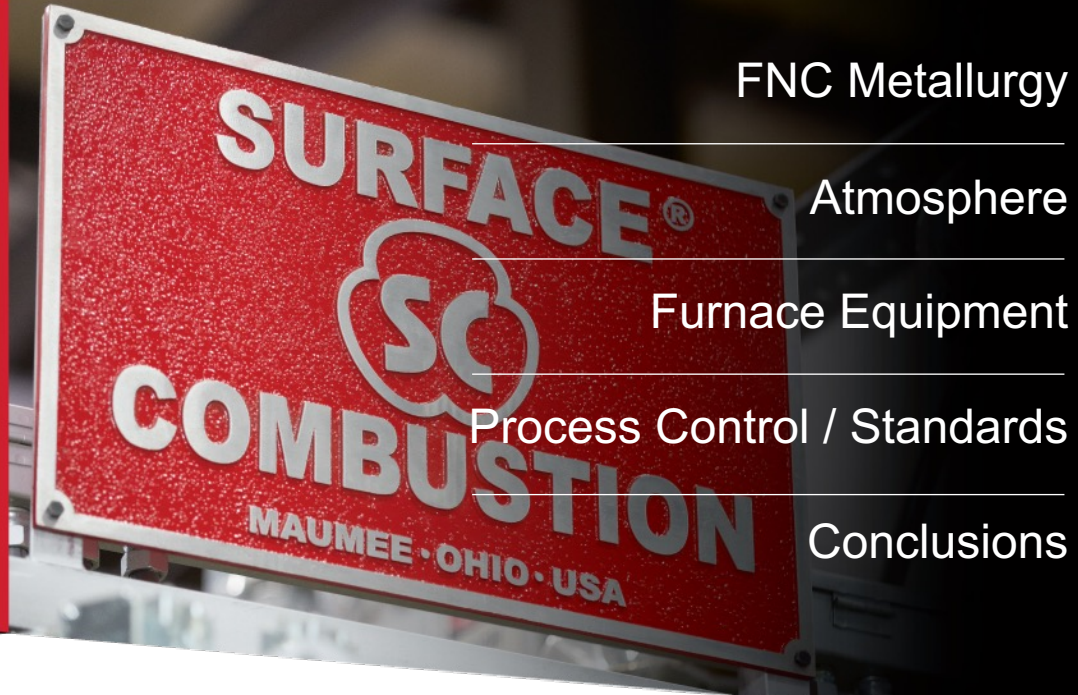


Ferritic Nitrocarburizing (FNC) Processes & Applications

Benjamin T. Bernard | Surface Combustion, Inc.



Overview



FNC Metallurgy

Atmosphere

Furnace Equipment

Process Control / Standards

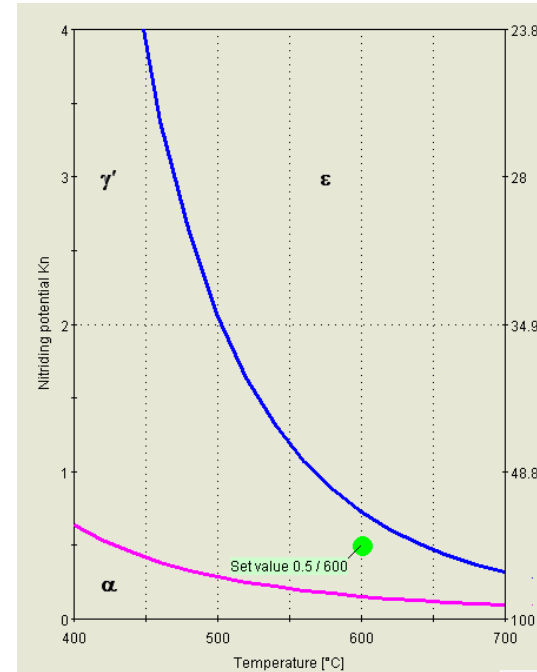
Conclusions

Ferritic

- Ferritic implies temperatures less than the A1 line (1400°F(760°C)) in the iron-carbon phase diagram
 - No BCC to FCC transition
 - Solubility of N in Steel is limiting factor during FNC, lower temperatures
- Available nitrogen from ammonia dissociation
 - $\text{NH}_3 \rightarrow \text{N}(\text{g}) + 3/2(\text{H}_2)$
 - $K_n = p\text{NH}_3/p(\text{H}_2)^{3/2}$
- Nitrogen Diffuses Into The Steel
- Nitrogen Reacts With The Nitride-Forming Elements
- Hardening Results From This

