Deloro Stellite is a global provider of innovative solutions to challenging wear problems.

We deliver advanced wear protection to extend the life of components in demanding environments where heat, corrosion and abrasion are prevalent.
FusionStell™ Cladding process

- A novel technology to metallurgically bond a thin layer of Stellite with full density onto metal substrates
- The coating offers the wear resistance of a cast cobalt component on a non-cobalt substrate, typically steel
- Properties of the FusionStell™ coating the same as cast alloy
  - Chemical composition identical
  - Hardness the same
  - Finish the same as equivalent cast alloys
- No Fe-dilution or heat affected zone as in hardfacing of Stellite
- More consistent coating quality than spray & fuse coatings

FusionStell™ Process

- Stellite powder is mixed with water, organic binder, and various additives to form a slurry
- Substrate components are dipped into the slurry and the metal coating adheres to the component surface
- The coating is air dried, before sintering in a vacuum furnace
FusionStell™ samples

Outside diameters

Inside diameters

Complex shapes

Metallurgically bonded coatings

Outide diameter

Gr 21

20 μm

Inside diameter

Stellite 12 coating on Stellite 12 casting

Stellite 720 on ID of 9Cr1Mo pipe
FusionStell™ Coated 9Cr-1Mo Return Bends

FusionStell™ Applications
Good Coating Bond Strength

- Bend test showed good bonding of FusionStell™ Stellite 720 coating onto 9Cr-1Mo with no coating delamination

Bend test sample & set-up

Bend test results

Substrate compatibility

- Certain substrates cannot be subjected to high temperature sintering
- No problems with Stellite 6 & 12, but very hard coatings have limitations

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<tbody>
<tr>
<td>Stellite 6 &amp; 12</td>
<td>✔️</td>
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<td>(hardness range 40 – 46 HRC)</td>
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<td>Very hard Stellite</td>
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<td>✔️</td>
<td>✔️</td>
<td>440C</td>
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<td>9Cr1Mo*</td>
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<tr>
<td>T400, T800</td>
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<td>9Cr1Mo*</td>
<td>✗</td>
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<td>(hardness range 53 - 56 HRC)</td>
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* fine cracks in the coating
Substrate Mechanical Properties

- Mechanical properties of steels recovered with post-coating heat treatment
  - Austenitic steels unaffected
  - Precipitation hardened and martensitic steels fully recovered

- Most cast alloys properties not significantly affected
  - Typically a slight reduction in yield strength

- Wrought alloy properties reduced between 15 - 25% due to grain growth
  - Yield strength mostly affected

![CAST IN 718](image1)

![Wrought IN 625](image2)

Stellite Alloy Chemistries

<table>
<thead>
<tr>
<th>Alloys</th>
<th>Cr</th>
<th>W</th>
<th>Mo</th>
<th>C</th>
<th>Hardness, HRC</th>
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<tr>
<td>Stellite 6</td>
<td>29</td>
<td>4.5</td>
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<td>1.2</td>
<td>39 - 43</td>
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<tr>
<td>Stellite 12</td>
<td>29</td>
<td>8</td>
<td>-</td>
<td>1.8</td>
<td>47 - 51</td>
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<td>Stellite 1</td>
<td>31</td>
<td>12.5</td>
<td>-</td>
<td>2.5</td>
<td>51 - 58</td>
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<tr>
<td>Stellite 720</td>
<td>33</td>
<td>-</td>
<td>18</td>
<td>2.5</td>
<td>55 - 60</td>
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</tbody>
</table>

- Wear properties of the coating is determined by both the alloy chemistry and manufacturing process
High Temperature Hardness

- Stellite alloys retain hardness above 900°F better than 9Cr1Mo

![Graph showing hardness vs. temperature for Stellite alloys and 9Cr1Mo P91.]

Better Wear Resistance than Hardfacing

![Bar chart comparing ASTM G65-B abrasion wear resistance between Stellite 720, Cast Stellite 6, Weld layer Stellite 6 (low and high dilution), and AISI 410.]
High Temp Erosion in FCCU environment

Erosion at 700°C at 60° angle
with an Al₂O₃ catalyst used for fluidized catalytic cracking

Weld Overlays in Return Bends

Limitations of Stellite weld overlays
- Over-heating of substrate
- High welding rate cause large HAZ
- High Fe-dilution & Ni-dilution reduce wear properties of Stellite
- Irregular surface effect flow rates
Return Bend with Weld Overlay

Hardness traverse across fusion line

9Cr1Mo | IN 625 | Stellite 6 | Stellite 1

Dilution in Weld Overlays

Composition Traverse Across the Fusion Lines

9Cr1Mo | IN 625 | Stellite 6 | Stellite 1

± 30% Fe+ Ni dilution | 10-15% Fe + Ni dilution
Why is Dilution important?

