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PRECIZE: A NOVEL APPROACH TO DECARBONIZING SPECIALTY BINDERS THROUGH HYDROGEN COMBUSTION

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ABSTRACT

Addressing the significant CO_2 emissions from calcium aluminate cement (CAC) production is a critical challenge for the building and infrastructure sectors, with fossil fuels accounting for a large portion of the greenhouse gas (GHG) footprint. To tackle this, we initiated the PRECIZE *(PRocédé ÉCologique et Innovant de liants de spécialité Zéro Émission)* project, a strategic collaboration with Air Liquide, "Laboratoire de Génie Chimique" (LGC) in Toulouse, and "Conditions extrêmes et Matériaux: Haute Température et Irradiation" (CEMHTI) in Orléans. Funded by the French state as part of the France 2030 program and operated by ADEME, this initiative is a strategic component of our commitment to science-based targets. One of the key objectives of this project is to demonstrate a scalable pathway to decarbonize CAC production by replacing fossil fuels with a carbon-free alternative like hydrogen. Our study presents the methodology and findings of a successful 12-day pilot trial conducted at our Dunkerque site, detailing the progressive transition from a mixture of 100% natural gas to a 100% hydrogen. The results of this extensive pilot trial will be presented in this paper. We will provide a comprehensive analysis of the impact on CAC quality and performance, as well as on kiln behavior and stability.

INTRODUCTION

The PRECIZE project, a France 2030 initiative led by Imerys Aluminates and supported by ADEME, aims to decarbonize calcium aluminate production using hydrogen combustion. Central to this project is the validation of the proprietary Furnace Innovative Technology (FIT), following a successful 12-day industrial trial at the Dunkirk pilot plant in May 2025. Beyond fuel substitution, the study evaluates the impact of H_2/O_2 combustion on clinker mineralogy, refractory corrosion, and the calibration of 3D CFD models. This paper details the trial methodology and provides a technical assessment of hydrogen's viability as a primary energy source. These findings establish the foundational scaling laws required to transition this low-carbon technology to full-scale industrial manufacturing.

METHODS

FIT pilot Operating principle

The FIT pilot is located at the Imerys Aluminates site in Dunkirk. This patented[1] furnace, developed over several years, has validated the production of calcium aluminates using alternative fuels. It also demonstrates the feasibility of producing clinker from alternative decarbonated raw materials sourced from the circular economy.
As part of the PRECIZE project, the pilot has been re-engineered with new refractories to accommodate a hydrogen combustion process. The process involves precisely dosing and conveying raw materials (limestone and bauxite with a small correction with sand) into the furnace via a screw feeder. A specialized multi-fuel burner was developed by consortium partner Air Liquide. Before injection, the hydrogen pressure is reduced to the required levels. The combustion sequence begins with the introduction of natural gas and/or hydrogen, using pure oxygen as the oxidizer for both. The burner targets the material pile to produce a molten clinker that exits the furnace in a liquid state, while combustion and reaction fumes are evacuated through the chimney.

Campaign

The campaign began and concluded with natural gas to establish a baseline. The hydrogen proportion was increased in 25% increments every two days, with a proportional decrease in natural gas, reaching 100% H_2 as shown in Figure 1., with a temporary return to natural gas on Day 7 due to supply logistics (Sunday). Although volumetric CO_2 emissions in the flue gas decreased as expected, residual CO_2 remained present even at 100% H_2 injection, due to the calcination of limestone within the process.

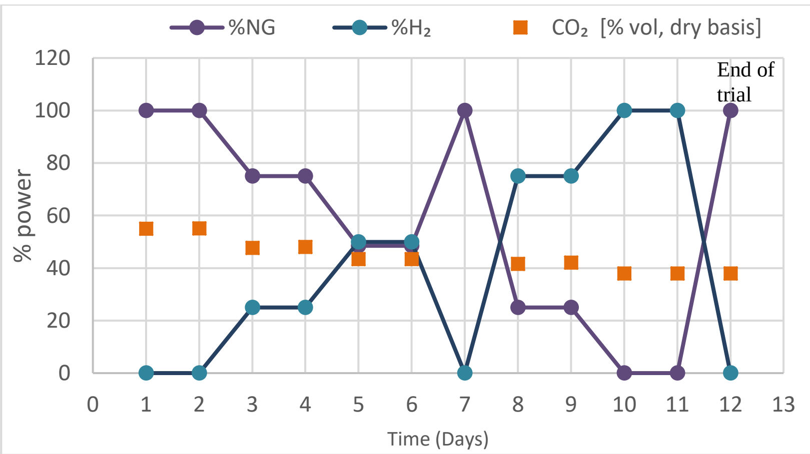

Figure 1. Evolution of Hydrogen and Natural Gas Power Consumption vs. Volumetric CO_2 Percentage

Air Liquide supplied the gaseous hydrogen via semi-trailers Figure 2, with an on-site pressure-reduction station regulating the flow. For the oxygen supply, a large-capacity storage tank was refilled throughout the campaign. To ensure precise monitoring during these transitions, a rigorous sampling protocol was implemented : samples were collected three times per shift. This systematic approach provided representative data to validate the material's consistency as the hydrogen ratio increased. The size of the sampler Figure 3 was designed and validated to obtain similar results to our Fusion plants.

