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Gamma Ray Scanning As Troubleshooting Tool For Unusual And Large Diameter Refinery Vacuum Columns

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SUMMARY

Gamma scanning of trayed and packed columns is widely used to obtain density profiles and identify on-line problems such as; damaged tray or packing, foaming, flooding, maldistribution, weeping and entrainment etc. However, scanning of large diameter tray or packed columns requires expertise in handling high intensity gamma sources along with thorough understanding of distillation engineering. Engineers India Limited., and the Bhabha Atomic Research Centre undertook scanning of two such large diameter (8.4 m and 7.4 m) trayed and packed refinery vacuum distillation columns and successfully diagnosed the problems and suggested remedial actions. Radiography testing of small diameter columns can be used to confirm gamma scanning results. One such example for ammonia separation column is given.

INTRODUCTION

Gamma scanning technique is an invaluable tool for better understanding of dynamic processes taking place in industrial columns. The technique can be applied for troubleshooting, debottlenecking, predictive maintenance and process optimisation. The advantage is that troubleshooting exercises can be undertaken under actual operating conditions by using low activity radioactive sources. However, the source selection, equipment for handling radioactive source and strategy to be adopted for inspection, vary from situation to situation. Knowledge of column internals, the process taking place inside and expertise in handling radioactive sources are essential for undertaking gamma scanning and analysis of scan data. Case studies of a few unusual situations are presented in this paper wherein large activity 110 GBq of Ir-192 source has also been used with advantage over the conventionally used low activity (MBq) Co-60 sources for troubleshooting of large diameter refinery vacuum distillation columns. In another case, the integrity of ammonia separation column internals was first detected by scanning and then confirmed by radiography testing.

PRINCIPLE

The on-line problems of trayed or packed bed columns such as damaged tray or packing, foaming, flooding, maldistribution, weeping and entrainment etc. can be accurately determined by gamma scanning technique. The transmission of a narrow beam of radiation through any material is governed by the following equation :

$$I = I_0\, e^{-\mu . \rho . x}$$

I = transmitted radiation intensity through the column
I_0 = initial radiation intensity
μ = mass attenuation coefficient
ρ = average density of material in radiation path.
x = thickness of material in radiation path.

Since x is essentially constant in a column of fixed diameter and μ is constant for gamma energies between 0.3 to 3 MeV, the transmitted radiation intensity is proportional to process material density. The measured intensity is plotted against the column elevation and carefully interpreted by considering internal loading, hardware configuration of the column and discounting for the external obstructions in the radiation path.

Typical scan data for a trayed column shows a set of peaks and valleys indicating vapour space, tray position, liquid level on trays, flooding, dense froth etc. For packed beds, set of scans resulting from equilength chords, taken from different directions should overlap for uniform distribution and a lack of matching would not only indicate non-uniformity but also would show which scan line has vapour/liquid bias.

CASE - 1
GAMMA SCANNING OF TRAY TYPE VACUUM COLUMN

The distillation of heavier fractions of crude oils is carried out in vacuum columns to avoid use of high temperatures needed for distillation in atmospheric columns. The lower operating pressure of vacuum column (10-25 mm Hg) significantly increases the volume of vapour load per barrel vapourised. As a result, the vacuum distillation columns are much larger in diameters than the atmospheric towers. The vacuum distillation column of a refinery scanned, was designed to produce vacuum gas oil, spindle oil, light oil, inter oil (IO), heavy oil and short residue. Inter oil and heavy oil were used for lube base stock production directly. Figure 1 shows the configuration of the column. In order to maximise lube base stock production, a revamp of the vacuum column was taken up. The existing ballast trays were replaced by lower pressure drop venturi valve trays.

However, after the revamp when the column was started up, there was problem with compliance of product viscosity and product rate were less than desired. As a remedial action, the column was opened and 30% of the valves on trays were intentionally blocked with metal strips and welding rods to increase vapour velocities. In spite of this, performance of the column remained inadequate at the inter oil draw off, heavy neutral (HN) draw off, furnace recycle and mid pump around zones.

Gamma scanning of the above zones was undertaken to identify causes for malfunctioning as well as to find out the :

i) effect of increased mid pump around rate on IO draw off rate.
ii) effect of steam rate in the stripper in the HN draw off rate.
iii) effect of overflash rate on the furnace recycle rate.

