WORLD PIPELINES®

Volume 13 Number 10 - October 2013

Gazoduc Rocade Est-Quest:
336 km of API natural gas pipeline

WHY USE A DTS SYSTEM?

Hans Meulman, Toru Fukuzawa and Dwight Eldredge, Yokogawa, Corporation of America, explain the operation and application of DTS for leak detection in pipelines.

As most pipelines will develop multiple leaks during operation, leak detection systems are required. There are many methods for detecting pipeline leaks. Based on the particular characteristics of the application, each method has advantages and drawbacks.

Distributed temperature sensing (DTS) is a method that has been used for more than 20 years. DTS is often the best choice when a leak results in a temperature differential between the ambient air and the escaping liquid or gas. Temperature differentials generally occur when the pipeline product is at a high pressure, a high temperature or a low temperature, all relative to ambient, which is characteristic of many pipelines.

DTS is accomplished with fibre optic sensing systems that act as a sensor and measure temperatures along the entire length of an optical fibre. The fibre is installed along the outside of the pipeline within protective sheathing. Exact installation location is dependent on the relative area(s) of the anticipated temperature differential generated by a leak, and on other factors such as available mounting space.

DTS rapidly detects and accurately locates seepage (slow leaks), at weld points and pipeline fittings, as well as sudden leaks (pinholes and significant cracks or ruptures).

Leak detection with DTS

A DTS leak detection system will quickly and accurately pinpoint the exact location of leaks, often before any other detection technology. Even a small leak will result in a significant temperature differential, one that can be detected by a DTS system. Most DTS systems can measure temperatures with an accuracy of a few degrees, more than sufficient for leak detection.

Products in pipelines are often under significant pressure, and a leak will cause a drop in temperature as the effluent exits the pipe. This is a result of the Joule-Thomson effect, a phenomenon observed when a compressed gas is released through an aperture or a porous material into an area of lower pressure. This produces a negative temperature effect on the immediate surroundings. Cryogenic products, such as LNG, also result in a measurable temperature differential at a leak point, regardless of pipeline pressure.

Lines carrying heated product, such as heavy oil, multi-phase products, molten products, heated water and steam, also lend themselves to DTS. This is due to the local temperature increases, which occur as the product escapes. The temperature differential in these cases is a rise, as opposed to products under pressure at temperatures near ambient, where a leak causes a temperature drop.

Other methods of temperature measurement are impractical for leak detection because they are designed to measure temperature at a specific point, rather than along the long distances typically traversed by pipelines. In contrast, a DTS system measures temperature along the entire length of the fibre optic cable, typically at around 1 m intervals.

One leading DTS system measures temperatures at a distance of 6 km, totalling 6000 points of measurement. The system's transceiver can measure temperatures for 6 km both upstream and downstream of its installation point, for a total coverage of 12 km per each transceiver. Multiple transceivers with accompanying fibre optic cables can be used to provide coverage for long pipelines, totalling hundreds or thousands of kilometers in distance.

The fibre optic cable is installed at the point where the temperature differential is most pronounced. For example, a pipeline transporting ammonia would have the cable installed at the top of the pipe. As the temperature drops it would be experienced there for a leak at any point along the entire circumference of the pipe. Other applications might require

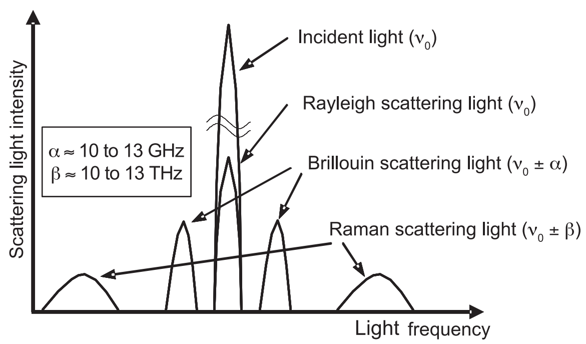

Figure 1. Incident light introduced into an optical fibre produces three main types of scattering lights: Rayleigh, Brillouin and Raman.

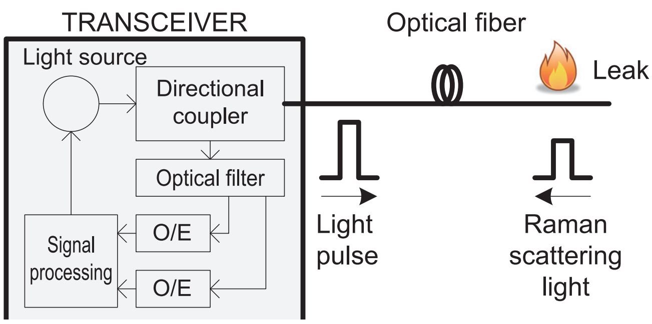

Figure 2. A light pulse is generated by the transceiver, and the intensity of the Raman scatterling light is measured by the transceiver, pinpointing temperature changes along the length of the fibre optic cable.

