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EXPERIMENTAL DEVICE FOR OBTAINING CALIBRATION FACTOR FOR THE TOTAL COUNT TECHNIQUE

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ABSTRACT

Nuclear technologies have widely used on industry plants in order to help to solve troubles processes/design or just obtain information of them. The Total Count technique for flow measurement has as main advantages: being an absolute technique, because it is independent of additional devices readings unless the directly used for recording the radioactive cloud, requiring only a single detector to provide the final result; the independence of the internal volume of the transport duct, can be applied in the presence or absence of obstructions; no restriction as to the nature of the product or material to be conveyed; it is a noninvasive technique which allows real-time diagnostics. To use Total Count Technique, knowledge of a geometric calibration factor is required. Called Factor ***F***, it is obtained in the laboratory using an experimental apparatus to faithfully reproduce the geometry of the detection system and the pipeline that being analyzed and using the same radiotracer, therefore, its value is constant for each specific measuring system under survey. This experimental apparatus for obtaining the factor ***F*** consisting by a pipe of 2 "PVC, which simulates a transmission line, where they were deposited 500 ml oil and the use of a specific pipette for use viscous fluids were added sequentially aliquots (50.00 ± 0.01) µl radiotracer (radionuclide photopeak energy of 198 Au 411.8 keV) and analyzing data obtained by three distinct detection systems composed of detectors NaI scintillators 1" x 1" and a data acquisition system.

1. INTRODUCTION

In industrial plants, oil and oil compounds are usually transported by closed pipelines with circular cross-section. Fluid flow analysis is complex and not always subject to exact mathematics. Most of the empirical formulas proposed for the measurement of the flow in tubes is limited to the application in real conditions of the process that is close to the operational ones done in the laboratory. In this sense, coupled to a flow meter, auxiliary equipment is installed upstream, such as flow rectifiers, speed profile regulators, filters and measuring sockets, which can increase the measurement uncertainty by up to 5% [1]. If the flow rate is not homogeneous (single-phase) and the piping is not completely filled, the flow meter will not be able to measure correctly the volume flowing through it. The presence of entrained air or gas and impurities in liquids, even in small proportions, besides to promoting wear of pumps and meters components, causes large fluctuations in the measurements and anyone flow meter is able to distinguish phase in a pipe.

The unique properties of nuclear technologies provide to get information on real time with the plant on-stream, by the way, without disrupting the processes, and this hand, lead to economic benefits. The use of radiotracers in oil transport and processing industrial facilities allows calibrating flow meters, measuring mean residence time in cracking columns, locate points of obstruction or leak in underground ducts, as well as investigating flow behavior or industrial processes such as in distillation towers.

The total count technique avoids numerous restrictions on the use of mechanical flow meters in pipelines closed. It can be employed in large-scale flow and in all types of flow, even in partially filled ducts. Hull [2], in an oil pipeline linking the American states of Colorado and Utah, made an injection of radiotracer like piston kind and, with a Geiger counter, detected the passage of the radioactive cloud at different points in the pipeline. Although the counting curves had different formats, the areas below the curves were constant. These areas represented the total detected count of the activity of the radioactive cloud extracted from background radiation. This measurement got an uncertainty of 1-3% [3].

At total count technique, a small amount of radiotracer with known activity, $\boldsymbol{A}$, is detected by a detection system with well-defined geometry, which, positioned after homogenization distance, provides a total count, $\boldsymbol{N}$. The flow rate, $\boldsymbol{Q}$, can be obtained by Equation 1.

$$Q = \frac{A \cdot F}{N} \tag{01}$$

Where $\boldsymbol{F}$ is the calibration factor obtained at laboratory, and it has constant value, specific to each measurement system.

It is observed that the higher the flow be, the less time the radiotracer element will spend to cross the detection region, causing a lower count. Thus, by comparing two flows, Q_1 and Q_2, with the same amount of radiotracer, we have in each case the total counts, recorded in the detectors, N_1 and N_2, strongly dependent on the drag velocity of the radioactive cloud, and the relationship observed in Following Equation 2.9.

$$\frac{Q_1}{Q_2} \propto \frac{N_2}{N_1} \tag{02}$$

It follows that the total counts recorded, N_1 and N_2, are directly proportional to their respective activity, A_1 and A_2,

$$\frac{A_1}{N_1} = \frac{A_2}{N_2} \tag{03}$$

wherfrom,

$$\frac{Q_1}{Q_2} = \frac{A_1 \cdot N_2}{A_2 \cdot N_1} \tag{04}$$

or at an absolute form, we have Equation 2.21.

$$Q = \frac{A \cdot F}{N} \tag{05}$$

With an associated uncertainty calculated by Equation 2.23.

$$\delta Q = \quad Q \cdot \sqrt{(\frac{\delta A}{A})^2 + \ (\frac{\delta F}{F})^2 + (\frac{\delta N}{N})^2} \tag{06}$$

As presented in GONÇALVES [4], the uncertainties relative to δA/A and δF/F are low compared to δN/N, since this depends mainly on the accuracy in the discrimination of the counts referring to the photopeak of the contributions of other emissions and due to the Background radiation. Injecting low activity can make this discrimination difficult.

