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Irrigation Pumping Plant Efficiency Testing

Measuring Natural Gas at an Irrigation Pumping Plant

Nicholas Kenny, P.E. – Extension Irrigation Specialist, Texas A&M University

Accurately measuring natural gas consumption at an irrigation pumping plant is a vital aspect of evaluating engine and pumping plant performance. Unfortunately, determining natural gas consumption usually is not as simple as reading a natural gas meter.

This document will provide basic information about, as well as methods of, measuring natural gas from a common natural gas meter.

Natural Gas Basics

Natural gas is a compressible hydrocarbon fuel that commonly is found in deep underground rock formations, typically near petroleum reservoirs. Composed primarily of methane, natural gas in its processed form has a standardized energy rating of 1,000 Btu per cubic foot. In locations with natural gas pipelines and delivery infrastructure, natural gas has been a preferred fuel for irrigation motors due to low energy costs, continuous on–site delivery and compatibility with common internal combustion engine platforms.

Caterpillar 3406 - TA natural gas pumping plant.

Rockwell No. 750 diaphragm gas meter. From left to right, notice the isolation valve, regulators, meter, ¼ inch port with ball valve and inline gas filter.

Natural gas is measured in a volume, typically in cubic feet (ft3) or thousands of cubic feet (MCF). Some entities use "dekatherm" to relate the natural gas to its energy content, but in standardized gas, one MCF contains one dekatherm. The conventional unit of natural gas consumption at irrigation pumping plants is cubic feet per hour (ft3/hr.).

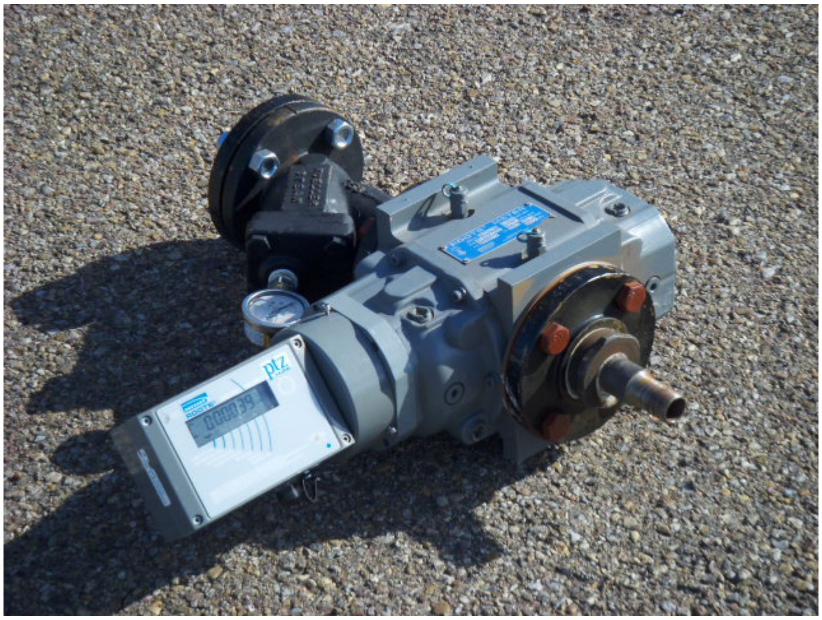
Since natural gas is a compressible gas, its on-site measurement is affected greatly by pipeline pressure, site elevation and temperatures (ambient and underground). Therefore, it is necessary to apply certain environmental correction parameters to accurately determine natural gas and, ultimately, energy consumption at an irrigation pumping plant.

The two useful methods for determining natural gas consumption at an irrigation pumping plant are: 1) physical measurement using a natural gas flow meter (gas meter) and 2) billing statements issued by the natural gas provider. Although helpful for budgeting and long-term use, billing statements usually are too general to be helpful with diagnosing pumping plant equipment. A gas meter, however, can provide immediate insight about engine and pumping plant performance.