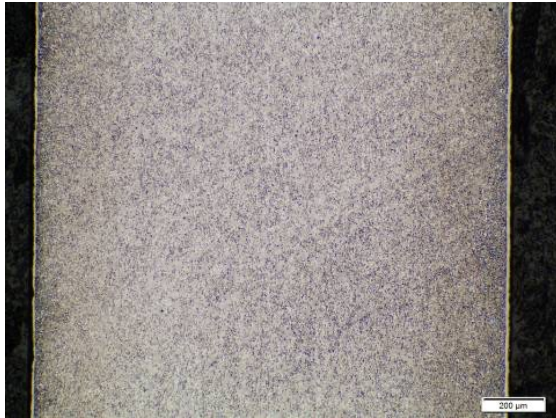
Nitride Forming Elements

- Chrome (Cr), Aluminum (Al), Iron (Fe)
 - Fe₃N (Epsilon)
 - Fe₄N (Gamma Prime)
- As alloying increases, the Nitrogen diffusion zone decreases



FNC Metallurgy

- Carbon Steel
 - Typical Specification
 - White Layer = 0.0005" (12.7 μ m)



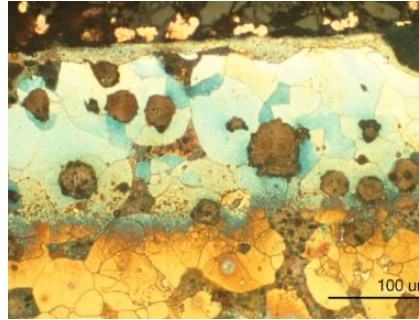
A. 50X mag.



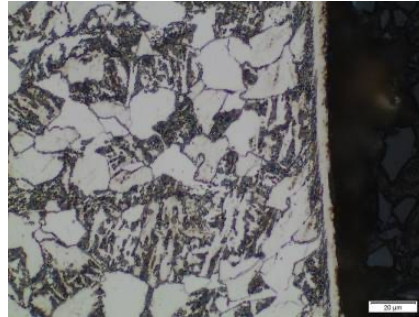
B. 200X mag.
(White Layer = 13-18 microns HV = 500)

FNC Metallurgy

- Ductile Iron
 - Ammonia / RX[®] Gas
 - WHITE LAYER =
 - 0.0006" avg. (15.2 μm)
 - Ammonia / N₂/CH₄
 - WHITE LAYER =
 - 0.0006" (15 μm)



