On-Line Diagnostics Techniques in the Oil, Gas, and Chemical Industry

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1. INTRODUCTION

Unfortunately, the vessels and pipelines in our refineries and chemical plants are not transparent. We cannot simply look at our plants to monitor the condition of internals, and see how the process is performing.

We rely on installed instrumentation for on-line information, but in certain instances this may not be sufficient. For example, it would be useful for pre-shutdown planning purposes to be able to look into a vessel while it is still on line, and accurately assess the condition and integrity of vessel internals, or the existence of process leaks, so that the shutdown can be planned more efficiently. If our plants develop operational problems, it would also be very useful to diagnose and identify the source of these problems on line, so aiding in their rectification, and timely return of the process to full capacity.

As our vessels and pipelines are not, and most likely never will be, transparent it is useful to have a range of on line non-intrusive techniques that can effectively 'look' through vessel and pipe walls to measure process parameters and identify plant problems.

Radioisotopes, specifically those that emit gamma-ray radiation, are ideally suited for this purpose, and have been used for specialist measurements in medical and industrial applications for many years. This paper will describe the various techniques available, giving examples of their use in industrial applications, and demonstrate how they can be used to improve process efficiency and save you money.

2. GENERAL OVERVIEW

There are four main types of radioactivity.

These are alpha particles, beta particles, neutrons, and gamma rays. Alpha and Beta radiation have limited use in industrial applications as they are very weakly penetrating. Neutrons have a very specific use, and will be mentioned later.

Gamma-rays are used for on line non-intrusive investigations because they will penetrate and pass through matter, such as steel for example, and be attenuated by that material to an extent that is directly proportional to its density and thickness. By measuring the relative attenuation of the transmitted gamma rays, accurate information can be inferred on the material that they have passed through.

The range of radioisotope techniques can be considered under two categories.

a) Sealed source scanning techniques

b) Unsealed Radioisotope Tracing Techniques

Sealed sources can be used to scan vessels and pipelines to identify such things as integrity of internals, levels and interfaces, deposits build-up, and other process anomalies.

A large range of unsealed radioisotope tracers, which can be in the form of gas, liquid or solid can be injected into a process on line. The tracer will mimic and follow the process material, and can be monitored by sensitive radiation detectors placed externally on vessels and pipelines. Flow rates and residence times can be measured, leaks and mal-distribution be identified.

The range of on line, non-intrusive Process Diagnostic Services that can be offered onshore are:

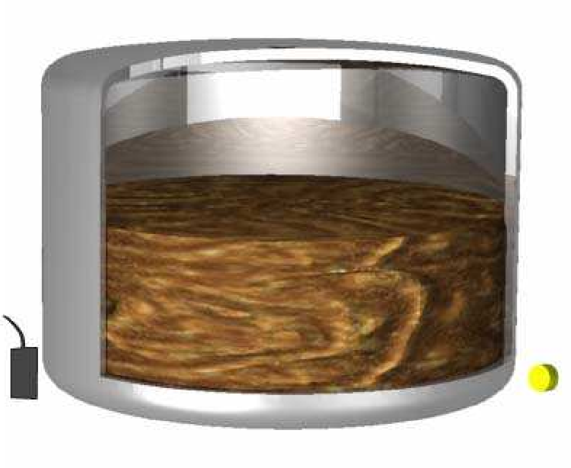
- ♦ Level Measurement
- ♦ Column Scanning
- ♦ Deposit and Blockage Detection
- ♦ Flow Rate Measurement
- ♦ Distribution Studies
- ♦ Residence Times
- ♦ Leak Detection and Bypassing – Heat exchangers, Reactors, Valves

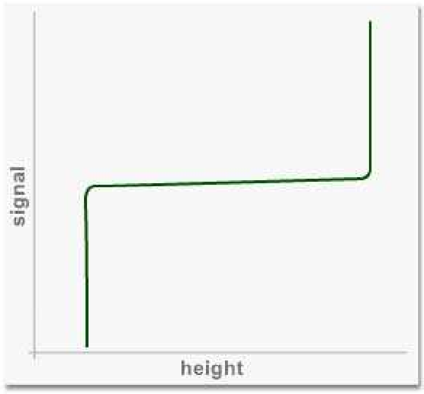
♦ FCCU Studies

Very little preparation is needed on site to carry out these services, for example there is no need to remove lagging from vessels or pipelines, and results are available immediately. If required, the studies can be repeated at various process rates and conditions.

3. SEALED SOURCE SCANNING TECHNIQUES

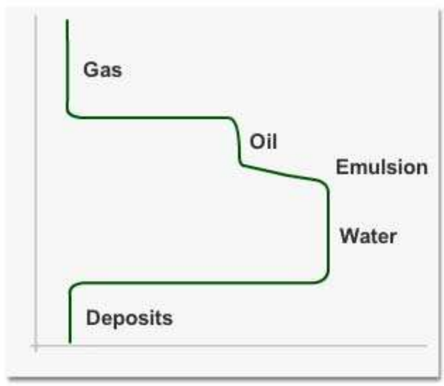
3.1 Level Measurement





By suspending a gamma ray emitting radioactive source on one side of a vessel, and a radiation detector on the other, we can measure the amount of gamma-ray absorption at set intervals down the length of the vessel. This is effectively the mean density of material between the source and detector at each point, and hence levels can be easily and quickly identified.

Another technique, named Neutron Backscatter, involves the use of a fast neutron emitting radioactive source. Neutrons are the same size as hydrogen molecules. They will penetrate lagging and steel, but if any hydrogenous liquid is present within a vessel or pipeline, the neutrons are rebounded (or scattered back) by the hydrogen out of the vessel as slow neutrons, and can be detected as they do so by a slow neutron detector. The source and detector are located within a small portable instrument that can be moved up and down the vessel walls to quickly and accurately locate levels and interfaces. The instrument is shown in use below.



