OPERATING
SECTION
REPORT

American Gas
Association

GAS MEASUREMENT MANUAL

(REVISED)

ORIFICE METERS

PART NO. THREE

CATALOG NO. XQ9011

A.G.A.
GAS MEASUREMENT MANUAL

ORIFICE METERS
PART 3.0

Authored by the Operating Section's
Transmission Measurement Committee

American Gas Association
1515 Wilson Boulevard
Arlington, Virginia 22209

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HISTORY

"The so called orifice meter is another comparatively recent suggestion ... (for the measurement of natural gas). Orifices calibrated by individual experiment from standardized pitot tubes, and the differential across the orifice recorded by automatic recording gauges, have now been on the market for several years. This well known principle of flow of fluid through a thin-edged orifice is very simple of application to pipeline, and seems to give promise of good results ..."

Thus wrote Frances P. Fisher of Bartlesville, Oklahoma, in a paper entitled "Establishing a Standard of Measurement of Natural Gas in Large Quantities" presented at the Spring meeting of the American Society of Mechanical Engineers in 1916.

It is difficult to trace with certainty the commercial use of orifice meters in this country. We do know that pitot tubes and gas holders were used to determine early orifice flow coefficients.

In about 1904, Thomas R. Weymouth constructed a flange top orifice meter using thicker than normal flanges, having tap holes drilled at one inch upstream and downstream from the orifice plate and using the downstream tap for the static pressure measurement. These experiments continued for several years and he made extensive use of a set of pitot tubes designed and constructed by Bert C. Oliphant. Weymouth later sold his orifice meter data, with all rights, to the Foxboro Company. In 1921, Foxboro published the data in their handbook, "The Orifice Meter and Gas Measurement."

At about the same time John C. Pew and H. C. Cooper, of the Peoples Natural Gas Company of Pittsburgh, started to conduct tests of orifices, but they used the upstream tap for their static pressure measurement.

Concurrently, B. O. Hickstein of the Empire Gas and Fuel Company was conducting tests using pipe tap connections; 2½ diameters upstream and 8 diameters downstream. Some of his work was presented in the A.S.M.E. paper, "The Flow of Air Through Thin-Plate Orifices," in 1915. Hickstein, undoubtedly, used pipe taps in order to confirm data which had been published in Germany by a man named Mueller. In 1918, the Metric Metal Works (later the American Meter Company) used Hickstein's pipe tap coefficient data in their handbook entitled "Measurement of Gas by Orifice Meter."

Professor Horace Judd, of Ohio State University, made some calibrations of orifice meters for the Bailey Meter Company. Judd located his high pressure tap at one pipe diameter upstream, and the low pressure tap at the approximate location of the vena contracta at the outlet of the orifice. Some of his work was reported in an A.S.M.E. paper, "Experiments on Water Flow Through Pipe Orifices," in 1916.

Before 1915, when Hickstein formally presented his findings, values of orifice coefficients were generally confidential. Even after papers began to appear, it was difficult to know whose data to use or how to apply it. Furthermore, Metric Metal Works was promoting pipe taps, Bailey Meter preferred vena contracta taps, and Foxboro used flange taps.

Needless to say, there was a great deal of uncertainty about the use of this "recent suggestion" for flow measurement, and numerous disagreements regarding the accuracy of orifice measurements ensued. Meters from different manufacturers, each measuring the same gas flow, could produce considerable differences and this set the stage for the National Bureau of Standards to become involved. Beginning in 1922 and continuing into 1925, tests on orifices were conducted at Edgewood Arsenal in Maryland. A description of the program and the results were given in NBS Research Paper 49, issued in 1929.

In 1924, a committee was formed that would later be known as the Gas Measurement Committee of the American Gas Association. This committee, with the aid of NBS, conducted a series of orifice research programs. These programs are briefly described in Appendix A of the A.G.A. Committee Report No. 3 (ANSI/API 2530). The committee published a preliminary report in 1927, and Gas Measurement Committee Report No. 1 was issued in 1930. In 1931, the committee joined with the Special Research Committee of Fluid Meters of A.S.M.E. to form a Joint Committee on Orifice Meters.

To fulfill the need for the determination of absolute values of orifice coefficients, a program at the Hydraulic Laboratory of Ohio State University, Columbus, was started in 1932. These tests, under the supervision of Professor Samuel R. Beitler, are commonly referred to as the "Columbus Tests." Data were collected using water in meter tube sizes from 1 inch to 15 inches. The data were analyzed by Dr. Edgar Buckingham and Howard S. Bean of the NBS. From these tests, empirical equations for the coefficients of both flange taps and pipe taps were developed.