+ Dilution of Stellite weld overlays from substrate is inevitable
  + Dilution is amount of Fe or Ni (when using IN625 butter layer) in the Stellite

+ Dilution in Stellite generally has the following effect:
  + Decreases hardness – more pronounced at higher temperatures
  + Decreases corrosion resistance
  + Decreases wear resistance

+ Erosion rate doubles when hardness decrease from 320 to 200 DPH

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Hot Hardness and the Effect of Dilution

+ Hot hardness is very important to ensure good wear resistance at higher operating temperatures

+ Hardness drops rapidly with increased Fe dilution, as shown by change in gradient
FusionStell™ 720 cladding on 9Cr1Mo

- The FusionStell™ process produces a ‘pure’ Stellite coating
- Dilution only occurs in the diffusion zone ensuring a metallurgical bond
- Diffusion zone is typically 0.001” thick

The hardness values of the 9Cr1Mo substrate are higher than normal as this sample did not receive a full HT cycle.

FusionStell™ coated Thermowells

- Thermowells for bitumen upgrading service coated with Stellite 720
  - Coating thickness 0.040” on 300 series SS base
  - Higher hot hardness than Stellite SF12

Coated Thermowell sheath after metallurgical analysis

Damaged spray & fuse thermowell
Ultrasonic Testing of FusionStell coatings

- No reliable method available to measure thickness and integrity of weld overlay Stellite coatings on ID’s of return bends

- UT results of FusionStell™ coated 9Cr1Mo demonstrated that coating thickness can be measured successfully

- FusionStell™ process provides smooth surface for intelligent pigging

- It is possible to inspect coating thickness of FusionStell™ return bends in-situ at regular intervals to determine remaining wear life

Weld overlay vs. FusionStell™ cladding

- Limitations of Stellite weld overlays on return bends
  - Welding parameters are ‘hot’ due to limited access and need for thick coatings
  - These ‘hot’ welding parameters results in very high dilution levels
  - Fe & Ni-dilution reduces the wear resistance of Stellite significantly
  - Weld overlay coatings cannot be inspected with UT due to cracking

- FusionStell™ offers superior coating properties
  - Demonstrated uniform coating deposition on various sizes of ID’s
  - Coating integrity demonstrated – diffusion bonded to the substrate
  - No Fe-dilution – wear resistance superior to a weld overlay
  - Process repeatability will ensure consistency – can be measured with UT
  - Enable pigging of the system with consistent coatings in the return bends
Benefits of FusionStell™ Technology

- The process can produce coated solutions not possible with any other technology such as internal diameters
- Metallurgically bonded coatings with excellent wear and corrosion resistance
- Engineered materials solutions for severe service environments
  - Select optimum coating compositions for a specific application

Overview of Deloro Stellite Group

- The company dates back to 1907 with the invention of a family of cobalt based alloys called “Stellite”, known for its superior wear resistance
- Today it is a global company with sales over $300 million, operating out of 6 countries, employing around 1,300 people
- Industry leader for solving wear and corrosion problems, and a supplier to diverse industry sectors
- Provider of a wide range of alloys and coatings that can resist aggressive and demanding environments

Kennametal has acquired the Deloro Stellite Group in March, and the company is now called Kennametal Stellite
Where are Stellite® Alloys Used?

- Family of alloys that exhibit excellent resistance to wear and corrosion
  - Main constituents of Stellite alloys are Co, Cr, W, Mo, C
  - Hardness from 32 – 63HRC

- Stellite® alloys out-perform other materials under conditions when two of the following three conditions are present:
  - Wear
  - Corrosion
  - High temperatures

- Good corrosion resistance due to high Cr content (28 – 32%)
  - Corrosion behaviour similar to 316 stainless steel

- Can be produced with a variety of manufacturing methods, including various casting and surfacing processes

Suite of Manufacturing Processes

Manufacture of components for high wear applications
- Variety of casting processes available within our network of six foundries
  - Sand casting
  - Centrifugal casting
  - Investment casting
  - Resin shell casting
  - Vacuum casting
- Machining and finishing of hard alloys to high surface finish specs
  - Modern machine shops at various locations
- Powder metallurgy products
- Wrought products
- Prototyping and Rapid Product Development
Suite of Manufacturing Processes

Wear-Resistant Coatings
- HVOF coatings
- Plasma Transferred Arc (PTA) welding
- Tungsten Inert Gas (TIG) Welding
- Submerged Arc Welding
- Metal Inert Gas (MIG) Welding
- FusionStell™ coatings

Wear-resistant materials
- Cobalt and Nickel welding consumables
  - Power, rod, wire & electrodes
- HVOF thermal spray powders

Coating equipment systems
- Jet-Kote® HVOF coating systems
- Starweld® & Hettiger® Plasma Transferred Arc (PTA) welding systems

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