The internal diameter of the columns was 5.6 m at the top, 8.4 m in the middle and 3.4 m at the bottom with shell thickness of 30 mm. Gamma scanning of such large diameter columns would usually require a Co-60 source of about 10 GBq. However, deviating from the usual procedure, the authors used a 110 GBq of Ir-192 in a remotely operated radiography camera. The camera body was placed on the platform of the column and the source was driven with a remotely operated cable into a directional collimator with 15° half solid angle. As shown in figure 2, by using such a collimator, the radiation intensity remains practically constant over 1 meter segment at a distance of about 8 meters.

This gives advantage of many detector positions for a single source position. Moreover, use of Ir-192 instead of Co-60, gives better contrast for detection of liquid & vapour phases.

INTER OIL DRAW OFF ZONE AND TRAY 12

Scan was taken in two stages at normal operating condition of $60 m^3$/hr. of mid pump around and in upset condition of $90 m^3$/hr of pump around liquid, from the inter oil draw off pan to vapor space of tray 12. Results are shown in Figure 3.
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tray behavior, tray was suspected to be entraining or weeping. Since scan across downcomer also showed presence of two phase mixture at the same elevation as that of the tray, it appeared that only entrainment was taking place. At higher rate of pump around, liquid IO draw off rate was reduced from 28 to 18 m^3/hr. Lower level of liquid in seal pan and nearly empty tray 12 deck, indicated dumping from tray 12 under upset condition.

HEAVY NEUTRAL DRAW OFF ZONE AND TRAY 8

Scan data were collected with and without steam in side-stripper. Figure - 4 indicates the scan results. Compared to scan under normal operation without steam, level of liquid in draw off box had considerably reduced when steam was charged in side-stripper. This corroborated a decrease in draw rate of HN from 17 to 10.5 m^3/hr. As the frothy liquid level in the seal pan also reduced appreciably, vapour bypassing of the downcomer was suspected. However, upper part of central downcomer showed behavior similar to normal operating condition. Non-uniform behavior of tray 8 could also be observed from scan data along different chords of tray 8.

FURNACE RECYCLE ZONE

Investigation was carried out at normal and increased overflash rate in this zone. Scan results are shown in Figure 5 Presence of liquid above flash zone was observed with normal overflash rate which could have been due to either entrainment from flash zone or dumping from tray 5 or both. At increased overflash rate, radiation intensity increased steeply above the flash zone indicating clear vapour space i.e. no appreciable entrainment from flash zone. At low overflash rate there could be dumping from trays or overflowing from the draw off box. Since scan showed low level of liquid in draw off box, seal pan might not be holding sufficient liquid and thereby creating vapour bypassing through the downcomer which might have caused preferential dumping. Based on the above studies, several modifications like providing chimney tray below IO draw off, bubble cap tray for furnace recycle draw (tray 5) and heavier valves on tray decks were suggested and performance improved substantially.

CASE 2
TROUBLESHOOTING OF A PACKED BED VACUUM COLUMN

In a packed bed vacuum column (I.D. 7.4m) of a refinery the separation between vacuum diesel and LVGO was not very good at reduced throughputs. The problem could be due to insufficient HETP (Height equivalent to theoretical plate) at lower throughput as the internal reflux flow was lower. The two packed beds at the top section of the column were scanned at normal (60 MT/day) and reduced (40 MT/day) throughputs with two HSD internal reflux rates (35 and 50 m^3/hr) to examine the performance of the bed.

The same remotely operated gamma ray exposure devise, as mentioned in Case-1 was used with a more intense (555 Gbq) of Ir-192 source in view of the packed bed,larger diameter and the shell thickness of the column.

Figures 6 and 7 indicate scan results. In one bed maldistribution was indicated upto 1 meter from bed top at lower throughput but at higher throughput maldistribution decreased. Also, as the internal reflux rate was increased, hold up in the bed increased. But in the other packed bed, severe maldistribution existed as shown by the non-overlapping scan data.

Based on results of the study, the column was opened and plugged spray nozzles cleaned/replaced which improved the column performance.

