



International  
Standard

**ISO 23936-4**

**Oil and gas industries including  
lower carbon energy — Non-  
metallic materials in contact  
with media related to oil and gas  
production —**

**Part 4:  
Fiber-reinforced composite  
materials**

*Industries du pétrole et du gaz y compris les énergies à faible  
teneur en carbone — Matériaux non métalliques en contact avec  
les fluides relatifs à la production de pétrole et de gaz —*

*Partie 4: Matériaux composites renforcés de fibres*

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at [www.iso.org/patents](http://www.iso.org/patents). ISO shall not be held responsible for identifying any or all such patent rights.

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 67, *Oil and gas industries including lower carbon energy*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 12, *Oil and gas industries including lower carbon energy*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

A list of all parts in the ISO 23936 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

## Introduction

Non-metallic materials are used in the petroleum, petrochemical and natural gas industries for a wide range of components. The purpose of this document is to establish requirements and guidelines for systematic and effective planning, for non-metallic material selection to achieve cost effective technical solutions, taking into account possible constraints due to safety and/or environmental issues.

This document is of benefit to a broad industry group ranging from operators and suppliers to engineers and authorities. It covers relevant generic types of non-metallic material (e.g. thermoplastics, elastomers, thermosetting plastics) and includes the widest range of existing technical experience.

This information aids in material selection. It can be applied to help avoid costly degradation failures of the equipment itself, which can pose a risk to the health and safety of the public and personnel or the environment. This document complements the document for metallic materials in sour service (the ISO 15156 series). It differs in the form of guidance provided to the user related to the potential degradation of desired properties when used in equipment for oil and gas production environments. The ISO 15156 series provides application limits and qualification requirements for metallic materials in H<sub>2</sub>S-containing environments which are related solely to relevant environmentally assisted cracking mechanisms.

Mechanical properties and the environmental stability of composite materials depend on the properties and environmental stability of matrix resins, fibres and fibre/resin bonding interfaces. This document focuses on the overall composite properties and their environmental stability. To permit this assessment this document utilizes flat plates and/or tubular shapes made specifically for these tests.

The document recognizes that a wider range of compounds and parameters influence the degradation of non-metallic materials and thus provides guidance to permit selection of materials for oil and gas exploration and production applications based upon stability in appropriate test conditions.

# Oil and gas industries including lower carbon energy — Non-metallic materials in contact with media related to oil and gas production —

## Part 4: Fiber-reinforced composite materials

**CAUTION** — Non-metallic materials selected using the ISO 23936 series are resistant to the given environments in the petroleum and natural gas industries, but not necessarily immune under all service conditions. This document allocates responsibility for suitability for the intended service in all cases to the equipment user.

### 1 Scope

This document provides general principles, requirements and recommendations for the assessment of stability of fibre-reinforced composite materials for service in equipment used in oil and gas production environments.

This document describes the procedures for comparative testing of composite materials consisting of polymers (thermoplastics and thermosets) and re-enforcing materials e.g. glass, carbon, aramid and metals as continuous fibres or woven fabric used in equipment for oil and gas production.

Testing and characterization of neat resins and fibre products are beyond the scope of this document.

The equipment considered includes, but is not limited to, non-metallic pipelines, piping, liners and downhole tool components.

Blistering by rapid gas decompression, coatings and compounded particulate- and short fibre-reinforced composites are excluded from the scope of this document.

### 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 175, *Plastics — Methods of test for the determination of the effects of immersion in liquid chemicals*

ISO 527-4, *Plastics — Determination of tensile properties — Part 4: Test conditions for isotropic and orthotropic fibre-reinforced plastic composites*

ISO 527-5, *Plastics — Determination of tensile properties — Part 5: Test conditions for unidirectional fibre-reinforced plastic composites*

ISO 1172, *Textile-glass-reinforced plastics — Prepregs, moulding compounds and laminates — Determination of the textile-glass and mineral-filler content using calcination methods*

ISO 1183-1, *Plastics — Methods for determining the density of non-cellular plastics — Part 1: Immersion method, liquid pycnometer method and titration method*

ISO 1268-1, *Fibre-reinforced plastics — Methods of producing test plates — Part 1: General conditions*

ISO 1268-3, *Fibre-reinforced plastics — Methods of producing test plates — Part 3: Wet compression moulding*