Most common gas meters are diaphragm or gear drive meters, both of which can be fitted with analog or digital displays. A gear drive gas meter with a digital readout is the recommended setup for a technical service provider or energy auditor who will test multiple pumping plants under multiple conditions since it can be programmed to automatically correct for the aforementioned temperature and pressure affects. Analog diaphragm meters are much more common at pumping locations and often are a source of confusion among those seeking to measure natural gas consumption.

Operator and Evaluator Safety

Any field testing or work near or around irrigation pumping plants requires an awareness of multiple occupational hazards. It is always a wise use of time to visibly inspect the pumping plant location prior to performing any work or testing. An inspection should identify pinch points, moving parts (driveshaft, belts, pulleys, etc.), slippery work areas, natural hazards, gas or oil leaks, etc. *All troublesome areas should be remedied or avoided, to the extent that any unsafe pumping plant should not be tested or operated.* Eye and hearing protection and closed toed footwear must be worn at all times an irrigation



Dresser-Roots Series B rotary gas meter with digital display. This meter is fitted with 1 inch barbed fittings and an inlet filter.

engine is running. High dexterity gloves are highly recommended during the testing process. Once these personal protection criteria are met, the evaluation may commence.

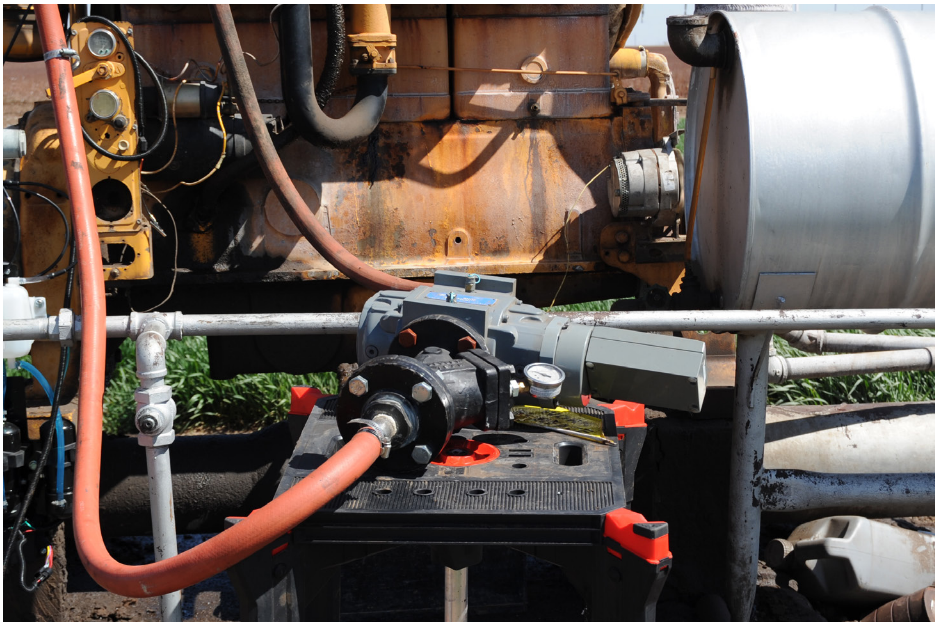
Measurement of Natural Gas at an Irrigation Pumping Plant

In many locations, an existing natural gas meter will be installed at the pumping plant location. An existing meter can be used for measurement only if the meter's correction factor is known (occasionally printed on the meter, listed on the billing statement or available from the gas company). The first step of the measurement is to identify the correction factor, if available. In cases where multiple engines are using the same meter, it will be necessary to isolate individual engines for individual tests.

In cases where it is not possible to identify the correction factor for an existing meter, it is recommended to install a portable natural gas meter of known calibration in the gas line. The first step in this process is to turn off the gas supply using an on-site isolation valve, typically in the gas line near the pumping plant. The gas line is then disconnected at a convenient point between the isolation valve and engine, usually at a pipe union, pipe fitting or hose fitting. Use caution as the gas line may still be pressurized.

The portable gas meter can now be installed in the gas line using 1 inch braided rubber hose (natural gas rated hose is preferred) and miscellaneous pipe fittings and barbs. Pipe fittings should be fitted with thread tape or a thread sealer (pipe dope) compound, and all hose fittings should be secured with hose clamps.

