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Multiphase Monitoring by Annihilation Radiation Coincidence Mode

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Abstract. A multiphase monitoring system employing nuclear techniques is reported, which is aimed to provide a rapid - decision tool in oilfield applications. Liquid phase time variation is monitored employing two large volume BaF_2 detectors. The radioisotope source of ^{22}Na is a positron emitter, therefore two antiparallel gammas are produced per decay, and phase flow in pipes is related to the count rate of gamma pulses in coincidence providing information on transient liquid phase during transport. Oil, gas, water fraction measurements were performed at a specialized test station assembled in our laboratory to model a wide range of field operating conditions. The time dependence of the mixed substances is monitored with the two most relevant hydrodynamic parameters, the density (type of the fluid) and the flow rate, in a LabView® environment. Performance of the monitoring system; its limitations and the possibility for further improvements are also provided.

Keywords: Multiphase Monitoring, Gamma Annihilation Radiation, Coincidence Mode.
PACS: 20.29.30.-h.

INTRODUCTION

Oil field exploitation is a primary objective to satisfy the worldwide energy requirement, and is a very important activity in Venezuela. From most wells, oil is produced with some liquid, solid particulate and gas. In the petroleum industry, multiphase flow occurs in pipelines and in oil and gas wells and its time variation has to be monitored. As the natural resource of this primary energy product is depleted, wells are equipped with artificial-lift systems as it occurs within the Venezuelan oil fields where water is pumped back. To enhance the extraction process, the industry requires monitoring equipments to have priory knowledge of the fluid characteristics before reaching the processing plant.

During the past decades, several type of multiphase metering [1, 2, 3] has been developed and some of them were installed permanently at the extraction site within a field to fulfill the requirement of the multiphase flow rate measurements. However the implemented methods developed so far, suffer from several draw back (size, high radioactivity of the sources in the case of nuclear techniques, etc.), and new technological solutions are expected to reach the production fields. The ability to measure multiphase parameters is essential for designing rugged equipment and in this

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study a compact low activity system for multiphase testing is given to further contribute with a solution to the problem.

PRELIMINARY CONSIDERATIONS

Gamma rays in water (H_2O), "oil" ($C_{10}H_{22}$) and sand (SiO_2) are attenuated depending on the total absorption coefficients of each one (μ) [4]. Those coefficients for these materials (cm^2/g) are given in Fig. 1a in the energy range of 10 keV to 2 MeV. We observe that the range of values differ only below 100 keV.

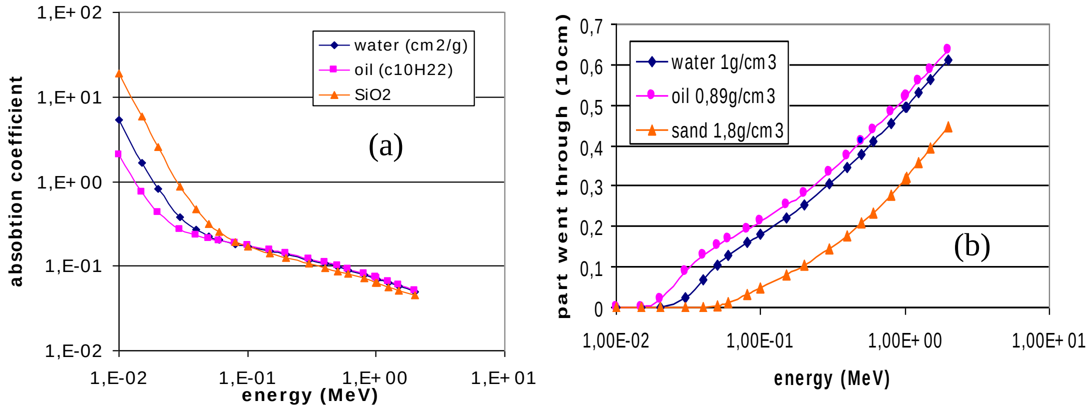

FIGURE 1. (a) Attenuation coefficients for the three specified materials. (b) Ratio of surviving gamma photons which traversed 10 cm of absorber.

Values of Fig. 1a are employed to estimate the gamma ray attenuation at a given energy and substance. The intensity "a" that is detected after an "x" thickness of material with density "ρ" is given by the well known exponential expression:

$$a = a_0 e^{-\rho\mu x} \quad (1)$$

Where "μ" is the absorption coefficient; in this case the factor "ρ" is the density of the fluid flowing in the pipe. Fig. 1b shows the energy dependence of this factor "a", assuming $x=10$ *cm* as an example, and densities of interest: water 1 g/cm^3, oil 0,89 g/cm^3 and sand 1,8 g/cm^3. Gas or air and pipe wall-attenuation was not considered in a first approximation.

EXPERIMENTAL SET UP

The nuclear monitoring device consists of a 1μCi positron emitting ^{22}Na source and two large volume scintillation detectors (BaF_2) coupled with a standard electronics chain. The two 511 keV photons produced in the positron annihilation are detected in coincidence by using two scintillation detectors which are positioned vertically between the 4" (or 2") diameter transparent plastic pipe of the test station. The radioactive source is placed at one side of the duct so that one of the two photons is detected directly, while the other is detected on the opposite side of the pipe, if it survives after the attenuation (see Fig. 2a). In this particular mode of the transmission experiment the background is reduced to a very low level, even without any shielding. Coincidence count rate will depend upon the fluid mixture (average densities and photon track path through the matter, see Fig. 2b) and on the scintillator detectors location (geometry); i.e. it is related to the mixture of gas, water and oil in a given percentage flowing in the transparent duct. The window values range between 0 to 100 % for oil, water, gas and sand. The fluid parameters are handled in a LabView® environment. Flow rate, pressure (both, up and down waters) and temperature values are displayed. The obtained data (fluid mixture's associated instantaneous count rate) corresponds to average values over fixed time interval set by the operator, so the time (internal condition) variations can be observed.

