

Cut the Heat, Save the Gas: Retrofitting Thermal Post-Combustion with Oxidation Catalysts [†]

Alexander Sigg *, Johannes Hofer, Michael Felsberger and Paul Piantino

P&P Industries AG, Liebenauer Tangente 6, 8041 Graz, Austria; johannes.hofer@pp-industries.at (J.H.); michael.felsberger@pp-industries.at (M.F.); paul.piantino@pp-industries.at (P.P.)

* Correspondence: alexander.sigg@pp-industries.at; Tel.: +43-316-26-97-414

[†] Presented at the 16th International Aluminium Conference (INALCO 2026), Trondheim, Norway, 10–12 June 2026.

Abstract

Retrofitting thermal post-combustion units with platinum-promoted honeycomb oxidation catalysts enables a transition from purely thermal to catalytic operation in industrial waste gas treatment. In aluminium recycling and downstream forming, where solvent vapours, oil aerosols and organic pollutants occur, the retrofit reduces the required operating temperature from 800–1000 °C to ~400 °C while maintaining high oxidation efficiency for VOCs and odorous compounds. The lower set point decreases natural gas demand by up to >80%, thereby reducing operating costs and CO₂ emissions without replacing existing abatement hardware. The concept is particularly suited to aerosol- and solvent-laden streams and fluctuating loads, providing a scalable modernisation pathway.

Keywords: catalytic oxidation; catalytic post-combustion; thermal post-combustion; natural gas reduction; VOC abatement; retrofit of waste gas treatment systems; CO abatement

1. Background and Motivation

Industrial aluminium production and recycling rely on thermal and mechanical unit operations that generate waste gas streams containing organic compounds. Depending on the process step (e.g., scrap preparation and decoating, degreasing, stamping/forming, machining, or thermal treatment), the exhaust may comprise solvent vapours, oil aerosols, hydrocarbons, carbon monoxide (CO), and other volatile organic compounds (VOCs). These constituents must be abated prior to atmospheric release to ensure regulatory compliance and to reduce environmental impact.

Conventional thermal post-combustion (TPC) systems are widely applied for this purpose. Oxidation is achieved through gas-phase reactions at elevated temperatures (typically close to 800 °C or higher), which results in high fuel demand to maintain the required reaction temperature and residence times.

To reduce fuel consumption and associated CO₂ emissions while maintaining high decomposition efficiencies, catalytic post-combustion (CPC) can be implemented either as a stand-alone concept or as a retrofit into existing TPC infrastructure. In the retrofit approach presented here, platinum-promoted honeycomb (PPH) catalyst modules are placed inside the existing TPC chamber; the catalyst hardware concept is illustrated in Figure 1. This integration enables stable operation at markedly lower set temperatures, with corresponding economic implications [1].



Academic Editor: Sigmund
Arntsen Tronvoll

Published: 3 August 2026

Copyright: © 2026 by the authors.

Licensee MDPI, Basel, Switzerland.

This article is an open access article distributed under the terms and conditions of the [Creative Commons](#)

[Attribution \(CC BY\) license](#).

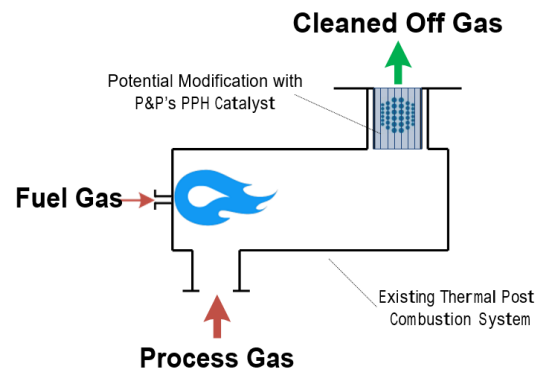


Figure 1. Concept for a combined thermal and catalytic post-combustion system using P&P's PPH catalyst.

