

Daniel® Liquid Turbine Flow Meter Technical Guide



TABLE OF CONTENTS

Turbine Meter Parameters.....	1
The Daniel Series 1200 and 1500 Liquid Turbine Flow Meter Systems.....	2
Turbine Meter Theory	3
Patented Floating Rotor.....	4
Magnetic Pickoff of Rotor Velocity	5
Turbine Meter Rotor and Bearing Design.....	6
Rimmed Rotors for Higher Resolution.....	7
Daniel Series 1200 Liquid Turbine Flow Meter.....	8
Daniel Series 1200 Liquid Turbine Flow Meter Design Features	9
Daniel Series 1200 Liquid Turbine Flow Meter Materials of Construction.....	10
Daniel Series 1500 Liquid Turbine Flow Meter.....	11
Daniel Series 1500 Liquid Turbine Flow Meter Design Features	12
Daniel Series 1500 Liquid Turbine Flow Meter Materials of Construction.....	13
Rangability of Liquid Turbine Flow Meters.....	14
Liquid Turbine Flow Meter Performance with Different Specific Gravities.....	14
Daniel Series 1500 Liquid Turbine Flow Meter Specific Gravity Adjustments	15
Meter Performance in High Viscosity Liquids	16
Installation and Operating Recommendations.....	17
Back Pressure	18
Turbine Meter Instrumentation	19

FORWARD

Daniel Measurement and Control is a recognized leader in the field of flow measurement. The Company is engaged solely in the design and manufacture of flow measurement equipment for custody transfer and fiscal duty applications for both gas and liquid. Daniel offers both individual products and systems, with the largest installed base of packaged meter and prover systems. Daniel continues to be the leader in measurement systems.

Daniel liquid turbine flow meters are the product of a continuous development process, and offer the best solution for modern liquid measurement requirements.

The range of liquid turbine flow meters includes the Daniel Series 1200 and 1500 Liquid Turbine Flow Meters, each of which is designed for specific industry segments. The Daniel Series 1200 Liquid Turbine Flow Meter is designed for applications in loading terminals and is used on a variety of refined product loading applications. The Daniel Series 1500 Liquid Turbine Flow Meter utilizes proven technology in a robust package designed for pipeline applications.

Daniel turbine meters have been proven on a variety of liquid metering applications, including crude oil, refined products, LPG, liquid ethylene and many other liquids. The characteristics of the turbine meter, which include excellent repeatability, longevity and simplicity, lend the technology to an increasing number of liquid measurement applications.

TURBINE METER PARAMETERS

These five terms are the most widely discussed parameters of turbine meter applications.

Linearity is the measure of variation in signal output across the nominal flow range of the meter. The turbine meter will have a nominal K-factor (number of pulses output for a given volume measured) and this value varies across the flow range of the meter. Linearity is a measure of the variance of actual output from the average K-factor. With modern electronics, linearization of the meter registration is possible within a flow computer, and thus further improvements in measurement accuracy is possible.

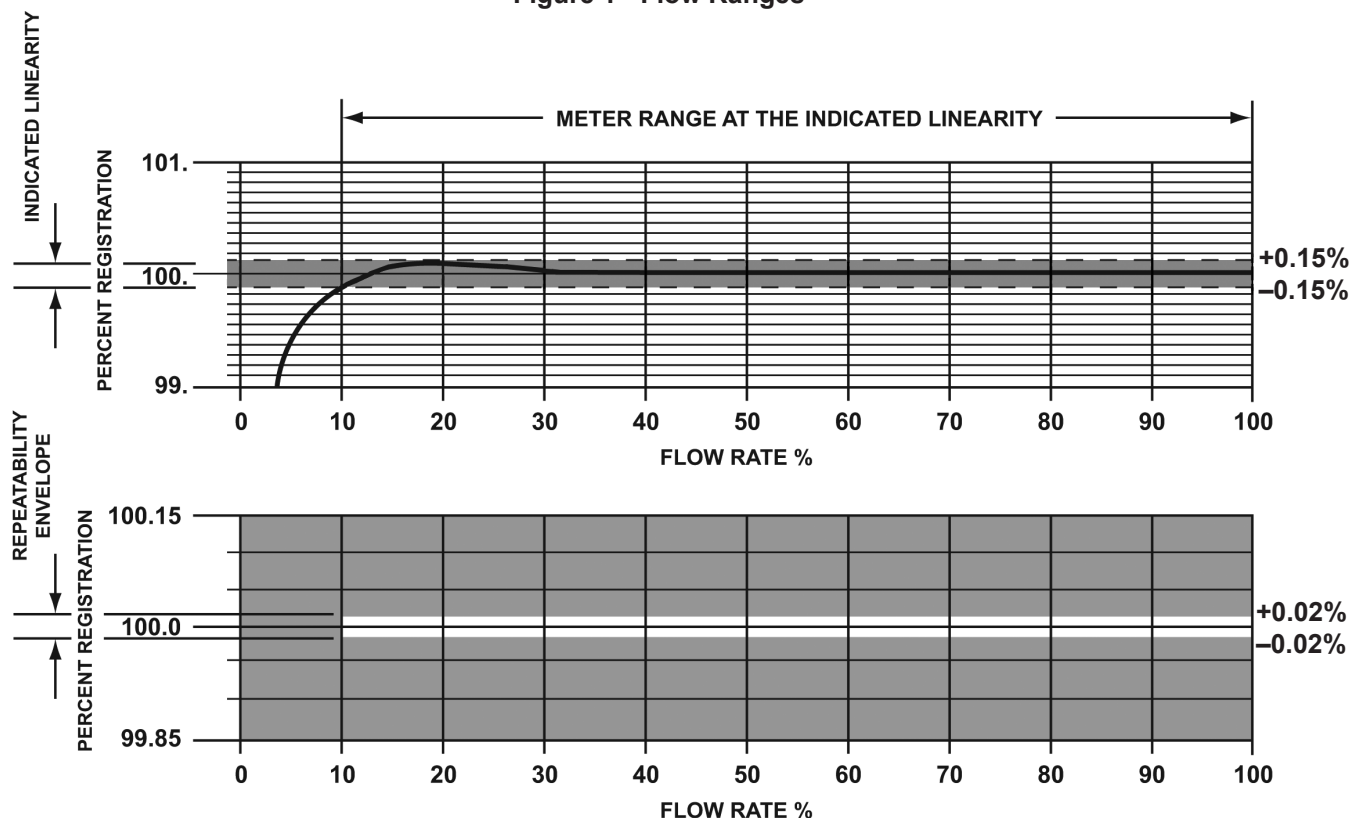
Repeatability is the ability of a meter to indicate the same reading each time the same flow conditions exist. Turbine meters exhibit excellent repeatability and, for many control applications, this is the most important parameter to be considered.

Accuracy is a measure of how close to true or actual flow the instrument indication may be. It is generally expressed as a percent of true volume for a specific flow range. This is a “worst case” rating. Accuracy at a particular flow rate may be an order of magnitude better than “rated flow range accuracy.”

Resolution is a measure of the smallest increment of total flow that can be individually recognized, normally defined by a single pulse. Turbine meters have an inherently high resolution.

Range is the ratio of maximum flow to minimum flow over which the specified linearity will be maintained. Normal range (or “turn-down”) is given as 10:1, although this may be exceeded in many cases, depending on meter size and required linearity.

Figure 1 - Flow Ranges



The Daniel Series 1200 and 1500 Liquid Turbine Flow Meter Systems combine turbine meters and electronic instrumentation to measure volumetric total flow and/or flow rate. Each Daniel turbine meter comprises of a cylindrical housing containing a precise turbine rotor assembly. The magnetic pickoff, or pickoffs, are mounted in a boss on the meter body. As fluid passes smoothly through the flow meter, it causes the rotor to revolve with an angular velocity proportional to flow. The rotor blades or rim buttons passing through the magnetic field of the pickoff generate a pulsing voltage in the coil of the pickoff assembly. Each voltage pulse represents a discrete volume. The total number of pulses collected over a period of time represents the total volume metered.

