

Heat Treating Industry, Processes and Equipment

Presentation Content

- *Heat Treating Industry and Processes Overview*
- *Heat Treating – A Video Presentation*
- *Gas Fired Metal Heat Treating Furnaces*
- *Heat Treating Atmospheres*
- *Electrical Heat Treating Systems (Furnaces)*
- *Process Heating Tools and Models for Heat Treating*
- *Emerging Gas-Fired Process Heating Equipment*

Heat Treating Industry and Processes

Overview



Heat Treating - At a Glance

WHAT IS HEAT TREATING?

Controlled Heating And Cooling of Metal to Change Its Properties and Performance.

Through:

- Change in Microstructure
- Change in Chemistry or Composition

Commonly Heat Treated Metals

Ferrous Metals

- Steel
- Cast Iron
- Alloys
- Stainless Steel
- Tool Steel

Non-ferrous Metals

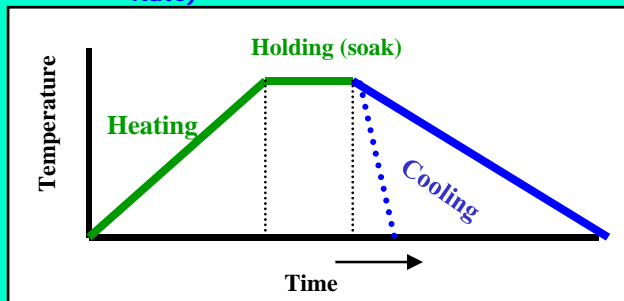
- Aluminum
- Copper
- Brass
- Titanium

Why Heat Treat?

- To improve Toughness
- To increase Hardness
- To increase Ductility
- To improve Machineability
- To refine Grain Structure
- To remove Residual Stresses
- To improve Wear Resistance

Typical Heat Treating Cycle

- Heating to the Control Temperature
- Holding at Temperature (Soak)
- Cooling (Rapid or at Slow / Controlled Rate)



Who Uses Heat Treating?

SIC	Industry
331	Steel Mills
332	Iron and Steel Foundries
34	Metal Fabrication
35 & 36	Machinery and Electrical/Electronic Equipment
37	Transportation Equipment
3398	Commercial Heat Treating
5051	Steel Service Centers

- **Primary Producers**
 - Steel Mills: Hardening of Bars, Rods Tubes, Pipes, etc.
 - Annealing of Plates, Sheets, Wires, etc.
- **Captive Plants**
 - Melt and Casting Shops, Forging Plants, Manufacturers of Automotive Parts, Farm and Earth Moving Machinery, Machine Tools, etc.
- **Commercial Heat Treaters**
 - Service Providers for a Variety of Heat Treating Processes for Different Parts to Manufacturers.

A Few Facts about Heat Treating

- Steel Is the Primary Metal Being Heat Treated. More Than 80% of Heat Treating Is Done for Steel.
- Heat Treating of Metals Represents Approximately 100 BCF Gas Load Nationwide.
- Heat Treaters Use Natural Gas to Supply About 2/3 of the Energy Used for Heat Treating (induction, vacuum & commercial atmospheres are the main competition).
- Current Share of Gas Decisions is about 50 / 50 Between Gas & Electric.

Metal Heat Treating

Topics of Presentation

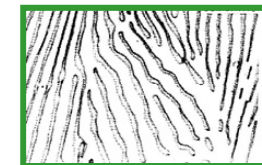
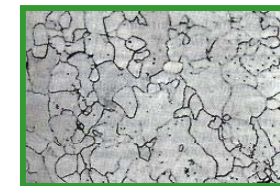
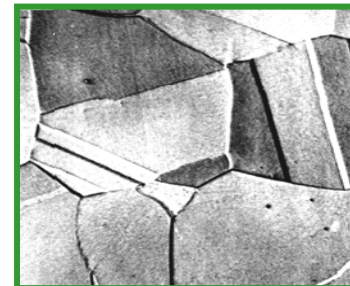
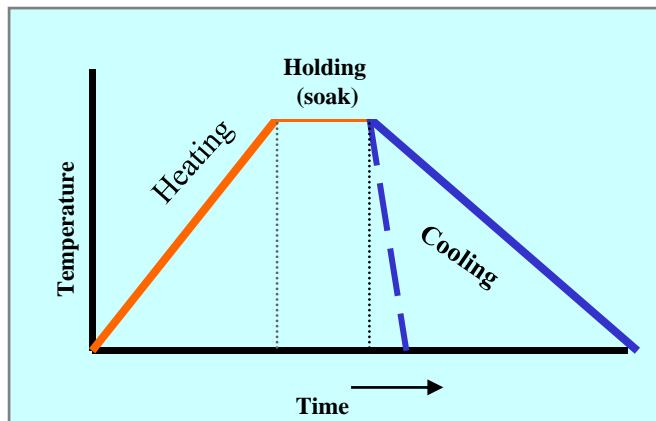
- What Is Metal Heat Treating?
- Where Is It Used?
- Why and How It Is Done?
- What Processes & Equipment Are Used for Heat Treating?

What is Heat Treating ?

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Why Use Heat Treating ?

In simple Terms....

- Soften a Part That Is Too Hard.
- Harden a Part That Is Not Hard Enough.
- Put Hard Skin on Parts That Are Soft.
- Make Good Magnets Out of Ordinary Material.
- Make Selective Property Changes Within Parts.

Who uses Heat Treating ?



- Aircraft Industry
- Automobile Manufacturing
- Defense Sector
- Forging
- Foundry
- Heavy Machinery Manufacturing
- Powder Metal Industries

What Industrial Sectors Use Heat Treating ?

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332	Iron and Steel Foundries
34	Metal Fabrication
35 & 36	Machinery and Electrical/Electronic Equipment
37	Transportation Equipment
3398	Commercial Heat Treating
5051	Steel Service Centers

Types of Heat Treaters

- **Commercial Heat Treaters**

- Heat Treating of Parts As “Job-shop”.
- Reported Under SIC Code 3398.
- Approx. 10% of All Heat Treating Production Is by Commercial Heat Treaters.
- Usually There Are 4 to 5 Captive Heat Treaters for Each Commercial Heat Treater Shop.

- **Captive Heat Treaters**

- Usually a Part of Large Manufacturing Business.
- They Usually Produce “Products” Rather Than Parts.
- Captive Heat Treating Is Scattered Through All Manufacturing SIC Codes (DEO has over 100 individual SIC’s for Heat Treaters).

