FUNDAMENTAL PRINCIPLES OF DIAPHRAGM DISPLACEMENT METERS

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INTRODUCTION

The first gas company in the U.S., The Gas Light Company of Baltimore, Maryland, founded in 1816, struggled for years with financial and technical problems while operating on a "flat rate" basis. Its growth was slow with the charge for gas service beyond the pocketbook of the majority.

By comparison, the New York Gas Light Company, founded in 1823, prospered and expanded. They had built their system on "the use of gas meters to measure the supply of gas to customers, and a large one to register the quantity made at the station before it is conveyed to the gasometers.

The pattern of operation used by this New York company was quickly copied by other companies throughout the East Coast, including the Baltimore company. Seeing the success, New York businessmen formed new gas companies in Albany, Boston, Philadelphia, New York, etc. and the new U.S. gas distribution industry began to flourish.

Since this early beginning, meters have been an important, integral element in every phase of gas industry operations. Various types of meters are used; diaphragm, rotary, turbine, and orifice; each serving a definite purpose and meeting specific requirements.

These four common types of meters can be broken down into two distinct categories: positive displacement and inferential. Diaphragm and rotary meters fall into the positive displacement category 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, on the other hand, have no measurement compartments to trap and then release the gas. These meters are inferential meters in that the volume passing through them is "inferred" by observing or measuring some physical characteristic.

COMPONENTS

A diaphragm meter is physically composed of: 1.) A body to contain the gas pressure and form part of the compartments that measure the gas, 2.) Diaphragms that move as gas pressure fluctuates on either side, 3.) Valve covers and seats that control the flow of gas into each side of the diaphragm, 4.) Linkage to connect the diaphragm with the valves and index, and finally 5.) The index which registers the number of revolutions of the entire mechanism. (See Figure 1.)

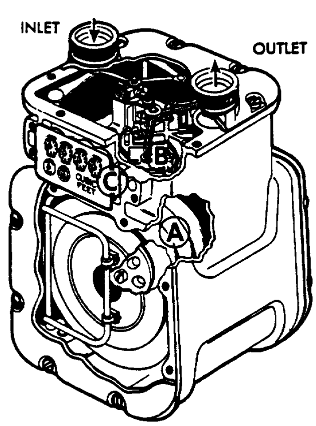


Figure 1. Diaphragm Meter

A diaphragm meter can be compared to a two-piston double-action engine in which the diaphragms correspond to pistons and the meter body to the cylinders. Each stroke of the diaphragm displaces a fixed volume of gas and the diaphragms operate 90^0 out of phase so that when one is fully stroked, the other is at mid-stroke

This provides a smooth flow of gas to the meter outlet and insures the meter will always start regardless of its static position. When a demand for gas is made on the downstream side of the meter, a pressure drop is created across the meter and its diaphragms. This differential, which amounts to 0.1" W.C., provides the force to drive the meter.

Above each diaphragm is a "D" shaped valve (See Figure 2.). Under the valve are three port openings that direct the flow of gas in and out of the case and diaphragm compartments. As the diaphragm expands, it forces the gas in the case compartment up through the case port. The valve directs the flow of gas into the center port that leads to the meter outlet. A similar process occurs when the diaphragm contracts. The stroke of the diaphragm is controlled by linkage in the upper port of the meter and a rod (flag rod) that extends down into the diaphragm compartment. The tangent link, as it is called, is attacked to the top of the meter crank and is adjustable in length. Increasing the tangent length increases the diaphragms' stroke which increases the meter proof and vice versa (See Figure3.)

The crank makes a certain number of turns per cubic cubic foot and transmits this motion to the front counter (index) by means of an axle shaft driven by a worn and wheel. The crank also drives the sliding valves, which are timed to the motion of the diaphragm.

