TECHNICAL SPECIFICATION

PTFE BELLOWS

DEP 31.38.82.31-Gen.

October 1995

DESIGN AND ENGINEERING PRACTICE

PREFACE

DEP (Design and Engineering Practice) publications reflect the views, at the time of publication, of:

Shell International Oil Products B.V. (SIOP)
and
Shell International Exploration and Production B.V. (SIEP)
and
Shell International Chemicals B.V. (SIC)

The Hague, The Netherlands,

and other Service Companies.

They are based on the experience acquired during their involvement with the design, construction, operation and maintenance of processing units and facilities, and they are supplemented with the experience of Group Operating companies. Where appropriate they are based on, or reference is made to, national and international standards and codes of practice.

The objective is to set the recommended standard for good design and engineering practice applied by Group companies operating an oil refinery, gas handling installation, chemical plant, oil and gas production facility, or any other such facility, and thereby to achieve maximum technical and economic benefit from standardization.

The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where DEPs may not cover every requirement or diversity of condition at each locality. The system of DEPs is expected to be sufficiently flexible to allow individual operating companies to adapt the information set forth in DEPs to their own environment and requirements.

When Contractors or Manufacturers/Suppliers use DEPs they shall be solely responsible for the quality of work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, the Principal will expect them to follow those design and engineering practices which will achieve the same level of integrity as reflected in the DEPs. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the Principal or its technical advisor.

The right to use DEPs is granted by SIOP, SIEP or SIC, in most cases under Service Agreements primarily with companies of the Royal Dutch/Shell Group and other companies receiving technical advice and services from SIOP, SIEP or SIC. Consequently, three categories of users of DEPs can be distinguished:

1) Operating companies having a Service Agreement with SIOP, SIEP, SIC or other Service Company. The use of DEPs by these Operating companies is subject in all respects to the terms and conditions of the relevant Service Agreement.

2) Other parties who are authorized to use DEPs subject to appropriate contractual arrangements.

3) Contractors/subcontractors and Manufacturers/Suppliers under a contract with users referred to under 1) or 2) which requires that tenders for projects, materials supplied or - generally - work performed on behalf of the said users comply with the relevant standards.

Subject to any particular terms and conditions as may be set forth in specific agreements with users, SIOP, SIEP and SIC disclaim any liability of whatsoever nature for any damage (including injury or death) suffered by any company or person whomsoever as a result of or in connection with the use, application or implementation of any DEP, combination of DEPs or any part thereof. The benefit of this disclaimer shall inure in all respects to SIOP, SIEP, SIC and/or any company affiliated to these companies that may issue DEPs or require the use of DEPs.

Without prejudice to any specific terms in respect of confidentiality under relevant contractual arrangements, DEPs shall not, without the prior written consent of SIOP and SIEP, be disclosed by users to any company or person whomsoever and the DEPs shall be used exclusively for the purpose for which they have been provided to the user. They shall be returned after use, including any copies which shall only be made by users with the express prior written consent of SIOP and SIEP. The copyright of DEPs vests in SIOP and SIEP. Users shall arrange for DEPs to be held in safe custody and SIOP or SIEP may at any time require information satisfactory to them in order to ascertain how users implement this requirement.

All administrative queries should be directed to the DEP Administrator in SIOP.

NOTE: In addition to DEP publications there are Standard Specifications and Draft DEPs for Development (DDDs). DDDs generally introduce new procedures or techniques that will probably need updating as further experience develops during their use. The above requirements for distribution and use of DEPs are also applicable to Standard Specifications and DDDs. Standard Specifications and DDDs will gradually be replaced by DEPs.

TABLE OF CONTENTS

APPENDICES

1. INTRODUCTION

1.1 SCOPE

This DEP is a revision of an earlier DEP with the same number, dated March 1979. It specifies requirements and recommendations for the design, manufacture and related testing, installation, inspection, packaging and transportation of bellows with a flexible body moulded from polytetrafluoroethylene (PTFE).

Bellows with one or more convolutions, whether or not provided with a metallic outer protection, are described in nominal diameters from 25 mm to 400 mm.

The general service temperature range for the bellows described is from minus 40 °C to plus 200 °C. The maximum operating pressure, which is dependent on the type of bellows and the service temperature, generally does not exceed 10 bar (ga). Operation under vacuum conditions is possible only to a limited extent; bellows designed for vacuum service only are excluded from the scope of this DEP.

