FUNDAMENTAL PRINCIPLES OF GAS TURBINE METERS

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INTRODUCTION

Gas measurement in the U.S. and around the world is dominated by diaphragm, rotary, turbine, and orifice meters. Each serves a different segment of the gas industry and each has its own set of advantages and disadvantages.

These four main types of meters can be broken into two distinct categories: positive displacement, and inferential. Diaphragm and rotary meters fall into the positive displacement group because they have well-defined measurement compartments that alternately fill and empty as the meter rotates. By knowing the volume displaced in each meter revolution and by applying the proper gear ratio, the meter will read directly in cubic feet or cubic meters.

Turbine and orifice meters have no measurement compartments to trap and then release the gas. These meters are categorized as inferential meters in that the volume passed through them is "inferred" by something else observed or measured. In the orifice meter the volumes are determined only by knowing the inlet pressure, differential pressure, plate size, and piping characteristics, all of which "infer" the flow rates that in turn can be integrated over time to provide the volume.

Turbine meters, also called velocity meters, "infer" the volume of gas passing through them by measuring the velocity of the gas stream. Gas moving through the meter impinges on a bladed rotor resulting in a rotational speed that is proportional to the flow rate. The volume is determined by counting the number of meter rotations. The purpose of this paper is to provide an overview for the installation, maintenance, and proving of axial flow type turbine meters.

THEORY OF OPERATION

As defined in A.G.A. Report #7, the turbine meter consists of three basic components (See Figure 1 and 1A)

1. The body which houses all of the parts and physically contains the gas pressure.

2. The measuring mechanism consisting of the rotor, rotor shaft, bearings, and necessary supporting structure.

3. The output and readout device which may be either a mechanical drive to transmit the indicated meter revolutions outside the body for uncorrected volume registrations or for electrical pulse meters, it would be the pulse detector system and all electrical connections needed to transmit the pulses outside.

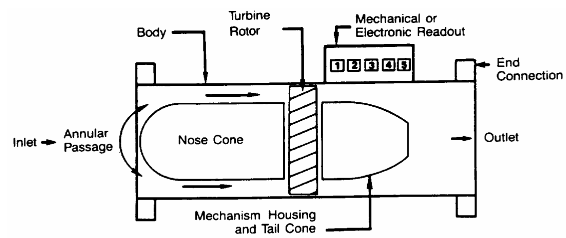


Figure 1.

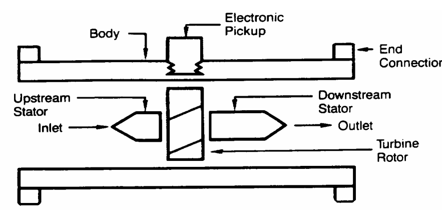


Figure 1A

Gas entering the meter increases in velocity as it flows through the annular passage formed by the nose cone or upstream stator and the interior of the body. The movement of the gas over the angled rotor blades exerts a force to the rotor causing it to rotate. The ideal rotational speed of the rotor is directly proportional to the flow rate of the gas. The actual rotational speed is a function of the annular passageway size and shape, and rotor design. It is also dependent on the load that is imposed due to internal mechanical friction, fluid drag, external loading, and gas density.

INSTALLATION

A.G.A. Report #7 was written to provide recommendations as to the correct method for installing turbine meters, using their associated corrective factors, and meeting the operating requirements that pertain to axial flow type meters.

Since the turbine meter is a velocity-measuring device, consideration should be given to both the upstream and downstream piping to insure a uniform velocity distribution of the gas through the meter and the rotor by reducing jetting or swirl. Construction of the turbine meter is such so as to minimize minor flow distortions that could affect meter performance.

Straightening vanes are recommended to eliminate swirls. These vanes or any type of integral flow conditioner will not remove any jetting actions and may actually enhance the jetting effect. The recommended installation (See Figure 2) for in-line turbine meters calls for a straight length of 10 pipe diameters upstream with a distance of 5 pipe diameters between the end of the straightening vanes and the meter inlet.

A length of 5 pipe diameters is recommended downstream. Both inlet and outlet pipe should be the same size as the meter. Upstream piping should be clean with no obstructions from flange gaskets, pressure taps, etc. The pressure tap should come from the meter as specified by the manufacturer while the temperature well, if required, should be 2.5 pipe diameters downstream from the meter.

