ON-LINE FLOW ASSURANCE SURVEYS TO DETERMINE PIPELINE DEPOSIT LOCATION AND INVENTORY

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1. INTRODUCTION

Tracerco have, over the past forty years, offered the **Tracerco Diagnostics™** technology to look at the performance of oil and gas process systems. The measurement services offered involve the use of radioactive sealed sources and unsealed radioisotope tracers to provide a rapid and detailed picture of systems performance whilst remaining on-line. These techniques are carried out on-line, external to the pipeline, with no interference to normal pipeline operations, and effectively allow us to 'look' through vessel and pipe walls to measure contents and process parameters.

This paper focuses on selected areas of the **TRACERCO Diagnostics ™** technologies that are used for ppipeline deposit measurements, specifically their location, amount, and profile within any length of pipeline.

This paper will show how the techniques are employed, the type of results that are achievable, and describe selected case studies.

2. BASICS OF RADISOTOPE TECHNOLOGY

There are four main types of radioactivity. These include alpha particles, beta particles, neutrons, and gamma electromagnetic radiation. Alpha and Beta emissions have limited use in industrial applications, as they are very weakly penetrating, and thus cannot be detected through a steel wall. Neutrons have a very specific use for diagnostic purposes and can be used to determine the presence and location of hydrogenous liquid within a process system. Electromagnetic gamma radiation is most commonly used for on-stream non-intrusive investigations, as the radiation emitted is able to penetrate and pass through matter, such as steel, allowing its detection at the outside walls of a process system.

Gamma radioisotopes are used in two fundamental physical forms:

a) Sealed source scanning techniques

b) Unsealed Radioisotope Tracing Techniques

A sealed source consists of a small pellet of a radioisotope that is sealed within a steel case. The source is mobilised to a place of work, used and then transported from the site after completion of a work schedule. Sealed sources can be used to scan through a pipe to identify such things as lining integrity, density of liquid present, presence of fluid or gas slugging, solids build-up and other process anomalies.

Unsealed radioisotopes are a radioactive solid, liquid or gas that follow a particular material through a system. Sensitive radiation detectors are placed on the outside surface of a pipe and detect the unsealed tracer presence upon its flow past specific positions. Careful consideration must be given to the type and amount of tracer used to ensure, if adding to a product stream, the material does not remain radioactive after completion of the project.

Due to the penetration ability of gamma emitting sealed and unsealed radioisotopes used, very little preparation is needed on site to carry out a measurement, for example there is no need to remove lagging from a pipeline, or if subsea no requirement to remove concrete coating if present. Due to the ability to rapidly gather data, studies can involve repeat testing at a variety of process rates and conditions, and results are available immediately.

In all of the above applications it is important to note that, due to the use of sensitive radiation detectors, the amount of radioactive material used is very low. Comparing the technologies with Non Destructive Testing, amounts used are some 1,000 times smaller. The on-line non-intrusive testing methods, and use of small levels of material, mean that there is no disruption to normal operations.

3. RADIOISOTOPE TECHNIQUES USED

3.1 Tracerco Diagnostics™ Scan

The application of radioactive gamma transmission scanning requires the use of a sealed source and a sensitive radiation detector set on adjacent sides of a pipe. The source and detector are at a fixed distance apart within a yoke. The yoke is positioned across the pipe. The transmitted radiation signal passing from the source through the vessel is recorded at the detector. An output of radiation intensity is produced. The radiation intensity is directly related to density by the following equation:

$$\mathbf{I = I_o e^{-\mu \delta x}}$$

Where I = radiation measured at the detector,

I_o = radiation intensity at source position

μ = constant for specific isotope

δ = density, x = distance between source and detector

The radiation intensity I_o of the source is constant, μ is a constant and if the distance is fixed by using a solid yoke, measuring the intensity I at the detector will allow bulk density between the two points to be measured.

This technique therefore can be used to determine changes in density due to gas slugging, oil in water or water in oil, solids build-up on the pipe wall or loss of lining from a pipe inner wall. The technique can be used for surface applications as well as sub-sea. Some typical project examples include:

- scale or sludge thickness in well flow lines and associated manifolds
- deposit in sub-sea lines
- deposit in flare and relief valve lines
- hydrate blockage in sub-sea gas lines
- air/liquid interface measurement in pipe lines
- slugging frequency within a sub-sea multiphase pipeline

3.2 Tracerco Diagnostics™ Flow Study

In industrial processes the need to measure flow of all types of material arises frequently. Radiotracer techniques have been found useful among the available methods, often offering advantage over the more conventional ones. Applications for which this technique is regularly used include checking or calibration of installed flowmeter's, measurement of flow in systems where no flowmeter's are installed and flow distribution studies in multiflow systems.

A pulse velocity method is the predominant method used. This involves the injection of a sharp pulse of suitable radiotracer into the process stream and its passage downstream observed by a pair(s) of radiation detectors positioned externally on the pipe with the first detector sufficiently far from the injection point to ensure lateral mixing of tracer. By measuring the time interval between detector responses and knowing the distance between the detector the mean linear velocity can be calculated. If full bore turbulent flow can be assumed then the velocity can be converted to volumetric flow knowing the pipe internal diameter. Accuracy will depend on the precise circumstances but the mean velocity can usually be measured to better than ± 1%. The total accuracy on the volumetric flow depends on how accurately the internal diameter is known, and is typically 3-4% working from piping specifications, although this can be improved by measurement of outside diameter together with ultrasonic wall thickness measurements.

