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INSTRUCTIONS AND OPERATION OF SERIES 600 TANGENTIAL TURBINE METER

DESCRIPTION: The Series 600 Tangential Turbine Meter is a volumetric fluid flow instrument. It utilizes a freely suspended bladed turbine, positioned tangentially to the flowing stream, to sense the flow of fluid through the turbine meter. The fluid is conditioned through an orifice prior to reaching the rotor and thus, allows direct coupling with the fluid. The rotation is sensed by an external pickoff and electrical pulses represent a discrete amount of fluid, previously determined by calibration. This discrete amount of fluid is represented by the meter factor designated as a K-factor. The K-factor is defined as the constant number of pulses generated for a given volume of fluid.

The transducer consists of the following three (3) subassemblies:

1 - Housing and Retaining Rings
2 - Pickoff and Locknut
3 - Capsule and O-Ring

The basic materials are 300 Series Stainless Steel and 430 F Stainless Steel. Other materials are available by special order.

The bearings are normally aircraft quality ball bearings of 440 C Stainless Steel with options of Sapphire or Carbide cup and pivot.

Please refer to Figure 1 on Page 3 for full details of the assembly. It is not recommended that the repair on a Sapphire or Carbide pivot assembly be attempted in the field. The ball bearing unit may be field repaired (bearing kits are available).

NOTE: *Calibration will shift as much as one percent (1%) after replacing the bearings, and so, we recommend that you recalibrate.*

