SCHEDULE 2 Regulations 2(1), 6, 7(1) and (2)

Essential Safety Requirements

PART 1

GENERAL

1.—(1) The obligations arising from the essential safety requirements listed in this Schedule for pressure equipment also apply to assemblies where the corresponding hazard exists.

(2) The obligations arising from the essential safety requirements apply only if the corresponding hazard exists for the pressure equipment when it is used under conditions which are reasonably foreseeable by the manufacturer.

(3) The manufacturer must analyse the hazards and risks in order to identify those which apply to the equipment on account of pressure, and must then design and construct it taking account of that analysis.

(4) The essential safety requirements are to be interpreted and applied in such a way as to take account of—

(a) the state of the art and current practice at the time of design and manufacture; and

(b) technical and economic considerations which are consistent with a high degree of health and safety protection.

2.—(1) Pressure equipment must be designed, manufactured and checked, and if applicable equipped and installed, in such a way as to ensure its safety when put into service in accordance with the manufacturer's instructions, or in reasonably foreseeable conditions.

(2) In choosing the most appropriate solutions, the manufacturer must apply the principles set out below in the following order—

(a) eliminate or reduce hazards as far as is reasonably practicable;

(b) apply appropriate protection measures against hazards which cannot be eliminated;

(c) where appropriate, inform users of residual hazards and indicate whether it is necessary to take appropriate special measures to reduce the risks at the time of installation and/or use.

(3) Where the potential for misuse is known or can be clearly foreseen, the pressure equipment must be designed to prevent risks from such misuse or, if that is not possible, adequate warning given that the pressure equipment must not be used in that way.

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·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

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 notified 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.

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.

PART 3

MANUFACTURING

Manufacturing procedures

19. The manufacturer must ensure the competent execution of the provisions set out at the design stage by applying the appropriate techniques and relevant procedures, especially with a view to the aspects set out in this Part.

Preparation of the component parts

20. Preparation of the component parts (for example forming and chamfering) must not give rise to defects or cracks or changes in the mechanical characteristics likely to be detrimental to the safety of the pressure equipment.

Permanent joining

21.—(1) Permanent joints and adjacent zones must be free of any surface or internal defects detrimental to the safety of the equipment.

(2) The properties of permanent joints must meet the minimum properties specified for the materials to be joined unless other relevant property values are specifically taken into account in the design calculations.

(3) For pressure equipment, permanent joining of components which contribute to the pressure resistance of equipment and components which are directly attached to them must be carried out by suitably qualified personnel according to suitable operating procedures and for pressure equipment in categories II, III and IV, operating procedures and personnel must be approved by a competent third party which, at the manufacturer's discretion, may be—

(a) a notified body; or

(b) a recognised third-party organisation.

(4) In order to carry out the approvals referred to above, the third party must perform examinations and tests as set out in the appropriate harmonised standards or equivalent examinations and tests or must have them performed.

Non-destructive tests

22. For pressure equipment, non-destructive tests of permanent joints must be carried out by suitable qualified personnel provided that for pressure equipment in categories III and IV, the personnel must be approved by a recognised third-party organisation.

Heat treatment

23. Where there is a risk that the manufacturing process will change the material properties to an extent which would impair the safety of the pressure equipment, suitable heat treatment must be applied at the appropriate stage of manufacture.

Traceability

24. Suitable procedures must be established and maintained for identifying the material making up the components of the equipment which contribute to pressure resistance by suitable means from receipt, through production, up to the final test of the manufactured pressure equipment.

Final assessment

25. Pressure equipment must be subjected to final assessment in accordance with paragraphs 26 to 28.

Final inspection

26.—(1) Pressure equipment must undergo a final inspection to assess visually and by examination of the accompanying documents compliance with the requirements of these Regulations, for which purpose tests carried out during manufacture may be taken into account.

(2) So far as is necessary on safety grounds, the final inspection must be carried out internally and externally on every part of the equipment, where appropriate in the course of manufacture (for example where examination during the final inspection is no longer possible).