As the detection is done after homogenization of the radiotracer in the medium, the calibration factor F, can be determined in a static model, according to the observations of HULL [2] and GASPAR [3]. In order to obtain the calibration factor F, in this case, a pipe, closed at one end, a homogenized fluid-tracer mixtures with known concentration are added. The detector is fixed to the tube, with the same Geometry of the duct under study, so that the diameter of the pipe is fully filled within the detection region.

Since the instantaneous counting rate R is proportional to the tracer concentration C, then:

$$R \ \propto C \tag{07}$$

F * being the constant of proportionality:

$$R = F^* \cdot C \tag{08}$$

by dimensional analysis, it follows that:

$$F^* = \frac{R\,[\frac{contagens}{s}]}{C\,[\frac{kBq}{l}]} \quad ou\ ainda \quad [\frac{contagens}{kBq} \cdot \frac{l}{s}] \tag{09}$$

Observing Equation (05), we have:

$$Q\left[\frac{l}{s}\right] = F\left[\frac{contagens}{kBq} \cdot \frac{l}{s}\right] \cdot \frac{A\,[kBq]}{N\,[contagens]} \tag{10}$$

If N is the total number of counts and R, the instant counting rate, it follows that:

$$N = \int R \, dt \tag{11}$$

as the flow rate, Q, is constant, this results in:

$$\frac{dq}{dt} = Q \tag{12}$$

substituting in Equation 11 the Equations 05 and 12, we have:

$$N = F^* \cdot \frac{1}{Q} \int C \, dq \tag{13}$$

however

$$\int C \, dq = A \tag{14}$$

Substituting in Equation 13, we have:

$$N = F^* \cdot \frac{1}{Q} \cdot A \tag{15}$$

wherefrom

$$Q = F^* \cdot \frac{A}{N} \tag{16}$$

the comparison of equations 05 and 16 leads to:

$$F = F^* \tag{17}$$

In this way, it is concluded that the F* and the static model F are fully compatible.

2. MATERIALS AND METHODS

2.1: Radiation Detection Systems

NaI scintillation detectors 1" x 1" connected to Ludlum system were used to detect the radiotracer injected for determine the calibration factor F, and to measure the radioactivity of samples were used a standardized electronic set of nuclear instruments modules (NIM).

The collected signals by detector 2 from ten injected aliquots are represented in Figure 1. The count levels were discriminated using a linear adjustment as shown in figure 2.

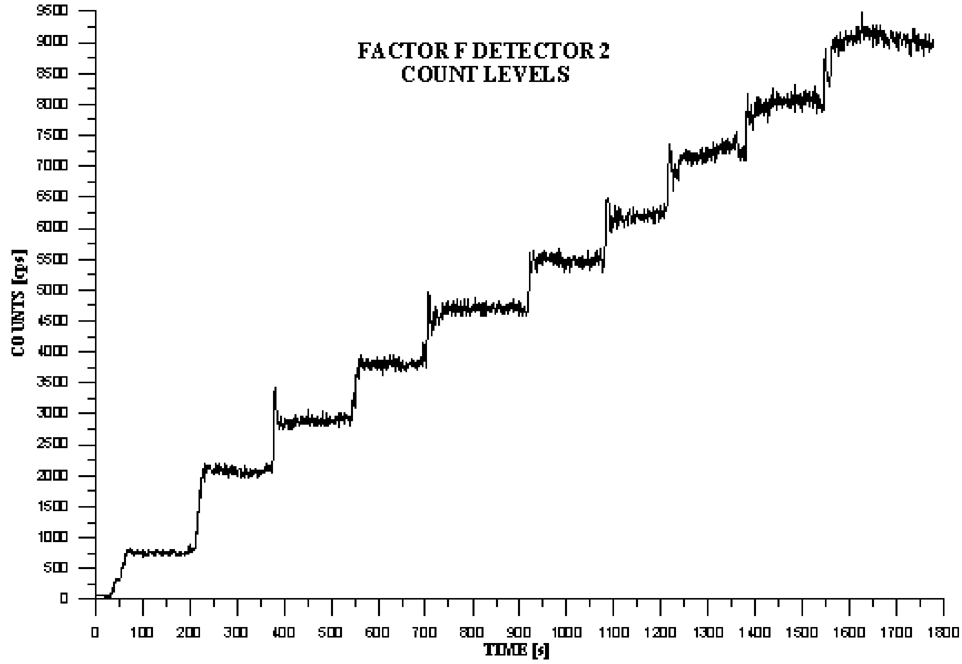

Figure 1: Signals from aliquots.

