

Employer
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Project
**High-efficient combined heat and power facility utilizing renewable sources (OHB
II - line K1)**

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PART III, APPENDIX 14.11

FIBRE-REINFORCED PLASTIC (FRP) AND PLASTIC WELDS



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1. GENERAL

The Contractor shall ensure all constructions in Fibre-Reinforced Plastic (FRP), pipes, equipment and welds of polyolefins (plastic) follow the requirements in this appendix.

The demanding process environment requires all FRP constructions and plastic welds to be designed, dimensioned, manufactured and erected with particular focus on obtaining a quality that will ensure faultless operation and a lifetime of minimum 200.000 hours.

- The selection of materials and laminate build-up shall be selected with particular attention to the fluid properties of the media (chemical composition, acid, base, osmotic reaction etc.), loads, temperatures, pressures, vibrations and abrasion under normal operation and in abnormal conditions.
- Methods of manufacture shall be selected to provide the best possible properties of the final product on the basis of the specified design.
- FRP-work during erection shall be made to at least the same quality as factory made constructions.
- Best practice shall be used when performing polyolefin welds. It must be ensured by the contractor that welders are educated sufficiently and capable of complying with the requirements in this appendix. Documentation that the welders have undergone sufficient education shall be supplied upon the Employer's request.

2. CODES OF PRACTICE, STANDARDS AND OTHER REQUIREMENTS

Unless otherwise specified the following codes and standards of the latest issue will apply for glass fibre constructions (FRP):

- EN 13121:2008 "GRP tanks and vessels for use above ground"
- DIN norm nr. 16966 "Glass fibre reinforced polyester resin (UP-GF) pipe fittings and joints; Laminated joints; Dimensions"
- Local codes of practice, standards and requirements

Furthermore, the Contractor must ensure the instructions from raw material suppliers shall be followed, especially regarding post cure.

3. SCRUBBERS, VESSELS, TANKS AND DUCTS

It shall be noted that FRP equipment (vessels and pipes etc.) must not be used together with strong alkaline medias.

For use of FRP equipment in contact with deionised and demineralised water, the Contractor shall give special attention to the requested chemical barrier layer specification for this application and provide detail for the Employer's review and comment.

3.1 Design, materials and laminate build-up of FRP

Raw materials for FRP shall be selected to suit the properties of the media contained in the tank/vessel etc. and the process environment with particular attention to resistance to the temperatures and the chemical environment as well as the abrasiveness.

High temperature resistant vinyl ester shall be used wherever relevant.

ECR glass fibre shall be used for reinforcement only, e.g. Advantex or equivalent. Carbon fibre may also be used where this may be relevant and as agreed by the Employer.

The chemical barrier layer shall be no less than 2.5 mm with a fraction of reinforcement fibres of 20-30% unless otherwise agreed for the specific use. Tanks, vessels and other equipment intended for water with low content of salt like flue gas condensate, boiler make up water and similar, the chemical barrier layer shall be no less than 4.0 mm.

Special attention shall be given to methods for avoiding blister formation i.e. wet in wet production, for instance by preventing enclosures of air bubbles and ensuring bonding between structural laminate and chemical barrier layer through precise timing and curing and proper wetting of all reinforcement materials.

High temperature exposed areas shall preferably be protected by PFA skirts or similar, and carbon fibres shall be incorporated in the FRP in areas where the temperature may be fluctuating, e.g. areas covered by quench sprays.

