1 INTRODUCTION

1.1 Brief Introduction and problem statement
Wet gas is generally defined as a volume of gas having a gas volume fraction (GVF) greater than 90%, but less than 100% (Geng et al., 2006). The existing multiphase flow meters mainly work for flows where the GVF is between 0% and 90% and the single phase flow meters such as the standard orifice cannot be used for wet gas flow measurement because of the significant measurement error (Li Yi et al., 2009). Hence, many industries still depend on bulky three phase separators to measure wet gas flow rate, where the process is complex and costly. Accurate wet gas metering is important, particularly for oil and gas industry, in terms of hydrocarbon allocation and revenue generation (Agar et al., 2002).

Throughout the years, several well-known companies such as TEA, Solartron, Roxar, PECO, FRAMO and Agar have developed different types of wet gas meters by employing different metering principles and technology, ranging from pressure differential to microwave and vortex shedding technologies (Li Yi et al., 2009). In recent years, wet gas measurement using differential pressure (DP) flow meters like Venturi and orifice is gaining popularity in the oil and gas industry owing to the relative ease of operation and low cost compared to the multiphase flow meters. In order to further improve the standard design, modifications have been proposed especially for the orifice meter. The slotted orifice meter is one such version of the standard design found to be better performing by several researchers. This design was reported to be substantially less sensitive to upstream flow conditions and generating a smaller permanent head loss compared to the standard orifice with the same beta ratio. Static pressure recovery was also found to be faster than the standard orifice. It was noted that in stratified flow conditions, liquid stream was able to pass through the perforations of the slotted orifice at the bottom of the pipe, which could eliminate the water retention effect commonly observed in standard orifice plates [(Geng et al., 2006), Morrison et al.,1994-2001)]. Moreover, the slotted orifice with low beta ratio was found to be more sensitive to liquid presence, but less sensitive to flow pattern changes. This particular behavior makes the slotted orifice a better choice for wet gas metering compared to the standard orifice (Geng et al., 2006). Based on the literature study, it is considered worthwhile to investigate the effect of geometry of slots on the wet gas meter performance. This has been done by CFD modeling of the wet gas flow as it provides deeper insight into the flow field. Rectangular slots with
varying aspect ratio and circular slots (all having $\beta$ ratio 0.4) are considered in this study. The performance of these slotted orifices has also been compared with that of a standard orifice meter with the same $\beta$ ratio.

The error introduced in the DP meter reading by the presence of liquid has to be corrected for an accurate measurement of the wet gas flow. For this purpose, semi-empirical correlations based on theoretical analysis and experimental data have been developed over the years by many researchers. The details of these correlations are given elsewhere [(Lide et al., 2007, Steven et al., 2007)]. All these correlations work on the same principle as the single phase correlation, such that the gas mass flow rate is calculated using Eq. (1). However due to the bias in the measurements of wet gas flows, a correction factor is applied to mitigate the over-reading of the gas mass flow rate. In this work, the performance of the wet gas correlations for gas flow prediction has also been reported.

$$m_g = \frac{C_d}{\sqrt{1 - \beta^4}} \varepsilon A_c \sqrt{2 \rho_g \Delta P_g}$$

1.2 Motivation

One of the biggest problems encountered in measuring natural gas flows occurs when liquids flow with the gas. Traditional gas meters are not designed to cope with such wet gas flows. The main issues when dealing with wet gas flows include knowing how wet the gas is, knowing how wet gas affects flow measurement and knowing what systems exist to correctly measure the wet gas flow. Wet gas flow metering is of increasing importance to the natural gas production industry. Therefore, wet gas flow testing facilities are also of increasing importance to the industry. State-of-the-art wet gas flow testing facilities allow the research and development and verification of wet gas flow metering technologies by meter manufacturers, operators and regulatory authorities. This proposal describe the CFD simulation study on the effects of velocity and pressure distributions in wet gas metering using slotted orifice flow meter.

Wet gas flow is a flowing mixture of gas and liquid where the liquid makes up a relatively small part of the mixture by volume. The liquid can be made up of hydrocarbons and/or free water. The flow conditions dictate how the liquid phase is dispersed throughout the pipe. The
description of the physical distribution of the liquid phase with the gas phase is termed the flow pattern (or the flow regime). The flow pattern has a considerable influence on the reaction of most meters to the wet gas flow.

At relatively high pressures and flow rates for horizontal or vertical flow, the flow pattern could be mist, where all the liquid flows in small droplets entrained in the gas. At relatively low pressures and flow rates for horizontal flow, the flow pattern could be stratified, where the liquid flows at the base of the pipe with the gas flowing above. However, in many cases moderate pressures and flow rates produce complicated and transient flow patterns that are difficult to predict theoretically due to the fact that they are influenced by many factors: meter orientation, fluid velocity, liquid properties, pipe size, liquid/gas ratios and others. This inability to predict the flow pattern theoretically drives the need for wet gas flow facilities to replicate actual field conditions in order to test wet gas meter systems.

Several terms are commonly used to describe the relative amounts of liquid and gas in a flowing stream. A qualitative term for describing the amount of liquid with the gas is the "liquid loading." There are several quantitative terms: gas volume fraction (GVF) is the volume of the gas flow divided by the total volume of fluid flowing. Liquid load is the ratio of liquid-to-gas-mass flow rates. Another term commonly used is the Lockhart-Martinelli parameter. This is a non-dimensional method of describing the relative wetness of a gas.

Industry has found the development of accurate wet gas flow meters a difficult task. Attempting to meter wet gas flow with a gas flow meter can cause many problems. Many gas flow meter designs have been tested with wet gas flows. The most commonly tested and used gas meter with wet gas flow is the differential pressure (DP) meter (e.g. orifice, cone, Venturi meters). Liquid presence with a gas flow induces a DP meter to produce a higher differential pressure than would exist if the gas flowed alone. According to many technical papers, the gas flow rate errors induced by a liquid’s presence with a gas flow can be 10 and greater percent.

Other meter types such as Coriolis, turbine and ultrasonic meters have been tested with wet gas flows. Wet gas flow causes all these meter types to have significant measurement issues. The generic Coriolis, turbine and ultrasonic meters will--in general--incur significant gas flow rate measurement errors for trace liquid entrainment with the gas flow. At moderate to high liquid loading wet gas flows they can fail completely and give no flow rate predictions.