In addition to level measurements, the Neutron Backscatter technique can be used to accurately measure interfaces such as oil/water or oil/sludge, because of the differing hydrogen content between the two phases. It can also be used to measure the quality of any interface, i.e. the extent of any foam or emulsion bands. The technique is typically used on:

♦ Heat Exchangers
♦ Distillation Columns

- Reactors
- Pipelines
- Separators
- Storage Tanks

3.2 Column Scanning

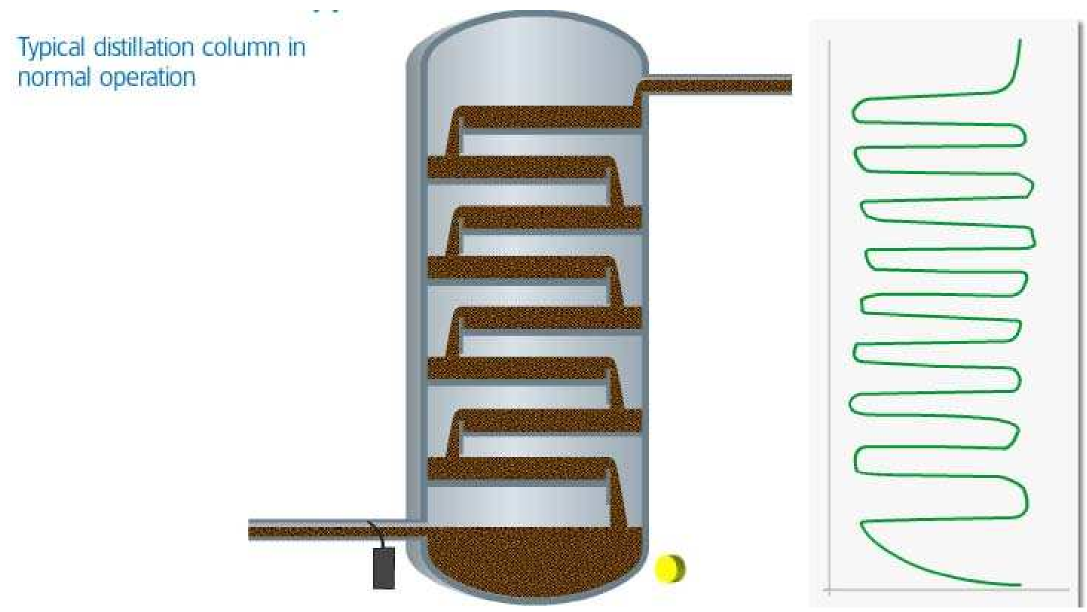
We can use the same gamma-ray transmission scanning technique described in 3.1 above to investigate column performance. No preparation of the column is needed; all that is required is access above the region that is to be scanned, usually the top of the column. As mentioned earlier, lagging does not need to be removed.

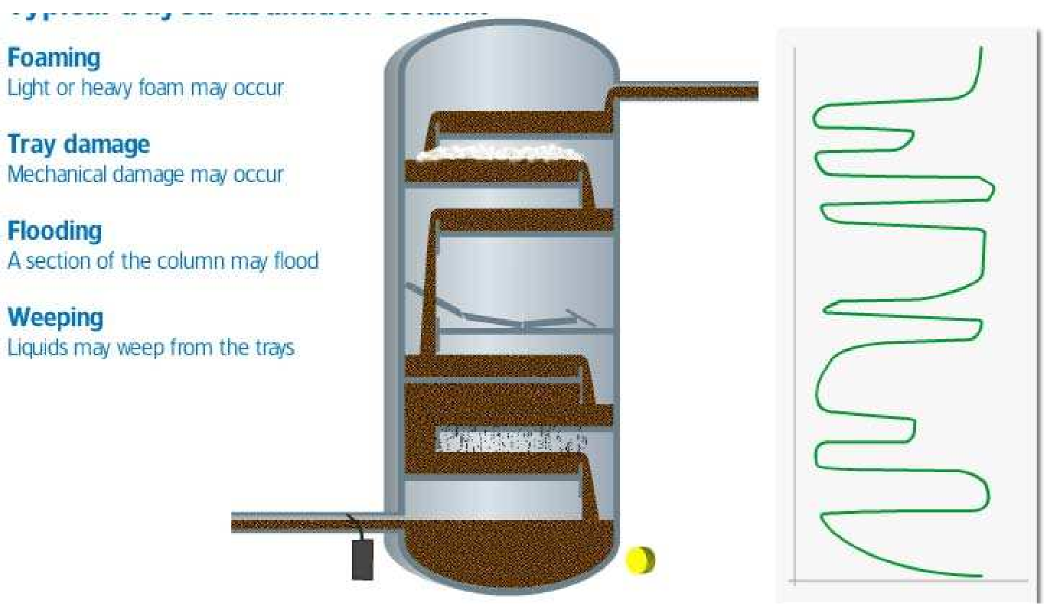
By lowering a radioactive source and detector down a column diametrically opposite each other, and taking measurements of mean density as they are lowered, a 'picture' can be formed showing what is happening within the column.