While catalytic total oxidation as such is an established abatement principle, the novelty of the present contribution lies in demonstrating a retrofit pathway for existing TPC infrastructure in aluminium-processing applications. The contribution therefore consists in linking catalyst integration, process adaptation, and case-based energy/economic evaluation within one retrofit concept rather than in proposing a new oxidation mechanism.

Unless stated otherwise, the quantitative performance values presented in this paper refer to a defined retrofit case calculation and selected catalyst test data. They should therefore be interpreted as case-specific engineering results rather than as universally transferable values for all thermal post-combustion systems.

Catalytic oxidation promotes heterogeneous surface reactions and thereby lowers the activation energy of VOC oxidation. As a consequence, comparable conversion levels can be obtained at temperatures in the range of approximately 400 °C, depending on the exhaust composition and respective residence time of the process gas stream within the catalyst [2].

Among the catalyst families used for VOC abatement, platinum-group metal formulations are commonly selected due to their high intrinsic activity and stability under oxidising conditions. Honeycomb monolith geometries provide a high geometric surface area at low pressure drop, which is advantageous for large volumetric flow rates typical of metallurgical exhaust streams [2].

The catalyst modules discussed in this contribution are platinum-promoted honeycombs (see Figure 2) designed for total oxidation, i.e., the conversion of CO and organic compounds to carbon dioxide (CO₂) and water, respectively.

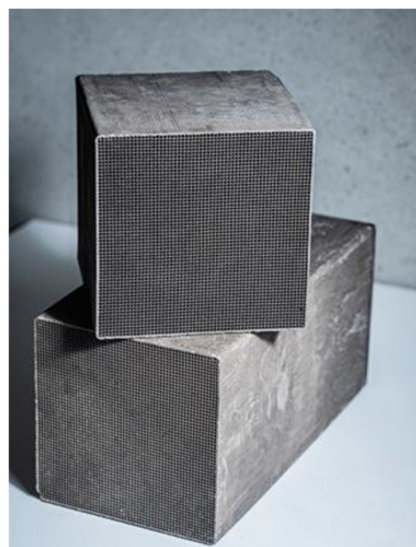


Figure 2. P&P's platinum-promoted honeycomb (PPH) catalyst. Indicative figure.

As indicated by the catalyst-module concept in Figure 1, the retrofit relies on integrating PPH catalysts with high geometric surface area and low pressure drop into the existing TPC units.

2. Catalytic Total Oxidation: Reaction Principle and Operating Window

In purely thermal oxidation systems, VOC destruction occurs through homogeneous gas-phase reactions that require very high temperatures. Catalysts provide an alternative reaction pathway through heterogeneous surface reactions. When exhaust gases pass over the catalytic surface, oxygen molecules and gaseous pollutants adsorb onto the catalyst, followed by reaction and desorption into the process gas stream [3,4].

Platinum-group metals are particularly effective catalysts due to their high catalytic activity and chemical stability. These catalysts are widely used in environmental catalysis to treat process gas streams and to support compliance with environmental regulations [2,3].

The catalysts developed by P&P Industries AG use a platinum-promoted formulation supported on a honeycomb monolith structure. In the investigated application context, no mechanically induced attrition of the monolith structure was observed over 16,000 operating hours and one inspection per year. However, long-term catalyst stability remains application-specific and depends on the contaminant spectrum of the exhaust gas. Additional advantages in this application can be deduced to

- High geometric surface area of $1\text{--}2\cdot 10^6\text{ m}^2/\text{m}^3$ enabling efficient catalytic reactions;
- Low pressure drop allowing treatment of large gas volume flows;
- Uniform gas distribution supporting high conversion;
- Mechanical stability suitable for industrial operation;
- Potential for extended service life under suitable operating conditions;
- Low mechanical abrasion risk due to the structured monolith design.

Depending on poison type and exposure level, partial performance recovery after appropriate regeneration may be possible [5].

The honeycomb substrate typically consists of ceramic materials with thousands of parallel channels. A washcoat layer containing the active catalytic materials is applied to the channel walls (typically ranging from several tens of micrometers in size) maximising the available reaction surface and avoiding the loss of active species due to long diffusion distances, as can be observed in extruded catalysts [3,5].

