TECHNICAL SPECIFICATION

# GLASS-LINED STEEL EQUIPMENT AND PIPING

DEP 30.48.70.30-Gen.

July 1998

**DESIGN AND ENGINEERING PRACTICE**

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## APPENDICES

# 1. INTRODUCTION

## 1.1 SCOPE

This new DEP specifies requirements and gives recommendations for the manufacture, inspection and supply of equipment, ancillaries and piping components made of glass lined carbon steel.

Installation, operation and maintenance aspects are also included in the scope of this DEP.

## 1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

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This DEP is intended for use in chemical plants and, where applicable, in oil refineries and gas plants.

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

## 1.3 DEFINITIONS

### 1.3.1 General definitions

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

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

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

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

### 1.3.2 Specific definitions

Glass lining - the process of producing an intimately bonded glass layer onto a base material. In industrial applications, this is also known as "enamelling" and "vitreous enamelling".

## 1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets.

Other documents referenced by this DEP are listed in (11).

## 2. MATERIALS

2.1 BASE METAL

### 2.1.1 General

As glass lining properties are influenced by the chemical composition of the steel, special glass lining steel qualities have been developed in co-operation between glass lining and steel Manufacturers. Generally, fine-grained carbon steels are used.

Steels having a tensile strength of more than 480 MPa should not be glass-lined due to the increased risk of stress-induced glass lining failures at highly stressed areas.

### 2.1.2 Welding and welding materials

Welded equipment items shall be fully normalised before the glass lining process, in order to remove stresses that may cause deformation during the high temperature firing cycles of the glass lining process. Normal post-weld heat treatment (stress relieving) is not sufficient.

2.2 GLASS LINING

The glass lining shall consist of a number of subsequent layers, i.e. one or more ground coats to provide a good bond to the steel substrate and various top coats to provide the required chemical or mechanical resistance. The glass lining shall be applied by the wet spraying, wet pouring or dual spray/dust method. Powder dusting shall be limited to local patch-ups only.

The service life of glass linings in corrosive service is mainly determined by the thickness ratio of ground coat(s) to topcoats as only the latter are the real anti-corrosion barrier. Ground coat(s) shall, therefore, not constitute more than 40% of the total thickness and shall not be more than 0.6 mm in thickness.

The Principal shall indicate the type of chemicals and the intended service of the equipment or piping ordered.

The Manufacturer shall indicate and confirm the type, quality and properties of the glass linings applied for the specified service.

### 2.2.1 Chemical resistance requirements

2.2.1.1 Resistance to acids

A representative sample of the glass lining shall not show any porosity and the weight loss shall not be more than 0.50 $g/m^2$ per 24 h (approximately 0.08 mm/yr) at the condensate-facing surface after having been tested in accordance with ISO 2743. The absence of porosity after the test shall be verified with a high voltage direct current spark test set at 10 kV.

2.2.1.2 Resistance to alkalis

A representative sample of the glass lining shall not show any porosity and the weight loss shall not be more than 2.50 $g/m^2$ per 24 h (approximately 0.4 mm/yr) after having been tested in accordance with ISO 2745. The absence of porosity after the test shall be verified with a high voltage direct current spark test set at 10 kV.

2.2.1.3 Resistance to boiling water and water vapour

A representative sample of the glass lining shall not show any porosity and the weight loss shall not be more than 0.30 $g/m^2$ per 24 h in the vapour phase after having been tested in accordance with ISO 2744 The absence of porosity after the test shall be verified by a high voltage direct current spark test set at 10 kV.

2.2.1.4 Resistance to high temperature corrosion

Representative samples of the glass lining shall not show any porosity and the weight loss

shall not be more than 2.25 g/m$^2$ per 24 h after having been exposed to 20%wt HCl at 40 °C for 24 hours and not more than 3.00 g/m$^2$ per 24 h after having been exposed to 0.1 N NaOH at 140 °C for 24 hours in accordance with DIN 51174.The absence of porosity after the tests shall be verified by a high voltage direct current spark test set at 10 kV.

### 2.2.2 Physical properties requirements

2.2.2.1 Resistance to thermal shock

Representative samples of the glass lining shall be tested in accordance with DIN 51167. The crack formation limit shall be at least 210 °C.

2.2.2.2 Resistance to mechanical shock

Representative samples of the glass lining shall be tested in accordance with DIN 51155. The absorbed energy shall be at least 70 Nm.

2.2.2.3 Freedom from pores

Representative samples of the glass lining shall be tested in accordance with ISO 2746 or ASTM C 537. At the set test conditions, i.e. with a dry and clean glass lining surface and at ambient temperature (not higher than 30 °C) and a voltage of 20 kV, there shall be no indications of pores.

2.2.2.4 Lining thickness

Representative samples of the glass lining shall be tested in accordance with ISO 2808 and shall comply with (3.1.4.1).

### 2.2.3 Test requirements and results

Test samples shall be made fully in accordance with the normal manufacturing processes, i.e. with the same number and thickness of ground and cover coats, and the same firing temperatures and sequences.

NOTE: Firing temperatures and sequences may need adaptation to suit the metal mass.

Samples used in any of the above tests (2.2.1, 2.2.2) shall be visually inspected before being tested. They shall show a homogeneous glass lining structure and be free from inclusions (chamotte and iron oxide) or any defects.

### 2.2.4. Exceptions

Glass lining types solely intended for prevention of product build-up and/or product contamination shall be clearly distinguished by type indications (code numbers).

For such types, the Principal may consider an adapted test programme and/or less stringent test results.

For particular services (erosive, mechanical or thermal shock) and odd-shaped items, the use of semi-crystalline glass may be considered. The Manufacturer shall indicate his intentions to apply this and an adapted test programme shall be agreed between the Principal and the Manufacturer.

## 2.3 GASKETS

Gaskets shall be 100% bi-axially expanded PTFE with ultra-high molecular weight fine powder resin, without binders or fillers.

## 3. MANUFACTURE AND PRODUCTION TESTING

Production testing is the testing of glass-lined items on a specific order. Depending on the type, number, intended service and experience with the Manufacturer, the extent of production testing may be adapted by the Principal. This section deals with the requirements and execution which shall be employed during production testing.

