# Catalytic Combustion Technology

Innovative mesh technology that reduces NOx emissions, increases reuse, and improves durability

Catator

The phenomenon of catalysis has been recognised for centuries, with the concept first introduced by the Swedish scientist Berzelius in 1835. Today, catalysis has evolved into one of the most significant industrial technologies, playing a critical role in the majority of chemical processes.

Catalytic combustion, as a means of energy production, represents a relatively recent development in the field of catalysis. Although pioneering research began several decades ago, the area has experienced rapid growth in recent years. Technological advancements now make it feasible to replace conventional flame-based combustion systems with catalytic alternatives, paving the way for the commercial adoption of this technology across a broad spectrum of domestic and industrial applications.

For more than three decades, Catator has specialised in catalytic combustion, leveraging its extensive experience to develop a unique wire-mesh catalyst produced using a patented manufacturing process. This innovation has been successfully evaluated in a variety of applications.

Mesh-based catalysts (as shown in Figure 1) offer significant advantages over conventional monolithic and pellet-based catalysts. They exhibit superior thermo-mechanical stability and shape flexibility, enabling the development of innovative and compact reactor designs.

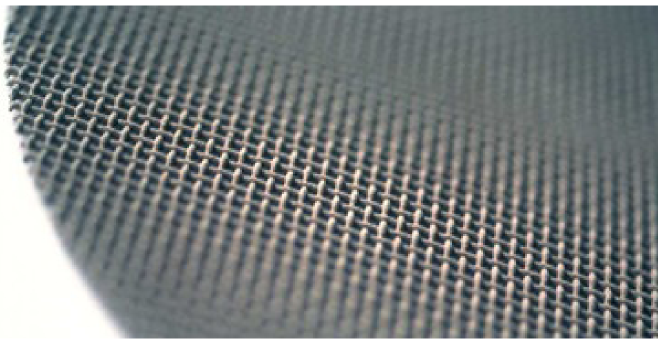

**Figure 1.** Catator´s mesh-based catalyst.

## Catalytic Combustion – A Flameless Combustion Technology

### *Theory*

The mechanism of catalytic combustion differs fundamentally from that of conventional flame combustion. In catalytic combustion (see Figure 2), the reaction is initiated through interaction with a catalytic material, typically a precious metal or a metal oxide such as palladium, platinum, or copper. At sufficiently low gas velocities, combustion occurs entirely on the catalyst surface. However, as the gas load increases, intermediate reaction regimes are reached in which free radicals are generated and released into the gas phase. These free radicals significantly accelerate the combustion process. The principal reaction regimes - pure catalytic combustion, hybrid combustion, and heterogeneously assisted homogeneous combustion - are defined by increasing the power load of the gas per square metre of mesh catalyst (kW/m² catalyst).

Although it is technically feasible to achieve near-zero NOx emissions in the pure catalytic combustion regime, the associated power load is generally too low for practical applications. To address this, Catator has developed catalytic burners designed to operate in the transition zone between pure catalytic combustion and hybrid combustion - known as CataLite® Burners. This approach enables the design of compact catalytic burners that deliver high efficiency while maintaining compliance with both current and anticipated emission regulations.

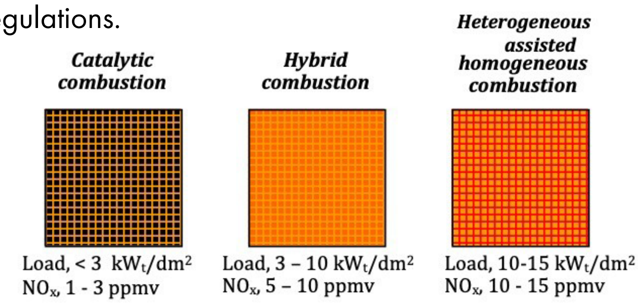


**Figure 2.** Examples of different combustion regions and colour change as the mesh goes from dark brownish colour (pure catalytic combustion) to more and more intensive red colour in heterogeneous assisted homogeneous combustion.