- ISO 1268-4, *Fibre-reinforced plastics — Methods of producing test plates — Part 4: Moulding of prepregs*
- ISO 1268-5, *Fibre-reinforced plastics — Methods of producing test plates — Part 5: Filament winding*
- ISO 1268-7, *Fibre-reinforced plastics — Methods of producing test plates — Part 7: Resin transfer moulding*
- ISO 1268-9, *Fibre-reinforced plastics — Methods of producing test plates — Part 9: Moulding of GMT/STC*
- ISO 2781, *Rubber, vulcanized or thermoplastic — Determination of density*
- ISO 6721-11, *Plastics — Determination of dynamic mechanical properties — Part 11: Glass transition temperature*
- ISO 7822, *Textile glass reinforced plastics — Determination of void content — Loss on ignition, mechanical disintegration and statistical counting methods*
- ISO 11357-2, *Plastics — Differential scanning calorimetry (DSC) — Part 2: Determination of glass transition temperature and step height*
- ISO 14126, *Fibre-reinforced plastic composites — Determination of compressive properties in the in-plane direction*
- ISO 14127, *Carbon-fibre-reinforced composites — Determination of the resin, fibre and void contents*
- ISO 14129, *Fibre-reinforced plastic composites — Determination of the in-plane shear stress/shear strain response, including the in-plane shear modulus and strength, by the plus or minus 45 degree tension test method*
- ISO 14130, *Fibre-reinforced plastic composites — Determination of apparent interlaminar shear strength by short-beam method*
- ISO 15024, *Fibre-reinforced plastic composites — Determination of mode I interlaminar fracture toughness,  $G_{IC}$ , for unidirectionally reinforced materials*
- ISO 15114, *Fibre-reinforced plastic composites — Determination of the mode II fracture resistance for unidirectionally reinforced materials using the calibrated end-loaded split (C-ELS) test and an effective crack length approach*
- EN 2564, *Aerospace series – Carbon fibre laminates – Determination of the fibre, resin and void contents*
- ASTM D792, *Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement*
- ASTM E1131, *Standard Test Method for Compositional Analysis by Thermogravimetry*
- ASTM D2290, *Standard Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe*
- ASTM D2344, *Standard Test Method for Short-Beam Strength of Polymer Matrix Composite Materials and Their Laminates*
- ASTM D2412, *Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading*
- ASTM D3039, *Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials*
- ASTM D3171, *Standard Test Methods for Constituent Content of Composite Materials*
- ASTM D3410, *Standard Test Method for Compressive Properties of Polymer Matrix Composite Materials with Unsupported Gage Section by Shear Loading*
- ASTM D3418, *Standard Test Method for Transition Temperatures and Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry*
- ASTM D3518, *Standard Test Method for In-Plane Shear Response of Polymer Matrix Composite Materials by Tensile Test of a  $\pm 45^\circ$  Laminate*

ASTM D5229, *Standard Test Method for Moisture Absorption Properties and Equilibrium Conditioning of Polymer Matrix Composite Materials*

ASTM D5379, *Standard Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method*

ASTM D5448, *Standard Test Method for Inplane Shear Properties of Hoop Wound Polymer Matrix Composite Cylinders*

ASTM D5449, *Standard Test Method for Transverse Compressive Properties of Hoop Wound Polymer Matrix Composite Cylinders*

ASTM D5450, *Standard Test Method for Transverse Tensile Properties of Hoop Wound Polymer Matrix Composite Cylinders*

ASTM D5528, *Standard Test Method for Mode I Interlaminar Fracture Toughness of Unidirectional Fiber-Reinforced Polymer Matrix Composites*

ASTM D6641, *Standard Test Method for Compressive Properties of Polymer Matrix Composite Materials Using a Combined Loading Compression (CLC) Test Fixture*

ASTM D7028, *Standard Test Method for Glass Transition Temperature (DMA T<sub>g</sub>) of Polymer Matrix Composites by Dynamic Mechanical Analysis (DMA)*

ASTM D7078, *Standard Test Method for Shear Properties of Composite Materials by V-Notched Rail Shear Method*

ASTM D7905, *Standard Test Method for Shear Properties of Composite Materials by V-Notched Rail Shear Method*  
*Standard Test Method for Determination of the Mode II Interlaminar Fracture Toughness of Unidirectional Fiber-Reinforced Polymer Matrix Composites*

NPL (2020) Measurement Good Practice Guide No. 38, *Fibre Reinforced Plastic Composites – Machining of Composites and Specimen Preparation*; National Physical Laboratory (UK)<sup>1)</sup>

### 3 Terms and definitions and abbreviated terms

#### 3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

##### 3.1.1

##### **composite material**

fibre-reinforced material system consisting of thermoplastic or thermoset polymers and reinforcing materials in the form of long and continuous glass, carbon and/or aramid fibres or woven fabric

##### 3.1.2

##### **fabricator**

producer of test plates and specimens

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1) Available at [www.npl.co.uk](http://www.npl.co.uk).

### 3.1.3

#### glass transition temperature

$T_g$   
characteristic value of the temperature range over which the glass transition takes place and at which the *composite material's* (3.1.1) mechanical properties change from elastic (glassy) state to viscous (rubbery) state

Note 1 to entry: The assigned glass transition temperature ( $T_g$ ) may vary, depending on the specific property and on the method and conditions selected to measure it [for instance, by differential scanning calorimetry (DSC) or by dynamic mechanical analysis (DMA)].

