

OCTOBER 2025

foundrymag.com

FOUNDRY

Management
& Technology®

WASTE-HEAT RECOVERY

Thermal energy can be captured from furnace exhaust streams, cutting fuel consumption, extending equipment life, and lowering emissions—without sacrificing performance.

IN THIS ISSUE

Thermal behavior in shape memory alloys

A new direction for molten iron

Real-time spectrometry for melt chemistry

Where are the new robots?

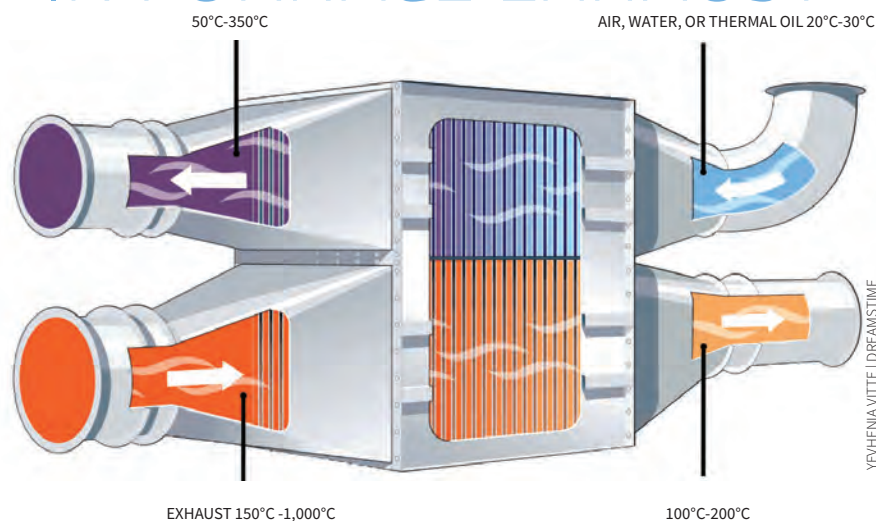
Putting AI to work in the plant



By recovering thermal energy from furnace exhaust streams and reusing it, operators can reduce fuel consumption, extend equipment life, and lower emissions—without sacrificing product quality.

BY SCOTT HARRIS

WASTE-HEAT RECOVERY IN FURNACE EXHAUST



Heat pipe gas-to-air preheaters capture exhaust energy by transferring heat from flue gases to incoming combustion air through sealed, self-contained heat pipes. [ECONOTHERM]

Energy efficiency is one of those issues, and widely discussed, because melting primary or secondary metal alloys is estimated to contribute more than two-thirds of total energy use and greenhouse gas emissions in many operations.

This concern for efficiency adds to the fact that increasingly tighter environmental regulations are piling cumulative pressure on operators to adopt cleaner melting technologies. In fact, a recent report from the International Energy Agency (IEA) recognized heavy industries, such as those with melting processes, as among the most important actors in the world's shift toward a net-zero emission energy system.

Confronting these challenges involves continuous innovation in furnace design and operating best practices. Waste-heat recovery is an area of special interest to many manufacturers. By recovering thermal energy from furnace exhaust streams and re-using it, operators can reduce fuel consumption, extend equipment life, and lower emissions—without sacrificing product quality.

UNDERSTANDING THE CHALLENGES

Melting consumes a lot of energy. Operators, therefore, need to optimize the performance of their furnaces to best manage their energy profile. In controlling the temperature, operators conserve not just energy but also protect equipment and ensure product quality. The opposite, excessive or uncontrolled heat, could lead to thermal stress, corrosion, and fouling—including loss of performance and high maintenance costs.

In aluminum melting, specifically, poor temperature control can also lead to oxidation



Typical shell-and-tube heat exchangers rely on fixed endplate connections, which makes them vulnerable to metal stress fatigue from fluctuating thermal loads during start-up or sudden heat-load changes. [ECONOTHERM]

and dross formation, with direct impacts on product quality.

Beyond process efficiency, melting furnaces are also a source of air and noise pollution, as they release airborne chemical hazards and dust. For manufacturers of steel, aluminum, and copper—all significant operators of melting processes—reducing carbon-dioxide emissions has become a central focus.

Foundries and diecasters employ a range of furnace types, depending on process and product:

CRUCIBLE FURNACES

Configured as either bale-out or hydraulic tilting, a crucible furnace is common for preparing molten metal. These furnaces are heated by natural gas, oil, electrical resistance, or induction.

