HELICAL TURBINE METERS FOR LIQUID MEASUREMENT
Class # 2202

Herb Decker
Director Upstream Sales
Faure Herman
6961 Brookhollow, West Drive, Suite 100
Houston, TX USA

Introduction

The helical turbine meter has been around for 85 years and has seen numerous improvements over this period. The swept wing rotor design has been introduced along with anti-fouling bearings and service in lines where DRA is present. Normally a helical turbine meter is used in either multi-viscosity crude or finished product pipelines where the meter is expected to provide a single meter factor over a wide range of products and viscosities. In recent times the helical has provided excellent performance in crude applications as high as 1,400 cSt. We will also cover application of the meter in custody transfer measurement to take advantage of its unique capabilities.

Theory of Operation

Flat Bladed and Helical turbines - how they differ

Flat bladed turbines typically have 10 to 12 blades that are located around the rotor hub at a fixed angle to the fluid. These blades pass through the fluid at a right angle chopping the fluid into discrete measured “packets” and the meter counts the number of packets over a given time period, such as minutes, hours, etc, outputting the count as a pulse stream. The helical bladed turbine typically has two helically curved rotors that rotate around the fluid and are in parallel with the fluid. Process fluid is passed through the helical meter as opposed to being chopped into discrete measured packets. Because of this feature the fluid forms a boundary layer along the rotor and remains attached until it reaches its shear point. The shear point of each fluid is determined by its viscosity with the most viscous fluids shearing first. The shearing resembles the pattern of air flowing around a flag pole which causes the flag to wave. The figures below demonstrate the operation of these two types of rotor blades.

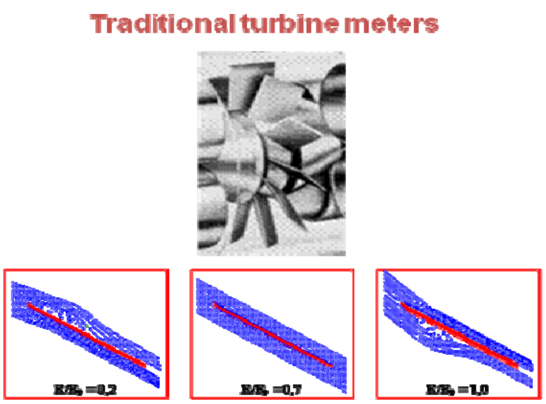

FIG 1

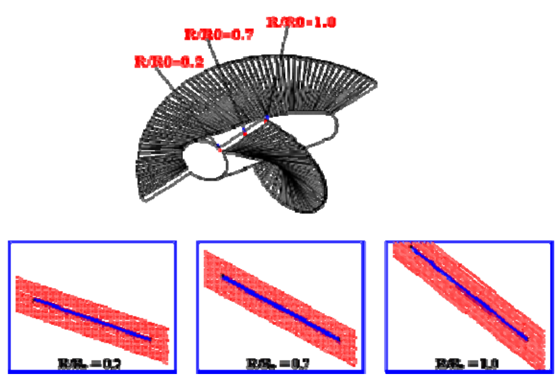

FIG 2

Shear and the blades- the primary determinant of the viscosity range of a given turbine meter is the point at which the fluid shears from the blade surface. With flat bladed turbines a good rule of thumb is to expect the maximum viscosity to be ten times the line size measured in centistokes or centipoises, i.e. a ten inch meter will accurately measure up to 100 centistokes. This specification applies at a 1:1 turndown and the maximum turndown at maximum viscosity will vary meter to meter but rarely will flat blades achieve more than 2:1 to 3:1. Beyond the shear point the meter performance drops off dramatically.

