NORSOK STANDARD

COMMON REQUIREMENTS

QUALIFICATION OF NON - METALLIC SEALING MATERIALS AND MANUFACTURERS

M-CR-710
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CONTENTS

1 FOREWORD

This standard has been developed by the NORSOK Standardisation Work Group for the widest possible national and international application.

The basis is two existing proposals for new NACE-standards on ageing and explosive decompression, respectively. When the NACE-standards have been established this NORSOK standard will be substantially reduced, by omitting ANNEXES A and B. Annexes A and B are normative.

2 SCOPE

The Standard defines the requirements for critical non-metallic sealing materials (polymers) for permanent use subsea including well completion, X-mas trees, control systems and valves, and topside valves in critical gas systems.

This standard covers the requirements for qualification of non-metallic sealing materials for use in these applications.

The intent of the requirements is further to establish that the manufacturer has a sufficient understanding and experience with the given materials to produce them in the required shapes and sizes with acceptable properties.

The aim is that a successful qualification of a manufacturer and a specific material shall be valid for a majority of the future development projects and for different operators.

3 NORMATIVE REFERENCES

See table 1 below for relevant standards for polymers, mainly thermoplastic materials and elastomeric materials.

Table 1: Standards applicable for thermoplastic materials and elastomeric materials respectively.

STANDARDS		THERMO-PLASTICS	ELASTOMERS
ASTM D 638	Test Method for Tensile Properties of Plastics.	X	
ASTM D 695	Test Method for Compressive Properties of Rigid Plastics.	X	
ASTM D 746	Test Method for Brittleness Temperature of Plastics and Elastomer by Impact.	X	X
ASTM D 790	Test method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials.	X	
ASTM D 792	Test Methods for Specific Gravity and Density of Plastics by Displacement.	X	
ASTM D 1043	Test Method for Stiffness Properties of Plastics as a Function of Temperature by means of a Torsion Test.	X	
ASTM D 1525	Test Method for Vicat Softening Point for Plastics.	X	
ASTM D 2990	Test Methods for Tensile, Compressive and Flexural Creep and Creep Rupture Test of Plastics.	X X	
DIN 53453	Testing of Plastics, Impact Flexural Test.	X	
ISO 868	Determination of Indentation Hardness by Means of a Durometer (Shore hardness).	X	
ISO 1133	Plastics - Determination of Melt Flow Rate of Thermoplastics.		
Description of Arrhenius method:		(X)	(X)
(ASTM D 3032	Method of Testing Hook-up Wire Insulation)		
ASTM D 395	Test Method for Rubber Property - Compression Set (method B).		X
ASTM D 412	Test Method for Rubber Properties in Tension.		X
ASTM D 1141	Specification for substitute ocean water.		X
ASTM D 1414	Methods of Testing Rubber O-rings.		X
ASTM D 2240	Test Method for Rubber Property - Durometer Hardness.		X
BS 1806	Standard Inch Sizes of O-rings		X
ISO D 34	*Tear resistance, method A*		*X*
ISO 1432	*Rubber vulcanised - low temperature stiffening (Gehman test)*		*X*
ISO R 812	*Method of test for temperature limit of brittleness for vulcanised rubber*		*X*
ISO 1817	*Vulcanised rubbers - Resistance to liquids - methods of tests*		*X*

