Introduction

This paper is intended to give a high-level overview of flow computers and their place in electronic gas measurement in the American Petroleum Institute (API) 21.1 standard for those who are new to the industry or looking for a refresher of the basic application usage of flow computers.

As natural gas and various hydrocarbons move from the well head to the burner tip, there are several electronic devices in the field used for measurement and control. The electronic flow computer is referred to in API 21.1 as a secondary device. Many contracts between companies either buying and/or selling gas often stipulate that measurement falls into compliance of API 21.1. This paper will focus primarily on the electronic flow computer.

API 21.1 Overview

Electronic Gas Measurement (EGM) consists of a number of components, which work together to measure and record gas flow. API 21.1 is a standard written by the American Petroleum Institute, which describes the minimum specifications for electronic gas measurement used in the measurement and recording of flow for custody transfer applications utilizing industry recognized primary measurement devices. The EGM includes the electronic measurement of Pressure (PT), Flow (FT), Temperature (TT) and/or Gas Analysis and calculates volume and energy quantity of natural gas.

The specifications also include: EGM System Algorithms, Audit and Record

Fig. 1. Electronic Gas Measurement (EGM) as defined in API 21.1.
### Electronic Flow Computer Basics

The overall basic function of an electronic flow computer is to calculate and record flow rate using industry standard algorithms as natural gas and other hydrocarbons pass through a meter of a segmented section of pipeline. These meters could be, but not limited to, orifice meters, linear meters, ultrasonic meters, or Coriolis meters.

For a typical orifice measurement application, it requires a differential pressure transmitter, static pressure transducer and temperature probe. Many flow computers use a multivariable transmitter that can measure differential pressure and static pressure in one transmitter.

For a typical turbine meter, rotary meter or diaphragm meter application, it requires a static pressure transducer, temperature probe and pulse generating device, e.g. mechanical index.

For other flow meters, such as an ultrasonic meter or Coriolis meter application, the flow computer may use pulse signals from the respective meter, pressure sensor and temperature sensor for computing corrected volume.

### Basic Components

An electronic flow computer typically consists of the following main components:

- Enclosure
- Processor Board
- Display
- Keypad
- Pressure Transducer
- Temperature Probe
- Multivariable Transmitter
- Pulse Generating Device
- Mechanical Index
- Local Communication Port
- Remote Communications Options
- Operating Software
- Power Supply

While the above are typical components, each application requires its own combination of basic components.
The **Display** provides a way to view designated parameters locally at the flow computer. 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 LCDs are designed to display a limited number of characters. In this case, the parameter value is preceded by a letter designator, e.g., CV for corrected volume.

Most manufacturers allow for different parameters to be scrolled through by pressing a button or touching a magnet on a designated area.

If a magnet is allowed to control scrolling, a magnetically activated reed switch is used on the display PCBA.

A **Keypad** is used for local data entry. The keypad allows for configuration or flow computer parameters, or for selecting which parameters will be viewed on the local display. Not all flow computers may be equipped with a keypad.

A **Pressure Transducer** is a sensor used in measuring flowing gas pressure. The pressure transducer 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.

A **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. Typically, the temperature probe has a metal jacket with an encapsulated RTD and a flexible wire up to thirty feet in length. The wires from the probe are connected to the processor analog input or RTD input.

The probe is inserted into the thermowell that is installed in a gas pipeline. In some cases the temperature probe is inserted into the meter temperature port.

**Fig. 4. Example of a pressure transducer inside the enclosure**

**Fig. 5. Example of a temperature probe**

A **Thermowell** is a tubular fitting used to protect temperature sensors installed in the gas pipeline. A thermowell consists of a tube closed at one end and mounted in the process stream.

The thermowell facilitates inserting and removing a temperature probe to measure a gas flow temperature without the need to shut off gas to the gas flow. The adaptor is used with the temperature probe to thread and secure the probe into the thermowell. The thermowell is selected based on the gas pipe size.

