2013 International Nuclear Atlantic Conference - INAC 2013
Recife, PE, Brazil, November 24-29, 2013
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR - ABEN
ISBN: **978-85-99141-05-2**

FLUID DYNAMICS CHARACTERIZATION OF RISER IN A FCC COLD FLOW MODEL USING GAS RADIOTRACER

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ABSTRACT

Was carried out the characterization of a diameter small riser of a cold flow model of a circulating fluidized bed (CFB), with aid of a radioactive tracer. Compressed air and catalytic cracking of petroleum flow through solids pneumatic transport regime, made of transparent material (glass, acrylic, PVC, polycarbonate) for study of problems in Fluid Catalytic Cracking (FCC) unit and development of methods of measurement of fluid dynamic parameters. The CFB model consisted of a mixer component solid-gas (compressed air at 25 ° C and 200 kN/m^2; cracking catalyst with an average diameter of 72μm and specific mass of 1,500 kg/m^3), comprising a riser pipe glass 0.02m internal diameter and 1.8m height, a gas solid separation vessel by flash effect, with the filter in the gas outlet, and a return column (a glass tube with an internal diameter of 0.0254m) to redirect the catalyst for the riser base. Recorded data allowed studies on residence time distribution of the gaseous phase in the riser, with the identification and characterization of the flow of gas-solid components in the CFB riser of small diameter. A plug flow type with deviations due to back mixing of catalyst close to the walls, associated with the density difference between this component was observed.

1. INTRODUCTION

In the reactor a cracking FCC unit, catalyst (finely divided solid) and oil vapors coming from the base of the distillation column to drain under vacuum and diluted upward transport of solids [1]. In the riser, such as is commonly called a reactor, the conversion occurs in those heavy distillates of low molecular weight products and high commercial value. In a riser the ideal flow mixture of catalyst and oil vapor have uniform speeds and a homogeneous distribution. In a real flow, in the same reactor, the combined actions of gravity, friction with

the walls of these fluids and the collisions between the catalyst particles, causing deleterious effects of back mixing due to which the solid phase flow with lower velocity than the gas-phase [2].

The study on conversion and selectivity in a FCC process shows that it is necessary to correlate information about the solid and gaseous phase, so that the flow parameters have adequate interpretation. In the investigation of the flow parameters, the nuclear techniques have contributed significantly to the understanding of the process of cracking in FCC reactors type [3].

Radioactive tracers are isotopically labeled molecules whose atoms studied are radioactive. It kind of tracer most commonly used because have low detection limits. The radioisotopes used depend on material properties, radiation energy and half-life. tracers Radioactive are suitable for continuous measurements, for emitting radiation (gamma and beta) with high sensitivity and low interference, and facilitate obtaining information flow in areas of difficult access, independent of temperature, pressure and walls thickness of the container. Among the radioactive tracers, widely used in studies in the oil, there is tritium in the form of tritiated water, considered the tritium tracer ideal is cheaper than most radioisotopes, but it is more difficult to measure due to low-energy radiation, requiring more sophisticated equipment for your detection. Besides tritium, are widely used plotters beta 14-C and 35-S [4].

A substance with desired feature can be turned into a radioactive tracer for "irradiation" of nuclear facilities, specifically by neutron irradiation. These tracers can be obtained in large quantities with relatively low cost. Note that the tracer must present high cross section for thermal neutrons, produced the radionuclide should emit gamma radiation measurement by gamma-ray spectrometry, and have good time half-life to allow for the counting after cooling period between the end of irradiation and activity measurement [5]. The amount of tracer used as a stable element depends on the neutron flux available; with a high neutron flux required small amount of element stable activation analysis.
To use an substance to produce radioactive tracer is needed [6]:
- the selection and introduction of the chemical form of the tracer in the system being studied;
- careful removal of the samples with the material that will be marked avoiding and external contamination and;
- the submission of samples for neutron activation analysis product identification of nuclear reaction as well as measurement of tracer present in the material.

In this work, cooperation with the IPEN/SP enabled the production of the gas radiotracer $CH_3{}^{82}Br$ ($T_{1/2}$ = 36h), which although require special care in the preparation and use, proved suitable for measurements. The instrumental arrangement of measures used is described in detail. The methodology used in these measurements is given in literature and is based on determination of the tracer transit time.

2. MATERIAL AND METHODS

2.1. Methodology

A instrumental arrangement for velocity measurements of the gas phase was installed on the riser of a simplified model of the Fluid Catalyst Cracking unity, while the injection system of

the radioactive tracer is attached to the input line of the gas phase in a riser. The flow velocity is obtained by measuring the time transit of the tracer. The gas phase was marked with a radioactive tracer that is injected into the base of the riser. Two radiation detectors arranged along the riser monitor the passage of the tracer, is represented by two peaks obtained concentration versus time. The abscissa of the distance between two characteristic points of peaks such as center of mass was used to compute the transit time.

