Install Waste Heat Recovery Systems for Fuel-Fired Furnaces

For most fuel-fired heating equipment, a large amount of the heat supplied is wasted as exhaust or flue gases. In furnaces, air and fuel are mixed and burned to generate heat, some of which is transferred to the heating device and its load. When the heat transfer reaches its practical limit, the spent combustion gases are removed from the furnace via a flue or stack. At this point, these gases still hold considerable thermal energy. In many systems, this is the greatest single heat loss. The energy efficiency can often be increased by using waste heat gas recovery systems to capture and use some of the energy in the flue gas.

For natural gas-based systems, the amount of heat contained in the flue gases as a percentage of the heat input in a heating system can be estimated by using Figure 1. Exhaust gas loss or waste heat depends on flue gas temperature and its mass flow, or in practical terms, excess air resulting from combustion air supply and air leakage into the furnace. The excess air can be estimated by measuring oxygen percentage in the flue gases.

Waste Heat Recovery

Heat losses must be minimized before waste heat recovery is investigated. Figure 2 highlights opportunities for energy savings.

The most commonly used waste heat recovery methods are preheating combustion air, steam generation and water heating, and load preheating.

Preheating Combustion Air. A recuperator is the most widely used heat recovery device. It is a gas-to-gas heat exchanger placed on the stack of the furnace that preheats incoming air with exhaust gas.

Suggested Actions

- Use PHAST with current and projected energy costs to estimate energy savings from waste heat recovery.
- Contact furnace or combustion system suppliers to calculate payback or return on investment.

Resources

U.S. Department of Energy—
For additional information on process heating system efficiency, to obtain DOE's publications and Process Heating Assessment and Survey Tool (PHAST) software, or learn more about training, visit the BestPractices Web site at www.eere.energy.gov/industry/bestpractices.

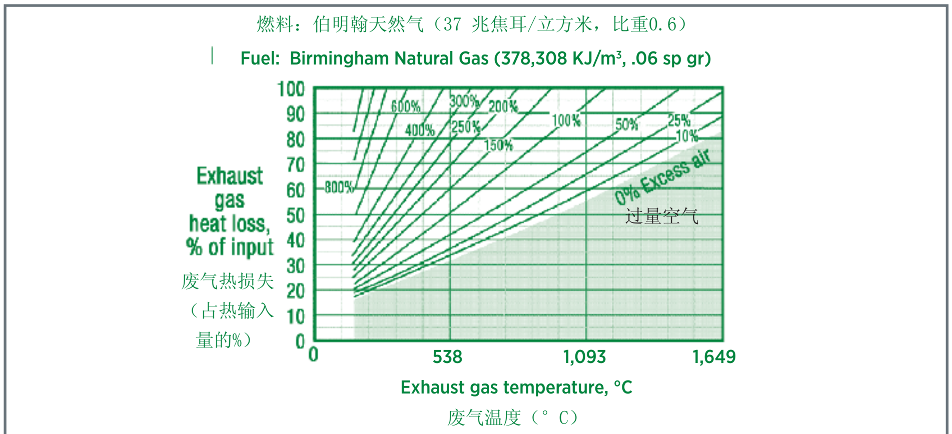

Figure 1. Heat in flue gas. 图1： 烟气中的热量

Designs rely on tubes or plates to transfer heat from the exhaust gas to the combustion air and keep the streams from mixing. Another way to preheat combustion air is with a regenerator, which is an insulated container filled with metal or ceramic shapes that can absorb and store significant thermal energy. It acts as a rechargeable storage battery for heat. Incoming cold combustion air is passed through the regenerator. At least two regenerators and their associated burners are required for an uninterrupted process: one provides energy to the combustion air while the other recharges.

Steam Generation and Water Heating. These systems are similar to conventional boilers but are larger because the exhaust gas temperature is lower than the flame temperature used in conventional systems. Waste heat boilers can be used on most furnace applications, and special designs and materials are available for systems with corrosive waste gases. Plants that need a source of steam or hot water can use waste heat boilers, which may also work for plants that want to add steam capacity. However, the waste boiler generates steam only when the fuel-fired process is operating.

