SERIES 1800
STRUCTURAL STEELWORK

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STRUCTURAL STEELWORK

1800 (08/14) General

1800.1 (08/14) Introduction and basis of execution

1 (08/14) This Series is part of the Specification for Highway Works. Whilst this Series is particularly relevant to the subject matter in its title it must be read in conjunction with the general requirements in Series 000 and 100 and with all other Series relevant to the specification for the particular Works to be undertaken.

2 (04/21) The Contractor shall supply and install all structural steelwork in accordance with this Series. Any requirement to be fulfilled by the constructor in this Series and contract specific Appendix 18/1 is a requirement on the Contractor.

3 (04/21) The terms 'execution' and 'constructor' have been used throughout this Series to be compatible with the terms used and defined in BS EN 1090-2:2018.

4 (04/21) The basis for the execution of structural steelwork in this Series shall be BS EN 1090-2:2018, with options and requirements described in this Series; see 1800.3.

1800.2 (04/21) Clause numbering and cross referencing

1 (04/21) The Clause and sub-Clause numbering and headings in Clauses 1801 to 1812 in this Series adopt those in BS EN 1090-2:2018, Clauses 1 to 12 respectively, except that the Clause and sub-Clause numbers are pre-fixed by '180' for Clauses 1 to 9 and '18' for Clauses 10, 11 and 12.

2 (04/21) The numbering of paragraphs in this Series bears no specific relationship to the order of paragraphs presented in BS EN 1090-2:2018.

3 (04/21) Cross reference to a specific paragraph within this Series is by sub-Clause number followed by the paragraph number in brackets.

1800.3 (04/21) Options and additional requirements

1 (04/21) Where the requirements specified in BS EN 1090-2:2018 are to apply to this Series without amendment, the heading of the related sub-Clause in this Series is followed by the abbreviation (AEN) (i.e. as in BS EN 1090-2:2018).

2 (04/21) Where there is a choice between two or more different requirements in a sub-clause in BS EN 1090-2:2018 the selected requirement(s) shall be as described in this Series. All other requirements in that sub-clause in BS EN 1090-2:2018 shall apply to this Series unless otherwise described in this Series.

3 (04/21) Where requirements are described in this Series, the requirements in the related sub-clause in BS EN 1090-2:2018 shall also apply to this Series unless otherwise described in this Series.

4 (04/21) Contract specific Appendix 18/1 shall be referred to for any contract specific requirements where the heading of the sub-Clause in this Series is followed by the abbreviation (18/1). Other contract specific Appendices shall be referred to for any contract specific requirements where the heading of the sub-Clause in this Series is followed by (XX/Y), where XX/Y refers to the contract specific Appendix in question. For example, for contract specific Appendix 19/1 relating to Series 1900, the abbreviation (19/1) is used.

5 (04/21) Where a requirement in BS EN 1090-2:2018 is qualified in that standard by the words 'unless otherwise specified', the requirement shall not be amended unless it is described otherwise in this Series or in contract specific Appendix 18/1.

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1800.4 (04/21) Qualification of constructors (18/1)

1 (04/21) In order to satisfy the general assumptions stated in BS EN 1990:2002+A1:2005, 1.3 (2) relating to the execution of structures designed to the Eurocodes, all structural steelwork executed in accordance with this Series shall be undertaken by a constructor which has the necessary technical capability and competence for the general type and value of work to be undertaken. These requirements will be satisfied by registration and audit through a registration scheme such as the Register of Qualified Steelwork Contractors Scheme for Bridgeworks (RQSC, see www.steelconstruction.org) to the levels appropriate for the value and technical complexity of the structural steelwork.

2 (04/21) The constructor shall undertake a review to confirm that their technical capability and competence is sufficient for the execution of the particular works described in contract specific Appendix 18/1. The review shall be documented, and shall be submitted to and approved by the Overseeing Organisation in advance of execution. The documented review shall be treated as an execution record and shall form part of the execution documentation; see 1804.2.2 and 1804.2.4. The review shall include supporting evidence that shall cover the following as a minimum:

a) details demonstrating compliance with 1800.4 (1), 1800.5.1 (1) and 1807.1 (2);

b) type and size of construction works;

c) product forms and thicknesses;

d) material grades and qualities;

e) types of process equipment;

f) execution quality requirements;

g) qualification of personnel; see 1806.5.3.1 (11), 1807.3 (2), 1807.4.2, 1807.4.3 and 1812.4.1; and

h) QSC requirements; see 1803 (1)

1800.5 (08/14) Quality management schemes

1800.5.1 (08/14) Execution of steelwork

1 (04/21) In order to satisfy the requirements stated in BS EN 1990:2002+A1:2005, 2.5 relating to quality management measures in the execution of structures designed to the Eurocodes, the constructor shall have an independently certified quality management system complying with BS EN ISO 9001 in place for all structural steelwork executed in accordance with this Series. This requirement will be satisfied by the constructor being registered to National Highway Sector Scheme 20 'The Execution of Steelwork in Transportation Infrastructure Assets', as stated in Appendix A.

1800.5.2 (08/14) Supply of mechanical fasteners

1 (04/21) The requirements stated in 1812.2.1 (2) for the verification of mechanical fasteners, as covered by BS EN 1090-2:2018, 5.6, will be satisfied through mechanical fasteners being supplied by an Organisation registered to National Highway Sector Scheme 3 'Stocking and Distribution Activities for Mechanical Fasteners', as stated in Appendix A.

1800.5.3 (04/21) Supply of structural steel products

1 (04/21) The requirements stated in 1812.2.1 (4) for the verification of structural steel products, as covered by BS EN 1090-2:2018, 5.3, will be satisfied through structural steel products being supplied by an Organisation registered to National Highway Sector Scheme 3B 'Stocking and Distribution Activities for Structural Steel Products', as stated in Appendix A.

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1800.6 (04/21) CE/UK Marking

1800.6.1 (08/14) General

1 (04/21) Conformity assessment of structural steel components shall be undertaken in accordance with BS EN 1090-1:2009+A1:2011. A declaration of performance under a CE/UK marking in accordance with the Construction Products Regulations shall be provided for all structural steel components. The declaration of performance shall include a declaration of Structural Characteristics in accordance with 1800.6.2 (1).

1800.6.2 (08/14) Declaration of structural characteristics

1 (04/21) In the property declaration for 'Structural Characteristics' of a structural steel component, the entry for 'Manufacturing' shall read as follows:

'According to component specification "X", which specifies the relevant BS EN 1090-2 requirements and execution class(es).'

where:

"X" is the component specification reference defined in 1800.6.3 (1).

1800.6.3 (08/14) Component specification reference (18/1)

1 (04/21) The component specification reference to be adopted for the conformity assessment of a structural steel component shall be as stated in contract specific Appendix 18/1.

1800.6.4 (08/14) Component specification

1 (04/21) The component specification for a structural steel component shall comprise the following:

a) this Series; and

b) contract specific Appendix 18/1.

1801 (08/14) Scope

1 (04/21) This Series shall apply to the execution of all permanent structural steelwork, and to all temporary structural steelwork including that required for the execution of permanent structural steelwork.

1802 (08/14) Normative References

1 (04/21) For normative references not given in BS EN 1090-2:2018 see Appendix F.

2 (04/21) For normative references of parts of standards not given in BS EN 1090-2:2018, see PD 6705-2:2020, Annex D.

