Measuring Mixed Gas at the Endpoint

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Energy Nexus | Annual Technical Conference

Fuelling the Future

Introduction Disclaimer

- About myself
  - I have been in gas measurement for 45 years.
  - Started in Measurement for Laclede Gas Company D/B/A Spire Energy headquartered in Saint Louis, Missouri.
  - Left Spire (retired) and started at Romet Limited in 2018.
  - To understand how to measure mixed gas at the end-point, I would like to give a little background on gas meters and how I got involved in measuring mixed gas through my observations, and experience.
  - Measuring mixed gas involves ultrasonic technology but differs from ultrasonic measurement.
  - I am not selling any product, I mean no disrespect to any product, I am merely trying to invoke thought and educate everyone on the technology by sharing my experiences.

Introduction

- Started developing an ultrasonic meter with a local university but quickly went down the rabbit hole trying to determine how to measure the energy value of gas including mixed gas.
- When the energy value changed, the flow rate changed.
- Then how do you determine if the flow rate changed because of increased flow or energy value change?
- I want to review those processes, starting with different meter technologies.
- Ended up eliminating flow and focusing on measuring mixed gas.
- Other gases
  - Renewable Natural Gas, Sew Treatment Plants, Farms, etc.

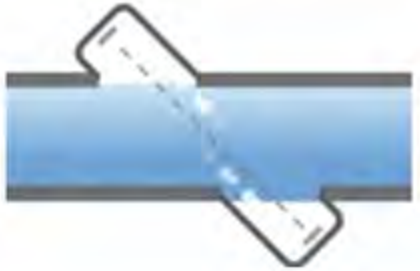
Setting the Foundation of

Measuring Mixed Gas at the Endpoint

Types of Meters

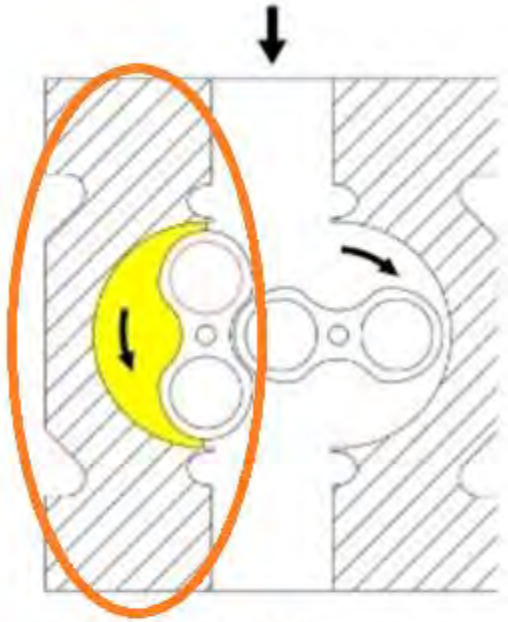
Positive Displacement and Inferential

Inferential Gas Meter



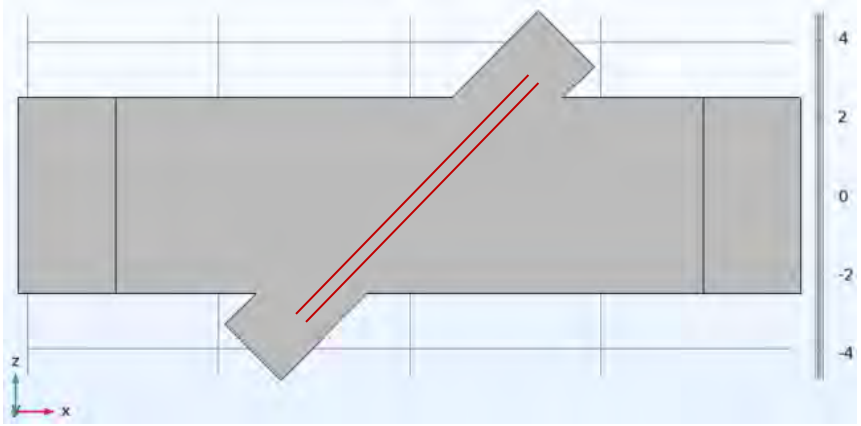
Positive Displacement Gas Meter

- **Positive displacement meter measures the volume of gas in cubic feet or cubic meters.**
- **It does not matter the amount of energy (Giga Joules / BTU) in the gas.**



When the right impeller reaches the vertical position, a finite volume of gas is captured between the cavity and the left impeller.

- Ultrasonic sound wave's time of flight (TOF) is measured along the red line, both with and against the direction of gas flow.



- *14 Burners*
- *16,384 Flow rates*

- *How do you determine if the flow changed due to another burner being turned on OR gas density?*

Speed of Sound in Gases

Acoustic velocity in different gases

The speed of sound (acoustic velocity) depends on the density and the bulk modulus elasticity of a gas.

Here is a list of speeds of sound for some gases at atmospheric pressure.
You can also › calculate the speed of sound here based on the gas properties of your application.

