QVF

PROCESS PLANT COMPONENTS

P 301 e.1

PROCESS PLANT IN BOROSILICATE GLASS 3.3

QVF process plant and pipeline components manufactured from borosilicate glass 3.3 are widely used as the basis for the construction of complete process systems throughout the chemical and pharmaceutical industries, as well as many related areas such as food and drink production, dye works and the electroplating industry. One reason for this widespread use is the special properties of borosilicate glass 3.3 (see below), complemented by the use of other highly corrosion resistant materials such as PTFE and ceramics. Secondly, borosilicate glass is an approved and proven material in the construction of pressure equipment.

Another point which should be mentioned in this context is the great reliability of the positive and high performance connection of all components. This is achieved by the use of flat buttress ends, properly designed and optimised throughout the range of nominal sizes to comply with the special requirements of the material, and a reliable flange system.

The full range of standard components and associated equipment available is described in the following sections of this catalogue.

Chemical composition of borosilicate glass 3.3

The special properties – especially its high chemical resistance, its resistance to temperature and its low coefficient of linear expansion – of the borosilicate glass 3.3 exclusively used by QVF for the construction of glass plant and pipeline are achieved by strict adherence to its chemical composition, which is as follows:

Table 1

Component	% by weight
SiO_2	80.6
B_2O_3	12.5
Na_2O	4.2
Al_2O_3	2.2
Trace elements	0.5

Properties of borosilicate glass 3.3

The very wide use of this material throughout the world in the chemical and pharmaceutical industries as well as many other allied areas, is mainly due to its chemical and thermal properties (see also ISO 3585) together with a great number of other benefits that distinguish borosilicate glass 3.3 from other materials of construction. These include special properties such as

- smooth, non-porous surface
- no catalytic effect
- no adverse physiological properties
- neutral smell and taste
- non-flammability
- transparency

Chemical resistance

Borosilicate glass 3.3 is resistant to chemical attack by almost all products, which makes its resistance much more comprehensive than that of other well-known materials. It is highly resistant to water, saline solutions, organic substances, halogens such as chlorine and bromine and also many acids. There are only a few chemicals which can cause noticeable corrosion of the glass surface namely hydrofluoric acid, concentrated phosphoric acid and strong caustic solutions at elevated temperatures. However, at ambient temperatures caustic solutions up to 30% concentration can be handled by borosilicate glass without difficulty.

Borosilicate glass 3.3 can be classified in accordance with the relevant test methods as follows (see also ISO 3585 and EN 1595):

Table 2

Hydrolytic resistance at 98 °C	Hydrolytic resistance grain class ISO 719-HGB 1
Hydrolytic resistance at 121 °C	Hydrolytic resistance grain class ISO 720-HGA 1
Acid resistance	Deposit of Na2O < 100 mg/dm² to ISO 1776
Alkali resistance	Alkali resistance class ISO 695-A2

Further information about acid and alkali attack can be obtained from the following figures.

The corrosion curves in fig.1 show a maximum for different acids in the concentration range between 4 and 7 N (HCl for example at the azeotrope with 20.2 wt %). Above that the reaction speed decreases markedly so that the eroded layer amounts to only a few thousandths of millimetre after some years. There is, therefore, justification for referring to borosilicate glass 3.3 as an acid-resistant material.