CASE - 3
AMMONIA SEPARATOR COLUMN

The Ammonia separator column investigated, was installed about 5 years back and has been malfunctioning for over a year. The column was about 1 m in diameter with shell thickness of 16 mm and tray thickness of 3 mm. Number of trays were 45 having tray spacing of 300 mm. Ammonia was separated by distillation process. From the product samples taken at different locations of the column, it was clear that there was some serious problem in the column. The purity at the top of the column was expected to be 95% of ammonia by weight, whereas the observed purity was between 45-65%. This reduction in ammonia purity, resulted in reduced production of the final product (Ethyl Amine), by about 1 Tonne/day, resulting in considerable revenue loss. The feed to the column was on tray 28, consisting of water, alcohol and ammonia, but this also had some amount of CO_2 due to reaction of alcohol and other input components. The reaction of CO_2 with NH_3 resulted in the production of ammonium carbamate, which is highly corrosive. The tray support and trays in the column were made up of carbon steel, which under the action of ammonium carbamate can get corroded with time and could result in the collapse of the trays, particularly in the region nearer to feed location . Gamma Scanning of the column was thus undertaken to investigate the internal condition of the column.

Gamma scanning was carried out using a collimated 1.8 GBq Iridium - 192 source and detector/ratemeter system. Scanning was done between tray position 2 & 43. Column externals didnot permit scanning the remaining tray positions. The transmitted radiation intensity vs column height plot was made to infer the internal condition of the column and is shown in figure 8.

The major sources of error associated with gamma scanning of small diameter columns are the following;

- loss of source - detector alignment due to swing.
- scatter of radiation by air towards detector when a panoramic type of collimator is used.

These problems were minimised by using a channel support for source and detector collimators to eliminate swing and using a uniform narrow beam hole collimator instead of panoramic or conical type collimator. From the plot of the scan data shown in figure 8, the following observations were made;

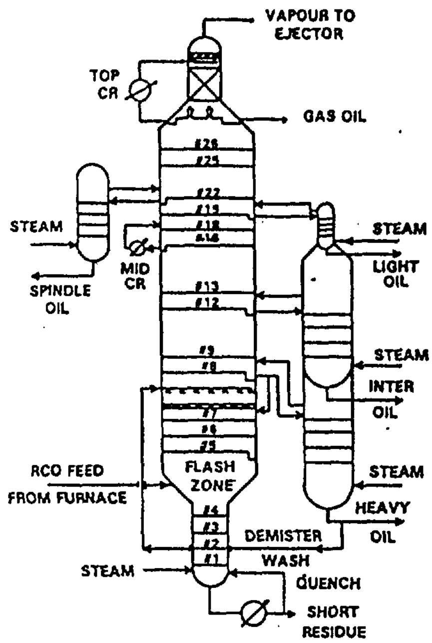
- Flooding was observed between trays 4 to 10, & 39 to 42.
- Debris were found on many trays including number 12 (see below)
- Tray numbers 13, 14, 16, 18, 20, 25, 26 & 27, were observed to be missing.
- Trays 29 to 32 & 36 to 38 were found to be damaged.

RADIOGRAPHY TESTING

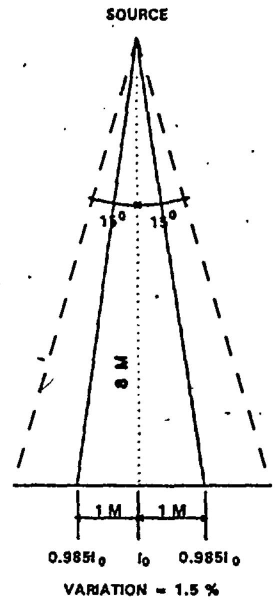
Radiography testing was carried out at suspected random locations to confirm gamma scanning results. For this, a remotely operated Gamma camera with 1200 GBq (32 Ci) Iridium-192 source was used. A medium speed, medium contrast X-ray film, Agfa D-7, of size 30x40 cms, was used with lead screens. Insulation of the size of film, was removed from the column, on the film side. Source to film distance of 110 cm, parallel to downcommers, was used for exposures. Radiographic exposures were carried out at tray positions 12, 24, 29, 39 & 40. The radiographs clearly showed the damaged column internals and confirmed gamma scanning results.