4 DEFINITIONS AND ABBREVIATIONS

4.1 Definitions

Accelerated test	A test at temperature and pressure values chosen to accelerate seal degradation effects.
Seal cross-section diameter	The free height of the seal at room temperature, measured normal to the direction of fluid pressure-drop across the seal. Normally the mean of three measurements at different circumferential positions.
Interference	[(Seal cross-section diameter) - (seal-housing recess height)], each measured normal to direction of fluid pressure drop across seal.
Compression Set, %	100 x (Pre-test Interference -Post-test Interference)/Pre-test interference.
Elastomer	A material compounded from polymers and other constituents, then cured to form a rubbery material.
Explosive decompression	Rapid pressure drop in a gas containing system causes the gas trapped inside an elastomer (polymer) to expand. The pressure drop rate must be faster than the diffusion rate of the gas inside the polymer.
Fluid (or media)	A gas or liquid or a mixture of these.
Polymer	A high molecular weight organic compound, natural or synthetic, whose structure can be represented by a repeated small unit, the mer. Polymer includes both elastomer and thermoplastic materials.
Reference Fluids	
• For ageing	(i) 90% iso-octane, 10% toluene (“synthetic oil”) (ii) Methanol (iii) Air (iv) Methane (v) 33 vol % of (i), 33 vol% of seawater, 33 vol % gas phase made of 1% H_2S, 10 % CO_2, 89 % CH_4. (vi) 33 vol % of (iv), 33 vol% of seawater, 33 vol % gas phase made of 5 % H_2S, 10 % CO_2, 85 % CH_4.
• For ED	(a) 100% Methane gas (b) 10% Carbon dioxide, 90% Methane gas.
Reference Period	A period in the following series of selected durations: 1 week, 2 weeks, 4 weeks, 13 weeks, 26 weeks, 1 year, 2 years.

Reference Pressure	A pressure value in the following series of values: 2, 50, 100, 200, 300, 500, 750, 1000 bar (± 5%). 30, 725, 1450, 2900, 4350, 7250, 11875, 14500 psi (± 5 %).
Reference Seal	A seal in one of the following sizes (BS 1806): (i) Size no. 325 O-ring (Cross section: 5,33 mm, ID: 37,47mm). (ii) Size no. 312 O-ring (Cross section: 5,33 mm, ID: 15,24mm).
Reference Temperature	A temperature value in the following series of values: 60, 80, 100, 120, 140, 160, 180, 200, 220, 240 °C (±1%).
Room Temperature	20°C, nominal.
Seal Type	A seal design of specified geometry, size and orientation. For standardisation, it is recommended to use a Reference Seal size when this is representative for the seal geometry and size in question.

4.2 Abbreviations

ED = Explosive Decompression
QC = Quality Control

5 FUNCTIONAL REQUIREMENTS

Material selection shall be based on evaluation of compatibility, functionality under service loading, service environment and the design lifetime. The following should be considered as appropriate to the seal requirements and evaluated when selecting the material:

- Physical and mechanical properties (Hardness, tensile strength, elongation, modulus of elasticity, compression set, tear resistance, etc.)
- Resistance against high pressure extrusion or creep
- Resistance against thermal cycling, and dynamic movement
- Resistance against rapid decompression
- Long term behaviour
- Documented field performance
- Shelf life

The polymers used shall be from the same material manufacturers as used for seal material qualification, using same manufacturing route and procedures.

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

6 DOCUMENTATION REQUIREMENTS

Required documentation of material properties is given in Table 2. Both requirements to performance documentation (D) as well as quality control (B) are given. Each batch of material shall be supplied with a traceable material certificate, including properties and characteristics as given for quality control in table 2.

This section defines the minimum requirements for production control and quality control during manufacturing. The final procedures w.r.t. key parameters and tolerances shall be defined based on results from qualification testing.

Table 2: Required documentation of Material Properties. (Characteristics which are not relevant for expected service conditions can be omitted). Guidelines on selection of standards are given in parenthesis.

