LIFE Project N°:
LIFE05ENV/F/000082
DIDEM

Improved tile and brick drying performance by recovery of the latent heat of water condensation in order to reduce Greenhouse gas emissions

Layman report

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Abstract:

C.T.M.N.C., in partnership with CERIC, is supported by the environmental body Life Environment to study the process of cocurrent drying for terra cotta products. The process aims at reducing energy consumption by recovering latent heat from dryer effluents.

Within the framework of the project, C.T.M.N.C, in partnership with ENSCI, has designed a climatic enclosure for the laboratory scale simulation of cocurrent drying of terracotta products. Instead of changing the atmosphere in accordance with the distance travelled in the dryer, it varies according to time passed. Controlled for temperature and relative humidity, the climatic enclosure is set up in a C.T.M.N.C laboratory. It measures linear shrinkage, product mass loss and airspeed in the enclosure.

The process validation period has been completed.

1. climatic enclosure equipped with automatic control equipment

For a feasibility study of co-current drying using moisture laden air, laboratory scale drying was necessary as a prerequisite to drying on an industrial scale. A climatic enclosure prototype capable of reaching that target had to be developed, i.e.: a capability of controlling atmospheres very precisely under the conditions stated above.

1.1. General description of the prototype

Designing a prototype is often critical and the choice of supplier is a determinant factor. The choice of supplier in our case was limited because only three suppliers were capable of designing such a machine (Figure 1). BIA Climatic was the company with whom we drew up the specification sheet (APPENDIX IV) for the fabrication of the machine.

1.1.1.1. *Findings*

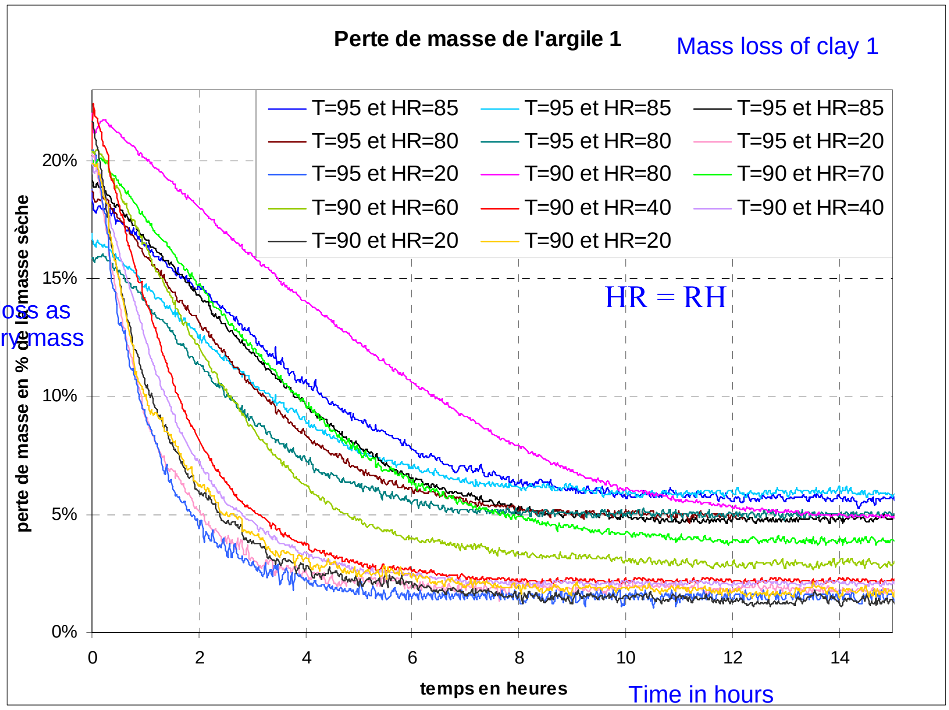


Figure 2

Erreur ! Source du renvoi introuvable. represents the mass loss of clay sample 1 under the conditions of temperature and relative humidity shown above. Clay samples 1 and 2 reach residual moisture percentages similar to percentages prevalent under industrial conditions and dry with no apparent defects. Furthermore, drying time for those clays under those conditions is comparable to drying time under industrial conditions (APPENDIX V for shrinkage and mass loss curves).

