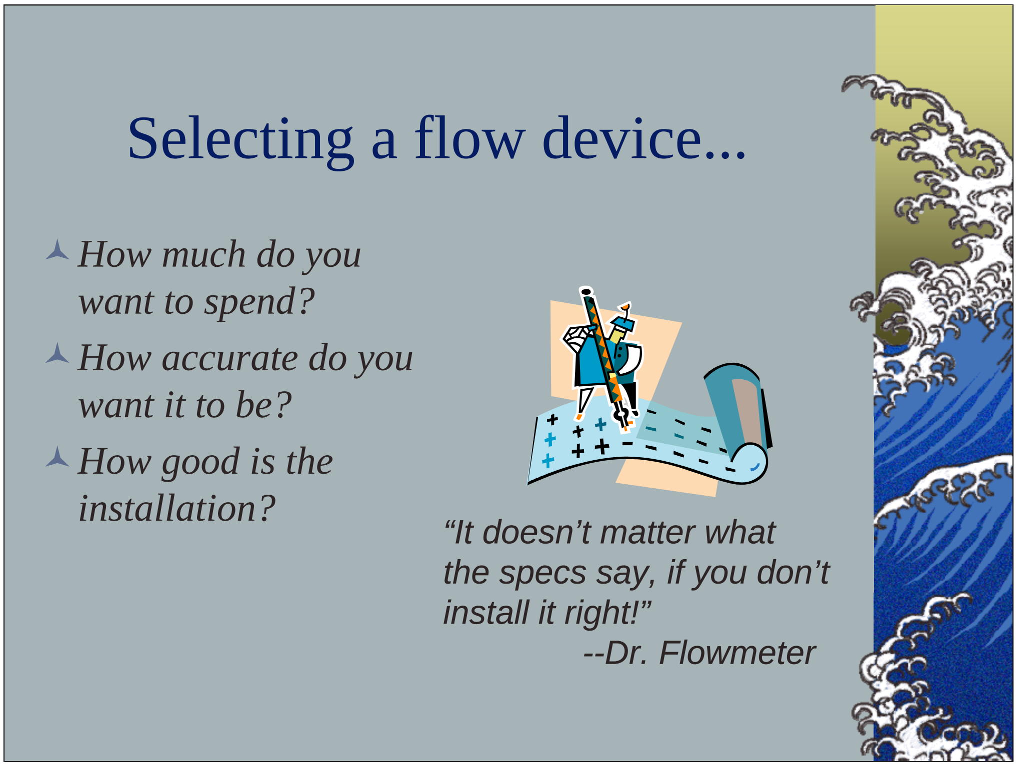

The first cuts are obvious: liquid, solid, air, gases…each cut separates out huge numbers of flow meter types. Let's say your flow is liquid. The second cut is obvious here, too: full pipe, not full pipe.

So far, we're clear. What is the next cut?

The one I use is price. Most other people use other cuts, but it all comes down to this. Can I spend under $1000 USD or can I spend more? Why price? Because price separates the most number of flow meters of any possible cut I could make. Why the dollars figure? Because the figure of $1000 seems to be a clear dividing line between "inexpensive" and "expensive" flow elements.