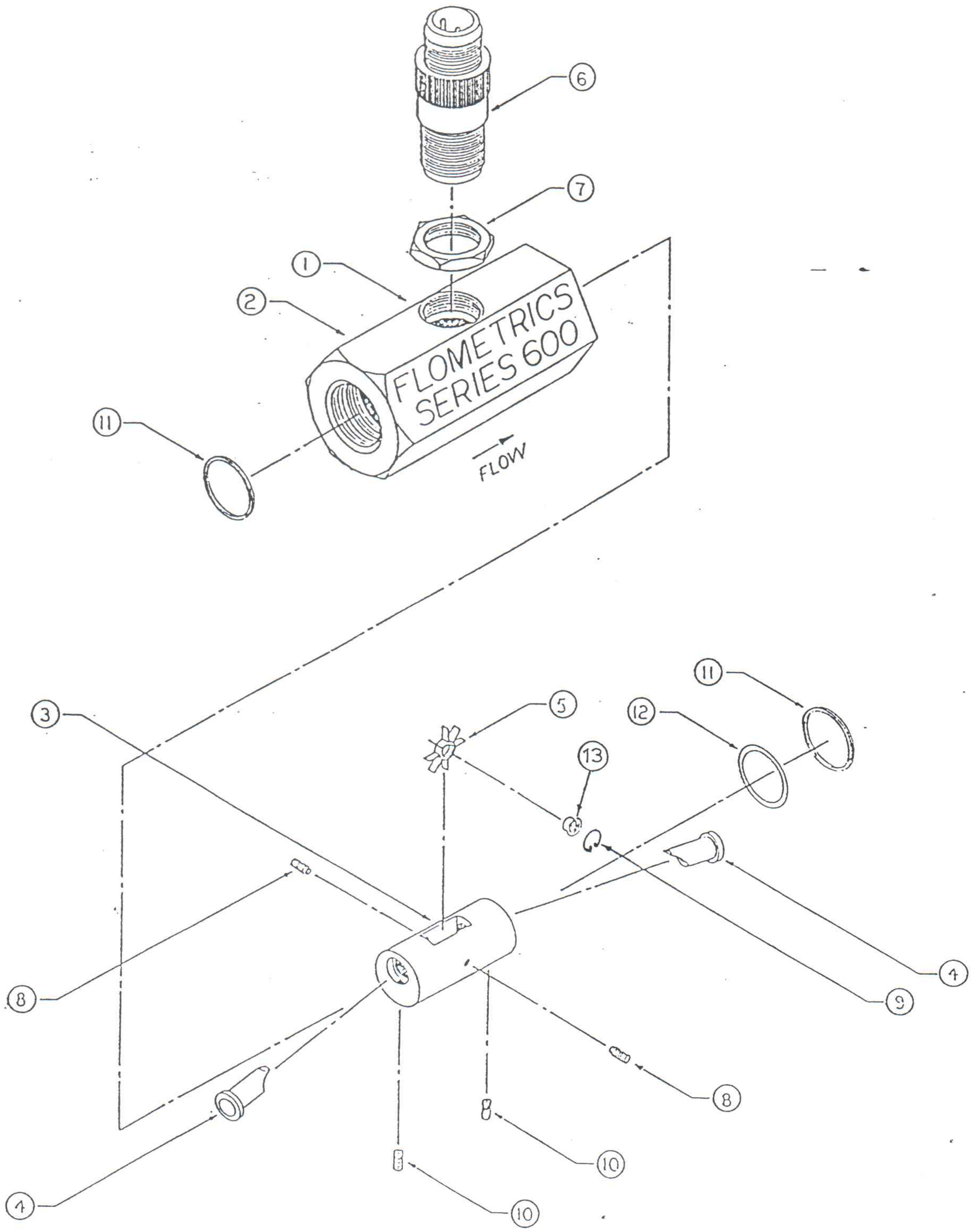

FIGURE 1. EXPLODED VIEW OF SERIES 600 TANGENTIAL TURBINE METER

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DISASSEMBLY: (Refer to Figure 1 on Page 3.)

The Capsule is removed from the DOWNSTREAM end—of– the housing. Reach in the *Downstream* end with a small screwdriver and remove the O-ring. (This makes removal of the snap ring much easier.) Mark the *Downstream* end of the Capsule as you remove it from the housing.

Prior to disassembly of the Capsule, we suggest it be heated to free the Loctite. Heat the entire Capsule at 350°F for 20 minutes.

Remove the 4-48 set screw orifice lock from the Downstream end of the capsule with a small screwdriver. Remove the bearing retainer screws and allow the rotor to drop slightly in the cavity. *GENTLY* tap on the edge of the orifice (the end closest to the rotor) with a brass or aluminum punch until it slides from the Capsule.

CAUTION: Do not damage the rotor as you remove the orifice. We suggest that you use a 1/8 inch diameter brass or aluminum punch. The rotor may be rotated within the cavity to remove without removing the upstream orifice. The bearing is held in the rotor with a wire retaining ring which may be removed using a magnifying loop and pointed scribe. HINT: remove this ring with assembly placed inside a plastic bag so as not to lose the retaining ring. Slide the bearing out and replace with a new unit. Replace the retaining ring and check that it is fully seated. Reassemble in reverse order using Loctite 420 or equal on the screws.

DO NOT OVER TIGHTEN THE BEARING SCREWS!

