SANDVIK® 3R12/4L7
COMPOSITE TUBES FOR RECOVERY BOILERS
AND OTHER BOILER APPLICATIONS

TECHNICAL SPECIFICATION
Sandvik has produced composite tubes since the early 1970’s and more than 3 million meters have been delivered for boiler installations around the world.

The tubes are used in corrosive steam boiler applications, such as waterwalls, evaporators and superheaters in biomass, municipal waste, fired boilers and different types of waste heat boilers in the metal smelting and gasification processes.

The first product 3R12/4L7 (304L/SA210A1-P265GH) was developed for use in waterwalls in black liquor recovery boilers (BLRB).

To date, such composite tubes have been installed in more than 300 recovery boilers around the world. The first commercial installation in 1972* still operating successfully (2016).

From inspection of recovery boilers, the corrosion behaviour of composite tubes is well documented. Laboratory investigations after prolonged operation show a perfect bond between the stainless and carbon steel components and only a few cases of corrosion.

The overall performance of Sandvik 3R12/4L7 composite tubes installed in furnace walls indicate general service life of well over 40 years*.

**FOR MORE SEVERE CONDITIONS**

For more severe conditions two, more resistant outer components alloys, Sanicro™ 38 and Sanicro 67, are available.

Sanicro 38 was developed for the floor in recovery boilers and the more recently developed Sanicro 67 in case corrosive conditions are too severe for Sanicro 38. These products have considerably improved resistance against stress corrosion and thermal fatigue induced cracking as well as improved corrosion resistance.

For more information, see the respective product sheets for: Sanicro 38 and Sanicro 67.

**FOR HIGHER STEAM PRESSURES**

For higher steam pressures Sandvik offer optional inner load carrying components in 16Mo3 or SA210 Grade C. For more information, see page 6 FOR HIGHER STEAM PRESSURES.
GRADES

OUTER COMPONENT
Sandvik® 3R12, EN 1.4306, ASTM 304L

INNER COMPONENT
Sandvik 4L7, EN 1.0425, P265GH, ASME SA 210 Grade A1 or ASME SA210 Grade C

INNER COMPONENT
Sandvik 3Mo1, EN 1.5415, 16Mo3, (ASME SA 209 T1, lower Mo content)

CHEMICAL COMPOSITIONS (NOMINAL), %

<table>
<thead>
<tr>
<th>SANDVIK</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Ni</th>
<th>Mo</th>
</tr>
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<tbody>
<tr>
<td>3R12</td>
<td>&lt;0.030</td>
<td>0.5</td>
<td>1.3</td>
<td>&lt;0.030</td>
<td>&lt;0.015</td>
<td>18.5</td>
<td>10</td>
<td>-</td>
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<tr>
<td>4L7</td>
<td>&lt;0.20</td>
<td>0.3</td>
<td>0.7</td>
<td>&lt;0.025</td>
<td>&lt;0.020</td>
<td>&lt;0.30</td>
<td>-</td>
<td>&lt;0.08</td>
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<tr>
<td>3Mo1</td>
<td>0.012-0.20</td>
<td>0.35</td>
<td>0.40-0.90</td>
<td>&lt;0.025</td>
<td>&lt;0.020</td>
<td>&lt;0.30</td>
<td>0.3</td>
<td>0.25-0.35</td>
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DIMENSIONS, STANDARD SIZES

<table>
<thead>
<tr>
<th>OUTSIDE DIAMETER</th>
<th>TOTAL MINIMUM WALL THICKNESS</th>
<th>THICKNESS OF STAINLESS COMPONENT</th>
<th>MINIMUM THICKNESS OF COMPONENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>inch</td>
<td>mm</td>
<td>inch</td>
</tr>
<tr>
<td>38</td>
<td>1 1/2</td>
<td>5.00</td>
<td>0.197</td>
</tr>
<tr>
<td>50.8</td>
<td>2</td>
<td>5.08</td>
<td>0.200</td>
</tr>
<tr>
<td>63.5</td>
<td>2 1/2</td>
<td>6.53</td>
<td>0.257</td>
</tr>
<tr>
<td>76.2</td>
<td>3</td>
<td>6.58</td>
<td>0.259</td>
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PERMISSIBLE VARIATIONS IN STRAIGHTNESS

Out-of-straightness max 1.5 mm/1000 mm (0.06 inch/39.4 inch).

SPECIFICATIONS

Sandvik specification 7-1-0009
PED 97/23/EC
EN 10216-2, EN 12952 Annex C
ASME Code Section I and Section II
VD-TÜV Werkstoffblatt 541 03.2001

Figure 3. Metallurgical bond in a composite tube of Sanicro 28/4L7 (UNS N08028/SA210-A1). The stainless layer is at the top of the figure.