In trayed columns we can identify:

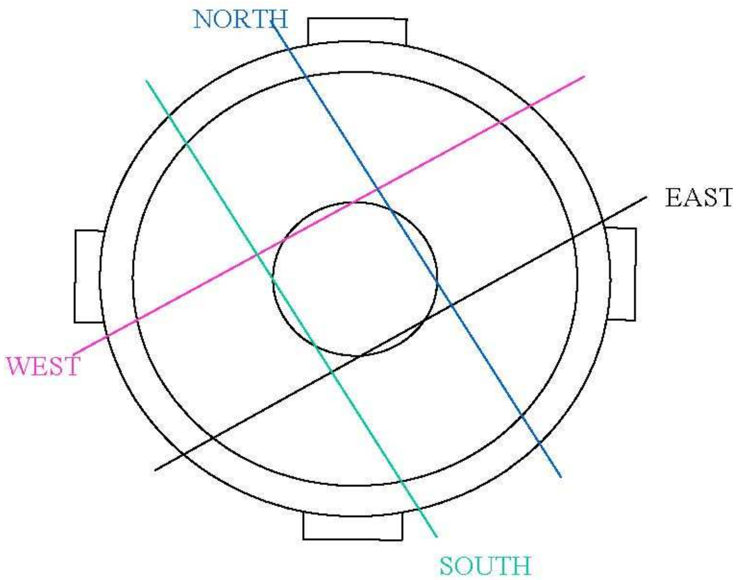
- Liquid levels on trays
- Areas of foaming or liquid weeping
- Tray positions
- Tray damage and debris
- Flooded regions

Regions of high density, e.g. a tray plus liquid or a flooded region, will attenuate the signal to a greater extent than areas of low density, e.g. vapour regions.

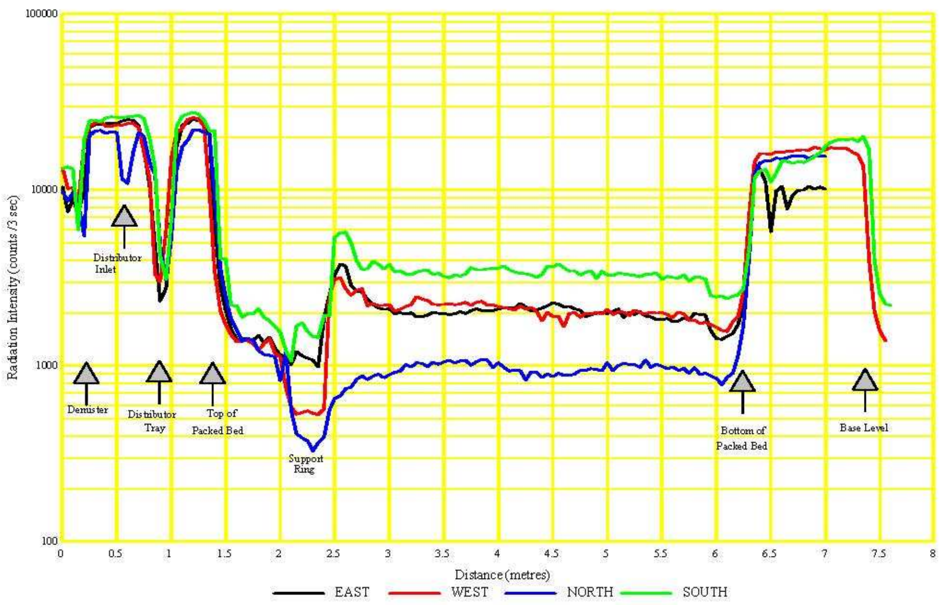




The same technique can be used for packed bed columns to establish the position of beds, and also identify any mal-distribution through the beds. By selecting a series of comparable scan lines through the bed, we can measure the mean density of material across each region and establish if mal-distribution is occurring, as shown in this example below.



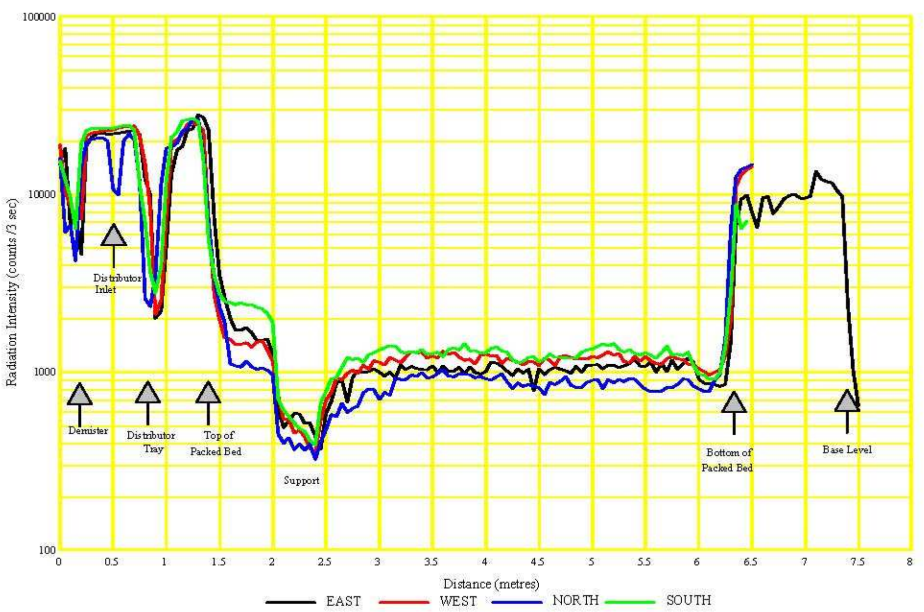
MAL-DISTRIBUTION THROUGH PACKED BED Fig 1



It is clear from the graph that the region intersected by the North scan line displayed a much greater mean density through the length of the bed than the region intersected by the South scan line. As the other East and West scan lines are very similar, the indication was that there was a preferential flow of liquid through one region of the bed.

The density difference was constant throughout the length of the bed, indicating a problem with the distribution of liquid onto the bed. The column was subsequently opened to effect repairs and a large hole was confirmed to be present on the North side of the distributor tray, causing liquid to preferentially flow down this side. After the repair was made and the column brought back on line, repeat sets of scans were taken. These are shown below for comparison.

