

Downhole Perforating Tools

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Downhole Perforating Tools

1 Scope

This specification provides requirements and guidelines for the design and use of downhole perforating tools and related equipment, as defined herein for use in the petroleum and natural gas industry.

This specification provides the requirements for reporting and validating operational ratings of downhole perforating tools that are not addressed by any current standards or specifications. Thus:

- providing well-defined operational ratings for functionality of downhole perforating tools as provided by the supplier/manufacturer;
- defining levels of quality control (QC) for downhole perforating tools including validation requirements, acceptance testing, performance ratings, and service center requirements.

2 Normative References

The following referenced documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any addenda) applies.

API Specification 5C3, 7th Edition, *Calculating Performance Properties of Pipe Used as Casing or Tubing*

API Specification 5CT, 10th Edition, *Specification for Casing and Tubing*

API Recommended Practice 19B, 3rd Edition, *Recommended Practices for Evaluation of Perforators*

API Recommended Practice 67, *Recommended Practice for Oilfield Explosives Safety*

ASNT SNT-TC-1A, *Personnel Qualification and Certification in Nondestructive Testing*

ASTM A36/A36M, *Standard Specification for Carbon Structural Steel*

ASTM A370, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*

ASTM E8, *Standard Test Methods for Tension Testing of Metallic Materials*

ASTM E18, *Standard Test Methods for Rockwell Hardness of Metallic Materials*

ASTM E23, *Standard Test Methods for Notched Bar Impact Testing of Metallic Materials*

ASTM E45, *Standard Test Methods for Determining the Inclusion Content of Steel*

ASTM E94/E94M, *Standard Guide for Radiographic Examination Using Industrial Radiographic Film*

ASTM E112, *Standard Test Methods for Determining Average Grain Size*

ASTM E164, *Standard Practice for Contact Ultrasonic Testing of Weldments*

ASTM E213, *Standard Practice for Ultrasonic Testing of Metal Pipe and Tubing*

ASTM E273, *Standard Practice for Ultrasonic Testing of the Weld Zone of Welded Pipe and Tubing*

ASTM E309, *Standard Practice for Eddy Current Examination of Steel Tubular Products Using Magnetic Saturation*

ASTM E570, *Standard Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products*

ASTM E587, *Standard Practice for Ultrasonic Angle-Beam Contact Testing*

ASTM E709, *Standard Guide for Magnetic Particle Testing*

ASTM E2033, *Standard Practice for Radiographic Examination Using Computed Radiography (Photostimulable Luminescence Method)*

ASTM E2698, *Standard Practice or Radiographic Examination Using Digital Detector Arrays*

ASTM E3024/E3024M, *Standard Practice for Magnetic Particle Testing for General Industry*

ISO 9712, *Non-destructive Testing – Qualification and Certification of NDT Personnel*

NACE MR0175/ISO 15156, *Petroleum and Natural Gas Industries—Materials for Use in H₂S-containing Environments in Oil and Gas Production*

3 Terms, Definitions, Acronyms, and Abbreviations

3.1 Terms and Definitions

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

3.1.1

assembly

Product composed of more than one component.

3.1.2

carrier

A component of a perforating gun assembly that houses the internal components such as shaped charges, detonation cord, charge holders, and other items. The carrier may have different configurations on the outside diameter. Typical OD configurations may be scalloped, grooved, or slickwall. Scalloped and grooved features usually are designed to align with the trajectory of the perforating jets.

3.1.3

cut condition

The percentage of the remaining cross-sectional area that is capable of supporting a tensile load or force applied to the target.

3.1.4

differential pressure

Difference between internal and external pressure or the difference in pressure across a closure mechanism or seal.

3.1.5

downhole perforating tools

Assemblies, components, and parts that are used to convey, initiate, detonate, actuate, retain, anchor, and release the perforating tool string. Perforating tools as defined in this document includes cutters and severing tools.

3.1.6**energetics**

Materials contained in downhole perforating tools that may not be classified as explosives but that provide a release of energy.

3.1.7**firing head**

Device used to initiate the detonation as related to downhole operations.