PROPERTIES	PLASTICS	ELASTOMERS
· Melt flow viscosity (ISO 1133).	**D/B**	
· Softening point (ASTM D 1525).	**D**	
· Specific gravity (ASTM D 792).	**D/B**	**D/B**
· Hardness (ISO 868/ASTM D 2240).	**D/B**	**D/B**
· Tensile properties and elongation (ASTM D 638/D 412/D 1414).	**D/B**	**D/B**
· Flexural properties (ASTM D 790).	**D**	
· Compression strength (ASTM D 695).	**D**	
· Compression set (ASTM D 395/ASTM D1414). At service temperature.		**D**
· Rheometer trace/curve.		**D/B**
· Temperature tolerance limits (ASTM D 1043).	**D**	
· Tear resistance (ISO D 34).		**D**
· Impact strength (DIN 53453).	**D**	
· Low temperature characteristic (ISO R 812 or Gehman test ISO 1432/ASTM D 746).	**D**	**D**
· Resistance to creep under permanent tensile and compressive loads (ASTM D 2990).	**D**	
· Measurement of glass transition temperature.		**D**
· Fluid exposure test (*).		**B**

LEGEND:

D: Properties to be documented for each supplier for each type of material.
Nominal values with tolerances shall be given (Data Sheet).

B: Properties to be documented on a batch-wise basis, 3 samples per test per batch. The acceptance criteria shall be established prior to the test and based on qualification test results.

(*) Fluid exposure test:
The test fluid shall be reference fluid (i), section 4.
The test temperature shall be equal to the service temperature and test duration shall be until saturation. The test shall otherwise be performed according to ISO 1817 and weight and volume change measured.

7 REQUIREMENTS FOR QUALIFICATION OF MANUFACTURERS

7.1 General requirements

In order to be qualified, the manufacturer shall document that he has manufactured materials and performed the testing required for the relevant product type and has met the requirements for the materials.

The testing shall be performed on products from regular production or from test production made according to the normal production route and with regular production equipment. The qualification test results shall be valid for 10 years and then re-evaluated together with quality control documentation before new qualification tests are performed.

This standard specifies the required minimum numbers of tests that must be performed in order to document the material compatibility with the service conditions and environments. The qualification testing shall apply for the polymer materials on a one-off basis. If well documented in-service experience with traceable production records can be presented, it should not be necessary to perform qualification testing. For later supplies of identical material from the same vendor, a quality control of each batch of material will be sufficient.

7.2 Validity of qualification

The qualification shall be repeated if there are changes in the production route, the manufacturing procedures or the specified composition or properties of the products which exceeds the limits defined based on results from qualification testing.

If production is carried out at different plants/locations, a separate qualification is required for each plant.

8 QUALIFICATION OF NON-METALLIC SEALING MATERIALS

8.1 General

The technical requirements for non-metallic seals are divided into two sections. The first section defines the ageing test requirements and the second defines the requirements for explosive decompression testing. The different test regimes shall be decided upon based on analysis of service requirements for the different equipment components and the material in question. Such assessment shall address all fluids coming into contact with the polymer and the nature of these fluids, both on the high pressure and low pressure side. The service life of the seal material in the relevant service environment shall be evaluated using appropriate techniques.

8.2 Requirements for Ageing Tests

8.2.1 General

This document defines test procedures for the prediction of the progressive degradation of non-metallic seals exposed to fluids at elevated pressure and temperature over an extended

period of time. It is applicable where it is required to predict service life in a specific application or for the comparison of the performance of different seal materials.

If no previous knowledge about a seal material behaviour in a certain fluid exist, an initial pre-check test shall be performed. The test duration shall be sufficient to reach saturation of the fluid in the material at the test temperature. If no immediate changes in volume or weight occurs, then the ageing test can start.

During accelerated testing, the supplier shall limit the test temperature so it can be ensured that the same chemical and/or physical processes will occur as during service.

The seal shall be tested in a constrained mode. For elastomers, the standard constraint shall be a flange or spigot/sleeve stack arrangement whereby the standard O-ring is compressed by 20% of its original section. The flange or spigot/sleeve stack arrangement shall be submerged in the test fluid. No pressure difference over the O-ring seal is required. Test seals shall be the same as service seals whenever possible.

When extrapolating data from the present procedures appropriate statistical techniques shall be applied. For example, if progressive degradation is dependent on a single chemical ageing process, a method based on Arrhenius equation/method may be used as described in ASTM D 3032.

