Types of stainless steel and welding controls applied in the pharmaceutical industry for product-contact areas.
Agenda

• Biozeen Introduction
• Stainless Steel
• Types of Stainless Steel used in biopharmaceutical industry
• Selection of the Stainless Steel
• Welding in bioprocess equipment & Welding Management System
• Controlling welding
• Welding Documentation
Noble Cause, Unique Model

Integration Services

Training, Research & Regulatory Services

Design Build

Total Solution Partner to the Biotech World
NOBLE CAUSE, UNIQUE MODEL

**Design Build Solutions**
- Bioreactor systems
- Fermentor systems
- Process systems
- CIP and SIP systems
- Filtration systems
- Bio-Kill systems
- Sanitary Vessels
- Crystallizers
- Interconnection piping

**Automation Solutions**
- Plant Automation
- PLC Programming
- DCS Systems
- Automation Upgradation

**Technology Services**
- Process Design
- Process Optimization
- Contamination trouble shooting
- Process Validation
- Project Management

**Research & Development**
- Efficiency improvement studies
- Glycosylation
- Perfusion with micro carriers
- Algae culture
- High cell density of VERO / CHO cell lines

**Manpower Training**
- Fermentation Technology
- Mammalian Cell Culture Technology
- Downstream Processing
- Sterilization & Filtration Technology
- Bioprocess Engineering
- Regulatory Aspects & Documentation

**BioZEEN Regulatory Services**
- Filter Train Optimization Study
- Compatibility Study
- Product based Integrity Study
- Bacterial Retention Study
- Protein & Preservative Binding Study
BiOZEENites

- **Head Quarters:** Bangalore
- **Employees:** 225
- **Number of Business Lines:** 6
- **Number of Product Lines:** 8

**Chart:**

- Technology & Processes
- Automation & Instrumentation
- Bioprocess
- Training & Research
- BioZEEN Regulatory Services
- Procurement
- Project Management
- Management & Support
BiOZEEN DESIGN & BUILD INFRASTRUCTURE

Manufacturing Workshop

- Campus spread across 4 Hectares
- Floor area of 35,000 Sq. ft
- Executed Bioreactor/ Fermenter from 1L to 10000L
- In-house facility for electro polishing

- State-of-the-art Quality Control Units
- Clean and Black utilities
- Boilers, Chillers, Compressors, WFI generators

Integrated FAT centre
BioZeen Design & Build Infrastructure

Manufacturing Workshop

- State-of-the-art New Manufacturing Centre located in Hardware Park, Bangalore, India
- Floor area of 50,000 Sq. ft
- Operational since June 2018
BiOZEEN DESIGN & BUILD INFRASTRUCTURE

Manufacturing Workshop

- State-of-the-art New Manufacturing Centre located in Hardware Park, Bangalore, India
- Floor area of 50,000 Sq. ft
- Operational since June 2018
Manufacturing Workshop

- State-of-the-art New Manufacturing Centre located in Hardware Park, Bangalore, India
- Floor area of 50,000 Sq. ft
- Operational since June 2018
Stainless Steel
Stainless Steel

The date was June 4, 1912

Harry Brearley was in charge of the Brown-Firth Research Laboratory in Sheffield, England.

While the lab was investigating ways to eliminate rust in gun barrels, Mr. Brearley noticed that a discarded steel sample from an earlier test was not rusting while the other samples rusted.

Two months later, on August 20, 1912, stainless steel was cast for the first time
Stainless Steel

Even though many people were involved in finding Stainless Steel, records consider Mr. Brearley as the inventor of Stainless Steel!

(No work is done without documentation)
Types of Stainless Steel

Today, there are 200 types of Stainless steels available.

As these 4 elements change,

- Type of stainless steel change
- Composition Changes
- Properties Changes
Types of Stainless Steel

- **Austenitic**: High Chromium and Nickel content of the grades in this group provide superior corrosion resistance and very good mechanical properties (e.g., 304, 304L, 316, 316L)

- **Super austenitic**: A subgroup of austenitic stainless steels. Having elevated levels of nickel, chromium, and molybdenum compared with standard austenitic stainless steels. May have other additions (e.g., nitrogen and/or copper) to increase strength and resistance to pitting corrosion and stress corrosion cracking in the presence of chlorides. (e.g., 904L(N08904), 6MO/254SMO (S 31254), AL-6XN (N08367))

- **Ferritic**: A higher corrosion resistance than martensitic grades, but are mostly inferior to the austenitic grades. These grades are straight Chromium steels with no Nickel (e.g., 409, 405, 430, 444)
Types of Stainless Steel

- **Martensitic**: A group of stainless alloys made to be corrosion resistant and hardenable (using heat treating). Chromium steels without nickel. Used where hardness, strength, and wear resistance are required like filter holder support and cross flow filter bars etc. (eg: 410, 420, 440A, 440C)

- **Duplex**: Duplex grades are a combination of austenitic and ferritic material. Twice as strong as the austenitic and ferritic grades. Better toughness and ductility than the ferritic grades, they do not reach the levels of the austenitic grades. Duplex grades have a corrosion resistance very close to the austenitic grades such as 304 and 316. Grade 2205 is the most widely used in the duplex class

- **Precipitation hardening**: Precipitation hardening stainless steel can be strengthened and hardened by heat treatment. This offers the designer a unique combination of fabric-ability, strength, ease of heat treatment, and corrosion resistance not found in any other class of material. These grades include 17Cr-4Ni (17-4PH) and 15Cr-5Ni (15-5PH)
### Table 1: Austenitic Stainless Steel Chemical Compositions (Weight Percent)

