TURNKEY **Natural Gas** Measurement

Ultrasonic flowmeter optimizes gas pipeline allocation system

By Mehmet Duzen

BOTAS, the state-owned oil & gas company in Turkey, recently installed a natural gas pipeline allocation system at its natural gas compressor station at Çayirli, a town in the Erzincan Province of Eastern Turkey. The system included a 42-inch ultrasonic flowmeter (Figure 1), one of the largest in the world, as well as supporting instrumentation from Emerson Daniel Measurement and Control.

The compressor station pressurizes natural gas to 75 bar on the Erzincan pipeline at a flowrate that varies between 510,000 to 2,040,000 Sm^3/hour (432 to 1,729 MMSCF/day) throughout the year.

Unlike many allocation systems, which typically consist of instrumentation and analyzers from various manufacturers, the Erzincan system was delivered as a complete package that was designed, configured, and commissioned by Daniel Measurement and Control (*daniel.com*). The system was designed with various redundant features to meet client requirements.

Six other pipeline instrumentation companies bid on the project, but Emerson's Daniel Measurement and Control was the only company that could supply all of the required equipment, instrumentation, and local engineering support along with a redundant system. This simplified the engineering and operational requirements for BOTAS (*botas.gov.tr*), because it only had to deal with a single engineering company. It also reduced the overall cost.

Another reason for awarding the contract to Daniel was its technical knowledge and domain expertise. For example, Daniel worked with BOTAS to perform calculations that allowed a reduction in line size from 46 inches to 42 inches, a change that resulted in substantial savings without affecting the system's design pressure.

Gas Ultrasonic Flowmeters

Ultrasonic flowmeters are widely used in the natural gas industry for custody transfer and other critical applications because they cause no pressure drop, which is a critical parameter, especially on compressor station applications. Also, they are immune to problems caused by contaminants, have no moving parts, and offer enhanced diagnostic capabilities. Other benefits of ultrasonic flowmeters include:

- Accuracy of +/-0.1 percent
- Large turndown of 100-to-1
- Bi-directional flow measurement capability
- Wet gas tolerance
- Fault tolerance; meters remain relatively accurate even after a transducer failure.

Ultrasonic flowmeters are based on the transit-time principle, measuring the time of ultrasound pulses between a pair of transducers determines fluid velocity. Each pair of transducers acts alternately as transmitter and receiver. Sound pulses travel diagonally across the pipe, downstream with the flow, and upstream against the flow. The difference in transit times of the downstream-directed pulses and the upstream-directed pulses is proportional to the average flow velocity along the acoustic paths, and is converted into an output signal and display of volumetric flowrate.

However, a single velocity measure-

Figure 1. *Daniel Measurement and Control's 42-inch SeniorSonic ultrasonic flowmeter installed in the BOTAS pipeline.*

ment path does not accurately represent flow. Therefore, multiple paths are measured inside the flow tube when high accuracy is required. The number of measurement paths and their geometrical arrangement is a main differentiator among ultrasonic flowmeters.

The Daniel 42-inch SeniorSonic ultrasonic flowmeter used in this system (Figure 2) measures transit times on four parallel chords.

A major attribute of ultrasonic flowmeters that brings substantial benefits to operators is meter diagnostics, which fall into two categories:

- **Functional diagnostics:** monitors meter health and any signs of hardware or firmware degradation.
- **Process diagnostics:** monitors stability of conditions in the metering stream to ensure they are suitable for applications where high accuracy and reliable performance is critical.

A diagnostics package integrated with the Daniel gas ultrasonic meter provides BOTAS operators with an intuitive view of meter functionality and status, and allows them access to real-time process

Figure 2. *BOTAS natural gas compressor station at Çayirli, a town in the Erzincan Province of Eastern Turkey.*