The sinusoidal signal from each pickoff has low amplitude and may not normally be relied upon for transmission distances over 20 feet (6 meters). The signal must, therefore, be amplified. This is achieved with a preamplification board mounted on the turbine meter. These pulse signals are typically transmitted to control room instrumentation such as flow computers, and may also be required to input to prover computers which calculate, display, transmit, control or record the flow sensed by the rotor. The results may be displayed as pulse-counts or standard engineering units, such as gallons, barrels, etc.

All Daniel Series 1200 and 1500 Liquid Turbine Flow Meters have, as standard, the Universal Mounting Box (UMB) which may be fitted with one or two pickoffs and the dual channel preamplifier. The pickoff mountings are oriented so that the outputs from the pickups are 90° electrically out of phase. The Daniel Series 1500 Liquid Turbine Flow Meter may be supplied with two UMBs, offering up to four pulse outputs. Alternate pairs across the 2 UMBs are also 90° electrically out of phase.

Flow Computer

4-20 mA

rate total

pulse from coil

PREAMP

CONDITIONS AND AMPLIFIES PULSE

MRT

CONVERTS TO 4-20 mA

Daniel manufactures the Series 1200 and 1500 Liquid Turbine Flow Meters, the adjacent tube sections, and the electronic instrumentation. Each meter is precisely flow calibrated before shipment.

The Meter Systems are used to provide measurement information in fluid transport, petroleum and chemical processing, custody transfer of liquids, blending systems, and in product batching in field or plant operations. The repeatability of the systems ensures quality measurement of fluids over a wide range of flow rates, temperatures, compositions and viscosities.

TURBINE METER THEORY

The basic theory behind Daniel's electronic liquid turbine meters is relatively simple. Fluid flow through the meter impinges upon the turbine blades which are free to rotate about an axis along the center line of the turbine housing. The angular (rotational) velocity of the turbine rotor is directly proportional to the fluid velocity through the turbine. These features make the turbine meter an ideal device for measuring flow rate.

The output of the meter is taken by an electrical pickoff(s) mounted on the meter body. The output frequency of this electrical pickoff is proportional to the flow rate. In addition to its excellent rangeability, a major advantage of the turbine meter is that each electrical pulse is also proportional to a small incremental volume of flow. This incremental output is digital in form, and as such, can be totaled with a maximum error of one pulse regardless of the volume measured.

The turbine meter and associated digital electronics form the basis of any liquid metering system. An expanding blade hanger assembly holds the turbine rotor in alignment with the fluid flow. The angle of the turbine blades to the stream governs the angular velocity and the output frequency of the meter. A sharper blade angle provides a higher frequency output. In general, the blade angle is held between 20° and 40° to the flow. Lower angles cause too low of an angular velocity and loss of repeatability, while larger angles cause excessive end thrust.

FLOW RATE IS PROPORTIONAL TO ANGULAR VELOCITY

Figure 3 below is a cross section of the internals of a Daniel turbine meter. Flow through the turbine meter is from left to right. The forward and rear suspension act as flow guides so that fluid motion through the meter is parallel to the meter centerline. Flow impinging upon the angular blade causes the rotor to spin at an angular velocity proportional to flow rate.

Figure 3 - Liquid Turbine Flow Meter Cross Section

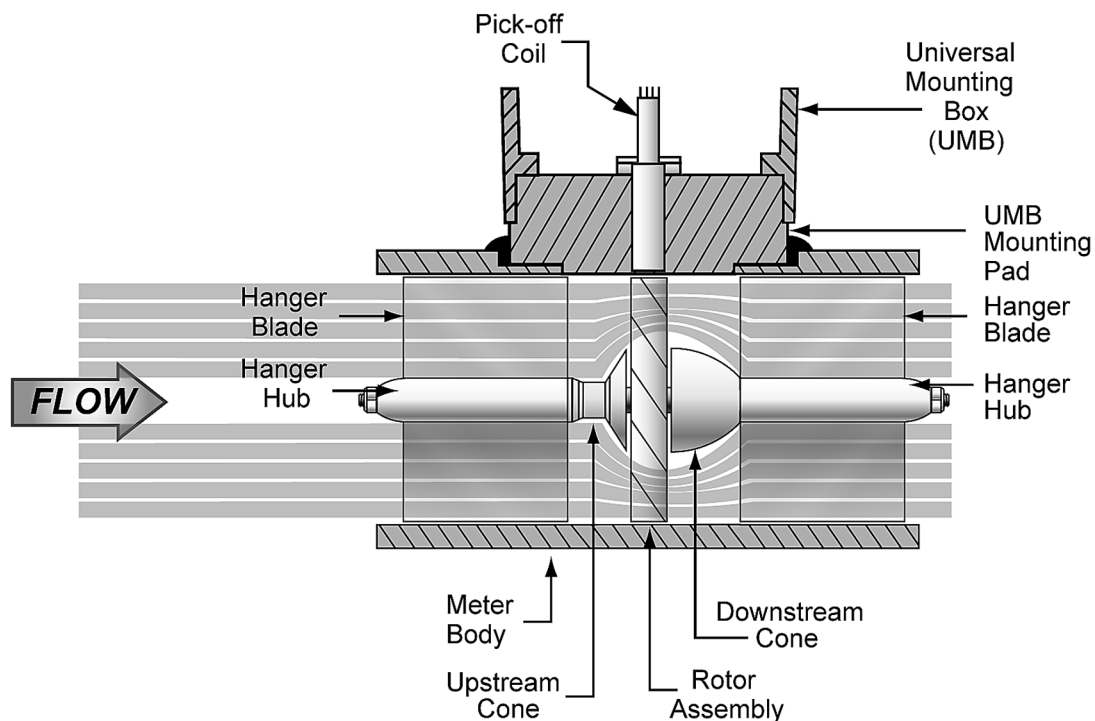
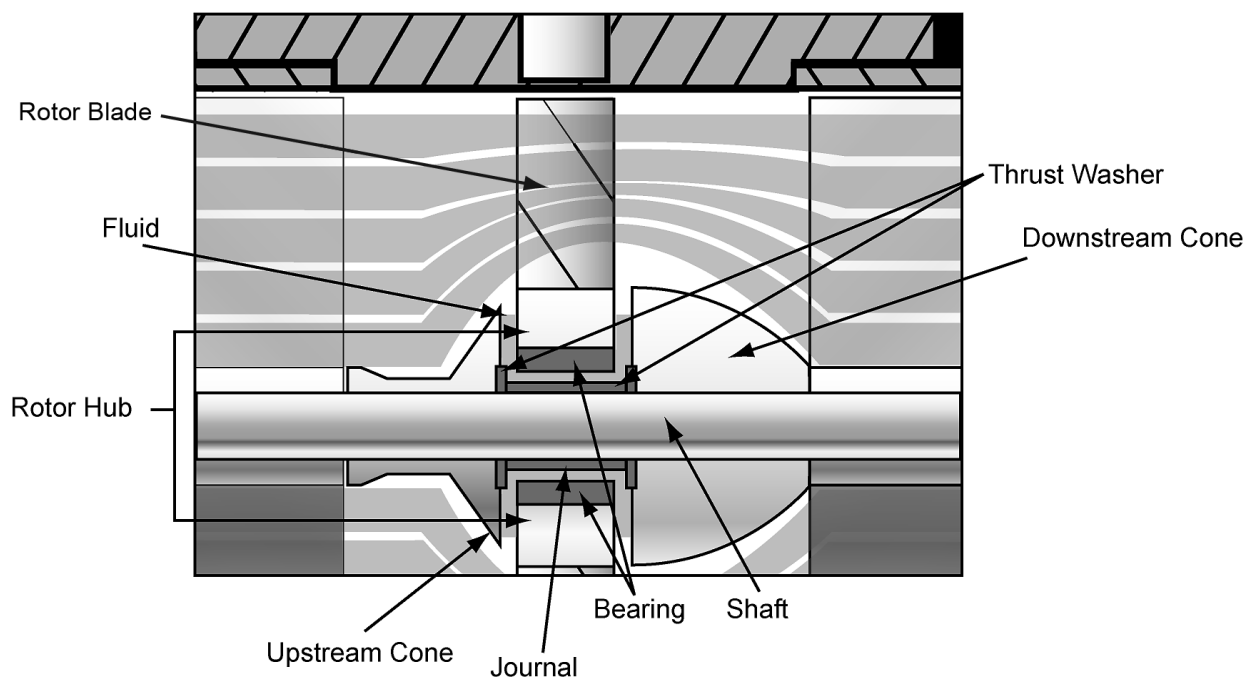


Figure 4 - Rotor Assembly Cross Section



PATENTED* FLOATING ROTOR

Flowing fluid enters the turbine through the forward suspension. When it encounters the sharp angle of the cone, the stream is deflected outward, increasing in velocity and causing a slight static pressure drop. As the fluid leaves the blade area, flow has redistributed. Velocity is reduced slightly and the static pressure has increased proportionally.

