A New Approach for Finding and Quantifying Residual Contamination in Pipes and Ducts

Demonstration of a New Technology for D&D

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VISTA ENGINEERING TECHNOLOGIES, L.L.C., has developed a new, minimally invasive technology called PCUT (Pipeline Characterization Using Tracers) for *detection, location and quantification* of residual contamination in pipes and ducts using gaseous tracers (patent pending). PCUT can be used in support of deactivation and decommissioning (D&D) of piping and ducts that may have been contaminated with hazardous chemicals such as chlorinated solvents, petroleum products, radioactive materials, or heavy metals.

PCUT … detection, location, and quantification of residual contamination in pipes and ducts using gaseous tracers.

Measurement Approach. Tracer gases are injected into one end of the pipe and are measured with an on-line gas chromatograph at the other end of the pipe. One of the tracers is a conservative tracer, i.e., it will not dissolve, adhere, or interact with the contaminant of interest. The other tracer (or tracers), are selected so they will dissolve, adhere or interact with the contaminant of interest. The *presence* of the contaminant is determined from the shape of the measured concentration curve. The *amount* of contaminant within the pipe or duct is determined by measuring the difference in the arrival times between the conservative and the other tracers at the extraction point in the pipe. The *location* of the contamination is determined by introducing a perturbation to the advection flow field after the interactive tracer (or tracers) has reached the contamination.

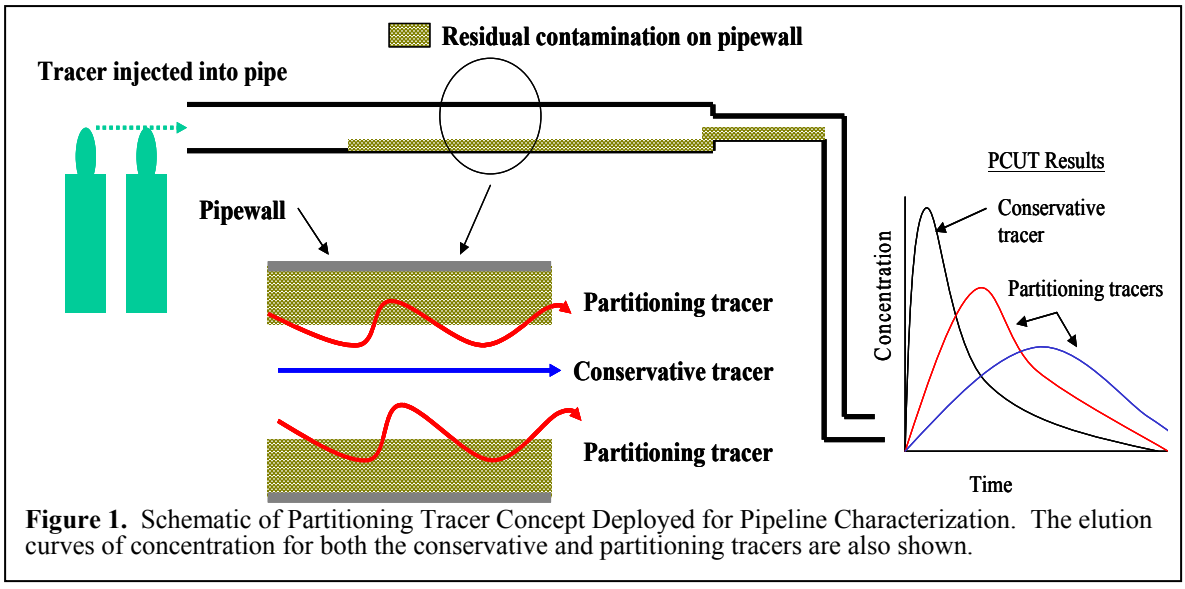

Figure 1. Schematic of Partitioning Tracer Concept Deployed for Pipeline Characterization. The elution curves of concentration for both the conservative and partitioning tracers are also shown.

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Advantages of the Technology. The PCUT approach offers significant advantages over conventional pipe or duct inspection techniques because 1) tracer movement is not impacted by pipe diameter or configuration, 2) there are no moving parts or equipment that must be introduced into the pipe, 3) there is no sparking potential or ignition source with gaseous tracers, and 4) there are no decontamination requirements.