<table>
<thead>
<tr>
<th>Common Name</th>
<th>UNS No.</th>
<th>C</th>
<th>Cr</th>
<th>Ni</th>
<th>Mo</th>
<th>N</th>
<th>Mn</th>
<th>Cu</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>201</td>
<td>S20100</td>
<td>0.15</td>
<td>16.0-18.0</td>
<td>3.5-5.5</td>
<td>-</td>
<td>0.25</td>
<td>5.50-7.50</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>301</td>
<td>S30100</td>
<td>0.15</td>
<td>16.0-18.0</td>
<td>8.0-8.0</td>
<td>-</td>
<td>0.10</td>
<td>2.00</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>301L</td>
<td>S30403</td>
<td>0.030</td>
<td>17.5-19.5</td>
<td>8.0-12.0</td>
<td>-</td>
<td>0.10</td>
<td>2.00</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>305</td>
<td>S30500</td>
<td>0.12</td>
<td>17.0-19.0</td>
<td>10.5-13.0</td>
<td>-</td>
<td>0.10</td>
<td>2.00</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>321</td>
<td>S32100</td>
<td>0.08</td>
<td>17.0-19.0</td>
<td>9.0-12.0</td>
<td>-</td>
<td>0.10</td>
<td>2.00</td>
<td>-</td>
<td>Ti 5x(C+N)</td>
</tr>
<tr>
<td>347</td>
<td>S34700</td>
<td>0.08</td>
<td>17.0-19.0</td>
<td>9.0-13.0</td>
<td>-</td>
<td>2.00</td>
<td>-</td>
<td>-</td>
<td>Cb 10xC to 1.00</td>
</tr>
<tr>
<td>309S</td>
<td>S30908</td>
<td>0.08</td>
<td>22.0-24.0</td>
<td>12.0-15.0</td>
<td>-</td>
<td>2.00</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>310S</td>
<td>S31008</td>
<td>0.08</td>
<td>24.0-26.0</td>
<td>19.0-22.0</td>
<td>-</td>
<td>2.00</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>316L</td>
<td>S31603</td>
<td>0.030</td>
<td>16.0-18.0</td>
<td>10.0-14.0</td>
<td>2.00-3.00</td>
<td>0.10</td>
<td>2.00</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>317L</td>
<td>S31703</td>
<td>0.030</td>
<td>18.0-20.0</td>
<td>11.0-15.0</td>
<td>3.0-4.0</td>
<td>0.10</td>
<td>2.00</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>317LMN</td>
<td>S31726</td>
<td>0.030</td>
<td>17.0-20.0</td>
<td>13.5-17.5</td>
<td>4.0-5.0</td>
<td>0.10-0.20</td>
<td>2.00</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>904L</td>
<td>N08904</td>
<td>0.020</td>
<td>19.0-23.0</td>
<td>23.0-28.0</td>
<td>4.00-5.00</td>
<td>0.10</td>
<td>2.00</td>
<td>1.00-2.00</td>
<td></td>
</tr>
</tbody>
</table>
# Types of Stainless Steel

## Table 2: Common Ferritic Stainless Steel Chemical Compositions (Weight Percent)

<table>
<thead>
<tr>
<th>Common Name</th>
<th>UNS No.</th>
<th>C</th>
<th>Cr</th>
<th>Ni</th>
<th>Mo</th>
<th>N</th>
<th>Mn</th>
<th>Cu</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>409</td>
<td>S40910</td>
<td>0.030</td>
<td>10.5-11.7</td>
<td>0.50</td>
<td>-</td>
<td>0.030</td>
<td>1.00</td>
<td>-</td>
<td>Ti 6x(C+N) to .50 Cb 0.17</td>
</tr>
<tr>
<td></td>
<td>S40920</td>
<td>0.030</td>
<td>10.5-11.7</td>
<td>0.50</td>
<td>-</td>
<td>0.030</td>
<td>1.00</td>
<td>-</td>
<td>Ti 8x(C+N) min. Ti 0.15-0.50 Cb 0.10</td>
</tr>
<tr>
<td></td>
<td>S40930</td>
<td>0.030</td>
<td>10.5-11.7</td>
<td>0.50</td>
<td>-</td>
<td>0.030</td>
<td>1.00</td>
<td>-</td>
<td>(Ti+Cb) [0.08+8x(C+N)] to 0.75 Ti 0.05 min.</td>
</tr>
<tr>
<td>405</td>
<td>S40500</td>
<td>0.08</td>
<td>11.5-14.5</td>
<td>0.60</td>
<td>-</td>
<td>-</td>
<td>1.00</td>
<td>-</td>
<td>Al 0.10-0.30</td>
</tr>
<tr>
<td>430</td>
<td>S43000</td>
<td>0.12</td>
<td>16.0-18.0</td>
<td>0.75</td>
<td>-</td>
<td>-</td>
<td>1.00</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>434</td>
<td>S43400</td>
<td>0.12</td>
<td>16.0-18.0</td>
<td>-</td>
<td>0.75-1.25</td>
<td>-</td>
<td>1.00</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>436</td>
<td>S43600</td>
<td>0.12</td>
<td>16.0-18.0</td>
<td>-</td>
<td>0.75-1.25</td>
<td>-</td>
<td>1.00</td>
<td>-</td>
<td>Cb 5xC to 0.80</td>
</tr>
<tr>
<td>439</td>
<td>S43035</td>
<td>0.030</td>
<td>17.0-19.0</td>
<td>0.60</td>
<td>-</td>
<td>0.030</td>
<td>1.00</td>
<td>-</td>
<td>Ti [0.20+4(C+N)] to 1.10 Al .15 max.</td>
</tr>
<tr>
<td>444</td>
<td>S44400</td>
<td>0.025</td>
<td>17.5-19.5</td>
<td>1.00</td>
<td>1.75-2.50</td>
<td>0.035</td>
<td>1.00</td>
<td>(Ti+Cb) [0.20+4(C+N)] to 0.80 max.</td>
<td></td>
</tr>
<tr>
<td>20-3-3</td>
<td>S44600</td>
<td>0.030</td>
<td>25.0-28.0</td>
<td>1.0-3.5</td>
<td>3.0-4.0</td>
<td>0.040</td>
<td>1.00</td>
<td>(Ti+Cb) 0.20 to 1.00 and (Ti+Cb) 6x(C+N) min.</td>
<td></td>
</tr>
</tbody>
</table>
Table 3: Common Martensitic Stainless Steel Chemical Compositions (Weight Percent)

<table>
<thead>
<tr>
<th>Martensitic Stainless Steels</th>
<th>Common Name</th>
<th>UNS No.</th>
<th>C</th>
<th>Cr</th>
<th>Ni</th>
<th>Mo</th>
<th>N</th>
<th>Mn</th>
<th>Cu</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>410</td>
<td>S41000</td>
<td>0.08-0.15</td>
<td>11.5-13.5</td>
<td>0.75</td>
<td>-</td>
<td>-</td>
<td>1.00</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>420</td>
<td>S42000</td>
<td>0.15 min.</td>
<td>12.0-14.0</td>
<td>0.75</td>
<td>0.50</td>
<td>-</td>
<td>1.00</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>440A</td>
<td>S44002</td>
<td>0.60-0.75</td>
<td>16.0-18.0</td>
<td>-</td>
<td>0.75</td>
<td>-</td>
<td>1.00</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>440C</td>
<td>S44004</td>
<td>0.95-1.20</td>
<td>16.0-18.0</td>
<td>-</td>
<td>0.75</td>
<td>-</td>
<td>1.00</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
# Types of Stainless Steel