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ELECTRICAL CONNECTIONS AND PICKOFF: The pickoff is removed by loosening the locknut and backing it out by hand. Reassembly is finger tight on the pickoff and wrench tight on the locknut.

The electrical connection is per MS3102A-10SL-4P and the mating connector is per MS3106A-10SL-4S. Recommended wire is a 2 wire shielded and jacketed 24 gauge. Shield should float at the turbine meter and be grounded at the readout or amplifier.

INSTALLATION: The Series 600 Turbine Meter is unique in that it may be mounted in any orientation and DOES NOT require straightening sections. We recommend horizontal installation since this is the orientation in which it was calibrated.

Filtration is a must with any precision instrument and we recommend 50 Micron or better for optimum performance.

Teflon tape works well as a pipe sealant however, turbine meters do not measure fibrous or stringy fluids. Therefore, we recommend a liquid or paste sealant.

Bypass sections are strongly suggested to avoid overspeed on start up systems. The Series 600 withstands up to 100 percent overspeed for short periods (note that repeated overspeed will shorten bearing life).

Control valves should be downstream of the turbine meter. Any flow should be initiated slowly since a dry line might shock the turbine meter. Once the line has been filled, the turbine meter should be insensitive to fluid velocity step changes and hydraulic shock.

Care should be should NOT to locate the Series 600 meter close to strong magnetic fields as exposure may induce noise voltage and cause problems with the signal. Amplifiers and converters are available should you find problems with the signal due to surroundings.

