Amid growing environmental concerns, companies worldwide face increasingly stringent regulations surrounding the transportation of oil and other hazardous liquids through pipelines. Some of these regulations specifically address the very real threat of pipeline leakage, and for good reason: even a miniscule leak can have catastrophic consequences if it remains undetected. Historically, spills and explosions resulting from pipeline leakage have endangered human health, killed off livestock and fish, and destroyed crops and other valuable land. These types of accidents can also devastate the economic wellbeing of oil companies.
Frank Fromm, Business Developer, Siemens AG Industry Automation, USA, reveals new innovations in leak detection for hydrocarbon applications.

and the industry as a whole, in the form of costly product losses and fines, as well as severe reputation damage. In order to ensure the integrity of their pipelines and remain in compliance with new and tougher laws, a greater number of businesses are now making the conscientious decision to install advanced leak detection systems. These systems are capable of detecting both the presence and location of a leak, allowing a pipeline operator to address the situation quickly and effectively – before the leak can harm property or people.

A variety of leak detection systems are currently available. However, not all systems are created equal, and corporations
must thoroughly evaluate the benefits of each before making a final decision. A leak detection system should demonstrate consistently high levels of sensitivity, accuracy, reliability and robustness. It should be easy for a pipeline operator to learn, understand and use. Ideally, the system should also integrate software with instrumentation in order to enhance performance and simplify maintenance.

After reviewing several recent US and international laws pertaining to leak detection for pipelines, this article will take a detailed look at one innovative leak detection system and demonstrate how a Taiwanese petrochemical company put this system to good use.

New regulations necessitate leak detection
While some statistics indicate that the average number of hazardous liquid pipeline failures in the US and Europe has dropped throughout the past two decades, the need for diligence on the part of oil companies will only increase in the coming years. Major leakage incidents continue to occur worldwide each year and can have severe consequences for all involved. A few recent examples include:

- In 2006, more than 150 people died after a leaking oil pipeline exploded on the outskirts of Lagos, Nigeria. Another leakage-related explosion occurred in Lagos later that same year, resulting in several hundred more deaths.
- In 2010, an oil pipeline at a pumping station in central Mexico exploded as a result of leakage and killed at least 27 people, injured 52 others and damaged more than 100 homes.
- Also in 2010, several holes in an underground pipeline led to an oil spill in Romeoville, Illinois, a suburb of Chicago. More than 250,000 gallons of oil infiltrated a retention pond as well as the town’s wastewater treatment plant, causing a spike in the cost of wholesale and retail gasoline. The Romeoville incident was the second major leak of an oil pipeline owned by one particular energy corporation in a two-month span, and numerous lawsuits against the company are now pending.

As a result of occurrences like these, many governments are now taking steps to more carefully regulate the transportation of hazardous liquids and ensure that oil companies are continuously monitoring their pipelines for leaks. What follows are several examples of recommended guidelines and laws recently enacted in the US and Europe.

**API 1130 (US)**
In 2007, the American Petroleum Institute published *API 1130: Computational Pipeline Monitoring for Liquid Pipelines*. Limited in scope to single-phase liquid pipelines, *API 1130* is a recommended practice focusing on the design, implementation, testing and operation of computational pipeline monitoring (CPM) systems, or leak detection systems. To assist a pipeline operator in selecting the most appropriate CPM for a specific application, *API 1130* defines four performance metrics: sensitivity, accuracy, reliability and robustness.

**Title 49 of the Code for Federal Regulations (US)**
The US Department of Transportation Pipeline and Hazardous Materials Safety Administration has developed a series of regulations governing pipeline safety known as *Title 49 of the Code for Federal Regulations* (parts 190 - 199). While the scope of *Title 49* is far-reaching, part 195.444 makes specific reference to CPM systems, stating that any system installed on a pipeline that transports hazardous single-phase liquids must comply with the operating, maintenance, testing, recordkeeping and training guidelines set forth by *API 1130*.

**Technische Regel für Fernleitungsanlagen (Germany)**
First proposed in 2002, the *Technische Regel für Fernleitungsanlagen* (Technical Rule for Pipeline Systems, or *TRFL*) requires all new pipeline systems in Germany transporting flammable or otherwise hazardous liquids to be monitored continuously for leaks. Unlike *API 1130*, the *TRFL* does not focus on the design or implementation of leak detection systems, but simply specifies the detection and localisation functions that are required of any leak detection system installed on a pipeline.

