Diagnosis of Distillation Column Problems Using New Generation Gamma-Ray Scanning Gauge

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Abstract: *The Gamma-Ray scanning technique effective means for the diagnosis and identification of installations and process's problems in general and in particular in the case of distillation columns without aborting the production process. Because of the different difficulties that can complicate a scan's profile interpretation and in order to benefit from the continuous advent of the new technologies in the electronics and the data processing fields, the team of the division of instrumentation and industrial application at the National Centre of Nuclear Energy, Sciences and Techniques conducts a project aiming the elaboration of an expert system for acquisition, processing and interpretation of the data delivered by the gauge used for the Gamma-Ray scanning. This system consists of two main modules. The first one is for the preparation and control of the scans' progress conditions. The second is developed in order to make the automatic analysis and interpretation of the scans' profiles more reliable, easy and effective. In a first step, we have developed software which permits real time control of all the elements that come into play at the time of the realization of an exploration by Gamma-Ray scanning.*

Keywords: *Gamma-ray scanning, distillation columns, expert system.*

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1. Introduction

The diagnosis based on the gamma-ray scanning technique plays a more and more important role in the resolution of installations and process problems. In comparison to all non destructive control techniques that are used in the practice, the Gamma-Ray scanning provides, in real time, the clearest vision of the production conditions within a reservoir of process. This powerful diagnosis tool used since about 40 years ago, permits:

- To save money.
- To improve the output of the process within the industrial installations.
- To reduce the periods where the production is stopped while indicating when a column must be kept in working or when it must be stopped.
- It is a technique that allows "to see", in real time, the hydraulic performances of a column while functioning.

The countries which possess big petrochemical installations appeal more and more to the Gamma-Ray scanning, as effective means of identification of process's problems in the distillation columns, without aborting the production process.

In order to benefit from the continuous advent of the new technologies in the electronics and the data processing fields to improve the reliability and effectiveness of this technique, the team of the division of instrumentation and industrial application at the National Centre of Nuclear Energy, Sciences and Techniques (CNESTEN – Morocco) conducts a project aiming the elaboration of an expert system for the acquisition, the processing and the interpretation of the data delivered by the gauge used for the Gamma-Ray scanning.

In a first stage of this project, we have conceived software which permits real time control of the totality of all the elements directly or indirectly bound to the conduct of the scan. A data acquisition module has also been elaborated permitting to obtain the measures with a high precision. These two components are in phase of test.

The present article will be organised as follows. First, we remind the principle of the technique of the Gamma-Ray scanning. Then, we will describe the proposed expert system and detail the elaborated components.

2. The Gamma-Ray Scanning Principle

At the time of a distillation column scanning (or of a similar reservoir), a small adequate sealed radioactive source and a detector are moved down simultaneously, with a small increment, on opposite sides along the lift of the column Figure 1. A profile of relative density of the column's content is obtained. Analysing the obtained profile and comparing it to a mechanical scheme of the column, some conclusions can be

deduced concerning the possible mechanical damages of the trays as well as some working conditions of the column, like obstructions, blockages, or other process's abnormalities [1].

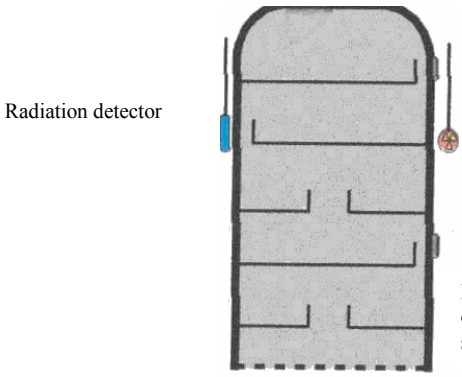


Figure 1. Principle scheme of the gamma-ray scanning of a distillation column.

The quantity of gamma radiation absorbed or transmitted by the material placed between the radioactive source and the detector gives an indication of the nature and the real quantity of this material. The gamma radiation transmission through a material is given by the following Equation 1:

$$I = I_0 e^{-\mu\rho x} \quad (1)$$

where:

- I is the intensity of radiation transmitted through the material.
- I_0 is the intensity of the incident radiation (without any interfering medium with the transmission of the radiation).
- μ is the coefficient of absorption of the measured material.
- ρ is the density of the material.
- X is the thickness of the material (length of the course of the radiation through which it is transmitted).