Gas	ft/s	m/s
Hydrogen (27°C)	4330 ft/s	1320 m/s
Methane (27°C)	1476 ft/s	450 m/s

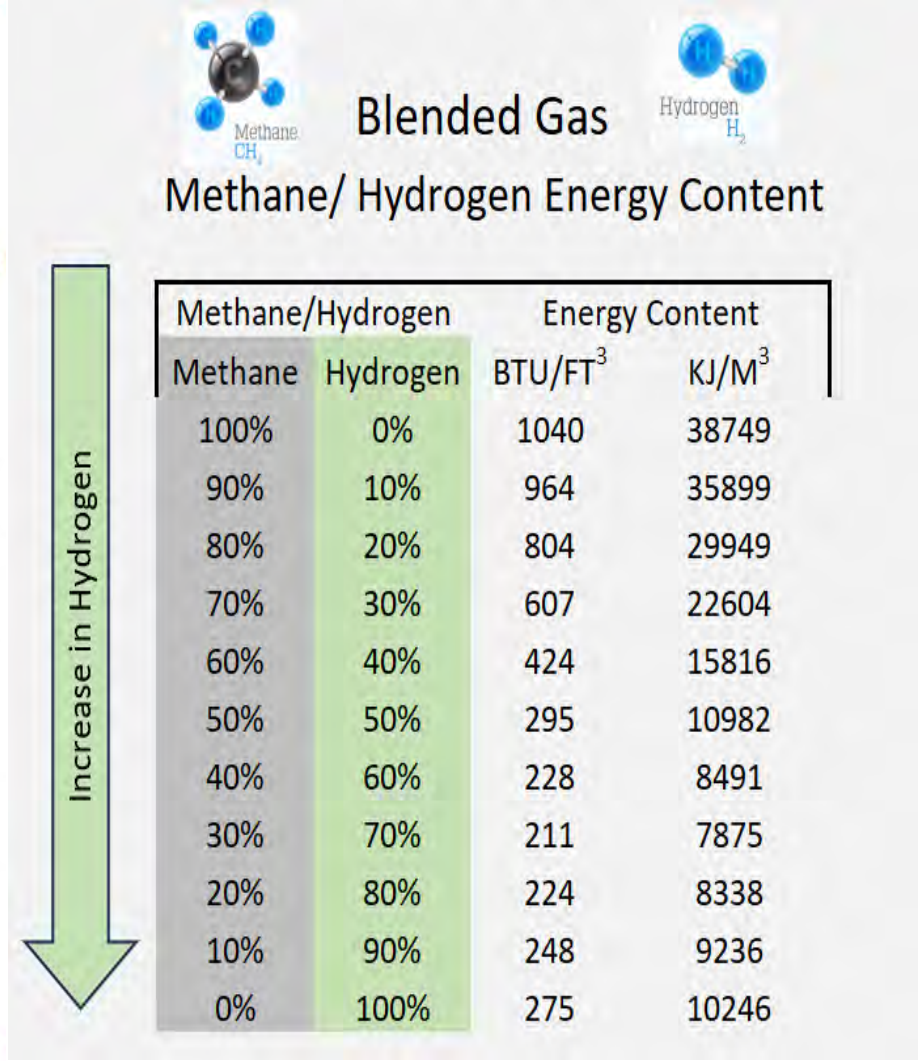
ROMET

CANADA BEST MANAGED COMPANIES

- Natural Gas across North America energy values fluctuate.
- Using BTU the energy fluctuates by 171 BTU or 18.6%.
- RNG, Peak Shaving, Hydrogen mix, etc. change the btu value.

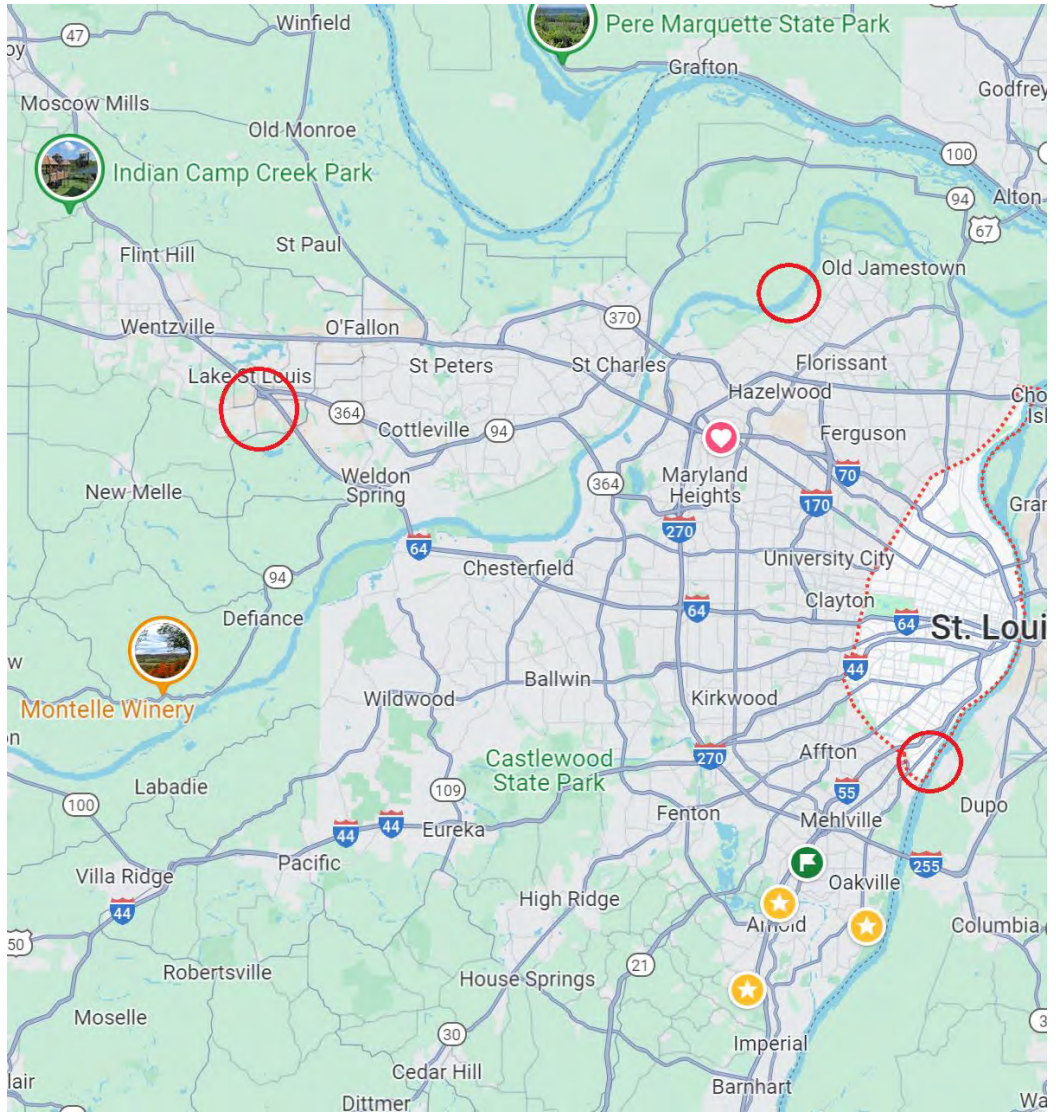
Table 25. Heating value of natural gas
Btu per cubic foot

