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May 30, 2006

To: Ms. Sylvie Gingras
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Subject: ISO/TC11 Liaison Report to ISO/TC197

Letter No.: ST-LLC-06-015

Dear Ms. Gingras:

In my capacity as ISO/TC11 (Boilers and Pressure Vessels) observer to ISO/TC197 (Hydrogen), please note the following status of activities related to ISO/DIS 16528 "Boilers and Pressure Vessels".

- The FDIS Ballot is due to close at the end of July 2006.
- The next meeting of TC 11 is scheduled for August 2006 in conjunction with the ASME Boiler and Pressure Vessel Code meetings in Henderson, NV, USA.
- The latest drafts of ISO/DIS 16528 Parts 1 and 2 are attached for information.

Best Regards,

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cc: Kevin Ennis, (Chair, ISO TC11)

Date: 2005-11-13

ISO/DIS 16528 Part 1

ISO TC 11 /SC /WG 10

Secretariat: ANSI

Boilers and pressure vessels — Part 1: Performance requirements

Chaudières et récipients sous pression —Partie 1: Exigences de performance

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 16528 was prepared by Technical Committee ISO/TC 11, *Boilers and pressure vessels*.

This edition cancels and replaces ISO/TS 16528:2002.

ISO 16528 consists of the following parts, under the general title *Boilers and pressure vessels*:

— *Part 1: Performance requirements*

— *Part 2: Standards fulfilling the requirements of Part 1.*

Introduction

This part of ISO 16528 specifies performance requirements for boilers and pressure vessels, to ensure the integrity of the pressure boundary.

An important safety requirement is the suitable provision of technical requirements taking into account the various modes of failure that can occur in pressure equipment. Guidance is given on these modes together with the criteria for satisfying these.

There are significant differences among countries in regulating the supply and operation of pressure equipment. These differences include compliance with specific standard(s) limiting source or specification of materials, use of specific inspection bodies, and discriminatory certification systems or import licenses. However, those standards have a proven history of supporting public safety and good commercial operating experience.

This part of ISO 16528, which is performance based standard, will enable those standards to co-exist providing an approach that can accommodate technical innovations, existing regulatory frameworks and market needs. Compliance with the requirements of this part of ISO 16528 does not relieve parties from obligations under local, national or international laws or regulations.

ISO 16528 Part 2 provides a procedure to identify existing prescriptive standards that fulfil the requirements of this part of ISO 16528.

Boilers and pressure vessels — Part 1: Performance requirements

1 Scope

This part of ISO 16528 defines the performance requirements for the construction of boilers and pressure vessels.

It is not the intent of this part of ISO 16528 to address operation, maintenance and in service inspection of boilers and pressure vessels.

In relation to the geometry of pressure containing parts for pressure vessels, the scope of this part of ISO 16528 includes the following:

a) The welding end connection for the first circumferential joint for welded connections

b) The first threaded joint for screwed connections

c) The face of the first flange for bolted, flanged connections

d) The first sealing surface for proprietary connections or fittings

e) Safety accessories where necessary.

In relation to the geometry of pressure containing parts for boilers, the scope of this part of ISO 16528 covers the following:

a) Feedwater inlet (including the inlet valve) to steam outlet (including the outlet valve), including all inter-connecting ‘tubing’ which may be exposed to a risk of over-heating and cannot be isolated from the main system.

b) Associated safety accessories.

c) Connections to boilers involved in services such as draining, venting, desuperheating, etc.

This part of ISO 16528 does not apply for nuclear components, railway and marine boilers, gas cylinders or piping systems, and mechanical equipment, e.g. turbine and machinery casings.

2 Terms and definitions

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

2.1
boiler
an assembly intended for generation of steam or hot water above atmospheric pressure.

2.2
pressure vessel
a housing designed and built to contain gases or liquids under pressure.

2.3
certification
procedure by which a third party or manufacturer gives written assurance that a product, process or service conforms to specified requirements

Note Adapted from ISO/IEC 17000:2004

2.4
conformity
fulfilment of specified requirements

2.5
construction
processes which include design, material specification, manufacture, inspection, examination, testing and conformity assessment of boilers and pressure vessels

2.6
contracting party
Individual or organization procuring boilers or pressure vessels for a user or for resale

2.7
designer
organization or individual that performs design of boilers and pressure vessels in compliance with a standard

2.8
examination
activity carried out by qualified personnel using qualified procedures to assess that given products, processes or services are in conformance with specified acceptance criteria

2.9
inspection
activity to check that the results of required testing or examinations comply with specified requirements

2.10
manufacturer
the individual or legal entity who is responsible for the construction of boilers or pressure vessels in accordance with:

— the specifications provided by the contracting party; and

— the requirements of the standard applicable to the boiler and pressure vessel under consideration

Note: The manufacturer may entrust subcontractors with all or part of the operations or works (including design or assembly), after informing (if applicable) the third party inspection body. The manufacturer remains fully responsible for the operations or works subcontracted.

2.11
maximum allowable pressure
the maximum pressure for which the equipment is designed

2.12
owner
Individual or organization having legal title to the boiler or pressure vessel.