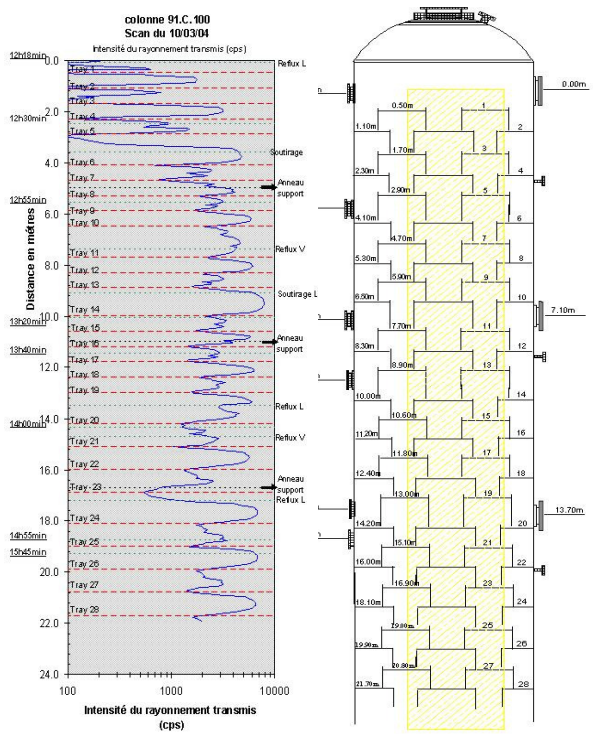
The interaction of the radiation with the concerned medium results in variations of the intensity of the transmitted radiation beam. These variations can be analysed and linked to the properties of the medium inside a closed reservoir. The gamma transmission equation through a medium describes an exponential attenuation which can be interpreted as function of the product's properties like the thickness and the density of the material (i.e., mass by surface unit) of the absorbing environment. These considerations, applied to the practical case of a column are translated by the following facts:

- When radiation, issued from a radioactive source, pass through a medium containing a tray with an aired liquid, a good part of this radiation is absorbed and the radiation quantity reaching the detector is relatively small.
- If a beam of radiation passes through a non aired liquid, the most part of this radiation is absorbed by the medium and the intensity is weak.
- When the radiation beam passes through steam, in this case a small quantity of material is present to absorb the radiation. That means high intensities of radiation are transmitted to the detector.

To sum up, a scan using gamma radiation of a column can detect and localize regions of liquid and steam within this one. It can make the discrimination between the liquid aeration and can detect the levels (heights) of foam or aerosol in the steam regions.

While measuring the changes of density, a great deal of information can be recorded and can be analysed in order to inspect the performance of the column. Every tray as well as the space situated above "narrates the history" of its working state. A tray functioning correctly has a reasonable level of aired liquid showing a fast decrease of the gradient of the density as far as reaching a clear steam space just below the following tray.

To illustrate, we give on the Figure 2 bellow, the profile of the scan of a part of an atmospheric distillation column of diameter of 5.70 meters while using a radioactive source of Cobalt 60Co of 80mCi [2].



(a) The profile of the scan. (b) The scanned part scheme.

Figure 2. Example of the profile of the scan of a part of an atmospheric distillation column.

3. Expert System for the Gamma-Ray Scanning

3.1. Description of the Expert System

The interpretation of a scan profile such as the one of the Figure 2 is not always easy and it depends in a very large way on the experience and the aptitude of the team that takes charge of the control. This results because of the diversity of the phenomena in relationship to the process just as the different mechanical components of the columns, internal as well as external ones, that are different from the standard elements usually taken into account at the time of the interpretation of the obtained profiles. These components, which interfering with the radiations crossing the column, complicate the profile obtained while superimposing them to the results directly linked to the process.

Whence the interest to have a system able to take into account the maximum of information that the team charged of the control dispose before the starting of the scan as well as that those which may be obtained during its progress. Any team practicing the technique of Gamma-Ray scanning would like to have such a system because it would not only permit to improve the quality of the well service but also to reduce its duration. The system that our team conducts the elaboration consist of an expert system for the acquisition, the processing and the interpretation of the data delivered by the gauge used for the Gamma-Ray scanning. This system is composed of the two following main modules:

- A module of preparation and control of the scans' progress conditions.
- A module of automatic analysis and interpretation of the scans.

