In simple terms, industrial heat treating furnaces are insulated enclosures designed to deliver heat to workloads for thermal processing. Basic elements of construction include an outer shell, refractory walls, hearth, roof, a source of heat (electricity or combustible fuel), and a means of accepting a workload, moving it through the furnace (if necessary), and removing it.

Generally, furnaces are classified by heat source (combustion of fuel, or by conversion of electric energy to heat) and by two broad categories: batch and continuous.

Fuel-fired (combustion type) furnaces are most widely used, but electrically heated furnaces are used where they offer advantages that cannot always be measured in terms of fuel cost.

In batch-type furnaces, loads are placed in the furnace, the furnace and its loads are brought up to temperature together, and depending on the process, the furnace may or may not be cooled before it is opened and the load removed, which generally is through a single charging and discharging door. Batch furnace configurations include box, car bottom, bell, elevator, pit, vacuum, and pot.

Continuous furnaces move the work while it is being heated. They operate in uninterrupted cycles as the workpieces move through them. Material passes over a stationary hearth, or the hearth itself moves. Continuous-type furnaces can be classified as either straight-chamber furnaces or rotary-hearth furnaces. Straight-chamber furnaces can be classified as pusher type; walking beam type; conveyor type such as roller hearth, and continuous belt; and furnaces with tumbling or inertia action of the parts for movement.

tomats that can be shifted sideways, allowing the use of more than one bottom per furnace. Another design, the through-type furnace, can be loaded from one end and discharged from the opposite end. Longer furnaces have multiple heating and control zones. Operating temperatures range from 200 to 2400°F (95 to 1300°C).

Heat Treating Applications
- Annealing; e.g., castings
- Hardening
- Normalizing
- Stress relieving
- Aging
- Carburizing
- Malleabilizing
- Tempering
- Spheroidizing
- Homogenizing

Heating Applications
- Reheating for forging
- Investment casting bakeout
- Carbon baking
- Ceramic mold firing

Advantages
- Ideal where larger loads cannot be handled by forklift
- Temperature uniformity
- Similar to box furnace, but has removable car hearth assembly
- High speed heating with afterburner
- Furnaces may be small (e.g., 6 × 6 × 6 ft, or 2 × 2 × 2 m), or huge, occupying the space of an entire building

Limitations
- Are cost effective only if units are operated on a regular basis
- Are nonatmospheric
- Lack flexibility

(See page 60 for suppliers of car-bottom furnaces)

PIT FURNACE
These furnaces are vertically loaded, and heat treated parts are contained in baskets or resting on fixtures. Sizes range from small, floor-mounted units to large pit-mounted types. Work often is shielded from heating units by baskets or fixtures, and recirculating fans are almost always required to ensure uniformity of heating. Heating methods include direct firing, radiant tube heaters, and electric resistance heaters. Operating temperatures range from 300 to 2400°F (150 to 1300°C).

Heat Treating Applications
- Annealing, including long-cycle annealing of ferrous and nonferrous parts
- Hardening
- Tempering
- Drawing
- Normalizing
- Stress relieving
- Steam treating
- Homogenizing
- Carburizing
- Carbonitriding
- Carbon restoration
- Bluing
- Nitriding
- Solution heat treating

Advantages
- Uniform temperature
- Accommodates long, heavy loads
- Flexibility

Limitations
- Overhead handling required for loading and unloading
- Effective hearth areas; about 300 lb/ft² (1,465 kg/m²)
- Potential for decarburization and scaling
- Pit construction costs

(See page 63 for suppliers of pit furnaces)

BELL AND HOOD FURNACE
These furnaces consist of refractory lined covers equipped with heating devices in the form of direct firing burners, radiant type burners, and electric resistance heating units. Covers can be lifted off stationary bases by overhead cranes and relocated to spare bases. One cover can be used with several bases, providing efficient use of covers while coils or long bars are being loaded, cooled and unloaded. Inner mufflers may be used for controlled atmosphere operations. Rapid cooling facilities also are available. The operating temperature range is 300 to 2200°F (150 to 1200°C).

