

TECHNICAL SPECIFICATION

PTFE BELLOWS

DEP 31.38.82.31-Gen.

September 2002

DESIGN AND ENGINEERING PRACTICE



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TABLE OF CONTENTS

1.	INTRODUCTION	4
1.1	SCOPE.....	4
1.2	DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS	4
1.3	DEFINITIONS	4
1.4	CROSS-REFERENCES	4
1.5	SUMMARY OF CHANGES SINCE PREVIOUS EDITION	5
2.	MATERIALS	6
2.1	PTFE MEMBRANE	6
2.2	METALLIC COMPONENTS.....	6
2.3	GASKETS	6
3.	DESIGN	7
3.1	GENERAL	7
3.2	MANUFACTURER	7
3.3	DESIGN DETAILS	7
3.4	FIELD OF APPLICATION	8
4.	MANUFACTURING	9
4.1	PTFE MEMBRANE	9
4.2	METALLIC COMPONENTS.....	9
4.3	DIMENSIONS	9
5.	QUALIFICATION PROGRAMME	10
5.1	PRODUCT FAMILY AND PRODUCT FAMILY REPRESENTATIVE	10
5.2	TESTING.....	10
6.	QUALITY PROGRAMME	12
6.1	GENERAL	12
6.2	QUALITY CONTROL EQUIPMENT	12
6.3	PTFE MATERIAL	12
6.4	PTFE BELLOWS	12
6.5	DOCUMENTATION	13
6.6	MARKING	13
7.	INSTALLATION	14
7.1	GENERAL	14
7.2	APPLICATION OF INTERNAL SLEEVES.....	14
7.3	HAZARDS	14
8.	PACKAGING	15
9.	REFERENCES	16

1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for the materials, manufacture, qualification, testing and inspection of polytetrafluoroethylene (PTFE) bellows. It is a revision of an earlier DEP with the same number and title, dated October 1995. A summary of changes to the DEP is listed in (1.5).

This DEP covers full PTFE and PTFE-lined metallic bellows with one or more convolutions and nominal diameters ranging from DN 25 to DN 500. Operating temperature is typically between -30 °C and 230 °C and pressures up to 14 bar maximum. Vacuum condition is possible only to a limited extent.

Within the scope of this DEP, not all aspects of PTFE bellows can be standardized because of the existing differences in design and manufacturing methods.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

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

This DEP is intended for use in oil refineries, gas plants, chemical plants, oil and gas production facilities and supply/marketing installations.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP the Contractor shall determine by careful scrutiny which of the requirements are 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

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

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

The **Principal** is the party that 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.

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced in this DEP are listed in (9).

1.5 SUMMARY OF CHANGES SINCE PREVIOUS EDITION

The previous edition of this DEP was dated October 1995. Other than editorial changes, the following are the main changes since that edition:

Old section	New section	Change
1.1	1.1	Revised range of applicable nominal diameters and operating temperatures
2.1	2.1	Added requirements for mechanical properties and specific gravity
3.2	3.3	Added design details
	3.4	Added experience envelope
4	7	Renumbered and added sections on internal sleeves and hazards
5 & 6	5.1	Added concept of product family and product family representative
5 & 6	5.2	Added high temp., low temp., vacuum and re-qualification
	6.6	Added section on marking
7	5 & 6	Requirements now defined in 5 and 6
Appendix 1		Deleted
Appendix 2		Deleted
Appendix 3		Deleted
Appendix 4		Deleted - table moved to 4.3.2

2. MATERIALS

2.1 PTFE MEMBRANE

2.1.1 Grade

Only virgin PTFE conforming to ASTM D 1457, Type I, III and IV, without any addition of pigments shall be used for the production of PTFE bellows.

The material shall be compatible, over the full design temperature range, with the fluid being contained.

2.1.2 Tensile property

The minimum tensile strength of PTFE material, specified in (2.1.1) and tested according to ASTM D 638, shall be:

Manufacturing Technique	Minimum Tensile Strength at Break (MPa)	Minimum Elongation at Break (%)
Extruded or moulded	26.0	275
Paste extruded - extruded direction - transverse direction	26.0 21.7	275 220

2.1.3 Density

Specific gravity for PTFE material, specified in (2.1.1) and tested in accordance with ASTM D 792, shall be:

- Types I and IV – specific gravity: 2,140 kg/m³ to 2,190 kg/m³;
- Type III – specific gravity: 2,130 kg/m³ to 2,210 kg/m³.