, The « Lab » entry deals with the trials shown above and the « Factory » entry sets out the findings obtained by the maker.

	Clay 1	**Clay 2**
Shrinkage	Lab: shrinkage completed in less than 5 hr (1.5 to 5 hr) for all trials excl. 90°C/(90, 85 and 80 % RH) and 95°C/90 % RH (between 8 and 10 hrs). Factory: shrinkage completed in less than 5 hr.	Lab: shrinkage completed in less than 5 hr (1.5 to 5 hr) for all trials excl. those at 90°C/80% RH (8½ hr). Factory: shrinkage completed after 12 hr drying time

Mass loss	Lab: mass stabilized after 5 to 10 hr drying for all residual humidity trials from 1.5 to 5.8% of dry mass. Factory: 7 hr drying with 3% relative humidity.	Lab: mass stabilized in less than 9 hr with a residual moisture of from 2 to 5.5% for all trials excl. those at 95 and 90 °C/80 RH (6.5 et 8.5 %). Factory: 15 hr drying time with 3% relative humidity.
State of surface	Lab: no apparent cracks	Lab: no apparent cracks

Trial findings from the first part of the validation stage

1.1.1.2. Findings of the second trials campaign

Apart from drying times under cocurrent conditions slightly longer than under industrial conditions for clay 1, the trials show that the two drying processes result in products with similar properties (**Erreur ! Source du renvoi introuvable.**).

Clay and type of drying	**Drying**				**Deflection 3 points (MPa)**	**Frost**		**Open porosity of baked products**
	Shrink age	Time	Residual water	Time		State	Mass loss	
Clay 1 ind	4.5%	6hr	3.0%	7hr	Mean=4.4	OK	≤0.1%	9.2%
Clay 1 CoC	4.5%	9hr	2.5%	16hr	Mean=4.1	OK	≤0.1%	8.8%
Clay 2 ind	3.1%	11hr	3.0%	15hr	Mean=6.0	OK	≤0.1%	34.0%
Clay 2 CoC	3.0%	8hr	3.5%	15hr	Mean=5.7	OK	≤0.1%	35.7%

Table 2: Findings on product properties by comparing two methods of drying

2. Energy evaluation of the drying process

Partially or fully extracting a solvent from a material is energetically costly. Thermal drying consumes 2.5 MJ (latent heat of vaporization) to evaporate one kilogram of water. Conventional dryers can use up to three times that quantity of energy. The cost for drying terracotta products is evaluated to be 3,960,000 GJ of primary energy, i.e.: roughly 15% of energy consumed by the roof tile and brick industry in Europe (source: ADEME).

2.1. *Basic principle of counter current drying*

Two types of dryers are generally used by the industry: chamber dryers (where products are static) and tunnel dryers (where products move). Tunnel dryers, generally incorporating the counter current method, are most commonly used for roof tiles and bricks (Figure 3). Products outputting the dryer are subjected to hot, dry air (between 100 and 110°C). At that stage of drying, the products have a low water content (2 to 3%) and can therefore tolerate air with a fairly high dryng power. The air flows in the opposite direction to product travel and supplies the heat required for the evaporation of the liquid and leads to the formation of vapour. The relative humidity of air increases and its temperature decreases until it is extracted. Outputting air at 40°C and 85% relative humidity encounters the products entering the dryer, water content of products is close to 20% of the dry mass. At the start of drying, the product cannot tolerate air with a drying power (a concept to describe the air's capacity to absorb water vapour) that is too high at the risk of causing crusting and leading to high moisture and temperature gradients in the material.