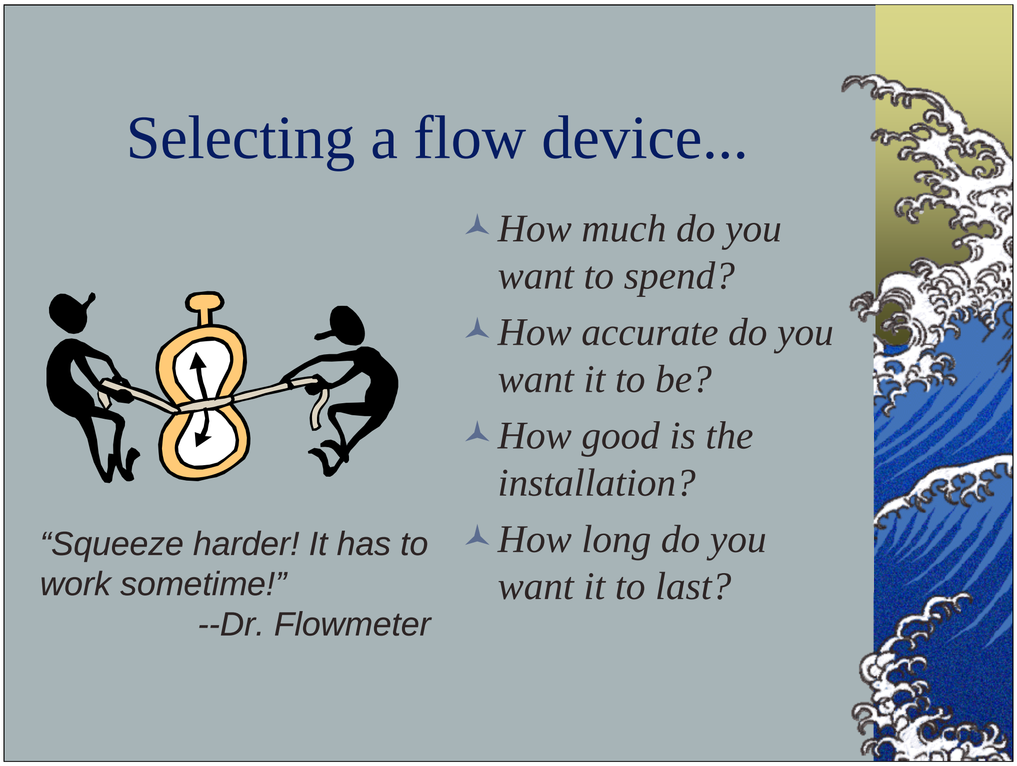



Other cuts can be made, too. Some of them might make you go back and reconsider the price cuts. For example, it is hard to find a 4" (100 mm) flow meter with 1% of indicated rate accuracy for under $1000. Therefore, if you need very high accuracy, you might be constrained to spend more than $1000 for the meter. Look at the application. Does it require high accuracy, or, more likely, is it an application that requires good repeatability? Repeatability is usually cheaper than accuracy. If all you need is a good repeatable signal, say, to control a valve or feed a chemical, you will be paying more than you need to for a flow meter if you buy a highly accurate one. Paying for accuracy is only important in precision batching or custody transfer. That's one of the reasons I use price as a major cut.




High temperature or high pressure might also make you reconsider the price cut. Wide flow rangeability may require another look, too. If you need a 20:1 turndown, you can get several relatively inexpensive meters for most applications. If you need a 100:1, or 300:1 turndown, however, your available choices diminish rapidly. Chemical compatibility is another cut that might make your flow meter choice more expensive. There are few meters available in larger than 1" sizes that are highly corrosion resistant, and most are expensive. Abrasion resistance is another consideration.


At the end of this process, you will find yourself with one or possibly two flow meter types that have survived your cuts. The last thing you should consider is the useful life expectancy you want. Once you have selected based on life you are again down to price. Pick the least expensive if there are more than one left. This one is the only one that meets all your requirements. This is a very simple process and it usually results in selecting the right flow meter. It is the one I use, and I recommend it, because it will provide you with something no other selection process will. It will not over-engineer the meter. You will not buy any more flow meter than you need to.




There are, however, people who use, as much as possible, the same flow meter for every application. I call this, "design by shoehorn."