An appropriate pressure gauge should be installed along the natural gas line at this point to determine the line pressure at the natural gas meter. *The pressure gauge must be installed on the same side of the pressure regulator as the natural gas meter.* It is convenient to install the pressure gauge on the natural gas meter itself if a ¼ inch NPT port is available. It often is beneficial to have a variety of pressure gauges, since the gas pressure can range from a few ounces to over 30 psi, depending on where the gas meter is located. (Note: If using a portable diaphragm meter, it is recommended that the gas meter be installed after the regulator to prevent damage to the meter, since many meters are rated to 20 psi.)



Gas meters are directional, so installation orientation is critical.

Once all connections have been made, the isolation valve should be opened to pressurize the lines. The gas line and all fittings should then be inspected for leaks (sound and smell). If no leaks are identified, the engine can be started and brought to normal operating conditions. This may take a few minutes to allow for pumped water to fill and pressurize pipelines. A gas pressure reading should then be recorded for use in calculating the correction factor.

The next step is to measure the uncorrected natural gas flow. On an analog gas meter, first identify the needle gauge that measures in cubic feet. This needle gauge typically will make a measurement of 10 cubic feet in one rotation. Next, measure and record the elapsed time it takes for the meter to displace 10 cubic feet of gas. Record the uncorrected fuel volume and the associated elapsed time.

To determine the actual gas flow rate, the uncorrected gas volume must be corrected to account for elevation, line pressure and temperature. This is necessary to match standard billing contracts as well as reference to the actual energy that is being delivered to the engine. *If the correction factor for the meter and location are known, the corrected gas volume is directly determined by multiplying the uncorrected gas volume by the correction factor.*

If it is determined that a calculated gas volume correction is needed, the next step is to identify the site elevation. Since atmospheric pressure is a measure of the pressure exerted upon the Earth's surface by the air directly above the surface, the site elevation can provide a simple estimation of this pressure. The site elevation can be collected from a portable GPS unit, obtained from a reference map or estimated from a nearby community and then compared to an Atmospheric Pressure at Elevation Chart (below).

In areas where a local weather station or meteorological network is available, the meteorological report of current atmospheric pressure also can be used in determing the pressure effect for natural gas correction. Metorological reports typically list atmospheric pressure in kPA, mmHG or inHg, so a unit conversion to psi is necessary for the purpose of the included equations and processes. (1 PSI = 6.894 kPA = 51.715 mmHg (Torr) = 2.037 inHg)

The process to determine the corrected volume when a correction factor is not known is derived from the Combined Boyle's / Charles' Gas Laws, using the equation below. The temperature portion of the correction factor commonly is omitted due to its small influence during most months of the year. *A self-correcting gas meter*

Elevation (ft.)	Atmospheric Pressure (psi)
Sea level	14.70
250	14.56
500	14.42
750	14.29
1,000	14.16
1,250	14.04
1,500	13.91
1,750	13.79
2,000	13.70
2,200	13.60
2,400	13.50
2,500	13.41
2,600	13.40
2,700	13.35
2,900	13.30
2,800	13.25
3,000	13.20
3,100	13.15
3,200	13.10
3,300	13.05
3,400	13.00
3,500	12.95
3,600	12.90
3,700	12.85
3,800	12.80
3,900	12.75
4,000	12.70
4,500	12.45
5,000	12.20
6,000	11.80
7,000	11.30
8,000	10.90
9,000	10.50
10,000	10.10
11,000	9.71
12,000	9.34
13,000	8.97
14,000	8.62

will automatically correct the displayed volume and this calculation step can be bypassed.

$$V_c = V_u * \left[\frac{P_{line} + P_{atm}}{P_{meter} + P_{base}}\right] * \left[\frac{460 + T_{base}}{460 + T_{line}}\right]$$

Where: V_c = corrected natural gas volume (ft3)
V_u = uncorrected natural gas volume (ft^3)
P_{line} = gas line pressure (psi)
P_{atm} = atmospheric pressure at site elevation (from chart or local weather data)
P_{meter} = gas meter drive friction loss (psi)
P_{base} = standard or base atmospheric pressure, typically 14.7 psi (psi)
T_{base} = standard, contract, or base gas temperature, typically 60° F (°F)
T_{line} = delivery temperature of natural gas as measured at the meter (°F).

