
**Petroleum and natural gas industries —
Downhole equipment — Packers and
bridge plugs**

*Industries du pétrole et du gaz naturel — Équipement de fond de
trou — Garnitures d'étanchéité (packers) et bouchons mécaniques
d'isolation de fond*



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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 14310 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 4, *Drilling and production equipment*.

This second edition cancels and replaces the first edition (ISO 14310:2001), which has been technically revised.

Introduction

This International Standard has been developed by users/purchasers and suppliers/manufacturers of packers and bridge plugs and is intended for use in the petroleum and natural gas industry worldwide. This International Standard is intended to give requirements and information to both parties in the selection, manufacture, testing and use of packers and bridge plugs. Further, this International Standard addresses supplier/manufacture requirements that set the minimum requirements with which it is necessary that suppliers/manufacturers comply to claim conformity with this International Standard.

This International Standard has been structured to allow for grades of increased requirements both in quality control and design validation. These variations allow the user/purchaser to select the grade required for a specific application.

The three quality grades provide the user/purchaser with a choice of requirements to meet a specific preference or application. Quality grade Q3 is the minimum grade of quality offered by this product standard. Quality grade Q2 provides additional inspection and verification steps, and quality grade Q1 is the highest grade provided. Additional quality requirements can be specified by the user/purchaser as supplemental requirements.

Seven standard design-validation grades (V0 to V6) provide the user/purchaser with a choice of requirements to meet a specific preference or application. Design validation grade V6 is the minimum grade and represents equipment where the validation method has been defined by the supplier/manufacture. The complexity and severity of the validation testing increases as the grade number decreases.

It is necessary that users of this International Standard be aware that requirements above those outlined in this International Standard can be needed for individual applications. This International Standard is not intended to inhibit a supplier/manufacture from offering, or the user/purchaser from accepting, alternative equipment or engineering solutions. This can be particularly applicable where there is innovative or developing technology. Where an alternative is offered, it is necessary that the supplier/manufacture identify any variations from this International Standard.

Petroleum and natural gas industries — Downhole equipment — Packers and bridge plugs

1 Scope

This International Standard provides requirements and guidelines for packers and bridge plugs as defined herein for use in the petroleum and natural gas industry. This International Standard provides requirements for the functional specification and technical specification, including design, design verification and validation, materials, documentation and data control, repair, shipment, and storage. In addition, products covered by this International Standard apply only to applications within a conduit. Installation and maintenance of these products are outside the scope of this International Standard.

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 2859-1, *Sampling procedures for inspection by attributes — Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection*

ISO 3601-1, *Fluid power systems — O-rings — Part 1: Inside diameters, cross-sections, tolerances and designation codes*

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

ISO 9000, *Quality management systems — Fundamentals and vocabulary*

ISO 9712, *Non-destructive testing — Qualification and certification of personnel*

ISO 11960, *Petroleum and natural gas industries — Steel pipes for use as casing or tubing for wells*

ISO 15156, (all parts), *Petroleum and natural gas industries — Materials for use in H₂S-containing environments in oil and gas production*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 9000 and the following apply.

3.1

assembly

product comprised of more than one component

3.2

bridge plug

mechanical device installed in, and used for blocking fluid (liquid or gas) communication in, the conduit and not installed in a designed receptacle

3.3

casing

pipe extending from the surface and intended to line the walls of a drilled well

3.4

casing size

nominal casing outside diameter (OD) as specified in ISO 11960

3.5

component

individual part of an assembly

3.6

conduit

casing, tubing or liner, either metallic or non-metallic

3.7

design validation

process of proving a design by testing to demonstrate conformity of the product to design requirements

NOTE Seven standard design validation grades (V6 to V0) are specified in 6.5.

[ISO/TS 29001]

3.8

design verification

process of examining the result of a given design or development activity to determine conformity with specified requirements

NOTE These activities are described in 6.4.

[ISO/TS 29001]

3.9

drift diameter

minimum inside diameter (ID) of a packer, expressed as the OD of the drift bar utilized during assembly inspection, as outlined in 7.4.11

3.10

end connection

thread or other mechanism connecting the packer or bridge plug to the conduit

3.11

exposed component

flow-wetted component (3.13), **internally wetted component** (3.18), and/or component contacted by well fluid below the packing element

3.12

extrusion gap

radial gap between the maximum rated casing ID and the minimum OD immediately adjacent to the packing element

3.13

flow-wetted component

component (3.5) that comes in direct contact with the dynamic movement of well fluids in the flow stream

3.14

gauge OD

maximum specified product OD

3.15**grade**

category or rank given to different requirements for quality or design validation

3.16**heat-traceable**

traceable to a unique heat treatment (heat) of material

3.17**inflatable packing element**

packer or bridge plug packing element energized to form a seal by applying fluid pressure directly to the element

3.18**internally wetted component**

flow-wetted component (3.13) and any component out of the flow stream, but contacted by well fluids through a port or other passage to the flow-wetted area

3.19**job lot**

batch of material or components that have undergone the same process or series of processes

3.20**job-lot traceable**

⟨parts⟩ identifiable as originating from a job lot that designates the included heat(s)

3.21**liner**

pipe that does not extend from the surface and is intended to line the walls of a drilled well

3.22**mandrel**

component(s) of a packer that contain(s) the end connections and provide(s) a conduit through the packer

3.23**manufacturing**

process and actions performed by an equipment supplier/manufacture that are necessary to provide finished component(s), assemblies and related documentation that fulfil the requests of the user/purchaser and meet the standards of the supplier/manufacture

NOTE Manufacturing begins when the supplier/manufacture receives the order and is completed at the moment the component(s), assemblies and related documentation are surrendered to a transportation provider.

3.24**NACE service**

packers or bridge plugs whose **type 1 components** (3.41) are manufactured from materials that comply with ISO 15156 (all parts)

3.25**non-conformance**

non-fulfilment of a specified requirement

3.26**packer**

mechanical device with a **packing element** (3.27), not installed in a designed receptacle, used for blocking fluid (liquid or gas) communication through the annular space between conduits by sealing off the space between them

3.27

packing element

seal on a **packer** (3.26) or **bridge plug** (3.2) that blocks fluid communication by sealing on the ID of the conduit

3.28

performance envelope

graph that illustrates the combined effects of differential pressure and axial loads on a packer or bridge plug at the rated temperature

3.29

permanent packer

permanent bridge plug

bridge plug (3.2) or **packer** (3.26) that has no design feature for intact removal from the conduit, necessitating substantial destruction for its removal

3.30

pressure reversal

change in the direction of the pressure differential across the packing element from above to below or vice versa

3.31

qualified person

individual with characteristics or abilities gained through training or experience, or both, as measured against established requirements, such as standards or tests that enable the individual to perform a required function effectively

3.32

repositionable packer

repositionable bridge plug

bridge plug (3.2) or **packer** (3.26) that meets the definition of **retrievable packer (retrievable bridge plug)** (3.33) and has a design feature facilitating its relocation inside the conduit (without removal) while re-establishing its intended function

3.33

retrievable packer

retrievable bridge plug

bridge plug (3.2) or **packer** (3.26) that has a design feature facilitating its removal from the conduit substantially intact

3.34

seal

device providing a barrier to the passage of liquid and/or gas

3.35

shear device

component designed to disconnect under a predetermined load

3.36

standard service

packer (3.26) or **bridge plug** (3.2) whose components might or might not be manufactured from materials that comply with ISO 15156 (all parts)

3.37

substantive design change

change to the design, identified by the supplier/manufacturer, that affects the performance of the product in the intended service condition

3.38**temperature-cycle range**

specified range of temperature fluctuation over which the product is designed to operate

NOTE The temperature-cycle range is applicable anywhere within the product's temperature range.

