

7. Process Heating

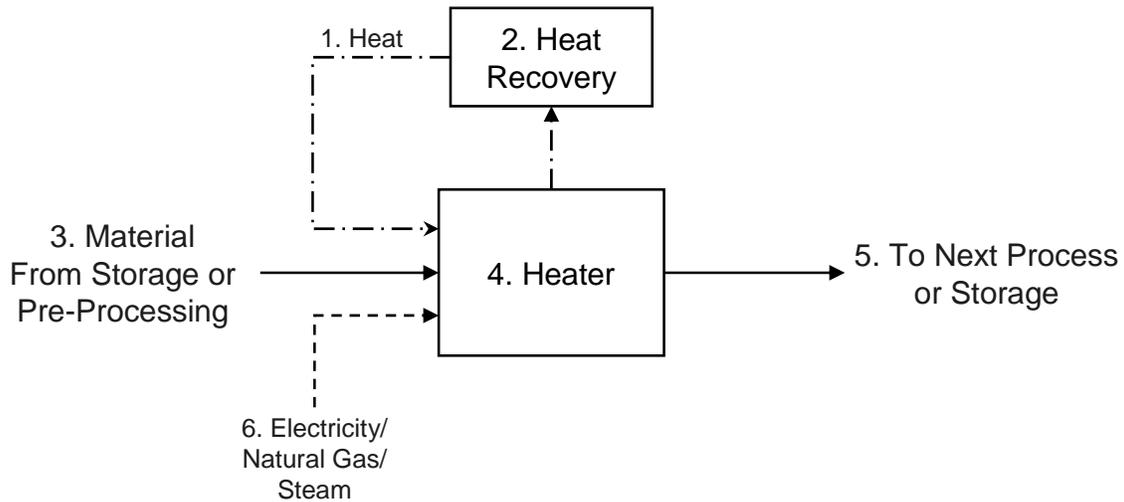


Figure 7.1 – Process heating layout

Process heating denotes all methods of heat transfer used to produce a manufactured good. The energy used to generate the heat can come directly from the combustion of a fuel, electricity, or by means of steam or hot water. In the food industry, process heat is often used for drying, cooking, or accelerating separation processes.

PROCESS HEATING SYSTEM OVERVIEW (REFER TO FIGURE 7.1 ABOVE)

Generation

Heat can be directly or indirectly generated. With direct heaters, the heat is produced within the end use equipment and material (e.g., direct electric heaters). Indirect heaters, on the other hand, use energy transformed to heat by separate equipment (e.g., generated by a boiler or heat exchanger).

Electric heaters can also be divided into the following categories:

- dielectric heaters
- resistance and induction heaters
- infrared (IR) heaters

Note that heaters are categorized according to the method used to generate the heat. Dielectric heaters use the heat generated by an electric field that alternates at radio or microwave frequencies. The radiated heat is absorbed by the material at a rate dependent on its physical properties. Resistance and induction heaters utilize an electric current to heat the material. Resistance heating can be direct or indirect. Direct resistance heating occurs as the electric current is passed directly through the material. Indirect resistance heating uses a heating element that, in turn, transfers heat either to the product or a fluid (liquid or gas) medium. IR heaters utilize electromagnetic wave radiation to directly heat

the material area that is exposed to the infrared waves without heating the surrounding environment.

Heat Transfer

In general, heat can be transferred in one of three different ways or in any combination of the following: convection, conduction, or radiation. Convection occurs when two fluids (liquid or gas) at different temperatures mix together. Convection can be forced or free, depending on whether the fluids mix with the assistance of a fan or naturally by temperature differences.

Conduction heat transfer takes place when the heating source is in direct contact with the object being heated. For example, conduction occurs when a heating element is immersed in water.

Radiation, or radiant heat transfer, occurs when energy in the form of electromagnetic waves is emitted from a material and absorbed by a substance. Heat is only generated when the waves reach the target and not during the transmission process. As examples, microwave ovens and infrared heaters use radiation heat transfer.

ENERGY SAVINGS OPPORTUNITIES AND RELATED BEST PRACTICES

The following paragraphs describe various opportunities for energy savings related to process heating. The U.S. Department of Energy has developed a program that identifies energy saving opportunities. The program is called “Process Heating Assessment and Survey Tool (PHAST)” and is available at no cost on the Industrial Technologies webpage²¹. On this same site, the Department of Energy offers other programs that can be used to assist in making energy-efficiency decisions.

Heat Generation

Efficient Combustion

In order for combustion to take place, there must be a mixture of fuel and air (i.e., oxygen). Since the imperfect mixing of air and fuel molecules makes it nearly impossible to supply the precise volume of air needed for perfect combustion, it is generally recommended that a small amount of excess air be available to assure that complete combustion takes place. If too much air is used during the combustion, energy is vented in the exhaust and stack temperature rises. If not enough air is present in the mixture, incomplete combustion takes place and fuel is wasted. Take into account that air entering the combustion chamber from equipment leaks will also change combustion efficiency.

Periodic testing and adjustments to the burner are recommended to ensure efficient combustion. All air leakage and infiltration to the equipment should be stopped. Contact the burner manufacturer for safety procedures and instructions before doing adjustments, and always adhere to the applicable codes. Combustion analyzers can be used to measure

²¹ http://www.oit.doe.gov/bestpractices/software_tools.shtml.

stack gases and determine O₂ levels and combustion efficiency. Adjustments to the air/fuel mixture should be done at different firing rates along the air/fuel ratio curve to assure good combustion efficiency. Beyond energy savings, nitrogen oxides (NO_x) formation is also greatly decreased with reductions of excess air.

