Types of Heat Treating Equipment for Fasteners

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The choice of heat treating equipment varies with application. Selecting the right style and type of equipment will ensure the highest quality product.

Fastener heat treatment (see **Figure 1**) can be performed in a wide variety of furnaces and ovens and fastener designers should understand the choices available to them.

Heat treating equipment is normally supplied in one of two main types: batch or continuous. The fundamental difference between these two styles is not in the materials of construction, although there are differences due to inherent design requirements, but instead the key difference lies in how workloads are positioned in the units and how they interact with the atmosphere within the furnaces.

Heat treating equipment can further be divided into (atmosphere and vacuum) furnaces and ovens.

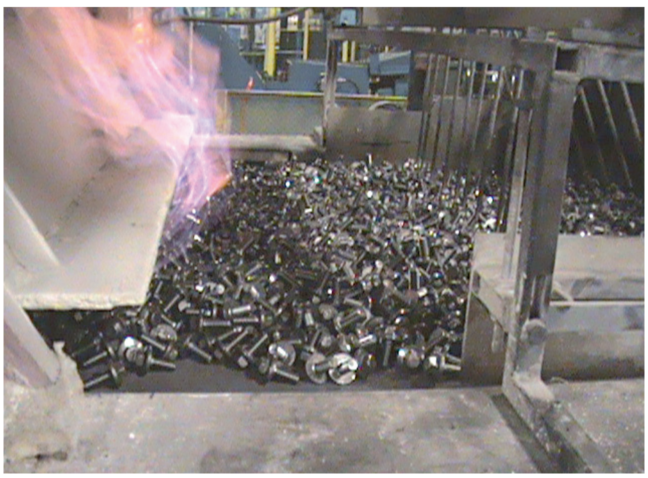

Fig. 1 — Typical production load of fasteners entering a furnace for hardening.

Furnaces

The primary sources of energy to heat workloads in furnaces are (natural) gas and electricity. Alternative energy sources such as other hydrocarbon fuels (propane, etc.) and oil can also used. Furnaces can be classified in a number of ways as summarized in **Table 1**.

Batch units tend to involve large, heavy workloads processed for long periods of time. In a batch unit, the work charge is typically stationary so that interaction with changes in the furnace atmosphere are performed in near equilibrium conditions. Batch furnace types include:

- Bell furnaces.
- Box furnaces.
- Car bottom furnaces.
- Elevating hearth furnaces.
- Fluidized bed furnaces.
- Gantry furnaces.

Table 1[2]. Classification of Furnaces.

Criteria	Distinguishing Feature	Remarks
Method of Heating	Combustion of Fuel	Gas (natural, other hydrocarbon, manufactured, tank) or oil (tar)
	Electricity	Electrical resistance (metallic, ceramic, other); Electric arc (melting); Electrical induction (heat treating, melting)
Method of Handling Charge	Batch	Work remains stationary
	Continuous	Work moves continuously within the equipment.
	Intermittent	Work moves periodically
Internal Atmosphere	Air	
	Other	Generated, synthetic, elemental, mix
Exposure of Charge to Atmosphere	Open	Exposed charge, single heat transfer.
	Closed	Muffle design (isolated charge, double heat transfer)
Type of Hearth	Stationary	Slab, skid, rails.
	Moveable	Belt, car, roller, rotating table, screw, shaker.
Liquid Bath	Salt	
	Other	Molten lead, fluidized bed

- Mechanized box furnaces (also called "sealed quench" or "integral quench", or "in-out" furnaces).
- Pit furnaces.
- Salt pot furnaces.
- Split or wraparound furnaces.
- Tip-up furnaces.
- Vacuum furnaces.

Of all the batch furnace types, integral quench furnaces (see **Figure 2**) are the most common for fastener heat treatment.

