

Co-combustion considerations

Christian Helmreich and Klaus Eichas, ROCKTEQ GmbH, discuss the various adaptations cement plants must make to their pyroprocess in order to achieve the efficient combustion of alternative fuels.

The co-combustion of alternative fuels (AF) which are called solid recovered fuels (SRF) or coarser refuse-derived fuels (RDF) is now a very common technology in cement kilns with and has been in-use for around 25 years now. This article reflects the technical developments in combustion engineering working with solid alternative fuels in the main burner providing an outlook into the future of pyroprocessing.

Historic development of AF co-combustion on main burners:

The first co-combustion of solid alternative fuels was trialled in Europe during the 90s, beginning with smaller wood chips and fuel derived from residues and waste. Shredded and pre-sorted residues were injected into the

kiln due to the high process temperature. AF injection means burning the solid alternative fuel at the main burner. It follows that tyres are fed into the kiln inlet and coarser RDF is fed to the calciner.

During this time, in the early 90s, the 3-channel kiln burner was the industry-standard burner in cement production (see Figure 1A) which was designed for coal, oil, or natural gas as its fuels. That design included an axial air channel with a ring-type tip, a coal channel with a divergent outlet nozzle tip, and an inner radial air channel with a radial air swirler of 20 – 40° in the flow direction.

The first trials of solid AF co-incineration were made with those adapted 3-channel-kiln burners with basic pneumatic feeding equipment with a steel pipe to the centre of the burner. Some burners were adapted simply by removing the oil gun from the burner's centre and using that oil gun carrier pipe for the pneumatic injection of SRF. The low classified fuel was burned together with coal, with a low thermal substitution rate (TSR). Restarting the burner without the oil gun was difficult as was the handling of the oil gun. A few 3-channel-burners have been modified as shown in Figure 1B with a half-moon-shaped SRF channel in the burner centre while keeping an oil gun and ignitor for normal operation.

Another burner modification made for alternative fuels was to install an external AF feeding pipe at the top of the main burner (backpack) in order to inject solid alternative fuels (see Figure 1B2). The co-incineration

was working sufficiently with an average burner momentum of 3 – 5 N/MW, but the TSR was still low.

In parallel, the development of low NO_x burners came up. Simply stated, the low NO_x technology works on the principle of staged combustion in order to avoid high flame temperatures. The primary air channels (axial and radial air) are located outside the *main fuel coal*, while in the flame centre recirculation zones are created along with a minimised O₂ content.

This mechanism avoids immediate fuel ignition and fast combustion reactions enabling a reduction in the high peak flame temperatures followed by high thermal NO_x emissions.

The low NO_x-designed kiln burners with their lower combustion peak temperature and longer flames did not align with the updated technical requirements. Subsequently, a new generation of burner was born (see Figure 1C). These new multifuel-burners were designed to work with at least three different fuels such as coal, oil, and SRF in the burner centre, and compatible with up to six different fuels. Since this point, a significant design change has taken place. The burner momentum and outer burner diameter were enlarged by the centrally arranged SRF pipe(s). Some kiln burners were equipped with an additional gas channel for start-up or full operation cases, which increased the burner in diameter and weight once more.