Proof test

27.—(1) Final assessment of pressure equipment must include a test for the pressure containment aspect, which will normally take the form of a hydrostatic pressure test at a pressure at least equal, where appropriate, to the value laid down in paragraph 40.

(2) For category I series-produced pressure equipment, the test referred to above may be performed on a statistical basis.

(3) Where the hydrostatic pressure test is harmful or impractical, other tests of a recognised value may be carried out provided that additional measures, such as non-destructive tests or other methods of equivalent validity, must be applied before such other tests are carried out.

Inspection of safety devices

28. For assemblies, the final assessment must also include a check of the safety devices intended to check full compliance with the requirements referred to in paragraph 14.

Marking and labelling

29.—(1) In addition to the CE marking referred to in regulation 49 and the information to be provided in accordance with regulations 13(1)(b) and 23(1), the following information must be provided—

(a) for all pressure equipment—

(i) the year of manufacture;

(ii) identification of the pressure equipment according to its nature, such as type, series or batch identification and serial number;

(iii) essential maximum/minimum allowable limits.

(b) depending on the type of pressure equipment, further information necessary for the safe installation, operation or use and, where applicable, maintenance and periodic inspection of the pressure equipment such as:

(i) the volume V of the pressure equipment in L;

(ii) the nominal size for piping DN;

(iii) the test pressure PT applied in bar and date;

(iv) safety device set pressure in bar;

(v) output of the pressure equipment in kW;

(vi) supply voltage in V (volts);

(vii) intended use;

(viii) filling ratio kg/L;

(ix) maximum filling mass in kg;

(x) tare mass in kg;

(xi) the fluid group;

(c) where necessary, warnings fixed to the pressure equipment drawing attention to misuse which experience has shown might occur.

(2) The information referred to in sub-paragraph (1) must be given on the pressure equipment or on a dataplate firmly attached to it, with the following exceptions—

(a) where applicable, appropriate documentation may be used to avoid repetitive marking of individual parts such as piping components, intended for the same assembly;

(b) where the pressure equipment is too small, for example in the case of accessories, this information may be given on a label attached to that pressure equipment;

(c) labelling or other adequate means may be used for the mass to be filled and the warnings referred to in sub-paragraph (1)(c), provided it remains legible for the appropriate period of time.

Operating instructions

30.—(1) When pressure equipment is made available on the market, it must be accompanied, as far as relevant, with instructions for the user, containing all the necessary safety information relating to—

(a) mounting including assembling of different pieces of pressure equipment;

(b) putting into service;

(c) use;

(d) maintenance including checks by the user.

(2) Instructions must include information affixed to the pressure equipment in accordance with paragraph 29, with the exception of serial identification, and must be accompanied, where appropriate, by the technical documents, drawings and diagrams necessary for a full understanding of these instructions.

(3) If appropriate, these instructions must also refer to risks arising from misuse in accordance with paragraph 2(3) and particular features of the design in accordance with paragraph 5.

PART 4

MATERIALS

31.—(1) Materials used for the manufacture of pressure equipment must be suitable for such application during the scheduled lifetime unless replacement is foreseen.

(2) Welding consumables and other joining materials need only comply with the relevant requirements of subparagraphs (3), (4)(a) and (5), in an appropriate way, both individually and in a joined structure.

(3) Materials for pressurised parts must—

(a) have appropriate properties for all operating conditions which are reasonably foreseeable and for all test conditions, and in particular—

(i) they must be sufficiently ductile and tough;

(ii) where appropriate, the characteristics of the materials must comply with the requirements of paragraph 41;

(iii) due care must be exercised in particular in selecting materials in order to prevent brittle-type fracture where necessary;

(iv) where for specific reasons brittle material has to be used, appropriate measures must be taken;

(b) be sufficiently chemically resistant to the fluid contained in the pressure equipment, and in particular the chemical and physical properties necessary for operational safety must not be significantly affected within the scheduled lifetime of the equipment;

(c) not be significantly affected by ageing;

(d) be suitable for the intended processing procedures;

(e) be selected in order to avoid significant undesirable effects when the various materials are put together.