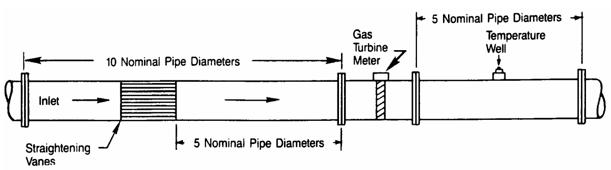


Figure 2. AGA Recommended Installation

Restricting and/or throttling devices, such as partially opened valves or regulators, are not recommended in close proximity to the meter since they tend to increase jetting and swirl. When necessary, any such throttling device should be installed an additional 8 nominal pipe diameters upstream or 2 diameters downstream from the meter.

In addition to the recommended installation, alternative types of installations are allowed where there are space limitations with the understanding that there may be some associated loss in meter accuracy because of jetting and swirl.

Short coupled installations (See Figure 3) use a minimum of 4 nominal pipe diameters upstream with the straightening vanes located at the inlet of the piping. The distance between the end of the straightening vanes and the inlet of the meter should be at least 2 nominal pipe diameters. The meter run is connected to the vertical risers with standard tees or elbows.

Reducing fittings may be used at the tee or elbow but only one pipe size reduction is recommended. Valves, regulators, strainers, or filters should be installed on the risers

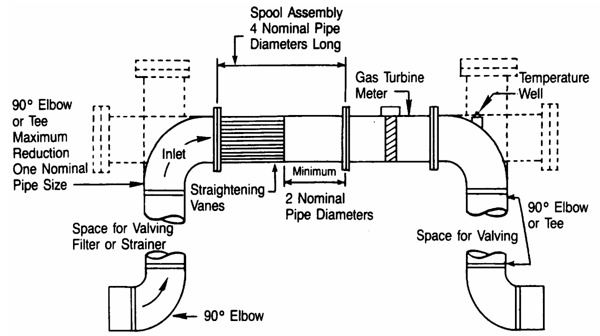


Figure 3. Short Coupled Installation

Close-coupled installations are shown in Figure 4. The meter design must incorporate integral flow conditioners upstream of the rotor. The meter is connected to the risers with a tee or elbow and the maximum reduction recommended is one pipe size. Any valves, regulators, strainers, or filters must be installed on the risers.

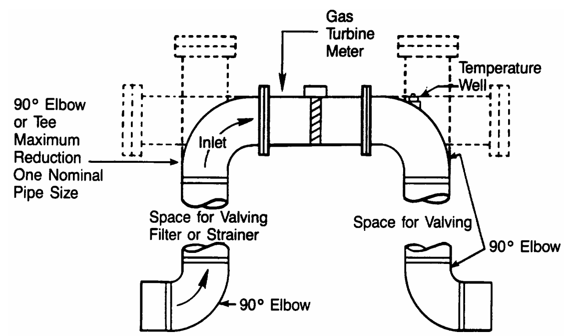


Figure 4. Close Coupled Installation

Recommendations for angle body turbine meter installations are shown in Figure 5. The meter run is connected to the inlet riser with either a 90-degree elbow or tee that may be reduced by one pipe size if necessary. With straightening vanes, the length of the upstream piping may be 5 pipe diameters with at least 2 pipe diameters between the end of the straightening vanes and the inlet to the meter. Without straightening vanes, the upstream piping should be at lease 10 pipe diameters long. Any valves, regulators, strainers, or filters should be on the risers

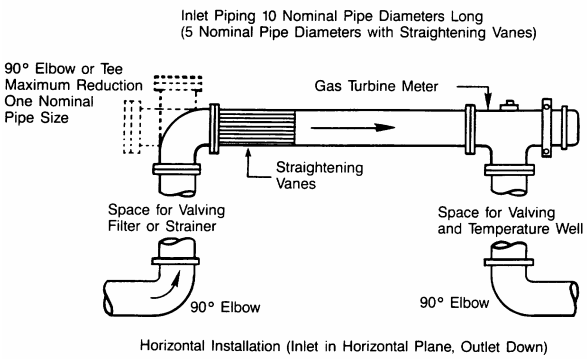


Figure 5. Angle Body Installation

INSTALLATION CONSIDERATIONS

To protect the turbine meter from the dust, dirt, and scale that may occur during certain system operations, it is important that either a strainer or filter be installed upstream of the meter to increase its bearing life. Filters can trap small dust particles down to 10 microns. A differential pressure gauge should be installed across the filter or strainers to indicate excessive pressure drops from a build up of foreign matter in the strainer screen or filter element.

