Batch Ovens: The Inside Dope
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Effective batch processing requires more than simply loading a product into an oven. Carefully selecting the airflow pattern, product loading method and controls required for your process will ensure that you produce acceptable product every batch.

Virtually every manufactured product requires the introduction of heat at some point during the production process. Yet purchasing the proper piece of thermal processing equipment is rarely an easy or casual consideration. Understanding the basics can simplify the job of specifying your thermal processing equipment.

First, the fundamentals. An oven is an insulated enclosure or tunnel that operates at temperatures from slightly above ambient to 1,250°F (676°C). Loading configurations take two essential forms -- batch or continuous -- and the most common sources of heat are electricity, natural or propane gas, steam, hot water and fuel oil. The heated air usually is introduced into the work area with forced convection.

Laboratory vs. Industrial Batch vs. Continuous Ovens

The three essential oven categories are laboratory, industrial batch and continuous process. Their distinguishing characteristics are their construction, product-handling functions and operational flexibility.

Laboratory units typically have a temperature range of slightly above ambient to 650°F (343°C) and range in size from 2 to 32 ft^3. Construction differs from industrial batch ovens in that laboratory designs have positive-latch doors, pressure-release panels, stainless steel interiors, solid-state controllers and contactors, and an epoxy/chemical-resistant exterior coating. A laboratory oven's relatively small capacity lends itself to processing test samples or light-duty production of "smaller" parts and product.

Industrial batch units operate at temperatures from slightly above ambient to 1,250°F and range in size from 3 ft^3 and up. The two general categories of industrial batch ovens are shelf/cabinet and truck/walk-in. Typical features include an aluminized steel interior, fully adjustable duct work, scratch-resistant enamel paint on the exterior, digital setpoint controller and UL-listed control panel. These units are suited for processing larger quantities of product in a single batch.

Because they usually are designed for a specific product or production rate, conveyor units tend to be less flexible than batch ovens. Temperature range is the same as the industrial batch -- up to 1,250°F -- but this type of oven operates on a continuous or indexing basis through one or multiple heat zones. In general, conveyor units tend to be oriented toward automated production of greater quantities of small-to-medium-sized product. The type of conveyance system depends used on the product line, volume of work to be produced and temperature to be obtained.

Airflow Patterns

The airflow pattern employed is an essential component of successful oven selection and operation. If the wrong airflow is coupled with the wrong product loading configuration, the results can be undesirable. Six basic airflow patterns commonly are utilized: horizontal/vertical, vertical/horizontal, vertical/top down, vertical/bottom up, full horizontal and full horizontal/vertical.

With *horizontal/vertical airflow*, the air is supplied from the oven's side walls and returned to a duct or opening on the oven's ceiling. It is most applicable in production situations where the parts are larger in nature and are loaded into the oven on a flatbed cart or skid.

With *vertical/horizontal airflow*, air is supplied from ducts located on the oven's ceiling; the return ducts are located on each side wall. This airflow pattern typically is used when a vertical-type airflow pattern is needed in a truck or walk-in oven.

With *vertical/top down airflow*, air is supplied via ducts located in the oven's ceiling; the return ducts are located in the floor. Alternatively, with *vertical/bottom up airflow*, these positions are reversed. Both patterns are suited for production scenarios where the product is hung or smaller sized parts are placed on perforated shelves. (If product is loaded onto shelves in ovens employing these airflow patterns, the shelves must be perforated to allow air to pass with minimal obstructions.)

With *full horizontal airflow*, air is supplied by ducts located on one side of the oven; the return ducts are located on the opposite side. This pattern is designed for products that are loaded on shelves or hung. The combination of loading configuration and airflow allows the recirculated air to pass above and below each shelf, encircling the product with air.

A *full horizontal/vertical airflow* pattern is best suited for applications that require extremely tight temperature uniformity in a horizontal/vertical airflow pattern. For example, if two carts are loaded side-by-side into the oven with a space between them, this airflow pattern will allow the air to travel to a top return duct without obstruction.

