THE DEVELOPMENT OF MCMENON **ISO WEDGE**

Introduction and History

Wedges belong to a family of flowmeters based on differential pressure measurement, where a restriction in the flow causes a measurable and repeatable pressure drop. This pressure drop is a function of flowrate and can be used to calculate either mass or volume flow of the fluid. Wedge flowmeters have proved themselves in challenging applications over many years and are often the go to technology for air-entrained liquids, slurry flows and any difficult to meter fluid in general [1].

A wedge meter consists of an asymmetrical wedge which protrudes into the flowing fluid. Like most restriction based primary elements, before standardization, the actual geometry of the restriction was manufacturer dependent [2]. The exact dimensions, extrapolation to larger pipe internal diameters and operating envelopes may have been proprietary information. One such design of wedge flowmeter that gained popularity was the Taylor wedge as shown in Figure 1[3].

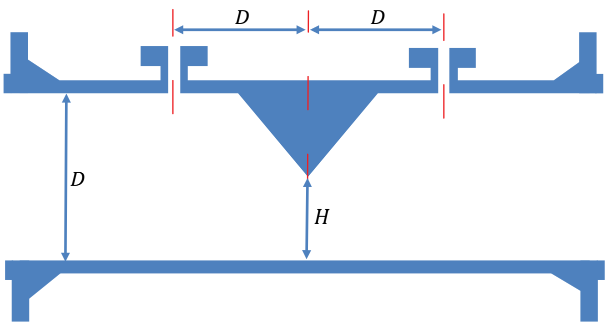

Figure 1: Taylor wedge geometry

The Taylor wedge has the tappings located at one pipe diameter (D) upstream and downstream from the apex of the wedge with the tappings themselves being of small bore screwed connections or 2 or 3 inch branches on the pipe with flanged connections. The wedge size can be changed to suit the application with larger wedges producing a larger differential pressure.

Typically, wedges are defined by the height of the flow area H divided by the internal pipe diameter D as shown in Figure 1. This provides a non-dimensional value to compare wedges of different sizes.

By measuring the differential pressure caused by the wedge element the mass flowrate q_m can be calculated through

$$q_m = Kd^2 \varepsilon \frac{\pi}{4} \sqrt{2\Delta p \rho} \quad \text{.........} \ (1)$$

where ε is the expansibility of the fluid (ε=1 for liquids), Δp is the measured differential pressure, ρ is the fluid density and Kd^2 is the calibration factor related to the wedge geometry and flow coefficient. Tables of Kd^2 have been prepared that can generally predict the value to within 2% of the actual value found during a calibration[1]. The parameter d^2 can also be written as $(D\beta)^2$ where β is the square root of throat to pipe flow areas.

The calculation for β is relatively simple for other styles of primary element[4] such as orifice plates and Venturis and can be given as

$$\beta_{orifice} = \frac{d}{D} \quad \text{.........} \ (2)$$

where d is the throat diameter. For wedges, as the throat is the segment of a circle rather than a circle the equation is more complex but still represents the same idea, a ratio of the throat to pipe flow areas[1].

$$\beta = \sqrt{\frac{1}{\pi}\left(\arccos\left(1-\frac{2H}{D}\right) - 2\left(1-\frac{2H}{D}\right)\sqrt{\frac{H}{D}-\left(\frac{H}{D}\right)^2}\right)} \quad \ldots (3)$$

The Taylor wedge has been an industry leading design for many years and delivers excellent performance for customers. The design was popularized by many manufactures, including ABB[3], and is now one of the products offered by McMenon[5] through the divestment of the Workington factory from ABB in 2018.

Standardization

As mentioned previously, many designs of primary elements including wedge flowmeters are manufacturer specific. However, to make it easier for end users in industry it is often beneficial to standardize designs and operations of equipment in order to realize significant benefits that can be obtained. Written standards cover limits of operation, engineering constraints as well as standard calculation methods. Benefits to industry when equipment is standardized include:

- Much wider understanding of design and fluid mechanics
- Trusted performance and equation development
- Competitive pricing between manufacturers
- Cumulative track record
- Increase in innovation through research collaboration
- Larger market uptake

ISO 5167 is the current group of standards for differential pressure flowmeters and now covers the majority of the most common types of primary elements. ISO 5167 (1980) replaced early standards like R541 (1967) for orifice and nozzles and R781 (1968) for Venturis and has subsequently been revised in 1991 and 2003. A further revision is being completed in 2021 with ISO 5167-3 (2020) [9] already completed.

