Knowing What's Inside From the OUTSIDE

Clamp-on ultrasonic flowmeters leveraged for sophisticated interface measurements

By John Accardo

Many petroleum pipeline companies transport multiple hydrocarbon liquids (e.g., diesel fuel, gasoline, and jet fuel) through a single common pipe. Between each liquid sits an interface where the flowstream transitions from one product to another. Pipeline operating companies depend on instrumentation to indicate which fluid is flowing through their pipe at any given time and when an interface occurs—information that is vital for proper management of pipeline operations.

For example, as flow arrives at a terminal, different product types must be routed to specific storage tanks. By knowing exactly when an interface arrives, valving can be controlled to route the new fluid to its respective tank and buffer liquids can be separated if they are present. Additionally, certain additives, such as drag reducing agent (DRA), may only be injected into specific fluids; therefore, positive identifica-

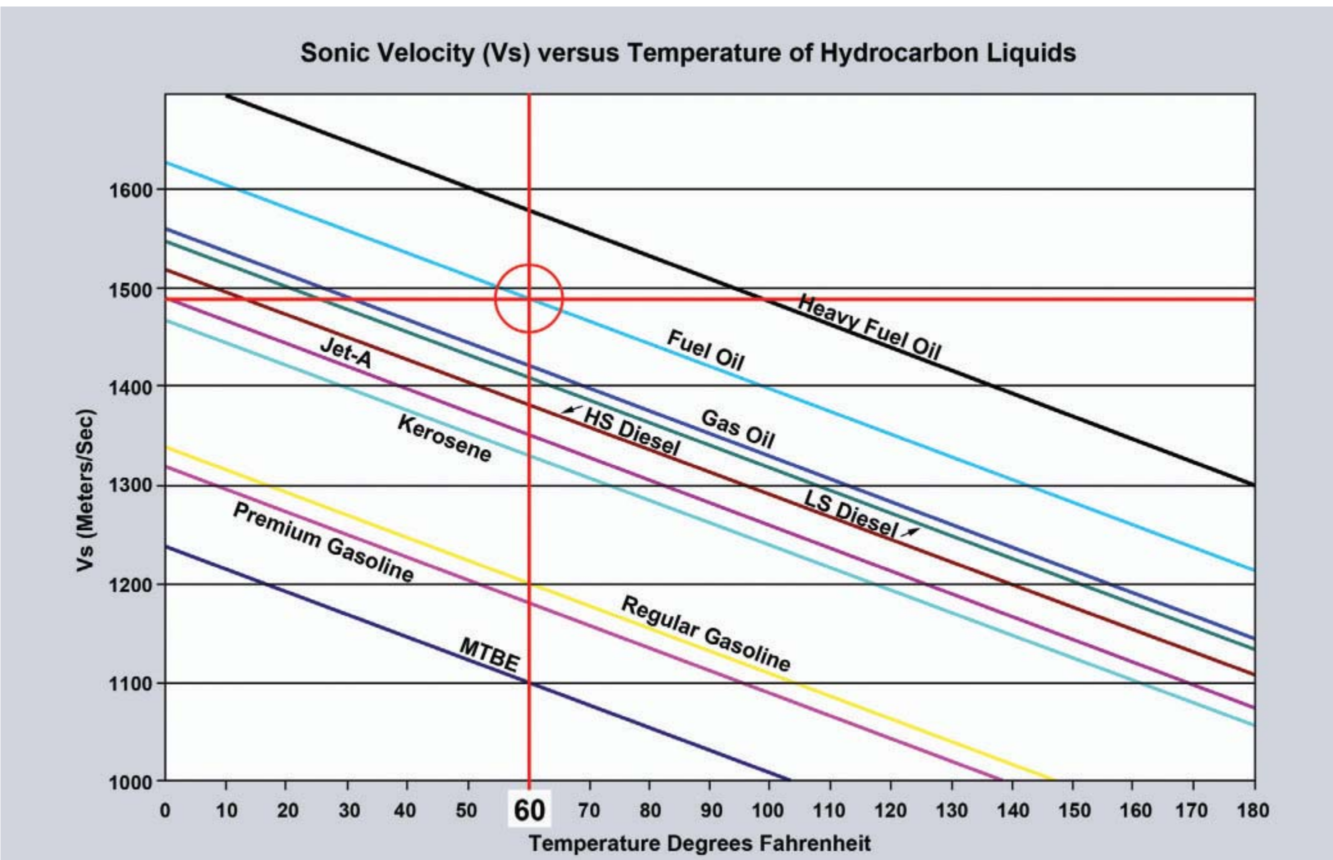

Figure 1. *Liquid slope table demonstrating the effect of temperature on the sonic velocity of liquid hydrocarbons.*

tion of a fluid in the pipe eliminates the potential for contamination. It is also important to avoid having any obstructions in the pipeline, which will degrade or destroy the effectiveness of the DRA by breaking the polymer chain. Further complicating the instrumentation requirement is the issue of pigs—no, not sloppy workers, but rather pipeline pigs used to remove interior pipe wall fouling. Pigs require an unobstructed path to pass safely through the pipeline segment and complete their task.

The Non-Intrusive Solution

The natural answer is a non-intrusive instrument that will allow utilization of DRA to improve operational efficiency of the pipeline and will not interfere with pigging. A clamp-on ultrasonic flowmeter checks all the requirement boxes, making it an ideal option. Using a clamp-on meter for product identification offers numerous benefits, including inexpensive installation, no loss of pressure, no interruption of pipeline operation for maintenance or service, and an overall low cost of ownership, plus the aforementioned absence of protrusions into the pipeline interior. But that is only the beginning. Clamp-on flowmeters are available in several versions for the highest possible level of versatility—standard volume (the subject of this article), precision volume to monitor and correct for variations in dynamic