

BS EN ISO 23936-2:2011



BSI Standards Publication

Petroleum, petrochemical and natural gas industries — Non-metallic materials in contact with media related to oil and gas production

Part 2: Elastomers

bsi.

...making excellence a habit.
AVA Documents™
Document Sharing Hub

National foreword

This British Standard is the UK implementation of EN ISO 23936-2:2011.

The UK participation in its preparation was entrusted to Technical Committee PSE/17/-/7, UK experts in ISO TC 67 Working Groups.

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

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© BSI 2012

ISBN 978 0 580 71167 1

ICS 75.180.01

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 January 2012.

Amendments issued since publication

Date	Text affected
------	---------------

English Version

Petroleum, petrochemical and natural gas industries - Non-metallic materials in contact with media related to oil and gas production - Part 2: Elastomers (ISO 23936-2:2011)

Industries du pétrole, de la pétrochimie et du gaz naturel -
Matériaux non métalliques en contact avec les fluides
relatifs à la production de pétrole et de gaz - Partie 2:
Élastomères (ISO 23936-2:2011)

Erdöl-, petrochemische und Erdgasindustrie -
Nichtmetallische Werkstoffe mit Medienkontakt bei der Öl-
und Gasproduktion - Teil 2: Elastomere (ISO 23936-
2:2011)

This European Standard was approved by CEN on 14 December 2011.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.



EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: Avenue Marnix 17, B-1000 Brussels

Foreword

This document (EN ISO 23936-2:2011) has been prepared by Technical Committee ISO/TC 67 "Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries" in collaboration with Technical Committee CEN/TC 12 "Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries" the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2012, and conflicting national standards shall be withdrawn at the latest by June 2012.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

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

Endorsement notice

The text of ISO 23936-2:2011 has been approved by CEN as a EN ISO 23936-2:2011 without any modification.

Contents

Page

Foreword	iv
Introduction.....	v
1 Scope	1
2 Normative references	1
3 Terms, definitions and abbreviated terms	2
3.1 Terms and definitions	2
3.2 Abbreviated terms	4
4 Technical requirements	4
5 Documentation requirements	5
6 Requirements for manufacturers.....	6
6.1 General requirements	6
6.2 Validation of compliance	7
7 Qualification of elastomer materials (ageing and RGD).....	8
7.1 General	8
7.2 Requirements for ageing tests.....	8
7.3 Requirements for rapid gas decompression testing	9
8 Qualification of elastomeric materials in bonded flexible hose	9
8.1 General	9
8.2 Qualification of bonded flexible hose liner material.....	10
8.3 Qualification of bonded flexible hose – Layers outside the liner.....	14
9 Qualification of elastomeric materials in other large components	15
9.1 General	15
9.2 Qualification of elastomeric materials in flexible joints	15
9.3 Qualification of elastomeric materials in blow-out preventers.....	15
9.4 Qualification of elastomeric materials for packers	16
Annex A (normative) Test media, conditions, equipment and procedures for ageing of elastomeric materials	17
Annex B (normative) Test media, conditions, equipment and procedures for rapid gas decompression testing of elastomeric materials.....	26
Annex C (informative) Most commonly used elastomeric materials	40
Annex D (normative) Procedure for estimation of material service life using the Arrhenius relationship	42
Annex E (informative) Physical and chemical ageing	47
Annex F (informative) Rapid gas decompression (RGD).....	62
Bibliography.....	66

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 23936-2 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*.

ISO 23936 consists of the following parts, under the general title *Petroleum, petrochemical and natural gas industries — Non-metallic materials in contact with media related to oil and gas production*:

— *Part 1: Thermoplastics*

— *Part 2: Elastomers*

The following parts are planned:

— *Part 3: Thermosets*

— *Part 4: Fibre-reinforced composite*

— *Part 5: Other non-metallic materials*

Introduction

ISO 23936 is intended to be of benefit to a broad industry group, ranging from operators and suppliers to engineering companies and authorities. ISO 23936 covers relevant generic types of non-metallic material (thermoplastics, elastomers, thermosetting plastics, fibre-reinforced plastics, etc.) and draws upon a wide range of existing technical experience, which has never before been summarized in a technical standard.

ISO 23936 does not cover polymeric coatings such as thermal insulation and paint that are applied to the outside of components but that are not in contact with oilfield fluids.

The evaluation and qualification process described in this part of ISO 23936 is intended to ensure that the user of non-metallic materials has sufficient understanding and knowledge of the applicable materials to obtain acceptable performance in the specified environment, and that the user can rely on stable quality to meet given specifications. A quality system is useful to ensure compliance with the requirements of this part of ISO 23936.

Successful qualification of a manufacturer and a specific material is intended to be valid for other projects and different operators. The consideration of qualification of a manufacturer is at the discretion and determination of the purchaser, normally on the basis of documentation provided by the manufacturer, as required in this part of ISO 23936 or any specific additional documentation.

The purchaser is responsible for ensuring (if necessary, with external competence) that the manufacturers selected are qualified.

This part of ISO 23936 is based on NORSOK standard M-710.

