Pre-pilot Plant Studies on Fluidized Combustion of Liquid Fuels"

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FLUIDIZED COMBUSTION OF CONVENTIONAL PETROLUM-DERIVED FUEL

- ***Fluidized Bed Combustion of conventional liquid fuels (i.e. commercial products of oil refining) is possible (Barker and Beacham, 1980), but still not appealing from an economic point of view.***
- ***Its application, however, as a "ultra-clean" or "mild combustion" technology may prompt newer interest.***

OBJECTIVES OF THIS WORK

- *to check feasibility and significance of bubbling bed combustion of gasoil on a pre-pilot scale plant (FBR370).*
- *to investigate extension of stationary combustion to temperature < 850°C.*
- *to understand and to describe the fluidized bed combustion mechanism of gasoil at medium-to low temperatures.*

FBR370

Bed operating conditions

$D_t = 370$ mm

$d_p = 725$ µm

$U\text{-}U_{mf} = 0.5$ m/s

Nominal air excess factor = 1.3

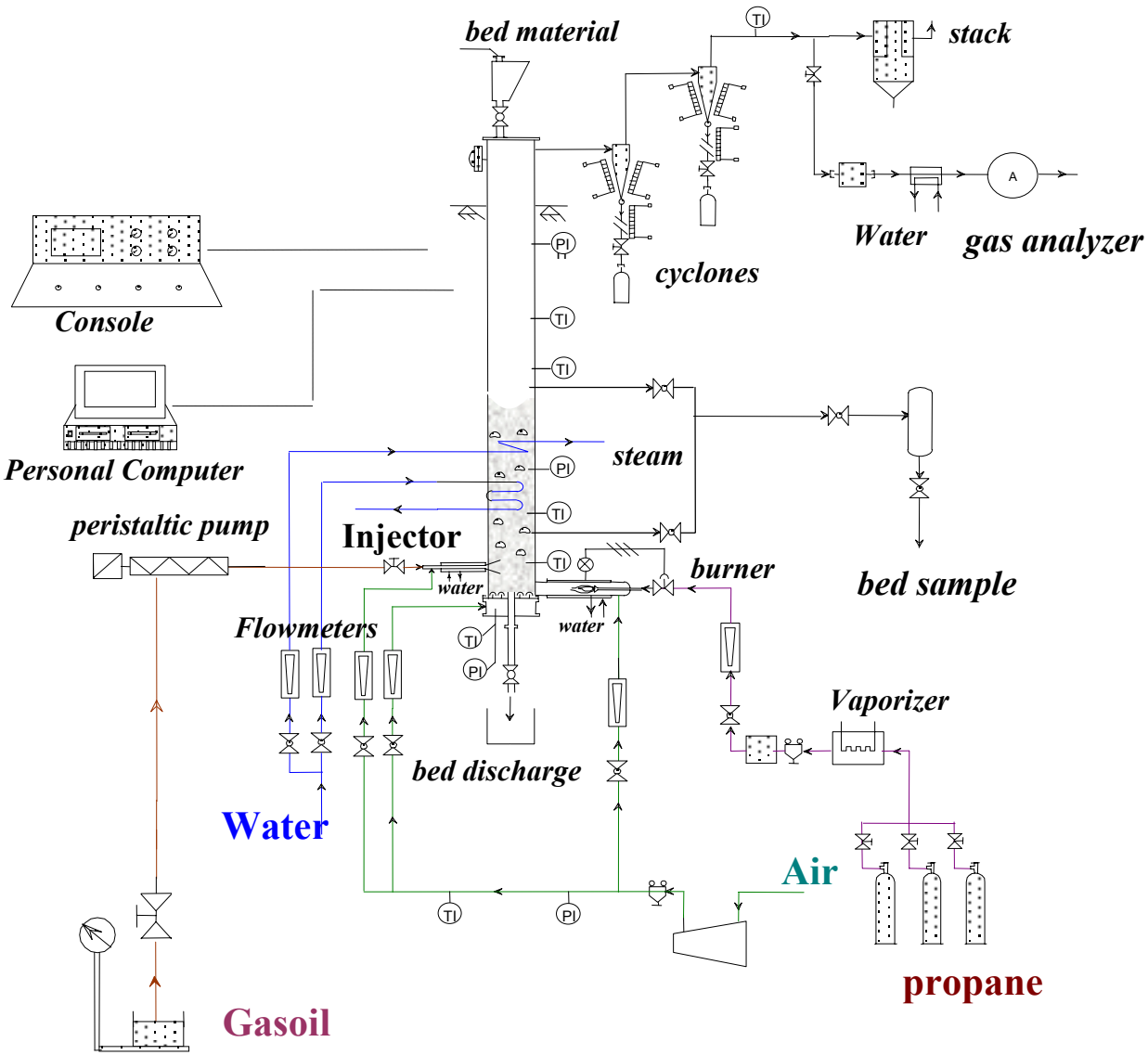
$T_{bed} = 650 \div 850$ °C

$H_{eb} = 600 \div 900$ mm

Injection condition

$u_0 = 20 \div 240$ m/s

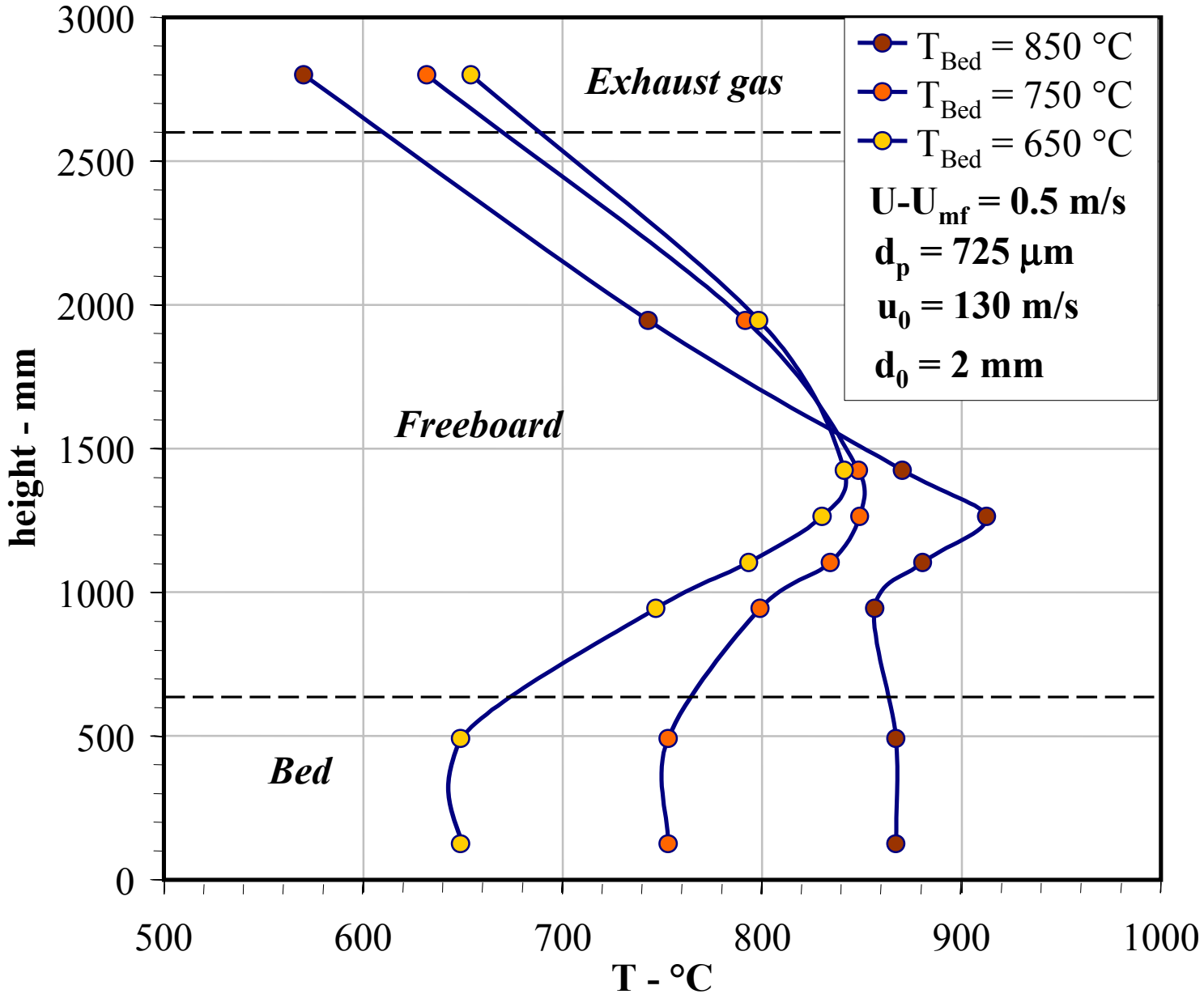
$d_0 = 2 \div 4$ mm



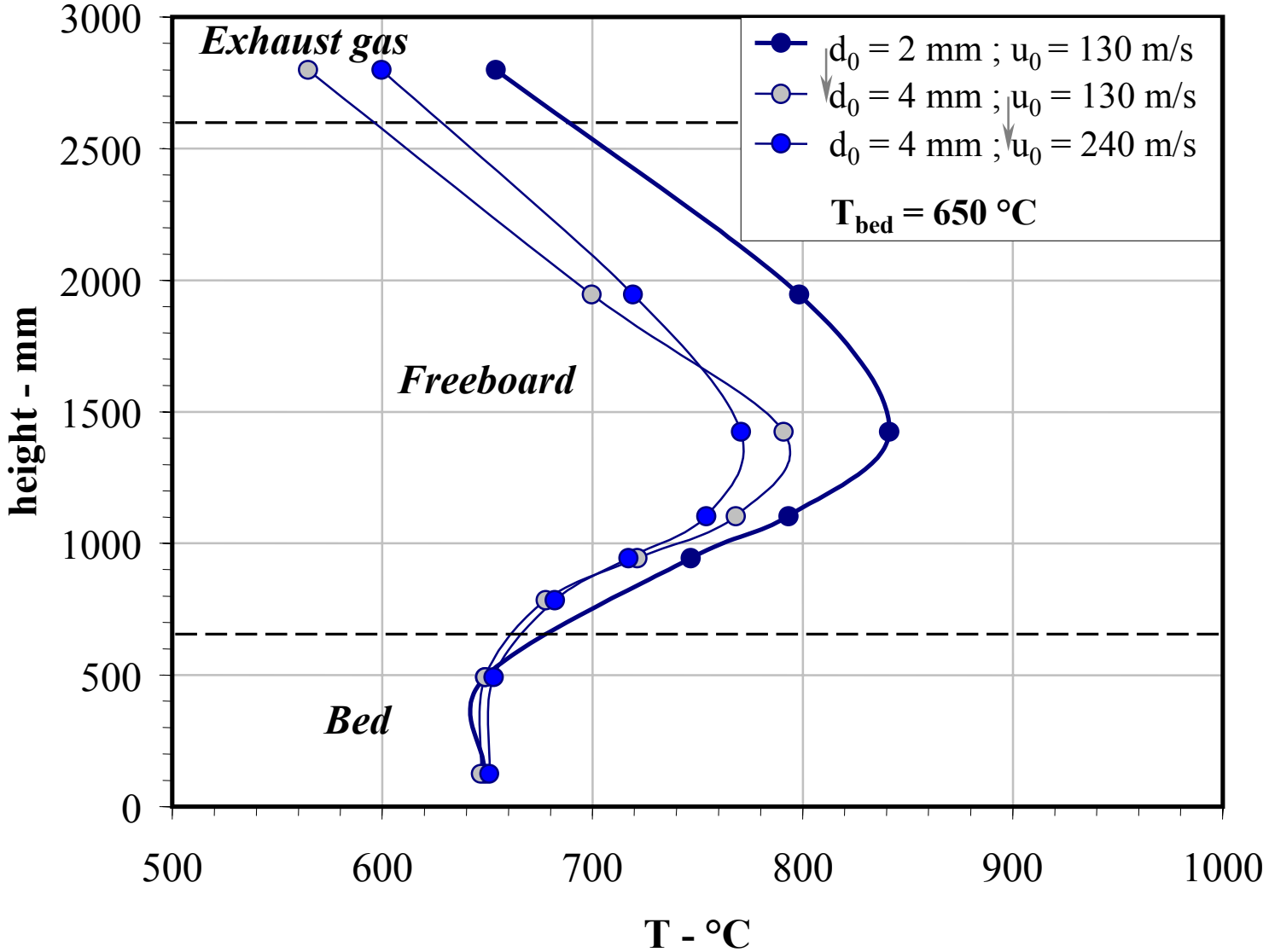
Experimental measurements

- *Stationary combustion.*
- *Temperature profile along vertical axis.*
- *Concentration profiles along radial distance in the "splash zone".*
- *Concentration profiles along radial distance at the injection point.*