Commonly Heat Treated Metals

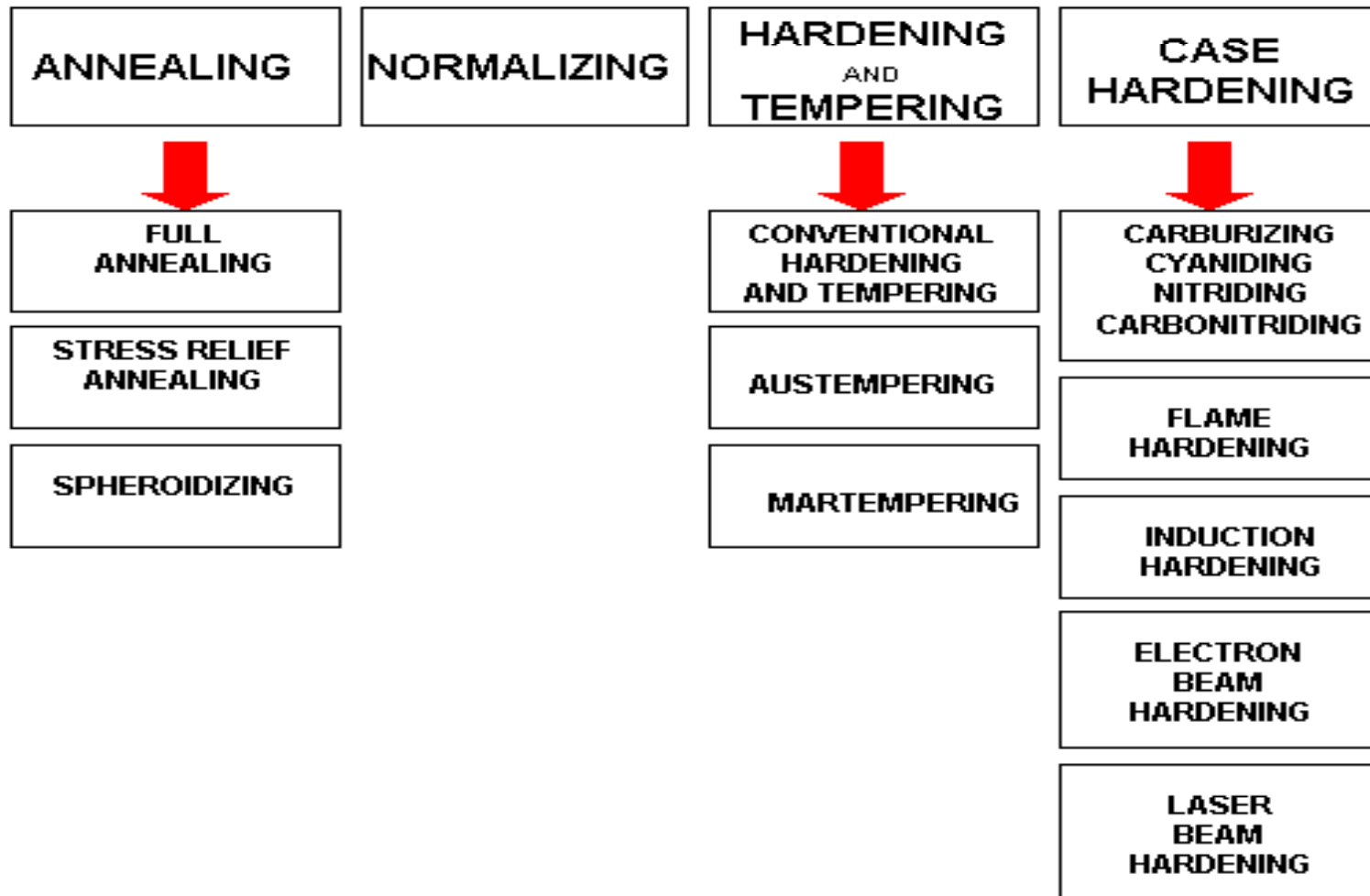


- **Ferrous Metals**
 - Steel
 - Cast Iron
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 - Tool Steel
- **Non-ferrous Metals**
 - Aluminum
 - Copper
 - Brass
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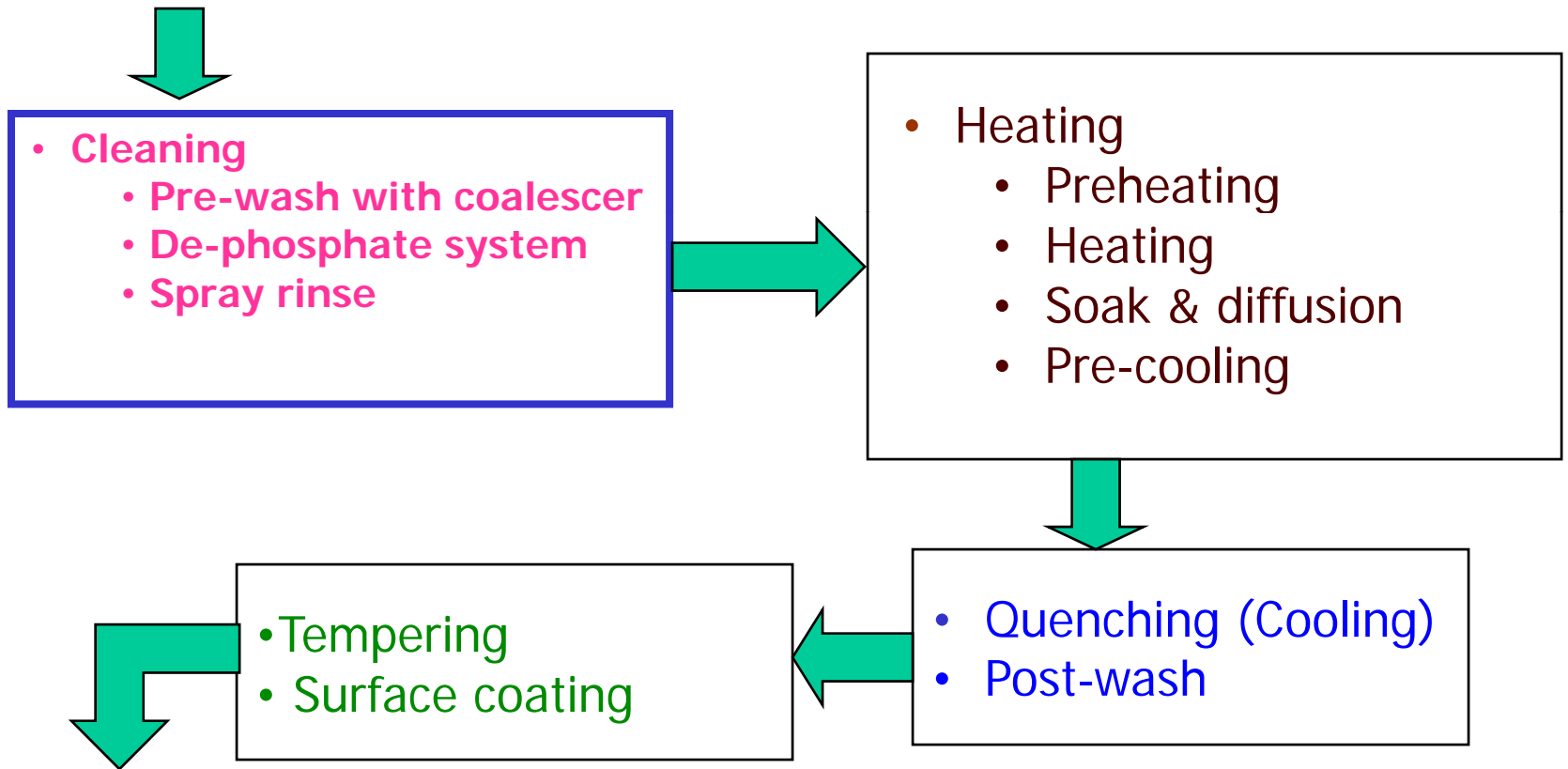
More Than 80% of Heat Treating Is Done for Steel

Heat Treating Processes



Steps in Heat Treating Operation

- **Loading**



- **Unloading**

Commonly Used Equipment for Heat Treating Operations

- Metal Cleaning (Wash-Rinse) Equipment
- Gas fired furnaces
 - Direct fired using burners fired directly into a furnace
 - Indirect fired furnaces: radiant tube, muffle, retort etc.
 - Molten salt (or lead) bath
 - Fluidized bed
- Electrically heated Furnaces
 - Induction heating
 - Electrical resistance heating
 - Other (i.e. Laser, electron-beam etc.)
- Quench or cooling equipment
- Material handling system
- Testing and quality control laboratory equipment

Gas Fired Metal Heat Treating Furnaces



**Carbottom
Furnaces**



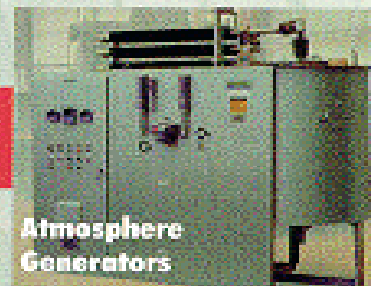
**Integral Quench
Furnace Systems**



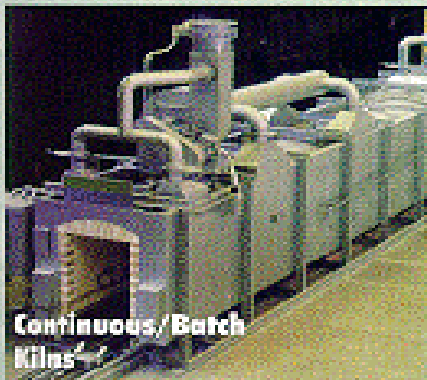
**Box Furnaces
All Types**



**Vacuum Heat Treat
Equipment**



**Atmosphere
Generators**



**Continuous/ Batch
Kilns**



**Continuous
Furnace Systems**



**Top Loading
Pit Furnaces**

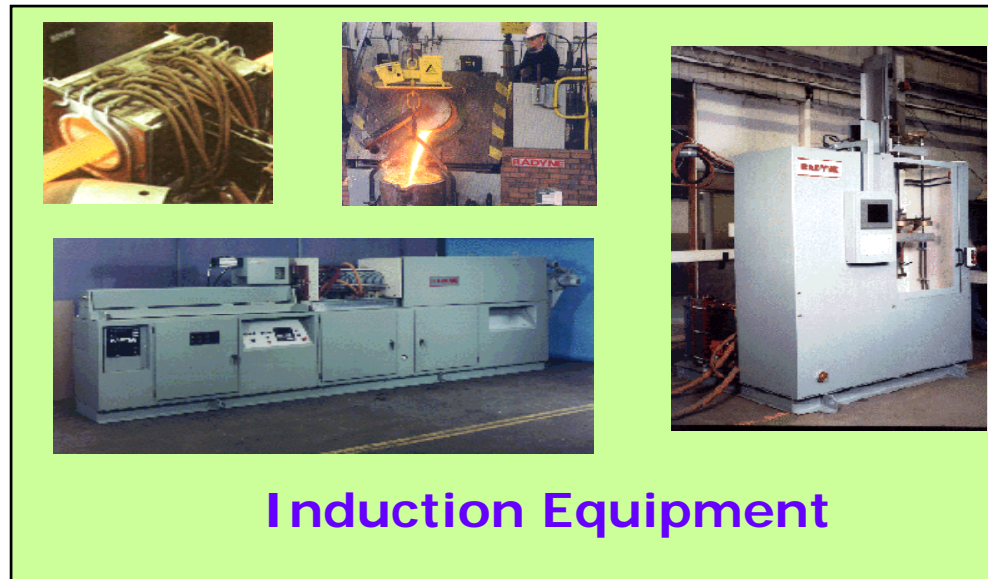
Electrically Heated Equipment for Metal Heating



Electric Atmosphere Furnace

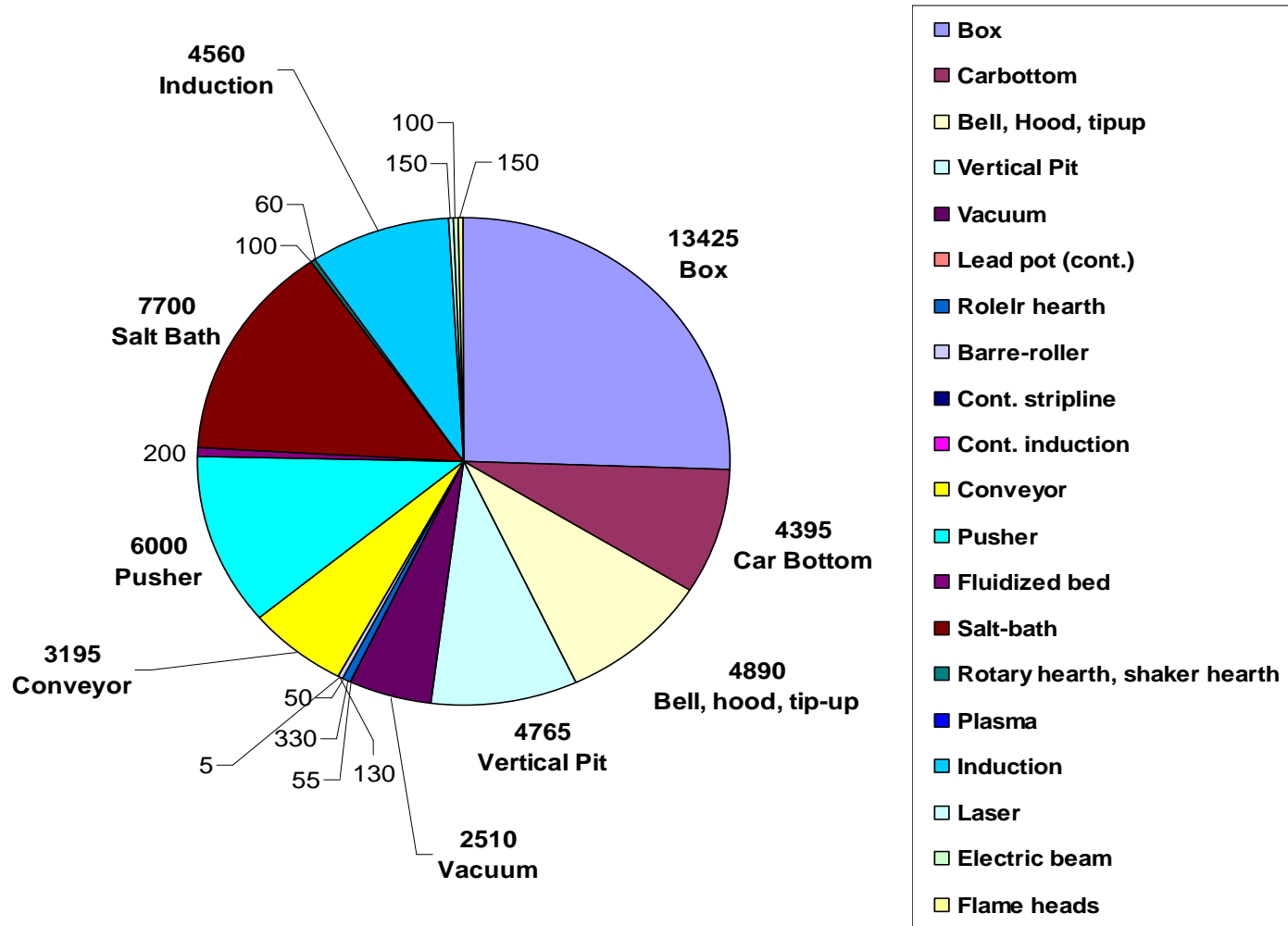


Vacuum Furnace



Induction Equipment

Types of Heat Treating Furnaces



Heat Treating Processing Equipment

Gas Fired Furnaces



Atmosphere Furnaces for Heat Treating - At a Glance

- Heat treating furnaces can be *Batch* type or continuous
- The furnaces are heated by: Direct fired gas burners, Radiant tubes or Electric heating elements
- More than 60% of the total energy used for heat treating is used for heating the load

- Components of a typical heat treating line
- Loading station
 - Parts washer and dryer
 - Heat treating furnace (carburizer, hardening furnace, vacuum furnace etc.)
 - Atmosphere supply (generator or commercial)
 - Quench
 - Washer and dryer
 - Tempering furnace
 - Unloading
 - Quality control – inspection

Types of Heat Treating Furnaces

Atmospheric

- Operated at ambient (atmosphere) pressure.
- Load is heated and cooled in presence of air or special gases (process atmospheres), in liquid baths or in a fluidized bed.

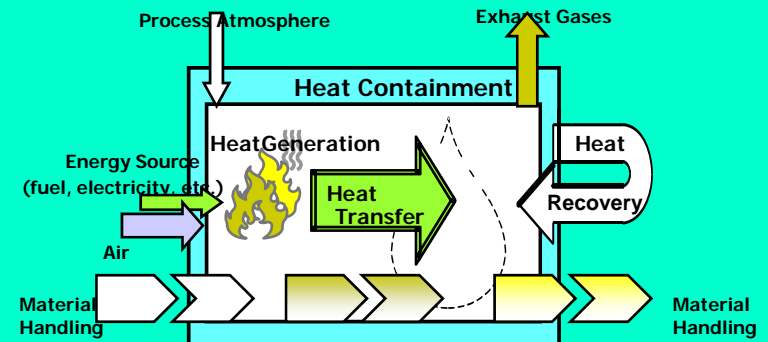
Vacuum

- Operated at vacuum or sub-atmospheric pressure.
- May involve high pressure gas cooling using special gases.
- Includes ion or plasma processing equipment.

