Effect of Noise Generated by Pressure Control Valves on Ultrasonic Gas Flow Meters

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KOREA is one of large LNG importers (38.7 MT in 2014, 16% of World LNG)

KOGAS is solely responsible for nation’s import and supply of natural gas
Natural gas imported to Korea has been provided and distributed from pressure regulation and metering stations to domestic customers which are power plants and city gas companies.
Supplied natural gas has been pressure-controlled to 10 bara and 40 bara by pressure control valves of several type such as globe and axial in pressure regulation and metering stations depending on customers’ needs.
KOGAS Custody Transfer Flowmeters

- Orifice Flow Meters (1986~)
  - Power Plants
  - City Gas Companies

- Turbine Flow Meters (1997~)
  - City Gas Companies

- Ultrasonic Flow Meters (2012~)
  - Power Plants
  - City Gas Companies
    Not yet but under considering

- Orifice meters and turbine meters have been used for more than 10 years. Ultrasonic flowmeters have been applied to newly establishing metering stations since 2011 instead of orifice meters and turbine meters.
Flow Measurement Traceability Chain

KRISS High Pressure Flow Standard System

Sonic nozzle Bank

- 300 m³/h X 5
- 200 m³/h X 1
- 100 m³/h X 1
- 50 m³/h X 1

Working Standard

- Turbine Flowmeter

- 1,600 m³/h X 6

Device Under Test

- Turbine Flowmeter
- Ultrasonic Flowmeter

- 50-10,000 m³/h
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V Conclusion
Ultrasonic flowmeters have been applied to newly establishing metering stations. But city gas company line with low pressure is considered.
Ultrasonic frequency range noise generating by pressure control valve can interfere with the operating signal of ultrasonic flow meter.
## Pressure Control Valves in KOGAS

<table>
<thead>
<tr>
<th>Type</th>
<th>Manufacturer</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Globe</td>
<td>Pietro Florentini</td>
<td>345</td>
</tr>
<tr>
<td>Axial</td>
<td>Emerson</td>
<td>138</td>
</tr>
<tr>
<td>Axial</td>
<td>Grove</td>
<td>119</td>
</tr>
<tr>
<td>Axial</td>
<td>WEAGA</td>
<td>74</td>
</tr>
<tr>
<td>Globe</td>
<td>Valvitalia</td>
<td>70</td>
</tr>
<tr>
<td>Axial</td>
<td>AMC</td>
<td>37</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>783</strong></td>
</tr>
</tbody>
</table>

- Pressure control valves of several type such as globe and axial in pressure regulation and metering stations depending on customers’ needs.
Noise Measurement in Metering Station

- Characteristics noise propagation from PCV to metering station
- Safe and available noise measurement methods for Natural gas (Temperature/Pressure Tap, Purge Line)

- Measuring Pipe Section
- Temperature/Pressure Tap
- Purge line
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I Korea Natural Gas CTMS (Custody Transfer Measurement System)

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KRISS High Pressure Gas Flow Standard system

<table>
<thead>
<tr>
<th>Gas Type</th>
<th>Flow Generation Method</th>
<th>Pressure Range</th>
<th>Flow Capacity</th>
<th>Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>Blow-down</td>
<td>0.1 - 5 MPa</td>
<td>30 – 10,000 m³/h</td>
<td>0.18%</td>
</tr>
</tbody>
</table>
Pressure Control Valves in KRIISS System

[Globe type]

- Multi-hole Cage Guided PCV
- Dome Loaded PCV

[Axial type]

- Emerson Tatarini FL(KOGAS)
PCV Noise Measurement Set-up

#2 Noise Measurement

#1 Noise Measurement

2nd Pressure Control Valve

Flow

USM

Sonic nozzle

PCVs

To Sonic nozzle

Flow

70D

30D

4D
PCV Noise Measurement Set-up

#1 Noise Measurement

PCVs

USM

#2 Noise Measurement

2nd Pressure Control Valve

Flow

To Sonic nozzle

Sonic nozzle

#3 Noise Measurement

#4 Noise Measurement

4D

30D

70D
Ultrasonic Gas Flowmeter

Characteristics
- Four-path (eight transducer) chordal design

Meter Performance
- Flow calibrated accuracy is ±0.1% of reading relative to lab over entire flow calibration range
- Repeatability is ±0.05% of reading for 1.5 to 30.5 m/s (5 to 100 ft/s)

Velocity Range
- Nominal 0 to 30 m/s (0 to 100 fps) with over-range performance exceeding 38 m/s (125 fp/s) on some sizes

Emerson Daniel SeniorSonic
3414 Gas Ultrasonic Flow Meter

Fluid Types
- Hydrocarbons, industrial gases, H₂S limit 10,000 ppm (1%)

Fluid Temperature
- T-22: -50°C to 100°C (-58°F to +212°F)
- T-21: -20°C to 100°C (-4°F to +212°F)

Operating Pressure
- 345 to 27,579 kPa (50 to 4,000 psig)

Operating Frequency
- 125 kHz
Ultrasonic Noise Measurement

#1 Noise Measurement

#2 Noise Measurement

Signal Conditioner (PCB 483C05)