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

8.3 Requirements for explosive decompression testing

8.3.1 General

This document gives test procedures for measuring the effect on non-metallic materials of rapid de-pressurisation after periods at elevated temperature and high pressure in dry gaseous environments. Further, guidance notes for interpretation of the results is also given. The supplier should evaluate for which applications this failure mode is relevant. It is applicable when testing O-rings or other seal types in either a free unconstrained state or constrained in a specified fixture design.

The test media, conditions, procedure, test equipment, inspection procedure and test report requirements are described in Annex B.

SAFETY PRECAUTIONS: The test procedures involve the use of high pressure gases which may be flammable and may have toxic effects. These media may be extremely hazardous if not handled correctly. The reader shall ascertain and implement the appropriate safety precautions before commencing any test work.

ANNEX A (NORMATIVE)

TEST MEDIA, CONDITIONS, EQUIPMENT AND PROCEDURES FOR AGEING.

A1 TEST REQUIREMENTS

A1.1 Ageing Test Media

Tests fluids shall be representative of the seal application environment, using a Reference Fluid whenever possible. The fluid exposure of the seal from both sides need to be considered.

All chemically active substances, even small amounts (e.g. 0.1.-1%) shall be included in the test, if they will be present in service. When evaluating test fluids also the use of drilling fluid, hydraulic fluids, corrosion inhibitor, scale inhibitor and stimulation fluids (HCl/HF), both concentrated and mixtures thereof shall be considered.

For a particular application all relevant aspects of the operational environments to which the seal may be exposed in service should be simulated.

The composition of all fluids to which the test seal is exposed shall be detailed in the Test Report.

A1.2 Ageing Test Conditions

A1.2.1 Test Temperatures

Test temperatures shall be representative for the seal application, using Reference Temperature values whenever possible.

If accelerated results are required for extrapolation, tests shall be run at a minimum of three test temperatures. The service temperature and the next two higher Reference Temperatures should be used for this purpose. In accelerated tests particular care is required to ensure that reactions occurring are representative of those which will occur in service.

Test temperature versus time details shall be fully described in the Test Report.

A1.2.2 Test Pressure

Test pressures shall be representative of the seal application, using a Reference Pressure whenever possible.

The pressure versus time details shall be fully described in the Test Report.

A1.2.3 Exposure Period

The exposure period for the compatibility check should be chosen to give the same degree of saturation of the test seal, by the test fluid, as in service.

The duration of the ageing test (the period after reaching saturation in the test) should be large compared with the time to reach saturation, if this is the situation occurring in service. Thus reflect the service life of the component.

A1.3 Ageing Test Specimens

Seal material(s) shall be the same compound from the same manufacturer and preferably the same cross sectional dimensions as the service seal.

A1.3.1 Constraint level

The seal shall be tested in a constrained mode. For elastomers, the standard constraint shall be a flange or spigot/sleeve arrangement whereby the standard O-ring is compressed by 20% of its original section diameter.

A2 EQUIPMENT

A2.1 Test Vessel

The test vessel shall be rated for use at the test temperatures and pressures and the metallic materials shall be compatible with the test fluid. The fluid capacity shall be such that the ratio of fluid to seal volume is greater than 25:1. The vessel shall be capable of being purged to remove air before testing. The seals shall be tested in a constraint condition and exposed to the test fluid from both sides.

For elastomers, the standard constraint shall be a flange or spigot/sleeve arrangement whereby the standard O-ring is compressed by 20% of its original cross section. The flange stack or spigot/sleeve arrangement shall be submerged in the test fluid. No pressure difference over the O-ring seal is required.

A2.2 Fluid Mixtures

If a service fluid is a mixture of gas and liquid, or of immiscible liquids, then the constituent fluids can stratify such that different parts of a seal are exposed to different fluid phases and/or chemistry. It is therefore important that the test conditions take account of the service conditions in this respect. It is an advantage to perform agitation of the test fluid, if service fluid constituents are uniformly distributed.