Petroleum, petrochemical and natural gas industries — Non-metallic materials in contact with media related to oil and gas production —

Part 2: Elastomers

1 Scope

ISO 23936 describes general principles and gives requirements and recommendations for the selection and qualification of non-metallic materials for service in equipment used in oil and gas production environments, where the failure of such equipment could pose a risk to the health and safety of the public and personnel, or to the environment. It can be applied to help avoid failures of the equipment itself. It supplements, but does not replace, the material requirements given in the appropriate design codes, standards or regulations.

This part of ISO 23936 describes the requirements and procedures for qualification of elastomeric material used in equipment for oil and gas production.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 34-1:2010, *Rubber, vulcanized or thermoplastic — Determination of tear strength — Part 1: Trouser, angle and crescent test pieces*

ISO 37, *Rubber, vulcanized or thermoplastic — Determination of tensile stress-strain properties*

ISO 48, *Rubber, vulcanized or thermoplastic — Determination of hardness (hardness between 10 IRHD and 100 IRHD)*

ISO 815-1, *Rubber, vulcanized or thermoplastic — Determination of compression set — Part 1: At ambient or elevated temperatures*

ISO 2781, *Rubber, vulcanized or thermoplastic — Determination of density*

ISO 2921, *Rubber, vulcanized — Determination of low-temperature retraction (TR test)*

ISO 3601-3:2005, *Fluid power systems — O-rings — Part 3: Quality acceptance criteria*

ISO 7619-1, *Rubber, vulcanized or thermoplastic — Determination of indentation hardness — Part 1: Durometer method (Shore hardness)*

ISO 13628-10:2005, *Petroleum and natural gas industries — Design and operation of subsea production systems — Part 10: Specification for bonded flexible pipe*

ASTM D297, *Standard Test Methods for Rubber Products — Chemical Analysis*

ASTM D395, *Standard Test Methods for Rubber Property — Compression Set*

ASTM D412, *Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers — Tension*

ASTM D624, *Standard Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers*

ASTM D1414, *Standard Test Methods for Rubber O-Rings*

ASTM D1415, *Standard Test Method for Rubber Property — International Hardness*

ASTM D2240, *Standard Test Method for Rubber Property — Durometer Hardness*

API 17K, *Specification for Bonded Flexible Pipe*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms, definitions and abbreviated terms apply.

3.1 Terms and definitions

3.1.1

accelerated test

test undertaken under conditions designed to speed material deterioration

NOTE This is usually accomplished by increasing temperature, in order to raise chemical reaction rates, but fluid concentration and stress are variables which can also be manipulated.

3.1.2

asset operator

person who operates an asset, who has knowledge of well parameters and who transmits this information to the **user** (3.1.15)

NOTE 1 An asset can be a well, a production train, a plant, etc.

NOTE 2 Well parameters can be fluid exposure, temperatures, pressures, duration, etc.

3.1.3

compression set

difference between the original sample height and the post-test height, divided by the interference, expressed as a percentage

3.1.4

elastomer

rubber

amorphous material mechanically mixed with other constituents to form a rubber compound, which is then shaped by flow into articles by means of the manufacturing processes of moulding or extrusion, and then (invariably) chemically cured at elevated temperature to form an elastic insoluble material

3.1.5

fluid

medium such as a gas, liquid, supercritical gas, or a mixture of these

3.1.6

interference

difference between the original sample height and the height of spacer bar, each measured in the same direction as the direction of compression

3.1.7

compound manufacturer manufacturer

producer of the elastomer material or of semi-finished products made from elastomer materials

3.1.8

modulus

tensile stress at a given elongation

NOTE In the rubber industry, the modulus at 50 % elongation is often chosen.

3.1.9

polymer

high molecular weight molecule, natural or synthetic, whose chemical structure can be represented by repeated small units which collectively form molecular chains

NOTE This material class has three main sub-groups: elastomers, thermoplastics and thermosets.

3.1.10

rapid gas decompression

RGD

depressurization

explosive decompression

rapid pressure-drop in a high pressure gas-containing system which disrupts the equilibrium between external gas pressure and the concentration of gas dissolved inside any polymer, with the result that excess gas tries to escape from the solution at points throughout the material, causing expansion

NOTE If large enough, and if the pressure-drop rate is faster than the natural gas diffusion rate, blistering or rupturing can occur.

3.1.11

room temperature

temperature of $(23 \pm 2) ^\circ\text{C}$

3.1.12

seal cross-section

cross-section diameter

CSD

free height of a seal at room temperature, measured normal to seal diameter in the direction of compression in the test

NOTE The measurement is taken at three circumferentially equidistributed positions.

3.1.13

seal type

seal design of specified geometry, size and orientation

EXAMPLE An O-ring.