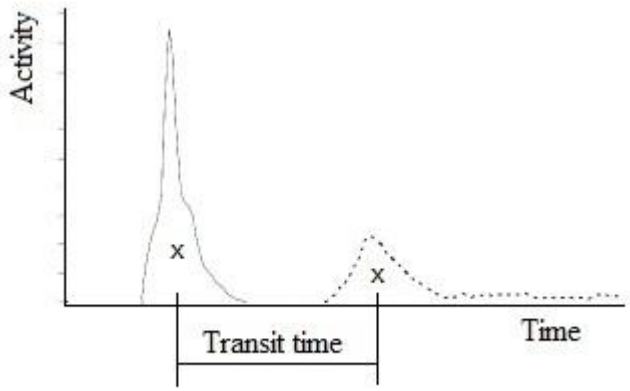

Figure 1: Graphical determination of the transit time with aid of radioactive tracer

Each scintillation detector NaI (Ti) type was connected to a line count in pulse counter which is substituted by a multichannel in a function "multiscaller". The monitoring was obtained by analog processing rather than digital. The projection of the images of the peaks in the multichannel video was used to set collimation of the detectors during preliminary tests with the intention set the resolution of the system. After each measurement the output data are recorded on a printer and the transit time was calculated using the Equation (1):

$$\bar{t} = k \cdot n \tag{1}$$

where:
t - mean transit time of the tracer, s
k - rate constant of the focus multiscaller, s/channel
n - number of channels traversed by the focus between the characteristic points of the two peaks, -

2.2 Experimental Setup

The experimental setup used in this work consists of a simplified model of a circulating fluidized bed (Figure 2). Catalyst cracking and compressed air circulating through the riser to simulate um diluted conveying of solids in a Fluid Catalytic Cracking (FCC) unit. Catalyst and air are separated by gravity on top of it, in a chamber of the flash type. The air exits through a chimney and catalyst returns by one column (down comer) to the base of the riser. The simplified model is made of glass so you can make visual observations about their flow, of a component or two simultaneously components. The height of the riser is 0.9m and its inner diameter is 0.02 m.

Detectors were placed at distances of 0,70m from each other and the first 0,10m above the base of the riser. These measurements were obtained by calculating the distances in the test section with the help of Equation (2) [7]:

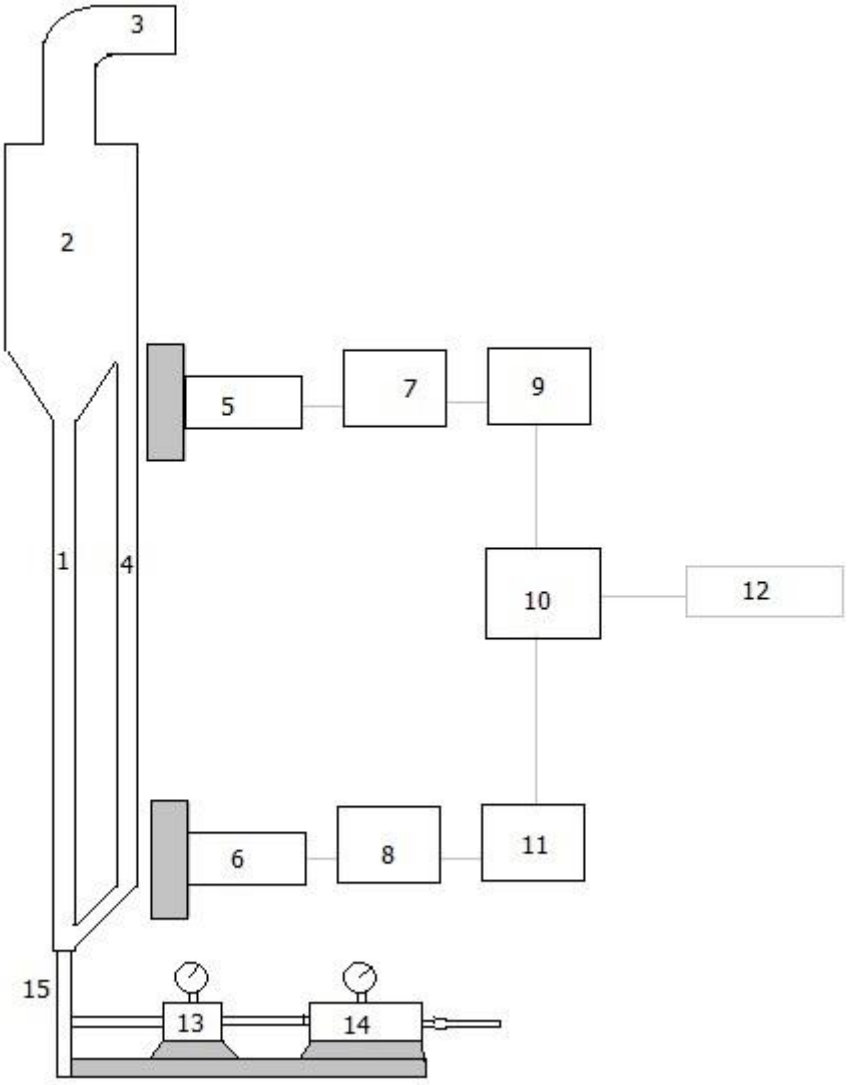

Figure 2: Experimental Setup: 1 - riser; 2 - flash camera; 3 - chimney; 4 - return column; 5, 6 - detectors; 7, 8 - amplifiers; 9, 11 - discriminators; 10 - multichannel; 12 - computer; 13, 14 - injection system; 15 - air line

$$L = 4{,}5 \cdot p \cdot \left(p + \sqrt{N}\right) \tag{2}$$

where:
L - distance between detectors, m

N - distance between the injection point and the first detector, m
p - ratio of the transit time and the time of passage of tracer opposite the detector, -

In the simplified model 500 g of catalyst were maintained in circulating and steady state. The tracer was transferred to admission cylinder, heating the capsule in which was stored at low temperature. The pressure at the injector was set at 30 psig at each run. This pressure was in a range of safety against disturbances in the flow, which would be observed by changes in the shape of the peaks, as described in the literature [8] - [9]. There were four successive injections of the tracer, with which was measured four times the transit time of the gas phase in the riser model. The curves obtained with the detection of the radioactive tracer, allow to observe well defined peaks, indicating that the measures adopted method does not introduce flow disturbances in experimental conditions which are well reproducible.

2.3 Gas Radiotracer and Injection System

The $CH_3{}^{82}Br$ was chosen for labeling the gas phase. Was produced by means of neutron induced nuclear reaction in a target bromide acetate. At room temperature, this compound is gaseous, and because the properties of ^{82}Br ($t_{1/2}$ = 36,0h; γ = 554keV - 71%; 777keV - 83%), it is suitable for velocity measurements in closed conduits.

The methyl bromide was cooled, liquefied at 12^{o}C and encapsulated in aluminum to be irradiated. The target was exposed to a neutron flux of $10^{13}n/cm^2/s$ for 30 minutes at the research reactor of IPEN/CNEN, São Paulo. After irradiation yielded a specific activity of 0.0225Ci/g with a total activity of 54 mCi.

The injection system consists basically of two cylinders, one for intake and one for the tracer injection. The cylinder inlet is provided with two inputs, one for the tracer and other for compressed air. Both operate by means of check valves. Through gauges installed on the cylinder injection and intake can control the pressure in the system. The injector cylinder volume is 1/5 volume of cylinder intake and is connected to the supply pipe of the gas phase through a shut-off valve (Figure 2).

The injector was built in carbon steel and tested to pressures greater than 100 psi, without danger of rupture of the connections. Were performed fluid static tests with compressed air, with the injector pressurized to 100 psig and immersed in water, remaining under observation for 10 hours. A wall of lead was raised the height of the injector of tracer to reduce the permissible levels, the radioactivity in the area of operation.

The air discharge chimney to the atmosphere was constructed with 6,0m tall on the outside of the room where the simplified model was installed. For the amount of tracer used by 0.3 g in $CH_3{}^{82}Br$ injection corresponding to an activity of 5.4 mCi, this care ensures operator safety.

3. RESULTS AND DISCUSSION

There were four runs with injections of the gas tracer, measuring this way four transit times of gas phase in the riser of the simplified model. The curves obtained with the tracer passes

by the point where the detectors are installed is shown in Figure 3, obtained with aid of a computer program using MatLab® software. In this program the curve of the tracer activity A(t) allows to find the residence time function from E(t) function. To obtain the E(t) curve from the C(t) curve, the program just divided C(t) by the integral:

$$\int_0^t C(t)dt \tag{3}$$

which is just the area under the C curve. This area can be found using integration techniques.

$$E(t_i) = \frac{C(t_i)}{\sum_1^n C(t_i) \cdot \Delta t_i} \tag{4}$$

E(t) is the most often used of the distribution functions which are related to reactor analysis.