The difference between the two velocity pressures causes the rotor to move upstream into the fluid flow. This upstream force would be great enough to cause the rotor to strike the forward thrust bearing, were it not for the slight offset. The cross sectional area of the cone is slightly smaller than that of the rotor hub so that some of the flow impinges directly upon the rotor hub, generating a downstream thrust. As a result, the rotor floats in balance between upstream and downstream cones, pushed forward by the pressure difference across the blades and pushed backward by the flow impingement. The only bearing surface other than the measured fluid is the cemented carbide sleeve bearing insert. (See Figure 4)

In bi-directional meters, the downstream cone is replaced by a second upstream cone and rangeability in the reverse flow direction is reduced.

* U.S. PATENT NO. 3,948,099, PATENTS IN OTHER COUNTRIES

MAGNETIC PICKOFF OF ROTOR VELOCITY

The angular velocity of the turbine rotor is taken through the turbine meter wall by means of a magnetic pickoff. The stainless steel meter body is non-magnetic and offers negligible effect on a magnetic field set up by a permanent magnet in the pickoff coil.

Turbine blades, made of a paramagnetic material (which properties cause it to be attracted by a magnet), rotate past the pickoff coil, generating irregular shaped voltage pulses. The frequency of these pulses is linearly proportional to the angular velocity of the rotor and thus to the flow rate. Additionally, each pulse is incrementally proportional to a small unit of volume. The amplitude of the pulses will vary in proportion to blade velocity but is not considered in the measurement process. Flow rate and total flow information is transmitted by frequency and by counting (totalizing) the pulses.

The permanent magnet produces a magnetic field which passes through the coil and is concentrated to a small point at the pickoffs. In Figures 5 and 6 below, as a turbine blade (A) moves into close proximity to the pickoff point, its magnetic properties cause the magnetic field to deflect to accommodate its presence. This deflection causes a voltage to be generated in the coil. As the blade passes under the pickoff point (B), this voltage decays, only to build back in the opposite polarity as the leaving blade - now in position (C). This causes the magnetic field to deflect in the opposite direction. So as each blade passes the pickoff, it produces a separate and distinct voltage pulse. Since the fluid surrounding each blade represents a discrete unit of volume, each electrical pulse also represents a discrete unit of volume. Turbine meter output is rated in pulses per gallon, pulses per liter, or other standard engineering units.

Figure 5 - Assembly of Daniel® UMB showing dual pickoff configuration

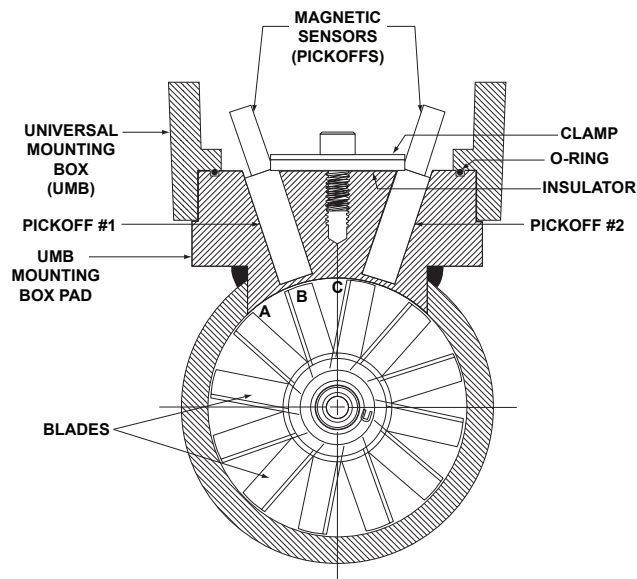
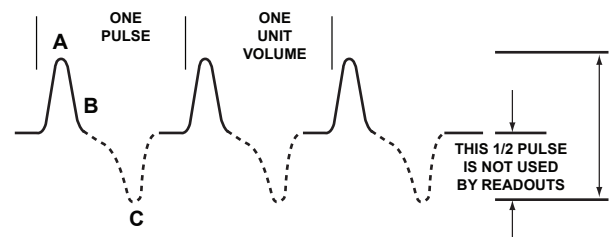


Figure 6 - Voltage Output, Peak to Peak



TURBINE METER ROTOR AND BEARING DESIGN

The primary differences in turbine meter technology are in the design of the rotor and bearings.

The rotor is an assembly of up to twelve (in some designs this number is greater) blades locked into a hub, which rotates on a bearing or bearings. For light liquid applications that require viscosities of 5cSt or less, and specific gravities of less than 0.75, the rotor does not normally need a rim (sometimes referred to as a shroud). For measuring the more viscous liquids and in larger size turbine meters (i.e. 8" and above) a rim is fitted to ensure sufficient rigidity in the rotor. A rim also offers the advantage of higher pulse resolution; with a bladed rotor the number of pulses per revolution is limited to the number of blades, and in a rimmed rotor the number of pulses per revolution corresponds to the number of buttons or slots in the rim.

For intermittent duties on light, clean hydrocarbons that may be found at tank truck terminals, ball bearings may be used for a rotor bearing. Proper design of rotors with ball bearings will use two ball races and a short axle upon which the rotor is fitted. Where space is constrained the ball races may be fitted directly into the rotor hub. This design is particularly suited to low and varying flow rate applications, and is utilized on the Daniel Series 1200 Liquid Turbine Flow Meter, designed primarily for distribution applications such as load racks. In these installations, liquids handled are typically light, refined products.

Pipeline applications often require continuous operation at fixed flow rates. Here the design of the turbine meter must offer sufficient longevity to minimize maintenance intervals. In these applications, tungsten carbide journal bearings are used, which offer exceptional longevity. As tungsten carbide is extremely hard wearing, designs utilizing this sort of bearing are often applied to more demanding measurement applications, such as crude oil.

It should be noted here that the limitations on viscosity are related to the rangeability of the turbine flow meter. As the viscosity of the measured liquid increases, the K-factor variations at different flow rates increase. Thus to maintain the linearity of the meter at the required level, as the viscosity of the measured liquid increases, the turn-down, or rangeability of the meter must be reduced. So for typical pipeline applications, where the flow meter will operate at just one flow rate (or a very limited range of flow rates) a turbine meter may be used to measure flows of high viscosity liquids. The Daniel Series 1500 Liquid Turbine Flow Meter is designed for pipeline applications, and is equipped with robust internals suited to continuous measurement of a wide range of liquids.

There may be a single hanger or hangers upstream and downstream of the rotor. In the Daniel Series 1200 Liquid Turbine Flow Meter there is a single upstream support for the rotor, and in the Daniel Series 1500 Liquid Turbine Flow Meter there are both upstream and downstream hangers.

Bearings may be either ball bearings or tungsten carbide journal bearings. Since ball bearings are used to provide improved performance on low flow rates and on clean product, they are a reliable, cost effective solution.

The Daniel Series 1200 Liquid Turbine Flow Meter deploys a cantilevered twin ball bearing design. Utilizing a rotating shaft on two ball bearing units, the Daniel Series 1200 Liquid Turbine Flow Meter is available in 1", 1.5", 2", 3" and 4" line sizes. For more demanding applications, a tungsten carbide journal bearing assembly is available as an option.

Lightweight bladed rotors of this type mounted on ball bearings are particularly suited to the intermittent duty cycles typical in loading rack applications. The design application is limited to clean refined products. In the event that the turbine is used on slightly dirty products, the use of tungsten carbide journal bearings is recommended. Tungsten carbide bearings are extremely hard wearing and used in turbine meters on a range of applications from LPGs to crude oils.