Continuous furnaces are characterized by the movement

Fig. 2 — Batch style integral quench furnace (photograph courtesy of Surface Combustion, Inc.).

of the workload in some manner, and the environment surrounding the workload changes dramatically as a function of the position of the work charge. Continuous furnace types include:

- Cast link belt furnaces.
- Humpback furnaces.
- Mesh belt furnaces.
- Monorail furnaces.
- Pusher furnaces.
- Roller hearth furnace.
- Rotary drum (rotary retort) furnaces.
- Rotary hearth furnaces.
- Shaker hearth furnaces.
- Vacuum furnaces.
- Walking beam furnaces.

Of all the continuous furnace types, mesh belt conveyor furnaces (see **Figure 3**) are the most common for high-volume production demands in the fastener industry.

Fig. 3 — Mesh belt conveyor furnace for hardening and case hardening fasteners (photograph courtesy of Williams Industrial Furnaces).

With respect to heat treating furnaces, there are a number of special purpose types including:

- Continuous slab and billet heating furnaces.
- Electron beam surface treatment equipment.
- Induction heating systems.
- Laser heat treating equipment.
- Quartz tube furnaces.
- Resistance heating systems.
- Rotating finger furnaces.
- Screw conveyor furnaces.

Table 2 summarizes the different processes that can be used in each type of equipment.

Vacuum Furnaces

Vacuum furnaces can be classified, according to the mode of loading, into horizontal (see **Figure 4**) and vertical furnaces and can be batch or continuous (multi-chamber) designs.

Heat treatment in vacuum furnaces is characterized by special conditions with regard to the design of the furnaces as well as the control of temperature and vacuum level dur-

Table 2. Common Applications of Heat Treating Furnaces[2].

Furnace Style	Application Use
Bell	Aging, Bluing, Hardening, Nitriding, Solution Heat Treatment, Stress Relieving, Tempering
Box	Aging, Annealing, Carburizing, Hardening, Malleabilizing, Normalizing, Solution Heat Treatment, Stress Relieving, Tempering
Car Bottom	Annealing, Carburizing, Hardening, Homogenizing, Malleabilizing, Normalizing, Spheroidizing, Stress Relieving, Tempering
Cloverleaf	Annealing, Carbon Restoration, Carbonitriding, Carburizing, Hardening, Normalizing, Tempering
Continuous Slab	Carburizing, Homogenizing, Solution Heat Treatment
Conveyor	Austempering, Annealing, Brazing, Carbon Restoration, Carbonitriding, Carburizing, Hardening, Homogenizing, Spheroidizing, Tempering
Electron Beam	Hardening (surface)
Elevator Hearth	Aging, Annealing, Hardening, Malleabilizing, Solution Heat Treatment, Stress Relieving, Tempering
Fluidized Bed	Carbonitriding, Carburizing, Hardening, Nitriding, Nitrocarburizing, Steam Treating, Tempering
Humpback	Annealing, Brazing, Hardening, Stress Relieving, Sintering
Induction	Hardening, Tempering
Integral Quench	Austenitizing, Annealing, Carbon Restoration, Carbonitriding, Carburizing, Hardening, Nitrocarburizing, Normalizing, Stress Relieving, Tempering
Ion	Carbonitriding, Carburizing, Nitriding, Nitrocarburizing
Laser	Annealing
Monorail	Annealing, Hardening, Normalizing, Stress Relieving, Tempering
Pit	Annealing, Bluing, Carbon Restoration, Carbonitriding, Carburizing, Hardening, Homogenizing, Nitrocarburizing, Nitriding, Normalizing, Solution Heat Treatment, Steam Treating, Stress Relieving, Tempering
Pusher	Annealing, Carbon Restoration, Carbonitriding, Carburizing, Hardening, Malleabilizing, Metallizing, Nitrocarburizing, Normalizing, Solution Heat Treatment, Sintering, Spheroidizing, Stress Relieving, Tempering
Quartz Tube	Hardening, Sintering
Resistance Heating	Aging, Annealing, Carbonitriding, Hardening, Normalizing, Stress Relieving
Roller Hearth	Bluing, Carbon Restoration, Carbonitriding, Carburizing, Hardening, Malleabilizing, Normalizing, Solution Heat Treatment, Spheroidizing, Stress Relieving, Tempering
Rotating Finger	Annealing, Hardening, Normalizing, Stress Relieving, Tempering
Rotary Hearth	Annealing, Austempering, Carbon Restoration, Carbonitriding, Carburizing, Hardening, Tempering
Salt Bath	Austempering, Carbonitriding, Carburizing, Hardening, Malleabilizing, Martempering, Nitrocarburizing, Normalizing, Tempering
Screw Conveyor	Annealing, Hardening, Stress Relieving, Tempering
Shaker Hearth	Annealing, Carbonitriding, Carburizing, Hardening, Normalizing, Stress Relieving, Tempering
Split	Annealing, Stress Relieving
Tip-Up	Annealing, Hardening, Malleabilizing, Normalizing, Spheroidizing, Stress Relieving, Tempering
Vacuum	Annealing, Brazing, Carbon Deposition, Carbonitriding, Carburizing, Degassing, Hardening, Nitrocarburizing, Normalizing, Solution Heat Treatment, Sintering, Stress Relieving, Tempering
Walking Beam	Annealing, Hardening, Normalizing, Sintering, Stress Relieving, Tempering