viscosity, and interface detection for indication of liquid interfaces and API gravity without the need for flow measurement. In addition, once the product is identified, a clamp-on flowmeter is capable of producing additional data for the pipeline company, including liquid density, accurate flowrate in standard volume or actual units, viscosity and dynamic Reynolds number correction, liquid condition and, of course, pig detection and reporting.

How Clamp-On Ultrasonic Meters Identify Liquids In a Pipe

All of this leads to a pressing question—how is it possible for a clamp-on meter to determine which product is inside the pipe without ever touching the fluid?

In a word, "liquid table." Okay, that is actually two words, but the concept is fairly straightforward. To understand how a liquid table works, we must first consider the principle of ultrasound. Sound waves propagate through a medium (in this case a hydrocarbon liquid) at a velocity that is a property of the liquid itself, known as its sonic velocity. This sonic velocity is the liquid's signature and is key in identifying the fluid inside the pipe, as well as its characteristic density and viscosity. In the real world, however, temperature (and to a lesser extent pressure) also play a part in determining the actual sonic velocity of a fluid. Fortunately, hydrocarbon liquids behave in a very predictable manner; that is, their sonic velocity values change linearly relative to temperature and pressure and by the same "slope" factors across liquid types (Figure 1).

Liquident	S.G.	Viscosity	Visc. Slop	Liquid Name
1100	0.6465	0.15	0.00001	MTBE (Additive for Oxygen)
1180	0.717	0.6	0.00001	LFP (Lead Free Premium)
1200	0.733	0.6	0.00001	LR (Leaded Regular)
1330	0.775	1.0	0.00001	KEROSENE
1350	0.818	1.16	0.00001	AV JET (AV Jet Fuel)
1380	0.819	1.95	0.00001	HSD (High Sulfur Diesel)
1410	0.885	2.75	0.00001	LSD (Low Sulfur Diesel)
1420	0.959	3.2	0.00001	GASSOIL (Sour Light Cycle Gas Oil)
1490	0.9300	119.00	0.00001	FO (Fuel Oil)
1579	0.9850	1049.00	0.00001	HFO (Heavy Fuel Oil)

Figure 2. *Generic liquid table*

Sonic Wave Propagation

Identification of the flowing liquid begins with the need to measure the actual sonic velocity of the liquid (called Vs) with extreme precision. But sonic velocity alone will not provide a positive identification since temperature has such a profound effect; as a result, any given Vs could be representative of multiple products if temperature is not taken into consideration. To be certain of a liquid's identity, Vs must be compared on equal terms.