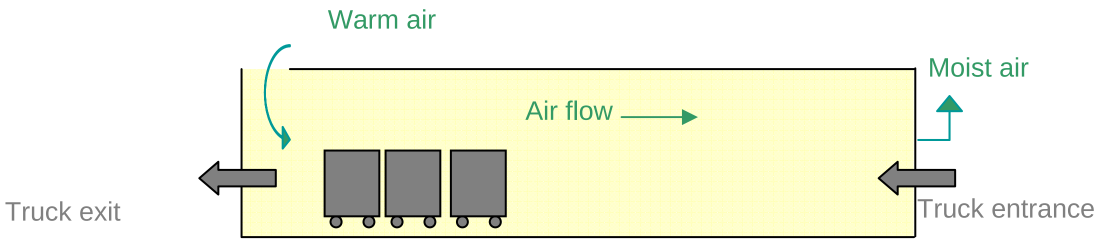


Figure 3: Diagram of a counter current drying tunnel

The air introduced is heated by burners fed with natural gas or LPG. The products are laid on the multi-shelved trucks or swing-trays and are conveyed from the dryer inlet to its outlet by the same vehicles. If the evaporation flow rate between the air and the product is considered constant, the energy variations of the air and product can be schematized as in Figure 4.

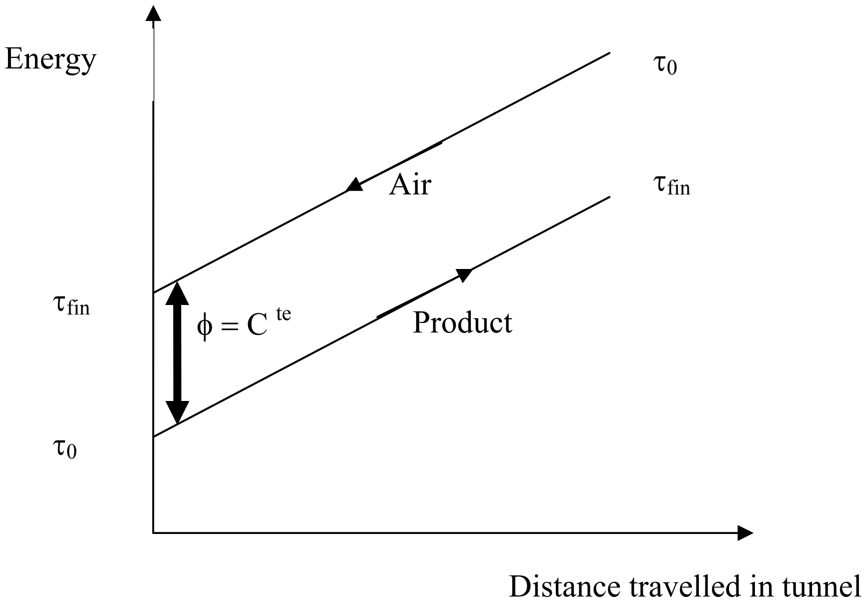


Figure 4: Energy changes of air and product in counter current tunnel

2.2. Basic principle of cocurrent drying

Cocurrent drying, unlike counter current drying, is not yet used for the manufacture of terracotta products. The diagram below illustrates the principle of operation of a co-current drying tunnel. The curve resembles that in the counter current system but contrary to the latter the air and products in the cocurrent system “flow” in the same direction. The moist products inputting the dryer are subjected to air with high drying power, the latter is then loaded with moisture while continuing to be heated until its output at the other end of the dryer. The system can be used to dry raw materials because the latter are able to tolerate high drying power air without deterioration. That is not the case for clayey products for which drying is a critical stage.