## 3.1 GENERAL

### 3.1.1 Design

The design of items shall be in accordance with the purchase order unless they are Manufacturer's standard items, in which case the Manufacturer shall submit fully detailed descriptions and drawings for checking and approval by the Principal.

### 3.1.2 Glass materials

The Principal shall indicate in the enquiry the intended operating conditions with emphasis on chemical loading and pressure and temperature loading.

The Manufacturer shall confirm that the type(s) of glass selected are suitable for the application stated by the Principal.

Acceptance test records shall confirm that the type(s) fulfil all requirements of chemical and physical properties (see 2.2.1, 2.2.2 and 2.2.3).

### 3.1.3 Surface preparation

All welds shall be ground flush with the surrounding surfaces. All corners shall be rounded off and contour changes shall be smooth and generously dimensioned to minimize stressing of the glass lining.

Welds shall be thoroughly inspected and repaired where necessary after they have been ground flush with the surface to be lined. Steel items shall then be grit blasted to grade Sa 2½ according to ISO 8501-1 and visually inspected for defects. All surface defects (including slag or porosity that may have been exposed by grinding) shall be ground out and repaired by welding where necessary. The weld-repaired surfaces shall be ground flush with the surrounding material. Prior to glass lining the repaired steel items shall be grit blasted once again to grade Sa 2½. If there are any remnants from earlier production steps (drawing oil, turning/drilling oil or excessive scaling), the Manufacturer shall include an additional cleaning step, e.g. pickling or alkaline washing, before the final grit blasting.

### 3.1.4 Glass lining

#### 3.1.4.1 Thickness

Depending on type and application, the following thicknesses shall be applied.

- Amorphous types shall have a minimum thickness of 1.0 mm and a maximum thickness of 2.0 mm. For piping the minimum thickness shall be 0.8 mm and the maximum thickness 1.8 mm.
- Semi-crystalline types shall have a minimum thickness of 1.2 mm and a maximum thickness of 2.2 mm.
- For glass linings intended solely for the prevention of product build-up and/or product contamination, the minimum thickness may be 0.8 mm and the maximum thickness 1.4 mm, if so offered in the quotation and accepted in the order.
- For small glass-lined parts and/or parts of special shape such as pump impellers, sealing rings, valve stems etc. special arrangements shall be made and agreed upon in the order. The minimum thickness shall be 0.8 mm.

On flat and convex surfaces, there may be a local increase in the maximum thickness of up to 0.2 mm. On flat and concave surfaces, there may be a local a local decrease in the minimum thickness of up to 0.2 mm. Such variations shall be gradual, without abrupt steps.

On flange faces the thickness shall not vary by more than 0.2 mm per 10 mm measured length. Thicknesses and variations thereof on flange faces shall apply over the entire gasket contact area; a gradual decrease of thickness towards the outer edge is allowed outside the gasket contact area.

Thickness measurements shall be performed according to ISO 2808 with an apparatus with

5% accuracy or better. The apparatus shall be calibrated with reference plates of a thickness in the middle of the expected thickness range. Calibration shall be repeated whenever a separate measuring session is started.

3.1.4.2 Pores

The whole glass lined surface shall be inspected for defects with a high voltage direct current spark tester according to ISO 2746. During testing the glass lining shall be clean and dry and at ambient temperature (but not higher than 30 °C). The tester should be equipped with an audible warning simultaneous with a spark discharge.

Since spark testing at high voltages can damage the glass lining if repeated too often, it is the Manufacturer's responsibility to carry out and record the initial production testing. Testing after assembly shall then be carried out at lower voltage settings as shown in Table 1 (second test).

NOTE: Continuous corona sparks should be disregarded.

**Table 1 Voltages to be used for testing**

| TYPE OF EQUIPMENT | VOLTAGE TO BE USED | | |
|---|---|---|---|
| | AT MANUFACTURER'S WORKS | | AT SITE INSPECTION ON ARRIVAL |
| | FIRST TEST (after glass lining) | SECOND TEST (after assembly) | |
| Process equipment [1] Storage vessels | 20 kV | 12 kV | 4 - 7 kV |
| Polymerisation vessels [2] | [3] | [3] | [4] |
| Vessel internals Piping components Pump and valve bodies | 20 kV | 12 kV | 4 - 7 kV |
| Pump and valve internals Small items | 12 kV | 7 kV | 4 - 7 kV |
| Internals with built-in instrument cells | 5 kV | 5 kV | [5] |
| Internals with built-in pH measuring element | [6] | [6] | [6] |
| Machined surfaces | 7 kV | 7 kV | [4] |

NOTES
1. Including pressure storage vessels.
2. Glass-lined parts solely intended for prevention of product build-up and/or product contamination shall be tested as stated in the order.
3. Normally visual inspection. If spark testing is required this shall be stated in the order with the required voltages (12 and 7 kV respectively).
4. No spark testing required and visual inspection sufficient. However, if spark testing is specified in the order then site inspection at 4 - 7 kV.
5. No spark testing required and visual inspection sufficient. However, if spark testing is specified in the order then site inspection shall be performed at 2 kV.
6. No spark testing.

3.1.4.3 Cracks

If the presence of cracks is suspected, e.g. owing to mechanical or thermal stresses, *Statiflux* testing shall be performedand there shall be no cracks.

3.1.4.4 Visual appearance

The entire glass lining shall be inspected visually for defects as mentioned in Appendix 1. Strain lining is not allowed. Further acceptance criteria are given in (3.2.4) for equipment and (3.3.4) for piping. A 10-fold magnification visual aid and a monochromatic lamp may be used to confirm the presence of defects.

### 3.1.5 Tolerances on dimensions

The tolerances on dimensions after glass lining shall be as follows:

| Item | Tolerances |
|---|---|
| Vessels | DIN 28005 |
| Agitator vessels | DIN 28006 |
| Columns | DIN 28007 |
| Piping | Appendix 3 |

## 3.2 EQUIPMENT (VESSELS, REACTORS, COLUMNS ETC.)

### 3.2.1 General

In addition to the general requirements of 3.1, the following requirements also apply.