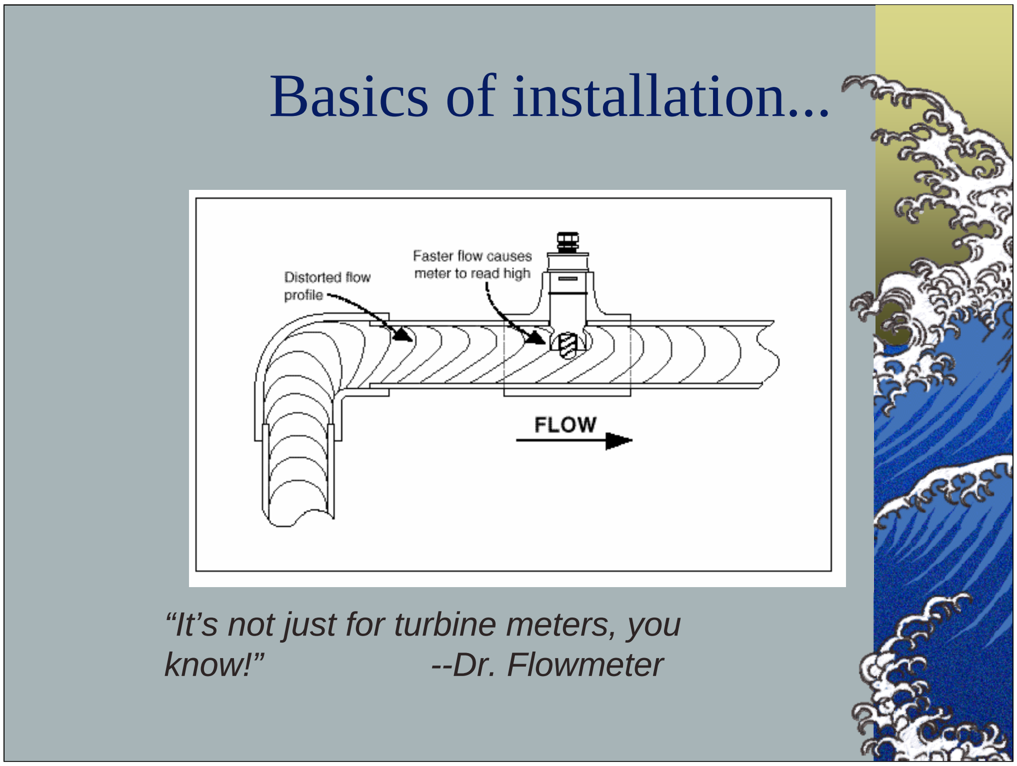
I know an engineer in a pharmaceutical plant who tries to use coriolis mass flow meters for every application, even the measurement of process water. They work, but it is a little overkill. I know a systems integrator who tries to use inexpensive paddlewheel flow sensors for every application, even high temperature and high viscosity applications. The amazing thing is that often they work too, but this might be referred to as "underkill." Flow measurement is both art and science. There is substantial knowledge that is simply learned, empirically derived behavior. It is experience. Here is some of mine.