A3 TEST PROCEDURE

A3.1 Introduction

A3.1.1 Measurements

This test procedure provides for the determination of change or rate of change of various physical properties of the test seal. All property measurements shall be made in the free state at Room Temperature. The measurements in A3.2 shall be made before test and those in A3.4 - A3.6 inclusive, shall be made after test. All measurements shall be recorded and reported in the Test Report.

A3.1.2 Reproducibility

The intention is to extrapolate or interpolate performance and thus three tests samples shall be run at each of a minimum of three Reference Periods for each of three reference temperatures.

A3.2 Seal Measurements Before Test

A3.2.1 Initial Cross-Sectional Diameter, Weight and Volume of Seal

Each seal shall be measured at three circumferentially equidistributed positions, with an accuracy of ±0.05 mm. The volume shall be measured by weighing the seal dry and wet. The individual and mean measured values shall be reported together with:

(i) Mean interference of the seal installed in its test housing.

A3.2.2 Initial Hardness, Tensile Strength, Elongation and E-modulus

The hardness, tensile strength, elongation and E-modulus of virgin material shall be measured according to the referenced procedures. In addition, the initial hardness of each seal shall be measured at three equidistributed positions on the axially-directed faces of the seal before mounting in the test fixture.

The individual and mean measured values shall be reported.

A3.3 Main Test Sequence

- Clean test vessel and housings.
- Install test seals, unlubricated, in the test vessel.
- Purge test vessel with nitrogen.
- Fill test vessel by replacing the purge gas with test fluid.

- Heat test vessel to the specified test temperature.
- Pressurise test media to the specified test pressure.
- Maintain test pressure and temperature for the specified test duration.

To reduce the risk of decompression damage the pressure should ideally be released as slow as possible over several weeks, but for practical reasons the following procedure is recommended:

- Cool down the autoclave to ambient temperature (recorded as the final date of ageing)

The pressure must not fall below 20% of test pressure or 40 bar, which ever is highest.

- Reduce pressure to 20% of test pressure or 40 bar, which ever is highest, at a rate of 10 bar pr. minute and leave the system for one week.
- Reduce the pressure further down to 5% (or max 10 bar) of test pressure at a rate of 10 bar pr. minute and leave the system for at least 24 hours.
- Reduce remaining pressure at a rate of 0,1 bar pr. minute.
- Remove seals from vessel without disturbing seals.
- Carry out post-test procedures in A3.4 - A3.6.

A3.4 Visual Inspection for Physical Damage

The test specimens, shall be visually inspected for external damage. The nature of any physical damage, set, embrittlement, swell, etc. and its location relative to the pressurised fluid, shall be recorded and reported in the Test Report.

A photographic record (10 x magnification) of specific features is desirable and should be included in the Test Report.

A3.5 Cross-Sectional Diameter, Weight and Volume After Test

The cross-sectional diameter after test shall be measured 24 hours after removal from the test vessel, as in A3.2.1. The measurement shall be reported as a “% Compression Set”:

% Compression Set = 100 x (Pre-test Interference-Post-test Interference)/Pre-test Interference.

Then measure the weight and volume.

A3.6 Mechanical Properties After Test

The hardness, tensile strength, elongation and E-modulus shall be measured, 24 hours after removal from the test vessel.

A4 AGEING TEST REPORT

The report shall clearly state the following:

A4.1 Test Seal Details

a. Seal type, manufacturer's reference, size
b. Seal material identification:
Manufacturer, polymer type, manufacturer's compound reference, batch number, cure date.

A4.2 Test Conditions

a. Test media identification.
b. Full details of test media composition.
c. Test temperature - time details, °C.
d. Test pressure - time details, bar gauge.
e. Test constraint (20%).
f. Test duration, hours.
g. Date and time of start and end of test.

