5-23-2016

Novel method to meassure fine particle circulation rates in draft tube conical spouted beds

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Novel Method to Measure Fine Particle Circulation Rates in Draft Tube Conical Spouted Beds

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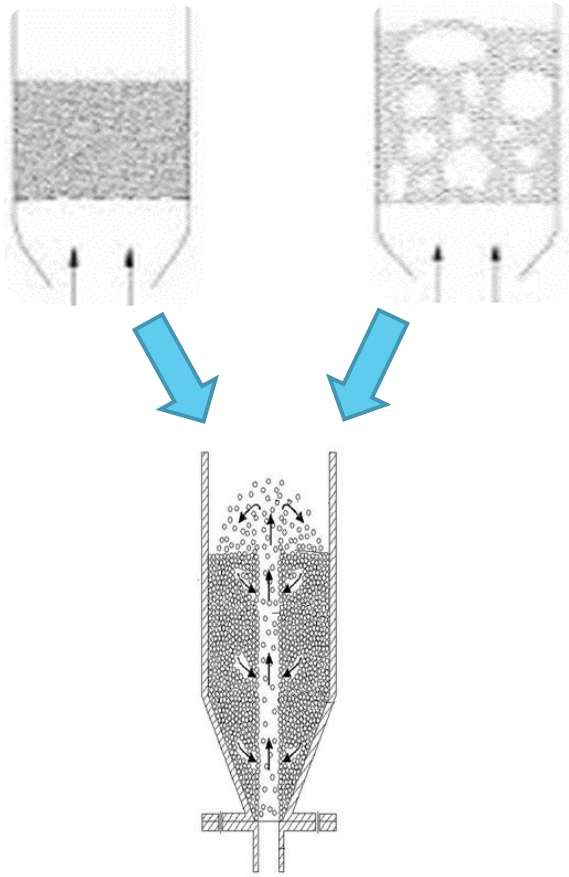
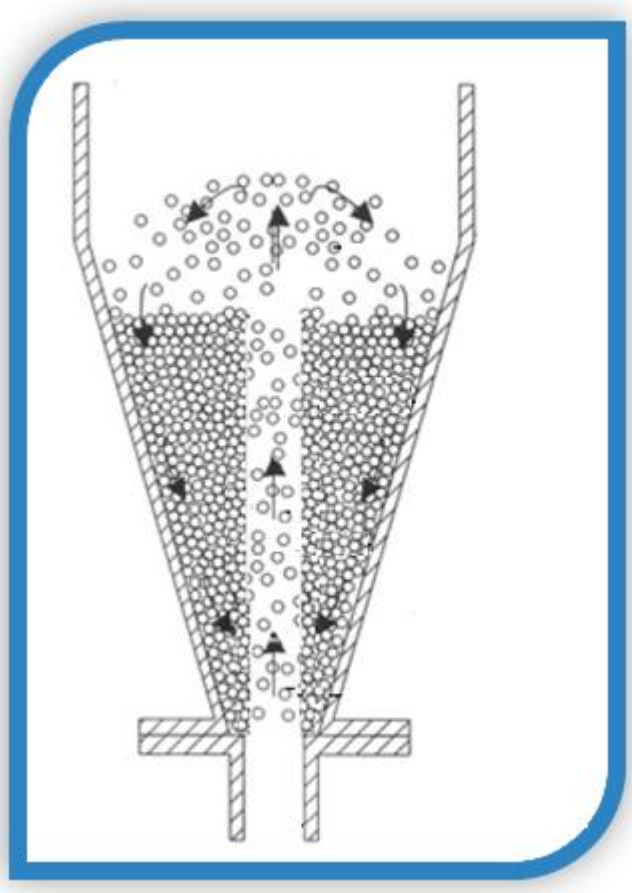
INTRODUCTION



- Spouted bed regimen is an alternative contact method to fixed and fluidized beds.
- The main difference with them lies in their cyclic movement of the particles.