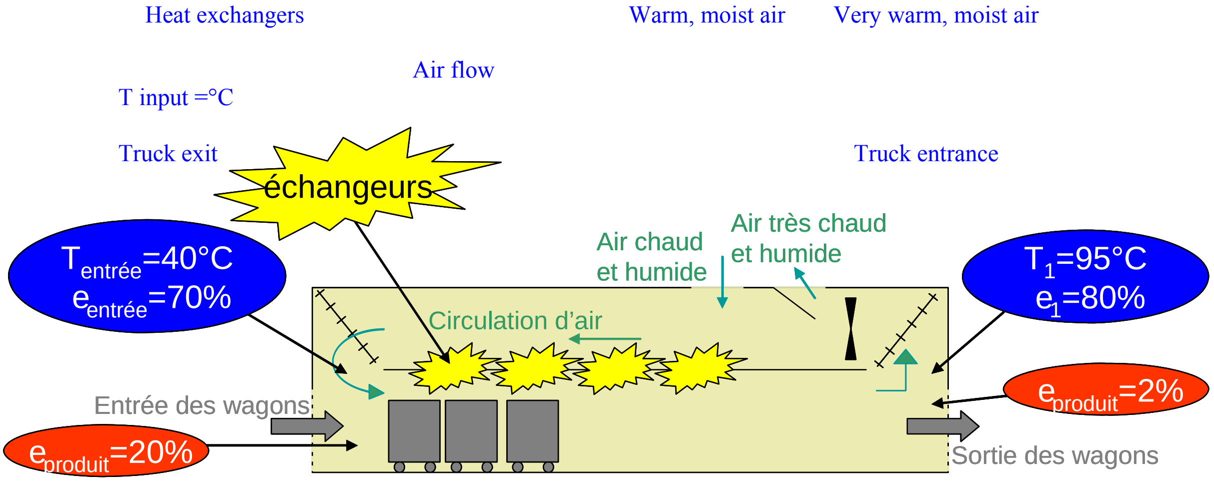
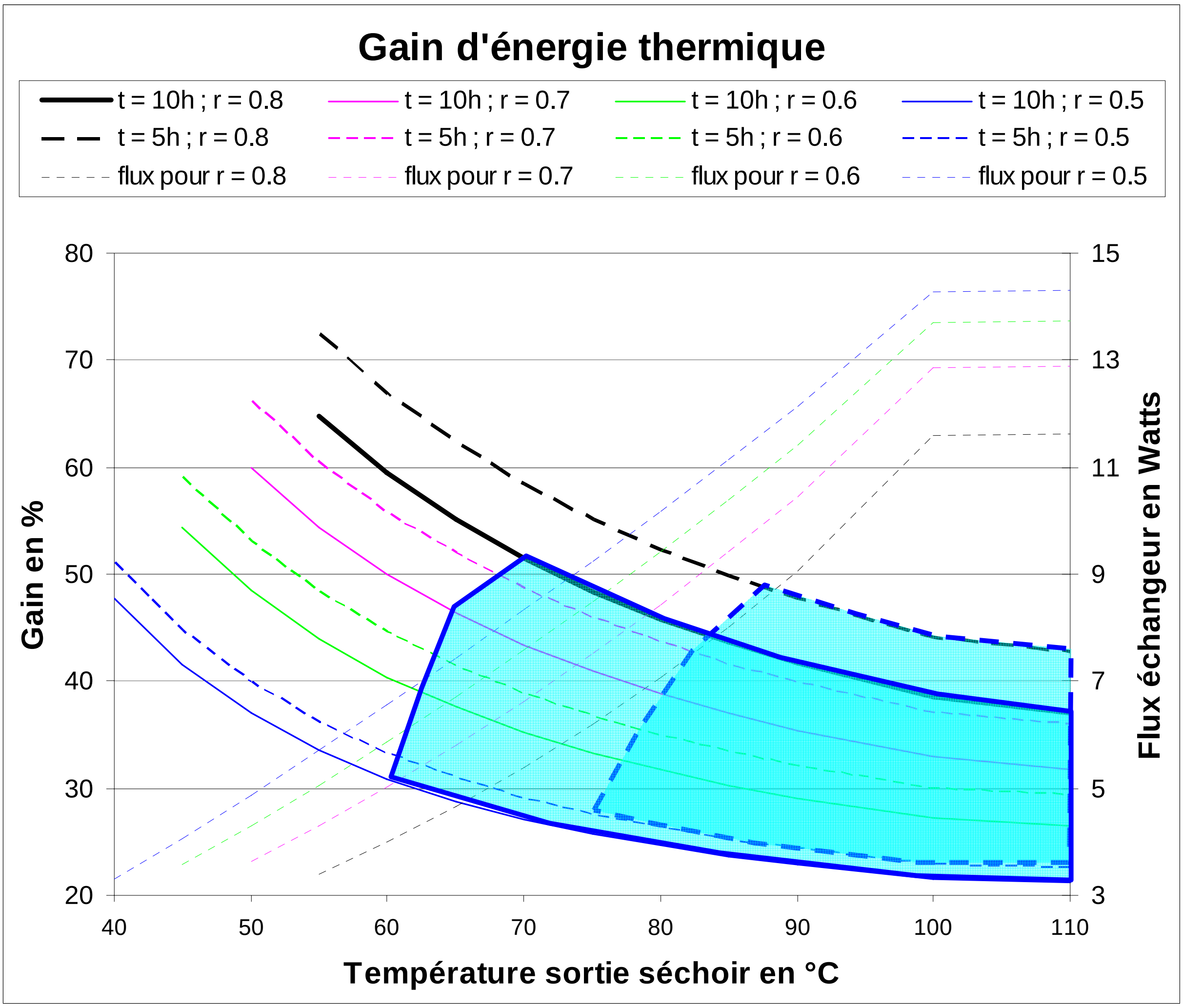