2.13
qualification
proof of suitability of an individual, process, procedure, or service to fulfil specified requirements

2.14
regulation
rules promulgated by a government authority in accordance with legal statutes or directives 2.15
safety accessory
devices designed to protect boilers and pressure vessels against the allowable limits being exceeded

Note Such devices include:

— devices for direct pressure limitation, such as safety valves, bursting disc safety devices, buckling rods, controlled safety pressure relief systems,

— limiting devices, which either activate the means for correction or provide for shutdown or lockout, such as pressure switches or temperature switches or fluid level switches

— safety related measurement, control and regulation devices

2.16
standard or code
document established and approved by a standard issuing body that provides for common and repeated use, mandatory requirements, guidelines or characteristics for activities or their results

Note: The term ‘standard’ used throughout this Part of ISO 16528 shall be considered equivalent to ‘code’ and vice versa.

2.17
testing
activity carried out to determine by specific procedures that one or more characteristic of a product, process or service meets one or more specified requirements

2.18
third party inspection body
organization that performs inspections on boilers and pressure vessels as provided for by standards and is independent from, themanufacturer, , contracting party, owner or user

2.19
user
organization or individual using or operating boilers and pressure vessels

3 Units of measurements

Measurements shall be in SI Units. Product standards that are only available in other units may be used.

4 Classification of boilers and pressure vessels

Due to the broad application of boilers and pressure vessels, this part of ISO 16528 does not provide a use based application scheme. This part of ISO 16528 addresses a minimum set of failure modes and technical requirements that will aid users of this part of ISO 16528 in determining appropriate applications.

5 Duties and responsibilities

5.1 General

It is essential that duties, responsibilities and interfaces between contracting parties, manufacturers and third party inspection bodies are clearly established. In general the duties and responsibilities are provided in 5.2 to 5.4.

5.2 Users and contracting parties

The user or the contracting party should establish the technical requirements for the boiler or pressure vessel taking into consideration factors associated with all aspects of use. The following is a summary of the major design elements that should be considered by the user in establishing these requirements:

a) Construction standard

b) Installation site or application of boilers and pressure vessels built for stock

c) Vessel classification

d) Vessel configuration and controlling dimensions

e) Design conditions, e.g. loads and load cases and environmental requirements

f) Design life (fatigue, creep, corrosion)

g) Materials of construction

h) Overpressure protection e.g. safety accessories

NOTE Where the manufacturer is the only party involved in the construction of boilers or pressure vessels (e.g., built for stock, turnkey units, etc.), the manufacturer also has the responsibilities of the user.

5.3 Manufacturers

The manufacturer is responsible for assuring that the boiler or pressure vessel complies with the user's requirements and with a standard fulfilling the requirements of this part of ISO 16528. Information documenting compliance with a standard fulfilling the requirements of this part of ISO 16528 and the user's requirements specification should be available in the manufacturer's documentation, including as a minimum:

a) Detailed and general assembly drawings.

b) Design calculations and analysis that establish the construction details.

c) Documentation of design by experiment or testing when employed.

d) Documentation of material, fabrication, examination and testing processes and results, e.g. forming, welding, heat treatment and radiography, etc.

e) A documented statement signed by the manufacturer and where appropriate verified by a third party inspection body that the boiler and pressure vessel complies with the applicable standard.

f) Any necessary operating or maintenance instructions.

5.4 Third party inspectors

It is the duty of inspectors to make all necessary inspections and verify that boilers and pressure vessels comply with all requirements of a standard fulfilling the requirements of this part of ISO 16528. The following is a summary of the major inspection categories:

g) Confirming requirements for design, material, welding, heat treatment, examination and testing.

h) When the manufacturer employs a quality system (see clause 8), monitoring of the manufacturer's quality control system.

i) Verifying the maintenance of records.

The inspector may be either:

— Independent from the manufacturer's organization and reporting to a third party organization.

— Independent of production but within a manufacturer's approved quality management system; or

— Within an independent inspection division of the user.

6 Design basis failure modes

6.1 General

The design shall consider the following failure modes, and specifically address those listed in 6.2. This requirement does not mandate detailed analysis of the failure modes listed in 6.2 if the design parameters for the boiler or pressure vessel do not require such an analysis, e.g. creep rupture would not need to be analysed for a pressure vessel operating at essentially ambient temperatures. In such cases, the designer shall document the reason for not addressing one or more of the failure modes listed in 6.2.

It is not the intent to describe in detail each potential failure mode. Annex A contains a brief description of some common failure modes for guidance.

6.2 Common failure modes

6.2.1 Classification

The possible ways in which pressure equipment might fail are classified into short term, long term and cyclic type failures, or a combination of these.

