

## SCHEDULE 2

### Essential Safety Requirements

## **PART 2**

### DESIGN

#### **General**

**3.—**(1) Pressure equipment must be properly designed taking all relevant factors into account in order to ensure that the equipment will be safe throughout its intended life.

(2) The design of pressure equipment must incorporate appropriate safety coefficients using comprehensive methods which are known to incorporate adequate safety margins against all relevant failure modes in a consistent manner.

#### **Design for adequate strength**

**4.—**(1) Pressure equipment must be designed for loadings appropriate to its intended use and must take account of other reasonably foreseeable operating conditions, including, in particular, the following factors—

- (a) internal/external pressure;
- (b) ambient and operational temperatures;
- (c) static pressure and mass of contents in operating and test conditions;
- (d) traffic, wind, earthquake loading;
- (e) reaction forces and moments which result from the supports, attachments, piping etc.;
- (f) corrosion and erosion, fatigue, etc.;
- (g) decomposition of unstable fluids.

(2) Various loadings which can occur at the same time must be considered, taking into account the probability of their simultaneous occurrence.

(3) Design for adequate strength must be based on either of the following—

- (a) as a general rule, a calculation method, as described in paragraph 5, and supplemented if necessary by an experimental design method as described in paragraph 6;
- (b) an experimental design method without calculation, as described in paragraph 5, when the product of the maximum allowable pressure  $PS$  and the volume  $V$  is less than 6 000 bar L or the product  $PS \cdot DN$  less than 3 000 bar.

#### **Calculation method**

**5.—**(1) As regards pressure containment and other loading aspects—

- (a) the allowable stresses for pressure equipment must be limited having regard to reasonably foreseeable failure modes under operating conditions, for which purpose safety factors must be applied to eliminate fully any uncertainty arising out of manufacture, actual operational conditions, stresses, calculation models and the properties and behaviour of the material; and
- (b) the calculation methods used must provide sufficient safety margins consistent, where applicable, with the requirements of Part 6.

- (2) The requirements set out above may be met by applying one of the following methods, as appropriate, if necessary as a supplement to or in combination with another method—
- (a) design by formula;
  - (b) design by analysis; or
  - (c) design by fracture mechanics.
- (3) As regards resistance—
- (a) appropriate design calculations must be used to establish the resistance of the pressure equipment concerned; and in particular—
    - (i) the calculation pressures must not be less than the maximum allowable pressures and take into account static head and dynamic fluid pressures and the decomposition of unstable fluids;
    - (ii) where a vessel is separated into individual pressure-containing chambers, the partition wall must be designed on the basis of the highest possible chamber pressure relative to the lowest pressure possible in the adjoining chamber;
    - (iii) the calculation temperatures must allow for appropriate safety margins;
    - (iv) the design must take appropriate account of all possible combinations of temperature and pressure which might arise under reasonably foreseeable operating conditions for the equipment;
    - (v) the maximum stresses and peak stress concentrations must be kept within safe limits;
    - (vi) the calculation for pressure containment must utilise the values appropriate to the properties of the material, based on documented data, having regard to the provisions set out in Part 4 together with appropriate safety factors; material characteristics to be considered, where applicable, include—
      - (aa) yield strength, 0.2 % or 1.0 % proof strength as appropriate at calculation temperature;
      - (bb) tensile strength;
      - (cc) time-dependent strength, i.e. creep strength;
      - (dd) fatigue data;
      - (ee) Young's modulus (modulus of elasticity);
      - (ff) appropriate amount of plastic strain;
      - (gg) bending rupture energy;
      - (hh) fracture toughness.
    - (vii) appropriate joint factors must be applied to the material properties depending, for example, on the type of non-destructive testing, the materials joined and the operating conditions envisaged;
    - (viii) the design must take appropriate account of all reasonably foreseeable degradation mechanisms (for example corrosion, creep and fatigue) commensurate with the intended use of the equipment and attention must be drawn, in the instructions referred to in paragraph 30, to particular features of the design which are relevant to the life of the equipment, for example—
      - (aa) for creep: design hours of operation at specified temperatures;
      - (bb) for fatigue: design number of cycles at specified stress levels;
      - (cc) for corrosion: design corrosion allowance.

(4) As regards stability aspects, where the calculated thickness does not allow for adequate structural stability, the necessary measures must be taken to remedy the situation taking into account the risks from transport and handling.

#### Experimental design methods **E+W+S**

6.—(1) The design of the equipment may be validated, in all or in part, by an appropriate test programme carried out on a sample representative of the equipment or the category of equipment.

(2) The test programme must be clearly defined prior to testing and accepted by the [<sup>F1</sup>approved] body responsible for the design conformity assessment module, where it exists.

(3) The test programme must define test conditions and criteria for acceptance or refusal and the actual values of the essential dimensions and characteristics of the materials which constitute the equipment tested must be measured before the test.

(4) Where appropriate, during tests, it must be possible to observe the critical zones of the pressure equipment with adequate instrumentation capable of registering strains and stresses with sufficient precision.

(5) The test programme must include—

- (a) a pressure strength test, to check that, at a pressure with a defined safety margin in relation to the maximum allowable pressure, the equipment does not exhibit significant leaks or deformation exceeding a determined threshold, for which the test pressure must—
  - (i) be determined on the basis of the differences between the values of the geometrical and material characteristics measures under test conditions and the values used for design purposes;
  - (ii) take into account the differences between the test and design temperatures;
- (b) where the risk of creep or fatigue exists, appropriate tests determined on the basis of the service conditions laid down for the equipment, for example hold time at specified temperatures, number of cycles at specified stress-levels;
- (c) where necessary, additional tests concerning other factors referred to in paragraph 4 such as corrosion and external damage.

