THE DEVELOPING ROLE OF HELICAL TURBINE METERS

Class No. 289

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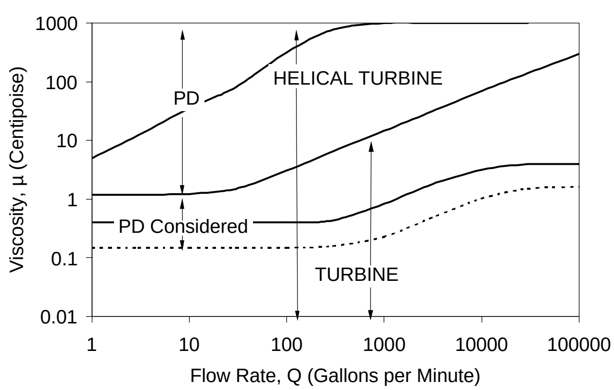
INTRODUCTION

Custody transfer measurement is a driving force behind the development of new technologies in the metering industry. With the ever changing cost associated with the exploration and development of our natural resources reserves, it is essential that these raw materials be measured both accurately and efficiently.

The primary means of custody transfer measurement of hydrocarbon products is by metering. While numerous meters are available in the industry, the turbine meter and the positive displacement meter have long been the meters of choice to provide accurate measurement of liquid hydrocarbon products in custody transfer applications.

The intent of this paper is to describe the technology of the helical bladed turbine meter and compare this technology to conventional turbine meters and positive displacement meters as they relate to custody transfer metering applications.



HISTORY

The conventional turbine flowmeter has been used in flow measurement applications for many years. Since the mid-forties, the turbine has been used in aeronautical applications with hydrocarbon measurement applications materializing in the sixties.

In 1953, the original helical bladed turbine meter was designed and primarily used in the aeronautical industry for measurement of fuel consumption and fuel transfer within an aircraft. The technology proved to be superior to conventional turbine meter technology with its ability to accurately measure products of varying viscosities and densities. In the mid-sixties, the technology was introduced to the oil and gas industry in the European marketplace and quickly found acceptance for crude oil measurement in the harsh environment of the North Sea. As the benefits of the helical technology proved itself in the North Sea, petroleum companies sought to utilize the technology in the United States.

The dual bladed helical turbine meter was introduced to the USA marketplace in the 1994, and has been confirmed to meet all of the requirements and recommendations of the American Petroleum Institute (API) for custody transfer measurement of liquid products. Specifically, it is covered in part by the “Measurement of Liquid Hydrocarbons by Turbine Meters” (Chapter 5, Section 3) in the Manual of Petroleum Measurement Standards.

METER CONSTRUCTION

Helical turbine meters are constructed similarly to conventional turbine meters. The basic elements are the same with exception given to the rotor or impeller shape and the measurement cartridge design. Basically all turbine meters consist of a body with flanged ends, a rotor or impeller assembly, a bearing assembly system and electrical system.

The body is used to house the measurement cartridge and is typically a carbon steel spool piece. The body can be made from several other materials as deemed necessary to accommodate the measured fluid characteristics. The body also contains the electrical pick-up assembly used to transform the mechanical rotation of the impeller to electrical pulses as measured by the flow computer or local totalizer.

The measurement chamber or cartridge assembly is constructed of 316L stainless steel and houses the rotor and the support crosspieces which contain the bearing assemblies. The crosspieces are constructed of stainless steel and house the journal bearing sleeves. The bearings are typically made of tungsten carbide for crude oil and most hydrocarbon products. For low lubricity fluids and chemical applications, other types of bearing assemblies made of ceramic, graphite or Teflon can be used.