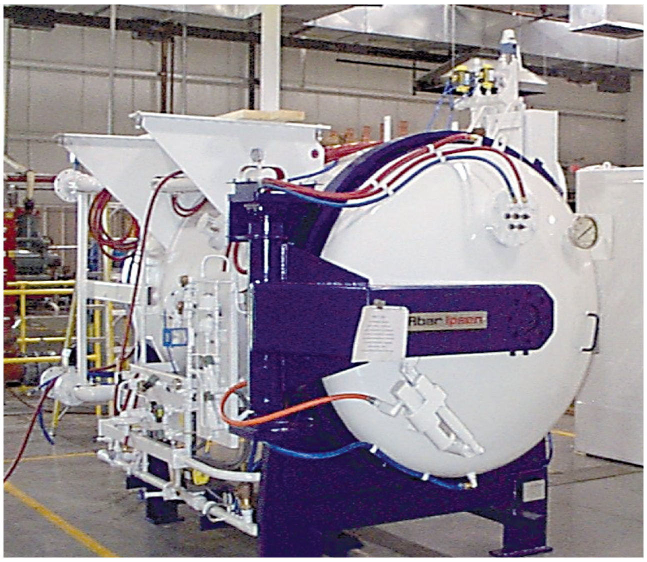

Fig. 4 — Batch vacuum furnace (photograph courtesy of Ipsen USA).

ing the heat treatment. The design of the furnaces generally depends on the size of the load, the pressure and temperature to be attained, and the medium (oil or gas) to be used in cooling the load. The main parts of a vacuum furnace include the following:

- Vessel.
- Pumping system.
- Hot zone.
- Cooling system.

Vacuum furnaces may be classified as hot wall or cold wall styles. The features of a cold-wall furnace include the following:

- Operating temperature in the range of 2400°F to 3000°F (1315°C 1650°C) or higher.
- Low heat losses and heat load released to the surroundings.
- Rapid heating and cooling performance.
- Tight (±10°F (5.5°C or better) temperature uniformity control.

Ovens

Ovens may be designed for intermittent loading, that is, one batch at a time (see **Figure 5**), or for a continuous flow of work using some form of conveyance through the unit. Oven equipment sizes vary dramatically, from small bench-top units in laboratory environments to huge industrial systems with thousands of cubic feet (cubic meters) of capacity. Ovens operate with air atmospheres, but may be designed to contain special atmospheres such as nitrogen or argon, or incorporate special construction such as adaptations for retorts that allow the use of special atmospheres for the processing of very specialized applications.