RIMMED ROTORS FOR HIGHER RESOLUTION

In the larger diameter Daniel Series 1500 Liquid Turbine Flow Meter (normally above 6" in line size), the resolution provided by a blade-type motor may be improved by the use of a rimmed (or shrouded) rotor. This construction is standard for Daniel meters of 8" and up. A lightweight stainless steel rim (or shroud) carries small paramagnetic buttons which provide a greater resolution of flow by generating more pulses per unit volume.

Daniel Series 1200 and 1500 Liquid Turbine Flow Meters are supplied with one Universal Mounting Box (UMB) as standard. This is attached to a boss, which in turn is attached to the meter body. This assembly may house two pickoffs, which are oriented such that their outputs are 90° electrically out of phase.

Figure 7 - Daniel® Series 1500 Liquid Turbine Flow Meter internals showing standard rimmed rotor

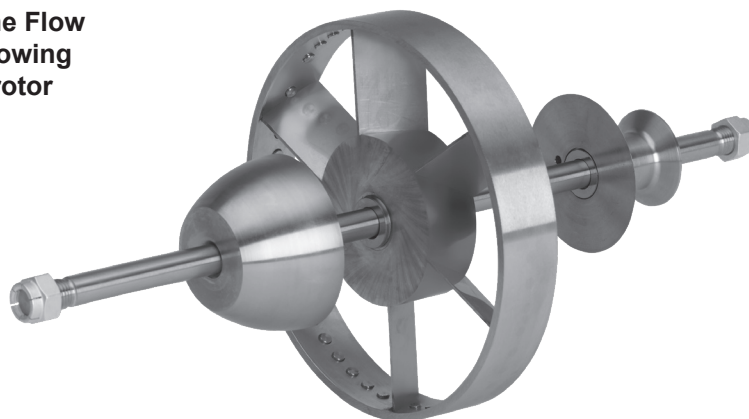
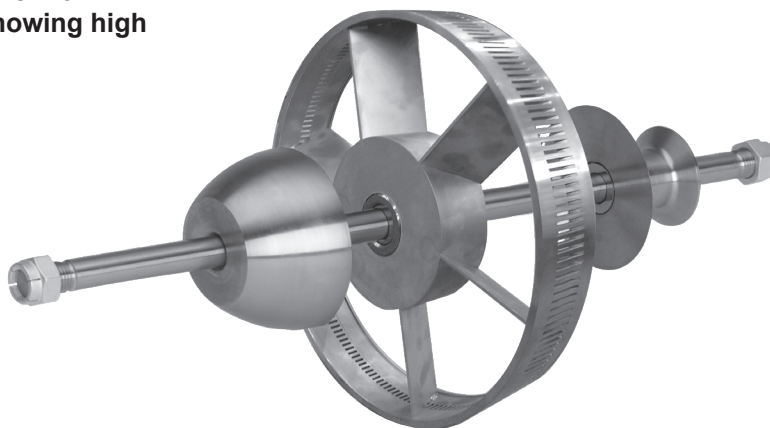


Figure 8 - Daniel® Series 1500 Liquid Turbine Flow Meter internals showing high resolution rotor



The Daniel® Series 1500 Liquid Turbine Flow Meter is also offered with a high resolution rotor. This rotor is designed with slots in the rim in place of paramagnetic buttons and provides a higher number of pulses per unit volume than the standard rotor which enables proving with a smaller pipe size prover.

DANIEL® SERIES 1200 LIQUID TURBINE FLOW METER

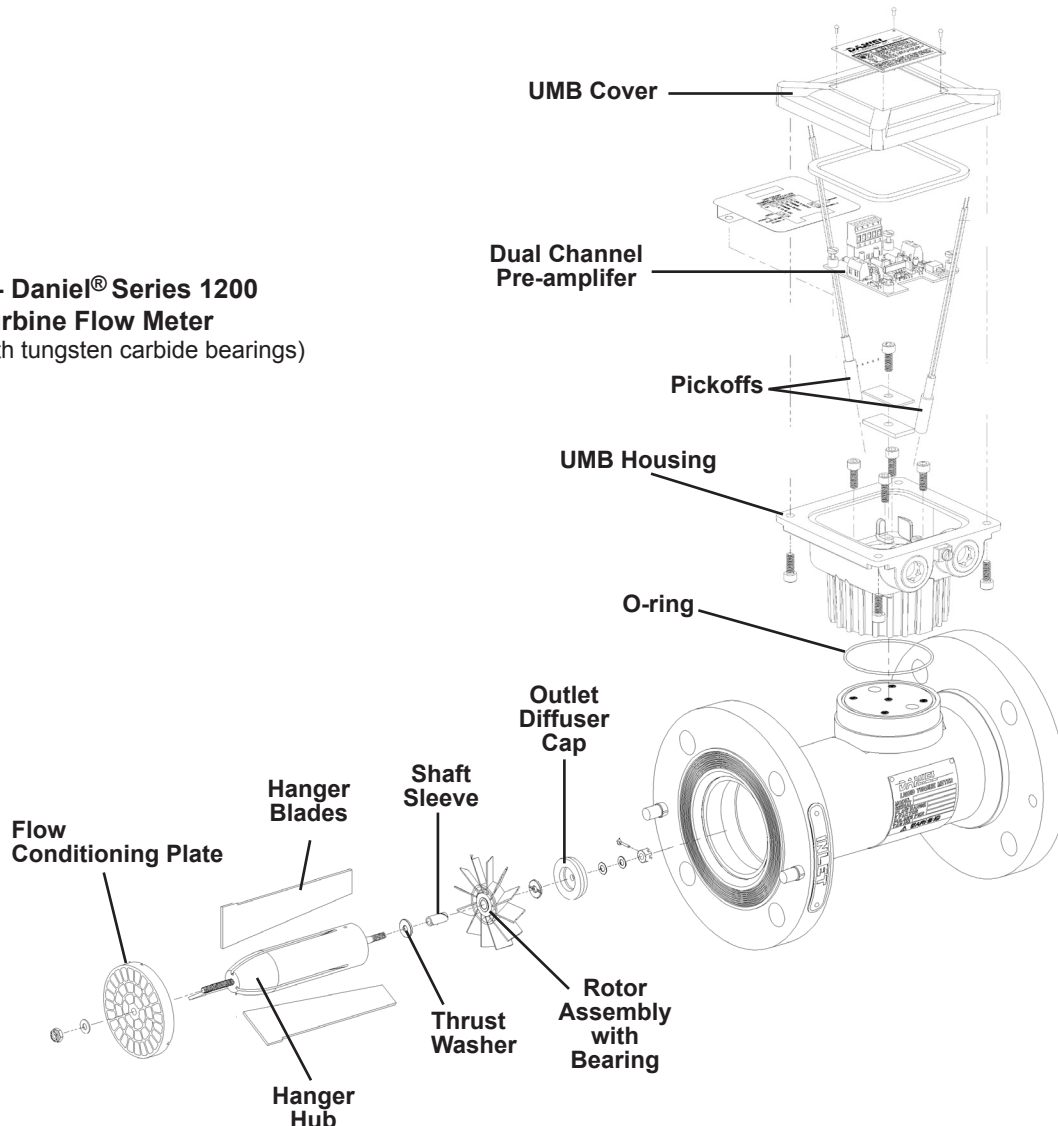
Daniel Series 1200 Liquid Turbine Flow Meters are designed specifically for load rack service where a vital characteristic is repeatability. The meter deploys a lightweight rotor which is supported on self-cleaning flow through ball bearings. As a result, the meter is versatile and is particularly suited to batch loading of light hydrocarbons. The meter has been used successfully on fluids with viscosities up to 6 centistokes. The meter can also be supplied with optional tungsten carbide bearings for more demanding applications

The meter features an upstream expanding hanger which centers the internals in the body, with cantilevered support of the rotor. The stainless steel ball bearings or the tungsten carbide bearings and the shaft are housed in the meter hub. The meter will operate in any plane, and is frequently used in the vertical orientation with flow upward to save space at a load rack.

The design includes an integral flow conditioning plate which allows operation without upstream flow straightening available on the 1.5", 2", 3" and 4" meters. This configuration is particularly valuable in vertical use at load racks.

