Gamma-ray scanning for troubleshooting, optimisation and predictive maintenance of distillation columns

This paper describes Non-disruptive and on-line inspection technique to diagnose process malfunctions and pinpoint internal damage within distillation columns in petroleum refineries and chemical plants

Distillation columns are considered as one of the most critical components in petroleum refineries, gas processing installations and chemical plants. Plant performance depends to a large extent on the ability of these columns to function as intended. Defective columns may lead to serious consequences to the plant operation and hence the quality of the product. Thus, when a distillation column experiences irregularities, it is urgently necessary to find out exactly what is happening inside the column. Any kind of problem can result in a large financial loss especially when it involves off-spec product, lost of production or unexpected shut down of the plant. The earlier the problem is identified and corrected, the lesser will be the loss and the cost to rectify it. In most cases, troubleshooting to pinpoint the cause of the problem in columns is conducted on-line. It seems that this is the only way column performances can be observed. Inspection while the column is in operation also enables continuous monitoring and assessment of the component.

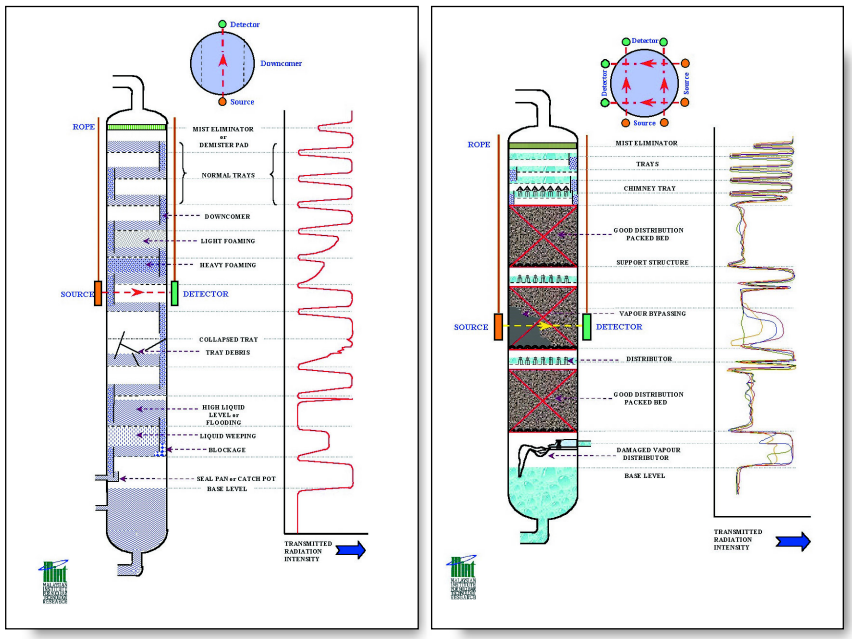
Gamma-ray scanning, often referred to as "column scanning", is a convenient, cost-effective, fast, efficient and non-intrusive technique to examine inner details of a distillation column, while it is in operation. Column scanning allows an engineer to study tray or packing hydraulics inside a column at any set of on-line condition. It provides essential data to optimise the performance of columns, extend column run times, track the performance-deteriorating effects of fouling and solids deposition, and identify maintenance requirements well in advance of scheduled turnarounds. This on-line knowledge can reduce repair downtime significantly.

By analysing the scanning results, a number of common malfunctions in trayed or packed columns can readily be determined, some of which are summarised in the following table.

In Malaysia and the surrounding region, the examination of process vessels (columns, separators, reactors,

Gamma scanning can identify a number of common malfunctions in columns.	
Mechanical problems	• Displaced or damaged trays, demister pads and packing • Corrosion resulting in partial tray damage • Missing, collapsed or buckled trays or manways • Out-of-place liquid or vapour distributors • Level control problems on chimney trays or base liquid level
Rate related problems	• Entrainment (slight, moderate, severe, jet flooding) • Weeping or dumping trays • Dry or flooded trays due to loading conditions • Unequal liquid levels on trays and in parting boxes, troughs and collectors
Process related problems	• Foaming on trays or in reboilers, condensers and accumulators • Maldistribution of vapour and liquid in packing • Liquid hold-up due to plugging and fouling • Superheated or subcooled feed or reflux

catch-pots etc.) in petroleum refineries, gas processing installations and chemicals plants using this technology is routine. Scans are frequently carried out on a spot-check basis to investigate column malfunctions. In addition, many process columns are scanned on a regular basis to provide early warning of deterioration in their performance. The examinations are carried out by highly experienced and well-trained engineers and technologists from the Plant Assessment Technology (PAT) Group at the Malaysian Institute for Nuclear Technology Research (MINT), Bangi, Selangor. Having being involved in the column scanning technology since 1980, PAT's technical staffs have performed hundreds of scans on various types of process columns across the country and around the region.