3.39**temperature range**

specified range of temperature over which the product is designed to operate

3.40**tubing**

pipe placed within a well to serve as a production or injection conduit

3.41**type 1 component**

⟨weld⟩ component that isolates pressure and/or may be loaded in tension as the result of axial loads on the packer or bridge plug during run-in, setting, *in situ*, or retrieval

3.42**type 2 component**

⟨weld⟩ component that does not meet the criteria of a **type 1 component** (3.41)

4 Symbols and abbreviated terms

AQL	Acceptance quality limit
COC	Certificate of compliance
ID	Inside diameter
MTR	Material test report
NDE	Non-destructive examination
OD	Outside diameter
QC	Quality control

5 Functional specification**5.1 General**

The user/purchaser shall prepare a functional specification for ordering products that conform to this International Standard and specify the following requirements and operating conditions, as applicable, and/or identify the supplier's/manufacturer's specific product. These requirements and operating conditions may be conveyed by means of a dimensional drawing, data sheet or other suitable documentation.

5.2 Type description

The user/purchaser shall specify, as applicable, the following type:

- packer or bridge plug;
- permanent, retrievable or repositionable.

5.3 Well parameters

The user/purchaser shall specify, as applicable, the following well parameters:

- dimensions, material, grade of the casing and tubing;
- end connections above/below the packer or bridge plug;
- well angle from the vertical at the setting position of the packer or bridge plug;
- deviations and restrictions through which the packer or bridge plug is required to pass;
- configuration of tubing (single or multiple strings) and other lines (electrical/hydraulic) that are required to pass through or by-pass the packer;
- relationship of packer or bridge plug with other well devices/tubing/casing by means of a well schematic drawing, if applicable;
- expected minimum and maximum values of production/injection pressures, pressure differentials, temperatures, changes in temperatures and flow rates;
- any other relevant well parameter(s).

5.4 Operational parameters

The user/purchaser shall specify, as applicable, any of the following operational parameters:

- installation method, including conveyance method and setting method;
- setting depth;
- retrieving or repositioning method and number of repositionings, if applicable;
- anticipated loading conditions, including combined loading (pressure, tension/compression) and torque, applied to the packer or bridge plug prior to and during setting, during use and during retrieving;
- expected setting temperature and anticipated temperature cycle during well operations;
- size, type and configuration of devices that will be run through the packer, if applicable;
- any other relevant operational parameters.

5.5 Environmental compatibility

5.5.1 General

If the user/purchaser has access to the corrosion property data of the operating environment based on historical data and/or research, he shall state to the supplier/manufacturer which material(s) has/have the ability to perform as required within the corrosion environment per the requirements of 5.5.3, as applicable. Otherwise, material compatibility shall be specified according to 5.5.2.

5.5.2 Well environment

The user/purchaser shall identify the density, chemical/physical composition, and the condition of the fluid and/or its components, including solid (sand production, scale, etc.), liquid and/or gaseous, to which the packer or bridge plug is exposed during its expected life cycle.

5.5.3 Material designation

5.5.3.1 If the user/purchaser chooses to specify materials, the following designations may be used:

- standard service (3.36);
- NACE service (3.24).

5.5.3.2 Material selection may be made for a group of components using the following designations:

- flow-wetted components (3.13);
- internally wetted components (3.18);
- exposed components (3.11);
- other components.

5.6 Compatibility with related well equipment

The user/purchaser, where applicable, shall specify the interface connection designs and material requirements, free-passage requirements, and external/internal dimensional limitations necessary to ensure that the product will conform to its expected application. The user/purchaser shall identify, as applicable, the following:

- top and bottom tubular connection(s) and the material and dimensions of the connections to the conduit(s);
- internal receptacle profile(s), bore dimensions(s), outside diameter, inside diameter and the respective locations;
- size, type and configuration of other products and conduits used in connection with this product.

5.7 Design validation

The user/purchaser shall specify the required design validation grade. This International Standard provides seven standard design validation grades (V6 to V0), as defined in 6.5.

5.8 Quality control

The user/purchaser shall specify the required quality grade. This International Standard provides three quality grades (Q3, Q2 and Q1) of quality control, as defined in 7.4.

6 Technical specification

6.1 General

The supplier/manufacturer shall prepare a technical specification that conforms to the requirements defined in the functional specification. If the technical specification does not fully meet the functional requirements, the supplier/manufacturer shall identify the differences to the user/purchaser. The supplier/manufacturer shall also provide the user/purchaser with the product data sheet, as detailed in 7.2.3.

6.2 Technical characteristics

The following criteria shall be met.

- The packer/bridge plug shall locate and seal at the specified location and remain so until intentional intervention defines otherwise. Exceptions to this are the effects of casing failure.
- While located and in service, the packer/bridge plug shall perform in accordance with the functional specification.
- Where applicable, the packer/bridge plug shall not compromise well intervention operations.

6.3 Design requirements

6.3.1 General

Products conforming to this International Standard shall be manufactured to drawings and specifications that are substantially the same as those of the same size, type and model product that was validated.

6.3.2 Design documentation

Design of products manufactured to this International Standard shall include documentation of those designs. This documentation shall include, as applicable, design requirements, assumptions, analysis methods, comparison with previous designs or operating history of similar products, calculations, manufacturing drawings and specifications, design reviews and/or physical testing results (such as design validation testing).

6.3.3 Materials

6.3.3.1 General

Materials (both metallic and non-metallic) and/or the service being provided shall be stated by the supplier/manufacturer and shall be suitable for the class of service and the environment specified in the functional specification. The supplier/manufacturer shall have documented specifications for all materials, and all materials used shall comply with the supplier's/manufacturer's documented specifications.

The user/purchaser may specify materials for the specific use and corrosion environment in the functional specification. If the supplier/manufacturer proposes to use another material, the supplier/manufacturer shall state that this material has performance characteristics suitable for all parameters specified in the well and production/injection parameters.

6.3.3.2 Metals

6.3.3.2.1 Specifications

The supplier's/manufacturer's specifications shall define the following:

- a) chemical composition limits;
- b) heat treatment conditions;
- c) mechanical property limits:
 - tensile strength;
 - yield strength;
 - elongation;
 - hardness.