BASIC OPERATING PRINCIPLE: Turbine meters sense the velocity of the flowing liquid to determine volumetric throughout. Like all non-positive displacement meters (i.e., orifice, venturi, vortex shedding, sonic, etc.) volume is inferred from either head or velocity. The rotor of the turbine meter senses the kinetic energy available in the liquid stream and translates it into rotational speed. In order to have an accurate registration, it is necessary that the rotor speed be proportional to the velocity. (This condition is basically met when sufficient kinetic energy is available to overcome the resisting forces which are mechanical friction (bearing) and fluid drag.)

PERFORMANCE: The most important factor of meter performance is obviously, accuracy. Since all turbine meters require a calibration to establish their flow coefficients (K-factors). Accuracy is not limited to the meter alone, but also must include the proving system on which it was calibrated. Because accuracy can be affected by the transfer calibration process, it is found that other factors more closely describe meter performance. These factors are listed in order of importance:

Repeatability
Reproducibility
Linearity
Rangeability
Response Time

REPEATABILITY: Repeatability is the ability of a turbine meter to repeat its calibration factor during a series of consecutive runs (all performed under identical flow conditions). Inherently, turbine meters are very repeatable (more so than most proving facilities). Probably the best method to measure meter repeatability is to run two similar meters in series and statistically analyze their "trackability" for 25 or more several-minute duration tests, at each flow rate. Even with this method, exact results are hard to obtain because operating conditions (i.e., flow rate, temperature, viscosity, density, and pressure) should be held constant throughout the entire series of tests. Since this is not normally possible on a test stand over several hours of testing, it may be necessary to correct the "trackability" test results for shifts in operation conditions using a statistical regression analysis technique.

Repeatability specifications should be expressed in terms of the statistical term sigma (Σ), which stands for "standard deviation from the mean value". By definition, there is a 68.3%, 95.5%, and 99.7% probability that the result from any given test will fall within one, two, and three sigma, respectively, of the true mean value. For example, if sigma is 0.005%, 997 times out of 1,000 the results will be within 3 sigma (or 0.015%) of the true mean value. Laboratory repeatabilities of up to 0.002% of the true mean values have been achieved.

REPRODUCIBILITY: This term is also sometimes called stability. It describes the ability of a meter to retain calibration over the long term (one week, one month, one year). Reproducibility is very much affected by the product condition. Dirty product can cause severe factor shifts as we will see later. For reasonably clean crude oils, stabilities of 0.05% of a one-year period have been recorded. Reproducibility behavior should be the determining factor in establishing meter calibration schedules.

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LINEARITY: The slope of the frequency versus flow rate curve describes the K-factor (pulses/volume) and the constancy of the slope characteristics linear operation. The linear range of a turbine meter is the flow range over which the calibration coefficient remains constant within stated limits. Precision turbine meters typically achieve linearities of ± 0.5% over a 10% to 100% flow range for products up to 40 SSU. Over the years advances have made it possible to readily offer ±0.25% linearities. Super-performing precision turbine meters with better than ±0.1% linearities and ±0.015% repeatability are achievable today and have successfully been placed into service.

RANGEABILITY: Depending on the size of the meter and product application, extended repeatable ranges of up to 100:1 are possible for precision turbine meters.

RESPONSE TIME: The capability to respond rapidly to unsteady flow conditions is a special characteristic of turbine meters. The transient response of a meter is normally expressed in terms of the time constant of the rotor which becomes a measure of the time required to react to a sudden change in fluid velocity. Typical time constants range from 10 milliseconds (4" meter) to 50 milliseconds (20 " meter).

FACTORS INFLUENCING METER PERFORMANCE: Exceptionally good accuracy can be obtained from precision turbine meters under proper operating conditions. However, it is important to understand how certain operating factors can significantly degrade meter performance. Here are some factors which will have a significant effect:

Velocity and Viscosity
Specific Gravity
Cavitation

FACTORS INFLUENCING METER PERFORMANCE (Continued)

Swirl and Velocity Profile
Erosion and Deposits

VELOCITY AND VISCOSITY: In order for a turbine meter to operate properly, it is necessary that it be operating in a turbulent flow state. A turbulent flow state is defined by a Reynolds Number, greater than 5,000 and less than 100,000. The Reynolds Number is directly proportional to flow rate and inversely proportional to meter size and velocity (see Figure 2).