REVERBERATORY MELTERS/HOLDERS

Gas-fired or electric, these furnaces primarily serve larger sand and lost-foam casting foundries.

GAS-FIRED DRY HEARTH FURNACES

These units are frequently used in permanent mold casting.

LOW-PRESSURE CASTING

These systems rely on pressurized holding furnaces with riser stalks feeding molten aluminum.

Among these applications, natural gas remains the predominant heat source. In secondary aluminum production, more than 75% of melting is done in gas-fired systems. Yet thermal efficiency is typically just 23%. This means exhaust gases—often 1,600°F to 2,200°F (871°C to 1,204°C)—carry away two to two-and-a-half times the heat delivered to the aluminum.

FURNACE EXHAUST AND RECOVERY POTENTIAL

The design of a melting furnace significantly affects the characteristics of its exhaust:

- **Overhead-extraction crucible:** The design operates by discharging gases above the crucible edge. It achieves strong melting performance and can save up to 20% energy compared to a side-discharge furnace. The downside is it releases corrosive gases that may degrade metal.
- **Side-discharge crucible:** These units operate without recuperator technology and offers good melt quality due to lower burn-off and hydrogen inclusions. However, the side-discharge design consumes 25% more power than overhead systems and provides lower melting performance overall.

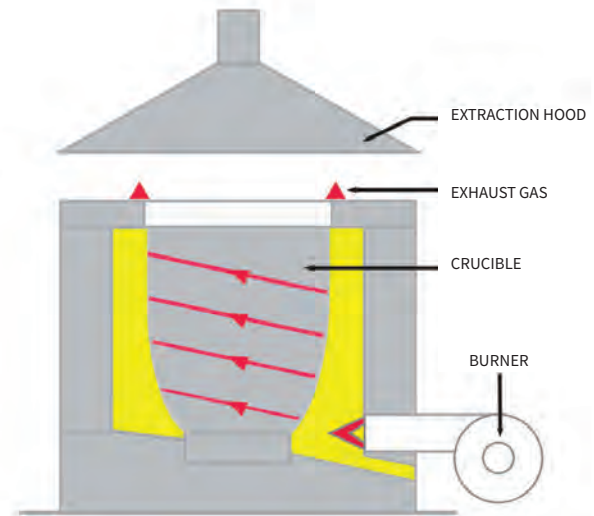
Aluminum furnaces often use fluxing agents containing chlorine, fluorine, and other corrosive elements. Combined with particulates such as aluminum oxide and magnesium, these conditions present challenges for heat recovery equipment, which must resist fouling and corrosion over long operating periods.

WASTE-HEAT RECOVERY SOLUTIONS

Heat pipe gas-to-air pre-heaters are one proven technology for capturing exhaust energy. Key features include:

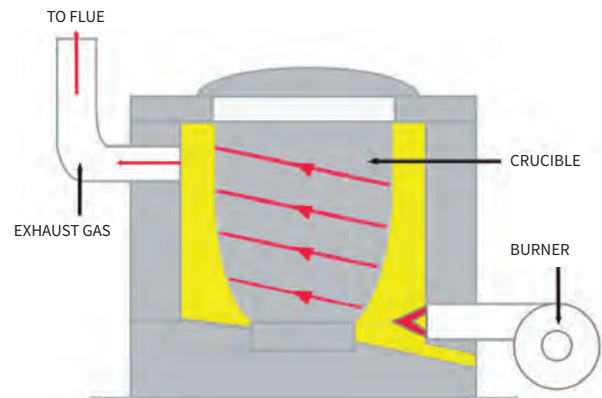
- **Scalability and modularity:** The modular design allows for on-site assembly. Also, the heaters can be designed for specific applications and expanded as needed.
- **Reactivity:** Fast reaction time offers different control options,

MELTING FURNACE WITH AN OVERHEAD-EXTRACTION-CRUCIBLE DESIGN



A melting furnace with an overhead-extraction-crucible design operates by discharging gases above the crucible edge. A side-discharge crucible melting furnace has no recuperator technology. [ECONOTHERM]

SIDE-DISCHARGE CRUCIBLE MELTING FURNACE



A diagram showing how side-discharge crucible melting furnace accommodates the recuperator technology. [ECONOTHERM]

making the units suitable for sensitive apparatus. Also, it does not require pre-heating.