We will use the example of an actual clamp-on ultrasonic flowmeter to describe this process in more detail. The Standard Volume meter is designed primarily for hydrocarbon liquid measurement, which is achieved through its use of high-precision sensors and their inherent acoustical "match" to the pipe's characteristics, to produce a coherent ultrasonic signal over a broad range of liquid types and sonic velocities. The meter also incorporates a precision platinum RTD to verify liquid temperature. With these two pieces of information, liquid identification can begin.

Temperature Slope

Since the (Vs) slope factor for hydrocarbon liquids is a known value, the measured Vs can be corrected to a standard (base) value, typically 60 F (Figure 1). This temperature-corrected (normalized) sonic velocity is known as "Liquident." Using Liquident instead of actual sonic velocity levels the playing field by eliminating the possibility of confusing one liquid for another due to temperature and/or pressure influences. With the Liquident value determined, it is a simple matter to identify the fluid. This is where the aforementioned liquid table comes into play.

Liquid Table Utilization

The flowmeter is equipped with an integral liquid table—essentially a mini-database of common hydrocarbon fuels/fluids and their inherent characteristics (Figure 2). Equipped with the newly calculated Liquident value, the meter consults the liquid table for the matching value that identifies (by name) the liquid currently being measured, as well as its density (Sg)

Typical clamp-on Ultrasonic Flowmeter installation on hydrocarbon pipeline

and viscosity at base temperature. By identifying the liquid at its base values the meter is then able to compute both the density and viscosity for actual pipeline conditions and present "live" density (Sg, API and Kg/M3) and viscosity data for both base and actual fluid conditions simultaneously. The Liquident value is also monitored for a programmable "rate of change" signaling the arrival of a fluid interface, which will provide the pipeline company with the data required to control the handling of the individual products.

As observed in Figure 2, the default liquid table is a collection of generic hydrocarbon liquids (fuels) and associated typical density and viscosity values at base temperature. The table is completely user-programmable to enable inclusion of additional liquids or for fine-tuning to the characteristics of a user's specific products. It is common practice to modify the liquid table at the time of initial installation on a new customer application. This phase, known as "optimization," enables adjustments to be made to better reflect the actual characteristics of a given company's products. New products can also be added to the table and products that will not be measured can be deleted. The table is capable of accommodating up to 32 different liquids in all. Once the liquid table has been optimized, the values can easily be transferred to the liquid table of each new meter installation, creating the desirable plug-and-play commissioning process.

What About Pressure?

To this point the effects of pressure on the liquid's sonic velocity have not been discussed. Pressure does influence the Vs of a liquid, but to a far smaller degree than temperature. Like temperature, the effect of pressure is to change a liquid's sonic velocity by a linear slope factor requiring a simple computation to compensate. For pipelines whose pressure varies significantly (i.e., several hundred PSI or more), standard analog inputs are available to accept a pressure input (4-20 mA). This input will enable the application of the pressure slope correction to the Liquident computation, further refining Liquident to account for pressure's influence. Pressure measurement is particularly beneficial when pipeline operations include several similar products (e.g., gasoline grades). Such products may have nearly identical base sonic velocity values, so adding pressure as a reference will greatly enhance the identification process.

Clamp-on flow measurement is an optimal choice for monitoring complex hydrocarbon applications in which multiple liquids flow through the same pipe. Through the use of a comprehensive and dynamic hydrocarbon liquid table, the clamp-on meter serves as a powerful tool for managing pipeline operations and intra-terminal flow. FC

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