### 3.1.4

#### lamina

ply  
thin, single sheet of long and continuous reinforcing fibres sharing the same orientation in a polymeric resin matrix built up into a flat or curved arrangement

### 3.1.5

#### laminates

combination of *laminas* (3.1.4)

### 3.1.6

#### manufacturer

producer of the materials used for creation of semi-finished and/or finished products

### 3.1.7

#### sizing

optional treatments usually applied to yarn by *manufactures* (3.1.6) for reasons that can include increasing fibre-matrix compatibility, as well as facilitating handling during manufacture

### 3.1.8

#### wet $T_g$

glass transition temperature (3.1.3) of the fluid saturated material

## 3.2 Abbreviated terms

|      |                                          |
|------|------------------------------------------|
| ATM  | accelerated testing method               |
| CA   | autoclave cured                          |
| CH   | hot-press cured                          |
| CNC  | computerized numerical control           |
| CO   | oven cured                               |
| COA  | certificate of analysis                  |
| COC  | certificate of conformity                |
| COV  | coefficient of variation                 |
| CU   | UV cured                                 |
| DMA  | dynamic mechanical analysis              |
| DSC  | differential scanning calorimetry        |
| GFRP | glass fibre reinforced polymer           |
| GMT  | glass fibre mat reinforced thermoplastic |

|           |                                         |
|-----------|-----------------------------------------|
| HDT       | heat deflection temperature             |
| HPHT      | high-pressure high-temperature          |
| IPS       | in plane shear                          |
| LF        | filament winding lamination             |
| LP        | prepreg lamination                      |
| LR        | vacuum-assisted resin-transfer moulding |
| LW        | wet layup lamination                    |
| MOL       | material operational limit              |
| NDT       | non-destructive testing                 |
| PA        | Polyamide                               |
| ppm (vol) | volume parts per million volume parts   |
| QC        | quality control                         |
| QD        | quality documentation                   |
| SEM       | scanning electron microscopy            |
| STC       | sheet thermoplastic composite           |
| TA        | autoclave consolidation                 |
| TI        | isothermal consolidation                |
| TP        | hot pressing                            |
| TGA       | thermogravimetric analysis              |
| UD        | unidirectional                          |
| UV        | ultraviolet light                       |

## 4 Technical requirements

### 4.1 General requirements

Composite selection depends upon material property characteristics and fluid ageing behaviour. This document establishes four levels of testing for the purpose of comparing the properties of various composite materials. The testing methods at the material level shall focus upon the laminate and specimen geometry and do not represent a functional application test which is beyond the scope of this document. The specimen layup described is to provide a consistent, common basis for generating comparable data for different composite materials. Specific testing shall be required for the actual layup for samples representative of the final product form. Material property data are generated at the four levels to allow consistent comparison of the subject materials. Generic data shall be derived per Level 1 and Level 2 including threshold criteria, solely for the purpose of producing information for preselection. Where the user requires accelerated ageing

material stability data in a multi-phase H<sub>2</sub>S containing fluid, Level 3 shall apply. Where the user requires the material stability data beyond 56 days and an attempted long-term life estimation, Level 4 shall apply.

**NOTE** Ageing of composites faces combined challenges. Polymer or thermoset ageing alone deals in most cases with quasi-isotropic material properties. Composites of any configuration furthermore deal with polymeric challenges as well as with highly anisotropic properties resulting from fibre and interface properties, which can age very differently than the matrix material. All effects can overlay and become apparent in different failure modes or shifts thereof over the ageing period.

Ageing experiments can be designed in the following way to extract meaningful information, especially with regards to establishing lifetime models with these complex effects in mind:

- a) identify possible ageing mechanisms for matrix material;
- b) identify possible ageing mechanisms for fibre material;
- c) identify possible ageing mechanisms for interface;
- d) differentiate between physical and chemical ageing;
- e) differentiate between reversible and irreversible ageing;
- f) identify probabilities for the above-mentioned mechanisms to occur simultaneously during test periods;
- g) rank mechanisms for severity;
- h) rank for material characterization or application related testing;
- i) exclude any unwanted ageing mechanism by physical/chemical exclusion of other ageing influences (monitored and protocolled), choosing variations in layout to promote specific failure, or some combination of both.

Level 1 conformity consists of the characterization and documentation of material properties in a material data report. It includes a COC for batch quality control testing. See [5.1](#) and [Table 2](#) for a list of the required material properties to be documented. Physical and mechanical properties shall be characterized on materials in their unaged condition. These standard properties assist with the selection of materials that meet a design specification. Some property tests are also used for quality assurance and control. Level 1 testing establishes a baseline for higher level testing.