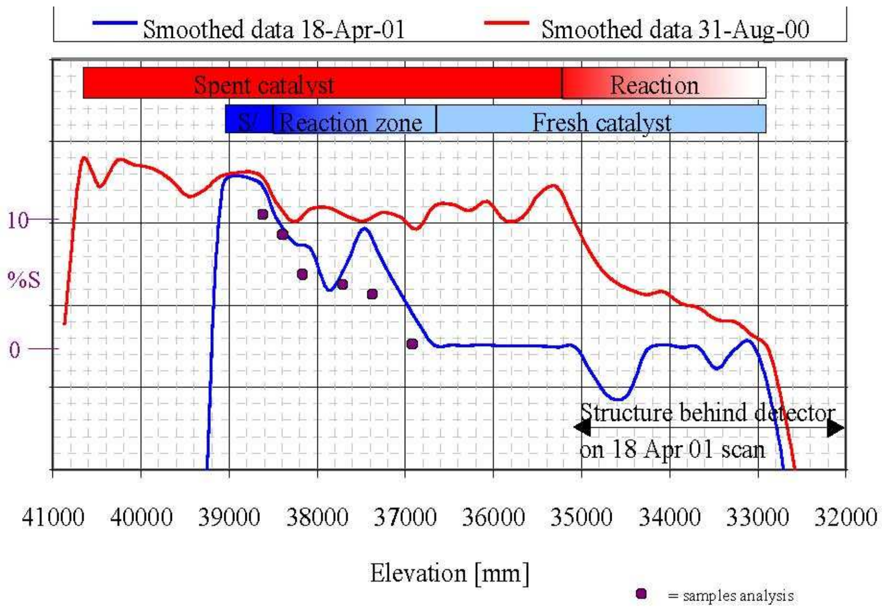
MAL-DISTRIBUTION THROUGH PACKED BED Fig 2



The second set of scans show the mean density of liquid through the bed to be much more uniform, and confirm that the cause of the mal-distribution was identified and repaired.

3.3 Zinc Oxide Bed Remnant Life Measurements (The Tracerco Maximizer™)

A variation of the gamma scanning service enables the remaining life of zinc oxide absorbent in sulphur removal systems to be determined. It relies on the fact that there is a density difference between the fresh zinc oxide and the used absorbent that has converted to zinc sulphide. The technique allows consumption of the absorbent to be monitored and the remaining life to be predicted, thus allowing maximum absorbent utilisation. Some customers have used the resulting information to confidently defer the replacement of absorbent until a later date. The method is suitable for vessels up to 2.5 metre diameter and 50mm wall thickness. A typical example is shown:



An initial scan of the vessel was carried out in August 2000 (red trace), which demonstrated that the absorbent was almost fully utilised, and in fact Sulphur breakthrough was detected in October 2000. A comparative scan was carried out 6 months after the bed had been changed in April 2001 (blue trace), and it can be seen that the Sulphur front was now at the top of the bed with approximately 4 metres of fresh absorbent remaining. As this plant was shut down a month after this scan, samples of the absorbent were taken and analysed for sulphur content for comparison purposes to verify the technique. The samples can be seen to match the scan very closely.

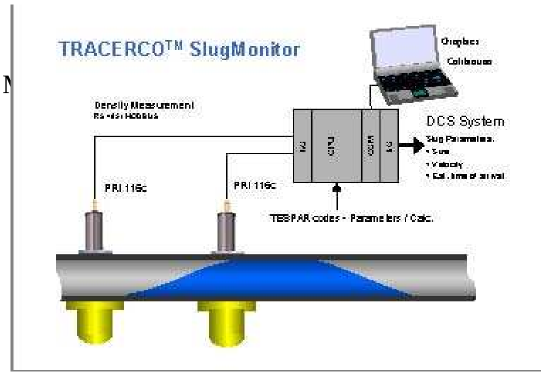
3.4 Deposit and Blockage Detection

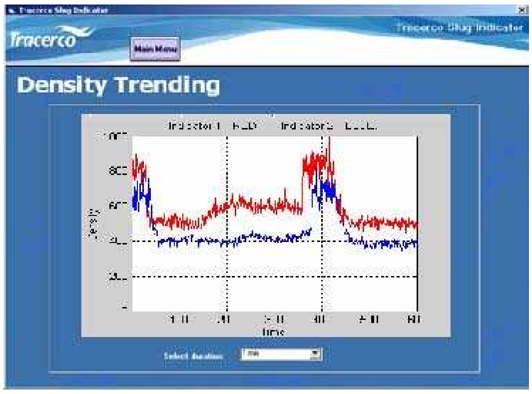
The same gamma-ray transmission technique can be used to locate blockages within pipelines or accurately quantify the amount of deposit within a liquid or gas line, for example coke build-up in overhead transfer lines. The source and detector are fixed diametrically opposite each other at a set distance apart by the use of a rigid yoke system, and measurements of mean density can be taken very quickly. Each measurement takes less than 30 seconds.

A variation of this technique can be used to measure the integrity of refractory lining.