1802.1 (04/21) Constituent products

1802.1.1 (04/21) Steels (AEN)

1802.1.2 (04/21) Steel castings (AEN)

1802.1.3 (04/21) Welding consumables (AEN)

1802.1.4 (04/21) Mechanical fasteners

1 (04/21) For normative references not given in BS EN 1090-2:2018 see Appendix F.

1802.1.5 (04/21) High strength cables (AEN)

1802.1.6 (04/21) Structural bearings

1 (04/21) For normative references not given in BS EN 1090-2:2018 see Appendix F.

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1802.2 (04/21) **Preparation (AEN)**

1802.3 (04/21) **Welding**

1 (04/21) For normative references not given in BS EN 1090-2:2018 see Appendix F.

1802.4 (04/21) **Testing**

1 (04/21) For normative references not given in BS EN 1090-2:2018 see Appendix F.

1802.5 (04/21) **Erection (AEN)**

1802.6 (04/21) **Corrosion protection (AEN)**

1802.7 (04/21) **Miscellaneous (AEN)**

1803 (08/14) Terms and Definitions

1 (04/21) Quantified service category (Abbreviated to QSC in this Series): Category that characterises a detail, component or structure (or part thereof) in terms of the circumstances of its use within specified limits of static and cyclic stressing. QSC is designated by one of the symbols F36, F56, F71, F90, F112 or F140. See also 1804.1.1 (2) and 1804.1.1 (3).

2 (04/21) National Accreditation Body: As defined in Series 100, Clause 104 (11).

3 (04/21) Exceptional Welding Process (Abbreviated to EWP in this Series): A welding process which is not covered by BS EN 1090-2:2018, Table 12 or Table 13. See also 1807.3.

4 (04/21) Factory production control (Abbreviated to FPC in this Series): The documented, permanent and internal control of production in a factory, in accordance with BS EN 1090-1:2009+A1:2011, 6.3.

5 (04/21) Inspection lot (for mechanical fasteners): As defined in BS EN ISO 3269.

1804 (08/14) Specifications and Documentation

1804.1 (08/14) **Execution specification**

1804.1.1 (08/14) **General (18/1)**

1 (04/21) The execution specification for structural steelwork shall comprise the following:

a) this Series; and

b) contract specific Appendix 18/1.

2 (04/21) Certain requirements in this Series are differentiated on the basis of QSC. These are given in the following sub-Clauses:

1805.3.1 (3)	Repair of the body of hollow sections
1805.3.3 (1)(2)(3)	Surface repair of steel products
1805.3.4 (1)	Internal discontinuity quality class in welded cross plates
1806.2 (2)(3)(4)	Identification marking methods
1806.4.4 (2)	Free edge hardness limits for machine plasma cut edges
1806.6.3 (1)(2)	Holing methods
1806.7 (1)	Minimum radii for cut outs

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1806.9 (1)	Execution of connections for temporary components
1807.2.2 (1)	Conditions for welding cold formed zones
1807.4.1.2 (2)	Imperfection limits used in qualification of welding procedures
1807.5.6 (1)	Restrictions on location and methods of removal of temporary welded attachments
1807.5.9.2 (1)	Execution of the continuity weld in permanent steel backing
1807.5.16 (1)	NDT checks of stray arc sites
1807.5.16 (3)	Direction of grinding of weld surfaces
1807.6.1 (2)	Weld acceptance criteria used for FPC during the work
1812.2.1 (5)	Testing requirements and acceptance levels for steel castings
1812.4.2.4 (1)(2)(5)	Scope of project specific supplementary weld NDT
1812.4.2.5 (1)	Final visual acceptance criteria for welds
1812.4.2.6 (1)	Final MT, PT, UT and RT acceptance criteria for welds
1812.4.4 (2)	Specific production tests on weld run-off coupon plates

3 (04/21) Where requirements are differentiated on the basis of QSC, the QSC for a detail, component or structure (or part thereof) is identified in contract specific Appendix 18/1.

1804.1.2 (08/14) **Execution classes**

1 (04/21) Certain technical requirements in BS EN 1090-2:2018 are differentiated on the basis of execution class. For these requirements the execution class given in each relevant sub-Clause in this Series shall apply. Where this Series, including contract specific Appendix 18/1, specifies a requirement which is common to more than one execution class all relevant execution classes are indicated. For example, if the specified requirement is the same for EXC2, EXC3 and EXC4 this is designated EXC2/3/4.

1804.1.3 (04/21) **Requirements for surface preparation for corrosion protection**

1 (04/21) All surfaces shall meet the preparation grades stated in 1810.2.

1804.1.4 (08/14) **Geometrical tolerances (AEN)**

1804.2 (08/14) **Constructor's documentation**

1804.2.1 (04/21) **Quality documentation (18/1)**

1 (08/14) Quality documentation shall conform to the requirements for EXC2/3/4.

1804.2.2 (08/14) **Quality plan**

1 (04/21) A quality plan for the execution of the works is required and shall include the items recommended in BS EN 1090-2:2018, Annex C and 1809.4.1 (1).

2 (08/14) The execution records shall include the constructor's drawings (including electronic files) for the execution of all components.

3 (04/21) The constructor's drawings (including electronic files) shall include the QSC and unique component mark information.

4 (04/21) Constructor's drawings in this Series shall be treated as working and fabrication drawings in accordance with Series 100.

5 (08/14) Execution records described in this Series shall be treated as quality records in accordance with Series 100.

1804.2.3 (04/21) **Safety of the erection works (AEN)**

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1804.2.4 (04/21) **Execution documentation**

1 (04/21) The execution documentation shall be treated as quality records in accordance with Series 100.

1805 (08/14) Constituent Products

1805.1 (08/14) **General (AEN) (18/1)**

1805.2 (08/14) **Identification, inspection documents and traceability**

1 (04/21) Stages of traceability shall conform to the requirements for EXC3/4.

2 (04/21) Specialist proprietary and/or bespoke products, including products for which the product manufacturer has declared a derogation under the Construction Products Regulation, incorporating non-standardised features, components or methods of manufacture, e.g. castings, forgings, cables and their terminations, energy absorbing devices, mechanical components such as movement joints and major bearings etc, shall be individually traceable.

3 (04/21) Small identical bespoke products such as special fasteners shall be traceable to their individual manufacturing lot.

4 (04/21) The identification of different grades and/or qualities of each individual constituent product shall conform to the requirements for EXC2/3/4.

1805.3 (08/14) **Structural steel products**

1805.3.1 (08/14) **General (18/1)**

1 (04/21) The following options for impact property verification shall apply:

a) Option 3 in BS EN 10025-1:2004, 7.3.2.2; the lowest test temperature shall be adopted; and

b) Option 3 in BS EN 10025-5:2004, 7.3.2.2 and 8.4.2; the impact properties of steel grade S355WP shall be verified.

2 (04/21) The following options for steel that is to be hot dip galvanized shall apply:

a) Option 5 in BS EN 10025-1:2004, 7.4.3; the product shall be suitable for hot-dip zinc-coating;

b) Option 1.4 in BS EN 10210-1:2006, 6.7.2; the product shall be suitable for hot dip galvanizing; and

c) Option 1.4 in BS EN 10219-1:2006, 6.8.2; the product shall be suitable for hot dip galvanizing.

3 (04/21) The following options for weld repair of hollow sections in zones of QSC F112 and F140 shall apply:

a) Option 1.5 in BS EN 10210-1:2006, 6.8.4; repair of the body by welding shall not be permitted; and

b) Option 1.5 in BS EN 10219-1:2006, 6.9.4; repair of the body by welding shall not be permitted.