All foreign material in the upstream piping should be removed before installing the measuring element and placing the meter in service. Special consideration should be given to the pipe between the strainer and/or filter since it may contain debris that will not have been removed.

Since upstream disturbances should be kept to a minimum, temperature wells should be installed downstream of the meter at a recommended distance of between 2 and 5 pipe diameters downstream. Because regulators or any throttling device may tend to cool the gas stream as it expands, the temperature well should be installed ahead of any valve or flow restrictor that may be downstream of the meter.

Pressure taps provided by the manufacturer on the meter body should be used as pressure taps for any recording or integrating instruments and during calibration. Use of any other tap locations may change the meter's calibration curve.

In any area where liquid contaminants are suspected a separator and/or drip tank should be considered since a high velocity liquid slug can cause damage to the rotor.

Over-range protection to prevent the meter from overspeeding may be needed. Although it may be operated up to 150% of the rated capacity for short periods of time, it is a good practice to limit the meter to approximately 120% of its maximum capacity. Either a critical flow orifice or sonic venturi nozzle may be used downstream of the meter provided that adequate pressure is available to compensate for the permanent pressure loss across the flow limitor. There is about a 50% pressure drop across critical flow orifices and between 10% to 20% drop with a sonic flow nozzle.

Blow down valves should be installed downstream of the meter and should be no bigger that 1/6 of the meter size

Meter Size	Blow Down Valve
2"	1/4"
3", 4"	1/2"
6", 8", 12"	1"

A good design for a turbine meter installation incorporating many of these recommendations would look very similar to Figure 6.

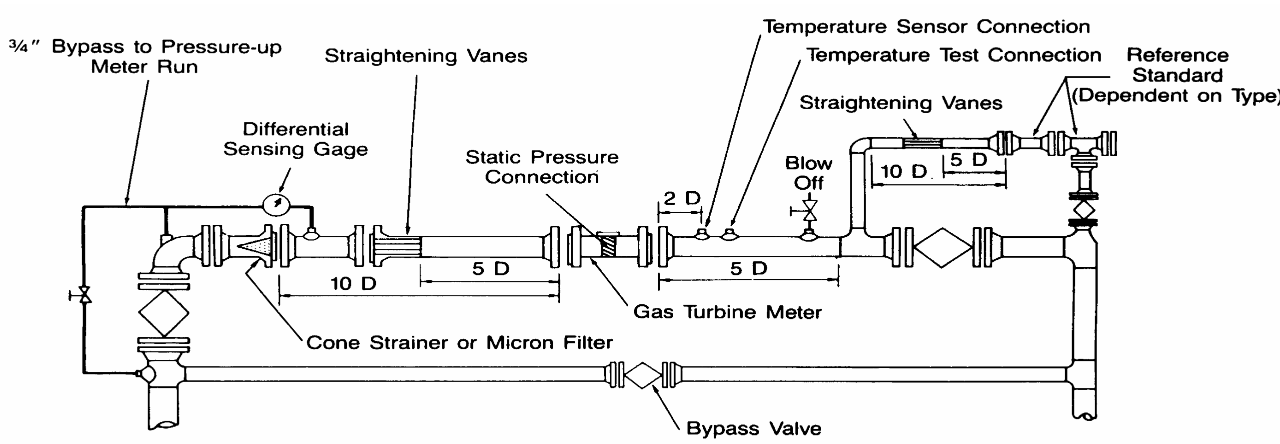


Figure 6. Turbine Meter Installation

INSTALLATION CHECK LIST

-Meter is sized properly for line pressure and load

-Meter has been lubricated

-Installation is in accordance with A.G.A. #7 recommendation and/or company standards

-Inlet and outlet meter connections are concentric to the pipe flanges and gaskets do not protrude into the flow pattern

-Filters, strainers, and associated equipment are provided where required

-Meter can be isolated and by-passed if needed

-Pressure blow down is sized properly and located downstream

-Provisions are made for in-line testing

-Pressure and/or temperature taps are provided if required

-No welding should be done with the internal mechanism in the meter

-If hydrostatic testing is done, a spool piece is recommended

MAINTENANCE/FIELD TESTS

Normal maintenance and field tests consist of lubrication, internal inspection, and spin testing. Prior to putting the meter in service, make sure it is lubricated and perform an initial spin test that will provide a reference time to future test results.