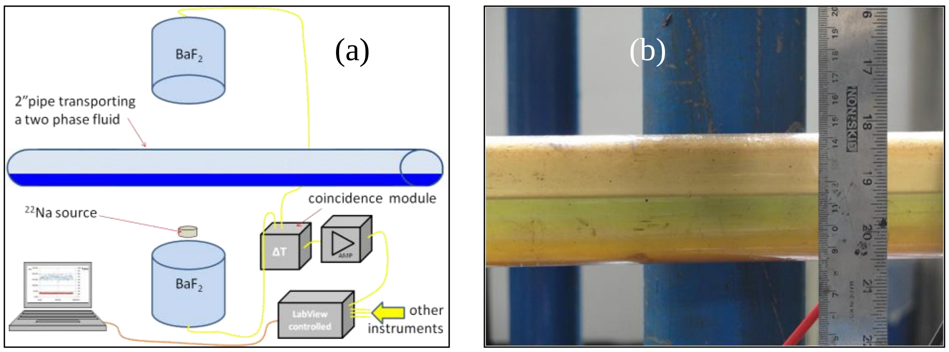

FIGURE 2. (a) Schematic of the experimental set up. (b) Picture of the 2" plastic (transparent) pipe with a mix of water and air.

RESULTS AND DISCUSSION

In order to evaluate the response (CPS) of the instrument, the first experiment was done to obtain measurements for the pipe filled with different materials in static conditions. Since this experiment was also used to set up the electronic, the counting was performed manually, using the rate meter indicator. The observed fluctuations (Fig. 3a) are due to the relatively low statistics, but replacing the manual counting for the automatic one, which may average over a large set of data, fluctuations are reduced as will be seen. Nevertheless, a clear discrimination is made for sand, crude oil and a mix of crude oil (70%) and water (30%). We show this experiment since over 30% of water a clear discrimination can be observed even with the manual counting. For water contents below this percentage (i.e. a sample more similar to pure crude oil), the electronic acquisition system should be employed to obtain a discrimination statistically supported. In the same set of measurement we include also lubricant oil with a density close to that of the crude oil. The results are not shown in the graph of Fig. 3a, since it overlaps the crude oil signal; in fact their averages are 180±7 for crude oil and 181±12 for the lubricant oil. This confirms that the main parameter to be monitored is the density, but more important is that the experiment shows the capacity of the system to detect the mixture between two phases with enough resolution. Also, crude with more than 10% (weight) of sand is well distinguished (not shown here). Lower limits of the monitoring device indicate that it can be employed in the case of heavy fluids.

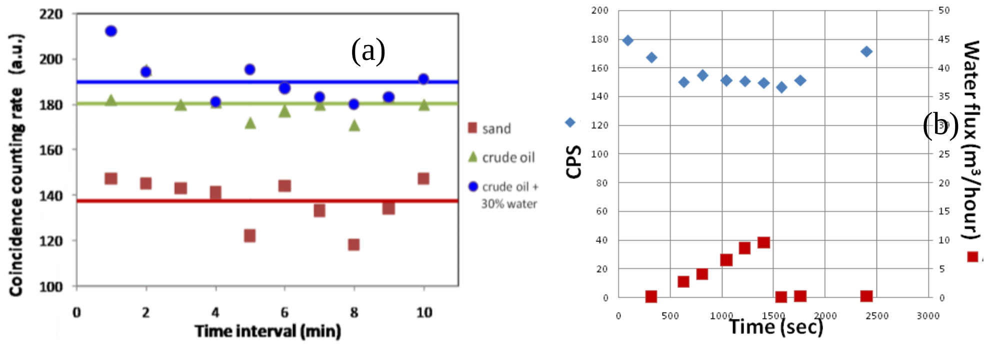

FIGURE 3. (a) Static exp. counting rates for different materials. (b) Dynamic test with air/water.

A second experiment to test the instrument temporal response consisted in monitor the pipe initially empty while is being filled (and then evacuated) with water in real dynamic conditions. Measuring of the water flux was undertaken simultaneously with the automatic LabView developed system; it is shown in Fig. 3b. It can be seen that the signal decrease as the pipe is getting filled, but once the pipe is full of water there are not appreciable changes with the flux. This behavior is expected since the flux values are low enough to maintain a laminar flux, so the density of the involved materials and its relative proportion are the responsible for the signal level.

CONCLUSION

A range of operational parameters and the response of the monitoring device, including its dynamic response, were tested. The instrument can be employed for on field applications. Some aspects related to the design of the equipment and the use of a low activity radioactive source constitutes a great advantage, regarding the radioprotection issues and the transportation and adaptability of the system. For higher fluxes it is expected to observe the different standard current patterns (as wave bunches) which in principle can also be characterized since the relatively fast response of the instrument.

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