A. 200X mag.



B. 500X mag.

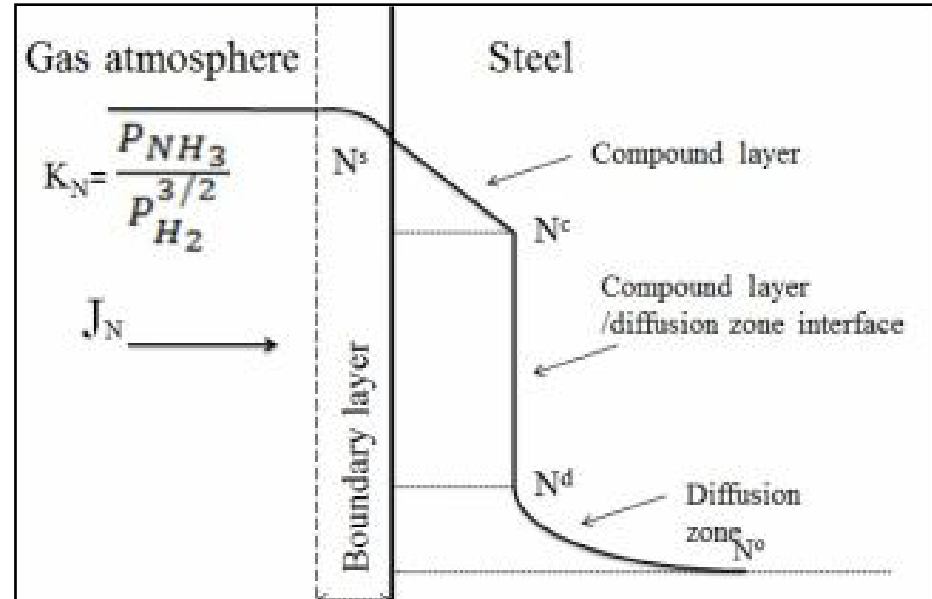
FNC Advantages



- Increase in Surface Hardness
- Increase Wear Resistance & Anti-Galling Properties
- Low Part Distortion Due to Low Operating Temperatures
700°F (370°C) to 1100°F (593°C)
- Improved Part Lubricity

FNC Advantages

- Improved Corrosion Resistance
- Improved Fatigue Life



Ref: CHTE NitrideTool®

FNC Atmosphere

- Ammonia (NH_3) based with myriad of available carrier gases and diluents
 - RX[®] Endothermic Gas and NH_3
 - RX[®] with dissociated NH_3 and $\text{N}_2(\text{g})$
 - DX[®] Exothermic Gas and NH_3



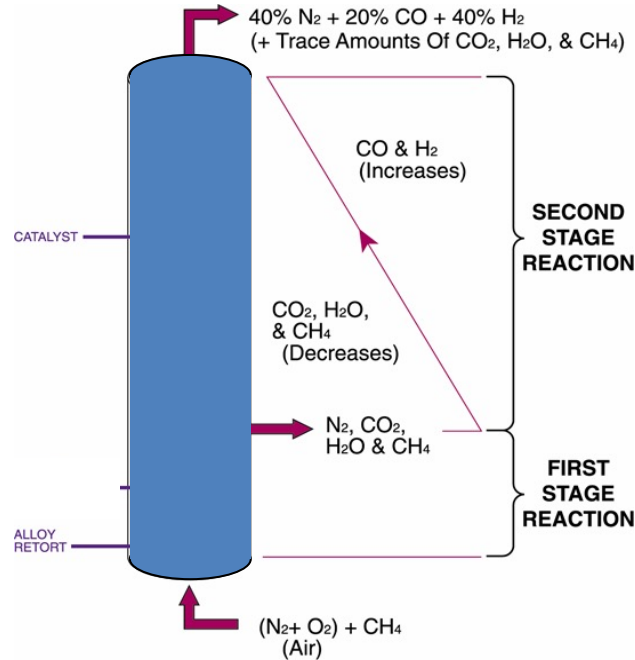
Typical Atmospheres & Processes

System	Residual NH ₃
Ammonia	55%
Ammonia / Nitrogen	55%
Ammonia / Endothermic Gas	42%
Ammonia / Nitrogen / CO ₂	21%
Ammonia / Nitrogen / CO	20%
Ammonia / Nitrogen / CH ₄	22%
Ammonia / Nitrogen / Air	24%
Ammonia / DX [®]	20%

- Pre-Oxidize / Pre-Heat
- Purge In With Nitrogen
- Introduce Process Gasses
- Purge Out / Process Cool
- Post Oxidize, If Required