Commonly used furnaces

- *Integral Quench Furnace (i.e. AllCase Furnace)*
- Roller hearth, shaker hearth, pusher, mesh-belt, Retort etc.
- *Vacuum furnace*
- *Fluidized Bed Furnace*
- *Car Bottom Furnace*
- *Salt Bath Furnace*
- *Pit furnace*

Major Components of a Furnace



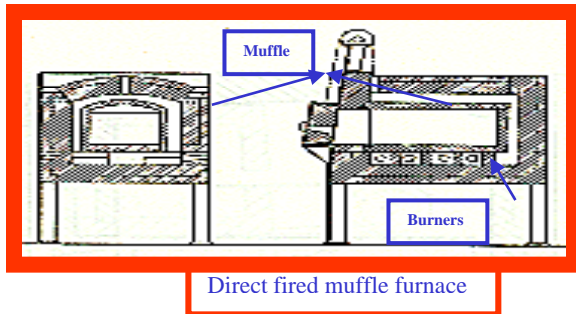
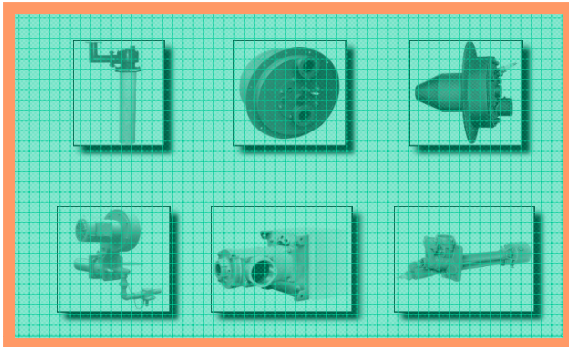
Heat Treating Furnaces

Two Primary Types

- Atmospheric
 - Operated at ambient (atmosphere) pressure.
 - Load is heated and cooled in presence of air or special gases (process atmospheres), in liquid baths or in a fluidized bed.
- Vacuum
 - Operated at vacuum or sub-atmospheric pressure.
 - May involve high pressure gas cooling using special gases.
 - Includes ion or plasma processing equipment.



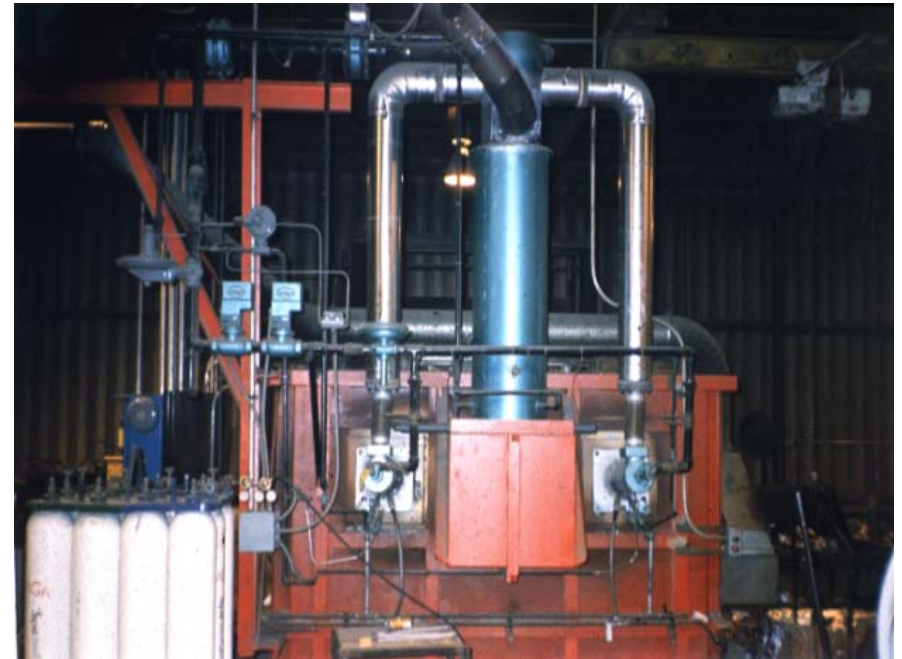
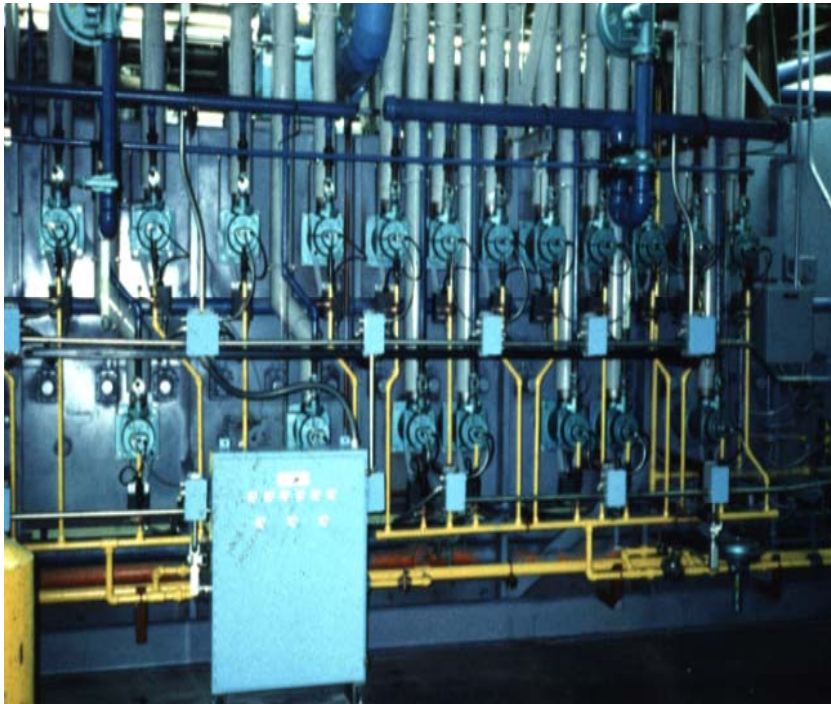
Heat Source for Gas Fired Furnaces



- Direct Fired Burners *
 - Radiant Tubes *
 - Muffle or Retort Heated by Outside Burners/Electrical Elements
 - Hot Oil or Steam Heating
- * These could be directly exposed to the work or can be outside a muffler a retort.

Typical Combustion System

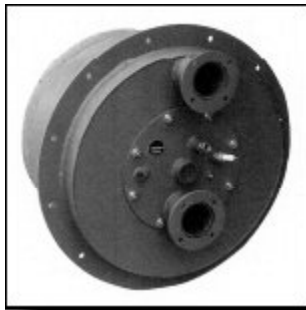
Direct Fired Furnaces
Multi-zone, Multi-Burner System



Indirect Fired Furnace
Radiant Tube Firing with
Recuperator for Preheating
Combustion Air

Two Major Issues Facing Natural Gas Heating

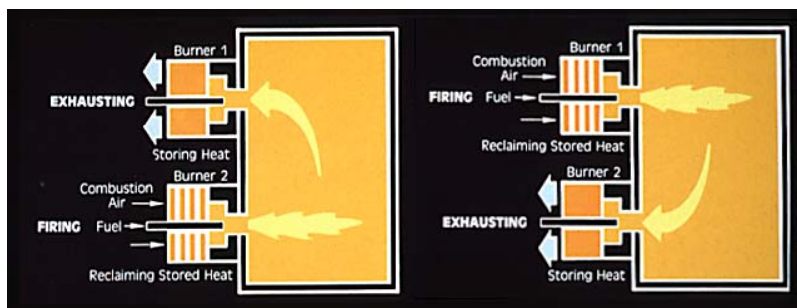
NOx Emissions and Efficiency



Low NOx



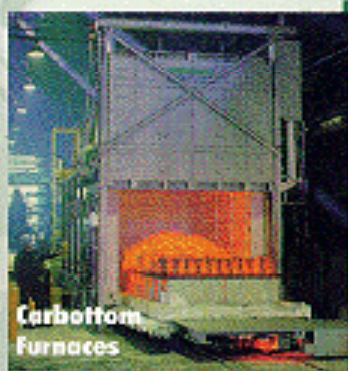
High Velocity



Regenerative Burners

- Low NOx burners are available for all temperature ranges.
- Use of recuperators, regenerative burners can increase efficiency of gas use by 25% to 40%.
- Proper combustion control and selection of right burners.

Gas Fired Metal Heat Treating Furnaces

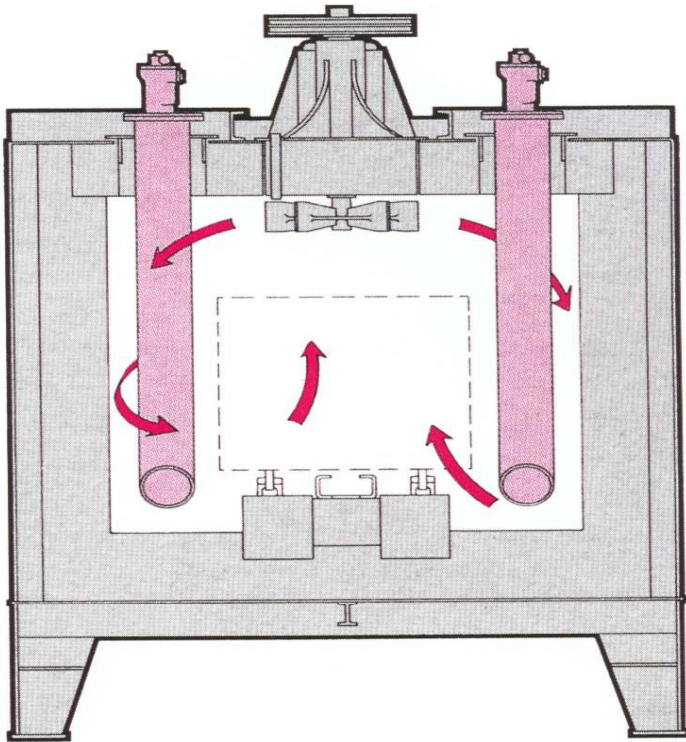


Integral Quench (IQ) Furnace



- “Work-horse” of Heat Treating Industry
- A Batch Furnace for Hardening & Carburizing
- Includes a Quench and Cooling Chamber
- Can Be Single Chamber (In-out) or Two Chamber
- Load From 800#s to 6,000#s
- Operating Temperature – Usually up to 1,800°F

Integral Quench (IQ) Furnace



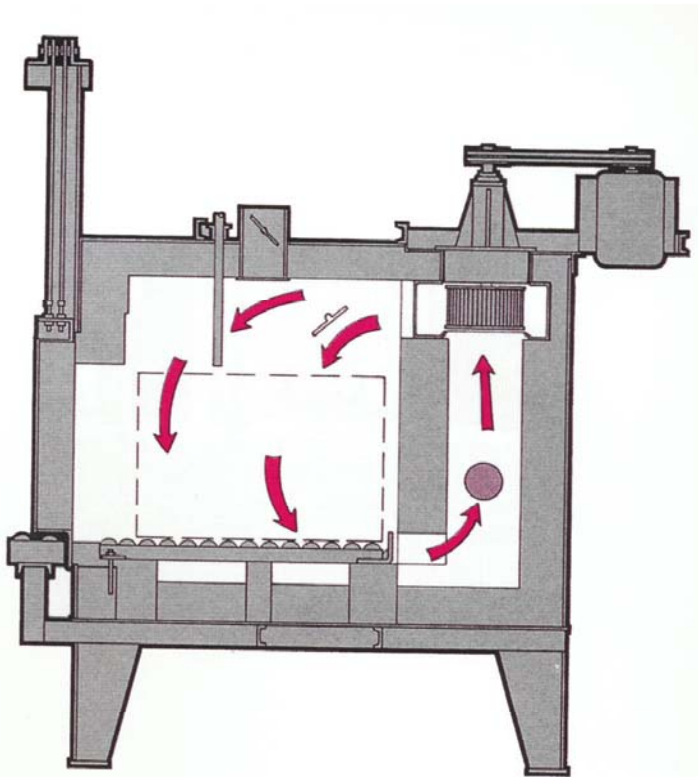
- Radiant Tubes (Gas Fired) or Electrically Heated.
- May or May Not Have a Muffle to Separate Load and Radiant Tubes.
- Process Atmosphere: Endo Gas, Equivalent Carburizing Gas Mixture or Neutral Atmosphere.
- Circulating Fan to Assist in Convection Heat Transfer.