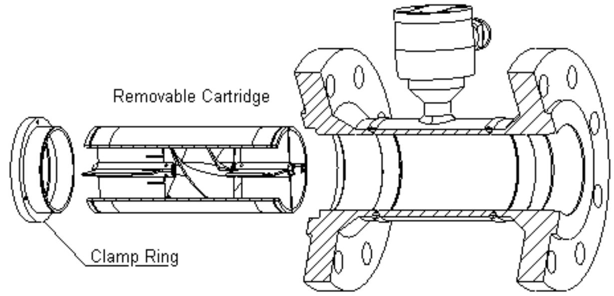
The rotor is typically constructed of titanium or aluminum depending on the metered fluid. The rotor is machined from a full billet of the selected material using sophisticated programmable machining equipment. Due to the physical size and mass of the helical rotor, the weight of the material used can significantly impact the meter's performance and longevity. It is important that the rotor respond quickly to changing flow rates and fluid conditions to ensure accurate measurement. It is also important that the weight of the rotor be minimized to achieve maximum bearing life. Titanium is the preferred metal for the rotor due to its lightweight characteristic, its durability and its ability to operate under harsh fluid conditions. Titanium is highly recommended for use in all crude oil and chemical applications. It is three times lighter than stainless steel and is very resistive to the corrosive and erosive elements of crude oil. Aluminum can be used in refined products, such as gasoline, diesel and aviation fuel and in other liquids where the product does not attack the structure of the material. One manufacturer of the helical meter uses aluminum coated with nickel or stainless steel impellers.

Another feature in the design and construction of the helical turbine is the cartridge design of the measurement chamber. The cartridge design allows to accommodate a changing flowrate during the life of a production field, and simplifies maintenance. For instance, a three inch meter has three options for flowrate capacity. The low-range meter will operate from 44 to 440 BPH, and the high range will operate 88 to 880 BPH with a middle range also available. This type of flexibility allows to maintain the existing meter body and piping configuration while replacing only the measurement chamber as production flowrates increase or decrease.

Typically the conventional turbine meter does not use a cartridge or measurement chamber design.

The impeller material is generally multi-blade stainless steel or aluminum utilizing a similar bearing system as the helical design.

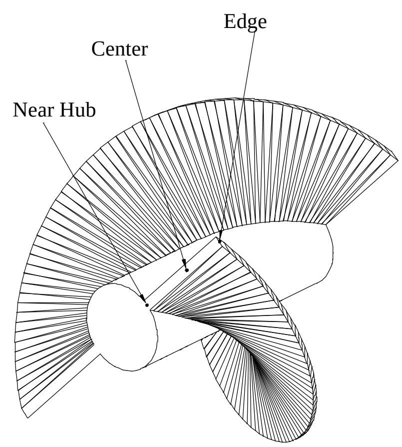
Helical meters are available in sizes from 0.5" to 20" with at least two flow range cartridges available for each size up to 12".



Removable Cartridge

THEORY OF OPERATION

The helical turbine meter is designed to accurately measure liquids from light viscosities to very heavy viscosities. Operating from less than 0.1 centipoise to over 1000 centipoise, the helical design measures fluids that range from LPG's to heavy crude oils. In the past, a conventional turbine meter would be used for the light product applications and a positive displacement meter would be used for heavier products, i.e., over 30 Cp. With the introduction of the helical design, the meter of choice for full range measurement is the helical turbine meter. It actually transcends the operating ranges of the conventional turbine and the positive displacement meters.



The reason the helical design lends itself to multi-viscosity measurements is the technology in the impeller design. The blades are designed to minimize the angle of incidence of the flow stream to the blade. This means that the impeller is actually machined so the fluid addressing the blade flows parallel to the blade on all points of the blade from the shaft to the outer edge. This parallel flow is achieved by machining a different angle at each point of radius on the rotor blades. These different angles compensate for the velocities of the blade at each radius on the blade.