# Basics of installation...

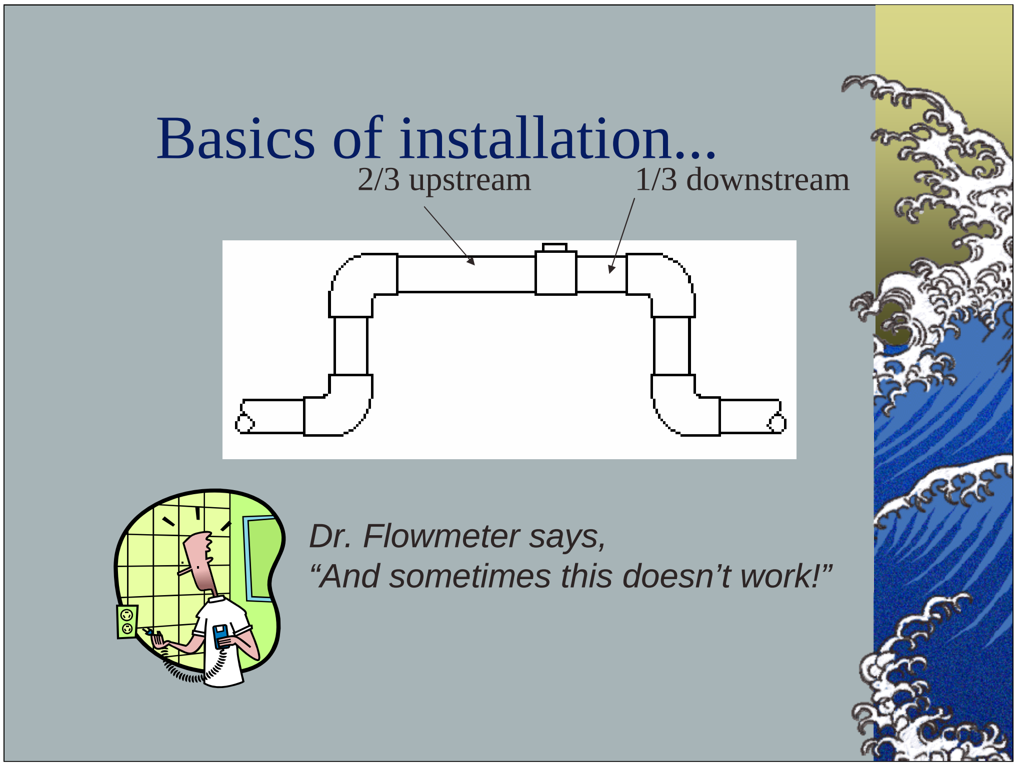
| Obstruction | Upstream Straight Pipe Run (minimum) |
|---|---|
| Concentric Reducer | 15 pipe diameters |
| Elbow or Tee (90°) | 20 pipe diameters |
| Two 90° Elbows Out-of-Plane | 50 to 100 pipe diameters |
| Partially Opened Valves | 25 pipe diameters |
| Thermowell, Chemical Injector, Strainer or Filter | 20 pipe diameters |
| Ball, Gate, or Butterfly Valve (wide open) | 14 pipe diameters |
| Spiraling or Corkscrewing Flow | 50 to 100 pipe diameters |

*"Rule of thumb! Rule of thumb! Ribbit!"*
*--Dr. Flowmeter*

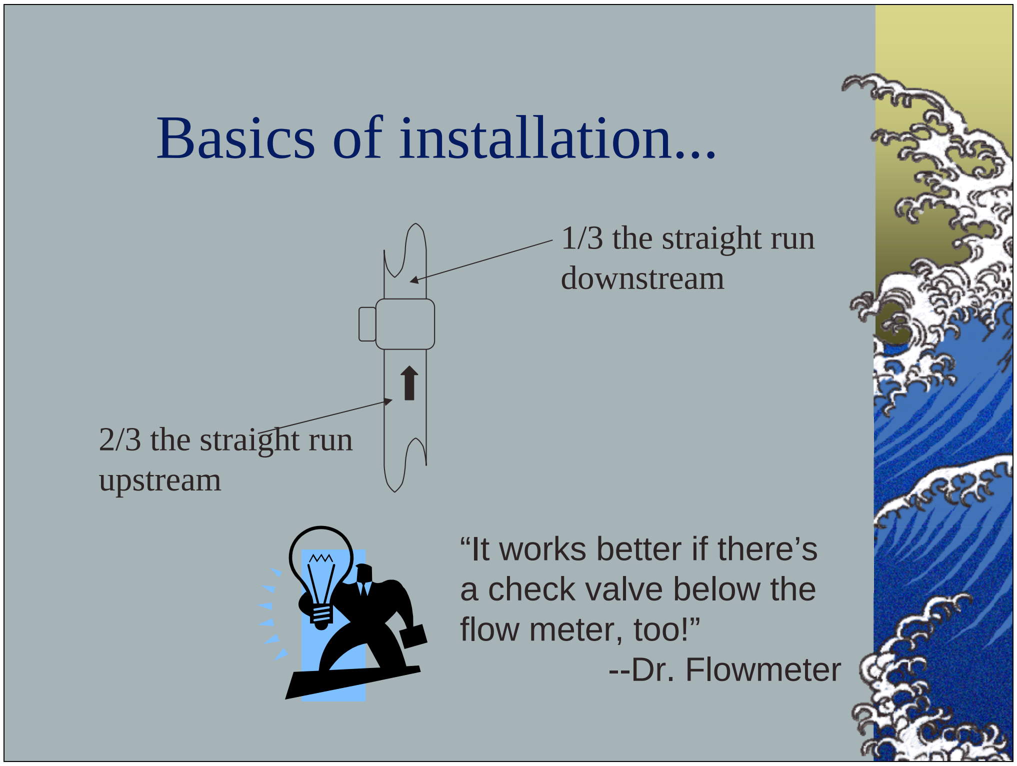
Many flow meter manufacturers tell you that you need at least 10 pipe diameters upstream and 5 diameters downstream of a flow meter of straight unobstructed pipe.   Most of these manufacturers have trouble with the question, "But I don't have 10 and 5, I have 3 diameters upstream, and 2 diameters downstream. What do I do now?"  There are two answers to the question.  The "straight" and "company approved" answer is, "Change your piping or your flow meter will not be accurate, or linear or repeatable."