Heat Treating Applications
- Annealing of both ferrous and nonferrous metals is a major application, including the processing of strip and wire coils. Tubular products, bars, and extruded shapes also are annealed or normalized.
- Hardening
- Nitriding
- Aging
- Bluing
- Tempering
- Stress relieving
- Solution heat treating

Heating Applications
- Brazing
- Coating

Advantages
- Can use atmospheres
- One cover can serve multiple bases
- May be heated using gas or electricity

Limitations
- Pit and overhead cranes are required
- Long process cycle times

(See page 59 for suppliers of bell and hood furnaces)
ELEVATING HEARTH FURNACE

This furnace is a reverse version of the bell and hood type. The enclosure is built on a platform and is stationary. Hearths are loaded or unloaded at floor level and elevated to fit into the bottom of the furnace, which is direct fuel fired, radiant tube heated, or electrically heated. This type of furnace design also is used in vacuum furnaces.

In solution treating aluminum, for example, the hearth can be lowered rapidly into a quench tank for minimum loss of heat before quenching. For ease of loading or unloading, the hearth also can be mounted on rails for movement outside the furnace area.

The furnace also has heating applications. It is ideal, for instance, in treating graphite components and rocket nose cones and nozzles. The operating temperature range is 600 to 2400°F (315 to 1315°C).

Heat Treating Applications
- Solution treating
- Hardening
- Aging
- Malleabilizing
- Tempering
- Annealing
- Stress relieving

Heating Applications
- Reheating for forging
- Brazing
- Sintering (firing)

Advantages
- Excellent thermal uniformity and atmosphere control
- Rapid heating and quenching
- Low dew points

Limitations
- Manual transfer of parts
- Limited effective hearth area
- Headroom requirements

(See page 61 for suppliers of elevating hearth furnaces)

INTEGRAL QUENCH (IQ) FURNACES

In this system, quenching takes place within the furnace. A means of transferring work through the furnace and quench is built into the equipment.

Construction often is similar to that of a box furnace, with a manually operated door or a conveyor or roller hearth and a quench tank at the discharge end. Work drops into the quench and is brought out by an inclined metal mesh belt conveyor. In a variation of this design, parts are placed into an alloy basket, which is moved into the furnace and heated. After the heating cycle, the basket may be lowered into the quench by an elevator, brought back up to the surface, and moved out of the furnace.

Furnaces are gas or electrically heated and protective atmospheres are required in some applications. Atmospheres are used, for example, in case hardening, hardening oil quenching steels, and in annealing precious metals. The operating temperature range is 1000 to 2050°F (540 to 1120°C).

Heat Treating Applications
- Case hardening
- Neutral hardening
- Clean hardening
- Normalizing
- Carburizing
- Nitrocarburizing
- Carbonitriding
- Annealing
- Carbon restoration
- Stress relieving
- Austenitizing

Heating Applications
- Sintering ferrous materials

Advantages
- Flexibility
- Transfer of work to quench under protective atmospheres

Limitations
- Relatively long downtime in changing processes
- Manual transfer of parts in low-volume production and testing application

(See page 62 for suppliers of IQ furnaces)

TIP-UP FURNACE

This design is a variation of the bell and hood or car-bottom furnaces. The furnace enclosure, high at one end or on one side, is provided with a hydraulic or mechanical elevating mechanism for lifting the unhinged end or side up to expose the base on which the work is placed. The base can be stationary and loaded using a fork lift truck, or movable and loaded using an overhead crane. The configuration of the furnace can be square, rectangular, or circular, and heating can be direct...
fire, radiant tube, or electric resistance. The operating temperature range is 600 to 2400°F (315 to 1315°C).

Heat Treating Applications
- Annealing of wire, long bars, rod, pipe, etc.
- Hardening
- Spheroidizing
- Normalizing
- Malleabilizing
- Tempering
- Stress relieving

Heating Applications
- Reheating for further processing or heating for forging

Advantages
- Absence of door opening reduces heat losses
- Excellent seal
- Atmosphere controlled
- Easy loading and unloading
- Gas or electric heating
- More efficient than car-bottom furnace
- Accommodates heavy loads
- Simple to control

Limitations
- Not cost effective when loading is light
(See page 64 for suppliers of Tip up furnaces)

WALKING BEAM/SCREW CONVEYOR FURNACES

In the walking beam furnace, work is lifted, moved forward, and dropped back on the hearth by means of a walking beam mechanism. In all other respects, the furnace is similar in construction to that of other continuous furnaces.