Load Preheating. If exhaust gases leaving the high temperature portion of the process can be brought into contact with a relatively cool incoming load (the material being heated), energy will be transferred to the load, preheating it and reducing the energy consumption. Load preheating has the highest potential efficiency of any system that uses waste gases. Load preheating systems can be difficult to retrofit and are best suited for continuous rather than batch furnaces.

Benefits

Benefits of waste heat recovery include:

- **Improved heating system efficiency.** Energy consumption can typically be reduced 5% to 30%

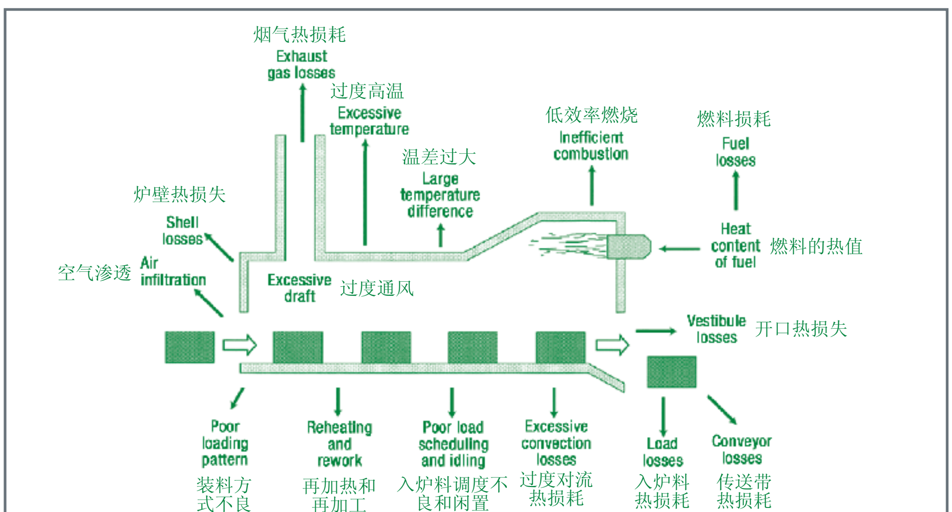

Figure 2. Heat losses. 图2： 热损耗

- **Lower flue gas temperature in chimney.** Less heat is wasted.
- **Higher flame temperatures.** Combustion air preheating heats furnaces better and faster.
- **Faster furnace startup.** Combustion air preheating heats furnaces faster.
- **Increased productivity.** Waste heat used for load preheating can increase throughput.

Potential Applications

Waste heat recovery should generally be considered if the exhaust temperature is higher than 538°C, or if the flue gas mass flow is very large.

为使用燃料的熔炉安装余热回收系统

对于绝大多数使用燃料的加热设备，供给的大量热量被作为废气或烟气浪费了。在熔炉中，通过混合并燃烧空气和燃料，生产热量。这些热量的一部分被用于加热设备和入炉料。当热传递达到实际极限时，熔炉中的燃烧废气通过烟囱向外排掉。但此时，这些烟气中仍有相当大的热能。在许多系统中，这是最大的单一热损耗来源。通过利用余热回收系统捕集烟气中的部分能源，从而提高能源利用效率。

对于使用天然气的系统，利用图1可以找出加热系统烟气中所含的能量占系统总热量输入的百分比。烟气的损失或余热取决于烟气温度和它的质量流，也就是过量空气。过量空气来自助燃空气的供给以及渗透进入熔炉中的空气量。过量空气可以通过测量烟气中的氧气成分获得。

