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Coriolis Metering Technology for CO₂ Transportation for Carbon Capture and Storage

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Abstract

Highly reliable and accurate Coriolis meters have been proposed for metering carbon dioxide in carbon capture and storage (CCS) operations to provide accurate flow measurements. However, there is a lack of calibration studies to quantify Coriolis measurements uncertainty for liquefied CO₂. In this study, a first of its kind apparatus was designed, built and used to calibrate an industrial scale Coriolis meter using CO₂ in liquid phase. The standard uncertainty of the meter was evaluated within the temperature range 290 to 293 K and at pressure 6.5 MPa.

Keywords: CCS, CO₂ metering, Coriolis meter, uncertainty, carbon dioxide

1. Introduction

Over the last two decades, there has been growing public concern [1, 2] about increasing CO₂ emissions [1] and the consequences in terms of climate change. Approximately 26 % of global CO₂ emissions were contributed from fossil fuel power generation [3, 4]. Therefore, carbon dioxide capture and storage (CCS) has been proposed as a short-term solution to significantly reduce CO₂ emissions [4]. CO₂ captured from power stations will be injected
into geological reservoirs to reduce these emissions [5-7]. Unfortunately, CCS has been slow to develop and achieve commercial success due to a lack of business models. Since accurate flow measurements are required for both commercial and regulatory purposes, a proven metering technology is required to accelerate CCS commercialization. Additionally, the UK Advanced Power Generation Technology Forum (APGTF) [8] have clearly stated that research and development for CO₂ accounting is needed to develop techniques for fiscal metering of CO₂ with impurities to an accuracy of ±2% in the gas phase and liquid phases. However, there are no published studies of accuracy in metering CO₂ in liquid phase. Accordingly, in this study, a calibration system was designed and built to evaluate the uncertainty for metering liquefied CO₂.

2. Material and experimental apparatus

A Coriolis meter was selected for this work, as it can directly measure mass and is expected to be hardly affected by temperature and pressure conditions [9]. The experimental method developed was based on a gravimetric calibration [10, 11]. Temperature, pressure and flow rate of the tests in this study were at temperature from (290 to 293 K), pressure at 6.5 MPa and flow conditions between (0.5 and 0.65 L/min). In this study, 99.9995 vol% of certified supercritical CO₂ from BOC was used. A calibration system was designed and built to determine measurement uncertainty of Coriolis meter using for liquid CO₂. A smallest industrial scale Coriolis meter (Krohne, OPTIMASS 6000-S08) with U tubes design was selected to quantify its uncertainty. A pressure transducer (GE, UNIK 5000) with 0.1% standard uncertainty and a thermo sensor integrated with Coriolis meter were used to monitor pressure and temperature during measurements. The calibration system was controlled via a data acquisition unit with data logged in automatically. Density, temperature and mass/volume flow rate from the Coriolis flow meter were recorded by A XFC 300 Data logger supplied by Krohne. The mass flow rate recorded by the Coriolis flow meter during a calibration was compared with that determined by the designed rig.

3. Results and discussion

Two calibration runs were conducted under different flow rates (0.5 and 0.65 L/min), temperature (290 to 293 K) and pressure at 6.5 MPa. During an experiment, completely constant temperature of the system was difficult to maintain due to friction heat generated by a piston pump head, leading to temperature fluctuation of 2 K. However, uncertainties evaluated were hardly affected because measured mass flow based on gravimetric calibration method is independent of temperature and pressure conditions [9]. Fig. 1 shows typical physical characteristics of the calibration run at pressure of 6.5 MPa with a pressure fluctuation of ±0.1 MPa, temperature between (290 and 292 K) and flow rate at 0.5 L/min. In Fig.1, all of densities of CO₂ recorded from Coriolis meter in the test runs are above 800 kg/m³ which indicate the calibration system was successful to remain measured CO₂ in liquid phase without any phase transition during a calibration.

Fig. 1. CO₂ physical parameters (temperature, pressure, volume flow rate and density) of a calibration run 1 recorded by the Coriolis meter
The measured error of Coriolis flow meter, $u$, was calculated using the following equation

$$ u = 100 \left( \frac{M_c dt - m_{\text{ref}}}{m_{\text{ref}}} \right) $$

(1)

Where $M_c$ is mass flow rate measured from Coriolis meter and $m_{\text{ref}}$ is mass of CO$_2$ pumped through Coriolis flow meter recorded by the high precision weight scale. $m_{\text{ref}}$ is calculated from the equation below

$$ m_{\text{ref}} = m_{\text{cylinder}} + m_{\text{pipeline}} $$

(2)

Where $m_{\text{cylinder}}$ is mass of CO$_2$ injected in storage cylinder and $m_{\text{pipeline}}$ is mass of CO$_2$ collected in the collection vessel. The measurement errors, $u$, are presented in Table 1. The measurement errors obtained in this study are -0.14 % and 0.04 % at temperature from run 1 and run 2, respectively, where 0.025 % is due to the measurement uncertainty of the weight scale.

### Table 1. Operating parameters and uncertainties measured using pure CO$_2$ in this study

<table>
<thead>
<tr>
<th>Run</th>
<th>Temperature (K)</th>
<th>Pressure (MPa)</th>
<th>flow rate (L/min)</th>
<th>Measurement error, $u$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>290-292</td>
<td>6.5 ± 0.1</td>
<td>0.5 ± 0.05</td>
<td>0.04 ± 0.029</td>
</tr>
<tr>
<td>2</td>
<td>291-293</td>
<td>6.5 ± 0.1</td>
<td>0.65 ± 0.05</td>
<td>-0.14 ± 0.021</td>
</tr>
</tbody>
</table>

### 4. Conclusions

A calibration system for evaluating measurement uncertainty of a Coriolis meter for liquefied CO$_2$ has been designed and built. The physical parameters monitored in the calibration runs indicate that CO$_2$ successfully remained in the liquid phase without phase transition during a calibration. Accordingly, the system was tested and validated to be able to determine uncertainty of Coriolis meter using liquefied CO$_2$. The maximum uncertainty obtained in this study is 0.14 %, being far less than required uncertainty of 2 % stated by APGTF. Further measurements needed to be conducted over a wide range of temperature and pressure representative of CCS operation conditions to quantify more reliable, consistent measurement uncertainty of Coriolis meter using in CO$_2$ in the liquid phase.

### 5. Acknowledgements

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