State or district	2024 3-month YTD
Alabama	1,028
Alaska	1,003
Arizona	1,033
Arkansas	1,021
California	1,041
Colorado	1,047
Connecticut	1,030
Delaware	1,034
District of Columbia	1,035
Florida	1,027
Georgia	1,028
Hawaii	918
Idaho	1,028
Illinois	1,045
Indiana	1,053
Iowa	1,067
Kansas	1,034
Kentucky	1,048
Louisiana	1,018
Maine	1,045
Maryland	1,040
Massachusetts	1,032
Michigan	1,058
Minnesota	1,061
Mississippi	1,024
Missouri	1,023
Montana	1,058
Nebraska	1,053
Nevada	1,046
New Hampshire	1,037
New Jersey	1,041
New Mexico	1,028
New York	1,033
North Carolina	1,033
North Dakota	1,053
Ohio	1,066
Oklahoma	1,036
Oregon	1,068
Pennsylvania	1,037
Rhode Island	1,029
South Carolina	1,031
South Dakota	1,088
Tennessee	1,027
Texas	1,019
Utah	1,047
Vermont	1,045
Virginia	1,048
Washington	1,089
West Virginia	1,078
Wisconsin	1,047
Wyoming	1,067



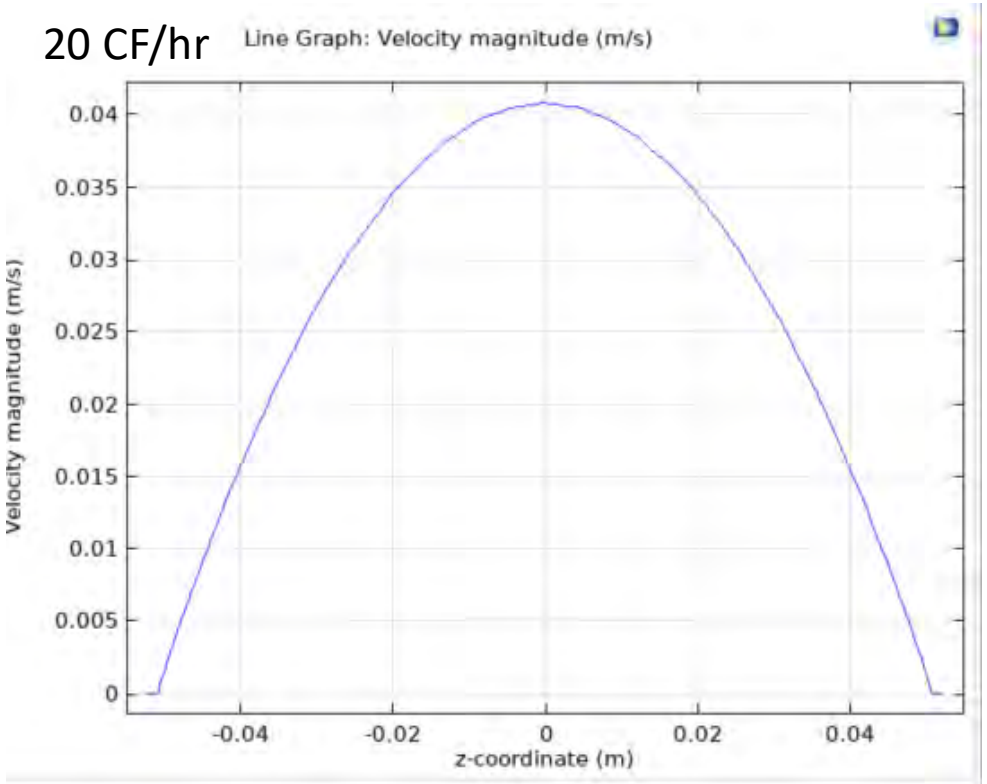
Distribution System

- Natural Gas btu variation, RNG, Peak Shaving, Hydrogen mix, etc.
- Injection point receives the highest concentration.
- The farthest point receives the least concentration.