A4.3 Pre-Test Measurements

The constraint on the O-ring shall be clearly indicated, (i.e. 20%).

a. Seal pre-test dimensions, (mm), weight and volume.
b. Seal pre-test hardness, Shore A.
c. Seal pre-test strength, elongation and E-modulus.
d. Initial linear interference, (mm).

A4.4 Post-Test Examination

a. Visual condition of the test specimens after test:
Structural damage, set, embrittlement, etc.
b. Mean cross-section, (mm), weight and volume.
c. Mean hardness, Shore A.
d. Compression set, %.
e. Post-test seal strength, elongation and E-modulus.

A4.5 Trends

Measurements from A4.4 shall also, where possible, be presented graphically as a plot against time according to Arrhenius equation/plot. A best fit line should be drawn to permit interpolation or extrapolation.

ANNEX B (NORMATIVE)

TEST MEDIA, CONDITIONS, EQUIPMENT AND PROCEDURES FOR EXPLOSIVE DECOMPRESSION TESTING.

B1 TEST REQUIREMENTS

B1.1 ED Test Media

In most cases selection of dry gas media is considered to provide adequate indication of the resistance of the elastomer to ED.

The resistance of elastomers to explosive decompression will in general depend on the test media used. It is recommended that the test media be selected to have a composition as close as possible to the service application. The two Reference Test media (section 4) are however recommended for standardisation purposes.

B1.2 ED Test Conditions

B1.2.1 Test Temperature

The test shall be conducted at the reference temperature which is closest to the service temperature or any higher reference temperature (ref. section 4). The test temperature shall be measured with a calibrated thermocouple transducer throughout the test and the measured temperature recorded and reported.

When performing the test, the temperature shall be increased to the test temperature and held for 10 minutes before applying the gas pressure. The temperature should be maintained during the decompression stage of the test as far as possible and cooling only started after pressure is at ambient, unless otherwise specified to represent specific service conditions.

B1.2.2 Test Pressure

The test shall be conducted at one of the following pressures: 100, 150, 200, 250, 300, or 400 bar which are closest to the service pressure. At high service pressures, a lower test pressure can be selected, but the test pressure shall be above critical pressure with respect to creating relevant ED loading. The test pressure shall be measured with a calibrated pressure transducer through out the test and the measured test pressure reported at the end of the test.

B1.2.3 Exposure Period

The standard initial exposure period shall be 72 hrs. (±4 hrs.). It shall be reasonably ascertained that the initial exposure period at test temperature is adequate for gas to saturate the elastomer seal of size specified in section 4. If time is shorter than the standard time, or non-standard seal sizes, are to be used, the correct minimum time shall be established for the testpiece size used by appropriate diffusion calculations using measured values for diffusion coefficient and gas solubility obtained at realistic pressures. If a non standard exposure

period is used, the justification for it shall be presented in the test report together with supporting evidence that the initial exposure period has been sufficient to ensure gas saturation.

B1.2.4 Decompression Rate

The standard decompression rate shall be 70 bar per minute (±10%). The decompression rate shall be measured and measured data included in the test report. A non-standard decompression rate shall be specified if required by service application conditions.

B1.2.5 Number of Decompression Cycles

The number of decompression cycles shall be 1, 5, 10 or 30 including the initial exposure period of 72 hours and this number shall be recorded in the test record. Each decompression cycle shall consist in reducing the gas pressure at the rate specified in clause B 1.2.4 while maintaining the test temperature constant, holding at near ambient pressure for 1 hour including decompression time, then repressurising to the test pressure and holding this test pressure for 23 hrs. (±1 hr.) before repeating the decompression cycle.

B1.3 ED Test Specimens

The standard test specimen should be a reference O-ring of size either 312 or 325. If a non-standard O-ring or seal type is specified its geometry shall then be reported in the test report.

The O-rings used for test purposes shall be of the same composition and shall be cured and (if applicable) postured using a time and temperature that provides a similar state of cure as seals to be used in service.

B2TEST EQUIPMENT

The test vessel shall be rated for use at the test pressure and temperature and shall be capable of being purged to remove air before testing is initiated.