Whilst this method is usually employed in basic flow measurement it has been successfully used in the area of **Flow Assurance**, where it is used to measure the location and extent of solids within a pipeline. In this application the flow rate through the system must be known and kept constant. Detectors are positioned at known distances apart along the pipeline. A pulse of tracer is added to the pipeline and its velocity past detector positions measured. Using the velocity and flow rate the average bore size can be calculated between detector locations. This measurement can give critical information prior to any proposed pigging operations are actually performed.

4. PIPELINE DEPOSIT MEASUREMENTS CASE STUDY - Tracerco Diagnostics™ Scan

A sub-sea 6-inch gas flow line was thought to be blocked by 'hydrate' with an approximate density of 0.98 g/cc. A gamma ray transmission survey was used at exposed sections of the pipeline, using an ROV with a fixed yoke scanning system attached. A radioactive sealed source was positioned on one side of the pipeline and the amount of radiation transmitted through it was measured with a radiation detector. The separation of the source and detector was kept constant ensuring that the intensity of transmitted radiation was a function of density of the medium it passed through. Thus it was possible, from measurements of radiation intensity at the detector and radiation intensity entering the pipe, to determine the density of material in the pipeline and make inferences about the distribution of flowing or deposited materials. Hundreds of measurements were taken at approximately one-metre intervals along the exposed pipeline, and this approach located and assessed the extent of the deposit within the pipeline.

The results can either be provided as a mean density of material across the pipeline, or if the approximate density is known the results can be shown as amounts of material in the line.

5. PIPELINE DEPOSIT PROFILE AND INVENTORY CASE STUDY - Tracerco Diagnostics™ Flow Study

A 12" NGL pipeline connects an offshore platform to an industrial area onshore. The pipeline was designed to allow a NGL flow rate of 4000 metric tonnes per day. The pipeline is 117Km long with a diameter of 12" and a fill volume of some 8,537 m^3. The system is sub-sea for 89 of the 117Km length and partially buried. The lowest point in the system lies within a tanker channel. The span of this section is some 4 Km. The NGL flow rate is significantly lower than design limits, therefore some restriction was postulated.

The continuous increase in production of hydrocarbon offshore lead to a requirement by the operator to optimise production in the NGL pipeline. In order to ascertain the current condition of the pipeline, an assessment was required to ascertain the capability of inspecting the pipeline utilising a MFL inspection tool. Prior to performing any inspection work, it was necessary to quantify the amount of any debris within the pipeline.

The radioisotope pulse velocity technique was used to measure the velocity of the NGL at numerous points along the line. Given the NGL flowrate through the pipe, it was possible to calculate the mean cross sectional area between these points and thus estimate any restriction within. A sharp pulse of radiotracer was injected at the platform into the 12-inch NGL pipeline. The NGL flowrate from the platform was monitored at hourly intervals throughout the course of the survey. The progress of this pulse was then monitored using a sensitive radiation detector mounted on an ROV, deployed from a dive support vessel, positioned at strategic locations along the pipeline. A record of the tracer pulse centroid was made along with the relative position of the ROV as the pulse passed the detector. Accurate locations for the ROV, and hence, radiation detector, were obtained from the vessel's dynamic positioning system. Once the pulse had passed the radiation detector, the ROV would be repositioned at a convenient location downstream of the tracer to await the arrival of the pulse once more. Again the time of the tracer pulse centroid and detector position were recorded. This procedure was repeated along the entire length of the pipeline to shore, whereupon fixed detectors monitored the progress of the pulse up to its arrival at the industrial area.

Provided accurate measurements of the actual flowrate of NGL through the pipeline were available, it was possible to compare these readings to the measurements taken by Synetix. Therefore, some time after the initial tracer injection, the NGL flowrate from the platform was measured using the radioisotope pulse velocity technique in an attempt to corroborate the flowrate readings supplied.

Velocity of the tracer pulse was successfully measured over 9 days. From the records of time versus distance, the velocity of the NGL was calculated. Areas of the pipeline that contained solids build-up or restrictions would exhibit a higher velocity (given a constant flowrate) than areas with no restrictions (full-bore flow). Provided full bore turbulent flow exists, it was possible to compare these measurements to given flowrate figures and hence calculate the effective internal diameter of the pipe. This was then used to calculate the degree of restriction in the pipe.

Results clearly showed areas of increased velocity in the first third of the pipeline, indicating that debris had been deposited on the upward slopes of the pipeline due to the flow being unable to transport solids up these inclines. The velocities measured were used to show the percentage restriction in the line, and showed that, over the first 35km the restriction was on average 20% of the bore but was up to 50-60 % at the 15km and 32km areas, with a total amount of deposit in the whole pipeline of 1600 m^3.

6. CONCLUSION

There is a large range of non-intrusive on-line inspection techniques available that enable difficult, and sometimes previously thought impossible measurements to be made. Radioisotope technology offers a powerful and well-proven inspection technique when problems are encountered or pipeline conditions are uncertain. The technology has been adapted in recent years to assist pipeline inspection and flow assurance issues, and is increasingly being used by operators and contracting companies world-wide.

This paper has covered some applications, but there are undoubtedly other applications of this technology yet to be discovered. Historically the application of these techniques has expanded purely due to customer requirements that lead to continuous innovation, and I am sure will continue to do so.