6.2.2 Short term failure modes

Failure modes due to the application of non-cyclic loads which lead to immediate failure can be classified as follows:

— Brittle fracture

— Ductile failures (crack formation, ductile tearing due to excessive local strains, gross plastic deformation and plastic instability (bursting)

— Excessive deformations leading to leakage at joints or other loss of function

—

— Elastic or elastic-plastic instability (buckling) –

6.2.3 Long term failure modes

Failure modes due to the application of non-cyclic loads which lead to delayed failure can be classified as follows:

- Creep Rupture

— Creep - excessive deformations at mechanical joints or resulting in unacceptable transfer of load

— Creep instability

— Erosion, corrosion

— Environmentally assisted cracking e.g. stress corrosion cracking, hydrogen induced cracking, etc

— **6.2.4 Cyclic failure modes**

Failure modes due to the application of cyclic loads which lead to delayed failure can be classified as follows:

— Progressive plastic deformation

— Alternating plasticity

— Fatigue under elastic strains (medium and high cycle fatigue) or under elastic-plastic strains (low cycle fatigue)

— Environmentally assisted fatigue, e.g. stress corrosion cracking or hydrogen induced cracking

6.3 Failure modes to be addressed

As a minimum, the following failure modes shall be taken into account in establishing design criteria and methods for boiler and pressure vessels:a) Brittle fracture

b) Ductile failures (crack formation, ductile tearing due to excessive local strains, gross plastic deformation and plastic instability (bursting)

c) Excessive deformations leading to leakage at joints or other loss of function

d) Elastic or elastic-plastic instability (buckling)

7 Technical requirements

7.1 General

The integrity of the pressure boundary of boiler and pressure vessel is based on the application of a combination of design techniques, material selection, manufacturing features and levels of inspection. The technical requirements for each are stated in the following subclauses.

7.2 Materials

7.2.1 General

Materials of pressure bearing parts, materials for non-pressure bearing parts (e.g. supports and attachments) and welding consumables used for the manufacture of boilers and pressure vessels shall be suitable for intended application and foreseeable unintended conditions.

7.2.2 Specification of materials

Material properties shall:

a) Be appropriate for all operating conditions which are reasonably foreseeable and for all test conditions, and in particular, they shall be sufficiently ductile and tough. Moreover, due care shall be exercised in selecting materials in order to prevent brittle fracture.

b) Be sufficiently chemically resistant to the fluid contained in the boilers and pressure vessels;

c) Not be adversely affected at operating conditions, e.g.-by ageing;

d) Be suitable for the intended fabrication procedures;

e) Be selected to avoid significant undesirable effects when dissimilar materials are employed.

The manufacturer shall specify any additional material properties required to support the design basis, e.g. impact properties.

7.2.3 Material certification

The manufacturer shall take appropriate measures to ensure that materials used conform to the requirements of specifications permitted by the applicable standards. The manufacturer shall obtain material identification and certification as required by the applicable material specification.

7.3 Design

7.3.1 Loadings and other design considerations

Boilers and pressure vessels shall be designed for loadings appropriate to their intended use including those induced by reasonably foreseeable operation conditions and external events (see clause 5).

Boilers and pressure vessels shall be designed for internal and /or external pressure at coincident material temperature(s).

As appropriate, the following conditions shall also be considered:

— Weight of the component under operating conditions and hydraulic pressure test conditions,

— Loads supported by or reacting on the component,

— Wind loading,

— Earthquake loading,

— Temperature differences due to transient conditions or differences in coefficient of thermal expansion,

— Fluctuations of pressure and temperature during normal operating and upset conditions,

— Degradation mechanisms, e.g. corrosion, erosion, creep and fatigue,

— Handling, transportation and installation loads, etc,

— Probability and magnitude of coincident loadings.

7.3.2 Design methods

a) Design methods shall address the integrity of boilers and pressure vessels by applying one or an appropriate combination of the following methods:Design by rule

b) Design by analysis c) Design by experiment or testing

These methods shall be based on a coherent system of design, including provisions for design input and recognition of modes of failure (see B.2).

7.3.3 Design margins

Design margins on material properties and types of design (including appropriate fabrication details) for boilers and pressure vessels shall address foreseeable failure modes under specified loading conditions.

Material properties to be taken into account, where applicable, include:

— Yield strength,

— Tensile strength

— Time-dependent strength, i.e. creep strength,

— Fatigue data,

— Modulus of elasticity,

— Strain,

— Impact strength,

— Fracture toughness.

7.3.4 Design factors

In addition to the design margins specified in 7.3.3, appropriate design factors (such as weld efficiency based on extent and type of examination, shape or size of component, etc.) to address uncertainties for manufacturing, complex stress fields and material behaviour shall be provided.

7.3.5 Means for examination

Boilers and pressure vessels shall be constructed to provide access for internal inspection.

Other means of examining the condition of boilers and pressure vessels may be applied, as appropriate, when physical access is not possible.

7.3.6 Draining and venting

When necessary, adequate means for draining and venting shall be provided for boilers and pressure vessels.

7.3.7 Corrosion and erosion

Where necessary, adequate allowance or protection against corrosion, erosion or any other chemical attack shall be provided, taking account of intended and reasonably foreseeable use.

7.3.8 Overpressure protection

7.3.8.1 General requirements

Pressure relief devices or systems for limiting overpressure shall be provided for boilers and pressure vessels. Protection systems shall be designed to prevent overpressure of boilers and pressure vessels beyond intended limit considering operation, classification and probability of an upset.

However, unrelieved pressure beyond design conditions may occur, providing the pressure is consistent with design margins for anticipated failure mode(s). If overpressure protection is provided by system design, an analysis shall be conducted to confirm that all credible operating and upset conditions have been accounted for including equipment and instrumentation malfunctions.

7.3.8.2 Types of devices

Types of devices shall be appropriate for intended loadings and reasonably foreseeable use, content and process environments of boilers and pressure vessels.**7.3.8.3 System Overpressure Protection Accessories**

The design and construction of safety accessories including pressure limiting devices, temperature limiting and monitoring devices shall be suitable for their intended use.