1805.3.2 (08/14) **Thickness tolerances**

1 (08/14) Thickness tolerance Class A shall be used.

1805.3.3 (08/14) **Surface conditions (18/1)**

1 (04/21) For plates and wide flats, the limits on surface discontinuities and ground areas shall conform to BS EN 10163-2 Class A or Class B unless otherwise stated in contract specific Appendix 18/1. Repair by welding shall not be carried out (subclass 3) on steels conforming to BS EN 10025-6 or where QSC F112 or F140 applies. Where repairs by welding are required, they shall conform to subclass 2 with the following additional requirements:

a) reports on weld repairs shall be submitted;

b) UT and MT shall be used for inspection of weld repairs; and

c) weld repairs on components with a QSC of F71 or F90 shall be rechecked on delivery.

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2 (04/21) For sections, excluding hollow sections covered by 1805.3.3 (3), the limits on surface discontinuities and ground areas shall conform to BS EN 10163-3 Class C or Class D unless otherwise stated in contract specific Appendix 18/1. Repair by welding shall not be carried out (subclass 3) for steels conforming to BS EN 10025-6 or where QSC F112 or F140 applies. Imperfections such as cracks, shells and seams shall be repaired if a permissible repair method is available; otherwise the affected product shall be treated as nonconforming. Where repairs by welding are required, they shall conform to subclass 2 with the following additional requirements:

a) reports on weld repairs shall be submitted;

b) UT and MT shall be used for inspection of weld repairs; and

c) weld repairs on components with a QSC of F71 or F90 shall be rechecked on delivery.

3 (04/21) For hot finished and cold formed welded hollow sections, surface defects in the body of the section shall be repaired in accordance with BS EN 10210-1 and BS EN 10219-1 respectively, subject to the restrictions in 1805.3.1 (3). Where repairs by welding are required, the following additional requirements shall apply:

a) reports on weld repairs shall be submitted;

b) UT and MT shall be used for inspection of weld repairs; and

c) weld repairs on components with a QSC of F71 or F90 shall be rechecked on delivery.

4 (04/21) Steel with pitted surfaces, i.e. rust grades C and D according to BS EN ISO 8501-1 shall not be used.

1805.3.4 (04/21) **Additional properties (18/1)**

1 (04/21) The following requirements shall apply to cross plates in welded cruciform and welded tee joints transmitting primary stresses through the plate thickness on a band of width four times the thickness of the plate each side of the proposed attachment.

a) for QSC F56, BS EN 10160 internal discontinuity quality class S_1 shall apply.

b) for QSC F71 and above, BS EN 10160 internal discontinuity quality class S_2 shall apply.

2 (04/21) Flange or web plates close to bearing diaphragms and /or single sided bearing stiffeners, where attached by welding, shall conform to BS EN 10160 internal discontinuity quality class S_1 in the areas defined in BS EN 1090-2:2018, 5.3.4.

3 (04/21) The precautions necessary to avoid lamellar tearing in tee, cruciform and corner joints shall be decided by the constructor, whether or not improved deformation properties to BS EN 10164 have been specified for the through plates. The guidance on suitable precautions given in BS EN 1011-2 and PD 6695-1-10 shall be followed.

1805.4 (04/21) **Steel castings (18/1)**

1 (04/21) The properties of delivered castings shall be evaluated by destructive and non-destructive testing as stated in 1812.2.1 (5).

1805.5 (08/14) **Welding consumables**

1 (04/21) For welding steels supplied to BS EN 10025-5 one of the following options for welding consumables shall be used.

a) one of the options 1, 2 or 3 of BS EN 1090-2:2018, Table 6; or

b) C-Mn consumables, but only for:

i) single run fillet welds not exceeding 8mm leg length using processes 135 and 121;

ii) butt welds using one run only per side; or

iii) the body of multi-pass fillet or butt welds except for the outer 3mm thick surface zones of the cap, root and ends (excluding any overfill). The surface zones shall be deposited using consumables conforming to options 1, 2 or 3 of BS EN 1090-2:2018, Table 6. See also BS EN 1090-2:2018, 7.5.10.

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1805.6 (08/14) **Mechanical fasteners**

1805.6.1 (08/14) **General (AEN)**

1805.6.2 (08/14) **Terminology**

1 (04/21) The 'part-turn' method of tightening of preloaded fasteners is similar to the 'combined method' in BS EN 1090-2:2018. However, it shall be restricted to Grade 8.8 assemblies of all class (K2, K1 and K0). It has reduced torque values in the first step and higher nut rotations in the second step; see 1808.5.1(5).

1805.6.3 (04/21) **Structural bolting assemblies for non-preloaded applications (18/1)**

1 (04/21) The surface finishes for structural bolting assemblies shall be as given in Series 1900, Table 19/2B.

1805.6.4 (08/14) **Structural bolting assemblies for preloading (18/1)**

1 (04/21) The following products shall be used for preloaded bolt assemblies using all tightening methods, except the HRC method:

a) bolt assemblies conforming to BS EN 14399-3 (HR type); and

b) nuts fully lubricated by the manufacturer after the nuts have been tapped (and, if relevant, after any coating passivation process has been completed). Lubricant coatings which are permanently liquid and could risk contamination of faying surfaces shall not be used.

2 (04/21) The surface finishes for structural bolting assemblies shall be as given in Series 1900, Table 19/2B.

3 (04/21) Electroplated property class 10.9 bolting assemblies shall not be used.

4 (04/21) Cleaning of property class 10.9 bolting assemblies prior to hot dip galvanising shall be by a mechanical process such as blast cleaning and not by pickling.

5 (04/21) Nuts of property class 10 shall be used with bolts of property class 8.8.

6 (04/21) Bolts of property class 10.9 shall not be used for assemblies tightened by the part turn method; see 1808.5.1 (4) and (5).

1805.6.5 (08/14) **Direct tension indicators (AEN)**

1805.6.6 (08/14) **Weather resistant assemblies**

1 (04/21) The chemical composition of weather resistant assemblies shall comply with the requirements for Type 3 Grade A fasteners to ASTM standard F3125/F3125M, or equivalent.

1805.6.7 (08/14) **Foundation bolts (18/1)**

1 (04/21) Reinforcing steels shall not be used for foundation bolts subject to applied tension forces.

1805.6.8 (08/14) **Locking devices (AEN) (18/1)**

1805.6.9 (08/14) **Washers (AEN)**

1805.6.9.1 (08/14) **Plain washers (AEN)**

1805.6.9.2 (04/21) **Taper washers (AEN) (18/1)**

1805.6.9.3 (04/21) **Plate washers (AEN)**

1805.6.10 (04/21) **Solid rivets for hot riveting**

1 (04/21) Solid rivets for hot riveting shall conform to BS 4620.

1805.6.11 (04/21) **Special fasteners (AEN) (18/1)**

1805.6.12 (04/21) **Delivery and identification**

1 (08/14) See 1800.5.2 (1).

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1805.7 (08/14) **Studs and shear connectors**

1 (04/21) Headed stud connectors shall be Type SD1 in accordance with BS EN ISO 13918.

1805.8 (04/21) **Reinforcing steel welded to structural steel (AEN)**

1805.9 (04/21) **Grouting materials (18/1)**

1 (08/14) Bedding mortars shall conform to the requirements of Series 2600, Clause 2601.

1805.10 (04/21) **Expansion joints for bridges (23/1)**

1 (04/21) Expansion joints shall conform to the requirements of Series 2300, Clause 2301 and contract specific Appendix 23/1.