**How it works**
In light of these and other regulations, installing a high-quality leak detection system has become a necessity for any corporation overseeing the maintenance and operation of oil pipelines. But how can a company determine which of the many existing solutions is the wisest investment?
One solution to consider is the Sitrans FUH1010 clamp-on ultrasonic leak detection system from Siemens. This system consists of two or more installation points along a pipeline known as site stations, each containing a Sitrans FUH1010 clamp-on ultrasonic flowmeter, a clamp-on RTD temperature sensor and a data communication device. The system is monitored by a master station, a computer that runs the leak detection software and polls each of the site stations for a wide range of data. The master station uses a compensated volume balance method that continually monitors differences in flowrate between each pipeline segment (the portion of the pipeline bounded by two site stations) and compares a 1 minute rolling average over intervals of 1, 5, 15 and 60 minutes. If the line balance deviates by more than a pre-established threshold, a product release alarm will sound.

In the event of a leak, a low-pressure wave (or pressure transient) is generated and radiates both upstream and downstream from the leak location at the speed of sound for the particular liquid flowing through the pipe. This drop in pressure will cause a decrease in the density of the liquid, thereby decreasing the liquid’s sonic propagation velocity ($V_s$) as well. As the site stations along the pipeline process $V_s$ approximately 80 times per second, this sudden decrease will be detected and time-stamped by each station. The master station can then determine the location of the leak by calculating the relative difference in arrival time of the pressure transient at each site station. For example, if the pressure transient arrived at both site stations at exactly the same time, the leak must have originated at the middle point of the monitored segment.

### Innovation and integration

The Siemens leak detection system provides a distinct benefit to oil companies seeking a method for identifying and locating pipeline leaks. Merging innovation with insight into customer needs, Siemens recently enhanced its already powerful leak detection software to ensure greater ease of use for pipeline operators.

The key is Siemens’ patented Simatic WinCC software, a Windows-based process visualisation system that has now been integrated to provide a dynamic graphic user interface (GUI) for the Siemens leak detection solution. Simatic WinCC allows a pipeline operator to visually identify pipeline locations on a map, complemented by straightforward graphs, charts, warning boxes and other visual cues (Figure 1). This improves process efficiency, as an operator viewing the master station will find it easy to understand what is happening across the pipeline, react instantly to any situation before it escalates, and pinpoint the locations of any leaks that do occur. Bearing in mind today’s environment of increased regulations, the enhanced software is ideal because it significantly decreases the amount of training required for pipeline operators to utilise the system effectively and offers the necessary alarm audit logs to meet regulatory requirements.

The Siemens leak detection system offers another competitive edge as well. While most suppliers offer only the software component of a leak detection system, Siemens provides a comprehensive package complete with software as well as all flow and temperature instrumentation. Since the Siemens software is designed to optimise all data provided by Siemens flowmeters and temperature sensors, users are assured the best possible performance under any operating conditions. This benefit also extends to the customer service experience, as Siemens assumes responsibility for the entire system and customers have only one call to make should any questions or problems arise.

### Case study: Taiwanese petrochemical company

A petrochemical company in Taiwan sought a replacement for its existing leak detection system, which had not been

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Table 1. Leak detection thresholds

<table>
<thead>
<tr>
<th>Configuration</th>
<th>1 minute</th>
<th>5 minutes</th>
<th>15 minutes</th>
<th>60 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard alarm threshold</td>
<td>3%</td>
<td>2%</td>
<td>1%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Standard visual trend</td>
<td>2.5%</td>
<td>1%</td>
<td>0.75%</td>
<td>0.25%</td>
</tr>
<tr>
<td>Threshold for petrochemical company test</td>
<td>0.5%</td>
<td>0.4%</td>
<td>0.25%</td>
<td>0.25%</td>
</tr>
</tbody>
</table>