By applying a porous catalytic coating to the wire-mesh substrate, known as CataLite® Coating, Catator has achieved exceptionally high catalytic activity. The company's proprietary manufacturing technology ensures outstanding durability and mechanical stability of the catalytic layer, outperforming conventional manufacturing methods. These advantages have been confirmed through extensive long-term evaluations and cyclic testing.

### *Application*

During operation, a pre-mixed stream of fuel and air is passed through the catalytic wire mesh, where combustion occurs on the catalyst surface. The heat generated is transferred to the surroundings via radiation and convection through the hot gases. The burner head can be manufactured in various configurations depending on the intended application, including cylindrical, flat, or coil-shaped catalysts, as illustrated in Figure 3.

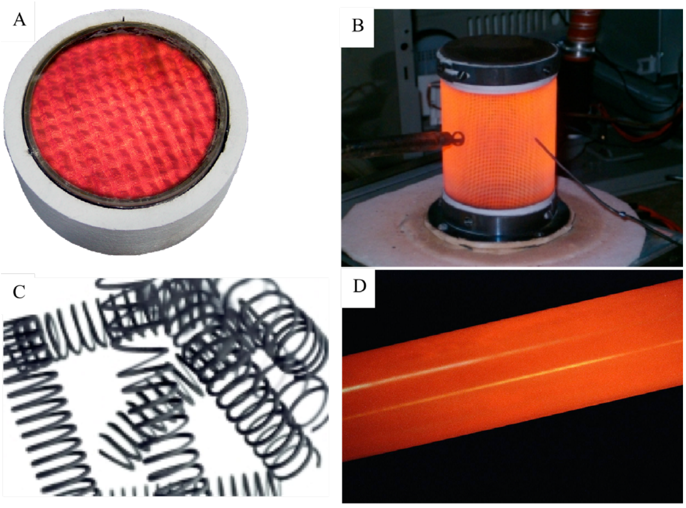


**Figure 3.** Examples of catalyst shapes used in the design of burners. A: Flat catalyst (axial gas flow). B: Cylindrical catalyst (Radial gas flow). C: Coil-shaped catalyst that is used inside a rod-burner design shown in D.

Experimental investigations using catalytic wire meshes and catalytic coils positioned downstream of burner flame ports have demonstrated significant potential for NOx reduction without increasing CO emissions or compromising thermal efficiency. In fact, NOx emissions can be reduced by more than 95% when replacing conventional flame combustion with catalytic combustion, such as CataLite® Burner. This indicates that the NOx problem can be effectively addressed through a simple, durable, and cost-efficient design modification incorporating a combustion catalyst.

## Simulation Methods

In addition to conventional design and prototype testing, numerical simulation has become an increasingly important tool for designing and evaluating systems at any scale. The models developed are complex, multi-physics representations that enable the creation of a "digital twin" of the combustor and its associated process components. This virtual model can be operated and tested rapidly, without physical risk, significantly accelerating the development process. Catator possesses substantial computational resources, including high-capacity workstations with a combined total of 60 processing cores, and employs Ansys Fluent as a three-dimensional Computational Fluid Dynamics (CFD) platform.

## Thermo-mechanical Stability

Catator's patented coating technology, CataLite Coating®, offers significant advantages over conventional catalytic coating methods, particularly in terms of mechanical stability and design flexibility. Extensive cyclic testing and long-term performance evaluations conducted over the years have consistently confirmed the high thermo-mechanical stability of Catator's catalysts.

A notable mechanical stability test was carried out by one of Catator's customers in Japan. This test compared the weight loss of catalytic material between a commercial automotive exhaust catalyst and Catator's mesh-based catalyst. The procedure involved subjecting each catalyst to heat treatment at 1000 °C for 24 hours, followed by ultrasonic cleaning. The results demonstrated that the Catator mesh catalyst exhibited six times lower weight loss than the commercial metal honeycomb catalyst (Figure 4), providing clear evidence of the superior mechanical stability of the catalyst layer on Catator's mesh.