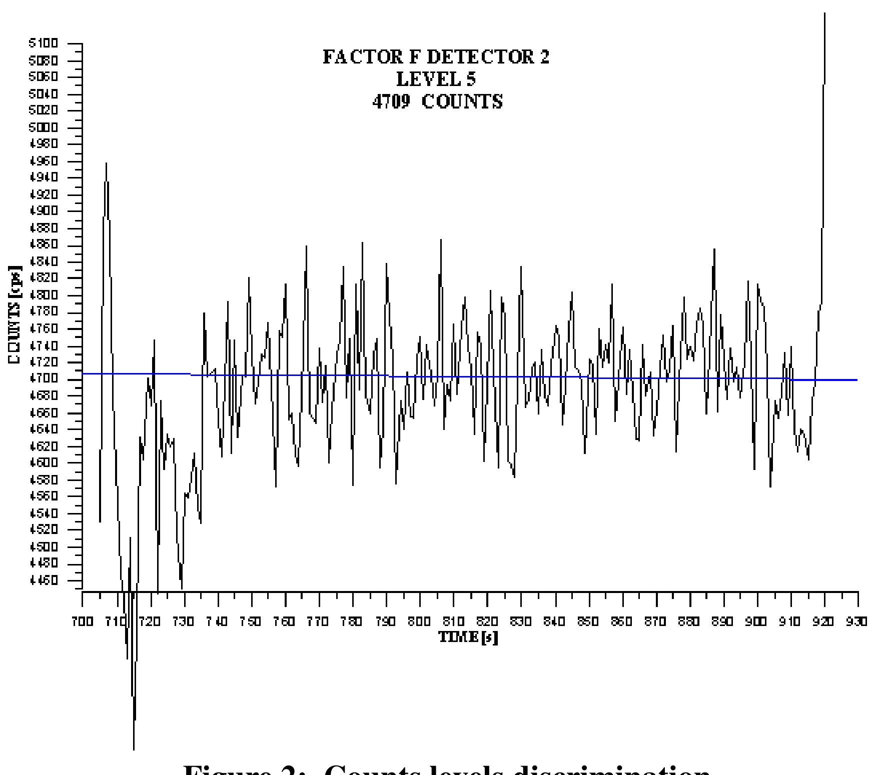

Figure 2: Counts levels discrimination.

2.2: Material transported

The use of the technique Total Count is independent of the nature of the material under study, since the guidelines for the choice of the radiotracer in marked [4]. For the implementation of the research were used Lubrax Essential oil © 20W50 API SJ / SJ ANP. 0139.

2.3: Determination of the calibration factor F

For the determination of the factor F, an apparatus was constructed. It's consisting by a pipe of 2" PVC, which simulates a transmission line, where they were deposited 900 ml oil, coupled to a detection system composed of three detectors accommodated in different positions in relation to the pipe, where Aliquots with (50.00 ± 0.01) µl of radiotracer, with (242 ± 2) kBq activity were deposited successively with

The tables below express the values of radiotracer concentration and signal counts from three detectors:

Table 1: Concentration and signal counts from detector 1.

CONCENT.[kBq/l]	INACCURACY	CPS DET-1	INACCURACY	%
269	2	379	19	5.1
538	3	435	21	4.8
807	4	494	22	4.5
1075	4	654	26	3.9
1344	5	742	27	3.7
1613	5	905	30	3.3
1882	5	1057	33	3.1
2151	6	1122	33	3.0
2420	6	1266	36	2.8

Table 2: Concentration and signal counts from detector 2.

CONCENT.[kBq/l]	INACCURACY	CPS DET-2	INACCURACY	%
269	2	686	26	3.8
538	3	1976	44	2.2
807	4	2855	53	1.9
1075	4	3731	61	1.6
1344	5	4648	68	1.5
1613	5	5378	73	1.4
1882	5	6147	78	1.3
2151	6	7255	85	1.2
2420	6	8006	89	1.1

Table 3: Concentration and signal counts from detector 3.