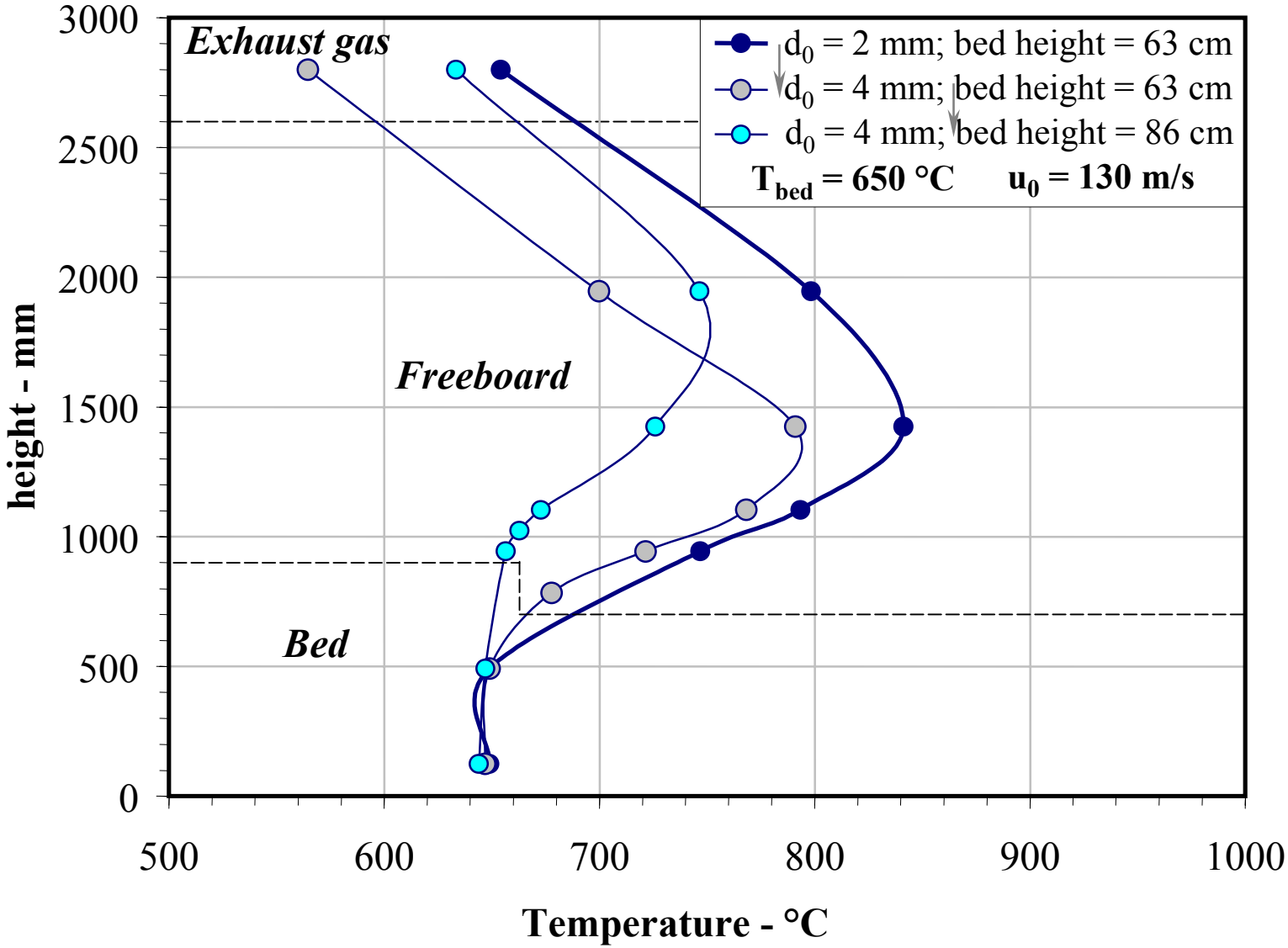
Temperature vs height



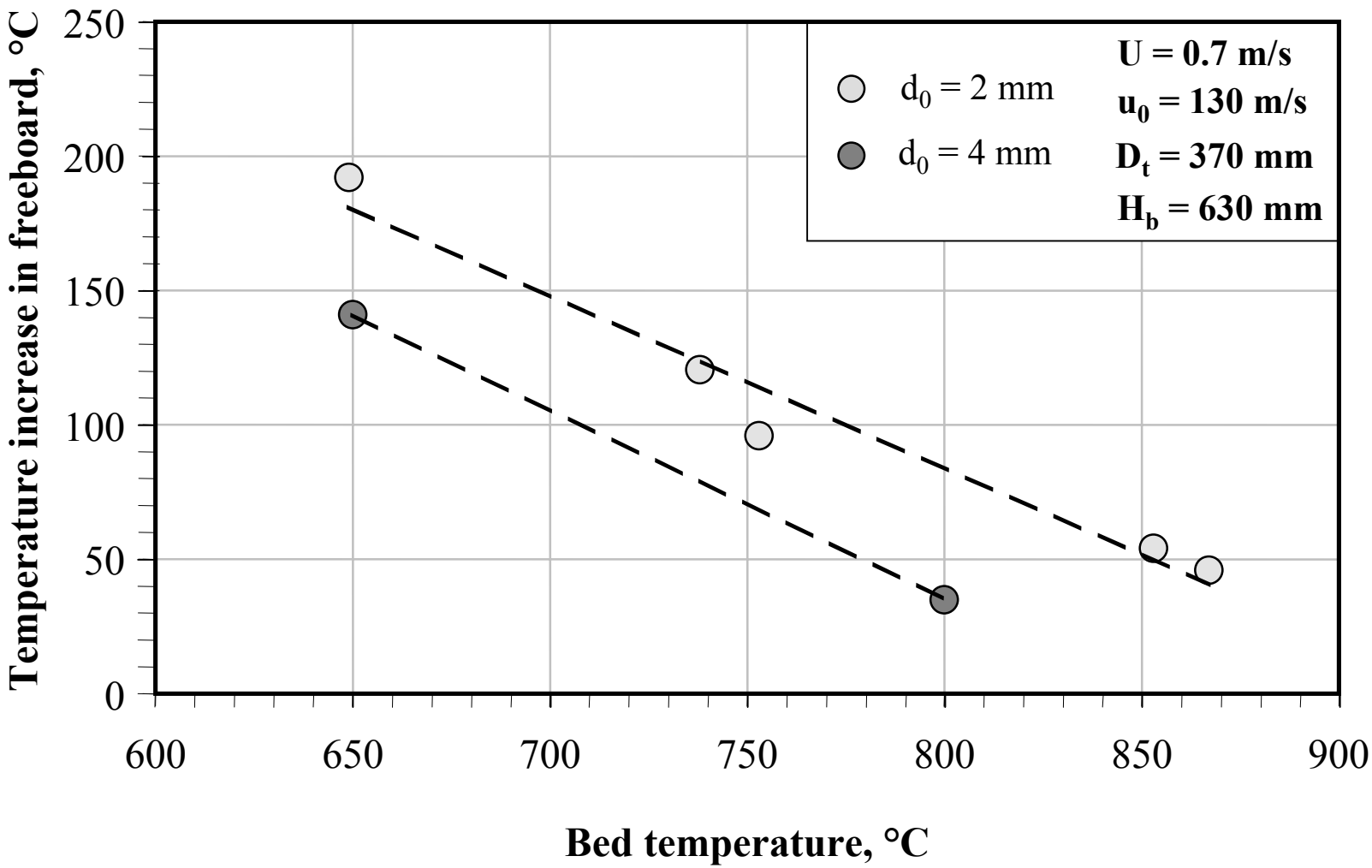
Temperature vs height



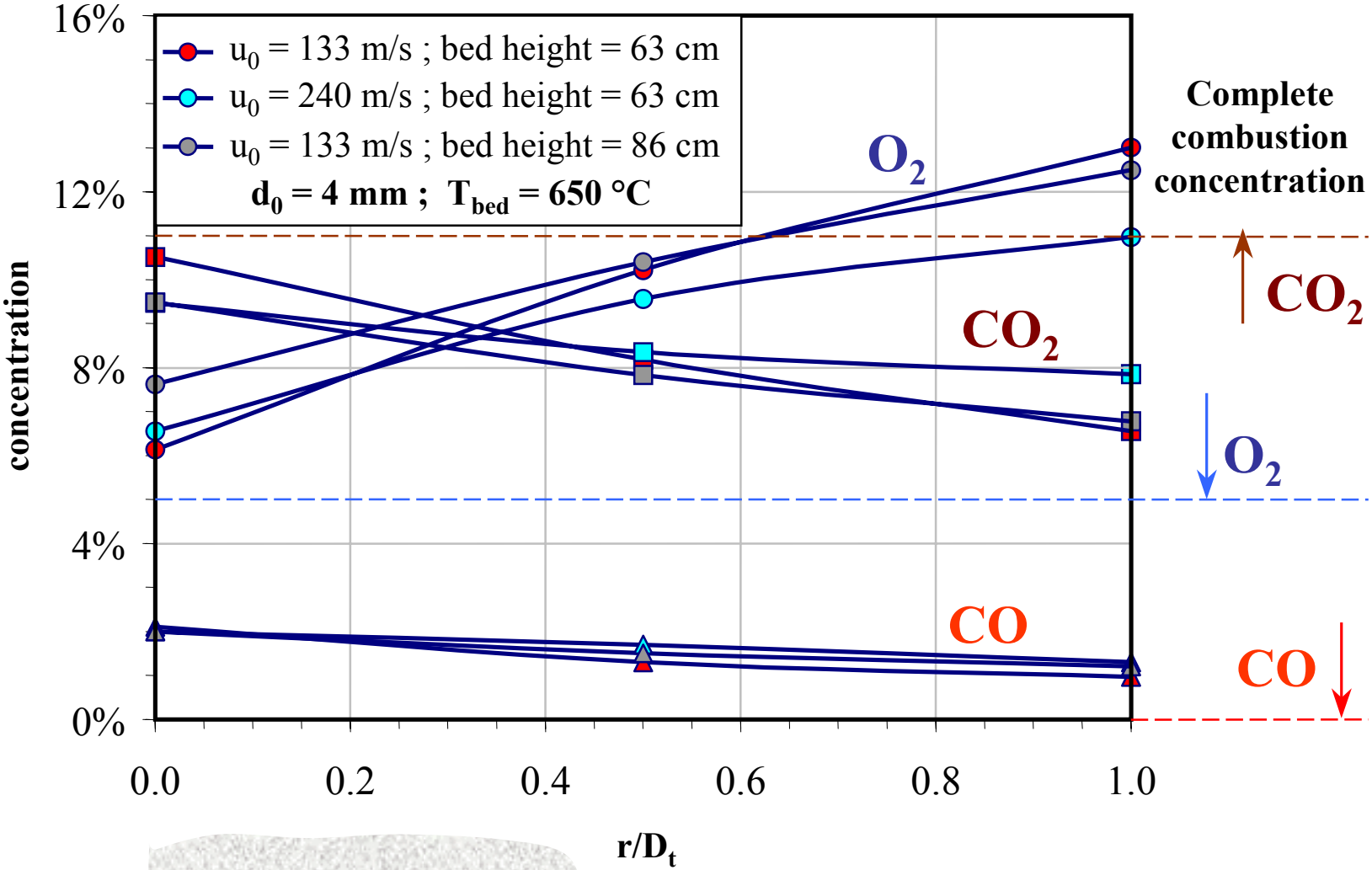
Temperature vs height

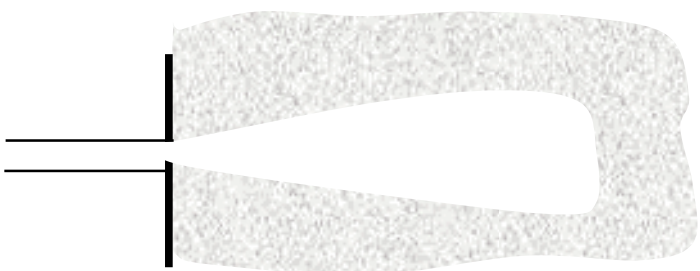


Temperature increase in the freeboard as a function of the bed temperature and nozzle size

