BRITISH STANDARD

BS EN 13121-2:2003

GRP tanks and vessels for use above ground —

Part 2: Composite materials — Chemical resistance

The European Standard EN 13121-2:2003 has the status of a British Standard

ICS 23.020.10

British Standards

National foreword

This British Standard is the official English language version of EN 13121-2:2003.

The UK participation in its preparation was entrusted to Technical Committee PRI/5, UK steering committee for CEN/TC210 GRP tanks which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this committee can be obtained on request to its secretary.

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the *BSI Catalogue* under the section entitled “International Standards Correspondence Index”, or by using the “Search” facility of the *BSI Electronic Catalogue* or of British Standards Online.

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EN 13121-2

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English version

GRP tanks and vessels for use above ground - Part 2: Composite materials - Chemical resistance

Réservoirs et récipients en PRV pour utilisation hors sol - Partie 2: Matériaux composites - Résistance chimique

Oberirdische GFK-Tanks und -Behälter - Teil 2: Verbundwerkstoffe - Chemische Widerstandsfähigkeit

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Contents

Foreword

This document (EN 13121-2:2003) has been prepared by Technical Committee CEN/TC 210 “GRP tanks and vessels”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2004, and conflicting national standards shall be withdrawn at the latest by April 2004.

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association and supports essential requirements of EU Directive 97/23/EC.

For relationship with this European Directive see informative Annex ZA, which is an integral part of this standard.

This standard is Part 2 of EN 13121 which in total covers materials, design, manufacture, inspection, delivery, installation and maintenance of GRP tanks and vessels for use above ground. This Part 2 specifies requirements for chemical resistance of composite materials used for GRP tanks and vessels for the storage or processing of fluids, for use above ground. The tanks and vessels may be factory made or site built, with or without lining.

Annexes A and B are normative. Annex C is informative.

This document includes a bibliography.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

European Standard EN 13121 consists of the following parts under the general title "GRP tanks and vessels for use above ground":

Part 1 — Raw materials — Specification conditions and acceptance conditions

Part 2 — Composite materials - Chemical resistance

Part 3 — Design and workmanship

Part 4 — Delivery, installation and maintenance

These four parts together define the responsibilities of the tank or vessel manufacturer, the materials manufacturers or suppliers and the purchaser.

The design and manufacture of GRP tanks and vessels involve a number of different materials such as resins, thermoplastics and reinforcing fibres and a number of different manufacturing methods. It is implicit that tanks and vessels conforming to this Standard should be made only by manufacturers who are competent and suitably equipped to fulfil all requirements, using materials manufactured by competent and experienced material manufacturers.

EN 13121-1 gives the requirements necessary to establish that the GRP material and any thermoplastic lining will have the required chemical and thermal resistance to the service conditions. EN 13121-1 specifies the requirements for the specification conditions and acceptance conditions for GRP and thermoplastic materials, which are necessary in order to establish the chemical resistance properties of these materials in accordance with this Part of the standard. EN 13121-2 gives the requirements necessary to establish that the GRP material and any thermoplastic lining willl have sufficient chemical and thermal resistance to service conditions. Part 2 defines the requirements for the protective layer and the structural laminate as well as defining methods for proof of suitability to meet the chemical/thermal effects caused by the fluids and of determination of the partial design factor, A_2, as required for design in accordance with prEN 13121-3. Five methods are described — use of Media Lists, use of resin manufacturers data, use of thermoplastics manufacturers data, service experience and sample testing. The manufacturer of the tank or vessel may choose any one of these methods subject to here being sufficient data available in that method for the particular application.

Together with the requirements and acceptance conditions for the raw materials determined in EN 13121-1, the design and workmanship requirements as determined in prEN 13121-3 and the delivery, handling, installation and maintenance recommendations given in EN 13121-4, EN 13121-2 completes the total standard's requirements.

1 Scope

This European Standard gives requirements for chemical resistance of composite materials used for GRP tanks and vessels for storage or processing of fluids, for use above ground. The tanks or vessels may be factory made or site built, with or without lining.

2 Normative references

This European Standard incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies.

EN 59, *Glass reinforced plastics — Measurement of hardness by means of a Barcol impressor*.

EN 590, *Automotive fuels — Diesel - Requirements and test methods..*

EN 13121-1:2003, *GRP tanks and vessels for use above ground — Part 1: Raw materials — Specification conditions and acceptance conditions.*

prEN 13121-3, *GRP tanks and vessels for use above ground — Part 3: Design and workmanship.*

EN 13121-4, *GRP tanks and vessels for use above ground — Part 4: Delivery, installation and maintenance.*

EN ISO 4599, *Plastics — Determination of resistance to environmental stress cracking (ESC) — Bent strip method (ISO 4599:1986).*

EN ISO 6252, *Plastics — Determination of Environmental Stress Cracking (ESC) — Constant-tensile-stress method (ISO 6252:1992).*

EN ISO 14125:1998, *Fibre-reinforced plastic composites — Determination of flexural properties (ISO 14125:1998).*

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

ISO 4433-1, *Thermoplastics pipes — Resistance to liquid chemicals — Classification – Part 1: Immersion test method.*

ISO 4433-2, *Thermoplastics pipes — Resistance to liquid chemicals — Classification — Part 2: Polyolefin pipes.*

ISO 4433-3, *Thermoplastics pipes — Resistance to liquid chemicals — Classification — Part 3: Unplasticized poly(vinyl chloride) (PVC-U), high-impact poly(vinyl chloride) (PVC-HI) and chlorinated poly(vinyl chloride) (PVC-C) pipes.*

ISO 4433-4, *Thermoplastics pipes — Resistance to liquid chemicals — Classification — Part 4: Poly(vinylidene fluoride) (PVDF) pipes*.

3 Definitions

For the purposes of this standard in addition to the definitions given in EN 13121-1:2003, the following definitions apply:

3.1
resin layer (RL)
a layer of resin with or without additives in accordance with clause 7 of EN 13121-1:2003, but without nonwovens or any other fibre

3.2
veil layer (VL)
a layer of resin with or without additives in accordance with clause 7 of EN 13121-1:2003, with one or two surface nonwovens

3.3
single protective layer (SPL)
a protective layer of resin with or without surface nonwovens to meet slight or less significant effects caused by service conditions

3.4
chemical resistant layer (CRL)
a protective layer of resin with or without surface nonwovens to meet more significant or major effects caused by service conditions.

3.5
thermoplastic lining (TPL)
a protective using thermoplastic materials as a lining to meet effects caused by service conditions

3.6
sample
a piece of laminate or thermoplastic sheet for purposes of testing

3.7
specimen
a piece of a sample prepared for purposes of testing

3.8
test piece
a piece of a specimen for purposes of mechanical testing only

3.9
maximum temperature T_m
temperature given by the resin manufacturer or the thermoplastics manufacturer referring to a specified fluid

3.10
maximum design temperature T_d
maximum temperature for determination of the partial design factor, A_2, by different methods of this standard.

4 Protective layers

4.1 General requirements

The inner surface of all laminates shall consist of a protective layer. The protective layer shall be either a single protective layer (SPL) or a chemical resistant layer (CRL) or a thermoplastic lining (TPL).

The type of protective layer shall be selected on the basis of the ability to prevent, or limit to an acceptable level, chemical attack on the laminate. In order to do this, it shall be chemically resistant to the service conditions, allow limited diffusion of service fluids and shall not suffer environmental stress cracking. The TPL may require stress relief to prevent environmental stress cracking, see prEN 13121-3.

The required thickness of the protective layer shall be in accordance with Table 1.

When required, flammability and/or electrical conductivity shall be taken into account and/or the protective layer shall be selected on the basis of its ability to maintain the purity of the service fluids.

The requirements for workmanship of the protective layer are defined in prEN 13121-3.

For application in contact with foodstuffs the relevant regulations shall be considered.