Level 2 conformity pertains to material stability (ageing) behaviour and shall be accompanied by a report. [Clause 6](#) provides requirements for Level 2 conformity. The effect of the first three fluids listed in [6.2.4](#) on material properties shall be investigated with real time ageing studies. A material's resistance to chemical/physical/mechanical change is determined.

Level 3 conformity pertains to material stability (accelerated ageing) behaviour and shall be accompanied by a report. [Clause 7](#) provides requirements for Level 3 conformity. The effects on material properties of three temperature aging evaluations shall be investigated. The intent of Level 3 evaluations is to accelerate material property changes specifically in multi-phase H<sub>2</sub>S-fluids.

Level 4 conformity pertains to a material stability (long-term) assessment of 180 days or longer. Level 4 attempts life estimation and shall be accompanied by a report. [Clause 8](#) provides requirements for Level 4 conformity. The intent of Level 4 assessment is to predict the material's progressive degradation; hence conformity threshold recommendations are offered for life estimation purposes. The report shall include a thorough account of data analysis, extrapolation, life estimation, and statistical confidence. Users shall evaluate the threshold criteria, life estimation results and all methodology to determine the suitability of materials for application.

All reports shall detail the testing and analysis that was performed as well as the edition of this document utilized at time of testing.

Laboratory studies using standard test conditions may not derive data that can be used for design purposes. The user may require fit-for-purpose testing or alternative testing to simulate production conditions to allow materials selection for final application. Component functional testing is not detailed in this document.

If there is scientific evidence on resistance of the material to the chemicals at the intended pressure and temperatures then such material may be exempt from Level 3 and Level 4.

## 4.2 Cautionary remarks

Designers should not assume that properties provided in a material data report as defined in [Clause 5](#) accurately represent those properties found in finished product geometries. The method of conversion is known to have an impact on these properties and that impact should be accounted for during design.

Life estimation usefulness and certainty can increase when longer term data are used to establish the degradation trend. Level 3 testing at durations up to 56 days are most useful for shorter term (up to 1 year) life estimations and can have reduced certainty for long-term (greater than 1 year) life estimations. Level 4 testing requires up to 180 day or longer data in an effort to create higher certainty in long-term life estimation.

In some cases, progressive degradation of composites over long periods of time at temperatures well above the target service temperature is not observed. The data and the attempted life estimation are still valuable because they demonstrate material stability in that test environment.

## 4.3 Traceability

For a final component to maintain its ISO 23936-4 material conformity, it shall be made from a composite material that conforms with this document. The entire compound manufacturing process shall be fully traceable. conformity records shall state the edition of this document used in the assessment. Reference to conformity with the ISO 23936 series shall include the part and edition (year) of the standard used e.g. ISO 23936-4:2024.

Each component and accompanying COC shall be traceable back to the compound manufacturer. Each company that participates in the manufacture of a compound that conforms with this document shall maintain traceability records for a minimum of 10 years that include its own manufacturing procedures, locations, and dates.

Further requirements on conformity and traceability over the supply chain can be found in relevant product standards and agreed between interested parties.

## 4.4 Test specimen identification

The specimen fabrication details shall be reported using the following identification code system. If the type of fibre or resin is a new class not covered below, the full designation shall be added in the datasheet.

### a) Material system:

A.1 Type of reinforcement fibre (e.g. carbon: CF, E-glass: EG, ECR-glass: ECR, S-glass: SG, aramid: AR, information regarding sizing and any additives, fibre modulus and precursor, bundle type, linear weight, tow size and type of weave, whenever applicable) and its grade should be included if made available. Designations for carbon, glass and aramid fibres can be provided according to ISO 13002, ASTM D578/D578M-23 and the EN 13003 series, respectively.

NOTE Discontinuous (short) fibre reinforced composites like veils composites are covered in ISO 23936-1.

A.2 Type of resin (e.g. epoxy: EP, Phenolic: PH, Vinyl ester: VE, unsaturated polyester: UP, Polyethylene: PE, bismaleimide: BMI, PEEK: PK, Polyphenylene sulfide: PPS, polyamide: PA, polyvinylidene fluoride: PVDF, polypropylene: PP) and its grade.

A.3 Type of fabric arrangement [e.g. woven roving: WR, stitch-bonded: SB, unidirectional (prepreg): UD, filament roving: FR, Braiding: BR].