The latest version from 2003 covers general principles, standard concentric orifice plates, nozzles and Venturis in parts 1 through 4[4,6,7,8]. In 2016, part 5[10] was released focusing on cone type flow meters and in 2019 part 6[11] has been released to cover wedge flowmeters and in particular a style of wedge that is referred to as an ISO wedge.

The ISO wedge differs from the Taylor wedge in location of the tappings– instead of a distance of one pipe diameter from the apex of the wedge, the ISO wedge has the tappings located one pipe diameter from the outside edges of the wedge.

This change results in all wedge meters of different sizes having a hydraulically similar distance between the tapping and wedge element which is not the case with the Taylor wedge. This small change in design may help in standardizing an equation for all H/D ratios and pipe sizes. Figure 2 shows the geometry layout of an ISO wedge.

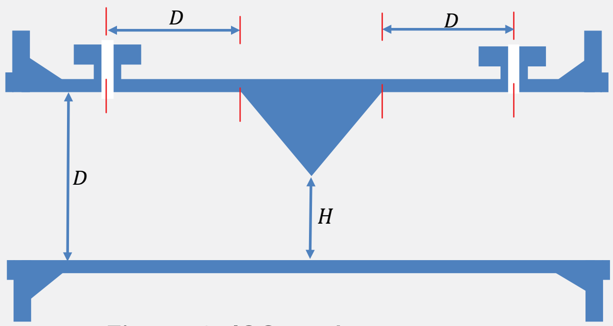

Figure 2: ISO wedge geometry

Manufacturing a wedge in compliance with ISO 5167-6 has all of the advantages listed above including being able to use the discharge coefficient C equation[11] within the standard which is

$$C = 0.77 - 0.09\beta \quad \ldots\ldots\ldots (4)$$

As it is a relatively new standard, the equation is not overly complex and currently has an uncertainty of 4%. It is likely that as more data is collected and shared from traceable calibration laboratories that the equation can be improved upon. This is analogous to what has happened with the concentric orifice plate equation over the past few decades where it has been improved and the uncertainty reduced.

The calculation of mass flow through an ISO wedge is given as

$$q_m = \frac{C}{\sqrt{1-\beta^4}}\varepsilon\frac{\pi}{4}(D\beta)^2\sqrt{2\Delta p\rho} \quad \text{...... (5)}$$

Equation 5 is equivalent to equation 1 and therefore[1]

$$K = \frac{C}{\sqrt{1-\beta^4}} \quad \text{........ (6)}$$

For the ISO wedge the calibration factor is therefore the discharge coefficient only and not a combination of flow coefficient and meter geometry as it is with the Taylor wedge. They are similar and comparable factors as long as the appropriate conversions are made and appreciation that they refer to different tapping locations.

The development of ISO 5167-6 and publication in 2019 provides an international standard for wedge type flowmeters that can hopefully build upon its long and successful history being used in many industries around that world. Given McMenon's constant drive to innovate and provide solutions for our customers, a project was initiated with the aim of providing an additional wedge solution for those end users requesting compliance with a recognized international standard.

McMenon ISO Wedge

McMenon have designed and constructed an ISO wedge in our state of the art 10,000 m2 factory located in Workington, Cumbria in the North West of England. The 14 inch schedule 40 carbon steel wedge meter was fabricated, machined and welded from raw materials all within the UK. The unit was calibrated in McMenon's onsite water calibration facility and found to match closely to equation 4 providing great confidence in the quality and precision of our manufacturing, traceability of our flow calibration references and the accuracy of the equation within ISO 5167-6. A successful comparison could not have been completed without these being correct.

The 14 inch McMenon ISO wedge is shown in Figure 3 and the calibration results are shown in Figure 4.

Figure 3:14 inch McMenon ISO wedge

Figure 4: McMenon ISO wedge test results

A further ISO wedge has been constructed which we believe to be the world's first ISO compliant wedge flowmeter built entirely in the Kingdom of Saudi Arabia. It was built by McMenon's joint venture in the region. Figure 5 shows the completed wedge.

The ISO wedge project marks a number of achievements for McMenon and highlights the drive for innovation and providing solutions to meet customer needs. This particular project covers manufacturing compliant with international standards, performance checking through high accuracy calibration capability and a world first through our international partnerships.

Figure 5: 2 inch McMenon ISO wedge

At McMenon, we embrace innovation and are constantly striving to introduce new solutions for our customers. The ISO wedge will be the first of many new or adapted products McMenon will be offering to market.

Please get in touch to find out more.

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References

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