3.1.14

thermoplastic

material capable of being repeatedly softened by heating and hardened by cooling through a temperature range characteristic of the plastic and, in the softened state, of being repeatedly shaped by flow into articles by moulding, extrusion or forming

3.1.15

user

person responsible for the selection of suitable materials for a service operation based on information received from the **asset operator** (3.1.2)

3.1.16

purchaser

party responsible for procuring the elastomer material or component

3.2 Abbreviated terms

BOP	blow-out preventer
BRE	base resistant elastomers
COC	certificate of conformance
CSD	cross-section diameter
DMA	dynamic mechanical analysis
DMTA	dynamic mechanical thermal analysis
DSC	differential scanning calorimetry
GMPHOM	Guide to Manufacturing and Purchasing Hoses for Offshore Moorings
HNBR	hydrogenated nitrile butadiene rubber
HP	high pressure
LNG	liquefied natural gas
NBR	nitrile butadiene rubber
OCIMF	Oil Companies International Marine Forum
PBR	polished bore receptacle
RGD	rapid gas decompression (rapid gas depressurization)
SPS	solubility parameter spectroscopy
TMA	thermo mechanical analysis

4 Technical requirements

Technical requirements depend on material property characteristics and specific functional tests for an application.

Elastomer selection shall be based on evaluation of compatibility with service environment, functionality under service and the design lifetime. This part of ISO 23936 covers materials tests and not functional tests. The following should be considered as appropriate to the component requirements and evaluated when selecting the material:

- a) adequate physical and mechanical properties (density, hardness, tensile strength, elongation at break, modulus of elasticity, compression set, tear strength, etc.); standard properties from which design specifications are selected and for quality assurance and control aspects;
- b) resistance against RGD events; a property of importance in high pressure gas sealing applications, covered in depth in this part of ISO 23936;
- c) long-term behaviour; resistance to chemical/physical change of the material; an important characteristic regarding sealing generally in the oil and gas sector, covered in this part of ISO 23936;
- d) low temperature flexibility; a property highly relevant to low temperature sealing applications;
- e) for large components exposed to gaseous production fluid, high pressure gas permeation; a property highly relevant to possible gas pressure build-up within the component structure, e.g. for hoses;
- f) resistance to high pressure extrusion or creep (functional tests not covered by this part of ISO 23936);
- g) resistance to thermal cycling and dynamic movement (functional tests not covered by this part of ISO 23936).

Clause 2 gives references to relevant standards for elastomeric materials. The standards describe the test methodology for performing particular materials tests. The test conditions and durations shall be as described in this part of ISO 23936 and shall take precedence in those cases where this part of ISO 23936 deviates from the referenced standards.

Long term (ageing) test objectives are described in Clause 7; procedural details are given in Annex A. RGD test objectives and procedures for elastomer O-ring seals are described in Clause 7 and Annex B.

It is the responsibility of the asset operator to provide all necessary information about service conditions and environment.

Information on elastomer characteristics is provided in Annex C.

5 Documentation requirements

NOTE The required documentation of material properties of thermoplastic materials is described in ISO 23936-1.

Required documentation of material properties is given in Table 1. Requirements pertaining both to documentation of properties and quality control are given. Each elastomer material used shall be traceable to the compound manufacturer and their quality control documentation as required in Table 1. Each batch of material shall be supplied with, as a minimum, a certificate of conformance (COC) and traceability information.

Table 1 also defines the minimum amount of production and quality control testing required during manufacturing of the elastomer materials. The final procedures, with respect to key parameters and tolerances, shall be defined based on results from testing performed according to this part of ISO 23936.

The user shall define the necessary requirements with tolerances in the purchase specification.

Guidelines on selection of standards are given in parentheses. Characteristics, which are not relevant for expected service conditions and/or material type, may be omitted.

Table 1 — Required documentation for elastomer material properties

Properties	Documentation	Quality control tests
Density (ISO 2781 or ASTM D297)	D ^a	B ^c
Hardness (IRHD/Shore A) (ISO 48/ISO 7619-1, ASTM D2240/ASTM D1415)	D	B
Tensile and elongation properties (ISO 37, ASTM D1414, ASTM D412)	D	B
Compression set (ISO 815-1, ASTM D395/ASTM D1414)	D	
Low temperature characteristics by DSC, DMA or TMA	D	
Tear strength (ISO 34-1:2010, Method A, ASTM D624)	D	
Temperature of retraction (ISO 2921)	D	
Ageing/RGD characteristics (Annexes A/B)	D	
High pressure gas permeation	DH ^b	
^a D: Properties to be documented for each supplier for each type of material. Nominal values with tolerances shall be given (Data Sheet). ^b DH: As for D, but specifically when using all large components exposed to high pressure gas. ^c B: Properties to be documented on a batch-wise basis, minimum 5 samples per test per batch with all results presented. The acceptance criteria shall be established prior to the test and based on qualification test results.		

Material property tests may also be omitted if users have documented performance-based functional tests that they use to approve rubber materials.

6 Requirements for manufacturers

6.1 General requirements

It is the requirement of the manufacturer to provide documents attesting that the material has been manufactured and tested appropriately and that the material has met the relevant quality control requirements in this part of ISO 23936.

The testing shall be performed on specimens produced from specific rubber formulations and, where possible, production procedures. The COC should include as a minimum density, batch hardness, tensile properties (moduli, strength, elongation at break), date of manufacture and (where referenced) the sample curing process. The COC should be signed by a quality representative. For large rubber components, tests on small components shall be suitable for the properties of the large component unless otherwise agreed between the interested parties.