### b) Laminate lamina orientation and stacking sequence in test specimen preparation:

B.1 Cross-lamina laminate 0/90 orientation,  $[0/90]_{ns}$ , where  $n$  represents the number of repeats and  $s$  stands for symmetrical stacking;

- B.2 UD laminate  $[0]_n$ ;
- B.99 other cross winded orientations like  $+\alpha / -\alpha$ .
- c) Lamination method:
  - C.1 Prepreg lamination (LP);
  - C.2 Vacuum-assisted resin transfer moulding (LR);
  - C.3 Wet layup lamination (LW);
  - C.4 Filament winding lamination (LF);
  - C.5 Tape placement welding (LT);
  - C.99 New lamination technology (method name).
- d) Consolidation method for thermoplastic composites:
  - D.1 Hot pressing (TP);
  - D.2 Isothermal consolidation (TI);
  - D.3 Autoclave consolidation (TA);
  - D.99 New consolidation technology (method name).
- e) Curing method for thermoset composites:
  - E.1 Oven cured (CO);
  - E.2 Hot-press cured (CH);
  - E.3 Autoclave cured (CA);
  - E.4 UV cured (CU);
  - E.99 New curing technology (method name).
- f) Specimen extraction orientation from  $[0/90]_{ns}$  and  $[0]_n$  laminate or arbitrary pipe layup:
  - F.1 Longitudinal (OL);
  - F.2 Transversal (OT);
  - F.3 In  $\pm 45^\circ$  direction (OD);
  - F.4 Perpendicular (hoop) to pipe axis (OP);
  - F.5 Along pipe axis (OA).
- g) Extraction method:
  - G.1 Sawing (ES);
  - G.2 Milling/Turning (EM);
  - G.3 Water jet (EW);
  - G.4 Laser (EL);
  - G.99 New extraction technology (method name).

h) Tabbing method (if required):

H.1 Tabbing before extraction (BB);

H.2 Tabbing of individual specimen (BI);

H.3 Un-tabbed specimen (BU);

H.4 Tabbing before ageing (BF);

H.5 Tabbing after ageing (BA);

H.99 New tabbing technology (method name).

The test specimen identification shall give the following information: test standard, specimen type, test speed and identification code.

EXAMPLE Sample test call out for an ISO 527-5 or ASTM D3039 tensile specimen of  $[0/90]_{ns}$  laminate in zero direction:

a) ISO 527-5: 2009, Type A, 2,0 mm/min (EG/EP/[0/90]<sub>5s</sub>/LP/TP/CO/OL/ES/BB);

b) ASTM D3039, Type A, 2,0 mm/min (EG/EP/[0/90]<sub>5s</sub>/LP/TP/CO/OL/ES/BB).

## 4.5 Validation of conformity

A composite loses its conformity if changes are made to the raw material supply, the composite matrix material formulation, reinforcement material, or the composite manufacturing process. New testing shall be done for each desired level of conformity.

If Level 4 conformity is complete prior to change, new Level 4 testing shall not be done if Level 1, Level 2 and Level 3 test results are equal or improved compared to previous Level 1, Level 2 and Level 3 test results.

If composite material manufacturing process is carried out at different plants/locations, a separate Level 1 conformity shall be done for each plant.

Level 1 to Level 4 testing shall not be done on the component if no compositional changes (other than due to cross-linking reactions) have been made to the matrix material during the conversion process, regardless of the conversion process being used. The influence of the conversion process on the physical properties and fluid ageing behaviour of the component is outside the scope of this document.

Level 1 conformity pertains to material property characterization of laminate and shall be documented by a material datasheet that details material properties, see [Clause 5](#), and documented by COCs for batch quality control testing in accordance with [Annex D](#).

Physical and mechanical properties shall be characterized in as-received condition. These standard properties assist with the selection of materials that meet a design specification. Some property tests are also used for quality assurance and control.

Level 2 conformity pertains to material fluid stability (ageing) behaviour and shall be accompanied by a report that details the testing that was performed, and the edition of this standard utilized at time of testing. This document provides requirements for Level 2 conformity, see [Clause 6](#).

The effect on material properties of Fluid 2.1 to Fluid 2.4 listed in [6.2.4](#) shall be investigated with real time ageing studies. A material's resistance to chemical/physical change is determined.

Level 3 evaluations include additional fluid stability (ageing) assessments such as fit-for-purpose tests or other assessments related to service conditions, see [Clause 7](#).

The intent of Level 3 assessment is to predict the material progressive degradation, in one of three specified fluids, Fluid 3.1 to Fluid 3.3, which includes a bespoke fluid. Properties to be measured are taken from Level 2, [6.2.5](#). There are no conformity requirements for Level 3 testing. Users shall determine acceptance criteria and suitability of materials for application.

All Level 3 activities should be accompanied by a report that details the approach undertaken in line with the application; including the test methods and results obtained.

## 4.6 Quality control for fabrication of laminated test plates

### 4.6.1 General

QC in this document focuses upon controlling the quality and processing consistency of the fabricated laminates and the test specimens extracted from them. This shall be achieved by:

- a) ensuring the laminate fabricator is given a specification for test plate manufacture listing the constituent materials and desired minimum laminate properties, in accordance with [Annex B](#);
- b) using methods of test specimen preparation as described in [Clause 5](#).

