Energy Measurement Using Flow Computers and Chromatography

Class 5130
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1. INTRODUCTION:

The means and methods of transfer of quantities of natural gas between buyers and sellers have been changing for many years. When coal gasification was used to fuel the streetlights in Atlanta, Ga. There was no reason to even measure the commodity. The municipality generated the gas, transported it, and burned it. When Frank Phillips started purchasing gas rights back in the 1930's, every one thought he was more than odd. Natural Gas was considered at that time a messy by-product of oil production that had to be disposed of. Even during the 1960's natural gas was still being flared at the wellhead in Oklahoma. During the 1940's, it was said that one could drive from Kilgore, Texas to Tyler, Texas at night without turning on the head light on your car due to all the gas flares. In this economic environment, measurement was not an issue; if you could sell the gas at all it was considered a business coup. Even then, a good price was 2 cents an MCF.

But when Henry Ford was building the Model T, gasoline was a refinery waste product that the heating oil manufacturers were glad to get rid of. Not so now. So, as with other cheap forms of energy, both the use and the infrastructure for natural gas grew.

Natural Gas prices were tied to oil prices very tightly until the 1990s. If oil went up, so did Natural Gas. When it went down, down came the gas prices. Even though many electric power plants had been built with the capability to burn multiple sources of energy, like coal, oil and Natural Gas, the increasing pressure to clean up the environment, caused Natural Gas to become the preferred energy source. This factor plus the maturing pipeline infrastructure have now led to Natural Gas becoming its own independent commodity.

In 1976 the Natural Gas Policy Act (NGPA) legislated that Natural Gas should be sold on the basis of energy instead of volume. This was done to right some wrongs that were occurring in gas measurement in the growing infrastructure in the USA. Due to the NGPA act, most natural gas custody transfer contracts today use MMBtu (1,2,3,5,7) rather than MCF as the accounting units of gas transfer. (Btu is the acronym for British thermal unit.) One Btu is the quantity of heat required to raise the temperature of one pound of water from 58.5^{o}F to 59.5^{o}F (about 1055.056 joules (SI))(3). The higher the Btu value, the more energy can be obtained from burning the gas. It doesn't take as many cubic feet of gas to heat the hot water tank if the gas is 1090 Btu instead of 940 Btu per SCF. The Btu, then, is the measure of the actual amount of heat energy contained in a cubic foot (CF) of this natural gas. An MMBtu (2,3) is calculated by:

Btu/CF* MMCF = MMBtu

With: Btu – British Thermal Units
CF – Cubic Foot
MMCF – Million Cubic Feet
MMBtu – Million Btu

So, this was the start of a growing need for timely gas quality information. Calorimetry, chromatography and finally on-line chromatography were born to the Natural Gas business. On line gas chromatography is today being chosen more often in the natural gas industry for monitoring of gas quality for the following reasons:

- The calculations of the gas volumes in modern electronic flow meters requires not only Btu(4,5,6,8) information, but specific gravity, Mol. % CO_2 and Mol. % N_2 as well.

- The current AGA-8 compressibility calculation equations also require a complete analysis for the "detailed method" of calculation of F_{PV} (8).

- While not nearly as instantaneous as calorimeters, GC's with modern micro-packed columns are providing faster analysis times.

- It is well known that the installation requirements for Chromatographs are less stringent than calorimetric methods.

2. ENERGY MEASUREMENT SYSTEM

The diagram in Figure 1, shows how an energy metering station might be configured. The gas flow for the metering station is accumulated in the system flow computer from the flow rate information received from each gas flow meter. Each flow meter independently measures and calculates the gas flow on its particular meter run.

The On-line Chromatograph takes a sample of the flowing gas from a common header and performs an analysis as fast as once every three minutes. This data is accumulated in the form of an average analysis database. This is required to provide for the needed analysis audit trail, to match the flow computer database. This allows the gas calculation to be done more precisely in the flow computers and allows the digital display on the flow computer to show actual energy flow.

Both the flow and analysis information can be sent out on communication links using serial digital communication protocols to PC based host software programs.