Within the limits of their design PTFE bellows are able to accommodate movements in piping systems in axial, lateral and angular directions; they also act as vibration absorbers. A typical PTFE bellows is shown in Appendix 1. Within the scope of this DEP it is emphasized that not all aspects of PTFE bellows can be standardized because of differences in design and manufacturing methods.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIPM, 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 facilites 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

1.3.1 General definitions

The **Contractor** is the party which 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 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.

1.4 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 (10).

2. MATERIALS

2.1 PTFE

Only virgin (not reprocessed) PTFE conforming to ASTM D 1457, type III, IV or V shall be used for the production of bellows; the PTFE raw material shall be appropriate to the manufacturing technique. Subsequently a maximum of 1% wt of additives, which shall be carefully homogenized, is permitted.

2.2 METALLIC PARTS

Metallic materials shall be as follows:

Component	Material	
Flanges	In accordance with the piping class (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
Outside protection	Stainless steel	ASTM A 240 - type 321 or 316L

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

2.3 BACK-UP GASKETS

In cases where a back-up gasket is installed between the metallic flange and the PTFE flange face, e.g. when PTFE bellows are connected to vulnerable equipment, a flexible graphite-based gasket should be used.

3. DESIGN AND FABRICATION

3.1 MANUFACTURER

The Manufacturer shall prove to the Principal's satisfaction that he has sufficient experience in the design and fabrication of PTFE bellows. The Manufacturer shall check the quality of the raw materials and test the final products manufactured therefrom. He shall also provide samples for qualification testing (6.), if requested by the Principal.

3.2 DESIGN

The Manufacturer shall state the maximum allowable operating conditions in the form of a pressure/temperature graph; vacuum conditions shall be shown. He shall also provide the data on maximum allowable axial, lateral and angular deformation.

Although PTFE bellows are able to accommodate movements in axial, lateral and angular directions (1.), their use should be limited as far as possible to axial movements only (Appendix 3).

Bellows shall be equipped with a device which restricts extension in all directions, within the values specified by the manufacturer (e.g. limit rods, limit ties). The flexibility of the bellows shall be characterized by the force per unit of deformation in each of the directions at ambient temperature and atmospheric pressure.

3.3 FABRICATION

3.3.1 Fabrication of flexible membrane

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

- paste extrusion
- ram extrusion
- isostatic moulding

These manufacturing processes are described in Appendix 2.

Forming and flaring operations shall be carried out at a temperature between 300 °C and 325 °C, followed by controlled cooling.

3.3.2 Metallic parts

Flanges shall conform to the requirements of the piping class (DEP 31.38.01.12-Gen.). Surfaces contacting the PTFE shall be machined to remove all cavities or projections.

Flanges shall have no sharp corners; the flange edges contacting the PTFE shall be rounded off to a minimum radius of:

- 3 mm for nominal diameters $\leq$ DN 100
- 4 mm for nominal diameters of DN 150 and DN 200
- 5 mm for nominal diameters of $\geq$ DN 250

The reinforcing rings shall be made of one complete piece and shall support the full circumference of the convolution root at the maximum recommended pressure and temperature conditions.

The limit rods shall not interfere with the freedom of angular, lateral and axial displacements (Appendix 3). The metallic outside protection shall be provided with an appropriate venting system to prevent pressure build-up between the PTFE and the protection.

Unless otherwise stated, all flanges shall be derusted and shop-painted with one coat of suitable zinc-rich epoxy-resin-based primer.

3.3.3 Dimensions

The wall thickness in any part of the PTFE body shall have a minimum value as stated in Appendix 4. The flared gasket face of the bellows shall be concentric to the bore and its minimum outside diameter shall conform to the dimensions of the appropriate raised face flanges (3.3.2).

To permit bolt alignment, the gap between the OD of the PTFE body and the ID of the metal flange shall be 5% of the ID of the metal flange (with a maximum of 4 mm). For bellows provided with a metallic outside protection this gap shall be between the outside diameter of the metallic protection and the bore of the metal flange.

4. INSTALLATION

The installation instructions given by the Manufacturer shall be strictly followed.

Furthermore the following rules shall be adhered to:

1. The bellows shall be installed in a stress-free condition, hence the adjoined piping shall not have been fixed when the bellows are installed.
2. The bolts of the limit rod, which are set by the Manufacturer, shall not be removed.
3. The flange faces shall be perpendicular to the axis of the piping and the bellows in order to prevent distortion of the bellows.
4. The bellows shall be inspected visually during installation for possible damage, condition of the flange facing and absence of foreign matter in between the convolutions.
5. The bolts shall be retightened 2-5 hours after the final process temperature has been reached to the bolt tightening torques as given by the Manufacturer.