Table 1 — Required thicknesses of protective layers

Protective layer	Required thickness mm
SPL	0,4 to 0,6
CRL	2,5 to 4,0
PVC-U	3,0 to 4,5
PP-H, -B, -R	3,0 to 6,0
PVDF	2,4 to 4,0
E-CTFE, FEP, PFA	1,7 to 4,0

4.2 Single protective layer (SPL)

The single protective layer SPL) shall be either a veil layer (VL) or a resin layer (RL).

4.3 Chemical resistant layer (CRL)

The chemical resistant layer (CRL) shall be a single or double veil layer (VL) followed by a layer or layers of either chopped strand mat or sprayed fibres with a total mass per unit area greater than or equal to 900 g/m^2. The fibre content shall be between 25 % and 35 % by mass.

Following the veil layer (VL), the subsequent chopped strand mats or sprayed fibres shall be applied before cure.

4.4 Thermoplastic lining (TPL)

All parts of the lining shall be manufactured from the same or compatible grade of material.

Linings of PVC-U are to be treated initially using a solvent based primer or the initial contact layer shall be applied using a specific bonding resin. Linings of PP, PVDF, E-CTFE, FEP or PFA shall have a glass or synthetic fibre fabric backing — branches up to 100 mm diameter may use chemically etched E-CTFE or PVDF linings.

The initial contact layer applied directly to the thermoplastic lining shall be reinforced with chopped strand mat with 300 g/m^2 to 450 g/m^2. The minimum bond strength of the reinforcement to the lining shall be in accordance with prEN 13121-3.

Subsequent to any forming or machining, the specified thickness shall be maintained. This may require initial use of a thicker lining material.

5 Determination of partial design factor, A_2

5.1 General

This clause defines the methods for determining the partial design factor, A_2, used for establishing the design factor K and the design factor F in accordance with prEN 13121-3.

Five methods are described and are summarised in Table 2; together with the maximum design temperature, T_d, applicable to each particular method.

The methods listed provide for situations where there are common material-/media lists given in annex A or manufacturers' data for resins or thermoplastics are available, and where there is documented service experience available in annex B or testing is required. Testing may be carried out in a laboratory and/or in-situ in an existing plant item by procedures given in annex C.

An overall view of handling these methods is given in figure 1.

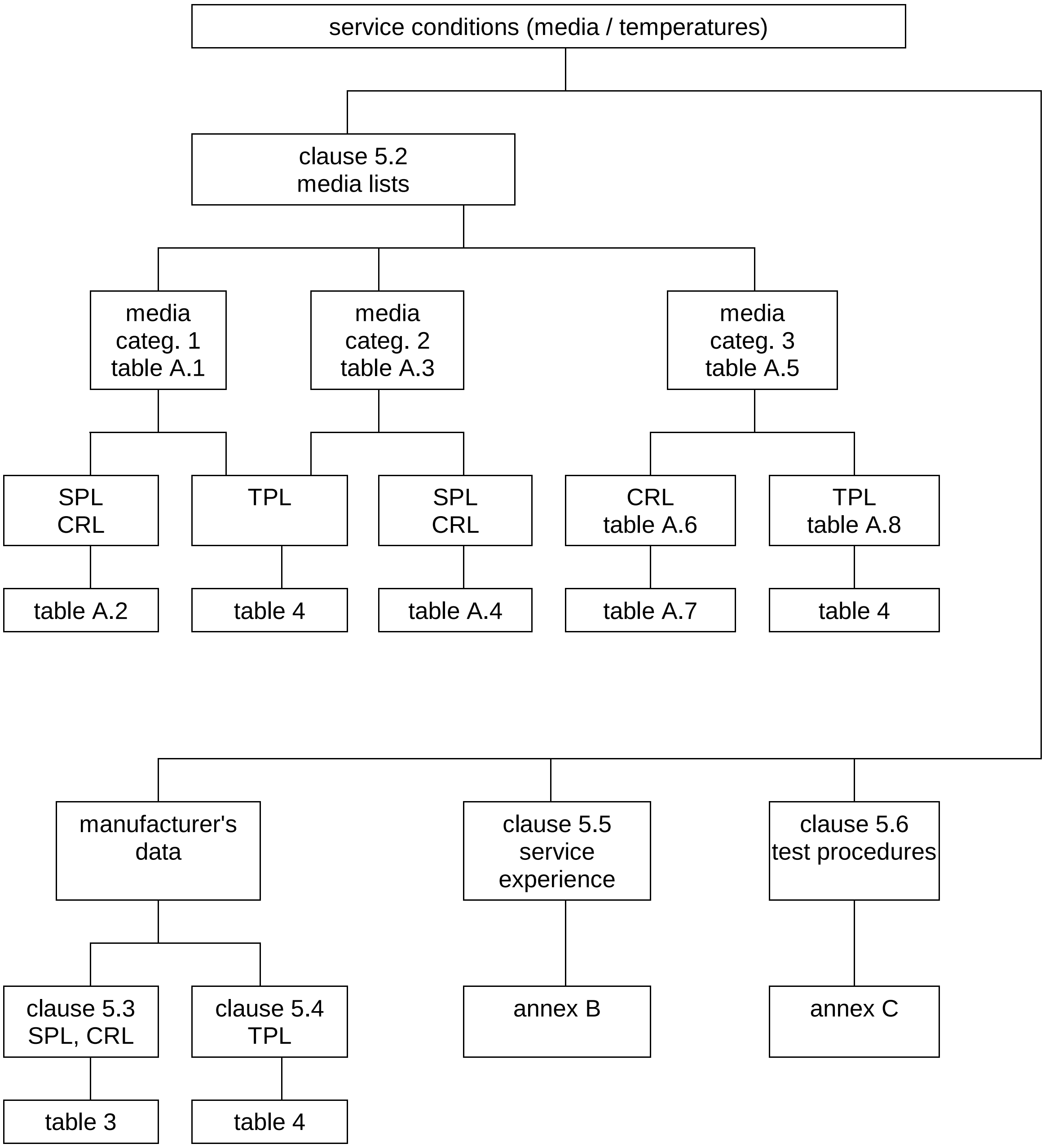


Figure 1 — Determination of partial design factor, A_2

It will often be possible to specify the partial design factor, A_2, by more than one of the above methods. In such cases it is permissible to choose the method which gives the lowest value of A_2.

The absence of data for a particular method is not indicative that a resin or TPL is unsuitable, it usually implies only that the service condition has not been studied using that particular method. This is especially so for the media lists which only give data for temperatures as shown in Table 2, for higher service temperatures, other methods may be used.

With regard to the service conditions, three possible situations can arise:

a) The service conditions can be considered identical to those for which data already exists. In this case the methods listed can be used directly.

b) The service conditions are sufficiently similar to those for which data already exists to allow direct use of the existing data. In this case a judgement on degree of similarity and use of existing data is required.

c) The service conditions are significantly different to any previously encountered and only those methods pertaining to the evaluation of test laminates shall be used.

It is particularly important that the chemical resistance is verified for the full range of service conditions, including any trace impurities e. g. organics or fluorides, and transient temperatures. In some cases there will be a need to take into account that the protective layer may be exposed to different phases of the service fluids, e. g. gas and liquid, and the phase boundary between them.

Table 2 — Maximum design temperature, T_d, used for determination of the partial design factor, A_2

Method of determination by	Maximum design temperature, T_d				
	SPL	CRL	PVC-U	PP-H PP-B PP-R	PVDF E-CTFE FEP PFA
lists of media					
— of category 1 (see Table A.1)	40 °C	100 °C	60 °C	100 °C	100 °C
— of category 2 (see Table A.4)	40 °C	80 °C	60 °C	80 °C	80 °C
— of category 3 (see Tables A.5 and A.8)	n. a.	60 °C	60 °C	60 °C	60 °C
resin manufacturer's data	40 °C	120 °C	n. a.	n. a.	n. a.
thermoplastics manufacturer's data	n. a.	n. a.	60 °C	100 °C	120 °C
service experience	40 °C	120 °C	80 °C	100 °C	120 °C
testing in laboratory/in-situ	40 °C	120 °C	80 °C	100 °C	120 °C
n. a. = not applicable					

5.2 Determination of partial design factor, A_2 by using media lists

The media lists when used with protective layers in accordance with clause 4, at different temperatures and concentrations, are given in annex A.