Nozzles shall be of the swaged type. Nozzles shall not be of the set-in or set-on type. Transitions in thickness of cylindrical parts shall be with a gradual slope, the slope being on the outside and the inside being flush.

If welds in steel items have to be examined by any non-destructive test method due to code requirements or the Principal's specification, this shall be done before grinding of welds and grit blasting.

It shall be demonstrated that the equipment has been given a separate normalising heat treatment after weld completion and before glass lining, this being a separate treatment and not part of any preceding hot forming operations.

### 3.2.2 Lining thickness

Lining thickness and variations shall be as specified in 3.1.4.1.

The surfaces to be checked shall be measured on a grid of width between 200 and 500 mm. Critical areas, such as short radii, transitions between unequal plate thicknesses, local changes of plate thicknesses (including external thickness changes such as for supports and reinforcements) and areas of possible high stresses, shall be measured separately on smaller grids.

Thickness on flange faces and on flange and nozzle curvatures shall be checked at regular distances and at different height levels, i.e.:

- for diameters 50 through 150 mm: at 6 points;
- for diameters over 150 mm: at equal distances of maximum 80 mm.

### 3.2.3 Freedom from pores

The entire glass lined surface shall be inspected for defects with voltages as given in 3.1.4.2.

A limited number of repairs may be made as shown in Table 2 and Table 3. Repairs shall be in accordance with Appendix 2. The Principal shall specify if no repairs are permitted (i.e. the item shall be specified to be “PLUG-FREE”).

**Table 2 Allowed number of shop-repaired spots in vessels and reactors**

| MAXIMUM NUMBER OF SHOP-REPAIRED SPOTS | | | | |
|---|---|---|---|---|
| NOMINAL VOLUME | VESSELS WITH SEPARATE COVER | | ONE-PIECE VESSELS | OTHER VESSELS |
| | VESSEL | COVER | | |
| up to 4 $m^3$ | 0 | 0 | 0 | 0 |
| 4 up to 10 $m^3$ | 1 | 1 | 1 | 1 |
| 10 up to 20 $m^3$ | N/A | N/A | 2 | 3 |
| 20 up to 32 $m^3$ | N/A | N/A | 3 | 4 |
| 32 up to 40 $m^3$ | N/A | N/A | 4 | 5 |
| 40 up to 80 $m^3$ | N/A | N/A | N/A | 6 |
| 80 $m^3$ and above | N/A | N/A | N/A | 7 |

NOTE: No repairs are allowed in:
- Nozzle flange faces, manhole and mounting cover faces.

- Nozzle necks.
- Nozzles with an inside diameter smaller than 150 mm.
- Vessel internals.

**Table 3 Allowed number of shop-repaired spots in columns**

| MAXIMUM NUMBER OF SHOP-REPAIRED SPOTS | | | |
|---|---|---|---|
| COLUMN DIAMETER | COLUMN HEIGHT | | |
| | up to 2000 mm | 2000 up to 5000 mm | 5000 mm and above |
| up to 600 mm | 0 | 0 | 0 |
| 600 up to 1200 mm | 0 | 1 | 2 |
| 1200 mm and above | 1 | 2 | 3 |

NOTE: No repairs are allowed in:
- Nozzle flange faces, manhole and mounting cover faces.
- Nozzle necks.
- Nozzles with an inside diameter smaller than 150 mm.
- Column internals.

### 3.2.4 Visual appearance

The lining shall be free of defects described in Appendix 1, some of which are repairable and some of which are not.

3.2.4.1 Unrepairable defects

Irrespective of the allowable number of repairs given in Table 2 and Table 3, the following shall be a reason for rejection or re-lining:

a) Defects which cannot be repaired by any method as indicated in Appendix 2, such as:
   - damage of a large surface area;
   - damage at an inaccessible location;
   - damage at a location where, owing to the geometry of the item, repair plugs cannot seal over their total circumference.

b) Spots where, after removal of inclusions, the lining thickness is less than the minimum allowable values.

c) Spots where, for removal of inclusions, the following grinding depths would be required:
   - 0.3 mm or more, if the remaining thickness would be 1.2 mm or less;
   - 0.5 mm or more, if the remaining thickness would be greater than 1.2 mm.

d) Spots where, after removal of inclusions by grinding and polishing, a repaired area remains with a diameter of 30 mm or larger.

e) Surfaces with:
   - line-shaped recessed glass lining
   - line-shaped series of blisters;
   - molten-in strain lines;
   - cracks;
   - not fully fused areas, recognisable by their rough corundum-like appearance;
   - deglassed areas (or over-crystallised areas in semi-crystalline types), recognisable by their dull and rough appearance;
   - boiled-up ground coat(s).

3.2.4.2 Repairable defects

The following defects may be repaired:

- defects revealed by high voltage spark testing;
- isolated spots showing a loss of thickness of more than 25% of the nominal thickness;
- spots with inclusions.

Inclusions may be chamotte and/or iron oxide inclusions. Chamotte particles shall always be removed; if the remaining glass lining structure is inhomogeneous it shall be rejected. Iron oxide particles shall be removed if:

- they are parallel to the surface and larger than 3 mm in any direction;
- they are clearly three-dimensionally shaped;
- they are not parallel to the surface.

If the remaining glass lining structure is inhomogeneous it shall be rejected. Repairs may be performed only within the limits of (3.2.4.1, b), c) and d)).

### 3.2.5 Tolerances on dimensions

Tolerances on dimensions shall be as specified in (3.1.5).

## 3.3 PIPING COMPONENTS

### 3.3.1 General

In addition to the general requirements of (3.1.3) the following requirements shall also apply. Changes of contour shall always be gradual and smooth. Transitions in thickness shall be with a gradual slope, the slope being on the outside and being flush on the inside. Transitions of cylindrical parts shall be straight and without steps.

If welds in steel piping items have to be examined by any non destructive test method, (according to code requirements or the Principal's specification) this shall be done before grinding of welds and grit blasting.