- **Variable operation capability:** With no fixed endplate connections like typical shell and tube heat exchangers, heat pipes are not affected by metal stress fatigue caused by changes in thermal loading during start-up, or sudden changes in heat load.
- **Multiple redundancy:** Independent pipe operation minimizes risk from single-point failures. This prevents cross-contamination as each heat pipe acts as an additional buffer between the two fluids.
- **Low fouling design:** Smooth pipe surfaces handle particulate or oil-laden streams more effectively.
- **Durability:** Materials resist erosion, corrosion, and thermal stress. Cleaning can be performed in place with manual or automated cleaning systems.

CASE STUDY: COPPER MELTING FURNACE

A U.S. wire manufacturer adopted a similar system as part of a government program aimed at improving the efficiency of energy-intensive industrial processes. An Econotherm heat exchanger was installed on a copper melting furnace, recovering 6.56 MMBtu/hr (1,921 kW) of waste heat, and reducing fuel consumption by up to 20%. The heat pipe heat exchanger and the necessary connecting air and exhaust ducting fit easily overhead within the plant.

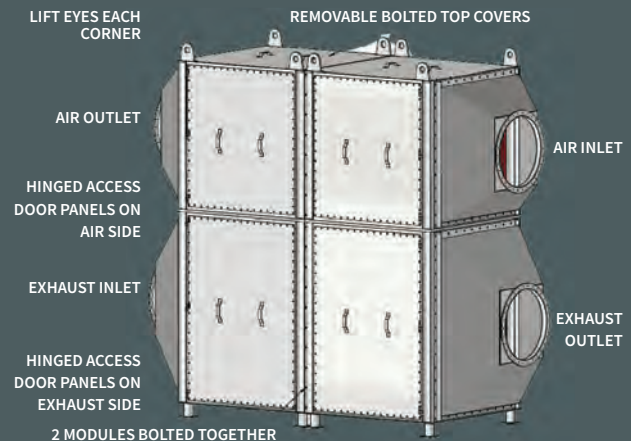
Operating parameters of the heat pipe heat exchanger are:

- Exhaust temperature in/out: 500°F/235°F
- Air temperature in/out: 100°F/405°F
- Exhaust/air mass flow: 94,000 lbs/hr
- Energy recovered: 6.56 MMBtu/hr /1,921 kW
- Payback period: 24-36 months

Energy costs, environmental laws and the natural constraints of high-temp processes make traditional methods insufficient. The future of industries operating melting furnaces will be defined by how operators balance operational efficiency with sustainability.

Recovering and reusing waste heat is only one of the measures metalcasters can adopt to improve their operational effectiveness and environmental performance. By reclaiming energy otherwise lost, operators can minimize fuel consumption, extend