Operations may be at any operating temperature. The top of the beam mechanism is covered with refractories in high-temperature applications. Firing is with burners mounted either in side walls or roof. Recuperation can be added to improve efficiency. Operating temperature range is 300 to 1750°F (150 to 955°C).

Advantages
- Continuous processing of heavy loads (walking beam)
- Continuous processing of long cylindrical parts (screw conveyor)

Limitations
- Part size
(See page 65 for suppliers of walking beam furnace)

ROTARY HEARTH FURNACE

This type of furnace is designed for continuous production and is unique in its construction; a ring-shaped configuration with fixed inside walls, outer walls, and roof. A movable hearth fits inside the walls and is indexed periodically, carrying the work with it. Work is placed on a hearth and removed after it has completed its cycle.

Furnaces can be roof or side fired or electrically heated. They have a variety of heat treating applications. Efficiencies vary with firing methods and construction. Furnace sizes range from around 6 to 100 ft (2 to 30 m) in diameter. Throughput depends on part size and the application. Parts within the size range include bearing, gears, saw blades, and billets for seamless tube production.

The advantage of this design is that continuous motion is obtained within a minimum of floor space. Charging and discharging can be handled by one operator. Either hard-burned refractories or ceramic fiber linings are used. Automatic temperature, fuel-air ratio, and pressure controls are commonly part of the system. The operating temperature range is 600 to 2400°F (315 to 1315°C).

Heat Treating Applications
- Hardening
- Annealing
- Carburizing
- Carbonitriding
- Carbon restoration
- Malleabilizing
- Normalizing
- Tempering
- Austempering

Heating Applications
- Billets
Preheating for forging
Investment casting bakeout
Ceramic firing
Press quench and reheat

Advantages
- Work normally moves through furnace back to initial loading zone
- High speed heating
- Modest space requirements
- Repeatability
- Simple to control
- Continuous production of small parts
- Easy to automate
- Low operating and maintenance costs
- Uniformity of atmospheres and temperatures

Limitations
- Automation required for loading and unloading
  (See page 64 for suppliers of rotary hearth furnaces)

**PUSHER FURNACE**
This is the simplest type of continuous furnace available for both heating and heat treating applications. The furnace does not have a built-in conveyor. Work is loaded onto trays or fixtures and is moved by being indexed by pusher mechanism mounted outside.
the furnace. Skid rails or alloy rollers are mounted inside the furnace and provide the surface on which work containers are pushed. The furnace can be end charged and discharged, side charged and discharged, or bottom charged and discharged. Types of furnaces include pusher skid tray, pusher roller tray, pusher roller rail, and pusher dog beam.

The design and method of handling favor package line systems made up of a heating/heat treating furnace, quench tank, washing, and draw furnace. The operating temperature range is about 300 to 1750°F (150 to 955°C).

Heat Treating Applications

- Annealing
- Carbonitriding
- Carburizing
- Hardening
- Normalizing
- Clean hardening
- Ferritic nitrocarburizing
- Malleabilizing

- Solution heat treating
- Tempering
- Stress relieving
- Carbon restoration
- Spheroidizing

Heating Applications

- Brazing
- Investment casting bakeout
- Ceramic firing
- Metallizing
- PM sintering
- Preheating parts

Advantages

- Benefits inherent in continuous processing, including high volume production of similar parts
- Tailored to application
- Simple mechanics, easy to maintain
- Positive positioning of work

Limitations

- Lack of flexibility—tailored to an application
- Space requirements
- Not cost-effective in low volume production
- High capital cost

(See page 63 for suppliers of pusher furnaces)

ROLLER-HEARTH FURNACE

The distinguishing feature of the roller hearth is its method of material handling; work is transported through the furnace on rollers. Rollers may be powered or work may be pushed over them by such means as air or hydraulic cylinders. Rollers are made of heat resistant alloys and often are water cooled, as are their bearings. Furnace size varies with application. The heating of large parts and plates is a frequent application, and the equipment also handles a number of heat treating operations.

