TECHNICAL SPECIFICATION

GLASS-FIBRE REINFORCED EPOXY AND POLYESTER VESSELS - MANUFACTURING REQUIREMENTS

DEP 31.22.30.34-Gen.

October 1995

DESIGN AND ENGINEERING PRACTICE

PREFACE

DEP (Design and Engineering Practice) publications reflect the views, at the time of publication, of:

Shell International Oil Products B.V. (SIOP)
and
Shell International Exploration and Production B.V. (SIEP)
and
Shell International Chemicals B.V. (SIC)

The Hague, The Netherlands,

and other Service Companies.

They are based on the experience acquired during their involvement with the design, construction, operation and maintenance of processing units and facilities, and they are supplemented with the experience of Group Operating companies. Where appropriate they are based on, or reference is made to, national and international standards and codes of practice.

The objective is to set the recommended standard for good design and engineering practice applied by Group companies operating an oil refinery, gas handling installation, chemical plant, oil and gas production facility, or any other such facility, and thereby to achieve maximum technical and economic benefit from standardization.

The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where DEPs may not cover every requirement or diversity of condition at each locality. The system of DEPs is expected to be sufficiently flexible to allow individual operating companies to adapt the information set forth in DEPs to their own environment and requirements.

When Contractors or Manufacturers/Suppliers use DEPs they shall be solely responsible for the quality of work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, the Principal will expect them to follow those design and engineering practices which will achieve the same level of integrity as reflected in the DEPs. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the Principal or its technical advisor.

The right to use DEPs is granted by SIOP, SIEP or SIC, in most cases under Service Agreements primarily with companies of the Royal Dutch/Shell Group and other companies receiving technical advice and services from SIOP, SIEP or SIC. Consequently, three categories of users of DEPs can be distinguished:

1) Operating companies having a Service Agreement with SIOP, SIEP, SIC or other Service Company. The use of DEPs by these Operating companies is subject in all respects to the terms and conditions of the relevant Service Agreement.

2) Other parties who are authorized to use DEPs subject to appropriate contractual arrangements.

3) Contractors/subcontractors and Manufacturers/Suppliers under a contract with users referred to under 1) or 2) which requires that tenders for projects, materials supplied or - generally - work performed on behalf of the said users comply with the relevant standards.

Subject to any particular terms and conditions as may be set forth in specific agreements with users, SIOP, SIEP and SIC disclaim any liability of whatsoever nature for any damage (including injury or death) suffered by any company or person whomsoever as a result of or in connection with the use, application or implementation of any DEP, combination of DEPs or any part thereof. The benefit of this disclaimer shall inure in all respects to SIOP, SIEP, SIC and/or any company affiliated to these companies that may issue DEPs or require the use of DEPs.

Without prejudice to any specific terms in respect of confidentiality under relevant contractual arrangements, DEPs shall not, without the prior written consent of SIOP and SIEP, be disclosed by users to any company or person whomsoever and the DEPs shall be used exclusively for the purpose for which they have been provided to the user. They shall be returned after use, including any copies which shall only be made by users with the express prior written consent of SIOP and SIEP. The copyright of DEPs vests in SIOP and SIEP. Users shall arrange for DEPs to be held in safe custody and SIOP or SIEP may at any time require information satisfactory to them in order to ascertain how users implement this requirement.

All administrative queries should be directed to the DEP Administrator in SIOP.

NOTE: In addition to DEP publications there are Standard Specifications and Draft DEPs for Development (DDDs). DDDs generally introduce new procedures or techniques that will probably need updating as further experience develops during their use. The above requirements for distribution and use of DEPs are also applicable to Standard Specifications and DDDs. Standard Specifications and DDDs will gradually be replaced by DEPs.

TABLE OF CONTENTS

APPENDICES

1. INTRODUCTION

1.1 SCOPE

This DEP is a revision of that with the same number dated March 1978.

This DEP covers the general requirements for the manufacture, inspection and transportation of non-jacketed vessels, manufactured by various wet lay-up processes from glass-fibre reinforced epoxy (GRE) and from glass-fibre reinforced unsaturated polyester (GRUP), both of which are glass-fibre reinforced thermosetting plastics (GRPs).

