



The Fluid Properties Meter

SwRI researchers develop innovative energy meter to determine natural gas properties

By Eric Kelner, P.E.

In recent years, a combination of rising demand and changing natural gas supplies has created variations in the properties of natural gas. This has raised safety concerns and operational issues for transporters, as well as questions about the ability of natural gas-fired end-use equipment to perform. If the current strong demand trend and variation in natural gas quality continue, producers and marketers will need more accurate, real-time monitoring of gas properties.

Prior to the 1990s, low gas prices and a growing natural gas-liquids market motivated producers to extract liquids such as propane and butane from the gas and sell them. This created a fairly lean (containing low concentra-

tions of condensable hydrocarbons) and uniform natural gas composition, with essentially no risk that natural-gas liquids would condense in a pipeline system. Since then, the narrowing price difference between natural gas liquids and natural gas itself has reduced interest in extracting and selling the liquids, thereby increasing the amount of unprocessed gas (containing relatively high concentrations of condensable hydrocarbons) flowing through the nation's pipelines. Unprocessed gas, which is more likely to contain condensed hydrocarbon liquids, increases the cost of transportation system operation and also creates safety concerns.

The problem is compounded because many gas producing reservoirs are becoming depleted and are producing gas with increasing concentrations of condensable

hydrocarbons. New resources, such as liquefied natural gas and coal-seam gas, bring additional variation in gas quality.

Gas quality variations also impact end-use equipment such as domestic burners and gas-fired turbines. Technologies that were created to reduce the amount of combustion-related emissions tend to increase the equipment's sensitivity to natural gas properties. Quality variations can increase emissions, reduce efficiency, cause flame instability and create engine knock.

Flexible, accurate, real-time monitoring will improve the infrastructure's ability to respond to variations in gas properties. However, because of high equipment costs, real-time gas quality monitoring only occurs at large-volume locations.

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An Innovative Solution

The Fluids Properties Meter, developed by engineers at Southwest Research Institute (SwRI), provides a low-cost alternative to traditional gas property determination methods. It can be used at locations within natural gas transportation systems where traditional equipment, such as a gas chromatograph, is cost-prohibitive. This innovative technology could enable gas transportation system operators to monitor gas properties at any point in the system, in real time, and allow them to respond quickly to changing conditions. It also can be used by industrial consumers as a fuel gas monitor or as a check for billing confirmation. Ultimately, it may provide more accurate billing for individual consumers.

In 1997, researchers in SwRI's Mechanical and Materials Engineering Division developed a method to infer natural gas properties by exploiting a relationship between those properties and several easily measured parameters. The method was licensed for commercialization to two manufacturers in 2005. One implementation of the technology is commercially

available; the other is in the prototype stage of development.

Traditionally, natural gas properties are determined through a chemical assay from a gas chromatograph, combined with individual species' properties and an equation of state. However, a gas chromatograph costs \$50,000 to \$100,000 per installation, so its use is limited to gas meter stations that flow large volumes of gas.

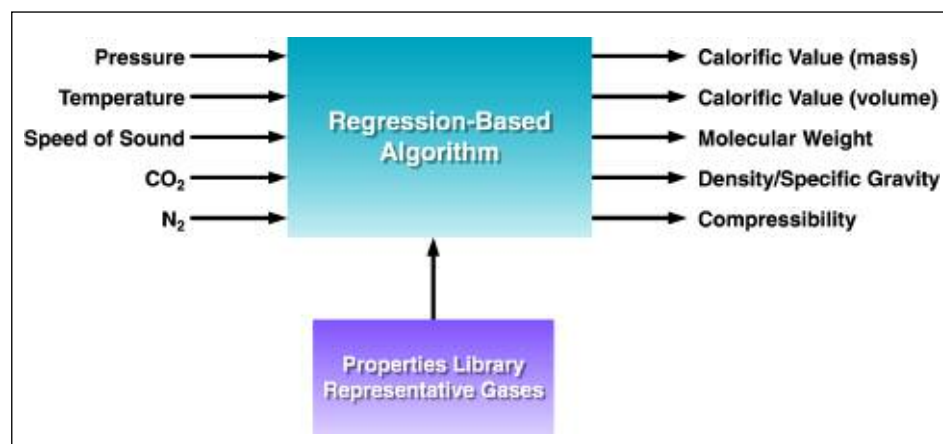
Meter stations with low-volume flow typically rely on composite samples that yield a rough average of the composition of the gas over time, or spot samples that provide a "snapshot" reading but cannot track variations over time. The SwRI method costs less than \$15,000, does not require a chemical assay, and still provides better accuracy than either spot or composite samples.

