TUFFTRIDE® TF 1 - Process

What is Nitrocarburizing?

A thermochemical treatment which enriches the surface of ferrous materials primarily with nitrogen and, at the same time with small amount of carbon.
TUFFTRIDE® QPQ

improves
- wear resistance
- corrosion resistance
- fatigue strength
- appearance

and is a
- economical
- environmentally friendly
- multi-purpose

process
TUFFTRIDE® TF 1 - Process

Media for Nitrocarburizing

- Salt bath
- Gas
- Plasma
- Powder
# Medium

Molten salt consisting of alkali cyanate and alkali carbonate

## Basic Reaction in the Molten Salt

**Nitrocarburizing Process**

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyanate (CNO⁻)</td>
<td>Nitrogen (N) + Carbonate (CO₃²⁻)</td>
</tr>
<tr>
<td>Nitrogen (N) + Iron (Fe)</td>
<td>Iron nitride (FeₓN)</td>
</tr>
</tbody>
</table>

**Regenerating with REG 1**

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbonate (CO₃²⁻) + REG 1</td>
<td>Cyanate (CNO⁻)</td>
</tr>
</tbody>
</table>

**Side Reaction**

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyanate (CNO⁻)</td>
<td>Cyanide (CN⁻) + Oxygen (O₂)</td>
</tr>
</tbody>
</table>
Structure of a TUFFTRIDE® treated surface

Compound Layer (CL)
- on the surface of a work piece
- consists of $\varepsilon$ - iron nitride
  (in the case of alloyed steels, also of special nitrides)

Diffusion Layer (DL)
- area below the compound layer
- nitrogen is solved atomically in the iron lattice
  (with unalloyed steels and slow cooling also in the form of iron nitride needles)
TUFFTRIDE® Process

Systematic Structure of the Compound Layer
The most important influences on the thickness of the compound layer are:

- Material
- Treating temperature
- Bath chemistry (e.g. cyanate content)
- Treating time
Effects of Composition of Material

An increasing content of alloying elements with constant treatment parameters causes:

- Decrease in thickness of the compound layer
- Decrease in total nitration depth
- Increase in surface hardness
Influence of various materials on the thickness of the compound layer

<table>
<thead>
<tr>
<th>Compound layer [µm]</th>
<th>SAE 1045</th>
<th>SAE 4140</th>
<th>SAE 3115</th>
<th>H 11</th>
<th>420</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAE 1045</td>
<td>15</td>
<td>14</td>
<td>13</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>SAE 4140</td>
<td>14</td>
<td>13</td>
<td>12</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>SAE 3115</td>
<td>13</td>
<td>12</td>
<td>11</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>H 11</td>
<td>12</td>
<td>11</td>
<td>10</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>420</td>
<td>11</td>
<td>10</td>
<td>9</td>
<td>8</td>
<td>7</td>
</tr>
</tbody>
</table>
Obtainable compound layer thickness in relation to the treating time

- **Compound layer thickness in µm**
- **TUFFTRIDE TF1 580°C**

**C15 - C45**
- Direct hardening alloy steel

**Hot work steel**
- 12 % Cr-steel H23
Total nitriding depth of various steels in relation to the treating time

TF-GR 068 E 1
Hardness Behaviour of Different Materials

TUFFTRIDE® Process

90 minutes TF 1 (580°C)

- 12% Cr - steel
- X40CrMoV5.1
- 42CrMo4
- C45
- Cast Iron

Vickers hardness [HV 0.3]

Distance from Surface [mm]
Surface hardness and case depth in relation to the chrome content

- Nitrogen penetration depth [mm]
  - According to hardness profile
- Chrome content [%]

Graph showing the relationship betweenNitrogen penetration depth and Chrome content, with hardness in the diffusion layer [HV 0.05] on the y-axis.
Treating Cycle

- Preheating on air (350 - 400°C)
- Nitrocarburizing in a TUFFTRIDE TF1 bath (usually at 580°C)
- Cooling
- Cleaning in a heated and agitated rinsing cascade
- (Short immersion in dewatering fluid)
Preheating

Reason
- Only completely dry components should be put into the bath!
- Temperature in TF 1 bath should not drop below 1000°F (540°C) or the formation of the compound layer will be negatively impacted.

Influencing Factors
- Temperature (normally 660-750°F) (350-400°C)
- Duration (usually 30-90 minutes, min. 30 minutes)

Important!
Too high a temperature, or too long a time, can lead to scaling.
(⇒ Poorer nitriding quality, high sludge formation)
Influencing Factors in Bath Performance

- Temperature
- Treating time
- Bath chemistry
  - CNO\(^{-}\) 35-38%
  - CN\(^{-}\) \(\leq 5\%
  - Fe \(\leq 0.02\%
- Aeration
Influence of treatment time on the compound layer

Compound layer [µm]

Treatment time [min]
Highly flexible because

- components requiring various treating times can be treated together in the salt bath
- various materials can be nitrocarburized in one charge
- the treating / processing time is very short
- the plants are of modular design so that fluctuations in throughput can be accommodated
- cooling mediums with different cooling rates (water, AB1 bath, forced air, nitrogen or vacuum) can be used
- TUFFTRIDE treatment is possible within a temperature range of 480°C - 630°C
Bath Chemistry