## Table 4: Common Precipitation Hardening Stainless Steel Chemical Compositions (Weight Percent)

<table>
<thead>
<tr>
<th>Precipitation Hardening Stainless Steels</th>
<th>Common Name</th>
<th>UNS No.</th>
<th>C</th>
<th>Cr</th>
<th>Ni</th>
<th>Mo</th>
<th>N</th>
<th>Mn</th>
<th>Cu</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>XM-13</td>
<td>S13800</td>
<td>0.05</td>
<td>12.3-13.2</td>
<td>7.5-8.5</td>
<td>2.00-2.60</td>
<td>0.01</td>
<td>0.20</td>
<td>-</td>
<td>Al 0.90-1.35</td>
<td></td>
</tr>
<tr>
<td>XM-12</td>
<td>S15500</td>
<td>0.07</td>
<td>14.0-15.5</td>
<td>3.5-5.5</td>
<td>-</td>
<td>-</td>
<td>1.00</td>
<td>2.5-4.5</td>
<td>Cb+Ta 0.15-0.45</td>
<td></td>
</tr>
<tr>
<td>632</td>
<td>S15700</td>
<td>0.09</td>
<td>14.0-16.0</td>
<td>6.5-7.7</td>
<td>2.00-3.00</td>
<td>-</td>
<td>1.00</td>
<td>-</td>
<td>Al 0.75-1.50</td>
<td></td>
</tr>
<tr>
<td>630</td>
<td>S17400</td>
<td>0.07</td>
<td>15.0-17.5</td>
<td>3.0-5.0</td>
<td>-</td>
<td>-</td>
<td>1.00</td>
<td>3.0-5.0</td>
<td>Cb+Ta 0.15-0.45</td>
<td></td>
</tr>
<tr>
<td>831</td>
<td>S17700</td>
<td>0.09</td>
<td>16.0-18.0</td>
<td>6.5-7.7</td>
<td>-</td>
<td>-</td>
<td>1.00</td>
<td>-</td>
<td>Al 0.75-1.50</td>
<td></td>
</tr>
</tbody>
</table>
# Types of Stainless Steel

## Table 5: Common Duplex Stainless Steel Chemical Compositions (Weight Percent)

<table>
<thead>
<tr>
<th>Duplex Stainless Steels</th>
<th>UNS No.</th>
<th>C</th>
<th>Cr</th>
<th>Ni</th>
<th>Mo</th>
<th>N</th>
<th>Mn</th>
<th>Cu</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>S31200</td>
<td>0.030</td>
<td>24.0-26.0</td>
<td>5.5-7.5</td>
<td>2.5-3.5</td>
<td>0.14-0.20</td>
<td>2.00</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>S31250</td>
<td>0.030</td>
<td>24.0-26.0</td>
<td>5.5-7.5</td>
<td>2.5-3.5</td>
<td>0.10-0.30</td>
<td>1.00</td>
<td>0.20-0.80</td>
<td>W0.10-0.50</td>
<td></td>
</tr>
<tr>
<td>S32001</td>
<td>0.030</td>
<td>19.5-21.5</td>
<td>1.00-3.00</td>
<td>0.80</td>
<td>0.05-0.17</td>
<td>4.0-6.0</td>
<td>1.00</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>S32003</td>
<td>0.030</td>
<td>19.5-22.5</td>
<td>3.0-4.0</td>
<td>1.50-2.00</td>
<td>0.14-0.20</td>
<td>2.00</td>
<td>-</td>
<td>-</td>
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<tr>
<td>S32101</td>
<td>0.040</td>
<td>21.0-22.0</td>
<td>1.35-1.70</td>
<td>0.10-0.80</td>
<td>0.20-0.25</td>
<td>4.0-6.0</td>
<td>0.10-0.80</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>S32202</td>
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<td>21.5-24.0</td>
<td>1.00-2.80</td>
<td>0.45</td>
<td>0.18-0.26</td>
<td>2.00</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>2304</td>
<td>0.030</td>
<td>21.5-24.5</td>
<td>3.0-5.5</td>
<td>0.05-0.60</td>
<td>0.05-0.20</td>
<td>2.50</td>
<td>0.05-0.60</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>2205</td>
<td>0.030</td>
<td>21.0-23.0</td>
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<td>2.5-3.5</td>
<td>0.08-0.20</td>
<td>2.00</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>2205</td>
<td>0.030</td>
<td>22.0-23.0</td>
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<td>3.0-3.5</td>
<td>0.14-0.20</td>
<td>2.00</td>
<td>-</td>
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<td></td>
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<td>S32508</td>
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<td>0.08-0.20</td>
<td>1.00</td>
<td>-</td>
<td>W0.05-0.30</td>
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</tr>
<tr>
<td>S32520</td>
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<td>24.0-28.0</td>
<td>5.5-8.0</td>
<td>3.0-4.0</td>
<td>0.20-0.35</td>
<td>1.50</td>
<td>0.50-2.00</td>
<td>-</td>
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<tr>
<td>255</td>
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<td>4.5-6.5</td>
<td>2.9-3.9</td>
<td>0.10-0.25</td>
<td>1.50</td>
<td>1.50-2.50</td>
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<tr>
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<td>6.0-8.0</td>
<td>3.0-5.0</td>
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<td>1.20</td>
<td>0.50</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>S32760</td>
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<td>24.0-28.0</td>
<td>6.0-8.0</td>
<td>3.0-4.0</td>
<td>0.20-0.30</td>
<td>1.00</td>
<td>0.50-1.00</td>
<td>W0.50-1.00</td>
<td></td>
</tr>
<tr>
<td>S32808</td>
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<td>27.0-27.9</td>
<td>7.0-9.2</td>
<td>0.8-1.2</td>
<td>0.30-0.40</td>
<td>1.10</td>
<td>-</td>
<td>W2.10-2.50</td>
<td></td>
</tr>
<tr>
<td>S32908</td>
<td>0.030</td>
<td>28.0-30.0</td>
<td>5.5-7.5</td>
<td>1.50-2.60</td>
<td>0.30-0.40</td>
<td>0.80-1.5</td>
<td>0.80</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>S32950</td>
<td>0.030</td>
<td>26.0-29.0</td>
<td>3.50-5.20</td>
<td>1.00-2.50</td>
<td>0.15-0.35</td>
<td>2.00</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>S39274</td>
<td>0.030</td>
<td>24.0-28.0</td>
<td>6.8-8.0</td>
<td>2.5-3.5</td>
<td>0.24-0.32</td>
<td>1.0</td>
<td>0.20-0.80</td>
<td>W1.50-2.50</td>
<td></td>
</tr>
<tr>
<td>S82011</td>
<td>0.030</td>
<td>20.5-23.5</td>
<td>1.0-2.0</td>
<td>0.10-1.00</td>
<td>0.15-0.27</td>
<td>2.0-3.0</td>
<td>0.50</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
# Types of Stainless Steel

## Summary of the main advantages of the stainless steel types

<table>
<thead>
<tr>
<th>Type</th>
<th>Examples</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferritic</td>
<td>410S, 430, 446</td>
<td>Low cost, moderate corrosion resistance &amp; good formability</td>
<td>Limited corrosion resistance, formability &amp; elevated temperature strength compared to austenitics</td>
</tr>
<tr>
<td>Austenitic</td>
<td>304, 316</td>
<td>Widely available, good general corrosion resistance, good cryogenic toughness. Excellent formability &amp; weldability</td>
<td>Work hardening can limit formability &amp; machinability. Limited resistance to stress corrosion cracking</td>
</tr>
<tr>
<td>Duplex</td>
<td>1.4462</td>
<td>Good stress corrosion cracking resistance, good mechanical strength in annealed condition</td>
<td>Application temperature range more restricted than austenitics</td>
</tr>
<tr>
<td>Martensitics</td>
<td>420, 431</td>
<td>Hardenable by heat treatment</td>
<td>Corrosion resistance compared to austenitics &amp; formability compared to ferritics limited. Weldability limited.</td>
</tr>
<tr>
<td>Precipitation hardening</td>
<td>17/4PH</td>
<td>Hardenable by heat treatment, but with better corrosion resistance than martensitics</td>
<td>Limited availability, corrosion resistance, formability &amp; weldability restricted compared to austenitics.</td>
</tr>
</tbody>
</table>
Types of Stainless Steel – Product Contact