Digitizer (NI PXI-5922)

Sampling rate = 1 MHz,
Sampling size = 1,000,000

PCB 132A 35
ICP type Dynamic pressure sensor
Resonant Frequency : 1MHz
Sensitivity 20.3 mV/kPa
Purge Line Test

Noise Measurement @ Purge line
Ultrasonic noise measurement

- Test Conditions
  - $\Delta P = 10$ to $40$ bara
  - $Q = 200$ to $6,400$ Nm$^3$/h
Ultrasonic noise measurement

- **Test Conditions**
  - $\Delta P = 10$ to $40$ bara
  - $Q = 200$ to $6,400$ Nm$^3$/h

- **Noise Measurements**
  - Sound Pressure Level [dB]
    \[
    \text{SPL}[\text{dB}] = 20 \log_{10} \frac{P}{P_{\text{ref}}} \quad P_{\text{ref}} = 20\mu\text{Pa}
    \]
  - 1/3 Octave Band Spectrum
    
    $f_c = 10, 12.5, 16, 20, 25, 31.5, 40, 50, 63, 80, 100, 125, 160, 200, 315, 400, 500$ kHz

![Diagram showing test conditions and noise measurements](image.png)
Ultrasonic noise at Dome Loaded Valve

- Noise measurement at closest location (1st, downstream 4D)
Ultrasonic noise at Dome Loaded Valve

- Noise measurement at closest location (1st, downstream 4D)
- Broad band spectrum from 10kHz to 500 kHz, Falls off from 50 kHz
- Overlap operating frequency of transducer (125 kHz)
Ultrasonic noise at Dome Loaded Valve

- Noise measurement at closest location (1\textsuperscript{st}, downstream 4D)
- Broad band spectrum from 10kHz to 500 kHz, Falls off from 50 kHz
- Overlap operating frequency of transducer (125 kHz)
Ultrasonic noise with broad band increase as pressure difference increase with fixed pressure difference.

![Graph showing sound pressure level vs frequency for different pressure differences and flow rates.](image-url)
Ultrasonic noise at Dome Loaded Valve

- Ultrasonic noise with broad band increase as pressure difference increase with fixed flow rate

![Graph showing sound pressure level (dB) vs. frequency (kHz) for different pressure differences.](image)
Ultrasonic noise at Dome Loaded Valve

- Ultrasonic noise generated by Dome loaded valve depend on pressure difference and flow rates.
- Similar noise spectrum distribution for various condition of $\Delta P$ and $Q$
Ultrasonic noise at Dome Loaded Valve

- Ultrasonic noise is proportional to pressure difference and flow rate\(^{1/2}\)
  \[
  \text{SPL} \propto \Delta P \times \sqrt{Q} \quad \text{(ISO 17089)}
  \]

- Mean SPL in the range of 10kHz to 500kHz and SPL at 125 kHz shows similar distributions

\[
\begin{align*}
\text{SPL(dB)} &= 0.0146 \times (\Delta P \times Q^{1/2}) + 136.04 \\
\text{SPL(dB)} &= 0.0130 \times (\Delta P \times Q^{1/2}) + 120.47
\end{align*}
\]
Ultrasonic noise at Globe Valve

- Ultrasonic noise generated by Globe valve depend on pressure difference and flow rates.
- Similar spectrum distribution with Dome loaded Valve
Ultrasonic noise at Globe Valve

- Ultrasonic noise is proportional to pressure difference and flow rate\(^{1/2}\)

- Mean SPL in the range of 10kHz to 500kHz and SPL at 125 kHz shows similar distributions

\[
\text{SPL (dB)} = 0.0075 \times (\Delta P \times Q^{1/2}) + 142.82
\]

\[
\text{SPL (dB)} = 0.0070 \times (\Delta P \times Q^{1/2}) + 129.69
\]
Ultrasonic noise at Axial Valve

- Ultrasonic noise generated by Axial valve depend on pressure difference and flow rates.
- Large broad band noise than Globe valves
Ultrasonic noise at Axial Valve

- Ultrasonic noise is proportional to pressure difference and flow rate\(^{1/2}\)

- Mean SPL in the range of 10kHz to 500kHz and SPL at 125 kHz shows similar distributions

\[
\text{SPL(dB)} = 0.0101 \times (\Delta PX Q^{1/2}) + 136.29
\]

\[
\text{SPL(dB)} = 0.0114 \times (\Delta PX Q^{1/2}) + 147.74
\]
Different characteristics of the generation for ultrasonic noise in pressure control valves depending on type of PCV

\[ \text{SPL(dB)} = 0.0070 \times (\Delta P \times Q^{1/2}) + 129.69 \]

\[ \text{SPL(dB)} = 0.0130 \times (\Delta P \times Q^{1/2}) + 120.47 \]

\[ \text{SPL(dB)} = 0.0101 \times (\Delta P \times Q^{1/2}) + 136.29 \]
Ultrasonic noise at Different Valves