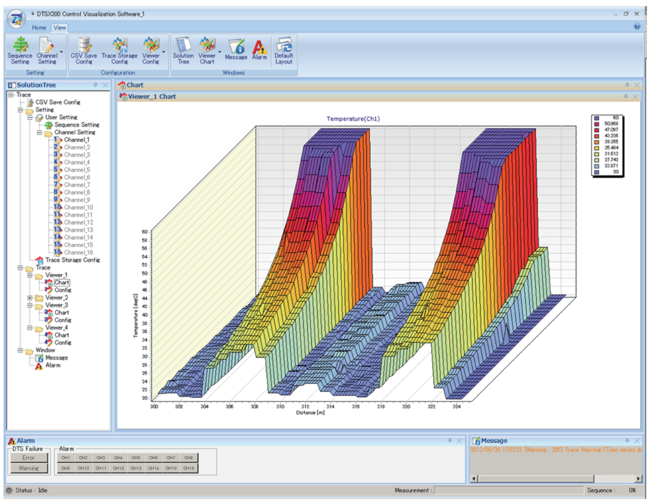

Figure 3. A specialised PC-based software package can be connected to the DTS transceivers to clearly depict pipeline temperature date on pre-configured screens.

the cable to be installed at some other location relative to the pipeline.

A DTS system operates as a semi-automatic leak detection system, providing information to allow operators to take action prior to automation and/or safety system activation. A semi-automatic system is one in which the detection of the leak takes place automatically, leading to an alarm signal in a continuously staffed control room. After validation of the signal, the operator can close the safety shut down and manually block valves. This operator achieves this by performing specific actions on the automation and safety systems in the control room.

DTS details

In a DTS system, the entire length of a specially designed optical fibre is used as a sensor. A transmitter, generally part of a transceiver, introduces laser light into the fibre, and this incident light scatters inside the optical fibre. Figure 1 shows the spectrum of scattering light in the optical fibre.

According to the scattering generation mechanism, scattering light is classified into three types: Rayleigh scattering light with a frequency equal to that of the incident light; Brillouin scattering light with a frequency shift of a approximately ±10 to 13 GHz relative to the incident light; and Raman scattering light with a frequency shift of approximately ±10 to 13 THz relative to the incident light. DTS systems use the temperature dependence of the Raman back scattering light intensity to measure temperatures.

Figure 2 shows a conceptual diagram of distributed temperature measurement. A light pulse is entered as incident light by the transceiver's transmitter. The transceiver's receiver then samples the intensity of the Raman back scattering light to determine temperatures and locations along the length of the fibre optic cable.

A light pulse is generated by the transceiver, and the intensity of the Raman scattering light is measured by the transceivers, pinpointing temperature changes along the length of the fibre optic cable.

DTS does not measure internal pipeline pressures, temperatures, or flows – so it is not affected by transients such as pump stop/start operations, operation of control valves, and changes in delivery rates – normal process conditions that can adversely affect other methods of leak detection. Viscosity changes, temperature changes, and phase changes, also have no adverse effect on DTS systems.

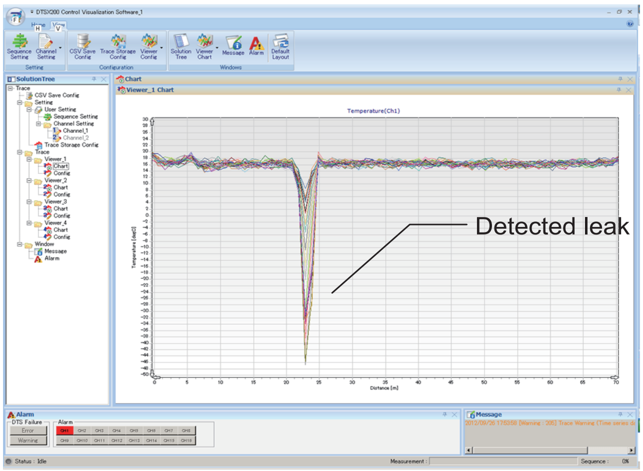

Figure 4. This specialised PC-based software package shows the result of leak detection in a high pressure ammonia pipeline. The temperature is measured every few seconds, and a decrease of approximately -40 °C is observed at the leak point.

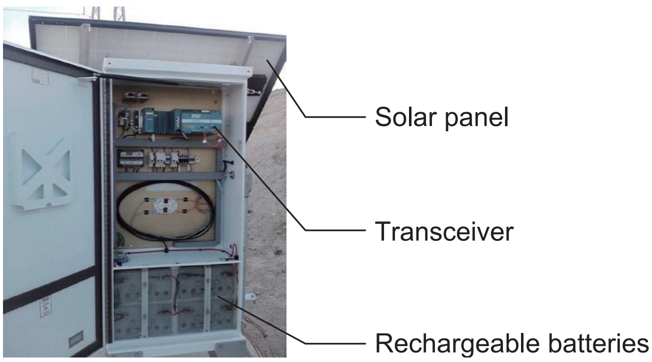

Figure 5. DTS systems must often be installed in remote locations with little or no acess to electricity, making solar power the best option.

