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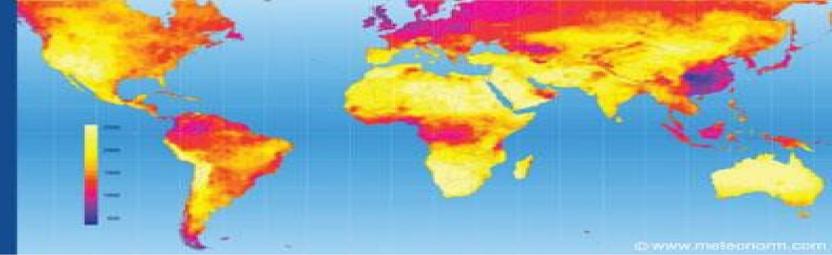
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Particle Flow Stability in Tubular Fluidized Bed Solar Receivers

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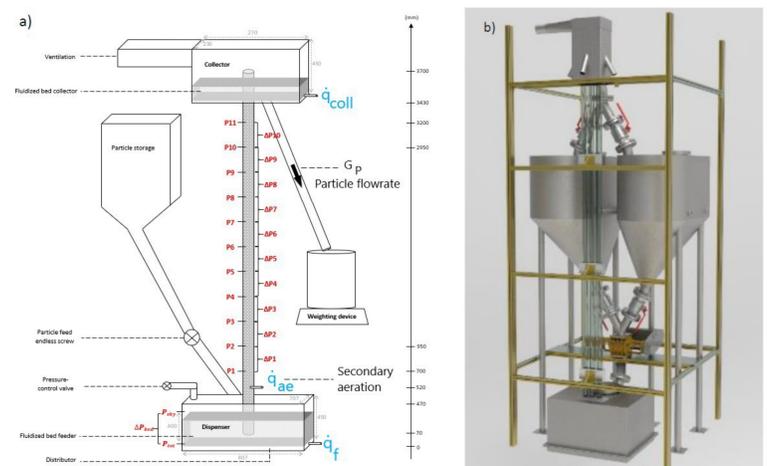
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Introduction

- Molten salt is the commonly used heat transfer fluid in solar towers, but **solar salt has limited operating temperatures** which limit the efficiency of the power block.
- To overcome this issue and reduce costs**, new particle receivers are under development worldwide as the **fluidized particle-in-tube** of the french National Center for Scientific Research. A pilot-scale test unit is currently under construction at Thémis, France, in the framework of the Next-CSP H2020 project [1]. A smaller cold mock-up was constructed to study the hydrodynamics of the particle suspension flow at PROMES laboratory.
- Depending on the values of two main parameters (namely the particle flowrate and the secondary air flowrate) the particle flow is either **stable** or **unstable**. When an instability occurs the total pressure in the system decreases and there are significant variations of the particle flowrate.
- Objective:** Define a **stability diagram** of the particle flow in order to determine the **secure operating conditions** for the full-scale unit.

Methodology

- Material:** olivine with a Sauter diameter of 30.0 μm (group A of the Geldart classification) [2]
- Fluidization** in a dispenser thanks to a homogeneously distributed air flowrate. By applying **pressure**, the fluidized bed passes into a 3m-long transparent glass tube of 4.5 cm internal diameter and is collected in a fluidized bed collector, creating a **particle flowrate** G_p .
- A **secondary air flowrate** q_{ae} is applied at an injection nozzle of **diameter** d_{ae} at the bottom of the tube.
- Analysis method:** The stability of the particle flow is studied as a function of the secondary air flowrate q_{ae} (Nm^3/s) and of the solid mass flux G_p ($\text{kg}/(\text{m}^2 \cdot \text{s})$).



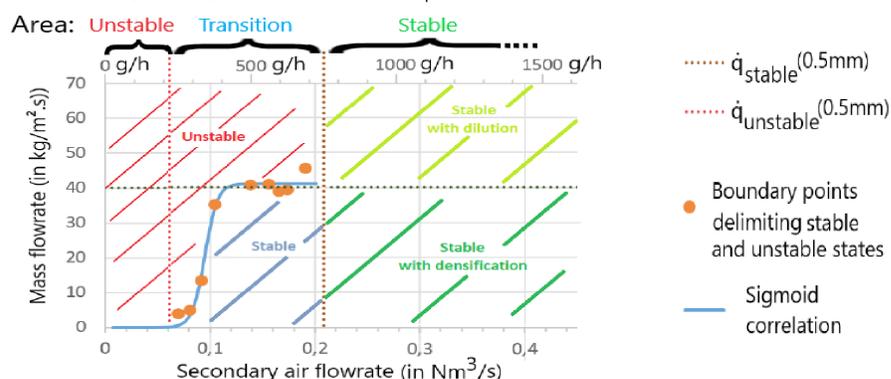
Schematic (a) and 3D (b) representation of the cold mock-up

Results

Stability diagram for q_{ae} in $[0 - 0,39] \text{ Nm}^3/\text{s}$ and G_p in $[0 - 200] \text{ kg}/(\text{m}^2 \cdot \text{s})$:

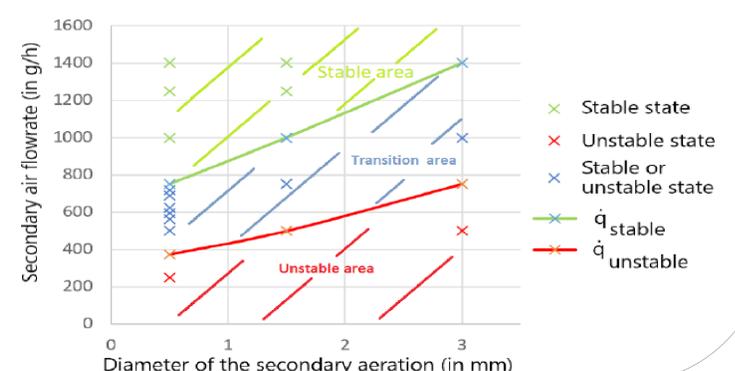
Two specific values of q_{ae} delimit two main domains.

- Unstable area:** For values of q_{ae} under a threshold air $q_{unstable}$, the mass flow is unconditionally unstable.
- Stable area:** For values of q_{ae} above a threshold q_{stable} , the particle flow is unconditionally stable.
- Transition area:** Between $q_{unstable}$ and q_{stable} , the mass flow is either stable or unstable depending on the value of G_p .



- The boundaries of these domains depend on the **nozzle's diameter** defined as an increase of $q_{unstable}$ and q_{stable} with d_{ae} .

- The evolution of $q_{unstable}$ and q_{stable} is **linear** for nozzle's diameters between 0,5mm and 3mm.



Conclusion

- A secondary aeration at the bottom of the tube is a **necessary condition** to get a stable particle flow.
- The aeration flowrate must overcome a **given threshold** to reach unconditional particle flow stability.
- The thinner the nozzle's diameter the smaller the air flowrate necessary to get unconditional stability.

References

- [1] <http://next-csp.eu/>
- [2] Kang Q., Flamant G., Dewil R., Baeyens J., Zhang H.L., Deng Y.M., 2019. Particles in a circulation loop for solar energy capture and storage. Particuology 43, p. 149-156. DOI: 10.1016/j.partic.2018.01.009