This DEP is primarily intended to guide a Manufacturer in making an appropriate bid and to enable the Principal to evaluate the bid.

Unless otherwise stated, these general requirements apply for both GRE and GRUP. Requirements applicable to only one specific material are so indicated.

This DEP also covers the constructions where a thermoplastics lining is used as an additional chemical barrier.

The design and installation of these vessels shall be in accordance with DEP 31.22.30.14-Gen.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIOP and SIEP, the distribution of this DEP is confined to companies forming part of the Royal Dutch/Shell Group or managed by a Group company, and to Contractors and Manufacturers/Suppliers nominated by them (i.e. the distribution code is "F", as defined in DEP 00.00.05.05-Gen.).

The DEP is intended for use in oil refineries, chemical plants, gas plants and, where applicable, in exploration and production and supply/marketing installations.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environmental, economic and legal aspects. In all cases, the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, installation, and commissioning or management of a project or operation of a facility. The Principal may sometimes undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant, authorized to act for the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions and abbreviations

GRE: glass-fibre reinforced epoxy (which is a GRP).

GRP: glass-fibre reinforced thermosetting plastic.

GRUP: glass-fibre reinforced unsaturated polyester (which is a GRP).

The term **vessel** also includes other items of equipment (e.g. tanks) to be made from GRP.

1.4 CROSS-REFERENCES

Where cross-references are made, the number of the section or sub-section referred to is shown in brackets.

All publications referred to in this DEP are listed in (7).

2. BASE MATERIALS

All base materials shall be new and uncontaminated. The base materials (e.g. resins, glass-fibre reinforcing materials, pigments, and other materials) when combined as a composite structure, shall produce vessels which meet the performance requirements of this specification. All base materials shall be specified in writing by the Manufacturer and certified by the raw materials Supplier(s) for each delivery.

All base materials shall be stored under dry and cool conditions, within the humidity and temperature limits to be stated by the raw materials supplier(s).

2.1 RESINS

2.1.1 Epoxy resins

Unless otherwise agreed, the vessels shall be made from a bisphenol A epichlorohydrin epoxy resin (e.g. "Epikote" 828) and an aromatic or cyclo-aliphatic amine-type curing agent. The Manufacturer shall describe the type of resin and curing system chosen.

2.1.2 Polyester resins

Unless otherwise agreed, the vessels shall be made from isophthalic acid polyester, bisphenol A-polyester or vinyl ester resin. The Manufacturer shall state the type of resin and curing system chosen.

2.2 GLASS-FIBRE REINFORCEMENT, FILLERS AND PIGMENTS

Glass-fibre reinforcement shall be made of E-type glass (i.e. low-alkali glass) meeting a standard such as BS 3691 or BS 3396 and shall have a finish (coupling agent) which is compatible with the epoxy resin or polyester resin.

Fillers shall not be added. Thixotropic additives added to the resin/curing agent mixture for viscosity control shall not exceed 2% by weight.

Pigments may only be added if they do not affect the performance of the components as defined in section (4) or if agreed with the Principal in order to fulfil special application requirements.

2.3 LINING MATERIALS

The inside of the vessels, and other surfaces which are to be exposed to the contained fluid, shall have a smooth, uniform, chemical resistant barrier.

The Principal shall choose the type of this barrier from the following:

either a resin-rich lining consisting of a surfacing mat (tissue) or a veil, which may be either a C-glass (i.e. chemical-resistant glass) or a synthetic fibre, (e.g. linear polyester fibres or polyacrylonitrile fibres) and the same resin to be used for the fabrication of the vessels. The thickness of the lining shall be at least 0.6 mm.

or a thermoplastics lining with a minimum thickness of 3 mm for PVC (polyvinylchloride) or PP (polypropylene), or of 2 mm for PVDF (polyvinylidene fluoride) or FEP (fluorinated ethylene propylene).

In both cases the laminate construction shall be provided with a resin-rich outer layer of at least 0.6 mm thick in order to improve weather resistance.

Neither the resin-rich lining nor the thermoplastics lining contribute to the mechanical properties.

2.4 ADHESIVES

In case adhesives are used, they shall be of an epoxy type formulated to be resistant to the fluid to be contained and suitable for the design temperatures and pressures.