Detailed engineering for each tank and vessel shall include, but not be limited to:

- Design drawing with internal and external beams and other supporting structures, man holes, stubs for nozzles, measurements etc
- Process environment foreseen during normal and abnormal operation.
- Specification of compound build-up
- Types and supplier of reinforcement materials, its pre-treatment and manufacturing.
- Vinyl ester types and supplier
- Raw material supplier specification of design
- Specification of laminate strength, layer build-up and thickness
- Specification of chemical barrier layer, layer build-up and thickness.
- Top coat, materials and thickness
- Colouring, RAL-code and materials
- Length and diameter of individual cylinders.
- Methods of manufacture including timing (or other conditions) between application of individual layers, curing time and temperatures
- Specification of laminated joining of cylinder elements and other factory-made joints

- Specification of joints to be made on site including curing conditions (temperature and time)
- Specification of quality checks, including cut-outs to be made, analysis of these and limit values of residual styrene etc.
- Quality assurance programme

The detailed engineering shall be submitted to the Employer for commenting and discussion in due time prior to commencing production.

At production it shall be ensured that the specification of the detailed engineering is followed, and this shall be reflected in the QA-programme.

It shall be ensured that the manufacturing and curing temperatures and times as specified by the raw material manufacturer are always kept. Manufacturing temperatures shall at all times be kept at no less than 20°C, and curing shall take place at elevated temperatures.

At secondary lamination of connections to branches, ducts etc. it shall be ensured that all edges are properly terminated to prevent flaking. Attention shall be drawn to grinding and proper definition of termination line of lamination.

The outer surface shall be treated to yield a smooth, uniform appearance by application of a gel coat of no less than 0.5 mm and a top coat of a colour (or transparent) approved by the Employer. Tests samples of outside surface treatment shall be made to reach agreement on quality and colour.

Cut outs from each cylinder shall be marked and separated in two, one for the Employer and one for the Contractor to be used for future reference.

Cut outs from each cylinder shall further be analysed for content of residual styrene and other critical parameters cf. table 24 EN 13121 part 3.

For each cylinder, top and bottom part and its joining the production shall be documented by a report containing but not limited to

- Materials of production (including batch numbers)
- Methods of production
- Production environment (temperatures, air humidity)
- Production timing (CBL start and end, strength laminate start and end etc.)
- Curing and post curing conditions (temperatures, times etc.)
- Any unplanned/unforeseen events

This report shall be composed throughout the course of production and it shall be available to the Employer upon request.

3.2 Repair etc.

Any post lamination, repair works and similar remediations needed on site must follow same codes and standards as applied for the constructions. On repair of damages the reason for their occurrence must be known and the original equipment manufacturer (OEM) shall be consulted prior to repair to ensure the design and construction is not compromised.

The contractor must ensure that any post lamination, repair works and similar remediations are made with material suitable and compatible with the original used resins and fibres etc. All recommendation from OEM and supplier of raw materials etc. must be followed.

On request the contractor shall be able to document compliance with requirement for post lamination, repair works and similar remediations made on the FRP construction.

4. FRP PIPING

The Contractor shall refer to Appendix A14.9 *Pressure Vessels, Tanks and Piping* for all FRP piping where relevant and appropriate.

The specification below applies in addition to the specification of Appendix A14.9 *Pressure Vessels, Tanks and Piping*.

Flanges and their raw materials shall be selected under due consideration to the media and process environment.

Use of compensators shall relieve the mechanical stresses and fatigue on FRP piping and joints caused by e.g. vibrations and hammering from starting/stopping pumps or opening/closing valves as well as thermal expansion etc. As a general rule, compensators shall be installed both upstream and downstream every pump when connected to FRP-piping.

The outer surface shall be treated to yield a smooth, uniform appearance by application of a gel coat of no less than 0.5 mm and a top coat of a colour (or transparent) agreed with the Employer. This also applies for on-site laminated joints. Test samples of surface treatment shall be made to reach agreement on quality and colour.

5. POLYMERIC EQUIPMENT AND PIPES

It shall be noted that equipment and piping etc. in polymeric material shall be carefully selected in respect to the media characteristics. The choice of polymeric material shall reflect possible extreme temperature (high and low) of both the media and the surrounding as well as pressure of media.