- **Type 316:**
  - 18% chromium, 14% Nickel and added Molybdenum
  - In combination increase its resistance to corrosion.
  - In particular, molybdenum helps to control the pit type attack of corrosion.
  - The “L” grades provide extra corrosion resistance **after welding.** (Carbon levels are kept to .03%)
Types of Stainless Steel – Product Contact Surface

- **Type 316L (1.4435):**
  - Slightly higher
- (17.0 to 19.0%) chromium,
- (12.5 to 13.5% Nickel) and
- (2.5 to 3.0%) Molybdenum.
- This grade stainless steel helps in control of delta control at the welding area.
- (outcome of the Basler Norm 2 that tried to reduce concerns of rouging)
Select the Right Stainless Steel

How do we select the right one for our application?

• Corrosive environment: Atmospheric, water, concentration of particular chemicals, chloride content, presence of acid
• Temperature
• Strength Required
• Metal Joining Process Required
• Degree of Forming Required
• Product Form Required
• Surface Finish Required
• Cost

When in doubt, please share the process details & chemicals that come in contact to the manufacturer to check the compatibility.
Stainless Steel Welding
Stainless Steel Welding

For pressure vessels, tanks, piping and tubing systems where the process contact surface of the weld is to be used “As is”,

- welding processes shall be limited to the inert-gas arc processes (such as gas tungsten-arc welding and plasma arc welding)
- the high energy beam processes (such as electron beam or laser beam welding), as defined in AWS A3.0
Gas Tungsten Arc Welding

Joining of metal by placing an arc in between the metals

Shielding with an inert gas or mixture.

With or without filler material

Manual or automatic (orbital welding)
Welding
Weld Controlling

S - Sulphur control in Steel

O - Oxygen control in Welding Gas

F - Ferrite control in Steel

T - Tungsten control in process
Weld Controlling - Sulphur

MM-5.2.1.1 Weld Ends.

Weld ends that are to be automatically welded shall have a Sulphur content between 0.005 wt. % and 0.017 wt. %

This requirement applies to the austenitic stainless steels

This requirement does not apply to materials used in the construction of process components, only to the weld ends of process components in their final form.
Oxygen contamination during welding leads to Discoloration and corrosion!

Notes:
1. The tube sample was prepared by making ten autogenous welds on the outside diameter of a 2 in. (50.8 mm) 316L stainless steel tube. Welds on 304L tubing showed no significant difference in heat tint from 316L. The welds were full penetration welds. The torch shielding gas was 95% argon, 5% hydrogen [99.998 with <2 parts per million (ppm) of oxygen, moisture, and hydrocarbons] to assure full penetration welds. The hydrogen addition to the torch shielding gas is considered to have no effect on the HAZ heat-tint oxide on the inside surface. To provide varying amounts of oxygen in the backing gas a compressed cylinder of medical grade air was added to 99.98% minimum pure argon (<2 ppm of oxygen, moisture, and hydrocarbons) and the oxygen was measured with a calibrated commercial oxygen indicator. The amount of oxygen in ppm in the backing gas was measured to be as follows:
   - No. 1–10
   - No. 3–50
   - No. 5–200
   - No. 7–1000
   - No. 9–12500
   - No. 2–25
   - No. 4–100
   - No. 6–500
   - No. 8–5000
   - No. 10–25000

2. The illustration should be used as a reference to identify the degree of heat-tint oxide by number and not to specify oxygen limits in the backing gas. The acceptable degree of heat tint can vary with different service environments. It should be considered along with the economics involved obtaining very low levels of heat tint when specifying acceptable heat tint level welds.

   The amount and visual appearance of heat-tint oxide can be influenced by factors other than oxygen, such as:
   - High levels of moisture in the backing gas will increase the degree of heat-tint.
   - Contaminates such as hydrocarbons, moisture, and some types of particulate on the surface prior to welding can influence heat-tint oxide levels.
   - Hydrogen gas in the argon backing gas can significantly reduce the amount of heat-tint oxide.
   - The metal surface finish can have a varying affect on the visual appearance of heat tint.

Figure 10. AWS D18.2 weld discoloration chart.
Weld Controlling - Oxygen

Oxygen contamination during welding leads to Discoloration and corrosion!
Weld Controlling - Oxygen

Oxygen contamination during welding leads to Discoloration and corrosion!

Without Oxygen Monitoring

With Oxygen Monitoring
Weld Controlling – Delta ferrite

Ferrite is a phase that may precipitate during solidification of austenitic stainless steel depending on the ratios of the alloying elements.

The presence of ferrite in austenitic stainless steel welds may reduce the corrosion resistance in some corrosive environments.

However, a minimum ferrite level may be required to maintain specific properties of particular product forms (e.g., castings) or is deemed necessary to prevent hot cracking of heavy wall weldments (e.g., vessels made from plate).

The ferrite level of as-solidified austenitic stainless steel welds can be determined from the WRC-1992 Constitution Diagram for Stainless Steel Weld Metals using

- Chromium equivalent Cr (eq) p %Cr + %Mo + 0.7%Nb and
- Nickel equivalent Ni (eq) p%Ni + 35%C + 20%N + 0.25%Cu.

The WRC-1992 Diagram predicts ferrite in Ferrite Number (FN).

The WRC 1992 Diagram is preferred for “300” series stainless steels and for duplex stainless steels. It may not be applicable to compositions having greater than 1% Si
Weld Controlling – Delta ferrite

Ferrite in welds of austenitic stainless steels can be controlled by one or more of the following methods:

(a) Post weld solution annealing

(b) Use of weld filler with increased nickel content

(c) Increase of nickel equivalent by addition of approximately 1–3 vol.% nitrogen to shielding gas

(d) Selection of heats of materials with high nickel to chromium ratios, such as the European steel grade 1.4435 (see Table MM-2.1-1) with a restricted Cr(eq) to Ni(eq) ratio 3 as per BN2
Weld Controlling – Delta ferrite

The Basler norm 2 (BN2) describes the special material requirements of 1.4435 according to DIN 17440 with clearly narrowed analysis limits for the alloy components and defined ferrite content (ferrite).