Natural gas is largely composed of paraffin hydrocarbons with properties that are interdependent because of their similar molecular structure. This interdependence

can be exploited to characterize hydrocarbon energy without performing a detailed assay. First, the concentrations of the diluents, or materials dissolved in the natural gas — predominantly nitrogen and carbon dioxide — must be quantified because they have no energy content, yet they affect the gas properties. These diluents normally account for a relatively small fraction of the whole natural gas mixture. The remaining hydrocarbon gas components can be characterized by inferential properties, without species differentiation.

In developing its energy measurement technique, SwRI selected the following inferential properties: the speed of sound as it travels through the gas, carbon dioxide concentration and nitrogen concentration. When the amounts of carbon dioxide and nitrogen in a natural gas mixture are quantified separately, the sound speed can be used to characterize the hydrocarbon components as a whole.

The natural gas sound speed was chosen as an inferential property because of the popularity of ultrasonic flow meters for natural gas applications. These meters measure sound speed as a byproduct of the flow rate measurement. The carbon dioxide and nitrogen concentrations were selected because they are the major gas components that dilute natural gas mixtures. The values of sound speed, carbon dioxide concentration and nitrogen con-



The SwRI energy measurement technique uses an inferential method to determine energy content and other gas properties.



SwRI licensed one application of the Fluid Properties Meter to Integrated Information Technologies. The module is commercially available.



The algorithm also can be implemented as an upgrade to existing flow computers, such as the one shown here.

centration are used as inputs for a data regression correlation that calculates the necessary chemical and thermodynamic properties, such as molecular weight, mass-based heating value, standard density, flowing gas density, molar ideal gross heating value and standard volumetric heating value, which is the product of the standard density and the mass-based heating value.

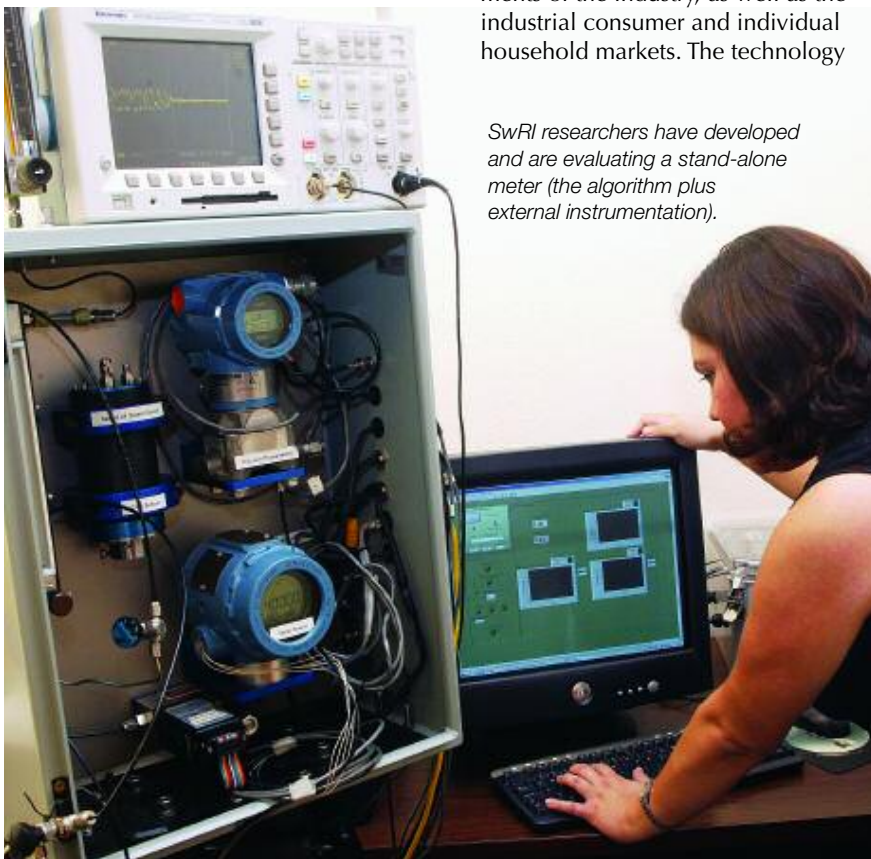
The accuracy of the SwRI data correlation algorithm was initially assessed by comparing its calculated results to the values calculated using SonicWare™, a commercial software product that can calculate the speed of sound of natural gas mixtures, and by a standard method that uses physical constants of paraffin hydrocarbons from Gas Processors Association (GPA) Standard 2145-94. This comparison found that there was close agreement between the SwRI energy meter's data regression correlation algorithm and the more conventional method. This demonstrated that the SwRI energy meter concept was fundamentally sound and that the method would provide accurate values for energy flow rate if the process variables used as inputs for the algorithm calculations are measured accurately.

