BASICS OF ELECTRONIC VOLUME CORRECTOR FOR NATURAL GAS

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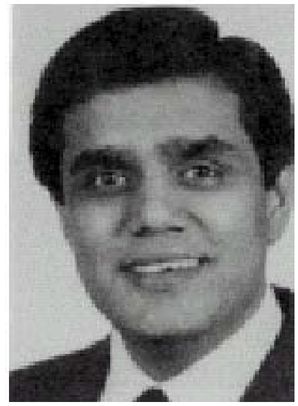

Introduction

Today, as we move natural gas from the well head to the burner tip, there are many electronic instruments used along the way for measurement and control. One such instrument is an *electronic volume corrector*.

In the natural gas industry, the *electronic volume corrector* is referred to as a secondary device used for measuring live corrected gas volume through either a turbine meter, rotary meter, or any positive displacement meter. Even though the *electronic volume corrector* functions like a flow computer, typically a secondary device used for measuring a gas volume through an orifice meter is referred as an *electronic flow computer*.

The focus of this paper is on only an *electronic flow corrector*. The paper is intended for the new user of an *electronic volume corrector*; however it may provide a review for the current users.

Basic Functions

The basic function of an *electronic volume corrector* is to totalize live, uncorrected gas volume flowing through either a turbine meter, rotary meter, or any positive displacement meter, and convert it to the live, totalized corrected gas volume by applying appropriate correction factors.

The *electronic volume corrector* totalizes the uncorrected gas volume by receiving pulse signals from the flow meter. The pulse signal represents the amount of gas in cubic feet through the flow meter. Most of the electronic correctors measure live flowing gas pressure and temperature.

The live pressure and temperature, along with the configuration parameters, are used to calculate appropriate correction factors. For an application where gas pressure and temperature varies by a negligible amount, the corrector uses fixed pressure and temperature for calculating appropriate correction factors instead of using live pressure and temperature.

The corrected gas volume, along with other related parameters, may be displayed on a local display. It also provides electronic data storage for hourly gas volumes, daily gas volumes and other related parameters.

Most of the *electronics volume corrector*s provide local and remote electronic communication with another computer for configuration and data collection.

Calculations

The flow of gas causes the meter drive to rotate at a speed proportional to the flow rate. The meter drive revolution is counted by the corrector in the form of a pulse input signal and converted to a totalized uncorrected gas volume. As the gas volume is totalized at a flowing pressure and temperature, the corrector corrects to the specified base conditions to get a live corrected gas volume. The calculations are performed based on the latest edition of AGA 7 (American Gas Association Report 7).

To understand the corrector's function it is important to understand how uncorrected gas flow, pressure, temperature, and supercompressibility come into effect for converting to corrected gas volume. This all begins with understating the basic gas laws.

The *basic gas law* relationship is expressed as follows:

For flowing condition

$$(P_f)(V_f) = (Z_f)(N)(\boldsymbol{R})(T_f)$$

For base condition

$$(P_b)(V_b) = (Z_b)(N)(\boldsymbol{R})(T_b)$$

Where,
P = Absolute pressure
V = Flowing Gas Volume
Z = Compressibility
N = Number of moles of gas
R = Universal gas constant
T = Absolute temperature

The subscript "*f*" indicates flowing condition, and subscript "*b*" indicates base conditions.

Since R is a constant for the gas regardless of pressure and temperature; and for the N is a same number of moles of gas, the two equations can be combined to get:

$$V_b = V_f \left(\frac{P_f}{P_b}\right)\left(\frac{T_b}{T_f}\right)\left(\frac{Z_b}{Z_f}\right)$$

Flow rate at flowing conditions can be represented by:

$$Q_f = \left(\frac{V_f}{t}\right)$$

Where,

Q_f = Volumetric flow rate at the flowing conditions

V_f = Volume measured at flowing conditions during time interval t

t = Time

Flow rate at base conditions can be represented by:

$$Q_b = Q_f \left(\frac{P_f}{P_b}\right)\left(\frac{T_b}{T_f}\right)\left(\frac{Z_b}{Z_f}\right)$$