Use of media lists is only applicable when considering use of a resin described in the resin groups in accordance with EN 13121-1. For other polyester, vinyl ester, furance and phenolic resins which are not in a resin group in accordance with EN 13121-1, then methods 5.3, 5.5 or 5.6 shall be used.

The list of media given in Annex A is not a comprehensive list of all media for which this Standard may be used. Additional data may be found using methods 5.3, 5.4 or 5.5

The lists do not apply for temperatures above 100 °C for category 1 media, not above 80 °C for category 2 media, not above 60 °C for category 3 media and for mixtures of media.

The lists apply to parts which have been either post-cured or not post cured in accordance with the recommendations of the resin manufacturer. By post cure is meant that the laminate shall be maintained for a minimum of 4 h at a minimum temperature of 80 °C or the *HDT* of the resin or in accordance with the recommendation of the resin manufacturer.

The partial design factor, A_2, is determined by taking account of the category of media, temperature, type of protective layer and resin group in accordance with the Table 2 of EN 13121-1:2003, type of fibre and post curing.

5.3 Determination of partial design factor, A_2 using resin manufacturer's data

5.3.1 Chemical resistance information supplied by resin manufacturers

The chemical resistance information supplied by resin manufacturers shall include details related to the cure of the material from which maximum temperatures, T_m, for different service conditions were determined; for example time and temperature of cure including post cure and heat deflection temperature (*HDT*).

5.3.2 Minimum *HDT*

The *HDT* of the cured resin of the tank or vessel shall be at least 20 °C higher than the maximum design temperature, T_d.

The maximum temperature, T_m, shall only be used by the manufacturer if the resin manufacturer's recommended conditions of cure and post cure will be followed during manufacture.

5.3.3 Partial design factor A_2

The partial design factor, A_2, using SPL or CRL, shall be determined in relation to the resin manufacturer's maximum temperature, T_m, for the service conditions and the maximum design temperature, T_d.

The interpretation of resin manufacturer's maximum temperature, T_m, data in terms of A_2, is given in Table 3.

Table 3 — Partial design factor, A_2, relating to the maximum design temperature, T_d, and the maximum temperature, T_m

Maximum design temperature, T_d °C	A_2 post cured[a]
$T_d = T_m$	1,4
$T_d = T_m - 10$	1,4
$T_d = T_m - 20$	1,3
$T_d = T_m - 30$	1,3
$T_d = T_m - 40$	1,2
$T_d = T_m - 50$	1,2
$T_d = T_m - 60$	1,1
$T_d = T_m - 70$	1,1

[a] Conditions as given in 5.2 or subject to agreement with the resin manufacturer.

5.4 Thermoplastics manufacturer's data

Use of chemical resistance data published by the manufacturer of the thermoplastic material or the manufacturer of the thermoplastic lining shall be restricted to data on materials which meet the characteristic properties of EN 13121-1.

Direct use of the above data shall be restricted to those service conditions for which the material or lining manufacturer gives a recommendation of suitability in the manufacturer's highest category.

In some cases, referring to the manufacturer of the thermoplastic material or lining, environmental stress cracking shall be considered by a sufficiently low stress level in production and service.

When the service fluids include organic media or their mixtures, diffusion may occur that is detrimental to the TPL bond to the structural laminate. Reference shall be made to service experience or test data for such media before final acceptance.

Table 4 gives the minimum values for the partial design factor, A_2, to be used at different design temperatures.

Table 4 — Partial design factor, A_2, relating to the maximum design temperature, T_d, for TPL

TPL Material	Maximum design temperature, T_d °C	
	$A_2 = 1,1$	$A_2 = 1,2$
PVC-U	≤ 60	—
PP-H, PP-B, PP-R	≤ 80	≤ 100
PVDF, E-CTFE, FEP, PFA	≤ 80	≤ 120[a]

[a] Subject to relevant service experience; see 5.5 and 5.6.

5.5 Service experience

This method takes account of situations where equipment is already in use containing the same or a similar service conditions. The equipment shall be in the form of an existing tank or vessel or as a pipe conveying the fluid.

The partial design factor, A_2, shall be evaluated by procedures given in annex B.

In all cases, the value of the partial design factor, A_2, shall be applicable to the same resin or lining as originally specified.

5.6 Test procedures

Test procedures, given in Annex C, define the requirements for testing and assessment of laminates with SPL, CRL or TPL in order to determine their suitability and to evaluate the partial design factor, A_2. Testing should be carried out by exposing specimen or samples of the material to the service fluid at the design temperature for specified times.

In testing the material may be exposed with stress or without stress and the material may be one side exposed to the test fluid or fully immersed.

Consideration is given, whether the material may might suffer environmental stress cracking in service. When this is considered possible, the suitability of the material should be qualified by testing with stress.

As a first result of tests, materials may be rejected as "unsuitable" or accepted as "suitable". Following qualification of the material as "suitable", the method given in C.3 then enables the determination of the partial design factor, A_2.

Annex A
(normative)

Determination of partial design factor, A_2, in accordance with media lists

A.1 Category 1 media

Category 1 media are listed in Table A.1.

For maximum design temperature ≤ 40 °C, the protective layer shall be a SPL or a CRL or TPL. For maximum design temperatures > 40 °C but ≤ 100 °C, the protective layer shall be a CRL or a TPL.

The value of the partial design factor A_2 for TPL shall be in accordance with Table 4. The value of the partial design factor A_2 for SPL and CRL protective layers shall be in accordance with Table A.2.

Table A.1 — Category 1 media

Medium	Medium	Medium	Medium
Ammonium Bromate, aq	Fatty acids (> 12 C-atoms), e.g. Oleic acid Palmitic acid Stearic acid	Nickel Sulphate, aq	Sodium Nitrate, aq
Ammonium Bromide, aq		Paraffin Wax	Sodium Phosphate, aq
Ammonium Chloride, aq		Potassium Aluminium Sulphate, aq	Sodium Sulphate, aq
Ammonium Nitrate, aq		Potassium Bromate, aq	Sodium Sulfite, aq
Ammonium Phosphate, aq	Fruit syrups (3 ≤ pH ≤ 8), e.g. Beet syrup Raspberry syrup Starch syrup	Potassium Bromide, aq	Sodium Thiosulphate, aq
Ammonium Sulphate, aq		Potassium Chlorate, aq	Starch, aq (5 ≤ pH ≤ 8)
Barium Chloride, aq		Potassium Chloride, aq	Sugar, e.g. Galactose Glucose, Sorbitol Fructose Mannose, Mannitol
Barium Nitrate, aq		Potassium Chromate, aq	
Brine, aq, sat	Magnesium Chloride, aq	Potassium Ferric Cyanide, aq	
Calcium Chloride, aq	Magnesium Nitrate, aq	Potassium Ferrous Cyanide, aq	
Calcium Nitrate, aq	Magnesium Sulphate, aq	Potassium Iodide, aq	
Calcium Sulphate, aq	Manganese-II-Chloride, aq	Potassium Nitrate, aq	Vegetable Oil, e.g. castor oil cotton seed oil soya oil wheat germ oil
Cobalt Chloride, aq	Manganese-II-Nitrate, aq	Potassium Nitrite, aq	
Cobalt Nitrate, aq	Manganese-II-Sulphate, aq	Potassium Phosphate, aq	
Copper-I-Chloride, aq	Mercury	Potassium Sulphate, aq	
Copper-II-Chloride, aq	Mercuric-I-Chloride	Seawater (3 ≤ pH ≤ 8)	
Copper-II-Nitrate, aq	Mercuric-II-Chloride	Silicon Oil/Grease	
Copper-I-Sulphate, aq	Mercuric-II-Nitrate	Sodium Bromate, aq	
Copper-II-Sulphate, aq	Molasses (3 ≤ pH ≤ 8)	Sodium Bromide, aq	
Diesel Oil, fuel oil (EN 590) (no aromatics, no methanol)	Nickel Chloride, aq	Sodium Chlorate, aq	
	Nickel Nitrate, aq	Sodium Chloride, aq	

NOTE For higher temperatures other methods may be used; see 5.5 and 5.6.