Preheating Combustion Air

All air in the air/fuel mixture consumes energy as it is heated to combustion temperature. A best practice is to preheat the combustion air using energy from a source that would otherwise be wasted, such as hot exhaust gasses. It is common to collect warmer air from places such as near the ceiling, or to use an air-to-air heat exchanger for the purpose of preheating combustion air. The warmer air can be collected from a point close to the ceiling or stack.

When retrofitting an existing system for preheating the air, attention must be paid to the capacity of the fans and the air/fuel ratio curve. Warmer air contains less oxygen per unit volume, thus a larger fan or additional fans, and changes to the burner firing rate settings may be needed to assure efficient combustion. A method known as pinch technology²² can be used to engineer an integrated heat recovery system that optimizes the balance between heat recovery and combustion efficiency.

Heat Recovery

Process heat is never fully used in its various applications, thus it is a source of energy if the heat can be recovered and used elsewhere. Commonly, heat exchangers are used for heating air for HVAC, combustion air, or liquids (water or products). In the food processing industry, the recovered heat is commonly used to heat water for wash stations. When high-temperature gases are being exhausted, the energy can be recovered and used on lower temperature applications. The U.S. Department of Energy estimates that potential energy savings from heat recovery can be as high as 25%.

Insulation

All process heating equipment loses some heat to the environment and therefore wastes energy. However, heat losses can be minimized by properly insulating the equipment. DOE's Industrial Technologies Program offers free software for choosing proper insulation material and thickness. The software is called 3E Plus and is available for free at the Best Practices webpage²³. According to the Industrial Technologies Program from DOE, good insulation has a potential energy savings of 2%-15% and a typical payback period of 3-12 months.

Heat transfer

With usage and time, equipment tends to become dirtied, and heat transfer becomes inefficient since the accumulation inside the equipment acts as insulation. It is a best

²² Pinch technology is a set of thermodynamically based methods for finding the minimum energy usage for a network of heat exchangers.

²³U.S. DOE ITP Best Practices, <http://www.oit.doe.gov/bestpractices>.

practice to frequently clean the heat transfer surfaces of indirectly heated systems, such as radiant tubes, steam coils, and electrical elements.

Direct heating systems are more efficient and easier to control than indirect systems. Because of these advantages, serious consideration should be given to replacing indirect heating systems with direct heating systems where retro fitting is possible.

Sensors and controls

DOE estimates that good process sensors, controls, and process management can result in an energy savings as high as 10%. To ensure ongoing savings, sensors and controls need to be regularly maintained and calibrated according to the manufacturer's procedure.

System Design

In many cases, changing the system design can significantly improve energy efficiency and throughput. Common effective changes involve altering equipment in order to contain the heat, thus decreasing the amount of energy that is wasted. As an example, heat can be contained by simply installing covers in places such as tanks and ovens, slightly changing the initial design of the equipment.

Local Heating

In some cases, decentralizing heating operations may improve the overall energy efficiency of the plant. In many cases, a central boiler produces steam for all heating purposes plantwide. As energy efficiency projects that recover wasted heat are implemented, the demand for steam tends to decrease, and the burners operate at lower, less efficient firing rates. When this occurs in a plant with multiple boilers, it may make sense to reduce the demand for steam even farther by installing local water heating stations that would allow the plant to shut off one of the boilers most or all of the time. The local heating equipment can be installed near the usage point, decreasing the losses from transportation. Please refer to Appendix A for more information on steam.

RESOURCES

Printed Material

Incropera, F.P. and Dewitt, D.P., Fundamentals of Heat and Mass Transfer, John Wiley & Sons, 5th ed., 2002.

Moran, M.J. and Shapiro, H.N., Fundamentals of Engineering Thermodynamics, John Wiley & Sons, 4th ed., 1999.

Mull, T.E., Practical Guide to Energy Management for Facilities Engineers and Managers, ASME, NY, 2001.

Singh, R.P. and Heldman, D.R., Introduction to Food Engineering, Academic Press, 3rd ed., 2001.

Wulfinghoff, D.R., Energy Efficiency Manual, Energy Institute, MD, 1999.

On-Line Tools

U.S. Department of Energy

Energy Efficiency and Renewable Energy – Industrial Technologies Program

Best Practices: www.oit.doe.gov/bestpractices

Process Heating: www.oit.doe.gov/bestpractices/process_heat

- Tip Sheets
- Technical Publications
- Supplement to the *Energy Matters* newsletter

Software Tools: www.oit.doe.gov/bestpractices/software_tools.shtml

- Process Heating Assessment and Survey Tool (PHAST)
- Steam System Scoping Tool
- Steam System Assessment Tool (SSAT)
- 3E Plus – Insulation Thickness Computer Program

Energy Information Bridge: www.osti.gov/bridge

Energy Matters: www.oit.doe.gov/bestpractices/energymatters/energy_matters.shtml

Online Chemical Engineering Information, Pinch Technology: Basics for Beginners: www.cheresources.com/pinchtech1.shtml.

The Carbon Trust: www.thecarbontrust.co.uk

Publications: www.thecarbontrust.co.uk/energy/pages/publication_search.asp

Organizations

Association of Energy Engineers: www.aeecenter.org

The Carbon Trust: www.thecarbontrust.co.uk/energy/pages/publication_search.asp

Gas Research Institute: www.gri.org

International Energy Agency: www.iea.org

Iowa Energy Center: www.energy.iastate.edu

Iowa State University Industrial Assessment Center (IAC): (515) 294-3080 or
www.me.iastate.edu/iac