

Design, Verification, and Application of Solid Expandable Systems

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Introduction

The goals of this recommended practice are to:

- 1) establish common terms and means that can be used by the manufacturers and end users,
- 2) educate the end users and manufacturers,
- 3) ensure that users, suppliers, and manufacturers understand and can identify the critical aspects of the technology,
- 4) accelerate the technology-expand the user base,
- 5) institute a uniform evaluation process, and
- 6) understand the reliability of the technology.

Users should be aware that requirements outlined in this document may be needed for individual applications. This document is not intended to inhibit a supplier/manufacture from offering, or the user/purchaser from accepting, alternative equipment or engineering solutions. This may be particularly applicable where there is innovative or developing technology.

Design, Verification, and Application of Solid Expandable Systems

1 Scope

This recommended practice establishes guidance for design, system verification, and application guidelines of solid expandable systems for the oil and gas industries. This document is not to be used as a specification for purchasing equipment; it is intended for consideration by users for well applications and the design of solid expandable systems.

Expandable systems will include drilling liners, hangers, connections, receivers, and launchers for downhole use as defined herein. Only permanently installed equipment/components are covered by this recommended practice. Slotted liners and tools used for the expansion of the tubular goods (such as, but not limited to, implementation tools, pumps, jacks, and expansion tools) are not addressed by this recommended practice.

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 applies (including any addenda/errata).

API Recommended Practice 5A5, *Field Inspection of New Casing, Tubing, and Plain-end Drill Pipe*

API Recommended Practice 5C5, *Procedures for Testing Casing and Tubing Connections*

API Specification 5CT, *Casing and Tubing*

API Specification Q1, *Specification for Quality Management System Requirements for Manufacturing Organizations for the Petroleum and Natural Gas Industry*

API Technical Report 5C3, *Calculating Performance Properties of Pipe Used as Casing or Tubing*

NACE TM0192 ¹, *Evaluating Elastomeric Materials in Carbon Dioxide Decompression Environments*

NORSOK M-710 ², *Qualification of nonmetallic sealing materials and manufactures*

3 Terms, Definitions, and Abbreviations

3.1 Terms and Definitions

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

3.1.1

assembly

Product comprised of more than one component.

3.1.2

casing

Pipe run from the surface or mudline and intended to line the walls of a drilled well.

¹ National Association of Corrosion Engineers, 15835 Park Ten Place, Houston, TX 77084, www.nace.org.

² Standards Norway, P.O. Box 252, NO-1326, Lysaker, Norway, www.standard.no.

3.1.3**connection**

Threaded assembly of tubular components.

3.1.4**connector**

One-piece tubular section, not including pipe or couplings, used for the purpose of joining or changing from one size, mass, or type of thread connection, to the same or another size, mass, or type of threaded connection.

3.1.5**coupling**

Internally threaded cylinder for joining two lengths of threaded pipe.

3.1.6**defect**

Imperfection of such magnitude as to warrant rejection of the product.

3.1.7**expandable drilling liner**

Pipe which may be expanded below the previously installed pipe used to extend the well.

3.1.8**expandable equipment**

Special purpose tools which are used to install or expand an expandable system; not permanently installed in the hole.

3.1.9**expandable system**

Elements that are run and permanently installed in the hole.

3.1.10**expansion methods**

Method used to generate expansion force.

NOTE For example, hydraulic or mechanical method or combination of both.

3.1.11**expansion ratio**

Calculated by subtracting the inner diameter of the pre-expanded cross section from the inner diameter of the post-expanded cross section and dividing that result by the inner diameter of the pre-expanded cross section.

NOTE The expansion ratio can be multiplied by 100 for the expansion percentage.

3.1.12**heat lot**

Material originating from a final melt.

3.1.13**hydraulic expansion**

Expansion process which uses fluid pressure to drive a cone and pipe, hence expanding the pipe.

3.1.14**imperfection**

Discontinuity or irregularity within the wall or on the pipe surface that can be detected by an appropriate NDT method.

3.1.15**inspection**

Process of measuring, examining, testing, gauging, or otherwise comparing, the unit of product with the applicable requirements.

3.1.16**job lot**

Definite quantity of product manufactured under conditions which are considered uniform as part of a continuous operation.

3.1.17**manufacturer**

A firm, company, or corporation responsible for marking the product to warrant that it conforms to this specification.

NOTE The manufacturer is responsible for compliance with the applicable provisions of this specification, and may be (as applicable) a pipe mill or processor; a maker of couplings, pup joints or connectors; or a threader.

3.1.18**mechanical expansion**

Expansion system which uses an axial force along with a cone to expand the pipe.

3.1.19**pipe**

Casing, tubing, plain-end casing liners, and pup joints as a group.

3.1.20**pipe mill**

A firm, company, or corporation that operates pipe-making facilities.

3.1.21**post-expansion**

State in which the pipe and/or connection is after the expansion process.

3.1.22**pre-expansion**

State in which the pipe and/or connection is before the expansion process.

3.1.23**processor**

A firm, company, or corporation that operates facilities capable of heat treating pipe made by a pipe mill.

