Leak Detection Technologies

Pipelines are used to transport water from very old times. Transportation through such buried or above-ground pipelines is also extended to transport crude oil, natural gas and other petroleum products routinely and over hundreds and thousands of kilometres. The networked pipeline travels underground, along river or sea beds, cuts through mountains and crisscrossed human dwellings and is a costly industrial asset. Much cheaper and safer than surface transport, this mode of transport also suffers from difficulties in surveillance to take timely action in case of leakage. Any leakage has serious HSE (Health, Safety and Environment) implications. Therefore, pipeline operators are always on the lookout for some Leak Detection tool which uses the operating data such as pressure and temperature and alerts in case of any leakage. Such tools, often software tools, are called LDS (Leak Detection Software) tools. Several technologies, primitive to state-of-art, are available for leak detection in cross-country pipelines.

This note discusses in brief the science behind various alternate technologies on offer for leak detection.

1. Volume Balancing

Any transportation network has source points where the metered quantities of fluid commodity enter the network and delivery points where metered quantities are delivered to the customers. If the network is leak proof, there should be no difference between the total incoming and total outgoing quantities. The volume balancing method works on the discrepancy between these two quantities, if any, and attributes it to leakage in the network and then decides the location and quantum of leak through simple steady state pressure drop calculations for the network.

This is the oldest technology and continues to be offered even today to unsuspecting operators.

2. Negative Pressure Wave

This is another method where pressures are monitored continuously at closely spaced points along the network. In a smoothly functioning network, pressure decreases along the direction of flow. This is basic physics. A leakage, whenever it happens disturbs this expected pressure gradient, which is then analysed for leak identification.

Unlike the volume balancing method which often works off-line, this method operates in real time.

The method ignores the fact that a network performance is never at steady state due to changes in incoming/outgoing flow rates. The method is known to give spurious alarms due to this reality of real life cross-country pipeline transportation.
The accuracy of the method depends almost directly on the distance between consecutive pressure monitors along the pipe route. The price to be paid for heavy instrumentation can be prohibitive.

3. Acoustic Emission

Any leak from a pressurised pipeline generates a low frequency sound due to the escaping fluid. This hissing sound is detected by travelling along the pipeline with acoustic detectors.

Such a method is useful as a surveillance tool or as a tool to actually pinpoint the exact location after some other tool has indicated a leakage over a range of pipeline length.

4. Fibre Optics

A leakage causes vibrations (that is why the leak makes noise). This vibration is also imposed on the pipeline itself and changes its own frequency of vibration. Also, a leakage could cause change in temperature of the soil around the leakage. For example, if natural gas flowing through a pipeline at high pressure leaks somewhere, it will cool significantly by the so called Joule Thomson effect (often reaching subzero temperatures). This will cool the pipe and the surrounding soil locally. Change in either temperature or vibration frequency can cause change in refractive index of the optic fibre run on the exterior of the pipe along its entire length.

This is used in this technique to identify a leakage event.

In a transient network, change in flow rates and the corresponding changes in pressure can cause vibrations in pipe. This itself can alter optic fibre's refractive index. The method is thus ridden with the curse of spurious alarms.

The method requires to be adopted at the time of construction itself as the optic fibre is led along with the pipe at the time of construction.

5. Copper Wire

For water carrying pipelines, this technique runs a continuous copper wire along the entire length of the pipeline. If water leaks out, the electrical conducting copper wire's resistance changes. The change in current carrying capacity of the wire is seen as pointing towards leakage.

The copper wire responds to any water that comes in contact with it. It could be due to other reasons external to the pipe such as from a nearby drain or even rain. The technique is therefore ridden with possibilities of spurious alarms more than any other technique.

6. Transient Simulation

All transportation networks, operate under significant transients. This is so because of multiple incoming (source) and outgoing (customer) points. Change in pressure and/or flow rate at any one of them will affect the entire network. In gas networks, the transients due to any change affect the network over a longer period of time due to compressibility of the medium. At the same time, the intensity of disturbance gets mitigated by the compressibility. It is unrealistic to expect any network to operate at steady state at any time.

This unsteady state or transience is captured by transient simulation of the network. Once validated, a network simulation behaves as the actual network would do in terms of pressures at various locations in the network. Any deviation in the prediction of pressures made by the simulator and the actual pressures reported by pressure monitoring instruments along the pipeline is a sure indicator of some fault in the network. If the fault seems to affect the transient pressure profiles at various locations in a particular pattern, it indicates with some degree of certainty the occurrence of leakage. The transient simulator then can fine tune the leakage location and quantum through rigorous simulation if necessary.

This transient model based approach stands the best chance of leak detection and avoidance or minimisation of spurious alarms.