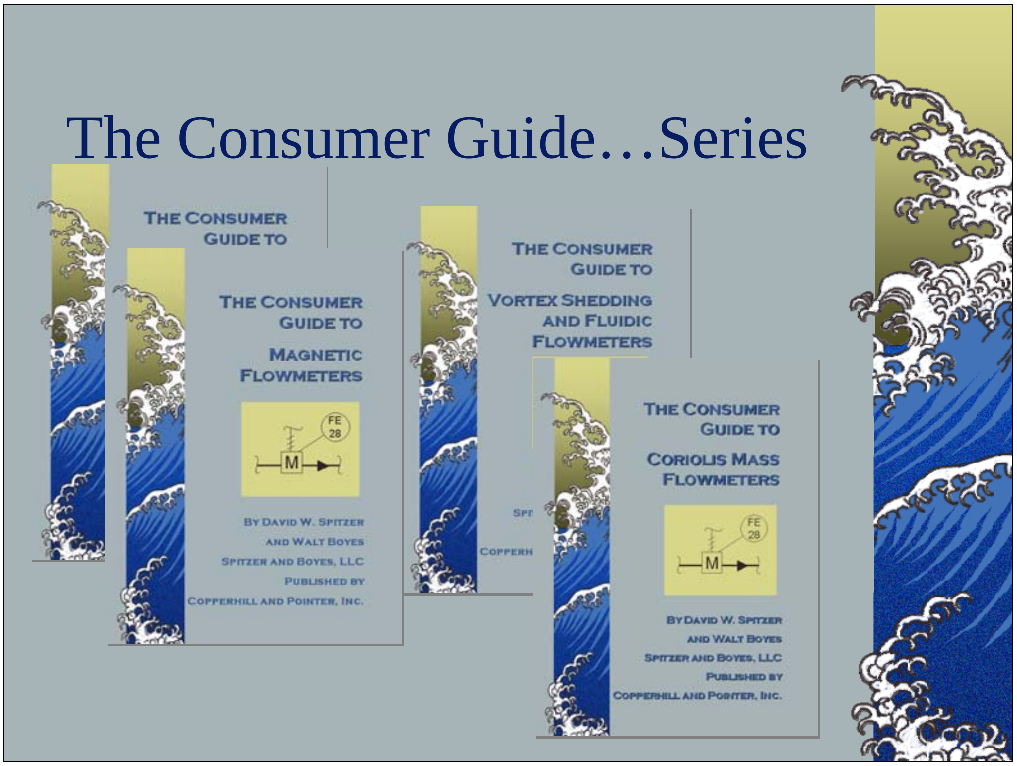

Of course, if changing the plumbing was an option, the poor victim wouldn't have called now would he? Yes, if you can change the plumbing you should always do that first. Too many times, we try to select a flow meter to cure a plumbing issue, and not reverse the process.