CONCLUSION

The results of gamma scanning and radiography testing were able to pin-point the type of malfunctioning of the columns investigated. Also, the plant operating authorities were convinced about the usefulness of these technologies for on-line investigations of the columns. The case studies described in the paper reveal the advantages of applying the gamma scanning and radiography techniques in troubleshooting of large diameter columns with unusual problems. The success in these studies is attributable to sharing of experience between process engineers and NDT personnel.

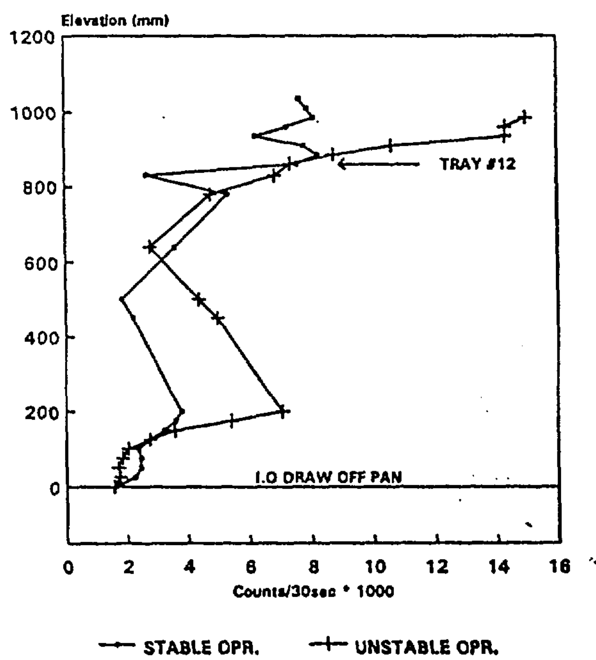