**Fig. 6. Example of a thermowell**

A **Multi-variable Transmitter** measures Differential Pressure (DP) as well as static pressure. This avoids the requirement of two transmitters to measure differential pressure and static pressure for the orifice flow measurement. Some multi-variable transmitters also measure temperature.

**Fig. 7. Example of differential pressure meter run with multivariable transmitter attached to electronic flow computer**
A **Pulse Generating Device** provides a pulse input signal proportional to the gas volume flowing through a gas meter. The pulse generating device may be a part of the gas meter or it is mounted on the instrument drive of the gas meter.

A **Mechanical Index** is a typical pulse generating device that also 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.

The **Power Supply** for the electronic flow computer is available in many options, such as AC/DC power, batteries, solar, thermo-electric generator, etc. The type of power supply is based on the power available at the site and/or how often the unit needs to be awake/asleep determined by time and communication requirements.

The **Battery Pack** is a widely used power source for electronic flow computers in the field. The battery packs are often installed directly inside the flow computer enclosure. The most popular types of battery packs include alkaline or lithium.

The battery must be replaced before it reaches the low voltage limit required to operate the flow computer. A low voltage alarm can be set inside the configuration of the flow computer.

The battery pack should be sized to handle both operation of the flow computer and the communication requirements. To preserve battery life, many electronic flow computers can be setup to wake up at periodic intervals to complete calculations and communications.

**Remote Communication Options** fall into the category of non-present communication between the electronic flow computer and the user. Remote communications are achieved often, but not limited to, use of cell modem or radio. This allows the user to communicate with the unit in the field from another location, such as a field office. Often times, a Supervisory Control And Data Acquisition (SCADA) or a measurement software is used to remotely collect data on an automated scheduled basis.

**Uninterruptible Power Supply (UPS)** consists of a rechargeable battery and AC to DC charger. The UPS is powered by AC voltage, typically 110VAC. Upon AC power failure, the flow computer can continue to run on backup/rechargeable battery until AC power is restored. Backup battery sizing is determined on how long the electronic flow computer is requested to run in case of AC power failure.

**Operating Software** is software that is loaded onto the user’s laptop or tablet to use to communicate with the electronic flow computer. This software, provided by the manufacturer, allows for system setup, configuration, data collection, maintenance and trouble shooting for the electronic flow computer.

The **Solar Power Supply** consists of a solar panel, mounting bracket, solar charger and a rechargeable battery. The solar panel is typically mounted onto a pole with the mounting bracket and adjusted in orientation to get the most sunlight exposure.
The size of the solar panel depends on how much average sunlight is available per day and how much charging current is required. The size of the rechargeable battery is determined on how long the flow computer should run without sunlight when awake.

Solar panels can be as small as 1 watt and directly mounted to the enclosure of the electronic flow computer. They can also be as large as 100 watts or more and require a large supporting structure/mounting bracket.

**Remote Communications**

There are many options available for remote communications with the electronic flow computer.

These may include:

- Dialup Phone Line
- Wireless Radio
- Cellular
- Ethernet
- Satellite

For each of the above options, the appropriate modem or interface board needs to be connected to the PCBA. Additionally, for each communication type, the proper baud rate (setting for the speed of communication) and any related communication parameters need to be setup in the flow computer.

The electronic flow computer is identified in the field by its unique Site Identification (ID), or identification address. This is important for the remote measurement system or SCADA system to identify the flow computer while communicating.

A **Dial-up Phone Line** uses a traditional telephone line to communicate with the flow computer. The flow computer requires being equipped with a dial-up modem.

**Wireless Radio** communications require a radio modem, transmitter/receiver, coax cable, and antenna. Any wireless radio communication requires line-of-site between the two radios.

There are two types of radios: licensed and unlicensed. 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** is becoming one of the most popular methods of communicating with electronic flow computers in the field. The flow computer requires being equipped with cellular modem, coax and antenna. Cellular modems use internet protocol (IP) technology. Instead of having a phone number like a land line, the cellular modem has an IP address (e.g. 11.56.73.128). This allows for the remote computer connected to the internet to be connected to the device in the field. The use of cellular modem requires signing up with a cellular service provider. Depending on the service provider, different technology modems are used. Most of the gas companies use the cellular service in Virtual Private Network (VPN) for security of communication.