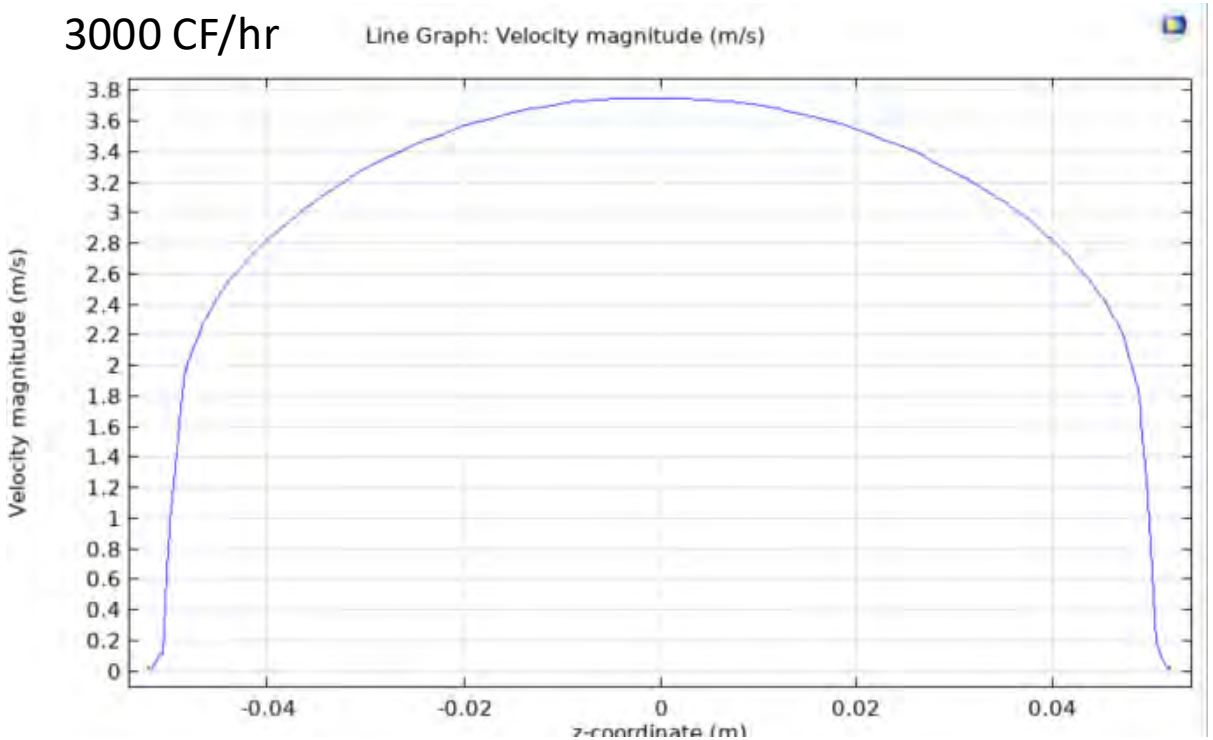


- Comparison of flow profile at a low and high flow rate
- Uniformity is much better in the high flow rate graph

20 CF/hr



3000 CF/hr



Direct integration of flow velocity profile give relative accurate value of flow rate, almost same as pre-set input value.