Gamma-ray absorption scans of a trayed column and a packed column.

Principle of measurement

Column scanning is a procedure whereby a process column is non-disruptively examined by moving a sealed radioactive source emitting gamma-ray in conjunction with a radiation detector along the exterior of the interposed column. Throughout the period of investigation, the radioactive material remains permanently encapsulated within a special source housing and makes no contact either with the column or with the process material. A source holder with an appropriate collimator is used to direct the radiation beam to the column. Interaction of the radiation with the medium of interest will produce changes in the intensity of the beam that can be correlated to the property of the medium.

The technique is based on the fundamental relationship:

$$I = I_o \exp(-\mu\rho x)$$

where I is the intensity of a beam of gamma-ray of initial intensity, I_o having traversed distance x in a material of density, r. The mass absorption coefficient, m, is constant for a given gamma-ray energy and material composition. This relationship shows that an increase in material density will reduce the radiation signal, or conversely a decrease in material density will result to an increase in the level of radiation intensity transmitted to the detector.

Radioactive sources used for distillation column investigations should be capable of penetrating the wall thickness of the column and the medium of interest. For this reason, high energy gamma-ray from Cobalt-60 or Caesium-137 is usually employed. It is worth to note that the strength of the sources used for this activity is extremely small such that the scan poses insignificant radiation hazard to plant personnel. For the sake of comparison, the level of radiation intensity for column scanning activity is approximately between 1/10000th to 1/1000th of the gamma-rays intensities used in examining welds.

Inspection procedure

Column scanning is generally performed without any pre-preparation of the column. All that is required is access to the uppermost platform. No insulation needs to be removed, and the scan does not interfere with the operation of the column. In practice, most columns have convenient platforms or walkways from which source and detector can be suspended and it is rare indeed that additional scaffolding or staging is required.

In performing measurements on a column, a source of gamma-ray is placed on one side of the column whilst a sensitive gamma-ray detector is placed on the opposite side. The source and detector are synchronously lowered down the exterior of the column in small increments while transmitted radiation-intensity measurements are being recorded via a portable nucleonic counting device. The system is then interfaced to a powerful portable computer to facilitate data storage and analysis. To ensure that the source and the detector are maintained in the same horizontal plane, especially in windy conditions, guide ropes are

normally used. Scans can be made across the diameter of the column. Or they can take place along a chord, to identify problems within a particular quadrant.

As the source and detector scan through a normal vapour space in a process column, a transmission peak is observed and when the "scan-line" intersects a structural material, such as a tray with aerated liquid, an absorption peak is observed. The end result of the scan is a density profile of the inside of the process vessel. For distillation column, correlating the changes in density seen in the scan profile with column internals and what is known from column service records yields an accurate picture of the unit's performance and physical condition.

Gamma-ray scanning for non-disruptive and on-line inspection technique to diagnose process malfunctions and pinpoint internal damage within distillation columns in petroleum refineries and chemical plants.

Distinguishing features of the technology

- Capable of non-disruptive and non-invasive investigation.
- Scans are performed on-line; hence, normal operation of the column is not disrupted. They are carried out completely external to the process.
- Full length scanning capabilities.
- No preparation of columns (for additional scaffolding or staging) and components dismantling is required. Only requires access from readily available platforms or walkways.
- Insulation or lagging need not be removed.
- Performs non-contact measurement, therefore, is not affected by high temperature, high pressure, corrosiveness etc.
- Utilises small amount of "sealed radioactive source" with in-built radiological safety features to comply with national and international legislative requirements.
- Applicable to all column sizes.
- Uses computer-aided data acquisition, retrieval and analysis system enabling fast, accurate and reliable results. Data collected and stored by computer can be used immediately as well as for future comparisons.