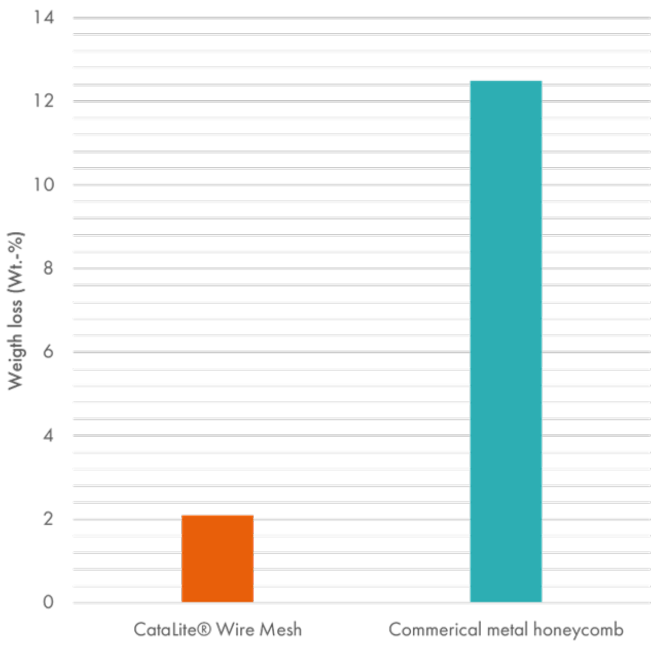


**Figure 4.** Results of the stability test (1000°C for 24h+ ultrasonic) on commercial metal honeycomb and Catator's mesh.

Catator's meshes are typically fabricated from FeCrAl-alloy wires, which have been extensively characterised with respect to oxidation behaviour under combustion conditions. Kanthal AB conducted a lifetime study of the mesh material as a function of operating temperature (Figure 5). In practice, the maximum wire-mesh temperature is usually maintained below 1000 °C; however, even at this temperature, the operational lifetime exceeds 20,000 hours.

Importantly, the design also aligns with circularity principles: once the service life is reached, the mesh can be recovered and reintroduced into the production cycle. In a closed-loop approach, the material can be fully recycled to produce new meshes for the same application. Alternatively, in an open-loop scenario, part of the recovered material can be reused in similar catalytic applications, while the remainder can be repurposed for other high-temperature or industrial uses—ensuring minimal waste and maximising resource efficiency.

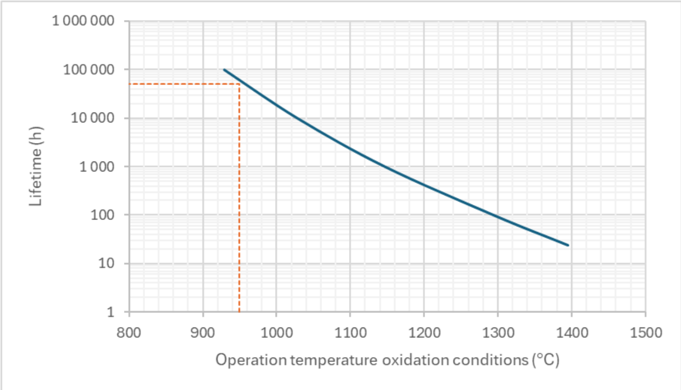


**Figure 5.** Lifetime of wire meshes as a function of operating temperature, based on results from Kanthal AB.

The long-term thermal stability of the catalyst was verified through cyclic testing, as shown in Figure 6. In this procedure, the combustion catalyst was electrically heated to approximately 900 °C and then rapidly cooled to around 400 °C. Remarkably, even after 100,000 thermal cycles, no measurable catalyst deactivation was observed.