- **Positive displacement meter measures the volume of gas in cubic feet or cubic meters.**
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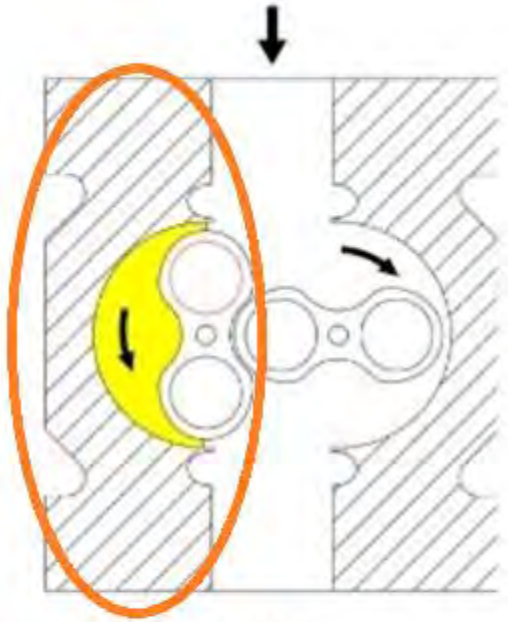
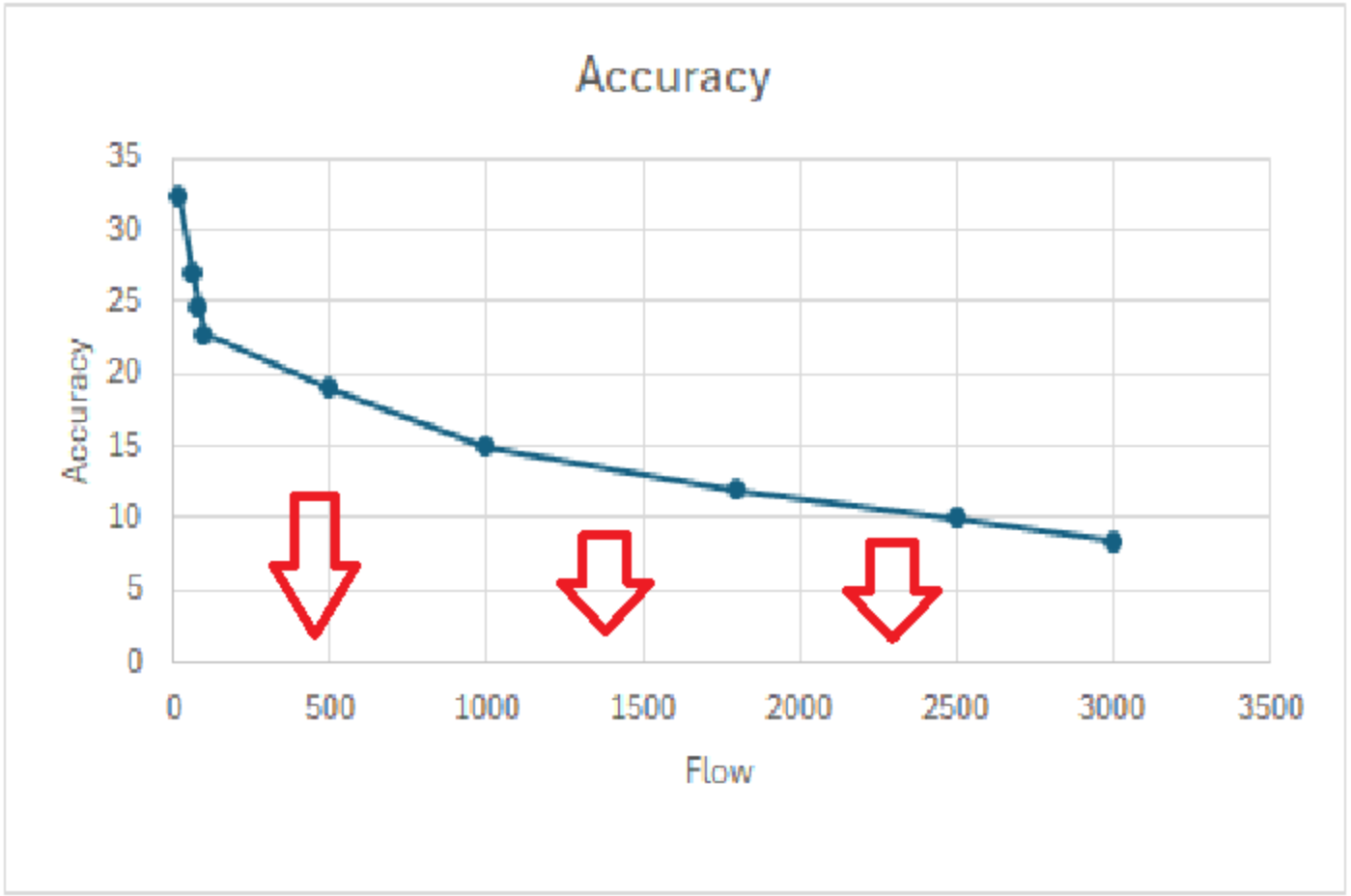


When the right impeller reaches the vertical position, a finite volume of gas is captured between the cavity and the left impeller.

- All data presented is for a 2-inch diameter pipe, with 100% methane flow

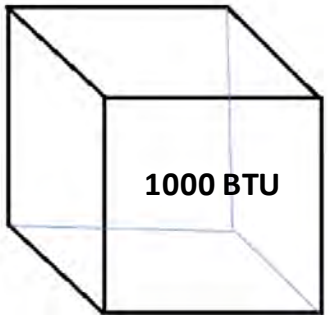
Flow Rate (CF/hr)	Volume Flow Rate(m^3/s)	Delta T (s)	Calc Flow Speed (m/s)	Calc Volume Flow Rate (m^3/s)	Relative Error (%)
20	1.66667E-04	5.55862E-08	0.10879201	2.20503E-04	32.30
63	4.95544E-04	1.58548E-07	0.310531894	6.29395E-04	27.01
80	6.29264E-04	1.97682E-07	0.387179526	7.84747E-04	24.71
100	7.86389E-04	2.43181E-07	0.476293077	9.65365E-04	22.76
3000	2.36111E-02	6.44844E-06	12.62480891	2.55883E-02	8.37

- Accuracy is determined by computer code or firmware.
- The resolution of the accuracy profile, flow range, and btu value is used to calculate the accuracy curve.
- Flow range limited by firmware.
- Sample rate battery life
- Any change in btu changes accuracy.

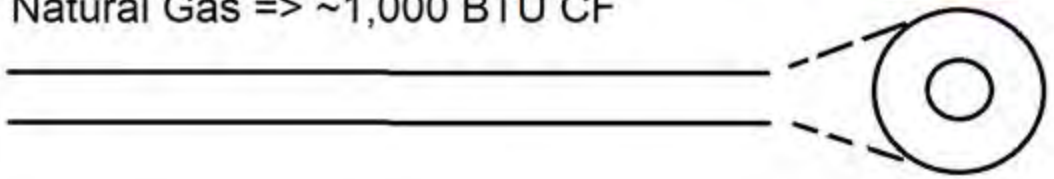


Measuring Mixed Gas

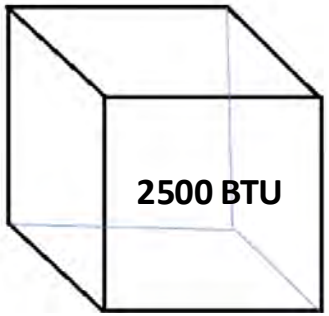
How do Appliances Handle Different Gases