Most turbine meters have provisions for a pressurized lubrication system. This consists of an external alemite fitting and lever-type oil gun which permits lubrication without taking the meter out of service. This is a simple procedure and in addition to replenishing the oil supply, it also flushes the bearing with fresh oil. Older style gravity lubrication systems can be converted to pressure systems, check with the manufacturer for correct parts.

The frequency of lubrication is a function of the operating conditions. Obviously, a meter subject to gas containing dust and/or liquid contaminants or running at elevated capacities and/or extended periods should be serviced more frequently. Manufacturers suggest monthly lubrication with the period extended as experience permits. Lubrication of the meter with an approved oil is a good, relatively inexpensive form of preventive maintenance.

Periodic internal inspection of the meter should be performed to ensure that components are in good working condition. The frequency of inspection is dependent on the severity of the service but should be done annually.

Follow recommended procedures for taking the meter out of service and remove any readout devices.

After bypassing if necessary, and isolating the meter, relieve the internal pressure using the blow-down valve. Once the internal mechanism is removed, visually inspect the interior of the meter body checking the internal flow guides or vanes for damage and removing any liquids or debris. Check the inside of the inlet and outlet flanges along with the gaskets to make sure they are in proper alignment and not interfering with smooth gas flow. Also inspect any seal tape within the body for any cuts or tears. This seal tape prevents gas from bypassing the annular passage through the rotor.
Check the internal mechanism flow passages and rotor for damage. The rotor should be checked thoroughly for accumulation of dirt, wear, missing blades, or other damage. Since it is the essential measuring element, any rotor with more than superficial damage should be replaced and the meter proved. After completing the visual inspection, the mechanism should be spin tested to determine its condition.

This test determines the relative condition of the meter and is not an accuracy test. With the cartridge place in a draft-free area and in its normal operating position, place suitable material against the side away from the rotor and with a finger or air jet; spin the rotor briskly, time how long it takes the rotor to come to a complete stop, and record this time. Repeat this procedure three times to come up with an average spin time. Compare this average time with the tables provided by the manufacturer for each size meter. This average spin time should also be compared with the initial spin test done when the meter was first installed.

If the spin time has not changed significantly, the meter is clean, and the internal parts show no damage; then the meter should not display any change in its accuracy. If the mechanical friction has increased, the resultant slower spin times indicate that the accuracy of the meter at low flow rates has degraded. If decreased spin time is encountered, the meter should be lubricated and the rotor spun-in to throw off any excess oil which can also contribute to slow spin times. The spin test should be redone to determine if acceptable times can now be achieved.

Whether the spin time is acceptable or not, it is a good practice to also check the intermediate gear train for binds. If possible, another spin test should be run with the readout device in place to also check it for binds that can affect low flow accuracy.

Another factor that can contribute to low spin time is low ambient temperatures. Even though the oil is a light viscosity, low temperatures affect it.

MAINTENANCE CHECKLIST

-Meter should be lubricated on a scheduled time period with recommended oil

-Filters or strainers should be checked for differential and/or pressure drop

-Before disassembly, make sure the meter is depressurized and the readout device is removed.

-Check the interior of the meter including seal tape, guides, and/or vanes for damage and remove any liquids and/or debris

-Check the cartridge flow passages and rotor for damage

-Conduct the spin test in a draft-free area. Perform three repetitions and average the spin times.

-If low spin time is encountered, lubricate the bearings, and spin the rotor several times to work the new oil in, and repeat the test

-Check the intermediate gear and readout device for binds

-Spin test with the readout device in place

PROVING

As stated earlier, the spin test is not an accuracy test but rather a means to determine the relative condition of the meter.

In order to determine the accuracy of any meter, it must be compared to a recognized standard. While there are several standards available such as low pressure flow proving, sonic nozzle proving, bell proving, and transfer proving, the last two are the most prevalent in the gas industry.

Because of the high flow rates associated with turbine meters, bell provers are not generally used for shop proving. However, manufacturers use large bell provers, 350 cf or 500 cf for special test and establishment of master meters by a process known as cascading. In this process, an engineering curve (15 points) is established for a 4" meter. Using the 4" meter as the master meter, an engineering curve is established for a 6" meter, 8" meter, and 12" meter. All of these tests are traceable to the National Bureau of Standards. These master meters are then used to transfer prove production meters and determine the normal six (6) point curve furnished with each meter.