7.4 Manufacture

7.4.1 Methods

Manufacturing methods and techniques shall be appropriate for all aspects of the fabrication process, considering degradation of materials from fabrication, heat treatment or forming etc.

7.4.2 Identification of materials

Identification of materials used for boilers and pressure vessels shall be ensured through appropriate measures like matching to mill certificates, positive material identification etc.

7.4.3 Preparation of parts

Appropriate methods for preparation of parts (e.g. cutting and forming etc.) shall be selected to assure that defects such as cracks or detrimental changes in the mechanical and chemical characteristics are avoided.

7.4.4 Welding

Appropriate welding processes shall be selected for materials to be used. Welded joints and adjacent zones shall be free of any surface or internal defects detrimental to production of adequate welds.

The mechanical properties of welded joints shall satisfy those specified for the materials to be welded unless other relevant property values are specifically taken into account in the design calculations.

Suitably qualified welders using qualified welding procedures shall perform welding of pressure parts, and non-pressure parts directly attached to pressure boundaries.

7.4.5 Welding procedure qualification

Welding procedures used in production of boilers and pressure vessels shall be qualified by a competent third party or under an international or national qualification scheme or in accordance with manufacturer's quality program. Qualification shall consider intended fabrication and operating conditions such as materials, welding positions etc. and shall include appropriate examination and tests.

7.4.6 Welder qualification

Welders engaged in production of boilers and pressure vessels shall be qualified by a competent third party or under an international or national qualification scheme or in accordance with manufacturer's quality program. Qualification shall consider intended fabrication conditions such as materials, welding positions etc. and shall include appropriate examination and tests.

7.4.7 Welder identification

Welders engaged in production of boilers and pressure vessels shall be identified.

7.4.8 Heat treatment

When there is a risk that the fabrication process will cause unacceptable changes in the properties of the material or weld, suitable heat treatment shall be applied at appropriate stage(s) of manufacture such as cutting, forming and welding etc.

7.4.9 Tolerances

Tolerances or ranges of welding grooves, weld reinforcement, dimensions and heat treatment shall be maintained at the appropriate stages of fabrication and on the finished boilers and pressure vessels.

7.5 Inspection, non-destructive testing and examination

7.5.1 General

Boilers and pressure vessels shall be examined for dimensional conformance and indications of imperfections by appropriate visual and non-destructive examinations.

7.5.2 Methods

Inspection and examination methods and any limitations shall consider material types, fabrication process, thickness, configuration, intended application, etc.

7.5.3 Procedures

Inspection and examination procedures shall be qualified by a recognized party or under national qualification scheme or in accordance with manufacturer's quality program.

7.5.4 Personnel qualification

Inspection and examination personnel shall be qualified by a recognized party or under national qualification scheme or in accordance with manufacturer's quality program.

7.5.5 Evaluation of indications and acceptance criteria

Criteria for evaluation of indications and acceptance criteria shall be consistent with material types and thicknesses, design factors and equipment applications.

7.5.6 Disposition of unacceptable imperfections

Methods of dispositioning (sentencing) unacceptable imperfections in component shall be suitable for the intended design and application and shall not impair the boiler and pressure vessel. Methods may include repair, demonstrating fitness for purpose or rejection.

7.6 Final inspection and test

7.6.1 Final inspection

Boilers and pressure vessels shall undergo a final inspection to assess visually and by review of the accompanying documents compliance with the requirements of the applicable standard. Tests carried out during manufacture may be taken into account. When practical, the final inspection must be carried out internally and externally on every part of the equipment; when access for a final inspection is not possible, appropriate inspections shall be made during the course of manufacture.

7.6.2 Final pressure test

Final assessment of boilers and pressure vessels shall include a test for pressure containment and, when necessary, beneficial prestressing. When possible, a hydrostatic test is recommended. When a hydrostatic pressure test is harmful or impractical, other tests of a recognized value may be employed. For tests other than the hydrostatic pressure test, additional measures, such as non-destructive tests or other methods of equivalent validity, must be applied before those tests are carried out.

7.7 Marking /labelling

Required information shall be physically marked on boilers and pressure vessels in accordance with the applicable standard. As a minimum, the information shall include a unique identification number or type or series identification, an indication of conformity, manufacturer's identification, for pressure vessel the maximum allowable pressure(s) at coincident design temperature(s), and; for boilers the maximum allowable pressure and design temperature at the boiler outlet. When physical marking is not practical, alternative means are allowed such as records traceable to the boiler or pressure vessel or a suitable label attached to the boiler or pressure vessel.

8 Conformity assessment

Boilers and pressure vessels shall be constructed under a system of conformity assessment agreed to by the parties concerned. Certification of conformity to the standard shall be supplied by the appropriate assessment body or manufacturer.