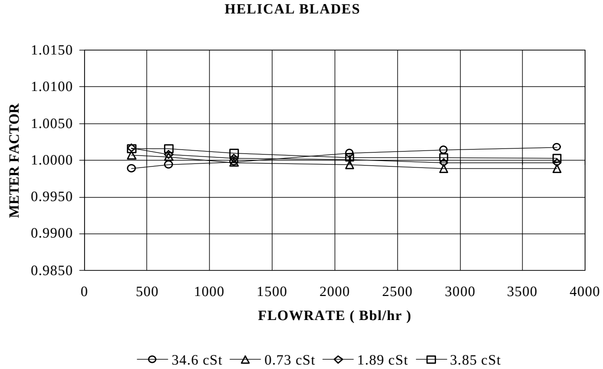
Because the fluid flows parallel to the blades with the helical meter, changes in fluid density and viscosity within the calibrated range of the meter will not adversely affect the performance of the helical meter.

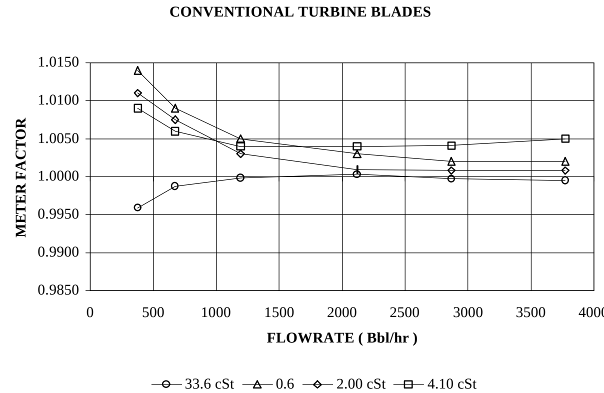
On the other hand, the conventional turbine meter does not lend itself to multi-viscosity measurement. The design of a conventional turbine meter's impeller blades is at a fixed angle. The fixed angle allows for the fluid to pass parallel on only one point of the blade. As the viscosity or density of the fluid changes even slightly, the parallel point shifts and causes the meter factor to also shift. The conventional turbine operates well provided the product is a light and consistent viscosity. The meter will repeat, but as the viscosity changes the meter factor and repeatability will be impacted as compared to the original calibrated conditions.

FLUID VISCOSITY

Turbine meters are sensitive to fluid viscosity. In some cases, it may be possible to develop an expression of the performance (error, correction factor, meter factor or K-factor) as a function of viscosity. However, this cannot be performed for turbine meters as a whole since blade profile, meter size, viscosity range and blade number are all influential in determining the actual performance variations with viscosity. Helical turbine meters are less sensitive to viscosity than straight bladed meters. Helical meters can be calibrated across a range of viscosities to ensure performance.

As you can see by the following charts, a conventional turbine meter is significantly impacted by changes in viscosity, which can occur by temperature variation of the product. These curves show typical changes in the meter factor with kinematic viscosity for straight and helical blades.



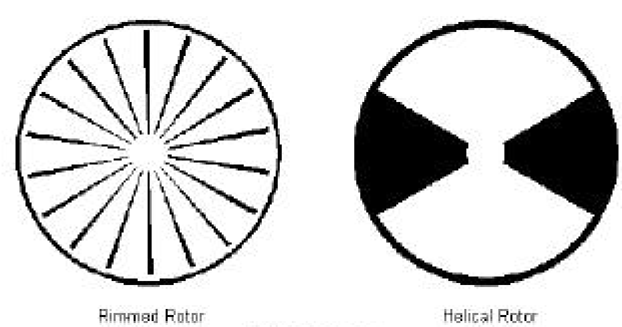


OPERATIONAL FEATURES

Because of the cartridge design of the helical meter, the meter is not subject to changes in line pressure as conventional turbines. Since the measurement chamber is a self-contained module that slides into the meter body, it does not expand or contract with the changes in line pressure. The pressure on both the internal and external surfaces of the cartridge is the same, thus eliminating the need for pressure correction due to expansion of the meter body.

Pressure drop through the measurement system is of paramount concern to all. The more pressure drop, the more horsepower required to pump the fluid through the pipeline. The pressure drop with the helical meter is significantly less than a conventional turbine meter and positive displacement meters.

