Nitriding and Ferritic Nitrocarburizing in the VDR(N) Furnace

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# VDR Specifications

<table>
<thead>
<tr>
<th>Sizes: M &amp; XL</th>
<th>Controls</th>
</tr>
</thead>
</table>
| ✽ Load dimensions (W x L x H):  
  ✽ M: 24” x 36” x 24”  
  ✽ XL: 36” x 48” x 36” | ✽ HydroNit® sensor measures the hydrogen content |
| ✽ Temperature up to 1,382 ºF (750 ºC) | ✽ Provides control of the nitriding potential (KN-control) |
| ✽ Gas or electrical heated | ✽ Nitro-Prof® control software utilizes process data acquisition |
| ✽ Pronox® offers post-oxidation control | |

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VDR(N) Benefits

**Uniformity:**

- Gas circulation within the retort can be optimized through increased efficiency and improved directional flow.
- Excellent temperature uniformity: ± 10 °F (± 5 °C)

**Versatility:**

- High quench intensity with new shut-off flaps on the cold and hot side of the cooling stream.

**Speed:**

- Cycle time reduced by up to 30%
VDR: Temperature Uniformity

- Gas flow optimization within the retort
- Heat transfer improvement reduces the temperature difference within the load
- The VDR furnace has an excellent temperature uniformity of $\pm 10 \, ^\circ F$ ($\pm 5 \, ^\circ C$)
More Speed = Greater Profit

To produce 10-15μm white layer:

- A conventional furnace requires 12 hrs.
- The VDR furnace requires eight hrs.
- The VDR furnace produces three batches/day instead of only two batches/day

4,000-pound sample load:
Ferritic nitrocarburizing for 4 hours at 1,060 ºF (570 ºC)
VDR: Atmosphere Control with HydroNit® Sensor

Goals:
- Controlled layer structure generation
- Reproducible layer structure and thickness
- Minimal process duration

Requirements:
- Measurement device for the continuous monitoring of atmospheric component (e.g., H₂)
- Continuous monitoring of the input gases
- Atmosphere and nitriding potential algorithm
- Cracked ammonia or hydrogen for the reduction of the nitriding potential
- Automatic gas flow controller
VDR: Atmosphere Control with HydroNit® Sensor

Results:
Using the HydroNit® sensor, process time and gas consumption are reduced by up to 30 percent.
Nitriding Cycle with Pre- and Post-Oxidation

- **Pre-oxidation Condition**: Heating Controlled Process
- **Nitriding Process**: 900°F-1020°F
- **Post-oxidation Process**: 840°F-970°F

**Gassing Compositions**:
- **Air**: 765 Torr
- **NH₃**: up to 100% total gassing
- **N₂**: up to 50% total gassing
- **H₂O**: 765 Torr
- **CO₂**: 300 °C – 400 °C
- **C₃H₈**: (480 °C – 550 °C)
- **Nitro-Prof**: 450 °C – 520 °C

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FNC Cycle with Pre- and Post-Oxidation

Pre-oxidation Conditioning Nitrocarburizing Post-oxidation Heating Controlled Process Cooling

Air NH₃ CO₂ C₃H₈ H₂O

N₂ 45% Total Gassing NH₃ 50% Total Gassing CO₂ 5% Total Gassing N₂ (45% total gassing) NH₃ (50% total gassing) CO₂ (5% total gassing)

Pressure 765 Torr <30 Torr 765 Torr <30 Torr

(300 °C – 400 °C) 570°F-750°F (550 °C – 590 °C) 1020°F-1095°F (450 °C – 520 °C) 840°F-970°F

Nitro-Prof®

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Pre-Oxidation and Oxinitriding: Improving Reaction Kinetics

- Reduces the incubation time of nitride formation
- Improves the uniformity of the compound layer thickness
- Increases the thickness of the $\varepsilon$-compound layer
Pronox®:
Corrosion Resistance Improvement

Heat Treatment Cycle:

- **Purge phase** (e.g., N₂)
- **Heating phase** in NH₃
- **Holding phase in NH₃** /carburization agent
- **O₂-control** with air or H₂O (Pronox®)
- **Purge phase** (e.g., N₂)

1,020 °F – 1,095 °F (550 °C – 590 °C)
840 °F – 970 °F (450 °C – 520 °C)

1,020 ºF – 1,095 ºF
(550 °C – 590 °C)

Load Image:
Corrosion resistance in salt spray test up to 400 hours!