Target delta ferrite is 3% at weld joint

Table MM-5.2.1.2-1  Predicted Ferrite Number (FN) Ranges for Various Austenitic Stainless Steel Product Forms and Welds

<table>
<thead>
<tr>
<th>Product Form</th>
<th>Expected FN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wrought product forms with sulfur levels less than 0.005%</td>
<td>0.5 to 4</td>
</tr>
<tr>
<td>Wrought product forms with a sulfur range of 0.005% to 0.017%</td>
<td>1.0 to 6</td>
</tr>
<tr>
<td>GMAW/GTAW using E316L [Note (1)]</td>
<td>4 to 12 [Note (2)]</td>
</tr>
<tr>
<td>SMAW using ER316L [Notes (3), (4)]</td>
<td>4 to 10 [Note (5)]</td>
</tr>
<tr>
<td>CF8M and CF3M castings</td>
<td>5 to 15</td>
</tr>
</tbody>
</table>
Weld Controlling – Delta Ferrite

Ferritoscope
Weld Controlling – Tungsten

Angle and profile of tungsten electrode is critical to maintain the weld bead width & profile
Weld Controlling – Welder

- Welding Management System
- Certified Skilled Welder
- Welding Procedure
- Welder Qualification
- Weld Coupons before job
Welding Management System
Welding Management System

Uniqueness of Welding Operation

- Successful operation for obtaining defect-free welds ("sound") is largely determined by the welders’ skill—called "Eye-Hand Motor-Coordination [EHMC]"

- The welder is a human being & hence subject to individual variability in traits & behaviors — eg, discipline, temperament, etc

- A large number of other engineering or technical factors need to be considered & planned in advance of the actual welding operations
Welding Management System

Other Unique features

- "Performance" of even the most "sound weld" during service can never be pre-determined but has to be assumed using corroborative inspection-reports, interpreting testing-results, judicious analysis, & good engineering judgment using experience gained from similar applications.

- Un-predictability of "Distortion" is unique to welded structures, in that no other process introduces such critical un-certainty; causing serious delays, damages, or very costly rejections.

- A wide range of "Welding Processes" are available & need to be carefully evaluated for the specific application; the most common ones for welding steel are: MMAW, TIG, MIG, SAW, Resistance, Stud, etc.
Welding Management System

Quality of Weld Vs Performance of Weld

- These two terms are often mixed-up & needs clarification here

- Quality of the weld refers to its “sound-ness” i.e. “freedom from defects”

- “Performance” refers to how well the weldment discharges its designed function under the service conditions that it encounters during its life-time

- Therefore, while quality of welding is **ESSENTIAL** to contribute to its performance in service, it is **NOT SUFFICIENT** to ensure it!!
Welding Management System

Expert Welder Vs Welding Expert
Welding Management System

**WPS, SWPS, WPQT**

- The Welding Procedure Specification [WPS] is the heart of the Weld Management System [WMS]

- WPS is a document which un-ambiguously prescribes all necessary details which enable the execution of the welding operation

- SWPS is a standardized form of WPS which has been proved by a reputed 3rd party & hence is allowed to be used without qualification testing [WPQT]
Welding Management System

Moving Forward

- Welders are certified on the basis of their skill-competency for executing qualified welding procedures [WPS] using a standardized set of variables.

- These qualified WPSs need to be validated to suit the job.

- The WPS is qualified thru mechanical testing to meet the structural strength & ductile-failure criteria called “design-performance”, while the WPO is tested for “soundness” or “quality.”

- The Rules governing such qualifications are universally adopted by industry worldwide thru Codes & Standards (e.g., ASME BPV Sec IX & ISO 1561X).
Welding Management System

Welding variables

- These are the specific inputs, values or factors which determine the outcome of the weld – either design-performance, soundness, or otherwise

- If all variables in the WPS are controlled during the execution of welding, the weldment can be expected to perform as designed
Welding Management System

Welding “variables” to be managed during the Operation

- **SUC**: Set-Up Conditions – ie how the different parts are juxtaposed against each other at the joint **prior to** start of welding

- **SWIP**: Sequence of Welding & Inspection Plan – ie the detailed **step-by-step actions** to realize the weld – including inspection stages & post-weld operations

- **RPC**: Recommended Parameters Chart- ie what values of operating conditions of the Process to use **during** welding
Welding Management System

Welding “Aspects” to be managed

- What about those factors which are to be planned in advance of the operation?

- Even if the skill-of-welding is to be eliminated thru a Robotic Arm, a lot of due diligence is required for selecting the right one for the application, & planning for procurement, installation & integration into manufacturing are required

- These need to be organized well in advance of the actual welding operation
Welding Management System

Road Map ...........

Level 5
Leadership

Level 4
Dedicated mechanisms &
Techniques

Level 3
Weld-Quality
management [WQMS],
Optimization
between productivity &
costs [WCP1]

Level 2
Engineers [WCPC] & Supervisors [WCP1]

Level 1
Welders /Operators/Technicians

Road Map For Establishing a Weld Management System [WMS]
Welding Management System

Welding GAP Audit

The welding requirements of the Organization are closely scrutinized & compared wrt the mapping of its:

1. Current disposition of technology, practices, people, systems, etc

2. State of preparedness to meet its desirable future-state

The Top Management of the Organization supports this review by being closely associated with the Welding-Gap Audit
Welding Management System

Welding GAP Audit

- The starting point is a self-assessment by the Top Management on the current dispositions & the aspirations of the Organization

- The Report with its Recommendations are used as the basis for charting out an Overall Road Map for establishing the WMS
Welding Management System

Welding GAP Audit

De-Burden your Welding !!

Are you developing a New Product / Process / Application involving welding?  

Yes  

Are there likely issues concerning Welding in the Upcoming Projects?  

Yes  

Does Performance of the Welded Product need to be enhanced?  

Yes  

Does the Process need to be controlled to fine / finer levels? (eg 6-Sigma ie @ 3.4 Defects / Million Opportunities)  

Yes  

Does the Lead-Time for Delivery need to be pruned?  

Yes  

Does the Welding Productivity need improvement?  

Yes  

Does the Cost need to be optimized?  


identifying the root cause, formulating a suitable solution, working out the Road Map, & enabling its implementation in a timely & cost-effective manner...
Welding Management System

Qualifications

1. Joint# Identified in the Weld-Map / Assy-Drg?
2. WPS # valid & approved?
3. Inspection cleared in writing?
4. Access available?
5. Backing required?
6. Fixturing against Distortion?
7. Tacking sufficient?
8. Cleanliness OK?
9. Positioning OK?
10. Crane reqd / avai?
11. Preheating reqd?
12. Safety-Scaffolding?
13. Work Environment comfortable?
14. Consumables available?
15. Egpt ready?
   - etc?