Field or shop transfer provers are also calibrated using an accepted standard and a thoroughly defined accuracy curve which is traceable to National Bureau of Standards that has been derived and furnished with each prover.

Normally a transfer prover system consists of the master meter, control console, flow rate control valve, pulse transmitter of gate switch for both master and field meters, blower with muffler, and associated pressure and temperature sensors (Figure 7). The connection between the master meter and the field prover is either fixed piping or flexible hose with quick disconnect couplings.

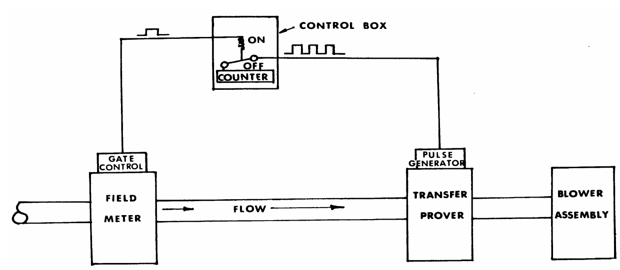


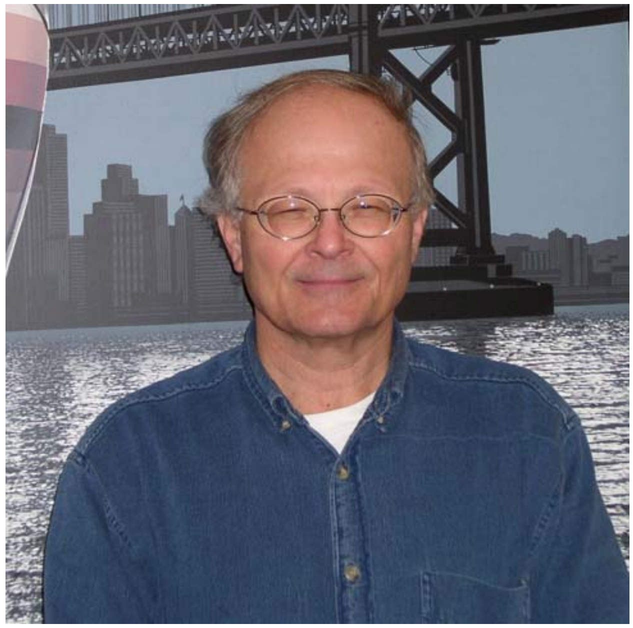
Figure 7 Transfer Proving

Vacuum testing with air drawn through both master and field meters is the common method used. In this procedure, the same volume of air is passed through both meters. By comparing this volume and applying master meter presets, along with corrections for pressure and temperature differences, the accuracy of the field meter can be calculated.

One method of proving turbine meter cartridges is to start an exchange program. A cartridge is tested in the shop, then taken to the field where it is exchanged with the field meter cartridge. The field meter cartridge is returned to the shop, where an in-test (as found) is done, any necessary repairs made, cartridge retested, and a new accuracy curve is generated. This cartridge is then used for field exchange on another meter.

This method offers the advantage of only having the meter out of service long enough to exchange cartridges. Meter manufacturers state maximum error for this exchange method is +/- .25% (American) and +/- .6% (Equimeter).

PROVING CHECKLIST



-Purge meter observing safety rules and proper procedures

-Install pulse transmitter on field meter, place temperature sensor as close to field meter outlet as possible

-Connect pressure tubing to tap provided for this purpose on the meter

-Leak test piping; if in-line proving, make sure valves are not leaking through

-Observe prover manufacturer's instructions for initiating prover, self-test, and actual test sequence

-Record results and calculate corrected proof

-Perform periodic maintenance and re-certification of the transfer prover

REFERENCES

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-Gas Measurement Manual, Part 4 Gas Turbine Metering, American Gas Association, 1985

-Gas Measurement Manual, Part 12, Meter Proving, American Gas Association, 1978

-Mm-1070, Rev 2, Equimeter MK-II and AAT Turbo-Meter Installation and Maintenance Instructions

-AIM 4700, Maintenance of American Gas Turbine Meters, American Meter Company
-AIM 4701/AIM 330.2C, Gas Turbine Lubrication Instructions, American Meter Company