### 3.3.2 Lining thickness

Lining thicknesses and variations shall be as given in (3.1.4.1).

The surfaces to be checked shall be measured randomly as far as accessible. Critical areas such as short radii shall be measured more intensively or even continuously.

Thicknesses on flange faces as well as on flange and nozzle curvatures shall be checked at regular distances and at different height levels, i.e.:

- for nominal diameters through 150 mm at 6 points;
- for nominal diameters over 150 mm at distances of maximum 80 mm.

### 3.3.3 Absence of pores

The whole glass-lined surface shall be inspected for defects with voltages as given in 3.1.4.2. No defects which fail the spark test are allowed.

### 3.3.4 Visual appearance

The pipe shall be free of visual defects described in Appendix 1.

### 3.3.5 Tolerances on dimensions

Tolerances on dimensions shall be as specified in Appendix 3.

## 3.4 HYDROSTATIC TESTING

Assembled equipment items (vessels, reactors, columns but also pumps and valves) shall be hydrostatically tested at 1.1 times maximum operating pressure. During testing all internals and original covers shall be mounted. Further nozzles shall be blinded off with temporary blind flanges. The gasket types to be used for normal operation shall be used during testing.

For equipment items with various pressure-containing non-connected compartments (i.e. jacketed vessels or columns), these compartments should be hydrostatically tested individually at their respective code-derived hydrostatic test pressure. However, since jackets are mounted after the main body has been glass lined, the following distinction shall be made:

If the main body has been hydrostatically tested before glass lining:

- the jacket shall be tested at its applicable hydrostatic test pressure while the main body is not pressurised, provided such a condition may occur during actual operation,

or

- the jacket shall be tested at its applicable hydrostatic test pressure while the main body is pressurised at its normal working pressure.

If previous hydrostatic testing has not been done:

- both pressure containing compartments shall be hydraulically tested individually at their applicable hydrostatic test pressure;
- if during actual operation one compartment is at pressure and the other at vacuum, the differential pressure shall be used to establish the hydrostatic test pressure for both compartments.

NOTE: If the vacuum or sub-atmospheric pressure is not known exactly, the differential pressure may be set at the highest maximum working pressure plus 1 bar.

The equipment shall be emptied and dried after hydrostatic testing.

## 3.5 ROTATING EQUIPMENT

Deviation from true circular rotation of impeller shafts shall be measured in the assembled position. If a mechanical seal is applied, the deviation shall also be measured at the seal position and shall be 0.08 mm maximum.

If stated in the order, a running test of at least 6 hours with water shall be performed.

Impeller assemblies delivered as separate items shall be tested by the Manufacturer for deviation of true circular rotation while turning. A test report with result for that particular assembly shall be prepared and presented to the Principal's representative.

Pump impellers shall be spark tested and visually inspected.

## 4. INSPECTION BY THE PRINCIPAL

The Principal shall specify if, and to what extent, he wishes to witness the Manufacturer's inspection and testing.

## 5. PAINTING

The outside surfaces of equipment and piping shall be painted in accordance with DEP 30.48.00.31-Gen.

## 6. RECORDS AND CERTIFICATION

The Manufacturer shall maintain quality records to demonstrate that the necessary checks have been carried out at all stages of production.

The Manufacturer shall submit a certified record of inspection and testing together with certificates and a statement of compliance with this DEP. Measured numerical values shall be included in this record.

The record of inspection and testing shall at least give:

- name of the Manufacturer;
- item(s) and item description;
- ordering details (ordering number, ordering date);
- drawing number(s);
- type and extent of tests (intermediate, final, re-testing);
- result of visual inspection;
- result of high voltage spark testing;
- result of *Statiflux* testing (if applicable);
- result of glass lining thickness testing;
- sketch giving position and number of repair plugs;
- result of dimensional/tolerances testing;
- result of rotational tolerances testing;
- result of hydraulic pressure testing;
- result of compliance testing;
- testing date, name and signature of inspector(s).

## 7. TRANSPORT

### 7.1 SEALING, SUPPORTING AND PACKING

Nozzles of equipment shall be covered by rubber or plastic protectors of such thickness that the flange faces are adequately protected against impact damage, extending sufficiently over the flange edges to protect them also against side impact. Alternatively, nozzles may be covered by wooden protectors, provided a soft layer is put in between to protect the glass lining and they extend far enough over the edges to protect against side impact.

Vessel internals, particularly impeller assemblies, shall be supported by wooden structures, using soft materials to protect the glass lining at contact points. The supporting structures shall be properly mounted and not mechanically forced into the vessels.

Piping items shall be protected by transporting them in crates. They shall be properly secured against moving in the crates and be separated by shock absorbing material.

Glass-lined items and/or crates containing glass-lined items shall clearly indicate the nature of the items or contents with warnings about the risk of breakage. Holding points for crane hooks and straps shall also be clearly indicated.

### 7.2 ANTI-CORROSION PROTECTION

Uncoated metal faces and/or machined metal faces shall be suitably protected against corrosion.

Jackets and half-coils shall be sealed off before transport. They should also be protected by a vapour phase inhibitor if long transport and/or storage times are envisaged.

### 7.3 ARRIVAL INSPECTION

After arrival on site and before being unloaded, the equipment shall be visually inspected and spark tested by the Principal as specified in (3). Inspection results shall be recorded by the Principal.

Any defects shall be reported to the Manufacturer.

Utmost care shall be taken during inspection, storage and installation to prevent damage to the glass lining, especially by personnel entering equipment or handling piping systems.

After being installed and before being put into operation, equipment and piping should again be visually inspected as far as possible (precommisioning inspection).

Presence of the Manufacturer's representative(s) at any of these inspections shall be agreed before and stated in the order.

## 8. INSTALLATION

### 8.1 GENERAL

During the installation of glass-lined equipment and piping, utmost care should be taken to avoid damage to the glass lining. Equipment should be handled with the nozzle covers in place.

### 8.2 LIFTING

For new equipment the lifting plan provided by the Manufacturer should be followed.