Table A.2 gives the type of protective layer required for the category 1 media at various design temperatures. In addition, the corresponding A_2-factors for post cured laminates are given.

Table A.2 defines also the resin groups in accordance with Table 2 of EN 13121-1:2003, which shall be used for the media of category 1 at various design temperatures.

At temperatures up to 60 °C the resin used for the structural laminate may be different from the resin used for the SPL or CRL. At temperatures above 60 °C a change of the resin shall only be permitted if relevant data of service, test or of the resin manufacturer are available.

NOTE When using different resins the thickness of the SPL or CRL may be required to be increased.

Table A.2 — Resin groups to be used for protective layers and structural laminates in contact with media of category 1 and partial design factors, A_2, for category 1 media at maximum design temperatures T_d

Maximum design temperature, T_d	Resin groups			A_2 post cured[a]
	SPL	CRL	Structural Laminate	
$T_d \leq$ 30 °C	1A-8	1A-8	1A-8	1,1
30 °C < $T_d \leq$ 40 °C	1B-8	1B-8	1A-8	1,2
40 °C < $T_d \leq$ 60 °C	use other methods	3-8	3-8	1,3
60 °C < $T_d \leq$ 80 °C	use other methods	4-8	4-8	1,4
80 °C < $T_d \leq$ 100 °C	use other methods	6-8	6-8	1,4

NOTE 1 Resin groups 1A-8 see Table 2 of EN 13121-1:2003.

NOTE 2 For higher temperatures other methods may be used; see 5.5 and 5.6.

[a] Conditions as given in 5.2 or subject to agreement with the resin manufacturer.

A.2 Category 2 media

Category 2 media are listed in Table A.3.

For maximum design temperatures, T_d, ≤ 40 °C, the protective layer shall be a SPL or a CRL or a TPL. For maximum design temperatures T_d, > 40 °C but ≤ 80 °C, the protective layer shall be a CRL or a TPL. The value of the partial design factor, A_2, for SPL and CRL shall be in accordance with Table A.4. The value of the partial design factor, A_2, for TPL protective layer shall be in accordance with 5.4, Table 4 taking into account the maximum design temperature, T_d, for each lining material given in Table A.3.

Table A.3 — Maximum design temperature, T_{d}, for category 2 media

Medium	CRL T_{d} °C	PVC-U T_{d} °C	PP-H, PP-B, PP-R T_{d} °C	PVDF, E-CTFE T_{d} °C	FEP, PFA T_{d} °C
Adipic Acid, aq	80	45	80	25	80
Alcohols (2 to 10 C-atoms), ≤ 20 % aq[a]					
e.g. Ethanol	60	40	60	60	60
Isobutanol	40	—	—	—	80
Isodecanol	60	—	—	—	80
Isopropanol	50	25	60	60	80
Propanol	60	25	60	60	80
Benzoic Acid, aq	80	40	80	80	80
Boric Acid, aq	80	40	80	80	80
Citric Acid, aq (≤ 50 %)	80	40	80	80	80
Glycols					
e.g. Butanediol 1,2	80	25	25	60	80
Butanediol 1,3	80	—	—	—	80
Butanediol 1,4	80	25	60	60	80
Diethylene Glycol	80	—	—	—	80
Dipropylene Glycol	80	—	—	—	80
Ethylene Glycol	80	60	80	80	80
Glycerin	80	60	80	80	80
Neopentyl Glycol	65	—	—	—	80
1,2-Propylene Glycol	80	—	—	—	80
Triethylene Glycol	80	—	—	—	80
Tripropylene Glycol	65	—	—	—	80
Hydrocarbons (5 to 10 C-atoms)					
e.g. Pentanes/Pentenes (≤ 50 °C)	70	25	25	80	80
Hexanes/Hexenes (≤ 50 °C)	70	25	—	80	80
Heptanes/Heptenes	80	—	—	80	80
Octanes/Octenes	80	—	—	80	80
Nonanes/Nonenes	80	—	—	80	80
Decanes/Decenes	80	—	—	80	80
Lactic Acid, aq (≤ 10 %)	80	25	80	25	80
Phosphoric Acid, aq (≤ 80 %)	80	60	80	80	80
Phthalic Acid(s)	80	25	60	80	80
Phthalates/Phthalic ester	65	30	30	30	80
Potassium Fluoride, aq[b]	60	60	80	80	80
Sodium Acetate, aq	80	60	80	80	80
Sodium Bicarbonate, aq	80	60	80	80	80
Sodium Fluoride, aq[b]	60	65	80	80	80
Sodium Tetraborate (Borax), aq	80	40	80	80	80
Succinic Acid, aq	80	60	60	60	80
Tartaric Acid, aq	80	25	60	60	80
Urea, aq (5 ≤ pH ≤ 8)	60	60	60	60	80
Water, not deionised or destilled	80	60	80	80	80

[a] higher concentration see Table A.5, media class VIII.

[b] synthetic or carbon veils/nonwovens shall be used

NOTE For higher temperatures see other methods; see 5.5 and 5.6.

Table A.4 gives the type of protective layer which shall be used for the media of category 2 at the various temperatures. In addition, the A_2-factors for post cured laminates are given.

Table A.4 defines the resin groups in accordance with Table 2 of EN 13121-1:2003, which shall be used for the media of category 2 at the various temperatures.

With the exception of phosphoric acid, at design temperatures up to 60 °C the resin and the type of glass fibre used for the structural laminate may be different from the resin and the type of glass fibre used for SPL or CRL. At design temperatures above 60 °C a change of the resin and the type of glass fibre shall only be permitted if relevant data of service, test; or of the resin manufacturer are available.

NOTE When using different resins the thickness of the SPL or CRL may be required to be increased.

Table A.4 — Resin groups to be used for manufacturing of protective layers and structural laminates in contact with media of category 2 and partial design factor A_2 for category 2 media at various design temperatures T_d

Maximum design temperature, T_d	Resin groups			A_2 post cured[a]
	SPL	CRL	Structural Laminate	
$T_d \leq 30$ °C	1B, 2-8	1B, 2-8	1-8	1,2
30 °C < $T_d \leq 40$ °C	2-8	2-8	1-8	1,3
40 °C < $T_d \leq 60$ °C	use other methods	3-8	3-8	1,4
60 °C < $T_d \leq 80$ °C	use other methods	6-8	6-8	1,4

NOTE Resin groups 1A-8 see Table 2 of EN 13121-1:2003.

[a] Conditions as given in 5.2 or subject to agreement with the resin manufacturer.

A.3 Category 3 media

Category 3 media are arranged into classes I to X and corresponding requirements for resin groups are listed in Table A.5.

The type of protective layer shall be a CRL or a TPL.

The type of fibre selected for the CRL shall be in accordance with Table A.6.

Table A.7 gives the partial design factor A_2, to be used for category 3 media applicable to a CRL.

For media classes III to IX, with the exception of hydrochloric acid and nitric acid, at design temperatures up to 40 °C the resin and type of glass fibre used for the structural laminate may be different from the resin and type of glass fibre used for the CRL. At design temperatures above 40 °C change of resin and type of glass fibre shall not be permitted.

At maximum design temperatures, T_d, above 40 °C a change of the resin or of the type of glass fibres used for SPL or CRL shall only be permitted if relevant service experience or relevant data by the manufacturer of raw materials are available.

NOTE When using different resins the thickness of the SPL or CRL may be required to be increased.

The value of the partial design factor, A_2, for TPL protective layers shall be in accordance with 5.4, Table 4, taking into account the maximum design temperature, T_d, for each lining material given in Table A.8.