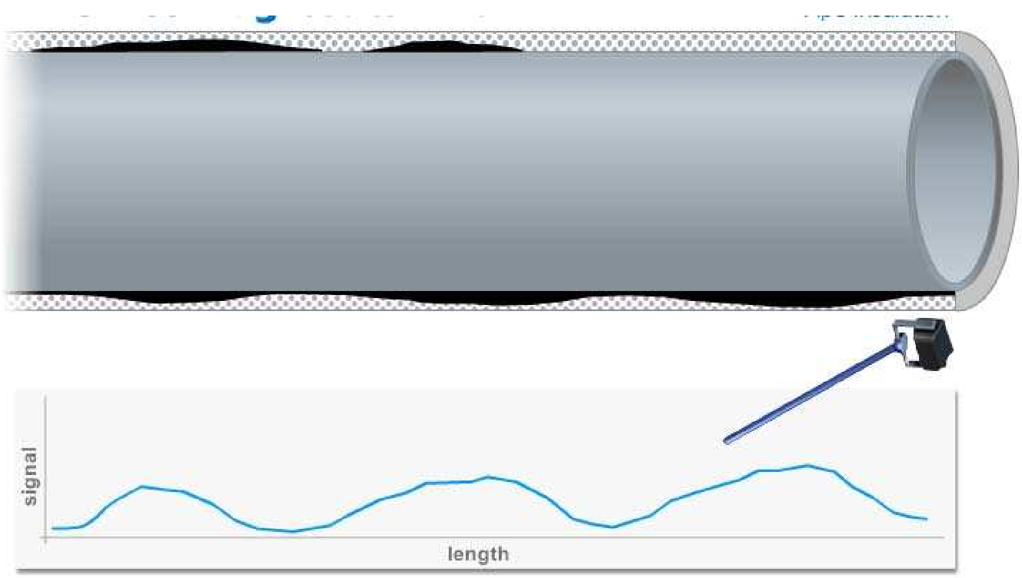
Alternatively a system can be fixed in place as a ‘densitometer’ and the line monitored continuously to establish build-up rate of deposit, or to identify the extent of effects such as liquid slugging in gas lines.

3.5 N





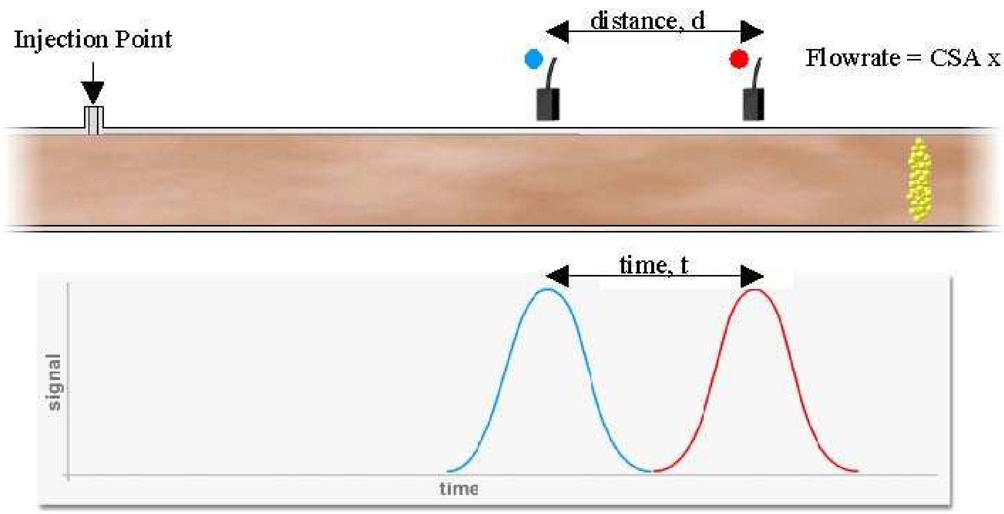
The Neutron Backscatter Technique mentioned earlier in this paper can also be used to determine the presence of moisture under insulation on vessels and pipework, and therefore serve as an early warning indicator of potential corrosion problems. The measurements can be taken very quickly, enabling long lengths of pipework to be surveyed in short periods of time.



4. UNSEALED RADIOISOTOPE TRACING TECHNIQUES

4.1 Flow Rate Measurement

By injecting a sharp pulse of radioisotope tracer that is compatible with the process under investigation, and by placing external radiation detectors at a known distance apart downstream, the time of flight of the tracer and hence its velocity can be very accurately measured. Accuracy's of ± 1 to 2 % can usually be achieved. If the pipe ID is known, the volumetric flow rate can be calculated.



This technique is used to measure the accuracy of installed flow meters, or measure the flow through lines where there is no installed meter. It can also be useful to measure the flow distribution split to banks of heat exchangers, or the split of process gas to ring burners in a furnace for example.

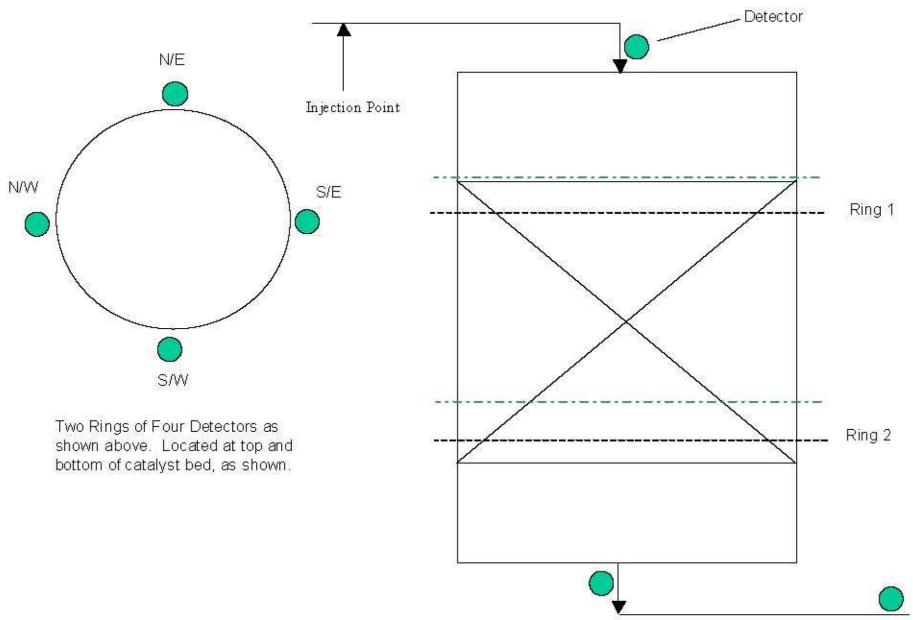
There is no need to remove lagging, and the signal from each detector is fed by cable to a central monitoring unit.