Construction and heating methods are similar to those of other continuous conveyor furnaces. Linings are constructed of fire brick or ceramic materials. Heating is electricity or fuel-fired burners. Electric heating requires the use of circulating fans. Controls include electric types for temperature and for
fuel-air ratios. Zone control is used where controlled rates of heating and cooling are required.

Rollers tend to bend when they are idle and must be kept in continuous motion while a furnace is being heated. The operating temperature range is 300 to 1800°F (150 to 980°C).

Heat Treating Applications
- Solution heat treating
- Stress relieving
- Bluing
- Spheroidizing
- Tempering
- Normalizing
- Malleabilizing
- Annealing, e.g., copper and brass tubing and coils
- Hardening including clean hardening
- Carburizing
- Carbonitriding
- Carbon restoration

Heating Applications
- Heating large parts and plates
- Heating for forming operations
- Brazing
- Sintering

Advantages
- Benefits of continuous processing and automation
- Efficient heat transfer
- Easy to load and unload
- Trays and fixtures not always required
- High volume production capability
- Reliability
- Minimum contact of conveyor with work

Limitations
- Heavy loads require high operating temperatures
- Tendency of rollers to bend when idle
- Relatively high maintenance cost

• Carbon restoration
• Annealing, including bright annealing, of ferrous and nonferrous metals
• Carbonitriding
• Austempering
• Carburizing
• Spheroidizing
• Homogenizing
• Steam treating

Heating Applications
- Brazing, including copper and silver brazing to ferrous and nonferrous metals
- Sintering, including under protective gas atmospheres
- Glass-to-metal hermetic sealing
- Curing
- Metal bonding
- Electronic or thick film hybrids and soldering
- Billet heating

Advantages
- Benefit of continuous processing
- High volume production
- Flexibility in loading
- Bright surfaces produced without oxidation
- Pickling not required
- Many available combinations of belt width, working heights, chamber length, and product volume per given application
- Heavy loading of multiple configurations possible with cast chain belt type conveyors
- Mesh belt type conveyors provide continuous processing of lightweight parts
- With slot/flight type conveyors, conveying surface is solid and flat
- With chain conveyor type, no belt is required; chain support is at ends of parts

Limitations (generic)
- Light loading
- Relatively short belt life

(See page 63 for suppliers of roller hearth furnaces)

CONVEYOR HEARTH FURNACE
These furnaces have moving hearths. Work is moved through the furnace by means of cast alloy link chain, roller chain, metal mesh, or other types of conveyors. Conveyors are of typical construction, with drives and sprockets, or drums, on head shafts. As with all conveyors, a take-up device compensates for chain or mesh wear. Conveyors may be entirely contained in a furnace, or the return half may be on the outside.

General furnace configuration is similar to that of the roller hearth. Many different designs and conveyor systems are available and what is suitable in a given application depends on the materials being handled and operating temperatures. Operating temperatures differ; for example, 300 to 2100°F (150 to 1150°C) for mesh belt type, 300 to 1750°F (150 to 955°C) for cast mesh belt type, 300 to 1600°F (150 to 870°C) for chain conveyor type.

Heat Treating Applications
- Tempering
- Hardening including clean hardening
- Normalizing

Hump-back belt conveyor type furnace. Courtesy of Abbott furnace Co.
SHAKER HEARTH FURNACE
The name, shaker hearth, refers to the method of moving work through a furnace. Generally, parts are small and are moved over the hearth by an electrically activated vibrating mechanism. The general configuration is tunnel-like, with a door at each end. Refractories are enclosed in a steel housing. Heat treating is a primary application. Furnaces may be direct fired or electrically heated. The operating temperature range is 300 to 1750°F (150 to 955°C).

Heat Treating Applications
- Hardening, including neutral hardening of carbon steel and light case hardening
  - Carburizing
  - Carbonitriding
  - Stress relieving
  - Normalizing
  - Annealing
  - Tempering
  - Austempering

Advantages
- Continuous processing of small parts
- Benefits of automation available
- Oil quench with oil cooler and conveyor extractor available
- Gas fired or electrically heated

Limitations
- Part size limited
- Noise in operation

(See page 64 for suppliers of shaker hearth furnaces)

ROTARY RETORT FURNACE
This type of furnace consists of a tightly sealed retort which rotates continuously, causing work to flow uniformly through the structure. Furnaces can be continuous or batch type, and are mainly used in heat treating, particularly in the bearing and chain industry where uniform deep case hardening is required.