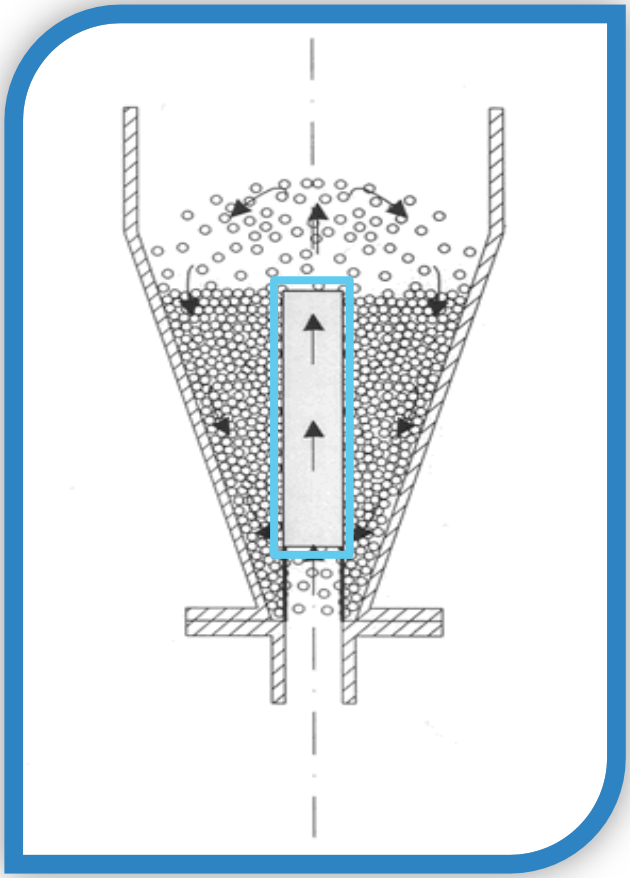
INTRODUCTION



- Spouted bed regimen is an alternative contact method to fixed and fluidized beds.
- The main difference with them lies in their cyclic movement of the particles.
  - Highly versatile in the gas flow rate.
  - Allowing operating with (1):
    - Particles of irregular texture.
    - Fine particles.
    - Particles with a wide size distribution.
    - Sticky solids.

(1) Olazar, M.; San Jose, M.J.; Alvarez, S.; Morales, A.; Bilbao, J. Design of conical spouted beds for the handling of low-density solids. Ind. Eng. Chem. Res., vol. 43, 655-661, 2004.

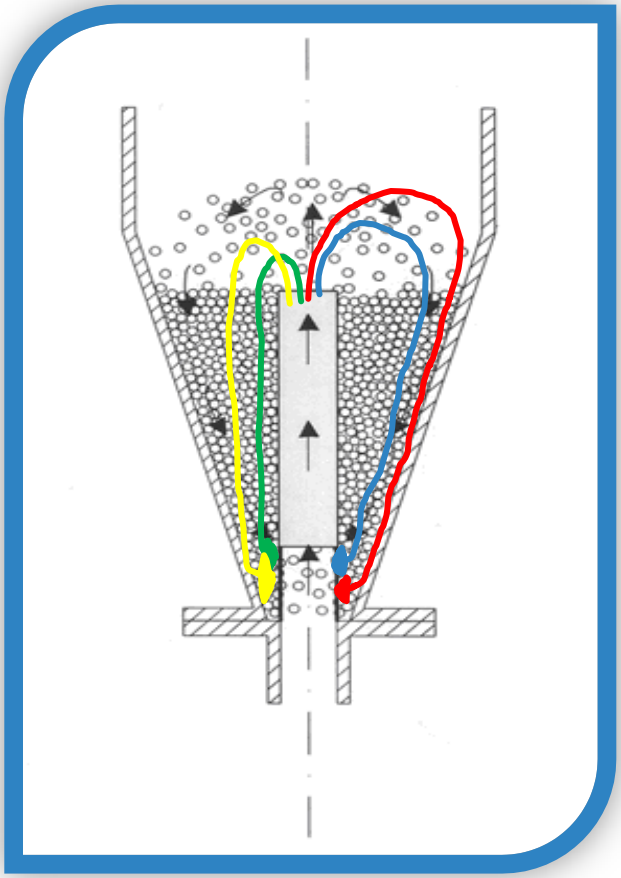
INTRODUCTION



- The use of draft tubes avoids instability.
- Advantages (2):
  - Greater flexibility in the operation.
  - Lower gas flow rate and pressure drop.
  - Solids of any size or nature may be treated.
- Disadvantages:
  - Lower degree of mixing.
  - Longer recirculation time.

(2) Altzibar, H.; Lopez, G.; Estiati, I.; Bilbao, J.; Olazar, M. Particle Cycle Times and Solid Circulation Rates in Conical Spouted Beds with Draft Tubes of Different Configuration. Ind. Eng. Chem. Res., vol. 52, 15959-15967, 2013.