Tempering or Draw Furnace



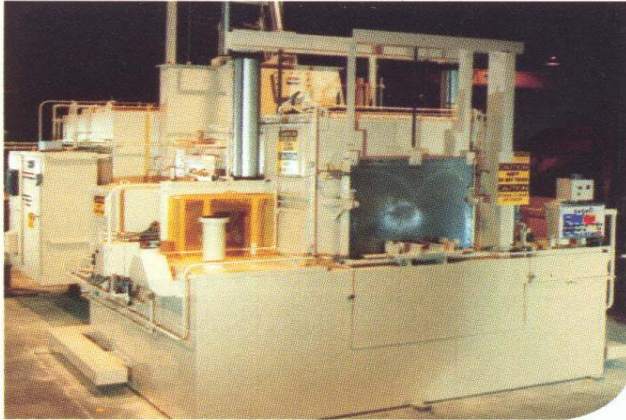
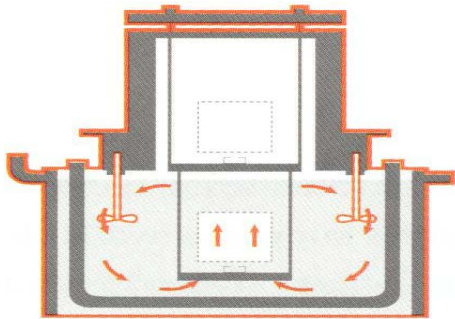
- Batch Furnace for Pre-heating, Tempering (after quench), Stress-relieving and Annealing.
- Operating Temperature Range: 350°F to 1,400°F.
- May Include Cooling System Using Air to Water Heat Exchanger to Accelerate Cooling.
- Direct Fired With Flue Gas Atmosphere (some Vacuum Temper Furnaces used).

Tempering or Draw Furnace



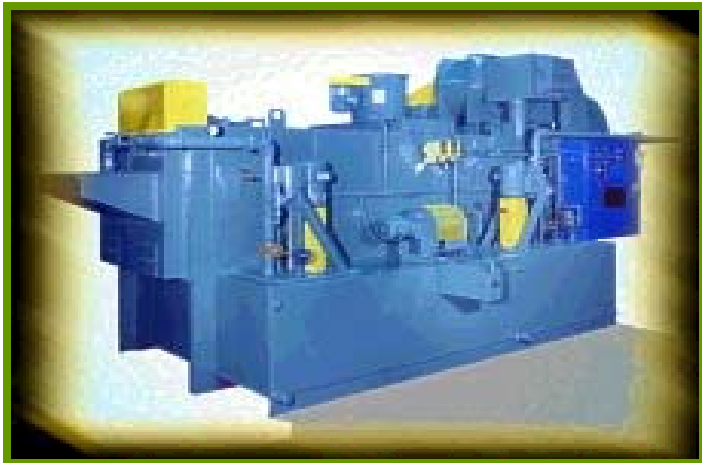
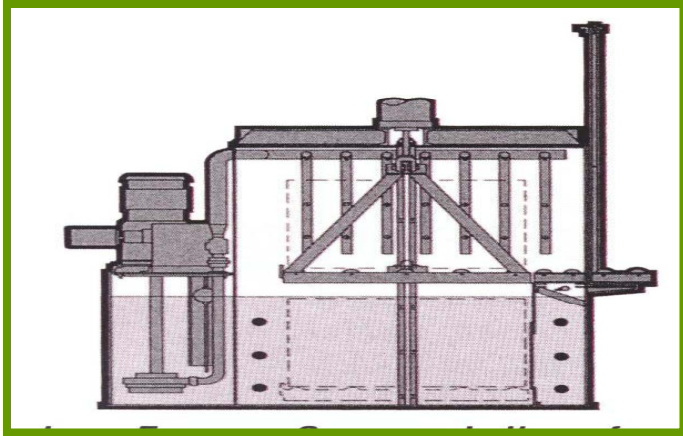
- Convection Heating Using a Recirculating Fan.
- Load Capacity; 1,000# to 3,500#.
- Includes a Plenum for Gas Distribution and Temperature Uniformity.

Quench Tank



- Directly Connected or Integral to a Furnace.
- The Liquid Can Be Water, Quench Oil or Polymer.
- Requires Heating and Cooling System to Maintain the Controlled Quench Temperature.
- Major Concern for Oil Quench: Fire, For All Other: Spill.
- Extremely Critical for Quality of the Parts Produced.

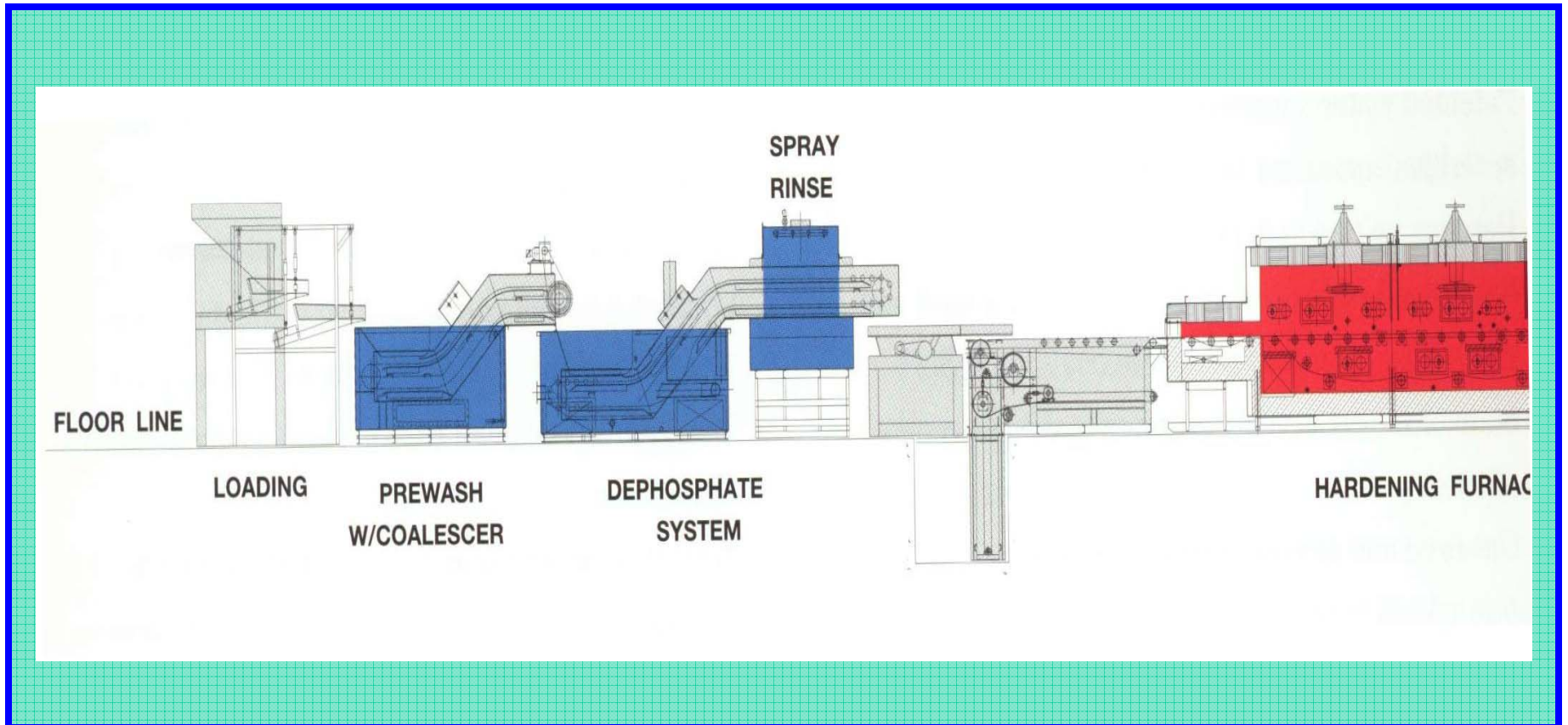
Parts Washer (Batch System)



- Used to Clean Parts (Remove Dirt, Machining Oil, Metal Chips, etc.).
- May Use Chemicals - Detergents .
- Includes Several Steps of Washing, Rinsing, Drying, etc.
- Requires Heating System Inside and Outside (for Liquids) the Washer.
- May Use Vacuum De-oiling.
- Requires Extensive Liquid Handling System to Assure Compliance with EPA Regulations.

