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# In-Service Identification of the Heterogeneous Zone in Petrochemical Pipelines by Using Sealed Gamma-Ray Sources ($^{60}Co$, $^{137}Cs$)

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**Abstract** In-service diagnoses of pipeline facilities are important for a systematic maintenance of them. Field applications by using sealed gamma-ray sources ($^{137}Cs/^{60}Co$) were performed to identify the heterogeneous zone in the pipelines of a distillation tower and a flare stack respectively. From the results, the heterogeneous zones in the pipelines were successfully identified. In the case of the pipeline connected to the distillation tower, a vapor pocket was detected in the fluid under hydrodynamic conditions, which could explain the reason for a decrease of the flow rate. In another case, an area with some amount of catalyst deposits was found at the bottom of the gas pipeline which was connected to the flare stack. And these findings provided important information for the process operators. Diagnosis technique by using gamma radiation sources has been proven to be an effective and reliable method for providing information on a media distribution in a facility.

**Keywords:** Pipe Scanning, Gamma Radiation, Sealed Gamma-Ray Source, Density Profile

## 1. Introduction

With a quantitative growth of the petroleum and petrochemical industry, the pipeline facilities which connect each process have increased simultaneously and a considerable annual budget is spent on the maintenance and repair of the facilities related to these processes. The diagnosis techniques for a pipeline efficiency in operation are few in Korea but studies on a pipeline diagnosis by using gamma-ray have been implemented by advanced countries since the 1960's. Radioisotopes were first applied for an industrial problem solving around the middle of the last century. Since then, their use has increased steadily. Today radioisotope techniques are used extensively throughout the world for a troubleshooting and an optimization of industrial process plants (IAEA, 2002). The economic benefits that may be derived from the use of radioisotope technology are large, a fact that has not been fully recognized by the relevant governments.

In this study, field applications of gamma-ray sources ($^{137}Cs/^{60}Co$) were implemented to identify the heterogeneous zone in the pipelines of a distillation tower and a flare stack respectively and to analyze the reasons for an abnormal operation of them (IAEA, 2004). The distillation tower was under the condition of a decreased flow in throughput, and the field operators thought that the main reason was not a structural problem in the trays because the trays had been newly installed within a couple of years. In the case of a flare stack, the operators wanted to know the condition of the pipelines owing to a long term operation of over 20 years.

## 2. Methodology

The experiment I ("Exp. I ") was carried out

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on the pipeline which was connected to the CDU (crude distillation unit) which had the role of an interconnection between the CDU and a following process during the transportation of crude oil. While the object of the experiment Ⅱ("Exp.Ⅱ") was the pipeline of a flare stack which functioned as a safe discharge of gas or highly volatile liquid produced during a process operation for the purpose of a prevention of a system explosion. The first experiment was performed to investigate the inner condition of the pipeline and to investigate the reason for the decreased flow. The second was performed to identify the existence of deposits accumulated at the bottom of the pipeline caused by a long term operation of the process. Each experiment was implemented by using sealed gamma-ray sources $^{137}Cs$ (0.662MeV: 20mCi) and $^{60}Co$ (1.17, 1.33MeV: 20mCi) relatively with a specially designed source holder to collimate the gamma-ray. Gamma radiation counts were measured by a detector (NaI) positioned outside the pipe-wall diametrically, opposite to the gamma source, with a regular space as the detector and source were lowered concurrently as shown in Fig. 1. The experiment was implemented by using a pneumatic scanner operated by compressed air (Kim et al., 2005).

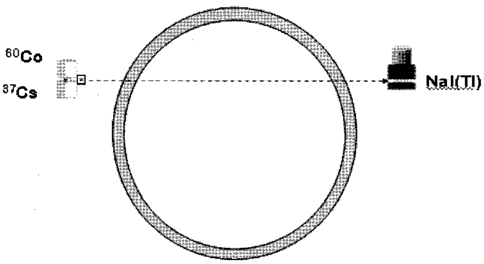



Fig. 1 Schematic diagram of the experiment method

The pipe had a geometrical symmetry with regards to the center of the pipe. Thus the path length of the gamma-ray will be different as the gamma-ray source and detector move around the pipe vertically. That is, the path length of the gamma-ray becomes a minimum when the source and detector are positioned at the center, while, as the deviation from the center of a pipe becomes larger, the length becomes larger (Fig. 2). Therefore we need to consider the effects of a variation in the path length when evaluating the information on a media apart from the pipe wall. The equation for considering a variation in the path length is as follows.