Figure 5. Fabricated lower furnace wall including air and smelt spout openings, by courtesy Andritz, Finland.

Figure 6. Welded membrane panel.

TOLERANCES

Permissible variations in O.D. and wall thickness
Outside diameter 38 mm (1 1/2 inch) ± 0.2 mm (0.008 inch)
50.8 mm (2 inch) ± 0.25 mm (0.010 inch)
63.5 mm (2 1/2 inch) ± 0.3 mm (0.012 inch)
76.2 mm (3 inch) ± 0.38 mm (0.015 inch)

Total wall thickness O.D. <50.8 mm (2 inch); +22%-0
O.D. ≥50.8 mm (2 inch); +15%-0

Thickness of stainless steel component
+ 0.60 mm (0.024 inch) – 0.40 mm (0.016 inch)
The thickness of the stainless steel component is verified by Eddy current testing of the entire length of each tube.

Figure 4. Schematic diagram of metallurgical bond testing.
WELDING

BUTT WELDING
In order to achieve a weld with optimum corrosion resistance and mechanical properties, butt welding of composite tubes should be carried out in such a way that dilution of the components is controlled.

The preferred welding method is MMA (SMAW/111) with covered electrodes. TIG (GTAW/141) and MIG (GMAW/131) are also acceptable methods.

Edge preparation, welding methods and filler metals should be chosen, so that the desired corrosion and mechanical properties are obtained.

Before welding the carbon steel component, the stainless steel layer should be removed by machining close to the joint, in order to minimize dilution, see Figure 7a. The carbon steel component is welded with an unalloyed filler metal, Figure 7b. The stainless component should be welded with an over-alloyed austenitic filler metal, see table.

A composite tube butt weld correctly performed will be free from embrittlement and resistant to stress corrosion cracking (SCC) from the water side.

PANEL WELDING
Two types of furnace wall panel are normally fabricated – the most common are membrane panels with tubes linked by fins, see Figure 6. Earlier boilers were also built with a tangential panel design i.e. with tubes joined directly by a weld. In both cases, shop welding must be carried out with a machine specially designed for the purpose.

The weld should not penetrate the stainless steel layer of the composite tube, as this could lead to the formation of a brittle structure in the load-carrying carbon steel component. Furthermore, excessive dilution of the stainless steel filler metal during fin welding with a carbon steel fin can also result in a brittle structure. Suitable welding processes and filler metals are shown in the table.

MEMBRANE WALL PANELS
Welding should be performed from both sides of the panel. In order to avoid embrittlement and subsequent cracking, dilution should be limited to an extent that can be tolerated by the filler metal. In addition, thick carbon steel fins should be bevelled in order to minimize dilution, see Figure 8.

TANGENTIAL WALL PANELS
Welding is performed in a single pass from the inside of the panel (furnace side) in the natural joint formed between the tubes, see Figure 9.

WELD & PASS | WELDING METHODS | FILLER METALS | CORRESPOND TO | MAX. HEAT INPUT kJ/mm (kJ/inch)
---|---|---|---|---
Butt weld root & filler run a | MMA | Matching | | Depending on load carrier used (1)
| TIG/MIG | Matching | | |
Butt weld top run b | MMA | Sandvik 23.12.2.LR | AWS A5.4 E309LMo-17 |
| TIG/MIG | Sandvik 24.12.LHF | AWS A5.9 ER309L |
Stainless fin membrane panel | MIG/SAW (2) | Sandvik 19.9.LSi | AWS A5.9 ER308LSi |
Carbon fin membrane panel | MIG/SAW (2) | Sandvik 29.9 | AWS A5.9 ER312 |
Tangential panel | MIG | Sandvik 19.9.LSi | AWS A5.9 ER308LSi |

(1) Higher heat input may be applied for the root and filler runs if the stainless peel off is increased.
(2) Contact Sandvik for advice.
(3) MMA is recommended for manual welding to ensure low penetration and to maintain mechanical strength.
(4) Sandvik 15W is suitable for SAW

Figure 7a. Edge preparation.
Figure 7b. Welding sequence.
Figure 8. Edge preparation of fins.
Figure 9. Welded tangential panel.
BENDING
Composite tubes can be bent by the same methods as those used for single component tubes, see Figure 10. The bond zone between the two materials does not reduce the formability of the tube. The bendability is therefore equivalent to that of the least ductile component. Cold bending can be carried out with a minimum bending radii of 1.3 x D. Hot bending is recommended for smaller radii.

