**A RADIOMETRIC METHOD FOR DETERMINATION OF THE OIL DROP SIZE DISTRIBUTION IN HYDROCARBON-WATER SYSTEMS**

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# A RADIOMETRIC METHOD FOR DETERMINATION OF THE OIL DROP SIZE DISTRIBUTION IN HYDROCARBON-WATER SYSTEMS

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## ABSTRACT

A radiometric method for determination of oil drop size distribution, similar to sedimentation radiometric method, is proposed for systems containing water and diesel oil labeled with iodine-131. The standard deviation of the proposed method was measured (3,2%). It was observed that the influence of the radiation detector position is insignificant.

The size distribution of the oil droplets must be regarded as one of the most important parameters affecting the kinetic and scale-up studies of hydrocarbon fermentations.

In order to determine such a distribution, the following radiometric method, similar to sedimentation methods described for powdered solid materials,[1-7] was developed in our laboratory.

Figure 1 shows the equipment used. The fermentation medium, containing a labeled hydrocarbon, is conveniently stirred in order to assure a uniform distribution of the oil droplets; the activity in a certain level, measured by means of a suitable radiation detector, will then be constant (Fig. 2, curve AB) whatever the detector position; at a certain moment $\theta$, the agitation is suddenly interrupted; the oil droplets slowly ascend and consequently the oil concentration and the measured activity in front of the radiation detector decrease (Fig. 2, curve BC) until the background level is attained (Fig. 2, curve CD).

Figure 2 represents a typical activity-time curve using distilled water and diesel oil labeled with iodine-131.

Let us call:

$S_o$ = oil concentration in front of the radiation detector when the medium is conveniently stirred = (oil mass)/(total volume of liquid).

$S$ = oil concentration in front of the radiation detector at a given time $T$ measured from the moment $\theta$ (see Fig. 2).

$Y$ = relative concentration of oil = 100 ($S/S_o$).

$H$ = distance from the radiation detector to the tank bottom.

$r$ = oil drop radius.

$d$ = $2r$ = oil drop diameter.

$g$ = acceleration due to gravity.

$b$ = time elapsed from $\theta$ to the moment the liquid medium stops; from this moment $b$ the oil drops freely ascend toward the liquid surface.

$t$ = $T - b$ = time measured from the moment $b$.

$v$ = ascending terminal velocity of drops.

$\rho_a$ = water density.

$\rho_o$ = oil density.

$\eta$ = water viscosity.

$\nu$ = water kinematic viscosity.

The experimentally obtained data lead to the empirical conclusion that the following equation is valid to represent the curve BC (Fig. 2):

$$Y = Y_o \cdot 10^{-\alpha T} \qquad (1)$$

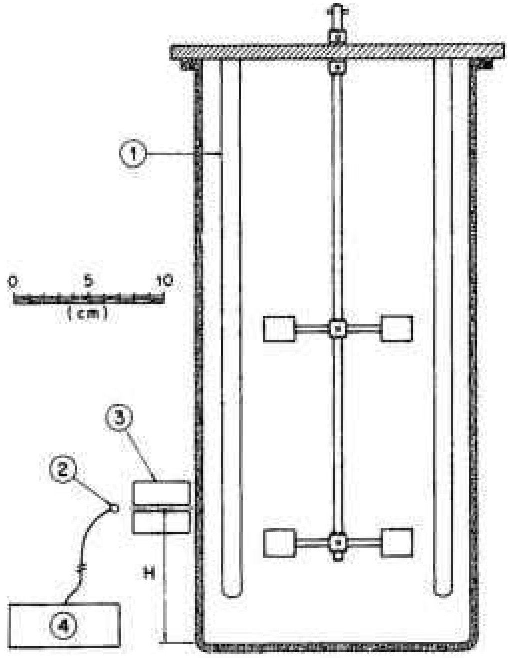


Fig. 1
Schematic representation of the fermentor: 1. four baffles at 90° position; 2. Geiger-Muller counter; 3. lead shield and collimating slit; 4. recorder.

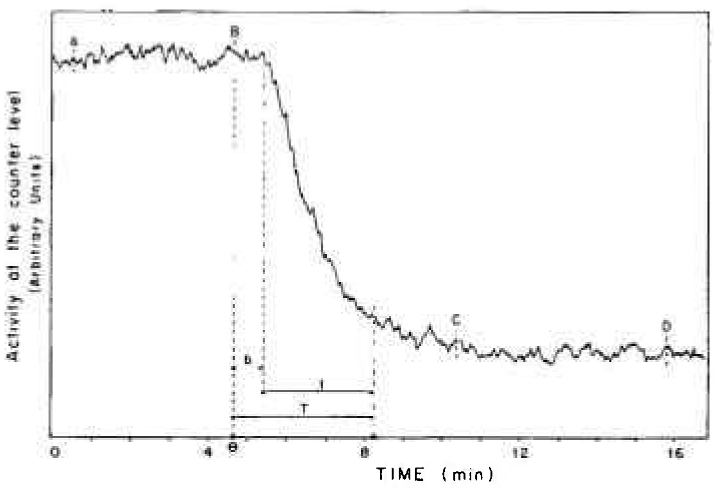


Fig. 2
Activity variation during a complete experiment. Oil concentration = 39.6 g/liter. Rotation speed of impeller = 670 rpm.

