Efficient Process Heating
*in the **Aluminum Industry***

Process heating consumes a large share of the energy used by the aluminum industry. Aluminum producers can reduce heat losses from various melters and furnaces to

cut process heating costs by 10 to 30%.

Capture energy savings opportunities in **your** plant by learning how to

- Improve operating practices
- Perform preventive maintenance and repair
- Make cost effective retrofits
- Enhance your furnace design
- Use advanced materials, sensors and controls, and integrated processing

Melting

Semi-Fabrication

Finishing

- Reheating
- Thermal processing
  - −Homogenizing
  - −Annealing
  - −Solution Heat Treating
  - −Aging
- Drying of coated parts
- Others

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and Renewable Energy
U.S. Department of Energy
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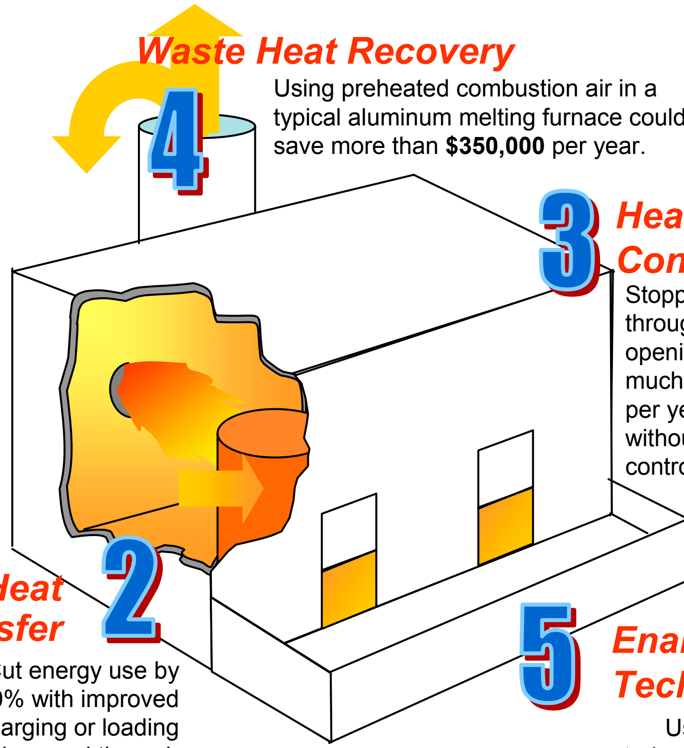
Find your route to more efficient *Process Heating*

Benefits:

- Lower energy costs
- Improve productivity
- Reduce melt losses
- Lower emissions of carbon monoxide, nitrogen oxides, and unburned hydrocarbons

Aluminum producers can cut process heating energy use 10-30% by improving operations in these five areas:



4 *Waste Heat Recovery*

Using preheated combustion air in a typical aluminum melting furnace could save more than **$350,000** per year.

1 *Heat Generation*

Reduce excess air and control the air-fuel ratio in a typical aluminum melting furnace* to save up to **$170,000** per year.

3 *Heat Containment*

Stopping air leakage through furnace openings can save as much as **$225,000** per year in a furnace without pressure control.

2 *Heat Transfer*

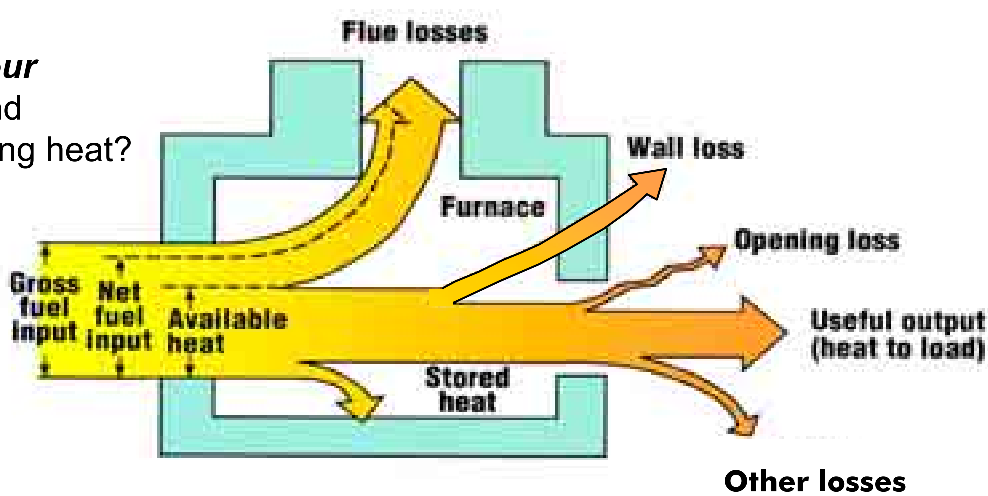
Cut energy use by 5-20% with improved charging or loading practices and through enhanced heat transfer.