Glass-lined equipment should be lifted using slings and ropes rather than chains. Ensure that adequate hooks are used and that they do not lever on the equipment surface. Vessels should be lifted using two cranes, each one capable of handling the full load, with the bottom lifting lugs used as tailing lugs. Bail bars should be used whenever possible.

Equipment should be lifted by the lifting lugs only, unless a vessel is delivered in the horizontal position whereby the lifting lugs are not in the horizontal plane. In that case the vessel should be lifted using slings around the cylindrical part of the shell.

**Under no circumstances shall lifting tackle be slung around the nozzles of the glass-lined shell or jacket.**

When rested in a horizontal position a vessel shall not be rotated by applying direct leverage to the shell.

### 8.3 MARKING

For identification purposes and to prevent damage all glass-lined items should be clearly and permanently marked on the outside:

*“GLASS-LINED, HANDLE WITH CARE”*

### 8.4 STORAGE

On-site storage of glass-lined equipment should be done in a clean location away from traffic, and packed in accordance with (7.1 and 7.2).

### 8.5 LEVELLING

For agitator vessels it is particularly important to ensure that the vessel is in a vertical position. The alignment should be checked using a spirit level on the agitator shaft between gear box and mechanical seal, and corrections to the vessel should be made as required.

### 8.6 CONNECTIONS

On factory-assembled vessels the main flange gaskets, agitator flange gasket and manway gaskets are tailor made and shall be replaced **in exactly the same position after disassembly.**

Clamped connections shall be assembled with the correct number of clamps and tightened in accordance with the Manufacturer’s specifications.

Bolted connections shall be tightened in accordance with the Manufacturer’s specifications.

The absence of flange misalignment shall be confirmed before connecting pipework to the equipment.

Jackets may have circulating agitating nozzles to improve the effectiveness of liquid heat transfer. Assemble jacket circulating or agitating nozzles in the proper direction as advised by the Manufacturer, e.g. assemble to give a clockwise flow direction around the jacket.

## 8.7 INSPECTION

After installation the vessel should be inspected visually for damages. See (10.1) for notes on vessel entry.

In agitated vessels all supports for baffles and agitator should be removed. Turn agitator by hand to make sure it is free, and to verify it has not been bent during moving or handling.

## 9. OPERATION

### 9.1 START UP

After the first temperature cycle all screwed connections shall be tightened to the torque specified by the Manufacturer.

### 9.2 THERMAL SHOCK

During operation the temperature of equipment and piping shall be kept within the Manufacturer's guaranteed thermal shock limits in order to protect the glass lining from thermal shock damage.

### 9.3 ACID SPILLS

Severe damage may be caused to glass-lined equipment if acid is spilled on the external surfaces. Acid spills cause a reaction with the steel which produces atomic hydrogen, which can penetrate through the vessel wall and cause the glass lining to be spalled off the steel surface.

**Every precaution should taken to avoid acid spills, e.g. flange leaks. Should an acid spill occur the affected area shall be flushed immediately with water.**

### 9.4 ELECTROSTATIC DISCHARGE

Materials with electrical relaxation times exceeding 0.1 s (e.g. solvents, pure or mixed with other liquids, solids and/or vapour phases) may lead to electrostatic discharge within the liquid, between the liquid and vapour, or between the liquid and the vessel wall or accessories. Static sparking can damage the glass lining. If possible, during operation the occurence of electrostatic sparking should be monitored in order to judge whether an early inspection shutdown is necessary.

### 9.5 STEAM HAMMER

The injection of hot steam into cold liquids can cause damage in the glass lining when rapid condensation (implosion) and subsequent shock waves occur. This phenomenon should be avoided through the use of proper mixing devices so that the steam is condensed before it enters the vessel.

## 10. MAINTENANCE

### 10.1 VESSEL ENTRY

Before dismantling the manway flange note the exact position of the gasket in relation to the flange, in order to replace it in exactly the same position. (The gasket may have been shimmed at the works). The manhole should be protected with plain adhesive tape so that it will not be scratched on entry. If it is necessary to use a ladder inside a glass-lined vessel, it should be ensured that it has suitably cushioned feet to prevent damage to the lining (cardboard is not suitable), and that a rubber mat or suitable other covering is laid in the place of work. Do not climb on the agitator or baffles!

Those who enter the vessel should wear clean, rubber-soled and heeled footwear and these should be put on only at the manway.

Glass lining is easily damaged by dropping tools, so rubber-covered inspection tools, secured against dropping, should be used wherever possible.

### 10.2 INSPECTION

Condition monitoring of glass-lined equipment is done primarily by visual inspection. A 10x magnifier and a monochromatic lamp may be used to confirm the presence of defects. Visual inspection may be supplemented by spark testing, with a voltage setting not greater than 7 kV.

If crack-like defects are suspected *Statiflux* testing should be performed.

### 10.3 REPAIRS

Any glass lining damage, however small, should be repaired as soon as possible. Tantalum repairs will ensure maximum dependability. All repairs shall be inspected during inspection shutdowns.

Repairs should be carried out as described in Appendix 2, in consultation with the Manufacturer.

If field repair is impractical it may still be possible to save a large part of the original equipment by having the entire unit reglassed. Equipment with through thickness holes may be salvaged by cutting out the damaged section and repair welding.

Reglassing is required if the location of damage makes effective repair impossible, or if the damaged area is too large.

### 10.4 WELDING

As a general rule, welding and flame cutting is not possible on glass-lined parts or in their immediate proximity. The Manufacturer should be contacted before attempting such work.

### 10.5 CLEANING OF THE JACKET SPACE

Heating or cooling media used in the jacket may cause a gradual build-up of rust or scale deposits that can hinder heat transfer. Acid scale and rust removing agents in the jacket of the glass-lined vessel endanger the glass lining due to hydrogen diffusing into or through the steel. Only those cleaning agents that passivate the steel surface and prevent the absorption of nascent hydrogen in the steel may be used. Alkaline cleaning agents which dissolve rust and scale by forming complex compounds may be freely used.