(4) The pressure equipment manufacturer must—

(a) define in an appropriate manner the values necessary for the design calculations referred to in paragraph 5 and the essential characteristics of the materials and their treatment referred to in subparagraph (3);

(b) provide in the technical documentation elements relating to compliance with the materials specifications relating to materials contained in these Regulations in one of the following forms—

(i) by using materials which comply with harmonised standards;

(ii) by using materials covered by a European approval for materials in accordance with regulation 50;

(iii) by a particular material appraisal.

(5) For pressure equipment in categories III and IV, a specific assessment of the particular material appraisal must be performed by the notified body in charge of conformity assessment procedures for the pressure equipment.

(6) The equipment manufacturer must take appropriate measures to ensure that the material used conforms with the required specification, and in particular, documentation prepared by the material manufacturer affirming compliance with a specification must be obtained for all materials.

(7) For the main pressure-bearing parts of equipment in categories II, III and IV, the documentation referred to in sub-paragraph (6) must take the form of a certificate of specific product control.

(8) Where a material manufacturer has an appropriate quality-assurance system, certified by a competent body established within the Union and having undergone a specific assessment for materials, certificates issued by the manufacturer are presumed to certify conformity with the relevant requirements of this paragraph.

PART 5

SPECIFIC PRESSURE EQUIPMENT REQUIREMENTS

32. In addition to the applicable requirements of Parts 1 to 4, the requirements in this Part apply to the pressure equipment covered by paragraphs 33 and 34.

Fired or otherwise heated pressure equipment with a risk of overheating as referred to in regulation 6

33.—(1) The requirements in sub-paragraph (2) apply to fired or otherwise heated pressure equipment with a risk of overheating as referred to in regulation 6, including—

(a) steam and hot-water generators as referred to in regulation 6(b), such as fired steam and hot-water boilers, superheaters and reheaters, waste-heat boilers, waste incineration boilers, electrode or immersion-type electrically heated boilers, pressure cookers, together with their accessories and where applicable their systems for treatment of feedwater and for fuel supply;

(b) process-heating equipment for other than steam and hot water generation falling under regulation 6(a), such as heaters for chemical and other similar processes and pressurised food-processing equipment.

(2) Pressure equipment of the type referred to in sub-paragraph (1) must be calculated, designed and constructed so as to avoid or minimise risks of a significant loss of containment from overheating; in particular it must be ensured, where applicable, that—

(a) appropriate means of protection are provided to restrict operating parameters such as heat input, heat take- off and, where applicable, fluid level so as to avoid any risk of local and general overheating;

(b) sampling points are provided where required to allow evaluation of the properties of the fluid so as to avoid risks related to deposits and/or corrosion;

(c) adequate provisions are made to eliminate risks of damage from deposits;

(d) means of safe removal of residual heat after shutdown are provided;

(e) steps are taken to avoid a dangerous accumulation of ignitable mixtures of combustible substances and air, or flame blowback.

Piping as referred to in regulation 6(c)

34. The design and construction of piping referred to in regulation 6(c) must ensure that—

(a) that the risk of overstressing from inadmissible free movement or excessive forces being produced, e.g. on flanges, connections, bellows or hoses, is adequately controlled by means such as support, constraint, anchoring, alignment and pre-tension;

(b) that where there is a possibility of condensation occurring inside pipes for gaseous fluids, means are provided for drainage and removal of deposits from low areas to avoid damage from water hammer or corrosion;

(c) that due consideration is given to the potential damage from turbulence and formation of vortices; the relevant parts of paragraph 11 are applicable;

(d) that due consideration is given to the risk of fatigue due to vibrations in pipes;

(e) that, where fluids of Group 1 are contained in the piping, appropriate means are provided to isolate 'take-off' pipes the size of which represents a significant risk;

(f) that the risk of inadvertent discharge is minimised; the take-off points must be clearly marked on the permanent side, indicating the fluid contained;

(g) that the position and route of underground piping is recorded in the technical documentation to facilitate safe maintenance, inspection or repair.