INTRODUCTION



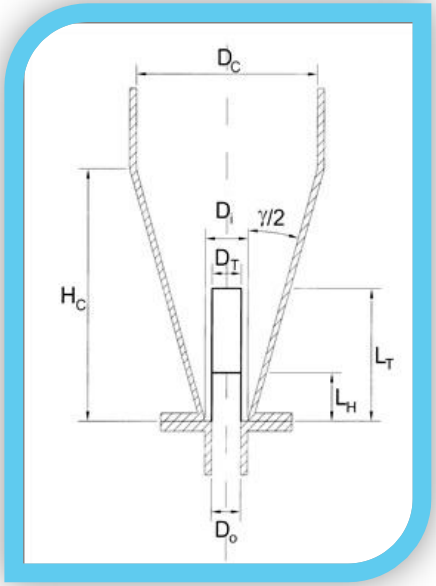
- Particle cycle time is defined as the time the particle takes to travel from the top of the annulus downwards and back again to its starting point.
- They can be deduced from solid flow patterns in the annulus (3).
- Average cycle time regulates energy and mass transfer, and influences chemical reactions (4).

(3) Epstein, N.; Grace, J.R. Spouted and Spout-Fluid Beds. Fundamentals and Applications. Cambridge University Press, 2011.

(4) Makibar, J.; Fernandez-Akarregi, A.R.; Alava, I.; Cueva, F.; Lopez, G.; Olazar, M. Investigations on heat transfer and hydrodynamics under pyrolysis conditions of a pilot-plant draft tube conical spouted bed reactor. Chem. Eng. Process., vol. 50, 790-798, 2011.