where $\alpha$ is a function of the experimental conditions. It is then possible to evaluate $b$ (Fig. 3):

$$100 = Y_o \, . \, 10^{-\alpha b} \therefore b = \frac{\log Y_o = 2}{\alpha}$$

and we may substitute eq. (1) by

$$Y = 100 \, . \, 10^{-\alpha t} \qquad (2)$$

Calling $F$ the oil fraction (in mass percent) that at the moment $t$ has passed in front of the radiation detector, we may write

$$F = 100(1 - 10^{-\alpha t}) \qquad (3)$$

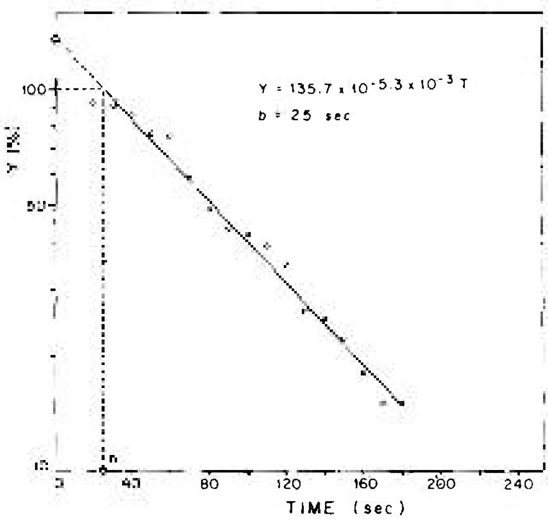


Fig. 3
Experimental points obtained from Figure 2. $Y$= relative concentration of oil at the Geiger-Muller counter level.

Assuming that the Stokes' law may be applied to the ascending oil droplets it is possible to calculate the radius of the smallest drop that, leaving the fermentor bottom, attained the detector level at time $t$:

$$r^2 = AH/t \qquad (4)$$

where

$$A = \frac{9\eta}{2(\rho_a - \rho_o)g}$$

Equations (3) and (4) give

$$F = 1000(1 - 10^{-\alpha AH/r^2}) \qquad (5)$$

This last equation permits calculation of the oil mass fraction present in the form of oil droplets with radius equal to or larger than $r$.

Obviously, the applicability of the Stokes' law is valid[8] only when the Reynolds number, defined by eq. (6), is smaller than 1. If this condition is not obeyed, suitable corrections must be applied.

$$\mathrm{Re} = vd/\nu \leqslant 1 \qquad (6)$$

In our case, as the density and the viscosity of the oil (at 30°C) are 0.8316 g/cm$^3$ and 5.031 g/cm.sec, the Stokes' law can be applied only if $r \leqslant 95 \times 10^{-4}$ cm.

The total activity in each experiment was about 5 mCi. The sensitivity of our measurement equipment permits the detection of 0.06 g/liter of diesel oil in front of the radiation detector.

Thirty experiments were carried out in the following conditions, in order to evaluate the standard deviation of the proposed method:

a) oil concentration = 39.6 g/liter;

b) rotation speed of the impeller = 480 rpm;

c) distance from the radiation detector to the fermentor bottom = 8 cm.

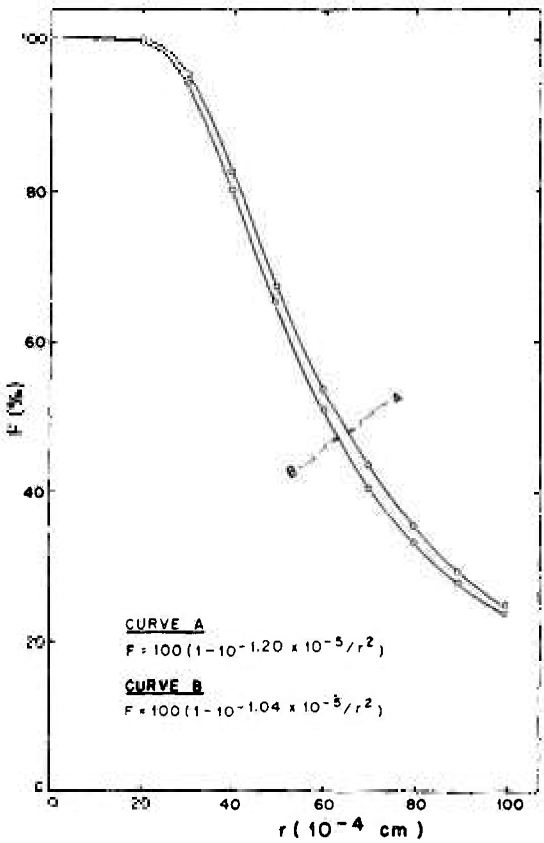


Fig. 4

Extreme curves obtained in 30 experiments. Oil concentration = 39.6 g/liter. Rotation speed of impeller = 480 rpm.

Figure 4 shows the obtained results. The average value of $\alpha$ and the corresponding standard deviation are

$$(6.2 \pm 0.2)\, 10^{-3}\, sec^{-1}$$

that is, a standard deviation as small as 3.2% was observed.

Experiments carried out with the radiation detector at two different distances from the fermentor bottom (8 cm and 13 cm) showed that the influence of the detector position is not significant.

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## RESUMO

Propõe-se um método de medida da distribuição de diâmetros de gotas de óleo em água, análogo ao método radiométrico de sedimentação, utilizando-se óleo diesel marcado com iôdo-131. Mediu-se a reprodutibilidade do método (desvio-padrão = 3,2%) e verificou-se que a posição do detetor de radiações não influi no resultado.

## RÉSUMÉ

Nous proposons une méthode de mesure de destribution des diamètres des gouttes d'huile dans l'eau, analogue à la méthode radiométrique de sedimentation, nous utilisons l'huile diesel marquée avec l'iode-131. Nous mesurons la reproductibilité de la méthode (écart-type = 3,2%) et nous avous vérifié que la position du détecteur des radiations n'influe pas sur les résultats.

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