Micrograph:

- **Oxidation Layer**
- **Compound Layer**
- **Base Material**

1 - 3 µm iron oxide layer Fe₃O₄
min. 8,6 % Nitrogen plus Carbon content
min. 15 µm ε – compound layer

Base material

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Post-Oxidation Control

Amount of oxygen will depend on:

- Post-oxidation temperature
- Load surface

Main reasons to control post-oxidation:

- Heat treatment reproducibility
- Optimized oxygen consumption

Therefore, only the optimized mV value with $\lambda$ sensor is necessary.

$\lambda$ Sensor position in the exhaust fume pipe
Post-Oxidation Summary

- Use of a low temperature: 840 °F (450 °C)
- Hydrocarbon addition at the end of the FNC process
- Cooling to post-oxidation temperature under ammonia and hydrocarbon
- Small difference between end of oxide layer and maximum N+C value
- Quenching after post-oxidation instead of slow cooling
Nitriding: Internal Gear

**Specification/Results:**

<table>
<thead>
<tr>
<th>Material</th>
<th>31CrMoV9V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitriding Temperature</td>
<td>960 °F (515 °C)</td>
</tr>
<tr>
<td>Process Duration</td>
<td>70 h</td>
</tr>
<tr>
<td>Nitriding Potential</td>
<td>4 – 4.5</td>
</tr>
<tr>
<td>Nitriding Depth</td>
<td>0.015” – 0.029”/0.018”</td>
</tr>
<tr>
<td>Compound Layer Thickness</td>
<td>Max 20µm/17µm</td>
</tr>
</tbody>
</table>

**Process Printout:**

**Microstructure:**

**Load Image:**

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### FNC: Balance Pin

#### Specification/Results:

<table>
<thead>
<tr>
<th>Material:</th>
<th>31CrMoV9V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitriding Temp.:</td>
<td>1,000 °F (540 °C)</td>
</tr>
<tr>
<td>Process Dur.:</td>
<td>18 h</td>
</tr>
<tr>
<td>Nitriding Pot.:</td>
<td>3</td>
</tr>
<tr>
<td>Surface Hrd.:</td>
<td>720 – 820 HV10/758 HV10</td>
</tr>
<tr>
<td>Compound L. Th.:</td>
<td>14 – 22µm/16.2µm</td>
</tr>
</tbody>
</table>

#### Process Printout:

![Process Printout](image1)

#### Load Image:

![Load Image](image2)

#### Microstructure:

![Microstructure](image3)
FNC: Inner Gear

**Specification/Results:**

<table>
<thead>
<tr>
<th>Material</th>
<th>4140/42CrMo4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitriding Temperature:</td>
<td>1,060 °F (570 °C)</td>
</tr>
<tr>
<td>Process Duration:</td>
<td>5 h</td>
</tr>
<tr>
<td>Nitriding Potential:</td>
<td>2.5</td>
</tr>
<tr>
<td>Surface Hardness:</td>
<td>550 – 650 HV10/630 HV10</td>
</tr>
<tr>
<td>Nitriding Depth:</td>
<td>0.4 – 0.55 mm/0.5 mm</td>
</tr>
<tr>
<td>Compound Layer Thickness:</td>
<td>8 – 35μm/14.3μm</td>
</tr>
</tbody>
</table>

**Process Printout:**

**Load Image:**

**Microstructure:**
The advanced process and furnace technology of Ipsen’s **VDR furnaces** make it possible to create uniform, repeatable nitrided or nitrocarburized layers on a variety of materials. Benefits include:

- Optimized uniformity of the hot gas flow and the increased hot gas volume flow result in a temperature uniformity of ±10 °F (±5 °C)
- Reduction in process time by up to 30% thanks to the VDR furnace’s new, external high speed cooler
- Increase in throughput as components are treated for a shorter span of time
Optimized Processes:

- Nitriding
- Oxinitriding
- Nitrocarburizing
- Oxinitrocarburizing
- Pre-oxidation
- Post-oxidation

Process Monitoring and Control:

- Gas-analyzers
- Oxygen-probe
- HydroNit® sensor
- KiNit sensor
- Atmosphere calculation model