INTERNATIONAL STANDARD

ISO 16708

First edition
2006-04-01

Petroleum and natural gas industries — Pipeline transportation systems — Reliability-based limit state methods

Industries du pétrole et du gaz naturel — Systèmes de transport par conduites — Méthodes aux états-limites basées sur la fiabilité

Reference number
ISO 16708:2006(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

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 16708 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 2, *Pipeline transportation systems*.

Introduction

The International Standard ISO 13623 allows the use of innovative techniques and procedures such as reliability-based limit state methods providing the minimum requirements of ISO 13623 are satisfied.

This International Standard provides the supplement to ISO 13623 in giving recommendations and specifying the framework and principles for the application of the probabilistic approach, i.e. “reliability-based limit state methods”.

Pipeline integrity management during design and operation are performed by the following two limit state approaches:

— a deterministic approach, with the use of safety or usage factors applied to characteristic loads and resistances; and

— a probabilistic approach, based on structural reliability analysis applied to the relevant limit states, e.g. reliability-based limit state methods.

Both approaches satisfy the safety requirements; implicitly by the deterministic approach (via earlier-calibrated safety factors) and explicitly by the probabilistic approach (a direct check on the actual safety level) as illustrated in Figure 1.

Significant differences exist among member countries in the areas of public safety and protection of the environment. Within the safety framework of this International Standard, such differences are allowed for and individual member countries can apply their national requirements for public safety and the protection of the environment to the use of this International Standard.

Petroleum and natural gas industries — Pipeline transportation systems — Reliability-based limit state methods

1 Scope

This International Standard specifies the functional requirements and principles for design, operation and re-qualification of pipelines in the petroleum and natural gas industries using reliability-based limit state methods as permitted by ISO 13623. Reliability-based limit state methods provide a systematic way to predict pipeline safety in design and operation.

This International Standard supplements ISO 13623 and can be used in cases where ISO 13623 does not provide specific guidance and where limit states methods can be applied, such as, but not limited to,

— qualification of new concepts, e.g. when new technology is applied or for design scenarios where industry experience is limited,

— re-qualification of the pipeline due to a changed design basis, such as service-life extension, which can include reduced uncertainties due to improved integrity monitoring and operational experience,

— collapse under external pressure in deep water,

— extreme loads, such as seismic loads (e.g. at a fault crossing), ice loads (e.g. by impact from ice keels),

— situations where strain-based criteria can be appropriate.

This document applies to rigid metallic pipelines on-land and offshore used in the petroleum and natural gas industries.

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 13623:2000, *Petroleum and natural gas industries — Pipeline transportation systems*

3 Terms and definitions

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

3.1
basic variable
load or resistance variable entering the limit state function including the variable accounting for model uncertainty in the limit state function itself

3.2
characteristic load
nominal value of a load to be used in determination of load effects

NOTE Characteristic load is normally based upon a defined fractile in the upper end of the distribution function of the load.

3.3
characteristic resistance
nominal value of a strength parameter to be used in determination of capacities

NOTE Characteristic resistance is normally based on a defined fractile in the lower end of the distribution function of the resistance.

3.4
characteristic value
nominal value to characterize the magnitude of a stochastic variable

NOTE Characteristic value is normally defined as a fractile of the probability distribution of the variable.

3.5
commissioning
activities associated with the initial filling of a pipeline with the fluid to be transported

[ISO 13623]

3.6
construction
phase comprising installation, pressure testing and commissioning

3.7
design life
period of time selected for the purpose of verifying that a replaceable or permanent component is suitable for the anticipated period of service

[ISO 13623]

3.8
design point
most probable outcome of the basic variables when failure occurs

NOTE The design point is the point on the limit-state surface with the highest probability density.

3.9
design value
value to be used in the deterministic design procedure, i.e., characteristic value multiplied by the safety factor

3.10
failure
loss of ability of a component or a system to perform its required function

3.11
fluid category
categorization of the transported fluid according to hazard potential

3.12
importance factor
dimensionless number between zero and one describing the contribution of a random variable to the overall uncertainty

3.13
inspection
processes for determining the status of items of the pipeline system or installation and comparing it with the applicable requirements

EXAMPLE Inspection can be by measuring, examination, testing, gauging or other methods.