Table A.5 — Resin groups suitable for the use with Category 3 media

Medium	Concentration	Design temperature		
		$T_d \le 30$ °C	30 °C < $T_d \le 40$ °C	40 °C < $T_d \le 60$ °C
I Inorganic/Alkaline/Alkaline hydrolising salts[a]				
Ammonium Hydroxide, aq, pH > 10	≤ 5 %	4-8	6-8	6-8
	> 5 %, ≤ 25 %	6-8	6-8	6-8
Calcium Hydroxide, aq, pH > 10	≤ 10 %	4-8	5-8	6-8
	> 10 %	4-8	4-8	6-8
Hydrazine Hydrate, aq	≤ 16 %	6-8	—	—
Potassium Hydroxide, aq, pH > 10	≤ 1 %	4-8	6-8	6-8
	> 1 %, ≤ 20 %	5-8	6-8	6-8
	> 20 %, < 50 %	5-8	6-8	6,7
Sodium Aluminate, aq, pH > 10	all	6-8	6-8	—
Sodium Hydroxide, aq, pH > 10	≤ 1 %	4-8	6-8	6,7
	≤ 20 %	5-8	6-8	6,7
	≤ 50 %	5-8	6-8	6,7
II Inorganic/Alkaline/Oxidising[a]				
Calcium Hypochlorite, aq, pH ≥ 12	≤ 17 % active Chlorine	4-8	5-8	6,7
Chlorinated lime, aq		5-8	5-8	6,7
Sodium Hypochlorite, aq, pH ≥ 12	≤ 16 % active Chlorine	4-8	5-8	6,7
III Inorganic/Acid/ Acid hydrolysing salts				
Aluminium Sulphate	all	1-8	1B,2-8	3-8
Hydrochloric Acid	≤ 18 %	4-8	6-8	6-8
	> 18 %, ≤ 37 %	4-8	6-8	8
Ferrous Chloride	all	1B,2-8	2,4-8	4-8
Ferric Chloride	all	1B,2-8	2,4-8	4-8
Ferrous Sulphate	all	1-8	1B,2-8	3-8
Ferric Sulphate	all	1-8	1B,2-8	3-8
Ferric Chloride/Sulphate	all	1B,2-8	2,4-8	4-8
Sulphuric Acid	≤ 50 %	1B,2-8	4-8	4-8
	> 50 %, ≤ 60 %	4-8	4-8	6-8
IV Inorganic/Acid/Oxidising				
Chromic Acid	≤ 10 %	2B,3-8	4-8	7,8
Nitric Acid	≤ 30 %	4-8	5-8	—
Perchloric Acid	≤ 20 %	3-8	—	—

Table A.5 *(continued)*

Medium	Concentration	Design temperature		
		$T_d \leq 30$ °C	30 °C $< T_d \leq 40$ °C	40 °C $< T_d \leq 60$ °C
V Organic/Alkaline				
N, N-Dimethyl Aniline		8	8	—
N, N-Diethyl Aniline		8	8	—
VI Organic/Acid				
Acetic Acid	≤ 10 %	1-8	1B,2-8	3-8
	≤ 50 %	2B,3-8	3-8	5-8
Formic Acid	≤ 10 %	2B,3-8	4-8	4-8
Oxalic Acid a	≤ 10 %	2B,3-8	3-8	3-8
Toluene Sulphonic Acid	≤ 50 %	4-8	4-8	5-8
VII Surfactants[b]				
$3 \leq pH \leq 8$	—	2-8	2B,3-8	3-8
$8 < pH \leq 9$		4-8	4-8	4-8
$pH > 9$		4-8	5-8	5-8
VIII Solvents				
Cyclohexanol	—	2,4,6-8	2B,4,7,8	—
Cyclohexanone	—	4-8	—	—
Ethanol, aq	> 20 %, ≤ 96 %	2,4-8	7,8	—
IX Oxidising agents				
Hydrogen Peroxide	≤ 30 %	4-8	7,8	7,8
Potassium Permanganate	≤ 50 %	2B,3-8	4-8	6-8
X Others				
Caprolactam, aq	≤ 50 %	4-8	4-8	—

[a] For media of classes I, II and VII and for oxalic acid nonwovens of synthetic or of carbon fibre shall be used.

[b] Types of surfactants are:

Alkyl Amino Polyglycolether
Alkyl Aryl Ammonium Salts (Na, K)
Alkyl Aryl Sulfonates
Alkyl Naphthol Polyglycolether
Alkylol Ether Sulphates
Alkylol Ether Phosphates
Alkyl Phenol Polyglycolether
Alkyl Phenol Polyglycolether(sulphates)
Alkyl-/Aryl Phosphates
Amides of Fatty Acids
Ethylene Diamine Polyglycolether
Na-, K- salts (EDTA salts) from Ethylenediamine Tetraacetic Acid
Na-, K- salts (NTA salts) from Nitrilo Triacetic Acid

NOTE 1 Resin groups 1A-8 see Table 2 of EN 13121-1:2003.

NOTE 2 For higher temperatures other methods may be used; see 5.5 and 5.6.

Table A.6 — Types of fibre in CRL

Media class	Media characteristics	VL	CSM
I	Inorganic/Alkaline/Alkaline hydrolysing salts	S	AR/E/E-CR
II	Inorganic/Alkaline/Oxidising/Alkaline hydrolysing salts	S	AR/E/E-CR
III	Inorganic/Acid/Acid hydrolysing salts	AR/C/E-CR	AR/E-CR
IV	Inorganic/Acid/Oxidising/Acid hydrolysing salts	AR/C/E-CR	AR/E-CR
V	Organic/Alkaline	C/E	AR/E/E-CR
VI	Organic/Acid	AR/C/E-CR	AR/E-CR
VII	Surfactants	C/E/S	AR/E/E-CR
VIII	Solvents	C/E	AR/E/E-CR
IX	Oxidising agents	C/E/S	AR/E/E-CR
X	Others	C/E/S	AR/E/E-CR

NOTE AR = AR-glass, C = C-glass, E = E-glass and E-CR = E CR-glass in accordance with Table 5 of EN 13121-1:2003. S = synthetic or carbon fibres.

Table A.7 — Partial design factor, A_2 for category 3 media at various design temperatures, T_d

Design temperature, T_d	CRL	A_2 for post cured[a]
$T_d \leq 30$ °C	obligatory	1,2
30 °C $< T_d \leq 40$ °C	obligatory	1,3
40 °C $< T_d \leq 60$ °C	obligatory	1,4

[a] Conditions as given in 5.2 or subject to agreement with the resin manufacturer.

Table A.8 — Maximum design temperature, T_d, for TPL with category 3 media

Medium	Concentration	Maximum design temperature, T_d, °C				
		PVC-U	PP-H, PP-B, PP-R	PVDF	E-CTFE	FEP, PFA
I Inorganic/Alkaline/Alkaline hydrolising salts						
Ammonium Hydroxide, aq	≤ 5 %	60	60	—	60	60
	≤ 25 %	40	60	—	60	60
Calcium Hydroxide, aq	≤ 10 %	60	60	—	60	60
	> 10 %	60	60	—	60	60
Hydrazine Hydrate, aq	≤ 16 %	—	40	25	—	—
Potassium Hydroxide, aq	< 1 %	60	60	—	60	60
	≤ 20 %	60	60	—	60	60
	> 20 %	40	60	—	60	60
Sodium Hydroxide, aq	≤ 1 %	60	60	—	60	60
	≤ 20 %	60	60	—	60	60
	> 20 %	40	60	—	60	60
II Inorganic/Alkaline/ Oxidising						
Calcium Hypochlorite, aq	all	60	40	25	60	60
Chlorinated Lime, aq		60	25	25	60	60
Sodium Hypochlorite, aq	< 16 % active chlorine	60	—	25	60	60
III Inorganic/Acid/Acid hydrolising salts						
Aluminium Sulphate	all	60	60	60	60	60
Hydrochloric Acid	≤ 18 %	60	40	60	60	60
	≤ 37 %	40	25	60	60	60
Ferrous Chloride	all	60	25	60	60	60
Ferric Chloride	all	60	25	60	60	60
Ferrous Sulphate	all	60	25	60	60	60
Ferric Sulphate	all	60	25	60	60	60
Ferric Chloride/Sulphate	all	60	25	60	60	60
Sulphuric Acid	< 50 %	60	25	60	60	60
IV Inorganic/Acid/Oxidising						
Chromic Acid	≤ 10 %	40	—	60	60	60
	≤ 30 %	40	—	60	60	60
Nitric Acid	≤ 5 %	60	30	60	60	60
	≤ 30 %	60	—	60	60	60
Perchloric Acid	≤ 20 %	40	40	60	60	60