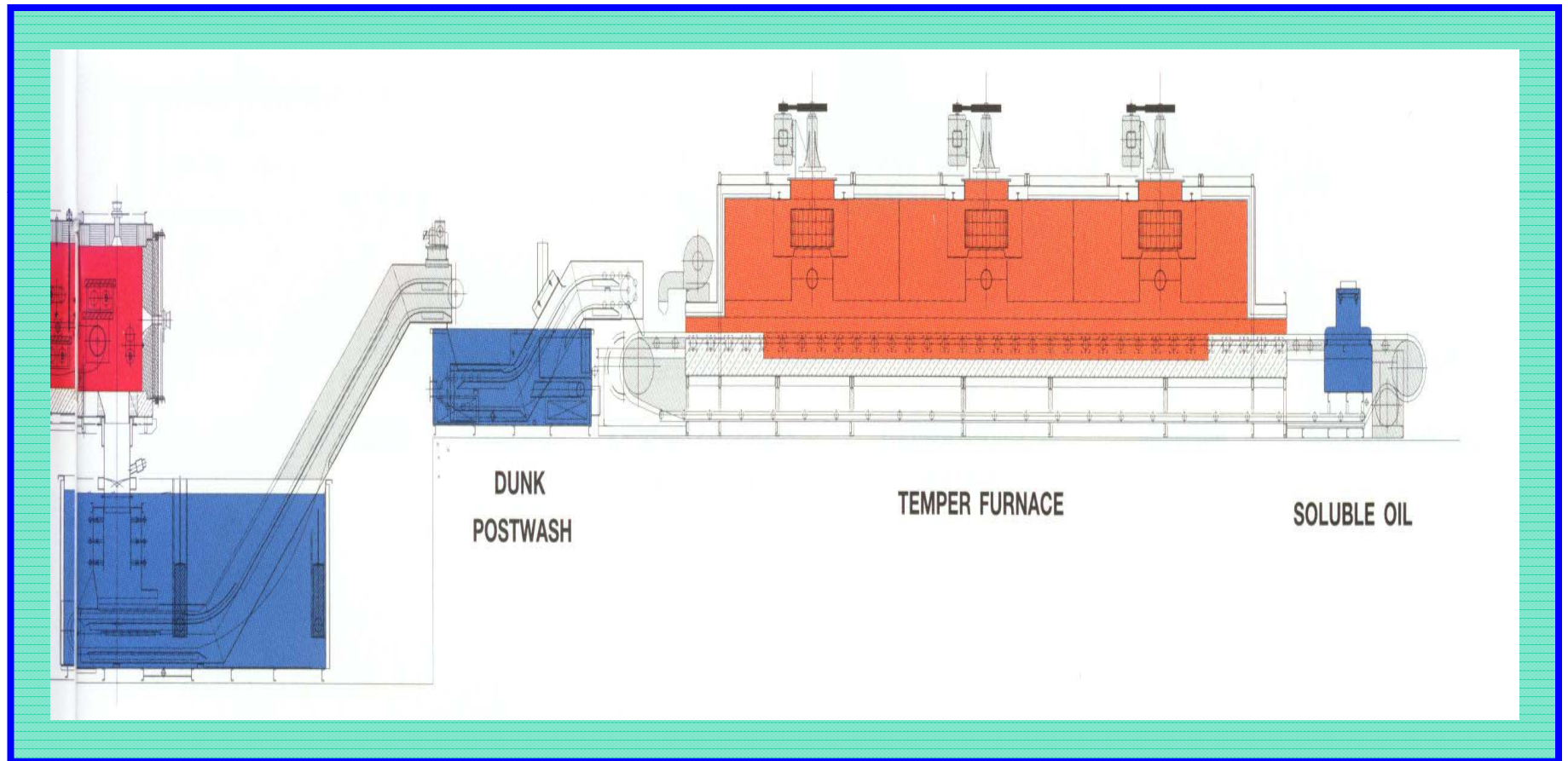
A Typical Heat Treating Line

Front Section with Pre-wash and Furnace

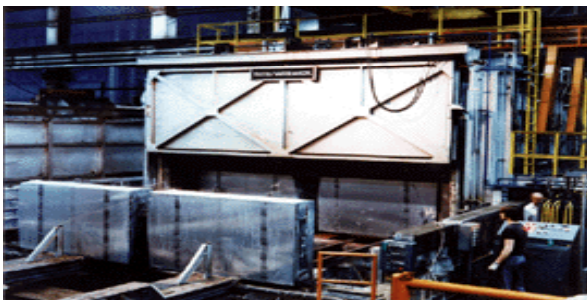


Heat Treating Line

Back Section with Tempering and Post-wash



Nonferrous Heat Treating Furnaces

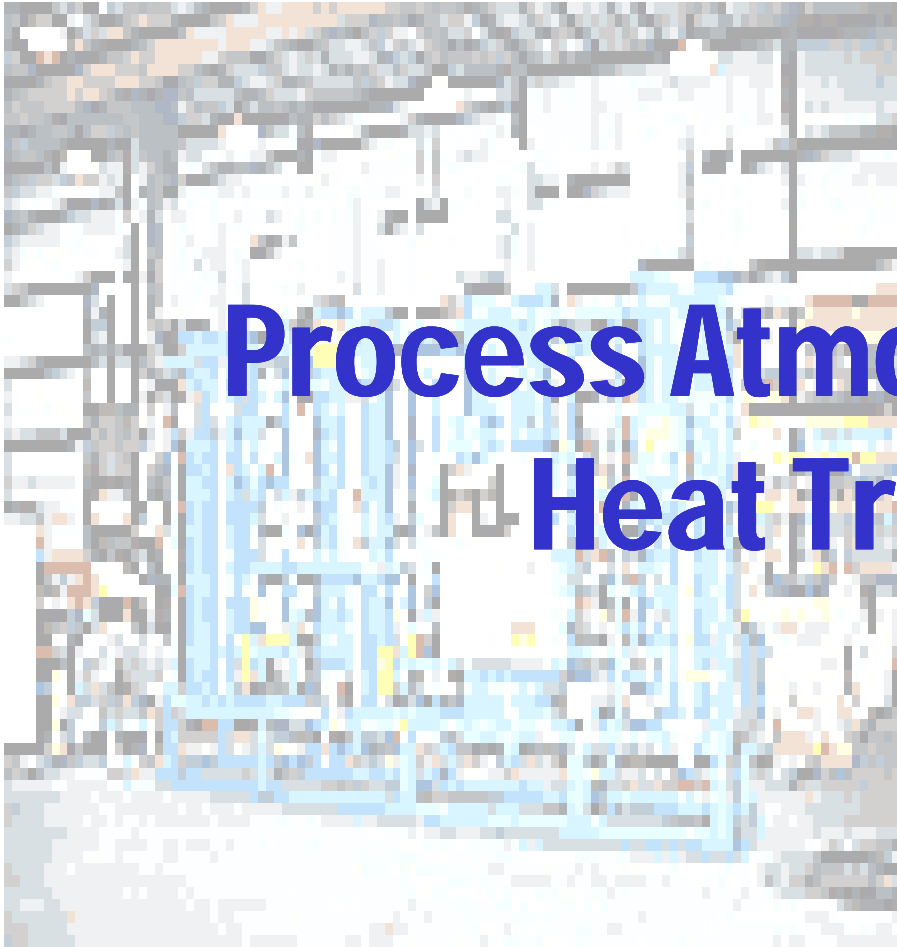


Types of Furnaces

- Coil/foil Annealing Furnaces
- Rod/wire Annealing Furnaces
- Log Homogenizing Furnaces
- Ingot Preheating Furnaces
- Aging Furnaces

- Indirect Heating
(Radiant Tubes or Electrical Resistance)
- Temperature Range 350°F to 1150°F
- Atmosphere With Dew Point Control
- May Includes Water Quench or Controlled Cooling

Process Atmospheres for Heat Treating



Process (Heat Treating) Atmospheres - At a Glance

What is a Process (heat Treating) Atmosphere?

A Mixture of Gases (CO, H₂, CO₂, H₂O and N₂) That Protects the Load or Reacts with the Load During Heat Treating

Why Use protective Atmospheres?

- To Prevent Oxidation, Loss of Carbon (Decarburizing), and Avoid Corrosion.
 - Most Gases Containing Oxygen (i.e. Air, Water Vapor [H₂O], Carbon Dioxide [CO₂] React With Iron, Carbon and Other Elements Present in Steel.
 - Reactivity Depends on Temperature and Mixture of Gases in Contact With Steel.

Types of Heat Treating Process Atmospheres

- **Protective**
 - To Protect Metal Parts From Oxidation or Loss of Carbon and Other Elements From the Metal Surfaces.
- **Reactive**
 - To Add Non-metallic (I.E., Carbon, Oxygen, Nitrogen) or Metallic (I.E., Chromium, Boron, Vanadium) Elements to the Base Metal.
- **Purging**
 - To Remove Air or Flammable Gases From Furnaces or Vessels.

Source of heat Treating Atmospheres

- Natural Gas (Hydrocarbon) - Air Reaction
 - Natural Gas - Steam Reaction
 - Ammonia Dissociation or Ammonia-air Reaction
- Or
- Mixture of Commercial Gases (N₂, H₂ and Hydrocarbons)

Commonly Used of heat Treating Atmospheres

- **Rich and Lean Endothermic (DX) Gas**
- **Rich and Lean Exothermic (RX) Gas**
(These can have low or high dew point)
- Dissociated Ammonia
- Hydrogen – Nitrogen Mixture
- Natural Gas (Hydrocarbon) - Air Reaction
- Natural Gas - Steam Reaction
- Mixture of Commercial Gases (N₂, H₂ and Hydrocarbons)

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- To Avoid and Eliminate Formation of Flammable or Explosive Mixtures

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Importance of Protective Atmospheres in Heat Treating

- Proper composition and concentration in a furnace is required to give the required surface properties for the heat treated parts.
- Loss of atmosphere “control” can result in unacceptable parts and result in major economic penalty - it can cost a lot!
- Atmospheres contain potentially dangerous (explosive, life threatening) gases and must be treated with “respect”.
- New advances in measurement and control of atmospheres in heat treating allow precise control of atmospheres to produce quality parts.

Commonly Used Atmospheres in Heat Treating

Protective and Purging

- Endothermic gases
 - Lean – high and low dew point
 - Rich - high and low dew point
- Nitrogen
- Mixture of N₂ and small amount of CO

Reactive

- Exothermic gases
- Mixture (or individual) of gases: Hydrogen, CO, CH₄, Nitrogen and other hydrocarbons
- Dissociated Ammonia (H₂ + N₂)

Source of Atmospheres

Requirement:

A Mixture of Gases (CO , H_2 , CO_2 , H_2O and N_2) That Give the Required Composition for the Processing Atmosphere.



- Natural Gas (Hydrocarbon) - Air Reaction
- Natural Gas - Steam Reaction
- Ammonia Dissociation or Ammonia-air Reaction



Or:


- Mixture of Commercial Gases (N_2 , H_2 and Hydrocarbons)

Use of Atmospheres in a Plant

Requirement:

A Mixture of Gases (CO, H₂, CO₂, H₂O and N₂) That Give the Required Composition for the Processing Atmosphere.

- Most plants have an in-house, centrally located, atmosphere gas generators for different types of atmospheres required in the plant
- In some cases one or more generators may be located for each “shop” or production area
- In many cases other gases (i.e. N₂, H₂, NH₃) are piped from storage tanks located within the plant premises and distributed by a piping system to furnaces.
- Gas flow is mixed, measured and controlled prior to its injection in the furnace.



The background image is a composite of two parts. The top part shows three glowing orange induction heating coils, each with a red rectangular component at its base. The bottom part is a technical diagram on a blue background. It features a central yellow coil with concentric white circles around it, representing magnetic field lines. Text labels include 'Induction Cell' and 'Magnetic Field'. At the bottom left, there is a small logo and the text 'Depth of current penetration: $d \propto \sqrt{1/\omega \mu \sigma}$ '. At the bottom right, there is a label 'Magnetic Field' with an arrow pointing to the field lines.

Electrical Heating Systems for Heat Treating

Electric Heating for Heat Treating - At a Glance

Type of Electric Heating

- Resistance Heating**
- Induction Heating**
- Direct Current
- Laser Heating
- Electron Beam Heating
- Plasma Heating
- Arc Heating

Cost Comparison
Electric vs. Natural Gas

Cent/Kwh	\$/MM Btu
4	12.34
5	15.42
6	18.51
7	21.59
8	24.67
9	27.76
10	30.84
11	33.93
12	37.01

Based on 90% efficiency
in distribution

Major Applications of Electric Heating for Heat Treating

- Vacuum Heat Treating Furnaces
- Sintering (Powder Metal) Furnaces
- Plasma or Ion Nitriding, Carburizing or Surface Coatings
- Low Temperature Tempering or Draw Furnaces
- Liquid (Water, Quench Oils or Polymer) Heating in Tanks
- Gas Generators (Endo Gas and Ammonia Dissociators)
- Salt Bath Furnaces
- Pit (Underground) Furnaces

Advantages Claimed By Electric System Providers

- "100 %" Efficient
- Better Temperature Uniformity and Controllability
- Can Be Used for Higher Temperature Processes
- Safe - No Explosion Hazards
- No Flue Gases to Deal With
- No Pollution or Emissions of NO_x Etc.
- Lower Initial Cost for Furnace
- Easy to Install and Operate
- Can Be Easily Automated

Disadvantages - Drawbacks

- Higher Operating Cost : 2 to 3 Times for Heat Treating Furnace Applications
- Heating Elements Burn-out, Short Life and Expensive to Replace
- Danger of Elements Shorting Due to Possibilities of Metal Parts Drop
- May Need Expenses for Substation, Transformer Etc.
- Corrosion, Soot Deposits Etc. For Applications With Process Atmosphere
- Longer Furnace Length for the Same Heat Input, Particularly for Continuous Furnace

Major Issues and Concerns

- Capital and Operating Cost
- Product Loss
- Environmental, Safety and Health
- Productivity and Quality
- Other factors

Electrical Heating Terms and Cost

Cost of Electric Heating

Cent/Kwh	\$/MM Btu
4	12.34
5	15.42
6	18.51
7	21.59
8	24.67
9	27.76
10	30.84
11	33.93
12	37.01

Based on 90% efficiency in
distribution

- Energy is measured in terms of Kilowatt Hour (Kwh).
- 1 Kwh= 3,413 Btu/hr.
- Electricity production is approximately 33% efficient based on energy required at the power plant.
- For an equivalent (delivered to the load) Btu basis electricity production emits 2 to 5 times more NO_x than the gas fired furnaces.
- Actual efficiency of application of heat could be in the range of 65% to 85%.