According to the burner supplier's technological philosophies, kiln burners were

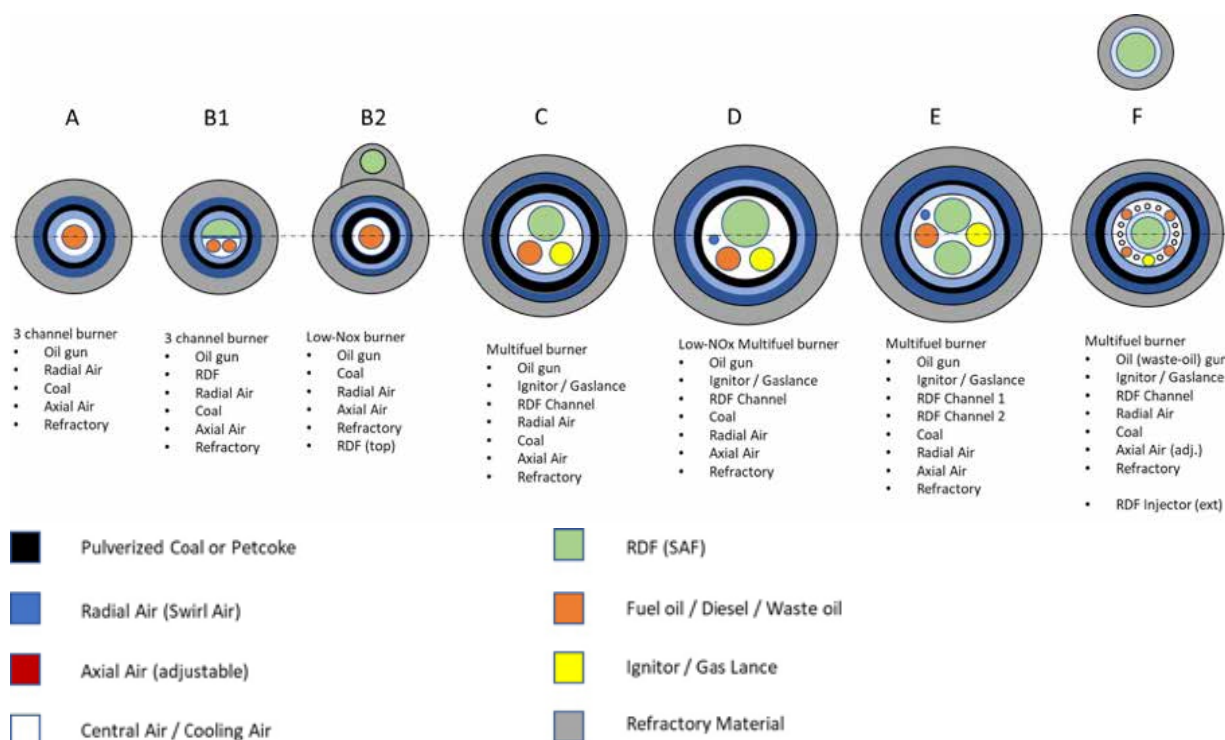


Figure 1.

engineered as multi-fuel burners according to low NO_x principles or in a 3-channel arrangement (see the difference between Figure 1C and Figure 1D). **To be precise, the position of radial air was inside coal or outside coal, as the major channel arrangement difference**. Besides that, the design and shape of the primary air tips were quite different with all suppliers. Most of them were showing a ring-type primary air / axial air nozzle-tip.

Some suppliers were already aware of the technological advantages of the free-jet design for primary air. Producers of kiln burners such as GRECO (Flexiflame), KHD (Pyrojet), Unitherm (M.A.S.) were supplying their burners according to the aerodynamic multiple air-jet design. Secondary air of a considerably higher temperature is drawn into the flame by the recirculation suction effect of the free-jets. In addition, the higher TSR along with and increased SRF/RDF mass-flow required a higher burner momentum of between 7 – 12 N/MW.

The enlarged outer diameter of the burner, in particular the larger diameter of the coal/pet coke channel, is due to the larger inner channel intended for carrying the SRF/RDF pipe(s), fuel oil gun, ignitor, and/or gas lances and requires special attention to the design of coal channel (see the difference between Figure 1D and Figure 1E). The hydraulic diameter and distance of the coal channel as well as the coal loading factor, all influence the ignition behaviour, combustion characteristics, and the

flame shape of the burner. Special attention needs to be taken when engineering the kiln burner for the co-incinerating of SRF with a high TSR to reduce the double-flame effect.

The NO_x emissions of kiln burners working with alternative fuels are typically low. The moisture content of SRF/RDF reduces the core flame temperature, its water content needs to be evaporated first until the fuel particles can be ignited and burned. There are pros and cons to a low NO_x burner design in combination with alternative fuel firing. These mainly depend on the fuel characteristics as well as the oxygen availability, clinker quality, kiln conditions, and secondary air temperature, amongst other factors. *Although not ideal for a high TSR, lower NO_x emissions from the main burner help to control the secondary measures for NO_x emission reduction.*

Today's kiln burner design:

All kin burners which are currently in use in the cement industry are designed for a multi-fuel operation. In the last 10 years, all kiln burner suppliers have changed their burner tips from a ring-slot to a multiple air-jet nozzle design if they were not using this design previously. It is obvious that the air jet design has the advantage of faster fuel ignition, better dispersion of AF in the flame (higher recirculation's), and therefore a higher clinker quality. Not to forget that those burners are working with an increased axial burner momentum of up to 7 – 12 N/MW, (because the SRF/RDF requires a greater oxygen

Table 1.

| | Pillard Novaflam Evo | Unitherm DT | ROCKTEQ | Dynamis D-Flame | KHD Pyrojet | FLS Jetflex plus | FCT Turbu-Flex |
|------------------------------------|----------------------------|---------------------------|--------------------------------|-----------------------|-----------------------|--|--|
| All fuels in coaxial design | no | no | yes | yes | no | no | no |
| Axial air (AA) | fixed | adjustable | fixed | fixed | fixed | adjustable | fixed |
| Axial air (AA) design | multiple, not uniform jets | rectangular-multiple jets | rectangular-multiple jets | multiple uniform jets | multiple uniform jets | multiple slot-jets | multiple, not uniform jets |
| Radial or swirl air (RA) | adjustable | fixed | fixed | fixed | fixed | fixed | fixed |
| Tangential air (TA) | n.a. | n.a. | n.a. | yes | n.a. | n.a. | depends |
| Radial air (RA) position | outside coal | CA inside coal | inside coal | inside coal | inside coal | inside coal | inside coal |
| Special AF Tool | air jets | pneuno-deflector | lifting air | support air | swirl air | pipe in pipe | AF Boost mode |
| | situated around AF-pipe | lifting air for AF | central air jets under AF-Pipe | under AF-pipe | pneumatic swirl | turning of axial jets to AF & retract inner tube | change of AA nozzle flow pattern (RDF swirl-air) |
| Air blower (up to 0,8bar) | - | - | AA | AA | AA + RA | - | AA |
| Radial air fan | AA + RA + CA | AA + CA | RA + CA | RA + TA | - | AA + RA | RA |

availability) while the mass of fuel and transport air is not considered in the formula.