This part of ISO 23936 specifies the required types of tests that shall be performed in order to document the material suitability and compatibility with test fluids specified in this part of ISO 23936 which are applicable to the intended application.

The testing shall apply for the elastomer materials and the results shall be valid as long as the requirements stated in 6.2 are satisfied. For later supplies of identical material from the same manufacturer, a quality control of each batch of material shall be sufficient. Table 2 lists typical quality assurance and quality control document templates showing imaginary data.

Table 2 — Typical quality assurance and quality control information

Material			
Manufacturer	Acme Seals, Inc.		
Compound grade	FabFluoro		
Elastomer type	ASTM D1418-05	FKM Type 3	
Lot/batch no.	FF2344rw4r/07		
Cure date	Q4 2010		
Typical Properties	Applicable standard	Unit	Value
Density	ISO 2781	g/cm ³	1,8
Hardness	ISO 48	IRHD	85
Tensile strength	ISO 37	MPa	21
Modulus at 50% elongation	ISO 37	MPa	10,1
Modulus at 100% elongation	ISO 37	MPa	18,5
Elongation at break	ISO 37	%	125

It may not be necessary to perform qualification testing for a particular material, if relevant successful well-documented in-service experience with traceable production records and quality control documentation is available to all relevant parties. This shall be agreed between interested parties.

Such documentation shall contain detailed information about service conditions such as time, temperature, pressure, fluid composition and chemicals added. An asset operator can, for example, provide the documentation of flawless service. The existing service temperature recorded therein shall be in the same range as for the new application (it shall be a maximum of 10 °C below), the existing service pressure shall not be more than 10 % below that for the new application, and the existing service life shall be a minimum of 50 % of design life.

The manufacturer who has tested and qualified his compound(s) can make a statement making this known. Such a statement shall define which parts of ISO 23936 are complied with. Further, the statement shall include whether the testing was done according to Annex A and/or Annex B, and define the fluid composition, conditions and overall duration for the testing.

6.2 Validation of compliance

The elastomer properties shall apply to each specific elastomer compound produced by each specific manufacturer. The existing elastomer data used by one purchaser may also be accepted by subsequent purchasers, provided the requirements in this part of ISO 23936 are still complied with.

A compound shall be re-tested if changes are made to the compound or the process. If compound mixing and/or moulding is carried out at different plants/locations, a separate qualification shall be performed for each plant.

NOTE All materials previously approved in accordance with NORSOK M-710 are approved in accordance with this part of ISO 23936.

7 Qualification of elastomer materials (ageing and RGD)

7.1 General

The technical necessities for the testing of elastomeric materials are divided into two parts:

- 7.2 defines the chemical ageing test requirements (see Annex A);
- 7.3 defines the requirements for RGD testing (see Annex B).

The test regimes shall be selected based on an analysis of the service conditions applying to the material in question, if these are known. Such an assessment shall include the nature and type of all fluids which contact the elastomer. The service life of the seal material in the relevant service environment shall be evaluated using appropriate techniques.

7.2 Requirements for ageing tests

7.2.1 General

This part of ISO 23936 defines test procedures for the prediction of the progressive degradation of elastomeric materials exposed to fluids at elevated temperatures over extended periods of time. It is applicable where it is necessary to forecast material life in a specific application and for directly comparing the performance of candidate elastomer materials. Other standards, such as API TR6J1, also provide methods to assess life of elastomer materials.

The objective is to assess the physical effects of the fluid on the elastomer and to thermally accelerate chemical reaction (if this occurs) between the fluid and the elastomer, causing tensile and related property levels to shift systematically towards a pre-defined limit of acceptability. The material is considered to have “failed” (i.e. reached the end of its useful life) when this limit is attained. These data are then used to quantify service life and suitability for service.

By running exposure tests with test fluids at three different elevated temperatures above the operating temperature, three different times to reach the acceptance boundary will result, with the highest test temperature producing the shortest “time to failure”. Plotting the log of failure times against the reciprocal of the test temperature should result in a linear trend, enabling an estimate of service life at the operating temperature.

For accelerated testing, the upper test temperature should be limited to give some confidence that only service-relevant chemical and/or physical processes will occur.

The preferred test piece geometry is the tensile dumbbell; various standards apply (see Table 1). The ageing of moulded sheet, for subsequent stamping-out of tensile test pieces, is not allowed. The elastomer shall be tested in unconstrained mode; that is, free-standing, with fluid able to freely access all surfaces.

When extrapolating data from the present procedures, appropriate statistical techniques shall be applied. For example, if progressive degradation is apparently dependent on a single chemical ageing process, a method based on the Arrhenius relationship shall be used as described in Annex D. It is recommended that results always first be assessed on an Arrhenius basis. If an Arrhenius relationship does not exist or ageing does not occur, see Annex E for further guidance.

Test media, conditions, equipment, procedures and test report requirements are described in detail in Annex A.