**Satellite** communication technology uses a satellite modem installed in an electronic flow computer with an antenna that provides communication with a satellite in the sky.

The satellite communicates with an earth station. The remote electronic flow computer communicates to the earth station’s computer to get the flow computer’s data.

Satellite communication supports two-way data communication. The data services is provided by a satellite service provider.

**Maintenance**

The electronic flow computer has minimal moving parts, so it requires minimal maintenance. Following certain maintenance guidelines will minimize 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, even though most circuit boards are 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. Any non-rechargeable battery pack, under normal operating conditions, will eventually drop below the voltage level needed to maintain minimum power for the flow computer. Its lifespan is determined by multiple variables specific to each flow computer, 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, the battery should be changed.

**Calibration** is a crucial element of any program of scheduled maintenance. Today, most of the electronic flow computers use software calibration. The software calibration does away with the need for laborious adjustments, thereby simplifying field calibration.
Other Electronic Flow Computer Features and Options

The electronic flow computer does more than just calculate gas and liquid flow.

**Historical Data** can be stored in the flow computer’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.

**Alarm** limits can be set with parameters to alert on a local display if parameters fall outside the alarm limits. It can also be 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** features allow the flow computer to minimize continuous power usage, thus extending the battery life. Today, flow computers 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.

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

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

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

**Flow Control w/ Pressure Override, Multiple Runs or Run Switching** may be supported with some of the flow computers on the market.

**Bidirectional Index** or Bidirectional Multi-Variable Transmitter is available for some flow computers in the market to measure gas flow in both directions.

**Chromatograph Interface** can be available for some flow computers using an additional serial communication link. This allows the Live AGA8 Detail Calculations that may be required to be performed for some advance applications.

A **Customer Interface** port can be available for some flow computers. This can be an additional serial interface that allows the customer system to collect the data from the flow computer. It also can be a simple pulse output from the flow computer representing proportional corrected volume.

API 21.1 Compliance

**Calculations**

The Electronic Gas Measurement (EGM) algorithms defines sampling and calculation methodologies and averaging techniques.

For differential pressure measurement, which is used most commonly in orifice measurement applications, the appropriate flow equations can be found in the latest revision of API MPMS Ch. 14.3 (AGA Report No. 3) or other approved differential pressure metering standards.

For linear meters, such as rotary, diaphragm or turbine meters, the appropriate flow equations are found in the latest revision of AGA Report No. 7. or other approved linear metering standards.

Equations of state for compressibility, are calculated using the AGA Report No. 8.

**Audit Trail and Records**

An EGM shall be capable of creating an audit trail by compiling and retaining satisfactory data for verification of hourly and daily quantities. The audit trail shall include proper units of measure for all reported values.

The main reason for retaining historical data is to provide support for the current and prior quantities reported on the measurement and quantity statements, such as a Gas Volume Statement.

The audit trail should include, but is not limited to unedited historical data, event logs, field test reports, edit reasons, configuration logs and supported information for the accounted for mass, volume or energy. API 21.1 refers to this as the Quantity Transaction Record (QTR). The QTR shall be collected and stored with enough resolution to allow for recalculation within 50 ppm per API MPMS Ch. 14.3, Part 4.

Below is a sample of records (not all) that makeup a QTR:

- Date and time
- Quantity (volume, mass, and/or energy)
- Flow time
- Integral value
- Meter output
- Static pressure average
- Temperature average
- Differential pressure average
The Configuration Log shall contain and identify all flow parameters, calculation methods, as well as general information used in the generation of a QTR.

The Event Log shall also be a part of the audit trail for each accounting period. The Event Log is used to note and record any exceptions and changes to the flow parameters contained in the Configuration Log that occur and have an impact on the QTR. Each time a constant flow parameter is changed in the system, the old and new value, along with the date and time of the change, shall be logged.