Rotor Design – Typically the helical rotor is manufactured from a single billet of either aluminum or titanium. The aluminum rotors are normally used when working with clean fluids containing no foreign objects and when measuring very light products such as LPG, etc. The weight of the rotor becomes important as fluids such as these have little or no lubricity and require carbon graphite bearings. The titanium rotors especially in larger line sizes are too heavy and cause premature failure of the bearings. Titanium rotors supplied with tungsten carbide bearings are the norm for crudes and fluids with foreign objects present. The titanium rotor is extremely hard and resists damage from impacting objects traveling at up to 30 feet a second (20.5 mph). The damage from foreign object impact is much higher in flat bladed turbines because; a) there are more blades occupying more of the throat of the meter and b) the flat blades pass through the fluid at a right angle to the fluid flow. The helical turbine blades on the other hand rotate around the fluid and are in parallel with the direction of flow. As a result even an object impact will tend to be less damaging as the object and the rotor are in the same plane.

Materials of construction

Bearing materials;

Tungsten carbide normally used with titanium rotors on crudes and dirty fluids.

Carbon graphite normally used with aluminum rotors on non lubricating fluids.

Meter Bodies – Meter bodies are the pressure boundary and are commonly available in carbon and stainless steels. Exotic materials are less common but may be used in specific applications.

Cartridges - normally 300 grade stainless steel but titanium has been used

Rotors – Titanium or aluminum

Bearings – bearings are the most critical components in that their operation can make or lose money for the user. There are only a few things that can cause issues with bearings. These include; dirt or grit getting between the bearing surfaces, loss of lubrication (running without a liquid present) and running the meter on a non lubricating fluid (tungsten carbide). Grit in the bearings is usually causes varying meter factor. It may be progressive or short term in nature. It is often asked what can I expect out of my bearings with regard to life expectancy. The nominal life expectancy for a bearing under ideal conditions is; running at full flow 24/7 for five years. This is an estimate that will be affected by the cleanliness of the fluid, the speed at which it is run and the lubricity of the medium. I have seen meters alive and well after 15 years in service. I have also seen meters that were run in an over speed condition that failed after only a year in service. Occasional over speed operation to a maximum of approximately 20% for short periods (5-10 minutes) will not drastically reduce bearing life.

Anti-fouling Bearings – Advances in bearing design has resulted in anti-fouling bearings being introduced. This type bearing creates lower differential pressures and therefore draws in less process to be used as lubricant and the design also reduces the heat load that must be carried away by the lubricating fluid. Reducing the amount of fluid and lowering the differential pressure reduces the ability to draw in dirt and grit.

Advantages of Removable Cartridges – Some of the manufacturers of helical turbines use removable cartridges which are calibrated independent of the meter body in which they are installed. This interchangeability allows the cartridge to be placed in any meter body with flange rating from ANSI 150 through ANSI 1500 with no loss of accuracy. In addition the cartridge may be removed from a field location such as a platform or remote metering station and sent to a proving location where the meter is mated with a local meter body and proven. Once the proving has been accomplished the cartridge is returned to the service location and reinstalled with no loss of accuracy. Since the cartridge is not the pressure boundary and the line pressure is applied to both sides of the cartridge, operating the meter in an ANSI 1500 loop and proving it in an ANSI 150 prover loop will not compromise the validity of the proving. This is a feature not available in turbine meters with the internals mounted within the meter body. A pre-calibrated spare cartridge may be placed in inventory to readily replace a cartridge removed for bearing change, etc. the meter need not be removed from the line but rather “rolled out” on two bolts and the exchange made. This reduces down time to under an hour and the spare does not need to be proven prior to being placed in service.

Accuracy verses viscosity verses Turndown – There is always confusion when we hear statements like +/-0.15% linearity (accuracy), 10:1 turndown and maximum viscosity of some value, 500 cSt for example. So what does that all mean when you get to the real world of measurement? Each of these statements as a standalone value are correct, the meter can meet each specification, however, when we combine these requirements the total capability of the meter will change. Let’s think of accuracy, turndown and viscosity as the three axes of a cube. (See figure 3 below)