Chemical compatibility as well as temperature and pressure compatibility shall not be limited to handling of media during normal operation, but also extreme operation condition shall be reflected as well as cleaning and maintenance condition.

Heat tracing of polymeric equipment and pipes are no allowed.

Threaded connection shall be avoided. In case disassembling of equipment and pipes etc. are necessary for maintenance purposes and similar, connection shall be made with unions on relevant positions.

Whenever piping for aggressive, harmful or hazardous chemicals etc. is made in polymeric materials, double piping system shall be applied to prevent accidental contamination of by leaks. The double piping system shall comprise of leak detecting system mounted at low spots.

Mechanical stresses and fatigue on piping, fitting and other equipment in polymeric material shall be avoided by appropriate use of compensators that relieve the load and moments on piping and joints etc. caused by vibrations and hammering from starting / stopping pumps, opening / closing valves, thermal expansion etc. As a general rule, compensators shall be installed both upstream and downstream from every pump when connected to piping in polymeric material.

It is essential to have sufficient and proper support of piping of other equipment in polymeric material. Pipes must have individual, dedicated supporting guidelines developed by its manufacturer and the manufactures recommendation of maximum distance between the supporting elements must be followed.

The type and number of pipe supports shall reflect the pipe including media and possible external loads.

All equipment mounted to pipes, that causes reactive forces in the pipe when operated (e.g. a valve) must have a dedicated separate support of its own, preventing transfer of the torque force onto the piping. Larger equipment like manometers, connectors, flowmeters and rotameters etc. are not allowed to "hang" on the pipeline without dedicated support.

6. POLYOLEFIN WELDS

Pipe ends and other plastic parts must be cleaned for loose contamination and checked for irregular shape, damage, or grit prior to welding. Damaged or deeply scored pipes may not be used. Any loose shavings must be removed from the welding machinery to avoid risk of contamination therefrom.

During welding, the necessary applied force specified by the pipe manufacturer must be complied with. The force shall be applied smoothly to ensure that the required pressure is not exceeded. Should the specified force be exceeded, the weld shall be discarded.

Welded pipes shall rest sufficiently according to the supplier's recommendations to avoid the risk of incomplete solidification of the weld. The rest time will be subject to pipe diameter, thickness and material.

All weld beads shall have a smooth and uniform surface after welding.

When welding is applied for pipes and equipment for media with abrasive materials (suspension and similar), special attention shall be made to the risk of forming local flow turbulences caused by the internal welding spouts. For such cases dedicated piping systems ensuring smooth internal surface achievements shall be used.

6.1 Requirements to butt fusion welds

The contractor shall inspect all welds. The point of contact between weld beads shall be clearly visible and may not be beneath the pipes outer surface. Welded pipes shall be aligned, and weld beads must be uniform and equal in size and shape. Differences in beads shall only be accepted if complying with the acceptance criteria shown in Figure 1 to Figure 3.