Where,

Q_b = Volumetric flow rate at the base conditions

$$Pressure\ Multiplier = \frac{P_f}{P_b}$$

Where,

$$P_f = P_g + P_a$$

P_g = Flowing pressure in gage units

P_a = Atmospheric pressure in absolute units

P_b = Base pressure, absolute units

$$Temperature = \frac{T_b}{T_f}$$

Where,
T_b = Base temperature in absolute units
T_f = Flowing temperature in absolute units
Absolute temperature (in degree Rankin) :
Absolute temperature (in Degree Rankin) :

$$(^{\circ}R = (^{\circ}F + 459.67^{\circ}$$

$$Compresssibility\ Factor = \left(\frac{Z_b}{Z_f}\right)$$

Where
Z_b = Compressibility at base conditions
Z_f = Compressibility at flowing conditions

The compressibility multiplier can be evaluated from the supercompressibility factor F_{pv}, as follows:

$$\frac{Z_b}{Z_f} = (F_{pv})^2$$

Supercompressibility values may be determined from the latest edition of AGA Report No. 8, or as specified in contracts or tariffs, or as mutually agreed to by both parties. The older supercompressibility calculations were determined from AGA NX-19 publication.

Basic Components

An *electronic volume corrector* typically consists of the following main components:

- enclosure
- processor board
- display
- keypad
- pressure transducer
- temperature probe
- mechanical index
- power supply
- local communication port
- remote communication options

Fig.1. Example of an electronic volume corrector manufactured by Eagle Research Corporation.

Enclosure is weather proof and suitable for outdoor use. Most of the enclosure provides a place for putting a security seal on the door or putting on a lock.

Processor board is the main brain of an *electronic volume corrector*. It is a printed circuit board assembly (PCBA) with all the electronic parts necessary for the volume corrector. The PCBA has appropriate connectors and terminals for the connection to other accessories, e.g., pressure transducers, temperature transducers, index wiring, display etc.

The processor board is nothing but a microprocessor based computer on a board. It has power supply regulators, microprocessor, memory, analog/digital converters, analog inputs, digital inputs, analog outputs, digital outputs, counters, signal conditioning and several supporting circuitries.

Fig. 2. Example of a microprocessor based processor board PCBA.

The processor board internally is powered by 5 or 3.3 VDC (Volts Direct Current) depending on the technology used on the board. The on-board power supply regulator allows the corrector to be powered externally by typically 12VDC. This voltage requirement may vary for different manufacturers, e.g., one corrector allows input power from 7 to 30 VDC.

Display provides a way to view the related parameters locally at the corrector. The display is a Liquid Crystal Display (LCD). The LCD may be a part of the processor board or a separate PCBA connected to the processor board.

Most of the LCDs are designed to display a limited number of characters. In this case, the parameter value is preceded by a letter designator, e.g., UV for uncorrected volume.

Different parameters may be scrolled by a button or by touching a magnet on a designated area. If the magnet is allowed for scrolling, a magnetically activated reed switch is used on the display PCBA.

Keypad is used for a local data entry. Keypad allows configuration of corrector parameters, or for selecting which parameters to view on the local display. Not all correctors may be equipped with a keypad.

Pressure transducer is a sensor used in measuring flowing gas pressure. It generates proportional electrical signals as a function of the pressure imposed on its pressure sensor element.

One side of the pressure transducer is connected to the processor board's analog signal input channel. The other side of the pressure transducer is connected to the pressure tap provided by the manufacturer on the gas meter.

Proper valve and tubing is installed to allow maintenance and calibration of the transducer. The pressure transducer is available in gauge or absolute types.