Table A.8 *(continued)*

Medium	Concentration	Maximum design temperature, T_d, °C				
		PVC-U	PP-H, PP-B, PP-R	PVDF	E-CTFE	FEP, PFA
V Organic/Alkaline						
N, N-Dimethyl Aniline		—	—	50	—	60
N, N-Diethyl Aniline		—	—	50	—	60
VI Organic Acid						
Acetic Acid	≤ 10 %	40	60	60	60	60
	≤ 50 %	40	60	60	60	60
Formic Acid	≤ 10 %	40	40	60	60	60
Oxalic Acid	≤ 10 %	40	40	60	60	60
Toluene Sulphonic Acid	≤ 50 %	—	—	40	50	60
VII Surfactants (see Table A.5)						
3 < pH < 8		60	—	60	60	60
8 < pH < 9		60	—	—	60	60
pH > 9		60	—	—	60	60
VIII Solvents						
Cyclohexanol		40	40	40	60	60
Cyclohexanone		—	20	25	25	60
Ethanol, aq	> 20 % and ≤ 96 %	40	60	25	60	60
IX Oxidising Agents						
Hydrogen Peroxide	≤ 30 %	60	—	—	60	60
Potassium Permanganate	≤ 50 %	60	—	60	60	60
X Others						
Caprolactam, aq	< 50 %	—	—	—	—	—
NOTE For higher temperatures other methods may be used; see 5.5 and 5.6.						

Annex B
(normative)

Determination of partial design factor, A_2, by service experience

B.1 Use on same or similar service conditions for more than 3 years

In cases where there is more than 3 years documented experience on the same or similar service conditions, then the same partial design factor, A_2, as that specified for the original equipment should be specified for subsequent or similar service conditions.

If the partial design factor, A_2, is not available it may be back calculated from the original design criteria.

B.2 Use on same or similar service conditions for more than 3 years if performance verified by internal inspection

In cases where there is more than 3 years documented experience on the same or similar service conditions and the condition of the inside surface of the equipment has been established to be satisfactory in accordance with appearance criteria in Table C.1 by an internal inspection, then a reduced partial design factor, A_2, may be specified for subsequent or similar service conditions. The reduced partial design factor, A_2, should be not more than 0,1 lower than the original design factor, subject to the lower limit of 1,1.

If the partial design factor, A_2, is not available it may be back calculated from the original design criteria.

B.3 Use on same or similar service conditions for less than 3 years if performance verified by internal inspection

In cases where there is less than 3 years but more than 6 months documented experience on the same or similar service conditions, and the condition of the inside surface of the equipment has been established to be satisfactory by an internal inspection, then the same partial design factor, A_2, may be specified for subsequent or similar service conditions.

If the partial design factor, A_2, is not available it may be back calculated from the original design criteria.

Annex C

(informative)

Evaluation of partial design factor, A_2, by testing in situ or by laboratory testing

C.1 Test methods for laminates

C.1.1 Sample preparation

C.1.1.1 Preparation

Sample should be prepared in accordance with the following procedure:

Prepare the surface of a clean smooth metal or glass plate for release of laminate by covering it with a suitable polyester release film.

Prepare the resin by catalysing and promoting according to the resin manufacturer's recommendations to obtain an approximate 30 min gel time at room temperature.

Prepare the reinforcing fibre by cutting to the required size. Only fibre with sizing and binder compatible with the resin to be tested should be used.

Place a 3,0 mm spacer around the extremities of the plate.

Pour the catalysed resin onto the release sheet and spread evenly with a suitable roller.

Position the surface non woven (see 6.2 of EN 13121-1:2003).

Roll it into the resin with a suitable roller.

Add more resin and spread evenly as before.

Position the chopped strand mats using mats of 450 g/m^2 or 300 g/m^2 to achieve a total nominal glass weight of 900 g/m^2 (see 6.3 of EN 13121-1).

Roll them sequentially into the resin using a suitable roller.

Position another surface non woven.

Roll it into the resin using a suitable roller.

Place a layer of a suitable polyester release film on the laminate surface.

Roll it using a flat roller.

Place a smooth clean metal or glass plate on top.

Allow to gel and cool for a minimum of 16 h.

Cut into specimen of a suitable size for testing in accordance with C.1.2 or C.1.3.

Any sealing of the specimen edges should be recorded.

Post cure the specimen in a dry hot air oven for times and temperatures as recommended by the resin manufacturer. The cure of the specimen schedule should be recorded.

Allow the specimen to return to room temperature slowly.

C.1.1.2 Characterisation

The thickness of the specimen should be measured with a suitable instrument and should be within a tolerance of ± 0,2 mm.

Barcol hardness should be measured on a reference specimen.

The resin to glass ratio should be determined by testing a representative sample using ISO 1172 and should be in accordance with 4.3.

The type and precise amount of resin, catalysts, accelerators, promotors and fibre reinforcements should be recorded.

A suitable reference mark should be made on the specimen.

C.1.2 Single side exposure test

C.1.2.1 General

This test pertains to the exposure of one side of a specimen to the liquid and the vapour phases of a test fluid at a specified temperature for a specified time.

The test temperature should be the design temperature.

Sufficient number of specimen, at least 8, should be used to ensure that all appraisal requirements should be fulfilled.

C.1.2.2 Test apparatus

The test apparatus (figure C.1) consists of a cylinder with connections, for a thermometer and a condenser, and a thermostatically controlled heating element.

At least four sets of the test apparatus should be used.

The material of the cylinder should be chemically resistant to the test fluid.

Both ends of the cylinder should be closed by specimen, sealed and fixed suitably.