6.3.3.2 Mechanical property verification

When required by the quality grade, the mechanical properties for type 1 metal components shall be verified by tests conducted on a material sample produced from the same heat of material. The material sample shall experience the same heat treatment process as the component it qualifies. Material subsequently heat-treated from the same heat of material shall be hardness-tested after processing to confirm compliance with the hardness requirements of the supplier's/manufacturer's specifications. The hardness results shall verify through documented correlation that the mechanical properties of the material tested meet the properties specified. The heat treatment process parameters shall be defined in a heat treatment procedure. Hardness testing is the only mechanical property test required after stress relieving. Material test reports provided by the material supplier/manufacturer are acceptable documentation when validated.

6.3.3.3 Non-metals

The supplier's/manufacturer's documented specifications for non-metallic compounds shall include handling, storage and labelling requirements, including the cure date, batch number, compound identification and shelf life, appropriate to each compound, and shall define those characteristics critical to the performance of the material, such as

- a) compound type;
- b) mechanical properties, as a minimum:
 - tensile strength (at break);
 - elongation (at break);
 - tensile modulus (at 50 % or 100 %, as applicable);
- c) compression set;
- d) durometer hardness.

6.3.4 Performance rating

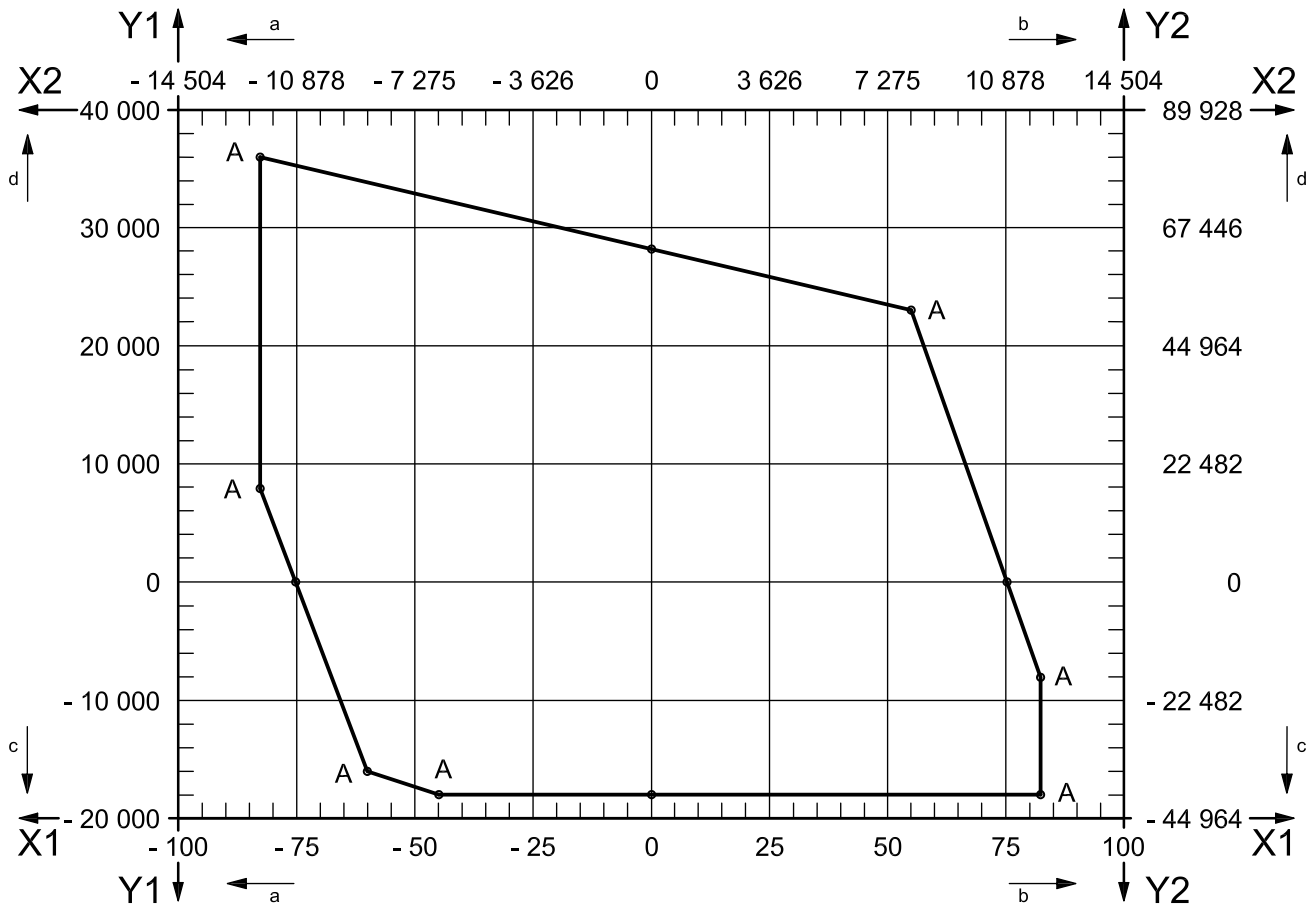
The supplier/manufacturer shall state the pressure, temperature and axial performance ratings, as applicable for the products. For packers and bridge plugs validated to grade V4 through grade V0, a rated performance envelope is required.

An example envelope is illustrated in Figure 1. The area within the boundaries defines the rated performance envelope. The lines forming the boundary of the envelope are defined as the maximum operational limits for the packer or bridge plug. Metal mechanical properties over the temperature range shall be considered when determining performance ratings.

Rated performance envelopes shall meet the following criteria.

- The rated performance envelope shall represent the supplier's/manufacturer's maximum ratings.
- "Above" and "below" on the pressure axis are defined as above and below the product and not internal to the product. If the envelope includes ratings based on pressure internal to the product, this shall be specified with the envelope or handled as an additional graph.
- Products with IDs shall be represented with the ID not plugged unless specified with the envelope.
- Shear devices shall be represented at 100 % of their minimum shear value.
- The ratings of the end connections shall not be included.

- The minimum and maximum casing or tubing IDs shall be specified with the envelope. The envelope shall be applicable over this entire specified ID range.
- Axis and sign convention shall be oriented as shown in Figure 1.
- More than one graph may be displayed with the envelope if a legend is included for explanation. For example, various shear device options can be displayed, as shown in Figure 2.
- The product(s) covered by the envelope shall be specified with the envelope.