2.2 METALLIC COMPONENTS

Metallic materials shall be:

Component	Material	
Flanges	In accordance with DEP 31.38.01.12-Gen.	
Reinforcing rings	Stainless steel	ASTM A 276 - type 316L
	Monel	ASTM B 164-A, class A
Limit rods	Carbon steel	ASTM A 307-B
Metallic bellows (PTFE lined)	Stainless steel	ASTM A 240 - type 321 or 316L

Environmental and/or service conditions may require different metal specifications, e.g., if there is a risk of stress corrosion, and a Materials/Corrosion Engineer shall be consulted.

2.3 GASKETS

Expanded polytetrafluoroethylene (ePTFE) type gaskets should be used for connections to other type of materials, e.g., metallic flange, glass, enamel, etc.

3. DESIGN

3.1 GENERAL

Within the limits of their design, PTFE bellows are able to accommodate displacements in piping systems in axial, lateral and angular directions, and they also act as vibration absorbers. Not all aspects of PTFE bellows are standardized in this DEP because of differences in design and manufacturing methods.

3.2 MANUFACTURER

The Manufacturer shall prove to the Principal that he has sufficient experience in the design and manufacturing of PTFE bellows. The Manufacturer shall check the quality of the materials used for the PTFE bellows. The Manufacturer shall also provide samples for qualification testing, if requested by the Principal.

3.3 DESIGN DETAILS

The Manufacturer shall state the allowable operating conditions, i.e., maximum pressure versus temperature (PT-graph), vacuum resistance, and allowable axial, lateral and angular displacement.

To restrict bellows deformation within the allowable limits, PTFE bellows shall be equipped with limit rods, especially needed during the installation phase.

PTFE bellows with nominal diameters between DN 25 and DN 500, and operating temperatures between $-30\text{ }^{\circ}\text{C}$ and $230\text{ }^{\circ}\text{C}$, are typically designed within the following ranges:

Number of convolutions	Distance between flanges (mm)	Axial +/- movement (mm)	Lateral movement (mm)	Angular rotation (degree)	Operating Pressure (bar)
2	30 to 150	5 to 20	5 to 10	5 to 10	< 14
3	40 to 160	15 to 30	6 to 15	10 to 20	< 10
5	70 to 250	15 to 35	15 to 20	20 to 30	< 6

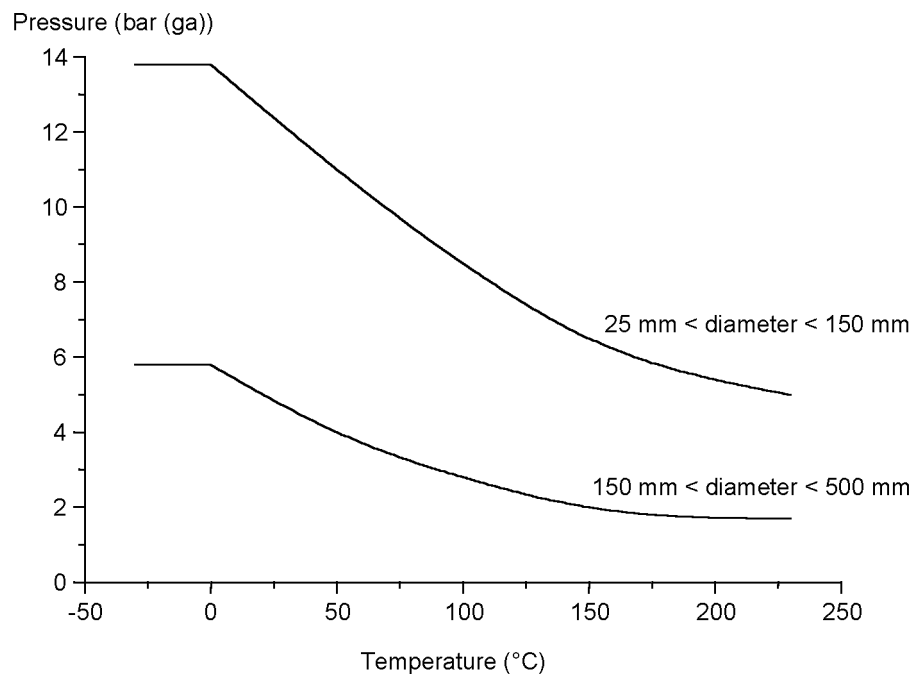
PTFE bellows shall not be designed to accommodate any torsion loads.