Sequence of Welding & Inspection Plan / Program* [SWIP]

1. Jigs & Fixturing available & ready?
2. Docs Approved?
3. How many Inspection Stages?
4. No of Unit Weld Lengths?
5. Is the Sequence marked?
6. Start- & End-Points marked?
7. Weld Size? Measuring Gauge?
8. No of Re-Starts?
9. Re-Start Locations?
10. Welding Directions?
11. No of Passes?
12. Distortion-measurement Locations?
13. Distortion-measurement Events?
14. Work during Cooling period?
15. Path programming / Teaching?
16. NDT / Production-Coupons?
17. Frequency of Testing?
18. Qualified Welders’ Stamps / Id#, etc

Recommended Parameters Chart [RPC]

1. Current Limits
2. Voltage Limits
3. Speed Limits
4. Heat-Input Rate Limits
5. Wire-Feed Rate Limits
6. Temperature (preheat / postheat) Limits
7. Inter-pass Temperature Limits
8. Start-cycle sequence OK?
9. End-cycle sequence OK?
10. Post-weld cooling / handling Period?
11. Post-weld Inspection Period?
   - etc.

*For Robotic Welding see SOP # 12290
Welding Management System

Overall Road Map

- This is a basic Project-Plan Document which divides the work into Phases, bifurcates the scopes & identifies the Key Change Agent

- The Project Manager & Project Leader are identified

- The Project Manager prepares the ORM
Welding Management System

**Detailing Road Map**

- This is jointly prepared by the Team Leader & the Project Manager

- In addition to detailing the above, it specifies the budgets, resources, schedules, re-structuring & re-organization, etc

- This detailed project plan is broken down into tasks ("Work Breakdown Structure")

- Broad phases for implementation are given in the next slide
Welding Management System

Stages of implementation of WMS

1. Establish the Top-Down “Organizational Framework” linking all the processes in the welding-functional chain for the product

2. Establish the Guidelines for Contract Review as related to Welding

3. Establish the Communication Sub-System, starting with Drgs released from the R&D / Design thru Mtls, SWIPs for Welders, etc, thru Insp & back to Mgmnt

4. Establish the traceability-routes for materials, consumables, processes, etc

5. Establish the WPS, WPAR, WPO, Sub-Systems; qualify the welders to meet the demand of skill-competency

6. Deploy the skills according to the MATRIX

7. Verify the performance from Service & feedback from Customer / User

8. Document all the above processes; review & improve
Welding Management System

Practising WMS

- After establishing the above processes, run thru the system for several cycles / iterations for all critical / identified jobs over a pre-determined period of time

- Track the history, experiences, feedbacks, etc, & update the documentation

- Improve & scale up in a calibrated manner to cover all the job-orders (or pre-determined %, as appropriate for the level of control – ie ISO 3834-2, 3, OR 4)

- When ready, apply for Certificate to Manufacturer’s Certification Body for Audit to ISO 3834 (or as appropriate)
Welding Management System

Concluding WMS

- The WMS can be implemented in any Organization where welding plays a critical role.

- The Organization can implement it systematically well in advance of actually executing major project-orders.

- The Welding-Gap Audit is the basic 1st step in implementation of WMS.

- Road Maps for successfully establishing the WMS can be formulated to suit the Organization’s needs.
Welding Controlling
Weld Controlling – NDT

- Radiography Inspection

- Dye Penetrant Test

- Borescope
Fig. M-J, 4-2 Discoloration Acceptance Criteria for Welds and Heat-Affected Zones on Electropolished UNS S31603 Tubing

The weld beads shown in the above photographs are the weld beads on the I.D. of the tubing. The area for comparison in each photograph is the area inside the red circle. The weld bead shall have no discoloration. Weld heat-affected areas on electropolished UNS S31603 tubing with discoloration levels no worse than Samples #1 through #4 in the as-welded condition are acceptable. Heat-affected zone discoloration levels more severe than that shown in Sample #4 are unacceptable. Sample #5 shows unacceptable weld and heat-affected zone discoloration levels for comparison. The user is cautioned that the colors observed during direct visual examination or television examination will be different viewing directly down (90 deg) at the surface compared with viewing at a lesser angle along the edge.

GENERAL NOTE: The user is cautioned that electronic versions or photocopies of these acceptance criteria shall not be used for evaluation of sample or production welds since subtle differences in color can influence weld acceptability. Minimally Appendix M explains the technique by which these acceptance criteria were determined.

This figure is also available as a stand-alone document from ASME as ASME BPE-EP.
# Weld Controlling – Documentation

## Checklist for Manufacturing Documentation of Bioprocess Equipments

<table>
<thead>
<tr>
<th>Document Type</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vessel</strong> (shell, lid and internal accessories) ++ Documents from 3rd Party</td>
<td></td>
</tr>
<tr>
<td>1. NDC Test Certificate for vessel components (contact part and non-contact part)</td>
<td></td>
</tr>
<tr>
<td>2. dimensional report</td>
<td></td>
</tr>
<tr>
<td>3. Fit-up reports</td>
<td></td>
</tr>
<tr>
<td>4. Nozzle set up reports</td>
<td></td>
</tr>
<tr>
<td>5. Welding procedure Qual</td>
<td></td>
</tr>
<tr>
<td>6. Welders Qualification certificate for welders not</td>
<td></td>
</tr>
<tr>
<td>7. Weld drawing</td>
<td></td>
</tr>
<tr>
<td>8. Weld log sheet</td>
<td></td>
</tr>
<tr>
<td>9. Quality certificate for TIG electrode</td>
<td></td>
</tr>
<tr>
<td>10. Quality certificate for filler wire</td>
<td></td>
</tr>
<tr>
<td>11. Quality certificate for Argon gas purity</td>
<td></td>
</tr>
<tr>
<td>12. Radiography Test Certificate only for seam welds</td>
<td></td>
</tr>
<tr>
<td>13. Radiography films</td>
<td></td>
</tr>
<tr>
<td>4. Dye Penetrant test report for no-tole welds</td>
<td>In contact with product</td>
</tr>
<tr>
<td>5. Dye Penetrant test report for seam welds</td>
<td></td>
</tr>
<tr>
<td>6. Vessel Hydro test (procedure + report) from BZ</td>
<td></td>
</tr>
<tr>
<td>7. Jacket Hydro test (procedure + report) from supplier</td>
<td></td>
</tr>
<tr>
<td>8. Vessel Drainability (procedure + report)</td>
<td></td>
</tr>
<tr>
<td>9. RA Report for vessel internal (external optional) final from BZ</td>
<td></td>
</tr>
<tr>
<td><strong>Pipes</strong> (purchased and used as it is)</td>
<td></td>
</tr>
<tr>
<td>1. NDC Test Certificate</td>
<td>In contact with product</td>
</tr>
<tr>
<td>2. Ra Test Certificate</td>
<td></td>
</tr>
<tr>
<td><strong>VALVES</strong></td>
<td></td>
</tr>
<tr>
<td>1. NDC Test Certificate for body</td>
<td>Not in contact with product</td>
</tr>
<tr>
<td>2. Electropolishing certificate</td>
<td></td>
</tr>
<tr>
<td>3. NDC Test certificate for diaphragm (FDA / USP)</td>
<td></td>
</tr>
<tr>
<td><strong>MACHINED CONNECTORS / Bolt Components (steel purchased and transformed at BZ)</strong></td>
<td></td>
</tr>
<tr>
<td>1. NDC Test Certificate for SS</td>
<td>In contact with product</td>
</tr>
<tr>
<td>2. Electropolishing certificate</td>
<td></td>
</tr>
<tr>
<td>3. Hasting drawing</td>
<td></td>
</tr>
<tr>
<td>4. Ra Graphs</td>
<td></td>
</tr>
<tr>
<td><strong>EQUIPMENT</strong></td>
<td></td>
</tr>
<tr>
<td>1. NDC Test certificate for piping O ring / gaskets + vessel lid</td>
<td>Not in contact with product</td>
</tr>
<tr>
<td>2. Weld map</td>
<td></td>
</tr>
<tr>
<td>3. Weld log sheet</td>
<td></td>
</tr>
<tr>
<td>4. Weld print outs</td>
<td></td>
</tr>
<tr>
<td>5. Welders Qualification certificate</td>
<td></td>
</tr>
<tr>
<td>6. Welding Qualification sample</td>
<td></td>
</tr>
<tr>
<td>7. Quality certificate for filler wire</td>
<td></td>
</tr>
<tr>
<td>8. Quality certificate for Argon gas purity</td>
<td></td>
</tr>
<tr>
<td>9. Passivation report</td>
<td></td>
</tr>
<tr>
<td>10. NDC Test certificate for piping O ring / gaskets + vessel lid</td>
<td></td>
</tr>
<tr>
<td><strong>Bore Scope</strong></td>
<td></td>
</tr>
<tr>
<td>1. Bore Scope images for process lines:</td>
<td></td>
</tr>
<tr>
<td>2. 100% for manual welds</td>
<td></td>
</tr>
<tr>
<td>3. 50% for orbital welds</td>
<td></td>
</tr>
</tbody>
</table>
## Weld Controlling – Documentation