Figure 5: Diagram of a counter current drying tunnel

Heat exchangers (or heat pumps) recover the latent heat of condensation from the water vapour contained in the air whose absolute humidity is very high (0.77 kg water / kg dry air at 95°C and 80% relative humidity) enabling the product to be heated gradually when it inputs the dryer.



2.3. Energy evaluation

Figure 6: Thermal energy gain and flow in the heat exchanger according to temperature at end of cycle

To conclude, the energy gain is thus restricted by the heat exchanger energy flow but on the other hand the energy flow in the exchanger can be optimized by increasing the surface areas of exchange between the two liquids (e.g.: by using an undulating surface or even blades).

Conclusion

The purpose of the LIFE-DIDEM project is to define the feasibility of cocurrent drying for terracotta products in order to cut energy consumption by the recovery of the latent heat of evaporation water from effluents followed by the recovery of water from condensation.

To realize that goal, a climatic enclosure prototype with automatic control equipment was designed and set up at the premises of CTMNC, the project coordinator, in partnership with manufacturers. That phase, preceded by a vital in-depth study of the mechanism of the drying of terracotta, was marked by two important initial steps: firstly, the design of the enclosure to enable the drafting of the specification sheet to comply with CTMNC conditions and, secondly, the selection of appropriate automatic control equipment required to validate the tested process.

A trials campaign was carried out with the equipment to compare the properties of clayey samples dried by the industrial process with others dried by simulating a cocurrent cycle. The results obtained for 3-point deflection on dry samples, frost resistance on baked samples and open porosity on baked samples proved to be similar whether the samples were dried by one or the other of the processes.

Furthermore, the energy evaluation demonstrates that energy gains are possible. Indeed, the new type of dryer shows that maximum energy consumption equivalent to half the consumption of an efficient conventional dryer can be envisaged.

This conclusion is all the more satisfactory that even today very few industrial dryers are equipped with energy recovery systems of any sort. The energy gain can be improved by increasing the exchange surface area of the dryer’s double wall.