5 *Enabling Technologies*

Use sensors and controls, process control methods, advanced materials, and design models and tools to optimize the four process areas.

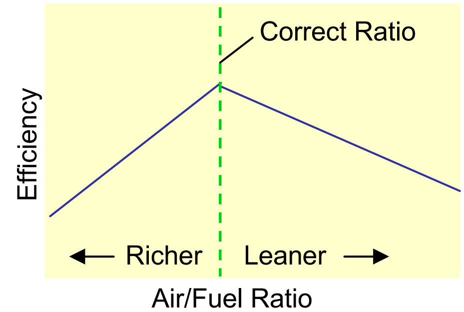
Additional Benefit: Emissions Reductions

How are ***your*** furnaces and melters losing heat?



Heat Generation

Heat is generated most efficiently when complete combustion is achieved with a minimum amount of excess air. Efficient combustion optimizes fuel use and lowers the production of NOx, volatile organic compounds (VOCs), and CO_2. Some of the best techniques for improving combustion efficiency are listed below.



Peak temperature and thermal efficiencies are attained when fuel is burned in an atmosphere with the chemically correct (stoichiometric) amount of air.

Control air-fuel ratio. Proper adjustment of the air-fuel ratio can cost-effectively reduce energy use by 5-25%. Operation with too little air allows incomplete combustion, wastes fuel, and emits CO and unburned hydrocarbons (UHCs). Too much air dramatically increases the volume of waste heat in exhaust gases and lowers thermal efficiency. Oxygen content should be less than 2% in flue gases for optimum combustion of most fuels.

Minimize air leakage into the melter or oven. Furnace sealing can prevent air from leaking into the furnace, which in turn keeps the air-fuel ratio consistent. Preventing cold air from entering the furnace can avoid excess fuel use and help maintain temperature uniformity. Keep seals tight.

Use burners with high turn-down capability. Burners that provide high turn-down and a constant air-fuel ratio over the entire range of firing can reduce fuel consumption, particularly for batch furnaces or furnaces with long idle times during the heating cycle. Select burners that produce the appropriate flame shape and size (e.g., high velocity or flat flame) for meeting the heating requirements of the load.

Stop Inefficient Heat Generation

Watch for…

- Cracks, hot spots, or cold spots in the burner block and refractory
- Flame instability
- Misalignment of air and gas valve linkages
- Excessive oxygen and CO in the furnace flue or exhaust gases

For more information, refer to the Process Heating Tip Sheet "Check Burner Air-to-Fuel Ratios"

You can SAVE!

For example…

Reducing excess air from 20% to 5% (from approximately 4% to 1% oxygen in flue gases) can reduce fuel costs by up to $170,000 per year.

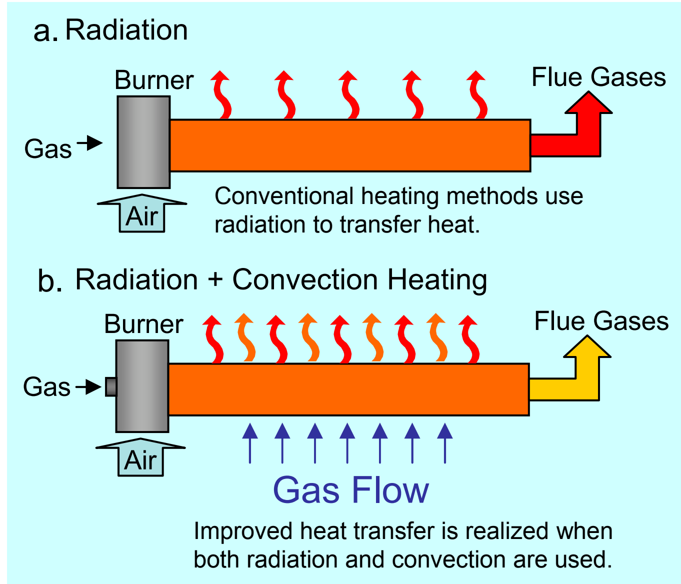
	Current	New
Furnace flue gas temp. (˚F)	1,900	1,900
Oxygen in flue gases (%)	4	1
Fuel consumption (MM Btu/hr)	30.00	25.82
Annual Savings	Base	$173,550

2 Heat Transfer

Heat is transferred from the heat source to the load by the following means:

- *Convection* (from the combustion products)
- *Radiation* (from the flame, furnace walls, or combustion products)
- *Conduction* (from the load surface to the interior of the load, through dross etc.)