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- Salt Bath Furnaces
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Electrical Heating Systems for Heat Treating

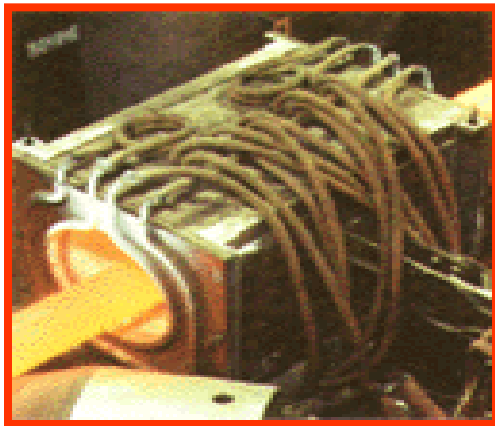


- **Resistance Electrical Heating Systems**

- Electrically Heated Conventional Furnaces
- Electrically Heated Atmosphere Furnaces

- **Electrically Heated Vacuum Furnace**

- Heating and heat treating
- Plasma Nitriding
- Plasma Carburizing
- CVD Coatings



- **Induction Heating**

Major Components of an Electrical Heating System

- Heating Elements
- Power Supply
- Power Control System Connected with the Furnace Temperature Control System
- Water Cooling System

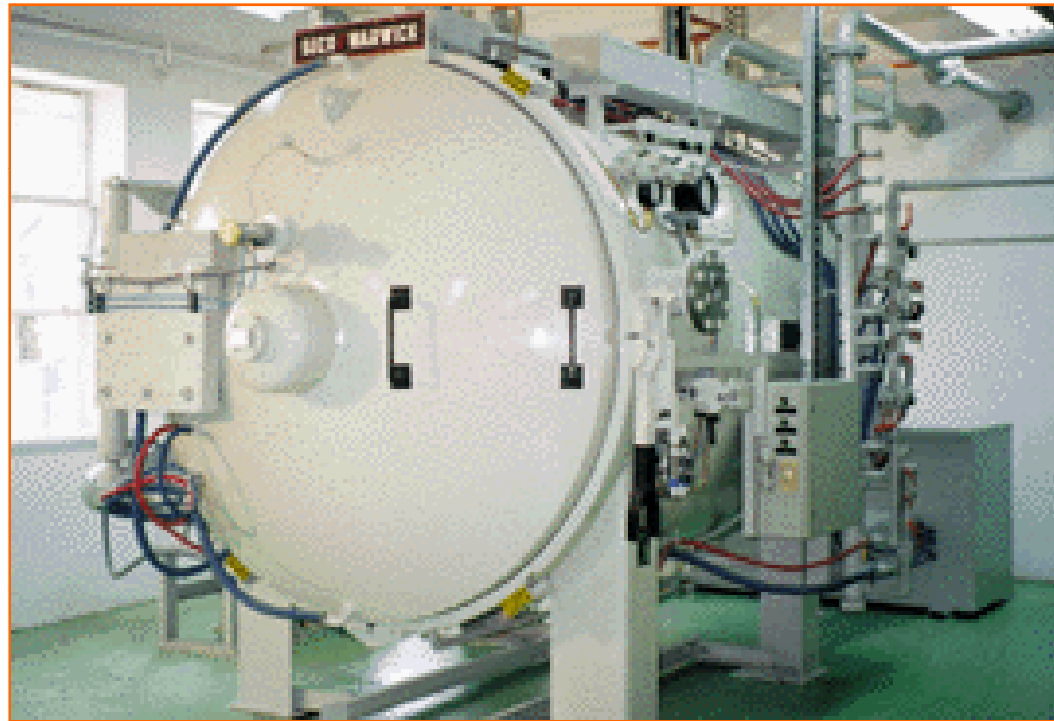
Electrically Heated Atmosphere Furnace



Notice:

- Electric heating elements connections
- Lack of burners, vents, air-gas piping or flue gas vents or ducts

Vacuum Furnaces



Features of an Electrically Heated Vacuum Furnace



- Vacuum Vessel With Water Cooled Shell
 - High Temperature Heating Elements (Graphite, Molybdenum, etc.)
 - Insulated Shield Between the Elements and Water Cooled Shell
- Gas Circulating Fan With Water Cooled Heat Exchanger and Gas Accumulator
- Water Re-circulating and Cooling System
- Vacuum Pumping System
- Controls
- Material Handling System

Primary Reasons for the Use of Vacuum Heat Treating

Negative:

- Higher Capital Cost
- Higher Utility (Electricity) Cost
- Higher Overall Operating Cost
- Lower Overall Capacity
- Less Flexibility

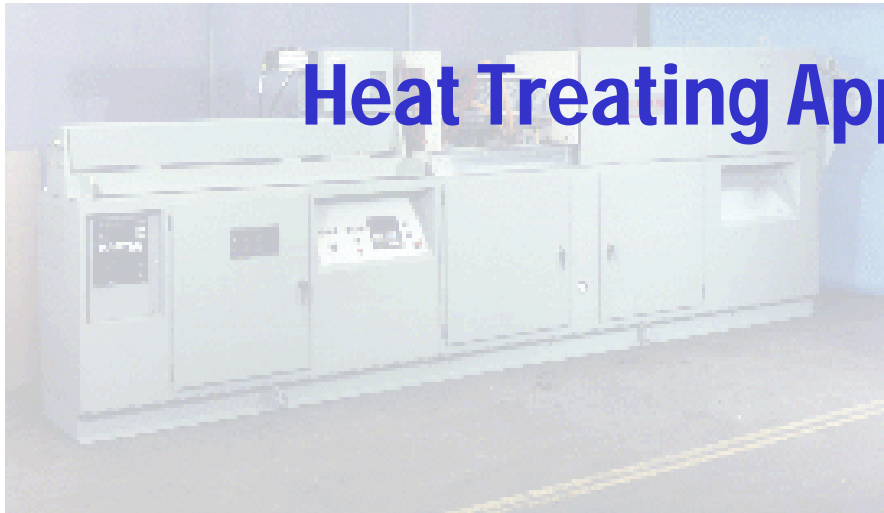
Positive:

- Process Repeatability
- Temperature Uniformity
- Reliability of Operations
- Better Operating Environment
- No or Low Environmental (Perceived Emission) Problems
- Automation - Better Application for Computer Control

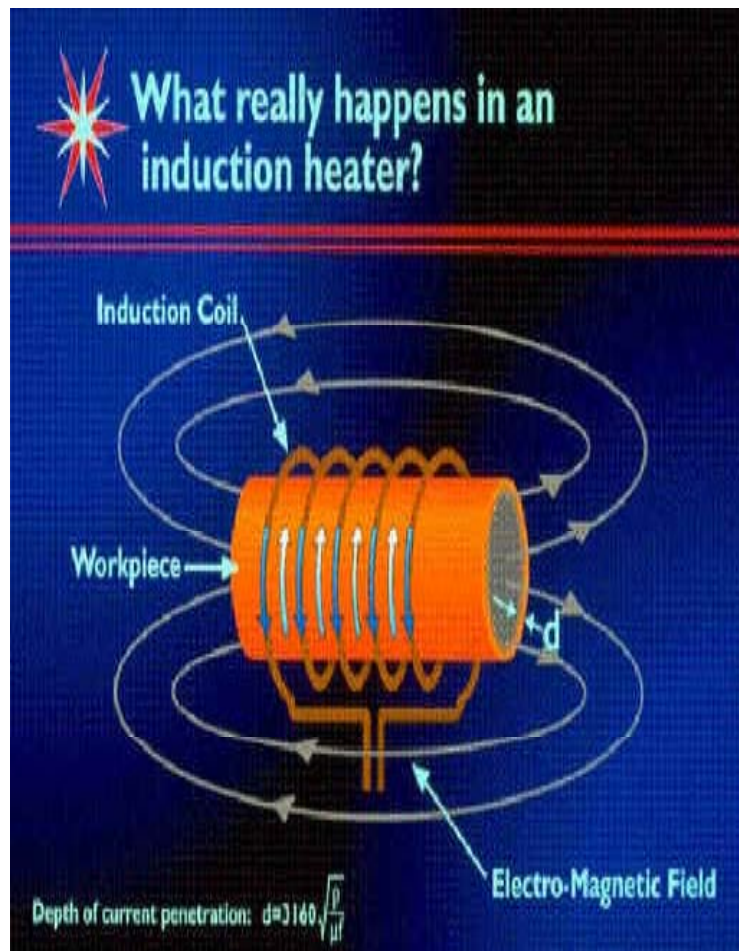


Induction Heating for

Heat Treating Applications

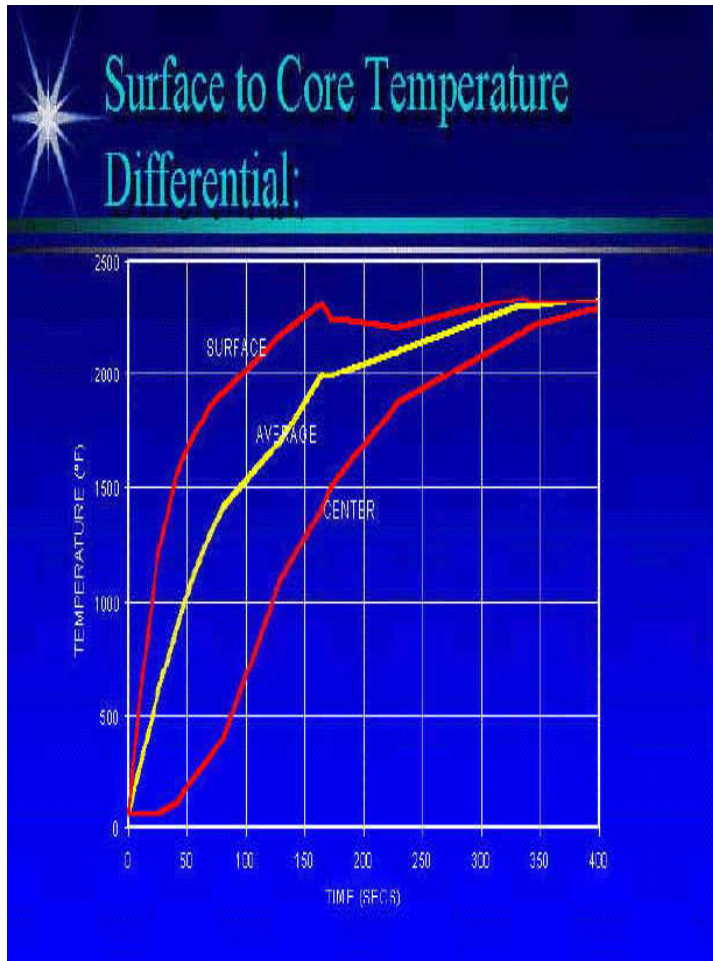


What is Induction Heating?



- Method of heating electrically conductive objects.
- No contact required between the object and source of heat.
- Heat can be applied to localized areas or surface zones.
- High surface heat flux - relatively short heating time.

Applications of Induction for Metal Heating



- Spot Heating - Brazing, Soldering, Local Heating, Spot Hardening.
- Surface Heating - Surface Hardening, Curing, Shrink Fit
- Through Heating - Tempering, Forging, Annealing, Through Hardening.
- Melting - Steel, Copper, Brass, Aluminum

Gas Fired Vacuum Furnaces

www.gasfiredvacuum.com



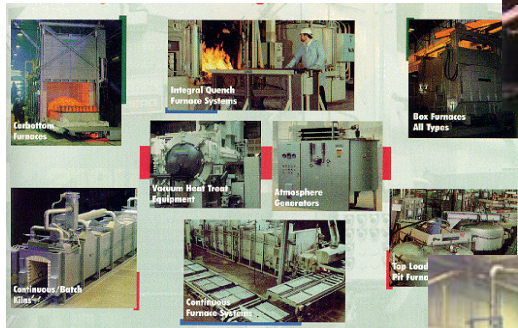
Presented under Available / Emerging Technologies

Process Heating Tools and Models*



These Tools will help you Prosper!

Thanks for Showing Us How!
Understanding IS the Key to Obtain Results!



*Content Partially Provided Through Dominion Participation in both the Energy Solutions Center's Heat Treat Awareness Consortium and the DOE BestPractices Program

Tools and Models

How to Use These Tools and Models

1. Discuss the fundamental cost differences between natural gas and electricity with customers. Electric cost is usually 3 to 5 times the gas cost on the basis of the total BTU's supplied to the process equipment.
2. For most plants, a relatively small number of all installed process equipment usually consume the largest amount of energy. Identify the top-users and gather basic information on energy use for all major energy use equipment in the plant.
3. For major energy using equipment, record name-plate data and analyze how and when energy is used. Then, estimate the efficiency of the process based on age of existing equipment (older is lower efficiency generally), actual data, referencing the charts included in these Tools and Models or by contacting the original equipment supplier.
4. The operation cost comparison for selected equipment can be completed by entering efficiency and energy cost information in the **Cost Comparison Calculator Model** cells OR by reading the general results, in certain cases, from the charts (see pg's 4 & 5).