7.2.2 Acceptance criteria for elastomers

The acceptance criteria shall be established prior to commencing the ageing test. The following criteria have been established as the maximum acceptable ranges for three particular properties; any relaxation of these

requirements shall be agreed upon by the user. A narrower acceptance range can be applied to any of these if required by circumstances.

- Hardness: +10/–20 units (+5/–20 units when initial nominal hardness is 90); applies to Shore A and IRHD scales
- Volume: +25 % /–5 %
- Tensile: ± 50 % [modulus (at 50 % or 100 % elongation), tensile strength, elongation at break]

Tensile test results shall be used to extrapolate the service life according to Arrhenius equation (see Annexes A and E). Other properties may be used by agreement between all parties.

7.3 Requirements for rapid gas decompression testing

7.3.1 General

This part of ISO 23936 gives test procedures for measuring the effect on elastomeric O-ring seals of rapid depressurization after periods at elevated temperature and high pressure in gaseous environments. In addition, guidance notes for interpretation of the results are provided. The supplier shall discuss with the user those applications for which this failure mode is relevant.

The test fluids, conditions, procedure, equipment, inspection procedure and test reporting requirements are described in Annex B.

7.3.2 Acceptance criterion

No seal cross-section shall have a rating of more than 3 (see Clause B.4).

8 Qualification of elastomeric materials in bonded flexible hose

8.1 General

Bonded flexible hose is the general class of flexible hose constructed from layers of elastomer and wire, wire fabric or textile fabric reinforcement that are bonded together by vulcanization during manufacture. The hose section from the internal to external diameter generally consists of the following:

- liner: inner layer of elastomer providing resistance to the fluids being transported;
- body layers: layers of reinforcement typically including textile fabric or parallel cords impregnated with elastomer, parallel steel wire cords impregnated with elastomer, and embedded helical wire. Infill elastomer layers may also be present;
- cover: outer layer of elastomer providing resistance to the external environment;
- insulation or buoyancy: an additional outer layer for hoses where either insulation or buoyancy is required.

The hose structure is integrated into suitable end fittings according to the specific design, usually by bonding of the elastomer to the metal end fitting with a suitable curable adhesive system during the vulcanization of the hose.

Bonded flexible hose usage can be generally classified into:

- a) lower pressure applications that are typically used for loading and discharge of liquids and LNG in offshore mooring situations;

- b) higher pressure applications used in oil and gas production.

For a), guidance is provided in GMPHOM/OCIMF [*Guide to Manufacturing and Purchasing Hoses for Offshore Moorings (Oil Companies International Marine Forum)*], including materials tests for the liner and cover materials for materials acceptance and prototype hose approval.

For b), ISO 13628-10 specifies material property requirements and test procedures for the qualification of liner, breaker and reinforcing layers in terms of mechanical/physical properties, thermal properties, permeation characteristics and compatibility/ageing properties covering all pressures.

In the context of this part of ISO 23936, the main consideration is the qualification of the liner material that is in contact with the fluids being transported. For the longer term, the effects of the permeation of fluids through the liner to other elastomer layers should also be considered as well as ageing effects on mechanical/physical properties. Because of the multi-layer construction of bonded hoses, not only should the properties of the individual elastomer layers be considered, but also the adhesion between layers including the bonding with the end fittings.

8.2 Qualification of bonded flexible hose liner material

8.2.1 General

Qualification should be according to the subclauses below, which are based on the existing guidelines mentioned in 8.1.

8.2.2 Guide to manufacturing and purchasing hoses for offshore moorings

The procedure of GMPHOM/OCIMF should be applied or adapted as appropriate with regard to materials test procedures. It possesses two clauses entitled Materials Tests, one under “Acceptance Tests” and one for “Prototype Hose Approval”; the most relevant should be agreed between supplier and purchaser and employed. Particular points are:

- a) Within both clauses termed Material Tests, for resistance to liquids, GMPHOM/OCIMF specifies the use of ISO 1817 using the conditions 48 h at 40 °C in the test liquid as a volume swell test, with a requirement of swell being no greater than 60 %.

NOTE GMPHOM/OCIMF specifies use of (ASTM) liquid C, which can still conform to this part of ISO 23936 if liquid C is stated to be the bespoke liquid agreed between participants (see Annex A).

This part of ISO 23936 allows the same procedure for use with a standard liquid selected to be reasonably representative of the composition of the service fluid to be transported or contained, in accordance with Annex A. Bespoke acceptance properties will be required if alternative low temperature requirements and/or products and/or service fluids are relevant.

- b) GMPHOM/OCIMF specifies for temperature resistance “no significant deterioration” at –20 °C using the Gehman test to ISO 1432.
- c) Under “Acceptance Tests”, GMPHOM/OCIMF also specifies adhesion testing between bonded layers of body and end-fitting elastomer using a standard peel test as described in ISO 36:2005, which specifies a test method for measuring the force required to separate two plies of fabric bonded with rubber, or a rubber layer and a fabric ply bonded together. The ply surfaces should be plane or nearly so, with no gross irregularities. Supplier and user should agree a threshold force for acceptance, based on experience.
- d) If the service temperature is higher than ambient, the material test temperature should be increased accordingly. The test conditions, test duration and acceptance criteria should be agreed between supplier and purchaser. Consideration to the temperatures and fluids chosen should be made with consultation to ISO 1817.