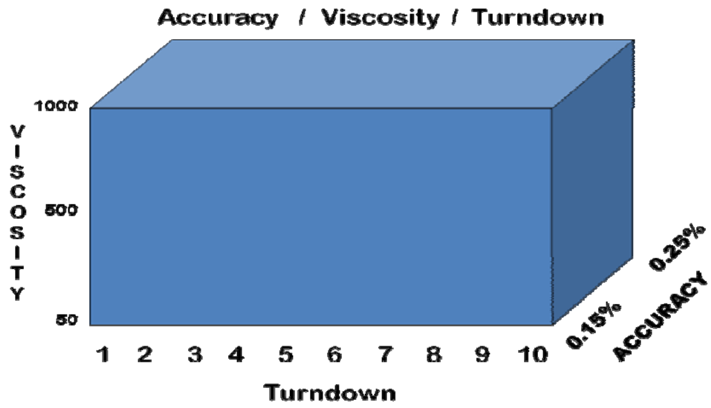

FIG 3

The volume of the cube is fixed, but can lengthen or shorten along any one of the sides but must be lengthen or shorten on one of the other two sides to maintain the fixed volume. As an example, I can provide more viscosity rangeability but must reduce either turndown, from a maximum of 10:1 to say 5:1, or decrease accuracy to +/-0.30% from +/-0.15%. Since we are speaking of custody transfer meters the accuracy remains fixed at +/-0.15%, therefore the only values that may be changed are turndown or viscosity. Because of this capability within the helical turbine meter each meter (rotor) will be unique.

Accuracy (linearity) A statement which defines the measurement error limit when a device is used under specific operating conditions. It is usually measured as inaccuracy and expressed as accuracy. The accuracy statement is expressed as the amount of rangeability at the stated accuracy, +/-0.15% for example.

Turndown – Turndown or rangeability is the region between the meters limits within which a quantity is measured and is expressed by stating the upper and lower limits. A turndown often seen in nominal specifications is 10:1

Viscosity – The viscosity is the fluid resistance to shear or flow and is a measure of the adhesive/cohesive or frictional fluid property. The resistance is caused by intermolecular friction exerted when layers of fluids attempt to slide by one another is commonly expressed in one of the following engineering units.

Dynamic (absolute) viscosity or the coefficient of absolute viscosity is a measure of the internal resistance of a fluid. Dynamic viscosity is the tangential force per unit area required to move one horizontal plane with respect to the other. It is expressed in centipoises (cP)

Kinematic Viscosity is the ratio absolute or dynamic viscosity to density a quantity in which no force is involved. Kinematic viscosity can be obtained by dividing the absolute viscosity of a fluid by its mass density. It is expressed in centistokes (cSt).

Viscosity Indexing – Extending the capability of your meter – Viscosity Indexing is a methodology by which a meter can be used to measure beyond its calibrated range. For example if the measurement range is 1,000 cSt but the meter was only calibrated for 500 cSt operation. The VI is a sixth order linear regression by which known calibration points can be used to estimate unproven values. The results of the regression are entered into a flow computer such as an OMNI 3000 or 6000. The feature that makes this exercise valid is that while the meter cannot predict the percentage of the error of the measurement point it will repeat that point to +/-0.02% (the base repeatability). This repeatability allows operations to bias the points on the curve and achieve linearity over the new measured range.

Helical turbine installation and flow conditioning requirements meet API 5.3 – Flow conditioning requirements for a helical turbine are the same as for any flow profile dependent flow meter. API chapter 5.3 covers installation of liquid turbine Meters and the minimum conditioning requirements for a custody transfer measurement. Figure 4 below details the configuration of a meter run.

