Advancements in burner designs, recuperative systems, and pulse-fired control algorithms are just a few of the technological improvements available to the heat treating/thermal processing industries to reduce energy costs.

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In today’s competitive market environment, heat treaters must focus on higher productivity, lower costs, increased product quality, and reduced environmental impact. Therefore, increasing throughput while simultaneously reducing per-unit fuel consumption and pollutant emissions are the keys to current and future success in the industry. Meeting the challenges to achieve these objectives will a large part be tied to improving the combustion system through the use of:

- Air/fuel ratio control
- Preventative maintenance
- Pulse firing
- Preheated air
- Recuperative systems

**Air/fuel ratio control.** While improvements, upgrades, and replacements of furnace systems, controls, and burners will help to achieve the above objectives, an area that cannot be overlooked is simple air/fuel ratio control. Assuming a cold air combustion system with 1900°F (1040°C) furnace exhaust temperature, simply tuning the burners to operate with 10% excess air rather than 30% excess air will result in a 15% fuel savings. Few companies would argue over saving 15% in what is often the highest cost of production.

**Preventative maintenance.** The best maintenance practices, such as repairing worn or damaged refractory or insulation, checking door seals, and ensuring positive furnace pressure via exhaust damper operation, will go a long way toward increasing overall furnace efficiency. Maintaining proper air/fuel ratio of the combustion system and eliminating air infiltration into the furnace not only will maximize fuel efficiency, but also will typically lower NOx emissions. A few hours spent on combustion system tuning and maintenance every six months can result in significant, on-going energy savings.

**Pulse firing.** Many heat-treating operations have used pulse-fired combustion control systems resulting in reduced fuel consumption, excellent temperature uniformity (product quality) and, in many cases, lower emissions. Pulse firing uses multiple high-velocity burners that fire high-

**Fig. 1 — Fuel savings versus air preheat temperature at a furnace temperature of 1900°F (1040°C).**
off or high-low to control tempera-
ture input. Burners are at or near their
maximum firing rates when “on.”
Therefore, they yield the highest pos-
sible convective heat transfer, which
continuously moves the products of
combustion (POC) through the en-
tire furnace resulting in excellent
temperature uniformity, and, there-
fore, the best product quality pos-
sible. Furthermore, this frequency-
firing method will reduce fuel
consumption because the burners are
only firing at their most efficient high
fire rating, which maximizes the en-
ergy reaching the product. Pulse
firing will actually reduce pollutant
emissions like NOx because typical
high velocity burners actually pro-
duce higher concentrations of NOx
at lower firing rates (with turndown).

Preheated air. While heat treating
processes are implemented in dif-
fering furnace designs with a variety
of control methodologies and atmos-
pheres, the principles behind re-
ducing per-unit cost via improved
combustion system efficiency (oth-
erwise known as available heat)
are similar. Preheating the com-
bustion air is a well-known,
effective technique to re-
duce fuel consumption. As
carbon dioxide (CO₂) emis-
sions come under more strict
government regulations, additional
benefits of preheating the combus-
tion air include reduced CO₂ emis-
sions as well as increased produc-
tivity via increased furnace through-
put. Figure 1 shows a graph of fuel
savings versus air preheat tempera-
ture at a furnace temperature of
1900°F.

How does preheated air save fuel?
• Preheating the combustion air
reduces the heat required for pro-
duction of combustion to reach exhaust
gas temperature, resulting in less fuel
required to do the same work
• Flame temperature is increased
• More heat is available to heat the
load or do useful work

Recuperative systems. Air pre-
heating techniques include the use
of plug-in recuperators (Fig. 2) or
single-ended radiant tube burners
for indirect firing, and central recu-
perators or regenerators for direct
fired furnaces.

Recent technology advancements
in direct-firing applications include
a recuperator direct coupled or inte-
grated into the burner design such
that the flue products from the fur-
nace are educted or drawn around
the recuperator to preheat the com-
bustion air to the burner (Fig. 3). Such
designs are being widely imple-
mented not only for their efficiency
but for their simplicity of field piping
and burner setup.

Burners equipped with built-in re-
cuperators can be installed, set up,
controlled, and maintained more
easily than burners fed from a cen-
tral recuperator because the air up
to the point of burner connection is
still ambient. This eliminates the
need, expense, and maintenance of
hot air piping.

Self-recuperative burners such as
the Ecomax (Fig. 3) are typically pulse
fired high-off. High-off pulse firing
results in the benefits that were pre-
viously discussed with the added fuel
efficiency of operating with hot air.

Efficiencies of self-recuperative
burners tend to be higher than indi-
rect (plug-in or central recuperators)
with heat losses are less than systems
incorporating additional piping and
hot air-control components. Added
benefits to the heat treating opera-
tion include better temperature uni-
formity of parts with potentially
fewer rejects. In terms of fuel savings,
a direct fired self-recuperative burner with 1100°F (595°C) air preheat in a 1900°F (1040°C) furnace would save approximately 32% on the fuel bill versus an ambient air fired burner.

The fuel-savings benefits of preheating combustion air via a recuperative system are obvious. However, one potential downside is higher NOx emissions which, with conventional burners, typically increase with air temperature. Fortunately, there are several technological advancements in burner design in recent years to alleviate this problem. One approach in direct-fired burners is extreme delayed mixing of the fuel and air streams, termed Invisiflame by Hauck. Compared with conventional nozzle mix style burners, the Invisiflame process stages the mixing of fuel and air such that flame temperatures are dramatically reduced, even when using preheated combustion air. Figure 4 shows such a burner and a corresponding Fluent (Fluent Inc., Lebanon, N.H.; www.fluent.com) computational fluid dynamic (CFD) illustration of the temperature field in the burner flame region shown in Fig. 5. It demonstrates that despite 900°F (480°C) preheated air, the peak flame temperature is only about 3000°F (1650°C), resulting in very low NOx emissions levels.

**Conclusion**

Advancements in burner designs, recuperative systems, and pulse-fired control algorithms are just a few of the technological improvements available to the heat treating/thermal processing industries. These advancements, when combined with good operating and maintenance practices, can lead to substantial cost savings, increased productivity, improved product quality with fewer rejects and reduced downtime.

As with any industry, there is no one burner, one control method, or one system that will act as a magic wand for increased productivity, improved product quality and reduced fuel costs. There are advantages and limitations for all system types. In the final analysis, the question remains: What change, upgrade, or improvement will be the best choice to achieve your goals?

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