As the quality control assessment can be undertaken by various members of the supply chain, it is essential to collate the results in QD; this ensures that material comparisons by testing according to this document are made without influence from fabrication variability.

The consolidation process has a significant influence on interlaminar or interface properties of the plates. The identification codes i.e. the time, temperature and pressure cycles of the test plate manufacture, volume fraction of fibres and stacking sequence, shall be reported.

Fabrication of plates shall be performed in accordance with [Annex B](#). Extraction of test specimen shall be performed in accordance with [Annex C](#).

### 4.6.2 Quality control for fabrication of plates

#### 4.6.2.1 General

In the fabrication of plates from which specimens are extracted, the governing quality control requirements shall be invoked for the constituent materials in accordance with [Annex B](#). Test plates shall be fabricated in accordance with the ISO 1268 series. ISO 1268-1 shall apply to all composites.

For thermoplastic composite ISO 1268-4 and ISO 1268-9 shall apply.

For thermoset composite ISO 1268-3, ISO 1268-4, ISO 1268-5, and ISO 1268-7 shall apply.

#### 4.6.2.2 Material and test plate specification

A material and test plate specification shall be agreed between the fabricator and the user, for the requested laminated test plates, in accordance with [Annex B](#). The specification shall detail the selected constituent materials, the processing method, the required plate dimensions, density, fibre content, discontinuity features (voids overall content, shape, size and distribution) and the glass-transition temperature ( $T_g$ ) of the fabricated laminated test plates. The specification shall also define the stacking sequence of the lamina and the QC acceptance criteria for the laminated test plates.

#### 4.6.2.3 Certificates of constituent materials

##### 4.6.2.3.1 General

COA and/or COC documents shall be provided with each constituent material.

##### 4.6.2.3.2 Certificates for UD-tapes for thermoplastic composites

The fabricator of thermoplastic plates for testing in accordance with this document shall only process UD-tapes which meet the minimal requirements of [Annex D](#). This can be guaranteed by the tape supplier based on acceptable QC/QD. Any missing QC/QD items shall be generated by the plate fabricator before processing of the UD-tapes.

#### 4.6.2.4 QC testing and analysis of composite

The inspection should follow the applicable part of the ISO 1268 series.

Laminates/tubes should be manufactured according to the following QC requirements during manufacturing:

- a) COA and/or COC for constituent materials;
- b) overlapping of tapes;
- c) gaps between tapes with acceptable tolerances;
- d) ensuring alignment of tape with those already laid;
- e) no wrapping of tapes;
- f) no dry fibres;
- g) no visible inclusions or foreign objects;
- h) no broken fibres or fibre wrinkles.

Laminates/tubes should be manufactured according to [Figure 1](#) and the following QC requirements for the finished product:

- no dry patches/fibres;
- no visible defects (fibre misalignment, holes, dips, wrinkles, warping, bubbles);
- check the through thickness quality by Non-destructive testing [e.g. C-scan, X-ray, microtomography, shearography, thermography, microwave, acoustic emission and their variations/combination].

NOTE QC guidance and requirements can be found in addition to the general requirements in ISO 1268-1 and the more specific preparation guidance in ISO 1268-2 to ISO 1268-9. These additional items aim to ensure production of quality laminates suitable for subsequent test specimen preparation for oil and gas exposure testing, see [Annex B](#).

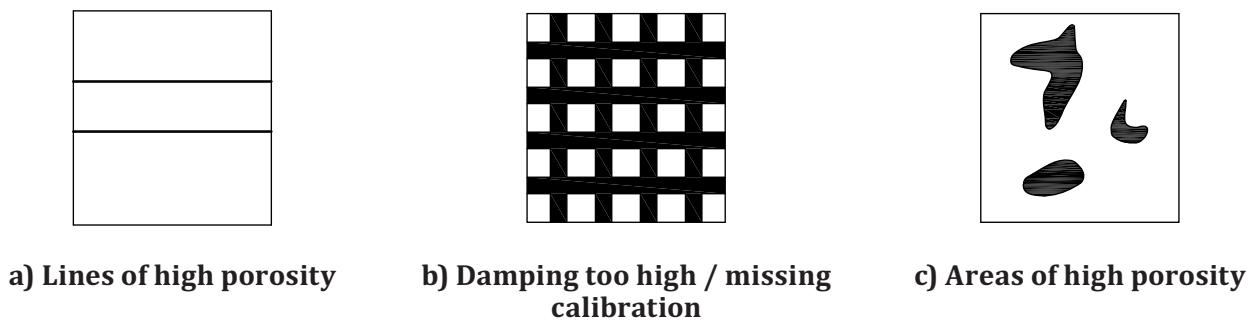


**Figure 1 — Examples of defects detected by NDT test methods**

Further information for defect types and NDT can be taken from the NCN (2007) Best-Practice Guide as well as other reference standards, such as ASTM D2563, ASTM D4385 and the ISO 14692 series and ISO 20144.

