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?**

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<thead>
<tr>
<th>SIC</th>
<th>Industry</th>
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<tr>
<td>331</td>
<td>Steel Mills</td>
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<td>34</td>
<td>Metal Fabrication</td>
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<tr>
<td>35 &amp; 36</td>
<td>Machinery and Electrical/Electronic Equipment</td>
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- **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?

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

Through:

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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
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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
  - Alloys
  - Stainless Steel
  - Tool Steel
- **Non-ferrous Metals**
  - Aluminum
  - Copper
  - Brass
  - Titanium

Steel Is the Primary Metal Being Heat Treated.

More Than 80% of Heat Treating Is Done for Steel
Heat Treating Processes

- Annealing
  - Full Annealing
  - Stress Relief Annealing
  - Spheroidizing

- Normalizing

- Hardening and Tempering
  - Conventional Hardening and Tempering
  - Austempering
  - Martempering

- Case Hardening
  - Carburizing
  - Cyaniding
  - Nitriding
  - Carbonitriding
  - Flame Hardening
  - Induction Hardening
  - Electron Beam Hardening
  - Laser Beam Hardening
Steps in Heat Treating Operation

- **Loading**
  - Cleaning
    - Pre-wash with coalescer
    - De-phosphate system
    - Spray rinse

- **Heating**
  - Preheating
  - Heating
  - Soak & diffusion
  - Pre-cooling

- **Tempering**
  - Surface coating

- **Quenching (Cooling)**
  - Post-wash

- **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
Electrically Heated Equipment for Metal Heating

Electric Atmosphere Furnace

Vacuum Furnace

Induction Equipment
Heat Treating
Processing Equipment
Gas Fired Furnaces
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.

**Types of Heat Treating**

<table>
<thead>
<tr>
<th>Atmospheric</th>
<th>Vacuum</th>
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<td>Operated at ambient (atmosphere) pressure.</td>
<td>Operated at vacuum or sub-atmospheric pressure.</td>
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<td>Load is heated and cooled in presence of air or special gases (process atmospheres), in liquid baths or in a fluidized bed.</td>
<td>May involve high pressure gas cooling using special gases. Includes ion or plasma processing equipment.</td>
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**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 Containment
- Heat Transfer
- Energy Source (fuel, electricity, etc.)
- Material Handling
- Exhaust Gases
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 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 Include Water Quench or Controlled Cooling
Process Atmospheres for Heat Treating
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.

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)

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.

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
Types of Process Atmospheres

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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, H2, CO2, H2O and N2) 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 (N2, H2 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.
Electrical Heating Systems for Heat Treating
Electric Heating for Heat Treating - At a Glance

Cost Comparison
Electric vs. Natural Gas

<table>
<thead>
<tr>
<th>Type of Electric Heating</th>
<th>Cent/Kwh</th>
<th>$/MM Btu</th>
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<tbody>
<tr>
<td>Resistance Heating</td>
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<tr>
<td>Direct Current</td>
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<td>18.51</td>
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<tr>
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<td>21.59</td>
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<td>9</td>
<td>27.76</td>
</tr>
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<td>30.84</td>
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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 NOx 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

- 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 NOx than the gas fired furnaces.
- Actual efficiency of application of heat could be in the range of 65% to 85%.

### Cost of Electric Heating

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- Low Temperature Tempering or Draw Furnaces
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- Gas Generators (Endo Gas and Ammonia Dissociators)
- Salt Bath Furnaces
- Pit (Underground) Furnaces
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*

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

These Tools will help you Prosper!

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

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

### Find Equivalent Electric Rate

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

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### Find Comparable Gas Rate

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<tr>
<td>Gas Equipment Efficiency</td>
<td>60%</td>
<td>% - Percent</td>
<td></td>
</tr>
<tr>
<td>Electricity Cost</td>
<td>4.5</td>
<td>Cents/kwh</td>
<td></td>
</tr>
</tbody>
</table>

Gas equipment provides cost savings when gas cost is equal to (or below) this gas cost | 9.31 | $/MM Btu (Mcf)

---

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

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>In the <strong>Base Case</strong> model, enter measured data in <strong>Green Cells</strong> 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.</td>
</tr>
<tr>
<td>2.</td>
<td>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.</td>
</tr>
<tr>
<td>3.</td>
<td>For the <strong>Modified Case</strong>, 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.</td>
</tr>
</tbody>
</table>

**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

<table>
<thead>
<tr>
<th>Furnace Flue Gas Temperature</th>
<th>Oxygen in Flue Gases</th>
<th>Excess Air</th>
<th>Combustion Air Temperature</th>
<th>Available Heat % of gross Heating Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deg. F.</td>
<td>%</td>
<td>%</td>
<td>Deg. F.</td>
<td>%</td>
</tr>
<tr>
<td><strong>Base Case</strong></td>
<td>1,600</td>
<td>6.1</td>
<td>38.3</td>
<td>100</td>
</tr>
</tbody>
</table>

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**
## Process Heat Cost Model
### Modified

<table>
<thead>
<tr>
<th>Furnace Flue Gas Temperature</th>
<th>Oxygen in Flue Gases</th>
<th>Excess Air</th>
<th>Combustion Air Temperature</th>
<th>Available Heat % of gross Heating Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deg. F.</td>
<td>%</td>
<td>%</td>
<td>Deg. F.</td>
<td>%</td>
</tr>
<tr>
<td><strong>Modified Case</strong></td>
<td>1,400</td>
<td>2.1</td>
<td>10.2</td>
<td>500</td>
</tr>
</tbody>
</table>

**Note:**

To Enter Data, “Double-Click” on the Green portion of the table cell. Then “Click” again in the cell until the cursor appears and make desired entry. Finally, “Click” once outside the cell to view results.

**Gas equipment provides savings when gas cost is equal to (or below) this gas cost**

$19.93

**Power Cost (Cents/kWh)**

0.045
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 innovate 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

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