RX[®] Atmosphere Generation

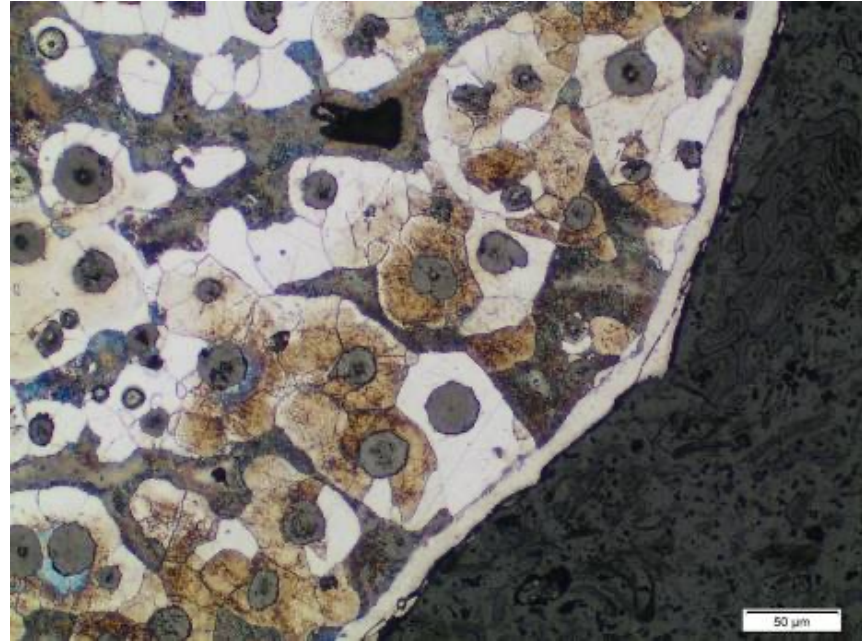
- Provides N₂, CO, H₂
- Additional Gases Needed for FNC:
 - NH₃
 - N₂(g)
 - CH₄
- LEL of RX[®] is 1400°F, so care should be taken to operate at FNC temperatures



Atmospheres

Atmosphere Varieties For Cast Iron:

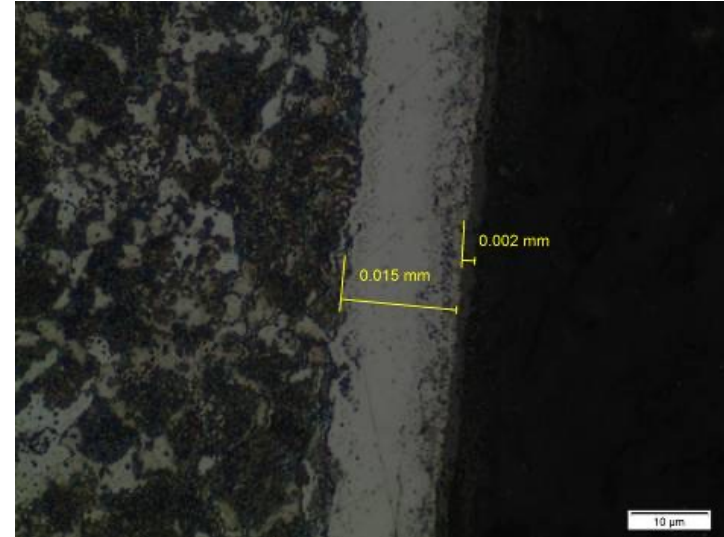
- A. 40% Endothermic, 60% Ammonia
- B. 35% Nitrogen, 5% Methane, 60% Ammonia
- C. 40% Ammonia, 55% Nitrogen, 5% Carbon Dioxide



200X mag.