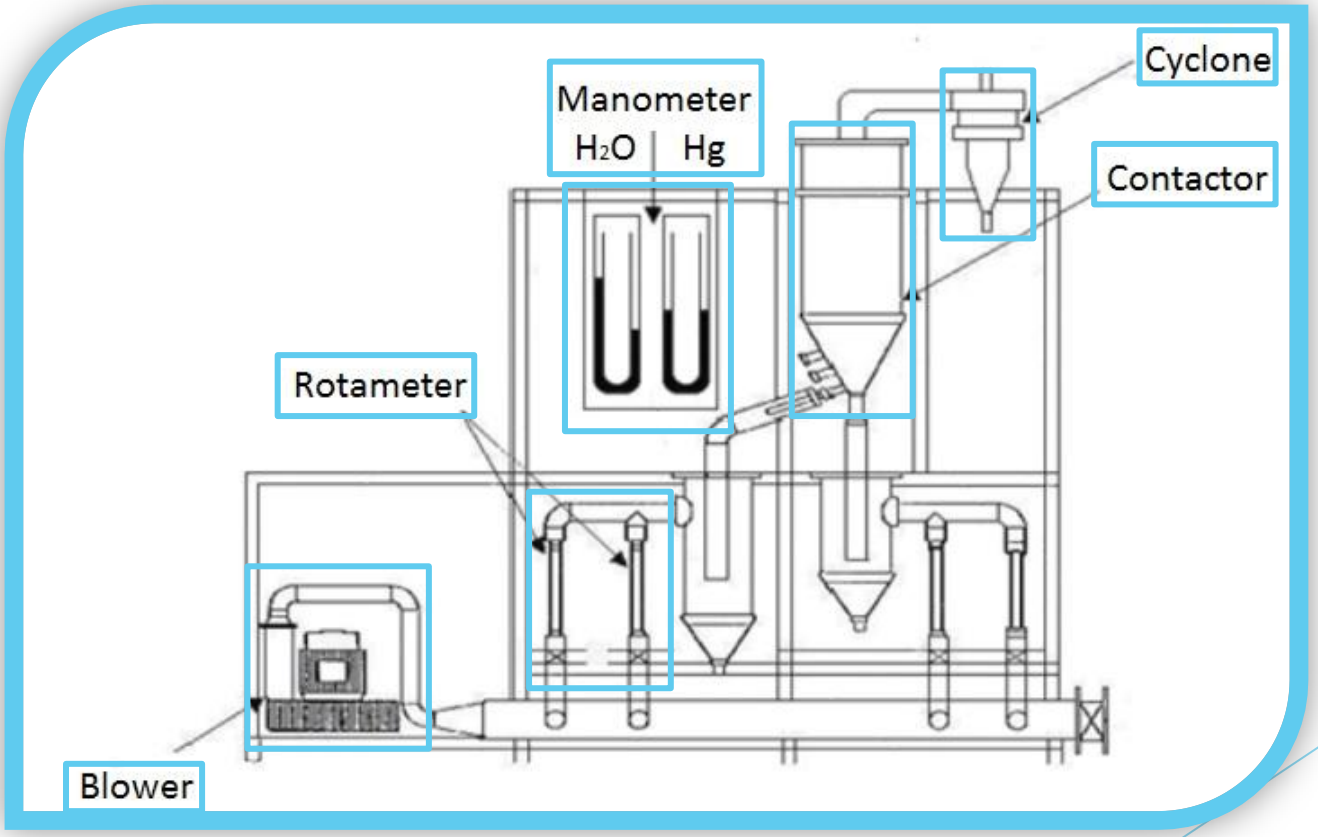
AIMS

- Setup a device and develop a methodology for measuring the circulation rate of fine particles in conical spouted beds.
  - Study the influence of different variables on the average cycle time (t_C), maximum cycle times (t_{Cmax}) and solids circulation rates (W_S) of fine particles:

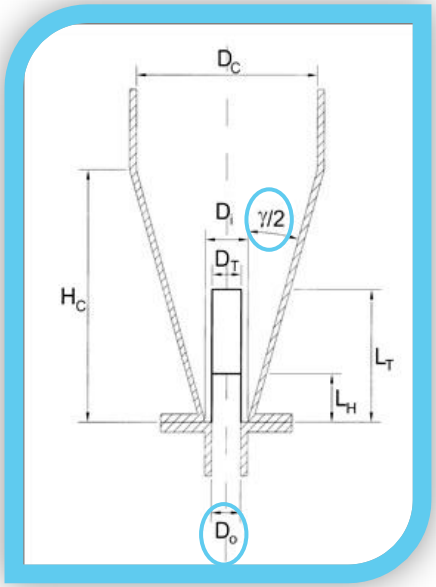


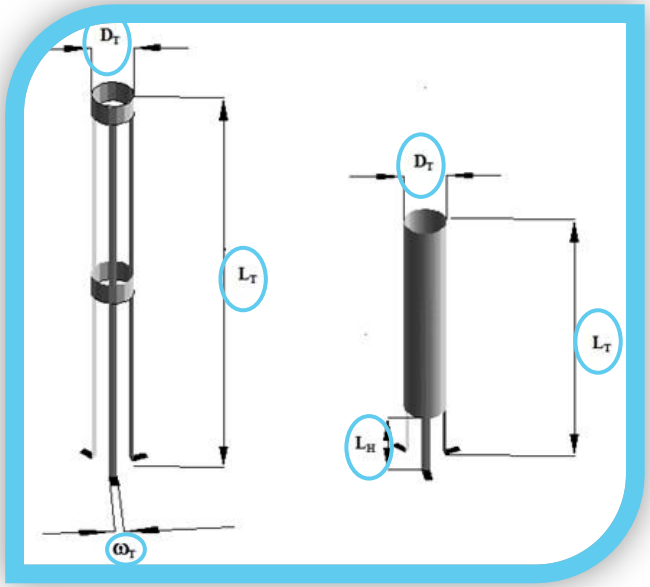
EXPERIMENTAL

- Experimental unit.



OPERATING CONDITIONS

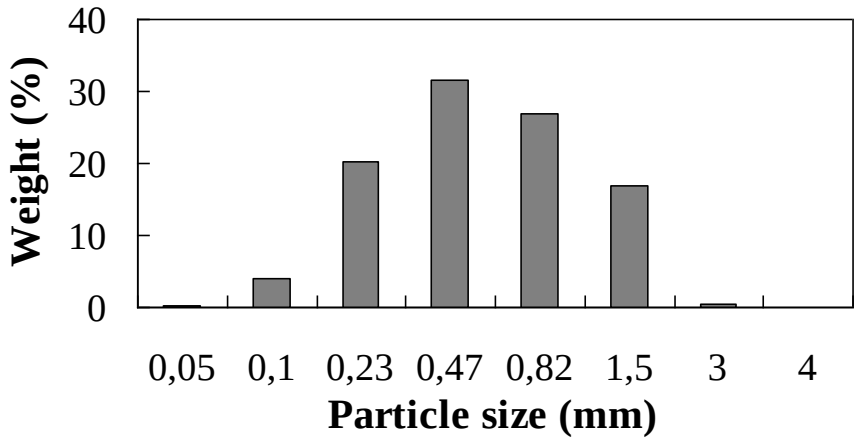




- γ: 28°, 36°, 45°
- D_0: 3, 4, 5 cm
- H_0 (bed height): 22, 27 cm
- L_T: 50 cm
- w_H: 1, 1.8, 2.5 cm
- D_T: 4, 5 cm
- L_T: 22, 27 cm
- L_H: 7, 15 cm
- D_T: 4, 5 cm

