Using Waste Heat for External Processes

The temperature of exhaust gases from fuel-fired industrial processes depends mainly on the process temperature and the waste heat recovery method. Figure 1 shows the heat lost in exhaust gases at various exhaust gas temperatures and percentages of excess air. Energy from gases exhausted from higher temperature processes (primary processes) can be recovered and used for lower temperature processes (secondary processes). One example is to generate steam using waste heat boilers for the fluid heaters used in petroleum crude processing. In addition, many companies install heat exchangers on the exhaust stacks of furnaces and ovens to produce hot water or to generate hot air for space heating.

Before attempting to use energy from higher temperature flue gases in lower temperature processes, engineers should take the following technical issues into consideration:

- ***Nature or quality of the flue gases.*** Flue gases from the primary processes should be clean and free of contaminants such as corrosive gases and particulates. Contaminants pose special handling problems for the gases and might affect the quality of work in the secondary process.
- ***Temperature of primary process flue gases.*** The temperature difference between the primary and secondary process should be high enough (at least 93°C), and there should be a sufficient amount of usable waste heat.
- ***Matching the heat demand of the secondary process with the heat supply from the primary process.*** The heat supply from the primary process should be sufficiently high to meet a reasonably high percentage of the secondary process heat demand.
- ***Matching the timing of the heat supply from the primary process and the heat demand in the secondary process.***
- ***Placement of primary and secondary heating equipment.*** The closer the primary and secondary process can be situated, the better.

Figure 2 shows some heating processes that commonly use waste heat from a higher temperature process, and the approximate range of waste gas temperatures they require. Sometimes lower temperature gases can be used if the heat recovery device is deliberately oversized.

Example

A plant uses a furnace with a firing rate of 10.6 GJ/hr, which discharges flue gases at 760°C (primary process). The plant also has a drying oven that operates at 204°C and requires 2.6 GJ/hr of heat (secondary process). The recoverable heat can be estimated using Figure 1. At 760°C, the heat content of the exhaust gases (at 10% excess air) is about 42% of the heat furnace input. Again using Figure 1, the heat content of exhaust gases at 204°C is approximately 20% (at 10% excess air). The *approximate* amount of heat that can be saved is 42% – 20% = 22% of the heat input to the primary process. The net heat available for the secondary process is approximately 0.22 x 10.6 GJ/hr = 2.3 GJ/hr. Actual savings would be greater than this because the available heat at the 204°C exhaust gas temperature is approximately 80% (see Figure 1 in Process Heating Tip Sheet #9, *Load Preheating Using Flue Gases from a Fuel-Fired Heating System*). The actual savings for the oven are thus 2.3/0.8 = 2.9 GJ/hr.

In this case, there is more than enough heat to meet the heat demand for the drying oven. It would be necessary to use additional heat in the oven if the exhaust gas heat from the furnace were not sufficient to meet the oven heat demand. At a fuel cost of $7.50 per GJ, the company can save $22.00 in fuel costs per hour. Assuming 8,000 hours of operation per year, annual savings are $175,000.

Suggested Actions

Questions to ask when evaluating the use of waste gases for heating secondary processes:

1. Is there a less expensive way to heat the secondary process?
2. Is the temperature of the flue gases high enough to heat the secondary process?
3. Do the flue gases contain enough transferable energy?
4. Are the flue gases compatible with the secondary process (as to cleanliness, corrosiveness, etc.)?
5. Can the primary process deliver energy to the secondary process in time?
6. Are the two processes close enough together to avoid excessive heat losses during waste gas transport?
7. Will the flue gases leave the secondary process at a high enough temperature to avoid problems with moisture condensation?
8. Can the exhaust ductwork and secondary process be designed to avoid excessive pressure resistance to the flue gases, or are additional means like exhaust fans necessary?

Resources

See also the *ASM Handbook*, Volumes 1 (1990) and 2 (1991), Materials Park, OH: ASM International; *Combustion **Technology Manual,*** Fifth Edition, Cincinnati, OH: Industrial Heating Equipment Association (IHEA), 1994; Handbook of Applied Thermal Design, E.C. Guyer and D.L. Brownell, eds., London: Taylor & Francis Group, 1999.

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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.

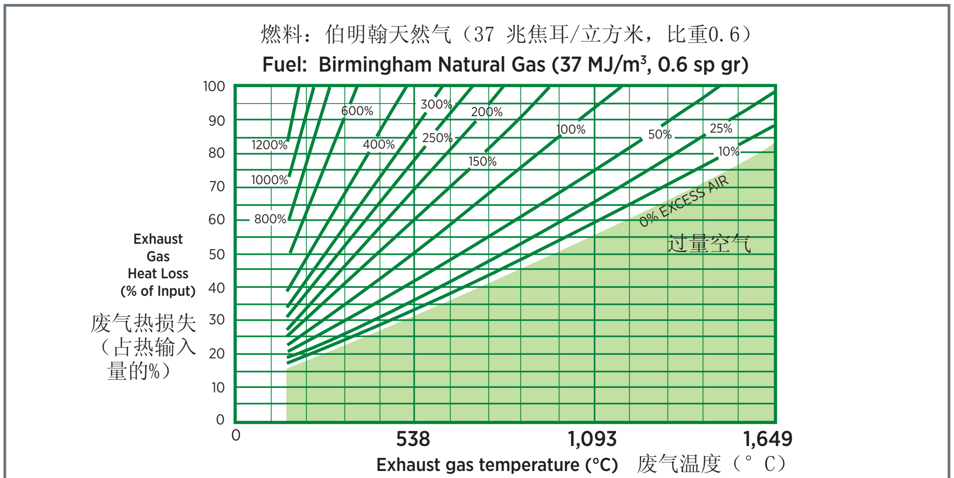

Figure 1. Heat loss in exhaust gases at various exhaust gas temperature and excess air percents[1]
图1. 在不同废气温度和过量空气比例状态下，废气带走的热损失[1]