3.4 FIELD OF APPLICATION

PTFE bellows are typically used in piping systems within chemical plants and refineries, transporting corrosive fluids.

The current experience envelope of PTFE bellows is illustrated in Figure 1.

Figure 1 Current Experience Envelope of PTFE Bellows



4. MANUFACTURING

4.1 PTFE MEMBRANE

Unless otherwise agreed by the Principal, the flexible PTFE membrane shall be fabricated by one of the following processes:

- ram extrusion;
- isostatic moulding;
- paste extrusion.

4.2 METALLIC COMPONENTS

Flanges shall meet the requirements of DEP 31.38.01.12-Gen. Surfaces contacting the PTFE shall be clean and free of rust, scale, or other protrusions, which may adversely affect the integrity or performance of the PTFE.

To reduce stress concentrations in the PTFE material as it is flared over the metallic flange face, the flange edges shall be manufactured to provide a minimum chamfer radius of 3 mm.

Limit rods shall not restrict the specified angular, lateral and axial displacements.

PTFE-lined metal bellows shall be provided with a venting system that will release any pressure built up between the PTFE lining and the steel, i.e., vent holes shall allow escape of permeating gas and also serve as leakage indicators.

Carbon steel flanges and low alloy steel flanges should be shop-painted with one coat of zinc-rich epoxy resin based primer. Stainless steel flanges shall not be painted with zinc-containing paints. Painting shall comply with DEP 30.48.00.31-Gen.

4.3 DIMENSIONS

4.3.1 General

The general arrangement and overall dimensions shall be in accordance with the purchase order and approved drawings. The outside diameter and hole spacing of flanges shall meet the requirements of ASME B 16.5.

4.3.2 PTFE membrane

The wall thickness in any part of the PTFE membrane shall be nowhere less than that specified by the Manufacturer, and local variations shall be not greater than 10 % of the average thickness. The allowable minimum specified thickness values shall be:

Nominal diameter (DN)	Minimum thickness (mm)
25	3
40	3
50	3.5
80	3.5
100	4
150	4
200	4.5
250	5
300	5
350	5
400	6
500	6

5. QUALIFICATION PROGRAMME

5.1 PRODUCT FAMILY AND PRODUCT FAMILY REPRESENTATIVE

5.1.1 General

The qualification programme consists of tests for quantifying bellows performance with respect to internal pressure, vacuum resistance, displacements, temperature, and cyclic pressure performance.

All tests shall be carried out, or witnessed and certified by an independent third party approved by the Principal. The qualification shall be documented in a qualification report.

In order to keep the total test burden within acceptable limits, the concept of a product family and family representative is used.

The definitions **product family** and **product family representative** are used in order to rationalize the requirements for qualification testing.

5.1.2 Product family

For PTFE bellows, the **product family** is defined as:

- 2-Convolute PTFE bellows;
- 3-Convolute PTFE bellows;
- 5-Convolute PTFE bellows;
- Other.

5.1.3 Product family representative

The **product family representative** is the bellows that is taken to be representative of that particular product family, e.g., DN 100, 3-Convolute PTFE bellows.

5.2 TESTING

5.2.1 Short-term burst test

The short-time hydraulic pressure strength of the PTFE bellows shall be determined by burst testing two replicate samples of the product family representative. Testing shall be performed at the Manufacturer's specified minimum and maximum operating temperature. The pressure to produce failure shall be applied gradually, and at such a rate that failure occurs within 5 min.

The short-term pressure strength of the qualified bellows shall be taken as 85 % of the lower burst pressure of two replicate samples.

