SUOMEN SOODAKATTILAYHDISTYS
FINNISH RECOVERY BOILER COMMITTEE

Finnish Recovery Boiler Committee

Recommendation for clad welding penetration of wall and floor composite tubes in black liquor recovery boiler furnace

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Translation

This document provides additional information when using standard series EN-12952. In the case of dispute, the EN standard applies.

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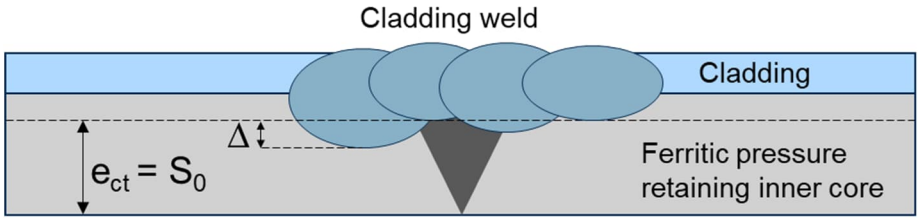
CONTENTS

RECOMMENDATION FOR CLAD WELDING PENETRATION OF WALL AND FLOOR COMPOSITE TUBES IN BLACK LIQUOR RECOVERY BOILER FURNACE

1 SCOPE OF APPLICATION

This recommendation applies to water-walls and floors made of composite tubes in black liquor recovery boiler furnace. Specifically, to cases where the clad welding of butt weld penetrates or there is a risk of penetrating to the calculated minimum wall thickness (e_{ct}) of the ferritic pressure retaining core material, i.e., the so-called S_0 area. The requirements of pressure equipment regulations and standard EN 12952 must be followed.

This recommendation can also be applied for repair welding (e.g. surface defects in composite tubes). This requires separate agreement with boiler owner and a notified body.



2 COMPLIANCE WITH THE STANDARD

According to water-tube boiler standard EN 12952-5: 2021*) [1] Appendix E, E.6.2.2.1: The clad welding may penetrate to the calculated minimum wall thickness of the ferritic pressure retaining core material with the following conditions:

a) filler and weld metal strength and toughness properties are fulfilling the ferritic pressure retaining inner core material properties;

b) qualification of welding procedures shall correspond completely the requirements of EN ISO 15614-7:2019**) and EN 12952 special requirements

c) maximum cladding weld penetration to the calculated minimum thickness (=S_0) area of the ferritic inner core material is 1,5 mm;

d) in prior to production a production test shall be carried out. In manual welding the test shall be done by every welder. In mechanical welding the test shall be done per each welding procedure;

e) non-destructive testing shall be carried out after cladding welding with the extent of standard EN 12952 requirements.

*)A harmonized version of water-tube boiler standard needs to be followed

**)2011 version of water-tube boiler standard refers to EN ISO 15614-1

3 DISCUSSION

Finnish Recovery Boiler Committee, Durability sub-committee ordered a study to demonstrate compliance with the requirements of the standard. The study included test weldings with different material and filler metal combinations, and their destructive examinations. [2]

The following recovery boiler furnace materials and clad weld filler metals were selected for the study:

- 304L, ferritic pressure retaining core material P265GH (Sandvik's trade name 3R12/4L7):
    - Filler metal 1: EN ISO 3581-A - E 23 12 L R (ESAB OK 67.60)
    - Filler metal 2: EN ISO 3581-A - E 27 31 4 Cu L R (Lincoln NiCro 31/27 and Elga Cromarod 383)
- Sanicro 38, ferritic pressure retaining core material P265GH:
    - Filler metal 2: EN ISO 3581-A - E 27 31 4 Cu L R (Lincoln NiCro 31/27 and Elga Cromarod 383)

The pressure retaining inner core material was welded with EN ISO 21952-A - W MoSi filler metal (ESAB OK Tigrod 13.09).

The following testing was carried out for the test welds: Tensile test at elevated temperature, impact toughness testing, hardness measurements, metallographic examination, chemical analysis, and ferrite measurement for weld material.

All the test results were acceptable for all material and filler metal combinations used in the tests. In addition, the penetration to the calculated minimum thickness (=S_0) area was below the maximum limit, 1.5 mm, defined by the standard.

The test arrangements and results are described in reports 2 and 5.

A theoretical Schaeffler evaluation was carried out for the clad weld:

- With E 27 31 4 Cu L R filler metal the structure was fully austenitic
- With E 23 12 L R filler metal the structure was
    - Sanicro 38 composite tube: either fully austenitic or austenitic with maximum ~10% ferrite
    - 304L composite tube: austenitic structure with approximately 5 – 15 % of ferrite. (If dilution rate increases, there is a risk for formation of brittle martensite.)