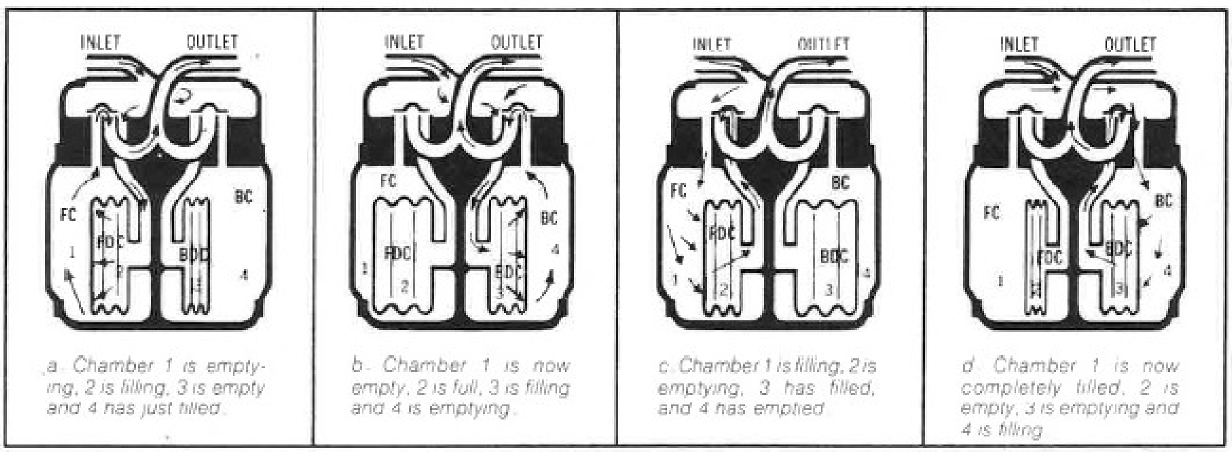


Figure 2. Movement in side a Diaphragm Meter

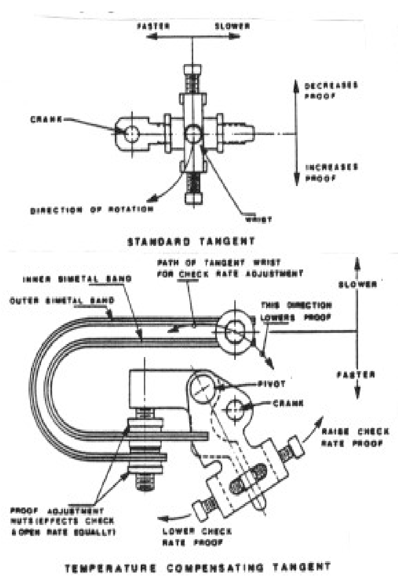


Figure 3. Tangent Adjustments

STANDARDS

To provide some common base for rating the capacity of various manufacturers' gas meters, the ANSI B109.1 gas meter standard establishes a set of guidelines for meters with a capacity of less than 500 Cubic Feet Per Hour. ANSI B109.2 is the standard for diaphragm meters handling more than 500 Cubic Feet Per Hour and ANSI B109.3 covers the "Rotary Type Gas Displacement Meter.

Both B109.1 and B109.2 define diaphragm type gas meter capacity as that volume of 0.60 specific gravity gas at an absolute pressure of 14.73 PSIA that will result in an average pressure drop through the meter of 0.5 inch of water column, using specified inlet and outlet connections. This capacity rating is not to be construed as a maximum capacity but as a common capacity rating base. Within the B109.1, meters are divided up into several classes:

Class	Capacity (ft^3/hr)	
	Minimum	Maximum
50	50	174
174	175	249
250	250	399
400	400	499

This standard calls for new meters to be ±1.0% accurate and ±2.0% after accelerated life tests. (See Figure 4. for small meter test apparatus.)

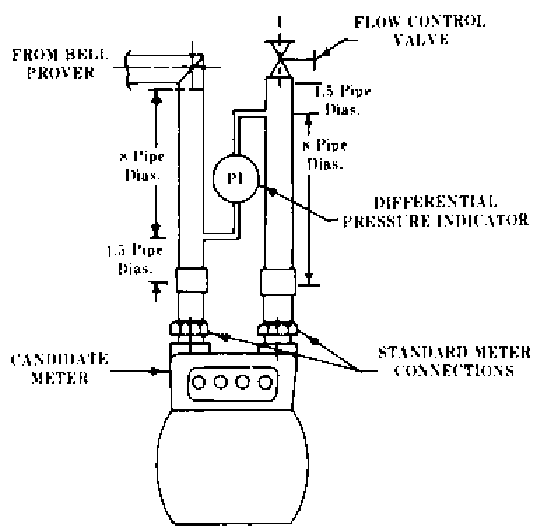


Figure 4. Test Apparatus

The B109.2 (500 Cubic Feet or More) also divides large volume meters into several classes.