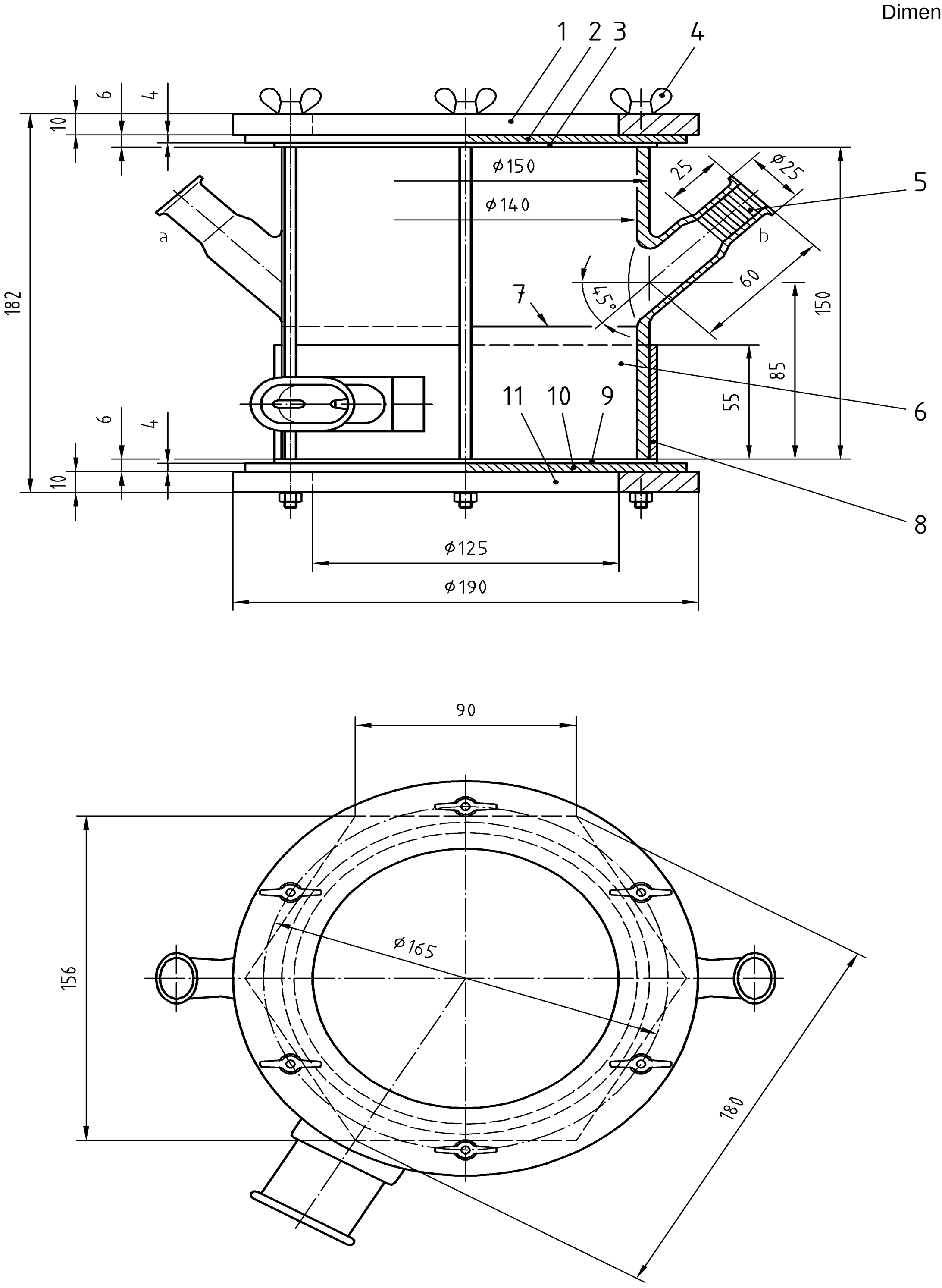
The heating equipment should maintain the test temperature of the liquid within ± 2 °C.

The apparatus may be used in the vertical position (see figure C.1) or in the horizontal position.

Other apparatus may be used, provided the sense of the test is maintained.

The heat may be applied by an external or an internal heating element situated below the liquid level. The test apparatus may be insulated.

Dimensions in mm



1 Flange
2 Test specimen (vapour phase)
3 Gasket (e.g. PTFE)
4 Six threaded studs (M6 × 200)
5 Two connection tubes (thermometer, condenser)
6 Glass cylinder
7 Liquid level
8 Heating element
9 Gasket (e.g. PTFE)
10 Test specimen (liquid phase)
11 Flange

Figure C.1 — Apparatus for single side exposure to fluid test preparation

Before starting the test the chemical composition and characteristic properties of the test fluid, e.g. colour, density, pH-value, should be determined and recorded. The specimen should be cut from samples, prepared in accordance with C.1.1.1.

The remaining parts of the samples should be used to determine reference values according to Table C.1.

The cylinders should be filled to approximately half of the volume with the test fluid.

If possible, the fluid level should be marked on each cylinder before heating to test temperature.

C.1.2.3 Test procedure

The test time starts when the test temperature is reached.

Each test apparatus should have an individual exposure time, e.g. 1, 4, 8, 16 weeks. The maximum exposure time should be at least 16 weeks.

During the test the appearance of test fluid should be observed. The test fluid should be replaced at intervals to maintain its original properties. The replacements of the test fluid should be recorded.

At the end of any exposure time and after the test fluid has cooled to room temperature the specimen should be removed. The specimen should be cleaned with water or another cleaning agent that does not attack the specimen. After cleaning the specimen should be dried by dabbing with a tissue without damaging to the surface of the specimen and should be visually inspected immediately.

C.1.2.4 Test results

After the specimen has been cleaned and dried the criteria in Table C.1 should be assessed.

Mechanical property testing should take place within 7 days on specimen stored in air tight containers.

For determination of flexural strength and flexural modulus in accordance with EN ISO 14125:1998, method A (three point loading), the test pieces should be cut from the specimen and from the reference specimen on the day of testing. The exposed surface should be in tension.

C.1.2.5 Test report

- The test report should indicate
- reference to this European Standard,
- characterisation of the sample and the fluid,
- any relevant test parameters in accordance with this test method,
- any relevant test parameters which deviate from this test method,
- individual and mean values of the characteristics determined on each specimen,
- any details not provided and any other circumstances which might affect the results,
- the dates of testing,
- name and signature of the responsible person.

The test report, the specimen, the residuals of samples should be kept by the laboratory or at a place as agreed between the purchaser and laboratory for at least six months.

C.1.3 Full immersion test

C.1.3.1 General

C.1.3.2 A sufficient number of specimen, at least 4, should be used to ensure that all appraisal requirements should be fulfilled.Test apparatus

The test apparatus consists of a vessel, chemically resistant to the test fluid, with connections, for a thermometer and a condenser, and a thermostatically controlled heating element.

The heating equipment should maintain the test temperature of the liquid within ± 2 °C.

C.1.3.3 Test preparation

Before starting the test the chemical composition and characteristic properties of the test fluid, e. g. colour, density, pH-value, should be determined and recorded.

The specimen (100 × 125 mm) should be cut from the sample, which should be prepared in accordance to C.1.1. The remaining parts of the samples should be used to determine reference values according to Table C.1.

All specimen should be placed in the vessel separated from each other and from the walls of the vessels.

The vessel should be filled with test fluid until all specimen are fully immersed.

The fluid level should be marked on the vessel, before heating to the test temperature.

C.1.3.4 Test procedure

The test procedure should be in accordance with C.1.2.4.

C.1.3.5 Test results

The test results should be in accordance with C.1.2.5.

C.1.3.6 Test report

The test report should be in accordance with C.1.2.6.

C.1.4 Testing "in situ"

C.1.4.1 General

This test pertains to the exposure of a specimen to the fluid at the service temperature. The test may be double sided or single sided and may be carried out inside an existing tank, vessel or pipe or the sample may be exposed in the form of a short length of adjacent piping at operating conditions.

A sufficient number of specimen, at least 4, should be used to ensure that all appraisal requirements should be fulfilled.

C.1.4.2 Test preparation

Before starting the test the chemical composition and characteristic properties of the test fluid, e.g. colour, density, pH, temperature, should be recorded.

Specimen should be prepared in accordance with C.1.1. Other specimen, e.g. piece of pipe, may be used, rovided the sense of the test is assured.

C.1.4.3 Care should be taken to ensure that each specimen is exposed in an equivalent manner to the test conditions and that they do not touch each other. Test procedureTest procedure

The test time starts when the specimen have been installed and the operating conditions are reached.

Where practicable specimen should be removed periodically. The minimum test time should be 3 months.

On removal from the vessel the test specimen should be cleaned with water or another cleaning agent that does not attack the samples. The cleaned specimen should be wiped dry and stored in an airtight container to prevent evaporation of the test fluid until testing.

C.1.4.4 Test results

The specimen should be evaluated in accordance with C.1.2.5.

C.1.4.5 Test report

The test report should be in accordance with C.1.2.6

C.2 Test methods for thermoplastic linings and welds

C.2.1 Single side exposure test

The test should be in accordance with C.1.2. The thickness of specimen should be in accordance with Table 1.

C.2.2 Full immersion test

The thermoplastic lining material should be tested by full immersion in the service fluid/s at the design temperature in accordance with ISO 4433-1.

The thickness of the specimen should be in accordance with Table 1.