The size of the test vessel shall be such that the ratio of the vessel's volume to the total specimen volume is greater than 25 to 1.

Testing shall be performed on both an unconstrained (free) O-rings and on O-rings constrained in the standard manner. The standard constraint shall be a flange or a spigot/sleeve arrangement whereby the standard O-ring is compressed by 20% (±1%) of its original section diameter.

Only ED-resistant seals shall be used to seal the pressure vessel since they will be subjected to the same conditions as the test seals.

B3 TEST PROCEDURE

Measure the initial dimensions of the test seal and inspect and record any initial defects. Only test seals whose visible defects are less than 1 mm in size should be tested. The outer diameter and the cross section diameter shall be measured at three places at approximately 120°C intervals to an accuracy of 0.1 mm or better.

- All tests shall be conducted with a minimum of three replicate seals.
- Measure the initial hardness of the seal if required as a QC check only.
- Mount the test seals on the test fixture. (No fixture for unconstrained seals).
- Place the test fixture inside the test vessel and seal the test vessel.
- Purge the test vessel with the test gas to remove any air.
- Charge the test vessel with a low gas pressure of 10 bar before heating.
- Heat the test vessel to the test temperature. Record the initial test temperature.
- Charge the test vessel with the test gas to the test pressure.
- Maintain the test pressure and temperature for the exposure period, recording temperature and pressure at regular intervals.
- At the end of the test period, check and record temperature, reduce the test pressure at the rate of 70 bar/minute, or the chosen rate. In the case of multiple decompression tests hold for 1 hour including decompression time at the low pressure then repressurise to the test pressure and repeat the previous step, but using an exposure period of 23 hrs.
- Cool the test vessel to near ambient temperature.
- Open the test vessel and remove the test samples (constrained and unconstrained).
- Remove the test seals from the fixture. Measure the seal dimensions and record the initial visual appearance of the seals paying particular attention to any blisters and cracks within 30 minutes.
- After a minimum period of 15 hours at ambient temperature and pressure, cut each test seal into 4 equal radial sections as shown in Fig. B.1 and examine the cross sections so produced for internal cracks with a microscope or other visual means providing at least 10x magnification. Record the observations either (A) in accordance with the full measurements inspection system described in clause B 4.1 or (B) in accordance with the rapid rating system described in clause B 4.2. Photos shall be taken for documentation of appearance.

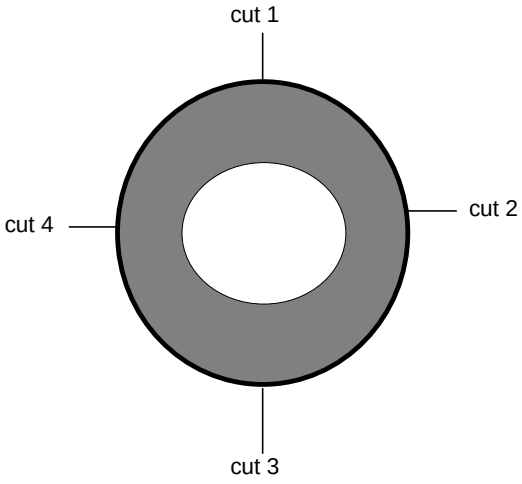

Fig. B.1. Sectioning of test O-rings in four.

B4 INSPECTION PROCEDURE FOR EXPLOSIVE DECOMPRESSION DAMAGE

Two alternative inspection procedures are included. The first, described in clause B 4.1 is a full measurement procedure which provides a quantitative measurement of the extent of explosive decompression damage. From it statistics of damage frequency may be derived. The second, described in clause B 4.2 is a rapid-rating system that is also derived from internal crack measurements and although not quantitative in the same way as B 4.1, is nevertheless objective and not dependent on the time of the observation.

B4.1 Full Measurement Procedure

For every cut seal section examined as per clause B 4.1, measure the length and number of each crack on each section and completing a table as per Table B.1 below.