SEE DANIEL SERIES 1200 LIQUID TURBINE FLOW METER DATASHEET FOR MODEL SELECTION MATRIX

**Figure 9 - Daniel® Series 1200
Liquid Turbine Flow Meter**
(Shown with tungsten carbide bearings)



DANIEL® SERIES 1200 LIQUID TURBINE FLOW METER DESIGN FEATURES

The following data is applicable for Daniel Series 1200 Liquid Turbine Flow Meter calibrated on mineral spirits.

Size (Inches)	Standard Flow Range	Extended Flow Range	Standard Flow Range	Extended Flow Range	Standard Flow Range	Extended Flow Range
	BBL/Hr	BBL/Hr	M3/Hr	M3/Hr	USGPM	USGPM
1	8.6 - 86	99	1.36 - 13.7	15.8	6.0 - 60	69
1.5	18.6 - 186	214	2.96 - 29.6	34	13 - 130	150
2	31.5 - 315	362	5.0 - 50	57.5	22 - 220	253
3	93 - 930	1,071	14.8 - 148	170	65 - 650	750
4	143 - 1,430	1,785	23 - 230	284	100 - 1,000	1,250

Linearity

Size (Inches)	Standard Linearity	Premium Linearity
1	+/-0.25%	N/A
1.5	+/-0.25%	+/-0.15%
2	+/-0.25%	+/-0.15%
3	+/-0.15%	N/A
4	+/-0.15%	N/A

Repeatability: +/-0.02% at any point throughout the minimum to extended maximum flow range.

Nominal K- factor

Size (Inches)	K-factor		
	Pulses/BBL	Pulses/M ³	Pulses/US Gal
1	33,600	211,360	800
1.5	16,800	105,680	400
2	7,560	47,556	180
3	2,184	13,877	52
4	966	6,077	23

Technical Guide

DAN-LIQ-Turbine Meter-TG-0807

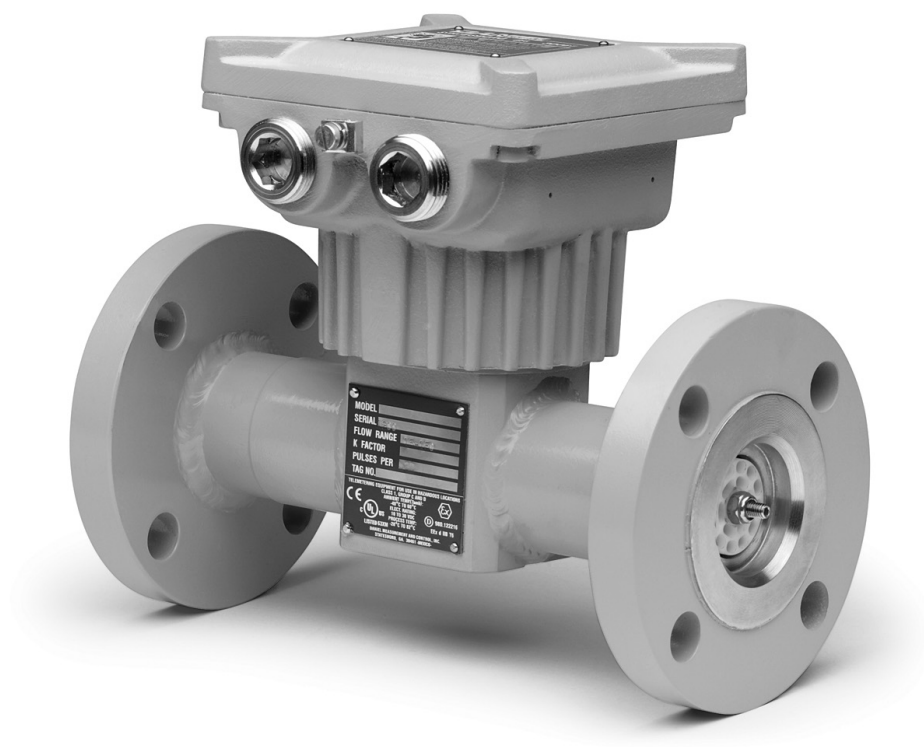
August 2007

DANIEL® SERIES 1200 LIQUID TURBINE FLOW METER MATERIALS OF CONSTRUCTION

	Standard	Optional
Body/Flanges	1" and 1.5" Stainless Steel	NA
	2" - 4" Carbon Steel	304 Stainless Steel
Suspension	Anodized Aluminum	None
Rotor Blades	400 Series Stainless Steel	None
Rotor Hub	Aluminum	None
Shaft	304 Stainless Steel	None
Bearings	430 Stainless Steel	Tungsten Carbide
Flow Conditioning Plate	Delrin® 150	Aluminum

Viscosity and Specific Gravity

Low specific gravities or high viscosities will reduce the flow range of the meter.



Daniel® Series 1200 Liquid Turbine Flow Meter

DANIEL® SERIES 1500 LIQUID TURBINE FLOW METER

The Daniel Series 1500 Liquid Turbine Flow Meter is designed for applications requiring rugged dependability with high accuracy and throughput. Used on pipelines, marine loading and other demanding systems, the internals used are well proven in the Daniel PT meter. The Daniel Series 1500 Liquid Turbine Flow Meter utilizes these internals in a body designed to accept a Universal Mounting Box (UMB) and the latest pickoff and pre-amplifier technology.

With upstream and downstream self-centering hangers, highly durable rotor assembly utilizing tungsten carbide sleeve and journal bearings, and a floating rotor design, the Daniel Series 1500 Liquid Turbine Flow Meter is suited to those applications where downtime is unacceptable.

In such applications, dual pulse transmission is normally used to allow the meter instrumentation (normally a flow computer) to check the fidelity of pulse transmission. The single UMB housing contains 1 or 2 pickoffs and a dual channel preamplifier. When configured with 2 pickoffs the square wave outputs are 90° electrically out of phase.

The Daniel Series 1500 Liquid Turbine Flow Meter (2" and up) is available with a second UMB as an option. For meters 3" and above in this configuration, it is thus possible to have up to 4 matched pulse outputs. Corresponding pairs are then 90° electrically out of phase.

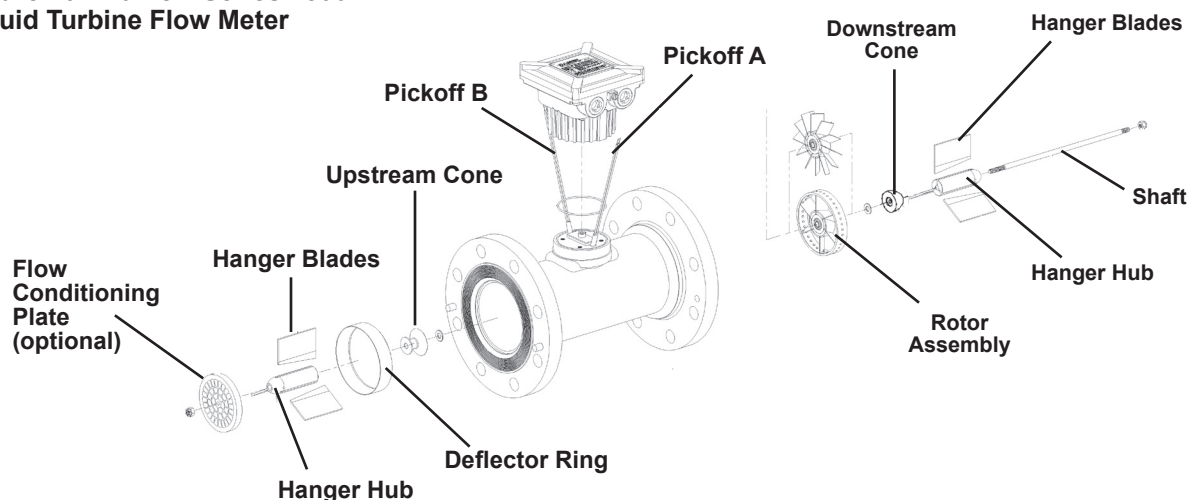
The Daniel Series 1500 Liquid Turbine Flow Meter utilizes only tungsten carbide journal bearings. In applications with fluids of adequate lubricity, a film of the measured fluid lubricates the journal which contributes to the enormous longevity of this design. These bearings are extremely hard (Rockwell A-94) and are polished with diamond paste to a smoothness of two micro-inches (a mirror finish).