### Filler Rod Certificate

**ISO 9001:2015 CERTIFIED**

**CUSTOMER:** BENAKA INDUSTRIAL PRODUCT  
**GRADE:** ER-316L/1.4430

**INVOICE NO.:** 4569/2018-2019  
**HEAT NO.:** V13129

**PRODUCT FORM:** STAINLESS STEEL WELDING WIRE

**DIMENSION:** 2.40mm  
**Tol.:** ±0.05mm

**IDENTIFICATION:** BOX NO.: HH 01-8  
**QUANTITY:** 200 KGS

**CONDITION:** BRIGHT DRAWN & CUT LENGTH (1000 MM)

<table>
<thead>
<tr>
<th>ELEMENTS</th>
<th>C%</th>
<th>Si%</th>
<th>Mn%</th>
<th>P%</th>
<th>S%</th>
<th>Cr%</th>
<th>Ni%</th>
<th>Cu%</th>
<th>Mo%</th>
<th>N%</th>
<th>Nb%</th>
<th>Ti%</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPECIFIED</td>
<td>0.03</td>
<td>0.65</td>
<td>2.50</td>
<td>0.03</td>
<td>0.02</td>
<td>18.00</td>
<td>11.00</td>
<td>2.50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MIN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>MAX</td>
<td>0.019</td>
<td>0.42</td>
<td>1.70</td>
<td>0.026</td>
<td>0.008</td>
<td>18.50</td>
<td>11.16</td>
<td>0.26</td>
<td>2.57</td>
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**RESULTS**

<table>
<thead>
<tr>
<th>RESULTS</th>
<th>UTS</th>
<th>YS (0.2%)</th>
<th>R.A. %</th>
<th>ELONGATION %</th>
<th>HARDNESS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N/mm²</td>
<td>N/mm²</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>577</td>
<td>430</td>
<td>----</td>
<td>40.00</td>
<td>--</td>
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</tbody>
</table>

**MECHANICAL PROPERTIES OF WELD METAL (ALL WELD)**
## Argon Gas Certificate

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>BGL Cylinder No.</th>
<th>Hydrogen (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BGL13680</td>
<td>2.07%</td>
</tr>
<tr>
<td>2</td>
<td>BGL1530</td>
<td>2.08%</td>
</tr>
<tr>
<td>3</td>
<td>BGL1607</td>
<td>2.07%</td>
</tr>
<tr>
<td>4</td>
<td>BGL12259</td>
<td>2.06%</td>
</tr>
<tr>
<td>5</td>
<td>BGL20746</td>
<td>2.07%</td>
</tr>
<tr>
<td>6</td>
<td>BGL22081</td>
<td>2.07%</td>
</tr>
<tr>
<td>7</td>
<td>BGL2371</td>
<td>2.06%</td>
</tr>
<tr>
<td>8</td>
<td>BGL24347</td>
<td>2.06%</td>
</tr>
<tr>
<td>9</td>
<td>BGL24380</td>
<td>2.06%</td>
</tr>
<tr>
<td>10</td>
<td>BGL24393</td>
<td>2.07%</td>
</tr>
</tbody>
</table>

Impurities:
BGL1607 - CH4 < 0.10 PPM

The Concentration of Impurities in this mixture AHM 98:2 are O2 < 1.0 ppm, H2O < 1.0 ppm and dew point 76°C. The Concentration of Argon on AHM is 0.8%. Remarks: Raw Material Purity - Hydrogen (99.999%) & Argon (99.9995%). Impurities of raw materials are O2 < 2.0 ppm, H2O < 2.0 ppm and THC < 0.5 ppm.

**Traceability Certification:**
1. The Product is prepared by using Weight/Pressure Gauge of Accuracy Traceable to National Standards through Regional Reference Standard Laboratory (Weights and Measures) Govt. of India.
2. The Product is certified using Reference Standard Traceable to NIST/NPL.
Weld Controlling – Documentation