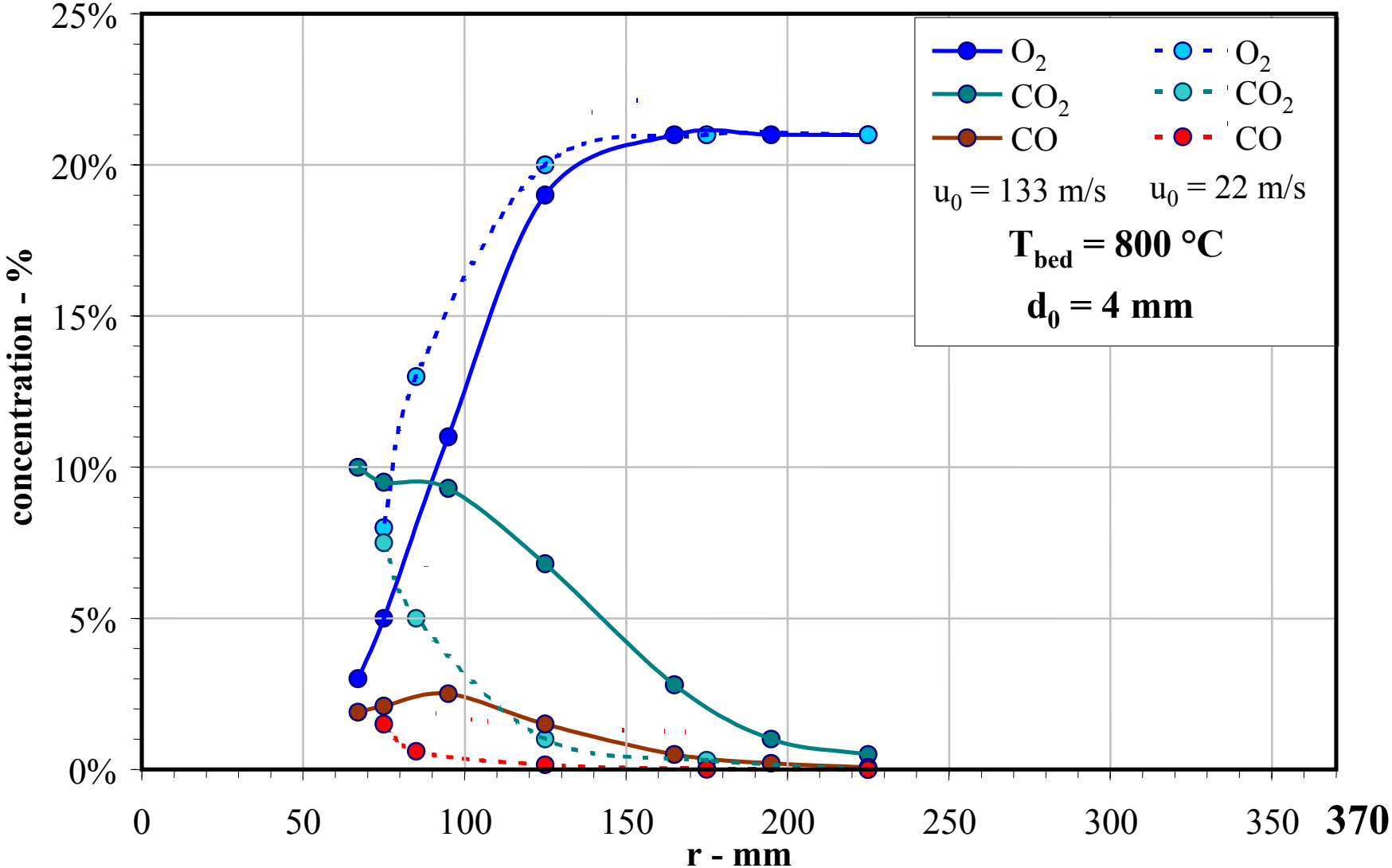


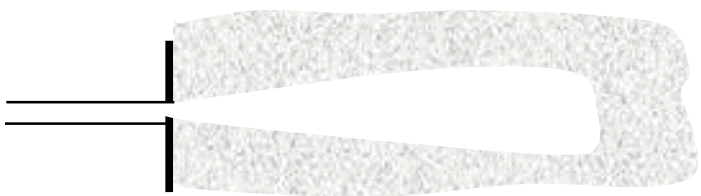
O_2 , CO_2 and CO concentration in the "splash zone" vs radial distance