The adhesive packaging shall have been stamped with the date of production and shall indicate the required storage conditions and date of expiration of shelf life.

At the date of shipment there shall be at least six months remaining shelf life if stored at 40 °C.

3. DESIGN AND FABRICATION

The Manufacturer shall prove that he is competent and suitably equipped to make GRP vessels, including fittings and flanges. Appendix 1 and Appendix 2 give examples of how to record the competence of laminators and welders of thermoplastics. The Manufacturer shall provide samples for testing, if required by the Principal.

The Manufacturer shall provide installation instructions and, if requested by the Principal, adequate supervision at all stages of installation.

3.1 DESIGN

The design shall be in accordance with DEP 31.22.30.14-Gen.

Drawings and calculations used as a basis for the design shall be approved by the Principal before manufacturing is started. The documents which have to be approved shall give the following details:

- Maximum operating pressure and temperature for continuous service.
- Dimensions of the pressure parts of the vessels, and a sketch of the laminate build-up where two components join (e.g., the transition from vessel shell to head, from vessel shell to nozzle, and from nozzle to flange).
- Manufacturing process.
- Laminate construction: type and thickness of inner and outer lining and reinforcing layers of the laminate build-up where two components join (e.g. the transition from vessel shell to head, from vessel shell to nozzle, and from nozzle to flange).
- Type of resin, form of reinforcement (type, number, mass per unit area, glass-fibre orientation, sequence) and any other components which may be present in the laminate.
- Types of reinforcement. If different types are used, they should be distributed regularly through the cross section and laid in alternating directions as much as possible.
- Calculation of the wall thickness, reinforcements, flanges, applicable torque values, and data on which the design is based.

  The reinforced wall thickness shall be at least 5 mm (and, for flanges, at least 40 mm).

3.2 FABRICATION

Unless otherwise agreed by the Principal, the fabrication/construction methods described below shall be used.

Any machined surface shall be sealed with epoxy resin or adhesive to prevent attack of the exposed glass fibres by chemicals.

3.2.1 Shell

The shell of the vessel shall be made by either filament winding or tape winding. With the tape winding method the various glass-fibre layers shall be applied cross-wise with 50% overlap; the seams of the various layers shall be laid staggered.

3.2.2 Ends

Semi-ellipsoidal ends should be used and should be made by the hand lay-up method using a steel "Korbbogen" type head as a mould. The reinforcement shall be in accordance with (2.2). The various layers shall be applied star-wise in such a manner that no wrinkling occurs; the seams of the various layers shall be laid staggered.

3.2.3 Flanges

The reinforcement of flanges shall consist of several layers of square weave and one or more layers of mat, while the intermediate layer may be a spun roving. Alternatively, flanges made in accordance with the hand lay-up filament winding manufacturing technique may be used. The laminate at the connection flange/nozzle shall be applied flush. The adhesive shall be in accordance with (2.5).

The outside diameter and drilling template of flanges shall be in accordance with ANSI B 16.5 class 150. The flanges shall be of the flat face type.

To prevent deformation of the flange, the hardness of the gasket shall be lower than the hardness of the flange surface and shall be in the order of 60-70° Shore A.

3.2.4 Branches, openings and compensation

Nozzles shall be made separately either by filament winding or tape winding. GRP pipe materials in accordance with DEP 31.38.70.37-Gen. may also be used. After post-curing has been finished a hole shall be cut in the vessel wall to suit the nozzle. An adhesive as specified in (2.4) shall be used for adhesive bonding of the nozzle into the wall. In order to reduce stress concentrations near the hole, the connection between the nozzle and the wall shall be reinforced with additional glass-fibre reinforcement.

Branches shall be as short as practicable.

All openings and branches shall be compensated by the use of additional laminates. Compensated openings in domed ends should be located so that the attachment and any additional reinforcement is entirely within a circle of radius 0.4 D_i, concentric with the axis of the shell (where D_i is the inside diameter of the shell).

Openings in vessels subject to external pressure shall be designed in accordance with the rules for vessels subject to internal pressure, but taking a design pressure of 1.5 times the external pressure.

NOTE: Openings shall not be made in the knuckle of ends or in the knuckle of conical shells.