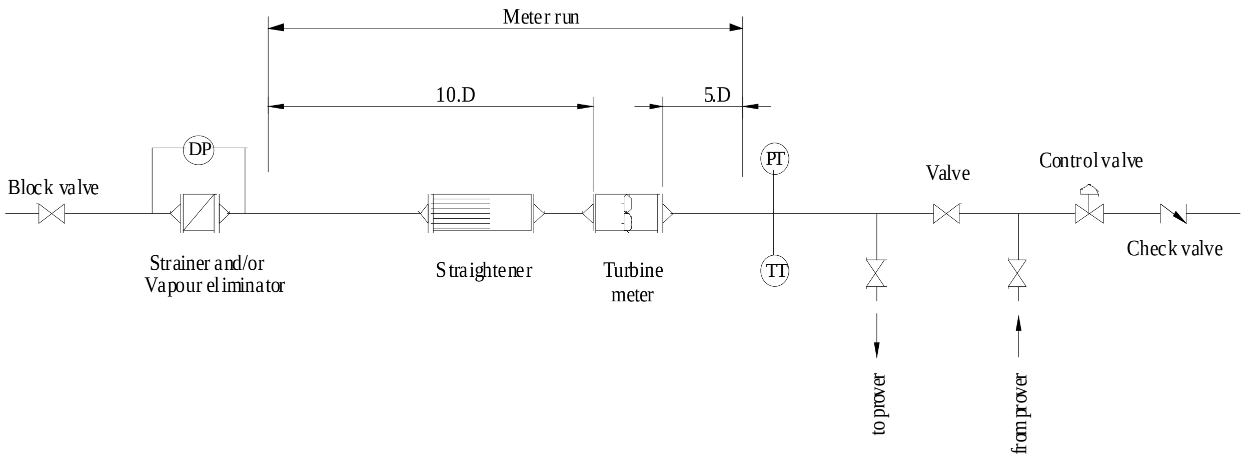

Figure 4

This diagram depicts a “normal “configuration. The upstream piping and devices will determine what specific type of conditioning is required to provide a consistent symmetrical profile. API has a work Group studying flow conditioning and the effects of piping on the performance of the conditioners and ultimately the meter itself. It appears the long accepted concept of 10 diameters upstream and five down with a conditioner or 20 diameters upstream may be insufficient to fully condition a profile dependent meter. The straight run requirements are very much dependent on the upstream piping configuration and the devices installed ahead of the meter run.

Of all the influences on the performance of a custody meter run, beyond the quality of the meter selected, upstream piping and type device(s) and location relative to the meter run are the most critical. Typically upstream of meter runs we find elbows (single and multiple, in and out of plane), Tees, valves, reducers, strainers and headers. Each of these devices will produce a unique output profile that will require a flow conditioner designed to correct that specific issue. Some devices, particularly strainers, produce a variable output profile based on the conditions within the strainer. A full basket or foreign material stuck to the mesh in front of outlet will produce very different profile shapes and require very different conditioning.

Moving the strainer upstream of a known profile generator such as an elbow or reducer will significantly reduce the complexity of the conditioning. The output of an elbow while asymmetrical is consistent allowing a single conditioner type to solve the asymmetry.

Many times flow conditioning elements are part of the upstream meter run and are designed to remove asymmetrical profiles and generate a symmetrical profile the meter is expecting to see.

Typical flow conditioning elements include tube bundles (7, 9, 19 tube symmetrical or stacked), plates, Vortab types and combinations of these in the “high performance” types. Knowing the type of profile deprivation will determine the type of conditioner required.

Performance in a DRA (Drag Reducing Agent) environment – with the changing demographics and increased demands for hydrocarbons the ability of the suppliers to deliver through existing pipelines has been severely challenged. To move more fluid the supplier can add pipeline capacity, increase throughput on existing lines or remove bottlenecks to flow. New pipelines and increasing pumping capacity are expensive solutions. A breakthrough occurred when DRA (drag reducing agent) was invented. Adding DRA to a line reduces the friction to flow and allow more fluid to flow through existing lines without increasing pumping capacity. DRA is a polymer string and comes in many forms from water and alcohol based to hydrocarbon based. DRA with its long polymer string and has a tendency to build up on moving part measurement technologies. Regardless of the base or fluid the goal is the same, reduce friction and increase flow. This includes PDs, flat bladed turbines and some helical designs. The failure mode is that the DRA will build up on the moving parts gradually over time changing the mass of the moving parts. This added mass will cause the meter to under report. When the meter is taken off line and checked it is found to be in calibration. This is because the DRA has fallen off the moving parts when they stopped rotating and is drained away when the line is cleaned. The meter is returned to service and proves but again slowly over time the under report returns. The way to spot a DRA problem is to review the proving reports over a period of time. There will be a regular pattern (sawthoothing) with the meter returning to original meter factor each time it is stopped.