1805.11 (04/21) **High strength cables, rods and terminations (AEN) (18/1)**

1805.12 (04/21) **Structural bearings (18/1) (21/1)**

1 (04/21) Bridge bearings shall conform to the requirements of Series 2100 and contract specific Appendix 21/1.

2 (04/21) Structural bearings other than bridge bearings shall conform to the requirements stated in contract specific Appendix 18/1.

3 (04/21) The guidance given in PD 6703 on the execution of bearings shall be followed, where relevant.

1806 (08/14) Preparation and Assembly

1806.1 (08/14) **General (AEN)**

1806.2 (08/14) **Identification (18/1)**

1 (04/21) A suitable identification system shall identify each finished component to the documentation supplied for its constituent product(s).

NOTE: Examples of types of documentation are given in BS EN 1090-2:2018, 12.2.1, Note 1.

2 (04/21) Hard stamps, punched or drilled marks shall only be used for zones with a QSC of F56 and below.

3 (04/21) Soft or low stress stamps shall only be used for zones with a QSC of F90 and below.

4 (04/21) No type of marking process involving deformation of or removal of metal from the surface shall be used for zones with a QSC of F112 and above.

5 (04/21) Markings shall be visible when steelwork is assembled and erected; see 1806.10 (3) d) and 1809.6.2.

1806.3 (08/14) **Handling and storage (AEN)**

1806.4 (08/14) **Cutting**

1806.4.1 (08/14) **General (AEN)**

1806.4.2 (04/21) **Shearing and nibbling**

1 (04/21) All sheared edges shall be ground or filed normal to the thickness direction of the plate to remove all visible signs of drag lines and glass-like surfaces.

1806.4.3 (08/14) **Thermal cutting**

1 (04/21) The quality of cut surfaces shall conform to the requirements for EXC3/4.

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2 (04/21) Isolated faults such as gouges, melting beads and oxide remainders, as described in BS EN ISO 9013:2017, 7.2.1, shall be smoothly dressed out by grinding, linishing or machining.

1806.4.4 (08/14) **Hardness of free edge surfaces (18/1)**

1 (04/21) Free edge surfaces with hardnesses exceeding 380 (HV10) values shall be ground, linished or machined until sufficient material has been removed such that the 380 (HV10) limit is not exceeded, subject to the exceptions in 1806.4.4 (2).

2 (04/21) Unless prohibited in contract specific Appendix 18/1, the hardness limit stated in 1806.4.4 (1) need not apply to straight machine plasma cut plain edge surfaces away from stress raising zones (SRZs), see 1806.4.4 (3), where all the following conditions are met:

a) the steel grade does not exceed S420;

b) the plain edge surfaces are not subject to a QSC above F71 (subject to 1806.4.4(3));

c) the plain edge surfaces are not subject to subsequent cold forming (unless fully fused over the full length and width by subsequent welding); and

d) procedure tests have been carried out to verify that the proposed method of surface preparation of the plasma cut edge can readily achieve the cleanliness and profile stated in Series 1900, where corrosion protection of the edges is required.

3 (04/21) The requirements in 1806.4.4 (1) shall apply to machine plasma cut edge surfaces in SRZs, which include all cut surfaces within 25mm of stress raising features such as re-entrant corners, openings or weld terminations on the edge, subject to a QSC of F56 and above, except in cases where it can be demonstrated that the QSC does not exceed F36.

1806.5 (04/21) **Shaping**

1806.5.1 (08/14) **General (AEN)**

1806.5.2 (08/14) **Hot forming (AEN)**

1806.5.3 (08/14) **Flame straightening**

1806.5.3.1 (04/21) **General**

1 (04/21) Documented procedures for correction of distortion using flame straightening shall be developed for all steel grades and for the following typical modes of distortion:

a) an out-of-plane bow of a flat element;

b) an in-plane bow of a flat element or a bow about the minor axis of an open section; and

c) a bow about either axis of a hollow section or about the major axis of an open section.

2 (04/21) The method of heating shall be by oxy-acetylene fuel gas using equipment with purpose made heating nozzles. The fuel gas mixture, nozzle size and arrangement, flame distance, heat zones and sequence of heating shall be specified.

3 (04/21) The surface temperature of the heated zones shall be measured and controlled using a contact pyrometer or temperature sensitive crayons.

4 (04/21) Maximum surface temperatures, according to the material groups and delivery conditions, shall not be greater than:

a) 625 °C for steels conforming to BS EN 10025-2, BS EN 10025-3, BS EN 10025-5 and BS EN 10210, but excluding those supplied in the "+M" delivery condition; or

b) 550 °C for steels conforming to BS EN 10025-4, BS EN 10025-6 and BS EN 10219, including any other steels supplied in the "+M" delivery condition.

NOTE: For stainless steel grades see 1806.5.3.2.

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5 (04/21) The temperatures in 1806.5.3.1 (4) a) and b) are irrespective of the temperatures reached during any flame straightening procedure trials.

6 (04/21) The cooling phase down to 350 °C shall be unassisted. Below this temperature cooling by an air blast is permitted. Quenching by water shall not be used except where permitted for stainless steels, see BS EN 1090-2:2018, 6.5.3.2 c).

7 (04/21) The use of passive restraints during the heating cycle is permitted. Active application of force during the heating cycle, for example by jacking, shall not be used.

8 (04/21) For steel grades greater than S355, procedures shall be qualified by applying the method to a test piece of appropriate form and known rolling direction, thickness and material grade.

9 (04/21) Following completion of the qualification test and cooling to ambient temperature, a set of longitudinal tensile, impact and hardness tests shall be taken from 2 mm below the material surface of the heated zone where the maximum specified temperature had been sustained for the longest period. The results, as tested in accordance with BS EN 10025-1, shall demonstrate that the specified mechanical properties of the product have been maintained.

10 (04/21) A conforming procedure qualification test shall qualify procedures within the following limits:

a) all material grades and subgrades up to and including those tested;

b) all element thicknesses up to and including that tested; and

c) the number of full thermal cycles per heat zone up to and including the number applied in the test.

11 (04/21) Flame straightening personnel shall be assessed and approved by the welding coordinator to ensure satisfactory understanding and capability of implementing the documented instruction for correction.

1806.5.3.2 (04/21) **Additional requirements for stainless steels**

1 (04/21) Flame straightening of stainless steels shall not be undertaken on duplex, low nickel austenitic and martensitic grades. Flame straightening of other stainless steels grades shall not be undertaken without the prior approval of the Overseeing Organisation.

1806.5.4 (08/14) **Cold forming (AEN) (18/1)**

1806.6 (08/14) **Holing**

1806.6.1 (08/14) **Dimensions of holes (AEN) (18/1)**

1806.6.2 (08/14) **Tolerances on hole diameter for bolts and pins (AEN)**

1806.6.3 (08/14) **Execution of holing**

1 (04/21) Round holes for fasteners or pins shall be drilled, or be punched at least 2mm undersize in diameter and reamed after punching, where any of the following conditions apply:

a) the material thickness is greater than 3mm;

b) the QSC is F71 or higher; or

c) the joint is made using preloaded bolting assemblies.

2 (04/21) The restrictions on forming slotted holes shall be as for round holes as stated in 1806.6.3 (1), except that:

a) machining (e.g. reaming, milling) shall be used to complete slotted holes formed by drilling or punching;

b) hand thermal cutting of slotted holes shall not be permitted in any material thickness; and

c) slotted holes shall not be permitted in zones with a QSC above F112.