All ovens share one common requirement with regard to airflow: The air must be able to pass, with minimal restrictions, from the supply duct to the return duct. If properly adjusted, this will ensure good temperature uniformity.

Temperature Uniformity and Control Sensitivity

Uniform temperatures within the oven work area help ensure a uniform product. Temperature uniformity is defined as the widest temperature deviation, in °F or °C, between the highest and lowest points within a given work area. It is important to note that +/-5°F actually represents a difference of 10°F.

Several factors impact work area uniformity: controller calibration; thermocouple calibration and placement; oven temperature; air circulation (cfm); airflow pattern employed and loading configuration; heat losses via walls; amount of metal-to-metal contact; and placement of the load within the oven.

To ensure good temperature uniformity, the loading configuration must be properly mated with the appropriate airflow pattern. If it is not, the air may be cut off or reduced to such an extent that good uniformity cannot be achieved. For example, in processes that require the product to be set upon flat, solid shelves, a vertical airflow pattern is the most inappropriate airflow to specify. With this combination of airflow and loading, the air would be blocked and not allowed to follow the desired path to the return duct. Because ovens transfer heat via movement of air, the oven will not perform as desired. By contrast, if flat, solid shelves are coupled with a full-horizontal airflow pattern, the oven will perform properly. The air will flow above and below each shelf, across the product.

Once the proper airflow pattern has been selected for the product and loading style, it is important to identify other oven characteristics that improve the oven's uniformity and performance.

The first is the volume or cubic feet per minute (cfm) of air that passes through the work chamber. As a general rule (although there are some exceptions), the more cfm an oven produces, the better the uniformity and the resulting product.

The second factor, which is closely linked to the first, that impacts oven uniformity is fan selection. To ensure adequate air velocity, the fan and motor must be sized properly and rated for the oven's rated maximum temperature. Keep in mind that as air's temperature increases, it becomes thinner and lighter. The motor and fan must be sized to ensure that an appropriate amount of cfm is provided. Also, be sure the fan is rated to withstand the high temperatures of the oven heat chamber.

The third component affecting uniformity is the interaction between the air -- both fresh and recirculating -- and the heat source. The return duct and fresh air inlet must be strategically placed so that the recirculated and fresh air meet on the negative side of the fan, before the airstream passes through the heat source. Once heated, the blended airflow exits the supply duct and passes into the oven work area. Some of the air will enter the return duct while the rest will be ventilated out of the exhaust port or forcefully exhausted from the work area by a powered exhaust system. By positioning the fresh air inlet and ventilation/exhaust opening properly, a slight positive pressure will develop, ensuring that fresh air is introduced via the fresh air inlet and not at possible leak spots (i.e., door seals).

Although important in every oven, the cfm rating, motor sizing, fan design and fresh-air-to-exhaust ratios and placement become increasingly critical to the successful balance of an oven as its operating temperature increases.

Control Sensitivity. No matter how carefully you work to ensure temperature uniformity by addressing the factors above, your process will operate poorly if the control is inaccurate. Therefore, it is important to ensure that the control instrument not only accurately measures but also properly reacts to temperature fluctuations at a given setpoint. This issue is critical for one simple reason: If an oven's instrumentation is not reading accurately, it cannot respond accurately.

For example, an oven may have a uniformity reading of +/-2°F and a setpoint of 300°F. At first glance, it seems that the oven will perform effectively. But, if the control sensitivity is poor, the temperature can continuously swing above and below the setpoint by 25°F. The result: Even with a tight temperature uniformity reading, the oven will perform poorly due to the lack of control sensitivity and the inability to hold the oven at a given setpoint.

Product Loading Options

Batch ovens have multiple means by which to load product, but the most popular are shelves and carts. Available in several configurations, typically shelves rest on rails that are attached to the side of the oven via keyhole slots. As a variation on this theme, roller shelves, which allow the load to be moved in and out of the oven with minimal effort, can be used. Roller shelves also are useful when product has to be picked up with an overhead hoist or crane.

For truck-in or walk-in style units, carts typically come in three configurations -- shelf, hanging or flatbed. Each style can be rated to different weights for varying processes, and each style tends to be more compatible with a particular airflow.

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