8.2.3 ISO 13628-10 and API 17K

ISO 13628-10 and API 17K specify property tests for liner and reinforcing layers (see Tables 9 and 11 in API 17K:2005) and describe test procedures and acceptance criterion for fluid permeability (liquid and gas), blistering, fluid compatibility, ageing and void formation (the last being a component test), concerning interlayer failures. Much of ISO 13628-10 and API 17K is useful for incorporation in this part of ISO 23936, but some variations are required.

8.2.4 Requirements for gas permeation

Gas permeation testing should be made at appropriate high pressure on a specimen from liner or other layer material, and procedures shall vary depending on conditions and fluid type. Test gases shall be in accordance with Tables A.2 and A.3, using the bespoke category for testing single gases.

For high pressure (HP) gas permeation testing of an elastomer material, a test assembly pressure cell with the following features is required.

- a) A chamber which can be pressurized to high pressure by a gas supply. This will be separated from a low pressure chamber by a suitably sealed elastomer test piece. Facilities for continuous monitoring of the pressures in the high and low pressure chambers are required.
- b) Heating (insulated band heater) facilities and temperature monitoring and control of the permeation cell to within ± 2 °C.

Test times are governed by diffusion characteristics of candidate elastomers (see Annex E). In one test arrangement, test pieces of test elastomer of diameter 10 mm are bonded during vulcanization into a suitable holder. Moulding pressure shall be high to minimize porosity and microporosity. The test specimen holder is installed and sealed in the HP permeation cell. A porous steel sinter necessary for supporting the specimen is inserted appropriately. The cell is then heated to test temperature and allowed to equilibrate before applying test gas to the specimen and pressurizing. As a minimum, the following test conditions shall apply:

- high pressure (P_1): hose design pressure, may be used if pipe design pressure is not known;
- temperature (T): service, or three higher temperatures for three accelerated tests followed by Arrhenius-extrapolation of the three resulting data points to service (see Annex D).

The pressure increase due to permeation in the low pressure chamber with time may be converted to the rate of gas permeation (cm^3/s at standard temperature and pressure), assuming the gas to be ideal, by Equation (1):

$$\frac{dq}{dt} = \left(\frac{\partial P_2}{\partial t} \right) \left(\frac{273 \times V_{lp}}{T_{lp}} \right) \quad (1)$$

where

V_{lp} is the volume of the low pressure chamber;

T_{lp} is the temperature (ambient) of the low pressure chamber.

P_2 is expressed in atmospheres.

The permeation coefficient Q can be obtained from the gradient, at steady state conditions, of the permeated gas pressure versus time plot using Equation (2) (see also Annex E):

$$\left(\frac{q}{t} \right) = QA \left(\frac{P_1 - P_2}{h} \right) \quad (2)$$

where

h is the specimen thickness;

P_1 is the pressure in the high pressure chamber;

P_2 is normally zero unless stipulated otherwise.

The initial transient stage of the test can be used to provide an estimate of the diffusion coefficient D , as shown in Equation (3):

$$D = \frac{h^2}{6\tau} \quad (3)$$

where time-lag τ is the value of time where the back-extrapolated steady state line intersects the time axis.

The solubility coefficient s is then determined from Equation (4):

$$Q = D \times s \quad (4)$$

The concentration c of a single gas absorbed into the polymer surface may be calculated from Equation (5):

$$c = s \times P_1 \quad (5)$$

The measured criteria are the permeation coefficient Q in $\text{cm}^2/\text{s}/\text{atm}$, the diffusion coefficient D in cm^2/s , the solubility coefficient (s) in atm^{-1} , and the dimensionless (i.e. $\text{cm}^3 \text{ gas}/\text{cm}^3 \text{ elastomer}$) concentration c applying at the high pressure face. For a lining material contacting an essentially impermeable layer (e.g. external steel piping), c will eventually be achieved (or nearly so) throughout. For a series of accelerated tests, these coefficients can be used for Arrhenius extrapolations (see Annex E). Q values can be used to predict permeation rates through hose liners (see Annex E). D can be used for rough estimates (root mean squares) of migration distance within the material after time t , using $(2Dt)^{1/2}$. Experience suggests that breakthrough time can reasonably be taken as $1/2(\tau)$.

For mixed gases – yielding apparent coefficients only by the above procedures – any following estimates should be for guidance only.

The presence of the steel sinter support may reduce measured permeation rates. For tests carried out as above, this observation should be included on the test report.

8.2.5 Requirements for RGD

RGD performance for hose linings according to this part of ISO 23936 should follow the procedures of 6.2.3.2 in ISO 13628-10:2005 or API 17K, but using gas compositions taken from Tables A.2 to A.4 of this part of ISO 23936.