Figure 10. Bent Sandvik® 3R12/4L7 composite tube. The bond zone is fully intact.

HEAT TREATMENT
Stress relieving of composite tubes after cold bending or welding can be undertaken without any loss of strength or corrosion resistance. Stress relieving should be performed at 650°C (1200°F) for 30 minutes

INSPECTION
Experience shows that composite tube boilers require less inspection than carbon steel tube boilers, in spite of the fact that composite tubes often handle a more corrosive environment, i.e. higher tube temperature and more aggressive melts, combined with higher chloride and potassium contents. Composite tube units normally shut down only once a year for inspection and maintenance of the boiler.

DELIVERY CONDITION
Composite tubes are normally delivered in the cold finished and solution annealed condition, which means that, in addition to close tolerances, the tubes have smooth and clean surfaces. This facilitates both visual inspection and non-destructive examination.

FABRICATION AND WELDING
Further technical data on fabrication, welding etc. is available on request.

FOR HIGHER STEAM PRESSURES
Recovery boiler steam pressure has increased during later years which means that the saturated steam temperatures and thereby the surface metal temperatures are increasing (100bar=311°C and 150bar=343°C).

This means that thicker load inner component walls are required to cope with the design standards.

To reduce the need for increased tube wall thickness Sandvik offers two stronger inner component options as follows.

**For boilers designed under ASME Boiler and Pressure Vessel Code:**
1. ASME SA210 Grade C which has 7% - 17% higher max allowable stress values than the standard SA210 A1 component

Table showing max allowable stress values for ASME SA210 Grade A1 and Grade C (internal denomination for both 4L7)

<table>
<thead>
<tr>
<th>GRADE</th>
<th>TC 300</th>
<th>325</th>
<th>350</th>
<th>375</th>
<th>400</th>
<th>425</th>
<th>450</th>
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<tr>
<td>SA210A1</td>
<td>MPA</td>
<td>118</td>
<td>118</td>
<td>118</td>
<td>105</td>
<td>88.9</td>
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<tr>
<td>SA210 C</td>
<td>MPA</td>
<td>138</td>
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<td>123</td>
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<td>1.15</td>
<td>1.17</td>
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**For Boilers designed under European PED rules:**
2. EN10216-2 EN1.5415, 16Mo3 with 13% to 95% higher strength values than the standard P265GH component

Table showing creep rupture and minimum proof RP02 at elevated temperature and creep strength according EN 10216-2 for P265GH (internal denomination 4L7) and 16Mo3 (internal denomination 3Mo1)

<table>
<thead>
<tr>
<th>GRADE</th>
<th>TC 400C</th>
<th>410C</th>
<th>430C</th>
<th>440C</th>
<th>450C</th>
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<tr>
<td>P265GH</td>
<td>MPA</td>
<td>141</td>
<td>141</td>
<td>141</td>
<td>141</td>
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<tr>
<td>16Mo3</td>
<td>MPA</td>
<td>159</td>
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<td></td>
<td>1.13</td>
<td>1.13</td>
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<table>
<thead>
<tr>
<th>GRADE</th>
<th>TC 400C</th>
<th>410C</th>
<th>430C</th>
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<tr>
<td>P265GH</td>
<td>MPA</td>
<td>128</td>
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<td>1.22</td>
<td>1.37</td>
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These two optional higher strength materials, SA210 Grade C and EN10216-2 16Mo3 allow for design with thinner tube walls compared to normal SA210A1 and P265GH components.
Sandvik Group
The Sandvik Group is a global high technology enterprise with 50,000 employees in 130 countries. Sandvik’s operations are concentrated on five business areas in which the group holds leading global positions in selected niches: Sandvik Mining, Sandvik Machining Solutions, Sandvik Materials Technology, Sandvik Construction and Sandvik Venture.

Sandvik Materials Technology
Sandvik Materials Technology is a world-leading developer and manufacturer of products in advanced stainless steels and special alloys for the most demanding environments, as well as products and systems for industrial heating.

Quality management
Sandvik Materials Technology has quality management systems approved by internationally recognized organizations. We hold, for example, the ASME Quality Systems Certificate as a materials organization, approval to ISO 9001, ISO/TS 16949, ISO 17025 and PED 97/23/EC. We also have product and/or shop approvals from bodies such as TÜV, JIS, DNV and Lloyd’s Register.

Environment, health and safety
Environmental awareness, health and safety are integral parts of our business and are at the forefront of all activities within our operation. We hold ISO 14001 and OHSAS 18001 approvals.

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