Aga-Rayburn

A case study of our work together
Case Study

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Kitchen range manufacturer Aga-Rayburn is a very traditional firm, yet at the same time one that is keen to exploit new technology. At the company’s Coalbrookdale foundry, the Air Products APCOS™ oxy-fuel injection system has cut coke consumption in two cupola furnaces by nearly 40%. The project is saving over £132 000 a year and has also improved operating flexibility.
So many companies claim to combine tradition with innovation that it's easy to feel the phrase has lost its meaning. That is, until you discover a foundry that can trace its origins back to the start of the industrial revolution, yet remains at the leading edge of furnace technology.

Aga-Rayburn’s iron foundry at Coalbrookdale, Shropshire, stands near the site on which iron was first smelted using coke instead of charcoal, at the beginning of the 18th century. Nearly three centuries later, the foundry has played an important role helping Air Products develop its pioneering APCOS™ technology for firing cupola melting furnaces with oxygen and natural gas.

Largely thanks to APCOS™, Aga-Rayburn has been able to raise the thermal efficiency of its two small cold-blast cupolas from less than 30% to more than 45% — a performance that more than matches that of long-campaign, hot-blast cupolas. Coke consumption has fallen by 38%, from around 145 kg per tonne of iron melted to 90 kg/t iron. Melting capacity has increased from 6 t/h to more than 12 t/h, sulphur levels are lower, heating time is shorter and the furnaces are easier to control.

APCOS™ has eliminated the need to add pig iron and manganese to the charge, and the foundry can now control silicon levels using
ferrosilicon dust instead of the more expensive ferrosilicon briquettes. Emissions of sulphur and nitrogen oxides and carbon dioxide have fallen, and soon Coalbrookdale plans to reduce its solid waste too by taking advantage of the system's ability to inject dust back into the furnace. So far, Aga-Rayburn estimates the total saving at £132 000 a year.

“This is a good idea that works,” says Tom Hogan, technical manager at the Coalbrookdale foundry. “We’re pretty chuffed with it, actually.”

**Plant with a past**

Coalbrookdale on the river Severn has been the site of iron working since the early 16th century. In 1709 the ironmaster Abraham Darby used Coalbrookdale as the base for his new smelting process, in which coke replaced the increasingly expensive charcoal. By 1779, when the famous iron bridge over the Severn was built, Coalbrookdale was also equipped with cupola furnaces for melting pig iron.

After more than a century at the forefront of the industrial revolution, most of Coalbrookdale now enjoys peaceful retirement as the Ironbridge Gorge industrial museum. But thanks to the lasting popularity of cast-iron stoves and kitchen ranges, the foundry now operated by Aga-Rayburn remains very much a working site.
Coke has been the primary fuel for cupola furnaces since the 18th century.
In the 1930s Coalbrookdale’s then owner, Allied Iron, developed its best-selling Rayburn stoves there. In the 1950s Allied Iron bought the stove business of Swedish company Aga, which had a factory in nearby Telford, and Aga-Rayburn was born. In 1963, when the Glynwed engineering group acquired Allied Iron, the Telford factory became the assembly site for both product lines, while Coalbrookdale made the castings.

At the heart of the foundry are the two cold-blast, acid-lined, short-campaign cupolas, each with eight 150-mm tuyeres in a shell diameter of 2130 mm. Before the APCOS™ system was installed, the cupolas used a lining thickness of around 480 mm to give a nominal internal diameter of 1170 mm.