Because diffusion rate is proportionate to the square of distance migrated, soak times for hose linings should be increased from those used for testing small seals by a factor, K , which relates distances to be migrated in seals and hoses raised to the power of 2. This factor to calculate the soaking time is as shown in Equation (6):

$$K = (h/r)^2 \quad (6)$$

where

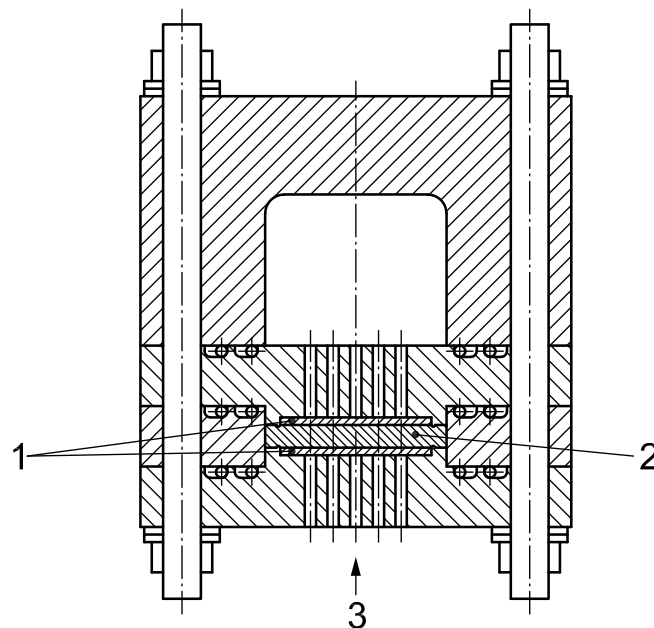
h is the hose lining thickness with fluid entering the lining from one exposed surface only;

r is the radius of the seal cross-section for the test arrangement described in Annex B.

The starting point is a seal cross-section radius of 2,66 mm with a minimum soaking time of 68 h.

The specimen for RGD testing of hose lining should include some fabrication to allow assessment of the elastomer's RGD resistance when supported as in service. Single textile fabric layers should sandwich the elastomer lining layer. The specimen should be moulded to the required thickness and cured in a plunger mould. Moulding pressure should be 0,7 MPa¹⁾ to be similar to that met in hose manufacture or as agreed between interested parties. Lining thickness including fabrics should be 3 mm to 4 mm and specimen diameter 30 mm, or as similarly agreed. Fabrics should be rubberized and of the type used in the manufacture of hoses for this service.

Figure 1 shows the specimen and portholes for high pressure gas to enter it through one face only. More portholes above the specimen allow permeated gas to arrive in a vented chamber (a vertical line showing the vent). Figure 2 shows the test arrangement with a stack of seal jigs located in a suitable pressure chamber (to accommodate test pressure plus a safety factor), and the vented gas led outside it.

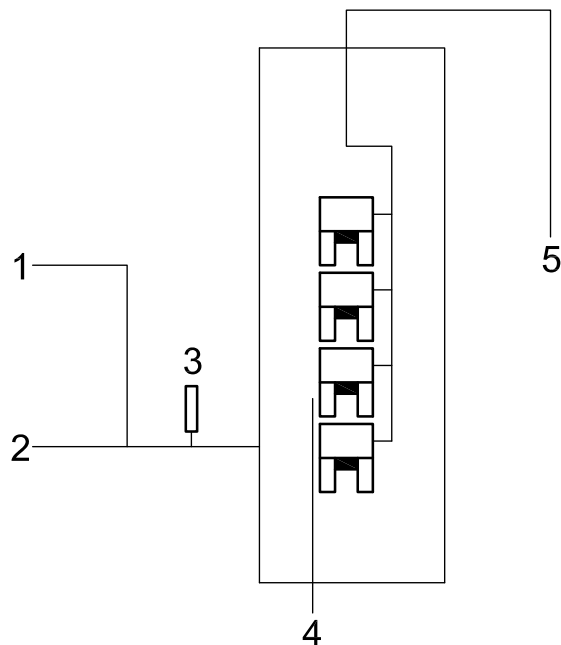


Key

- 1 fabric layers
- 2 elastomer
- 3 high pressure gas

Figure 1 — RGD test jig holding fabricated specimen; HP gas applied unidirectionally

1) 1 bar = 0,1 MPa.



Key

- 1 gas in
- 2 PC controlled blowdown
- 3 pressure transducer
- 4 thermocouple
- 5 permeated gas vent

Figure 2 — Hose lining jigs stacked in a pressure chamber during testing

The temperature, pressure, number of test cycles, decompression rate and acceptance criteria of ISO 13628-10 and API 17K shall apply.

Test fluids should be selected from Tables A.2 to A.5 in this part of ISO 23936; those from Table A.3 and Table A.5 (sour conditions) should only be used if gas emitted during decompression can be handled safely.

8.2.6 Requirements for ageing tests

In ISO 13628-10 and API 17K, the test liquid used for exposure tests is chosen by the component purchaser; to comply with this part of ISO 23936, liquids given in Tables A.1, A.4 and A.5 should be used. Ageing as a materials test procedure should use the same approach as that taken in this part of ISO 23936 for seal elastomers (Clause 7), with the acceptance criteria also being the same.