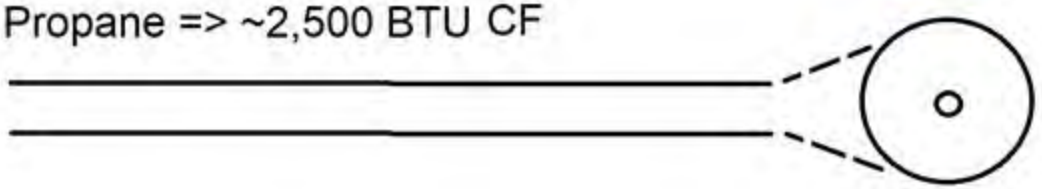
Natural Gas => ~1,000 BTU CF



100,000 BTU
Natural Gas



Propane => ~2,500 BTU CF



100,000 BTU
Propane

Manufacturer

SPECIFICATIONS

	NATURAL GAS		PROPANE GAS	
HEATING VALUE	1000 BTU	37.3 MJ/m³	2550 BTU	90.0 MJ/m³
SPECIFIC GRAVITY	0.63	0.63	1.53	1.53
GAS PRESSURE AT MANIFOLD	3.5" W.C.	0.87 kPa	10" W.C.	2.49 kPa

OVEN INPUT – STANDARD DEPTH

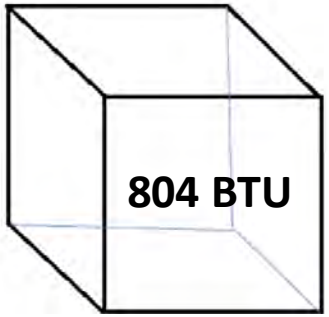
PER BURNER	20,000 BTU/HR	5.9 kW	20.000 BTU/HR	5.9 kW
PER OVEN	40,000 BTU/HR	11.8 kW	40,000 BTU/HR	11.8 kW

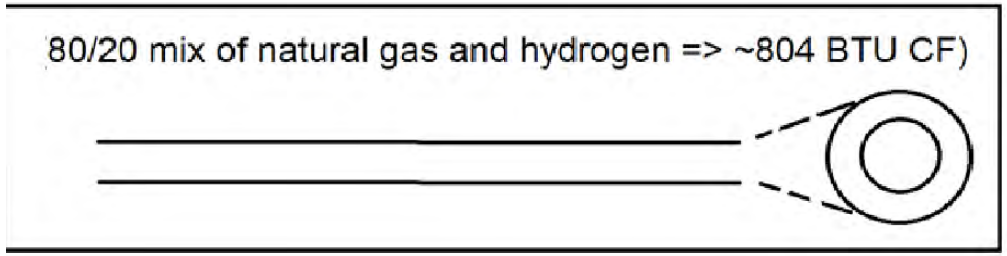
OVEN INPUT – DEEP DEPTH

PER BURNER	23,000 BTU/HR	6.8 kW	23.000 BTU/HR	6.8 kW
PER OVEN	46,000 BTU/HR	13.5 kW	46,000 BTU/HR	13.5 kW

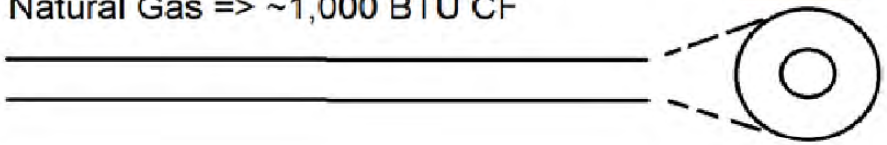
BURNER ORIFICE SIZE

STANDARD DEPTH	#44	2.18mm	#55	1.32mm
DEEP DEPTH	#43	2.26mm	#54	1.40mm





Natural Gas => ~1,000 BTU CF



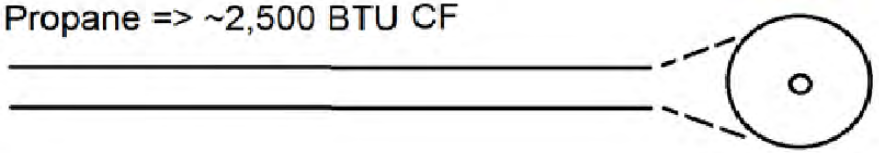
100,000 BTU
Natural Gas

80,400 BTU
80/20 Mix
Natural Gas/H2

100,000 BTU
Natural Gas/Hydrogen

100,000 BTU
Propane

Propane => ~2,500 BTU CF



- *14 Burners*
- *16,384 Flow rates*

- *How do you determine if the flow changed due to another burner being turned on OR gas density?*

Theory – Remove Flow, Measure Density

- Two ultrasonic transducers perpendicular to mixed gas flow eliminate the speed of sound calculation for flow and allow for the density of the gas to be calculated. This percentage of mixed gas can be displayed or remotely communicated.

Proof of Concept

- The simulation results for sound speed were validated using various equipment and mixed gas concentrations, including two ultrasonic transducers, a function generator, an oscilloscope, a ground source, mixed nitrogen-oxygen cylinders, a pressure regulator, and a jig.