CONCENT.[kBq/l]	INACCURACY	CPS DET-3	INACCURACY	%
269	2	17	4	24.3
538	3	69	8	12.0
807	4	120	11	9.1
1075	4	158	13	8.0
1344	5	205	14	7.0
1613	5	250	16	6.3
1882	5	275	17	6.0
2151	6	330	18	5.5
2420	6	352	19	5.3

Through the data related in the previous tables, graphs were developed and linear adjustments were made, as shown in figure 3. The angular coefficient of the set line represents numerically the Factor F.

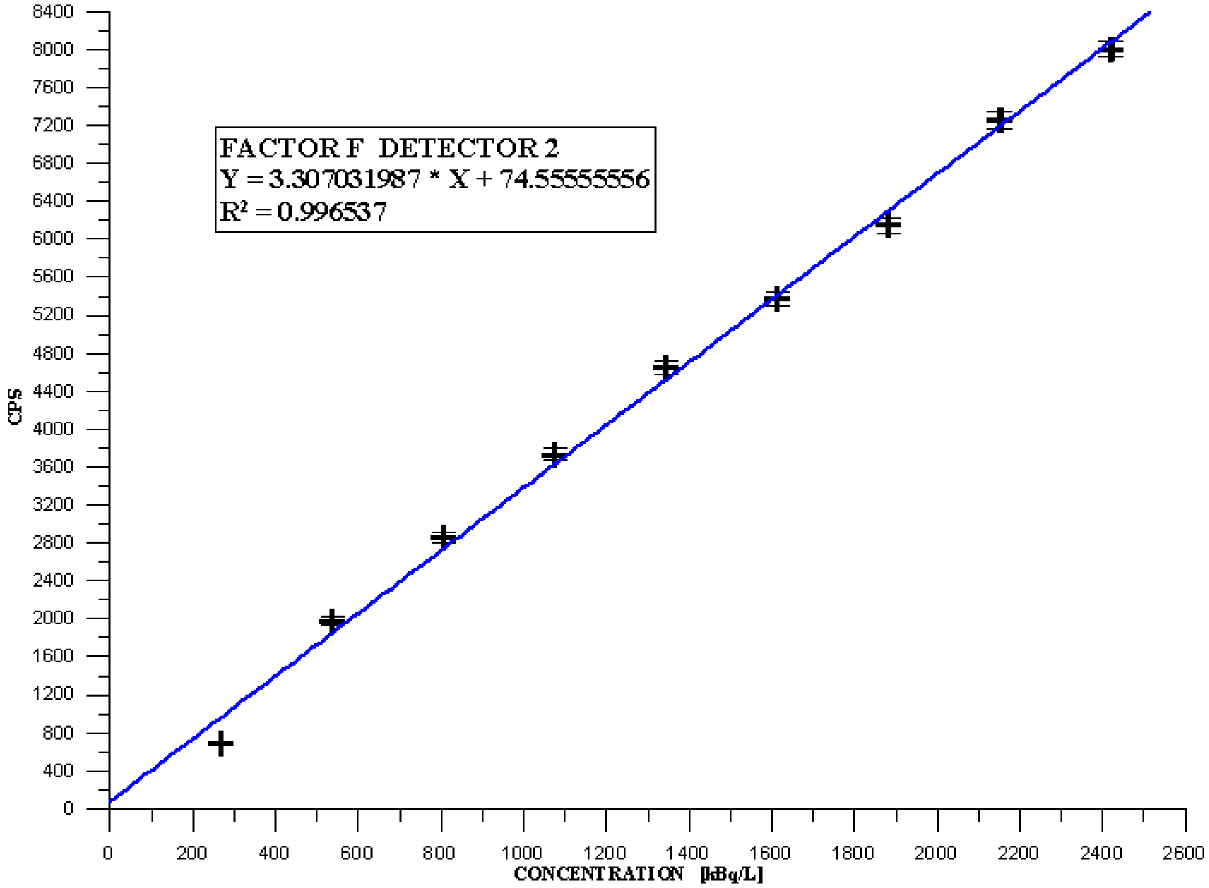

Figure 3: Data fitting.

3. CONCLUSIONS

The use of the experimental apparatus proved to be effective to obtain the Factor F, in which the following values were obtained F_1 = (0.2621), F_2 = (3.307) and F_3 = (0.933) respectively for the detection systems 1,2 and 3.

Notably the number of counts influences the uncertainty of the experiment. It is observed in the detection system 3, the low counts greatly increase the precision of the experiment, as shown in table 3.

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