3.14
limit state
state beyond which the pipeline no longer satisfies the design requirements

NOTE Categories of limit states for pipelines include serviceability limit state (SLS) and ultimate limit state (ULS).

3.15
limit-state design
structural design where specific limit states relevant for the actual case are explicitly addressed

NOTE A limit-state design check can be made both using the deterministic approach or using the probabilistic approach where uncertainties are modelled.

3.16
limit state function
function of the basic variables, which has negative values when the structure fails and positive values when the structure is safe

3.17
load
any action causing deformation, displacement, motion, etc. of the pipeline

3.18
load combination
set of loads acting simultaneously

3.19
load effect
effect of a single load or load combination on the pipeline

EXAMPLE Load effects include stress, strain, deformation, displacement.

3.20
location class
geographic area classified according to criteria based on population density and human activity

[ISO 13623]

3.21
maintenance
all activities designed to retain the pipeline in a state in which it can perform its required functions

[ISO 13623]

NOTE These activities include inspections, surveys, testing, servicing, replacement, remedial works and repairs.

3.22
maximum allowable incidental pressure
MAIP
maximum allowable internal pressure due to incidental operation of the pipeline or pipeline section

3.23
maximum allowable operating pressure
MAOP
maximum allowable pressure at which a pipeline, or parts thereof, is allowed to be operated

[ISO 13623]

3.24
mean value
first order statistical moment of the probability distribution function of the considered variable

3.25
mill test pressure
test pressure applied to pipe joints and pipe components upon completion of manufacture and fabrication at the mill

3.26
model uncertainty
uncertainty in the predictions of a selected calculation model that remains when the exact values of all input parameters are known

EXAMPLES Load model, strength model, function model for the pipeline.

3.27
nominal wall thickness
specified wall thickness of a pipe, which is equal to the minimum design wall thickness plus the negative manufacturing tolerance and the corrosion allowance

3.28
normal operation
conditions that arise from the intended use and application of the pipeline, including associated condition and integrity monitoring, maintenance and repair

NOTE Normal operations includes steady flow conditions over the full range of design flow rates, as well as possible packing and shut-in conditions.

3.29
ovality
deviation of the pipeline perimeter from a circle, having the form of an elliptical cross-section

3.30
pipeline
those facilities through which fluids are conveyed, including pipe, pig traps, components and appurtenances, up to and including the isolating valves

[ISO 13623]

3.31
offshore pipeline
pipeline laid in maritime waters and estuaries seaward of the ordinary high water mark

[ISO 13623]

3.32
on-land pipeline
pipeline laid on or in land, including lines laid under inland water courses

[ISO 13623]

3.33
reliability
ability of a component or a system to perform its required function without failure during a specified time interval

NOTE Reliability equals 1 minus the failure rate, P_f.

3.34
risk
combination of the probability of an event and the consequences of the event

[ISO 17776]

NOTE Individual risk is related to the risk of a single person injury/death and societal risk is the risk of human safety in the entire society affected by the pipeline.

3.35
safety class
concept to classify the criticality of pipelines

3.36
safety factor
γ
factor by which the characteristic value of a variable is multiplied to give the design value

3.37
specified minimum tensile strength
SMTS
minimum ultimate tensile strength required by the specification or standard under which the material is purchased

3.38
specified minimum yield strength
SMYS
minimum yield strength required by the specification or standard under which the material is purchased

[ISO 13623]

3.39
system reliability
reliability of a system of more than one element, or the reliability of an element which has more than one relevant failure mode

3.40
target safety level
maximum acceptable failure probability level for a particular pipeline and limit state condition

4 Symbols and abbreviated terms

4.1 Symbols

C_{f} consequences of a given failure

P_{f} probability of a failure, i.e. the actual failure rate calculated

$P_{\mathrm{f,\ target}}$ target safety level, equal to the target probability of failure

R resistance or the capability of a structure or part of a structure to resist load effects