3.1.24**product**

Pipe, coupling, connector, coupling stock, and coupling blank, either individually or collectively, as applicable.

3.1.25**solid expandable**

A tubular that does not have penetrations through the wall of the pipe body and is intended to be expanded.

3.2 Abbreviations

COC certificate of conformity

EC expandable casing

ER expansion ratio

HAZOP	hazard and operability (study)
ID _{post}	ID of pipe after expansion
ID _{pre}	ID of pipe before expansion
JSA	job safety analysis
MTR	material test report
NDT	nondestructive testing
SDS	safety datasheet (formerly MSDS)
SES	solid expandable system
UTS	ultimate tensile strength
TLE	test load envelope

4 Functional Specification

4.1 Functional Requirements

The user/purchaser may choose to prepare a functional specification for ordering products that uses this document as a guideline, and specify the requirements defined herein, as applicable, and/or identify the supplier's/manufacturer's specific product by the unique identifier. These requirements and operating conditions may be conveyed by means of text, dimensional drawing, datasheet, or other suitable documentation.

4.2 Type Description

The user/purchaser shall specify the following type of expandable system:

- a) mechanical,
- b) hydraulic, or
- c) combination of both.

4.3 Well Parameters

The user/purchaser should provide the following well parameters:

- a) wellbore schematic,
- b) intended service life,
- c) fracture gradient/pore pressures,
- d) bottom hole pressure/bottom hole temperature, and
- e) other relevant well parameters.

4.4 Operational Parameters

The user/purchaser should specify which of the following operational parameters apply:

- a) installation method (including conveyance method and expansion method),
- b) rig capacities/configuration,
- c) drill pipe,
- d) geographical location,
- e) timing of installation,
- f) fluid system, and
- g) other relevant operational parameters.

4.5 Environmental Compatibility

As this recommended practice addresses expandable drilling liners and associated equipment, corrosion and environmental cracking requirements are not addressed. The user needs to be aware of pre- and post-expansion conditions. NACE MR0175/ISO 15156 limits cold work and is applicable in the unexpanded condition. As such, other specific tests may be conducted in the expanded condition by, or at the request of, the user/purchaser to potentially qualify the expanded product for the intended service environment.

4.6 Performance Envelope

When required to evaluate the performance of the expandable system under combined loading situations, a performance envelope should be requested by the purchaser.

5 Technical Specification

5.1 Technical Characteristics

The supplier/manufacture shall prepare and provide to the user/purchaser the technical specification that responds to the requirements outlined in Section 4. The supplier/manufacture shall also provide to the user/purchaser the technical data required by Section 6.

5.2 Design Criteria

5.2.1 General

Expandable systems shall be designed to meet the requirements of the functional specification. Final approval of the design should be performed and documented by qualified personnel other than the person who created the design originally.

5.2.2 Design Requirements

5.2.2.1 The supplier/manufacture shall establish and provide the following:

- a) internal yield pressure,
- b) collapse pressure,
- c) minimum tensile/compressive strength ratings (excluding end connections),

- d) pre- and post-expansion yield strength,
- e) geometrical dimensions, and
- f) operational capabilities required to meet the requirements of this recommended practice.

5.2.2.2 The manufacturer shall also provide:

- a) identification of the critically stressed components of the product and the mode of stress,
- b) calculation of the critical stress level in the identified component(s) based upon the maximum loads in the functional specifications,
- c) identification of related tools necessary for the full functionality of the expandable system, and
- d) related tools design requirements and their interface with the specific expandable system.

The minimum acceptable material condition and minimum acceptable material yield shall be used in the calculations, and the calculations shall include consideration of temperature limit effects and thermal cycles where applicable. Metal mechanical properties de-rating shall be in accordance with an established code or practice, such as ASME BPVC, Section II, Part D.

Where applicable, specialized and/or intermittent conditions, such as pressure testing with temporary test plugs, shall also be considered.

5.2.2.3 For manufacturer-assembled equipment and replacement components or subassemblies, the following apply:

- a) component and subassembly identification is required; and
- b) additive dimensional tolerances of components and subassemblies shall allow the expandable equipment to perform as designed without limitation, regardless of the date or batch of manufacture.

For each unique expandable system assembly, the components or subassemblies shall be interchangeable with other batch lots of the same unique expandable system assembly and shall produce a product which continues to meet the design validation requirements.

Expandable system equipment conforming to this recommended practice should be manufactured to drawings and specifications that are the same as those of the expandable system equipment that has passed the applicable validation test.

5.2.3 Design Documentation

Documentation of designs for each size, type, and model shall include the following:

- a) design requirements,
- b) functional and technical specifications,
- c) methods,
- d) assumptions,
- e) comparison with previous designs,

- f) design calculations, and
- g) design reviews and validation evaluation/testing procedures/acceptance criteria and their approved results.

Design requirements shall include operating pressures and operational loads, as well as material, environmental, and other pertinent requirements upon which the design is based.

Drawings, manufacturing specifications, material specifications, and material certifications, including yield strength, end connection identification, and the validation test results, shall be retained.