Overall, the inferential method determined density, molecular weight, sound speed at standard conditions, density at standard conditions, mass-based heating value and volumetric heating value, to within ± 0.02 percent, relative to those properties as calculated or measured using standard industry methods. The accuracy decreased as diluent concentrations reached levels greater than about 6 mole percent each of nitrogen and carbon dioxide.

Cooperating with Industry and Government

Initial funding for the SwRI project was through a cooperative agreement with the U.S. Department of Energy (DOE). Once the feasibility of the method was demonstrated, the natural gas industry supported the project through the Gas

Technology Institute, the Pipeline Research Council International and individual natural gas production, transportation and distribution companies. Today, the technology is nearing the final stage of commercialization and is supported by a joint industry project that comprises seven natural gas industry companies that represent all segments of the industry, one of the two manufacturers and SwRI. The project is completing its second year.



SwRI researchers have developed and are evaluating a stand-alone meter (the algorithm plus external instrumentation).

Because ultrasonic meters provide sound speed as an output, the algorithm combined with an ultrasonic meter provides a measurement of energy flow rate.

is modular, lending itself to implementations from simple, less accurate applications to complex, high-accuracy stand-alone instruments.

The algorithm can be applied in combination with an ultrasonic meter and a flow computer. In this application, existing measurements and assumed constant values are used as inputs to the algorithm. In this "algorithm-only" application, the sound speed (determined by the ultrasonic meter), gas pressure and gas temperature are provided by existing, on-site instrumentation. The carbon dioxide and nitrogen concentrations are either entered into the algorithm as constants via a flow computer, or taken from a gas chromatograph if they are being used as a redundant measurement. One advantage of this application is that, with the exception of the algorithm itself, it relies on existing equipment.

This application has been licensed to Integrated Information Technologies (IIT), a company specializing in supervisory control and data acquisition systems. In the IIT application, the Fluid Properties Meter algorithm is applied using the speed of sound from an ultrasonic meter at pipeline pressure and temperature, with expanded intelligence developed by IIT that improves the determination of the diluent values.

A diluent reference table has been implemented that allows the user to pre-define multiple gas supply points in the pipeline and the typical diluent concentrations at those points. The Fluid Properties Meter then calculates a weighted average value for the diluents at the installed location using these supply point values and a ratio identifying the contribution of each supply point at the location. This concept allows the end user to develop a "knowl-

The stand-alone meter was field-tested at a station in south Texas. After failure of the reference gas chromatograph, the Fluid Properties Meter continued to accurately track heating value.



edge base" model of the pipeline and to represent this model in the Fluid Properties Meter. IIT is developing additional intelligence to use flow rates at the supply points as additional inputs to the model for improved accuracy of the diluent values at the installed location. Interest from local distribution companies, a segment of the gas industry that distributes gas to communities nationwide, has been high.