5.2.2 Cycle test

To demonstrate the ability of PTFE bellows to withstand cyclic loading, two replicate samples of the product family representative shall be subjected to 100,000 cycles at a maximum of 10 cycles per minute, at their maximum specified axial extension, or at a combination of maximum axial and lateral extension. Testing shall be performed at the Manufacturer's specified minimum and maximum operating temperature. A total of 100,000 cycles shall be completed without any signs of damage (6.4.1).

5.2.3 High Temperature test

To demonstrate the ability of PTFE bellows to withstand heat ageing, two replicate samples of the product family representative shall be tested at a temperature of 230 °C for 48 h. After cooling down to ambient temperature, the PTFE membrane shall not show any signs of damage (6.4.1).

5.2.4 Low Temperature test

To demonstrate the ability of PTFE bellows to withstand low temperature, two replicate samples of the product family shall be tested at a temperature of -30°C for 48 h. After warming up to ambient temperature, the PTFE membrane shall not show any signs of damage (6.4.1).

5.2.5 Vacuum testing

To demonstrate the ability of PTFE bellows to withstand vacuum loading, two replicate samples of each product family shall be vacuum tested. Testing shall be performed at the Manufacturer's specified minimum and maximum operating temperature. The short-term vacuum resistance of the qualified bellows shall be taken as 85 % of the lower collapse pressure of two replicate samples.

5.2.6 Requalification

Changes to a bellows by an amount beyond that agreed with the Principal shall invalidate the bellows' previous qualification. Examples of changes in the bellows design requiring re-qualification are defined in Table 1:

Table 1 – Changes in bellows design, requiring requalification:

PTFE membrane	- Type of PTFE - PTFE manufacturing technique
Reinforcing rings	- Material type - Thickness
Design	- Geometry and dimensions of bellows - Thickness of PTFE membrane - Number of convolutions
Manufacturing plant	- Transfer of manufacture of qualified product from one plant to another

6. QUALITY PROGRAMME

6.1 GENERAL

The bellows Manufacturer shall have a suitable and accredited quality assurance system.

The Manufacturer shall identify manufacturing processes and activities that affect bellows performance and shall ensure that these processes and activities are adequately controlled. Critical processes or activities for which procedures should be developed and maintained include, but are not limited to, the following:

- raw material acceptance;
- raw material storage;
- bellows manufacturing;
- training and certification of workforce personnel;
- training and certification of inspectors;
- marking, packing, handling and transportation.

6.2 QUALITY CONTROL EQUIPMENT

All inspection, measuring, and testing equipment shall be maintained and calibrated.

Test pressure measuring devices shall be either pressure gauges or pressure transducers with a full-scale range of no more than two times the test pressure and shall be accurate to at least ± 0.5 % of full-scale range. A dead weight testing device shall be available at the Manufacturer's facility to calibrate gauges. All pressure measuring devices shall be calibrated with a dead weight pressure tester or other suitable device, every six months.

6.3 PTFE MATERIAL

6.3.1 PTFE Grade

The grade of the PTFE (2.1.1) used for the manufacture of the flexible membrane shall be determined in accordance with ASTM D 1457, at a frequency of 1 % of continuous production.

6.3.2 Tensile properties

Tensile strength and elongation at break of the PTFE (2.1.2) shall be determined in accordance with ASTM D 638, at a frequency of 1 % of continuous production.

6.3.3 Density

Density of the PTFE (2.1.3) shall be determined in accordance with ASTM D 792, at a frequency of 1 % of continuous production.

6.4 PTFE BELLOWS

6.4.1 Microscopic and visual examination

Microscopic examination of PTFE bellows at 10 times magnification or visual examination by means of transmitted light, at a frequency of 1 % of continuous production, shall show no voids, foreign inclusions or other internal defects that affect the performance of the bellows.

6.4.2 Dimensions

Dimensions and tolerances of PTFE bellows, including the thickness of PTFE membrane (4.3.2), shall conform with Manufacturer's specifications, and shall be measured at a frequency of 1 % of continuous production.