Small but perfectly formed
With a melt rate of around 6.5 t/h and castings weighing less than 150 kg the Coalbrookdale foundry is small, but its technical requirements are fairly stringent. Although strength is not the main issue, the thin cross-sections of many of the stove parts make good casting technique essential. Even more important is surface finish. The vitreous enamelling process applied to most of the components costs more than the casting itself, so it is essential to avoid impurities that could spoil the surface finish. In particular, this means keeping sulphur levels below 0.1%.
Thin cross section castings produced at Coalbrookdale.
The idea of using oxy-fuel burners to reduce coke consumption came to Tom Hogan in 1996, when he heard a conference presentation on APCOS™. At that time APCOS™ was mainly used to dispose of baghouse dust and other foundry wastes by incorporating it into the cupola slag. Waste disposal continues to be an important application for APCOS™, especially in countries such as Germany where landfill costs are high. Tom Hogan’s thoughts, however, turned more towards saving money by replacing coke with natural gas.

Back in 1992 he had worked with Robert Mills from the Air Products Commercial Technology team, to install an oxygen system that provided up to 5% oxygen enrichment using “through tuyere” injection. Now it looked as if the time was right to see what else could be done with oxygen. Together, Tom Hogan, Gary Heayn and Chris Thomas (also from the Commercial Technology team) explored the idea of using APCOS™ to cut coke consumption.

To pay for itself, they calculated, the system would have to allow the coke level in the charge to be reduced to around 11%, from the existing figure of 15%. Gary Heayn worked out the amount of gas the system would require, and specified suitable burners.

Aga-Rayburn also spoke to other gas suppliers, but found that the oxy-gas injection systems they offered all required water cooling. “The fact that
The APCOS™ burner installed on the cupola.
only Air Products had a burner that didn’t need a big cooling system as well was a major benefit. That combined with the technical support that Air Products were able to give sealed it for us,” says Tom Hogan.

**Lighting-up time**

Two new oxy-fuel burners were fitted to one of the cupolas, and on 10 August 1998 the APCOS™ system was commissioned using a charge containing 14% coke. By the end of the first week the coke level was down to 9–10%, and one week later Aga-Rayburn was able to show that oxy-fuel firing would work satisfactorily at a coke level of only 6–7%.

The cupolas needed several modifications apart from the APCOS™ burners themselves. First were the tuyeres. The use of oxy-gas combustion resulted in a big drop in the volume of air passing through the tuyeres. To maintain the correct gas velocities, Aga-Rayburn used sleeves to reduce the diameter of the tuyeres from 150 mm to 125 mm, and cut the number of tuyeres from eight to six.

The lower gas volumes also gave rise to lower pressures inside the cupola, which in turn produced some difficulties in controlling the levels of molten metal and slag. To start with, the slag level rose to the point where it attacked the burner tips, giving a burner life of only a week. The project team was able to cure the problem
by lowering the weirs controlling the slag and iron levels, lowering the taphole and raising the three tuyeres carrying the burners.

Increased melt rate caused some difficulties. With a charge containing only 6–7% coke, the burners gave us a melt rate of 13 t/h, or twice the required figure.

The first step towards reducing the melt rate to the desired 6–7 t/h was to increase the coke charged to 9%. Next, the project team tried reducing the internal diameter of the cupola from 1170 mm to 760 mm by increasing the refractory thickness. Unfortunately the resulting high temperatures at the inside face of the refractory gave unacceptably short refractory life. In the end, says Tom Hogan, they compromised on an internal diameter of 915–965 mm. The instantaneous melt rate is still higher than necessary, but because the cupolas now heat up much more quickly than before, they can be controlled simply by turning the cupola on and off.

Once the oxy-fuel burners were running satisfactorily, the second phase of the project added an injection system for ferrosilicon dust. The injectors worked well as long as the firing rate and injection rate remained constant, says Tom Hogan, but tended to block whenever the system was shut down and started up again. The team managed to solve this problem by adjusting the control system so that it ramps down the
injection rate before shutting down the cupola, and ramps it up again during start-up.

Reaping the rewards
The oxy-fuel burners have been working satisfactorily since November 1998, and the rewards are clear. “It’s been adopted by all the operatives,” says Tom Hogan. “They all know how to work the system, and now they wouldn’t be without it.”