The produced test plates shall be flat; both surfaces shall be smooth, free of cracks, voids, dry fibres, fibre wrinkles or undulation, non-uniform fibre distribution, visible impurities, and visible delamination.

Thickness, width, and length shall be measured and reported. Thickness of the plate shall be uniform and shall be measured in multiple distributed locations, being representative for the composite design concept.

For the examination of porosity, internal delamination and damage, methods like microscopy on polished cross-sections (see ISO 7822), ultrasonic, X-ray tomography, thermography, their variations/combination, or alternative methods with comparable qualitative examination level shall be used.

Where the above fibre content and void content testing methods are inappropriate due to the fibre matrix combinations, alternative methods may be utilized.

The certified properties in [Table 1](#) of the laminated plate and/or tubes shall be determined per corresponding test standards and shall meet the requirements specified in the material specification. Frequency of this testing shall be agreed between the manufacturer and the purchaser based upon the criticality of the delivered components.

**Table 1 — QC testing and analysis of composite**

| Certified property                                                                                                           | Density                                 | Fibre content                                                                                                            | Void content <sup>a</sup> | Cured composite<br>$T_g$                                                                    |
|------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------|--------------------------------------------------------------------------------------------------------------------------|---------------------------|---------------------------------------------------------------------------------------------|
| Test standard                                                                                                                | ISO 1183-1;<br>ISO 2781 or<br>ASTM D792 | ISO 1172 for<br>glass fibre or<br>EN 2564 or ISO 14127<br>for<br>carbon fibre or<br>ASTM D3171 or<br>ASTM E1131<br>(TGA) | ISO 7822 or<br>ASTM D3171 | ISO 6721-11 for DMA or<br>ISO 11357-2 for DSC or<br>ASTM D7028 DMA or<br>ASTM D3418 for DSC |
| <sup>a</sup> Other reference/complementary standards are ASTM D2563, ASTM D4385 and ISO 14692-4:2017, Annex A and ISO 20144. |                                         |                                                                                                                          |                           |                                                                                             |

#### 4.6.2.5 Documentation to be supplied with the test plates/tubes

The test part fabrication report should follow the part of the ISO 1268 series that is applicable for the tested material.

The identification code system in accordance with [4.4](#) shall be used in any report.

### 4.7 Test specimen preparation, quality control and identification

#### 4.7.1 Preparation of test specimens

Test specimens shall be prepared using repeatable methods that meet requirements of test standards given by [Table 2](#) for the flat specimen from panels or by [Table 3](#) for the curved specimen from pipes. The composite material supplied should be a true representative for final products. If it is not true representative, the final product result can vary.

#### 4.7.2 Quality control of specimen preparation

Test specimen extraction processes shall follow the requirements of the corresponding mechanical test standards. Special attention shall be paid to the direction of cutting (with respect to the principal fibre direction) in test plates and pipes. Dimensions and geometric requirements shall be measured and inspected for the extracted specimens. The surface finish of the machined or polished specimen edge surfaces shall be free of delamination and any machining damage in accordance with NPL (2020) Measurement Good Practice Guide No. 38.

## 5 Level 1 – Material property characterization

### 5.1 General

Standard tensile, compression, in-plane shear, interlaminar shear and fracture toughness tests are the tests for mechanical characterization of laminated composite materials (see [Table 2](#)). The tests in [Table 2](#) and [Table 3](#) shall be performed for the Level 1 mechanical property characterisation. All mechanical testing shall be performed at room temperature in unaged condition.

Table 2 — Mechanical tests on the flat specimen from panels

| Test denomination                                 | Standard                                            | Stacking sequence | Test direction with respect to fibre direction |
|---------------------------------------------------|-----------------------------------------------------|-------------------|------------------------------------------------|
| Tensile properties                                | ISO 527-5 or ASTM D3039                             | $[0]_n$           | 0° and 90°                                     |
|                                                   | ISO 527-4 or ASTM D3039                             | $[0/90]_{ns}$     | 0°                                             |
| Compression properties in the in-plane direction  | ISO 14126 or ASTM D3410 or ASTM D6641               | $[0/90]_{ns}$     | 0°                                             |
| In-plane shear stress/shear strain response       | ISO 14129 or ASTM D3518 or ASTM D5379 or ASTM D7078 | $[0/90]_{ns}$     | ±45°                                           |
| Apparent interlaminar shear strength <sup>a</sup> | ISO 14130 or ASTM D2344                             | $[0]_n$           | 0°                                             |
| Mode I interlaminar fracture toughness            | ISO 15024 or ASTM D5528                             | $[0]_n$           | -                                              |
| Mode II interlaminar fracture toughness           | ISO 15114 or ASTM D7905                             | $[0]_n$           | -                                              |

<sup>a</sup> Specimen size may require modifications from ISO 14130 recommended values. It is acknowledged that it may be difficult to obtain valid failure modes for thermoplastic matrix composites.

