Calculating Performance Properties of Pipe Used as Casing or Tubing

API RECOMMENDED PRACTICE 5C3
EIGHTH EDITION, FEBRUARY 2026



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Introduction

Performance design of tubulars for the petroleum and natural gas industries, whether it is formulated by deterministic or probabilistic calculations, compares anticipated loads to which the tubular may be subjected to the anticipated resistance of the tubular to each load. The load and/or resistance may be modified by a design factor.

Both deterministic and probabilistic approaches to performance properties are addressed in this document. The deterministic approach uses specific geometric and material property values to calculate a single performance property value. The probabilistic method treats the same variables as random and thus arrives at a statistical distribution of a performance property. A performance distribution in combination with a defined lower percentile determines the final design equation.

Both the well design process itself and the definition of anticipated loads are currently outside the scope of standardization for the petroleum and natural gas industries. Neither of these aspects is addressed in this document. Rather, it serves to identify useful equations for obtaining the resistance of a tubular to specified loads, independent of their origin. It provides limit state equations (see annexes) that are useful for determining the resistance of an individual sample whose geometric and material properties are given, and design equations that are useful for well design based on conservative geometric and material parameters.

Whenever possible, decisions on specific constants to use in a design equation are left to the discretion of the user.

For equations related to performance properties, extensive background information is also provided regarding their development and use.

Equations presented here are intended for use with pipe manufactured in accordance with API 5CT, API 5DP, and API 5L, as applicable. These equations and templates may be extended to other pipe with due caution. Pipe cold-worked during production is included in the scope of this document (e.g. cold rotary straightened pipe). Pipe modified by cold working after production, such as expandable tubulars and coiled tubing, is beyond the scope of this document.

Application of performance property equations in this document to line pipe and other pipe is restricted to their use as casing/tubing in a well or laboratory test and requires due caution to match the heat treat process, straightening process, yield strength, and so forth, with the closest appropriate casing/tubing product. Similar caution should be exercised when using the performance equations for drill pipe or for collapse of cold-expanded API 5L pipe.

This document and the equations contained herein relate the input pipe geometry, material, and manufacturing parameters in API 5CT, API 5DP, and API 5L to expected pipe performance. The design equations in this document do not imply a warranty of performance. Manufacturers are typically licensed to produce tubular products in accordance with manufacturing specifications that control the dimensions and physical properties of their product. Design equations, on the other hand, are a reference point for users to characterize tubular performance and begin their own well design or research of pipe properties.

This document is not a design code. It only provides equations and templates for calculating the properties of tubulars intended for use in downhole applications. This document does not provide any guidance about loads that can be encountered by tubulars or about safety margins needed for acceptable design. Users are responsible for defining appropriate design loads and selecting adequate safety factors to develop safe and efficient designs. The design loads and safety factors will likely be selected based on historical practice, local regulatory requirements, and specific well conditions.

Unless otherwise specified, all equations and listed values for performance properties in this document assume a benign environment and material properties conforming to API 5CT, API 5DP, and API 5L. Other environments may require additional analyses, such as that outlined in Annex D.

In the interests of worldwide application of this document, the API Subcommittee on Tubular Goods (SC5) has decided, after detailed technical analysis, that certain documents listed in the Bibliography and prepared by API-SC5 or other technical committees are interchangeable in the context of the relevant requirement with the relevant document prepared by the International Organization for Standardization (ISO) or ASTM International. These latter documents are cited in the running text following the API reference and preceded by or, for example, “API XXXX or ISO YYYY” or “ISO YYYY or ASTM ZZZZ.” Application of an alternative document cited in this manner may lead to technical results different from the use of the preceding API reference. However, both results are acceptable, and these documents are thus considered interchangeable in practice.

In this document, data are expressed in both the International System of Units (SI) and the United States Customary (USC) system of units. For a specific order item, it is intended that only one system of units be used, without combining data expressed in the other system.

Calculating Performance Properties of Pipe Used as Casing or Tubing

1 Scope

This document illustrates the equations and templates necessary to calculate the various pipe properties, including the following:

— pipe performance properties, such as axial strength, internal pressure resistance, and collapse resistance;

— minimum physical properties;

— product assembly force (torque);

— product test pressures;

— critical product dimensions related to testing criteria;

— critical dimensions of testing equipment;

— critical dimensions of test samples.

Pipe performance properties under dynamic loads and pipe connection sealing resistance are excluded from the scope of this document.

Throughout this document tensile stresses are positive.

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.

API Specification 5B, *Threading, Gauging, and Inspection of Casing, Tubing, and Line Pipe Threads*

API Specification 5CT, *Casing and Tubing*

API Specification 5L, *Line Pipe*

ASME [1] *Boiler and Pressure Vessel Code*

ASTM E1152-95 [2], *Test Method for Determining J-R Curves*

ASTM E1928, *Standard Practice for Estimating the Approximate Residual Circumferential Stress in Straight Thin-walled Tubing*

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[1] American Society of Mechanical Engineers, Two Park Avenue, New York, New York 10016, www.asme.org.

[2] ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.