4 CONCLUSIONS ON THE STUDY

Based on the study, the clad welds welded with both filler metals fulfilled the requirements of standard EN 12952-6:2011 [3] (latest revision EN 12952-5:2021 [1]) [4]. Based on the results it is possible to penetrate to the calculated minimum thickness area (S_0) with both filler metals. However, it is recommended to use E 27 31 4 Cu L R when the clad welding penetrates to the S_0-area. Reasoning for this:

- VdTÜV Kennblatt 00898.05 (01.07) [5] for filler metal OK 67.60 (E 23 12 L R) recommends maximum operating temperature of 300°C for dissimilar welds
- VdTÜV Kennblatt 02594.07 (01.07) [6] for filler metal NiCro 31/27 (E 27 31 4 Cu L R) recommends maximum operating temperature of 450°C
- E 23 12 L R filler metal has a risk of martensite formation with high dilution rates
- A thin carbon diffusion zone, with possibly unfavorable microstructure, forms in the weld side at the vicinity of fusion line. This diffusion zone is thinner when welding with E 27 31 4 Cu L R filler metal.

5 OTHER THINGS TO NOTE

When the clad welding penetrates or there is a risk of penetrating to the calculated minimum wall thickness (S_0) area of the ferritic pressure retaining core material, a special attention needs to be addressed to preliminary preparations and Non-Destructive Testing (NDT).

PRODUCTION TESTS

In this recommendation the purpose of production test is to determine the depth of clad welding penetration. In addition to following recommendations, the welder always needs to have the qualifications required by the standard for the work in question.

- The production test is required prior starting the production regarding both workshop and installation site.
    - For workshop production:
        - In manual welding the test shall be done by every welder unless the welder has a valid production test qualification.
        - In mechanical welding the production test shall be done per each welding machine setting.
    - For installation site: For clad welding, the test shall be done by every welder unless the welder has a valid production test qualification.

- Execution of production tests and range of qualification:
    - The manufacturer is obliged to ensure that production tests have been carried out in accordance with this instruction, unless otherwise agreed in writing.
    - A summary list of qualified production tests shall be provided for the installation site. Regarding workshop manufacturing, documentation is provided upon request.
    - The production test is executed as a butt weld to the composite tube. The material grade and dimensions of the composite tube used in the production test are not essential variables in determining the qualification. However, the composite tube material used in the production test is recorded in the protocol.
    - The range of qualification for filler metals and welding positions used in production tests are given in tables 1 and 2.
    - The tube pitch used in production test cover the same and larger tube pitches.
    - Tangent tube water wall and window welding may require a separate production test.

Table 1: The range of qualification for filler metals used in production tests (the use of filler metal E 23 12 L R in production test may be required to demonstrate that the clad welding does not penetrate to the calculated minimum wall thickness, e_{ct}.)

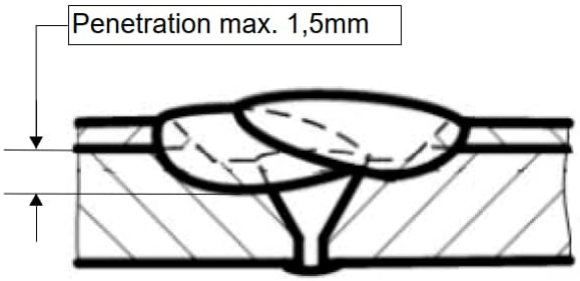
Filler metal of the production test	**Range of qualification**	
	E 27 31 4 Cu L R	E 23 12 L R & +Mo
E 27 31 4 Cu L R	**X**	**X**
E 23 12 L R & +Mo	-	**X**

Table 2: The range of qualification for welding positions in testing (in respect of penetration).

Welding position	**Range of qualification**	
	PC	PH
PC	**X**	-
PH	**X**	**X**

- A cross-sectional sample is prepared from the production test sample for macroscopic examination. The depth of penetration of the clad weld to the ferritic pressure retaining inner core material or weld shall be measured. The quality of the cross-sectional sample needs to be adequate for reliable measurement of the penetration.

- Acceptance criteria: Maximum cladding weld penetration to the ferritic inner core material is 1,5 mm.



- Validity: An approved production test is valid for 12 months from the date of acceptance of the production test, unless otherwise agreed in writing. (Provided that the welder's qualifications are valid.)

- Production tests also qualify for repair welding (e.g. a surface defect in a composite tube). (See 1 Scope of Application)

PEELING OF COMPOSITE TUBE

The following recommendations do not apply to low-pressure boilers in which the working allowances (minimum wall thickness of the ferritic inner core subtracted by S_0) is at least 1.38 mm and where there is no practical risk for the remaining wall thickness to go below S_0 and for the clad welding to penetrate to the S_0 -area.

- Before welding the butt weld, the cladding of the composite tube must be removed ensuring that all the cladding material is removed from the area to be welded. The cladding must not be diluted with the butt weld of the pressure-retaining part.

- However, the peeling should be minimized to prevent unnecessary removal of pressure retaining core and to ensure that remaining thickness after peeling does not go below e_{ct}- i.e. S_0-limit.