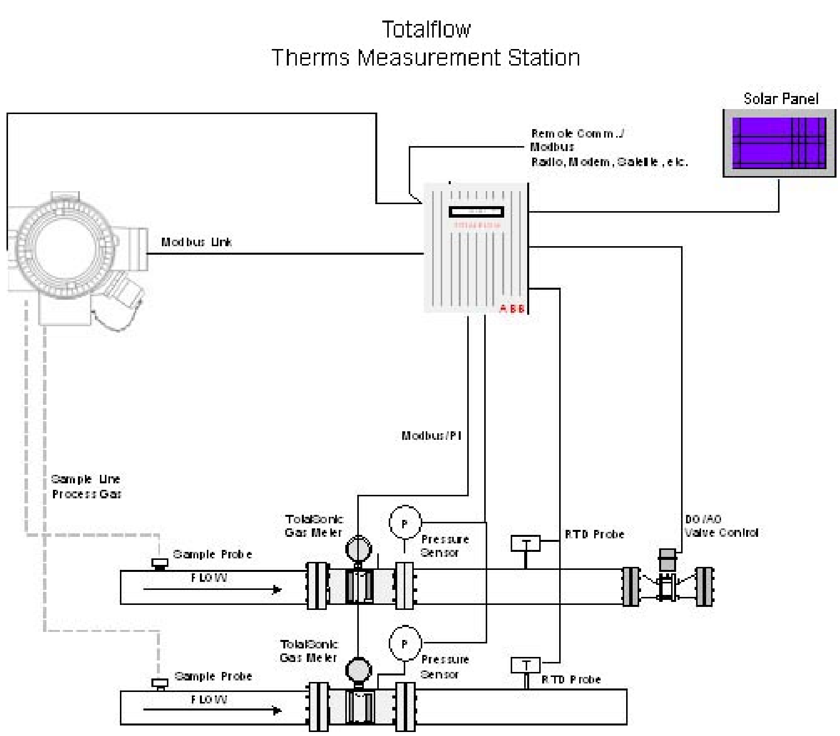


Figure 1: Total Energy Measurement system

2.1. Btu ANALYZER / GAS CHROMATOGRAPH

The Btu Analyzer, Figure 2, is based on gas chromatograph principle. This device automatically takes gas samples from the gas pipeline and breaks the sample down to determine its molecular composition and heating value with custody transfer accuracy. The resulting information is required to calculate the gas density, super compressibility and its energy content. Using this modern type gas analyzing equipment, information about the gas composition is available within minutes. The on board controller will store the analytical results in registers from which the latest data values can be read by the system computer. These data register are updated whenever a new analysis is completed which is about every 3 minutes.

Standard serial communication links (RS232, RS 422 and RS 485) using Modbus protocol allow easy access to the latest analytical gas data by flow computers, supervisory systems and computers running Man-Machine Interfaces (MMI). Available are 3 remote and one local communication port. Supported communication protocols range from remote/local MMI, engineering interface to printers/consoles, ASCII (HCIA) host computer interface, Modbus, DSFG and PTB printouts.

An overall modular design reduces the mean-time-to-repair from weeks to as short as hours. The required time between calibrations has been extended to months using state of the art digital technology.

Figure 2:
Btu Analyzer

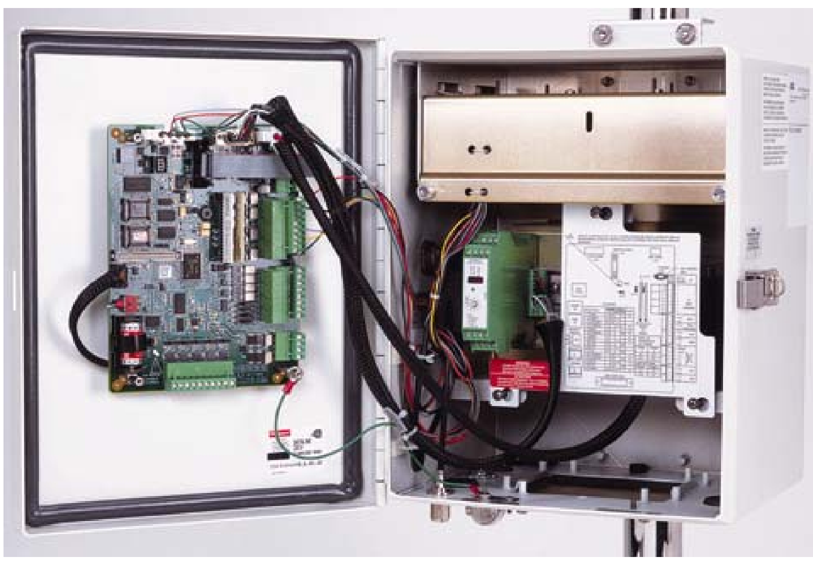
2.2. RTU/FLOW COMPUTER

The RTU, Figure 3, in this system is used as the central processor unit. It reads the flow data from the flow meter as well as the analysis data from the chromatograph. The RTU calculates an accurate flow rate and energy valve from the data.

The RTU is designed so it can be solar or AC powered. It has a 2 by 24 display for displaying user selectable data. For orifice applications the RTU has an internal multi variable transmitter for measuring AP and DP. The RTU can measure data from up to five meter tubes.

The RTU's standard IO consists of 5 analog inputs, 4 digital inputs, and 4 digital outputs. Additional IO modules can be added to the RTU as needed to fit your requirements.

In addition to the flow measurement the RTU can be used for additional site automation such as tube switching, valve control, gas blending, etc. The RTU supports a trend database for trending additional IO points.



The RTU can supports three on board communications ports. One local RS-232 port for communication with a hand held programming device and two other remote ports that can be either RS-232 or RS-485 ports. The remote ports support a variety of protocols such as modbus ASCII, modbus RTU and Totalflow protocols. Additional serial ports can be added using the plug in IO modules.

Additionally, the NGC analyzer shown in Figure 2 is capable of performing RTU functions due to the powerful on board processor. By bringing in primary and secondary element inputs, such as a multivariable transmitter, Figure 4, the onboard processor can perform volume measurement calculations as well as providing the gas quality information needed to do energy measurement calculations.