The empirical answer is: "Divide your straight run in thirds and locate the centerline of the sensor at the point which is 2/3 of the distance from the start of the straight run section. If you are using an insertion, or point-velocity sensor, make sure you put the sensor at the outside edge of the pipe where the velocity is highest." Now why does this work? Well, when it works, it is because it minimizes all of the "design sins" you are committing. Putting the flow sensor at the 2/3 distance point gives you as much straight run as you can get without getting involved in problems from the downstream flow obstruction. In case of point velocity sensors putting the sensor into the flow stream at the high side of the disturbed velocity profile makes them more repeatable, although they will usually read high.



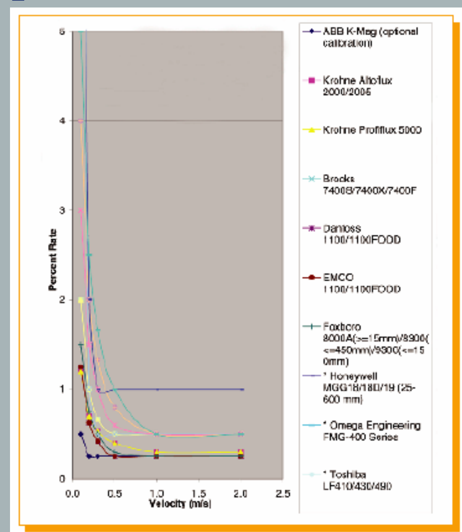

Putting a flow sensor into a vertical line with flow going up usually makes it work better even in disturbed flow profiles too, because you are using gravity to help develop the profile. A vertical riser installation usually helps combat entrained air or gases in a liquid stream, too.




Eleven years ago, David Spitzer and I set out to produce a set of guides to help end users cut through the obfuscation and confusion of multiple vendors' specifications. We called it the Consumer Guide series, and we're still at it..

# All Magmeters are not created equal…

- *We compared all of the known manufacturers and models of magnetic flowmeter in the world.*




In 2001, Spitzer and Boyes, LLC did a unique study of the world's magnetic flowmeters. What we found was that flow meters, even magmeters, were not commodity products. This led directly to the Consumer Guides. Here's what we did.

We divided magnetic flowmeter models into groups and compared their performance and reference accuracy against all the other models in the same group. The groups were: Ceramic-lined, Electrodeless, Low Flow (smaller than 12mm/1inch), Medium Flow (between 12mm/1 inch and 300-450mm/12-18 inch), High Flow (larger than 300-450mm/12-18 inch), High Noise, Low Conductivity, Partially Full, Sanitary, Fast Response and Two-Wire. Here is a graph from the study, showing some of the ceramic lined meters compared against each other. Note the very large variations in inaccuracy, especially at low flow rates.