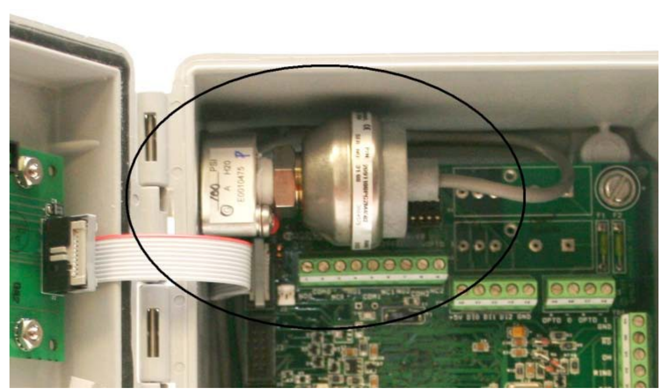

Fig. 3. Example of a pressure transducer inside a corrector.

Temperature probe is a Resistive Temperature Detector (RTD) sensor used in measuring flowing temperature. It generates proportional electrical signals as a function of the temperature imposed on the RTD. The temperature probe has a metal jacket with an encapsulated RTD and a flexible wire up to thirty feet of length. The wires from the probe are connected to the processor analog input or RTD input.

The probe is inserted in the thermo well that is installed in a gas pipeline. In some cases the temperature probe is inserted in to the meter temperature port.

Fig. 4. Example of a temperature probe.

The Thermowell is a pressure-tight receptacle that is inserted in the gas pipeline. The temperature probe is inserted in the thermowell. The thermowell facilitates inserting and removing a temperature probe to measure a gas flow temperature without the need to shut off the gas flow. The adapter is used with the temperature probe to thread and secure the probe in to the thermowell. The thermowell is selected based on the gas pipe line size.

Fig. 5. Example of a vertical index.

Mechanical index provides the mechanical counter readout for uncorrected gas volume. It also has a mechanism to provide a pulse input signal proportional to the gas volume to the processor's pulse input.

It is mounted on the meter base in such a way that the meter's instrument drive couples with the index's shaft mechanism. The instrument drives the mechanical shaft of the index. The index may have a gear adjustment to change the final output shaft revolution ratio. The final output shaft has a magnet that activates hermitically sealed reed switches upon every revolution to generate a pulse signal for the processor. The reed switch may be a part of the circuit board integrated to the index or installed in the corrector with a close proximity to the output shaft of the index.

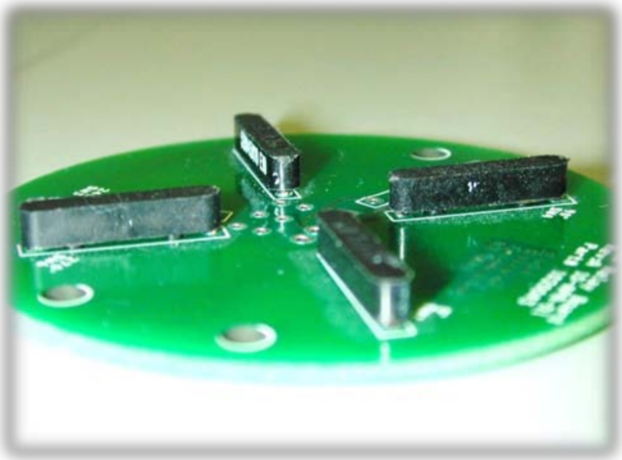

Fig. 6. Example of a circuit board with reed switches for the pulse generation from a rotating magnet on an index shaft.

When setting up the corrector the internal index mechanism can be adjusted for a meter's clockwise revolution or counter clockwise revolution. The masking kit is use to mask the mechanical readout of the index to represent cubic feet with proper multipliers.

The index may come with vertical or horizontal counter readouts.

Power supply for the corrector is available in several different types such as battery pack, uninterrupted power supply (UPS), Solar Power Supply, and Thermoelectric Generator. The power supply is normally sized based on the corrector's daily run/sleep time and communication requirements.

Local communication port is typically a serial port with a connector on the side of the corrector enclosure. The serial port allows communication to a laptop or a handheld computer locally. A special data communication cable may be required between the corrector and the computer.