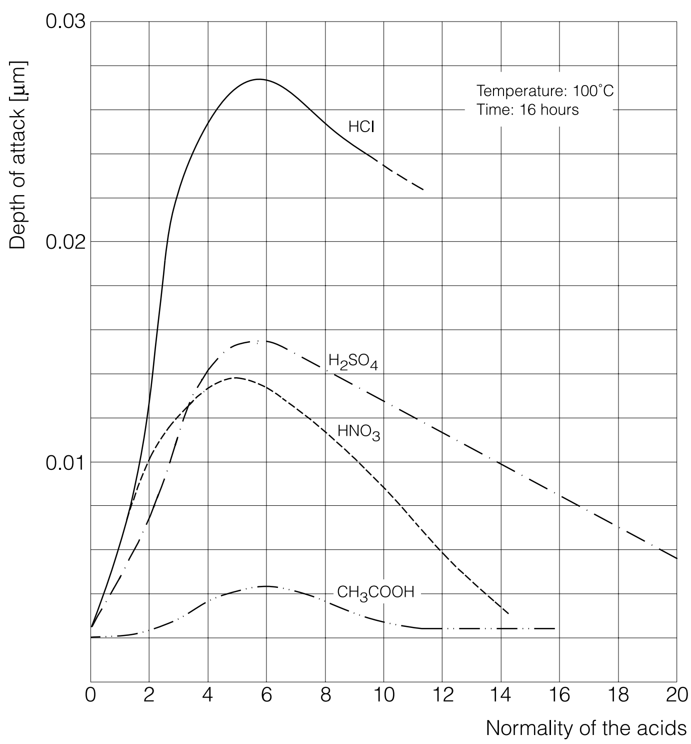

Fig.1
Acid attack on borosilicate glass 3.3 as a function of concentration

It can be seen from the corrosion curves in fig. 2 that the attack on the glass surface initially increases as the concentration of the caustic solution increases but after exceeding a maximum it assumes a virtually constant value. Rising temperatures increase the corrosion, while at low temperatures the reaction speed is so low that reduction of the wall thickness is hardly detectable over a number of years.

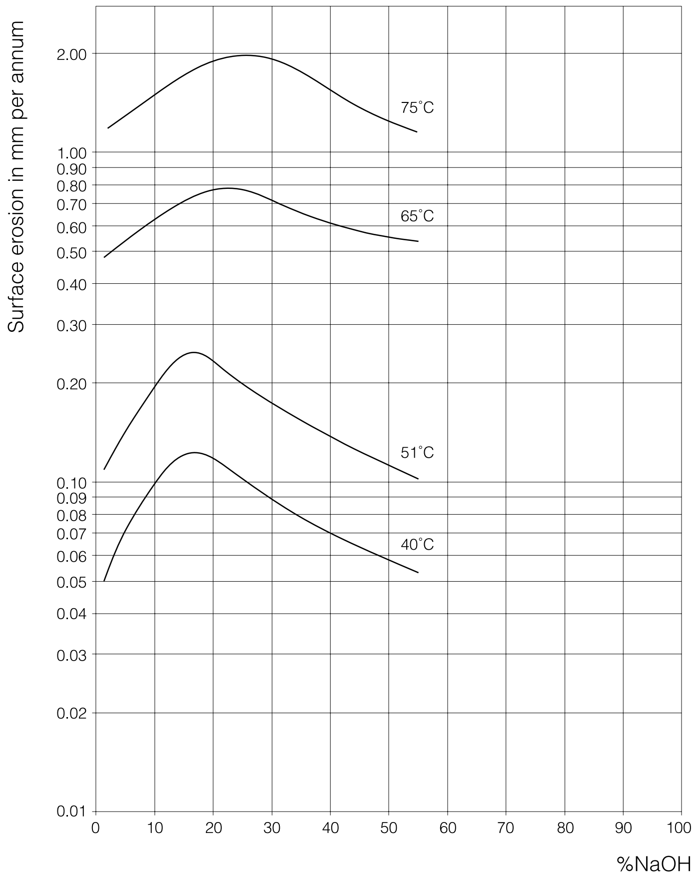

Fig. 2
Alkali attack on borosilicate glass 3.3 as a function of temperature

Physical properties

Borosilicate glass 3.3 differs from other materials of construction used for process plant not only because of its virtually universal resistance to corrosion (see above) but also because of its very low thermal expansion coefficient. There is, therefore, no need for expensive measures to compensate for thermal expansion resulting from changes in temperature. This becomes of particular significance in the layout of long runs of glass pipeline.

The most important physical properties for the construction of plant are listed below (see also ISO 3585 and EN 1595).

Table 3

Mean linear thermal expansion coefficient	$\alpha_{20/300} = (3.3 \pm 0.1) \times 10^{-6}\ K^{-1}$
Mean thermal conductivity between 20 and 200°C	$\lambda_{20/200} = 1.2\ W\ m^{-1}\ K^{-1}$
Mean specific heat capacity between 20 and 100°C	$C_{p\ 20/100} = 0.8\ kJ\ kg^{-1}\ K^{-1}$
Mean specific heat capacity between 20 and 200°C	$C_{p\ 20/200} = 0.9\ kJ\ kg^{-1}\ K^{-1}$
Density at 20°C	$\rho = 2.23\ kg\ dm^{-3}$

Optical properties

Borosilicate glass 3.3 shows no appreciable light absorption in the visible area of the spectrum, and consequently it is clear and colourless.