4.2 Distribution Studies

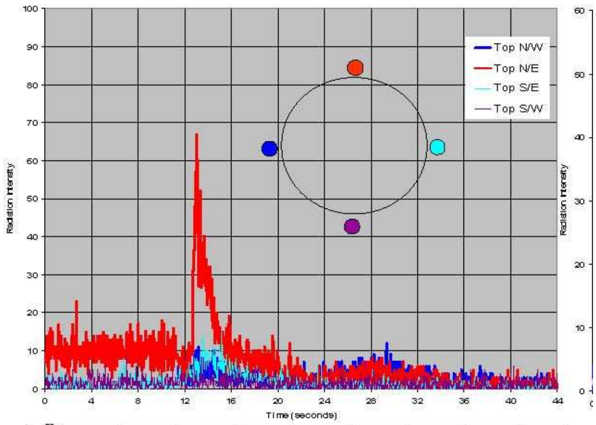
Radioisotope tracers can also be used to monitor the flow distribution of gas or liquid through structured packing or catalyst beds, to accurately identify the proportion of fluid flowing through each segment of the bed.

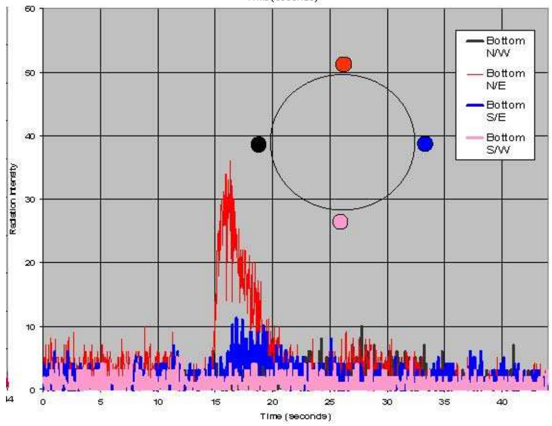
As in 4.1 above, a tracer compatible with the process is injected into the inlet line to the vessel under investigation, and its progress monitored by external radiation detectors placed at strategic positions around the vessel walls.

In the example below of a packed catalyst bed within a pre-reformer vessel, detectors were placed on the inlet and exit lines of the vessel, and two rings of four detectors were placed at the top and bottom of the bed as shown below.



The responses from each ring of detectors are shown.

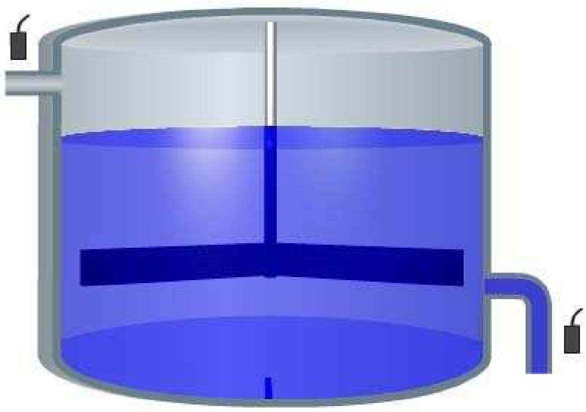




These graphs clearly show a greater response from the detectors on the North/East (N/E) side of the vessel at both the top and bottom of the bed, indicating gross mal-distribution down this side of the vessel.

4.3 Residence Time Determination

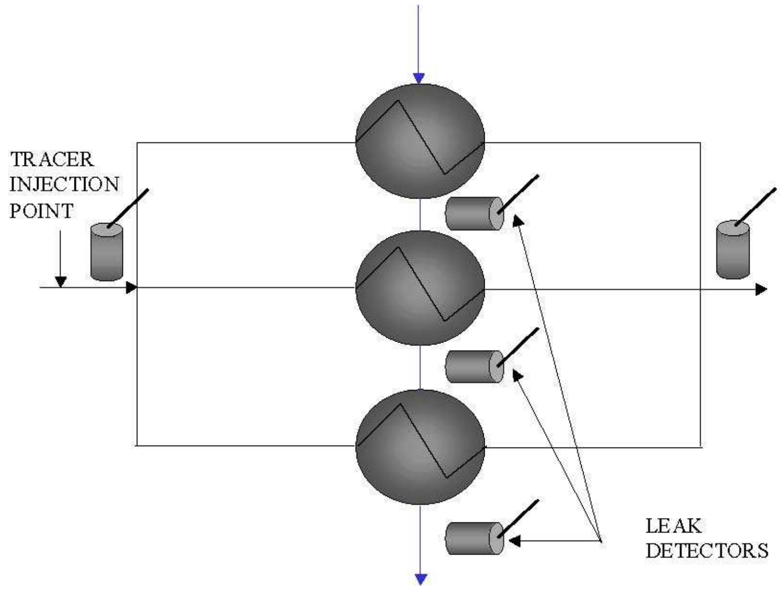
The same radioisotope tracer injection technique can be used to accurately measure the residence time of any process vessel, by placing detectors on the inlet and exit lines of the vessel to monitor the tracer as it passes. By analysing the shape of the exit pulse, we can also determine the type of mixing that is occurring in the vessel.