Because the activation energy of the oxidation reaction is drastically lowered by the catalyst, efficient VOC destruction and CO oxidation can occur at temperatures as low as 400 °C, depending on gas composition, catalyst formulation, and fluid dynamic conditions [6,7].

In the CO-oxidation experiment shown in Figure 3, even lower reaction temperatures can be achieved. The results also underline the influence of fluid dynamic conditions, such as hourly space velocity, on conversion: the higher the process gas velocity, the higher the temperature required for complete CO oxidation [6].

The experiment was conducted using a feed gas containing 2250 ppm(v) CO and air. The installed catalyst volume was 90 mL. The reported conversion values refer to steady-state conditions after a period of at least 5 min in which conversion results remained constant.

Inlet pollutant fluctuations like heavy metals were not considered and must be evaluated for the specific application.

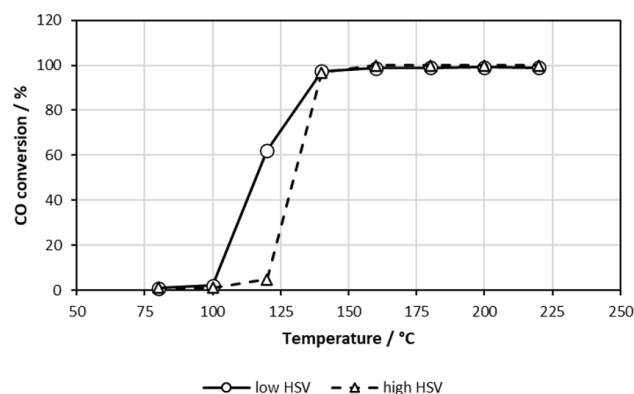


Figure 3. Conversion experimental data for P&P's platinum-promoted honeycomb catalyst. The experiments were performed at different hourly space velocities (HSV). Test conditions: CO inlet concentration = 2250 ppm(v); balance = air; catalyst volume = 90 mL.

3. Catalyst Performance and Robustness in Metallurgical Exhaust Gas

Industrial exhaust gases in metallurgical processes often present challenging boundary conditions for catalytic systems. In addition to VOCs and CO, exhaust streams may contain [8]:

- Oil aerosols and lubricant residues;
- Particulate matter;
- Sulphur-containing compounds (e.g., SO₂, H₂S, COS, CS₂, etc.);
- Halogenated hydrocarbons;
- Fluctuating pollutant concentrations.

In such challenging operation environments, catalyst poisoning is widely observed. Catalyst deactivation in industrial VOC oxidation is commonly associated with competitive adsorption, fouling, masking of active sites, sulphate/chloride formation, and thermally induced structural changes [4,9]. In particular, sulphur- and chlorine-containing species, as well as aerosols and particulate matter, can reduce catalytic activity depending on concentration level, exposure time, and regeneration strategy. Accordingly, robustness in metallurgical exhaust treatment should be understood as application-dependent tolerance rather than universal resistance.

The presented catalyst concept addressed robustness by combining a structured low-pressure-drop monolith design with a platinum-promoted active phase and application-specific operating control. In a plant placed in the off-gas stream of a secondary metallurgical facility, stable operation was maintained for 16,000 h campaigns in gas streams containing up to 5 ppm hydrogen fluoride, with no drastic deactivation observed.

However, the long-term tolerance window remains dependent on the actual contaminant spectrum of the treated exhaust gas.

Key findings can therefore be summarised as follows:

1. **Robust catalytic formulation:** optimised platinum dispersion to maintain activity while limiting sensitivity to potential poisons;
2. **Resistance to catalyst poisons:** formulation intended to tolerate moderate concentrations of sulphur- or halogen-containing compounds.

These design characteristics enable reliable operation even in demanding metallurgical applications where conventional catalytic systems might otherwise suffer from rapid deactivation, providing a practical alternative to conventional TPC systems.