ROCKTEQ has always designed its high momentum kiln burners in axis-symmetric design (see Figure 1F), with the aim of a stable, hot and short flame to maximise the RDF utilisation in the kiln. An additional smaller and adjustable SRF satellite burner situated above the kiln burner inside the kiln hood is offered to inject SRF directly into the hot secondary air with higher O₂ availability, faster ignition and an enlarged burnout time, to avoid premature fuel drop-out into the clinker bed. The kiln burner diameter can be designed smaller, which is favourable for coal combustion resulting in a shorter, more uniform flame shape.

Fuels:

Coal:

When changing fuel change from coal to pet coke along with a change in the volatile matter or LHV heating value, it is recommended to adjust the outlet speed of pulverised fuel in order to control the flame formation in accordance with the volatile matter, plume distance, and flame length (combustion reaction time). The outlet speed can be adjusted either by:

- ▶ Conical design of coal nozzle with compensator setting.
- ▶ Varying the transport airspeed by air adding air at the burner.

| Table 2. | |
|-----------------|---|
| | CO ₂ emissions (g CO ₂ /MJ) |
| Pet coke | 101 |
| Coal | 96 |
| Tyres | 85 |
| Plastics | 75 |
| Waste oil | 74 |
| Natural gas | 54 |
| RDF | 9 |
| Animal meal | 0 |
| Waste wood | 0 |
| Straw/rice-husk | 0 |

Having none of these tools in the main burner is not ideal for setting the flame. Achieving an especially high TSR requires a good understanding of the combustion mechanism as the coal mass-flow rate decreases in favour of higher AF usage-rates *concerning double flame formation*.

When using hard-to-ignite fuels with low volatile matter like pet coke or anthracite, theoretically the fineness can be reduced by finer grinding for a faster ignition (smaller particles have a smaller surface and are ignited faster), but with higher grinding costs (OPEX).

Injection of alternative fuels (AF):

Most of the burner suppliers have tools or equipment to influence the centrally arranged AF injection tube, to reduce fuel drop-out onto the clinker bed. A simple acceleration in AF delivery can lead to it shooting through the flame along with a double-flame formation which creates worse conditions for the clinker. A high free lime, and reduced C₄AF, content, and a brownish colour can be observed in the clinker produced in these conditions. Research has confirmed that kiln-burner designs with a higher O₂ availability inside the flame centre will promote the ignition reaction, especially for AF.

When increasing the thermal substitution rate for AF at the kiln, it is recommended to install a satellite burner. The satellite burner's has advantages in AF-combustion control are:

- ▶ Higher oxygen availability.
- ▶ Pre-drying of AF by secondary air before ignition.
- ▶ Adjustable AF-trajectory independent of the main burner.
- ▶ Higher fuel retention time for burn-out.
- ▶ Less cooling of main burners flame.

When considering that a typical 2-dimensional plastic foil with a size of 30 x 30mm (1.18 x 1.18 in.) is 74 000-times heavier than a coal particle, it is clear that that combustion reaction is much delayed in relation to coal. The combustion reaction characteristics of AF are evaporating the fuel moisture (water content) → followed by devolatilisation of volatile matters → ignition (at 300 – 500°C) → char burn-out.

CO₂ Emission reductions:

SRF/RDFs with organic components have a big advantage, as they reduce CO₂ emissions and CO₂ certificates (see table 2). The use of organic fuels like saw dust, dry sewage sludge, or any other biological fuel reduces fuel costs and may also reduce dependencies on AF fuel suppliers.

The disadvantage is the low LHV as well as the higher moisture content with a delay-time in the combustion process. The drying of fuel moisture and a well-designed fuel feeding and combustion concept would allow a very high TSR and an increased clinker quality when using alternative fuels.

The AF-Booster System®:

ROCKTEQ will soon present a new system to pre-process RDF/SRF as it reduces the fuel moisture using a two-step drying process and classifies the RDF/SRF for the ideal preparation for the combustion process at the right injection point to increase the TSR above 90%. The alternative fuel will be controlled and prepared to reduce the ignition time, enhance the pyrolysis process and reduce the overall flame length, which means avoiding longer double flames. The clinker quality can be maintained by reduced fuel drop-out. The biomass content can be increased therefore, thus more costly CO₂ emissions are reduced. In the end, the result is an OPEX saving on fuel costs and CO₂ certificates along with a higher flexibility in the AF-fuel market.

Future outlook:

The use of oxyfuel or hydrogen in the main burner is not very complicated, modifications can be made, but the investment in infrastructure needs to happen. For the short term, the increased usage of less climate-damaging fuels (see Table 2) is necessary. The increased use of classified and dried AFs with biomass has the potential to reduce CO₂ emissions on the way to finally reach the net zero CO₂ emission goal in 2050.

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