Integration with SCADA systems

Most pipelines are monitored and controlled by supervisory and control data acquisition (SCADA) systems. A DTS system is typically interfaced to the SCADA system to provide operators and engineers with the information they need to monitor and control pipeline operation.

In most cases, the DTS transceivers will communicate with the SCADA system over a dedicated digital communications link, generally ethernet-based. The information from the transceivers can be put into standard industry formats including WITSML, LAS and MODBUS, depending on the SCADA system requirements and capabilities.

Certain manufacturers of DTS systems offer specialised PC-based software that connects directly to the DTS transceivers, generally via ethernet-based communications links. These software packages allow operators to view DTS data on pre-configured screens, saving SCADA system configuration time. Special features are also included to more clearly depict DTS data (Figure 3).

The PC-based software is usually connected to the SCADA system, again via an ethernet-based communications link. This allows the SCADA system to display alarms and events in an overview fashion, and direct personnel to the specialised PC-based software system for more detailed information.

Alarm configuration is a key step when implementing a DTS system, any changes due to ambient temperature transients must be accounted for when configuring alarms. In certain scenarios, such as with buried or insulated pipelines, the fibre optic sensing cable can be isolated from the ambient thermal environment. Consequently, it is not necessary to measure and compensate for ambient temperatures.

However, in cases of above-ground or un-insulated pipelines, any changes due to ambient temperature must be remotely sensed, and then filtered using algorithms in order to remove false alarms. Ambient temperatures can be measured over relatively large areas with correspondingly fewer sensors, as ambient temperatures are typically similar for many kilometers of a typical pipeline installation.

A SCADA system will require custom programming to filter out the false alarms caused by ambient temperature changes, while specialised PC-based software packages will typically have these and other features particular to DTS systems built in (Figure 4).

Figure 5 shows an application example of a DTS system at a resource mining site. Infrastructure such as power and communications is often not developed at this and other pipeline sites. In this example, power is supplied with solar panels and rechargeable batteries, and wireless modems are used for communications with the host system. In this case, the host system is a specialised PC-based software package designed to work with the specific DTS system.

Although DTS works well in many applications, there are other methods of leak detection that may perform better in certain conditions, particularly when the pipeline product is not being transported under pressure or at a significant temperature difference from ambient.

Other approaches

In addition to DTS systems, there are several other systems for detecting leaks in various pipeline applications. These include chemical sensors, infrared cameras, flow measurement, level measurement, pressure measurement, acoustic and seismic.

Chemical sensors only measure the presence of vapors due to leaks in a relatively small area, and require frequent maintenance and re-calibration. It is generally not feasible to purchase, install and maintain, large numbers of chemical sensors over the length of a long pipeline.

Infrared camera systems can cover larger areas than point-based temperature sensors such as thermocouples and RTDs, and can be useful for leak detection in short lengths of pipelines. For longer pipelines many infrared cameras would be required, increasing costs.

Measurement of changes in flow, level and pressure, will detect large leaks or pipeline breakages, but will generally not sense minor leaks. Flow, pressure and level measurement, will have delays based on velocity, compressibility and distance from the leak. In addition, these measurements are affected by normal transients in pipeline operations.

In case of minor leaks – which happen more frequently – flow, pressure and level sensors, will often not be able to detect the leakage. As most large leaks and breakages start as small leaks, the best time to detect problems is early on, making these systems unsuitable for most pipeline leak detection applications.

Acoustic systems sense leaks by measuring the change in sound generated by a leak. These systems are very sensitive to the external noise and vibrations generated by the rotating machinery generally installed on pipelines, such as pumps and compressors. The same issues apply to seismic systems, which rely on the changes in vibration generated by leaks.

Conclusion

If the material in the pipeline is at a higher pressure than ambient, and/or at a temperature significantly higher or lower than ambient, then DTS is often the best method for leak detection. DTS systems can operate over a long distances, with an individual transceiver covering thousands of kilometers. A DTS system can consist of an unlimited number of transceivers, making DTS viable for even the longest pipelines.

With all pipelines, the best time to detect a leak is when it first begins, before it increases in size. A DTS system can detect very small leaks, providing the leak generates the required temperature differential in the area of the detecting fibre optic cable.

In combination with a SCADA system, a DTS system offers a complete solution to monitor pipelines and provide real-time information to operators, and to deliver details concerning the condition of the pipeline to other technical personnel.

As compared with most other leak detection methods, DTS systems need little maintenance and require only minimal amounts of power, easing installation and upkeep over the widely distributed areas in which many pipelines are installed.