4. Retrofit Integration and Process Control

One of the major advantages of catalytic oxidation technology is its ability to modernise existing emission-control systems through retrofit integration.

Many aluminium-processing facilities already operate thermal post-combustion units installed decades ago to comply with environmental regulations. Replacing these systems entirely would require substantial investment and plant downtime.

Instead, catalytic modules can be integrated directly into the existing reaction chamber or the exhaust pipe of a thermal oxidiser. In such configurations, the catalyst effectively converts the system into a catalytic post-combustion unit while preserving the installed infrastructure. Therefore, investment costs arise primarily from catalyst purchase and installation.

Typical retrofit steps include:

- Installation of catalytic honeycomb modules inside the oxidation chamber or at the outlet;
- Adjustment of burner operation and temperature control to the catalytic set point;
- Optimisation of gas-flow distribution across the catalyst face;
- Integration of monitoring and control systems for safe operation;
- Legal and compliance work for the adaption of the TPC unit.

The performance figures reported in this publication refer to different metrics and should therefore not be interpreted as directly identical values. For the current case, a 50% reduction in energy demand is assumed. Under more favourable retrofit operating windows, natural gas savings of up to 80% may be achievable due to a stronger reduction in burner duty; however, the present operating conditions do not allow this higher saving potential to be realised. Figure 4 represents a calculation of relative overall energy demand for this defined batch process and boundary conditions, resulting in the discussed energy demand reduction. Table 1 further translates this case into normalised operating expenditure, where the combined TPC/CPC configuration reaches 41% of the baseline OPEX. The latter value includes not only fuel demand but also the assumed maintenance and cost normalisation framework of the selected case.

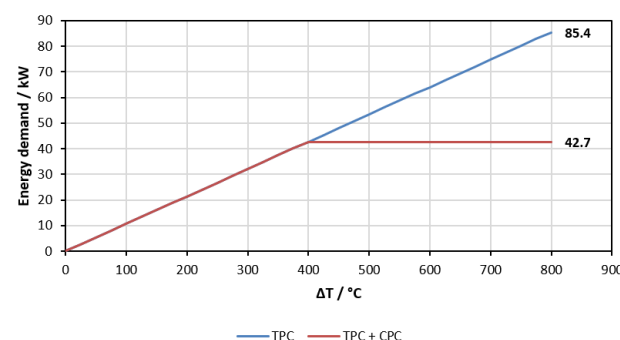


Figure 4. Calculated relative energy demand of a reference thermal post-combustion system (TPC) and a retrofit configuration with catalyst-assisted operation (TPC/CPC) for a process gas flow of 300 Nm³/h [10,11]. The process gas was considered to be air, as its physical properties did not differ significantly from those of the actual process gas composition evaluated. The comparison is based on a batch-type operating profile, a TPC set temperature of 800 °C, a catalyst-assisted set temperature of 400 °C, and the corresponding burner duty, under otherwise identical boundary conditions. The diagram represents a case-specific calculation and not a universal performance value.

Table 1. Comparison of operating expenditure (OPEX) for the operation of a thermal post-combustion system and thermal post-combustion system modified with a catalytic post-combustion system based on P&P's platinum-promoted honeycomb catalysts.

Cost	TPC *	CPC **
Energy costs/%	98%	39%
Catalytic converter/%	0%	0%
Maintenance/%	2%	2%
Sum/%	100%	41%

* Thermal post-combustion; ** catalytic post-combustion.

In the present case calculation, OPEX comprises fuel-related operating costs and routine maintenance and is reduced by 59% compared with the state-of-the-art TPC case when applying the combined thermal–catalytic approach (see Table 1). No additional regular mechanical maintenance specific to the catalyst module was assumed beyond scheduled visual inspection and condition assessment; under these assumptions, the catalyst itself is considered effectively maintenance-free.