Data and Results

- The study used ultrasonic transducers to measure the speed of sound in a gas medium, comparing it to a simulated speed. The correlation between the actual and simulated speeds of sound allowed for the determination of the composition of the mixed gas.
- The model simulation of mixed gases was useful in determining the anticipated or theoretical velocity of sound in the blend of gases. The simulation used Nitrogen-Oxygen molar ratios, temperature, and specific heat constants to compute the theoretical speed of sound in a gas mixture. The results showed high accuracy in obtaining the percentage error between the simulation and experimental results. The study also used a Romet rotary flow meter to determine the volume of the mixed gas concentration during flow.

The model simulation of mixed gases proved to be beneficial in determining the anticipated or theoretical velocity of sound in the blend of gases. Within this simulation, ANSYS Fluent and MATLAB employ Nitrogen-Oxygen molar ratios, temperature, and specific heat constants to compute the theoretical speed of sound in a gas mixture consisting of Nitrogen and Oxygen. Table 2 displays these values at a temperature of 15 C.

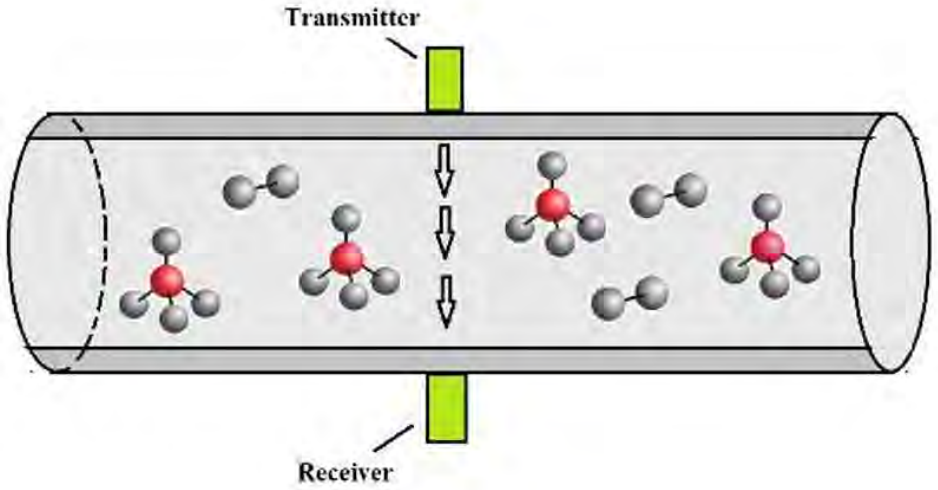
Oxygen Molar Percentage	**Nitrogen Molar Percentage**	**Simulation Speed of Sound (m/s)**
25%	75%	340.63
33%	67%	338.63
50%	50%	334.48
75%	25%	328.59

Table 2

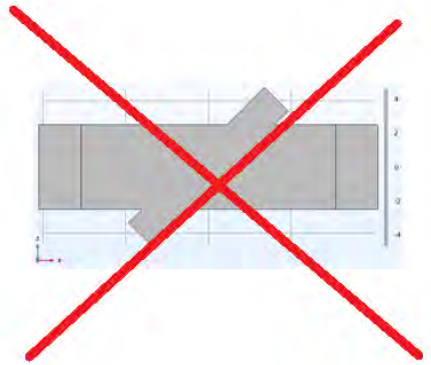
- A Romet rotary flow meter was used to measure the concentration of mixed gas, with accuracy within the specified tolerance. The meter accurately measured oxygen molar percentage, flow rate, temperature, and experimental and theoretical speed of sound.

	Flow Rate (CF/Hr)	Temperature (°C)	Experimental Speed of Sound (m/s)	Theoretical Speed of Sound (m/s)	Error %
50%	203	19	333.3	336.78	1.02
50%	244	19	333.3	336.78	1.02
Air Test with fan blower	240	22.3	344.48	344.68	0.058

The speed of sound was then compared to the simulated speed of sound. By analyzing the correlation between the actual and simulated speeds of sound, the composition of the mixed gas can be inferred and validated for current measurements. Drawing 1 illustrates a sound wave passing through a mix of natural gas and hydrogen to determine the concentration of each gas.