Class	Capacity (ft^3/hour)	
	Minimum	Maximum
500	500	899
900	900	1399
1400	1400	2299
2300	2300	3499
3500	3500	5599

(Figure 5. shows a typical test stand used to determine meter capacities for large volume meters.)

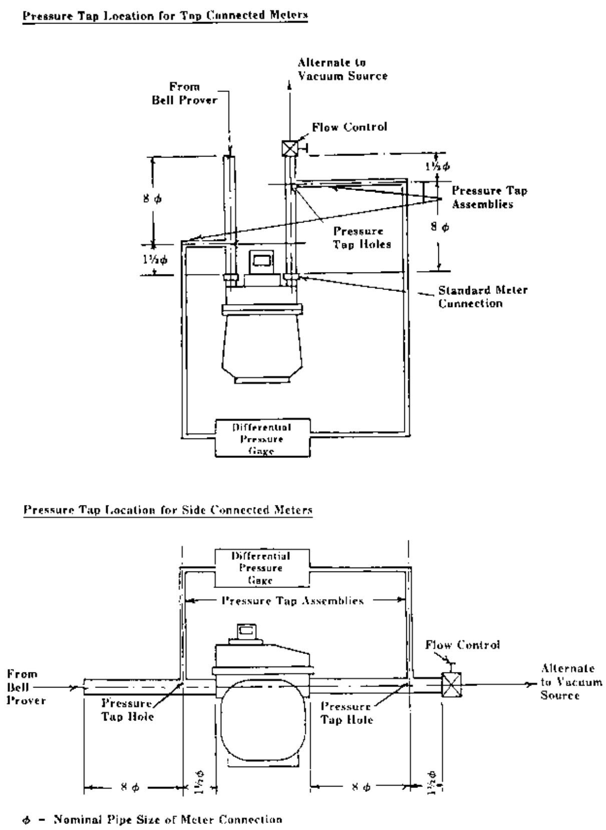


Figure 5. Large Meter Test Apparatus

Diaphragm meters meeting the requirements of both B109.1 and B109.2 will measure the gas flow to a pilot light starting at .25 ft^3/hour for a Class 250 meter and smaller and up to 7 ft^3/hour for a class 3500. The allowable accuracy at this flow is $\pm$10%. A typical accuracy curve for a diaphragm meter is shown in Figure 6.

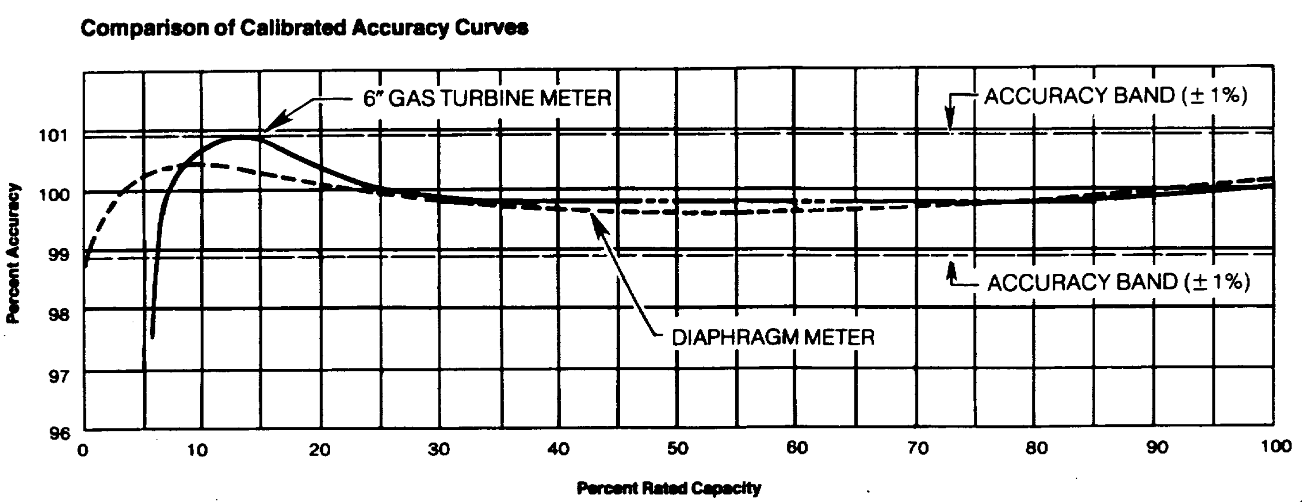


Figure 6. Diaphragm Meter Accuracy

In addition to the capacity of the meter, its body must be physically constructed to withstand the internal pressure of the gas. Modern diaphragm meters have sufficient structural integrity to withstand a minimum shell test of 10 PSI. This is necessary to meet the federal rules contained in Part 192 of Title 49, Department of Transportation, Office of Pipeline Safety regulations.