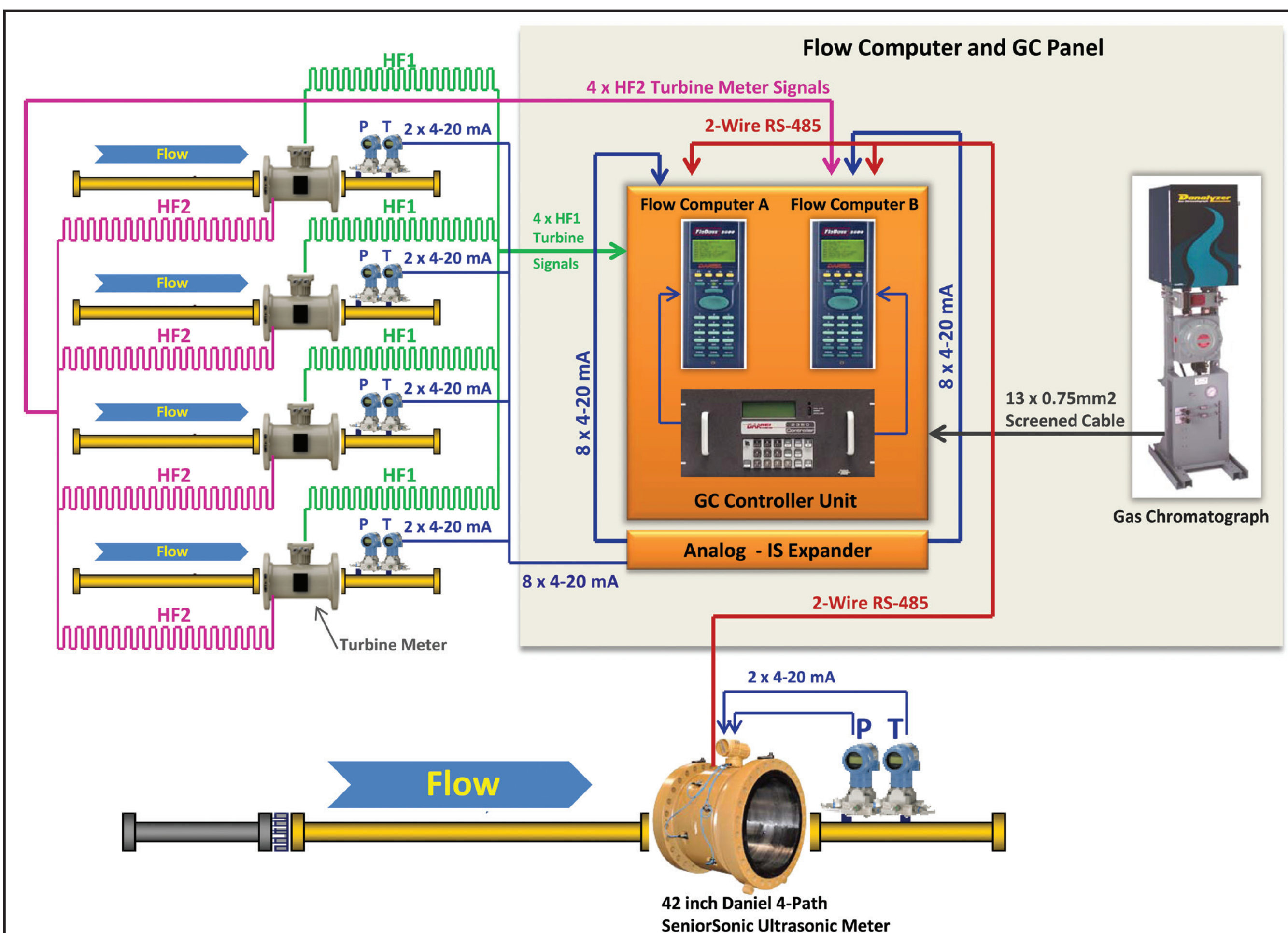

Figure 3. *The allocation station on the Erzincan pipeline is fed with pressurized gas from four compressors. A 42-inch ultrasonic flowmeter, flow computers, and a gas chromatograph make the necessary measurements.*

Table 1: Natural Gas Composition	
Components	**Mole Percentages**
Methane	81.74501
Ethane	7.56130
Propane	5.50491
Isobutane	1.42323
n-Butane	1.49864
Isopentane	0.40214
n-Pentane	0.28643
n-Hexane	0.36973
Carbon Dioxide	0.96299
Nitrogen	0.24562

conditions. This ensures that system accuracy remains within specification and alerts operators to address maintenance alarms before they lead to failure.

Making Allocation Measurements

The compressor station includes four turbine compressors, which operate with three units running and one unit as a spare. The compressors feed pressurized natural gas into a 42-inch pipeline, which then flows through the allocation system.