Assuring conformity may be accomplished by one or a combination of the following systems:

a) **Manufacturer's use of a quality system:** Manufacturer's use of a quality system commensurate with the type of boiler or pressure vessel being produced and the methods of design and manufacture. Criteria or methods of recognition of quality systems shall be specified.

b) **Third-party inspection:** Inspection performed by third-party inspection bodies. In this case, criteria for the qualification and recognition of such inspection bodies shall be specified.

c) **Inspection by users:** Inspection performed by users of boilers and pressure vessels. In this case, definitions of user inspection organizations and qualification criteria for inspectors shall be specified.

d) **Accreditation of manufacturers:** Accreditation of manufacturers responsible for conformity. In this case, programs of accreditation shall be specified. Such accreditation programs shall provide equal treatment of qualified manufacturers.

e) **Inspection by manufacturer:** Inspection performed by the manufacturer of the boilers or pressure vessels. In this case, criteria for the inspections, inspection organization and inspectors shall be specified.

Annex A
(informative)

Description of some common failure modes and limit states

A.1 Failure modes

A.1.1 Ductile failure

This failure mode should be taken into account for all loading conditions of boilers and pressure vessels. Ductile failure is due to unstable gross plastic yielding resulting in unstable reduction of thickness or unstable crack growth.

Local plastic deformations which remain confined enough to exclude any risk of collapse are permitted by the design rules covering ductile failure provided that the parent material and the welded areas have a sufficient plastic deformation capacity.

The concept of gross plastic deformation applies to the overall vessel pressure boundary. Under this condition, some sections or whole regions yield and no increase in load beyond this limit is possible.The mechanical characteristic relating to the resistance of the material against gross plastic deformation is the yield strength.Plastic instability occurs under increasing loading, when after considerable yielding, the increase in strength of the material by work hardening can no longer compensate for the section reduction induced by the plastic deformation.

The mechanical characteristic relating to the resistance of the material against plastic instability is the tensile strength. The prevention of ductile failure is ensured by means of the same design rules, through the concept of nominal design stress which introduces a sufficient margin on yield strength as well as tensile strength, explicitly or implicitly.

NOTE When in the Standard it is stated that a rule covers failure by gross plastic deformation, it implicitly means that it also covers failure by plastic instability.

A.1.2 Creep rupture

These modes of failure affect vessels whose design temperature is high enough to lead to gradual material yielding under constant loading.

This mode of failure should be taken into account only under operating conditions including temporary excursions that can be foreseen by the designer.

The nominal design stress is usually based on factor(s) applied to the creep rupture stress of the material. In some standards a review may be required after 2/3 of the design life has been used.

A.1.3 Brittle fracture

Prevention of this mode of failure under loadings of mainly static nature shall be the subject of specific requirements. Fracture toughness properties should be specified for the materials. Adequate heat treatment following forming and welding operations is important to prevent brittle fracture and this should be clearly

defined by the standard. Similarly where a vessel is operating at colder temperatures, the critical defect sizes permitted may be smaller than those at normal operating conditions.

Most standards specify a minimum temperature at which the hydrostatic test should be carried out.

A.1.4 Leakage at mechanical joints

Generally, the rules in a standard tend not to cover failure due to leakage at mechanical joints. However, there may be functional requirements e.g. tightness, limitations with respect to deformation, gasket seating, etc. which are the subject of specific calculation rules or of particular construction provisions (i.e tightness of bolted flange connections)

A.1.5 Buckling

This failure mode generally results from elastic or elastic-plastic instability under compressive stresses; certain specific rules of the standard, such as the design rules for shells under external pressure, torispherical vessel heads, etc are based on it.

This failure mode shall be considered for all loading conditions for a vessel subject to compressive stresses. In order to prevent such a failure, checks should ensure that applied loadings do not exceed the loadings of the same nature which would result in collapse, divided by a suitable design factor.

The method used shall take into account the possible geometric imperfections, within the limit of the values permitted by the standard.

A.1.6 Progressive plastic deformation (incremental collapse)

Failure by progressive plastic deformation can occur in vessels subjected to combined loadings, some of which remaining fairly uniform, whereas others showing large cyclic variations.

It results in a cumulative increase in deformation under the action of these repeated variations. Should a risk of failure by instability exist, progressive plastic deformation would have a worsening effect on this risk.

This failure mode shall be taken into account only for normal operating conditions. In practice, operating conditions leading to progressive plastic deformation are rare. The most commonly known case is thermal ratchetting, which may affect vessels subjected to great periodic variations in temperature of the fluid contained, the pressure remaining constant or slightly variable.

The shakedown criterion (twice yield criterion) used in many standards cover the risk of failure by progressive plastic deformation. Fulfilling this criterion is usually sufficient but may not be necessary. A standard may give the manufacturer the possibility to justify the absence of failure by progressive plastic deformation using any other means.

Note when the shakedown criterion is not fulfilled, the most common result is alternating plasticity (low cycle fatigue) not progressive plastic deformation.

A.1.7 Fatigue cracking

Failure by fatigue cracking affects vessels subject to variable loadings. This failure may occur for a fairly low number of cycles in regions where plastic deformation occurs at each cycle (alternating plasticity). It may also occur for a very large number of cycles in the elastic range even when the stress range is small, e.g. in the case of vibrations, in stress concentration areas.

Fatigue cracking shall usually only be taken into account for normal operating conditions.

Special attention is necessary when fatigue loading occurs under creep conditions as this can significantly reduce the permissible number of cycles.

A.1.8 Environmentally induced failure mechanisms

Wastage due to corrosion or erosion and failures due to environmentally induced cracking, etc. are often referred to in a standard but the method of addressing these is usually left to the designer.

