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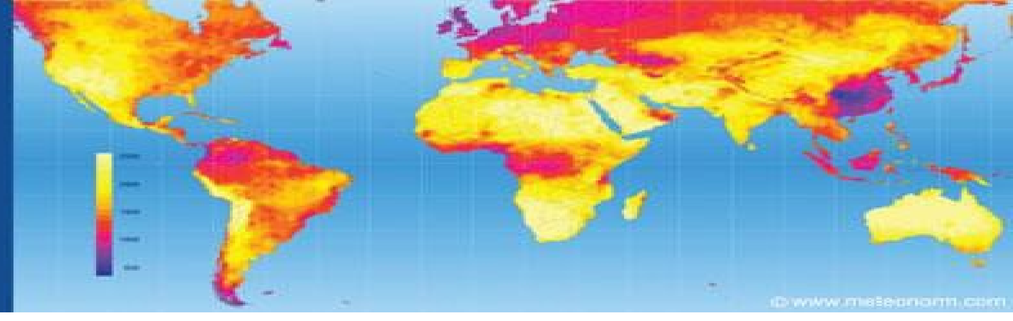

Particle Flow Stability in Tubular Fluidized Bed Solar Receivers

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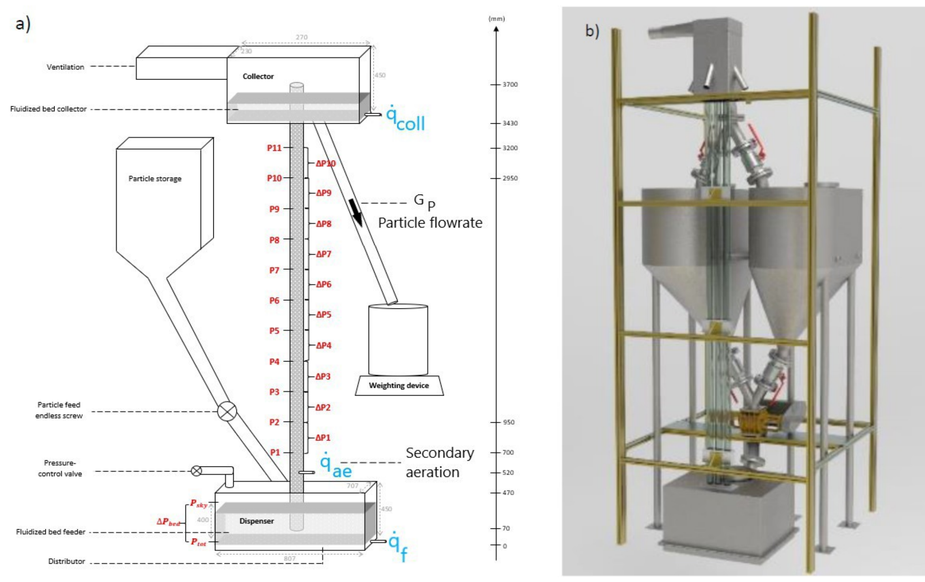
Introduction

- 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

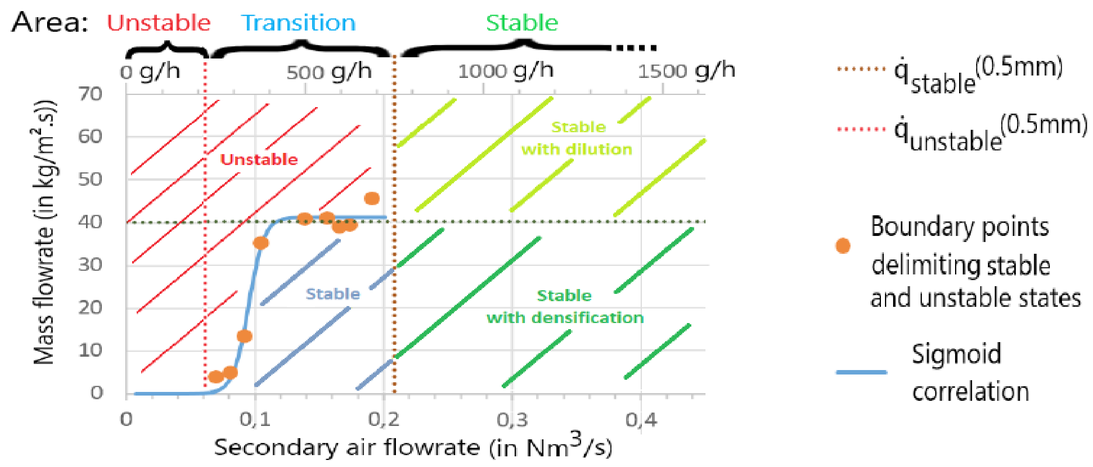
- **Material:** olivine with a Sauter diameter of 30.0 µm (group A of the Geldart classification) [2]
- **Fluidization** in a dispenser thanks to a homogeneously distributed air flowrate. By applying **pressure**, the fluidized bed passes into a 3m-long transparent glass tube of 4.5 cm internal diameter 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} (Nm3/s) and of the solid mass flux G_P (kg/(m².s)).



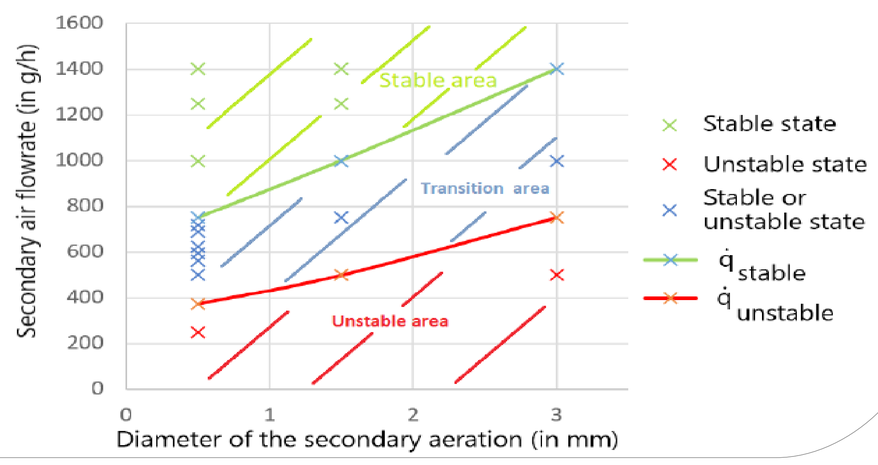
Schematic (a) and 3D (b) representation of the cold mock-up

Results

- **Stability diagram for q_{ae} in [0 – 0,39] Nm³/s and G_P in [0 – 200] kg/(m².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.
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