Demonstration Test. The PCUT technology was experimentally demonstrated in the laboratory using three partitioning tracers in a 23-ft section of 2-in.-diameter PVC pipe contaminated with diesel fuel. The middle section of the pipe was a 10-ft long, 3-in.-diameter section of PVC pipe that held a 0.5-in. layer of diesel fuel. An inert gas was selected as the conservative tracer, and two fluorocarbons were selected as the partitioning tracers; nitrogen was used to transport all of the tracers from the inlet to the outlet of the pipe. Partitioning tracers are those compounds that preferentially diffuse into the contamination and then elute from the contamination when the tracer mixture has proceeded down the pipeline. This is similar to what occurs in a Gas Chromatograph (GC) column, where the various compounds are delayed by the fixed phase on the column surface and therefore elute later than other compounds.

Demonstration Test Results. The results of the technology demonstration tests are presented below. Two sets of tests were conducted, (1) one set with contamination and (2) one set without contamination. Figure 3a shows the elution curve of tracer concentration for one of the partitioning tracers (Partitioning Tracer #2) without the presence of the diesel contamination, and Figure 3b shows the concentration curve for the same tracer with the contamination present. There is a clear and unambiguous difference between the two curves in terms of magnitude, shape, and time of arrival of the center of mass. Since the conservative tracer is not affected by the presence of contamination, it can be used to replicate the response of the partitioning tracer that would have been obtained if no contamination were present in the pipe. The conservative tracer response is then compared to the response of the various partitioning tracers in an actual pipe measurement when contamination is present as the fundamental part of the detection algorithm. Figure 4 superimposes the concentration curves of the conservative tracer with and without the contamination present and the second partitioning tracer without the presence of the contamination. Figure 4 clearly illustrates that the conservative tracer behaves nearly identically to the partitioning tracer when no contamination is present and can be used as a reference when contamination is present.

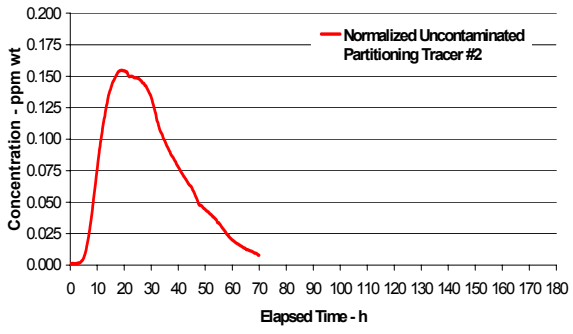

Figure 3a – Partitioning tracer #2 *without* contamination present in the pipeline.

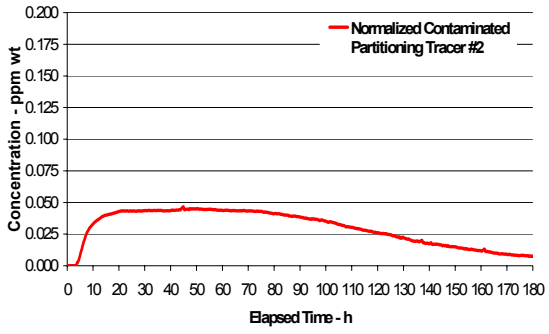

Figure 3b – Partitioning tracer #2 *with* contamination present in the pipeline.

There is a clear and unambiguous difference between the conservative and partitioning tracer concentration time histories in terms of magnitude, shape, and time of arrival, which is due to the presence of contamination within the pipe or ducting system.

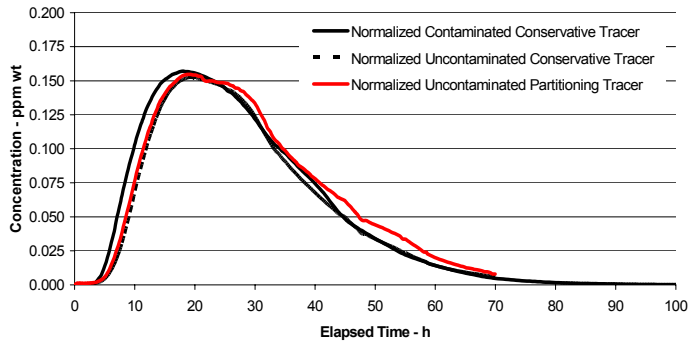

Figure 4 – Comparison of conservative tracer with and without contamination and the second partitioning tracer without contamination.