Recommended scanning programme

In keeping a systematic and a complete record of column operating conditions, it is highly recommended that a regular programme of column scanning should be implemented as follows:

- *Troubleshooting Scan*™ *or Diagnostic Scan*™ : Diagnose operational, mechanical and process related problems. Gain empirical confirmation of models and simulations. Locate bottlenecks through real-time analysis.
- *Blank Scan*™ *or Dry Scan*™: Scanning of internal structures of a column before operation or during shutdown.
- *Reference Scan*™ : Record normal operating profile after start-up or during commissioning for baselining. Verifies the system design and optimise system performance.
- *Performance Scan* ™ : Evaluate existing column

performance and develop project engineering. Study tray or packing hydraulics at any set of on-line conditions. Investigate the effectiveness of antifoam addition.

- *Scheduled Scan™ or Periodic Scan™* : Routine scans should be conducted quarterly, half-yearly, annually or at a pre-determined period for predictive maintenance and life assessment programme. Periodically monitor the progress of fouling, plugging and corrosion. Identify maintenance requirements well in advance of scheduled turnarounds.
- *Prior Shutdown Scan™* : Checking the internal condition of a column prior to a shutdown. Schedule parts and materials to be on-hand prior to a turnaround.

National and International recognition

Gamma scanning has been successfully used to investigate various types of trayed and packed columns in petroleum refineries, gas processing installations and chemical plants in Malaysia and nearby region. The successful utilisation of this technology has been recognised both nationally and internationally. MINT, in co-operation with the International Atomic Energy Agency (IAEA) in Vienna, have organised several training courses to promote this technology, to scientists and engineers from Regional Co-operative Agreement (RCA) member countries, including Australia, China, Bangladesh, India, Indonesia, Japan, the Republic of Korea, Malaysia, Mongolia, Myanmar, New Zealand, Pakistan, the Philippines, Sri Lanka, Thailand and Vietnam. The courses and workshops have also been attended by a number of participants and observers from European countries, the Middle East and the African continent.

Radiological safety

Column scanning uses a "sealed radioactive source", which emits gamma radiation. The strength of the source is very minimal (between 1,000 to 10,000 times less activity) compared to those mostly used in industrial radiography. The source holder is designed with in-built radiological safety features to ensure that exposures to the inspection team and plant personnel or the public do not exceed permissible limits recommended by the International Commission on Radiological Protection (ICRP) and the IAEA, as well as the regulatory guidelines of the Atomic Energy Licensing Board (AELB) of Malaysia.

Concluding remarks

The application of radioisotope techniques, in particular, gamma-ray scanning, can help improve the efficiency of a distillation column or it can pinpoint the reason for a decline in performance, thus yielding large savings through avoidance of loss of production and wasted maintenance effort. Column scanning is only a small subset of the many applications of radioisotope technology encountered in practice. The technique is straightforward, quick, sensitive, unambiguous and safe. Realising the importance of the technology, considerable efforts have been undertaken by MINT towards promoting and expanding its usage in Malaysia and around the world. To ensure effective use of this technique, MINT encourages and welcomes collaboration and participation from the petroleum and chemical industries. But more important, and what is expected, is the readiness of the industries to accept and adopt the technology.

Hydrocarbon Asia thanks Dr Jaafar Abdullah for contributing this paper.

Dr Jaafar is the Manager and Principal Research Scientist of Plant Assessment Technology Group, Industrial Technology Division, Malaysian Institute for Nuclear Technology Research (MINT), Bangi, Selangor. He has been involved in a wide variety of research and development using radioisotope technology for industrial plant assessment since 1980. As the pioneer of gamma scanning technology in Malaysia and the surrounding region, his experience in using the technology for investigating and troubleshooting various types of process columns in petroleum refineries and chemical plants is extensive. He is recognised by the International Atomic Energy Agency (IAEA) as an expert and consultant in the field of industrial applications of radioisotopes. He received his B.Sc in Physics, M.Sc in Nuclear Technology from University of Surrey, UK and Ph.D in Materials Engineering from University of Wales Swansea, UK. He has published substantial amount of scientific papers, consultation documents, technical reports and articles. He has won a number of awards both nationally and internationally for his outstanding innovations in the field of radioisotope technology. He is a member of several professional organisations and societies, which include MNS, MSNT, IPM, IMM and MARS. He was the chairman of MSNT technical and training committee.