Nitride (Process Gas) Tradenames

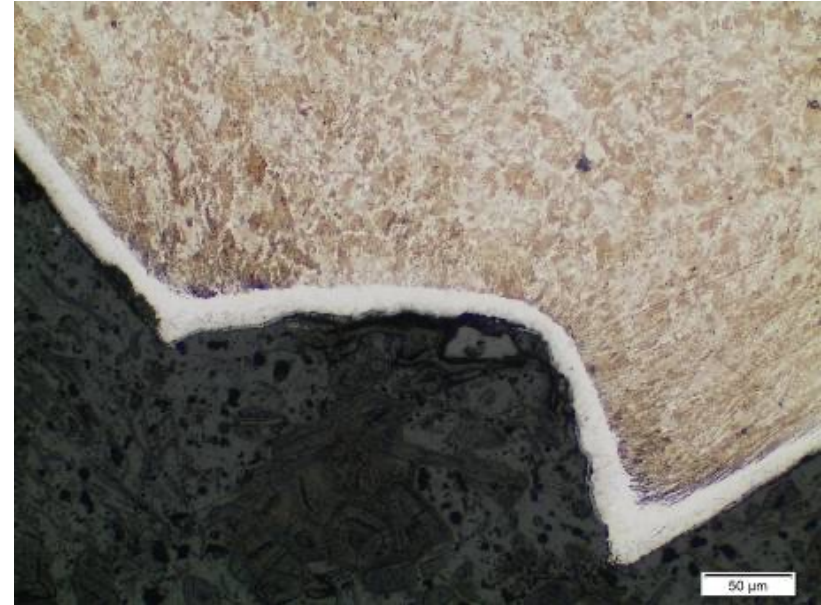
- Triniding™
 - NH_3 , $\text{N}_2(\text{g})$ and CH_4
 - Epsilon or Gamma prime
- Lindure®
 - RX^\circledR and NH_3
 - Epsilon
- Nitroflex®
 - NH_3 , CO_2 , N_2
 - $\text{N}_2 + \text{N}_2\text{O}$ for blackening
 - Epsilon with deep diffusion layer covered with black oxide



Triniding is a trademark of Surface Combustion
Lindure is a registered trademark of Bodycote
Nitroflex is a registered trademark of Linde

FNC Pre-Process Considerations

- Hardened/Tempered
- Stress Relieve
 - T should be less than FNC temperature
- Thoroughly Cleaned
- Optional
 - Pre-oxidize (N_2O or H_2O)
 - Shot Blast
 - Machine
 - Phosphate Coat
 - Acid Etch (Activation)



Furnace Designs for FNC

- Batch Integral Quench Furnaces
- FNC Furnaces
- Pit Furnaces
- Cover & Base Furnaces
- Horizontal Retort Furnaces
- Vacuum Furnaces
- Continuous Furnaces
- Companion Equipment
- Ion Furnaces