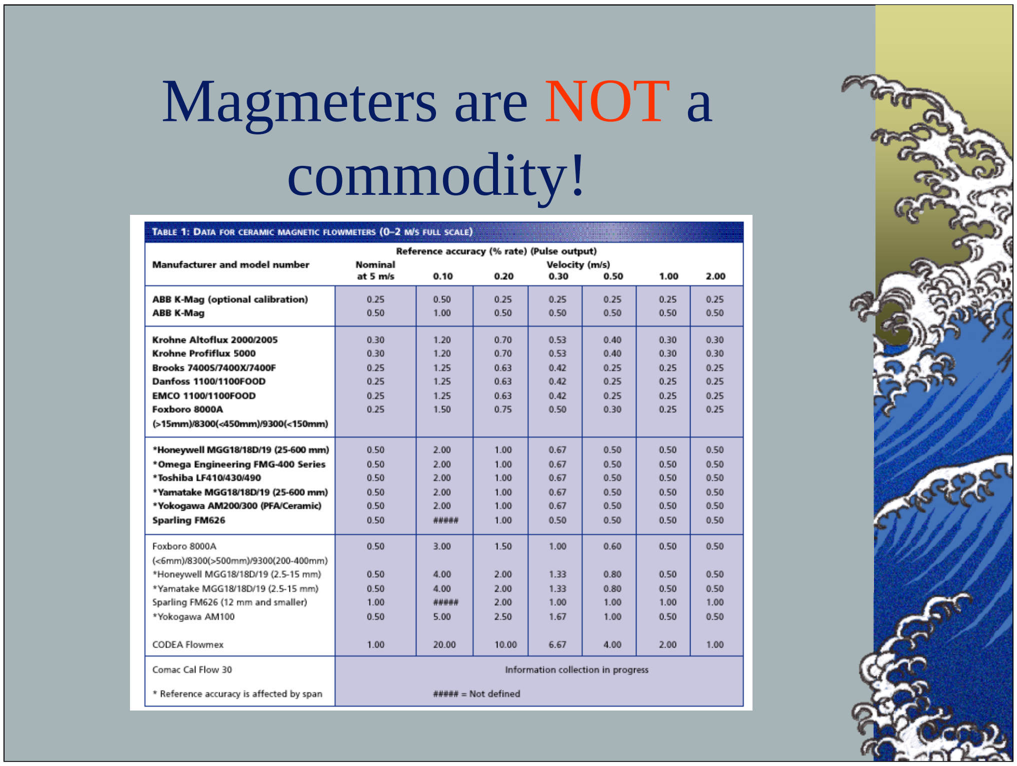
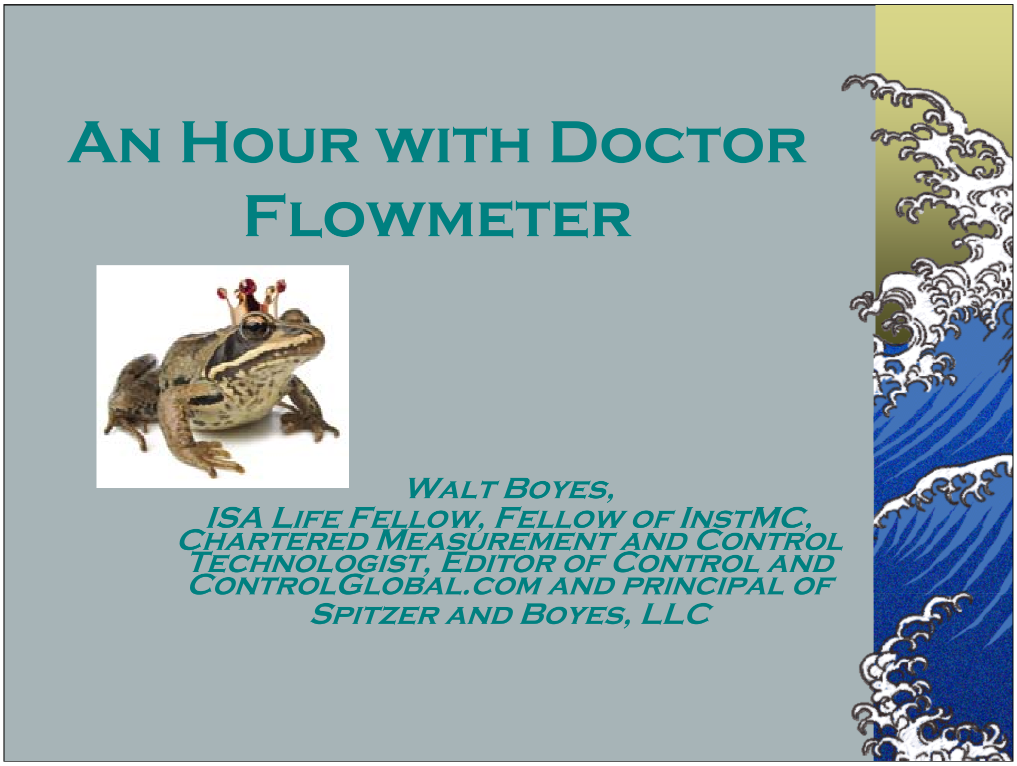