With borosilicate glass 3.3, the transmission of UV light, which is of great importance for photo-chemical reactions, is somewhat greater in the middle spectrum than with normal window glass. The chlorine molecule absorbs in the 280 to 400 nm range, and thus from the levels of transmission shown in fig. 3, it can be seen that plant made from this material is, therefore, ideal for chlorination and sulphochlorination processes.

If photosensitive substances are being processed, it is recommended that brown coated borosilicate glass 3.3 be used. This special coating reduces the UV light transmission to a minimum, since the absorption limit, as can also be seen from the figure below, is changed to approximately 500 nm.

Sectrans coated glass components, which have an absorption limit of approximately 380 nm, are also ideal for these applications.

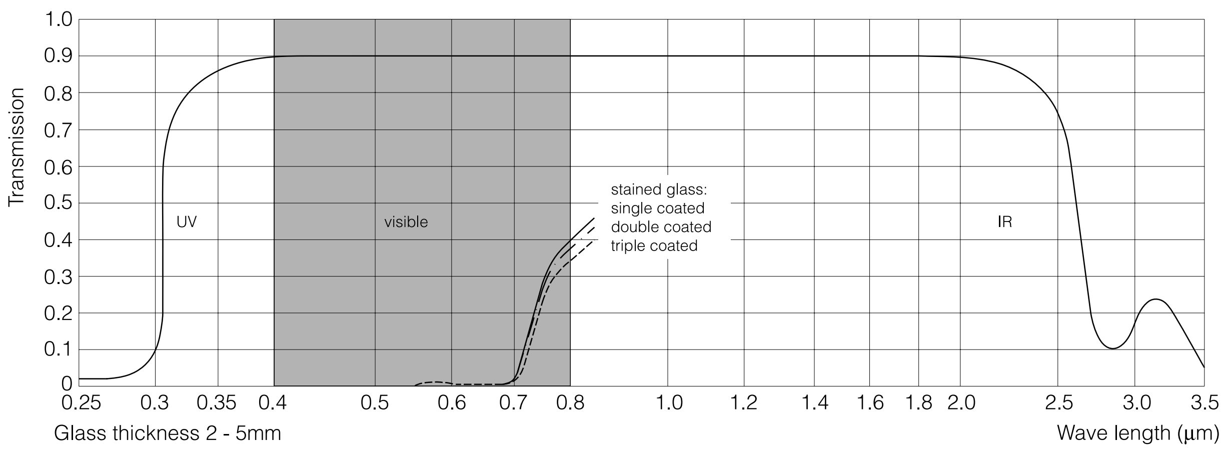

Fig. 3
Transmission curves for borosilicate glass 3.3

Mechanical properties

The permissible tensile strength of borosilicate glass 3.3 (see table 4) includes a safety factor which takes into account practical experience on the behaviour of glass and, in particular, the fact that it is a non-ductile material. Unlike other materials of construction used for similar purposes, it is not able to equalise stresses occurring at local irregularities or flaws, as happens in the case of ductile materials such as metals. The safety factor also takes into account additional processing which components may have undergone (ground sealing surfaces), handling of the glass (minute surface damage) and permissible pressures and temperatures to which it may be subjected in use.

The design figures indicated in the table below and specified in EN 1595 therefore apply to the permissible tensile, bending and compressive stress to which glass components may be subjected taking into account the likely surface condition of the glass in service.

Table 4

Strength parameters	Tensile and bending strength	K/S = 7 N mm^{-2}
	Compressive strength	K/S = 100 N mm^{-2}
Modulus of elasticity		E = 64 kN mm^{-2}
Poisson‘s ratio (transverse contraction figure)		ν = 0.2

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Permissible operating conditions

The permissible values for operating temperature and pressure must always be seen in combination. The reason for this is the thermal stresses that result from temperature differences between the inner and outer surfaces of the glass component. These stresses are superimposed on the stresses resulting from the working pressure. Higher thermal stresses therefore result in a reduction of the permissible working pressure. Thermal insulation reduces the thermal stresses and can, therefore, become a requirement of an installation.

Jacketed glass components are dealt with on page 1.10.

Permissible operating temperature

Borosilicate glass only deforms at temperatures which approach its transformation temperature (approximately 525 °C) and up to this point it retains its mechanical strength. The permissible operating temperature is, however, considerably lower – normally around 200 °C – for glass components, provided that there is no sudden temperature shock and that the components are not specially marked (see page 1.8). In exceptional cases, which call for special precautions, temperatures up to 300°C are also possible.