余热回收

在进行余热回收之前必须将热损耗降到最低。图2显示了降低热损耗的机会所在。

最常用的余热回收的方法包括预热助燃空气、生产蒸气、热水和预热入炉料。

预热助燃空气

换热器是最常用的热回收设备。它是安装在熔炉烟囱上的热交换机，利用烟气预热进入的空气。根据管道等将烟气的热量传递给助燃空气，并避免气流发生混合。

建议采取的节能行动

- 利用过程加热评估工具（PHAST工具）计算目前和改进后的能源成本，从而估算余热回收带来的节能量。
- 联系熔炉或燃烧系统供应商，计算投资回收期或投资回报率。

资源

美国能源部——如需进一步了解过程加热系统能效的信息，获取美国能源部的报告以及过程加热评估工具（PHAST工具），或想进一步了解有关培训，请访问美国能源部工业技术项目“最佳实践”的网站 www.eere. energy.gov/industry/bestpractices。

预热助燃空气的另外一个办法是利用蓄热器。蓄热器是一个隔热的容器，内有金属或陶瓷可以吸收并储存大量的热能。它相当于是热能的可充电可储存电池。冷的助燃空气进入后穿过蓄热器。对于不间断的工艺而言，至少需要两个蓄热器，以及配套的燃烧器。一个蓄热器向助燃空气提供能源，而一个蓄热器储蓄能源。

生产蒸气和热水

这些系统与传统锅炉类似，但是更大，因为废气温度比传统系统的火焰温度低。余热锅炉可用于绝大多数熔炉工艺，也有针对腐蚀性废气而专门设计并利用特殊材料的系统。需要蒸气或热水的工厂可利用余热锅炉，希望增加蒸气容量的工厂也可利用余热锅炉。但是，余热锅炉只有在主工艺运行时才能生产蒸气。

预热入炉料

如果温度较高的工艺的废气可以用于预热温度相对较低入炉料（将要加热的材料），废气的余热将转移到入炉料上，从而对它进行预热，降低总能源消耗。对于任何利用废气的系统，预热入炉料有最大的能效潜力。入炉料预热系统可能很难进行改造，而且最适用于连续式的熔炉，而不是间歇式的熔炉。

余热回收的好处

余热回收的好处包括：

- 提高加热系统效率。通常可降低能源消耗的5%到30%。
- 降低烟囱内的烟气温度。减少浪费的热量。
- 提高火焰温度。预热的助燃空气可更好且更快地加热熔炉。
- 更快地启动熔炉。预热的助燃空气能更快地加热熔炉。
- 提高生产能力。利用余热对入炉料进行预热可提高产量。

潜在的应用

- 如果烟气温度高于538° C（即1，000° F），或者烟气质量流非常大的时候，通常应该考虑采用余热回收。

BestPractices is part of the Industrial Technologies Program Industries of the Future strategy, which helps the country's most energy-intensive industries improve their competitiveness. BestPractices brings together emerging technologies and best energy-management practices to help companies begin improving energy efficiency, environmental performance, and productivity right now.

BestPractices emphasizes plant systems, where significant efficiency improvements and savings can be achieved. Industry gains easy access to near-term and long-term solutions for improving the performance of motor, steam, compressed air, and process heating systems. In addition, the Industrial Assessment Centers provide comprehensive industrial energy evaluations to small- and medium-size manufacturers.

“最佳实践（BestPractices）”是工业技术项目“未来产业”战略的一部分，它可帮助高能耗的产业提高竞争力。“最佳实践（BestPractices）”提供新兴技术以及最佳能源管理实践方面的信息，帮助公司改善能源效率，提高环保绩效，并提升生产效率。

“最佳实践（BestPractices）”强调工厂系统的重要性，从工厂系统的角度实现能效的大幅提高，并获得显著的节能量。企业可获得提高风机、蒸汽系统、空气压缩系统和过程加热系统绩效的近期和长期的解决方案。此外，工业评估中心向中小型企业提供全面的工业能源评价。

U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy

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美国能源部能源与可再生能源办公室支持能源效率和可再生能源技术的研究和开发，从而促进美国经济发展，提供更清洁的环境，并提高美国的能源独立性。工业技术项目与美国的工业企业合作，致力于改进工业能源效率和环境保护。