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Predicting Loss of Containment in Surface Pipeline using Computational Fluid Dynamics and Supervised Machine Learning Model to Improve Process Safety in Oil and Gas Operations

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Abstract : Loss of containment is the primary hazard that process safety management is concerned within the oil and gas industry. Escalation to more serious consequences all begins with the loss of containment, starting with oil and gas release from leakage or spillage from primary containment resulting in pool fire, jet fire and even explosion when reacted with various ignition sources in the operations. Therefore, the heart of process safety management is avoiding loss of containment and mitigating its impact through the implementation of safeguards. The most effective safeguard for the case is an early detection system to alert Operations to take action prior to a potential case of loss of containment. The detection system value increases when applied to a long surface pipeline that is naturally difficult to monitor at all times and is exposed to multiple causes of loss of containment, from natural corrosion to illegal tapping. Based on prior researches and studies, detecting loss of containment accurately in the surface pipeline is difficult. The trade-off between cost-effectiveness and high accuracy has been the main issue when selecting the traditional detection method. The current best-performing method, Real-Time Transient Model (RTTM), requires analysis of closely positioned pressure, flow and temperature (PVT) points in the pipeline to be accurate. Having multiple adjacent PVT sensors along the pipeline is expensive, hence generally not a viable alternative from an economic standpoint.A conceptual approach to combine mathematical modeling using computational fluid dynamics and a supervised machine learning model has shown promising results to predict leakage in the pipeline. Mathematical modeling is used to generate simulation data where this data is used to train the leak detection and localization models. Mathematical models and simulation software have also been shown to provide comparable results with experimental data with very high levels of accuracy. While the supervised machine learning model requires a large training dataset for the development of accurate models, mathematical modeling has been shown to be able to generate the required datasets to justify the application of data analytics for the development of model-based leak detection systems for petroleum pipelines. This paper presents a review of key leak detection strategies for oil and gas pipelines, with a specific focus on crude oil applications, and presents the opportunities for the use of data analytics tools and mathematical modeling for the development of robust real-time leak detection and localization system for surface pipelines. A case study is also presented.

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