A.2 Limit states

The limit state should be taken into account when considering any particular failure mode.

A limit state is defined as a structural condition when the design performance requirements are not met and is classified as either an ultimate or a serviceability limit state.

An ultimate limit state is a structural condition (of the component or vessel) associated with burst or collapse, or with other forms of structural failure which may endanger the safety of people e.g. failure by gross plastic deformation, rupture caused by fatigue, collapse caused by instability of the vessel or part of it, etc.

A serviceability limit state is a structural condition (of the component or vessel) beyond which the service criteria specified for the component are no longer met e.g. deformation or deflection which adversely affects the use of the vessel, leakage which affects efficient use of the vessel but does not compromise safety or cause an unacceptable environmental hazard, etc.

Annex B (informative)

Guidance on Selection of Standards

B..1 Purpose The purpose of this Annex is to describe the types of standards which are available and to give guidance on their selection. It is not the purpose of the Annex to define how to select a particular standard but to give an understanding of the issues to be considered when making a selection. It is also not the intent to recommend any specific standard for any particular application.

B.2Background

Pressure vessel and boiler standards result from the consensus distillation of experience, research and development. They have proven to be a successful means of ensuring optimal performance, safety, economy in trade and compliance with regulations.

One thing common to all standards is that they must address the various failure modes applicable to boilers and pressure vessels. This evaluation of failure modes can be carried out by different methods and some standards may not cover all potential failure modes.

Before specifying the use of a standard there should be an awareness of the various failure modes that the standard being considered addresses.

B.3 Introduction

This Annex contains information on the two main types of standards and the way in which they tend to address failure modes. The different design methods which may be applied are also described together with other aspects such as plant operation that may have to be taken into consideration.

In general the responsibility for compliance of boilers or pressure vessels with a standard is with the manufacturer. However, the user or the contracting party is responsible for defining the service conditions. and the potential failure modes must be considered in the design. In addition the user may also specify which standard should be used. The user therefore requires some basic knowledge of failure modes to understand how standards address these in order to ensure the operating conditions of the boilers or pressure vessels are adequately addressed.

The designer may mitigate against failure modes through a combination of design techniques, material selection, manufacturing features, levels of inspection and operation of the boilers and pressure vessels.

B.4 Types of Standards

Conceptually there are two basic types of standards or system of standards, those which cover basic requirements and those which cover comprehensive requirements. In practice most standards do not fit directly into one or other of these two types but the concept generally applies. In some cases these two types may be combined in one standard, and in other cases a standard may lie somewhere between these two extremes.

A basic standard would be applicable to boilers or pressure vessels planned to be subject to steady state operational conditions (no rapid temperature changes, nominal load cycles, etc) where there is minimum design effort required, essentially based on mandatory formulae for determining wall thicknesses, etc. In general the failure modes are addressed by the use of limits which result in relatively low stresses when the loadings are applied and this also accommodates secondary effects which are not considered in detail.

A comprehensive standard would be applicable to both low duty and severe duty vessels. The allowable design stresses are relatively higher than those in a basic standard and a design assessment to address the applicable failure modes should be carried out by competent engineers. . In this type of standard there is usually detailed methodology directly addressing the failure modes that could result in failure of the pressure vessel or boiler.

In both cases failure modes can be addressed through more than just design calculations e.g. limitations on use of materials, welding techniques, heat treatment requirements, etc. Geometric features may also be specified to minimize the stress concentration factors for cyclic loading or

excessive local strains. The acceptable limits for non-destructive examination may also vary depending on the failure modes being considered.

There is usually a level of involvement by a third party inspection body, either inherent within the standard or specified by regulation, which may vary depending on the type and service of the pressure equipment.

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B.5 Design methods

The majority of standards cover failure modes through what is generally known as ‘design by rule’ or ‘design by formulae’ where prescriptive formulae are applied to determine the shell thickness, compensation for nozzle openings, etc. These normally provide satisfactory designs for pressure loading of a typically non-cyclic nature. However, according to the criteria which are used when basic failure modes are assessed, a margin may exist permitting a certain number of operational fatigue cycles (e.g. 500 cycles based on experience) rather than have the standard directly address loads such as thermal cycling, rapid start up and shutdown. Standards may provide different criteria according to the classification of load cases into normal operating conditions, occasional conditions and exceptional conditions.

Design by analysis may be used as an alternative or to supplement ‘design by rule’ applications and may have to be used for cases not covered by the ‘design by rule’ criteria e.g. significant fatigue, thermal transients, environmental loadings, etc. It may also be used in cases where the specified manufacturing tolerances are exceeded and require a more accurate evaluation of the stresses in a component.

There tends to be two methods by which design by analysis is applied.

a) The first is a design where specific failure modes are directly addressed and assessed against limit states i.e. the structural condition beyond which the design performance requirements are not satisfied. This normally entails the investigation of a component’s safety under the influence of specified combinations of loading with respect to specified limit states. Such an approach was often used to develop the rules used in ‘design by rule’ – particularly in those standards which are product specific.

b) The second method is based on stress categories which involves the interpretation of stresses calculated on an elastic basis into primary, secondary and peak stresses at any point in a part of a vessel and then assess these against specified maximum allowable limits for each category and their combinations.