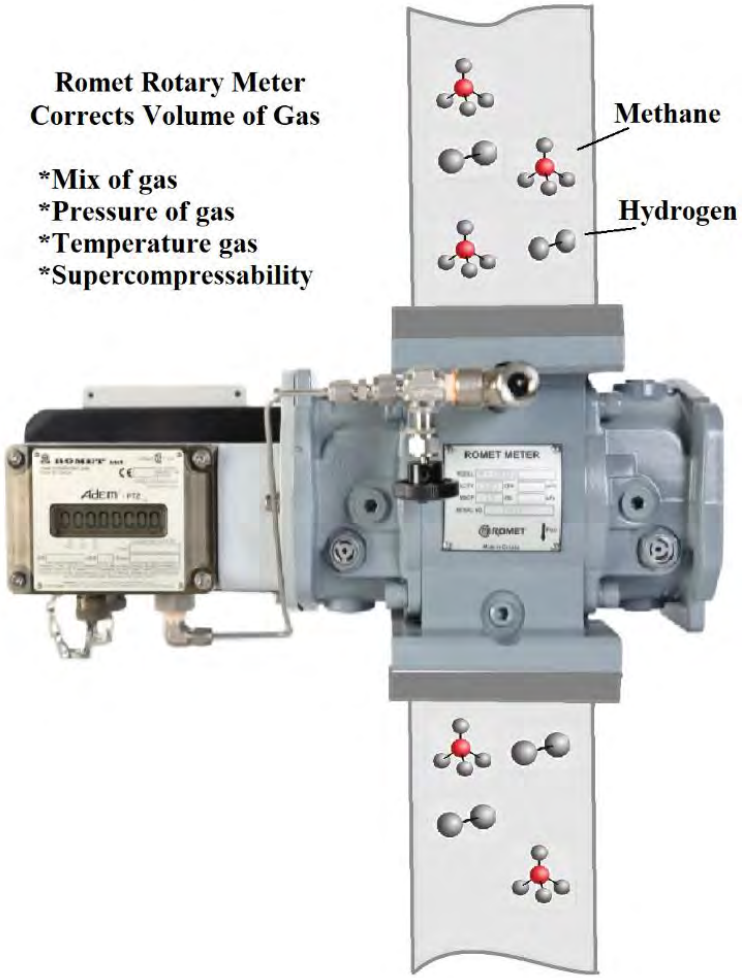


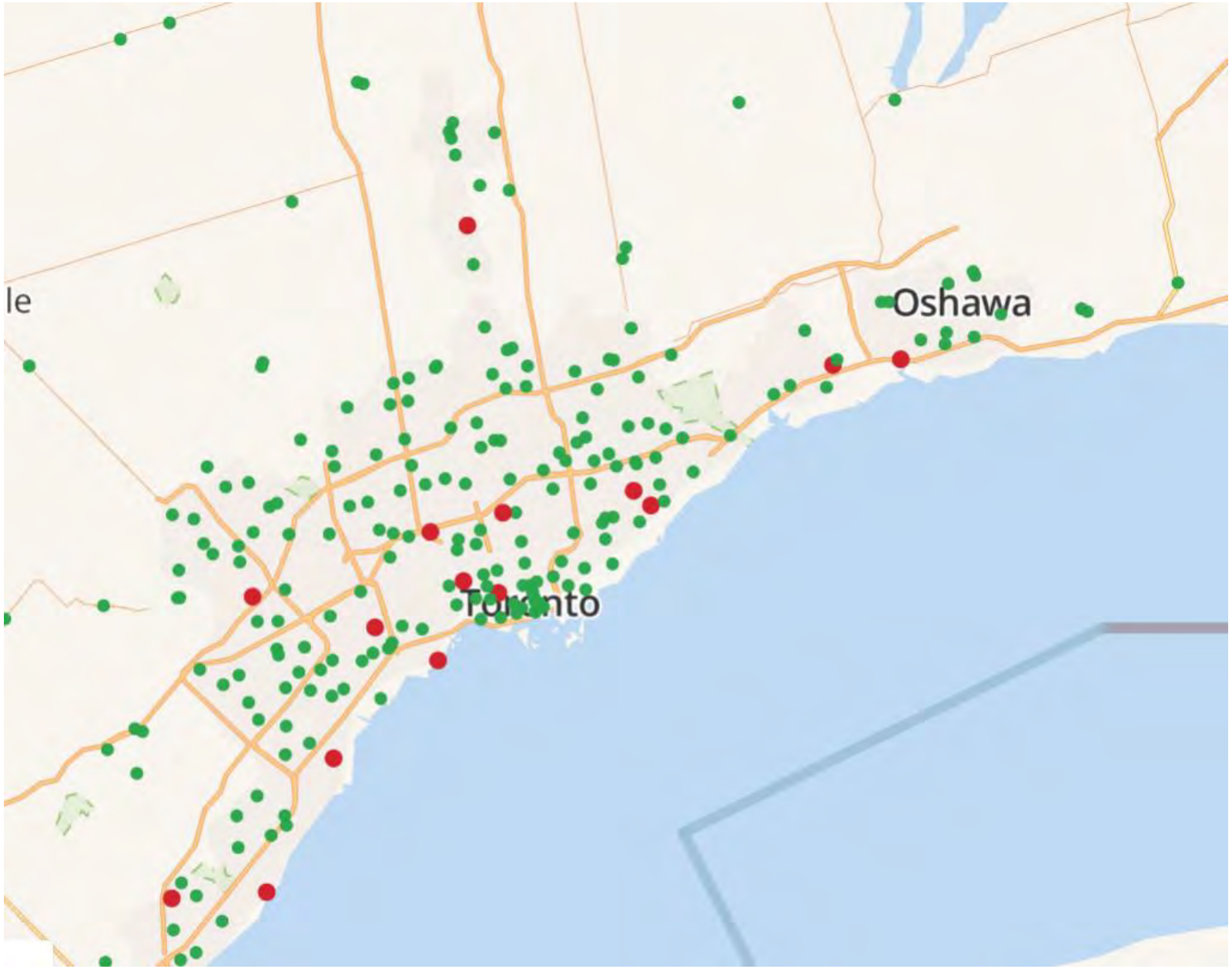
Drawing 1



Romet Rotary Meter
Corrects Volume of Gas

***Mix of gas**
***Pressure of gas**
***Temperature gas**
***Supercompressability**




Oshawa
Toronto

Conclusion

- Romet has developed a patented ultrasonic technique for measuring the concentration value of blended gas using a rotary meter. This is a fundamental solution for accurately measuring the gas concentration at the endpoint.

- Questions?