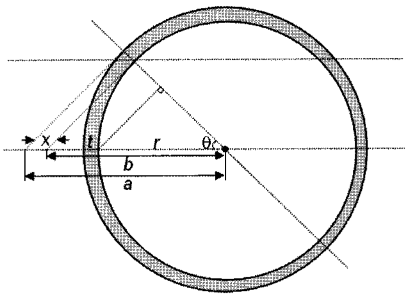



Fig. 2 Geometrical variation of the gamma-ray path length in a pipe

*Thickness of the Shield*

$$\cos\theta = \frac{r+t}{a},\ \cos\theta = \frac{r}{b}$$

$$a = \frac{r+t}{\cos\theta},\ b = \frac{r}{\cos\theta} \quad (1)$$

$$x_{wall} = 2\times x = 2\times\left(\frac{r+t}{\cos\theta} - \frac{r}{\cos\theta}\right) = 2\times\frac{t}{\cos\theta}$$

Where $r$ is the radius of a pipeline, $\theta$ is the angle between the point where gamma source and a detector are positioned and horizontal line at the center of a pipe, $x$ is a horizontal thickness of a pipe wall and $x_{wall}$ refers to the total thickness of a pipe wall at which gamma-ray passes at the certain position with an angle of $\theta$. The length of $a$ and $b$ are shown in Fig. 2. With a consideration of Eqn. 1, the density of an internal media in a pipeline can be measured by an application of Lamber-Beer's law ($I=I_o x\ Exp(-\mu\rho t)$).

$$\rho_{internal} = C\times(A - B\times ln\, I_{meas.}) \quad (2)$$

$$\because A = \frac{ln(I_0) - \mu_{eff}^{steel}\cdot\rho_{steel}\cdot 2t/\cos\theta}{\mu_{eff}^{media}\cdot 2r\cdot\cos\theta},$$

$$B = \frac{1}{\mu_{eff}^{media}\cdot 2r\cdot\cos\theta}$$

$C = Geometry\ correction\ factor$

Where, $\rho$ is the density of a material, $\mu_{eff}$ is the effective mass attenuation coefficient, $t$ is the thickness of a pipe wall, and $r$ is the inner diameter of a pipe respectively.

## 3. Results and Discussion

A preliminary test (reference scan) was carried out on a 44 inch pipeline to confirm the ability of the proposed method for a detection of a heterogeneous area in a pipeline. The empty pipeline was scanned by using a $^{60}Co$ source and an additional scan was followed with a plastic structure inserted in the pipeline. The density of the plastics was 1.250 g/cm$^3$ and they were piled up to 45 cm from the bottom of the pipe. The results of the reference scans are shown in Fig. 3. Distorted configuration in the density profile affected by the plastic structure was identified successfully in Fig. 3. Even a welding mark was detected at the exact position of a pipeline.

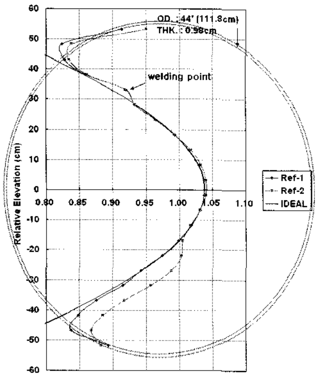
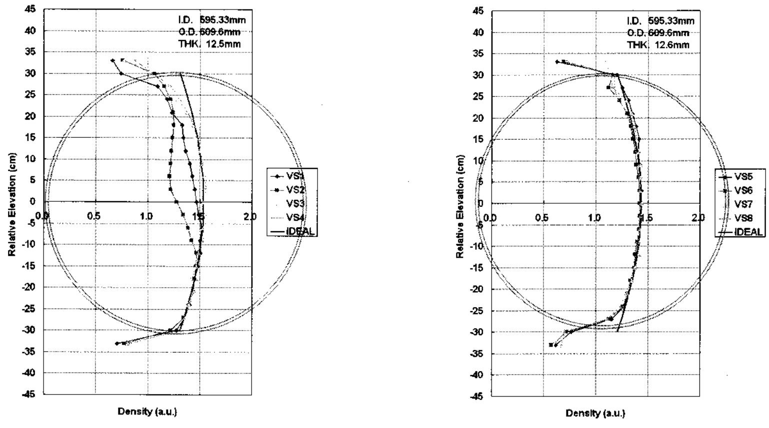