Primary stresses limits are used to protect against sustained loads leading to ductile failure and secondary stress limits are usually associated with loads that are self-limiting. Peak stresses are additional to primary and secondary stresses and are associated with stress concentration that require a fatigue assessment.

Generally, a basic standard uses a ‘design by rule’ methodology whereas a comprehensive standard may include the ‘design by rule’ methodology as well as one or both of the ‘design-by-analysis’ approaches.

When ‘design by rule or analysis’ methods do not fully address a unique configuration, experimental methods may be applied.

B.6 Selection of Standards

In addition to taking into account probable failure modes other factors may need to be considered in the selection of a particular standard for any specific application.

These include aspects such as:

- the manufacturer’s familiarity with a specific standard.
- the accreditation and competence of the manufacturer.
- the level of involvement of the Inspection body and any supplementary regulations required to enforce this.
- margins within a standard in terms of design and acceptance criteria.
- particularly arduous conditions which may necessitate the application of a comprehensive standard or additional precautions.
- risk management of critical equipment where assessments are made of hazards, feasible failure modes, likelihood of failure and consequences.
- failure analysis to help determine and identify probable failure causes, methods of avoiding repetition and possible improvements by innovation.

B.7 Product Life Cycle

The assessment and mitigation for failure modes may not be fully addressed in a standard as these may be addressed by other means through the full life cycle of the equipment from design through

to operation and maintenance. Although this is out with the scope of ISO 16528 in that it does not address operation, maintenance and in-service inspection they are included here for reference as they can influence the approach taken to addressing failure modes.

Aspects which should be taken into account include the following:

Operation of the equipment should be within the specified design limits but consideration may have to be given to the possibility of these being exceeded in which case the likelihood of failure by different modes can be seriously increased.

Training of operators on the background of the various practices aimed at achieving safety of people and plant and the protection of the environment through prevention of failures.

In-service inspection to assess acceptability, avoidance or rectification of any degradation. Most countries have legislative requirements for inspection of pressure equipment though it's life. The scope and frequency of this may mitigate the requirement for detailed analysis at the design stage. Conversely the design analysis may indicate increased frequency of examination.

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ISO/DIS 16528 Part 2

ISO TC 11/SC /WG 11

Secretariat: ANSI

Boilers and pressure vessels — Part 2: Procedures for fulfilling the requirements of ISO 16528-2 Part 1

Chaudières et récipients sous pression — Partie 2: Normes répondant aux exigences de la Partie 1

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 16528 was prepared by Technical Committee ISO/TC 11, *Boilers and pressure vessels*, Subcommittee SC, .

ISO 16528 consists of the following parts, under the general title *Boilers and pressure vessels*:

— *Part 1: Performance requirements*

Part 2: **Procedures for fulfilling the requirements of ISO 16528-2 Part 1**

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Introduction

ISO 16528 Part 1 specifies performance requirements for boilers and pressure vessels.

There are commonly used national/regional standards that have a proven history of supporting public safety and have good commercial operating experience. It is the intention of ISO 16528 Part 2 to provide a process to identify national/regional standards that satisfy the performance requirements of ISO 16528 Part 1.

Boilers and pressure vessels — Part 2: Procedures for fulfilling the requirements of ISO 16528-2 Part 1

1. Scope

2. ISO 16528 Part 2 provides a procedure and a standard format for standard issuing bodies to demonstrate that their standards fulfil the performance requirements of ISO 16528 Part 1.**Terms and definitions**

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

2.1
standard or code
document established and approved by a standard issuing body that provides for common and repeated use, mandatory requirements, guidelines or characteristics for activities or their results

Note: The term ‘standard’ used throughout this Part of ISO 16528 shall be considered equivalent to ‘code’ and vice versa.

2.2
standard issuing body
organization that promulgates a boiler or pressure vessel standard

3. Conformance procedure

ISO 16528 Part 1 establishes performance requirements for the construction of boilers and pressure vessels. The intent of ISO 16528 Part 2 is to have these performance requirements amplified and expanded by detailed standards that satisfy two criteria:

a) The standard includes requirements that address the failure modes in accordance with clause 6 of ISO 16528 Part 1.

b) The standard adequately addresses the requirements specified in clauses 7 and 8 of ISO 16528 Part 1.

Clause 4 includes formatted conformance tables. A task force of experts from ISO/TC 11 is available to assist standard issuing bodies to complete these tables and the secretariat to review them.

When available, the completed conformance tables shall be published on the official website of ISO/TC 11, after the secretariat of ISO/TC 11 has reviewed the tables for completeness and understanding. The publication on the ISO/TC 11 website does not imply adoption of the standard as an ISO standard, nor approval by ISO of the detailed technical requirements. Standard issuing bodies may publish the completed tables and indicate the standard conforms with ISO 16528 Part 1 after they have been posted on the official ISO website.

4. Conformance tables

Table 1 shall be used to express which failure modes are addressed in a standard.

The first part of Table 1 lists the principal failure modes defined in clause 6.2 of ISO 16528 Part 1. As a minimum these must be completed by identifying whether a particular standard addresses the failure mode or not, or recognises the failure mode but does not address it in detail.

It is not required that a standard address all the failure modes listed in clause 6.2 of 16528 Part 1. If a standard does not address one or more of the failure modes listed in ISO 16528 Part 1, clause 6.2 an explanation shall be provided defining the limitations in the standard's scope or application relative to the failure mode(s) not addressed.

