	Name of the PhD candidate: **Nicolas LOPEZ FERBER** Title of the PhD thesis: **Development of a modular high temperature air/ceramic thermal energy storage process and development of a waste-based ceramic usable in such system** Dates (start/end): 11/2015 – 11/2018
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Context and objectives

Thermocline sensible thermal storage is already used in some industrial fields (CSP and industrial ovens regenerators), however these devices are currently limited by the materials employed (synthetic oils and molten salts for CSP plants, costly refractory materials for oven regenerators). In addition, the required amount of TES material is estimated around 20Mt/y for CSP only. These considerable amounts imply the need for a cheap, widely available and easy to produce material. The main objectives of this PhD study are,

1) To develop a new sintered ceramic, using Municipal Waste Incinerator Bottom Ashes and waste clay as raw materials. This method is more relevant for mass-scale production using techniques already widely available in the ceramic industry.
2) To design a pilot (for around 200 kg of storage materials) for thermocline sensible thermal storage using conventional ceramics (alumina). This matches with the current R&D at ETC for the development of a modular thermal storage unit, operating between 500°C and 1000°C, which fills the gap between the molten salts systems (<600°C) and the high temperature regenerators (>1000°C). This storage system can also be used for a wide variety of industrial configurations. Pilot tests are performed for simulating different industrial situations (in terms of operating parameters, HTF flow rate and temperature).

Approach

The feasibility of thermocline development into an air/ceramic TES process was investigated with a first pilot available at Eco-Tech Ceram. This pilot allowed only the charging phase. In this work, a second pilot has been designed and built which allows investigating both charging and discharging phases, under different conditions.

Regarding material elaboration, plate-pressing has been the approach during the first half of the PhD, but we chose to focus on the extrusion of cylindrical pellets, which is a more effective design for mass production of packed bed media and is a more common method of shaping ceramic green bodies.

Main results

In the investigated experimental domain, the performances of the storage pilot do not depend on discharge flow rate (Fig1.a), allowing such system to supply heat at different power level in the discharging phase, according to the needs of the process using the recovered heat. It has also been found that strongly degraded mass flow rate during charge didn't decrease the performances of the system in the discharging phase (Fig1.b). Also, an air flow with unstable temperature during charge can still be used by the system, and discharged with high efficiency, implying that thermocline systems could handle low-quality heat resources.

Regarding sintering process, we moved from the production of pressed plates (Fig2.a) to produce cylindrical pellets (Fig2.b). This implied developing an extrusion protocol. For these cylpebs, the highest density was 2.55 for 40%wt clay formulation, fired at 1125°C. Lowering clay ratio generally decreases fired density. It is interesting to note that

extrusion allows to reach higher densities than uniaxial pressing, which is beneficial for thermal storage applications.

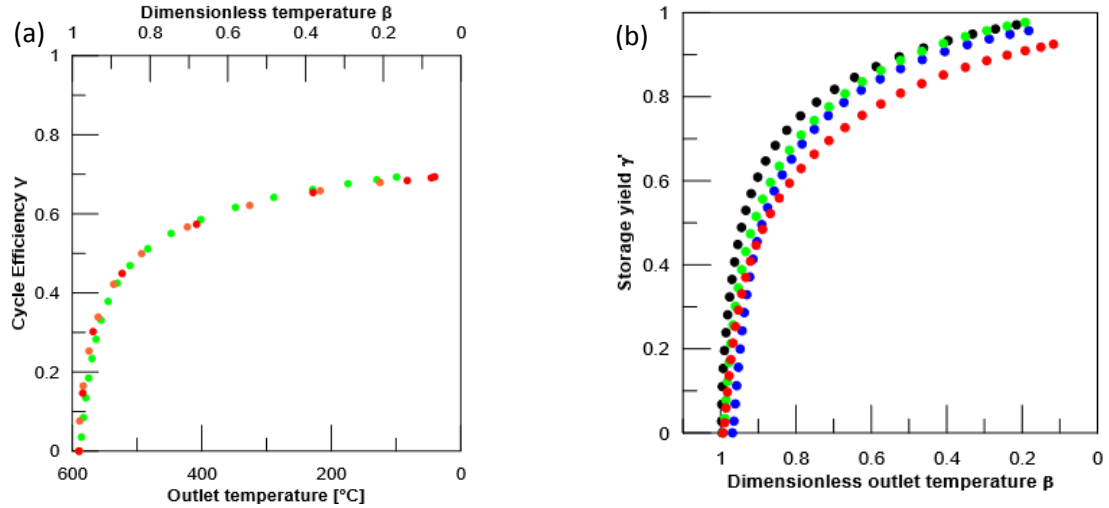

Figure 1. (a) Cycle efficiency as a function of outlet temperature for 123 (●), 72(●), 39(●) kg/h discharge flow rate. (b) Storage yields for constant heat resource (●), flow rate step (●), flow rate oscillation (●) and temperature oscillation (●) as a function of dimensionless outlet temperature during discharge

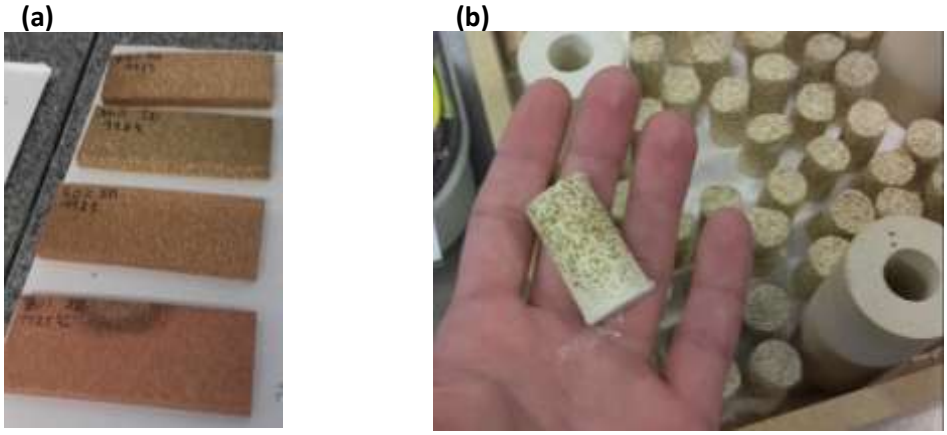

Figure 2. (a) Pressed plates with 20, 30, 40, 70 %wt of clay, fired at 1125°C. (b) Extruded cylpeb (20%wt clay) fired at 1100°C.

international conferences

Air/Ceramic packed bed thermocline storage system at pilot scale-influence of operationg conditions on system behaviour (7th international conference on engineering for waste and biomass valorisation, standard oral, Prague (Czesh Republic), 2-5 July 2018)

Innovative ceramic thermal storage material elaborated from municipal incinerator bottom ashes (7th international conference on engineering for waste and biomass valorisation, standard oral, Prague (Czesh Republic), 2-5 July 2018)