OPERATING CONDITIONS

- Material used:
  - Building sand:



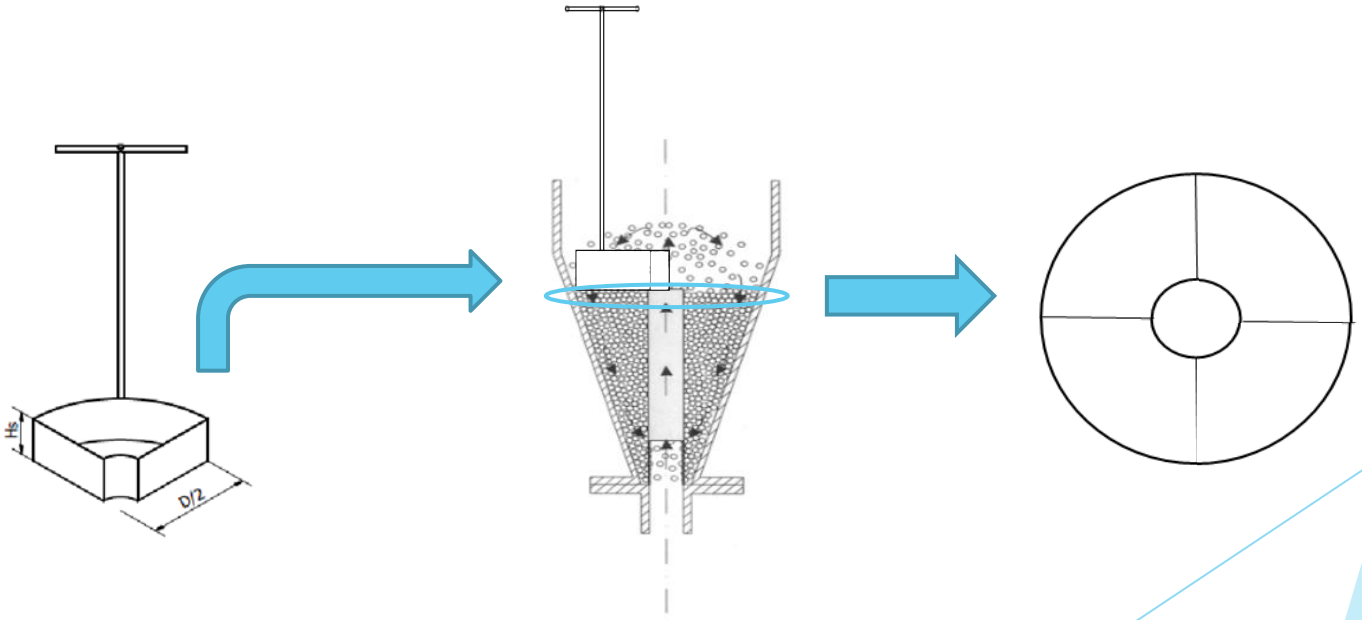
$$\overline{dp} = \left(\frac{1}{\sum \frac{X_i}{dp_i}} \right) = 0{,}6\ mm$$

Density: 2358 kg/m^3

  - Glass beads:
    - dp: 4 mm
    - Density: 2400 kg/m^3

MEASUREMENT PROCEDURE

- A device has been developed for collecting solids in the fountain and determining the solid circulation mass flow rate.
- It consists in a blunt sector (1/4 of the full circle) made of polypropylene and is placed on the bed annulus.



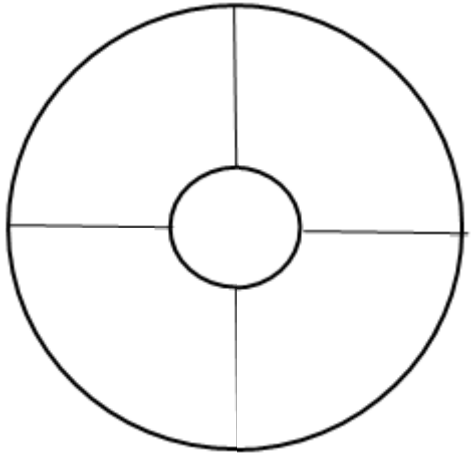
MEASUREMENT PROCEDURE

- The diameter of the sector (tip included) should be the same as the upper diameter of the static bed height, D_b, which is a function of the static bed height and cone angle:

$$D_b = 2 \cdot tg\left(\frac{\gamma}{2}\right) H_0 + D_i$$

$$D = D_b - D_T$$

- Four samples have been taken on the bed surface, one in each quarter on the surface.