Figure 5 represents a normalised economic case calculation based on the retrofit assumptions defined in this section, including catalyst investment, installation cost, and the OPEX difference between the reference TPC and the combined TPC/CPC configuration. The return-on-investment (ROI) curve combines measured operating data from of the project partner in aluminium industries (generated over one year of industrial operation) with the documented retrofit investment cost. Based on the combined CAPEX and OPEX assessment, the test case indicates a break-even point at approximately 2.4 years after the retrofit (see Figure 5), beyond which net savings occur. Because the existing TPC case does not require additional investment, its cumulative ownership cost is 0 at the outset, whereas catalyst purchase and installation costs were considered for the combined approach and served as the basis for data normalisation. Accordingly, Figure 5 should be interpreted as a normalised economic case calculation rather than directly measured long-term accounting data from a full industrial follow-up period.

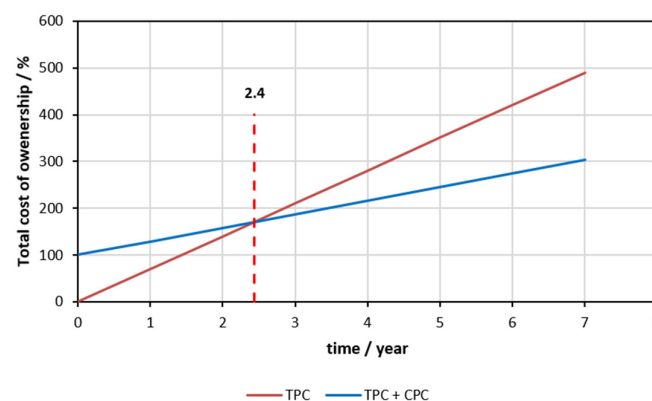


Figure 5. Return-on-investment calculation for the retrofit case shown in Figure 4 and Table 1, based on normalised CAPEX and case-specific OPEX assumptions calculated for an industrial case being installed in summer 2026.

5. High-Impact Use Cases in Aluminium Recycling and Processing

The aluminium industry is particularly well suited for catalytic post-combustion technologies due to the nature of its emissions, which can include VOCs, odorous compounds and CO, depending on process conditions.

During scrap recycling, aluminium materials often contain coatings, adhesives, oils, or plastic residues. When heated during thermal treatment processes, these contaminants release VOCs and hydrocarbons that must be removed.

Similarly, forming and machining processes such as stamping, rolling, cutting, and extrusion use lubricants and cooling oils that can produce aerosol-laden exhaust gases.

In many facilities, these emissions are treated using thermal oxidisers operated with significant safety margins. Catalytic retrofits allow these systems to maintain high decomposition efficiency while reducing energy consumption.

Industrial installations using catalysts from P&P Industries AG demonstrate VOC oxidation under fluctuating process conditions, which is relevant for scrap-processing operations where pollutant concentrations can vary.

High-impact applications include:

- Aluminium scrap pre-treatment furnaces;
- Coating-removal processes;
- Forming and stamping operations;
- Thermal treatment of lubricated metal parts;
- Surface-treatment lines.

In such applications, catalytic post-combustion enables effective treatment of fumes, solvent vapours and incomplete-oxidation products at reduced temperatures.

6. Key Findings

Retrofitting existing thermal post-combustion units with platinum-promoted honeycomb catalysts provides a practical pathway to shift VOC abatement and CO oxidation from the high-temperature TPC regime toward catalytic operation. As visualised in Figure 4, this shift is associated with a lower relative energy demand for the combined thermal–catalytic configuration compared with the TPC baseline, consistent with operation moving from approximately 800 °C toward about 400 °C.

For aluminium recycling and downstream forming applications, robustness against aerosols and typical contaminants is a primary design requirement. These challenges are addressed by the specialised formulations of the P&P PPH catalysts.

Economically, the retrofit case is characterised by low CAPEX, since major hardware (e.g., steel construction, heat exchanger, automation/safety) is assumed to be available from the existing TPC unit. Under these assumptions, OPEX shows a reduction to about 41% of the TPC baseline (see Table 1). This translates into a return on investment after approximately 2.4 years for the combined TPC/CPC operation, as indicated in Figure 5.