High stress concentrations in the region of a hole in a wall for connecting a nozzle shall be reduced by an additional reinforcement consisting of several layers of resin reinforced square weave. This reinforcement shall extend over the wall and nozzle.

The overlay laminate of the shell shall be adequate to carry the shell loadings that would have been carried by that portion of the shell.

3.2.5 Static electricity

Measures to prevent static electricity (such as the application of an electro-conductive external coating or wire mesh gauze) are not required unless specified by the Principal.

4. TECHNICAL REQUIREMENTS

4.1 GENERAL

All vessels shall be free from imperfections beyond the limits specified in (4.3). The vessels shall have a uniform linear density, resin content and surface finish.

The laminate shall consist of an inner lining (2.3), followed by several layers of resin-impregnated glass fibre reinforcing and a resin-rich outer layer. The resin-rich layers shall be smooth and uniform.

The raw materials shall be checked against the sales specification as given by their manufacturer.

The Manufacturer shall check the mixing ratio of resin and curing agent for each production batch (or every 8 hours, whichever is more frequent) and shall keep a permanent record of the results.

4.2 DIMENSIONS

The general arrangement and dimensions shall be in accordance with the final approved drawings. The difference between the largest and smallest measured inside or outside diameter (ovality) in any cross section shall not be more than $0.007\ D_i$ or $0.007\ D_o$ respectively.

The vessel shall be visually examined, and if there is evidence of variation in wall thickness the area in question shall be explored and its thickness determined. Any underthickness greater than 10% of the thickness specified in the approved design and calculation documents shall not extend by more than a distance 'L' from the centre of the underthick area. The distance 'L' is defined by the following formula:

$$L = 0.5\sqrt{Rt}$$

where R = the inside radius of the shell

and t = the nominal wall thickness

The wall thickness shall be determined by measuring the samples taken from cut-outs or by non-destructive methods (e.g. ultrasonic or magnetic). The number of measurements shall be increased if a deviation from the specified wall thickness is detected.

4.3 VISUAL EXAMINATION

The quality of the laminate shall be examined visually with regard to:

- porosity : the presence of numerous visible small craters in the laminate;
- air inclusions : air entrapment within and between the layers of reinforcement, usually spherical in shape;
- delamination : the separation of the layers in the laminate;
- damage : scratches, cracks, indentations and delamination caused by rough handling during manufacturing;
- resin-rich and resin-starved areas.

The inside shall have a smooth and uniform lining and be in accordance with ASTM D2563 level I. The outside shall be classified according to level II of ASTM D2563, with the following exceptions:

- air bubble : maximum 2 mm each, with a maximum of 3 bubbles per 1000 mm^2;
- pimple : level III;
- pit : level III, but depth less than 10% of the wall thickness.

Repairs are not allowed, unless approved by the Principal.

4.4 LABORATORY TESTING

4.4.1 Curing

GRE

The degree of curing should be determined by boiling samples taken from wall cut-outs in acetone (dimethyl ketone) for 3 hours. After boiling and drying to constant weight the samples shall not show more than 2% loss of weight.

Alternatively, the degree of curing may be assessed by determination of the transition temperature by differential scanning calorimetry (DSC) or differential thermal analysis (DTA) in accordance with ASTM D3418. The glass-transition temperature shall be at least 110 °C.

GRUP

The degree of curing should be determined by testing the residual styrene content in accordance with DIN 16945. The residual styrene content shall not be more than 2%.

Alternatively, the degree of curing may be assessed by determination of the transition temperature by differential scanning calorimetry (DSC) or differential thermal analysis (DTA) in accordance with ASTM D3418. The glass-transition temperature shall be at least 75 °C.

4.4.2 Glass content

The glass/resin ratio determined from samples taken from wall cut-outs shall be tested in accordance with EN 60 or ASTM D2584.

The glass content shall be between 40% and 70% wt. The glass content of any additional reinforcement at openings (3.2.4) shall not be less than 35% wt.

4.4.3 Consistency of the laminate

The glass content of two samples taken from one wall cut-out shall be determined in accordance with EN 60 or ASTM D2584. The difference in the glass content between the two samples shall not be more than 5% wt.

