This Case Study demonstrates the environmental, economic and technical benefits of using ceramic filters to reduce black smoke emissions in investment casting foundries.

Incomplete combustion of wax residues during the firing of investment casting moulds can produce substantial emissions of black smoke. To comply with the Environmental Protection Act 1990, emissions from foundries must not exceed the limits specified in the Secretary of State's Process Guidance Note PG2/4(96).

Cronite Precision Castings decided against two commonly used methods for smoke abatement - afterburners and excess air - and chose instead to install ceramic filters on its rotary furnaces. Installation and commissioning were carried out over two consecutive weekends to limit adverse effects on production. The filters have proved reliable and effective, consistently reducing smoke emissions to well below the limits specified in PG2/4(96).

This Case Study has demonstrated the advantages of using ceramic filters at Cronite Precision Castings, including:

- Capital cost savings of over £15 000 compared with afterburner installations
- Low running and maintenance costs, saving £10 000/year compared with afterburner operation
- Emissions reduced to well below the limits specified in PG2/4(96)
- Technology applicable to any investment casting foundry - filters easily fitted to existing furnaces
**Black Smoke Emissions During Mould Firing**

In common with most of the industry, the production of shell moulds for investment casting at Cronite Precision Castings involves removal of the wax pattern assembly through the rapid melting of the wax in a pressurised steam autoclave (Fig 1).

The pattern assembly is designed to ensure that maximum drainage is achieved during the dewaxing process. Inevitably some wax remains after dewaxing, as a coating on internal mould walls; with more complicated shapes, over 10% of the wax can often remain trapped in internal cavities. During the initial mould-firing period, incomplete wax combustion can produce black smoke emissions (despite an excess of 10% oxygen in the burner flame). The Secretary of State’s Process Guidance Note PG2/4(96) specifies that mould firing should be free from visible smoke during normal operations and in any case should not exceed the equivalent of Ringelmann Shade 2 (40% obscuration) as described in BS2742:1969.

Cronite Precision Castings, part of the AFE Group, considered the use of several methods to reduce its black smoke emissions, including:

- afterburners to provide a second combustion stage for the wax soot;
- excess air, higher firing temperatures or loading fewer moulds to increase the combustion of wax in the firing furnace;
- ceramic filtration of emissions.

**Afterburners**

Cronite Alkast, another investment casting foundry in the AFE Group, has operated afterburners on its firing furnace for two years. In addition to high capital costs, the afterburners have high running costs, require frequent maintenance and have proved unreliable. Wax vapours interfere with the afterburner flame-detection safety system, leading to shutdown of the afterburner and the firing furnace, particularly when firing moulds with high residual wax content.

**Excess Air**

Black smoke emissions can be reduced by enhancing the conditions for wax combustion in the firing furnace through:
- increasing the air supply to the furnace;
- operating the furnace at a higher temperature;
- reducing the number of moulds loaded into the furnace.

This approach was followed by an investment casting foundry which operates a rotary furnace with four gas burners, two of which are operated on air alone. The furnace is operated at 1 200°C and is only loaded with shells to 25% of its available hearth capacity.

Cronite Precision Castings estimated that adopting a similar approach at its Crewkerne site would increase the total mould firing time by 50%, result in a 30% decrease in production during normal hours or increased overtime working, and increase fuel costs.

**Ceramic Filters**

In January 1996, having considered the alternatives, Cronite Precision Castings decided to install a ceramic filter unit on each of its two rotary furnaces. The filter units, which are self-contained and free-standing, were supplied fully assembled to allow rapid installation and commissioning - taking just one weekend for each filter unit.

The operation of a filter unit is illustrated in Fig 2. Each unit contains 36 one-metre elements constructed from vacuum-formed spun ceramic fibre. A pulse of air is blown across each element every 30 seconds to prevent a build-up of wax soot. This soot collects in a container at the bottom of the filter unit, for later disposal to landfill.

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**Fig 1** Removal of wax pattern assembly, and mould firing
A 3 kW fan draws exhaust air from the furnace through the filter unit. A pressure sensor within the furnace is linked to the filter unit control system, which adjusts a valve on the incoming air supply to the filter. This maintains a negative pressure within the furnace, minimising fugitive emissions.

**Operational Advantages**

The ceramic filter units installed at Cronite Precision Castings have proved robust and simple to operate, with low running and maintenance costs. Having few moving parts, the filters are well-suited to a high temperature, dusty and abrasive environment, requiring only routine servicing every six months to check:
- seals to the filter elements;
- condition of the ceramic filter elements;
- operational performance of the fan, pressure sensor, air supply valves, etc.

