Back to Basics: Proven Techniques for Emissions Reduction in Today's Furnaces

By Jim Checkeye, Bloom Engineering Company, Inc.

The subject of decarbonization has received a lot of attention in the aluminum industry, as companies make efforts to reduce the amount of CO_2 emitted per quantity of metal produced. In the secondary aluminum industry, a significant amount of energy is used to process this wonderful (and infinitely recyclable) metal. Natural gas is the primary fuel of choice these days. Since it is a hydrocarbon (containing carbon, which converts to CO_2 in the combustion process), many are looking at alternative fuels, such as hydrogen, to mitigate their overall carbon (CO_2) output. However, until such fuels become more readily available, what can be done at present?

There are numerous things that can be done today with furnaces, and their combustion systems, to make a significant impact, while still being ready for hydrogen or any other low or no-carbon fuel in the future. Proven techniques exist that consistently increase efficiency, lower fuel usage, and thereby reduce CO_2 output.

Furnace Pressure Control

The key features of good furnace pressure control are an appropriately sized flue and damper arrangement. Flue sizing should consider the volumetric flow of products of combustion (POC). Flues are typically sized based on target velocities at the furnace's operating temperature and/or pressure drop calculations. When designing a flue and pressure control damper arrangement, it is important to understand how the combustion system will be designed to operate. Both maximum and minimum firing rates need to be determined. In the case of certain burner systems, such as regenerative, roughly 80% of the POC is extracted via a path other than the flue (through the exhausting burner and eventually an extraction fan). All such aspects need to be considered.

Without good furnace pressure control, one of two major things can happen, and neither is desirable. First, if the pressure gets too high, hot gases will exit at any opening, gap, or leaky seal. If the hot gases are being forced out around the door perimeter, damage is going to happen.

But this is not the worst of it. Second, if the furnace pressure becomes negative, ambient air will be drafted into the furnace from any available gap. Keeping furnace door seals clean and well maintained is critical to helping keep out unwanted air should the furnace pressure become negative. All ambient air that comes into the furnace will be heated from the ambient furnace heat until it reaches the furnace's temperature, robbing the process of energy *(Figure 1)*. Aside from efficiency impacts, there are other reasons to keep out unwanted air. Increases of air leaking into the furnace will elevate the furnace atmosphere's oxygen concentration, leading to increased melt loss of the case of molten furnaces, and increased NO_X emissions.

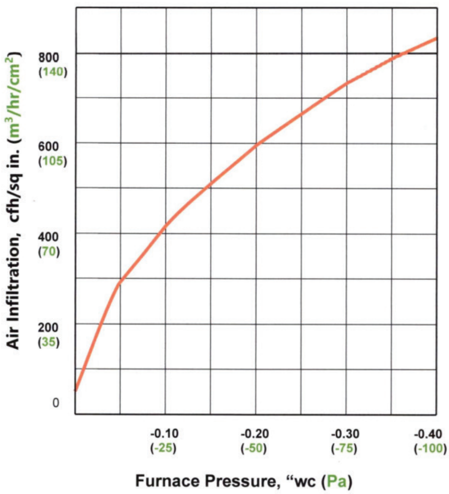

Figure 1: Furnace pressure graph, showing how negative furnace pressure affects air infiltration

Here are some key thoughts on furnace pressure control. Identify the process and furnace operation parameters. Review and double-check flue size against these parameters. In most cases, if the flue size is off, it is more often larger than it needs to be. Reducing the flue size is easier than making it larger. If the system currently has a furnace pressure device (damper of some sort), does it work as needed? If not, can it be modified to do so? These devices must walk a fine line between being robust enough to survive at the temperatures they need to work in, while providing good control, and also need to be maintainable. If the system does not have a furnace pressure control device, why not? Any attempt to control furnace pressure is better than none. Keep an eye on furnace pressure readings and look at the damper now and again to make sure it moves as the combustion system power modulates. And always make sure the furnace pressure port is clear.

Air-to-Fuel Ratio Control

Optimized combustion requires delivering the correct proportions of air (the most common source of oxidant) and fuel to the burners. The chemically perfect amount of oxidant-to-fuel is referred to as stoichiometric. While over the years flow measurement and flow control components have advanced significantly, providing improvements in accuracy, the measurements and control are not guaranteed to be wholly accurate given several factors. Taking this into consideration, delivering less than the required amount of air will rapidly result in very high levels of carbon monoxide (CO). To avoid the likelihood of this happening, ratio systems are set to operate with excess air (often noted as "XSA"). However, too much XSA will result in a loss of combustion efficiency and can have adverse effects on processes sensitive to higher levels of oxygen in the furnace atmosphere. An example of this would be increased dross. Higher levels of XSA can also lead to NO_X emission increases with most burner types. A typical setting for aluminum applications is 10% XSA (meaning there is 10% more air than is required for a stoichiometric condition). The resulting furnace atmosphere, barring any tramp air leaking into the furnace, is approximately 2% O_2 (dv).