3.1.8**model**

Equipment with unique components and operating characteristics, which differentiate it from other equipment of the same type with different configurations.

3.1.9**operating manual**

Publication issued by the manufacturer, which contains detailed data and instructions related to the design, storage, installation, operation, and maintenance of equipment.

3.1.10**operational pressure**

The maximum external pressure under which equipment will perform during normal operating conditions.

3.1.11**perforating gun**

Device used to perforate oil and gas wells using shaped explosive charges.

3.1.12**pipe recovery cutter**

Device that intentionally cuts or severs oilfield tubulars and drill pipe using expelled material. These include explosive (jet), thermite, and chemical. This specification does not include mechanical, abrasive, and water jet.

3.1.13**product family**

A group of assemblies in which the same design configuration principles apply to materials, geometry, and functionality.

3.1.14**qualified person**

An individual or individuals with competencies gained through training and experience as measured against established requirements, such as standards or tests that enable the individual to perform a required function.

3.1.15**service center**

A location where equipment is inspected, repaired, and tested to maintain supplier/manufacturer specifications. A service center is a physical location apart from the well site.

3.1.16**shot density**

The number of shots per unit of length.

3.1.17**size**

Relevant dimensional characteristics of the equipment as defined by the supplier/manufacturer. Perforating gun sizes are defined by nominal OD dimension of carrier tubing.

3.1.18**spacer**

Device used to stagger the spacing of perforating guns within a tool string.

3.1.19**survival pressure**

The maximum allowable pressure exposed to a tool during conveyance.

3.1.20**test pressure**

Pressure at which the equipment is tested based upon all relevant design criteria.

3.1.21**type**

Equipment with specific functionality that can be differentiated by model and unique characteristics, which differentiate it from other functionally similar equipment.

3.1.22**Type 1 component or weld**

A component or weld that isolates pressure and/or may be loaded in tension as the result of axial loads on the perforating tool during run-in, activation, detonation event, in situ, or retrieval.

3.1.23**Type 2 component or weld**

A component or weld that does not meet the criteria of a Type 1 component.

3.2 Acronyms and Abbreviations

COC	certificate of compliance
ID	inside diameter
MTR	material test report
NDE	nondestructive examination
NDT	nondestructive testing
OD	outside diameter
PSL	product specification level
QC	quality control
QL	quality level
UNS	unified numbering system

4 Functional Specification**4.1 General**

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

4.2 Product Type Description

The user/purchaser should specify the following product type(s):

- perforating gun;
- pipe recovery cutter;
- conveyance connectors;
- booster;
- firing head;
- gun anchor/hanger;
- release tool;
- setting tool.

4.3 Well Parameters

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

- dimensions, material, and grade of the casing and tubing;
- end connections;
- well angle from the vertical;
- deviations and restrictions product must pass through;
- configuration of tubing (single or multiple strings);
- location and orientation of other lines (electrical, hydraulic, fiber optic);
- relationship of the perforating tool with other well devices, tubing, casing by means of a well schematic drawing, if applicable;
- expected minimum and maximum values of production or injection pressures, pressure differentials, changes in temperatures, and flow rates;
- maximum pressure;
- maximum temperature;
- maximum expected time at temperature and pressure;
- wellbore fluids and/or gases;
- known conditions of well structure or equipment such as scaling, paraffins, NORM, corrosion;
- depth of zones and correlation process (short joints, radioactive markers, etc.);
- any other relevant well parameter(s).

4.4 Operational Parameters

The user/purchaser should specify the following operational parameters:

- installation method, including conveyance method;

- activation method and number of times activated or manipulated;
- equipment operating depth (setting, activating, or firing);
- retrieving method;
- representative well schematic;
- well pumping operations including fluids and solids composition, flow rates, and exposure time;
- anticipated loading conditions, including combined loading (pressure, tension/compression) and torque, applied to the perforating tool prior to and during activation, during use, and during retrieving;
- expected activation temperature and anticipated temperature profile, exposure time during well operations, and completion processes;
- size, type, and configuration of devices to be run through or over the perforating tools;
- any other relevant operational parameter(s).