- Rapid slope with $\Delta PXQ^{1/2} \rightarrow$ Dome Loaded Valve
- Large Sound Pressure Level at operating frequency $\rightarrow$ Axial Valve

\[ SPL(dB) = 0.0070 \times (\Delta PXQ^{1/2}) + 129.69 \]
\[ SPL(dB) = 0.0130 \times (\Delta PXQ^{1/2}) + 120.47 \]
\[ SPL(dB) = 0.0101 \times (\Delta PXQ^{1/2}) + 136.29 \]
Ultrasonic noise at Different Valves

- Similar spectrum distribution in Dome loaded and Globe Valves
- Large broad band noise in Axial valve

\[ \Delta P = 20 \text{ bar, } Q = 4,800 \text{ Nm}^3/\text{h} \]
Ultrasonic noise Propagation and Attenuation

- Noise measurement at 4 different locations (downstream 4D, 30D, 110D, 140D)
Ultrasonic Noise Propagation and Attenuation

- Noise measurement at 4 different locations (downstream 4D, 30D, 110D, 140D)

- Characteristics of noise propagation and attenuation

\[ P(x) = P_0 \cdot e^{\alpha \cdot (2\pi f \cdot x)} \]

- \( f \): frequency
- \( \alpha \): attenuation coefficient
- \( x \): propagation distance
Ultrasonic noise decays exponentially with downstream distances (4 measurement location)

\[ P(x) = P_0 \cdot e^{-0.000295 \cdot x} \]

\[ \Delta P \times Q^{1/2} = 850 \]
\[ \Delta P \times Q^{1/2} = 950 \]
\[ \Delta P \times Q^{1/2} = 1,400 \]
\[ \Delta P \times Q^{1/2} = 1,600 \]
\[ \Delta P \times Q^{1/2} = 2,000 \]
Ultrasonic Noise Attenuation at Globe Valve

- Similar noise attenuation with Dome Loaded Valve

\[ P(x) = P_0 \cdot e^{-0.000302 \cdot x} \]

Sound Pressure Level @ 125 kHz [Pa]

Downstream distance from PCV [mm]
Similar noise attenuation with Dome Loaded and Globe Valve

\[ P(x) = P_0 \cdot e^{-0.000312 \cdot x} \]

Sound Pressure Level @ 125 kHz[Pa]

Downstream distance from PCV[mm]
Signal-to-Noise (SNR) of Ultrasonic Flowmeter

- SNR of Ultrasonic Flowmeter at extreme condition (Closest location, 1st)
- Evaluate Interfering effect with Noise in various condition of ΔP and Q

\[
SNR = \frac{\text{Signal Sound Level by USM}}{\text{Noise Sound Level by PCV}}
\]
SNR of USM with Dome Loaded Valve

- SNR of USM falls with increasing Pressure difference and Flowrate.
- USM failed in the range over $\Delta P X Q^{1/2} = 1,000$ and SPL = 133 dB
SNR of USM with Globe Valve

- SNR of USM falls with increasing Pressure difference and Flowrate.
- USM failed in the range over $\Delta PXQ^{1/2} = 650$ and SPL = 133 dB.
SNR of USM with Axial Valve

- USM failed in experimental condition of Pressure difference and Flowrate
Signal-to-Noise (SNR) of Ultrasonic Flowmeter

- SNR of Ultrasonic Flowmeter at stable condition (4th, Downstream 140D)
High SNRs (>25) in all conditions of Pressure difference and Flowrate
SNR of USM with Globe Valve

- High SNRs (>20) in all conditions of Pressure difference and Flowrate

![Graph showing SNR vs. ΔP × Q^{1/2} for different paths.](image)
• Operational SNRs (>15) in all conditions of Pressure difference and Flowrate
- Almost same characteristics of spectrum distributions

![Graph showing sound pressure level vs. frequency for different pressures and flow rates.](image-url)
Purge Port Test

- Almost same characteristics of the generation for ultrasonic noise which is proportional to pressure difference and flow rate\(^{1/2}\)

- Purge port for ultrasonic noise by PCV is feasible in NG metering station.
Conclusion

- In Korea, ultrasonic flowmeters have been applied to newly establishing metering stations instead of orifice meters and turbine meters.

- Ultrasonic frequency range noise generating by pressure control valve can interfere with the operating signal of ultrasonic flow meter.

- Ultrasonic noise measurements for various different pressure & flowrate conditions and types of pressure control valves used in metering stations are conducted in high pressure gas flow standard system of KRISS.
Conclusion

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- Ultrasonic frequency range noise generating by pressure control valve can interfere with the operating signal of ultrasonic flow meter.

- Ultrasonic noise measurements for various different pressure & flowrate conditions and types of pressure control valves used in metering stations are conducted in high pressure gas flow standard system of KRISS.

- Different characteristics of the generation for ultrasonic noise depending on type of Pressure control valve:
  - Rapid ratio of Ultrasonic noise to PQ in Dome Loaded Valve
  - Large broad band noise in Axial Valve

- Similar Ultrasonic noise attenuation in all Pressure Control Valve

- Evaluate Interfering effect with SNR of Ultrasonic Flowmeter at extreme condition

- Purge port test is feasible in NG metering station.
Thank you for your kind attention!