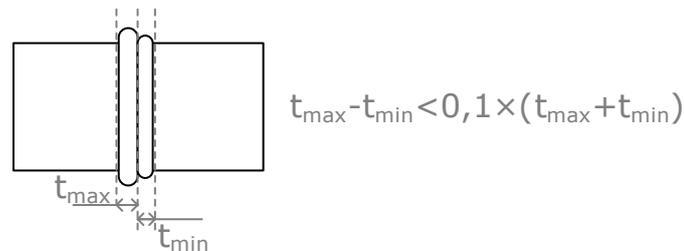


Figure 1 Acceptance criteria for difference in bead widths

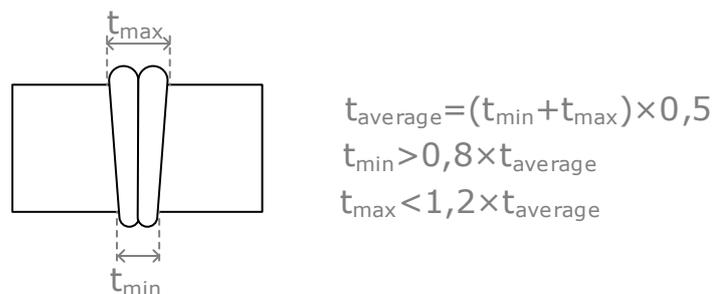


Figure 2 Acceptance criteria for non-uniform bead widths

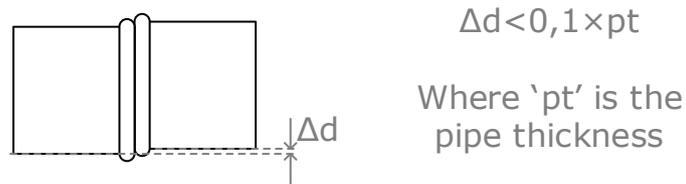


Figure 3 Acceptance criteria for misaligned pipes

6.2 Requirements to socket fusion welds

Pipe and socket may not be supplied by different manufacturers. The pipe shall be scratched/scraped prior to welding, unless specified otherwise by the manufacturer. Furthermore, the immersion depth shall be clearly marked on the pipes and follow the recommendations of the manufacturer. The tolerance of the immersion depth shall be $\pm 2\text{mm}$ unless otherwise specified by the manufacturer.

The contractor shall inspect all welds. The point of contact between weld beads shall be clearly visible and may not be beneath the outer surface of the pipe.

It is a requirement that all socket welds have two visible and uniform weld beads, as depicted in Figure 4.

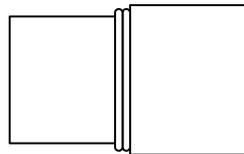


Figure 4 Double weld bead. Both visible and uniform

Figure 5 to Figure 7 shows examples of insufficient welds which shall be discarded.

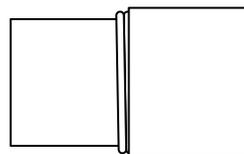


Figure 5 2nd weld bead not fully visible

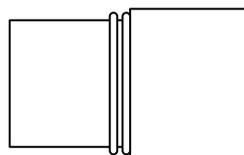


Figure 6 Gap between weld beads

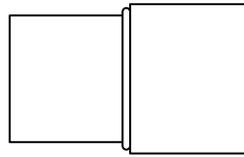


Figure 7 2nd weld bead missing

6.3 Requirements to electrofusion welds

When using electro electrofusion welding, it shall be ensured that the medium to be carried in the pipe cannot chemically react with the socket heating coil, which may deteriorate the quality of the weld over time.

Pipe and socket may not be supplied by different manufacturers. The pipe shall be scratched/scraped prior to welding, unless specified otherwise by the manufacturer. Furthermore, the immersion depth shall be clearly marked on the pipes and follow the recommendations of the manufacturer. The tolerance of the immersion depth shall be ± 2 mm unless otherwise specified by the manufacturer.

If either pipe ends and the socket become unaligned during or after welding, the weld shall be discarded.

Weld with visible socket material on the pipe or visible heating coils, as shown in Figure 8, shall be discarded.

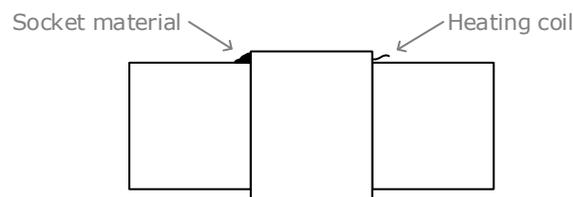


Figure 8 Visible socket material on the pipe or visible heating coil

7. INSULATION

Where process media has a temperature no higher than 65 °C insulation shall not be required of FRP / polyolefin components when the sole purpose of such insulation is to maintain low surface temperature unless requested for the particular item.

Insulation may be used to reduce condensation in the stack pipe and ducts and to enhance heat recovery by limiting the heat loss.