Weld Isometric Diagram
**Weld Log**

<table>
<thead>
<tr>
<th>Weld no.</th>
<th>Welding Procedure</th>
<th>Description</th>
<th>Heat no./lot no.</th>
<th>Welding Date</th>
<th>Welder ID/Sign</th>
<th>Inspect Date</th>
<th>Acceptance</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bw 60</td>
<td>Manual</td>
<td>1/2&quot; x 1&quot; x 1/4&quot; PS</td>
<td>54241.5254/6x6</td>
<td>29-APR-2019</td>
<td>-</td>
<td>29-APR-2019</td>
<td>Yes</td>
<td>-</td>
</tr>
<tr>
<td>Bw 61</td>
<td>Manual</td>
<td>1/2&quot; 3/4&quot; etub 6&quot;</td>
<td>A64x4</td>
<td>27-APR-2019</td>
<td>-</td>
<td>27-APR-2019</td>
<td>No</td>
<td>-</td>
</tr>
<tr>
<td>Bw 64</td>
<td>Manual</td>
<td>1/2&quot; 3/4&quot; PS</td>
<td>54238/12x4</td>
<td>29-APR-2019</td>
<td>-</td>
<td>29-APR-2019</td>
<td>Yes</td>
<td>-</td>
</tr>
<tr>
<td>Bw 65</td>
<td>Manual</td>
<td>1/2&quot; 3/4&quot; Ew/4&quot;</td>
<td>20x535</td>
<td>20-APR-2019</td>
<td>-</td>
<td>20-APR-2019</td>
<td>No</td>
<td>-</td>
</tr>
<tr>
<td>Bw 66</td>
<td>Manual</td>
<td>1/2&quot; 3/4&quot; PS</td>
<td>54242/12</td>
<td>20-APR-2019</td>
<td>-</td>
<td>20-APR-2019</td>
<td>No</td>
<td>-</td>
</tr>
<tr>
<td>Bw 67</td>
<td>Manual</td>
<td>1/2&quot; 3/4&quot; PS</td>
<td>54242/12</td>
<td>20-APR-2019</td>
<td>-</td>
<td>20-APR-2019</td>
<td>No</td>
<td>-</td>
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<tr>
<td>Bw 68</td>
<td>Manual</td>
<td>1/2&quot; 3/4&quot; PS</td>
<td>54243/12</td>
<td>20-APR-2019</td>
<td>-</td>
<td>20-APR-2019</td>
<td>No</td>
<td>-</td>
</tr>
<tr>
<td>Bw 69</td>
<td>Manual</td>
<td>1/2&quot; 3/4&quot; PS</td>
<td>54244/12</td>
<td>20-APR-2019</td>
<td>-</td>
<td>20-APR-2019</td>
<td>No</td>
<td>-</td>
</tr>
</tbody>
</table>
Traceability and Identification
Weld Printout
# Weld Controlling – Documentation

## Welder Qualification

**WPS-Reference:** 004 Rev.01

**Mr. Mansoor Pasha**  
**W12**

**Employer:** M/S. Bangalore Biotech Labs Pvt. Ltd  
**Code / Testing standard:** BS EN ISO 9600-1: 2017

**Employer:** M/S. Bangalore Biotech Labs Pvt. Ltd  
**Code / Testing standard:** BS EN ISO 9600-1: 2017

<table>
<thead>
<tr>
<th>Weld test details</th>
<th>Range of approval</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Welding process(es)</strong></td>
<td><strong>Tig(141)</strong></td>
</tr>
<tr>
<td><strong>Transfer Mode</strong></td>
<td>NA</td>
</tr>
<tr>
<td><strong>Product type (plate or pipe)</strong></td>
<td>T</td>
</tr>
<tr>
<td><strong>Type of weld</strong></td>
<td>BW</td>
</tr>
<tr>
<td><strong>Joint type</strong></td>
<td>P BW ss gb</td>
</tr>
<tr>
<td><strong>Parent Material group(s)/subgroups</strong></td>
<td>ISO CR 15608 Group 8.1</td>
</tr>
<tr>
<td><strong>Filler material group (G)</strong></td>
<td>FM5</td>
</tr>
<tr>
<td><strong>Filler material (Designation)</strong></td>
<td>Solid (S)</td>
</tr>
<tr>
<td><strong>Shielding gas</strong></td>
<td>Argon: Hydrogen Mixture (or equivalents) EN ISO 14175: AHM</td>
</tr>
<tr>
<td><strong>Auxiliaries (e.g. backing gas)</strong></td>
<td>Argon: Hydrogen Mixture (or equivalents) EN ISO 14175: AHM</td>
</tr>
<tr>
<td><strong>Type of current and polarity</strong></td>
<td>DCZN</td>
</tr>
<tr>
<td><strong>Material thickness (mm)</strong></td>
<td>1.60</td>
</tr>
<tr>
<td><strong>Deposited thickness (mm)</strong></td>
<td>NA</td>
</tr>
<tr>
<td><strong>Outside Pipe diameter (mm)</strong></td>
<td>OD 50.8</td>
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<tr>
<td><strong>Welding position(s)</strong></td>
<td>H-L045</td>
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<tr>
<td><strong>Weld details</strong></td>
<td>(ss, gb)</td>
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</table>

**Additional information:** available in WPS 004

<table>
<thead>
<tr>
<th>Type of qualification tests</th>
<th>Performed and accepted</th>
<th>Not tested</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Visual testing</strong></td>
<td>✔️</td>
<td>☐</td>
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<tr>
<td><strong>Radiographic testing</strong></td>
<td>✔️</td>
<td>☐</td>
</tr>
<tr>
<td><strong>Macroscopic examination</strong></td>
<td>☐</td>
<td>☒</td>
</tr>
<tr>
<td><strong>Fracture test</strong></td>
<td>☒</td>
<td>☐</td>
</tr>
</tbody>
</table>

**Name of the Examiner:** D. Sundaresan  
**Place:** Banglore  
**Date of issue:** 26/04/2018  
**Signature of Examiner:** [Signature]

[Image of a welder's qualification certificate]
Weld Controlling – Documentation

Welder Qualification

QW-484A - WELDER PERFORMANCE QUALIFICATION (WPQ)  
(See QW-301, Section IX, ASME Boiler and Pressure Vessel Code)

Welder's name: Mr. Mansoor Pasha  
Identification No.: W12

Test Description
Identification of WPS followed: 011 Rev 00 DT 04.01.2017
Specification and type/grade of Base Metal:  
ASME SECCII PART A.ED.2015 ASTM A270/SA213/SA213M
TYPE 316L

Testing Condition and Qualification limits
Welding variables (QW-350)
Welding Process
Type
Backing
Plate or Tube
Base metal P. Number to P. Number
Filler metal or Electrode specification
Filler metal or Electrode Classification
Filler Metal F Numbers
Consumable Inserts (GTAW or PAW)
Filler type (solid/metal or flux cored/powder)
Deposit thickness for each process
Position(s)
Vertical Progression (uphill or downhill)
Type of fuel gas (OFW)
Inert gas backing (GTAW, PAW, GMAW)
GTAW current type

Actual values
GTAW
Manual
Without Backing
Pipe (OD 12.7mm)
P8 to P8
None
None
None
None
None
None
1.65 mm
6G
Downhill
NA
AHM (Argon 98% & Hydrogen 2%)
DCEN

Range Qualified
GTAW
Manual
With or Without Backing
Plate & Pipe (OD ≥ 12.7mm)
P1 thro P15F, P34, P41 Thro P49
None
None
None
None
None
None
1.65 mm
All
Downhill
NA
AHM (Argon 98% & Hydrogen 2%)
DCEN
Weld Controlling – Documentation

Weld Coupon
References

• ASME BPE 2016

• https://www.nickelinstitute.org/media/1702/highperformancestainlesssteels_11021_.pdf

• Guidelines for the welded fabrication of nickel-containing stainless steels for corrosion resistant services Nickel Development Institute o Reference Book, Series N 11 007

• DESIGN GUIDELINES FOR THE SELECTION AND USE OF STAINLESS STEEL Nickel Development Institute o Reference Book, Series N 9014

• ASME Section VIII (Rules for Construction of Pressure Vessels)

• ASME Section IX (Welding, Brazing & Fusing)

• ASME Section II (Materials)
Thank You!