4.4.4 Adhesion of thermoplastics inner lining to laminate

The minimum bond strength of the reinforcement to the thermoplastics lining shall be 7 N/mm^2 in direct shear and 5 N/mm width in peel when tested in accordance with the methods as described in Appendix 3 and Appendix 4, respectively.

4.4.5 High-frequency spark testing of thermoplastics inner lining

The welds in the thermoplastics liners shall be spark-tested with a voltage calculated as follows, and shall not show any sparking.

$V = 6 (1 + t)$ kV, with a maximum of 25 kV

where t = wall thickness in mm.

To do this test, a conducting wire or a conducting carbon veil shall be inserted behind the welds.

NOTE: The testing device should be of an induction type, otherwise the conducting wire or carbon veil shall be connected and earthed.

5. TESTING, INSPECTION AND DOCUMENTATION

5.1 TESTING

5.1.1 General

This section describes the minimum number of acceptance tests required for each order.

Additional tests may be specified in the order.

Samples for testing are taken from discs which are cut out of the wall at those places where nozzles will be installed. The manufacturer shall indicate on the discs from where they have been cut.

5.1.2 Visual examination

Visual examination shall be carried out as in accordance with (4.3).

External surface cracks (e.g. caused by the hydrostatic pressure test, transport or storage) shall not exceed Level III of ASTM D2563.

5.1.3 Laboratory testing

Laboratory testing shall be carried out as described in (4.4).

5.1.4 Thermoplastics inner lining

The thermoplastics inner lining shall be checked according to (4.4.4) and (4.4.5).

5.1.5 Hydrostatic testing

The vessels shall be pressure-tested with water at a pressure of 1.5 times the design pressure for at least 4 hours. During the pressure test no weeping shall be evident.

If during pressure-testing a flange connection shows leakage, the following procedure shall be followed:

- Relieve pressure completely.
- Check the correct bolt stress using a torque wrench (because it is possible that, owing to the flow of the gasket, the bolt stress has decreased).
- Apply test pressure again.
- If the flange is still leaking, the flange shall be disconnected for inspection of the gasket and flange face.

NOTE: The leakage should never be remedied by applying a higher bolt stress than that which has been prescribed, since this can lead to damage of the nozzle. After pressure-testing, all flange bolts shall be tightened using a torque wrench.

5.2 INSPECTION BY THE PRINCIPAL

The Principal shall indicate in the order whether or not he wishes to inspect during manufacture, and if so the Principal shall indicate the extent of his involvement, which may typically include attendance:

- during winding;
- when test samples are being taken;
- while the nozzles are being attached;
- during hydrostatic testing.

5.3 DOCUMENTATION

5.3.1 Quality Control

The Manufacturer shall keep a traceable record of all quality control tests performed and shall maintain this record for a minimum period of five years from the date of manufacture.

5.3.2 Certification

The Manufacturer shall submit a certified record of inspection and testing together with a statement of compliance with the requirements. These shall also include the certificates of the steel parts, if any.

6. PACKAGING

The vessels shall be packaged and transported in a manner which will ensure arrival at their destination in a satisfactory condition and which will be acceptable to the Principal. Nozzle flanges shall be covered with non-metallic discs.

7. REFERENCES

In this DEP, reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

SHELL STANDARDS

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Glass-fibre reinforced epoxy and polyester vessels - design and installation	DEP 31.22.30.14-Gen.
Requirements for glass-fibre reinforced epoxy and polyester pipes and fittings	DEP 31.38.70.37-Gen.

AMERICAN STANDARDS

Pipe flanges and Flanged fittings	ANSI B 16.5

Issued by:
American National Standards Institute
11 West 42nd street, 13th. floor
New York
NY 10036, USA

Visual defects in glass-reinforced plastic laminated parts	ASTM D2563
Ignition loss of cured reinforced resins	ASTM D2584
Transition temperatures of polymers by thermal analysis	ASTM D3418

Issued by:
American Society for Testing and Materials
1916 Race St.
Philadelphia Pa 19103
USA.

BRITISH STANDARDS

Woven glass fibre fabrics for plastics reinforcement	BS 3396
Specification for E glass fibre rovings for reinforcement	BS 3691

Issued by:
British Standards Institution
389 Chiswick High Road
London W4 4AL
England, United Kingdom.