S load effect on a structure or part of a structure

γ safety factor

$g(x)$ limit state function

D pipe diameter

L gouge length of impacts

d gouge depth of impacts

d_d dent depth of impacts

f_imp frequency of occurrence of impacts

f ovality

σ_y yield strength

σ_u ultimate tensile strength

t time

$f_x(x)$ joint distribution

$I(x)$ indicator function

$H(x)$ event margin

C vector of serviceability constraints

ΔK stress intensity factor range

p random pressure variable

λ scale parameter

S_C characteristic load effect

$S_\mathrm{C,E}$ environmental load effects

$S_\mathrm{C,F}$ functional load effects

R_C characteristic value of component resistance, based on characteristic values of material properties

f_C characteristic values of material properties, for example yield strength

γ_i partial load effect factors

η_R resistance or strength usage factors

γ_m partial material factors

$\Delta\alpha$ additive partial geometrical quantities

4.2 Abbreviated terms

ALS accidental limit state

CTOD crack tip opening displacement

FLS fatigue limit state

LRFD load and resistance factor design

MAIP maximum allowable incidental pressure

MAOP maximum allowable operating pressure

QRA quantitative risk analysis

SLS serviceability limit state

SMTS specified minimum tensile strength

SMYS specified minimum yield strength

SRA structural reliability analysis

ULS ultimate limit state

5 Principles for design and operation

Pipeline design and operational principles can be implemented using different methods with varying levels of detail as indicated in Figure 1. In order of decreasing level of detail, these methods are quantitative risk analysis (QRA) and structural-reliability analysis (SRA), both of which are probabilistic, and the deterministic limit-state design methods [partial safety-factor design and load and resistance-factor design (LRFD)], which are collectively termed LRFD in this document.

The LRFD formats apply partial safety factors to the characteristic load and resistance properties, representing more traditional design for pipelines. This is the format applied in ISO 13623 by the use of the hoop stress design factor and the equivalent stress design factor, i.e. one partial factor only. This approach is classified as deterministic, as no quantitative information about the safety margin is given. The partial safety factors in the LRFD format have to be calibrated by the use of reliability-based methods prior to the publication to satisfy its design requirements and provide a satisfactory safety margin. The routine use of the LRFD formats do not, therefore, require the partial safety factors to be determined. In LRFD approaches (see left side of Figure 1), the load and resistance are defined by their characteristic values and partial safety factors are applied separately (as required) to the characteristic values of load, resistance and material properties.

Application of the probabilistic approach (SRA and QRA) involves the steps on the right hand side of Figure 1. The limit-state definition is generally the same as for the LRFD. In this approach, load effects and resistance are represented by probability functions, given in terms of distribution type, mean value and standard deviation. This approach is classified as probabilistic, as quantitative information about the safety margin in terms of reliability or the complementary failure probability is given. The most comprehensive probabilistic method is QRA, as it takes into consideration the consequences of failure.

The format and requirements for the reliability-based limit state method are described in Clause 6.