O_2 , CO_2 and CO vs radial distance at the injection height





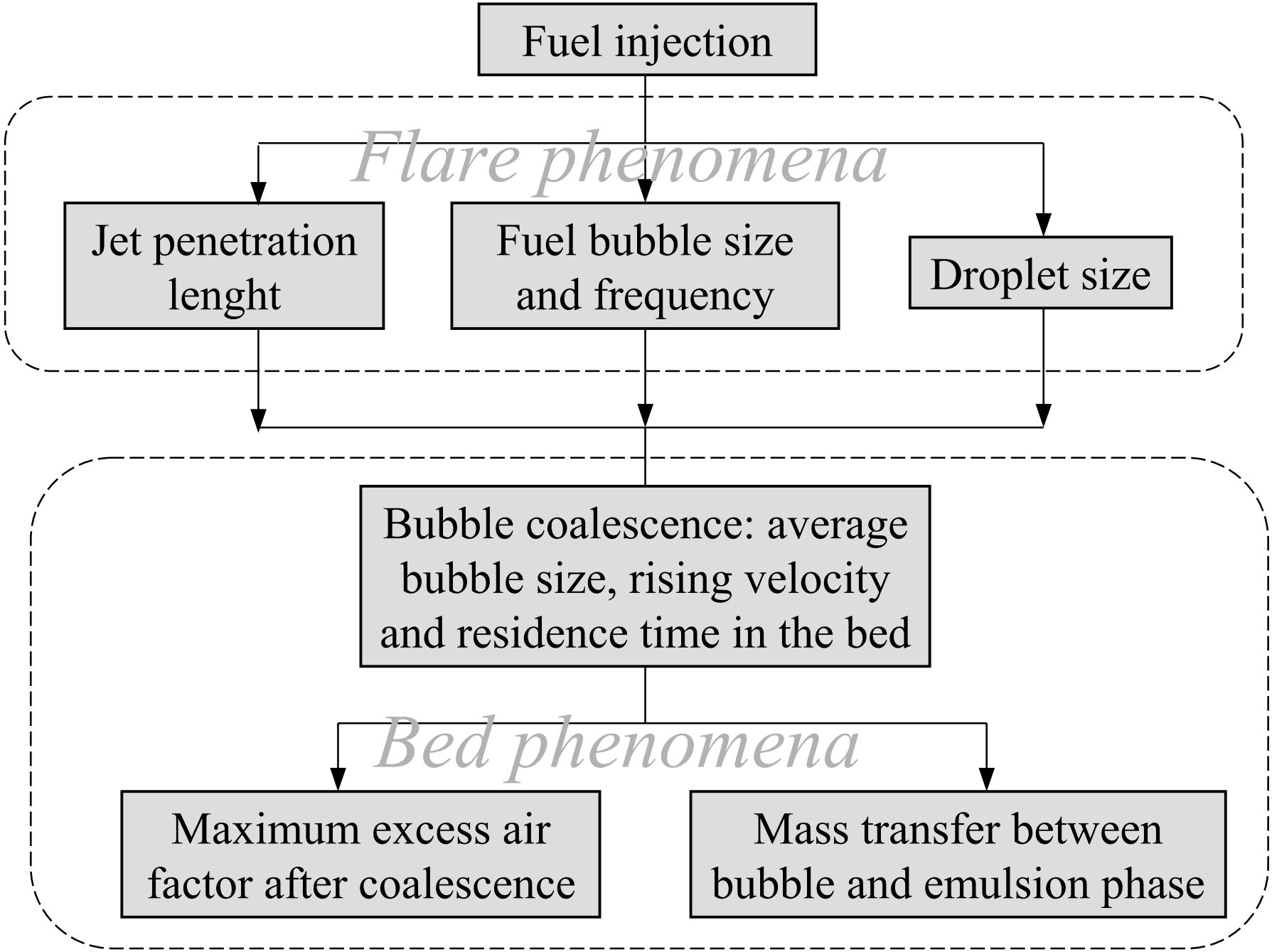
Experimental observation

Freeboard temperature increase respect to bed temperature for $T_{bed} < 850$ °C.

Non- uniform concentration in the freeboard and in the bed (dead bed combustion zone).

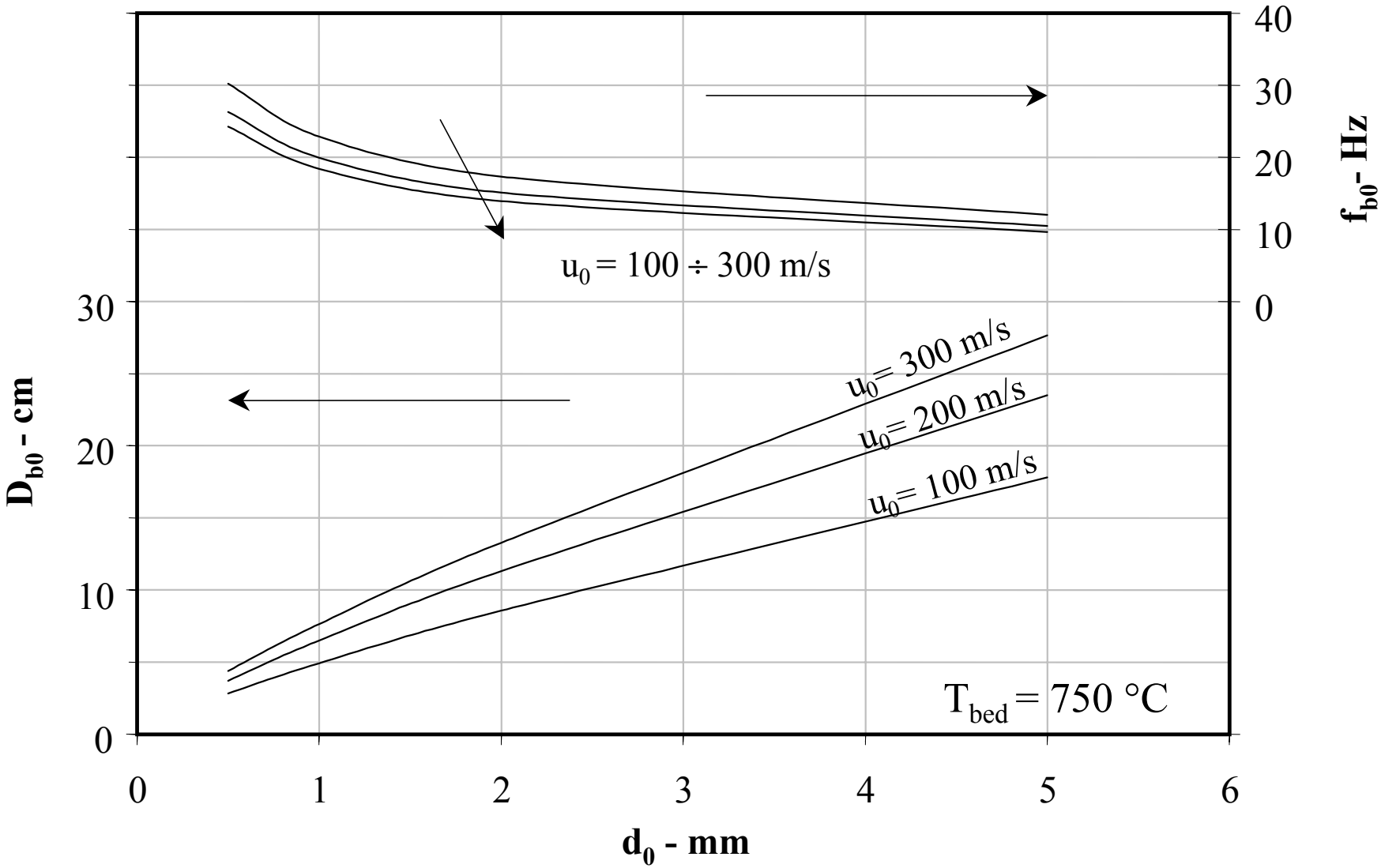
Post-combustion in the freeboard.

Insufficient fuel-air mixing in the bed.