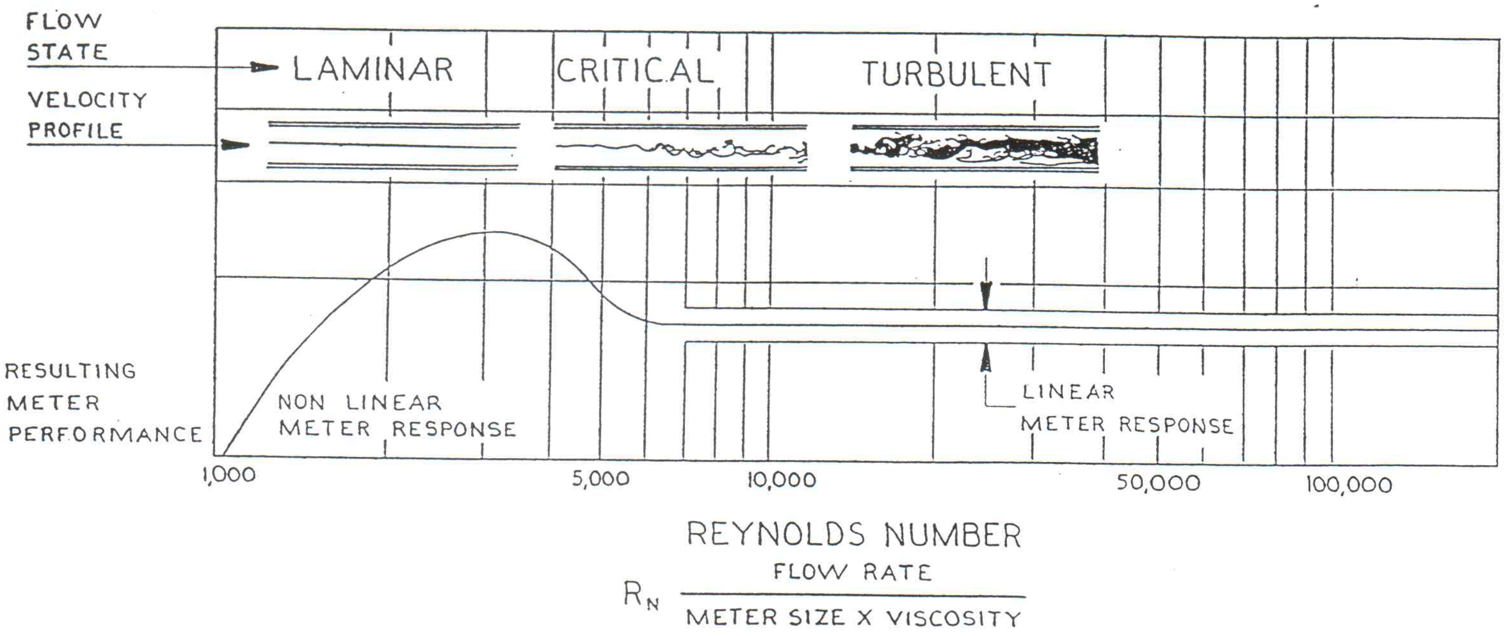

FIGURE 2. REYNOLDS NUMBER

The effect of viscosity change on the accuracy of a turbine meter is two fold in that it will change the linear rangeability of the meter and will also cause a K-factor shift (pulse output per given volume through the meter) at a given flow rate. By the former we mean that an increase in viscosity will cause a decrease in Reynolds Number, therefore worsening the low flow characteristics. This increase in viscosity will also reduce the maximum acceptable flow rate through the meter at a given pressure drop. It should be noted, however, that if the additional pressure drop is not an adverse factor that over-ranging the turbine meter is not generally detrimental. The effect of viscosity change on K-factor is very significant. However, for large differences in viscosity a change factor of 0.1% to 0.5% and even higher is not uncommon. This difference could obviously result in a substantial metering error. It is therefore essential that the meter be proved on the product and at the conditions in which it is to operate in order to insure that the K-factor has been properly established. Meter performance can also be expressed in terms of a Universal Viscosity Curve (UVC) which accounts for the viscosity effect.