## 11. REFERENCES

In this DEP reference is made to the following publications:

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

**SHELL STANDARDS**

| | |
|---|---|
| Index to DEP publications and standard specifications | DEP 00.00.05.05-Gen. |
| Painting and coating of new equipment | DEP 30.48.00.31-Gen. |

**INTERNATIONAL STANDARDS**

| | |
|---|---|
| Vitreous and porcelain enamels - Determination of resistance to condensing hydrochloric acid vapour | ISO 2743 |
| Vitreous and porcelain enamels - Determination of resistance to boiling water and water vapour | ISO 2744 |
| Vitreous and porcelain enamels - Determination of resistance to hot sodium hydroxide | ISO 2745 |
| Vitreous and porcelain enamels - Enamelled articles for service under highly corrosive conditions - high voltage test | ISO 2746 |
| Paints and varnishes - Determination of film thickness | ISO 2808 |
| Preparation of steel substrates before application of paints and related products - Visual assessment of surface cleanliness - Part 1: Rust grades and preparation grades of uncoated steel substrates and steel substrates after overall removal of previous coatings. | ISO 8501-1 |

*Issued by:*
*International Organisation for Standardisation*
*1 Rue de Varembé*
*CH-1211 Geneva 20*
*Switzerland.*
*Copies may also be obtained through the national standards organisation.*

**GERMAN STANDARDS**

| | |
|---|---|
| Flanged pipes and flanged steel fittings enamelled, PN 10 and 16 | DIN 2873 |
| Flanged steel pipes and flanged steel fittings glass lined; technical delivery conditions | DIN 2876 |
| General tolerances for glass lined vessel | DIN 28005 |
| General tolerances for fabrication of agitator vessels, glass lined steel agitator vessels | DIN 28006 |
| General tolerances for columns, glass lined steel columns | DIN 28007 |
| Testing of vitreous and porcelain enamels; impact test | DIN 51155 |
| Determination of the crack formation temperature resulting from a thermal shock in enamels for the chemical industry | DIN 51167 |
| Testing of vitreous and porcelain enamels; corrosion tests in closed systems | DIN 51174 |

*Issued by:*

*Beuth Verlag GmbH*
*Burggrafenstrasze 4 - 10*
*D-1000 Berlin 30*
*Germany*

**AMERICAN STANDARDS**

| | |
|---|---|
| Standard test method for reliability of glass coatings on glassed steel reaction equipment by high voltage | ASTM C 537 |

*Issued by*
*American Society for Testing and Materials*
*1916 Race Street Philadelphia*
*PA 19103 -1187*
*USA*

## APPENDIX 1 GLASS LINING DEFECTS

### 1. GENERAL

A summary of the most commonly recognised defects is given below. In a modern, well-controlled glass lining process hardly any of these defects should occur. To assist in recognising repairable defects, they are marked * for repairable and ** for non-repairable.

### 2. FINAL STAGE DEFECTS

2.1 BLISTERING*

A bubble-like appearance on the surface of the material, the bubbles ranging in size from about 1.5 mm to over 6 mm in diameter, generally as a result of gas evolution from molten material.

2.2 CHIPPING*

Fracturing or breaking away of fragments of the material, usually due to excessive lining thickness or sharp convex corners.

2.3 CRACKS**

2.4 DIMPLING*

Dimples, sometimes with black specks in the centre, caused by improper slurry composition or contamination. A dimple may also be a burst blister which has not completely been covered by subsequent coat(s).

2.5 FISH SCALING**

Small, half-moon shaped fractures, detaching them selves from the material, largely due to gas development from the substrate and originating from the ground coat. This defect may show up considerable time after an item has been glass lined.

2.6 GLASS EYE**

Large, unbroken blisters in a finished glass lining.

2.7 ORANGE PEEL*

Characteristic uneven surface of a glass lining indicating processing faults.

2.8 REBOILING**

Small, black spots in a fused cover coat due to small gas entrapments or to contaminants in the slurry.

2.9 SCUMMING**

Dull or cloudy appearance of a fused glass lining due to faults in the composition or due to (sulphate) contaminants when firing is done in a gas fired oven.

2.10 SHORE LINING**

A series of parallel, wavy lines or shallow grooves in the surface of a cover coat, due to too rapid drying.

2.11 SPALLING**

Failures of glass lining due to internal stresses, usually characterised by slivers of material breaking away with a conchoidal type of fracture. Also referred to as flaking-off, shaling or flying.

2.12 STRAIN LINING**

A series of parallel, thin, dark lines visible in a fused cover coat due to exposure of ground coat. When the underlying cover coat is shining through the lines will be of a light colour. They arise at areas where for some reason stresses are exerted on an "unfinished" glass lining, particularly during cooling.

2.13 TEARING**

A layer of cover coat breaking up during fusion and giving a discontinuous surface, showing the ground coat through it, caused by faulty slurry composition or drying too rapidly.

## APPENDIX 2 REPAIR METHODS

### 1. GENERAL

Various repair methods are available, i.e.:

a) Repair plug, single piece, materials see below;
b) Repair plug, three piece, materials see below;
c) Repair plate;
d) Repair sleeve, tantalum, filled phenolic resin, fluorocarbon-type polymer;
e) Repair screw or plug, materials see below;
f) Repair cement.

The single piece repair plugs (a) may be applied by the Manufacturer without prior consultation but only within the limits as mentioned in (3.2.3). Normally, such repair plugs will be made of tantalum. However, due to the limitations mentioned under 2 below, plugs made of platinum/iridium may also be considered. Only after consultation with the Principal may it be decided to use plugs (e) to repair sealing faces of flanges and covers or for short radii of nozzle necks. For this particular type of repair (e) screws made of platinum/iridium may also be considered.

NOTE: The repair methods b, c, d and f mentioned above are on-site repair methods for existing equipment, normally not applicable to new equipment.

### 2. LIMITATIONS

Tantalum plugs (1a) shall not be used if atomic hydrogen may be present, if sulphuric acid in concentrations above 96% weight may be present or if metal inserts of metals other than tantalum in an electrolytically conductive medium are present.