**CN⁻ Content (≤ 5%)**

- Dependent on throughput and sludge content
- Too much reduces the lifetime of the pot and affects the regeneration reaction
- Is influenced by the aeration
Regenerating with REG1

1. Determine the required amount of regenerator from tables in the operating instructions

2. Measure exactly the amount of regenerator required to 100 g

3. Using a shovel, carefully add the regenerator in small portions to the aerated bath
Bath Chemistry

CNO⁻ Content (35-38%)

- Maintained through addition of REG 1
- Too much causes thick compound layers with too much porosity
  \( \Rightarrow \) Lowering of wear and corrosion resistance
- Too little reduces nitriding activity and leads to thinner compound layers
  \( \Rightarrow \) Lowering of wear and corrosion resistance
Influence of Sludge Content on the Compound Layer
TUFFTRIDE® - Process

Cooling Media

- Water
- Oxidative cooling bath (AB1 bath)
- Forced air
- Nitrogen
- Vacuum
- (Oil)
Formation of the diffusion layer at different cooling rates
Material: 1015

90’ TF1 (580°C) ⊗ SW

20 μm

90’ TF1 (580°C) ⊗ 10’ AB1 (350 °C) ⊗ SW
Advantages of an AB1 Bath

- **Significant increase in corrosion resistance**
- **Oxidation of salt residue from TF1 bath to carbonate**
- **Less distortion because of gradual cooling**
- **Better running properties**
Oxidation in AB1 Medium

Molten salt consisting of alkali nitrate, alkali hydroxide and alkali carbonate

Basic Reactions in the Molten Salt

Detoxification Reaction

Cyanide (CN⁻) + Nitrate (NO₃⁻) → Carbonate (CO₃²⁻) + Nitrite (NO₂⁻)
Cyanate (CNO⁻) + Nitrate (NO₃⁻) → Carbonate (CO₃²⁻) + Nitrite (NO₂⁻)

Oxidation of the Compound Layer

Iron nitride (FeₓN) + Nitrate (NO₃⁻) → Magnetite (Fe₃O₄) + Nitrite (NO₂⁻)

Regeneration

Nitrite (NO₂⁻) + Oxygen (O₂) → Nitrate (NO₃⁻)
Influencing Factors in AB 1® Bath

Temperature 660-750°F (350-400°C)
- Influences the oxidation potential
- Determines the solubility of the carbonate

Sodium Nitrate Content (NaNO₃ : 8-15%)
- Influences the oxidation potential
- Is partially reduced to sodium nitrite during the bath reaction

Sodium Carbonate Content (Na₂CO₃ : approx. 30%)
- Formed by the oxidation of cyanide and cyanate
- Too much:
  - Makes cleaning of parts more difficult
  - Leads to formation of a bath crust and building of sludge on bottom of pot
Influencing Factors in AB 1® Bath

**Agitation**
- Necessary for an even temperature and homogeneous bath composition
- Ensures heat dissipation when load is brought in

**Aeration**
- Oxygen in the air oxidizes sodium nitrite (NaNO₂) back to sodium nitrate (NaNO₃)

**Important!**
- Too much oxidation potential ⇒ reddish colored parts
- Too little oxidation potential ⇒ reduced corrosion resistance
  ⇒ inconsistent dark coloring
AB 1 Bath

Warning signs that something is wrong!

- Bath is not liquid at 750°F (400°C).
- No foaming, no reaction when load is brought in.
- (Brown-coloured salt melt)
## Influencing Factors in the Quenching Tank

<table>
<thead>
<tr>
<th><strong>Temperature</strong></th>
<th><strong>&lt; 104°F (&lt; 40°C)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher temperatures cause reddish coloration</td>
<td></td>
</tr>
</tbody>
</table>

**Salt Content**
- Too high AB 1® salt content
  - Can lead to talc on parts
  - Makes cleaning more difficult (especially in hard water)
- Fresh rinse water must contain some AB 1 salt (< 1%) to reduce the high surface tension
  - Building of gas bubbles; discoloration of the parts

**Agitation**
- Avoids localized hot areas
- Improves cleaning effectiveness
Diagram of a TUFFTRIDE® - plant

Fresh water

Cleaning Cascade

Cold Water Rinse

10%

1.0%

0.1%

DC

LSU

STT

STT

SWQT

H.E.F.
durferrit
### Requirement of Washing Water for Different Rinsing Techniques

<table>
<thead>
<tr>
<th>Rinsing technology</th>
<th>Amount of waste water</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
</tr>
<tr>
<td>Rinsing tank</td>
<td>100</td>
</tr>
<tr>
<td>2 rinsing tanks</td>
<td>20</td>
</tr>
<tr>
<td>2-step washing cascade</td>
<td>2.25</td>
</tr>
<tr>
<td>3-step washing cascade</td>
<td>0.65</td>
</tr>
<tr>
<td>4-step washing cascade</td>
<td>0.33</td>
</tr>
</tbody>
</table>

Source: Dr. Rolf Stiefel
Institute for Industrial Hydroeconomy and Aircleaning, Cologne
Influencing Factors in the Rinse Cascade

Temperature 140-175º F (60-80ºC)
- Heat increases the dissolving of salt residues

Salt Content
- The lower the salt content, the more effective the cleaning

Agitation
- Fast water flow speeds up the dissolving of salt residues
- Improves the cleaning effectiveness