VACUUM COLUMN CONFIGURATION
FIGURE : 1

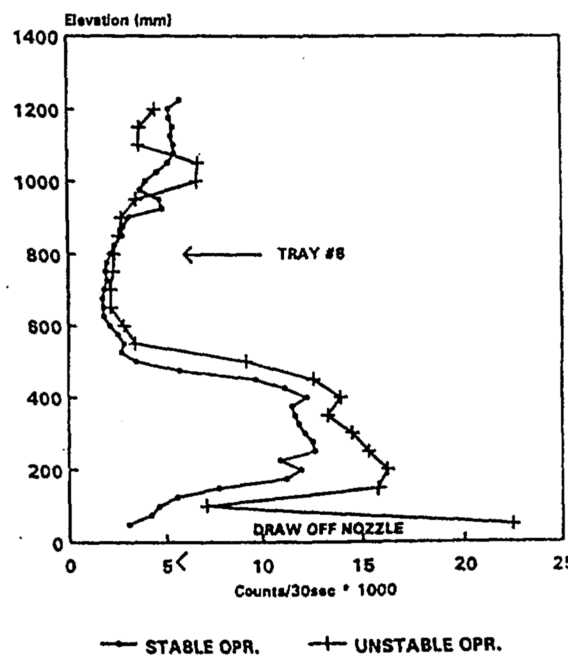


RADIATION PROFILE FOR LARGE DIAMETER COLUMNS

FIGURE 2



I.O.SECTION DRAW OFF PAN AND TRAY #12
FIGURE : 3



HEAVY OIL SECTION DRAW OFF
FIGURE : 4

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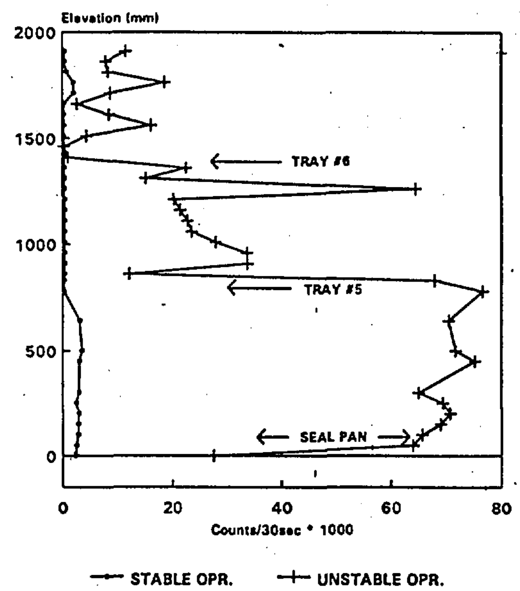
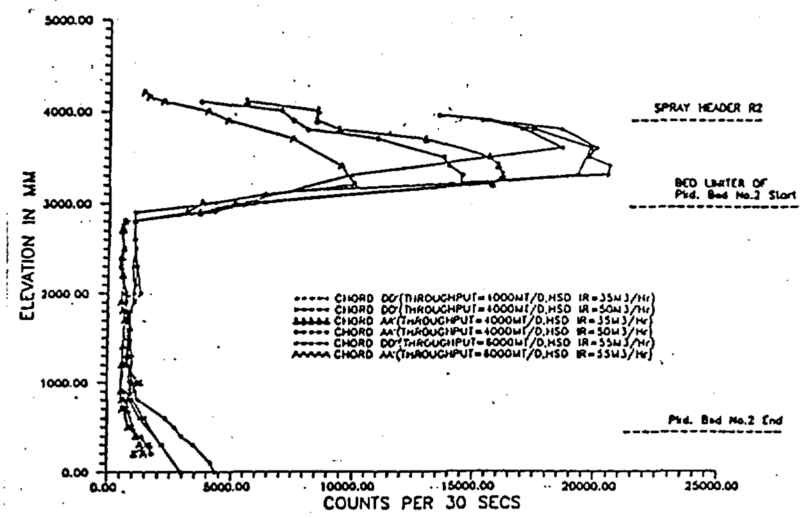
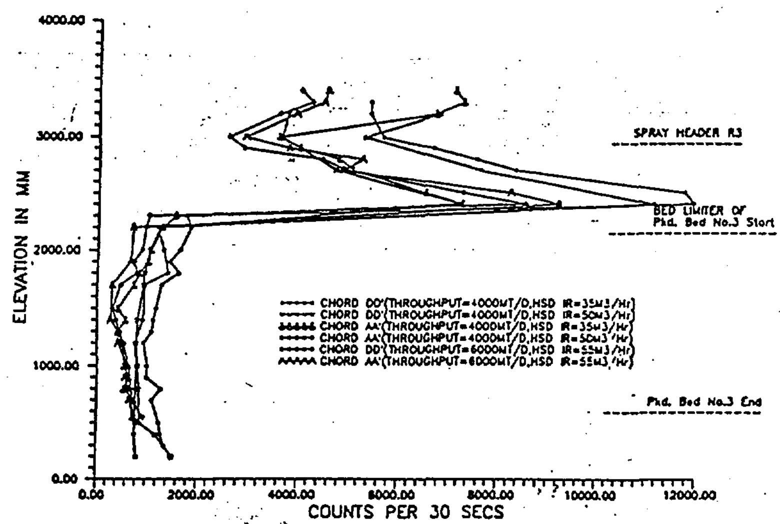


FURNACE RECYCLE SECTION
FIGURE : 5



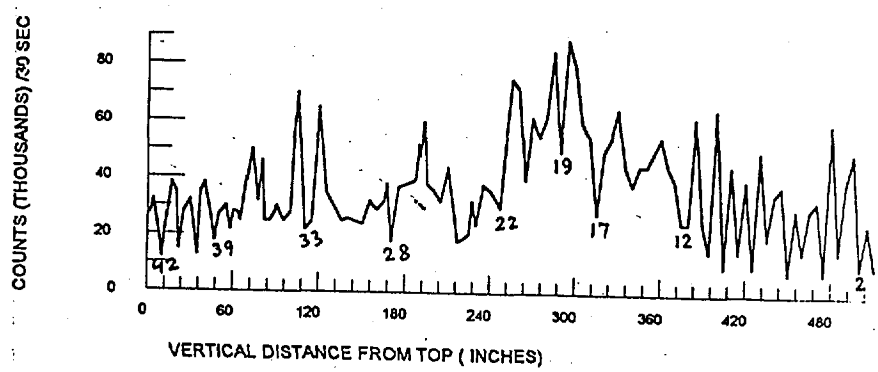
SCAN OF VACUUM COLUMN

FIGURE 6



SCAN OF VACUUM COLUMN

FIGURE 7



GAMMA SCAN OF AMMONIA
SEPARATOR COLUMN
FIGURE 8