Today, many correctors have wireless communication options, e.g., Bluetooth wireless.

Besides doing the live corrected gas volume calculations, *Remote communication options* are a great benefit to an *electronic volume corrector*. One of the main innovations the electronic revolution is having the ability to communicate remotely with the field device.

There are several remote communication options available with correctors. This includes dial-up phone line, wireless radio, cellular modem, Ethernet, and satellite. For each option, appropriate modem or interface boards need to be connected to the corrector's processor board.

Power Options

Battery Pack is a portable power supply that can be installed inside the corrector. The most popular types of battery packs include alkaline batteries or lithium batteries. It is important to have fuse and/or current-limiting resistor in the battery pack to prevent over heating or explosion in case of an accidental shorting of battery terminals.

Fig. 7. Example of a battery pack.

These batteries are not rechargeable. The battery must be replaced before it reaches the low voltage limit required to run the corrector. To optimize the battery life the corrector can be setup to wake-up at a periodic interval to do the calculations, e.g., every 10 minutes. Also the battery should be sized to handle any data communication requirements.

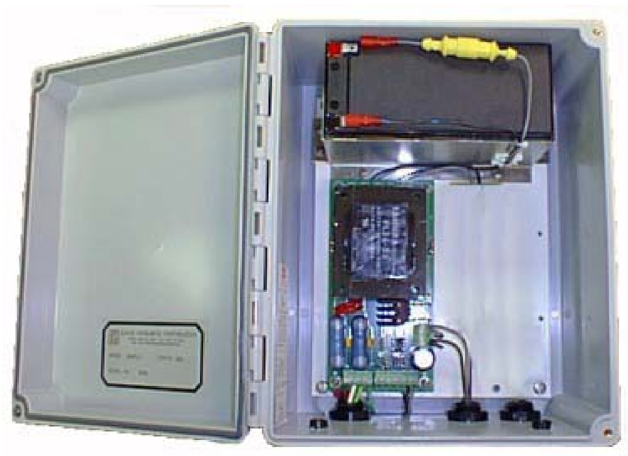

Fig. 8. Example of an Uninterrupted Power Supply.

Uninterrupted Power Supply (UPS) consists of rechargeable battery and Alternating Current (AC) to DC charger. The UPS is powered by AC voltage, typically 110 VAC. Upon the AC power failure, the corrector keeps on running due to the rechargeable battery. The size of the battery depends on how long the corrector can operate during the power failure.

Solar Power Supply consists of a solar panel, mounting bracket, solar charger, and a rechargeable battery. The solar panel is mounted on a pole with a mounting bracket. The solar panel surface is adjusted to get the most direct sun exposure. The size of the solar panel depends on how much average sun light is available per day and how much charging current is required. The size of the battery depends on how long the corrector should run without sunlight.

Thermoelectric Generator (TEG) burns gas from the pipeline to generate heat, then converts heat into an electrical energy. It also has a rechargeable battery. The size of the TEG and the battery depends on the power requirement of the corrector to operate continuously.

Other Remote Communication Options

As mentioned earlier, there are several remote communication options available with correctors. This includes dial-up phone line, wireless radio, cellular modem, Ethernet, and satellite. For each option appropriate modem or interface boards needs to be connected to the corrector's processor board.

For each communication type the proper speed of data communication (baud rate) and any related communication related parameters needs to be setup in the corrector.

Another important parameter is unique "Site ID", corrector identification address. This is important for the remote measurement system or supervisory control and data acquisition system (SCADA) to identify the field corrector while communication with it.

Dial-up Phone Line uses plain old telephone line to communicate with the corrector. The corrector requires being equipped with a dial-up modem. This is common form of remote communication.

Wireless Radio communication option requires radio modem, transmitter/receiver, coax cable, and antenna. Any wireless communication requires line-of-site between two wireless radio devices. There are two types of radios: licensed and unlicensed radio. Licensed radios require a dedicated frequency license from the Federal Communications Commission (FCC). The most popular unlicensed radios are frequency hopping spread spectrum (FHSS) type radios.