The ultrasonic flowmeter measures gas flow in the main pipeline, and a Daniel gas chromatograph (GC) analyzes the gas (Figure 3). Gas energy flowrate (kJ/hr) is determined by multiplying the volumetric flowrate (m^3/hr) as measured by the ultrasonic meter by the calorific value (ISO 6976) (kJ/m^3) as measured by the GC.

The GC reports the energy and provides the detailed gas composition data that are used for the volumetric flow measurement. In addition to providing measured calorific values, it ensures quality flow measurements by providing compositional data necessary to calculate the speed of sound. Speed-of-sound comparisons assure the field technician that the entire system is within specifications and that the system meets requirements.

The instrumentation for the Erzincan pipeline compressor station includes:

- Four-path 42-inch Emerson Daniel SeniorSonic ultrasonic flowmeter
- Emerson Rosemount pressure and temperature transmitters
- Two Emerson Daniel flow computers
- Emerson Daniel 2350A gas chromatograph controller
- Emerson Daniel Model 570 Danalyzer gas chromatograph (GC) complete with calibration gas and helium bottles, as well as regulators

Analyzing the Gas

The composition of natural gas includes a variety of components (Table 1), some of which are contaminants that can reduce pipeline integrity over time. At Erzincan, contaminant monitoring is combined with energy measurement for a complete allocation system analysis.

The GC (shown in the right corner of Figure 3) takes its samples directly from the pipeline, analyzes the gas for CH_4 to C_6+, N_2 and CO_2, and calculates heating value, relative density, compressibility, and Wobbe index.

The GC is designed to operate unattended in hazardous areas. If adjustments or troubleshooting are needed, its GC controller's Windows-based software allows complete control and operation of the gas chromatograph through a local operator interface panel, or via remote connections.

The GC controller can link to multiple PC workstations via RS-485, RS-422, and Ethernet. Supported protocols include Modbus over RS-422 and RS-485, as well as Modbus TCP over Ethernet. This allows remote diagnostics, polling of alarms, and access to chromatogram reports on workstations from anywhere in the GC controller network.

Organizing Inputs

The GC controller receives information regarding gas composition from the GC Analyzer via analog signals.

The ultrasonic meter's onboard electronics platform/transmitter collects the pressure and temperature 4-20mA outputs. It sends this data, plus volume