Cost Comparison for Gas Compared to Electrical Heat

Factors affecting energy cost include 1) Efficiency of gas and electrically heated furnaces 2) Cost of gas and electricity and 3) Number of hours equipment is operated.

Tools and Models

Factors affecting efficiency of gas-fired equipment

1. Flue (exhaust) gas temperature
2. Oxygen (or CO_2) in flue gases
3. Combustion air temperature (to the burner)
4. Oxygen injection or enrichment (if any) in the incoming combustion air

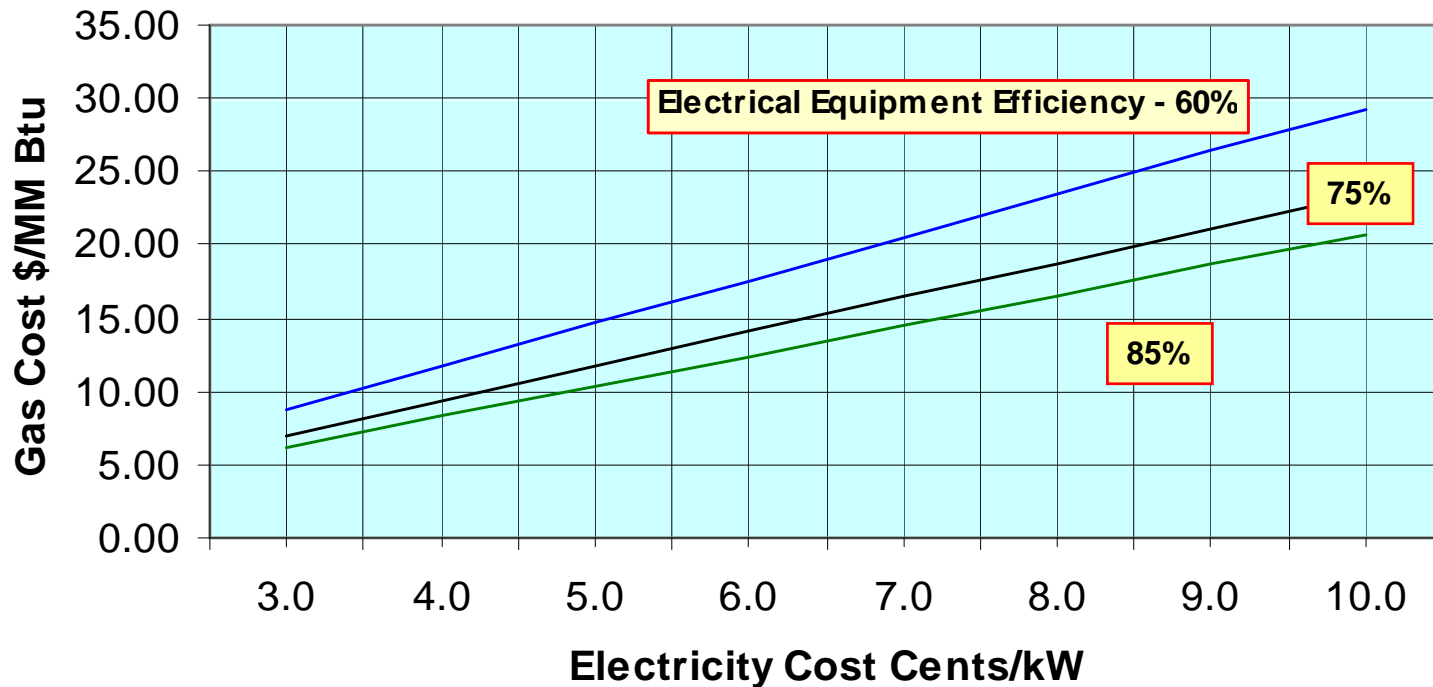
Factors affecting efficiency of electric equipment

1. Power factor
2. Losses in distribution system (from meter to use)
3. Water cooling of components
4. Induction coil and load coupling

Process Heating Cost Comparison
Gas Cost Equivalent for Electric Process

*1: If Efficiency is different than the three shown here use the **Cost Comparison Calculator**

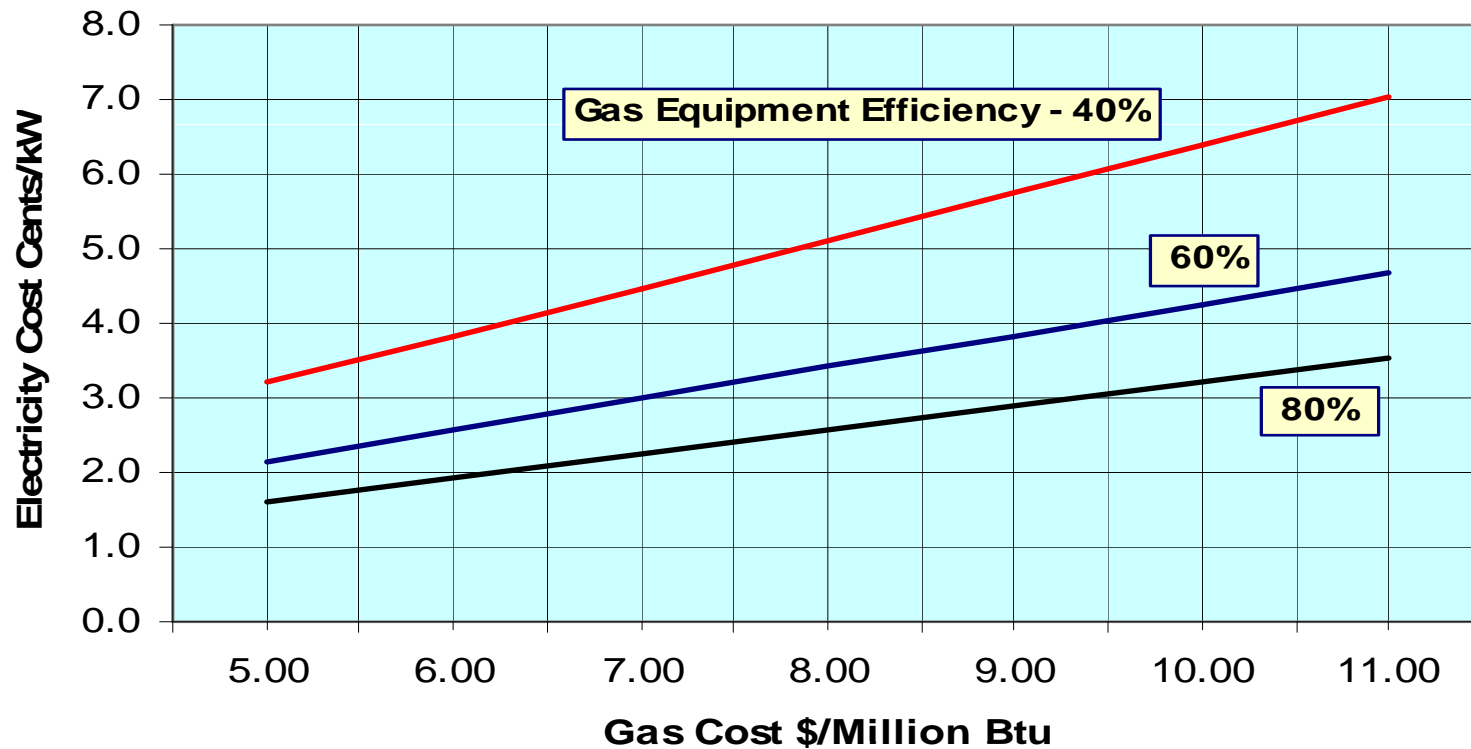
Gas Cost vs. Electric Cost
(Electric Heating "Efficiency" at 60, 75 or 85%) *1



Process Heating Cost Comparison
Electric Cost Equivalent for Gas Process

*1: If Efficiency is different than the three shown
use the **Cost Comparison Calculator**

Electric Cost vs. Gas Cost
(Gas Equip. Heating Efficiency at 40, 60 and 80%) *1



Cost Comparison Calculator

Find Equivalent Electric Rate

Gas Equipment Efficiency	60%	% - Percent
Electric Heating Efficiency	85%	% - Percent
Gas Cost	\$5.50	per million Btu (Mcf)
Gas equipment provides cost savings when electric power cost is equal to (or higher) than this power rate	2.7	Cents/kW

Note: To Enter Efficiency & Energy Cost Data, "Double-Click" on the Green portion of the table cell. Then "Click" again in the cell and make desired entry. Finally, "Click" once outside the cell to view results. Do NOT Enter Information in Blue Cells.

Find Comparable Gas Rate

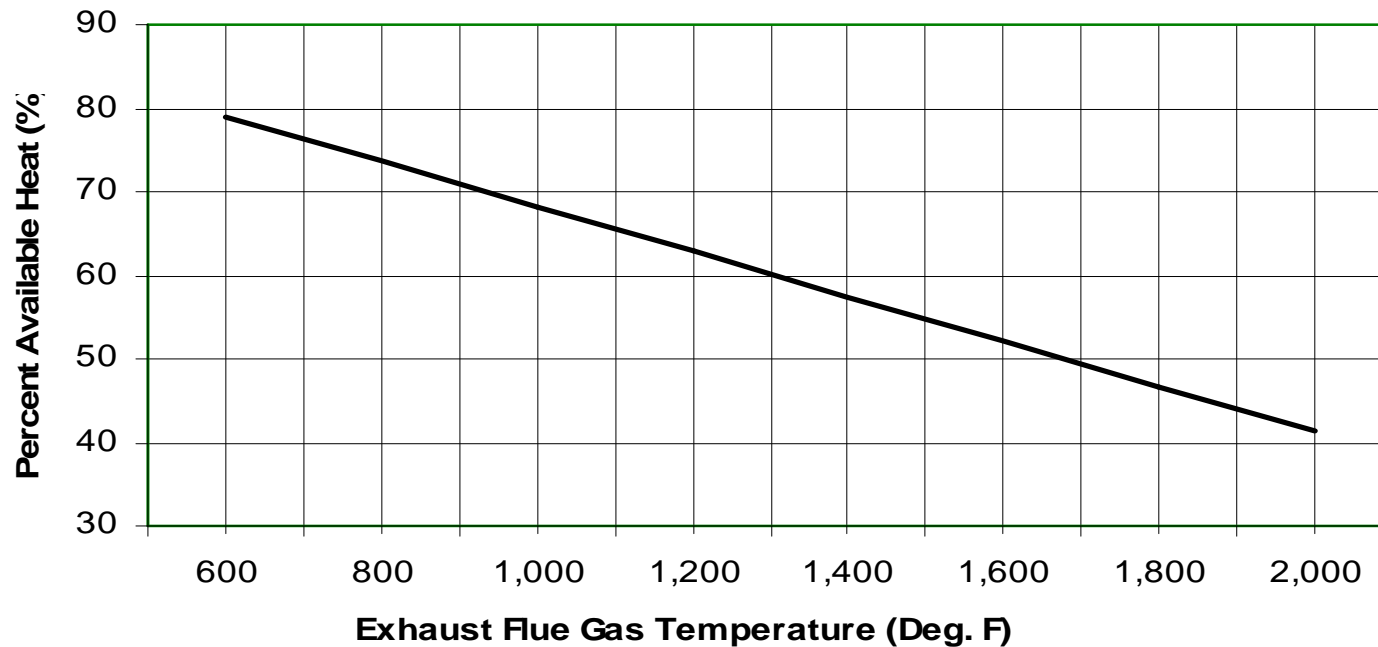
Electrical Equipment Efficiency	85%	% - Percent
Gas Equipment Efficiency	60%	% - Percent
Electricity Cost	4.5	Cents/kwh
Gas equipment provides cost savings when gas cost is equal to (or below) this gas cost	9.31	\$/MM Btu (Mcf)

Tools and Models - Determining Gas Efficiency

Available Heat in Gas-Fired Systems

Assumption; 10% Excess air, or 2% O₂ in flue gases

Available heat is the maximum possible "efficiency".
Generally, efficiency is 75% to 90% of the available heat shown on this graph.