The complete system might be in use by teams taking charge of controls using the Gamma-Ray scanning method. In a first stage of this project, we have conceived an application which allows the acquisition and the control of the gamma-ray scanning parameters.

3.2. The Developed Modules

The conceived software permits real time control of all elements directly or indirectly bound to the conduct of the scan. Thus, a module of data acquisition has been elaborated to make the measurements' recording with a high precision while taking into account the corrections sampling time. This module is also endowed with big capacity of memory [3]. The different blocks of the developed system can be represented by the synoptic scheme that Figure 3 shows [4].

The acquisition module is formed of a sophisticated electronic data acquisition card. It is a multi channel card endowed with a microcontroller programmable in-situ. This card permits:

- To record the nuclear counting.
- To control the high voltage power cards supplying the detector.
- To calibrate the gauge.
- To record some possible additional physical parameters.
- To communicate with the control software through the RS485 connexion.

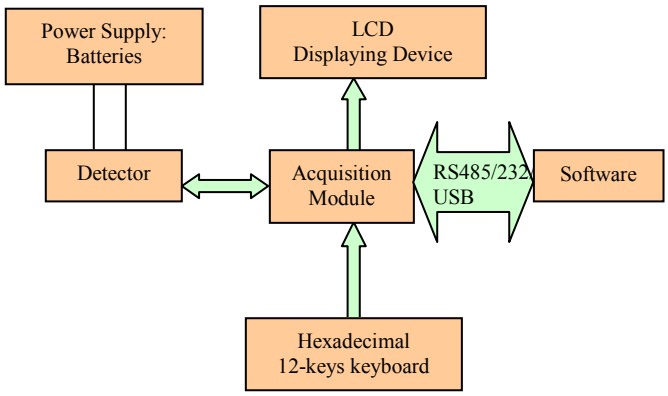


Figure 3. The synoptic scheme developed system of the gamma-ray scan.

This module is also equipped with a 12-keys keyboard and with an LCD display device to visualize and to validate the measurements and also to introduce the acquisition parameters. All the system including the high voltage cards is powered by batteries.

On a portable computer, software that facilitates use and data processing at the time of the measurements using Gamma-Ray scanning is installed. This software permits to monitor the elements of the gauge while communicating with the electronic module described above, as well as the display and the processing of the data. Besides, it allows the follow-up in real time of the scan's progression, particularly by progressive signalisation of the different internal and external components of the column that may interfere with the radiations [4].

Figure 4 bellow illustrates the main interface of the developed software. It shows a chart zone for scan profiles which represent the variations of the nuclear radiation counting received by the detector according to the browsed height of the scanned column. Some numerical displaying zones permit to indicate in real time the useful information such as the detectors position, the current measurement and its duration. A zone for the control of motors used for the automatic motion of the source and the detector is also available.

4. Conclusion

For improving diagnosis purposes and efficient use of the Gamma-Ray scanning technique, we proposed the elaboration of an expert system able to take into account a maximum of information that we dispose before the starting of a distillation column's scanning

as well as that those which may be obtained during the scan progress.

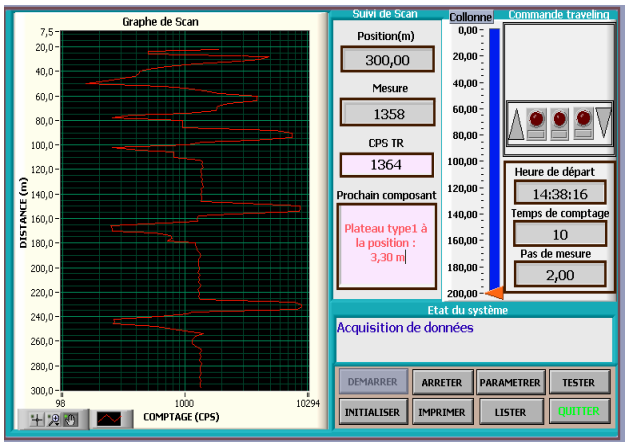


Figure 4. The main window of the developed software.

This system is composed of two principal modules. The developed module permits to make data acquisition and processing during the Gamma-Ray scanning more reliable and effective. This component of our system consists of software which allows monitoring the elements of the gauge. Besides, it allows the follow-up in real time of the scan's progression.

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