Table B.1 Example of table for listing number and length of cracks.

Seal Ref. No.	**Number of Cracks per section**				**Total Crack Length (mm) per section**			
	#1	#2	#3	#4	#1	#2	#3	#4
xyz-1								
xyz-2								
xyz-3								

NOTE: The total crack length per section is the sum of every individual crack length per cut seal section. The average crack length per section may be obtained by dividing the total crack length per section by the number of cracks per section.

Obtain replicate results for a minimum of three replicate seals tested under the same conditions. The average and statistical distribution for the resulting set of 12 replicate measurements of crack length L and number of cracks N may then be taken as the representative numbers for the final test report. Thus L and N are defined as the average of 12 replicate measurements.

B4.2 Rapid Rating System

Examine four cut sections by microscopy using a magnification of at least 10x. For each section record a rating between 0 and 6 according to Table B.2 below.

Table B.2 Description of rating number system.

Description	Rating #
No internal cracks, holes or blisters of any size	0
Few small internal cracks (6 or less), each less than 1 mm in size	1
More than 6 small internal cracks, each less than 1 mm in size	2
Few internal cracks (6 or less), each less than 4 mm in size but with at least one crack larger than 1 mm	3
Many internal cracks (more than 6) in the size range 1-4 mm	4
One or more internal crack larger than 4 mm	5
Complete separation of the seal into fragments	6

Record the rating of each seal by listing the individual ratings for each cut section in the order of the highest first to the lowest last. Thus a rating for a whole seal of 1000 means that one cut section had a few small cracks of rating #1 but no other cut section had any crack at all. Rating of 5422 would mean that one section had one or more cracks larger than 4 mm, one section had more than 6 cracks in the range 1 - 4 mm and the other two sections had many cracks smaller than 1 mm.

The "overall rating" for a set of three replicate seals is defined on a worst case basis as the highest rating for each section over the three replicates. Thus if the rating for 3 seals were 1000, 3210, 4100, the overall rating would be 4210.

Comparisons between materials shall be based on overall or average ratings made on the same basis and with the same number of replicate seals.

B5 GENERAL GUIDANCE NOTES

This section contains general guidance notes pertinent to explosive decompression testing and the interpretation of the results for service performance of seals. The photographs in figure B.2 illustrates typical ED damage and application of the rating system.

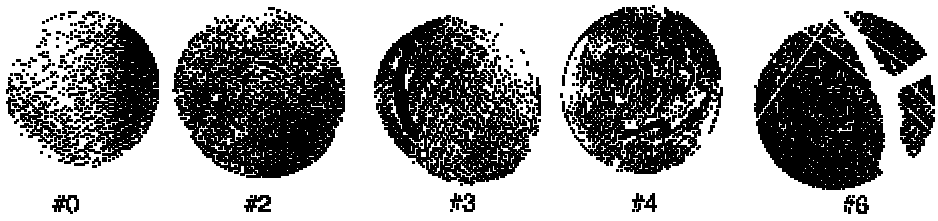

Fig. B.2. Photographs of typical seal sections with ED damage and rating system applied.

Tensile tests and hardness tests on O-rings with internal ED damage are not considered meaningful and so have been intentionally excluded.

B6 ED TEST REPORT

The test report shall state the following :

a) Date of tests.
b) Seal reference information, batch number, polymer type, trade name, supplier, date of vulcanisation etc.
c) Composition of test media.
d) Initial seal dimensions and any initial observation (e.g. surface defects).
e) State which seals were tested under constraint and under unconstraint conditions.
f) Temperature records, including heating and cooling.
g) Test pressure records, including decompression and re-pressurisation for multiple decompression tests.
h) Exposure period.
i) Seal dimensions after ED testing.
j) Explosive decompression damage by either rating system B4.1 or B4.2 and a statement of which rating system was used.
k) Any other pertinent observations or records, e.g. photographs of failed seal sections.