The end connections must be of sufficient size to allow easy passage of gas through the meter and can be some type of insert, NPT screw connections, or flanges. (See Table 1 for capacities and connections.)

Type	Maximum Working Pressure, PSI	Base Pressure Capacity at Atmospheric Pressure, CFH .60 sp. gr.		Type and Size of Connections
		1/2" Water Differential	2" Water Differential	
††AC-150	5	150	–	1/2" or 3/4" F.P.T.
††AC-175	5	175	–	3/4" or 1" M.C.
AC-250	5	250	–	3/4", 1" or 1 1/4" M.C.
AC-250	10	250	–	3/4", 1" or 1 1/4" M.C.
AC-630	25	630	1300	1", 1 1/4" or 1 1/2" M.C.
††AL-175	5	175	–	3/4", 1" or 1 1/4" M.C.
††AL-250	5	250	–	3/4", 1" or 1 1/4" M.C.
AM-250	5	250	–	3/4", F.P.T.
AM-250	10	250	–	3/4", F.P.T.
AL-425	10	425	900	1", 1 1/4" or 1 1/2" M.C.
AL-425	25	425	900	1", 1 1/4" or 1 1/2" M.C.
AL-800	20	800	1700	1 1/2" M.C. or 1 1/2" F.P.T.
AL-800	100	800	1700	1 1/2" F.P.T.
AL-1000	25	1000	2200	1 1/2" or 2" M.C.
AL-1000	100	1000	2200	1 1/2" F.P.T. or 2" M.P.T.
AL-1400	100	1400	3000	2" F.P.T.
AL-1400	100	1400	3000	3" F.P.T.
AL-1400	100	1400	3000	3" Ser. 15 Flange
AL-2300	100	2300	5000	4" F.P.T.
AL-2300	100	2300	5000	4" Ser. 15 Flange
AL-5000	100	5000	11000	4" F.P.T.
AL-5000	100	5000	11000	4" Ser. 15 Flange

Table 1. Diaphragm Meter Capacities

INSTALLATION

Figure 7. Typical Diaphragm Meter Installation

Diaphragm meters should always be shipped, stored, and installed in an upright position. Dust caps on the inlet and outlet connections should be left in place until the meter is installed. Caution should be used with meters that have been removed from service since they may contain gas within the diaphragm chambers.

The meter set should be in a location that is ventilated and readily accessible for examination, reading, replacement, or maintenance. The set should be protected from outside damage and at least three (3) feet from known sources of ignition or air intakes. Electrical isolation for cathodic protection purposes should be maintained.

A diaphragm meter should be installed as close to level as possible. Tests have indicated that tilting a meter will affect its accuracy since, at high angles, the valves tend to come off the valve seat and let the gas bypass the diaphragm chambers. Therefore, the inlet and outlet connections should be within ± 1/4" of each other.

The meter should be installed in a manner to avoid undue stress on the connecting piping or meter. The use of a meter bar may be a consideration. If there is foreign material such as sand, rust scale, or welding beads in the gas supply; then a filter or strainer should be provided on the inlet side. The meter should not be installed at the low point since it may act as a trap for liquids. By-pass piping or some other type of testing components, pressure taps, and over-speed protection should be considered.

Avoid having the meter body make direct contact with soil or concrete walls since alkali in concrete can cause premature corrosion. Under no circumstances should the meter be buried.

Hand-tighten the swivels first and then tighten with a wrench approximately three flats (approximately 20 ft-lb). Do not over tighten since damage to the rubber gasket inside the swivel cap may occur.

Check all connections for leaks.

Slowly pressurize the system.

MAINTENANCE

The diaphragm meter really does not require much maintenance other than a periodic proof test. Factors that affect meter accuracy include:

1. Internal Friction that increases meter differential. Excessively dirty or tacky valves or binds in the meter will cause higher differential pressures.