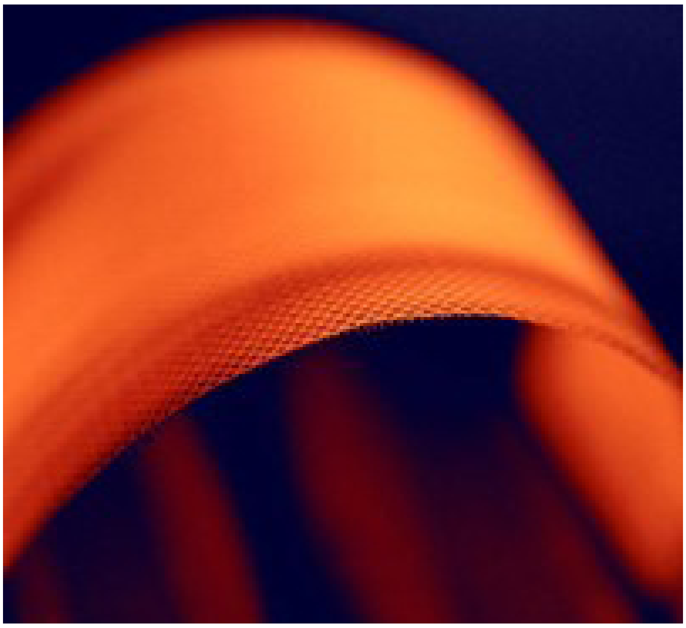

**Figure 6.** Cyclic test set-up.

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In addition, a long-term activity study was conducted in collaboration with Gaz de France (GdF). In this experiment, a wire-mesh catalyst operated at a high gas loading (approximately 3 kW/dm$^2$) for 10,000 hours without any detectable loss of performance. As illustrated in Figure 7, the catalyst maintained stable emission levels over the entire 10,000 h operation period, with NOx concentrations consistently below 2.5 ppm (with only a single outlier). CO and UHC emissions were negligible throughout the test, confirming both the long-term durability of the catalyst and its ability to ensure clean combustion under sustained high gas loading. These findings demonstrate the robustness of the catalytic system for extended real-life applications without measurable performance degradation.

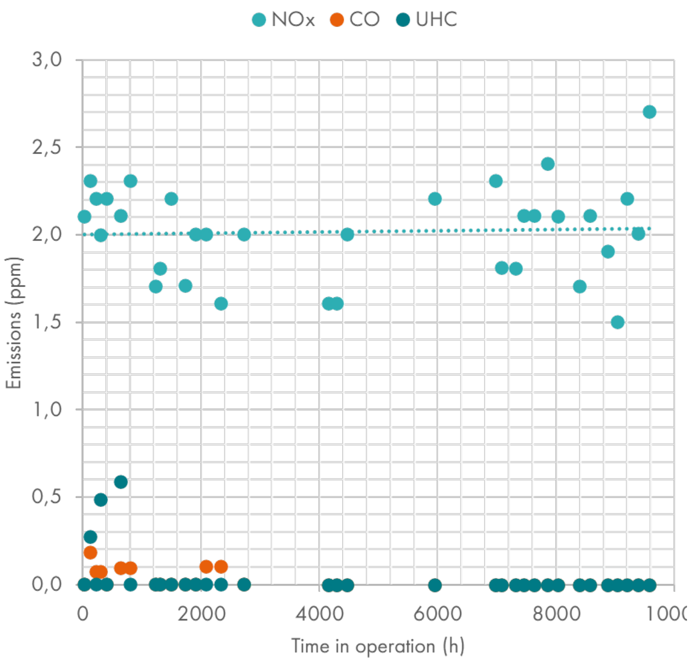


**Figure 7.** Lifetime tests performed by Gaz de France on a catalytic cooking plate with natural gas.

## Conclusion

Catator's advanced technology and extensive expertise have facilitated the commercialisation of high-activity catalysts capable of maintaining stability under elevated temperatures and prolonged operational conditions. The wire-mesh structure developed by Catator provides exceptional versatility, allowing the catalysts to be adapted to a wide range of applications and geometries. Among the primary applications are small-scale hydrogen production and the catalytic combustion of hydrogen-containing gases.

Catator remains committed to fostering collaborations with new partners and clients. The company is pleased to offer its technical expertise and experience in designing, dimensioning, and manufacturing catalytic solutions tailored to meet the specific requirements of your application.

Let us know how we can help you!
Please reach out for further information to
info@catator.com

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Based in Lund, Sweden, Catator is a world-leading technology develoment and integration partner for the commercialization of hydrogen and fuel cell technologies. Our mission is to accelerate the transition to a green hydrogen economy by creating the world's most compact, efficient and versatile solutions for hydrogen production, conversion and utilization.

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