Care should be taken to ensure that each specimen is exposed in an equivalent manner to the test conditions and that they do not touch each other.

A sufficient number of specimen, at least 5, should be used to ensure that all appraisal requirements should be fulfilled.

C.2.3 Environmental stress cracking test

Some service fluids may cause cracking in linings under the stress levels in the lining encountered in service. The origins of these stresses are:

(1) residual stress in the lining as supplied;

(2) additional stress following forming and/or welding;

(3) operational stresses.

The possibility of cracking should be stated. When such possibility is stated, it should be quantified by immersion testing under stress in accordance with the requirements of EN ISO 4599 or EN ISO 6252 or an alternative procedure agreed with a competent person. A sufficient number of specimen, at least 5, should be used to ensure that all appraisal requirements should be fulfilled.

If cracking is detected using these tests, the lining is not suitable.

C.2.4 Testing "in-situ"

The lining should be tested in accordance with C.1.4. The thickness of the specimen should be in accordance with Table 1.

C.3 Determination of partial design factor, A_2

C.3.1 Laminates with SPL/CPL

C.3.1.1 General

The partial design factor, A_2 should be determined using the assessment criteria and weighting factors described in Table C.1.

All criteria should be assessed. If a criterion is not assessed, an explanation should be given. The assessment of mechanical properties should always be included.

Table C.1 — Criteria for chemical resistance

Criteria	**Weighting factor** for single side exposure	**Weighting factor** for double side exposure	**Performance level**
Appearance			
Colour	2	2	0 - 5
Gloss retention	3	3	0 - 5
Opacity	3	3	0 - 5
Tackiness	4	4	0 - 5
Fibre prominence	4	4	0 - 5
Loss of surface resin	5	5	0 - 5
Blister formation	5	5	0 - 5
Crazing	5	5	0 - 5
Crack formation	5	5	0 - 5
Delamination	5	5	0 - 5
Dimensional stability			
Swelling (change in thickness)	8	4	0 - 5
Weight change	10	5	0 - 5
Barcol hardness in accordance with EN 59	5	5	0 - 5
Mechanical property retention			
Flexural strength	20	10	0 - 10
Flexural modulus	20	10	0 - 10

All criteria should be assessed after the relevant immersion time periods.

C.3.1.2 Evaluation of performance level

C.3.1.2.1 Appearance

Colour of the mould surface, after immersion in the medium, colour change should be assessed on a scale of 0 to 5. No change to the translucent initial colour (performance level - 0) to complete colour change and darkening (performance level - 5).

loss retention of the mould surface, after immersion should be assessed on the scale 0 (no loss in gloss from the original) to 5 (a matt surface)

Opacity after immersion should be assessed at performance level 0 (no change from the original) to 5 (total opacity and fibre whitening).

Tackiness after immersion should be assessed at performance level 0 (no perceived surfaced tackiness after immersion) to 5 (sticky surface with removal of material when touched). If level 5 is reached after the immersion period then the material should be rejected on this criterion alone.

Fibre prominence - the initial condition should be performance level 0 with fibre whitening at level 1 to level 5 representing blisters in the form of fibre prominence and small circular blisters at fibre overlaps.

Loss of surface resin - no loss of surface resin should be assessed at performance level 0 with surface resin loss resulting in performance level 5. If both resin and fibres are lost then the material should be rejected on this criterion alone.

Blister formation - should be assessed on the size and distribution of blisters from performance level 0 (no change from the original) through performance level 1 (a few tiny, 1 - 2 mm diameter blisters) to performance level 5 (moderate numbers of blisters in excess of 5 mm diameter).

If large numbers of blisters > 5 mm diameter occur or an occasional large blisters > 20 mm occurs then the material should be rejected on this criteria alone.

Crazing should be assesed at level 0 (no crazing) to level 5 (no more than the 50 % of the surface has crazed).

If crazing exceeds 50 % of the surface then the material should be rejected on this criteria alone.

Crack formation should be assesed at level 0 (no cracking) to level 5 (multi-cracking). Where multicracking has resulted in deep cracks and "break-up" of the material should be rejected on this criteria alone.

Delamination should be assessed at level 0 (no delamination) to level 5 (delamination up to 25 mm long).

C.3.1.2.2 Dimensional stability

Swelling (no change in thickness) should be assessed at level 0 (no thickness change) to level 5 (20 % increase in thickness).

Weight change should be assessed at level 0 (no weight change) to level 5 (5 % change in weight).

C.3.1.2.3 Barcol hardness

Barcol hardness should be assessed at level 0 (equivalent to no change) to level 5 5 (equivalent to a 50 % reduction in hardness).

C.3.1.2.4 Mechanical property retention

Results from bending tests shall be analysed using semilogarithmic plots of flexural strength and of flexural modulus, retention versus log (time), by asymptotic approximation of less than 50 % retention or at least linear extrapolation to the 50 % retention point. If at this point the time is less than 10 years then the material should be deemed to have failed the requirements for the medium and conditions of the test and rejected on this criterion alone.

No reduction in property after the test should be assessed at performance level 0 and 50 % reduction in property after 10 years at performance level 10.

C.3.1.3 Both properties (strength and modulus) should be assessed using the same performance level scales.Interpretation of performance levels

The performance level score from each test should be multiplied by the weighting factor for each criterion and combined to form a total for the range of tests carried out. The total should be compared with the maximum total, obtained by summing the product of each weighting for each criterion with the poorest performance rating for each of the tests carried out. For example, if colour, tackiness, crazing, retention of flexural modulus and retention of flexural strength are the measured criteria for immersion/double side exposure then the maximum (worse) score would be

$$2 \times 5 + 4 \times 5 + 5 \times 5 + 5 \times 10 + 5 \times 10 = 155.$$

Acceptance of the material for the application should be if the combined score of the test results is ≤ 50 % of the total score possible for the tests conducted.

C.3.1.4 Determination of partial design factor, A_2

The partial design factor, A_2, should be determined using the total assessment score as shown in Table C.2.

Meeting the minimum requirement, i.e. the assessment score from the tests conducted, including mechanical property evaluation, is 50 % of the total possible score then A_2 should have a maximum value of 1,4.

Where no deterioration has occurred over the duration of the assessment, i.e. the assessment score is less than 20 % of the total possible score then A_2 should have a value of 1,1.

Table C.2 — Determination of partial design factor, A_2

% of total assessment score	A_2
≤ 20	1,1
≤ 30	1,2
≤ 40	1,3
≤ 50	1,4
> 50	unsuitable for purpose

C.3.2 Laminates with TPL

Polyolefin materials should be evaluated and classified in accordance with the requirements of ISO 4433-2.

PVC-U materials should be evaluated and classified in accordance with the requirements of ISO 4433-3.

PVDF, E-CTFE, FEP and PFA materials should be evaluated and classified in accordance with the requirements of ISO 4433-4.

The methods used to classify other thermoplastics linings should be agreed between the purchaser and the manufacturer.

In all cases, provided that the material may be classified as "S" (satisfactory resistance) the value of the partial design factor, A_2, should be in accordance with Table 4.

Annex ZA
(informative)

Relationship between this European Standard and the Essential requirements of EU Directive 97/23/EC (PED)

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association to provide a means of conforming to Essential Requirements of the New Approach Directive 97/23/EC (PED).

Once this standard is cited in the Official Journal of the European Communities under that Directive and has been implemented as a national standard in at least one Member State, compliance with the clauses of this standard given in table ZA confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding Essential Requirements of that Directive and associated EFTA regulations.

Table ZA.3 — Correspondence between this European Standard and Directive 97/23/EC

Clause(s)/sub-clause(s) of this EN 13121-2	Essential Requirements (ERs) of Directive 97/23/EC	Qualifying remarks/Notes
4.1; 4.2; 4.3; 4.4	Annex I, 4.1	material properties
5.1; 5.2; 5.3; 5.4; 5,5; 5.6	Annex I, 2.6	chemical attack
Annex A	Annex I, 4.1	material properties

WARNING: Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

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