Furthermore, the metal wall temperature at the location of any plug should not exceed 200 °C as cold flow of the PTFE sealing ring will lead to leakage over time.

PTFE for sealing rings shall be virgin, unfilled PTFE. Because cold flow of the PTFE sealing ring may also occur at wall temperatures below 200 °C, proper tightening and re-tightening of the tantalum plug is essential.

The Manufacturer shall specify the tightening and re-tightening torques.

Gold plugs (1e) cannot normally be used at temperatures above 100 °C, except on flange faces.

### 3. APPLICATION

A plug (1a) may be used to repair damage smaller than 7 mm in diameter, provided it can be applied perpendicular to the surface and forms a reliable seal around the whole of its circumference.

The Manufacturer shall prepare a situation sketch indicating the location of the plug(s). The minimum distance between 2 plugs shall be 100 mm. The Manufacturer shall state the applied torque on the sketch.

### 4. EXAMPLES

Examples of the most generally applied shapes and dimensions are given in Figures 2.1 through 2.3.

**FIGURE 2.1 SINGLE PIECE PLUGS**

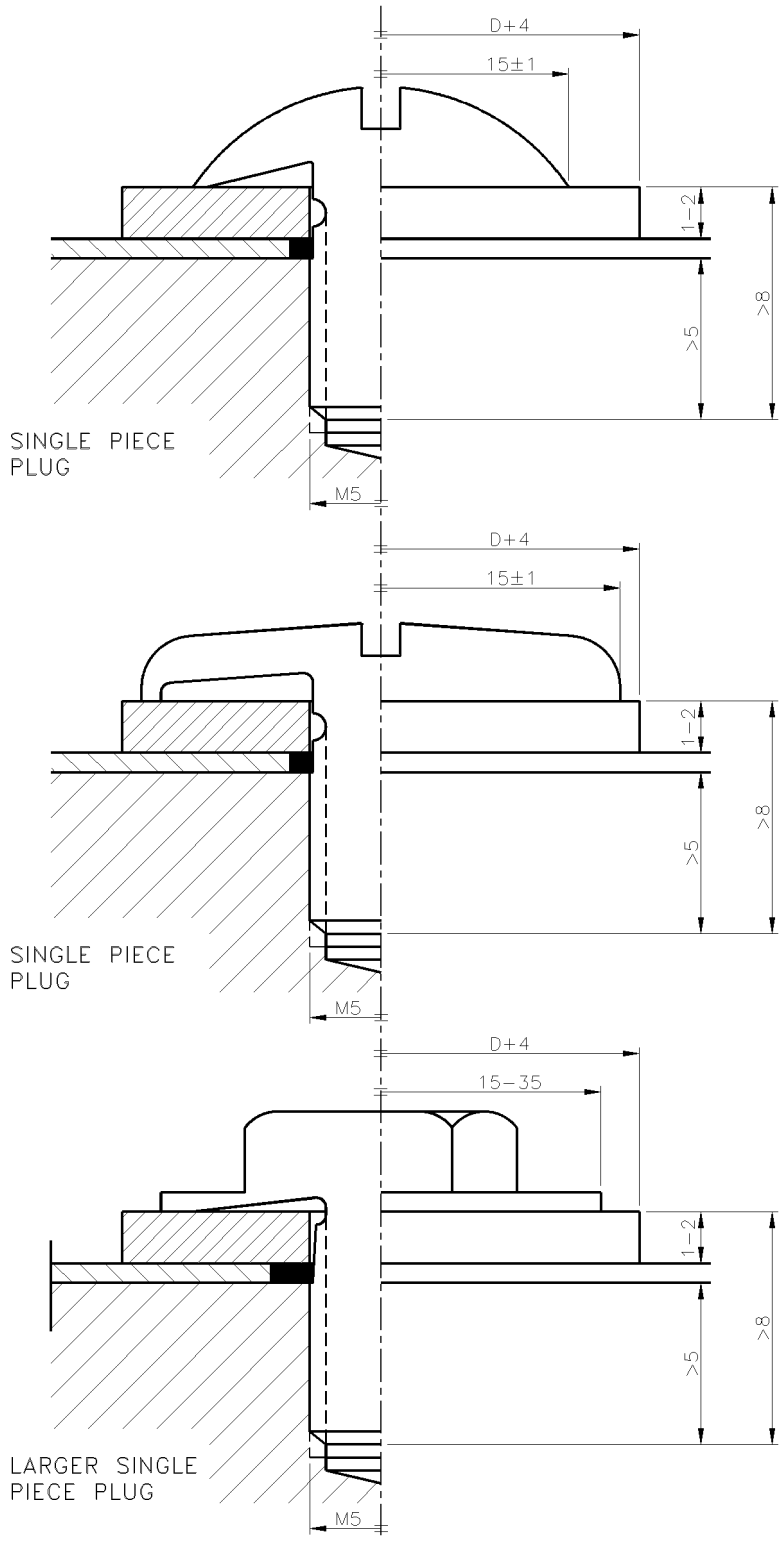


**FIGURE 2.2 THREE PIECE PLUG**

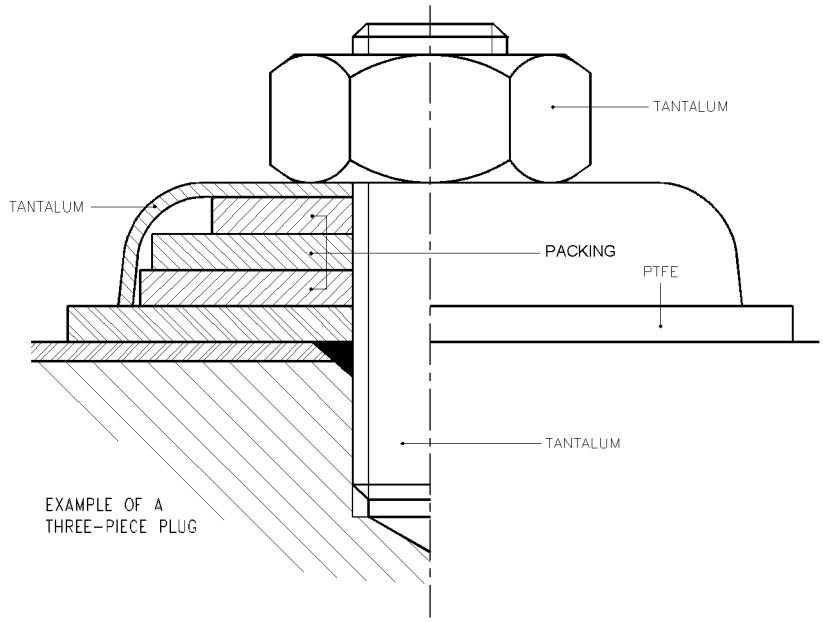
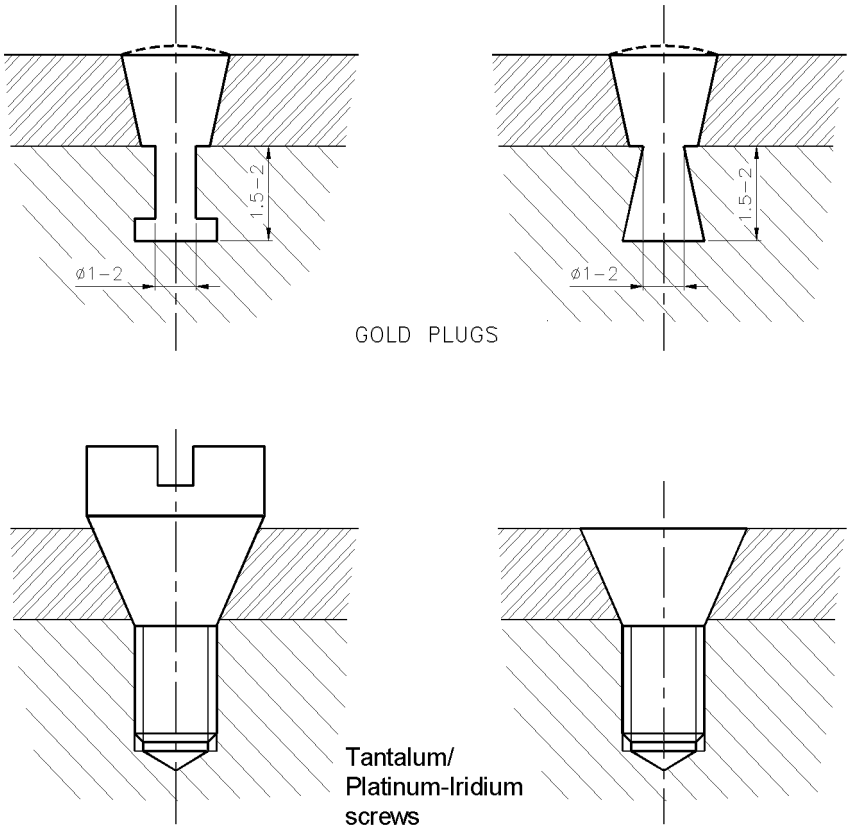



**FIGURE 2.3 SMALL PLUGS AND SCREWS**



## APPENDIX 3 DIMENSIONAL TOLERANCES FOR PIPING

### 1. PIPES

1.1 FLANGE ALIGNMENT

The flange face shall be perpendicular to the axis of the pipe, with a maximum deviation of:

| Nominal diameter (mm) | Maximum deviation (mm) |
|---|---|
| ≤ 50 | 0.8 |
| 65 to ≤ 100 | 0.9 |
| 125 and 150 | 1.0 |
| 200 and 250 | 1.0 |
| > 250 | 1.5 |