The Test Record shall be part of the audit trail and consists of any documentation (electronic or hard copy) generated in the testing of metering and analyzer equipment that would affect the calculation of measured quantities.

Common elements in a Test Record are:
- Calibration reports
- Primary device inspection reports
- Equipment change tickets
- Equipment maintenance and inspection reports

Data Availability

Data availability requirements are intended to ensure that the minimum necessary data is collected and retained in order to allow proper determination of the quantities measured by the EGM.

This data should be recorded either electronically or manually. Remote collection of this data, such as through a SCADA system or polling engine, is acceptable unless prohibited by statute, regulation, tariff, or contract.

Onsite data is typically stored in the flow computer of the EGM. Onsite data requirements for API 21.1 are summarized below:
- Minimum of seven days of hourly QTRs
- Minimum of seven days of daily operational data
- Constant flow parameters and manually entered input variables that affect quantity calculations
- Current values for live input variables or calculated variables
- Current value of gas analysis data
- Equipment information

The data retention period for the EGM audit trail is defined by regulation, statute, tariff, or contract.

Commissioning

Commissioning is the process of the initial verification and documentation that the EGM system is installed and functioning according to its specifications, design, and regulatory/contractual requirements.

For secondary devices, such as electronic flow computers, the manufacturer should provide documentation for field commissioning and calibration/verification procedures.

In addition, the range, operating, and environmental limits for all transducers/transmitters in the flow computer.

Factory calibrated devices from the manufacturer should include documentation of the testing and accuracy verifications, including equipment specification and performance documentation.

For final integrated EGM site commissioning, the following must be completed: verification of configuration, process input verified to tertiary device digital input, review and acceptance of diagnostic data. Additionally, at a minimum, verifications must be performed on differential pressure, static pressure, temperature, as well as any other points recommended by the manufacturer.

Equipment Verification and Calibration

The following EGM components require verification/calibration:
- Static pressure transmitters
- Differential pressure transmitters
- Temperature transmitters
- On-line analyzers
- Other EGM devices

Verification is the process of confirming accuracy of an EGM device, such as an electronic flow computer by the use of measurement or reference standards. The frequency of these verifications are based on contractual or mutual agreements between customers.

Calibration is the adjustment of an EGM device to conform to certified reference standards to provide accurate values over the user’s defined operating range. The frequency of calibrations are based on contractual or mutual agreements between customers.

Security and Data Integrity

Security is required to prevent unauthorized alterations of configurations and data which affect measurement integrity.

The electronic flow computer in the EGM system shall be configured to deny unauthorized access to configuration profiles and measurement data via unique access codes and/or
username and password.

All data records as required in API 21.1 shall be stored in such a way they cannot be altered. Procedures shall be implemented to detect deleted or missing records. There must not be any changes to the original data. Both original and edited data must be retained.

Software containing measurement algorithms for the electronic flow computer must contain the software version number loaded on the device. The software version number must be a unique identifier.

The electronic flow computer shall provide a battery backup capable of storing all data in the unit’s memory for no less than 35 days. If there is a primary power failure, the date and time of the failure must be logged in the audit trail, as well as the date and time when the unit returns to normal power status.

**Summary**

An electronic flow computer is one piece of an EGM system. The electronic flow computer collects live uncorrected gas or liquid volume through any type of meter and calculates corrected volume and energy. This is achieved by measuring live differential pressure, live flowing pressure, live flowing temperature, and/or by counting pulses from the meter. Additionally, other devices can feed the flow computer, such as an online chromatograph to provide additional data, which allows a more granular look at volume and energy.

Many calculations are performed inside the flow computer to obtain a corrected volume and energy.

With flexibility in communication and power technology, coupled with measurement standards such as API 21.1, reliable and accurate data can be obtained from most any measurement point.

**References**

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- www.eagleresearchcorp.com
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