5. QUALIFICATION

All PTFE bellows purchased to this specification shall meet the requirements of (2) and (3) and further shall be capable of meeting the qualification requirements specified in (6).

It shall be stated by the Principal at the time of enquiry or order whether and to what extent the qualification tests are required.

6. QUALIFICATION INSPECTION AND TESTING

6.1 GENERAL

If approved by the Principal, the tests required under this section may be performed on products from running stock. The number and size of the samples, the method of sampling and a time interval for repeating tests shall be established by agreement between the Manufacturer and the Principal.

Tests shall be performed by the Manufacturer or by an independent testing organization.

The PTFE membrane bellows provided with a metallic outer protection shall conform to the requirements mentioned in this section. This implies that the metallic protection has to be removed before testing can be carried out, in particular when testing complete bellows, see (6.3.1) and (6.3.2).

6.2 TESTING PTFE

6.2.1 PTFE grade

The grade of the PTFE used for the manufacture of the flexible membrane shall meet the requirements specified in (2.1).

6.2.2 Liquid Penetrant examination

The PTFE membrane shall be examined by liquid penetrant examination in accordance with ASTM E 165. There shall be no indications.

6.2.3 Visual examination

The PTFE membrane shall be uniform and free from voids, cracks and foreign inclusions, or other internal defects when examined by microscope at 10 times magnification.

6.2.4 Hardness

The PTFE shall have a minimum hardness of 52 Durometer type D when measured in accordance with ASTM D 2240.

6.2.5 Density (ASTM D 792)

The density of the PTFE shall be between 2140 and 2190 kg/m^3.

6.2.6 Tensile properties (ASTM D 638)

The minimum values stated below shall be the arithmetic average from test results obtained with samples taken in two directions perpendicular to each other, one of them parallel to the main axis of the bellows.

Manufacturing technique	Minimum tensile strength at break (N/mm^2)	Minimum elongation at break (%)
Paste extrusion	26.0	275
Ram extrusion	25.5	265
Isostatic moulding	25.5	280

6.2.7 Di-electric strength (ASTM D 149)

The minimum value for the di-electric strength when measured in accordance with the short-time method shall be as follows:

Sample thickness (mm)	Di-electric strength (kV/mm)
1.5	24
2.0	20
2.5	18
3 or higher	16

6.3 TESTING OF PTFE BELLOWS

6.3.1 Burst pressure test

The burst pressure of a PTFE bellows shall be at least four times the design pressure given by the manufacturer, after it has been subjected to 2000 cycles at 10 cycles per minute between its maximum axial extensions. The pressure and related temperature at which cycling is carried out shall be selected from the pressure/temperature graph supplied by the Manufacturer (3.2). The pressure to produce failure shall be applied uniformly at such a rate that failure occurs within 5 minutes. As a minimum two tests shall be carried out; one at ambient temperature and the other at 180 °C.

6.3.2 Cycle testing

No failure shall occur when a PTFE bellows is subjected to 100 000 cycles at 10 cycles per minute between its maximum axial extension, or a combination of axial and lateral extension, at a pressure and temperature selected from the pressure/temperature graph supplied by the Manufacturer (3.2).

6.3.3 Temperature test

The bellows shall be bolted to a mating flange and held at a temperature of 260 °C for 2 hours. After cooling, the PTFE flange face shall be examined again in accordance with (6.2.2) and (6.2.3).

7. PRODUCTION INSPECTION AND TESTING

7.1 INSPECTION AND TESTS

PTFE bellows shall be subjected to dimensional inspection, visual examination, liquid penetrant examination, holiday testing (if necessary) and a hydrostatic pressure test. A burst pressure test and a pressure shock test shall be applied if the bellows ordered are to be used for critical applications (this to be specified by the Principal).

The Principal shall indicate if he wishes to witness any of these tests.

7.1.1 Visual examination and liquid penetrant examination

Each PTFE bellows shall be inspected for dimensions and tolerances as follows:

In any part of the PTFE body the thickness shall not be lower than the values specified in Appendix 4. A plus tolerance of 10% on the thickness of the PTFE body is applicable. The diameter of the flared PTFE gasket face shall conform to the values specified in the appropriate flange standard for raised face flanges (3.3.2). The convolutions and the flared gasket face of the PTFE body shall be concentric to the bore of the PTFE bellows.

For each PTFE bellows, the root and crest of each convolution that is accessible shall be examined visually in accordance with (6.2.3).

For each PTFE bellows, the root and crest of each convolution that is accessible shall be examined by liquid penetrant in accordance with (6.2.2).