At sub-zero temperatures tensile strength tends to increase. Borosilicate glass 3.3 can, therefore, be used safely at temperatures as low as -80 °C.

These temperature limits should be regarded only as a guideline and must always be modified in accordance with the actual operating conditions of a given application. The individual operating conditions of some components in this catalogue must also be considered. Where such operating limits apply, they are detailed in the individual catalogue sections and component descriptions

Thermal shock

Rapid changes in temperature across the walls of glass components should be avoided during operation both indoors and outside. They result in increased thermal stress in the glass which, as described above, has an adverse effect on the permissible operating pressure of the plant components. Although it is not possible to give a definite figure applicable to all the operating conditions likely to be encountered in practice, a maximum permissible thermal shock of 120 K can be taken as a general guide.

Permissible operating pressure

Glass components in all nominal sizes that are basically cylindrical, domed and spherical can be used with full vacuum (-1 bar g), provided they are not specially marked otherwise.

Likewise the maximum permissible operating pressures (p_s) shown in tables 5 to 8 apply to these glass components as a function of their principal nominal size DN or diameter D (in the case of spherical vessels) and the internal (product side) and external (ambient) temperature difference ($\Delta\Theta$). Further details with regard to the sizing of borosilicate glass 3.3 components can be found in the next section.

The internal areas of heat exchangers are dealt with separately in Section 5 under the particular product description. In cases where glass equipment is operated with a gas pressure, appropriate safety precautions are required and our sales engineers will be happy to discuss these with you.

Depending on the shape and the particular working conditions, glass components can be used under certain circumstances at higher internal pressures. In these cases, the glass component is specially marked on in accordance with EN 1595.

General operating data

Operating temperature $T_B = 200$ °C
Temperature differences $\Delta\Theta \leq 180$ K
Heat transfer coefficient inside $\alpha_i = 1200$ Wm^{-2} K^{-1}, outside $\alpha_a = 11.6$ Wm^{-2} K^{-1}
All components are suitable for full vacuum $p_s = -1$ bar g

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Table 5: Glass components excluding spherical vessels

		Main nominal size DN												
		15	25	40	50	80	100	150	200	300	450	600	800	1 000
Glass component	p_s (bar g)	4	4	4	4	3	2	2	1	1	0.6	0.6	0.6	0.6

Table 6: Spherical vessels

		Nominal capacity (l) / Diameter D (mm)					
		10/280	20/350	50/490	100/610	200/750	500/1005
Spherical vessel	p_s (bar g)	1	1	0.6	0.6	0.6	0.3

Table 7: Bellows type valves

		Connection DN					
Valve		15	25	40	50	80	100
PVD, PED, PVA, DPVD, DPED, PVF, PVS, PVM, PES, PEM	p_s (bar g)	3	3	3	2	1.5	-
PRV, PRS, PRM, OF, BAS, BAL, BASP, PVW, PEV, PEVV	p_s (bar g)	3	3	3	2	1.5	-
SVF	p_s (bar g)	-	2	-	2	-	2

Table 8: Non-return valves, ball-valves, dirt traps

		Connection DN						
Valve		15	25	40	50	80	100	150
PFC	p_s (bar g)	-	3	3	2	-	1	-
NRV, RK, RKP, MV, KH, KHP, KHK, KHPP	p_s (bar g)	4	4	4	4	3	2	2

Design of glass components

The following parameters form the starting basis for calculating the strength of all the borosilicate glass 3.3 components listed in this catalogue:

- The permissible pressure.

  This ranges from -1 bar g (vacuum) up to a pressure of 4 bar g (DN 15 to DN 50) and 0.6 bar g (DN 1000) or 1 bar g (10l and 20l flasks) and 0.3 bar g (500l flasks).

- The permissible temperature difference ($\Delta\Theta$) between the outside area (ambient) and interior (product area).

  For standard glass components this has been fixed at 180 K which corresponds to the difference between the permissible operating temperature of 200 ºC and the ambient temperature of 20 ºC. At higher temperature differences the permissible pressure range will be reduced.

- The heat transfer coefficient (α_a) at the surface of the glass.

  This depends on the location of the installation and has a significant influence on the temperature difference $\Delta T = u \Delta\Theta s / \lambda$ between inner and outer surfaces of the glass wall of the component. Increasing values of the wall temperature difference results in a decrease in the permissible operating pressure or vacuum because of increased thermal stresses. The heat transfer values indicated in the table below have been selected on the basis of calculations and practical experience.