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3 (04/21) For holes formed by thermal cutting, isolated faults such as gouges, melting beads and oxide remainders, as described in BS EN ISO 9013:2017, 7.2.1, shall be smoothly dressed out by grinding, linishing or machining. See 1806.6.3 (1) and 1806.6.3 (2) b) for restrictions on the use of thermal cutting to form holes.

1806.7 (08/14) Cut outs (18/1)

1 (04/21) The minimum radius for re-entrant corners and notches shall be 5mm for QSC F56 and 10mm for QSC F71 and above, subject to a smaller radius not being required by contract specific Appendix 18/1.

2 (04/21) Punched cut outs shall not be permitted.

1806.8 (08/14) Full contact bearing surfaces (AEN) (18/1)

1806.9 (08/14) Assembly (18/1)

1 (04/21) All connections for temporary components shall be executed in accordance with the requirements of this Series including those described in contract specific Appendix 18/1, according to the QSC appropriate at each connection location. See also 1807.5.6.

2 (04/21) Connections for temporary components shall not result in the removal or addition of permanent material or introduction of permanent stress concentrating details, unless permitted by contract specific Appendix 18/1. Any filling of permitted temporary holes by welding shall be subject to qualification of the procedure(s) and the welder(s) using the preparation(s) and material thickness(es) to be used in production, and to specific testing.

3 (04/21) A record of the details of any connections for temporary components shall be provided and shall form part of the execution documentation; see 1804.2.2 and 1804.2.4.

1806.10 (08/14) Assembly check (18/1)

1 (04/21) Trial assembly shall be undertaken where required by contract specific Appendix 18/1.

2 (04/21) Where a full or staged trial assembly is undertaken, the correction of hole alignment by reaming of bolted splices, selection of pack thicknesses, correction of weld preparation fit-up and correct positioning of temporary alignment cleats shall be carried out during the trial assembly.

3 (04/21) The following requirements shall be taken into account, where applicable:

a) support of the assembly parts shall minimise self-weight stresses, where the unstressed camber profile is being checked;

b) correct alignment of assembly parts shall be re-established in staged trial assembly including correct relative levels of bearings;

c) differential temperature distributions throughout the steelwork shall be controlled or allowed for if exposed to direct sunlight when surveys are made;

d) unique marking for identification and orientation of individual members shall be used;

e) all shop welding and bolting shall be complete;

f) every bolt hole shall be proved with a bolt of identical size to those to be used at the site;

g) lack of fit between components shall not be corrected by bolt tensioning; and

h) the position and level of all bearings and primary control points shall be surveyed at the trial erection.

1807 (08/14) Welding

1807.1 (08/14) General (18/1)

1 (04/21) The BS EN ISO 3834 quality requirements shall conform to the requirements for EXC3/4, unless EXC2 is required by contract specific Appendix 18/1.

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2 (04/21) The constructor shall have a valid BS EN ISO 3834 certificate issued by a certification body accredited for the standard by a National Accreditation Body. The certified Welding Quality Management system shall be in accordance with the relevant part of BS EN ISO 3834 identified in 1807.1 (1).

3 (04/21) Permanent welds that are not described in contract specific Appendix 18/1 shall not be permitted.

1807.2 (08/14) **Welding plan**

1807.2.1 (08/14) **Requirements for a welding plan (AEN)**

1807.2.2 (04/21) **Content of a welding plan**

1 (04/21) When applying the conditions for welding cold formed zones according to BS EN 1993-1-8:2005, 4.14, Table 4.2, the 'predominantly static loading' condition shall be deemed to apply to a QSC of F56 and the 'fatigue predominates' condition to QSCs of F71 and above.

1807.3 (04/21) **Welding processes**

1 (04/21) A welding process which is not covered by BS EN 1090-2:2018, Table 12 or Table 13 shall be classified as an Exceptional Welding Process (EWP).

2 (04/21) An EWP shall conform to the relevant requirements of 1807 with the following additional provisions:

a) The welding procedure specifications (WPSs) shall include all essential and non-essential variables necessary for control of the EWP over the range of joint types, materials and thicknesses for which it is to be used. It shall also include fit up tolerances and details of jigging, other fixtures and measurement devices.

b) The WPSs shall also include details of any thermal processes to be used in conjunction with the EWP. These shall include tack welding, pre- and post-heating, other welding processes (including repair welds) and thermal cutting.

c) Each preliminary welding procedure specifications (pWPSs) in 1807.3 (2) a) and b) shall be qualified by pre-production tests in accordance with BS EN ISO 15613 followed by non-destructive and destructive testing in accordance with the requirements for the relevant weld type in BS EN 15614-1.

d) The range of qualification of the pWPS shall be in accordance with BS EN 15614-1 for the type of weld tested.

e) The welding personnel shall be qualified by performing the tests necessary for qualification of the pWPSs in 1807.3 (2) c) and d).

f) Evidence shall be provided to show that the welding coordination personnel have in-depth knowledge and experience of the EWP.

g) The proportion of production EWP welds subject to supplementary NDT shall be 2 levels higher than required by Table 18/4, Table 18/5 and Table 18/6; see 1812.4.2.4 (4).

h) The NDT procedures for welds made by an EWP shall be approved by an operator qualified to Level 3 of BS EN ISO 9712 for the technique(s) used.

i) Production EWP welds shall be tested in accordance with Table 18/11 except that the frequency of tensile and Charpy testing of in-line transverse butt welds in tension shall be 1 in 5 for all material grades.

j) The documentation for items 1807.3 (2) a) to f) shall be submitted to and approved by the Overseeing Organisation in advance of implementation of the EWP.

1807.4 (08/14) **Qualification of welding procedures and welding personnel**

1807.4.1 (08/14) **Qualification of welding procedures**

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1807.4.1.1 (04/21) **General (18/1)**

1 (04/21) For tack welds, the welding procedure specification (WPS) shall include the special deposition conditions and the tests stated in 1807.4.1.1 (4).

2 (04/21) The tolerances on cross section and length of the tack weld and any subsequent profiling requirements, such as feathering of ends, shall be specified in the WPS.

3 (04/21) To qualify the procedure for a tack weld where it is to be incorporated in the joint, the maximum permitted cross section of tack weld shall be used in the qualification test. The positions of the ends of the tack weld shall be marked on the test piece.

4 (04/21) Macroscopic examination and hardness testing shall be carried out within the tack weld length. This test is not required if the original test for qualifying the complete weld includes the tack weld tested as described in this paragraph.

1807.4.1.2 (08/14) **Qualification of welding procedures for processes 111, 114, 12, 13 and 14**

1 (04/21) Methods of qualification shall be in accordance with those permitted for EXC3/4 in BS EN 1090-2:2018, Table 12. Qualification by means of a standard welding procedure shall not be permitted.

NOTE: For method of qualification of tack welds see 1807.4.1.1.

2 (04/21) The welding coordinator shall take account of the fact that some of the imperfection acceptance limits in BS EN 15614-1 are less restrictive than are required for FPC purposes in BS EN 1090-2:2018, 7.6, particularly for the higher EXCs. Where the limits given in BS EN 15614-1 are less restrictive than are required for Fitness for Purpose (FFP) purposes in 1812.4.2.5 and 1812.4.2.6, the relevant WPS and associated welding procedure qualification record (WPQR) (where available) shall be reviewed to establish whether any additional controls need to be added to the WPS to ensure that the FFP limits will have an adequate probability of being met in production; for example, restrictions on tolerances for joint preparation/fit-up and welding parameters, and limitations on welding position. In cases of doubt that the FFP limits might not be met, a pre-production test of the joint concerned shall be carried out, followed by a non-destructive and/or destructive examination, as appropriate, to provide the necessary assurance.