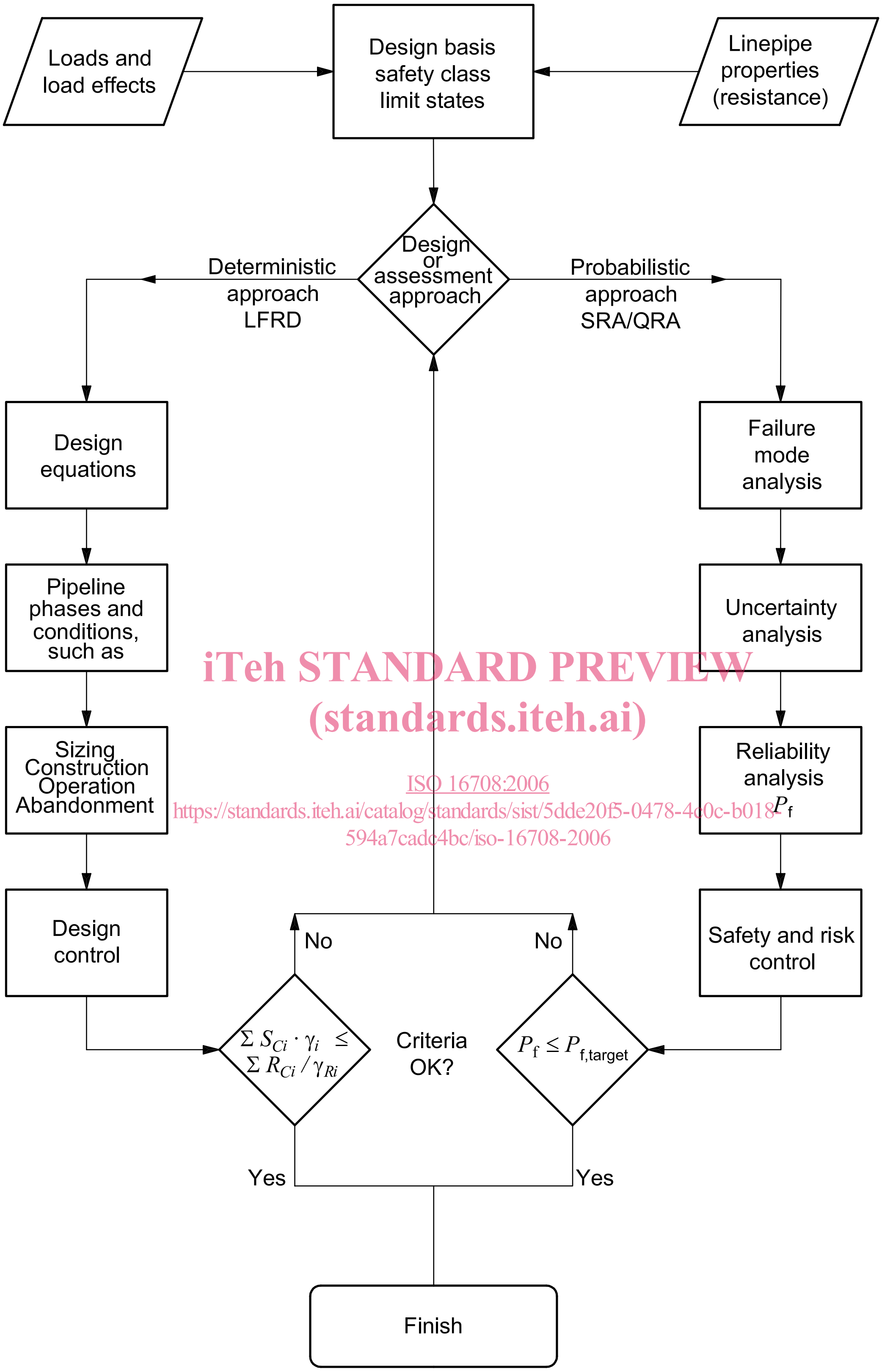

Figure 1 — Pipeline design and assessment approaches

6 Reliability-based limit state methods

6.1 General

Use of the reliability-based limit state approach shall include

— determining the design and operational data basis: data gathering, see 6.2,

— determining the safety requirements: targets, see 6.3,

— failure mode analysis; see 6.4,

— uncertainty analysis including estimation of probability functions; see 6.5,

— reliability analysis, see 6.6, and

— safety and risk assessment, see 6.7.

6.2 Design and operational data basis — Data gathering

Data gathering is collecting and defining all relevant information related to the pipeline to be considered and shall include the following information:

a) design basis and operational information including

— pipe system characteristics, e.g. pipe diameter, pipeline length, product composition, operating conditions (pressure, temperature), design life and interface facilities,

— definition of loads and load effects and associated hazards,

— definition of linepipe properties (resistance) and relevant pipeline capacities, and

— inspection and monitoring philosophy for operation, e.g. integrity management plan;

b) Hazard identification and classification of failure conditions including

— determination of limit state conditions which constitute structural non-compliance for the pipeline as judged against the safety requirements and constraints, e.g. partial or total loss of supply, any loss of fluid, loss of operability or serviceability without loss of fluid, and

— determination how the pipeline can become structurally non-compliant, in terms of loadings, resistance, and degradation; i.e. hazard identification.

Determination of operational requirements and classification of failure conditions shall be performed in accordance with Clauses 7 and 8.

6.3 Safety requirements — target

The objective of this step is to define the relevant safety requirements for the hazards/failure modes.

a) The target safety level shall be defined for all pipeline sections according to the location and consequence categorization in Clause 8;

b) Target safety levels shall be determined for all phases of the pipeline design life; e.g. construction, normal operation, and any temporary conditions.