Table 9

Location of installation	Heat transfer coefficient ($Wm^{-2} K^{-1}$)	Used for tables
Inside building, exposed to draughts	11.6	5 and 6
Outside, protected from wind	11.6	5 and 6

- The heat transfer coefficient (α_i) to be expected on the inner wall. This also influences the temperature difference (ΔT) between the outside and inside surfaces of the glass component. A value of 1200 $Wm^{-2} K^{-1}$ has been used for calculation purposes which covers cases generally occurring in practice.

The strength calculation itself is carried out on the basis of EN 1595 and the German AD-Regulations for pressure vessels.

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Marking of glass components

The basis for the marking of borosilicate glass 3.3 components is the Pressure Equipment Directive 97/23/EC and European Standard EN 1595 ("Glass Pressure Vessels"). Information additional to this included on the component is provided for quality assurance purposes (traceability, correct use by the customer, etc) and has been approved by the Notified Body responsible for monitoring our compliance with the directive.

The different marking possibilities listed in fig. 4 to 6 are used as follows:

Table 10

Fig. 4	Standard parts as catalogue
Fig. 5	Special parts with catalogue operating conditions
Fig. 6	Special parts whose permissible operating pressure and/or temperatures differ from the details in this catalogue

Contrary to table 10 components for DN 15 and DN 25 are supplied with no CE mark (see article 3, paragraph 3 of directive 97/23/EC on this point).

The following information can be obtained in detail from the marking:

Table 11

Part of mark	Meaning	Remarks
QVF-logo	Manufacturer of component	
CE 0035	CE mark with Notified Body's identification number	
Boro 3.3	Material borosilicate glass 3.3	
M, S, P	Place of manufacture	M=Mainz (D), S=Stafford (GB) P=Paris (F)
7	Strength parameter to EN 1595	
02	Catalogue issue	02=2002
123456	Batch serial number	Sequential number
PS150/1500	Catalogue item reference	For standard component
SK4712	Drawing number or special item reference	For special item with permissible operating pressure as the catalogue
p=-1/+5 bar	Permissible operating pressure	Deviating from the catalogue
ΔΘ≤180 K	Permissible temperature difference	Information relates to the permissible operating pressure, can possibly also deviate from the catalogue

QVF
CE 0035
BORO 3.3
M702-123456
PS150/1500

Fig. 4

QVF
CE 0035
BORO 3.3
M702-123456
SK 4712

Fig. 5

QVF
CE 0035
BORO 3.3
M702-123456
SK 4713
p = -1/+5bar
ΔΘ = 180 K

Fig. 6

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Safety flat buttress ends

In practice the buttress end areas of borosilicate glass components have to withstand not only the tensile and compressive stresses resulting from being operated under pressure or vacuum, and the thermal stresses caused by the operating temperature, but also the stresses set up by the bolting forces in the coupling. Engineering a safe buttress end therefore involves ensuring that the sum of these stresses is minimised. The design of the flange coupling and the fire polished sealing surface both make significant contributions to this end.

The major dimensions of the safety flat buttress ends can be found in the table below, in conjunction with the illustrations alongside.

Table 12

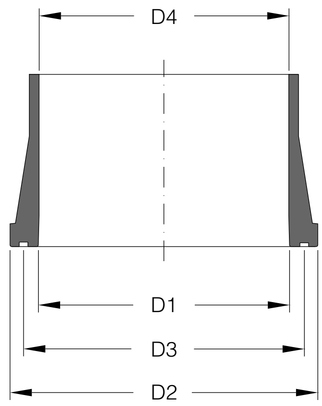
DN	D1	D2	D3	D4	Type
15	16.8	28.6	23	15.5 – 17.5	A
25	26.5	42.2	34	25 – 27	A
40	38.5	57.4	48	36.5 – 39.75	A
50	50.5	70	60.5	48 – 52	A
80	76	99.2	88	72 – 78	A
100	104.5	132.6	120.5	97.6 – 110	A
150	154	185	172	150 – 156	A
200	203	235	220	197 – 205	B
300	300	340	321	299 – 303	B
450	457	528	-	444 – 456	C
600	614	686.5	-	592 – 599	C
800	838 – 816	920	-	799 – 805	C
1000	1052 – 988	1093	-	976 – 983	C

Glass components with safety flat buttress end can be connected direct to spherical ended components by means of the glass or PTFE adaptors described in Section 2 "Pipeline Components".