Note: The PTFE membrane of bellows with a metallic outer protection may be examined from the inside only, otherwise both inside and outside surfaces shall be examined.

7.1.2 Holiday test

If the bellows passes the examinations performed under (7.1.1) but is still suspected of containing defects, then a metal tape (normally aluminium) shall be inserted in the bellows and a holiday test shall be performed in accordance with ASTM D 5162. The acceptance criterion shall be zero holidays.

7.1.3 Hydrostatic pressure test

Unless otherwise agreed by the Principal, each bellows shall withstand a hydrostatic pressure test without failure at room temperature for a period of 3 minutes. The pressure shall be 1.5 times the design pressure of the specific bellows. The design pressure shall be taken from the pressure/temperature graphs supplied by the Manufacturer (3.2).

7.1.4 Burst pressure test

If specified by the Principal, one out of ten bellows of the same type and size, with a minimum of one bellows, shall be pressure-tested to failure at room temperature. The burst pressure shall be at least four times the design pressure.

In the event of a failure below this pressure level, retesting frequency shall be agreed with the Principal.

7.1.5 Pressure shock test

When specified by the Principal each bellows shall be tested to withstand a 7-bar shock pressure at room temperature when fully extended or retracted in axial direction.

In the event of failure, the retesting frequency shall be agreed with the Principal.

8. CERTIFICATION

The Manufacturer shall provide certificates in accordance with ISO 10474 type 3.1.B covering the following:

- the PTFE material (section 2.1) used in the bellows qualification testing (section 6)
- the metallic parts (section 2.3) used in the bellows qualification testing (section 6)
- the qualification tests (section 6)
- the PTFE material (section 2.1) used in the bellows supplied
- the metallic parts (section 2.3) used in the bellows supplied
- the production tests (section 7)

9. PACKAGING

Each PTFE bellows shall be packed separately in a manner that will ensure arrival undamaged at its destination.

The flange faces shall be protected by weather-resistant end covers fixed through at least four bolt holes to avoid damage during transport, handling and storage. These plates will also prevent stretching of the flared PTFE flange faces.

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

Each PTFE bellows shall be provided with a nameplate to show the nominal diameter, the manufacturing date and Manufacturer's name. With each bellows an instruction sheet shall be packed showing the recommended installation procedure, bolt tightening torques, maximum extended length, neutral length (3.2) and retracted length. A pressure/temperature graph shall also be enclosed.

10. 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.
MF piping classes	DEP 31.38.01.12-Gen.

AMERICAN STANDARDS

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 methods for dielectric breakdown voltage and dielectric strength of solid electrical insulating materials at commercial power frequencies	ASTM D 149
Test method for tensile properties of plastics	ASTM D 638
Test method for specific gravity (relative density) and density of platics by displacement	ASTM D 792
Specification for PTFE molding and extrusion materials	ASTM D 1457
Test method for rubber property - Durometer hardness	ASTM D 2240
Standard practice for discontinuity (holiday) testing of nonconductive protective coating on metallic substrates	ASTM D 5162
Standard test method for liquid penetrant examination	ASTM E 165

Issued by:
American Society for Testing and Materials
1916 Race Street, Philadelphia
Pa 19103, USA.