The rotor may be blade-type or rimmed-type. Rimmed (or shrouded) rotors have the advantages of greater structural strength and the possibility of higher resolution, as a greater number of paramagnetic buttons than of blades may be used on the stainless steel rim. A bladed rotor is limited to 1 pulse per blade per revolution, with the practical limit for the blades being 12. With a rim, or shroud, there may be up to 64 pulses (buttons) per rotor revolution.

The high resolution (HR) rotor option for the Series 1500 rotor is available in 6" through 16" sizes. In this design the rotor rim is a slotted 400 series stainless steel, designed with twice as many slots in the HR rotor as buttons on the standard rotor.

SEE DANIEL SERIES 1500 LIQUID TURBINE FLOW METER DATASHEET FOR MODEL SELECTION MATRIX

Figure 10 - Daniel® Series 1500 Liquid Turbine Flow Meter



Technical Guide

DAN-LIQ-Turbine Meter-TG-0807

August 2007

The deployment of this high resolution rotor in each of the sizes available gives a nominal K-factor twice that of the standard meter and allows for proving with a smaller size prover.

The rimmed design is available as an option on 3"-6" turbines, and is standard on 8" and larger.

Whatever the design of meter and rotor configuration, the blades are locked and welded into the desired angular position, forming a solid, one piece rotor.

In the Daniel Series 1500 Liquid Turbine Flow Meter both up and downstream shaft supports are deployed. The expanding hanger principle is used to ensure positive self-centering of the internals. The shape of the internal cones results in a reverse differential pressure that counterbalances the downstream thrust on the rotor, thus allowing the rotor to float on a fluid cushion. This floating action ensures long life and minimal maintenance. (See Figure 10)

DANIEL® SERIES 1500 LIQUID TURBINE FLOW METER DESIGN FEATURES

The following data is applicable for Daniel Series 1500 Liquid Turbine Flow Meter calibrated on mineral spirits or water.

Size (Inches)	Standard Flow Range BBL/Hr		Extended Max Flow BPH w/20% Duty Cycle	Standard Flow Range M3/Hr		Extended Min Flow Range USGPM $\pm .75$ (1" - 2.5") $\pm .50$ (3" - 18")	Standard Flow Range USGPM		Extended Max Flow Range USGPM w/20% Duty Cycle
	Min	Max		Min	Max		Min	Max	
1	10	100	116	1	15	5.6	7	70	81
1.5	21	214	247	3	34	12	15	150	173
2	36	360	411	6	57	20	25	250	288
2.5	57	571	657	9	91	32	40	400	460
3	100	1,000	1,150	16	159	56	70	700	805
4	184	1,850	2,126	29	294	104	129	1,295	1,488
6	420	4,200	4,830	67	668	235	294	2,940	3,381
8	850	8,500	9,776	135	1,351	476	595	5,950	6,843
10	1,200	12,000	13,800	191	1,908	672	840	8,400	9,660
12	1,800	18,000	20,700	286	2,862	1,008	1,260	12,600	14,490
16	2,800	28,000	32,200	445	4,452	1,568	1,960	19,600	22,540
18	4,000	40,000	46,000	636	6,359	2,240	2,800	28,000	32,200

Linearity

Size (Inches)	Standard Linearity	Premium Linearity
1" - 2.5"	$\pm 0.25\%$	$\pm 0.15\%$
3" - 18"	$\pm 0.15\%$	$\pm 0.1\%*$
		$\pm 0.07%*$

*5 to 1 turndown

Repeatability: $\pm 0.02\%$ at any point throughout the minimum to extended maximum flowrange.

Viscosity and Specific Gravity

Low specific gravities or high viscosities will reduce the flow range of the meter.

Technical Guide

DAN-LIQ-Turbine Meter-TG-0807

August 2007

Nominal K-Factor

Size	Pulses/BBL	Nominal K-Factor Pulses/M ³	Pulses/US Gal
1	21,000 (BLADE)	132,100 (BLADE)	500 (BLADE)
1.5	9,660 (BLADE)	60,766 (BLADE)	230 (BLADE)
2	5,334 (BLADE)	33,553 (BLADE)	127 (BLADE)
2.5	2,730 (BLADE)	17,173 (BLADE)	75 (BLADE)
3	2,016 (BLADE) 4,620 (RIM)	12,682 (BLADE) 29,062 (RIM)	48 (BLADE) 110 (RIM)
4	1,000 (BLADE) 3,000 (RIM)	6,290 (BLADE) 18,864 (RIM)	23.8 (BLADE) 71.4 (RIM)
6	235 (BLADE) 1,000 (RIM) 2,000 (HR RIM)	1478 (BLADE) 6,290 (RIM) 12,580 (HR RIM)	5.6 (BLADE) 23.8 (RIM) 47.6 (HR RIM)
8	500 (RIM) 1,000 (HR RIM)	3,145 (RIM) 6,290 (HR RIM)	11.9 (RIM) 23.8 (HR RIM)
10	250 (RIM) 500 (HR RIM)	1,572 (RIM) 3,144 (HR RIM)	6 (RIM) 12 (HR RIM)
12	200 (RIM) 400 (HR RIM)	1,258 (RIM) 2516 (HR RIM)	4.8 (RIM) 9.6 (HR RIM)
16	100 (RIM) 200 (HR RIM)	629 (RIM) 1,258 (HR RIM)	2.4 (RIM) 4.8 (HR RIM)
18	100 (RIM)	629 (RIM)	2.4 (RIM)

DANIEL® SERIES 1500 LIQUID TURBINE FLOW METER MATERIALS OF CONSTRUCTION

Item	Standard	Optional	Optional
Meter body and flanges	304 Standard 1" and 1.5"	NA	316 SS
	CS Standard 2" and up	304 SS	316 SS
Suspension	304 SS	304 SS	316 SS
Rotor Blades (Rim Type)	304 SS	304 SS	316 SS
Rotor Blades (Blades Type)	430 SS	430 SS	Nickel 200
Sleeve Bearings	Tungsten Carbide	Tungsten Carbide	Tungsten Carbide
Journal Bearings	Tungsten Carbide	Tungsten Carbide	Tungsten Carbide
Rotor Hub	430 SS	430 SS	316 SS
Rotor Rim 3" and 4"	316 SS	316 SS	316 SS
Rotor Rim 6" - 18"	304 SS	304 SS	316 SS
Rim Buttons	Hi Mu 80	Hi Mu 80	Hi Mu 80
Cones	304 SS	304 SS	316 SS
Shaft	316 SS	316 SS	316 SS
Tolerance Ring	304 SS	304 SS	316 SS

RANGEABILITY OF LIQUID TURBINE FLOW METERS

The flow ranges indicated in the previous tables show a nominal flow range -- with a turndown of 10:1 - at which the turbine will report measurement repeatable to the indicated specification based on measurement of clean liquids such as water (specific gravity 1, viscosity 1cSt) and mineral spirits (specific gravity 0.78, viscosity 1.8cSt).

Where liquids with properties outside of the range described by these liquids are to be measured, the meter flow range will be affected.

Extended flow rates on intermittent duty cycles are permitted and shown in the flow meter design features table on page 12. It should also be noted that the use of the meter in the extended flow range should be limited to a 20% duty cycle.

LIQUID TURBINE FLOW METER PERFORMANCE WITH DIFFERENT SPECIFIC GRAVITIES

Liquid turbine meters are affected by changes in liquid density. When measuring liquids with specific gravities of 0.7 or less, the minimum flow rate of the meter must be increased to maintain the linearity of the meter within the required limits. In this application, the maximum flow rate may be increased to allow for greater rangeability.

It is vital that proper back pressure be maintained (refer to page 18 for the formula for determining required back pressure). Failure to do so may result in flashing and cavitation, which will cause over ranging of, and damage to, the meter. Liquids with low specific gravities generally have high vapor pressures and high coefficients of thermal expansion. When measuring these liquids, it is extremely important that proper installation, measurement and proving practice be followed to provide stable temperatures and to negate the potential for poor measurement and possible system damage.