In addition to the failure modes identified in clause 6.2 of ISO 16828 Part 1 a standard may address one or more of the failure modes listed in clause 6.1 of ISO 16528 Part 1. These should be listed in the second part of Table 1 using the same criteria as for the first part.

Table 2 shall be used to express which rules or requirements directly affect how the standard addresses the selected failure mode (for each failure mode identified in Table 1). The footnotes to Table 2 give guidance on the requirements of each part of the table.

Table 3 shall be used to express how the technical requirements of ISO 16528 Part 1 are dealt with in the standard.

Table 1 — Failure mode summary

STANDARD [a]:	
FAILURE MODE SUMMARY [b]	
Failure Modes according to ISO 16528 Part 1 clause 6.3	**Addressed (Y / N / P) [c]**
Brittle fracture	
Ductile failure	
Excessive deformation leading to leakage or other loss of function	
Elastic or elastic-plastic instability (buckling)	
Additional Failure Modes according to ISO 16528 Part 1 clause 6.2	**Addressed (Y / N / P) [c]**

[a] Provide full title of the standard and revision or addenda level

[b] Failure modes addressed by this form (See ISO 16528 Part 1)

[c] Y – failure mode addressed by standard
N – failure mode not addressed by standard
P – failure mode recognized by standard but complete details not addressed.

Table 2 — Detailed Failure Mode Checklist

STANDARD :
FAILURE MODE [a] :
EXPLICIT DESIGN [d]
References [b] :
Comments [c] :
IMPLICIT DESIGN [e]
References:
Comments:
FABRICATION DETAILS [f]
References:

Comments:
MATERIAL REQUIREMENTS [g]
References:
Comments:
EXAMINATION REQUIREMENTS [h]
References:
Comments:
TESTING REQUIREMENTS [i]
References:
Comments:
USE / APPLICATION LIMITS [j]
References:
Comments:

a Failure mode addressed by this form (See Table 1)

b Provide specific clause or paragraph references (including the title, if any) indicating where relevant rules can be found. These references need not be exhaustive, but should be detailed enough to establish that the standard adequately addresses the selected failure mode.

c Provide explanatory comments indicating the background for the approach employed or other material that might be useful. For example, brief description of failure theor(ies) used should be provided. References to academic papers and empirical testing methods used to establish rules are encouraged.

d Reference(s) to rules or requirements that directly affect how the standard addresses the selected failure mode, e.g. formulas for sizing wall thickness of components for resisting ductile burst.

e This section may be used to provide references and comments when design tables, empirically based rules or other approaches are employed whose derivation is not obvious. It may also be used to provide general information on design margins (safety factors) on material properties, etc. Many successful standards do not provide explicit design rules for certain failure modes yet do employ combinations of material control, temperature limits or other means to provide adequate protection against failure. This section may be used to provide information on how his standard indirectly addresses certain failure modes when explicit rules are not provided.

f References for fabrication details relevant to the selected failure mode, e.g. control of cylinder ovality, weld profiling, control of tolerances, etc. For example, control of cylinder ovality is important for prevention of buckling of externally loaded vessels. This section should be used to describe such fabrication controls relevant for the designated failure mode.

g Relevant requirements for base and welding materials, e.g. control of YS/UTS ratios, provisions for addressing strain hardening, applications of heat treatment, etc. Assuring that fabrication processes have not adversely affected material properties beyond acceptable limits can be important for preventing certain types of failures. This section should be used to describe such controls.

h References for NDT or visual inspection relevant to the selected failure mode. (If NDT is correlated to design factors, this should be noted.)

i Provisions for final testing, i.e. hydrostatic or leak tests should be noted with specific information on normal test pressures and control of test lower and upper test pressures.

j An explanation shall be provided defining the limitations in the standard's scope or application relative to Part 1 Clause 6.2 failure mode(s).

Table 3 — Detailed technical requirements checklist

ISO 16528 Part 1 Clause	Description	Reference Standard Clause(s)	Description	Comments
7.2.1	Materials - General			
7.2.2	Specification of materials			
7.2.3	Material certification			
7.3.1	Design – loadings and other design considerations			
7.3.2	Design methods			
7.3.3	Design margins			
7.3.4	Design factors			
7.3.5	Means for examination			
7.3.6	Draining & venting			
7.3.7	Corrosion & erosion			

7.3.8.1	Overpressure protection - general			
7.3.8.2	Types of devices			
7.3.8.3	Safety accessories			
7.4.1	Manufacture - methods			
7.4.2	Identification of materials			
7.4.3	Preparation of parts			
7.4.4	Welding			
7.4.5	Welding procedure qualifications			
7.4.6	Welder qualifications			
7.4.7	Welder identification			
7.4.8	Heat treatment			
7.4.9	Tolerances			
7.5.1	Inspection & examination (I&E) – General			
7.5.2	I&E methods			
7.5.3	I&E procedures			
7.4.4	I&E personnel qualification			
7.5.5	Evaluation of indications & acceptance criteria			
7.5.6	Disposition of unacceptable imperfections			
7.6.1	Final inspection			
7.6.2	Final pressure test			
7.7	Marking/labeling			
8	Conformity assessment			