This work formed the basis for A.G.A. Measurement Committee Report No. 2 published in 1935, and Report No. 3 published in 1955. The coefficient equations were also used in the fourth edition of "Fluid Meters" published by A.S.M.E. in 1937, and later in the fifth and sixth (last) editions.

It should be noted that the flange tap equations developed by Dr. Buckingham and the pipe tap equations by Mr. Bean were derived from carefully drawn curves of the crossplotted data on 20 inch by 24 inch graph paper. Data points to them were not just numbers to be fed to a computer as might be done today. It is, indeed, a tribute to the quality of the work done by Sam Beitler, Dr. Buckingham and Howard Bean that, even after nearly 50 years, their work still serves as the basis for orifice metering worldwide.

INTRODUCTION

Description

As its name implies, an orifice meter utilizes an orifice for its basic component in the measurement of natural gas. The placing of an orifice in a pipe in which there is gas flow creates a pressure difference across the orifice. This pressure difference is measured, along with static pressure and other variables, and then translated into flow rate through the use of flow equations.

When natural gas (or any other fluid) flows through an orifice, the stream continues to decrease in cross section for a short distance downstream of the orifice as shown in Figure 3.1.1. The area of the minimum cross section is known as the "vena contracta." Strictly speaking, the area of the vena contracta should be used in the flow equation. However, there is no satisfactory method for measuring this minimum jet area, whereas, measuring the diameter of the orifice and, thus, calculating its area is a relatively simple matter. By experiment, the amount of contraction has been found to depend primarily upon the orifice to meter tube diameter ratio (beta ratio) and the properties of the fluid. With any one fluid, and the same differential pressure, the relative amount of jet contraction increases as beta decreases. This is because as the fluid particles near the wall of the meter tube converge toward the orifice bore, they obtain a greater radial velocity inward when beta is small than when beta is large. Thus, the orifice coefficient will increase for the same size orifice placed in a smaller diameter meter tube. It has become customary to consider a complete orifice meter as being composed of the two major elements, the primary and the secondary element.

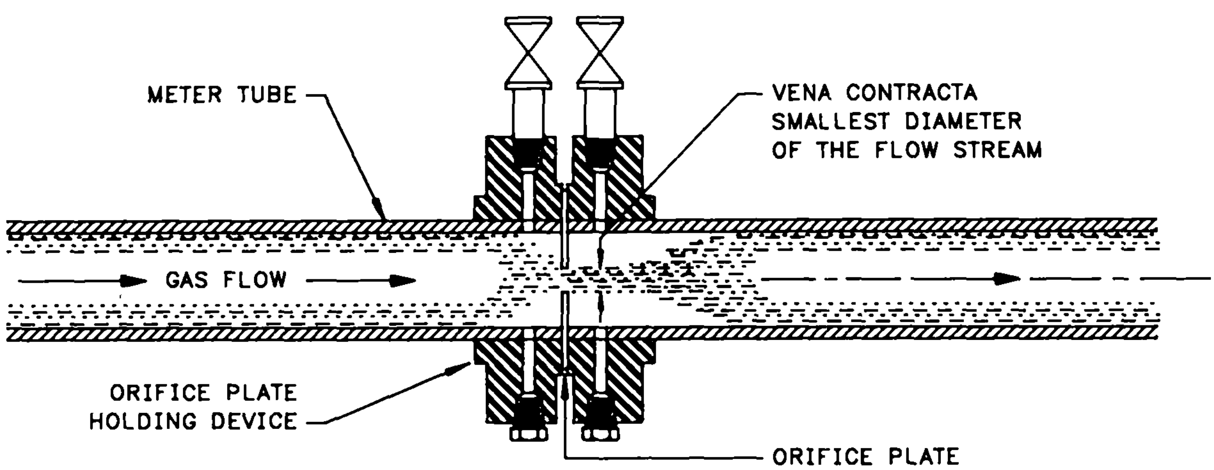

Figure 3.1.1—Representation of the primary element of an orifice meter

The first of the two major elements is the differential pressure producing device called the "primary element." This primary element is composed of

- *Meter Tube*—A length of special straight pipe upstream and downstream of the orifice through which the fluid flows.
- *Plate Holder*—The orifice plate holding and positioning device (an orifice flange or an orifice fitting) installed as an integral part of the meter tube to hold the orifice plate in a position perpendicular and concentric to the flow of fluid.