Figure 2. Hydrogen semi-trailers secured by chain-link fencing and mandatory safety clearance distances

Figure 3. Clinker cooling in sampler

KEY FINDINGS

Product Quality: The clinker’s chemistry, mineralogy, and color remained entirely unaffected by the switch to hydrogen/oxygen combustion, ensuring a seamless transition for existing applications. Chemical analyses under 75% and 100% H_2 atmospheres demonstrate the same proportions of major oxides—lime, alumina, iron, and silica—as observed in commercial calcium aluminate (Ternal Fondu). Regarding mineralogy, phase distributions remained consistent with reference values. Chemical compositions were accurately measured using X-ray Fluorescence (XRF), while mineralogical phases were determined via X-ray Diffraction (XRD) and quantified using the Rietveld refinement method.

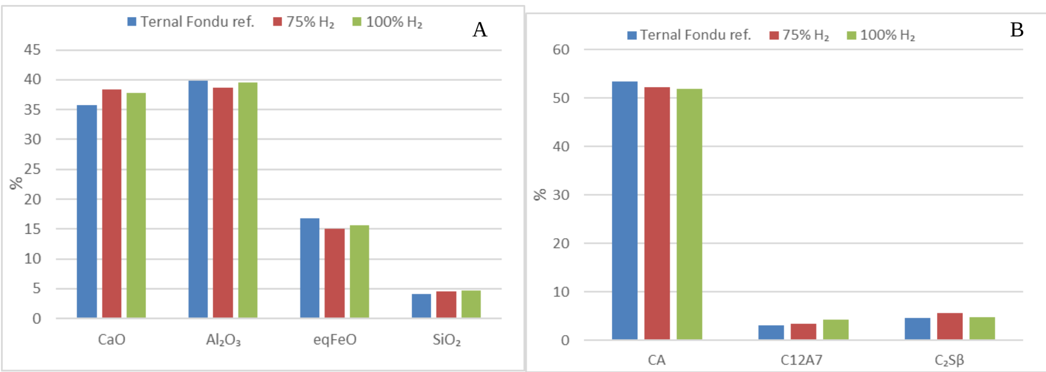

Figure 4. Comparison of major chemical oxides (A) and mineralogical phases (B): Clinker produced with 75% and 100% H_2 vs. standard Fondu.

Product Performance : Extensive application tests confirmed that the product works exactly as expected. Setting times and mechanical strengths (flexural and compressive) are equivalent (75% to 100%) to our traditional commercial calcium aluminate product (Ternal Fondu). These results were strictly validated according to international standards and internal protocols:

- Mortar Preparation: According to EN 14647.
- Setting Time : Measured via Vicat needle under demineralized water with an additional 700g mass, according to EN 196-3.
- Mechanical Strength: Test bars prepared according to EN 196-3.

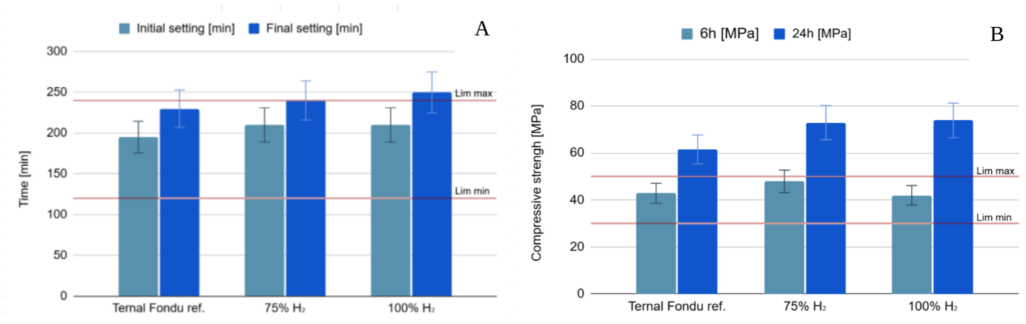

Figure 5 : Comparison of setting times (A) and compressive strengths (B) of clinker produced with 75% and 100% hydrogen vs. standard Fondu.

Kiln stability: The furnace performed reliably throughout all project phases. Furthermore, a post-mortem analysis confirmed that the refractory materials showed no signs of degradation despite the tough, hydrogen-rich and H_2O atmosphere.

CONCLUSION

The pilot tests for FIT technology, conducted as part of the Precize Project, have successfully validated the use of oxy-hydrogen combustion for the production of calcium aluminates at the Imerys Aluminates site in Dunkirk. Experimental results demonstrate that performance remains consistent, with the product's physicochemical properties staying strictly unchanged compared to conventional methods. This study represents a world-first demonstration of oxy-hydrogen as a primary fuel source for calcium aluminate fusion, offering a significant breakthrough for the decarbonization of high-temperature industrial processes.

REFERENCES

[1] Patent Publication No. WO/2017/009581, filed under the title « Process for manufacturing Calcium Aluminates ».