1.2 STRAIGHTNESS

The maximum allowable deviation for pipe straightness shall be 1.25 mm per 1000 mm length.

1.3 FLATNESS OF FLANGE FACE

The maximum allowable deviation between any two points shall be:

| Nominal diameter (mm) | Maximum deviation (mm) |
|---|---|
| ≤ 50 | 1.5 |
| 65 to ≤ 100 | 1.5 |
| 125 and 150 | 1.5 |
| 200 and 250 | 2 |
| > 250 | 3 |

1.4 LENGTH

The overall length shall have the following tolerances:

| Length (mm) | Tolerance (mm) |
|---|---|
| ≤ 120 | + 0 / - 3 |
| > 120 to ≤ 315 | + 0 / - 3 |
| > 315 to ≤ 1000 | + 0 / - 4 |
| > 1000 to ≤ 1500 | + 0 / - 5 |
| > 1500 to ≤ 2000 | + 0 / - 6 |
| > 2000 to 3000 | + 0 / - 7 |

## 2. FITTINGS

### 2.1 FLANGE ALIGNMENT

The flange face shall be perpendicular to the axis of the pipe, with a maximum deviation of:

| Nominal diameter (mm) | Maximum deviation (mm) |
|---|---|
| ≤ 50 | 0.8 |
| 65 to ≤ 100 | 0.9 |
| 125 and 150 | 1.0 |
| 200 and 250 | 1.0 |
| > 250 | 1.5 |

### 2.2 STRAIGHTNESS

The maximum allowable deviation in straightness of individual legs shall be 0.5 mm per 100 mm length.

### 2.3 FLATNESS OF FLANGE FACE

The maximum allowable deviation between any two points shall be:

| Nominal diameter (mm) | Tolerance (mm) |
|---|---|
| ≤ 50 | 1.5 |
| 65 ≤ 100 | 1.5 |
| 125 and 150 | 1.5 |
| 200 and 250 | 2 |
| > 250 | 3 |

### 2.4 LENGTH

The length of the individual legs etc. shall have the following tolerances:

| Nominal diameter (mm) | Tolerance (mm) |
|---|---|
| ≤ 50 | + 0 / - 3 |
| 65 to ≤ 100 | + 0 / - 3 |
| 125 and 250 | + 0 / - 4 |
| > 250 | + 0 / - 4 |

### 2.5 ALIGNMENT

Bends and elbows shall not deviate from the specified angle by more than 1 degree.