Cellular Modem is becoming one of the most popular methods of communicating with electronic volume correctors. In the past, cellular technology supported circuit switched data. This allowed a dial up phone modem from a remote computer to connect with a field corrector. This technology has been phasing out.

Today, cellular modems use internet protocol (IP) technology. Instead of having a phone number, the field cellular modem has an IP address (e.g. 11.56.73.128). This allows the remote computer connected to the internet to communicate with the field corrector. The data service is provided by most wireless phone service providers. Depending on the service provider, different technology cell modems are used.

Satellite Modem installed in a corrector with an antenna that provides communication with a satellite in the sky. The satellite communicates with an earth station. The remote measurement computer communicates to earth station's computers (servers) to get the field corrector's data. Today, satellite communication supports two-way data communication. The data service is provided by a satellite service provider.

Setup and Configurations

For the proper operation of the corrector, each corrector is setup initially for related calculation parameters, power management parameters, alarm limits, and communication parameters. The following is a partial list of related parameters that are required to setup for the calculations.

Cubic Feet per Pulse (CF/Pulse) is a value representing how many cubic feet of gas each pulse received from a meter represents. This can be determined by knowing the cubic feet per revolution of the meter and the pulse per revolution of the index or an external pulser.

Uncorrected Volume Accumulator Multiplier value represents how the uncorrected gas volume is totalized, e.g., 1000 represents MCF.

Corrected Volume Accumulator Multiplier value represents how the corrected gas volume is totalized, e.g., 1000 represents MCF.

Atmospheric Pressure value can be obtained by using a manometer at the site. Otherwise, it can be obtained by the following equation which is based on National Oceanic and Atmospheric Administration publication, *U.S. Standard Atmosphere, 1976*.

$$P_a = 14.6960\ x\ (1 - 0.00000686\ x\ Elevation)^{5.2554}$$

Base Pressure is a value of an absolute pressure at a base condition, typically 14.73 PSIA.

Base Temperature is a value of an absolute temperature at the base condition, typically 60 °F.

Supercompressibility Method is specified to let the corrector know if it would use AGA NX19, AGA 8 Gross method 1, AGA Gross Method 2 or AGA detailed method to calculate the supercompressibility.

Wakeup Interval is a value, most likely in seconds, to let the corrector know how often to wake up and do full calculations. This is to take advantage of a power management feature of correctors to maximize the battery life.

Installation Considerations

Mounting of a corrector is dictated by the kind of flow meter available, and by space requirements. Most of the meters are available or can be ordered with an instrument drive. The corrector can mount directly on an instrument drive. In some cases the corrector without an index can be pipe or wall mounted. In these cases, an external pulser, or the pulse signal directly from the meter, is connected to the corrector.

Grounding is an important part of installing electronic equipment. Always follow the local, state, and National Electric Codes for proper wiring and grounding practices. In the event the gas pipe is cathodically protected, care should be taken not to ground cathodic protection. In this case it is important to isolate the electronics from the pipe line using isolation flanges, couplings, etc.

Surge Protection is an important way of protecting the electronics from external surges through the field wiring. Any field wiring entering and leaving the *electronic volume corrector* should be protected with a surge protector. The surge protector is only effective if it is grounded properly. In case of a surge on a field wire it may sacrifice the surge protector; however, it may save costly electronics.

Hazardous location is another consideration when installing the field devices. For classification of locations for electrical installations in gas utility areas, refer to the publication by A.G.A report XL1001, (December 2010).

Calibration

It is important that all the measured parameters are accurate. To ensure accurate measurement, the pressure and temperature should be verified against a known standard. In case the deviation is detected the calibration should be performed to bring the transducer in compliance. Even though pressure and temperature *electronic volume correctors* are calibrated from the factory, upon field installation the calibration must be verified to detect any installation related effects.