The data on the following page are for the Daniel Series 1500 Liquid Turbine Flow Meter, and similar effects will be observed in all design of turbine meters.

DANIEL® SERIES 1500 LIQUID TURBINE FLOW METER SPECIFIC GRAVITY ADJUSTMENTS

S.G. = 1 (.7 to 1)

Meter Size	Minimum Linear			Maximum Linear		
	BBL/Hr	M³/hr	USGPM	BBL/Hr	M³/hr	USGPM
1	10	1.59	7	100	15.90	70
1.5	21.4	3.40	15	214	34	150
2	35.7	5.68	25	357	56.76	250
2.5	57.1	9.08	40	571	90.78	400
3*	100	15.9	70	1,000	159	700
4*	185.7	29.52	130	1,850	295	1,295
6*	420	66.77	294	4,192	667.7	2,935

S.G. = 0.5

Meter Size	Minimum Linear			Maximum Linear		
	BBL/Hr	M³/hr	USGPM	BBL/Hr	M³/hr	USGPM
1	22.9	3.64	16	116	36.4	81
1.5	50	7.95	35	246	79.5	172
2	84.3	13.40	59	411	134	288
2.5	134.3	21.35	94	657	213.5	460
3*	235.7	37.47	165	1,150	374.7	805
4*	435.7	69.27	305	2,127	692.7	1,489
6*	988.6	157.2	692	4,830	1,572	3,381

S.G. = 0.3

Meter Size	Minimum Linear			Maximum Linear		
	BBL/Hr	M³/hr	USGPM	BBL/Hr	M³/hr	USGPM
1	32.9	5.23	23	116	52.3	81
1.5	71.4	11.35	50	246	113.5	172
2	118.6	18.56	83	411	185.6	288
2.5	190	32.21	133	657	322.1	460
3*	331.4	52.69	232	1,150	526.9	805
4*	612.8	97.43	429	2,127	974.3	1,489
6*	1,393	221.5	975	4,830	2,215	3,381

* Rim type rotor not recommended, use blade type rotor only.

METER PERFORMANCE IN HIGH VISCOSITY LIQUIDS

Increases in viscosity of the measured liquid will reduce the rangeability of the flow meter. Generally, the minimum flow rate of the meter will have to be increased to maintain the linearity rating of the meter.

The increased flow rate may be determined according to the following ratio:

$$\text{Sizing ratio} = \frac{\text{Liquid Viscosity (Centistokes)}}{\text{Nominal Line Sizes}}$$

Sizing Ratio	Minimum Flow (% of Normal Maximum Flow Rate)
1	Use Normal Minimum Flow Rate
1.5	20%
2	25%
2.5	30%
3	35%
4	40%
5	45%
6	50%
7	55%
8	60%

Example:

The sizing ratio of a 4-inch turbine meter measuring a liquid of 8 cSt is 8/4, or 2. The normal maximum flow rate of this size of meter is 1450 GPM. The new minimum flow rate is 25% of 1450, or 362.5 GPM. The flow rate for this application is now 362-1450 GPM, with standard linearity (+/-0.15%) and repeatability of (+/-0.02%) maintained.

Note: Use of the turbine meter on high viscosity liquids at the maximum extended flow range is allowable, but may increase the wear rate of the turbine.

The pressure drop through the meter may be estimated (for low to medium viscosities) according to the following formula:

$$DP = (PD) \times (\mu)^{1/4} \times (SG)^{3/4}$$

or

$$DP = (PD) \times (v)^{1/4} \times (SG)$$

Where:

DP = Estimated pressure drop

PD = Pressure drop for water at expected flow rate

μ = Absolute viscosity in centipoises

v = Kinematic viscosity in centistokes

SG = Specific gravity

Note: $\mu = (v) \times (SG)$

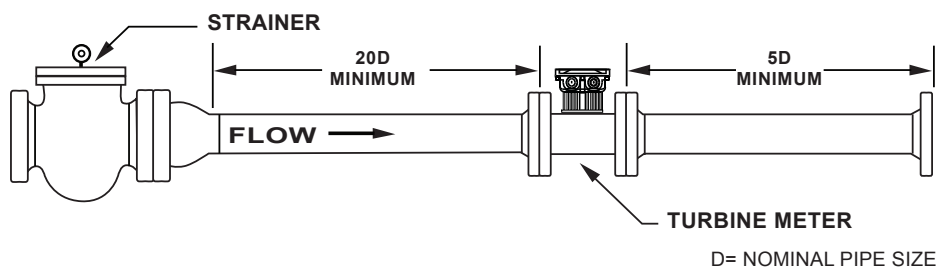
INSTALLATION AND OPERATING RECOMMENDATIONS

For a turbine meter to perform without increased uncertainty and in a repeatable and accurate manner, the flowing stream must be free of rotational components. The internal assembly supports of a turbine meter offer a slight straightening effect, but additional flow straightening is normally required.

Generally, upstream flow straightening is effected through the use of adequate upstream straightening sections, which often comprise a set of straightening vanes or a tube bundle. Guidance on this subject is offered in the API Manual of Petroleum Measurement Standards, Chapter 5, Section 3.

For turbine flow meters of 2-inches and less, straightening vanes are not normally used. For most installations, twenty diameters of upstream pipe should be provided for adequate flow straightening. (See Figure 11)

Figure 11 - Small Diameter Meter Tube



For line sizes 2-inches and larger, upstream flow straightening sections are normally supplied with straightening vanes. With this construction, the upstream straightening section need only be ten diameters in length.

Daniel supplies upstream and downstream flow straightening sections in either carbon steel or stainless steel, as required by the application. The standard design offered is the two-section tube, with a single upstream and single downstream straightening section. The upstream section contains the tube bundle, which is securely located within the pipe section. (See Figure 12)

Flow straightening sections may in fact be supplied in any configuration, with any line connection and to any specified length. In some installations, a three section flow straightening configuration is required. By using this configuration ready access to the straightening vanes is afforded. (See Figure 13)

Figure 12 - Two-Section Meter Tube

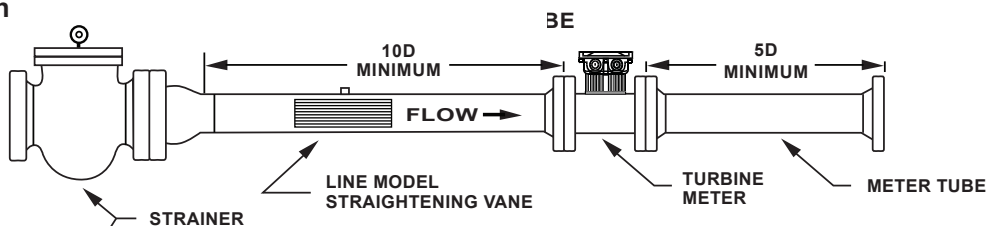
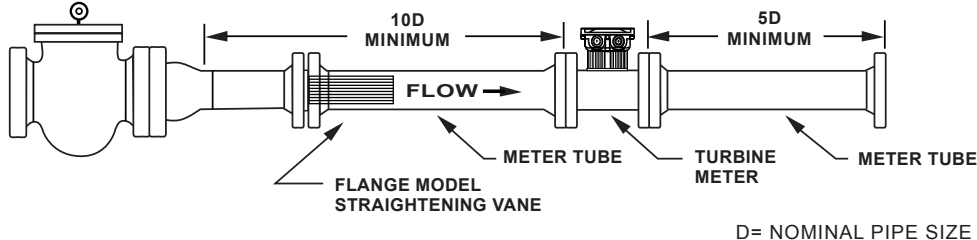


Figure 13 - Three-Section Meter Tube



In some circumstances, the use of a Flow Conditioning Plate (FCP) is possible. The flow conditioning plate is available from 3" to 6" for the Daniel Series 1500 Liquid Turbine Flow Meter, and is standard on the Daniel Series 1200 Liquid Turbine Flow Meter (with the exception of the 1"). When supplied, the FCP is an integral part of the turbine meter. The FCP serves to reduce swirl in the same way as flow straightening sections, and is of particular significance where piping installations do not permit long upstream sections, such as in load racks where space is at a premium.

BACK PRESSURE

It is essential to maintain sufficient back pressure on the turbine meter to prevent flashing and cavitation. This is particularly important when measuring liquids with high vapor pressures, such as LPGs.