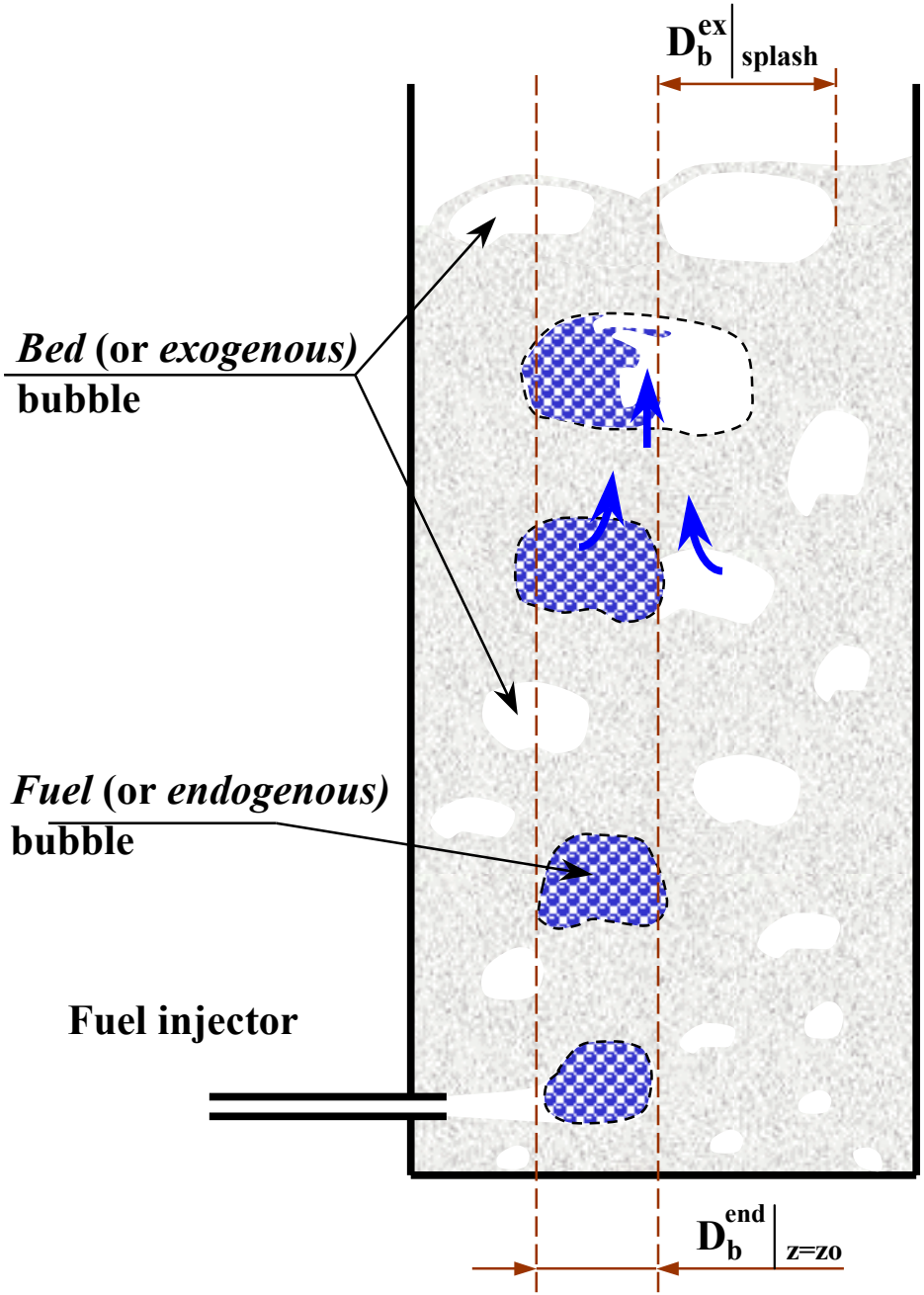

Fuel injection
Flare phenomena
Jet penetration lenght
Fuel bubble size and frequency
Droplet size
Bubble coalescence: average bubble size, rising velocity and residence time in the bed
Bed phenomena
Maximum excess air factor after coalescence
Mass transfer between bubble and emulsion phase

Frequency and initial diameter of the fuel bubble as a function of the nozzle diameter

(according to Davidson and Schuler, 1960)