4.5 Environmental Compatibility

4.5.1 General

If the user/purchaser has access to the corrosion property data of the operating environment based on historical data and/or research, they should state to the supplier/manufacturer which material(s) has the ability to perform as required within the corrosion environment. Otherwise, material compatibility should be specified according to 4.5.2.

4.5.2 Well Environment

The user/purchaser should identify the density, chemical/physical composition, and the condition of the fluid and/or its components, including solid, liquid, and/or gas, to which the perforating tool is exposed during its expected life cycle.

The user/purchaser should identify when compliance with NACE MR0175/ISO 15156 (all parts) for sour service is required.

4.5.3 Storage and Transportation Environment

The user/purchaser should reference the storage and transportation requirements as defined by the supplier/manufacturer. If deviations are requested by the user/purchaser, the deviations should be specified in the purchase order or request for services.

4.6 Compatibility with Related Well Equipment

The user/purchaser should identify the following:

- top and bottom tubular connection(s), the material (including any supplemental and/or annex requirements required in an internationally recognized standard such as API 5CT or API 5CRA), and dimensions;
- internal receptacle profile(s), bore dimension(s), outside diameter (OD), inside diameter (ID), and the respective locations;
- configuration of other products and conduits to be used in connection with this product, including material, size, and type;

— retrieving requirements such as fishing neck, internal or external profile, or other geometry.

4.7 Design Validation

The user/purchaser should specify the required design validation grade. This specification provides five design validation grades (V4 to V0), as defined in 5.5 and the annexes. The selected design validation grade applies to all validation testing per applicable annexes.

4.8 Quality Control

The user/purchaser should specify the required quality level (QL). This specification provides three quality levels (QL3, QL2, and QL1) of QC, as defined in 6.4.1.

5 Technical Specification

5.1 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 to the user/purchaser the product datasheet defined in 6.2.3.

5.2 Technical Characteristics

The following criteria shall be met:

- The product shall perform in accordance with the functional specification during installation, activation, operation, and retrieval.
- Where applicable, the product shall not compromise well intervention operations.

5.3 Design Requirements

5.3.1 General

Products conforming to this specification shall be manufactured to drawings and specifications that are substantially the same as those of the same size, type, and model of product that was validated. See applicable scaling limitations related to validation in 5.7.

5.3.2 Design Documentation

Design of products manufactured to this specification shall include documentation of those designs. This documentation shall include 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).

5.3.3 Materials

5.3.3.1 General

Materials (both metallic and nonmetallic) shall be stated by the supplier/manufacturer and shall be suitable for the environment specified in the functional specification. The manufacturer shall have documented specifications for all materials, and all materials used shall comply with the manufacturer's documented specifications.

Material substitutions require approval by a qualified person from the supplier/manufacturer and the supporting documentation incorporated into the manufacturing records.

5.3.3.2 Metals

5.3.3.2.1 General

Steel tubulars for perforating gun carriers shall be specified as per Annex A. All other metals shall be specified as per 5.3.3.2.2 and 5.3.3.2.3.

5.3.3.2.2 Specifications

The manufacturer's specifications shall define:

- a) unified numbering system (UNS) number or chemical-composition limits;
- b) heat treatment conditions;
- c) mechanical property limits:
 - 1) tensile strength;
 - 2) yield strength;
 - 3) elongation;
 - 4) hardness.

5.3.3.2.3 Mechanical Property Verification

When required by the user/purchaser, the mechanical properties for 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 (or processes) as the finished component it qualifies.

5.3.4 Performance Rating

The supplier/manufacturer shall state the performance ratings for the following: pressure, temperature, axial loads, disconnect, (re)connect, and tubing movement, as applicable for the products.

5.4 Design Verification

5.4.1 General

Design verification shall be performed to ensure that each perforating tool design meets the supplier/manufacturer's technical specifications, including:

- all conveyance methods;
- operational processes;
- removal methods and tools;
- contingencies; and
- all rated functionalities.

Design verification includes activities such as design reviews, design calculations, testing, 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.