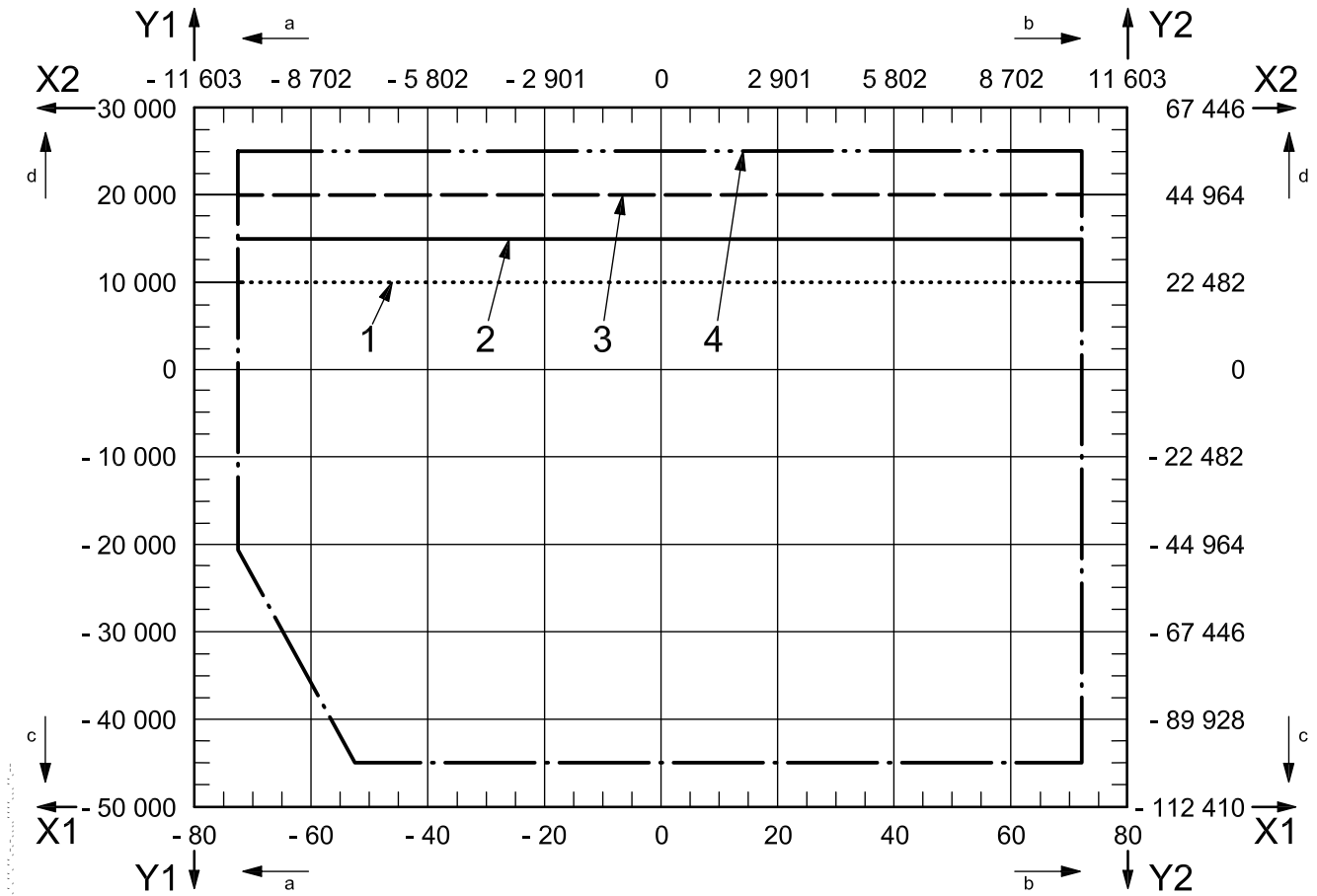


Key

- | | | | |
|----|-----------------------------------------------|---|--------------|
| X1 | pressure, expressed in megapascals | a | Above. |
| X2 | pressure, expressed in pounds per square inch | b | Below. |
| Y1 | force, expressed in decanewtons | c | Compression. |
| Y2 | force, expressed in pounds | d | Tensile. |

NOTE Points labelled "A" are intersection points of two or more operational limits.

Figure 1 — Example of a rated performance envelope



Key

- | | | | |
|----|------------------------------------------------|---|------------------------------------------------|
| X1 | pressure, expressed in megapascals | 3 | envelope for 20 000 daN (44 964 lb) shear ring |
| X2 | pressure, expressed in pounds per square inch | 4 | envelope for 25 000 daN (56 205 lb) shear ring |
| Y1 | force, expressed in decanewtons | a | Above. |
| Y2 | force, expressed in pounds | b | Below. |
| 1 | envelope for 10 000 daN (22 482 lb) shear ring | c | Compression. |
| 2 | envelope for 15 000 daN (33 723 lb) shear ring | d | Tensile. |

Figure 2 — Example of shear device options

6.4 Design verification

Design verification shall be performed to ensure that each packer and bridge plug design meets the supplier's/manufacture's technical specifications, including conveyance and removal methods/tools. Design verification includes activities such as design reviews, design calculations, comparison with similar designs and historical records of defined operating conditions. Verification results shall be approved by a qualified person and records of the results shall become a portion of the design documentation.

6.5 Design validation requirements

6.5.1 General

This International Standard specifies seven grades of design validation for which the product shall be supplied. Products shall be supplied to at least the design validation grade specified.

The supplier/manufacturer shall document the validation test procedure and results and shall have on file material specifications and drawings that show all the applicable dimensions and tolerances of parts contained in the validation-tested product. Pre-test and post-test dimensional inspection of critical operational areas, as determined by the supplier/manufacturer, shall be conducted, documented and maintained by the supplier/manufacturer. Validation test results and dimensional inspection results shall be approved by a qualified person other than the person performing them and records of the results shall become a portion of the design documentation.

The validation grades are the following:

- V6: supplier/manufacturer-defined;
- V5: liquid test;
- V4: liquid test plus axial loads;
- V3: liquid test plus axial loads plus temperature cycling;
- V2: gas test plus axial loads;
- V1: gas test plus axial loads plus temperature cycling;
- V0: gas test plus axial loads plus temperature cycling plus zero bubble acceptance criterion.

Bridge plugs may be run and tested without axial load; however, all validation grades are applicable.

Products qualified to higher grades of design validation may be considered qualified for the lower grades of design validation in accordance with Table 1.

Packers or bridge plugs validated to grade V5 through grade V0 shall not be rated for use in casing or tubing sizes and masses (weights) that can have a maximum ID larger than the ID used in the validation test.

Table 1 — Design validation grade hierarchy

Design validation grade	Grades covered
V0	V0, V1, V2, V3, V4, V5 and V6
V1	V1, V2, V3, V4, V5 and V6
V2	V2, V4, V5 and V6
V3	V3, V4, V5 and V6
V4	V4, V5 and V6
V5	V5 and V6
V6	V6

6.5.2 Validation test requirements

6.5.2.1 General

The supplier/manufacturer shall document all parameters and results of the evaluations that demonstrate conformance to the validation grade. Test data shall identify the leak rate for the duration of the subject test. If no leakage occurred, this shall be clearly stated.

6.5.2.2 Grade V6 — Supplier/manufacturer-defined

The supplier/manufacturer defines the validation method and acceptance criteria.

6.5.2.3 Grade V5 — Liquid test

The supplier/manufacturer shall adhere to the following test parameters and criteria for conformance to this validation grade.