Fig. 3 Vertical density profile of the reference scan

CDU and flare stack pipelines are filled with liquid and gas respectively and their results are shown in Fig. 4 and 5. They show typical elliptical circles and they correspond to the shapes of the pipes well (Kim et al., 2002; Lee et al., 1998a; Lee et al., 2002b). The minimum counts were detected at the center of the pipe because the path length of the media is longest at that point. The measured counts also increased as the detection points moved up and down. A decrease in the detected counts means an increase in the density of the inner media. The higher the density of the material, the lesser the amount of radiation that gets through; Therefore significantly large gamma rays are transmitted through a vapor compared to a liquid phase (Tjugum et al., 2002). Foreign elements were found successfully at some regions which were different to the densities of the surroundings.

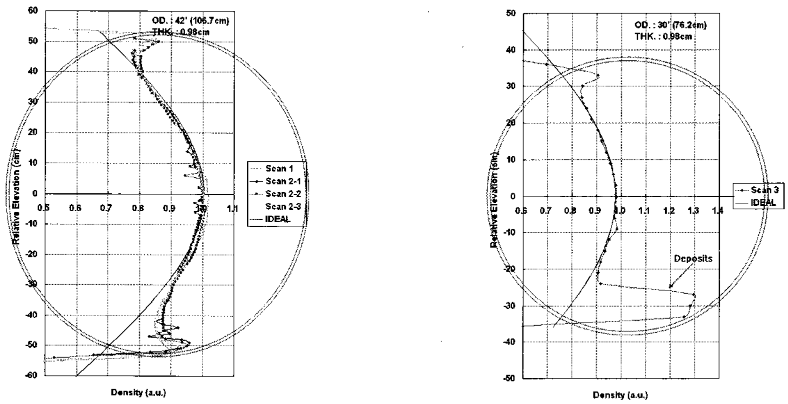
In Figs. 4(a) and (b), the results showed a homogeneous distribution of the pipe filled with a liquid media. But some sections which are different from the density of the surrounding were found at the upper part of VS1 and VS2 (Fig. 4 (a)). These are considered to be caused by the fact that the thickness of the pipeline was decreased because of a corrosion due to a long term operation or there was a vapor pocket in the pipeline which is different in its density with the surroundings. However, the existence of a vapor zone is a more plausible inference, rather than a corrosion of the pipeline thickness, when considering the fact that the pipe facilities were newly installed. Therefore the decrease in the flow during this process could be considered to be from a vapor pocket in these regions. This conclusion was confirmed from the fact that the phenomenon of the decrease in the flow disappeared after an additional establishment of a ventilation line was made in the region between VS1 and VS2.

While, in Fig. 5, the regions of scan 1-3 showed the typical results of a pipeline filled with gas-type media except at the top and bottom of the pipeline. In the results of the flare stack pipeline, all the scanning areas were covered with a scale-layered dust when compared with the results of the ideal scan whose pipe was empty and had no defects in the pipe wall. Especially at the bottom of a pipeline in scan 3 (Fig. 5(b)), a settlement zone which was considered as catalyst deposits was found. The existence of solid particles in the media composed of gas caused a decrease in the count detection of the gamma-ray and an increase in the density of the inner media.




(a) (b)

Fig. 4 Vertical density profile of the CDU connection pipeline




(a) (b)

Fig. 5 Vertical density profile of flare stack pipeline

## 4. Conclusions

The regions different from the density of the surroundings in the pipeline composed of a heterogeneous media were successfully identified by using sealed gamma sources. This can provide information about the distribution condition of the inner media and the defects of the pipe itself, from which process operators can estimate the in-service condition of a pipe on the spot (real-time control). The application of gamma-ray to the facilities related to the petrochemical industry can be considered to provide valuable information to the process operators.

## Acknowledgement

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