Maximizing heat transfer can create energy savings of up to 25% by shortening melting or heating times for the aluminum and increasing furnace productivity. Uniform heat distribution in the furnace and along charge surfaces indicates good heat transfer. Basic ways to improve heat transfer in the furnace are explained below.



Use high-velocity burners or recirculating fans. The use of high-velocity burners and/or recirculating fans enhances convection by distributing the hot combustion gases uniformly throughout the furnace. This enhanced convection increases heat transfer to the load and improves temperature uniformity within the furnace, thereby reducing heating time, increasing productivity, improving product quality, and lowering heat demand per unit of output.

Clean heat transfer surfaces. A simple way to maximize heat transfer is to maintain clean surfaces on all indirectly heated systems, such as radiant tubes, steam coils, and electrical elements. Any contamination or fouling can reduce heat transfer, increase surface temperatures, and shorten the service life of heating system components.

Install a variable flame burner. Use of a variable-flame burner can increase the heat transferred to the load—especially in the case of aluminum melters, in which the load changes from a solid to a liquid. The flame shape and size can be controlled to meet the different heat requirements for first melting the solid charge material and then holding the liquid metal.

Enhance Heat Transfer

Watch for…

- Improper loading of charge materials
- Hot spots within the furnace or on heating elements/radiant tubes
- Continuous impingement of flame on charge material or bath
- Excessive vibration, broken seals, or excessive power use associated with the recirculating fan

For more information, refer to the Process Heating Tip Sheet *"Waste Heat Reduction and Recovery."*

You can SAVE!

For example…

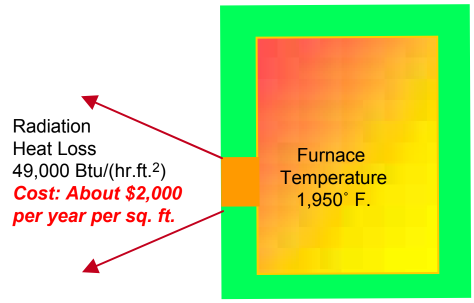
Proper loading of aluminum coils in annealing furnaces can significantly reduce soak and cycle times. (Heat transfer is maximized in an axial direction.) Proper loading also improves temperature uniformity within the coil and reduces scrap rates.

Use of fans with a high flow rate, adjustable-speed drives for fan motors, and high-velocity jets can also reduce heat time and increase furnace productivity.

All of these actions potentially translate into large dollar savings.

3 Heat Containment

Relatively minor and low-effort maintenance tasks such as fixing air leaks, closing furnace openings, and maintaining insulation in the furnace walls and doors can improve heat containment. Collectively, such measures can save up to $50,000 per year in a typical aluminum melter. Techniques to improve heat containment are listed below.



Furnaces and ovens operating at high temperatures may experience significant radiation losses through open doors or other openings in the furnace enclosure.

Install proper insulation. Installing and maintaining the proper type of refractories and insulation for melters and furnaces can reduce heat losses substantially. Cracks, breaks, and erosion of insulation can quickly increase the amount of heat escaping the process. When rebuilding or working on furnaces or ovens, the types and thicknesses of the refractories and insulation should be evaluated and corrected as appropriate.

Maintain proper furnace pressure. Prevent air leakage. Furnace draft or the negative pressure created by the “chimney” effect in a furnace promotes air leakage through the furnace openings. Door seals, gaskets, and other “hidden” openings should be checked for possible air leakage. Replace or repair any damage. Investigate new seal types and materials that may improve performance. Maintaining a balanced (zero) or slightly positive pressure inside the furnace can also minimize air leakage. In addition to saving energy, minimizing air leaks can help maintain more uniform temperature in the furnace and load.