Coalescence mechanism



$$D_b^{ex}\big|_{splash} = f(H_{eb})$$

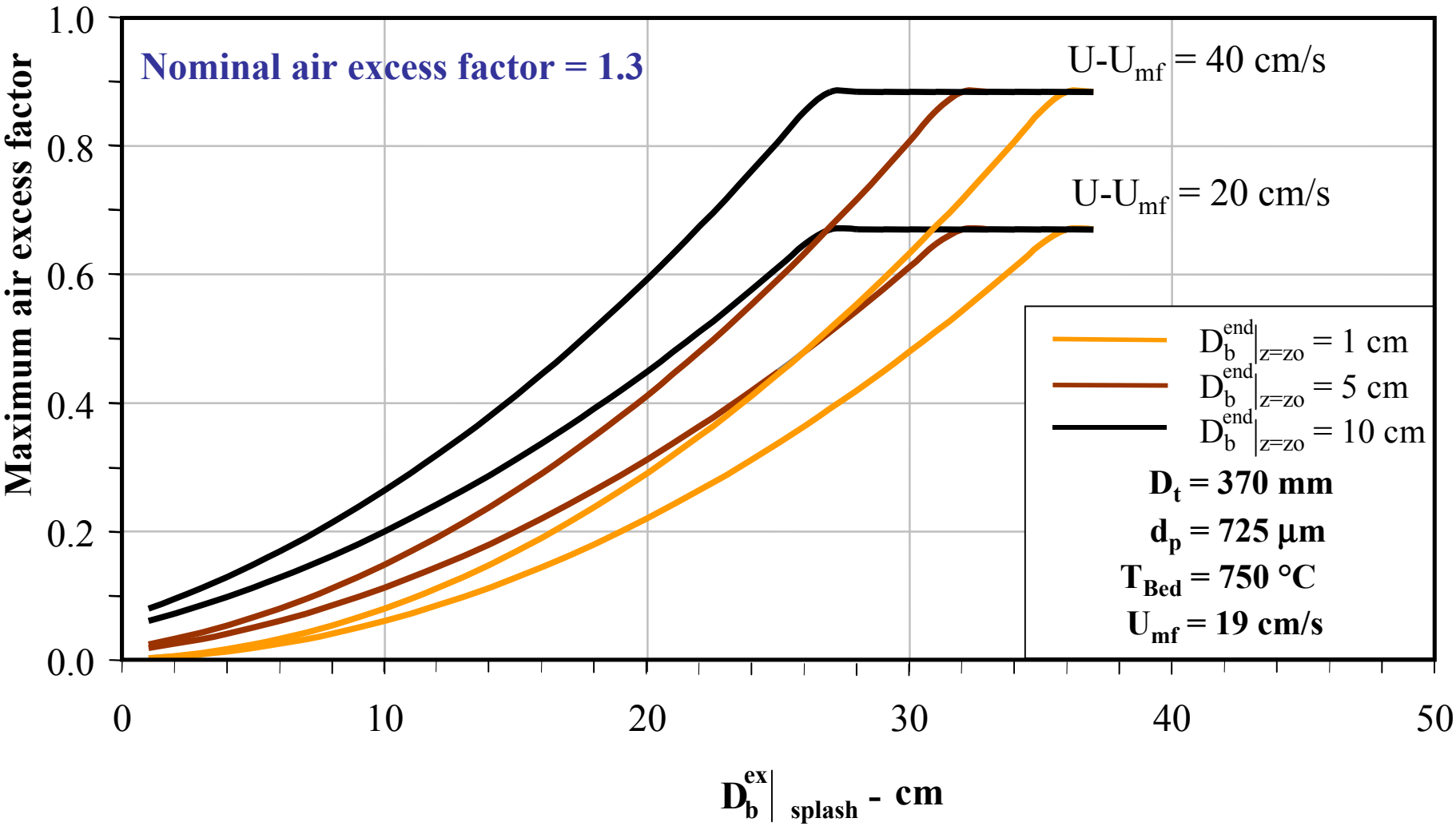
$$D_b^{end}\big|_{z=zo} = f(u_0, d_0)$$

$$\alpha \le \alpha^{nominal} \cdot \frac{(U - U_{mf}) \cdot \frac{\pi}{4}\left(D_b^{end}\big|_{z=zo} + D_b^{ex}\big|_{splash}\right)^2}{U \cdot \frac{\pi}{4} D_t^{\,2}}$$

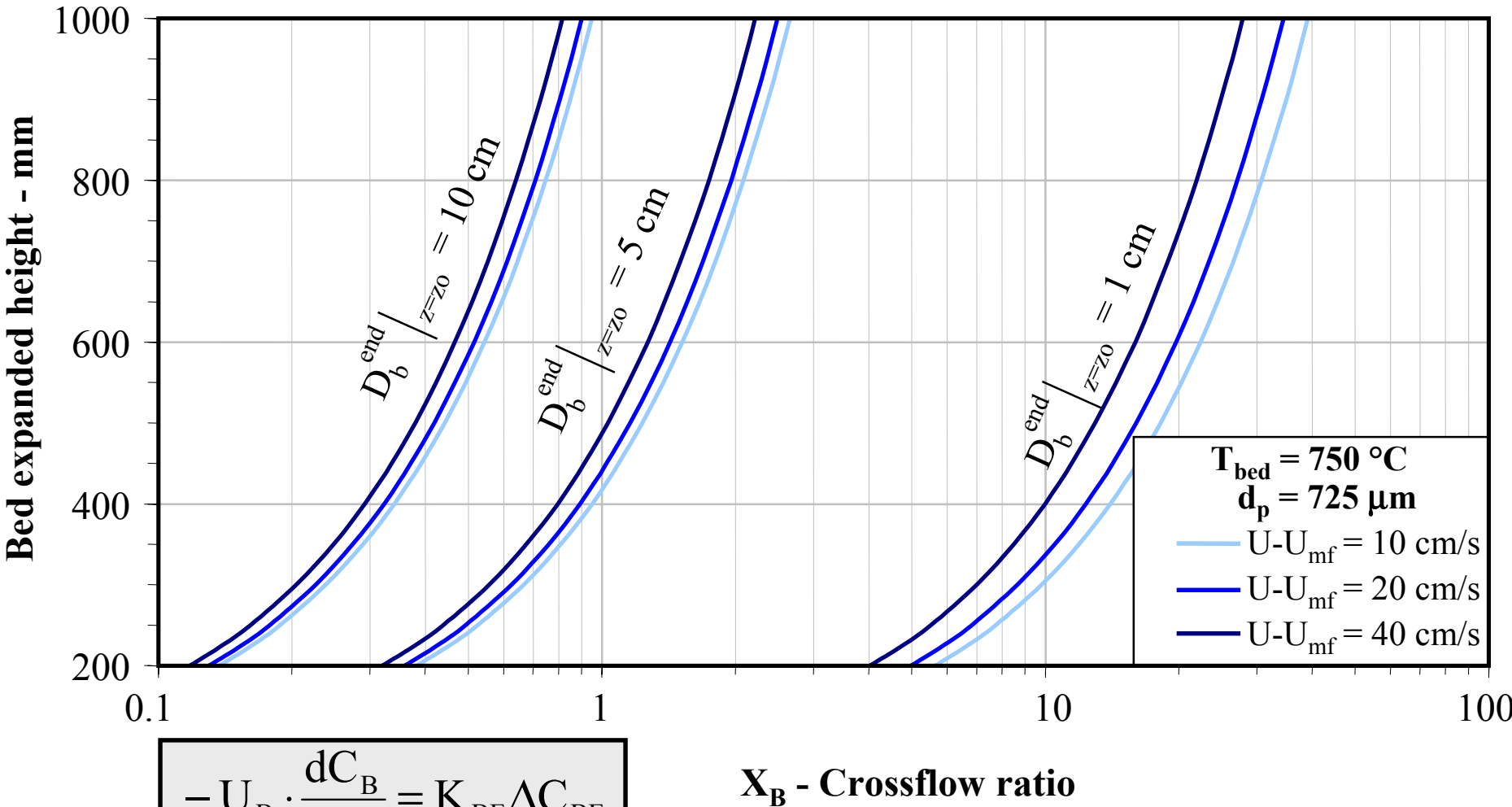
α = air excess factor

$\alpha \uparrow$ $\quad D_b^{end}\big|_{z=zo} \uparrow$ $\quad H_{eb} \uparrow$

Maximum air excess factor in endogenous bubbles at the top of the bed only for coalescence



Cross-flow ratio of fuel bubble as a function of expanded bed height, initial bubble diameter and excess of minimum fluidization



$$-U_B \cdot \frac{dC_B}{dz} = K_{BE} \Delta C_{BE}$$

$$X_B = \tau_B \cdot K_{BE}$$

NEAR-FUTURE ACTIVITIES

- ***Test campaign with FBR80 in presence of gasoil atomization.***

- ***Adaptation of the ultraviolet-visible absorption spectrscopy technique developed by Borghese et al. (2000) to measurements of carbon nano-particles and/or other organic species in the exhausts of gasoil-fired fluidized bed.***

- ***Start-up of development work of a predictive mathematical model of bubbling bed combustion of gasoil.***

- ***A more accurate analysis of effective bed combustion efficiency and of freeboard post-combustion phenomena.***