4.4 Leak Detection / Bypassing

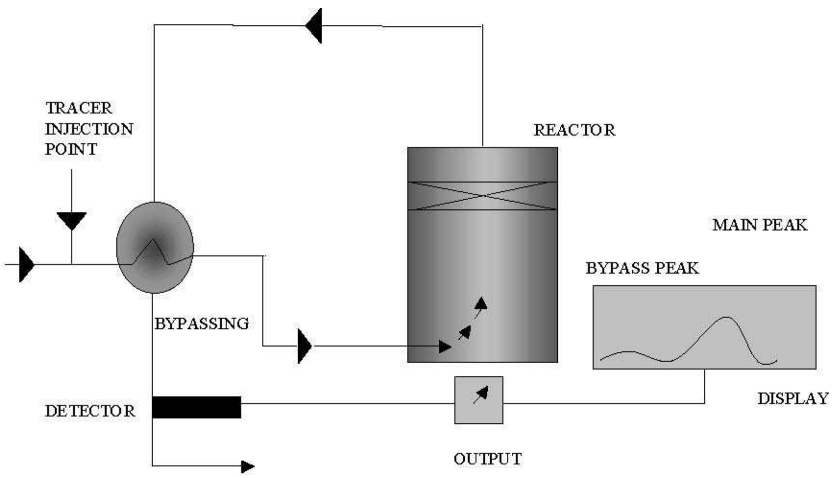
4.4.1 Heat Exchangers

If we inject a suitable radioisotope tracer into the high-pressure inlet line to a bank of heat exchangers, and place radiation detectors on the low-pressure exit lines of each exchanger in the bank, we can identify the individual exchanger that is leaking.



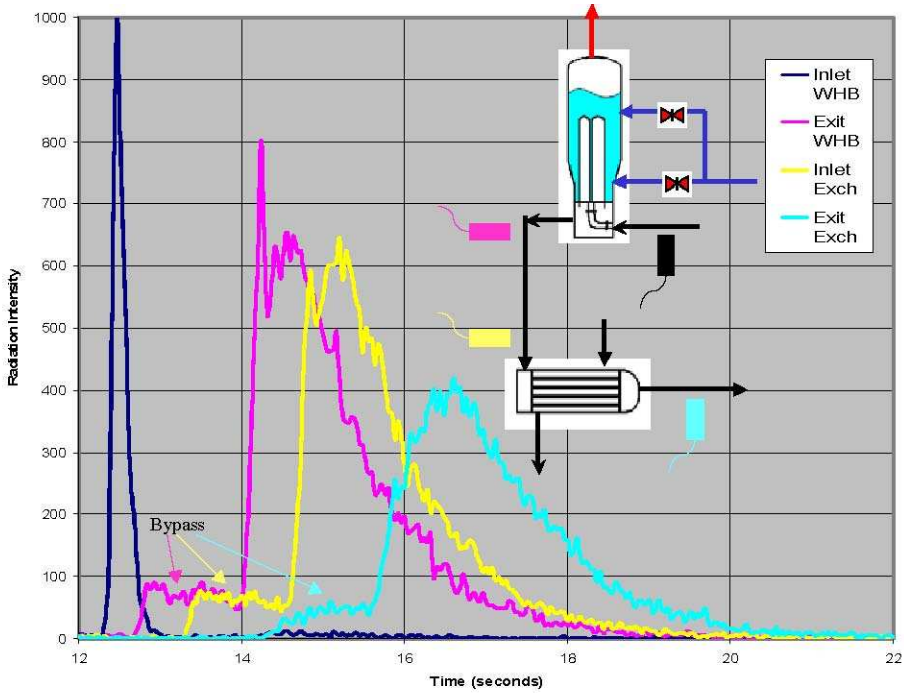
This is a very useful tool for shutdown planning purposes, so that the repairs can immediately be focussed on the exchanger that is leaking, rather than wasting valuable time and money testing each exchanger in turn during the shutdown.

The same technique can be used to confirm the presence of a leak in a feed-effluent exchanger/reactor system when it is unclear if observed inefficiency is due to poor catalyst performance, or the fact that an exchanger is leaking, causing a proportion of the process to bypass the reactor. This is done as shown below, and any initial leak through the exchanger will be observed as a small bypass peak before the main peak exit the reactor is observed.



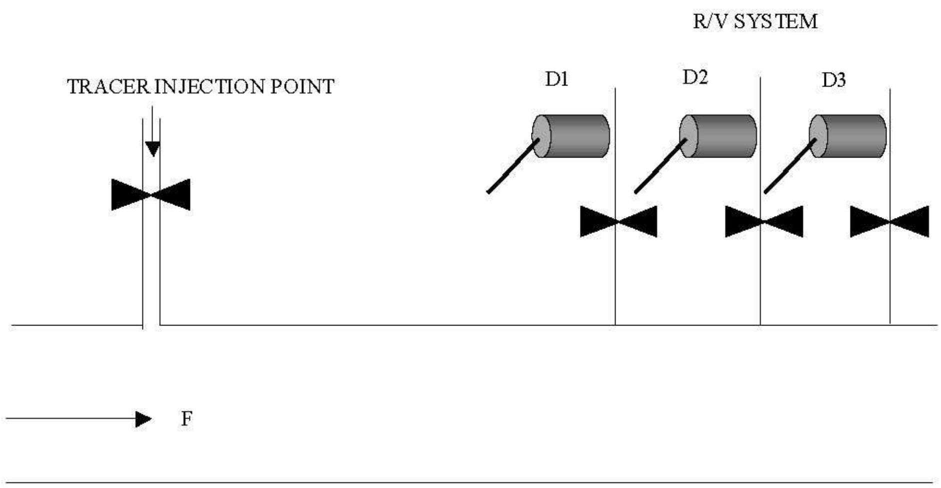
4.4.2 Vessel Internal Bypassing

In the example below, a waste heat boiler was not operating efficiently, with the exit temperature of the process gas much higher than expected. There was a suspicion that this may be due to internal bypassing of some of the gas at an inlet flanged bellows arrangement, and as a planned plant shut down was imminent, a tracer test was requested to confirm this theory. A suitable radioisotope tracer was injected and detectors placed on the gas exit line to analyse the exit pulse. The arrangement and subsequent detector responses are shown.



As can be seen from the graph, initial bypass peaks were observed at each detector, prior to the main pulse of tracer being observed. This conclusively proved that internal bypassing was occurring, and a replacement bellows inlet device was ordered to be installed in the forthcoming shut down.