- Set in maximum rated casing or tubing ID $\pm 0,76$ mm ($\pm 0,030$ in) (see 6.5.1).
- Set with the minimum rated setting force or pressure (± 10 %).
- Test products with inflatable packing elements horizontally. Centralization at one end of the test fixture is acceptable.
- Products with no anchoring devices or anchoring devices that hold in one direction may be restrained by the test fixture to prevent movement in the un-anchored direction(s).
- Set and run entire test at or above maximum rated temperature.
- Test at or above maximum rated differential pressure.
- Perform a minimum of two pressure reversals at or above maximum rated pressure from above to below or vice versa.
- Use a liquid test medium of water, with or without additives, or hydraulic oil. The density shall be less than $1\,100$ kg/m³ (68,67 lb/ft³). Liquid shall be visibly free from particulate matter or other material that can plug a small leak.
- Maintain a minimum hold period of 15 min for pressure tests.
- Acceptance criterion: no more than 1 % reduction in the maximum rated differential pressure over the hold period after sufficient time has been allowed for stabilization. Time period for stabilization is at the discretion of the supplier/manufacturer.
- Use the supplier's/manufacturer's specified methods to remove the retrievable-type packers/bridge plugs at the end of the test.

6.5.2.4 Grade V4 — Liquid plus axial load test

The supplier/manufacturer shall adhere to the following test parameters and criteria for conformance to this validation grade.

- Set in maximum rated casing or tubing ID $\pm 0,76$ mm ($\pm 0,030$ in) (see 6.5.1).
- Set with the minimum rated setting force or pressure (± 10 %).
- Test products with inflatable packing elements horizontally. Centralization at one end of the test fixture is acceptable.
- Products with no anchoring devices or anchoring devices that hold in one direction may be restrained by the test fixture to prevent movement in the un-anchored direction(s).
- Set and run the entire test at or above the maximum rated temperature.
- Test at or above the maximum rated differential pressure.

- Perform a minimum of two pressure reversals at or above the maximum rated pressure from above to below or vice versa.
- Test to all intersection points of the rated performance envelope.
- Test those packers or bridge plugs having shear-release features at their maximum rated shear load. For safety, the shear device can be replaced with a stronger shear device that can adequately withstand the maximum shear load.
- Use a liquid test medium of water, with or without additives, or hydraulic oil. The density shall be less than $1\,100\text{ kg/m}^3$ ($68,67\text{ lb/ft}^3$). Liquid shall be visibly free from particulate matter or other material that can plug a small leak.
- Maintain a minimum hold period of 15 min for pressure tests.
- Acceptance criterion: no more than 1 % reduction in the maximum rated differential pressure over the hold period after sufficient time has been allowed for stabilization. The time period for stabilization is at the discretion of the supplier/manufacturer.
- Use the supplier's/manufacturer's specified methods to remove the retrievable-type packers/bridge plugs at the end of the test.

6.5.2.5 Grade V3 — Liquid plus axial loads plus temperature cycling test

The supplier/manufacturer shall adhere to the following test parameters and criteria for conformance to this validation grade.

- Set in maximum rated casing or tubing ID $\pm 0,76\text{ mm}$ ($\pm 0,030\text{ in}$) (see 6.5.1).
- Set with the minimum rated setting force or pressure ($\pm 10\%$).
- Test products with inflatable packing elements horizontally. Centralization at one end of the test fixture is acceptable.
- Products with no anchoring devices or anchoring devices that hold in one direction may be restrained by the test fixture to prevent movement in the un-anchored direction(s).
- Set and run the entire test, except temperature cycling, at or above the maximum rated temperature.
- Test at or above the maximum rated differential pressure.
- Perform a minimum of two pressure reversals at or above the maximum rated pressure from above to below or vice versa.
- Test to all intersection points of the rated performance envelope.
- Test those packers or bridge plugs having shear-release features at their maximum rated shear load. For safety, the shear device can be replaced with a stronger shear device that can adequately withstand the maximum shear load.
- Test a minimum of one temperature cycle. Start the temperature cycle at or above the maximum rated temperature and cool down by at least the maximum rated temperature-cycle range. A pressure hold is required at the low end of the temperature-cycle range and after heating back up to the maximum rated temperature.
- Use a liquid test medium of water, with or without additives, or hydraulic oil. The density shall be less than $1\,100\text{ kg/m}^3$ ($68,67\text{ lb/ft}^3$). Liquid shall be visibly free from particulate matter or other material that can plug a small leak.

- Maintain a minimum hold period of 15 min for pressure tests.
- Acceptance criterion: no more than 1 % reduction in the maximum rated differential pressure over the hold period after sufficient time has been allowed for stabilization. The time period for stabilization is at the discretion of the supplier/manufacturer.
- Use the supplier's/manufacturer's specified methods to remove the retrievable-type packers/bridge plugs at the end of the test.

6.5.2.6 Grade V2 — Gas plus axial load test

The supplier/manufacturer shall adhere to the following test parameters and criteria for conformance to this validation grade.

- Set in maximum rated casing or tubing ID $\pm 0,76$ mm ($\pm 0,030$ in) (see 6.5.1).
- Set with the minimum rated setting force or pressure (± 10 %).
- Test products with inflatable packing elements horizontally. Centralization at one end of the test fixture is acceptable.
- Products with no anchoring devices or anchoring devices that hold in one direction may be restrained by the test fixture to prevent movement in the un-anchored direction(s).
- Set and run the entire test at or above the maximum rated temperature.
- Test at or above the maximum rated differential pressure.
- Perform a minimum of two pressure reversals at or above the maximum rated pressure from above to below or vice versa.
- Test to all intersection points of the rated performance envelope.
- Test those packers or bridge plugs having shear-release features at their maximum rated shear load. For safety, the shear device can be replaced with a stronger shear device that can adequately withstand the maximum shear load.
- Use a gas test medium of air, nitrogen or other gas or mixture of gases.
- Maintain a minimum hold period of 15 min for pressure tests.
- Acceptance criterion: no more than 20 cm³ of gas accumulated in a graduated cylinder over the hold period after sufficient time has been allowed for stabilization. The time period for stabilization is at the discretion of the supplier/manufacturer. The bubble rate shall not increase during the hold period. Graduated cylinders for accumulated gas shall be at atmospheric pressure.
- Use the supplier's/manufacturer's specified methods to retrieve the retrievable packers/bridge plugs at the end of the test.

6.5.2.7 Grade V1 — Gas plus axial loads plus temperature cycling test

The supplier/manufacturer shall adhere to the following test parameters and criteria for conformance to this validation grade.

- Set in maximum rated casing or tubing ID $\pm 0,76$ mm ($\pm 0,030$ in) (see 6.5.1).
- Set with the minimum rated setting force or pressure (± 10 %).