Reduce radiation losses. Heat can escape the furnace by radiating from furnace openings, such as partially open doors or uncapped furnace stacks. Installing radiation shields and minimizing the frequency and duration of door openings are simple, low-cost methods to save energy.

Prevent Heat Losses

Watch for…

- Unnecessary opening and improper closing of the furnace door
- Localized cold spots within the furnace (they indicate air leaks)
- Damaged or worn refractories
- Hot spots, cracks, or insulation detachment in the heater shell and casing
- Stack dampers that are stuck in one position

For more information, refer to the Process Heating Tip Sheet *“Waste Heat Reduction and Recovery.”*

You can SAVE! $

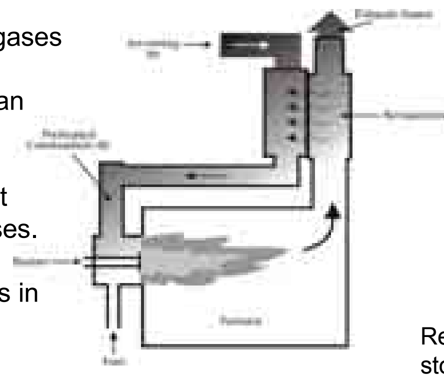
For example:

Air leakage through furnace openings, particularly moving parts such as furnace doors, can result in large heat losses. For a melting furnace without pressure control, even a ¼-inch gap around one door can cost as much as $225,000 per year.

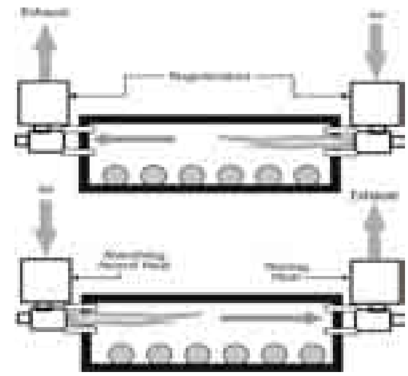
Stack height (ft.)	20
Opening size (area in sq. in.)	120
Average temp. flue gases (˚F)	1,750
Furnace draft (inch water column) at the opening	0.20
Air infiltration (cu. ft./hr.)	70,557
Annual cost of energy wasted	$225,212

4 Waste Heat Recovery

Waste heat recovery systems extract energy from furnace exhaust gases and recycle it back into the process. Significant efficiency improvements can be achieved by using the recovered heat to preheat the combustion air or charge material, generate steam, heat water, or supply heat to other processes. Recuperators are generally used to recover heat from clean flue gases (as in aluminum reheating or heat treating furnaces), whereas regenerators with ceramic heat transfer media are used with flue gases containing contaminants (as in aluminum melters).



A recuperator is a gas-to-gas heat exchanger placed on the furnace stack.



Regenerators contain two or more heat storage sections. Flue gases and combustion air take turns flowing through each, alternately heating the storage medium and then withdrawing from it.

Preheat combustion air. Waste heat recovery devices (whether regenerative burners or recuperators) placed in the flue gas outlet or exhaust stack can extract a large portion of the thermal energy in flue gases and transfer it to the incoming combustion air. Processes operating above 1,400˚ F are generally good candidates for combustion air preheating, although it may also be used cost-effectively in processes with temperatures as low as 1,000˚ F.

Preheat the charge/load. Transferring heat from high-temperature exhaust gases to the relatively cool incoming load can reduce the energy required in the furnace and lower the energy that escapes in the exhaust gases. Heat from furnace flue gases can be used to dry the charge and preheat the load for melting furnaces or to preheat the load for heating and heat treating furnaces.

Cascade waste heat. The heat from exhaust gases can be used as a source of heat for lower-temperature process heating equipment. For example, waste heat boilers can use the thermal energy from flue gases to generate hot water or steam. Waste heat from heat treating furnaces can also be used in aging or paint-drying ovens. To maximize benefits of the heat recovery, the downstream heating equipment must be in operation while the furnace is operating

Enhance Heat Recovery

Watch for…

- Fluctuations in combustion air temperature as the furnace firing rate changes. (Make sure the air-fuel ratio is maintained as the combustion air temperature changes.)
- Possible air leakage into the exhaust gas (High oxygen in exhaust gases indicates possible air leakage from the recuperator.)
- Any pressure drop in the air or flue gas (Investigate possible plugging of passages within the recuperator or regenerator.)