With fewer blades in the flow stream, there is considerable more free space for the fluid to flow. In a conventional turbine with multiple blades, the amount of free space is reduced thus causing an increase in pressure drop.



FREE SECTION

MAINTENANCE

Maintenance of the helical meter is typical of conventional turbine meter maintenance. Since there is only one moving part in the meter, maintenance of a turbine meter is considered to be very low. As is the case with all custody transfer meters, strainers should be used to keep large solid particles from striking the meter. It is also important that all turbine meters and PD meters operate free of air in order to avoid a catastrophic failure.

In the event there is a catastrophic failure due to solid particles or a column of air, as mentioned above, the cartridge design of the helical meter makes it easy to change the measurement chamber with a spare very quickly. This feature reduces repair time, cost, and system downtime. Maintenance of the PD meters is generally very expensive and repairs result in significant downtime and require maintenance crews with heavy machinery to replace the inner mechanisms. The cartridge assembly for a six inch helical meter with a flow capacity of 3800 BPH weighs approximately thirty pounds. Replacement can usually be accomplished in under one hour by simply rolling the meter body, removing the failed assembly, installing the spare and reinstalling the meter.

EFFECTS OF PARAFFIN AND DEBRIS

Trash, filamentary debris, and paraffin are all components of crude oil and can affect accurate measurement. The helical meter with only two blades is less susceptible to the effects of these elements in the flow stream than conventional turbines and PD meters. As in the description of pressure drop between the conventional rotor and helical rotor, the effects of trash also are a result of the free space available for flow. Because there are only two blades with the helical meter, the opportunity for debris to become lodged on the blade is greatly reduced. Whereas with the conventional turbine, trash can become deposited on the blade much easier and greatly affect measurement accuracy.

Paraffin and waxy buildups on a helical can occur. However, because of the rotor design, the waxy buildup will be uniform on the blade due to the parallel flow of the fluid to the blade. The buildup is even and therefore does not cause the blade to be unbalanced as is the case with a conventional turbine. An unbalanced rotor can result in increased wear on the bearing assembly causing premature failure and maintenance.

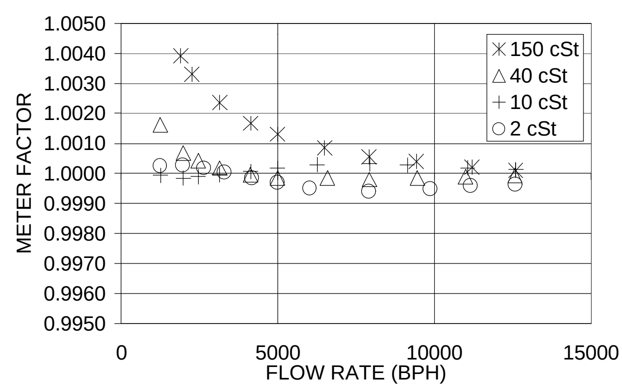
METER CALIBRATION

Most turbine meter manufacturers perform a single fluid calibration on their meters to establish the unit's K-factor (pulses per unit volume). The fluid typically used is water or a light solvent.

This type of calibration is adequate for conventional turbine meters that will be measuring a single viscosity fluid in the field. However, for the helical meter, which is designed for multi-viscosity and heavy viscosity measurement, a single fluid calibration is not sufficient.

In order to ensure the meter will operate linearly through the viscosity ranges specified, it is essential that the helical meter be calibrated and tuned using fluids of similar viscosities to the actual application.

When the meter is calibrated on these various fluids it is often necessary to adjust or tune the blades to achieve optimum performance. For instance, if a meter is specified to operate from 2 to 150 centistokes, in order to ensure linearity and repeatability through this range of viscosities, it is necessary to calibrate the meter on four separate products. Each meter is verified to operate within +/- 0.15% on all products through the flowrange, thereby providing a meter that meets or exceeds custody transfer requirements as specified by API.