Table 2. Dynamic state leak detection and location test

<table>
<thead>
<tr>
<th>Leak hole size</th>
<th>Leak start time</th>
<th>Leak catch time</th>
<th>Flow rate</th>
<th>Leak volume</th>
<th>Time to detect leak</th>
</tr>
</thead>
<tbody>
<tr>
<td>¾ in.</td>
<td>15:04</td>
<td>15:07</td>
<td>202 m³/h</td>
<td>50 litres</td>
<td>3 minutes</td>
</tr>
<tr>
<td>12 in. gate valve (1.5 turns)</td>
<td>17:49</td>
<td>17:52</td>
<td>202 m³/h</td>
<td>1342 litres</td>
<td>3 minutes</td>
</tr>
<tr>
<td>¾ in.</td>
<td>18:20</td>
<td>18:21</td>
<td>202 m³/h</td>
<td>43 litres</td>
<td>1 minute</td>
</tr>
</tbody>
</table>

Table 3. Static state leak detection and location test

<table>
<thead>
<tr>
<th>Leak hole size</th>
<th>Leak start time</th>
<th>Leak catch time</th>
<th>Flow rate</th>
<th>Leak volume</th>
<th>Time to detect leak</th>
</tr>
</thead>
<tbody>
<tr>
<td>¾ in.</td>
<td>14:00</td>
<td>14:03</td>
<td>0 m³/h</td>
<td>189 litres</td>
<td>3 minutes</td>
</tr>
<tr>
<td>½ in.</td>
<td>14:41</td>
<td>14:43</td>
<td>0 m³/h</td>
<td>178 litres</td>
<td>2 minutes</td>
</tr>
<tr>
<td>¾ in. (60% open)</td>
<td>15:01</td>
<td>15:03</td>
<td>0 m³/h</td>
<td>59 litres</td>
<td>2 minutes</td>
</tr>
<tr>
<td>¾ in. (30% open)</td>
<td>15:26</td>
<td>16:00</td>
<td>0 m³/h</td>
<td>189 litres</td>
<td>34 minutes</td>
</tr>
</tbody>
</table>

Figure 2. The testing segment provided by the Taiwanese petrochemical company, consisting of a single underground pipeline transporting diesel oil.

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functioning properly for quite some time. The faulty system was installed on a 50 km segment of a 181 km underground pipeline carrying various hydrocarbon products. Before determining which vendors could participate in a large project bid, the company required that interested contenders (including Siemens) participate in a week-long on-site test of their leak detection solutions. The company had three basic requirements in choosing a new system: accurate detection of accidental product release, accurate determination of product release location, and the ability to identify pipeline product theft. The third requirement was the most challenging, as theft generally occurs at exceedingly low rates of flow for short periods of time. Therefore, the winning system would need to demonstrate a high enough level of sensitivity to detect even the smallest of pressure transients.

The testing segment provided by the petrochemical company (Figure 2) comprised 119 km of a single underground pipeline that transported diesel oil at flowrates ranging from 0 - 300 m³/hr. To participate in the test, Siemens installed three clamp-on ultrasonic flowmeters (labelled A, B and C) along the pipeline with an Ethernet connection between each meter, and one master station with its own Ethernet connection in the control room (not shown in the diagram). Two segments (A-B and B-C) were monitored for leak detection and leak location. The distance between A and B was 55 km, and between B and C was 64 km.

Based on the petrochemical company’s operating conditions, Siemens set up four different leak thresholds for the leak detection test (Table 1).

To conduct the test, the petrochemical company randomly simulated leaks of various sizes by opening the ball valves and gate valves at differing levels and speeds. The company was particularly interested in the performance of the leak detection system when the gate valves were opened slowly, as this action might generate a pressure transient too small for less sensitive systems to detect. The tests were conducted at dynamic flow state one day (Table 2) and at static flow state the next day (Table 3).

The Siemens leak detection system was able to detect product release and location at both dynamic and static flow states with similarly high accuracies. In fact, during these particular tests, the system located several product releases within ±20 m. In addition, it detected a 90 litre product release, representing a mere 0.045% flow change from the nominal flow and demonstrating the impressive sensitivity of the system.

Based on the test results and overall meter performance, Siemens was invited to make a bid on the new pipeline project. Ultimately, the Taiwanese petrochemical company came to recognise the numerous benefits offered by this solution and chose to move forward with installing the clamp-on ultrasonic leak detection system from Siemens.