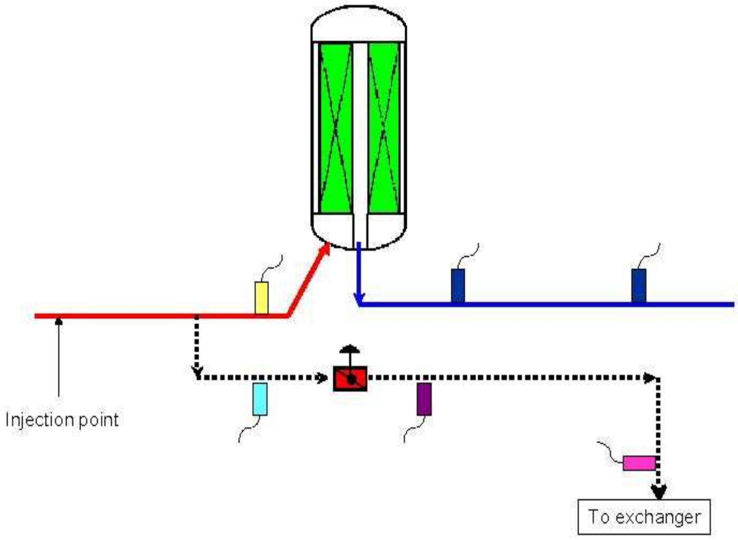
4.4.3 Passing Valves

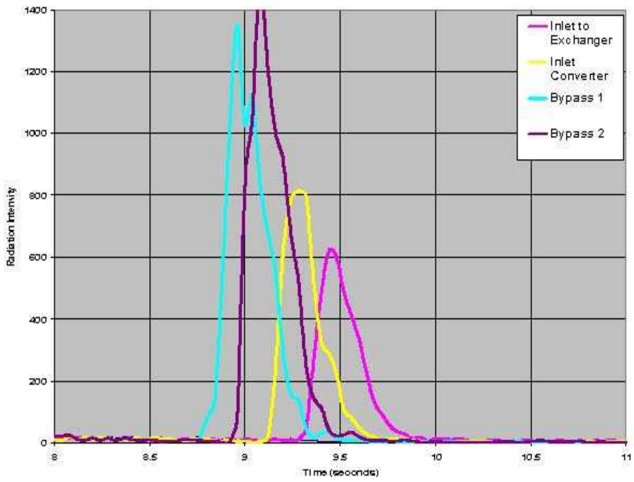


If it is suspected that valves are passing, on a relief valve system for example, a suitable radioisotope tracer can be injected upstream of the valves, and radiation detectors placed downstream of each valve under investigation as shown below. If any of the valves are leaking, the radiotracer will follow the leak and be detected by the relevant detector.

Alternatively, as in the following example, valves in bypass lines around reactors, which are expected to be closed, can similarly be tested.

As part of a program of work to assist in pre-shutdown planning, a customer wanted to establish why his reactor was not performing as efficiently as expected. The reasons could either be poor catalyst performance, internal bypassing of the catalyst bed, or leakage through a faulty bypass valve that should have been closed. A radioisotope tracer was injected, and detectors placed as shown below.

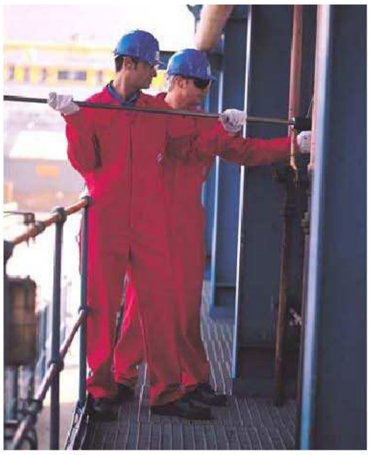


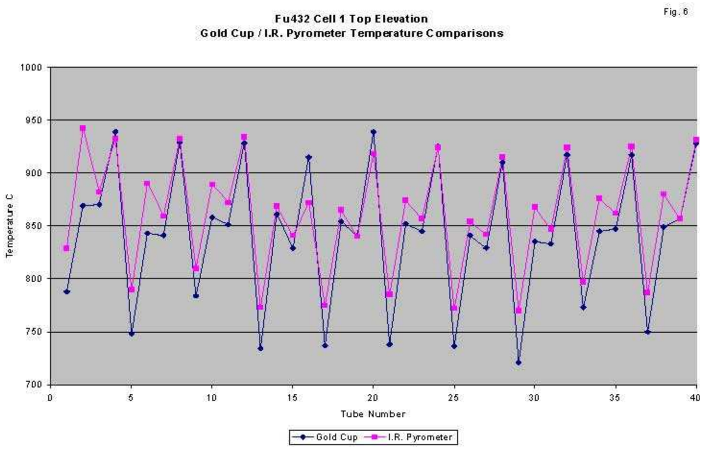


No internal bypassing was observed at the detectors on the reactor exit line, but both detectors observed leakage through the bypass valve, as shown.

5 REFORMER TUBE TEMPERATURE MEASUREMENTS

A direct contact thermocouple temperature measurement service can be used to determine the accurate operating temperature of reformer tubes. The technology is known as the 'Gold Cup' Pyrometer, and the measurements are performed using a water-cooled probe that is placed into a reformer and makes physical contact with the tube; the reading being taken immediately the probe makes contact with the tube. This technique ensures that only the energy due to the tube temperature is measured and any reflected energy that can cause externally sighted IR pyrometers to give incorrect readings is excluded. The probe is inserted via the furnace peepholes.





As Infrared pyrometers tend to give tube wall temperature readings that are higher than the actual temperature (typically 30 to 50 degrees Celsius), the gold cup technique enables operators to confidently increase process rates and run at higher temperatures if required, in the knowledge that tube life is not affected. The gold cup service can also be used to accurately calibrate plant IR pyrometers on site.