Allcase[®] Batch Integral Quench Furnaces



Typical Furnace For Gaseous FNC With Both An Oil Quench And Atmospheres Quench

Batch Integral Quench Furnaces

- Processes

- FNC
- Post Oxidation
- Carbonitriding
- Carburizing

- Advantages

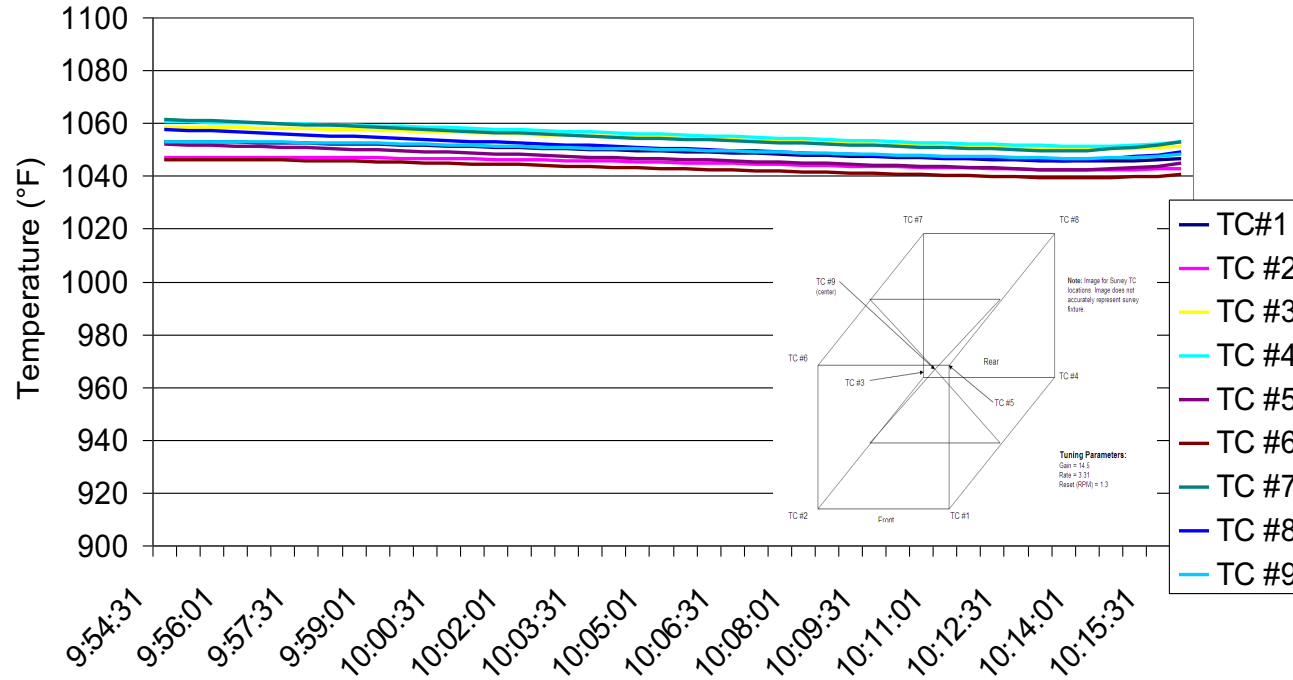
- High Productivity On Short Process Cycles (3-4 hours)
- Automated Load/Unload
- Also Designed For High Temperature Processes
- Oil/Polymer Quench Ability
- Atmosphere (N_2 or $RX^{\text{®}}$) cooling with Top Cool
- Slow Ammonia Dissociation

- Disadvantages

- Not Recommended For Classical Gas Nitriding Because Of No Retort (refractory lined)



BIQ Temperature Uniformity - FNC



FNC Quench Furnaces

- Processes
 - FNC
 - Atmosphere Tempering
- Advantages
 - Optimized Design for Low Temperature FNC Process
 - Smaller Footprint
 - Less Volume for Heating / Process Gases
 - High Productivity On Short Process Cycles
 - Automated Load/Unload
 - Top Cool Option Available

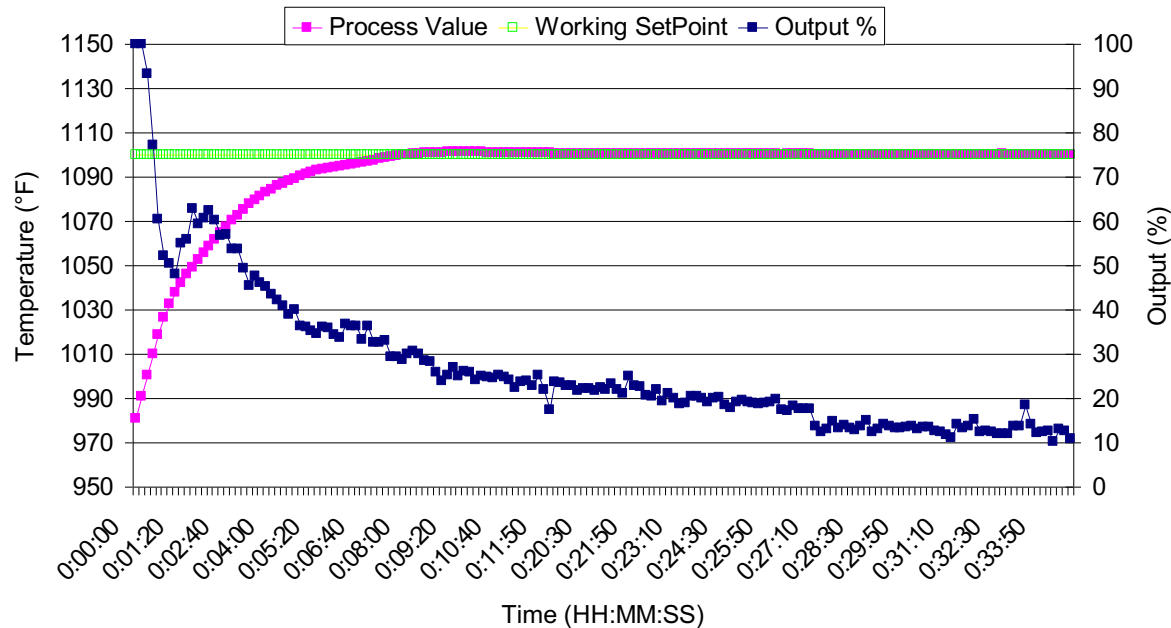
- Disadvantages
 - High temperature (>1250°F (677°C)) processes cannot be done in this furnace



