DEVELOPMENT OF ORIFICE METER STANDARDS

www.daniel.com

INTRODUCTION

This paper is for the purpose of reviewing how we have arrived at the orifice meter standards, what is their value and what we can expect in the future. It is of value to review this background since respect for the orifice standards (and other standards) has diminished. This can lead to real chaos for the gas industry. The last way you want to solve your measurement problems is based on personal opinions – this is the purpose of the standards, because it represents consensus data with legal standing.

HISTORY

The modern orifice meter for natural gas measurement dates back to 1912 when Thomas Weymouth published an ASME paper on his orifice meter based on tests he had run since 1904. The meter had flange taps. (1” upstream and 1” downstream).
The Foxboro Company licensed his work and began building an orifice meter to his findings soon after. At the same time Metric Metal Work (later American Meter Company) made a meter that used pipe taps (2.5D, 8D) and Bailey Meter Company made a meter that used vena contracta taps. All of these developed their own coefficients and mechanical installation requirements independently. In the same time period, Professor Judd of Ohio State University developed coefficients on concentric, eccentric and segmental orifice plates. Metric Metals published “Measurement of Gas by Orifice Meter” in 1918 written by H.P. Westcott. The Foxboro Company published their Book “The Orifice Meter and Gas Measurement” in 1921 Bailey published data on their own orifice meters. These were the first handbooks prepared for the natural Gas Industry.

All of these different device handbooks and tests led to questions by the users of the proper manufacture and use of orifices particularly when two of the devices were used in series and different answers were obtained. Questions were asked of two gas industry organizations:
Natural Gas Association of America (natural gas interests); American Gas Measurement Association (manufactured gas interests); and a government Bureau, the Natural Bureau of Standards (NBS).

At a meeting of the Natural Gas Association of American NGAA in 1922, Howard Bean (of the NBS) made a pitch for help in planning and running a program to help resolve some of the questions they had been asked on orifice meters. The NGAA told him they weren’t interested – in fact they just as soon the NBS kept it’s nose out of the Gas Metering business.

At about the same time period the Bureau of Mines who was responsible for the collection of royalties on gas production on Indian lands in Oklahoma asked the NBS to supply them with official data on how to measure natural gas.

All of this made it obvious that there was a dire need for some sort of basic data and standard for use of the orifice.

NBS TESTS

Based on these needs the NBS allocated $2,000.00 to conduct a project to obtain the official data. This lead to a search of the literature and a visit to the manufacturers and users of orifice meters including Weymouth, (Foxboro Consultant), Bailey (Bailey Meter Co.), Republic Flow Meter Co., Professor Judd (Ohio State University) and Kerr of Ohio Fuel Gas Co. In addition, the NBS obtained access to a potential test facility that could be built at the Edgewood Arsenal of the Chemical Warfare Dept.

To help plan the facility and these tests, Bean of NBS made a pitch to the American Gas Measurement Association for help in planning a program. They reacted with an extensive program of their own to be run in Chicago and asked that Bean of the Bureau participate. This test used a 24-inch meter tube with 14 different orifice plates. Pressure gradients across the orifice meter were the most important data developed.

In 1927 the Natural Gas Association had re-contacted Bean to help them in their orifice meters questions after their rebuff in 1922 of his offer to help. The NGA became the Natural Gas Department of the American Gas Association. A joint committee of the American Society of Mechanical Engineers (ASME) was formed in 1931 with the American Gas Association, which was a further consolidation interest in gas measurement to a single working group.

OTHER TESTS

Other test and data developed during this time included Cleveland Holder test -1925- (8, 10 and 16 inch meter run tests), Buffalo disturbance tests –1926–(upstream pipe fittings effects), disturbance and rate-of-flow tests –1927-(expansion factor, rate-of-flow, flange form and supercompressibility Test–1928- (expansion factor, effect of recesses, Boyles law effect, coefficient effect), Orifice Installation conditions –1929 and 30-(vanes, thermometer wells, roughness of pipe, flange effects, orifice centering), Edwedgewood Tests –1922-1925- (discharge coefficients), and Chicago Holder Tests –1923,24- (low pressure orifice use).

AGA-1

All of this data was included in AGA-1 published in 1930. This followed a preliminary report published in 1927 and revised in 1929. This was the first "Industry Standard" on orifice meters. This document was a cosponsored publication of the Gas measurement Committee and the NBS. The introduction stated:

"This is not a final report, but is made with the understanding that the committee will continue its analytical studies of the data already developed. The committee also fully expects that it will be necessary for it to conduct further work of its own. This will make necessary one or more supplemental reports, in which data will be summarized and the mathematical principles announced, which are the basis of the present report, and such modifications and extensions will be made as additional data and further study may require."

No sooner than the AGA-1 was published work was begun on AGA-2 that would include better orifice coefficients. It was agreed that Professor. Biether at Ohio State University (OSU) would run the tests. They were run 1929-31 with additional data in 1932 and 1933. This data became the definitive coefficient data on flange taps and was the basis of orifice meter coefficients for over 60 years until the latest database published in November 1992. The OSU tests were an amazingly good data set, but consisted of only 303 data points and it covered meter tubes 2 inch through 16-inch sizes.