Instructions providing methods for the safe assembly and disassembly of the product, and stating the operations that are permitted to preclude failure and/or non-compliance with the functional and technical requirements, shall be retained. Instructions providing methods for safe field use shall be defined in the product specific operating manual.

5.3 Materials

5.3.1 Introduction

Material selection and understanding is critical for the successful use of solid expandables. Fitness for purpose needs at various downhole conditions should be considered by the designer. Since the solid expandable is transformed in-situ the pre- and post- material requirements should be documented in a material specification. The end user needs to obtain a "material fingerprint", or profile of the material in pre- and post- expanded conditions, from a pre-qualified supplier. The end user should also consider the change in properties at the expected temperatures. Limits of expansion from a stress and strain point need to be understood so that the reliability of the expandable is not compromised. Installed metallic or nonmetallic components used in the solid expandable need to be thoroughly documented with regard to service conditions and material performance.

Materials, and/or the service, shall be documented by the supplier/manufacturer and shall be suitable for the functional specification. Materials used shall comply with the mandatory supplier/manufacture's written specification that includes chemical and mechanical property limits.

The user/purchaser may specify materials for the specific environment in the functional specification. If the manufacturer proposes to use another material, the manufacturer shall state that this material has performance characteristics suitable for the parameters specified in the well and production/injection parameters as agreed by the user/purchaser. This applies to metallic and non-metallic components.

Material substitutions from those materials used in a validated product are allowed without further validation testing. The supplier's/manufacture's selection criteria for these substitutions shall be documented and the substituted material shall conform to the design, functional and technical requirements of this recommended practice. Material substitutions require approval by a qualified person using the methods and practices used to accept the original material and the supporting documentation shall be incorporated into the manufacturing records.

5.3.2 Metallic Material Specifications

5.3.2.1 The manufacturer's specifications shall define the following:

- a) chemical composition limits,
- b) heat treatment conditions,
- c) mechanical properties:
 - 1) tensile strength (min—max),

- 2) yield strength (min—max),
- 3) elongation (min),
- 4) hardness (min—max), and
- 5) impact energy/toughness (min).

5.3.2.2 The manufacturer's specifications may also define requirements for the following (specifying temperature as appropriate):

- a) physical property requirements:
 - 1) modulus of elasticity,
 - 2) Poisson's ratio,
 - 3) coefficient of thermal expansion, and
 - 4) magnetic properties/concerns.
- b) product condition:
 - 1) surface roughness,
 - 2) coating requirements/coating types on OD and ID,
 - 3) straightness,
 - 4) ovality,
 - 5) eccentricity, and
 - 6) dimensional tolerances.

5.3.3 Expandable Tubular Manufacturing Methods

Thermomechanical process description of the material shall be disclosed within the certified material test report and included in the material specification.

The manufacturer shall specify and approve the allowable manufacturing methods for expandable tubulars prior to the acceptance of production items. Acceptable manufacturing methods are typically welded and seamless. Each method has certain benefits, and limitations or concerns, with regard to the application. These include, but are not limited to, the following:

- attributes of eccentricity,
- tolerance,
- surface finish/contour, and
- weld quality.

To assure the product meets the required needs, it may be advisable to apply a source approval process, or at a minimum, the qualification of vendors, for critical applications. Other manufacturing methods may be acceptable but should be evaluated before use.

NOTE Some manufacturing operations that may need limits are:

- a) source/process qualification needs,
- b) straightening (pre acceptable limits), and
- c) inspection for allowable defect size and orientation on the OD and ID in the pre-expanded condition.

Depending upon the severity of the design, one may wish to have varying limits on defect size limits and degree of straightening allowed. With higher 0.2 % yield strengths and expansion levels, it would be expected that the capability of the material would be reduced with larger pre-existing defects.

5.3.4 Nonmetallic Materials

5.3.4.1 General

Elastomer components depend on the strength and elasticity of the elastomer to maintain a pressure-tight seal. The mechanical properties of elastomers typically change with time. The change in properties and the rate of change are influenced by the environmental conditions and the chemical exposure history of the elastomer. The primary attributes that should be considered when evaluating elastomer materials are mechanical strength, temperature stability, chemical compatibility, explosive decompression behavior (depending on the pressure environment), and compression set behavior (retention of elasticity). High temperatures can lead to rapid degradation of elastomer properties. The degradation can be exhibited by loss of elasticity (hardening), cracking, increased compression set, and loss of mechanical strength.

5.3.4.2 Nonmetallic Material Specifications

The manufacturer's written specifications for nonmetallic compounds shall include handling, storage, and labeling 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 the following:

- a) compound type,
- b) mechanical properties, as a minimum:
 - 1) tensile strength (at break),
 - 2) elongation (at break),
 - 3) tensile modulus (at 50 % or 100 %, as applicable; elastomers only),
- c) compression set (elastomers only),
- d) durometer hardness,
- e) yield strength (thermoplastics only),
- f) elongation at yield (thermoplastics only), and
- g) Young's modulus (thermoplastics only).

5.3.4.3 Nonmetallic Material Verification

Verification shall establish that the material used is suitable for the specific configuration, environment and application. The evaluations or tests shall include:

- a) mechanical loads,
- b) applied pressure,