EUROPEAN STANDARDS

Glass reinforced plastics; determination of loss on ignition	EN 60

Issued by:
European Committee for Standardization
Rue Brederode 2
B-1000 Brussels
Belgium.

GERMAN STANDARDS

Testing of resins, hardeners and accelerators and catalyzed resins — DIN 16945

Issued by:
Beuth-Verlag GmbH
Burggrafenstrasse 6
D-1000 Berlin 30
Germany.

APPENDIX 1 ESTABLISHMENT OF LAMINATOR'S COMPETENCE

1. **Scope**

This Appendix gives requirements for establishing the competence of a laminator of glass-fibre reinforced plastics.

2. **General**

A laminator's competence shall be considered adequate if all the following points have been satisfied:

2.1 A laminator shall have passed a test in accordance with this Appendix; proof of this is given by a laminator's competence certificate that contains at least all the data indicated in the specimen shown at the end of this Appendix.

The test may be taken separately, but may also form part of an examination at the end of a vocational training course.

2.2 If this test has been taken more than six months before the performance of the work concerned:

Registration kept by the Manufacturer in accordance with Section 5 and to be shown at the request of the Principal shall show that during the preceding six months the laminator has successfully performed laminating within the validity range of the laminator's competence certificate (see Section 4 of this Appendix).

2.3 The laminating to be performed shall be within the validity range of the laminator's competence certificate (see Section 4 of this Appendix).

In the case of work performed off the manufacturer's premises, instead of the laminator's competence certificate and/or registration in accordance with Section 5 an identification card in accordance with Section 6 of this Appendix may be shown.

3. **Performance**

- For the laminator's competence test, one sample shall be prepared in accordance with a drawing and/or description previously accepted by the Principal.
- The sample shall be visually assessed in accordance with Section 4.3 of this DEP.
- The sample shall be examined in accordance with the laminate specification. The results shall satisfy the requirements made in the specification.
- The Principal shall advise whether he wishes to witness the preparation of the samples and the performance of the test.

4. **Validity range**

This section states the laminating procedure variables and the range within which these may change without invalidating the laminator's competence certificate.

4.1 *Material*

The validity range shall comprise the laminate specification applicable to the sample.

4.2 *Laminate shape*

The following laminate shapes are distinguished:

- flat hand laminate;
- curved hand laminate;
- winding laminate;
- flange;
- inlaminated metal parts.

The validity range shall comprise the laminate shape used for the sample.

5. **Laminator's registration**

The registration referred to in 2.2 and 2.3 of this Appendix shall contain the following data on each laminator:

- name;
- reference to and dating of competence certificate;
- dates of performance of laminating work within the validity range of the relevant competence certificate;
- laminate specification and laminate shape;
- inspection body and results of visual examination and destructive testing of the laminating work.

6. **Identification card**

The identification card referred to in Section 2.3 of this Appendix shall contain the following data:

- name of the laminator;
- laminate specification(s) and laminate shape(s) for which the laminator's competence certificate(s) is (are) valid;
- dating of the laminator's competence certificate(s);
- last date of performance of laminating work within the validity range of the competence certificate concerned.

LAMINATOR's COMPETENCE CERTIFICATE

Laminator's name:

Details of the test laminate
Laminate specification:
Laminate shape;

Test results of the test laminate
Visual examination, see report No.: dated
Destructive test, see report No.: dated
Tests carried out in the presence of:

Validity range

Laminate specification:
Laminate shape:

The undersigned certifies that the above data are correct and that the test results satisfy the requirements stated.

Date: Manufacturer's signature:

APPENDIX 2 QUALIFICATION OF WELDING PROCEDURE AND WELDER FOR THERMOPLASTICS LINING

WELDING PROCEDURE AND WELDER QUALIFICATION

The Manufacturer shall demonstrate that the welding equipment, the welding preparation and the welding operation to be applied comply with the welding specification. He shall also record all welding details. The Manufacturer shall demonstrate by means of test welds that the welders, in following the welding specification (within the appropriate welding parameter ranges), produce acceptable welds. After approval of the test welds the subsequent production welding shall be performed in accordance with the qualified welding specification.