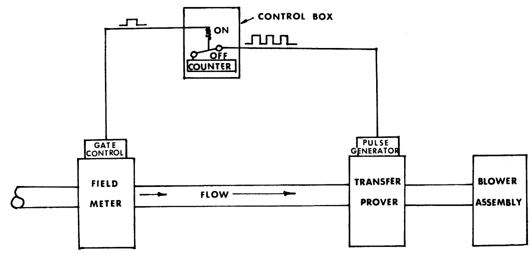
2. Maintaining Constant Diaphragm Displacement. A precise and stable diaphragm displacement is required for each stroke of the meter. Therefore, the effective cross-sectional area of the diaphragm and the diaphragm stroke must remain constant.

3. External Leaks. Any external opening, such as cover gaskets, index seal box, or meter connections that lets gas escape will affect its accuracy.

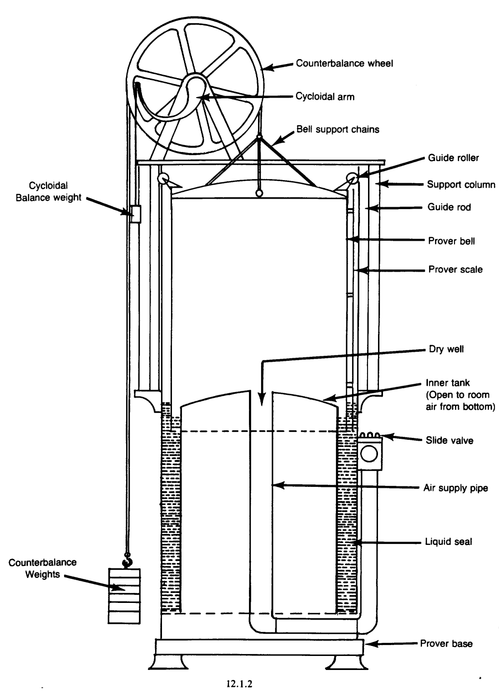
4. Internal leaks. These will cause the meter to run slow and are usually found in areas such as the diaphragm assembly, valves, or flag rod seals.

5. Wear. This can affect accuracy in several ways. Wear at either end of the short flag arm or in the tangent bearing will cause the check rate proof to decrease while not appreciably affecting the open rate proof. Wear of the crank or crank arms will affect the timing of the valves that will increase the open rate proof.

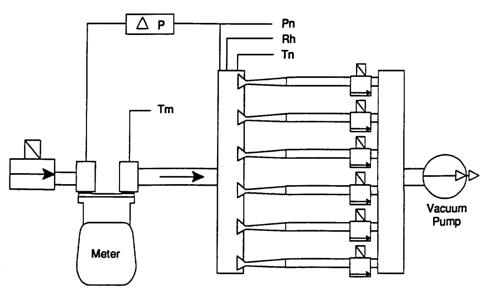
To determine the accuracy of a diaphragm meter, it must be tested or proved using conventional testing equipment such as a transfer prover, bell prover, or sonic nozzle prover. (See Figure 8. for examples.)



A. Transfer Prover



B. Bell Prover



C. Sonic Nozzle Prover

Figure 8. Proving Methods

CONCLUSION

Diaphragm Positive Displacement meters are and will continue to play a major role in natural gas measurement in the U. S. for the foreseeable future. Understanding how they work, their specifications, and how to install and maintain them are critical to having them perform in an acceptable manner.

REFERENCES

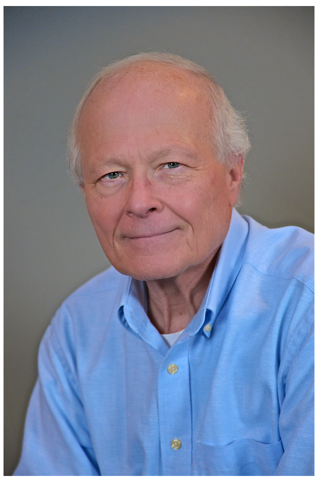
-Gas Measurement Manual, Part Two, Displacement Measurement, American Gas Association, 1985.

-ANSI B109.1, 2000, Diaphragm Type Gas Displacement Meters, American gas Association

-ANSI B109.2, 2000, Diaphragm Type Gas Displacement Meters, American Gas Association

-ANSI B109.3, 2000, Rotary Type Gas Displacement Meters, American Gas Association

-Product Specification, Aluminumcase Meter, Domestic Size, American Meter Company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