For more information, refer to the Process Heating Tip Sheet *"Preheated Combustion Air"*

You can SAVE!

For example:

Combustion air preheating to 900˚ F for a typical melting furnace can save up to $350,000 per year.

	Current	New
Furnace flue gas temp. (˚F)	1,900	1,900
Combustion air temp. (˚F)	100	900
Fuel consumption (MM Btu/hr)	30.00	21.41
Fuel savings (%)	Base	28.6
Annual savings ($/year)	Base	$356,258

5 Enabling Technologies

Pay attention to control systems. Regular operation, calibration, and maintenance of process sensors and controls improve the performance and efficiency of the furnace. Additionally, process controls are needed to apply some of the energy-saving technologies discussed in the previous sections. Modern sensors and controls technologies and systems can be used to avoid over-firing of burners, prevent overheating of refractories, maintain furnace pressure, monitor exhaust gas temperature, and analyze exhaust gases to control emissions for aluminum furnaces. Specifically, furnace control systems enable measurement and control of the burner air-fuel ratio, the oxygen content (as well as other gases) in stack emissions, and the draft or pressure.

Installation and use of control systems in such control schemes can reduce energy use by up to 10% while maintaining smooth operation of a furnace, maximizing system efficiency, and enhancing product quality.

Consider use of advanced materials. Proper application of advanced refractories and engineered materials in the furnace can improve heat transfer, prevent furnace leaks, and decrease heat storage and losses in the furnace walls.

Advanced materials can reduce energy use by non-productive loads, such as fixtures and trays, saving up to 25% of energy costs.

Use of process models. Using predictive modeling to optimize furnace design and operation can lower capital costs, increase productivity, improve product quality, and reduce energy consumption per unit of output. Process simulation models can be used to cut energy costs by 10%.

Additional Benefit: Emissions Reduction

Efficient process heating systems can substantially reduce emissions. In each of the previous sections, many actions to improve energy efficiency also reduce emissions because less fuel is needed to heat the aluminum. For example, proper control of the fuel-air ratio with new-generation burners and heating systems will allow more complete combustion, decreasing CO and VOC formation and NOx emissions.

Some additional steps you can take to decrease NOx, CO, and SOx emissions include

- Use low-NOx or ultra-low-NOx burners.
- Use oxy-fuel burners of proper design to decrease mass of flue gases.
- Maintain and control burner operations to eliminate formation of soot or combustible gases (CO, O_2) in flue gases.
- Use the energy-saving techniques described in earlier sections.

Thermal Efficiency Checklist

- ❑ Control air-fuel ratio.
- ❑ Minimize air leakage into the melter or oven.
- ❑ Use burners that provide high turn-down and proper flame size and shape.
- ❑ Use high-velocity burners or recirculating fans.
- ❑ Clean heat transfer surfaces.
- ❑ Install a variable-flame burner.
- ❑ Install and maintain proper insulation.
- ❑ Maintain proper furnace pressure. Prevent air leakage.
- ❑ Reduce radiation losses—close the openings or install radiation shields.
- ❑ Preheat combustion air.
- ❑ Preheat the charge/load.
- ❑ Cascade waste heat.
- ❑ Pay attention to control systems.
- ❑ Consider use of advanced materials for furnace refractories, insulation, and fixtures.
- ❑ Use process models.
- ❑ Use low-NOx or ultra-low-NOx burners
- ❑ Use oxy-fuel burners of proper design to decrease mass of flue gases.
- ❑ Maintain and control burner operations to eliminate formation of soot or combustible gases (CO, O_2) in flue gases.

*Unless otherwise indicated, estimated energy and cost savings in this document are based on a typical aluminum melting furnace with base operating conditions as described below:

- Production rate: 15,000 lbs./hr.
- Energy use: 2,000 Btu/lb. 30 million (MM) Btu/hr.
- Combustion air temperature: 80˚ F to 100˚ F.
- Operating temperature: 1,900˚ F.
- Operating hours: 24 hours/day, 7 days/week, 52 weeks/year with 95% availability
- Fuel cost: $5.00 per MM Btu (natural gas)

Photos courtesy of Seco/Warwick Corporation and North American Manufacturing Company.
Prepared by Energetics, Inc. with technical material and direction provided by E3M, Inc.

For tip sheets and additional information, please visit the Aluminum pages of the Office of Industrial Technologies web site:
www.oit.doe.gov