- Test products with inflatable packing elements horizontally. Centralization at one end of the test fixture is acceptable.
- Products with no anchoring devices or anchoring devices that hold in one direction may be restrained by the test fixture to prevent movement in the un-anchored direction(s).
- Set and run the entire test, except temperature cycling, at or above the maximum rated temperature.
- Test at or above the maximum rated differential pressure.
- Perform a minimum of two pressure reversals at or above the maximum rated pressure from above to below or vice versa.
- Test to all intersection points of the rated performance envelope.
- Test those packers or bridge plugs having shear-release features at their maximum rated shear load. For safety, the shear device can be replaced with a stronger shear device that can adequately withstand the maximum shear load.
- Test a minimum of one temperature cycle. Start the temperature cycle at or above the maximum rated temperature and cool down by at least the maximum rated temperature-cycle range. A pressure hold is required at the low end of the temperature-cycle range and after heating back up to the maximum rated temperature.
- Use a gas test medium of air, nitrogen, or other gas or mixture of gases.
- Maintain a minimum hold period of 15 min for pressure tests.
- Acceptance criterion: no more than 20 cm³ of gas accumulated in a graduated cylinder over the hold period after sufficient time has been allowed for stabilization. The time period for stabilization is at the discretion of the supplier/manufacturer. The bubble rate shall not increase during the hold period. Graduated cylinders for accumulated gas shall be at atmospheric pressure.
- Use the supplier's/manufacturer's specified methods to remove the retrievable-type packers/bridge plugs at the end of the test.

6.5.2.8 Grade V0 — Gas plus axial loads plus temperature-cycling test plus zero-bubble acceptance criterion

The supplier/manufacturer shall adhere to the following test parameters and criteria for conformance to this validation grade.

- Set in maximum rated casing or tubing ID $\pm 0,76$ mm ($\pm 0,030$ in) (see 6.5.1).
- Set with the minimum rated setting force or pressure (± 10 %).
- Test products with inflatable packing elements horizontally. Centralization at one end of the test fixture is acceptable.
- Products with no anchoring devices or anchoring devices that hold in one direction may be restrained by the test fixture to prevent movement in the un-anchored direction(s).
- Set and run the entire test, except temperature cycling, at or above the maximum rated temperature.
- Test at or above the maximum rated differential pressure.
- Perform a minimum of two pressure reversals at or above the maximum rated pressure from above to below or vice versa.
- Test to all intersection points of the rated performance envelope.

- Test those packers or bridge plugs having shear-release features at their maximum rated shear load. For safety, the shear device can be replaced with a stronger shear device that can adequately withstand the maximum shear load.
- Test a minimum of one temperature cycle. Start the temperature cycle at or above the maximum rated temperature and cool down by at least the maximum rated temperature-cycle range. A pressure hold is required at the low end of the temperature-cycle range and after heating back up to the maximum rated temperature.
- Use a gas test medium of air, nitrogen, or other gas or mixture of gases.
- Maintain a minimum hold period of 15 min for pressure tests.
- Acceptance criterion: zero bubbles of gas accumulated in a graduated cylinder over the hold period after sufficient time has been allowed for stabilization. The time period for stabilization is at the discretion of the supplier/manufacturer. Graduated cylinders for accumulated gas shall be at atmospheric pressure.
- Use the supplier's/manufacturer's specified methods to remove the retrievable-type packers/bridge plugs at the end of the test.

6.6 Design changes

All design changes shall be documented and reviewed against the design verification and design validation to determine if the change is a substantive change (see 3.37). A design that undergoes a substantive change becomes a new design requiring design verification as specified in 6.4 and design validation as specified in 6.5. Design changes identified as non-substantive shall include documented justification.

The supplier/manufacturer shall, as a minimum, consider the following:

- stress levels of the modified or changed components;
- material changes;
- functional changes.

Changes to a component or series of components may be identified as a substantive change and require design validation. This may be done by testing only the component or series of components rather than the entire assembly. The test shall adequately simulate the loading conditions that would be present if the entire assembly were tested. The supplier/manufacturer shall document the detailed test results and analysis that demonstrate that the component test adequately simulates the required loading conditions. Evaluation results shall be approved by a qualified person (see 3.31) other than the person performing them, and records of the results shall become a portion of the design documentation.

6.7 Design validation by scaling

6.7.1 General

Within the same casing size or tubing size, scaling may be used to validate variations in a product family in accordance with the requirements and limitations of 6.7.2 and 6.7.3. This applies to products validated to grade V5 through grade V0 in accordance with 6.5.

6.7.2 Product family for scaling

A product family is a group of assemblies that meets the following design requirements:

- configuration: the design principles for the geometry, materials and functionality are the same;
- design stress levels: the design stress levels in relation to material mechanical properties are based on the same criteria.

6.7.3 Limitations of scaling

Scaling is allowed to validate a product family within a given casing or tubing size with the following limitations.

- A validation test shall be run on the product with the largest extrusion gap (see 3.12).
- A validation test shall be run on the product(s) with the thinnest and thickest cross-section packing element(s).
- Packing elements and anti-extrusion components shall be of the same geometry and materials as the tested product.
- The ID of the packing element(s) and OD of the component under the packing element(s) shall be the same as the tested product.
- Scaling shall not be used to cover products with higher pressure ratings, a higher temperature range, a larger temperature cycle range, higher axial load ratings or larger rating envelopes than the tested product.

6.8 Other validations

Repositionable packers and bridge plugs shall undergo supplemental validation testing that includes resetting and testing in accordance with the requirements and acceptance criteria of the supplier/manufacturer.

6.9 Assembly verification

Each packer and bridge plug assembly shall be verified in accordance with 7.4.11.

7 Supplier's/manufacturer's requirements

7.1 General

Clause 7 contains the detailed requirements necessary to verify that each product manufactured meets the requirements of the functional and technical specifications. These include requirements for documentation and data control, product identification, quality control, functional testing, repair, redress, shipping and storage.

7.2 Documentation and data control

7.2.1 General

The supplier/manufacturer shall establish and maintain documented procedures to control all documents and data that relate to the requirements of this International Standard. These documents and data shall be maintained to demonstrate conformance to specified requirements. All documents and data shall be legible and shall be stored and retained in such a way that they are readily retrievable in facilities that provide a suitable environment to prevent damage or deterioration and to prevent loss. Documents and data may be in any form or type of media, such as hard copy or electronic media. All documents and data shall be available to, and auditable by, the user/purchaser.

All documentation and data associated with design verification, design validation and design change justification shall be maintained for ten years after the date of last manufacture.

Quality-control documentation includes all documents and data necessary to demonstrate conformance to 7.4.1 through 7.4.15. Quality-control documentation shall be retained by the supplier/manufacturer for a minimum of five years from date of manufacture. These shall be available to and auditable by the user/purchaser.

7.2.2 Operating manual

An operating manual shall be available for all products supplied in accordance with this International Standard.

Operating manuals shall contain at least the following information:

- manual reference number;
- operational procedures and related tools;
- pre-installation inspection procedures;
- storage recommendations;
- a representative drawing showing major dimensions (ODs, IDs and lengths);
- special precautions and handling.