Unique Round Design (US Patent 4,963,091)

Low Temperature FNC Furnace

Time Temperature Curve



Pit Furnace (with Retort Assembly)

- Processes

- Nitriding
- Nitro-Carburizing
- Oxynitriding
- Pre-Oxidation
- Post Oxidation (Bluing & Blackening)

- Advantages

- Custom Sizes Available
- Retort & Load Can Be Removed From Heating System To Improve Productivity
- Top Cool Option Available

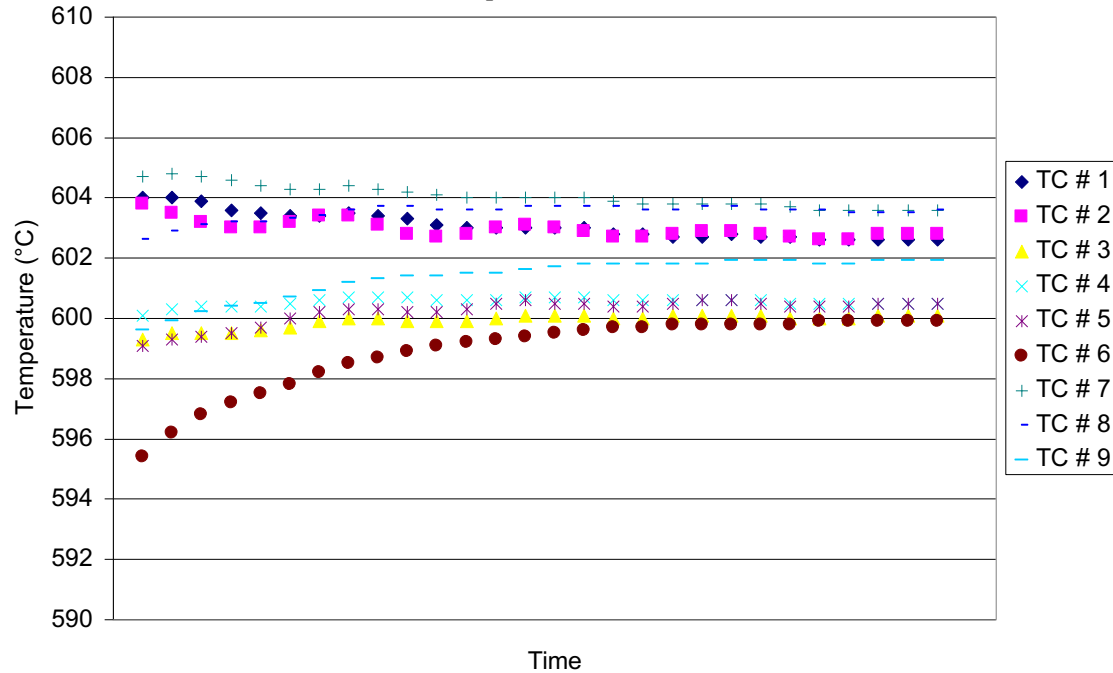
- Disadvantages

- Atmosphere Piping Must Be Disconnected During Load/Unload
- Not Productive For Short Cycle Processes
- Slower Cooling by External Coolers Compared to Oil Quench