**Environmental Monitoring**

Environmental monitoring of particulate emissions from the filter units was carried out as part of the installation contract. Smoke emissions from the furnace stacks were assessed using the British Standard Ringelmann chart (BS2742:1969) and found to be less than Ringelmann Shade 2 during mould-firing operations. Four measurements were taken to compare the filter’s performance for shell moulds with different amounts of residual wax. Comparison of measurements from the filter inlet and outlet showed that the unit had arrested over 97% of particulate emissions and in all cases the emissions were under 50 mg/m³ (Table 1). The filter collects about 5 kg of soot each day.

**Economic Analysis**

The costs associated with the filter unit installation at Cronite Precision Castings are shown in Table 2. In the first year, the installation realised savings in excess of £25 000 compared with estimated costs for the use of afterburners in this application.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Particulate emissions from the filter units</th>
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<tbody>
<tr>
<td>Number of moulds</td>
<td>Number of components</td>
</tr>
<tr>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>22</td>
<td>1 584</td>
</tr>
<tr>
<td>16</td>
<td>366</td>
</tr>
<tr>
<td>10</td>
<td>20</td>
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**Table 2** Cost comparison of an afterburner and a ceramic filter unit at Cronite Precision Castings

<table>
<thead>
<tr>
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<th>Capital cost (1995 prices)</th>
<th>Annual running &amp; maintenance costs</th>
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<tbody>
<tr>
<td>Afterburner*</td>
<td>£25 - 30 000</td>
<td>£10 500</td>
</tr>
<tr>
<td>Ceramic filter**</td>
<td>£10 000</td>
<td>Fan running costs £200, Maintenance costs £300</td>
</tr>
<tr>
<td>Saving</td>
<td>£15 - 20 000</td>
<td>£10 000</td>
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</table>

* Capital cost based on enquiries by Cronite Precision Castings to afterburner suppliers guaranteeing particulate emission levels of under 50 mg/m³. Running and maintenance costs estimated, based on the afterburners in operation at Cronite Alkaid.

** As this was the first installation on a rotary recuperative furnace, the two filter units at Cronite Precision Castings were installed and commissioned for a total cost of £20 000. However, it is estimated that, at 1996 prices, a single ceramic filter unit installed at a similar site would cost about £15 000.
Cronite Precision Castings Ltd

Cronite Precision Castings at Crewkerne, Somerset, has a turnover of £3.8 million (1995) and is a division of the AFE Group. The Company employs 70 people and manufactures a wide range of precision castings, from a few grammes up to 40 kg, for the aerospace, automotive and general engineering industries.

Comments from Cronite Precision Castings Ltd

At Cronite Precision Castings, we needed to install emission abatement equipment to our rotary furnaces before April 1997 to comply with the Environmental Protection Act. We investigated the options available and, to guarantee compliance with the emission levels, we were faced with choosing between afterburners and ceramic filter units. We chose the latter and, as anticipated, the ceramic filters have provided a robust, reliable solution with very low running costs. They required only minor adjustments to obtain optimum performance and the maintenance needed is minimal.

In addition to reducing our environmental impact, the low running and maintenance costs have allowed us to maintain our competitive edge in the production of high quality investment castings. We believe that the solution offered by ceramic filters is the most practical approach for the investment casting industry. Indeed, the results achieved at Cronite Precision Castings led me to specify ceramic filtration when purchasing a new firing furnace for Cronite Alkast.

Mr D Bond
Managing Director
Cronite Precision Castings Ltd

“...the ceramic filters have provided a robust, reliable solution with very low running costs.”

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Host Company: Cronite Precision Castings Ltd, Blacknell Lane, Crewkerne, Somerset TA18 7HE
Monitoring Company: March Consulting Group, Telegraphic House, Waterfront Quay, Salford Quays, Manchester M5 2XW
Tel No: 0161 872 3676
Fax No: 0161 848 0181
Mr J Reynolds

Equipment Manufacturer:* Glosfume Environmental Controls Ltd, 1 Shire Business Park, Wainwright Road, Worcester WR4 9FA
Tel No: 01905 457220
Fax No: 01905 457877
Mr C Withers

Equipment Supplier:* Castings Development Centre, 7 East Bank Road, Sheffield S2 3PT
Tel No: 0114 272 8647
Fax No: 0114 273 0852
Mr P Lodge

*There may be other suppliers and manufacturers of similar equipment. Please consult your trade directories or contact the Environmental Helpline which may be able to give you more details on request.