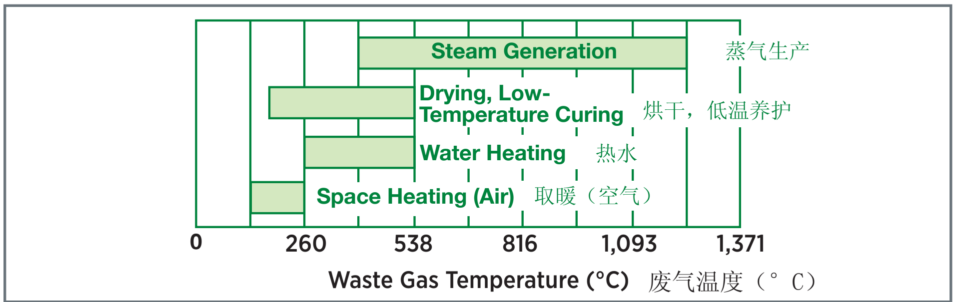

Figure 2. Typical secondary processes and approximate exhaust temperatures[2]
图2： 典型的次要工艺和废气温度的大致范围[2]

余热的利用

使用燃料的工艺排放出废气，废气的温度主要取决于工艺的温度以及余热回收的方法。图1显示了在不同的废气温度和不同比例的过量空气下，废气带走的热损失。高温工艺（主要工艺）排放出的废气中的能源可以被回收，并用于低温工艺（次要工艺）。例如，原油加工工艺中的流体加热器的废热可以用于废热锅炉生产蒸气。此外，许多公司在熔炉和锅炉的排气烟囱上安装了热交换器，利用余热生产热水或生产取暖所用的热空气。

在尝试将高温烟气的能源用于低温工艺之前，工程师应该考虑以下几个技术问题：

- 烟气的性质或质量。主要工艺的烟气应是干净的，并没有如腐蚀性气体或微粒等无污染物。污染物会给气体的处理带来特殊的问题，而且可能影响次要工艺的工作质量。
- 主要工艺的烟气温度。主要工艺和次要工艺的温度差应该足够大（至少93° C），而且应该有足够的可用余热量。
- 将次要工艺的热需求与主要工艺的热供给相匹配。主要工艺的热供给应该足够高，从而满足次要工艺热需求的较高的比例。
- 将主要工艺热供给的时间与次要工艺的热需求相匹配。
- 主要和次要工艺设备的位置摆放。在满足条件的情况下，主要和次要工艺间的距离越近越好。

图2显示了一些经常利用来自高温工艺余热的加热工艺，以及它们需要的废气温度的大致范围。有时，如果特意扩大余热回收的设备，也能利用温度更低的废气。

建议采取的节能行动

当评估余热是否能用于加热次要工艺时，请考虑以下问题：

1. 是否还有更便宜的方法来加热次要工艺？
2. 用于加热次要工艺的烟气温度是否足够高？
3. 烟气中是否含有足够的可转移的能源？
4. 烟气是否与次要工艺的要求相符合（如烟气的清洁度和腐蚀程度等）？
5. 主要工艺可以及时将能源送至次要工艺吗？
6. 主要工艺与次要工艺的位置是否足够近，从而避免在余热传输中额外的热损失？
7. 次要工艺排出的烟气的温度是否足够高，从而避免水分凝结带来的问题？
8. 是否可以将废气管道和次要工艺设计得避免对烟气出现过多的压力阻力？或者，是否需要额外手段（如排风机）？

资源

参见ASM Handbook, Volumes 1 (1990) and 2 (1991), Materials Park, OH: ASM International; Combustion Technology Manual, Fifth Edition, Cincinnati, OH: Industrial Heating Equipment Association (IHEA), 1994; Handbook of Applied Thermal Design, E.C. Guyer and D.L. Brownell, eds., London: Taylor & Francis Group, 1999.

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示例

工厂熔炉的燃烧率为10.6吉焦（GJ）/小时，排出的烟气温度为760° C （主要工艺）。工厂还有一台干燥箱，运行温度为204° C， 每小时需要2.6 吉焦的热量（次要工艺）。通过图1计算出可回收的热量。在760° C时，烟气（过量空气为10%）中的热含量为熔炉热输入的40%。 再次利用图1，可得知当烟气温度为204° C时，烟气中的热含量大约热输入的20%（过量空气为10%）。能够节约的热量大约为42%-20% = 22%，即大约可节约主要工艺热量总输入的22%。供次要工艺所用的净热值大约是0.22 x 10.6吉焦/小时 = 2.3 吉焦/小时。实际的节能量要比这个数值高，因为当烟气温度为204° C时，有效热量大约为80%（见过程加热建议报告#9“利用加热系统的烟气预热入炉料”中的图1）。干燥箱实际的节能量即为2.3/0.8 = 2.9 吉焦/小时。

在这个例子的情况下，有足够的余热满足干燥箱的热需求。在有些情况下，当熔炉的余热无法完全满足干燥箱的热需求时，可能有必要利用额外的热量。当燃料价格为$7.50美元/吉焦时，公司每小时可节省燃料成本$22.00美元。假设每年运行8,000小时，每年可节省$175,000美元。

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[1] Calculations by Richard Bennett, Janus Technology Group. 计算结果来自Janus Technology Group的Richard Bennett。

[2] Figure by Richard Bennett, Janus Technology Group. 此图来自Janus Technology Group的Richard Bennett。

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