The proper sizing of flow measurement and control devices is essential, whether installed to control each burner individually or for multi-burner zone control. Placement of devices within the system relative to each other, and proximity to other line devices or pipe fittings must also be taken into careful consideration. Flow measurement can also take measured line pressure and fluid temperature into consideration, by using a multi-variable transmitter, which further enhances the accuracy of the system. Then, when variables change, the system can adjust accordingly. For example, the combustion air supply in winter when it is 10°F outside versus mid-summer when it's over 90°F can have an impact on how the system performs. With this improved measurement technique, aluminum operations can know these variables are being considered.

The first step that should be taken is proper tuning of the control system in place, including identifying any obvious installation shortcomings that would affect accuracy. Secondly, consider upgrading to a better measurement and flow control system, if warranted.

Heat Recovery

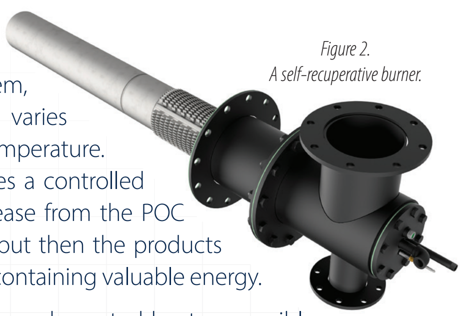

Figure 2.
A self-recuperative burner.

For a typical ambient air combustion system, the available heat (or combustion efficiency) varies significantly based on the furnace's operating temperature. The mixing and burning of air and fuel creates a controlled heat release within the furnace. This heat release from the POC provides work to the load, giving up energy, but then the products still escape the furnace at a high temperature, containing valuable energy.

Heat recovery is the method of capturing as much wasted heat as possible and reintegrating it back into the process. Since all the energy value of the fuel has already been paid for, utilizing heat recovery is advantageous. Several well-known techniques are available, including recuperators, regenerative burners, and specific furnace design. Note that this article does not intend to delve into significant detail on all these subtopics. Rather, it simply aims to highlight them. All applications presented should be reviewed by a knowledgeable professional before implementation.

One method is to use a recuperator, which is a device that extracts thermal energy from the POC and transfers it to the combustion air. A central recuperator is one option, installed after the furnace's flue, allowing all hot gases to pass through it. In this arrangement, the combustion air also flows through the recuperator, which is most commonly separated by a steel barrier from the POC, facilitating the transfer of heat from the hot POC to the incoming ambient combustion air. This is a fairly straightforward and effective process.

Alternatively, each burner can have a small recuperator built into it *(Figure 2, above)*, commonly referred to as a self-recuperative burner. In this scenario, hot POC is extracted from the furnace at each burner nozzle, enabling the heat transfer from POC to combustion air to occur within the burner itself.

Next is regenerative burner technology *(Figure 3)*. A regenerative combustion system uses a pair of burners, each of which has a media case filled with dense ceramic material, which periodically alternate between firing and exhausting. When exhausting, hot combustion products are pulled from the furnace through the burner head and its accompanying media case, increasing the temperature of the ceramic media, nearing the furnace temperature. When firing, cold air flows through the media case, increasing in temperature to provide oxygen for combustion. After a set period, the burners "cycle" and the previously exhausting burner transitions to firing mode. Regenerative burners capture and return most of the energy contained in the furnace's waste gases, thereby providing exceptional fuel efficiency for high process temperature applications.

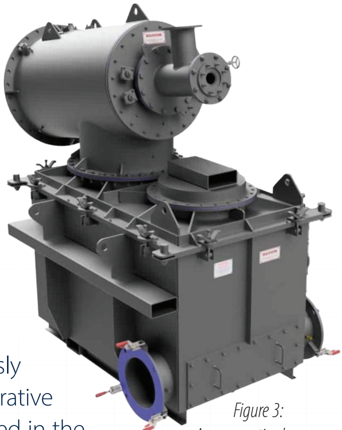

Figure 3: A regenerative burner.

The final heat recovery method is not specifically a device, but rather a furnace design approach, where heat-containing furnace POC is passed directly over the cold charge material. Two methods for this are tower melters and furnace flue sweat boxes. A tower melter is a furnace in which the cold-solid metal is charged into the specially shaped furnace flue. When charged properly and continuously, the POCs will pass through the nested charge, losing heat to it. Properly charged and operated tower melters can achieve excellent efficiencies, resulting in low specific gas consumptions rivaling those of regenerative systems. Tower melters can be used for specific applications.

A sweat box is typically accomplished by a door installed on the back of an appropriately designed furnace flue, relatively near to floor level. T-bar or sow ingot are loaded into the flue via the door, allowing them to absorb heat from the flue gases. This method is not to be compared to the effectiveness of a tower melter, but does provide an efficiency benefit.

Conclusion

In closing, furnace pressure control, air-to-fuel ratio control, and heat recovery have been in practice for years. Improvements have been made in every category since the concepts were initially introduced. Take the time to investigate them, reaping the benefits they provide in terms of efficiency and emissions reduction. As shared before, regardless of what fuel aluminum plants are using or will eventually use, it's important that they do it as efficiently as possible!