Pipeline Leak Detection Techniques

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Pipeline is the fastest and most reliable means of fluid transportation compared to other transportation modes like rail or road tankers. However, leakage is the main threat for pipeline transfer. The pipelines often carry hazardous materials and may pass through areas of human population. Any leak through the pipeline results in not only loss of product but also impacts environment and may pose a hazard to the nearby human population. Pipeline leak monitoring is also necessary to detect thefts. The leak detection techniques help to minimize the product losses. Selection of a reliable leak detection system is crucial in achieving safe and economical pipeline transport objective. This article briefly discusses various pipeline leak detection techniques and their working principles.

Characteristics of Leak Detection System:

Leaks can occur due to variety of reasons. Major reasons include corrosion, material fatigue, accidents, etc. There are various types of leak detection systems. The selected system shall have following characteristics.

- Sensitive to determine even the small leaks quickly
- Accurate in detecting leak location
- Reliable in leak detection – No false alarms
- Robust in detecting sensor failure and fallback arrangements

Below are some of the commonly used leak detection techniques

Smart Pigging System:

Pigging is a common practice used for cleaning of the pipelines. Besides cleaning, the pigging can also be used for leak detection. The pipeline pigs can be used to measure wall thickness, gather corrosion data inside pipeline and thus can help in accessing pipeline internal health condition.

Wall thickness reduction is an indication of corrosion. There are two commonly used methods for monitoring wall thickness. The first method is (similar to the MRI body scan machines) based on magnetic flux principle in which the pipeline is magnetized using strong permanent magnet. Sensor probes attached to the smart pig record the magnetic flux across the pipeline. The change in magnetic flux can provide an indication to change in pipe wall thickness. This method is however applicable only for steel pipes. The second method utilizes principle of ultrasonics. In this method, pipe wall thickness can be directly measured by using ultrasonic waves. The smart pig is used to transmit ultrasonic pulse inside the pipe and it receives the reflected signal. The time taken for an echo to return provides the data for deriving wall thickness.

Fiber Optic Cable:

The fiber optic cables can monitor the pipeline conditions on continuous basis. The leak detection is based on tracking the physical conditions at the leak site. Temperature is one such physical parameter which is tracked for leak detection purposes using optical fiber technology. Whenever a pipeline leaks, it affects the local temperature in the vicinity of leak. A drop in temperature can be noticed in case of leak in gas carrying pipelines due to 'Joule-Thomson' effect or the soil temperature changes can be noticed if a liquid carrying pipeline leaks. The main advantage of using fiber optic method lies in the fact that the temperature is recorded as a continuous profile and not as a point profile (like transmitters). Generally, doped quartz glass is used to make optical fibers. It has an amorphous solid structure as it is a form of silicon dioxide. Lattice oscillations are induced within the solid due to thermal effects. Whenever light falls onto such solids; (containing thermally excited molecular oscillations) the light particles or the photons tend to interact

with electrons of the molecule. Light then emits pulses that are reflected by molecules in the fiber optic cable. Magnitude of the reflected pulse provides data on the temperature at the place where the photon hits the molecule. Monitoring pipelines with fiber optic cables offers a good option for accurately localizing leaks.

Acoustic Method:

An acoustic method uses noise measuring sensors which are installed on outside of the pipeline to detect leaks. Any leak in the pipeline results in a low pressure area. As the fluid travels from a high pressure area to the low pressure area, it produces acoustic signals due to the turbulent movement. The noise profile created due to the leak is then compared with the baseline noise level. The deviations between the baseline noise and noise profile generated due to leaks helps in configuring leak alarms. Though the acoustic method is effective in detecting major leaks, it fails to capture smaller acoustic signals generated from very small leaks.

Wave Propagation Method:

The pressure profile of the pipeline changes due to leak. A sudden leak in the pipeline causes a sudden pressure drop in the pipeline. This results in a pressure wave. This pressure wave travels in both directions from leak at sonic velocity. Presence or occurrence of such pressure wave can be implied as a leak in the pipeline. The exact leak location can be estimated once the pressure wave is detected. Pressure wave travels in both the directions of leak. The time required for these pressure waves to reach pressure sensors is used to detect leak location. In case of the time taken by pressure wave to reach the both pressure sensors is same then, the leak location can be considered as at a middle point between these pressure sensors. This technique however has reliability issues. The wave propagation method system is effective only when the leak is of instantaneous and of significant size. The sensitivity can be lower as the alarm thresholds are often set high to avoid false alarms. This method sometimes fails to notice leak due to failure in detecting pressure wave generation at the moment of leak initiation.

Infrared Method:

Infrared method for leak detection is mainly used for leak detection especially from gas pipelines. This method is a non continuous, non contact type and used during inspection of the pipelines. This method is based on infrared radiation principle which can measure temperature and radiant energy of an object. Infrared video cameras with a special filter sensitive to selected spectrum of infrared wavelengths are developed over the years. Certain hydrocarbons have the ability to absorb infrared radiation. Infrared cameras can detect the radiation of gas pipeline and same can be noticed from the thermal images produced by it. Pipeline condition can be inspected by using infrared cameras through drones and any change in thermal image colours are implied as a leak in pipelines. Leaks in the liquid leaks can also be detected using infrared cameras, however sometimes the temperature difference between leaking pipeline and its surrounding soil can be small. In such cases, infrared cameras might not be sensitive enough to capture this small temperature difference.

Mass Balance / Volume Balance Method:

Mass balance method makes use of the instrumentation and SCADA system provided on pipelines. A leak free pipeline satisfies mass/volume balance equation and thus any difference in the quantity of material entering and leaving the pipeline is used to detect the leaks. As the pipelines provides fluids for various commercial activities, accurate measurements are required for determining commercial value transactions and this technique can take help of measurements already provided for commercial requirements. When the balances are done on volume basis, it is important that the flow meter readings are compared with a uniform base scale. The recorded values of temperature and pressure must be corrected to reference (NTP) conditions. For gas pipelines, it is a normal practice to increase its normal operating pressure and thus pack more gas inventory in the given pipeline length. This packing concept is

useful as it can serve as buffer volume to cater to peak demands. Special care is required for gas pipelines to correct the inventory readings to account for any line pack variations.

Dynamic modelling programs can also be implemented to account for such unsteady state situations. Real time transient models can also be developed based on temperature, pressure and flow data recorded on SCADA system. However, this type of real time modelling has historically proved difficult to successfully implement for online applications. This is due to the complexity of the modelling variables and calculations required.

Pressure Profile Analysis:

Pressure profile in the pipeline provides reasonably fare indication of any pipeline leak. The pipeline leak will result in lower than expected pressures at the receiver end. Leak will also result in decrease in downstream flow and consequently, there will be an increase in upstream flow. Consequently, the pressure gradient will decrease downstream of the leak and will increase upstream of the leak. The simultaneous occurrence of both i.e. change in pressure and change is an indication of a leak. It is a relatively inexpensive solution. However, pressure decline is not unique to a leak event, and false alarms may be common on transient lines.

Concluding Remarks:

Pipeline leaks may pose a threat to the safety of its surroundings. Apart from safety, the pipeline leak detection systems play a vital role in profitability of transfer. A wide variety of leak detection systems are available. Every method is though not suitable for every application. The leak detection systems should ideally be sensitive, accurate, reliable and robust. The selection of most appropriate or suitable method is based on the requirements and challenges posed by individual application. The other thing that influences pipeline leak type selection includes installation costs, maintenance requirements, etc.

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