Tools and Models - Determining Electric Efficiency

- **Available Heat for Electrically Heated Systems has ALL the same losses as gas-fired systems except Flue Gas Losses. Line losses from metering to application also exist.**
 - **If Unsure Of Actual Efficiency use 75% in the Cost Comparison Calculator.**
 - **Typical Electric System Process Efficiency Factors**
 - ✓ Vacuum – 60%
 - ✓ Induction Under 2,000 F – 65%
 - ✓ Induction Over 2,000 F – 40%
 - ✓ SCR - 75%
 - ✓ Resistance Elements – 85%
 - ✓ All Other - 75%
- Note: Contact your equipment supplier to verify actual factors**

Tools and Models - Base & Modified Cases

How to Use Two Models to Determine Base & Modified Energy Use

1. In the **Base Case** model, enter measured data in **Green Cells** that pertain to the current combustion system operating condition. If data is not known, a portable combustion flue gas analyzer and a thermocouple is needed to obtain this the Excess O₂ and Flue Gas Temp. information.
2. For most non-recuperated combustion systems, the flue gas temperature exiting the process will average between 100 and 200 F higher than the process temperature. Also, the flue gas oxygen content for many older combustion systems will range from 3 to 9%. Additionally, the combustion air temperature will correspond to the ambient conditions near the equipment. Unless you know, use 100 F.
3. For the **Modified Case**, recuperative combustion systems can provide a range of preheated combustion air temperatures. Most systems will preheat air to at least 400–600 F. Some will provide significantly more (as high as 200 F below operating temperature). If unsure, use 500 F and assist the customer in confirming the possible temperature with a qualified burner company or equipment supplier representative.

Cost Comparison for Gas Compared to Electrical Heat

Factors affecting energy cost include 1) Efficiency of gas and electrically heated furnaces 2) Cost of gas and electricity and 3) Number of hours equipment is operated.

Process Heat Cost Model

Base

	Furnace Flue Gas Temperature	Oxygen in Flue Gases	Excess Air	Combustion Air Temperature	Available Heat
	Deg. F.	%	%	Deg. F.	% of gross Heating Value
Base Case	1,600	6.1	38.3	100	43.50
Gas equipment provides savings when gas cost is equal to (or below) this gas cost			\$ 30.31	Note: After Entering Gas Combustion Data, Input the Current Power Cost to Determine the Gas Cost Point that Provides Savings	
Power Cost (Cents/kWh), enter in 0.045 format			0.045		

 Input Data in Green Cells

 View Result

Process Heat Cost Model Modified

	Furnace Flue Gas Temperature	Oxygen in Flue Gases	Excess Air	Combustion Air Temperature	Available Heat
	Deg. F.	%	%	Deg. F.	% of gross Heating Value
Modified Case	1,400	2.1	10.2	500	66.17
Gas equipment provides savings when gas cost is equal to (or below) this gas cost			\$ 19.93	Note: To Enter Data, “Double-Click” on the Green portion of the table cell. Then “Click” again in the cell until the curser appears and make desired entry. Finally, “Click” once outside the cell to view results.	
Power Cost (Cents/kWh)			0.045		

 Input Data in Green Cells

 View Result

Emerging Gas-Fired Process Heating Equipment

- **Gas Vacuum**

www.gasfiredvacuum.com

- **Fuel Based Nitrogen**

www.industrialcenter.org

- **Flame Treating Systems**

www.flamesys@gte.net

- **Composite Radiant Tubes**

www.griweb.gastechnology.org

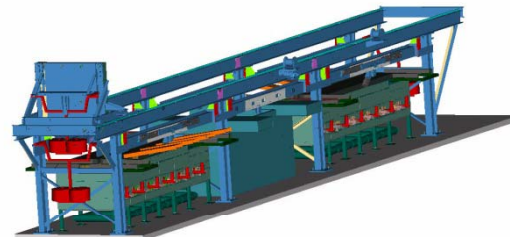
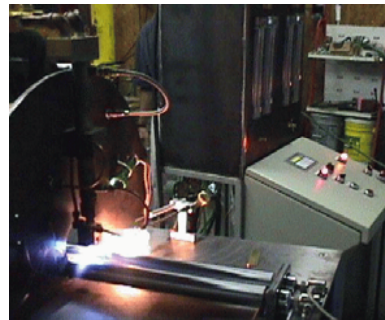
www.flox.com

www.shunk-inex.com

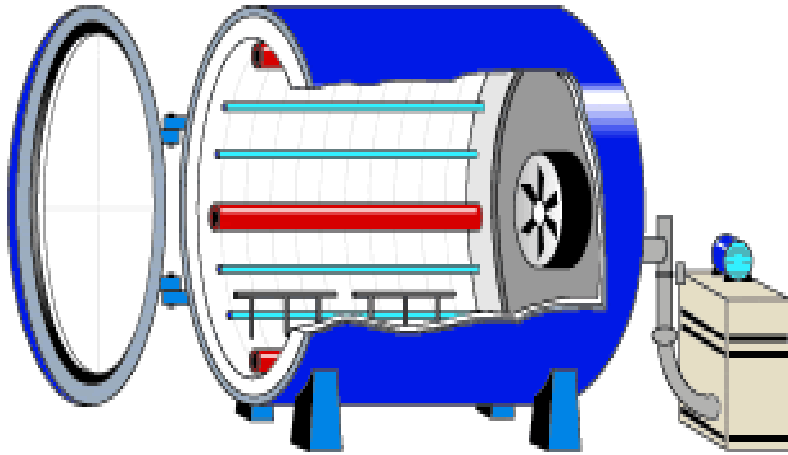
- **Fluidized Bed**

www.rapidheattreat.com

(available soon)



Gas-Fired Vacuum Furnaces (GFVF)



- (GFVF) are a credible and low maintenance alternative to electric vacuum furnaces.
- GFVF utilize innovative burner designs to treat more parts at lower costs while meeting or exceeding temperature uniformity and surface quality standards.
- There are many applications for this continually advancing technology.

- **Applications**

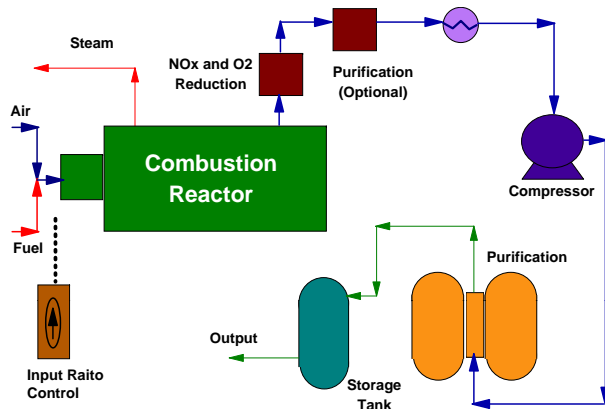
Heat treating to 1,850 F (higher temperatures available soon) including Normalizing, Annealing, Stress Relieving and others

- **Who to contact?**

Surface Combustion, Thermotech and AFC-Holcroft offer GFVF's. Visit the **"Resource Center"** section of www.gasfiredvacuum.com to contact them.

Web site: www.gasfiredvacuum.com

Fuel-Based Nitrogen (FBN) Atmosphere Generator



- Produces BOTH high-quality process atmosphere and steam. Natural gas used for boiler and atmosphere use is combined.
- NOx reductions measured at over 90% compared to standard systems.
- Reduces operating cost substantially. Recent installations report annual natural gas, maintenance and labor savings exceed \$250,000. \$500,000 annual saving have occurred.

• Applications

Ferrous and NonFerrous Annealing, Sintering, Brazing and Galvanizing of Rod / Wire, Sheet, Tube and other parts / shapes

• Who to contact?

Energy Resource Control Corp., Cleveland, Ohio
Phone: 440.734.2560 Fax: 440.779.9184

Web site: www.industrialcenter.org (click on "Technology Tour" button)

Flame Treating Systems, Inc. (FTSI)



- Natural gas FTSI units are efficient, economical and easy to install. Versatile designs with packaged and custom-designed options. PLC controlled for repeatable and reliable operation.
- FTSI reduces energy costs and can be installed in low and high temperature applications.
- Competes with induction at significantly lower capital cost.

- **Applications**

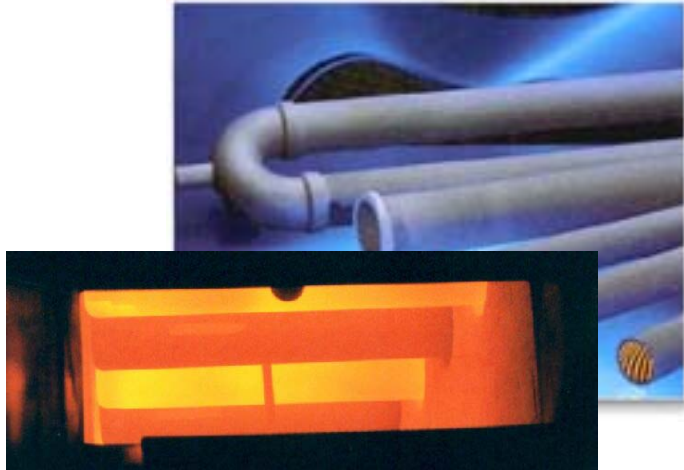
Hardening surfaces of parts, through heating prior to forming or forging, and preheating. Metals, plastics, and other process applications exist

- **Who to contact?**

Flame Treating Systems, Inc. Durham, NC
1.800.435.5312

Web site: www.flamesys.com

Composite Radiant Tubes (CRT)



- Available since the late-1980's, CRT's increase heat release, allow maximum process temperature for gas-fired system to rise, and offer longer life than standard alloy tubes.
- Combustion systems with CRT's can be supplied by almost every indirect burner supplier.
- Productivity of furnaces equipped with CRT's will usually increase.

- **Applications**

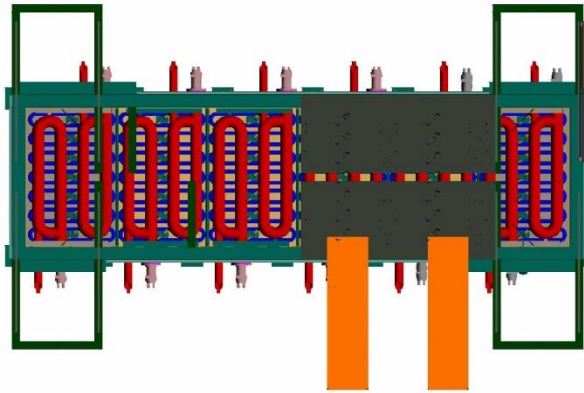
Steel, Metal Heat Treating, Ceramic, Glass and other industrial processes

- **Who to contact?**

Three Groups referenced – GTI, WS Thermal & Shunk-Inex. Others are active.
See Web sites

Web sites: www.griweb.gastechnology.org, www.flox.com & www.shunk-inex.com

Gas-Fired Fluidized Bed (FB)



- FB, compared to other heating methods, shortens heat-up times and promotes superior temperature uniformity resulting in more consistent part-to-part qualities.
- Indirect heating allows process gases to be introduced and reduces or eliminates the normal air volume needed to fluidize the bed.
- This new FB approach has been awarded DOE funding for aluminum castings processing. Higher temperature applications (steel) being pursued.

- **Applications**

Solution Heat Treat, Quench and Aging of aluminum castings (sand, squeeze cast, foam core), and forgings in automotive and other industrial applications

- **Who to contact?**

Technomics, LLC - Plymouth, MN
Phone: 763.383.4720 Fax: 763.383.4717 Email: info@rapidheattreat.com

Web site: www.rapidheattreat.com