# EXPERIMENTAL INVESTIGATION OF THE INSTALLATION EFFECTS ON VENTURI AND ORIFICE FLOW METERS

**M. Aichouni**(1), **B. Laribi** (2), and **P. Wauters** (3)

(1) *PhD, Maître de Conférences, University of Mostaganem, Mechanical Engineering Department, Algeria,*
(2) *PhD Candidate ,* (3) *Professor, The Catholic University of Louvaine, Brussels, Belgium.*

## Résumé

L'exactitude et la précision de mesure des débitmètres sont des paramètres métrologiques très importants pour la majorité des industries. La précision des débitmètres dépend principalement de leur position dans le pipeline. Les éléments de conduites tels que les vannes, les coudes et les élargissements brusques sont des sources de distortions et de perturbations pour l'écoulement. Dans le présent travail on présente les résultats d'une étude expérimentale portant sur l'effet des conditions non standards crées par des éléments de conduites sur la précision de mesure des débitmètres à pression différentielle type Venturi et plaque à orifice. Les résultats montrent que les conditions perturbées de l'écoulement peuvent être la cause d'erreur de mesure qui dépassent largement les erreurs limites tolérées par les normes internationales.

## Abstract

Accuracy and precision of flow meters are the most important metrological parameters in most industries dealing with increasingly expensive fluids. The accuracy of these devices depends mainly on their position in a pipe network. Pipe fittings such as valves, bends and other fixtures generate turbulence and swirl and distort the flow distribution in the pipe. The disturbance has been shown to alter significantly the measurement performances of the meters. In this paper we present results of an experimental investigation on the effects of non-standards operating conditions (axisymetric and swirling flows) on the accuracy of the Venturi and the orifice flow meters. The results showed that the error caused by such non-standards operating conditions can be very important and are well beyond the tolerated error limit by the existing international standards.

## Introduction

Accuracy and precision of flow meters are the most important metrological parameters in most industries dealing with increasingly expensive fluids. The accuracy of these devices depends not only on their construction and method of operation but also their position in a pipe network. Valves, bends and other fixtures generate turbulence and swirl and distort the flow distribution in the pipe. This disturbance can significantly alter the measurements made by flow meters downstream of these fittings.

For custody transfer of valuable fluids, accurate flow measurements are always required. Various research efforts have been made in order to improve the performance and the accuracy of flow meters. A fundamental understanding of the effects of flow meter operational conditions upon the discharge coefficient is necessary to reduce or to eliminate installation effects which decrease the accuracy of flow metres. In the recent years, concentrated research work in USA (NIST) (Mattingly, G.E., and Yeh, (1991, 1996), Morrison et al.(1992), Morrow et al. (1991), Brennan et al. (1991)), in the U..K (NEL) (Reader-Harris and Keegans (1986, 1999), and Laws et al. (1994)) and in France (CERT) (Gajan et al.(1991)) and in Algeria (Aichouni et al. (1998, 2000, 2001)) has been devoted to study experimentally and computationally the installation effects upon differential pressure flow meters. Most of these studies evaluated the effect upon the discharge coefficient of changing the location of flow conditioner with respect to the orifice meter. The major conclusions reported that significant errors can be registered if the flow meter is working under abnormal flow conditions. It is also concluded that more experimental and numerical research effort is still needed to improve industrial flow metering performances.

In this paper, results of a joint research program on the installation effects upon Venturi tube and orifice flow meters are presented. Axi-symmetric distortions (Uniform, jet and wake) and swirling flow (generated by a double 90 degrees elbows in separate planes) conditions effects on the performance of the meters are investigated experimentally. The Venturi flow meter tests were conducted at the fluid mechanic laboratory of the University of Mostaganem, (Algeria) while the orifice flow meter tests have been made at the Catholic University of Louvaine (Belgium). Details of the experimental facilities can be found in Aichouni et al. (2000) and Laribi et al. (2001).

## Results and Discussion

The purpose of the experimental programme was to determine the relative change of meter reading under different flow conditions; These include:

a) Axisymetric distorted flow profiles for the Venturi meter.
b) Highly swirling flow profiles for the orifice plate meter.

In the first part of the programme, three velocity profiles were generated by the gauze screens. This technique has been used in early work by Laws and Aichouni

(1990,1992) to create highly distorted flows in circular pipes. These velocity conditions, greatly exaggerate the maldistributions normally present in industrial flowmeter runs. They were used to demonstrate the cause and effect of axisymmetric distorted velocity profiles. The velocity distortions range from a jet profile with high centreline velocity and slower velocities near the pipe wall to a wake velocity profile with low centreline velocities. The second part of the work, orifice plate flow meter was tested under highly swirling flow condition generated by a 90° double elbow in different planes placed at different positions.