6.4.3 Mill Hydrostatic Test

PTFE bellows shall be hydrostatically tested at 1.5 times the nominal pressure rating, at a frequency of 5 % of continuous production. The pressure shall be increased gradually to a value of 50 % of the test pressure; thereafter the pressure shall be increased in stages of approximately 10 % of the test pressure. Test pressure shall be kept constant for a period not less than 15 min.

6.5 DOCUMENTATION

6.5.1 Quality Control

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

6.5.2 Certification

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

6.6 MARKING

Each bellows shall be marked with the following information:

- Manufacturer's name;
- Manufacturer's serial number;
- year of fabrication;
- nominal diameter;
- pressure rating;
- temperature rating;
- certifying mark of the Inspecting Authority, when applicable.

7. INSTALLATION

7.1 GENERAL

The Manufacturer shall issue assembly instructions, and these shall be strictly followed, irrespective of whether the installation is carried out by the Manufacturer, the Principal or third party.

The following shall be adhered to:

- limit rods, including stop (locking) nuts, shall not be removed, and shall be kept in the "as received" factory settings;
- flange covers shall only be removed when ready the bellows is ready to be installed;
- sealing faces shall be clean, smooth, and parallel;
- bellows for hot service shall be installed in nearly extended position;
- bellows for cold service shall be installed in nearly compressed position;
- bellows shall not carry any system-induced loads, i.e., pressure induced axial loading, torsion, etc., and fixed points (anchors) shall be incorporated in pipe systems where bellows are applied;
- bellows and connecting piping shall be adequately aligned, i.e., by means of pipe supports, with low friction, and at suitable locations;
- bolts shall not extend behind the bellows flange for more than 1 or 2 threads;
- applied bolt torque shall conform with the Manufacturer's installation instructions.

7.2 APPLICATION OF INTERNAL SLEEVES

Certain abrasive applications, such as slurries, or high velocity flow rates may damage the inside surfaces of the bellows convolutes or the radius surface at the end flares.

In such circumstances, a nozzle liner may be factory installed in the upstream side (inlet) of the bellows to help protect the unit or smooth out the flow. While such liners may greatly extend useful service life of the bellows, they will restrict movement unless all deflection is confined to straight axial compression and/or extension. Unless otherwise specified, overall length shall be 6 in.

7.3 HAZARDS

ASME B31.3, Appendix G, outlines recommendations for safeguarding piping systems, e.g., shielding of bellows through which hazardous fluids are conveyed by means of wrap-around safety shields.

Limit bolts with elastic stop nuts are factory set at the maximum travel position to prevent over-extension. Severe damage or personal injury can result if the limit bolts and stop nuts are removed or altered to exceed the factory setting, or if non-locking nuts are installed.

8. PACKAGING

Each PTFE bellows shall be packed in such a manner that it will arrive undamaged at its destination.

The flange (gasket) face shall be protected by an end cover or suitable protective means, which shall prevent damage of the flared PTFE flange face.

The end cover shall not be removed except for inspection, testing or installation. After inspection and/or testing it shall be re-installed immediately.

9. 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.

Piping classes – refining and chemicals DEP 31.38.01.12-Gen.

Painting and coating of new equipment DEP 30.48.00.31-Gen.

AMERICAN STANDARDS

Pipe flanges and flanged fittings ASME B 16.5

Process piping ASME B31.3

Issued by:

American Society Of Mechanical Engineers

ASME International

Three Park Avenue, M/S 10E

New York, NY 10016-5990

Specification for heat-resisting chromium and chromium-nickel stainless steel plate, sheet, and strip for pressure vessels ASTM A 240

Specification for stainless and heat-resisting steel bars and shapes ASTM A 276

Specification for carbon steel bolts and studs, 60,000 psi tensile strength ASTM A 307

Specification for nickel-copper alloy rod, bar, and wire ASTM B 164

Test method for tensile properties of plastics ASTM D 638

Test method for specific gravity (relative density) and density of plastics by displacement ASTM D 792

Specification for PTFE molding and extrusion materials ASTM D 1457

Issued by:

American Society for Testing and Materials

1916 Race Street, Philadelphia

Pa 19103, USA.

NOTE: The DEPs and most referenced external standards are available to Shell users on the Shell Wide Web (SWW) at <http://sww.shell.com/standards>.