After the corrected volume is determined by a self-correcting meter, a supplied correction factor or the process above, the natural gas flow rate is determined using the following equation:

$$Q_c = \frac{V_c}{ET} * 60$$

Where: Q_c = natural gas flow rate (ft3/hr.)
V_c = corrected natural gas volume (ft3)
ET = elapsed time (minutes)
60 = multiplier to convert minutes to hours

Finally, the potential horsepower, or input horsepower, is calculated based on standard energy content of natural gas. This figure is necessary in calculating engine efficiency and overall pumping plant efficiency. The simplified horsepower equation is as follows:

$$HP_{pot} = Q_c * 0.393$$

Where: HP_{pot} = potential or input horse-power of the natural gas fuel (HP)
Q_c = natural gas flow rate (ft3/hr.)
0.393 = constant based on standardized natural gas energy content

In following good field testing practice, it is strongly recommended that multiple measurements are taken to provide an average over a certain period of testing. In any instance where measurements include a manual stopwatch, a longer duration helps minimize operator error and improves the accuracy of the measurement. It also will be helpful to develop a calculation worksheet or computer spreadsheet to use during testing to keep the process in order and allow for on-site proofing of measureme.

Necessary Testing Tools / Equipment

In addition to basic hand tools, the following will be very helpful in properly measuring natural gas at an irrigation pumping plant:

- Portable natural gas meter, either self-correcting or with known calibration parameters
- Liquid filled pressure gauge in proper pressure range, typically ¼ inch NPT male threads
- Miscellaneous pipe fittings, threaded and barbed (1 inch generally is the most common)
- 1 inch gas hose or braided rubber hose, two lengths of approximately 5 feet each
- Hose clamps
- Thread tape or thread sealer (pipe dope)
- Stopwatch
- Probe thermometer (optional)

Nonstandardized Gas

The process included in this fact sheet identifies the method for testing *standardized natural gas with a nominal energy rating of 1,000 Btu per cubic foot.* In some cases where irrigation wells are close to oil or natural gas production wells, well-head or “hot” gas is used to power irrigation motors. Since raw natural gas energy content can vary across production sites, it will be necessary to perform an energy analysis of the gas to determine engine and pumping plant efficiency. Testing methods will be identical with the exception of calculating the potential horsepower of the consumed natural gas.

Natural Gas Correction Example

Using a half-pound drive natural gas flow meter at 3,500 feet elevation, 20 cubic feet of natural gas were consumed in an average of 1minute and 45 seconds during a recent pumping plant evaluation. The gas line pressure and temperature were measured at 12 psi and 75 degrees F, respectively. Determine the natural gas consumption rate and potential horsepower, assuming standardized natural gas.

Determine the corrected natural gas volume:

$$V_c = 20ft^3 * \left[\frac{12psi + 12.92psi}{0.5psi + 14.7psi}\right] * \left[\frac{460 + 60°F}{460 + 75°F}\right] = 31.86ft^3$$

Determine the natural gas consumption rate:

$$Q_c = \frac{31.86\ ft^3}{1.75\ min.} * 60 = 1{,}092.3\ \frac{ft^3}{Hour}$$

Determine the potential horsepower of the consumed natural gas:

$$HP_{pot} = 1{,}092.3\ \frac{ft^3}{Hour} * 0.393 = 429.3\ HP$$

References

The Application of Temperature and/or Pressure Correction Factors in Gas Measurement: Combined Boyle's and Charles' Gas Laws. 2003. Dresser Roots Meters andpsi Instruments. Houston, Texas. http://www.dresser.com/documents/RMI/meters_rm135_gas_laws08.pdf. Accessed 24 May 2012.

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William B. Richardson, LSU Vice President for Agriculture
Louisiana State University Agricultural Center
Louisiana Agricultural Experiment Station
Louisiana Cooperative Extension Service
LSU College of Agriculture

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