The combined approach of thermal and catalytic post-combustion, as presented by P&P Industries AG, enables improvements in both environmental performance and cost-effective process gas treatment in aluminium industries.

Author Contributions: Conceptualization, A.S. and J.H.; methodology, A.S. and J.H.; software, A.S.; validation, A.S., J.H. and M.F.; formal analysis, A.S.; investigation, A.S., J.H. and M.F.; resources, J.H.; data curation, P.P.; writing—original draft preparation, A.S.; writing—review and editing, J.H., P.P.; visualization, A.S.; supervision, J.H. and P.P.; project administration, P.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The original contributions presented in this study are included in the article.

Conflicts of Interest: All authors are employees of P&P Industries AG, the company whose Platinum-Promoted Honeycomb (PPH) catalysts and retrofit concept are discussed in this manuscript. The manuscript cites patent EP 4725 595 A1, 2026, attributed to Johannes Hofer. These relationships are disclosed for transparency. The authors declare no other financial or non-financial conflicts of interest.

References

1. Liu, R.; Wu, H.; Shi, J.; Xu, X.; Zhao, D.; Ng, Y.H.; Zhang, M.; Liu, S.; Ding, H. Recent progress on catalysts for catalytic oxidation of volatile organic compounds: A review. *Catal. Sci. Technol.* **2022**, *12*, 6945–6991. [CrossRef]
2. Heck, R.M.; Farrauto, R.J.; Gulati, S.T. *Catalytic Air Pollution Control*; John Wiley & Sons: Hoboken, NJ, USA, 2009; Volume 3.
3. Ertl, G.; Knözinger, H.; Schüth, F.; Weitkamp, J. *Handbook of Heterogeneous Catalysis*; Wiley-VCH Verlag GmbH & Co. KGaA: Weinheim, Germany, 2008; Volume 1.
4. Kamal, M.S.; Razzak, S.A.; Hossain, M.M. Catalytic oxidation of volatile organic compounds (VOCs)—A review. *Atmos. Environ.* **2016**, *140*, 117–134. [CrossRef]
5. EP 4725 595 A1; Insbesondere zur Umwandlung von Schwefeldioxid zu Schwefeltrioxid. European Patent Office: Munich, Germany, 2026.
6. Brummer, V.; Jecha, D.; Skryja, P.; Stehlik, P. Pilot VOC emissions mitigation by catalytic oxidation over commercial noble metal catalysts for cleaner production. *Clean Technol. Environ. Policy* **2023**, *25*, 2249–2262. [CrossRef]
7. Salomons, S.; Hayes, R.E.; Votsmeier, M.; Drochner, A.; Vogel, H.; Malmberg, S.; Gieshoff, J. On the use of mechanistic CO oxidation models with a platinum monolith catalyst. *Appl. Catal. B Environ.* **2007**, *70*, 305–313. [CrossRef]
8. Aarhaug, T.A.; Ratvik, A.P. Aluminium Primary Production Off-Gas Composition and Emissions: An Overview. *JOM* **2019**, *71*, 2966–2977. [CrossRef]
9. Neyestanaki, A.K.; Klingstedt, F.; Salmi, T.; Murzin, D.Y. Deactivation of postcombustion catalysts, a review. *Fuel* **2004**, *83*, 395–408. [CrossRef]
10. van der Vaart, D.R.; Vataavuk, W.M.; Wehe, A.H. The Cost Estimation of Thermal and Catalytic Incinerators for the Control of VOCs. *J. Air Waste Manag. Assoc.* **1991**, *41*, 497–501. [CrossRef]
11. United States Environmental Protection Agency. Air Pollution Control Cost Estimation Spreadsheet For Thermal and Catalytic Oxidizers. Available online: https://www.epa.gov/sites/default/files/2018-01/oxidizers_calc_sheet_finalversion_1-16-2018.xlsm (accessed on 1 June 2026).

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.