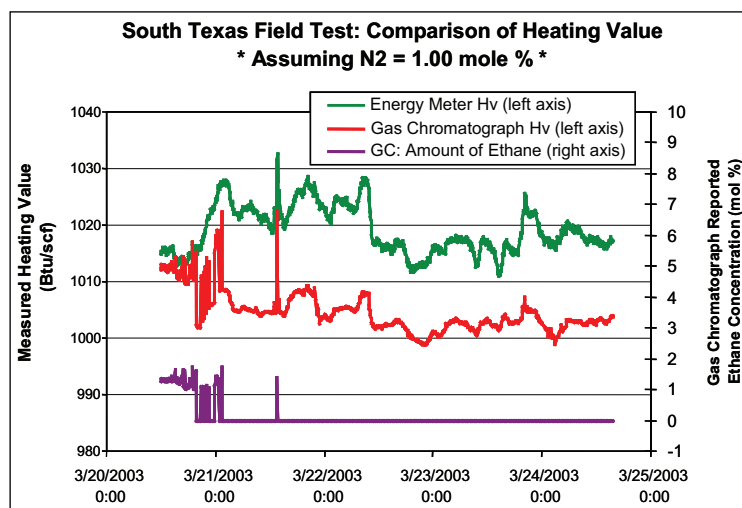
Accidental Proof of Value as a Backup

Another application that has attracted interest is the use of the Fluid Properties Meter as a redundant gas property measurement at large-volume measurement stations where gas chromatographs are the primary instrument for measuring gas properties. This application was field-tested at a natural gas custody transfer station in South Texas. The initial objective was to verify the accuracy of the Fluid Properties Meter. However, a gas chromatograph failure

showed that the technology could be used as a low-cost backup device.

Testing was conducted over five days. During that time, the amount of ethane detected by the reference gas chromatograph dropped to zero, indicating a malfunction in the chromatograph. This ethane detection error caused the heating value calculated using the chromatograph analysis to drop from an average of 1,012 Btu/scf prior to the failure, to 1,002 Btu/scf just after the failure.

Prior to the failure, the inferred heating value had agreed with the heating value calculated using the chromatograph analysis to within about 3 Btu/scf. After the failure, the difference between the inferred heating value and the chromatograph-calculated heating value increased to



approximately 16 Btu/scf. Enough data were collected during the first day to establish the performance of the module, so the inferred heating value for the period after the failure can be assumed to be within approximately 3 Btu of the reference heating value.

The reported ethane concentration was zero from March 21 at about 1:30 p.m. to March 24 at about 3:40 p.m. Using the average deviation of 13 Btu/scf and using an average station throughput of 300 million scf per day, the energy flow through the station for the three days was underreported by approximately 11,700 decatherms. If the price of natural gas during those three days was \$8 per decatherm, the value of the unaccounted-for gas was approximately \$93,600.

Left uncorrected, this error would have represented a significant loss to the delivering pipeline. If the error had been corrected using only the heating value as determined by the last "valid" analysis, the value of the unaccounted-for gas would still have been underestimated because of the significant increase in heating value (10 to 15 Btu/scf) after the failure.

Stand-Alone Gas Property Instrument

Another, more general application uses the Fluids Properties Meter by itself or in combination with any metering technology. In this application, the meter provides independent measurements of sound speed, nitrogen, carbon dioxide, pressure and gas temperature. If used in combina-



The stand-alone instrument can be combined with other metering technologies such as an orifice meter to provide energy flow rate.

ing in prototype development as part of the joint industry project.

Conclusion

The innovative, SwRI-developed, Fluids Properties Meter so far has proved to be a low-cost natural gas property measurement technology that enables transporters and consumers to monitor gas properties at

locations where traditional measurement previously had not been economically justified. The technology takes a step toward real-time monitoring and control of natural gas transportation systems. It also can be used by industrial consumers and even the general public. ♦

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tion with a flow meter, these measurements are entered into the algorithm via a flow computer and combined with the measured volumetric flow rate to provide an energy flow rate. If used by itself, the device simply outputs the desired gas properties. This application can be placed at any location within the pipeline system. A manufacturer of natural gas sampling equipment has licensed this application from SwRI. The manufacturer is participat-

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