8.3 Qualification of bonded flexible hose – Layers outside the liner

The cover material should possess good mechanical properties, including tear strength/impact resistance, to resist mishandling issues, etc.; low sea-water uptake should be demonstrated if the cover is subject to seawater immersion. Layers between liner and cover should be manufactured from elastomer types intermediate in characteristics between the two, each having evidence provided of good bondability to adjacent layers and to any fabric, textile, wire reinforcement, etc. embedded in them.

9 Qualification of elastomeric materials in other large components

9.1 General

For large components, although it is likely that component testing under particular conditions required by the user will take on increased relevance, materials testing will often still be required to aid material selection for the component and for qualification purposes. This clause describes qualification for elastomers in different components.

9.2 Qualification of elastomeric materials in flexible joints

9.2.1 General

Flexible joints are part of the subsea system used in the production and export transportation systems for offshore production platforms. The joints provide rotational flexibility at the connection points that reduces bending stresses and increases the fatigue life of the metallic components in critical regions. The flexibility is provided by a spherical joint that consists of a laminated construction of spherical layers of steel and elastomer bonded together during the vulcanization process. Rotational flexibility is achieved by shearing of the elastomer layers referred to as structural layers, whilst internal pressure and tension loads in the line are reacted by compression of these layers. The edges of the steel plates and structural elastomer layers may be protected from direct fluid/gas exposure by an elastomeric cover layer which is usually a similar material to the main structural layers. Typical constructions employ either nitrile butadiene rubber (NBR) or hydrogenated nitrile butadiene rubber (HNBR) materials. The fluids being carried are in contact with one side of the joint, whilst the other side is in contact with either seawater or air. Fluids transported include production fluids imported to the platform, and gas and oil exported from the platform after processing. Risers may also transport well injection fluids such as gas or water and any other additives to control wax build-up and to provide corrosion protection.

The flexible joint vendor will carry out a fatigue analysis using the specified conditions to demonstrate an acceptable life of the design to the user's satisfaction. Contributions from time dependent creep rupture failure under the mean components of the loading should be considered as well as cyclic fatigue damage arising from the dynamic components (see Reference [20]). Compression of the rubber layers due to pressure and tension loads results in concentrations of shear at the edges of the layers; in typical designs, these are highest on the seawater/air side of the layers.

9.2.2 Specific sections relating to the qualification of flexible joints

Fluid compatibility with the cover and structural layers is covered by ISO 1817.

The effects of fluid permeation through the cover layer and into the structural layers and bonds should be addressed, as should the effects of ageing in terms of their impact on the design life of the flexible joints. The effects of any chemicals used in the lines and which may come into contact with the elastomer may also need to be assessed in terms of chemical compatibility and swelling. The effects of gas decompression on the integrity of the cover layers and structural layers may also need to be addressed.

Due to the complexities involved regarding different design solutions that can limit fluid/gas exposure and how the rubber layers perform in protecting the structural layers, testing for fluid/gas exposure will need to be performed using test specimens and techniques agreed upon between the asset operator and the component manufacturer, including any third-party verification as required.

9.3 Qualification of elastomeric materials in blow-out preventers

9.3.1 General

Elastomeric seals employed in blow-out preventers (BOPs) should be qualified as appropriate in accordance with Clause 7. Test conditions based on operational conditions should be agreed upon by the user and/or asset operator. Other components are much larger, which will lead to some differences in approach.

9.3.2 Specific sections relating to the qualification of BOPs

The performance testing given in ISO 13533 or API 16A for elastomer materials should be followed using relevant standards. ISO 16070 covers flow control equipment which does not relate to packers. Additionally API 14A applies to surface and subsurface safety valves and again does not relate to packers. Ram shear seal elastomeric components should be specified and qualified with regard to an acceptable magnitude of appropriate properties and fluid resistance. Exposures to fluids should be based on the most appropriate of those tabulated in Annex A. RGD assessments should be based on the approach used for hoses rather than used for seals in 8.2, because they are also larger components.

9.4 Qualification of elastomeric materials for packers

This subclause refers to all types of packers including permanent and retrievable casing packers and bridge plugs, inflatable thru tubing, casing and open hole packers, and open hole mechanical packers. Use of this equipment may reflect both short- and long-term performance requirements.

Elastomeric seals employed in packers generally shall be qualified as appropriate according to Clause 7. Validation procedures for packer assemblies are covered in ISO 14310. Generally, for retrievable casing packers and bridge plugs, packing element sealing compounds should offer a combination of high extrusion resistance and adequate strain capability to pack off without suffering fracture. Maximum extrusion resistance of a permanent packer, due to typically near 100 % mechanical back up, is slightly less important than adequate strain capability. Inflatable packers should demonstrate high tear strength magnitudes and high extensibility at high temperatures, which should be specified from the options in Table A.6.

The requirements for qualification of materials for permanent packers, traditional and polished bore receptacle (PBR) shall be the same as for other large components. High pressure gas permeation testing may be required.

Drilling fluids and later production fluids may be contacted in sequence; testing may need also to be conducted in sequences to mirror this.