All components with safety flat buttress ends produce positive and high performance connections ensuring safety in operation when used in conjunction with the couplings described in Section 9 "Couplings". The following significant details are especially noteworthy in this context:

- Grooves in the fire-polished sealing surface in the DN 15 to DN 300 nominal size range securely locate the O-ring gasket in place and prevent it being pushed out by the internal pressure.
- Flexible gaskets (see Section 9 "Couplings") facilitate deflections of up to 3° so that even complicated systems can be laid out simply and securely.

A



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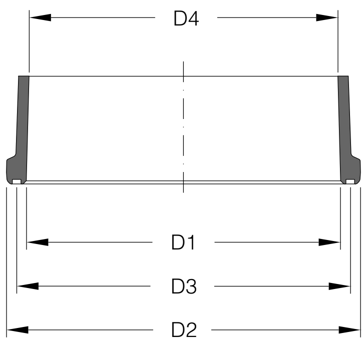

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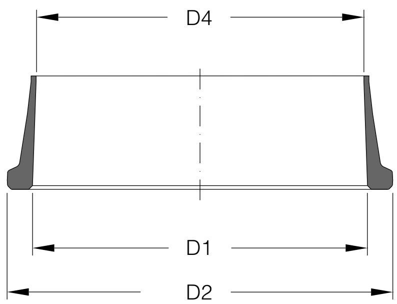

Jacketed glass components

These borosilicate glass 3.3 components provide a solution that meets requirements encountered in practice. They have proved their worth to excellent effect throughout the chemical and pharmaceutical industries as well as many related areas such as food and drink production, dye works and the electroplating industry. They are used not only to avoid heat loss for the purpose of saving energy but also where the product temperature has to be maintained to prevent crystallising or undesirable reactions. This is achieved without losing the benefit of being able to monitor the process visually.

Jacketed versions of all the major glass components of our modular system are available. The range therefore includes not only pipeline components but also valves and vessels as well as a wide variety of column components.

Jacketed components can be found in the appropriate section of this catalogue.

In the case of shorter pipe sections, fittings and spherical vessels up to 50 l nominal capacity, the jacket is one-piece and welded at both ends. In all other cases, the different linear expansion of the basic component and the jacket has to be compensated for by other means. On longer pipe sections the jacket is welded at both ends but it has a flexibly sealed expansion joint in the middle. On vessels it is welded only at the upper end and at the bottom it has a flexible seal.

The connections on the jacket are standard safety flat buttress ends. Further details on connection options can be found in the respective product description.

Permissible operating conditions

The permissible operating pressures for the inner part of jacketed components are identical to those for their non-jacketed counterparts (see page 1.7). However, deviations will arise in the permissible operating temperatures for the inner part and the permissible operating conditions in the jacket itself. These are caused by the permanently flexible seal, which absorbs the different expansion levels of the inner component and the jacket, but does not have the high temperature resistance and strength of borosilicate glass.

Permissible operating temperature:
Taking into account a sufficiently high safety factor, the permissible operating temperature for the inner component is -80 °C to +200 °C and for the jacket it is -50 °C to +180 °C. The maximum permissible temperature difference ($\Delta\Theta$) between the inner and outer areas is 180 K for heat transfer coefficients up to ∞_i = 1000 W/m^{2}K (inner component) and ∞_a = 120 W/m^{2}K (Jacket).

Permissible operating pressure:
The maximum permissible operating pressure in the jacket is +0.5 bar g up to an overall heat transfer coefficient of u = 70 Wm^{-2}K^{-1}. This average value can be expected during a heating process with thermal oil in the jacket and stirred liquid inside the vessel.

GMP-compliant installations

Special care is required in the selection of components and equipment for the construction of installations complying with GMP guidelines as regards their design and the materials of construction used. Because of its special properties, which are highly valued in the pharmaceutical industry, and when used in conjunction with materials on the FDA-approved list such as glass lined steel (vessels, valves) and PTFE (bellows, linings, cladding) borosilicate glass 3.3 guarantees that the build-up of deposits is avoided in areas in contact with the product. Minimum dead space to ensure complete draining and a capability for simple and effective cleaning are achieved by the design of the components, their layout and the selection of suitable valves. Stainless steel coupling and support material is available (see Section 9 "Couplings" and Section 10 "Structures & Supports") for the design of complete units complying with clean room conditions from the external aspect.