Heat Treating Applications
- Small ferrous and nonferrous parts
- Process and production testing
- Small volume production
- Hardening
- Tempering
- Austempering
- Annealing
- Carburizing
- Carbon restoration
- Carbonitriding

Advantages
- Operating efficiency
- Quiet
- Good space utilization
- Continuous processing of small parts
- Benefits of automation available

Limitations
- Mixing of product limited
- Parts should be small; i.e., 12 in. (305 mm) max diameter
- Nicking and burring of parts can be a problem

(See page 64 for suppliers of rotary retort furnaces)

ION/PLASMA NITRIDING/CARBURIZING FURNACE
Parts are surface hardened in this process. The furnace consists of a vacuum chamber in which a workload is suspended. Surface hardening takes place in the plasma of a current-intensive glow discharge. A regulated voltage is applied between the chamber and workpiece in a vacuum, producing the ionized ionitriding/carburizing plasma. The ground chamber well forms the anode, and the workpiece becomes the cathode.

After evacuation of air, a reaction gas (a nitrogen-hydrogen mixture in the case of nitriding, and a gas such as methane is the source of carbon for carburizing) is introduced, and a voltage is applied between the anode and cathode to start the corona discharge. The reaction gas is ionized in the corona discharge, causing the nitrogen gas (in nitriding) to accelerate toward the workpiece where the impingement cleans and depassivates the surface. Part of the kinetic energy is converted into thermal energy that heats the work uniformly. Nitrogen ions (in nitriding) react at the surface of the work,
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Heating and cooling rates can be controlled, providing good structural stability and minimum distortion of parts.

**Heat Treating Applications**
- Nitriding, i.e., extrusions and D2 tool steel
- Carburizing of steel

**Advantages**
- Heating and cooling rates are controlled
- Case depths are uniform
- Surfaces are hard, resistant to wear and fatigue
- Environmentally clean process
- Minimum distortion of parts
- Low operating costs

**Limitations**
- Depth of hardness
- Light to medium loading of work
- Fixturing required
- Temperature is adjusted to application

(See page 62 for suppliers of ion/plasma nitriding/carburizing furnaces)

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**Vacuum Furnace**

Two distinctly different types of vacuum furnaces are hot wall (no water cooling of the exterior walls) and cold wall (water-cooled walls). Three basic designs of vacuum furnaces are vertical top loading, vertical bottom loading, and horizontal loading. Various designs are available including single chamber units in which the entire operation consists of heating, holding, and cooling; two-chamber units in which a quenching or rapid cooling chamber is added for quenching in vacuum; and three-chamber units that have a cooling or preheating chamber. Furnace designs can be varied to fit a wide variety of processing requirements by changing chamber length or by adding internal doors, circulating fans, recirculating gas systems, and internal quenching systems.

Every vacuum furnace requires heating elements controlled to generate proper heating rates, suitable vacuum enclosures with access openings, vacuum pumping system, and instrumentation to monitor and display critical processing data.

Materials heat treated in vacuum furnaces include alloy steels and non-ferrous metals and alloys, tool steels, heat resistant alloys, and special steels. Heating applications include the production of carbon-carbon materials.

**Heat Treating Applications**
- Annealing, i.e., bright annealing
- Hardening
- Tempering
- Stress relieving
- Carburizing
- Nitriding
- Carbonitriding

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**Vacuum Furnace Applications**
- Brazing
- Sintering
- Diffusion bonding
- Production of carbon-carbon materials

**Advantages**
- Cleanliness
- Repeatability of results
- Ability to shut down totally between cycles
- High quality product
- Pressurized gas cooling
- Gas quenching to 20 bar

**Limitations**
- Higher capital cost

(See page 64 for suppliers of vacuum furnaces)
**Fluidized Bed Furnace**

Heat treating is carried out in a bed of mobile inert particles such as aluminum oxide. Particles are kept in suspension by the combustion of a fuel-air mixture flowing upward through the bed. Components are immersed in the fluidized bed as if it were a liquid, and heated by a hot fluid bed.