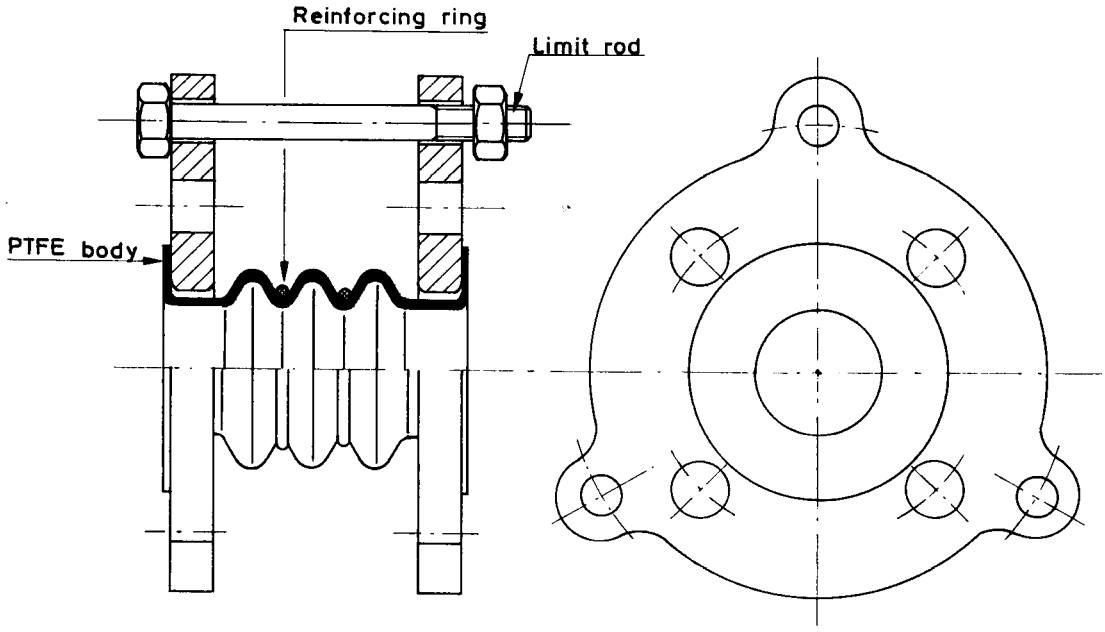
INTERNATIONAL STANDARDS

Steel and steel products - Inspection documents	ISO 10474

Issued by:
International Organisation for Standardisation
1, Rue de Varembé
P.O. Box 56
CH -1211 Geneva 20
Switzerland.

Copies can also be obtained from national standards organizations.

APPENDIX 1 TYPICAL PFTE BELLOWS WITH THREE CONVOLUTIONS



APPENDIX 2 DESCRIPTION OF VARIOUS FABRICATION TECHNIQUES FOR PTFE BELLOWS

PASTE EXTRUSION

Paste extrusion is basically a three-stage batch process.

In the first stage a preform is manufactured from a mixture of PTFE powder and approximately 25% weight of a volatile hydrocarbon oil, which acts as an external lubricating agent. The preform is manufactured at relatively low pressure and without supply of external heat. Although dimensionally stable, the PTFE preform is rather friable. The preform is subsequently placed in a mould or forced through an extruder die. The lubricating agent is removed after the final product shape has been moulded under pressure at elevated temperature. In the last stage the product is sintered at a temperature of approximately 380 °C and thereafter cooled to ambient temperature under carefully controlled conditions.

The product usually has a black colour, which originates from the carbon black used as an auxiliary extrusion aid.

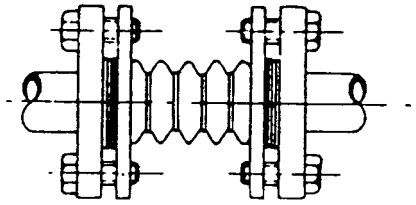
RAM EXTRUSION

Ram extrusion is a continuous process in which compaction of the granular PTFE at a relatively low temperature, sintering at a temperature of approximately 380 °C and cooling are carried out in a single piece of equipment. The extruder is fed by a reciprocating cylinder (ram) under high pressure. No additional materials are required to improve processing.

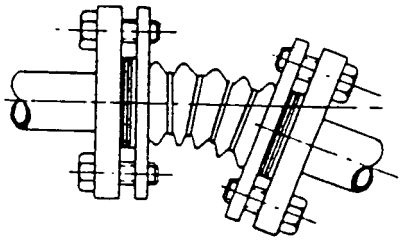
ISOSTATIC MOULDING

Isostatic moulding is a technique for preforming PTFE powder by applying hydrostatic pressure to a sealed flexible mould which contains the PTFE powder. The pressure applied to the mould is transmitted to the powder through the flexible mould parts, which are usually elastomeric membranes. Complicated shapes can be moulded by this technique. After preforming at moderate temperatures the moulding is sintered at a temperature of approximately 380 °C. No auxiliary materials are required in this process.

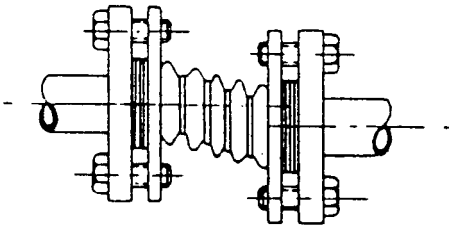
APPENDIX 3 TYPES OF MOVEMENT



axial deformation



angular deformation



lateral (or off-set deformation)

APPENDIX 4 MINIMUM WALL THICKNESS OF FLEXIBLE PTFE MEMBRANE

Nominal diameter (mm)	Minimum thickness (mm)
25	2.0
40	2.2
50	2.4
80	2.6
100	3.0
150	3.5
200	4.0
250	4.5
300	5.0
350	5.5
400	6.0