TEST WELDS FOR PROCEDURE AND WELDER QUALIFICATION

Three test welds shall be made for the welding procedure and welder qualification. The test welds should be made under the same conditions as those which will prevail during production welding.

The tests welds shall be inspected as follows:

Visual inspection

Visual inspection shall be carried out before, during and after welding. The check of the weld shall include the following criteria:

- **The weld joint shall be completely filled and the weld joint edges shall not be visible.**
- The weld joint shall be flush, i.e. there shall not be any 'reinforcement' above the weld joint.
- Filler rod and base material shall have fused.

  NOTE: At too low a welding gas temperature, the filler rod and the base material do not become sufficiently plastic, which results in notches, cavities and poor adhesion.
- The first bead shall properly penetrate the root of the weld joint.
- No cracks, pinholes, dirt, air inclusions or overheated parts shall occur in the weld. This should be detected by means of a high-frequency spark tester working at a voltage of 6 (1 + t) kV, with a maximum of 25 kV, where t = wall thickness in mm. For this test method a conducting backing wire or carbon veil is necessary.

  The root bead should be tested first at 10 kV, so that any faults can easily be removed and repaired before the next bead is applied.
- Narrowings, thickenings or large waves are not allowed in the separate beads.
- There are no specific acceptance criteria for the dimensions or shape of the ridge, however:
  - Too heavy a ridge might be indicative of too high a welding temperature, too long a heating time or too high a welding force.
  - A pronounced sharp notch in the core of the ridge may have been caused by too low a welding temperature or welding force.
  - Too high a gloss on the surface of the ridge indicates that the temperature during heating of the material was too high.
  - An irregularly shaped ridge may have been caused by inaccurate preparation, resulting in an unequal distribution of the heat over the weld faces.
  - The centre lines of the welds may not coincide, indicating that the weld faces have shifted in relation to each other (wall jump).

Destructive testing

Bend testing shall be performed in accordance with a procedure to be agreed between the Manufacturer and the Principal.

APPENDIX 3 SHEAR STRENGTH TEST OF BOND BETWEEN THERMOPLASTICS LINING AND LAMINATE

This test shall be carried out by the following procedure.

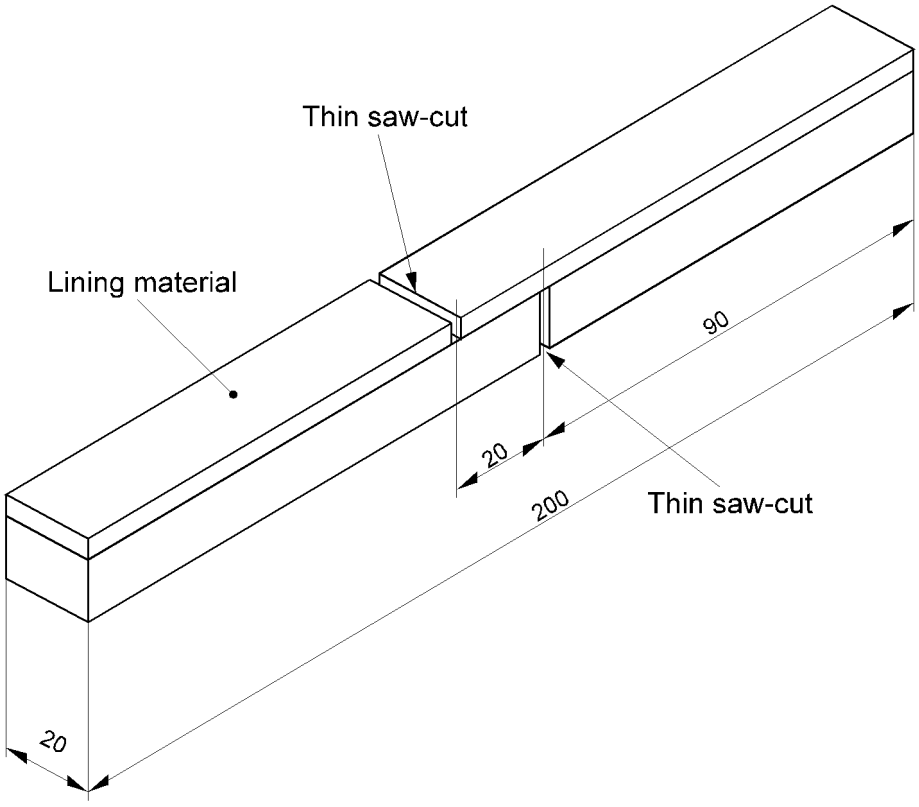
The specimen shall be cut from the full thickness of the laminate and lining and shall be of the form and dimensions shown in the figure below.