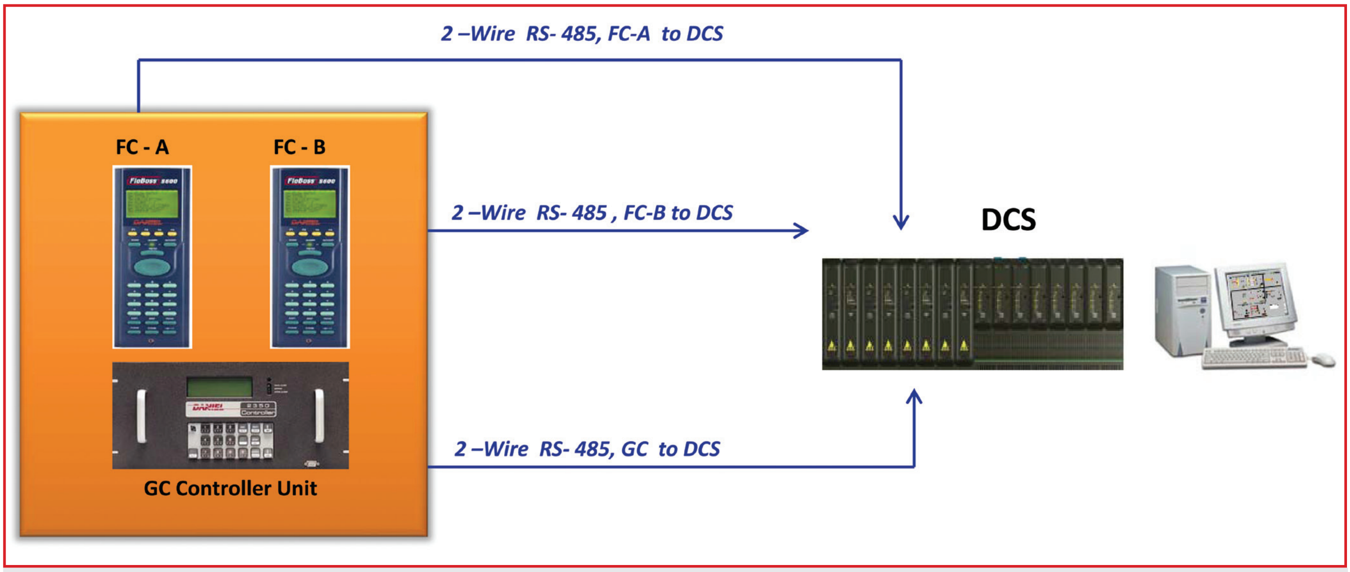

Figure 4. *The GC controller and two flow computers communicate with the DCS using Modbus over a RS-485 digital data link.*

Figure 5. *The availability of an accurate allocation metering system was a key requirement in the development of the new gas compression station that will serve the natural gas pipeline running across northern Turkey.*

flow measurement information, to the flow computers via an RS-485 link using the Modbus protocol.

Two flow computers—FC-A and FC-B (Figure 3)—receive inputs from the ultrasonic flowmeter and from four turbine flowmeters at the compressor stations. The input from the ultrasonic flowmeter is via an RS-485 link using the Modbus protocol. The inputs from the turbine flowmeters are via high frequency pulse signals.

The flow computers can provide pressure, temperature, flow, and other information via dual RS-485 Modbus communications links to the pipeline's distributed control system (DCS) and to plant operators.

An analog expander is used to double the analog signals that come from each pressure and temperature transmitter associated with the four turbine meters measuring fuel gas to each of the four compressors. The inputs to the expander are from the transmitters, and the doubled outputs go to each of the two flow computers.

Regarding Redundancy

In an allocation measurement system, downtime must be avoided to reduce metering and operational costs. Depending on how long such a system is out of service, operating cost could be significant. Redundancy was built into the system from the beginning to prevent such a problem and to achieve a high degree of metering performance, accuracy, and reliability.

Each flow computer receives measurements from all pressure, temperature, and flow instrumentation, plus the GC. Temperature and pressure signals from the transmitters installed downstream of the turbine flowmeters are doubled in the analog expander and then to each flow computer.

The turbine flowmeters send two high-frequency signals, one to each flow computer, and the 42-inch ultrasonic flowmeter sends data over two RS-485 communication links to each of the flow computers. Likewise, the GC sends data over two RS-485 communication links.

Therefore, all five gas streams are sending dual signals to the flow computers. If any of the systems fail, the others "step in" to continue the allocation system calculations.

The ultrasonic flowmeter and gas chromatograph use dual RS-485 digital data with Modbus Protocol links to communicate with the flow computers, and the flow computers and GC controller each use RS-485 to communicate with the DCS (Figure 4).

Process Parameters are sent from the flow computers to the DCS. The GC controller also sends the complete measured gas composition data directly to the DCS (Figure 4).

Modbus is used for several reasons. First, it has a longer wiring distance than fieldbus or Ethernet, allowing the gas ultrasonic meter, the GC, and the flow computer to connect to the control system more easily. Second, it has better RFI/EMI noise immunity, especially important in an environment with large motor-driven compressors.

Finally, Modbus makes it easy to connect multiple devices, including Windows-based systems.

Startup & Commissioning

Before shipping to the site, the system was tested at Daniel's facility in Houston to ensure product performance and integrity. Standard Factory Acceptance Test (FAT) procedures are applied to each system component before it is delivered to customers. The FAT test certifies the product was manufactured, tested, and inspected in accordance with the material specifications and customer requirements to ensure the product meets all specifications and is in compliance with industry manufacturing codes and standards.

The start-up and commissioning services were performed by Daniel. The complete system, including the 42-inch gas ultrasonic meter and the gas chromatograph were configured with the two S600+ flow computers via RS-485 Modbus communications, and the commissioning was successfully completed.

Compressor Station performance data shows that the meter is operating within the stated accuracy limits of +\-1.0 percent. Gas ultrasonic technology will help provide an accurate measurement of natural gas delivery and the overall transportation capacity of the pipeline, which supplies energy to a bulk of Turkey's residents (Fig 5). FC

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