To compare composite pipes without additional protection layer (thermoplastic liner, chemical barrier layer or topcoat) oversized pipe segments can be aged before extraction of the test specimen, see [Table 3](#).

Table 3 — Mechanical tests of curved specimen from pipes or pipe section/ring

| Test denomination                                        | Standard   | Stacking sequence                 | Test direction with respect to fibre direction |
|----------------------------------------------------------|------------|-----------------------------------|------------------------------------------------|
| Apparent hoop tensile strength <sup>a</sup>              | ASTM D2290 | $[0]_n$                           | 0° for hoop winding                            |
| In-plane shear stress/shear strain response <sup>a</sup> | ASTM D5448 | $[0]_n$                           | 0° for hoop winding                            |
| Apparent interlaminar shear strength <sup>a</sup>        | ASTM D2344 | $[0]_n$                           | 0°                                             |
| Transverse tensile properties of hoop wound              | ASTM D5450 | $[90]_n$                          | hoop winding                                   |
| Transverse compressive properties of hoop wound          | ASTM D5449 | $[90]_n$                          | hoop winding                                   |
| Crush test                                               | ASTM D2412 | $[-\alpha^\circ/+\alpha^\circ]_n$ | cross winding                                  |

<sup>a</sup> For most pipes 0° and 90° layers cannot be produced, due to the helical angle during winding. Therefore small angles are considered axial and angles close to 90°, but lower, are considered with hoop.

The tests listed in [Table 2](#) and [Table 3](#) consider only initial characterization of materials. Whenever deemed pertinent for composite equipment application, long-term properties like fatigue and creep (also called time to rupture or stress rupture) and their combination shall be considered, taking into account representative layouts (±α laminates, fibre and transverse direction, through-thickness), loads (tensile, compression, shear) and duration (number of cycles or hours). Documents like DNV-ST-C501 and ISO/TS 18226 can be consulted for additional information.

NOTE The tests listed in [Table 2](#) and [Table 3](#) can be used to characterise the effect of the exposure to the different chemical environments on the mechanical performance of the material. This can include, but not limited to, effect degradation of reinforcement, resin matrix and the reinforcement / matrix interfaces.

## 5.2 Reporting

The ISO 23936-4 material data report for each composite shall include as a minimum the following:

- a) manufacturer contact information;
- b) values for the documentation tests in [Table 2](#);
- c) test standards options such as method, specimen type, test speed;
- d) specimen identification call out for each test method.

## 6 Level 2 - Material stability (short-term)

### 6.1 General

One or more of the tests in accordance with [Table 2](#) or [Table 3](#) shall be performed in order to document the 28 day maximum material stability temperature in the reported test fluid (see [6.2.4](#)). The test procedure is listed in [Annex A](#).

In addition, real-time short-term thermomechanical evaluation and qualification may be performed according to [Annex E](#) if user values capturing properties measured at elevated temperatures.

When smaller samples are cut from larger panels, it is not unusual that those edges may represent a preferable way for fluid to diffuse into material core. The use of adhesives in the edges in order to try to prevent or at least minimize such phenomena should be carefully considered as, depending on sealing material used to cover these edges, fluid absorption of this material can be sometimes higher than the composite matrix itself, so, careful choice is recommended.

For the purposes of fluid exposure, it should be taken into account that material takes some time to saturate (wet, conditioning) and only when saturation is completed (or at a previously bespoke agreed level between interested parties), material ageing period starts. For the purposes of tracking material saturation, standards such as ISO 62, ISO 175, ISO 4433 series, ASTM D792, ASTM D5229, ASTM D1505 and ASTM D543 may be used as references. According to ASTM D5229, variations as small as 0,02 % in weight change for consecutive same-interval measurements can be used as references to determine that equilibrium has been attained.

Reference values (unaged dry and/or fluid saturated) shall be agreed between interested parties for the purposes of comparison between aged and un-aged samples.

### 6.2 Test criteria

#### 6.2.1 General

The conformity requires the following:

- a) exposure shall be performed in Fluid 2.1 through Fluid 2.3 listed in accordance with [6.2.4](#);
- b) Fluid 2.4 may also be tested and reported as bespoke;
- c) testing shall be performed on samples after fluid exposure in accordance with [6.2.3](#);
- d) Level 2 report shall be made available.

The test piece geometry shall be machined before exposure. Great care should be taken to ensure that test geometry is appropriate to get valid failures in post-exposure testing.

The composite material shall be exposed in unconstrained mode; that is, free-standing, with fluid able to freely access all surfaces.