Figure 5 superimposes the conservative tracer and the partitioning tracer concentration curves for two of the partitioning tracers during the contamination tests. The presence of contamination can be determined as soon as the peak of the conservative tracer curve arrives. Detection is accomplished by comparing the peak amplitudes of the conservative and partitioning tracer concentrations. Verification and quantification is accomplished once the exponential tail of the partitioning tracer is measured. The most rapid and most accurate estimates of the contaminant volume are obtained by mathematical extrapolation of the exponential tails of the partition tracers. Table 1 summarizes the results. The most accurate results are within 6% of the 1.5 L of diesel used to contaminate the 3-in.-diameter pipe section.

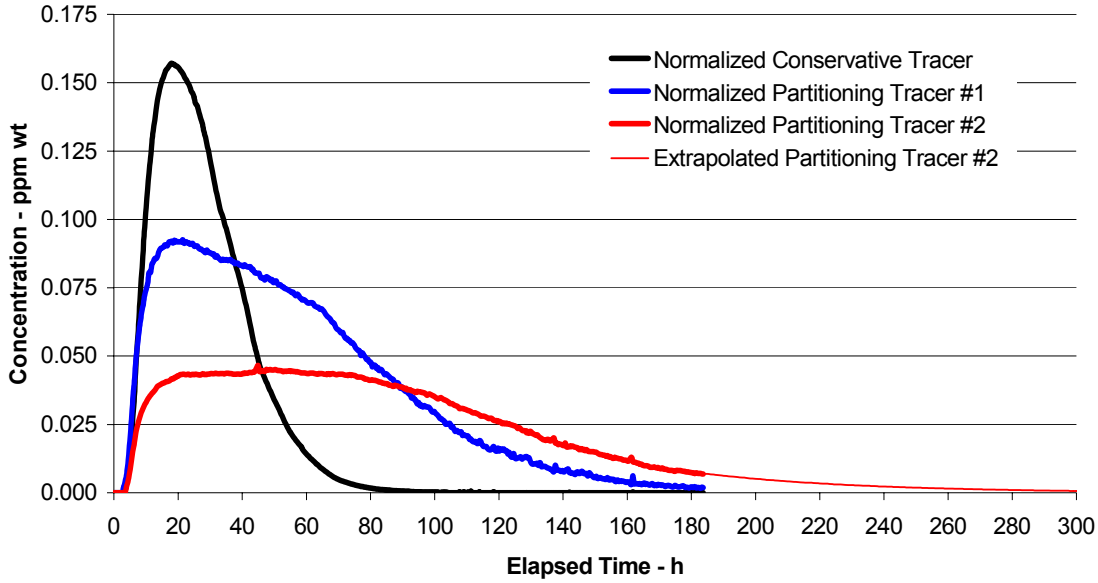

Figure 5 – Comparison of conservative and two partitioning tracer results from the *contaminated* pipeline.

Table 1. PCUT Estimation of the Volume of the 1.5 L of Diesel Fuel Contamination

Tracer Gas	**PCUT Volume Measurement** (L)	**Error** (%)
Partitioning Tracer #1	1.40	6.4%
Partitioning Tracer #2	1.29	13.7%

Summary. The laboratory experiments were extremely successful and clearly showed that PCUT can readily detect the presence of the diesel fuel and accurately quantify the volume of the thin layer of fuel injected on the bottom of the pipe. While not demonstrated in these tests, it is clear from the tests completed to date that it will also be possible to locate the contamination. It is equally clear from the results of the demonstration tests that if appropriate tracers are available or can be developed for the contaminants of interest, this remote sensing technique will work and will be very accurate. The next step is to demonstrate the PCUT approach in an actual pipe that may be contaminated with petroleum products or chlorinated solvents such as TCE, PCE and CCl_4. Additional tracers are under development for heavy metals and radionuclides of interest. If appropriate tracers are available, the PCUT approach should be able to address any pipeline characterization need.