- Removal of the cladding must be ensured

  - When mechanically peeling with a bevel machine, the removal of the cladding can be verified visually. For example, copper sulfate can be used as an aid if necessary.

  - In case of ovality of the tube or for other reasons, the remaining part of the cladding may need to be removed manually. In that case, for example, copper sulfate needs to be used as an aid.

  - The cladding must be peeled off from distance of at least 2 mm.

- Verification and documentation of remaining pressure-retaining wall thickness after tube peeling:

  - In connection with workshop fabrication

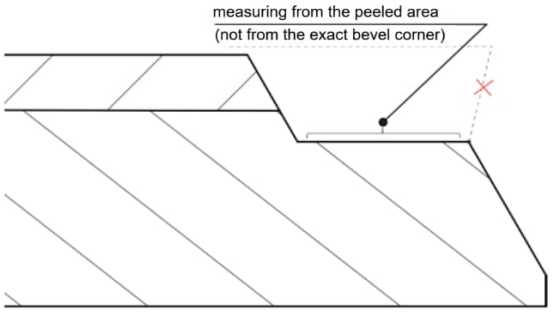
- The wall thickness is verified by production tests or by spot-check measurement. The method of verification shall be selected by the manufacturer.
- The remaining wall thickness must be at least S_0, otherwise the tube must be replaced.

o In connection with installation site (applies to old, existing wall or floor panels)

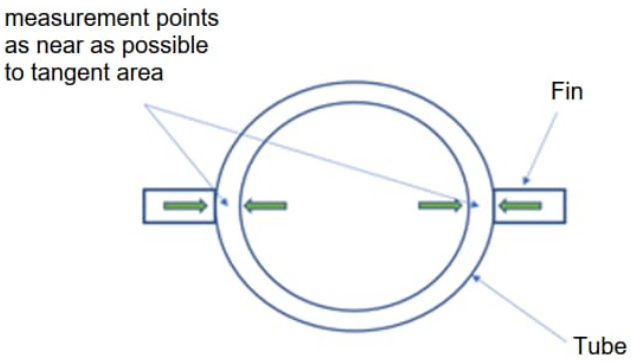
- When starting the work, the bevel machine settings are checked from the first tube to be beveled. The beveled tube end is measured to ensure that the minimum required wall thickness is met. Minimum required wall thickness is defined project-by-project basis.

- The scope of measurement, 100% or spot-check, is agreed in writing with the customer on a project-by-project basis.

- The wall thickness after peeling is measured from the bevel next to the starting point of peeling, see picture below.



- There must be at least four measuring points per tube to be measured.
- The aim of the measurements is to find the thinnest point of the tube.
- The aim is to take the measurement points near the tangent area or at the point that visually looks the thinnest.



- Wall thickness measurements taken after peeling are reported. The protocol shall contain at least the following information:
    - The minimum requirement for the wall thickness after peeling shown in the drawings (or agreed separately in the project)
    - Measurement scope (100% or in the case of a spot inspection, the inspection scope)
    - Individual wall thickness measurement results are not recorded in the protocol. Note! However, all measurement results below the agreed limit must be recorded.
    - Assurance that all measured values have met the minimum requirement agreed in the project.
- The dimension must be at least S_0, otherwise the tube must be replaced.

NON-DESTRUCTIVE TESTING

- A volumetric NDT inspection for composite tube butt welds shall be carried out after welding the pressure bearing weld of parent material. Volumetric inspection is not required for the production test piece.

- Before clad welding, it must be visually examined that the weld of the pressure-retaining part has not diluted with the composite layer.

- After the clad weld, the butt welds shall be inspected on the furnace side of the membrane wall with a liquid penetrant inspection method with the scope according to 12952-6:2021 [7].

6 REFERENCES

[1] SFS-EN 12952-5 Water-tube boilers and auxiliary installations. Part 5: Workmanship and construction of pressure parts of the boiler, 2021-12-31

[2] T. Kauppi, Kompoundputken pinnoitehitsin tunkeuman vaikutus päittäishitsin mekaanisiin ominaisuuksiin, Oulun yliopisto, Tekninen raportti, 31.10.2019

[3] SFS-EN 12952-6 Water-tube boilers and auxiliary installations. Part 6: Inspection during construction, documentation and marking of pressure parts of the boiler, 2011-12-12

[4] S0-linjaus – metallurgiryhmän raportti

[5] VdTÜV Kennblatt 00898.05 (01.07), OK67.60, DIN 8556 – E2312 L R 23

[6] VdTÜV Kennblatt 02594.07 (01.07), NiCro 31/27, EN 1600 – E2731 4Cu LR 12

[7] SFS-EN 12952-6 Water-tube boilers and auxiliary installations. Part 6: Inspection during construction, documentation and marking of pressure parts of the boiler, 2021-12-31

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Recommendation for glad welding penetration of wall and floor composite tubes in black liquor recovery boiler furnace
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