There are swept wing helical turbine meters available that have been specifically designed to operate in a DRA environment without loss of accuracy. They have been designed to eliminate collection points for the DRA. It should be noted that DRA also affects UFM even though they have no moving parts. The issue is in the beams seeing the DRA.

Proving helical turbines – Helical turbines have only two blades producing only about 20% of the pulses that a PD or flat bladed turbine will produce. This becomes an issue when sizing a prover in a new application or trying to use a helical in an existing installation. First it needs to be agreed the helical turbine is being used because it best meets the service conditions. Typically it is because the application calls for either multiple different single viscosity fluids or a multi-viscosity fluid covering a wide range. In sizing the prover for a new installation determine the k- factor of the meter (pulses per bbl, m3/h, etc) and divide 10,000 by that number and that is the volume between the switches of the prover. Existing installation conversion may be more difficult. Here we see two options; a) double chronometry and b) pulse multiplication. The double chronometry can be performed in the flow computer whereas the pulse multiplication is done in the preamp on the meter. Both methodologies will produce the number of pulses need to prove the meter.

Pressure drop – A major issue with flow measurement is the cost of making the measurement itself. One of the highest costs is the energy necessary to drive the meter. All of the energy in the pipe comes from a generated source, a pump. The cost to the operator for running the pump depends on several factors including flow rate, viscosity and pipe wall roughness to name three. One of the other costs is the amount of drop taken in the line caused by piping configuration and devices located in the pipe. Among these are the flow meters. The type meter makes a significant difference in the cost of making the measurement. Meters such as PDs and Coriolis take the highest pressure drops. Next largest would be flat bladed turbines and lowest of the moving part technology meters is the helical turbines. Helical turbines are only slightly higher than UFMs that typically take the least drop.

Helicals in high Viscosities - Due to the nature of the rotor and ability to maintain the boundary layer some of the helicals on the market today can reach viscosities of 1,400 cSt. Since these viscosities are beyond the capability of the available calibration labs on site calibration of the points beyond the labs reach is required. The helical will provide repeatability to +/-0.02% and these points are repeatable the points attained can be biased to achieve linearity. This process also requires the use of Viscosity Indexing algorithms. While PD meters can reach these viscosity levels and provide comparable performance the helical can also measure fluids such as condensate with no loss of accuracy. This capability places the helical turbine in a class by itself in multi-viscosity flow measurement

When not to use a helical turbine - the helical turbine like all custody metering technologies has its strong points and applications where it excels, however, there are times when the helical is the wrong choice. A helical would be a poor choice if there were large slugs of gas in the line or large foreign objects in the process fluid that could not be removed prior to making the measurement. Other reasons for not using a helical might be process temperatures above the capability of the meter or operating for prolonged periods beyond the max velocity of the meter. Extremely dirty or grit filled fluids would not be compatible with any moving part technology meter helicals included.

Conclusion

In Selecting the best meter for the application takes considerable experience and knowledge. Remember your job is to process or move hydrocarbons so whether you are new to measurement or an “Old Hand” seeking assistance in meter selection is a good thing. Metering technologies change and the thought process on flow conditioning is in flux. Seek out your meter supplier and pick their brain as to selecting the right solution. One thing to remember, the vendor that tells you a single technology or product as the answer to **ALL** your flow measurement needs is selling meters not solving your flow measurement need. Force fitting a meter technology into an application that isn’t right buys you continuing operational nightmares. Making the correct meter selection before it is in the pipe is always easier. Select vendors that are knowledgeable about your whole custody measurement environment not just how their meter works. As you can tell from the foregoing the making of an accurate repeatable flow measurement requires consideration of a myriad of flow related aspects. Select the knowledgeable vendor who is interested in your success rather than meeting quota.