Fundamentals of Air Heating with Gas

Introduction

This paper discusses the basic methods of heating air with gas burners for industrial process and make-up air applications. Industrial process heating includes ovens used in manufacturing a product, such as paint baking, chemical curing, or commercial bakery ovens. Make-up air heating involves building ventilation.

Heating Methods

Air heating is accomplished by either direct or indirect firing. The majority of industrial processes are direct fired, in which the combustion products are mixed with the air being used for processing. The air carries the heat and transfers the Btu's to the material. Almost all of the heat released by the fuel is used in heating the air stream, resulting in efficiencies of almost 100%.

Indirect firing is a method in which a heat exchanger transfers the heat from the combustion products to the airstream. The combustion products do not contact the work being heated. The efficiency of indirect heating is lower than direct firing. Therefore, indirect heating is used only for materials which must be dried to a very low humidity, or where combustion products are harmful to the material. In most cases, direct firing is preferable because of the simplicity of the equipment and the high efficiency obtained.

Burner Location

The burner, or heating equipment, can be located either externally or internally. When locating the burner externally, the burner, accessories, and usually the recirculating fan are combined in one separate unit and connected to the oven body by an external manifold or duct.

When locating the burner internally, the burner and circulating fan are incorporated in the oven body itself. Typical examples of this construction are bench, cabinet, and truck-type ovens.

For smaller ovens, the internal mounting should be used to enclose the parts within the insulated oven shell, minimizing heat losses. Larger ovens with very high heat input or a very high recirculating volume must be built with external heating units because the combustion equipment is too large to be economically enclosed within the oven shell. This is particularly true in tunnel conveyor ovens.

Another consideration is whether the burner will be located on the pressure side or suction side of the circulating fan. When located on the inlet, or suction side of the fan, the system is called **pull-through** because the air stream to be heated is pulled through the burner into the fan. In contrast, a **push-through** heater is one in which the gas burner is on the downstream, or pressure side of the circulating fan so that the air to be heated is pushed through the burner.

Air Flow

Ovens are classified as recirculating or non-recirculating.

A **recirculating** system is one in which some of the exhaust from the oven is brought back through the circulating fan or blower and reheated for delivery again into the oven. The amount of circulation depends upon the process and safety codes. This method is very efficient. Normally, maximum recirculation for line burners is 92% with provisions for proper distribution of fresh air. Return air temperature affects choice of burner and heater system.

A **non-recirculating** system is one in which heated air passes through the oven only once, and is then exhauster. This is the system used for make-up air or for spot heating where safety codes disallow any percent of recirculation.

The rate of circulation is expressed in air changes per minute, which means complete changes of oven chamber volume. The rate of circulation is a major influence on temperature accuracy, and six changes per minute is considered an absolute minimum. Ten to fifteen changes per minute can be used as a general guide in common ovens. When temperature accuracy is critical, it is best to go to 30, 50, and even 60 changes per minute.

The major problem in good oven design is achieving even pressure distribution throughout the full oven chamber. This even pressure distribution results in an even air flow and uniform temperature throughout the oven. Pressure screens on oven inlet and outlet ducts are used to provide this even pressure distribution. These pressure screens are the reason the recirculating fans are usually selected in a minimum range of 2-1/2" static pressure at 70°, leaving enough pressure at operating temperature to overcome the pressure drop at the pressure screens and around the work load.

Exhaust fans pull the air out of the oven chamber at approximately atmospheric pressure. Therefore, they must overcome only the resistance of the exhaust ductwork and can be rated in a range of 1/4 to 1/2" static pressure.

Heating Calculations

How much heat is required for a specific process? It is the sum of oven wall losses, product absorption loss, exhaust heat loss, and, if applicable, the heat required to remove moisture from the product.

Exhaust Heat Loss

A simple rule of thumb is:

$$\mathbf{Q \times 1.1 \times T_d = BTU/hr.}$$ where:

Q = Cubic feet per minute of process air being exhausted.

$\mathbf{T_d}$= Difference between air temperature entering the burner and the oven temperature. This assumes that the oven temperature is the same as the exhaust temperature.

Oven Wall Loss

Oven wall loss is the loss of heat through insulated panels and is determined by applying this formula:

$\mathbf{A_t \times F \times T_d = Btu/hr.}$ where:

$\mathbf{A_t}$ = The total number of square feet inside an oven, including walls, roof, and floor area.

$\mathbf{T_d}$ = Difference between oven temperature and room temperature.

F = A factor for thickness of oven panels. Some rules of thumb:

2" thick panels = .50

4" thick panels = .35

Product Heat Loss

Product absorption loss can be calculated with this formula:

$\mathbf{W \times S \times T_d = Btu/hr.}$ where:

W = Pounds per hour of product moving through the oven.

S = Specific heat of product. e.g., steel=0.12, aluminum=0.23, glass=0.19.

$\mathbf{T_d}$ = Difference between oven temperature and the temperature of the product entering the oven.

Moisture Heat Loss

If the oven is removing moisture from the product:

W x 1200 Btu = Btu/hr. where:

W = Pounds of water per hour being evaporated in the oven.

Economics

The economics of process air heating consist primarily of the cost of installation and the cost of maintenance. Installation costs include the costs of the burner, blower, valves, and other components; the assembly and mounting of these components; and the cost of piping, wiring, and sheetmetal work.

Maintenance costs include routine cleaning and possibly repair of burned out parts such as igniters, flame rods, thermocouples, and sometimes burner parts.

Make-Up Air

Make-up air is supplied directly from the outdoors to replace air that is being exhausted from a building. Without a make-up air supply, air that is exhausted from a building creates a negative pressure inside, pulling outside air in through the building cracks, window openings, and door openings. This puts a tremendous burden on the heating system in a building, especially in the winter.

In some manufacturing plants, the make-up air requirements may exceed several million cubic feet per minute. These quantities can be supplied only with a carefully engineered make-up air system.

The minimum temperature rise required from a make-up air system is 5° F or so. Maximum temperature rise is determined by the lowest outside temperature which may be expected during the winter months. In many industrial areas, a low of -10°F is not unusual, which means a maximum rise of 75°F for a delivery temperature of 65°, or a 90° rise for an 80° delivery temperature.

Make-up air temperatures are usually maintained at approximately 65-85°F. Once the delivery air temperature is determined, the total heat input is a function of outdoor temperature. As outdoor temperatures vary during the day, the heating equipment for make-up air must throttle to maintain desired delivery temperature. The ratio of maximum to minimum heat input required is called the turndown.

Contamination resulting from direct gas-fired burners is a concern of health codes. The two contaminants in question are nitrogen oxides (NOx) and carbon monoxide (CO). As a result of imperfect combustion, these two contaminants may be present in very small quantities. However, with proper equipment and adjustment, their presence is negligible.

In summary, a good make-up air system should provide:

1. Uniform heat distribution from the burner.
2. Turndown ratio from a minimum of 10:1 to as high as 30:1.
3. Complete combustion throughout the turndown range.
4. Stable flame at various velocities of air flow.
5. Economical, top quality performance.

Burner Capacity

The amount of heat required can be calculated with this formula:

$$\mathbf{Q \times 1.1 \times T_d = BTU/hr.}$$ where:

Q = Cubic feet per minute of process air being exhausted.

$\mathbf{T_d}$= Difference between outside air temperature and the make-up air delivery temperature.