Coke use has stabilised at 9% of the charge weight, or 90 kg per tonne of iron melted, compared to 15% previously. With flame temperatures of up to 2700°C, the cupolas reach their tapping temperature of 1500–1530°C much more quickly and are easier to control. “It used to be that after an hour’s shutdown we would be blowing for 30 or 40 minutes to get back up to temperature. Now it takes just four or five minutes,” says Tom Hogan.

Sulphur control has been another big success. Because natural gas contains virtually no sulphur, metal melted during the initial trials contained as little as 0.04% sulphur, compared to the target figure of around 0.14%. Originally the foundry had two strategies for controlling sulphur: the use of around 20% pig iron in the charge, and manganese addition. Now the cupolas run without pig iron or manganese, yet sulphur levels are still only around 0.09%. The improved surface finish that results from having lower
The APCOS™ system has been proven to be very user friendly.
sulphur has even eliminated the need for the castings to be annealed before the vitreous enamel is applied.

Before APCOSTM, carbon levels were also controlled by adding pig iron to the charge. Better carbon pickup and lower sulphur with oxygen combustion has allowed the pig iron, costing £140 /t, to be entirely replaced by scrap at £60 /t.

Injecting ferrosilicon dust instead of adding ferrosilicon briquettes or high-silicon pig iron saves up to £200 per tonne of silicon. In addition, silicon losses have fallen from 30% to 20%, and injection directly into the melt zone gives faster and better control of silicon levels.

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<thead>
<tr>
<th></th>
<th>Without APCOS™</th>
<th>Utilising APCOS™</th>
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<tbody>
<tr>
<td>General</td>
<td></td>
<td></td>
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<tr>
<td>Coke rate</td>
<td>15% of metallics</td>
<td>9.5% - 6.0% of metallics</td>
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<tr>
<td>Conventional oxygen</td>
<td>14 Nm³/tn Fe</td>
<td>14 Nm³/tn Fe</td>
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<tr>
<td>Enrichment (through tuyere injectors)</td>
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<td>Blast Air Volume (scfm)</td>
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<td>2700</td>
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<td>Alloy Additions</td>
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<td>FeSi Briquettes/500kg</td>
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<tr>
<td>FeMn</td>
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<tr>
<td>Tapped Analysis (%)</td>
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<td>S</td>
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<td>0.08</td>
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<tr>
<td>Tapping Temperature</td>
<td>1520 - 1550°C</td>
<td>1520 - 1640°C</td>
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<tr>
<td>Waste Generation</td>
<td>Baghouse/Filter</td>
<td>15.7 kg/tn Fe melted</td>
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<tr>
<td>Energy</td>
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<tr>
<td>Overall thermal efficiency</td>
<td>34%</td>
<td>42% - +50%</td>
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*Performance results at the Coalbrookdale foundry*
Substituting natural gas for coke has cut the amount of carbon dioxide generated by almost half, from 448 kg to 246 kg per tonne of iron. The reduced airflow through the cupolas means less nitrogen oxides, and the amount of dust generated has fallen by 30%. Sulphur dioxide emissions are also very low. Tom Hogan also added “Our environmental performance has improved and we now have spare capacity in our filter plant. Should we want to increase production significantly in the future we will be able to do so without having to carry out further investment on fume control.”

“So far, the overall savings are around £132 000 per annum”, says Tom Hogan, “this is a significant amount for a foundry the size of Coalbrookdale”.

The final piece of the jigsaw will be to use the injection system to dispose of foundry waste. Trials with APCOSTM elsewhere have shown that it is possible to inject up to 80 kg of material per tonne of iron without compromising metal quality.

Although Coalbrookdale does not currently need the extra capacity offered by the APCOSTM system, the ability to double the melt rate will probably be useful in the future, says Tom Hogan. The APCOSTM project is part of a £2.5 million investment project at the foundry to achieve quality improvements and meet rising demand for Aga and Rayburn stoves. “At most foundries, melt rate is the bottleneck,” says Tom Hogan. “Thanks to the APCOSTM system, that’s not the case here.”