For both meters, flow rate was first measured under fully developed flow condition (the meter being placed at some 100 pipe diameter from the entrance). Then abnormal flow conditions were created and the corresponding flow rate was measured. The flow rate error and the discharge coefficient shift were determined to see the effect of the installation effects on the meter reading. According to the standards ISO 5167 the flow rate was determined from the differential pressure measured through the meter under test. The discharge coefficient was determined as the ratio of the measured flow rate to the true flow rate. The percentage shift in the discharge coefficient was determined from the relationship :

$$\Delta C_d = \left( \frac{C_{d0} - C_d}{C_{d0}} \right) x100 \qquad (1)$$

Where $C_{d0}$ represents the discharge coefficient measured under standards conditions (fully developed flow condition) and $C_d$ being the discharge measured under non-standards operating conditions.

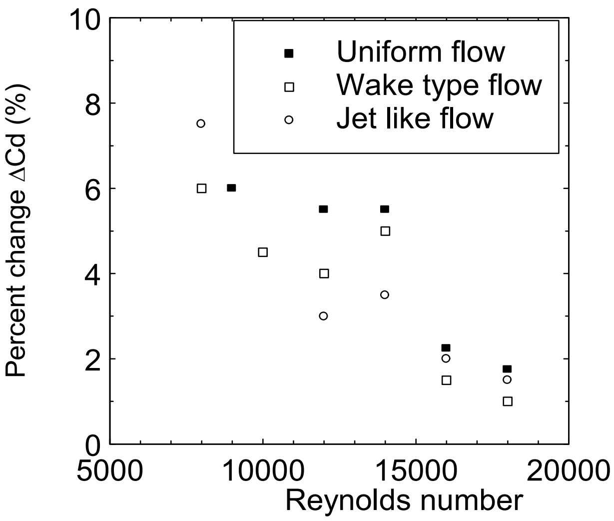


**Figure 1 – Discharge Coefficient Error of a Venturi flow meter operating under Different Upstream Flow Conditions**

Typical results are presented in figures 1 and 2 where the discharge coefficient shift is plotted as a function of the flow Reynolds number for both the Venturi tube and the orifice flow metes. It is clear from these figures that highly distorted flow conditions (axi-symmetric and swirl) can cause significant errors which are well beyond the tolerated limits by the standards. Errors in the meters performances ranged from ± 0.5 % to ±2.5% for the orifice meter and from ±1% to ±7.5% for the Venturi flow meter. The present results suggest that the meter error would decrease with the flow Reynolds number, Re.

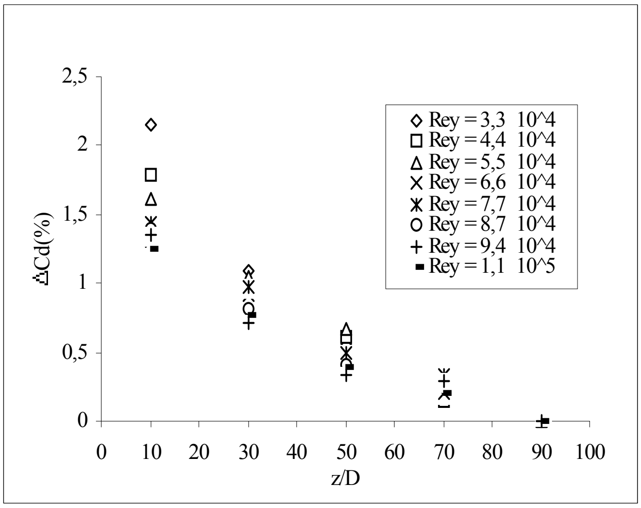


**Figure 2 – Discharge Coefficient error for the Orifice Flow meter placed at Different Locations Downstream of a 90° Double Bend (two different planes)**

# Conclusions

The present experimental study shows that the operating flow conditions have significant effects on the Venturi and orifice plate flow meter performance. Highly distorted flow conditions can cause errors up to ±7.5 percent on the discharge coefficient. These effects can be due to the flow instability in the meter caused by the approaching flow distortions.

In the light of the present experimental study and in order to avoid any measurement errors and as stated by the standards, the flow meter should be run under fully developed flow condition and kept clean and free of all extraneous material at all times. The author's opinion is that more research efforts should be continued to quantify the installation effects upon industrial flow meters. Further research is still undergoing to quantify measuring errors mainly for the orifice flow meter.

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