The necessary back pressure required is given by the equation:

$$BP = (\text{meter } \Delta P \times 2) + (VP \times 1.25)$$

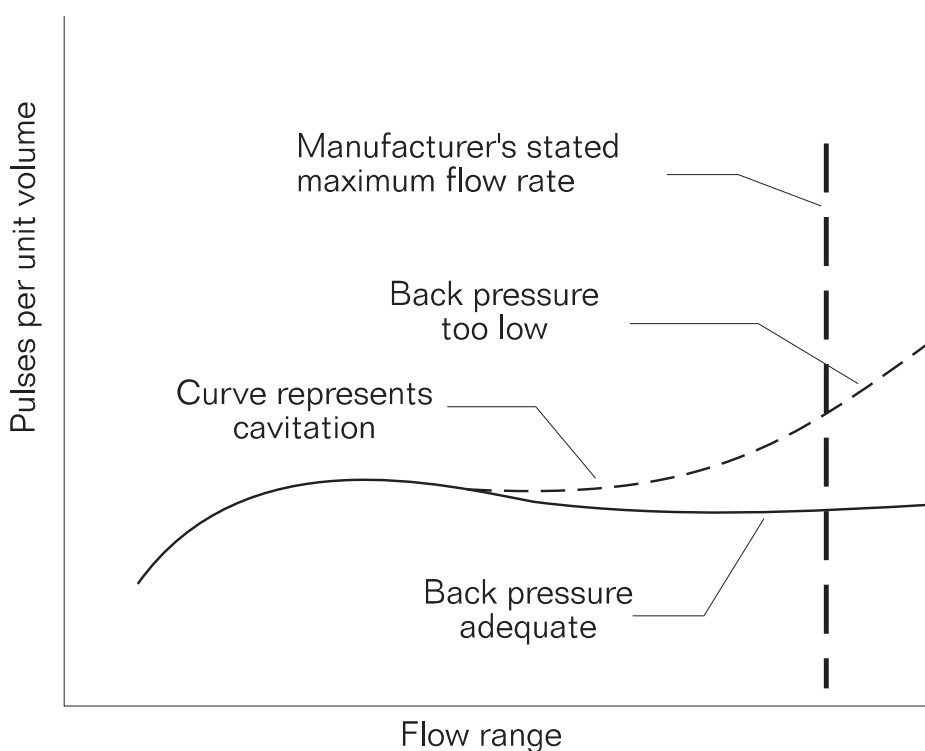
BP = Back pressure required

ΔP = Meter pressure drop at maximum flow

VP = Equilibrium vapor pressure of the liquid at the operating temperature, pounds per square inch absolute (psia), (gauge pressure plus atmospheric pressure.)

The pulses per unit volume / flow range curves below illustrate the effects of back pressure. Not only does insufficient back pressure lead to measurement inaccuracy, the resultant flashing and cavitation is extremely damaging to the flow meter and pipework.

Figure 14 - Effects of Back Pressure



TURBINE METER INSTRUMENTATION

The turbine pickoff coil has a high impedance and offers only a low voltage output. Transmission of flow signals requires low impedance and high voltage, and so amplification of the pickoff signal is required.

Daniel Series 1200 and 1500 Liquid Turbine Flow Meters are supplied with the UMB and a dual channel preamplifier as standard. The preamplifier shapes and conditions the pickoff output signal, rendering it suitable for transmission over distances of up to 3,000 feet, with the appropriate cabling.

The UMB allows for either one or two pickoffs. The outputs from the two pickoffs are 90° electrically out of phase, thus facilitating proper dual pulse fidelity checking.

Pickoff Specifications

- Type: 2-wire reluctance
- Resistance: 600-900 Ohms
- Inductance: 250 mH max.
- Output: Sinusoidal 40mV p-p minimum @minimum flow with preamplifier load
- Optional: 2, 3* or 4* pickoff coils
*with dual UMB

Preamplifier Performance - Dual Channel Preamplifier

Inputs:

- Supply voltage: 10 - 30 Vdc
- Minimum input signal amplitude: 40mV p-p minimum

Powered Pulse Output

- Output: 0 to 5V square wave
- Frequency range: 0 to 5 kHz
- Loading: 1 kOhm internal pull-up

Variable Voltage Output

- Output: 0 to supply voltage square wave
- Frequency range: 0 to 5 kHz
- Loading: 1 kOhm internal pull-up

Open Collector Output

- Output: Square wave
- Frequency range: 0 to 5 kHz
- Maximum voltage: 30 Vdc
- Maximum current: 125 mA
- Maximum power: 0.5 Watts

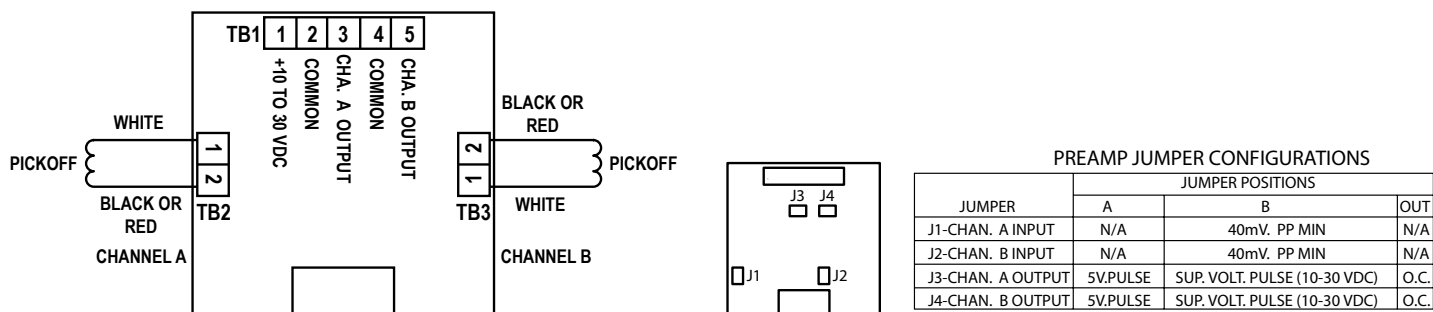
Transmission Distance

- Without preamp: 20ft (6.1m)
Belden 88442 or equivalent
- With preamp: 3,000ft (914m)
Belden 8770 or equivalent

Hazardous Area Classifications

- UL / CUL Class 1, Division 1, groups C&D
- Nema 4 UL, CUL
- CE certified EEx d IIB T6 (ATEX)

Figure 15 - Dual Channel Preamp Terminal Identification Customer Connections



**Emerson Process Management
Daniel Measurement and Control, Inc.
World Area Headquarters**

Houston, Texas, USA

T: 713-467-6000, F: 713-827-3880
USA Toll Free 1-888-FLOW-001
www.daniel.com

Calgary, Alberta, Canada

T: 403-279-1879, F: 403-236-1337
Alberta Toll Free 1-800-242-3197
Sales@Danielind-can.com
Service@Danielind-can.com

Stirling, Scotland - Europe, Middle East, Africa

T: +44 (0) 1786 433400, F: +44 (0) 1786 433401

Singapore - Asia Pacific

Emerson Process Management Asia Pacific Private Limited
T: +65-6777-8211, F: +65-6770-8001

Daniel Measurement and Control, Inc. ("Daniel") is a wholly owned subsidiary of Emerson Electric Co., and a division of Emerson Process Management. The Daniel name and logo are registered trademarks of Daniel Industries, Inc. The Emerson logo is a registered trademark and service mark of Emerson Electric Co. All other trademarks are the property of their respective companies. The contents of this publication are presented for informational purposes only, and while every effort has been made to ensure their accuracy, they are not to be construed as warranties or guarantees, expressed or implied, regarding the products or services described herein or their use or applicability. All sales are governed by Daniel's terms and conditions, which are available upon request. We reserve the right to modify or improve the designs or specifications of such products at any time. Daniel does not assume responsibility for the selection, use or maintenance of any product. Responsibility for proper selection, use and maintenance of any Daniel product remains solely with the purchaser and end-user. The Daniel Series 1200 and 1500 Liquid Turbine Flow Meters are protected by United States and International patents and patents pending.