Today, most of the electronic volume correctors use software calibration. The software calibration does away with the need for laborious adjustments, thereby simplifying field calibration.

For pressure, a dead weight tester, a hand pump or high end calibrator is available for the field calibration. For temperature, use of a dry block calibrator or temperature bath for calibration is recommended.

Maintenance

The electronic corrector has minimal moving parts, so it requires minimal maintenance. Following certain maintenance guidelines will minimize the corrector failure and increase the effective life.

Enclosure maintenance is a program of routine inspections to ensure the integrity of the door's seal and the various ports in the box's exterior. Excess moisture can ruin electronics if allowed to accumulate within the enclosure. Although most circuit boards are conformally coated to protect against humidity. The wiring connections and various exposed metal surfaces are susceptible to corrosion in extreme cases of interior humidity.

Ensure that the mounting arrangement for the unit is secure and provides a stable platform for termination of the pressure tubing, conduits, etc. Also, verify the integrity of the enclosure lid seal. Check the lid gasket for deterioration, chemical damage, tears, or compression. Check for damaged cord grips.

Battery Pack replacement may be necessary under certain circumstances. *A*ny non-rechargeable battery pack, under normal operating conditions, will eventually drop below the voltage level needed to maintain corrector power. Its lifespan is determined by dozens of variables specific to each corrector, and therefore difficult to predict.

The rechargeable battery pack, under normal operating conditions, should provide many years of productive service before needing to be replaced. When it becomes apparent that the rechargeable pack cannot maintain its charge during the hours without sunlight, replacement is in order.

Calibration is a crucial element of any program of scheduled maintenance. Today, most of the electronic volume correctors use software calibration. The software calibration does away with the need for laborious adjustments, thereby simplifying field calibration.

Other Features and Options

Today, an *electronic volume corrector* provides more features than a simple corrector.

Historical data can be store in the corrector's memory on an hourly or daily basis. Typical historical data can be uncorrected volume reading, corrected volume reading, average flowing pressure, average flowing temperature, supply voltage, ambient temperature, etc.

Alarms limits can be set with parameters to alert on a local display if parameters fall outside the alarm limits. It can also set up to report to the remote computer system via a communication link.

Audit trail is an important feature to record any changes made to the corrector. Typical audit trail records include date, time, old value, and new value of a parameter.

Power management feature allows the corrector to minimize continuous power usage, thus extending the battery life. Today, correctors can be configured to power up periodically to perform detailed calculations or power the communication devices only at predetermined times. Most of the communication devices consume large amounts of power.

External pulser is used when the corrector is required to be installed away from the meter. In some cases, a high speed pulser is use to derive more accurate flow rate. This may require additional signal conditioning.

External transmitters for pressure or temperature may be used with some correctors. The external transmitter may be of 4-20 mA current types. These transmitters may require 24 VDC supply.

Multiple runs may be supported with some of the correctors in the market.

Bidirectional Index is available for some of the correctors in the market to measure gas flow in both directions.

High Frequency Pulse Input may be handled by some correctors. This may require additional frequency conditioning circuits on board or on a separate board.

Live AGA8 Detail Calculations may be required to perform some advance applications. Some of the corrector can interface with the live field chromatograph, using a serial communication link, and get the required live parameters for AGA 8 super compressibility calculation. Most of the corrector applications only require NX-19 or AGA8 Gross method calculations.

Field Software

Field software allows the configuration, data collection, calibration, maintenance and troubleshooting of an *electronic volume corrector*. Typically, field communication software runs on laptop computers or handheld computers.

Summary

An *electronic volume corrector* totalizes live uncorrected gas volume flowing through either a turbine meter, rotary meter, or any positive displacement meter, and converts it to live totalized corrected gas volume by applying appropriate correction factors. This is done by measuring live flowing gas pressure, live flowing gas temperature, and by counting pulses from the meter. A complex calculation is performed to obtain a live corrected volume.

Today, many methods are available to power the correctors and many methods are available for the calculations.