Make two thin saw cuts in the specimen at right angles to the major axis, 20 mm apart and symmetrically about the transverse centre line. Make one cut through the full thickness of the thermoplastics material but not into the laminate and the second through the full thickness of the laminate but not into the thermoplastics material.

Keep the specimen at 20 $\pm$ 5 °C for not less than 3 hours immediately before testing, which shall be done at 20 $\pm$ 5 °C.

Clamp the specimen in the serrated jaws of a suitable tensile testing machine and in axial alignment with the direction of pull. Strain the specimen at a constant rate of 25 $\pm$ 6 mm/min.

The shear strength of the bond shall be calculated from the maximum load and the area under shear, and expressed in N/mm^2. The bond shear strength of the material under test shall be reported as the arithmetic mean of the bond shear strengths of all the test specimens. If the specimen breaks other than at the interface, or if the calculated shear strength is less than 7 N/mm^2, the test shall be repeated.



All dimensions are in millimetres

APPENDIX 4 PEEL STRENGTH OF BOND BETWEEN THERMOPLASTICS LINING AND LAMINATE

This test shall be carried out by the following procedure.

The specimen shall be cut from the full thickness of the laminate and lining and shall be of the form and dimensions shown in figure (a).

Make a saw cut at one end of the specimen at the interface of the laminate and thermoplastics material, across the width of the specimen and for 20 mm along its length.

NOTE: The saw cut should include, as far as possible, equal amounts of laminate and thermoplastics material.

Keep the specimen at 20 $\pm$ 5 °C for not less than 3 hours immediately before testing, which shall be done at 20 $\pm$ 5 °C.

Grip the laminate horizontally in the jaws of a vice or clamp and apply the load to the thermoplastics lining by means of weights until the load is just sufficient to peel the lining from the laminate. During this operation, ensure that the plane of the load remains perpendicular to the laminate/thermoplastics interface (see figure (b)).

The peel strength of the load shall be calculated from the total load at peel and the measured width of the specimen, and expressed in N/mm width. The bond peel strength of the material under test shall be reported as the arithmetic mean of the bond peel strengths of all the test specimens, and shall be at least 5 N/mm.

Figure (a) Thermoplastic-lined laminate specimen

All dimensions are in millimetres

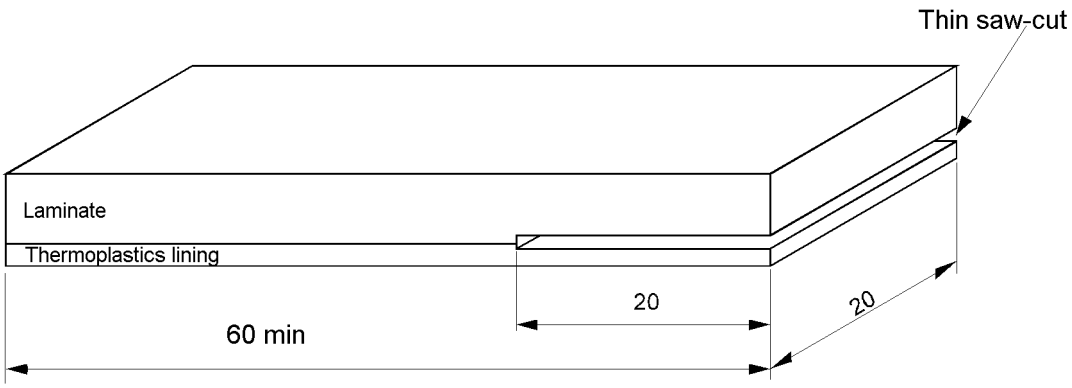


Figure (b) Assembly