7.2.3 Product data sheet

Product data sheets shall be supplied at delivery to the user/purchaser, as required in 6.1, and shall contain at least the following information, where applicable:

- name and address of supplier/manufacturer;
- manufacturer product number;
- manufacturer product name;
- product type;
- product characteristics;
- service provided;
- metallic materials;
- non-metallic materials;
- drift diameter;
- gauge OD;
- overall length;
- temperature range;
- temperature cycle range for V3, V1, and V0;
- rated performance envelope for V4 through V0;
- pressure rating for V6 and V5;
- top connection(s);
- bottom connection(s);

- casing or tubing range, size and mass and/or minimum and maximum casing or tubing IDs;
- conveyance method;
- maximum conveyance OD, inclusive of running/repositioning equipment, as applicable;
- setting method, including minimum (maximum, as applicable) setting force/pressure;
- retrieval method (if retrievable);
- repositioning method (if repositionable);
- quality grade;
- design validation grade;
- operating manual reference number.

7.3 Product identification

Each product furnished to this International Standard shall be permanently identified according to the supplier's/manufacturer's specifications. The supplier's/manufacturer's specifications shall define the type, method of application and location of the identifications. The following information shall be included as a minimum:

- manufacturer's identification;
- manufacturer's product number;
- date of manufacture (month/year);
- quality grade;
- design validation grade;
- for quality grade Q1, a unique serial and traceability number.

7.4 Quality control

7.4.1 General

This International Standard specifies three quality grades, Q1, Q2 and Q3, to which the product shall be supplied. Products shall be supplied to at least the quality control grade specified. Quality-control requirements are detailed in 7.4.2 through 7.4.15 and summarized in Table 2. Where there are no requirements listed in 7.4.2 through 7.4.15, the word "None" appears in Table 2.

Table 2 — Summary of quality requirements

Item	Quality grade ^a		
	Q3	Q2	Q1
Metallic material	COC or MTR	COC or MTR	Verify MTR for type 1 components COC or MTR for type 2 components
Non-metallic material	COC or MTR	COC or MTR	COC or MTR
Castings	COC	COC	COC
Heat treatment	COC (subcontractor) Job-lot verification (supplier/manufacturer)	COC (subcontractor) Job-lot verification (supplier/manufacturer)	COC (subcontractor) Job-lot verification (supplier/manufacturer) Heat treat certificate for type 1 components
Component traceability	Job-lot traceable for type 1 components	Job-lot traceable for type 1 components	Heat traceable for type 1 components
Component dimensions	Sampling plan	Sampling plan	100 % for type 1 components
Welding			
Type 1 welds	Visual	Surface NDE per sampling plan and visual	Surface NDE 100 % and visual
Type 2 welds	Visual	Visual	Visual
Hardness			
Type 1 components	None	Sampling plan	100 %
Type 2 components	None	None	None
Component NDE			
Type 1 components	None	Surface NDE per sampling plan	Surface NDE 100 %
Type 2 components	None	None	Visual
Shear devices	Shear verification	Shear verification	Shear verification
Assembly verification	None	Functional test ID drift	Functional test ID drift OD dimensional Torque documentation
Assembly traceability	None	None	Assembly serialization
QC documentation	Supplier/manufacturer retained	Supplier/manufacturer retained	Supplier/manufacturer retained
^a "None" indicates that there are no requirements listed in 7.4.2 through 7.4.15.			

7.4.2 Material

Material, metallic or non-metallic, used in the manufacture of components shall meet one of the following requirements:

- COC to the supplier/manufacturer stating that the material meets the supplier's/manufacturer's documented specifications, or
- MTR to the supplier/manufacturer so that the supplier/manufacturer can verify that the material meets the supplier's/manufacturer's documented specifications.

The supplier/manufacturer shall verify, through testing, that the chemical/mechanical properties of metallic materials meet the MTRs as specified for quality grade Q1 for type 1 components. Chemical/mechanical property determination shall be in accordance with a national standard or International Standard.

7.4.3 Castings

The casting subcontractor or supplier shall provide a COC to the supplier/manufacturer stating that the casting meets the supplier's/manufacturer's documented specifications.

7.4.4 Heat treatment

7.4.4.1 General

Heat treatment of components or raw material shall meet the following requirements.

- Heat treating shall be performed with heat-treating equipment that has been calibrated and surveyed.
- If heat treatment is performed by a subcontractor, the subcontractor shall provide a COC to the supplier/manufacturer stating that the heat treatment meets the supplier's/manufacturer's documented specifications.
- If heat treatment is performed by the supplier/manufacturer, heat treatment shall comply with the supplier's/manufacturer's documented specifications.
- For type 1 components, a heat treatment certificate showing actual times and temperatures is required for quality grade Q1.

7.4.4.2 Heat-treating equipment qualification

7.4.4.2.1 Furnace calibration

Furnace calibration shall meet the following requirements.

- a) Each furnace shall be surveyed within one year prior to heat-treating operations. When a furnace is repaired or rebuilt, a new survey shall be required before heat treating.
- b) Batch-type and continuous-type heat-treating furnaces shall be calibrated in accordance with one of the following procedures:
 - procedures specified in an International Standard or national standard, such as SAE AMS-H-6875A,
 - procedures specified in an International Standard or national standard, such as BS 2M 54,
 - manufacturer's documented specifications, including acceptance criteria that are not less stringent than the procedures identified above.

7.4.4.2.2 Instrumentation

Instrumentation shall meet the following requirements.

- Automatic controlling and recording instruments shall be used.
- Thermocouples shall be located in the furnace working zone(s) and protected from furnace atmospheres.
- The controlling and recording instruments used for the heat treatment processes shall have an accuracy of $\pm 1\%$ of their full-scale range.
- Temperature-controlling and -recording instruments shall be calibrated at least once every three months until a documented calibration history can be established. Calibration intervals shall then be established based on repeatability, degree of usage and documented calibration history.
- Equipment used to calibrate the production equipment shall have an accuracy of $\pm 0,25\%$ of the full-scale range.

7.4.5 Component traceability

Component traceability shall meet the following requirements.

- Type 1 components shall be job-lot traceable for quality grades Q2 and Q3.
- Type 1 components shall be heat-traceable for quality grade Q1.
- Components that are castings, or are manufactured from castings, shall be excluded from traceability for grades Q3 and Q2.

7.4.6 Component dimensional inspection

Component dimensional inspection shall be performed and shall meet the following requirements.

- Thread tolerances, inspection requirements, gauges, gauging practice, gauge calibration and certification shall conform to the specified thread-manufacturer's documented specifications.
- Dimensional tolerances of O-rings shall be in accordance with ISO 3601-1 or equivalent. Other packing elements shall meet dimensional tolerances of the supplier's/manufacturer's documented specifications.
- Type 2 components and all type 1 components for quality grades Q2 and Q3 shall be dimensionally inspected per a sampling plan that meets the requirements of an International Standard or national standard, such as ISO 2859-1 or ANSI/ASQC Z1.4.
- Type 1 components shall be 100 % dimensionally inspected for quality grade Q1.

7.4.7 Welds

Welds shall meet the following requirements.

- Type 1 welds (see 3.41) shall meet the requirements of an International Standard or national standard such as ASME Boiler and Pressure Vessel Code, Section IX.
- Each welded component shall be stress-relieved as specified in the supplier's/manufacturer's documented specifications that include acceptance criteria.