Tests run in 1932 investigated the effects of tap hole size and flange recesses. It was during the period in the mid 1920's that the natural gas began to be handled at higher pressures (i.e., 100 – 300 psig) than the manufactured gas industry had been accustomed to and the need for corrections for Boyles and Charles Law was recognized. Tests were begun to test the compressibility of gas at several locations including a well in California, which had gas pressures to 1000 psig and was mostly methane.

AGA-2

AGA-2 was published in 1935 and incorporated in the new test work that had been run – particularly the new coefficients developed by OSU and the compressibility data. It allowed the use of orifice meters over a much wider range. The results using AGA-1 and 2 are the same except for the addition of the supercompressibility factors.

At this time there were few questions to be answered so for approximately the next 20 years little data was developed and therefore no push to update the AGA Standard was made. The tests that were run beginning in 1945 included the following: The Rockville tests run in 1945-51 to determine the effects of installation piping including plug, globe and gate valves; elbows, orifice fittings, (rather than orifice flanges) and orifice tube roughness.

The National Bureau of Standard in 1950-51 ran tests that were extensions of the Rockville tests covering water tests on the meter tube to evaluate the roughness effects, pressure taps location and tap hole size.

U.S. Naval Boiler and Turbine Laboratory tests (1948-1954). These tests evaluate globe valves, expansion bends, and expansion factors for steam.

Refugio Large – Diameter Orifice Tube tests (1952-53). This data established orifice coefficients on 30-inch orifice flanges and fittings by comparing their data to eight-ten inch meter tubes whose volume was calculated from the original Ohio State data. This data showed that extrapolation of the original data could be done and allowed data to be filled in all sizes between 16 and 30.

Eccentric and Segmental Orifice Tests (1948-54) was run at the request of the ASME and did not impact the AGA standard since these orifices are not used for gas measurement.

AGA-3

AGA Report No 3 was published in 1955 to expand its application and to incorporate the new data and correct minor questions about practical application raised about AGA 1 and 2. In general, the results are consistent with results of AGA-1 and 2.

Additional testing on Pipe Roughness (1957-`960) and Ohio State University Flow Distribution Tests (1960-1962) were run to define roughness requirements and non-swirl distortions (axial profile effect) of upstream piping.

A revision of AGA-3 made in 1969 updated the report based on new data and new requirements (i.e., the use of computers), but the basic concepts were not changed, it simply made the

Report easier to use. It was decided at this time not to continue to increase the number on the revised reports. By keeping the same number, revising contracts would not be required. Adding such phrases of as reference AGA-3 the latest edition as revised from time to time and mutually agreed upon would allow the contracts to stand as written.

In 1975 the American Petroleum Institute (API) adopted AGA-3 and led in submitting it to American National Standards Institute (ANSI) where it was approved as a national standard in 1977, identified as ANSI/API 2530. The AGA had been successfully sued over another report and they didn't want to expose themselves to law suits so they turned the leadership of the AGA-3 over to the API.

In 1982-83 a further revision of the AGA-3 improved its clarity and ease of use. With all of these revisions the calculations still gave the same answer as the first edition. The compressibility was expanded as AGA-8 to cover more gas composition and pressure to 20,000 psi. Its revision was incorporated as part of AGA-3 by reference.

LATEST AGA-3

The 1990-92 Standard included new empirical orifice coefficients based on test work on oil, water, air and natural gas on 2, 3, 4, 6 and 10 meters in the US; and on water and/or natural gas on 4, 10 and 24 at European Labs. This data included some 10,000 data points of which 5500 flange tap tests points were used to curve match the data. A total database of some 16,000 data points was eventually collected with the final data used to check the original curve matching. This document recognized the wide use of computers by making equations with programs "the standard" replacing the previously used table data.

NEXT AGA-3

The 1992 AGA-3 is the last published Standard change, but as with all of its predecessors additional data is being developed today. Particularly in the area of upstream piping requirements and the use of straighteners (which was not investigated or changed since the 1955 standard). Likewise, any errors or changes that can not be taken care of by errata sheets will be corrected and reprinted. This is the reason that the document is published in four parts so that they may be individually republished without the other three being done at the same time. As new applications and questions are raised, further changes will be required to keep AGA-3 current.

SUMMARY

A number of people complain that the AGA-3 Report is too detailed, too technical, not practical and hard to use. However, as has been pointed out it represents a tremendous amount of data and knowledge collected over almost 70 years. It represents a consensus "best statement" on the use of an orifice by the gas industry personnel including workers in pipeline companies, production companies, distribution companies, processing plants, academia meter related equipment manufacturers, and government who hold jobs in management, operations, maintenance, sales, engineering, research and development and universities.

The AGA-3 Standard is the best that we know today and it is still going to be improved as we learn more about how to improve orifice measurement of gas. I recommend you refamiliarize yourself with this document and learn how to apply it properly. This will result in the best flow measurement available with the orifice meter.

Daniel® Measurement and Control
9750 W Sam Houston Pkwy N, Suite 100
Houston, Texas 77064 USA

info@daniel.com | +1 (346) 509-3700 | daniel.com