APPENDIX VI: laboratory validation phase

The drying of products at temperatures close to 100°C

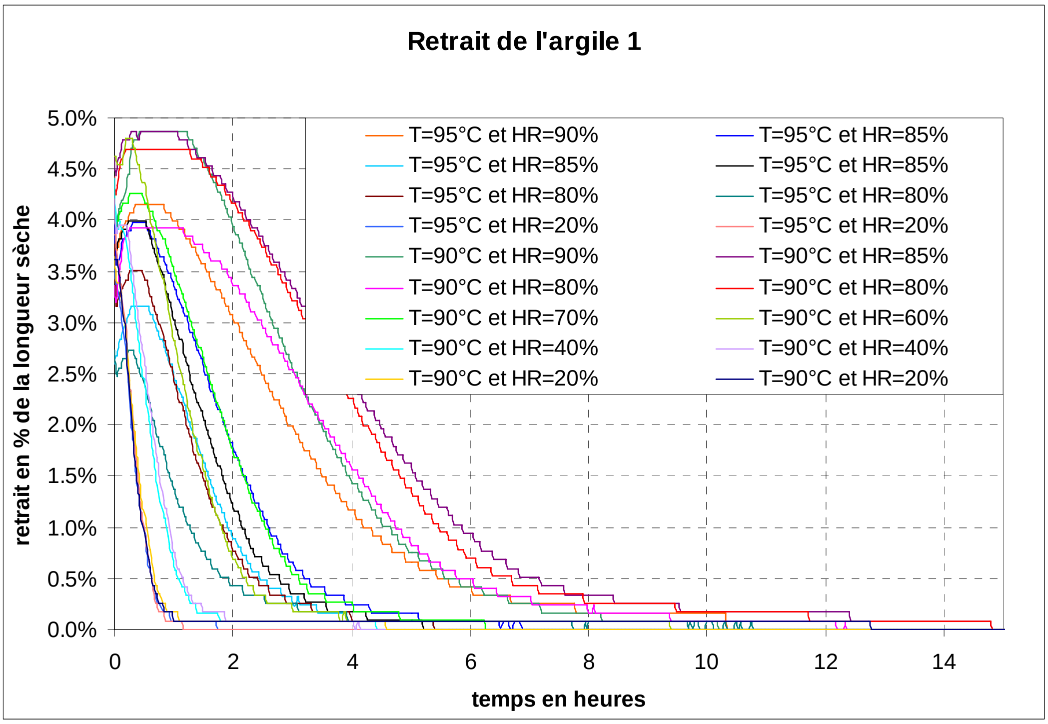


Figure 7

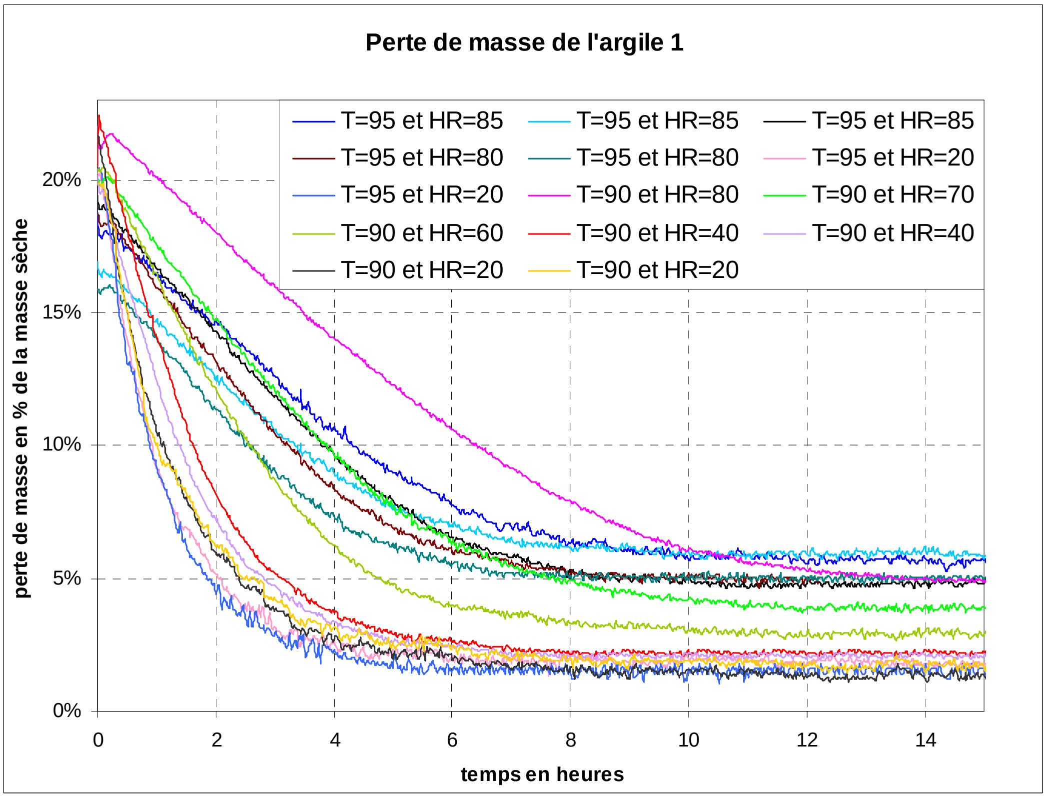


Figure 8

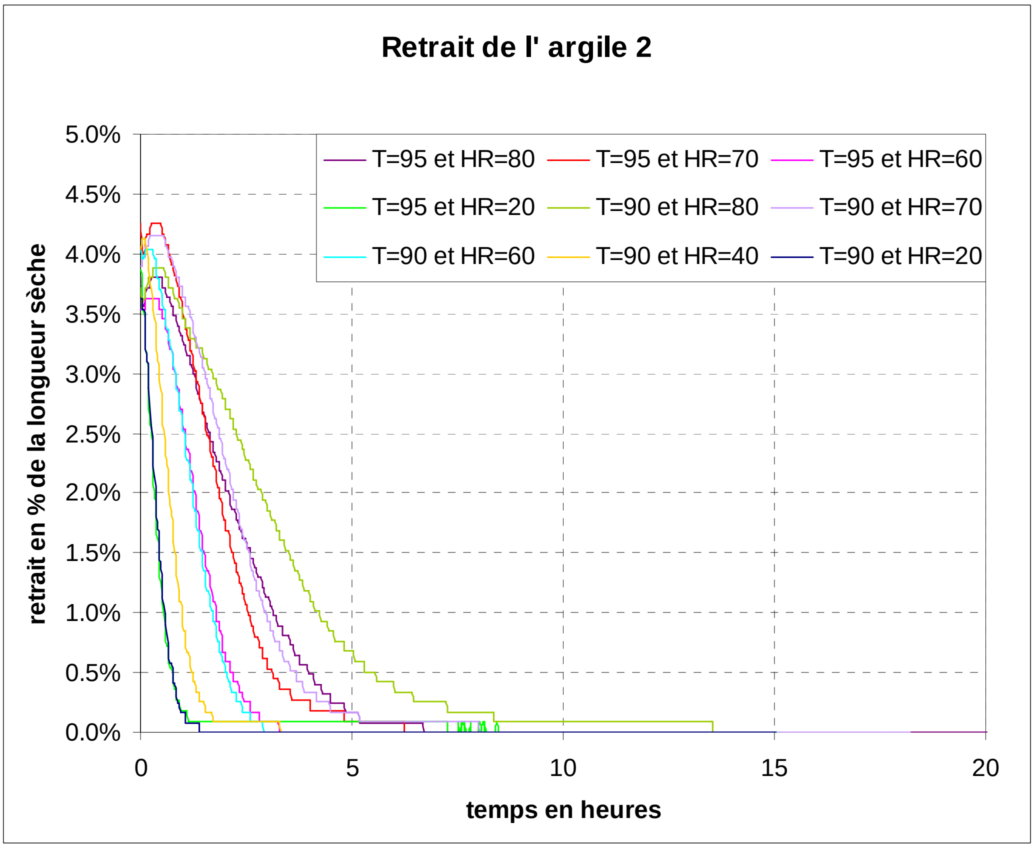


Figure 9

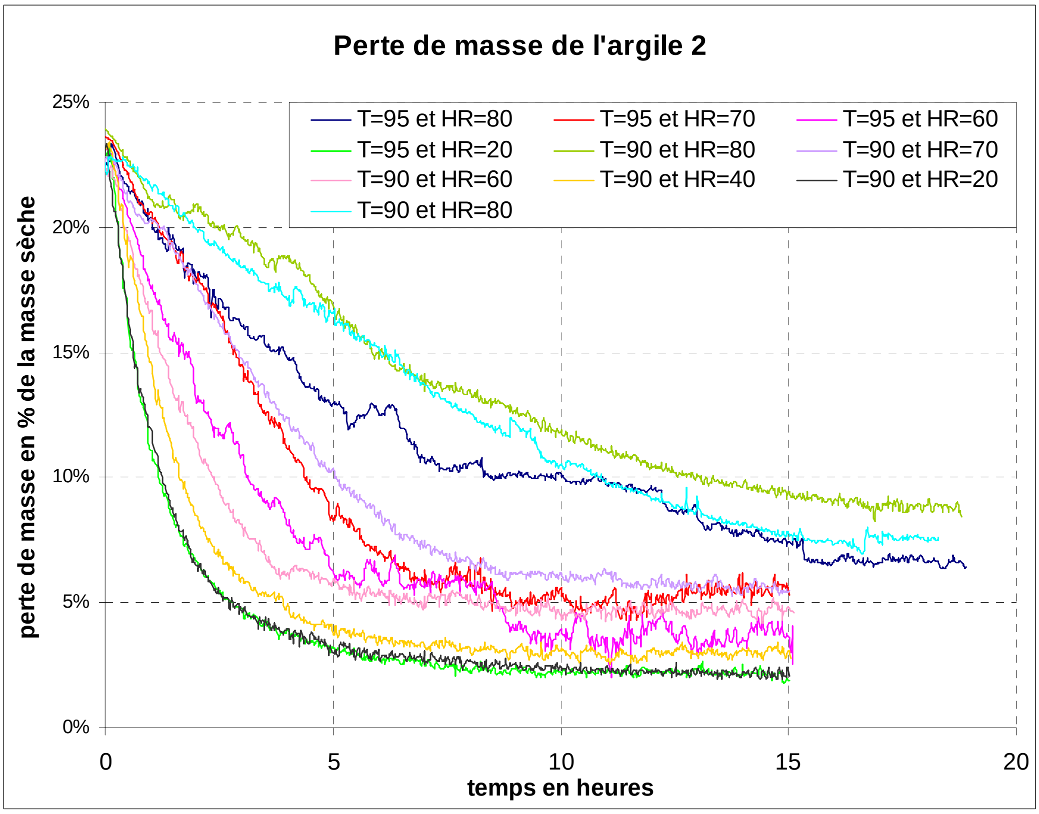


Figure 10

Abstract:

C.T.M.N.C., in partnership with CERIC, is supported by the environmental body Life Environment to study the process of cocurrent drying on terracotta products. The process is being tested to replace counter current drying, currently used by French roof tile and brick works, with the aim of reducing energy consumption and gas emissions harmful to the environment.

Within the framework of the project, C.T.M.N.C, in partnership with ENSCI, has designed a climatic enclosure for the laboratory scale simulation of cocurrent drying of terracotta products. Instead of changing the atmosphere in accordance with the distance travelled in the dryer, it varies according to time passed. Controlled for temperature and relative humidity, the climatic enclosure is set up in a C.T.M.N.C laboratory. It measures linear shrinkage, product mass loss and airspeed in the enclosure. What is more, a digital camera takes photos of the product during drying through a heated sight glass in order to observe possible cracks that might appear on the surface.

The process validation phase started with the characterization of clayey mixes from various industrial plants. Their properties were compared after subjecting them to two drying methods, industrial and cocurrent. Validation is based both on the results of those tests and on the energy evaluation simulating the consumption of both processes under industrial conditions.

Page 7 Schéma

Thermal energy gain
……. Flow for r = 0.8

Percentage gain
Exchange flow in watts
Output temperature from dryer in °C

Pages 9+10 Figures 7+9

Clay 1 shrinkage
shrinkage as % of dry length
time in hours

Pages 9+10 Figure 8+10

Loss of mass of clay 1
loss of mass as % of dry mass
time in hours