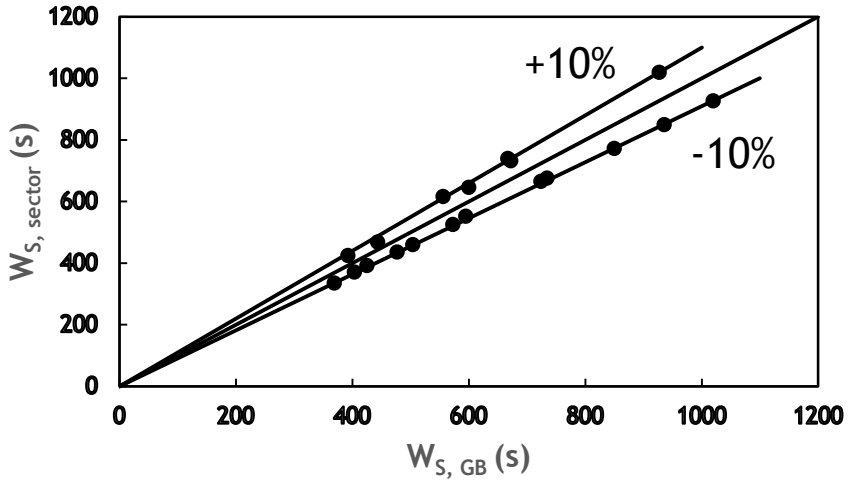


$$W_s = \frac{M}{t}$$

$$t_c = \frac{M_s}{W_s}$$

RESULTS

- Experimental runs with 4 mm glass beads proved that solid circulation rates measured with the two procedures differed less than 10 % in most cases.

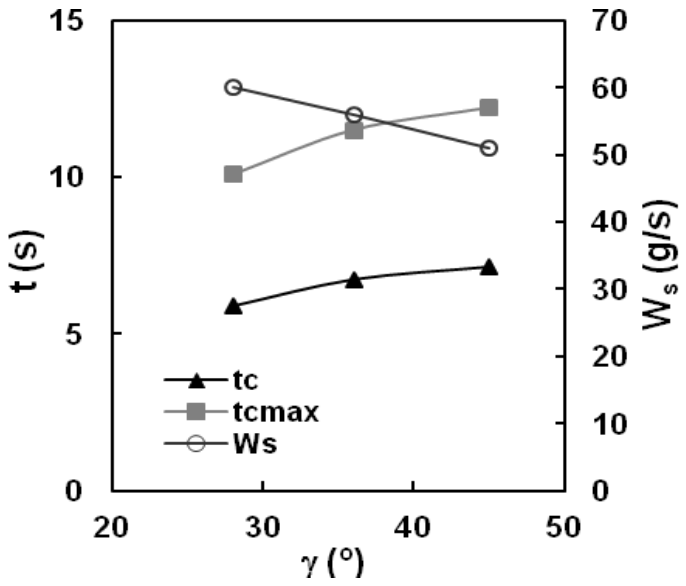


- The device was used to measure average cycle times with the sand beds.

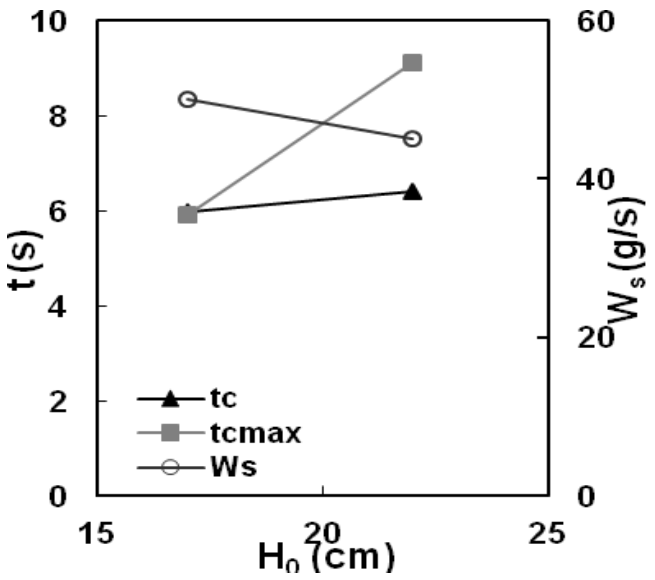
RESULTS

- Influence of:

Contactor angle



Height of static bed



$\gamma\uparrow\ t_c\uparrow\ t_{cmax}\uparrow\ W_s\downarrow$ (2)

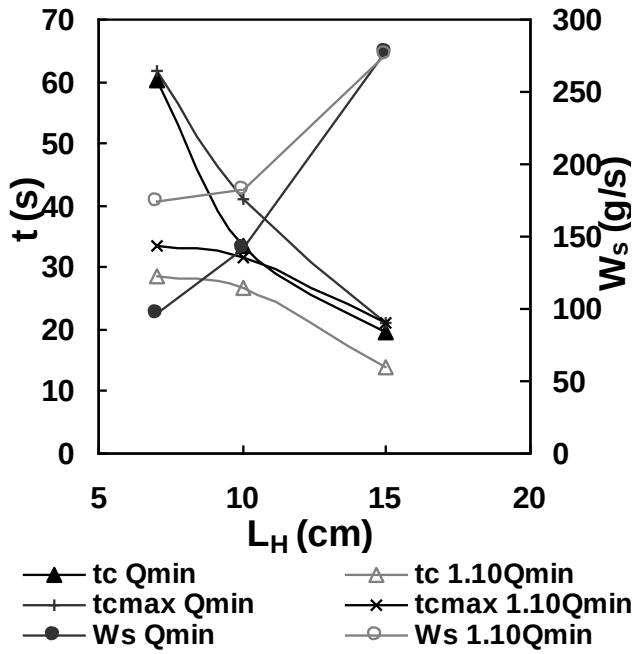
$H_0\uparrow\ t_c\uparrow\ t_{cmax}\uparrow\ W_s\downarrow$

(2) Altzibar, H.; Lopez, G.; Estiati, I.; Bilbao, J.; Olazar, M. Particle Cycle Times and Solid Circulation Rates in Conical Spouted Beds with Draft Tubes of Different Configuration. Ind. Eng. Chem. Res., vol. 52, 15959-15967, 2013.

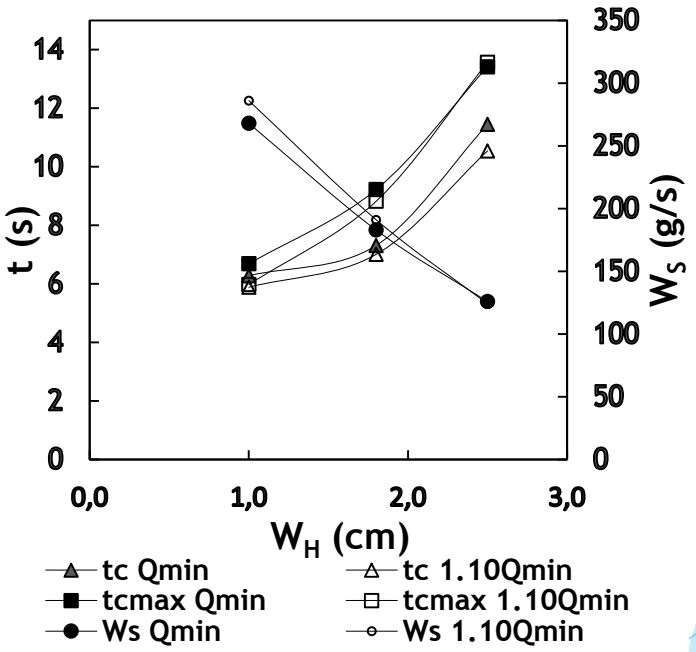
RESULTS

- Influence of:

Height of entertainment zone



Width of faces



$L_H \uparrow t_c \downarrow t_{cmax} \downarrow W_s \uparrow$

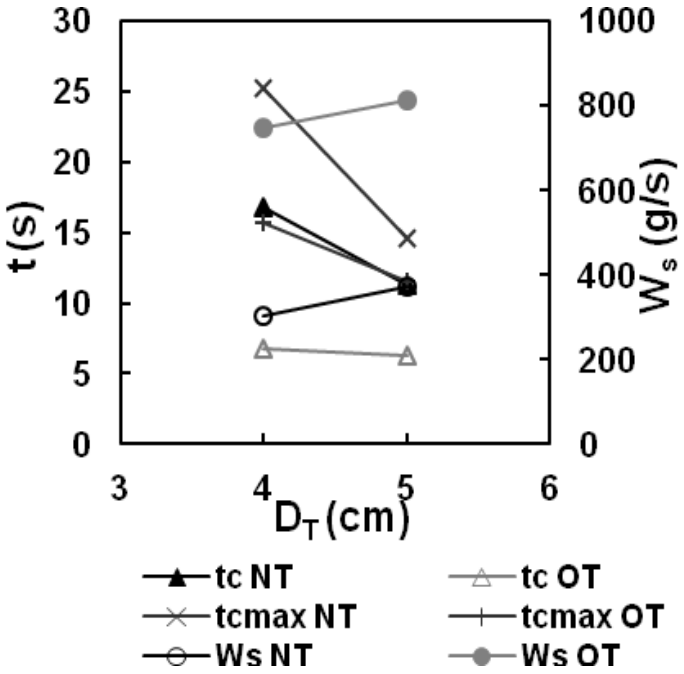
$W_H \uparrow t_c \uparrow t_{cmax} \uparrow W_s \downarrow$

$Q \uparrow t_c \downarrow t_{cmax} \downarrow W_s \uparrow$

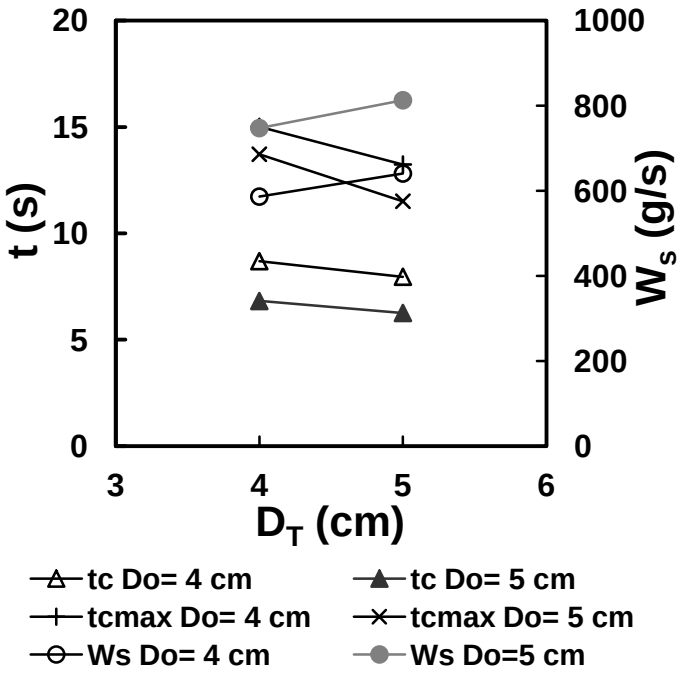
RESULTS

- Influence of:

Type of draft tube



Gas inlet diameter



$t_{c,\,NT} > t_{c,\,OT}$, $t_{cmax,\,NT} > t_{cmax,\,OT}$, $W_{s,\,NT} < W_{s,\,OT}$ $\quad D_0 \uparrow t_c \downarrow t_{cmax} \downarrow W_s \uparrow$

$D_T \uparrow t_c \downarrow t_{cmax} \downarrow W_s \uparrow$

CONCLUSIONS

- The device and methodology developed allow reliably measuring the circulation rate of fine particles in conical spouted beds.
- The trends observed show that an increase in contactor angle, height of the static bed and width of the faces of the draft tube lead to an increase in the average and maximum cycle times.
- Nevertheless, as the draft tube diameter, gas inlet diameter and height of the entrainment zone are greater the average and maximum cycle times are shorter.
- Solids circulation rates follow similar trends when using either open-sided or nonporous tubes, but the regime is much more vigorous with the open-sided tubes.

ACKNOWLEDGMENT

- This work has been carried out with the financial support of the Ministry of Economy and Competitiveness of the Spanish Government (Project CTQ2013-45105-R).
- I. Estiati is grateful for the Ph.D. grant from the Department of Education, University and Research of the Basque Country (BFI-2012-234).
- M. Tellabide is grateful for the Ph.D. grant from the Ministry of Education, Culture and Sport (FPU14/05814).

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