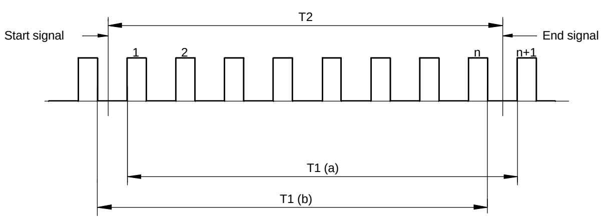
PROVING

API standards recommend 10,000 pulses per prove cycle for a custody transfer meter. This allows for a pulse resolution of .01% if a pulse is lost or missed between detector switches. Conventional turbine meters and PD meters have been proven with standard volume provers due to the high pulse count produced by these meters. One perceived limitation with the helical bladed meter is the low pulse count per unit volume whereby it is difficult to achieve 10,000 pulses.

As an example, with a six inch helical meter the K-factor is approximately 100 pulses per barrel. In order to achieve a proving with 10,000 pulses, a prover of at least 100 barrels capacity would be needed. Because this is unrealistic, the pulse interpolation method of proving is used. Pulse interpolation has been a standard for many years and was initially developed in order to decrease the space required and high costs for full volume provers. There are several methods of pulse interpolation of which the most common used is double chronometry.

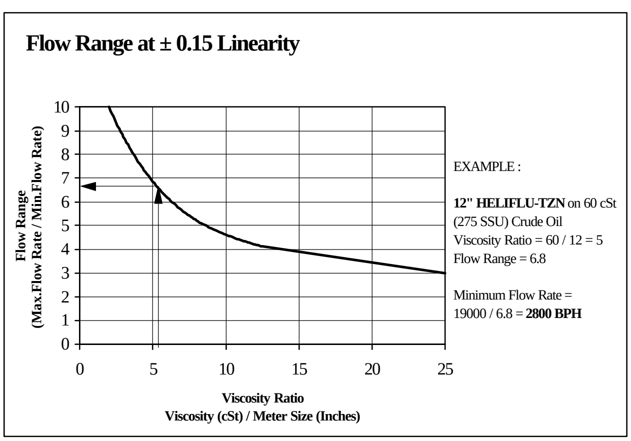
In conjunction with a high frequency clock from a flow computer and the detector switches of the prover, pulse interpolation allows to measure partial pulses during a prove and thus provide the resolution required by API standards. Following is the algorithm and representative drawing.

$$N_1 = N_m \frac{T_2}{T_1}$$



PERFORMANCE CHARACTERISTICS

The following chart reflects the helical performance in terms of accuracy at different viscosities.



In the above example, a 12" meter with a maximum flowrate of 19,000 BPH is measuring 60 cSt. crude oil. The viscosity ratio is calculated by dividing the viscosity by meter size. In this case the ratio is 5, which corresponds to a flow range of 6.8.

By dividing the maximum flowrate of 19,000 BPH by 6.8, we determine that the minimum flowrate possible to achieve +/- 0.15% linearity at 60 cSt. with this 12" meter is 2800 BPH.

CONCLUSION

The helical turbine meter has been accepted worldwide for custody transfer measurement of crude oils, refined products, chemicals and virtually any liquid requiring accurate fiscal measurement.

In applications that were traditionally limited to conventional turbines and positive displacement meters, the helical bladed meter has gained wide acceptance as the meter of choice for those applications. These applications include production, pipeline transportation, refineries, truck loading terminals, petrochemical plants, tanker loading and unloading and many other liquid measurement applications.

While all meters have a distinct advantage in various applications, the helical meter has proven to be useful in a broad range of fluids while also being cost effective to purchase, operate and maintain.

As new technologies continue to emerge in our industry for custody transfer measurement, the helical meter is at the forefront of these technologies.

REFERENCES:

- API-MPMS Chapter 5 Section 3 – Measurement of Liquid Hydrocarbons by Turbine Meters
- API-MPMS Chapter 4 Section 6 Pulse Interpolation