The UVC is formed by plotting the turbine meter K-factor (pulses per unit volume) in relationship to the ratio of flow rate over kinematic viscosity (v) (see Figure 3).

Typically, 30 points are used: 10 each for three different fluids. The 30 points are plotted on a common graph to form a smooth curve. Once this is done, the K-factor may be determined for any flow rate in fluid of any viscosity so long as the ratio of flow rate to viscosity [(FLOW RATE)/v] is within the range of values covered by the graph.

NOTE: This technique is currently not used in the oil industry, due to uncertainties in on-line viscosity measurement. It is foreseen, however, that the adaptation of UVC technology will occur within the foreseeable future since the computer instrument technology exists.

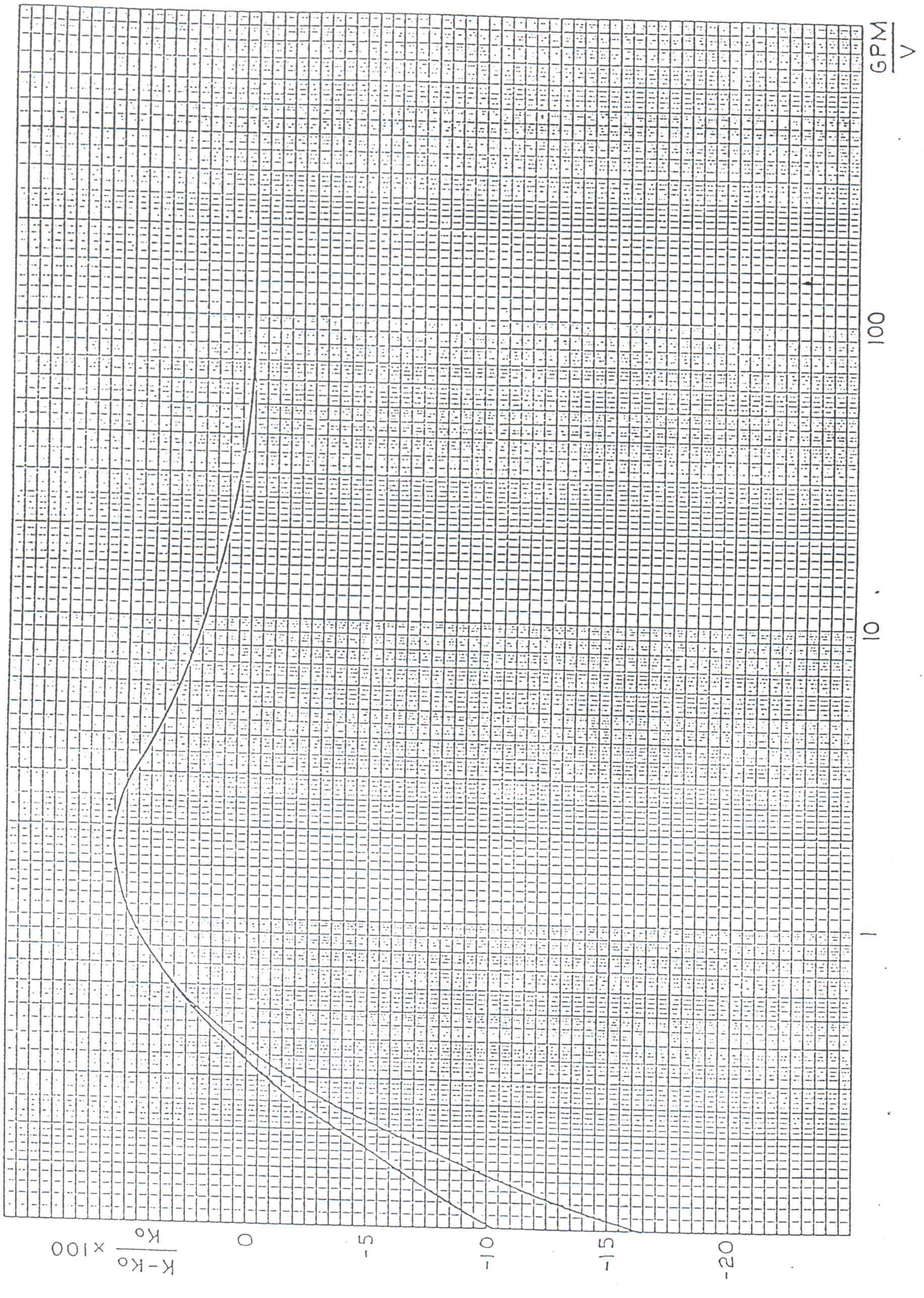

FIGURE 3. UVC PLOT

SPECIFIC GRAVITY: Another factor that has an effect on the performance of a turbine meter is specific gravity. In Figure 4, note that we have plotted meter Rangeability as a percentage against Specific Gravity for meters sized on a specific gravity of 0.8 to 1.0. You will note that as the specific gravity increases, the rangeability percentage decreases. Conversely, at the specific gravity of 0.5, the meter rating should be 140% of the standard rating (using a base condition of 0.8 specific gravity for the meter rating).

Assuming the meter is rated from 200 to 2,000 barrels per hour, this would mean that the new range of the meter would be 280 to 2800 barrels per hour (i.e., the maximum and minimum each multiplied by 1.4). As you have probably noted, the actual rangeability of the meter (i. e., 1 to 10) has not changed because both the maximum and minimum values are multiplied by a constant. However, the meter can operate over a linear range of 2520 barrels per hour (as opposed to the old 1800 barrels per hour). It is particularly important to consider this value with lighter products (butane, propane, ethane, etc.) in order to insure that the meter is operating in the linear range and also being properly utilized. The limitation for the over-ranging is due to mechanical restraints. Most meters can only be over-ranged to 150 percent.

CAVITATION: Low back pressure (BP) conditions can cause local vaporization of product in the rotor resulting in artificial fluid velocity increase, thereby dramatically increasing the K-factor of the meter. Good design with smooth inlet and outlet geometrics help minimize cavitation. API recommends BP = 2 P + 1.25 absolute vapor pressure. However, in some cases this formula may not suffice, particularly when operating in the extended range of a meter additional margins (1 P) are advisable.