**Table 1: Data for ceramic magnetic flowmeters (0–2 m/s full scale)**

| Manufacturer and model number | Reference accuracy (% rate) (Pulse output) Nominal at 5 m/s | Velocity (m/s) 0.10 | 0.20 | 0.30 | 0.50 | 1.00 | 2.00 |
|---|---|---|---|---|---|---|---|
| **ABB K-Mag (optional calibration)** | 0.25 | 0.50 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| **ABB K-Mag** | 0.50 | 1.00 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| **Krohne Altoflux 2000/2005** | 0.30 | 1.20 | 0.70 | 0.53 | 0.40 | 0.30 | 0.30 |
| **Krohne Profiflux 5000** | 0.30 | 1.20 | 0.70 | 0.53 | 0.40 | 0.30 | 0.30 |
| **Brooks 7400S/7400X/7400F** | 0.25 | 1.25 | 0.63 | 0.42 | 0.25 | 0.25 | 0.25 |
| **Danfoss 1100/1100FOOD** | 0.25 | 1.25 | 0.63 | 0.42 | 0.25 | 0.25 | 0.25 |
| **EMCO 1100/1100FOOD** | 0.25 | 1.25 | 0.63 | 0.42 | 0.25 | 0.25 | 0.25 |
| **Foxboro 8000A (>15mm)/8300(<450mm)/9300(<150mm)** | 0.25 | 1.50 | 0.75 | 0.50 | 0.30 | 0.25 | 0.25 |
| ***Honeywell MGG18/18D/19 (25-600 mm)** | 0.50 | 2.00 | 1.00 | 0.67 | 0.50 | 0.50 | 0.50 |
| ***Omega Engineering FMG-400 Series** | 0.50 | 2.00 | 1.00 | 0.67 | 0.50 | 0.50 | 0.50 |
| ***Toshiba LF410/430/490** | 0.50 | 2.00 | 1.00 | 0.67 | 0.50 | 0.50 | 0.50 |
| ***Yamatake MGG18/18D/19 (25-600 mm)** | 0.50 | 2.00 | 1.00 | 0.67 | 0.50 | 0.50 | 0.50 |
| ***Yokogawa AM200/300 (PFA/Ceramic)** | 0.50 | 2.00 | 1.00 | 0.67 | 0.50 | 0.50 | 0.50 |
| **Sparling FM626** | 0.50 | ##### | 1.00 | 0.50 | 0.50 | 0.50 | 0.50 |
| Foxboro 8000A (<6mm)/8300(>500mm)/9300(200-400mm) | 0.50 | 3.00 | 1.50 | 1.00 | 0.60 | 0.50 | 0.50 |
| *Honeywell MGG18/18D/19 (2.5-15 mm) | 0.50 | 4.00 | 2.00 | 1.33 | 0.80 | 0.50 | 0.50 |
| *Yamatake MGG18/18D/19 (2.5-15 mm) | 0.50 | 4.00 | 2.00 | 1.33 | 0.80 | 0.50 | 0.50 |
| Sparling FM626 (12 mm and smaller) | 1.00 | ##### | 2.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| *Yokogawa AM100 | 0.50 | 5.00 | 2.50 | 1.67 | 1.00 | 0.50 | 0.50 |
| CODEA Flowmex | 1.00 | 20.00 | 10.00 | 6.67 | 4.00 | 2.00 | 1.00 |
| Comac Cal Flow 30 | Information collection in progress | | | | | | |
| * Reference accuracy is affected by span | ##### = Not defined | | | | | | |

This chart shows clearly the differences between models, and even between models of the same manufacturer!  We found that the best selling meters were not necessarily the most accurate.

As Dr. Flowmeter says, “You pays yer money and you takes yer chance.” You can’t point and click your way to good flowmeter installations.You still have to do the engineering.




I hope you have enjoyed this session. I'll take questions if you aren't asleep.