and

$$\bar{t} = \int_0^\infty t \cdot E(t)dt \tag{5}$$

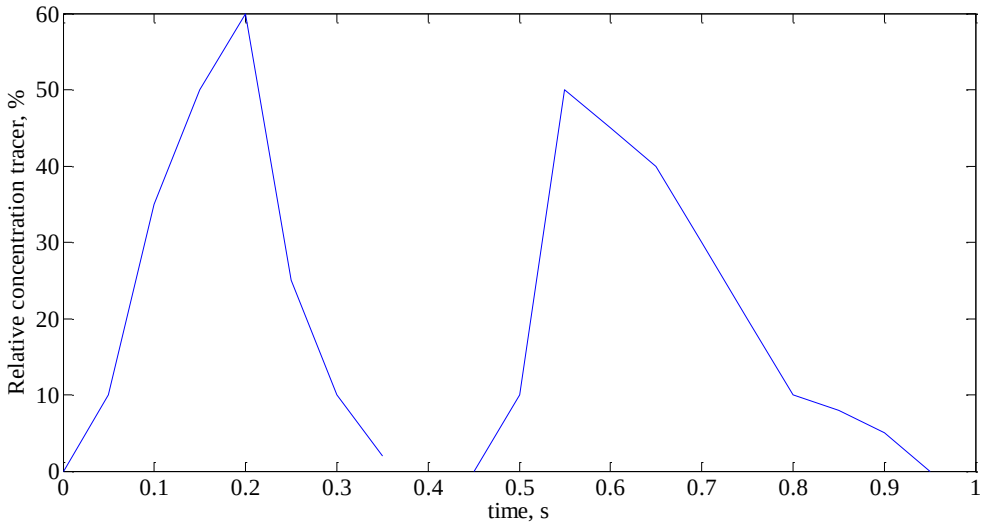

Figure 3: Gaseous tracer activity in function of the time

The average transit time of the gas tracer between detectors is 0.44 seconds. So the *C(t)* curve has been plotted for the its mass center of 0,44 seconds after injecting the tracer. The values of the variance and standard deviation were 0.009 s^2 and 0.094 s. Table 1 presents the values for the measurements of transit time.

Table 1: Transit time and dispersion coefficient values of the gas radiotracer in the riser of the simplified model

Run	Number of channels	Transit time, s	Dispersion Coefficient, m^2/s
1	110	0,44	32,7
2	115	0,46	33,5
3	110	0,44	34,2
4	103	0,41	32,9
	Average transit time, s	0,44	33,3
	Uncertainty, %	4,71	3,00

3. CONCLUSIONS

The flow of the riser of the FCC simplified model was characterized as a Plug Flow not ideal in function of considerable degrees of mixing and dispersion.

Gas radiotracer and the methodology employed allowed accurate measurements of the velocity of the gas phase in a circulating fluidized bed. The results showed good reproducibility with uncertainty in the measurements of the order of 4.71%.

The production of radioactive tracer in the Brazil is feasible as demonstrated by the production of $CH_3{}^{82}Br$, which can replace imported radiotracer in many applications.

ACKNOWLEDGMENTS

This template was adapted from the template for the American Nuclear Society Topical Meeting in Mathematics & Computations, Gatlinburg, TN, 2003 posted on the Internet. Acknowledge the help of colleagues, and sources of funding, if you wish.

REFERENCES

1. B. Peng, C. Zhang, J. Zhu, Numerical study of the effect of the gas and solids distributors on the uniformity of the radial solids concentration distribution in CFB riser, *Powder Technology* **212** pp. 89–102 (2011).

2. S. N. Khadzhiev, I. M. Gerzeliev, V. M. Kapustin, Kh. M. Kadiev, K. I. Dement'ev, O. A. Pakhmanova, Catalytic Cracking in Today's Deep_Conversion Refinery, *Petroleum Chemistry*, **51,** pp. 32–38 (2011).

3. C.C. Dantas, A.E. Moura, H.J.B. de Lima Filho, S.B. Melo, V.A. Dos Santos, and E.A.O. Lima, Uncertainty evaluation by gamma transmission measurements and CFD model comparison in a FCC cold pilot unit. Int. J. Metrol. Qual. Eng. **4**, pp. 9–15 (2013).

4. IAEA, *Radiotracer Applications in Industry: A Guidebook*. Technical Reports Series, n. 423, Vienna (2004).

5. G. E. Magio, Aplicações Industriales de Radiotrazadores y Fuentes Selladas de Radiación; Proyecto RLA-8-024 (ARCAL, 43), CNEA: Buenos Aires (2000).

6. C. V. ChrysikopouloS, P. Kruger, *Chelated Indium Activable Tracers for Geothermal Reservoirs*, SGP-TR-99, Stanford University, Califórnia (1986).

7. ISO 2975-7: Measurement of water flow in closed conduits -- Tracer methods -- Part 7: Transit time method using radioactive tracers (1977).

8. R.L. Hull, A.E. Von Rosemberg, Radiochemical tracing of fluid catalyst flow. *Ind. Eng. Chem.*, **12** 989-992 (1960).

9. E. Huntley, Gas residence time in FCC units. *Ind Eng. Chem*. 53, pp. 381-384 (1961).