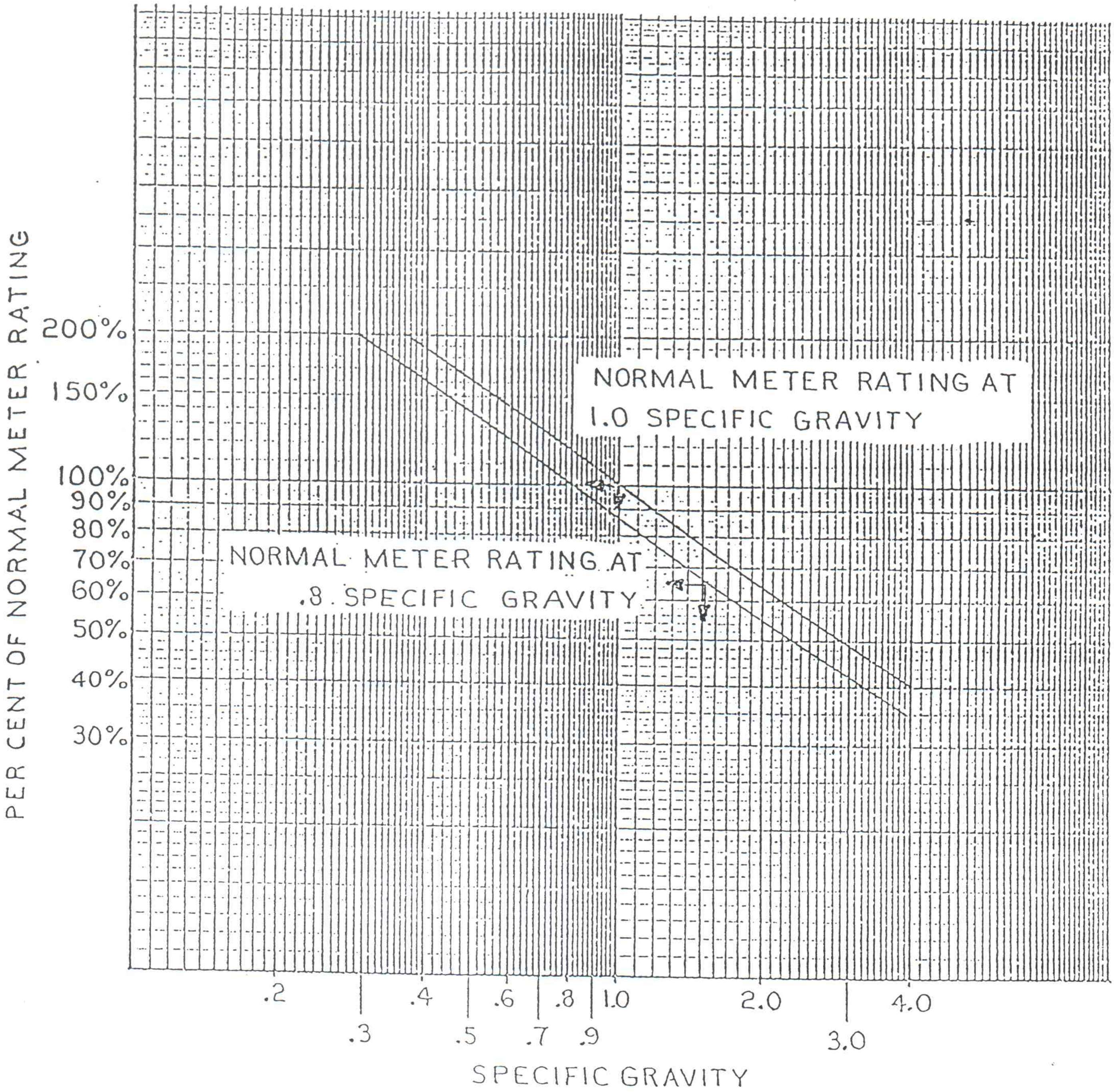

FIGURE 4. SPECIFIC GRAVITY RATING CHART

SWIRL AND VELOCITY PROFILE: The geometry of the flow boundaries (walls) upstream and immediately downstream of the rotor determines the fluid velocity profile and swirl rate at the rotor for a given viscosity and velocity. Any disturbance, particularly variable disturbances (gate valve, additive injection points, etc.), should be sufficiently distant both upstream and downstream from the rotor in order to avoid K-factor changes. Up and downstream flow straightening recommendations per API chapter 5 Flow Measurement evolved to stabilized conditions. Again, they should be regarded as minimum. Many experienced meter users interested in premium performing turbines have installed extra long straightening sections, some of which also contained downstream tube bundles.

EROSION AND DEPOSITS: Erosion typically causes a gradual deterioration of meter performance. Continuous factor shift in one direction combined with linearity changes are indicative of this condition. Good strainers and possibly settling tanks can help solve this problem. If erosion particles are sizable it may sometimes become necessary to install rotors with a reduced outer diameter,. The same holds true for waxy crude substances.

SIGNAL OUTPUT: The measurement information or reading can be obtained by mechanical, electrical, or optical means. Electrical detection or pick-up systems are most common today for precision type turbine meters.

ELECTRICAL SIGNAL DETECTION: Two types of electrical pick-up systems are in use today: magnetic and modulated carrier. The most common is the reluctance type magnetic pick-up.

MAGNETIC PICK-UP: Magnetic pick-ups can operate from cryogenic temperature up to 750°F. They can be used for most applications except for low flow rates where the magnetic drag on the rotor interrupts the performance of the flowmeter. When a magnetic pickoff is used on a turbine flowmeter, the magnetic field exerts a retarding force on the rotor. This drag can have a very significant effect on the performance of smaller turbine flowmeters. The magnetic drag force becomes less significant as the viscosity of the fluid media increases.

Magnetic pickoffs are divided into two types: reluctance and inductive. The reluctance type has a coil with a magnet located in its center. When this pickup is mounted on the flowmeter housing in the plain of rotation of the turbine rotor, a disturbance is created in the magnetic field each time a rotor blade passes through it. The change in the magnetic field produces a current in the coil. The magnetic pickoff thus produces a train of electrical pulses, the frequency of which depends upon the rate at which the turbine rotor blades disrupt the magnetic field.

In the inductive type of magnetic pickup, the magnetic slug is positioned in one of the turbine blades and the pickup is simply a coil around an iron slug. The passage of the magnetized rotor blade past the pick-up coil induces a current in the coil. This produces an identical electrical pulse train output as the reluctance type pickup.