#### Extent Information

- E1** This version of this provision extends to England and Wales and Scotland only; a separate version has been created for Northern Ireland only
- F1** Word in [Sch. 2 para. 6\(2\)](#) substituted (E.W.S.) (9.12.2021) by [The Product Safety and Metrology etc. \(Amendment\) Regulations 2021 \(S.I. 2021/1273\)](#), regs. 1, **10(a)(i)**

#### Experimental design methods **N.I.**

6.—(1) The design of the equipment may be validated, in all or in part, by an appropriate test programme carried out on a sample representative of the equipment or the category of equipment.

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  - (ii) take into account the differences between the test and design temperatures;
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#### **Extent Information**

**E2** This version of this provision extends to Northern Ireland only; a separate version has been created for England and Wales and Scotland only

#### **Provisions to ensure safe handling and operation**

7.—(1) The method of operation specified for pressure equipment must be such as to preclude any reasonably foreseeable risk in operation of the equipment, and particular attention must be paid, where appropriate, to—

- (a) closures and openings;
- (b) dangerous discharge of pressure relief blow-off;
- (c) devices to prevent physical access whilst pressure or a vacuum exists;
- (d) surface temperature taking into consideration the intended use;
- (e) decomposition of unstable fluids.

(2) In particular, pressure equipment fitted with an access door must be equipped with an automatic or manual device enabling the user easily to ascertain that the opening will not present any risk, and where the opening can be operated quickly, the pressure equipment must be fitted with a device to prevent it being opened whenever the pressure or temperature of the fluid presents a risk.

#### **Means of examination**

8.—(1) Pressure equipment must be designed and constructed so that all necessary examinations to ensure safety can be carried out.

(2) Where it is necessary to ensure the continued safety of the equipment, means of determining the internal condition of the equipment must be available (such as access openings allowing physical access to the inside of the pressure equipment) so that appropriate examinations can be carried out safely and ergonomically.

(3) Other means of ensuring the safe condition of the pressure equipment may be applied in any of the following situations—

- (a) where the pressure equipment is too small for physical internal access;
- (b) where opening the pressure equipment would adversely affect the inside; or
- (c) where the substance contained has been shown not to be harmful to the material from which the pressure equipment is made and no other internal degradation mechanisms are reasonably foreseeable.

#### **Means of draining and venting**

**9.** Adequate means must be provided for the draining and venting of pressure equipment at all stages of operation and testing (and in particular pressure testing) where necessary—

- (a) to avoid harmful effects such as water hammer, vacuum collapse, corrosion and uncontrolled chemical reactions;
- (b) to permit cleaning, inspection and maintenance in a safe manner.

#### **Corrosion or other chemical attack**

**10.** Where necessary, adequate allowance or protection against corrosion or other chemical attack must be provided, taking due account of the intended and reasonably foreseeable use.

#### **Wear**

**11.** Where severe conditions of erosion or abrasion may arise, adequate measures must be taken to—

- (a) minimise that effect by appropriate design, for example additional material thickness, or by the use of liners or cladding materials;
- (b) permit replacement of parts which are most affected; and
- (c) draw attention, in the instructions referred to in paragraph 30, to measures necessary for continued safe use.

#### **Assemblies**

**12.** Assemblies must be so designed that—

- (a) the components to be assembled together are suitable and reliable for their duty; and
- (b) all the components are properly integrated and assembled in an appropriate manner.

#### **Provisions for filling and discharge**

**13.** Where appropriate, the pressure equipment must be so designed and provided with accessories, or provision made for their fitting, as to ensure safe filling and discharge in particular with respect to risks such as—

- (a) on filling—
  - (i) overfilling or overpressurisation having regard in particular to the filling ratio and to vapour pressure at the reference temperature;
  - (ii) instability of the pressure equipment;
- (b) on discharge, the uncontrolled release of the pressurised fluid;
- (c) on filling or discharge, unsafe connection and disconnection.

### **Protection against exceeding the allowable limits of pressure equipment**

**14.**—(1) Where, under reasonably foreseeable conditions, the allowable limits could be exceeded, the pressure equipment must be fitted with, or provision made for the fitting of, suitable protective devices, unless the equipment is intended to be protected by other protective devices within an assembly.

(2) The suitable device or combination of such devices must be determined on the basis of the particular characteristics of the equipment or assembly.

(3) Suitable protective devices and combinations thereof comprise—

- (a) safety accessories as defined in regulation 2(1);
- (b) where appropriate, adequate monitoring devices such as indicators and/or alarms which enable adequate action to be taken either automatically or manually to keep the pressure equipment within the allowable limits.

### **Safety accessories**

**15.**—(1) Safety accessories must—

- (a) be so designed and constructed as to be reliable and suitable for their intended duty and take into account the maintenance and testing requirements of the devices, where applicable;
- (b) be independent of other functions, unless their safety function cannot be affected by such other functions;
- (c) comply with appropriate design principles in order to obtain suitable and reliable protection, including, in particular, fail-safe modes, redundancy, diversity and self-diagnosis.

### **Pressure limiting devices**

**16.** Pressure limiting devices must be so designed that the pressure will not permanently exceed the maximum allowable pressure PS; provided that a short duration pressure surge in keeping with the specifications laid down in paragraph 39 is allowable, where appropriate.

### **Temperature monitoring devices**

**17.** Temperature monitoring devices must have an adequate response time on safety grounds, consistent with the measurement function.

### **External fire**

**18.** Where necessary, pressure equipment must be so designed and, where appropriate, fitted with suitable accessories, or provision made for their fitting, to meet damage-limitation requirements in the event of external fire, having particular regard to its intended use.

**Changes to legislation:**

There are currently no known outstanding effects for the The Pressure Equipment (Safety) Regulations 2016, PART 2.