Heat transfer rates are up to ten times higher than those available in a conventional open-fired furnace. The combination of high heat transfer, excellent heat capacity, and uniformity of behavior over a wide temperature range makes the fluidized bed an ideal method for providing a constant temperature bath for many applications, including those of competitive processes, such as salt and molten metal baths.

The bed is heated either by gas firing, or by electric heating elements using a gas diffuser system to keep particles on the bed when it is in motion. Furnaces are fired internally for temperatures over 1400°F (760°C), and externally for temperatures under that.

Fluidized beds have a variety of applications, including continuous operations such as wire processing.

**Heat Treating Applications**
- Nitrocarburizing; i.e., ferritic type
- Nitriding
- Carbonitriding
- Carburizing
- Hardening; i.e., bright type
- Tempering
- Steam oxidizing
- Methanol can be used in deep case carburizing
- Can quench air hardening tool steels under nitrogen atmosphere
- Can harden and quench thick section parts

**Advantages**
- High thermal efficiency, meaning low fuel consumption and low operating costs
- Clean and safe process due to inert nature of fluidized bed media
- Short heat up time—beds can be shut down during periods of nonuse
- Media do not melt at normal operating temperatures, so immersed parts are not wetted, eliminating post-treatment cleaning and minimizing media makeup
- Short cycle times
- Simple load fixtures
- Repeatable cycles and results
- Can sequentially heat treat in same furnace
- No hazardous waste
- Methanol can be used in deep case carburizing
- Can quench air hardening tool steels under nitrogen atmosphere
- Can harden and quench thick section parts

**Limitations**
- Parts with threads not good application
- Limited part size
- Some surface oxidation produced in hardening high speed steel parts

(See page 61 for suppliers of fluidized bed furnaces)

**Pot (Salt Bath) Furnaces**

Baths of molten salt or metal have both heat treating and heating applications. Pot furnaces are unique in that the media being melted is the source of heat for these operations. Pots are externally heated by gas firing or electrically heated by immersion. Handling may be manual or mechanized. The upper operating temperature is around 1650°F (900°C).

**Heat Treating Applications**
- Austempering
- Martempering
- Hardening
- Tempering
- Carburizing
- Solution heat treating
- Aging treatment
- Reducing hydrogen embrittlement

**Advantages**
- Ideal for small loads
- Easy to change applications batch to batch

(See page 63 for suppliers of pot (salt bath) furnaces)

**Batch Type Ovens**

A common batch oven consists of an insulated enclosure with access doors on one end and is equipped with temperature controls, air circulation systems, and exhaust systems. Materials to be heated are placed on portable shelves or racks that are easily rolled in and out of the oven. The operating temperature range is between 300 and 1200°F (150 and 650°C).

**Heat Treating Applications**
- Tempering
- Solution heat treating
- Aging treatment
- Reducing hydrogen embrittlement

(See page 61 for suppliers of fluidized bed furnaces)
CONTINUOUS OVENS

A continuous oven with continuous conveyor system is essential to facilitate handling high production rates. Equipment requirements can range from what essentially is a batch oven with a pass-through conveyor to large units. More complex systems may include provisions to maintain several different temperature levels, air circulation rates, and exhaust gases. Operating temperatures range from 300 to 1200°F (150 to 650°C).

Heat Treating Applications
- General heat treating processes such as annealing, blackening, tempering, stress relieving, aging, reducing hydrogen embrittlement, and solution heat treating

Advantages
- Consistency of product
- Automation

Limitations
- Relatively high equipment cost
(See page 60 for suppliers of ovens)

Floor model electrically heated batch oven. Courtesy of Lucifer Furnaces Inc.

Large walk-in batch oven. Courtesy of Wisconsin Oven Corp.

- Many standard models to choose from
- Fast, uniform heat transfer
- Easy to operate
- Low maintenance costs

Limitations
- Not as efficient as continuous ovens
- Low volume production
(See page 59 for suppliers of ovens)

Large slat chain-conveyor continuous oven used to temper heavy parts. Courtesy of Wisconsin Oven Corp.

- Fast, uniform heat transfer
- High productivity
- Process control
- Clean processing

Floor model electrically heated batch oven. Courtesy of Lucifer Furnaces Inc.

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