3 (04/21) Alternatives to the cruciform tensile test to BS EN ISO 9018 for fillet welds on steel grades S460 and above shall not be permitted.

4 (04/21) Joints with restricted access for welding (e.g. slot and plug welds, shallow angle branch connections), shall be subject to procedure testing in accordance with BS EN ISO 15613.

1807.4.1.3 (04/21) **Qualification of welding procedures for other welding processes**

1 (04/21) Welding procedure qualification for welding process numbers 783, 784 and 786 shall be carried out by a welding procedure test in accordance with BS EN ISO 14555:2017, 10.2. For process 783, the examination and testing of test pieces shall be carried out in accordance with BS EN ISO 14555:2017, Table 1 for comprehensive quality requirements according to BS EN ISO 3834-2.

2 (04/21) Fillet, partial penetration and full penetration tee joint welds shall be qualified by a supplementary in-line butt weld procedure qualification record to demonstrate mechanical properties in accordance with BS EN ISO 15614-1:2017+A1:2019, Table 2 Footnote f.

3 (04/21) Qualification testing for welded joints involving reinforcing steel shall be carried out in accordance with BS EN ISO 17660-1, irrespective of whether a joint is nominally classified as ‘load’ or ‘non-load’ bearing.

4 (04/21) For preparation and qualification of procedures for welds made by an EWP, see 1807.3 (2) a) to d).

1807.4.1.4 (08/14) **Validity of a welding procedure qualification**

1 (08/14) Welding production tests shall be carried out in accordance with the qualification standard for the process concerned.

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1807.4.2 (08/14) **Welders and welding operators**

1807.4.2.1 (04/21) **General**

1 (04/21) Welders shall be qualified by specific test for welding of joints with restricted access; see 1807.4.1.2 (4).

2 (04/21) Welders of joints involving reinforcing steel shall be qualified in accordance with BS EN ISO 17660-1.

3 (04/21) For qualification of welders and welding operators for welds made by an EWP, see 1807.3 (2) e).

1807.4.2.2 (04/21) **Branch connections (AEN)**

1807.4.3 (08/14) **Welding coordination**

1 (08/14) Welding coordination shall conform to the requirements for EXC2/3/4.

2 (04/21) For welding coordination of EWPs, see 1807.3 (2) f).

1807.5 (08/14) **Preparation and execution of welding**

1807.5.1 (08/14) **Joint preparation**

1807.5.1.1 (08/14) **General**

1 (04/21) Where prefabrication primers are to be left on fusion faces or heat affected zones, the weld procedures shall be tested in accordance with the requirements for EXC2/3/4.

1807.5.1.2 (04/21) **Hollow sections**

1 (04/21) The guidance on joint preparation for joints between hollow sections given in BS EN 1090-2:2018, Annex E shall be applied.

1807.5.2 (08/14) **Storage and handling of welding consumables (AEN)**

1807.5.3 (08/14) **Weather protection (AEN)**

1807.5.4 (08/14) **Assembly for welding**

1 (04/21) The guidance on the assembly of hollow section components given in BS EN 1090-2:2018, Annex E shall be applied.

2 (04/21) For the assembly of hollow section components where access to the joint for welding is restricted, a pre-production welding test conforming to BS EN ISO 15613 shall be conducted using the tolerances on preparation and fit-up that give the most restricted access, to demonstrate that the required penetration can be achieved.

1807.5.5 (08/14) **Preheating (AEN)**

1807.5.6 (08/14) **Temporary attachments (18/1)**

1 (04/21) In accordance with EXC3/4, restrictions on the use of temporary welded attachments shall be as stated in contract specific Appendix 18/1, and as follows.

a) Temporary welded attachments shall not be permitted in zones of QSC F112 and above.

b) Temporary welded attachments shall not be permitted within 25mm of an edge.

c) Except where excluded in 1807.5.6 (1) d), removal of temporary welded attachments by thermal cutting, gouging or chipping is permitted provided that the finished cut surface of the remainder of the attachment is at least 3mm from the permanent member surface prior to grinding smooth. Remnants of temporary material proud of the permanent member surface shall be removed by grinding parallel to the member axis. The final ground surface shall be checked for freedom from cracking using magnetic particle testing.

d) Gouging and chipping shall not be used for the removal of temporary welded attachments on steel grades S460 and above, or where a QSC of F71 or above applies.

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1807.5.7 (08/14) **Tack welds**

1 (04/21) Tack welds shall conform to the requirements for EXC2/3/4; see 1807.4.1.1.

1807.5.8 (04/21) **Fillet welds**

1807.5.8.1 (04/21) **General**

1 (04/21) In the case of fillet welded joints with root gaps, compensation shall be made for loss of throat and effective leg length by increasing the deposit size accordingly; see Table 18/7, Note G).

1807.5.8.2 (04/21) **Fillet welds on member connections (AEN)**

1807.5.9 (08/14) **Butt welds**

1807.5.9.1 (08/14) **General (18/1)**

1 (04/21) Run-on and run-off pieces shall be used on all butt welds and shall conform to the requirements for EXC2/3/4, where access allows.

2 (08/14) Where a weld surface is required to be ground or machined flush, this shall be executed prior to non-destructive testing.

1807.5.9.2 (08/14) **Single sided welds (18/1)**

1 (04/21) Permanent steel backing shall only be used if described in contract specific Appendix 18/1. The continuity of permanent steel backing shall conform to the requirements for EXC3/4. The execution of the continuity weld shall depend upon the QSC related to stresses parallel to the axis of the backing component, as follows:

a) F36: no additional requirements;

b) F56 to F90: make continuous by full penetration butt weld at any stage, followed by surface crack detection; and

c) F112 to F140: make continuous by full penetration butt weld, followed by flush grinding and surface crack detection before assembly.

1807.5.9.3 (08/14) **Back gouging (AEN)**

1807.5.10 (08/14) **Welds on steels with improved atmospheric corrosion resistance**

1 (08/14) The requirements for the consumables to be used for welds on steels with improved atmospheric corrosion resistance are given in 1805.5.

1807.5.11 (04/21) **Branch connections**

1 (04/21) The guidance on the execution of branch connections in hollow sections given in BS EN 1090-2:2018, Annex E shall be applied.

1807.5.12 (08/14) **Stud welding**

1 (04/21) With reference to BS EN ISO 14555, the comprehensive quality requirements in accordance with BS EN ISO 3834-2 shall be adopted.

1807.5.13 (08/14) **Slot and plug welds (18/1)**

1 (08/14) The depth-to-minimum width ratio of the slot or plug hole shall not exceed that used for the weld procedure qualification test.

1807.5.14 (04/21) **Other weld types (AEN) (18/1)**

1807.5.15 (04/21) **Post-weld heat treatment (AEN)**

1807.5.16 (04/21) **Execution of welding (18/1)**

1 (04/21) Stray arc sites shall be checked for cracking by PT or MT on all steel grades for QSC F90 and above.

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2 (04/21) Deposits of weld spatter shall be removed from all surfaces where it is not permitted in accordance with Table 18/7, Note J) and Table 18/8, Note I).

3 (04/21) The direction of grinding of the surfaces of completed welds shall be parallel to the stress direction for welds with a QSC of F90 and above.