HEAT-PIPE HEAT EXCHANGER ON A COPPER MELTING FURNACE

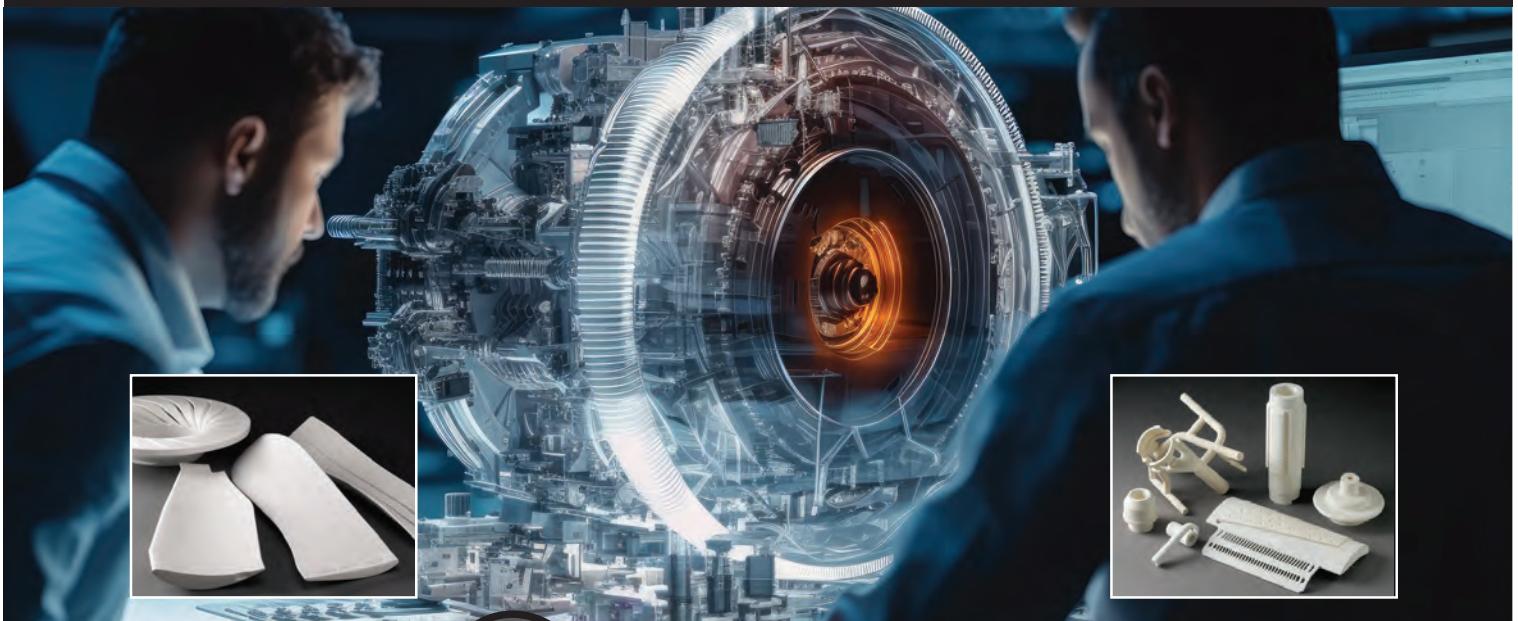


Schematic of a heat-pipe heat exchanger installed on a copper melting furnace at a U.S. wire manufacturer. The system was designed to recover more than 1,900 kW of waste heat. [ECONOTHERM]

furnace life and lower maintenance needs. As significant is the way such steps demonstrate the way minor variations in furnace practice can add up to real gains in competitiveness and sustainability.

Design engineers have unimaginable tools to
help create cutting-edge products.

Only Core-Tech cores can make their castings a reality!



High-Performance
Precision Ceramic Cores
for Investment Casting



CORE-TECH

www.core-tech-inc.com • 440-946-8324

Superior core strength,
exceptional tolerance control,
and flexibility in core materials.

CASE STUDY: GAS-FIRED ALUMINUM FURNACE

At Aisin Automotive Castings in London, KY, three gas-fired aluminum furnaces rated at 8 MMBtu/hr were equipped with a heat-pipe heat-exchange system designed and manufactured by Econotherm (UK) Ltd. and installed by MANTRA Innovative Systems. The units were designed to recover 500 kW of waste heat from the flue-gas stream to pre-heat combustion air, reducing fuel consumption by 15%.

Of note, the flue gas stream contained high particulate matter exhaust from the furnace.

Operating parameters of the heat-pipe heat exchanger:

- Exhaust temperature in/out: 400°C/266°C
- Air temperature in/out: 30°C/293°C
- Exhaust/air mass flow: 12,000 cfm /6,374 kg/h
- Energy recovered: 528 kW
- Recovered energy value: \$155K USD/year
- Payback period: 16 months

An inspection was conducted on System 1 after eight years in operation to evaluate the condition and performance of the energy recovery system, as well as evaluate the condition and performance of the heat pipes and the collection and return systems.

The heat pipes in System No. 1 used three heat transfer fluids: Napthalene, Rows 1-11; Toluene, Rows 12-25; and Dowtherm, Rows 26-36.

The pipes from System 1 were found to be in remarkably good condition, showing only minimal amounts of surface corrosion. The hot-gas side showed low corrosion from ash and was easy to clean. The air-preheating side was clean, too. Given the long duration of service in a difficult, highly acidic environment, this finding was considered a strong endorsement of the durability of heat pipe heat exchangers.

The achievement is considered even more remarkable given the operator confirmed the unit was never cleaned during its operational life, nor was the bypass system used during furnace acid flux cleaning—meaning the high-acid cleaning vapors were passed directly to the heat exchanger.

The removed pipes were subsequently thermal tested and found to be operating to within five percent of their installed specification, thus confirming minimal degradation of internal working fluids.

HEAT-PIPE HEAT EXCHANGER ON THREE GAS-FIRED ALUMINUM FURNACES



The heat pipe heat exchanger system installed on three gas-fired aluminum furnaces at Aisin Automotive Castings, London, KY. The installation was designed to recover 500 kW of waste heat from the flue gases, to pre-heat combustion air. [ECONOTHERM]

SCOTT HARRIS is Regional Director for Solex Thermal Science and Econotherm (UK) Ltd. He is a career-long technical sales specialist for electro-mechanical industrial equipment, with extensive experience providing engineered solutions for heat exchangers and energy systems. Contact him at scott.harris@solexthermal.com