We would be happy to advise you on the basis of the regulatory requirements applicable in each particular case and the guidelines drawn up by ourselves for the design of GMP-compliant plant.

Protection against mechanical damage

Borosilicate glass 3.3 components can be GRP wrapped or Sectrans coated to protect the glass surface against external damage such as scratching or impact. Both versions can be applied to almost all glass components irrespective of their shape. Both have excellent resistance to chemicals and weathering. They present no health risk and heating them does not give rise to any unpleasant odours or gases.

Coating or wrapping glass components does not increase their permissible operating pressure in any way.

External protection of borosilicate glass 3.3 pressure vessels against mechanical damage in working areas and areas subject to traffic can be provided by safety screens. The use of these is to be recommended and in some areas it is a legal requirement (e.g. to comply with Point 9 of the TRB 801 Technical Regulations for Pressure Vessels in Germany).

Coated and wrapped glass components

Sectrans is a highly transparent polyurethane-based coating that is applied to the glass component by spraying to a defined thickness. The permissible long-term operating temperature for this material is 140 °C, but it can also go up to 180 °C for short periods. Above 140 °C the coating can turn yellow, but this has no adverse effect on its protection function and transparency.

In the event of the glass being broken, the Sectrans coating provides protection against splintering. If no pressure is involved, limited protection against the product escaping is provided. However if the glass component is being used at the permissible operating pressure the contents can escape.

The coating incorporates UV protection so that it can be used for handling photosensitive substances.

GRP wrapping is semi-transparent, but its visual properties are not as good as Sectrans coating. The maximum permissible operating temperature for GRP wrapped glass components however is approximately 150 °C.

In the event of the glass being broken, the GRP wrapping also provides protection against splintering and if no pressure is involved it prevents liquid escaping. Where low pressure is involved, there is limited protection against the product escaping which provides an emergency evacuation capability in the event of breakdown.

When ordering Sectrans coated components the suffix "L” should be added to the catalogue reference given in this catalogue, e.g. "PS100/500L”. For GRP wrapped components the suffix "C” should be added , e.g. "PS100/500C”.

If Sectrans coated or GRP wrapped borosilicate glass 3.3 components are to be used in category 1 or 2 areas (formerly zone 0 or 1), they should have a conductive layer. Our sales engineers will be happy to advise you on this.

Safety screens

Simple versions, such as wire mesh or expanded metal in box-section frames are of course a low cost solution, but not user-friendly. This applies especially when the plant needs protection on all sides. There is no doubt that it is better to use transparent plastic safety screens with frames that are self-supporting or fixed to the support structure and which can be equipped with covered service openings.

The best solution is to use safety screens consisting of medium flexibility transparent PVC which has a high resistance to abrasion. To ensure good lateral stability, these have galvanised metal strips bolted on at the top and bottom. Hooks are also fitted to the top edge to enable the safety screen to be suspended from the structure. Swivelling versions and covered service openings guarantee optimum ease of use. The screens can be individually adapted to local conditions as they are subdivided into overlapping sections.

For installations where electrostatic charges can be expected the screens can be supplied with an antistatic coating. This reduces the conductor resistance to less than $10^{8}\Omega$. The temperature of use of this material is between -40 and +40 °C. It has limited resistance to organic substances and adequate resistance to inorganic substances.

Electrostatic Earthing

Where glass plant is operated in areas where there is a risk of flammable atmospheres occurring, then precautions must be taken against spark generation by the discharge of electrostatic charges. The extent of the precautions required is related to the likelihood of an explosive atmosphere occurring. EC Directive 94/9/EC lays down different categories (formerly zones) according to the risk of explosion. Details about the occurrence, assessment and avoidance of ignition risks resulting from electrostatic charges can be found in the German Chemical Association's Guideline ZH1/200 "Static Electricity".

Precautions are of special importance with glass plant due to the joint couplings, each of which can include a combination of conductive and non-conductive materials. If the area in which the glass plant is installed is classed as Category 1 (formerly Zone 0), or with chemicals of Explosion group IIC as Category 2 (formerly Zone 1), then conductive parts of the plant must be earthed if their charge capacity exceeds 3 pF.

Plastic flanges however, do not need to be earthed. Therefore, in the smaller nominal size range of glassware the earthing requirements can be significantly reduced, or even eliminated in some circumstances, by using plastic instead of metal flanges.