1807.5.17 (04/21) **Welding of orthotropic bridge decks (AEN)**

1807.6 (08/14) **Acceptance criteria**

1807.6.1 (04/21) **Routine requirements**

1 (04/21) The selection of EXC in BS EN 1090-2:2018, 7.6.1 for routine FPC acceptance criteria shall be determined by the manufacturer, according to the nature of their work in normal production.

2 (04/21) Acceptance criteria used for FPC during the work shall not be to a lower standard than that required for specific inspection of the work, taking into account the method of testing and QSCs required for the work; see 1812.4.2.5 and 1812.4.2.6 for acceptance levels for specific inspection and testing.

1807.6.2 (04/21) **Fatigue requirements**

1 (04/21) The method of specification and the acceptance criteria given in BS EN 1090-2:2018, 7.6.2 shall not be used in place of those given in Tables 18/7 to 18/10 for specific inspection of production welds. See 1812.4.2.5 and 1812.4.2.6.

1807.6.3 (04/21) **Orthotropic bridge decks**

1 (04/21) The requirements in BS EN 1090-2:2018, 7.6.3 shall not take precedence over the requirements for specific inspection and testing of welds in orthotropic bridge decks; see 1812.4.2.5 and 1812.4.2.6.

1807.7 (04/21) **Welding of stainless steels (AEN) (18/1)**

1808 (08/14) Mechanical Fastening

1808.1 (08/14) **General (AEN)**

1808.2 (08/14) **Use of bolting assemblies**

1808.2.1 (08/14) **General (18/1)**

1 (04/21) Welding of nuts, bolts or washers shall not be used on bolting assemblies above property class 4.6.

2 (04/21) Welding of property class 4.6 nuts, bolts and washers shall only be undertaken where stated in contract specific Appendix 18/1 and shall be subject to the requirements in 1807, 1812.4 and BS EN 1090-2:2018, 7. Weld procedure qualification shall be carried out in accordance with BS EN ISO 15613.

3 (04/21) Restrictions on the orientation of bolting assemblies shall be as stated in contract specific Appendix 18/1.

1808.2.2 (08/14) **Bolts (AEN) (18/1)**

1808.2.3 (08/14) **Nuts (AEN)**

1808.2.4 (08/14) **Washers (18/1)**

1 (08/14) Washers shall be placed under the nut or head of the bolt in non-preloaded assemblies whichever is rotated.

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1808.3 (04/21) **Tightening of non-preloaded bolting assemblies (AEN) (18/1)**

1808.4 (08/14) **Preparation of contact surfaces in slip resistant connections (18/1)**

1 (04/21) All surfaces which overlap each other in the final assembled connection excluding any painted edge strip around the perimeter of the connection shall be deemed to be 'contact surfaces'.

2 (08/14) The specified surface treatment applied to the friction surfaces shall be maintained until the surfaces are brought together and the connection assembled.

1808.5 (04/21) **Tightening of preloaded bolting assemblies**

1808.5.1 (08/14) **General (18/1)**

1 (04/21) At the snug tight stage, the exposed surfaces of the components being connected shall be aligned within 1mm where they emerge from beneath the cover plate(s) at the joint plane. If this tolerance is exceeded, the cover plate(s) shall be removed and corrective steel packing plates installed. The tolerance on thickness difference between the two components (including any packing plates) in BS EN 1090-2:2018, 8.1 shall also be met.

2 (04/21) In the case of preloaded lap joints subject to axial load acting in the plane of the friction surfaces, measures to limit the out-of-plane bending stiffness of cover plates shall be as stated in contract specific Appendix 18/1. Any additional contact surfaces shall be treated as contact surfaces in slip resistant connections.

3 (04/21) Where a connection is designed to transfer applied tensile forces through a flanged and bolted end plate, as a minimum, the area of the mating surfaces in direct line with the tension member cross section shall be in contact when all bolts are snug tight. Any remaining gaps in this zone shall be filled by steel shims prior to the application of the remaining preload. The following shall apply:

a) If necessary, bolts can be partially slackened to enable shims to be inserted.

b) The shims shall not be loose in the final snug tight stage.

c) In the event of a tapering gap, use of a purpose machined tapered steel shim is permitted.

d) As an alternative to 1808.5.1 (3) c), flat (parallel) steel shims of not less than 0.1mm and of not more than 0.2mm thick shall be inserted to refusal, in steps until the gap in the contact zone is filled, followed by retightening to the snug tight stage.

e) If sealing of the joint is required, the remaining gaps shall be filled with a corrosion protection medium compatible with the corrosion protection to be applied to the joint after final tightening of the bolting assemblies.

4 (04/21) Use of the part turn method is permitted for tightening preloaded bolts if all the following conditions apply:

a) the bolts are property class 8.8 and assemblies conform to 1805.6.4;

b) the required nominal minimum preloading force is not in excess of the values specified in BS EN 1090-2:2018, Table 18; and

c) the joint fit-up conforms to 1808.5.1 (1) or 1808.5.1 (3), whichever is applicable.

5 (04/21) The part turn method shall be carried out as for the combined method in BS EN 1090-2:2018, 8.5.4, except that:

a) the k-class of the bolting assemblies shall comply with 1805.6.2 (1);

b) in the first tightening step the nut shall be tightened to the specified torque, as given in Table 18/1; and

c) in the second tightening step the nut shall be tightened to the specified turn as given in Table 18/2.

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(04/21) **Table 18/1 Torque values for the part turn method – step one**

Bolt diameter d, mm	12	14	16	18	20	22	24	27	30	36
Torque value M, Nm	40	60	80	110	160	210	270	340	460	810

(04/21) **Table 18/2 Rotation values for the part turn method – step two**

Bolt diameters, mm	Grip length[A)], mm	Rotation, °
12 to 22	$t \leq 115$ $115 < t \leq 275$	180 (½ turn) 270 (¾ turn)
24 to 36	$t \leq 160$ $160 < t \leq 350$	180 (½ turn) 270 (¾ turn)
[A)] Equal to nominal thickness, *t*, in BS EN 1090-2:2018, Table 21		

6 (04/21) The torque method shall not be used for the tightening of preloaded bolts unless stated in contract specific Appendix 18/1.

7 (04/21) When direct tension indicators or HRC bolts are used, surfaces shall be brought into contact using temporary service bolts with the same grade and diameter as the permanent bolts.

8 (04/21) Any coating passivation process to be undertaken by the constructor shall only be undertaken after the inspection after tightening of the affected preloaded bolts has been completed.

1808.5.2 (08/14) **Torque reference values (AEN)**

1808.5.3 (08/14) **Torque method**

1 (04/21) Where the torque method is to be used, see 1808.5.1 (6), the *k* value shall be checked daily with torque wrenches in accordance with BS EN 1090-2:2018, Annex H and the torque for both tightening steps adjusted accordingly. Any assembly lots that fail to conform to this test shall be discarded.

1808.5.4 (08/14) **Combined method**

1 (04/21) For property classes 8.8 and 10.9 bolting assemblies to BS EN 14399-3, see 1805.6.4, the further rotation values in BS EN 1090-2:2018, Table 21 shall be amended as follows for the same thickness ranges:

a) replace 60° by 90° (¼ turn);

b) replace 90° by 120° (⅓ turn); and

c) replace 120° by 180° (½ turn).

2 (04/21) The *k* value shall be checked daily with the torque wrenches in accordance with BS EN 1090-2:2018, Annex H and the torque for the first tightening step adjusted accordingly. Any assembly lots that fail to conform to this test shall be discarded.

3 (04/21) The simplified value of $0.75M_{r,1} = 0.094dF_{p,C}$ shall not be used.