Pit Furnace

Time Temperature Chart



Cover & Base (Bell) Furnaces

- Processes
 - Nitriding
 - Nitro-Carburizing
 - Oxynitriding
 - Pre-Oxidation
 - Post Oxidation (Bluing & Blackening)
- Advantages
 - Custom Sizes Available
 - Atmosphere Piping, Probes, Flue All Remain Connected During Loading / Unloading
 - Multiple Base/Retorts Can Be Serviced By Common Heating Cover
- Disadvantages
 - Not Productive For Short Cycle Processes

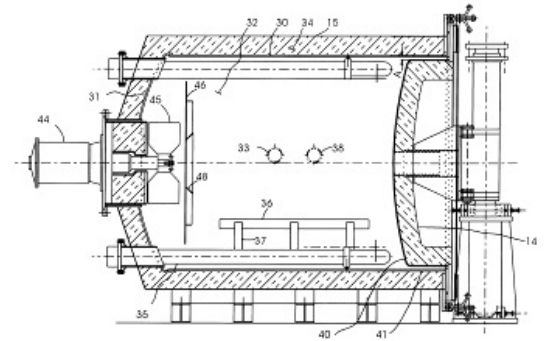


Horizontal Metalined™ Furnace



- Processes
 - Nitriding
 - Nitro-Carburizing
 - Oxynitriding
 - Pre-Oxidation
 - Post Oxidation (Bluing & Blackening)
- Advantages
 - Pit Requirements Eliminated
 - Fast Change in Atmosphere
 - Faster Cooling Compared to Pit Design
 - Automation of Loading/Unloading

- Disadvantages
 - Load Must Remain In Furnace Until Part Temperature Is Low



Inside/Out Vacuum Furnace: US Patent 6,283,749

Continuous Furnaces

- Processes
 - Nitro-Carburizing
 - Pre-Oxidation
 - Post Oxidation
 - Carbonitriding
 - Carburizing
- Advantages
 - Fully Automated
 - High Productivity On Similar Part Types
 - Ability To Do High Temperature Processes
 - Oil/Polymer Quench In Addition To Atmosphere Cooling
- Disadvantages
 - Frequent Cycle Changes
 - Not Designed For Large Part Sizes
 - Not Recommended For Classical Gear Nitriding



Companion Equipment

- Ammonia Dissociator
- Rich Fume Incinerator
- External Cooling System
- NX[®] Nitrogen Atmosphere Generator



Ion Nitriding Furnace

Process	Ion Nitriding	Gas Nitriding
Process Time	Up to 10% faster	
White Layer	<ul style="list-style-type: none"> • Can eliminate 90% H₂, 10% N₂ Gas • Mono-phase 	Always dual phase Ground off to prevent spalling
Parts Fixturing	Needs careful fixturing	Fixturing less important
Process Gas	N ₂ & H ₂ + (CH ₄)	Ammonia disassociated ammonia nitrogen
Masking	Simple Mechanical Placement	Plating required
Maintenance	<u>Moderate</u> <ul style="list-style-type: none"> • Vacuum pumps • Insulators 	<u>Moderate</u> <ul style="list-style-type: none"> • Air leaks (Seals)
Extra Equipment	<ul style="list-style-type: none"> • Nitrogen Tank • H₂ Bottle 	<ul style="list-style-type: none"> • Ammonia Tank • Dissociator or generator



Conclusion

- FNC is a value adding process which can be accomplished in many furnace arrangements and many process gas blends on most ferrous metals
- The FNC process can be controlled in a fashion to meet today's industry standards
- FNC offers many secondary benefits like energy savings, from lower operating temperatures, elimination of post heat-treat steps and increased wear & corrosion resistance
- Traditional Gas Nitriding and Ion (Plasma) Nitriding may be considered for the advantages of low temperature processing

Acknowledgements/References



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