7.4.8 Hardness inspection of components

Hardness inspection of components shall meet the following requirements.

- Type 1 components for quality grade Q2 shall be hardness-inspected per a sampling plan that meets the requirements of an International Standard or national standard, such as ISO 2859-1 or ANSI/ASQC Z1.4.
- 100 % of type 1 components for quality grade Q1 shall be hardness inspected.
- Type 2 components do not require hardness inspection.
- Hardness inspection of metallic components shall meet the requirements of an International Standard or national standard, such as ISO 6506-1, ISO 6507-1 or ISO 6508-1.
- The durometer hardness of O-rings or other elastomeric packing elements shall be determined in accordance with an International Standard or national standard, such as ASTM D2240 or ASTM D1415. A test specimen manufactured from each batch may be used.

7.4.9 NDE of components/welds

NDE of components and welds shall meet the following requirements.

- Welds shall be visually inspected per the requirements of an International Standard or national standard, such as the ASME Boiler and Pressure Vessel Code, Section V, Article 9.
- NDE for non-metallic components shall be visual inspection per supplier's/manufacture's documented specifications.
- NDE for metallic components shall be magnetic-particle inspection or liquid-penetrant inspection.
- Sampling procedures and the criteria for acceptance or rejection of a batch lot shall be in accordance with ISO 2859-1, general inspection level II, at a 2,5 AQL for O-Rings and a 1,5 AQL for other packing elements, until a documented variation history can be established. Sampling procedures shall then be established based on the documented variation history.
- Visual inspection of O-rings shall be in accordance with ISO 3601-3 or equivalent. Other packing elements shall be visually inspected in accordance with the supplier's/manufacture's documented specifications.
- Magnetic-particle inspection shall meet the requirements of an International Standard or national standard, such as ISO 13665 or ASTM E709.
- Liquid-penetrant inspection shall meet the requirements of an International Standard or national standard, such as ISO 12095 or ASTM E165.
- NDE acceptance criteria shall be according to the supplier's/manufacture's documented specifications.
- All NDE instructions shall be approved by a level III examiner qualified in accordance with ISO 9712.

NOTE For the purposes of these provisions, ASNT RP SNT-TC-1A is equivalent to ISO 9712.

- Type 1 components and welds for quality grade Q2 shall be NDE-inspected per a sampling plan that meets the requirements of an International Standard or national standard, such as ISO 2859-1 or ANSI/ASQC Z1.4.
- Type 1 components and welds for quality grade Q1 shall be 100 % NDE-inspected using liquid-penetrant or magnetic particles.
- Type 2 components for quality grade Q1 shall be visually inspected per the supplier's/manufacture's documented specifications.

7.4.10 Shear device verification

At least one shear device per heat lot shall be sheared in accordance with the supplier's/manufacture's documented procedure to verify that the shear value meets the supplier's/manufacture's documented specification.

7.4.11 Assembly verification

Assembly verification shall meet the following requirements.

- For quality grades Q2 and Q1, a low-pressure, internal test shall be performed on each packer by plugging the end connection(s) (see 3.10) and pressurizing to a minimum of 350 kPa (approximately 50 psi) using either liquid or gas as the test medium. One-piece mandrels or mandrels with only internal metal-to-metal sealing connections are excluded from this requirement. Test duration and acceptance criteria shall be defined by the supplier's/manufacture's documented procedures. Functional test data shall be recorded, dated and signed by the qualified person performing the tests.
- For quality grades Q2 and Q1, ID drift each packer per the supplier's/manufacture's documented specifications. ID drift shall apply only to packer IDs not designed as sealing surfaces (sealbores). Drift-bar diameter shall match the rated drift diameter of the packer. Drift-bar dimensions shall meet the requirements specified in ISO 11960.
- For quality grade Q1, the OD shall be inspected according to the supplier's/manufacture's documented specifications. OD dimensional inspection shall verify that the entire OD of the assembly is less than, or equal to, the maximum specified OD.
- For quality grade Q1, actual torque values for all metal-to-metal sealing connections shall be recorded and verified to be within the supplier's/manufacture's documented specifications. End connections are specifically excluded from this requirement.

7.4.12 Assembly traceability

Assembly serialization shall be used to provide traceability of all type 1 components within each assembly for quality grade Q1.

7.4.13 Manufacturing non-conformance

The supplier/manufacture shall establish and maintain documented procedures to ensure that an assembly or component that does not conform to specified requirements is prevented from unintended use or installation. This control shall provide for identification, documentation, evaluation, segregation (when applicable) and disposition of non-conforming assemblies or components.

The responsibility for review and authority for the disposition of non-conforming assemblies or components shall be defined by the supplier/manufacture. Non-conforming assemblies or components may be

- reworked to meet the specified requirements,
- accepted with or without repair by concession, or
- rejected or scrapped.

Repaired and/or reworked assemblies or components shall be inspected in accordance with the requirements of the appropriate quality grade and the documented specifications of the supplier/manufacture.

7.4.14 Calibration systems

Measuring and testing equipment used for acceptance shall be identified, controlled, calibrated and adjusted at specific intervals in accordance with an internationally recognized International Standard, such as ISO/IEC 17025.

Technologies for measuring and testing equipment with verifiable accuracies equal to, or better than, those listed in this International Standard may be applied with appropriate documentation and when approved by a qualified person.

Pressure-measuring devices shall be

- readable to at least $\pm 0,5\%$ of the full-scale range or less, as required to perform the specified measurement,
- calibrated to maintain $\pm 2\%$ accuracy of the full-scale range or less, as required to perform the specified measurement(s),
- used only within the calibrated range,
- calibrated with a master pressure-measuring device or a dead-weight tester.

Calibration intervals for pressure-measuring devices shall be a maximum of three months until a documented calibration history can be established. Calibration intervals shall then be established based on repeatability, degree of usage and documented calibration history.

7.4.15 Personal qualifications

Personnel performing NDE shall be qualified in accordance with an International Standard or national standard, such as ISO 9712, level 2 minimum, for evaluation and interpretation.

Personnel performing visual examinations shall have an annual eye examination in accordance with an International Standard or national standard such as ISO 9712, as applicable to the discipline to be performed.

All other personnel performing inspection for acceptance shall be qualified per the supplier's/manufacture's documented specifications.

8 Repair

Repair activities to packers and bridge plugs shall return the product to a condition meeting all requirements stated in this International Standard or the edition in effect at the time of original manufacture.

9 Shipment/storage

Packers and bridge plugs shall be stored per the documented specifications of the supplier/manufacture to prevent deterioration (for example caused by atmospheric conditions, debris, radiation, etc.) prior to transport.

Packers and bridge plugs shall be packaged for transport per the documented specifications of the supplier/manufacture to prevent normal handling loads and contamination from harming the equipment. These specifications shall address the protection of external sealing elements, sealing surfaces and exposed threaded connections.

Bibliography

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- [4] ISO 13665, *Seamless and welded steel tubes for pressure purposes — Magnetic particle inspection of the tube body for the detection of surface imperfections*
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