Fig. 5 — Batch oven for the heat treatment of aluminum fasteners (photograph courtesy of Wisconsin Oven Corporation).

The source of heat may be derived from combustion of fuel or electricity. Heat is transferred to the work primarily by natural gravity or forced convection, or by radiant sources if the temperature is high enough. Today, oven construction can be used in temperature applications up to 1400ºF (760ºC) although 1000ºF (538ºC) is a traditional upper limit. Oven technology utilizes convection heating, that is, the circulation of air, products of combustion or an inert gas as the primary means to heat a workload to temperature. Oven construction also varies considerably from furnace construction.

Selection of the type of oven involves the careful consideration of several variables. These variable include the following:

- Quantity of material to be processed.
- Uniformity in size and shape of the product.
- Lot size.
- Temperature tolerances.
- Effluent evolution, if any.

Batch systems may be classified as:

- Bell.
- Bench top.
- Cabinet.
- Truck.
- Walk-in.

Continuous systems include the following:

- Belt.
- Drag chain.
- Monorail.
- Pusher.
- Roller hearth.
- Rotary drum (or retort).
- Screw.
- Walking beam.

There are several design criteria for oven construction that includes:

- Operating temperature.
- Heating method.
- Thermal expansion of materials.
- Atmospheres.
- Airflow patterns.

The range of operating temperature is one of the main determinants of oven construction. Typically, all ovens are constructed of a double wall of sheet metal with insulation and reinforcing members sandwiched between the sheets. The insulation may be glass fiber, mineral wool or lightweight fiber material. The sheet metal lining for ovens may be of low carbon steel, galvanized steel, zinc-gripped steel, aluminized steel or stainless steel depending on the temperature requirement.

Several distinct changes occur in oven construction as the temperature increases. Problems, with expansion and sealing the interior from heat and atmosphere, become much more significant at higher temperatures.

For example, an oven system that is designed for operation at 400°F (205°C) will have mineral wool insulation, 4" (100 mm) thick.

By contrast, for an oven with a 700°F operating temperature, a thickness of 7" (175 mm) is required. Thermal expansion in large oven systems is generally compensated for by the use of telescoping panel joints in the walls, ceiling and floor. Door construction must incorporate similar expansion joints.

The type and quantity of airflow is important. For example, ovens designed for handling explosive volatiles such as paint drying or solvent extraction have special considerations including large air flow volumes to dilute the volatile gases, explosion relief hatches, purge cycles, powered exhausters, airflow safety switches and fresh air dampers.

Several different patterns of air flow can be used depending on the workload configuration. These air flow patterns include the following:

- Horizontal.
- Vertical.
- Combination (uniflow).

The method of heating an oven often depends not only on the availability of a particular fuel, but also on the process itself. Many processes cannot tolerate products of combustion from direct fired systems so indirect (radiant tube) firing or alternate energy sources need to be considered.

In addition, some means of heat transfer such as microwave heating are severely limited in the type of product that can be processed. Ovens are commonly heated by fuel (including natural gas or other hydrocarbons), steam or electricity. Infrared heating and microwave (radio frequency) can also be used.

Final Thoughts

The choice of heat treating equipment varies with application. Selecting the right style and type of equipment will ensure the highest quality product. Often times a number of furnace types can do the job, so the choices comes down to economy of operation.

Shops who do not operate 24 hours a day, seven days a week, or who are not in a position to dedicate staff to this endeavor may wish to consider batch equipment or vacuum processing or look at outsourcing to qualified commercial heat treaters. Other shops need to evaluate which technology is the best fit to their product mix and skill sets.

To learn more about the types of heat treating systems for fasteners, visit the website listed below.

www.heat-treat-doctor.com

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References:

[1] *Herring, D. H., Heat Treating Equipment, White Paper, 2003.*

[2] *Heat Treater's Guide: Standard Practices and Procedures for Steel, ASM International, 1982.*