Ohio Weather and How it Affects Energy Density at the Gas Meter

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ABSTRACT

The energy contained within natural gas that is consumed by a home is difficult to measure, as an uncompensated residential gas meter will record an intake of the same volume of natural gas at different temperatures. As seasons change, the temperature of the ground in which gas lines are installed fluctuates, which affects the density of natural gas as it is billed at the meter. Engineers have long understood this and have effectively compensated these meters for high volume customers but typically not for low volume, residential customers. Understanding these variances is the subject of the expository research project. According to the Ideal Gas Law, the density of gas is inversely proportional to a change in the temperature. We will be investigating how many BTUs of energy a residential customer would receive in excess due to changes in weather when measured by the cubic foot at the residential meter.

- As temperature decreases, the energy density of natural gas increases.
- As temperature increases, the energy density of natural gas decreases.
- Uncompensated gas meters will incorrectly measure the amount of natural gas the homeowner receives.

$$h_{NG} \cong 50\frac{MJ}{kg} \quad \textit{heating value of natural gas}$$

$$\dot{Q} = \dot{m}h_{NG} = \rho\dot{V}h_{NG}$$

$$\textit{thermal energy from volumetric flow rate, } \dot{V}\textit{, of natural gas}$$

$$P = \rho RT \quad \rightarrow \quad \rho = \frac{RT}{P} \quad \textit{ideal gas law}$$

Substitute for density,

$$\dot{Q} = \dot{V}\frac{Rh_{NG}}{P}T$$

Figure 1. Manipulation of Ideal Gas Law (Dr. Atherton).

Fuel / Region	15-16	16-17	17-18	18-19	19-20	20-21	21-22
Natural Gas							
Northeast							
Consumption (Mcf**)	57.4	61.5	65.3	66.8	61.1	62.2	62.4
Price ($/mcf)	10.18	10.70	11.37	11.67	11.72	11.77	14.29
Expenditures ($)	584	659	742	780	716	732	892
Midwest							
Consumption (Mcf)	63.6	64.8	73.9	76.9	69.7	70.6	70.3
Price ($/mcf)	7.55	8.28	7.83	7.82	7.44	7.80	10.85
Expenditures ($)	480	536	578	601	519	551	763

Figure 2. Average Consumer Prices and Expenditures for Heating Fuels During the Winter (U.S. EIA).

RESULTS

- The density of natural gas varies from .711 kg/m^3 at 60*F to .739 kg/m^3 at 40*F
- A 20*F difference in temperature yields a 2,515.72 cubic feet (2.5 Mcf) of natural gas unregistered at a residential gas meter
- This yields a 3.57% variance in the actual usage versus what is accounted for at the meter
- This variance in the volume of gas yields a savings of $7 to upwards of $20 over the course of 6 months.
- If a 1 million household service area averaged these same results, a distribution company would see over 2.5 million Mcf of natural gas unbilled for.
- Temperature compensated gas meters, such as those found at natural gas power plants and steel manufacturing plants, can use over 1000 Mcf of natural gas per day and do not experience any variance between actual natural gas consumed and the billed amount

2000-GAL. BOBTAIL

	Gallons Delivered (Uncompensated)	Gallons Delivered (Compensated)	Difference
Operating at 60°F	1700	1700	0
Operating at 80°F	1700	1644	−56
Operating at 30°F	1700	1780	+80

250-GAL. TANK FILLED TO 80%

	Meter Reading (Uncompensated)	Meter Reading (Compensated)	Difference
Filled at 60°F	200	200.0	0
Filled at 80°F	200	193.4	−6.6
Filled at 30°F	200	209.4	+9.4

Figure 3. Experiment of Compensated v. Uncompensated meter (Butane-Propane News).

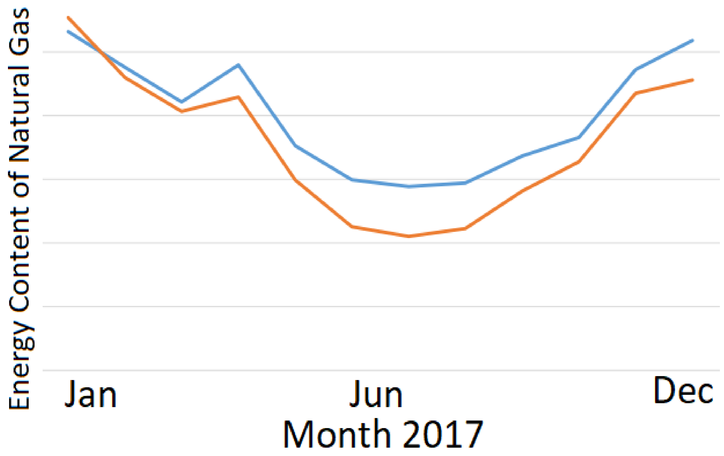

Figure 4. Differences in Energy Content by Location and Month of the year (2EA).

CONCLUSIONS

- As the temperature of natural gas increases, the energy density of the gas decreases, and vice versa. This poses a flaw in the gas meter as a change in temperature can affect your gas bill.
- Applications of the Ideal Gas Law have led to the compensation of gas meters that accurately measure natural gas usage for high volume customers using a different measuring device
- Although compensated gas meters contribute to increased accuracy, more research can always be done in receive even more accurate results.

FUTURE WORK

By divulging into a specific region and gathering information from a single natural gas distribution company, different results and conclusions could be made. For example, if the BTU content of natural gas is monitored and modified as the temperature changes, a nearly constant energy density could be had throughout the year.

References

2EA. "The Importance of Pressure and Temperature Compensation of Natural Gas Meters." *2EA*, 9 Feb. 2018, https://2ea.co.uk/the-importance-of-pressure-and-temperature-compensation-of-natural-gas-meters/.

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