Figure 3. X series RTU/FCU for integrating the USM and Btu data

Figure 4
NGC with multivariable transmitter

2.3. VOLUMETRIC GAS FLOW METER

The energy metering system described here (9) utilizes a compact and robust ultrasonic gas flow meter as shown in Figure 4. It uses the compact 3D flange-to-flange dimension configuration for all available sizes. Transducers are available in versions which require a depressurization on the meter body for transducer removal and in under pressure removable transducers using a special compact retraction tool.

For measurement the well-known and proven transient time ultrasonic measurement principal is applied, which together with the latest technology in signal processing results in a highly accurate and reliable volumetric gas flow meter. The sensor technology uses miniaturized ultrasonic transducers with very low pressure and temperature cross-sensitivity as shown in Figure 5. This enables the meter to operate over a wide temperature and pressure range down to ambient pressure. All transducers are constructed of titanium and do not require matching layers or dampening materials they are balanced mechanically and electronically. The resulting powerful transducer has greatly improved performance properties, which allows it to operate and function at ambient pressures and in gases with high CO_2 concentrations.

The volumetric flow rate is determined by integrating the actual flow velocity profile from local gas velocity information received from the ultrasonic paths distributed over the cross-section of the pipe. This information is processed by the onboard computer taking into account the meter's geometry and characteristics. Information about actual measured flow rate, path velocity, speed of sound and counted volume is then passed on to the system flow computer using a digital communication interface. Flow rate and flow direction information is also available over digital outputs.

The typical ultrasonic gas flow meter (Figure 4) has no moving parts and therefore is virtually maintenance free. A wide range of communication options including remote diagnostics reduces the overall required maintenance. The meter is capable to perform self-checks and to report any malfunction

directly to the operator. In case of intermittent or permanent path failures the meter can maintain operation using the remaining paths and substituting historical data for the failed path with minimal affect on the overall meter accuracy.
Additional meter information such as path velocities, speed of sound and diagnostic information is available via the serial communication interface .

Figure 4: Ultrasonic Gas Flowmeter

2.4. System Health Check

To assure proper system operation and high data quality each component of the system needs to function within set specifications. Therefore each measuring device constantly performs a number of operational and status checks. If problems or maintenance situations occur it is communicated to the system's central commuter, logged and made available to supervisory and/or monitoring systems. Each system component can be accessed with local and/or remote diagnostic software to determine operational status and to analyze problems.

A simple and powerful way to monitor system performance is by comparing the speed of sound information available from the ultrasonic gas flow meter to speed of sound for natural gas calculated from the gas composition analysis available from the gas analyzer. In order to perform this calculation a commercially available software package can be used or the method described in AGA 10 (10) can be licensed and programmed. Such calculations and comparisons will be performed in scheduled time intervals or continuously and customer set deviations and limits will trigger alarms and indicate system performance problems.

3. COMMUNICATIONS

The system flow computer communicates serially with the system gas analyzer. Modbus protocols for the Totalflow NGC 8200 gas analyzer and most other industry standard gas chromatographs and analyzing equipment are available. The flow computer is requesting the required information from the data register of the system gas analyzer. If an on-line gas analyzer is not available the required information can be entered into the flow computer and updated whenever new values are available.

Using a state of the art ultrasonic flow meter it is best to use the serial communication interface to the flow computer. Modbus protocols to the ultrasonic flow meters used in the gas measurement industry are available. Also, frequency and analog flow metering interfaces to other type of gas flow meters are offered.

All process relevant data are stored in the none-volatile memory of the flow computer averaged over a user selectable time interval. This information including trending files and the system monitoring data from the audit trail can be accessed through local and remote communication interfaces using modem, radio, satellite, etc. as shown in Figure 7.

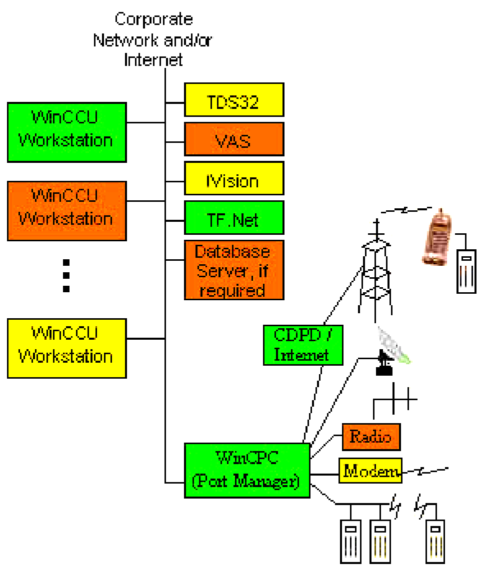


Figure 6: - Communication with corporate network and/or Internet

4. CONCLUSIONS

The new energy measuring system presented is based on well-known ultrasonic technology but offers a number of innovations. It shows not only a very compact meter for field use but also demonstrates the tight integration of the measuring system including solar power and radio communication to enable an use in remote locations.

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