PART 6

SPECIFIC QUANTITATIVE REQUIREMENTS FOR CERTAIN PRESSURE EQUIPMENT

35.—(1) The following provisions apply as a general rule, but where they are not applied, including in cases where materials are not specifically referred to and no harmonised standards are applied, the manufacturer must demonstrate that appropriate measures have been taken to achieve an equivalent overall level of safety.

(2) The provisions laid down in this Part supplement the essential safety requirements of Parts 1 to 5 in relation to the pressure equipment to which they apply.

Allowable stresses

36.—(1) In paragraph 37, the following symbols have the following meanings—

(a) $R_{e/t}$, yield limit, indicates the value at the calculation temperature of—

(i) the upper flow limit for a material presenting upper and lower flow limits,

(ii) the 1.0 % proof strength of austenitic steel and non-alloyed aluminium,

(iii) the 0.2 % proof strength in other cases.

(b) $R_{m/20}$ indicates the minimum value of the ultimate tensile strength at 20°C.

(c) $R_{m/t}$ designates the ultimate tensile strength at the calculation temperature.

37. The permissible general membrane stress for predominantly static loads and for temperatures outside the range in which creep is significant must not exceed the smaller of the following values, according to the material used—

(a) in the case of ferritic steel including normalised (normalised rolled) steel and excluding fine-grained steel and specially heat-treated steel, $^{2}/_{3}$ of $R_{e/t}$ and $^{5}/_{12}$ of $R_{m/20}$,

(b) in the case of austenitic steel—

(i) if its elongation after rupture exceeds 30%, $^{2}/_{3}$ of $R_{e/t}$

(ii) or, alternatively, and if its elongation after rupture exceeds 35%, $^{5}/_{6}$ of $R_{e/t}$ and $^{1}/_{3}$ of $R_{m/t}$,

(c) in the case of non-alloy or low-alloy cast steel, $^{10}/_{19}$ of $R_{e/t}$ and $^{1}/_{3}$ of $R_{m/20}$,

(d) in the case of aluminium, $^{2}/_{3}$ of $R_{e/t}$,

(e) in the case of aluminium alloys excluding precipitation hardening alloys $^{2}/_{3}$ of $R_{e/t}$ and $^{5}/_{12}$ of $R_{m/20}$.

Joint coefficients

38.—(1) For welded joints, the joint coefficient must not exceed the following values—

(a) for equipment subject to destructive and non-destructive tests which confirm that the whole series of joints show no significant defects: 1;

(b) for equipment subject to random non-destructive testing: 0.85;

(c) for equipment not subject to non-destructive testing other than visual inspection: 0.7.

(2) If necessary, in addition to the factors referred to in sub-paragraph (1), the type of stress and the mechanical and technological properties of the joint must also be taken into account.

Pressure limiting devices, particularly for pressure vessels

39. The momentary pressure surge referred to in paragraph 16 must be kept to 10% of the maximum allowable pressure.

Hydrostatic test pressure

40. For pressure vessels, the hydrostatic test pressure referred to in paragraph 27 must be no less than whichever is greater of the following—

(a) that corresponding to the maximum loading to which the pressure equipment may be subject in service taking into account its maximum allowable pressure and its maximum allowable temperature, multiplied by the coefficient 1.25;

(b) the maximum allowable pressure multiplied by the coefficient 1.43.

Material characteristics

41. Unless other values are required in accordance with other criteria that must be taken into account, a steel is considered as sufficiently ductile to satisfy paragraph 31(3)(a) if, in a tensile test carried out by a standard procedure, its elongation after rupture is no less than 14% and its bending rupture energy measured on an ISO V test-piece is no less than 27 J, at a temperature not greater than 20°C but not higher than the lowest scheduled operating temperature.