If it is necessary to earth metal parts this should be done by connecting them to an electric protective conductor (drives etc) or by fitting conductive earthed points to the components to be earthed. In the glass plant it is advisable not to earth all parts of the plant individually but to interconnect them in a continuous circuit. This can done by means of a main conductor located parallel to the column, pipeline etc to which the components requiring earthing can be connected. By "earthing" it is to be understood in this context that the conductor resistance,(i.e. the electrical resistance of the earthing between an electrode set up on one side and earth) is not greater than $10^{6}\Omega$.

All the mechanical connections used for an earthing must be so resistant that they match the demands occurring in operation. Only welds, soldered joints or protected bolted couplings may be used. They should not be interrupted at any point by nonconductive intermediate items. Also they may not be disconnected for repair work while the glass plant is in operation.

If Sectrans-coated or GRP-wrapped borosilicate glass 3.3 components are to be used in category 1 or 2 flameproof areas (formerly zone 0 or 1), they should have a conductive layer. Our sales engineers will be happy to advise you on this.

Marking of electrical equipment

With the introduction of EC directive 94/9/EC (ATEX 100a) additional marking of equipment for use in explosive atmospheres is required. This indicates the area in which the equipment can be used, i.e. new EC test certificates (replacing the conformity certificates to directive 76/117/EEC) do not now contain any special indication with regard to permissible use in a specific flameproof zone.

In process engineering installations, the relevant markings are "II 1G" and "II 2G" for measurement and control instruments and "II 2G" for motors, where "II" means the appliance group (allowing the appliance to be used in any area except mining), "1" or "2" the category (formerly zone) and "G" (standing for gases and vapours) the type of explosive atmosphere.

As the marking prescribed by CENELEC, e.g. "EEx e II T4" or "EEx ia IIC T6" has been retained and the information called for in ATEX 100a must be added, the full new marking for this equipment is "II 2G EEx e II T4" or "II 2G EEx ia IIC T6".

Risk analysis / residual risks

All the components and apparatus in the 2002 edition of the QVF catalogue have been subjected to a risk analysis in accordance with Directive 97/23/EC and the corresponding countermeasures are documented by QVF. To exclude risks above and beyond these resulting from improper use (Directive 97/23/EC, Appendix I, Section 1-3) the following points should be observed:

- Although borosilicate glass 3.3 is a material resistant to virtually all chemical attack, alkaline solutions, hydrofluoric acid and concentrated phosphoric acid can cause some erosion. If there is any concern that there may be a reduction in wall thickness, the required minimum wall thickness should be checked at regular intervals.

- Unstable fluids, substances that can decompose, call for special safety precautions in the use of glass plant.

- The permissible operating conditions in accordance with section 1 the catalogue, page 1.6, should be observed and compliance ensured if necessary by means of additional measures such as pressure relief valves, bursting disks, over-fill preventi on or temperature limiters.

  - Permissible operating pressures:
    The permissible operating pressure should be observed in every case, including when commissioning, checking for leaks and filling the plant.

  - Permissible operating temperature:
    The maximum operating temperature for glass components is 200°C and this should be observed and where necessary, e.g. with electrical heating or exothermic reaction, ensured by the use of suitable measuring equipment.

  - Permissible thermal shock:
    Borosilicate glass can withstand thermal shocks up to 120 K. For plants operating at temperatures in excess of 120 °C, and which are not protected by insulation, the thermal shock limit could be exceeded by cold water sprayed onto the equipment by a sprinkler system. To avoid this, sprinkler heads should not be mounted in the vicinity of unprotected glass process plant. In the event of a fire high temperatures may arise which could also result in breakage of the glass.

- Extra loads, such as reaction forces on side branches, are not permissible. Bellows should be included in interconnecting pipework to ensure a stress-free connection to the glass plant.

- **Mechanical damage / protective measures:**
  The tubular structure supporting the equipment or plant also provides protection against damage from external sources and prevents other items coming into contact with it.

  Parts of the plant which are located outside the structure must be protected against mechanical damage.

Parts of the plant, which can reach a surface temperature higher than 60° C in operation and which are located outside the support structure, must be provided with protection against contact.

Additional safety devices are available in the form of safety screens, spray guards, coated and wrapped glass components (see section 1 of the catalogue, pages 1.11 and 1.12).

- **Damage to heat exchangers:**
  Should damage occur to the coil batteries in coil type heat exchangers or the heat exchange tubes in shell and tube heat exchangers, the service fluid and product can become mixed.

  Media, wich could react resulting in the generation of pressure and temperature (exothermic processes), should therefore be kept separate.