MODULATED CARRIER PICK-UPS: To eliminate the magnetic drag on the rotor, a modulated carrier of CF type pick-up is used. This pick-up has no magnet associated with it. It is a coil which is part of an oscillator circuit. The passage of the turbine rotor blade through the RF field of the coil changes its impedance, which changes both the frequency and the amplitude of the oscillator output signal. An amplifier circuit is used to sense the change in signal amplitude, and outputs a pulse with frequency directly proportional to the rotational speed of the rotor.

MODULATED CARRIER PICK-UPS (Continued)

Since the magnetic drag is eliminated with the CF type pick-up, the performance of the turbine flowmeter is enhanced at low velocity and low density flows. The operating temperature range is less for CF type pick-ups than for magnetic pick-ups. They can be used at temperatures ranging from cryogenic up to 400°F. RF type pick-ups also require additional electronics for oscillator circuit and signal demodulator.

OPTICAL PICK-UPS: Optical pick-ups consist of a photoelectric cell and a light source, usually an LED. These are arranged on opposite sides of the rotor, so that a turbine blade passing between them creates an interruption or pulse, in the current emitted by the photoelectric cell. Since a pulse is created each time a blade passes between, an electrical pulse train proportional to the rotational speed of the rotor is produced.

Optics (with glass windows) allow construction of turbine flowmeters to consist of totally non-metallic materials. This permits the use of these flowmeters with a wide range of exotic and highly corrosive fluids.

MECHANICAL REGISTERS: Mechanical registers generally consist of a series of shafts and gears connecting the turbine rotor to a mechanical counter mounted on top of the flowmeter housing. This type is typically used on larger size precision type turbine flowmeters, due to the retarding effect and its associated negative performance influence.

CALIBRATION AND PROVING: Calibration or proving of a turbine flowmeter consists of passing a fluid through the meter and determining the meter's output per desired units of volume (K-factor) at a given condition. This is necessary since the actual K-factor for a flowmeter will vary from the theoretical or ideal K-factor due to machining tolerances and varying amounts of bearing drag in the case of new flowmeters, or damage and wear in the case of prior-service meters. Calibration reveals these variations and determines the correct K-factor for a specific flowmeter.

The term "calibration" is typically applied to this procedure as it is conducted by metrology labs or factory calibration laboratories. On the other hand, "proving" typically applies to dynamic verification of meter performance on site and under actual flow conditions.

Varying techniques are used as far as the first time factory calibrations are concerned. Single K-factor calibrations are used when a high degree of accuracy is not important. The K-factor is determined by running one or more calibration points and averaging the results. This average value is then stamped on the meter body as the K-factor.

The most commonly used technique for calibration consists of running 10 evenly spaced calibration points throughout the flowmeter's flow range. This data can be represented in tabular or line graph form to allow interpolation of values between the calibration points.

When a higher degree of accuracy is desired, 20 or more calibration points may be used. This "premium" calibration is usually necessary when linearization equipment is being utilized in conjunction with the flowmeter and it is necessary to know the meters characteristics over a very wide flow range.

SERIES 600 TANGENTIAL TURBINE METER

BILL OF MATERIALS

ITEM	QTY.	PART NUMBER	DESCRIPTION
NOT SHOWN		50009	BEARING - SHAFT
NOT SHOWN		50007	BEARING - PIVOT ASSY
NOT SHOWN		50003-1	ROTOR
NOT SHOWN		50001-1	PIVOT - BEARING HUB
13	1	SSRI-2 1/2 HA7	BEARING - RADIAL OPEN
12	1	MS28775-016	O'RING - BUNA N
11	2	RR-71-S	RETAINING RING - WOUND
10	2	MS51964-19	SET SCREW - HEX SOCKET
9	1	50002-2	RETAINING RING - ROTOR
8	2	30004-1	SUPPORT ROTOR
7	1	60018-1	NUT PLAIN - HEX
6	1		PICKOFF
5	1	50000-1	ROTOR
4	2	30002-	ORIFICE
3	1	30003-1	CAPSULE
1 & 2	1	30005-2	HOUSING (MS or NPT)