1808.5.5 (08/14) **HRC method**

1 (04/21) The preload shall be checked on sample assemblies for each assembly lot within seven days prior to use in accordance with BS EN 1090-2:2018, Annex H. Any assembly lots showing values of preload below the minimum specified value shall be discarded.

2 (04/21) The pre-tightening step shall be repeated until the shear wrench outer socket has stopped turning on all assemblies in a connection.

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1808.5.6 (08/14) **Direct tension indicator method (AEN)**

1808.6 (08/14) **Fit bolts (AEN)**

1808.7 (08/14) **Hot riveting**

1808.7.1 (08/14) **Rivets (AEN)**

1808.7.2 (08/14) **Installation of rivets (AEN) (18/1)**

1808.7.3 (08/14) **Acceptance criteria (AEN) (18/1)**

1808.8 (04/21) **Use of special fasteners and fastening methods (AEN) (18/1)**

1808.9 (04/21) **Galling and seizure of stainless steels (AEN)**

1809 (08/14) Erection

1809.1 (08/14) **General (AEN)**

1809.2 (08/14) **Site conditions (AEN)**

1809.3 (08/14) **Erection method**

1809.3.1 (04/21) **Design basis for the erection method (AEN) (18/1)**

1809.3.2 (04/21) **Constructor's erection method**

1 (04/21) The method of securing and sealing permanent formwork shall be as given in Series 1700.

1809.4 (08/14) **Survey**

1809.4.1 (08/14) **Reference system (18/1)**

1 (04/21) The reference temperature shall be 15°C, unless otherwise stated in contract specific Appendix 18/1. The reference temperature shall be recorded in the quality plan.

1809.4.2 (08/14) **Position points (AEN)**

1809.5 (08/14) **Supports, anchors and bearings**

1809.5.1 (08/14) **Inspection of supports (AEN)**

1809.5.2 (08/14) **Setting out and suitability of supports (AEN)**

1809.5.3 (08/14) **Maintaining suitability of supports (AEN) (18/1)**

1809.5.4 (08/14) **Temporary supports (18/1)**

1 (08/14) Levelling nuts or other devices providing temporary support shall be slackened off before final tensioning of foundation bolts where a post-tensioning force is specified, to allow the post-tensioning force to be transferred to the foundations.

2 (08/14) In the case of exposed steelwork and irrespective of bedding material, the minimum finished cover to steel packings or other steel temporary support devices left in position shall be 50mm.

1809.5.5 (08/14) **Grouting and sealing (18/1)**

1 (04/21) Unless otherwise stated in contract specific Appendix 18/1, the surfaces of steelwork and bearings that are to be in contact with grout or bedding mortar shall be treated in accordance with 1810.7.

1809.5.6 (08/14) **Anchoring (AEN)**

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1809.6 (08/14) **Erection and work at site**

1809.6.1 (08/14) **Erection drawings (AEN)**

1809.6.2 (08/14) **Marking (AEN)**

1809.6.3 (08/14) **Handling and storage on site**

1 (04/21) Procedures for restoration of damage shall be documented in accordance with the requirements for EXC2/3/4, and shall be submitted to and approved by the Overseeing Organisation in advance of implementation.

2 (08/14) The processes used for the restoration of damaged steelwork shall be in accordance with the requirements of this Series.

1809.6.4 (08/14) **Trial erection (AEN)**

1809.6.5 (04/21) **Erection works**

1809.6.5.1 (08/14) **General (AEN)**

1809.6.5.2 (08/14) **Temporary works (AEN)**

1809.6.5.3 (08/14) **Fit-up and alignment**

1 (08/14) The use of shims shall be avoided where possible by suitable controls on preparation, assembly and weld distortion and, if necessary, by machining.

2 (04/21) If welding is required for securing shims, it shall be carried out in accordance with BS EN 1090-2:2018, 7. The requirements of 1807 and 1812.4 shall also apply.

3 (04/21) Where steel shims are needed to correct the fit between members, particularly in preloaded tension joints, see 1808.5.1, and where gaps are variable across the interface, use of flat (parallel) steel shims is permitted as an alternative to a purpose machined tapered steel shim. The gap shall be filled by insertion of shims of not less than 0.1mm and not more than 0.2mm thick from the widest gap position until refusal. The excess material shall be cut off on completion.

1810 (08/14) Surface Treatment

1810.1 (04/21) **General (18/1) (19/1) (19/5)**

1 (08/14) Treatment of surfaces to receive corrosion protection shall be in accordance with Series 1900.

2 (04/21) The requirements for the execution of corrosion protection in BS EN 1090-2:2018, Appendix F shall be supplemented by those in Series 1900.

3 (04/21) The performance specification required by BS EN 1090-2:2018, F.1.2 shall be as given in contract specific Appendix 19/1.

4 (04/21) The prescriptive requirements for corrosion protection required by BS EN 1090-2:2018, F.1.3 shall be as given in Series 1900.

5 (04/21) With reference to BS EN 1090-2:2018, F.4, the requirements for friction surfaces and class of treatment or tests required for surfaces in slip resistant connections shall be as stated in contract specific Appendix 18/1.

6 (04/21) With reference to BS EN 1090-2:2018, F.4, where corrosion protection is specified, the requirements for corrosion protection and extent of surfaces to be painted at preloaded connections shall be as given in Series 1900, Clause 1906 and contract specific Appendix 19/5.

7 (04/21) With reference to BS EN 1090-2:2018, F.4, the extent of surfaces affected by preloaded bolts in connections that are not required to be slip resistant shall be as given in contract specific Appendix 18/1.

8 (04/21) The requirements for the protection of the lower embedded part of foundation bolts shall be as stated in BS EN 1090-2:2018, F.5, unless otherwise stated in contract specific Appendix 18/1.

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9 (04/21) With reference to BS EN 1090-2:2018, F6.3, for cold formed components that are to be galvanized after manufacture, the requirements for procedure qualification of the dipping process shall be as given in contract specific Appendix 18/1.

10 (04/21) With reference to BS EN 1090-2:2018, F6.3, the requirements for the inspection, checking and qualification of the preparation to be carried out before subsequent overcoating of galvanized components shall be as given in contract specific Appendix 18/1.

11 (04/21) With reference to BS EN 1090-2:2018, F.7.3, reference areas shall be as required by Series 1900, Clause 1915.

12 (04/21) With reference to BS EN 1090-2:2018, F.7.4, all hot dip galvanized components shall be subjected to post-galvanizing inspection.

13 (04/21) With reference to BS EN 1090-2:2018, F.7.4, components or specific locations that shall be subjected to additional NDT, and the scope and method of NDT shall be as given in contract specific Appendix 18/1.

1810.2 (08/14) **Preparation of steel substrates for paints and related products (18/1)**

1 (04/21) All surfaces shall meet the requirements of BS EN ISO 8501-3 preparation grade P2, except for edges which shall be rounded to a constant radius of not less than 2mm, the radius being tangential to the original surfaces; see BS EN ISO 8501-3:2007, Table 1 imperfection type 2.1, 2.2 and 2.3, and BS EN ISO 12944-3:2017, Fig. D.5 c).

1810.3 (04/21) **Weather resistant steels (18/1)**

1 (08/14) Exposed surfaces of uncoated weather resistant steel shall be blast cleaned to grade Sa2 to BS EN ISO 8501-1 to achieve a uniform surface. Any surfaces that are subsequently marked or contaminated shall be cleaned to a similar standard.

2 (08/14) Uncoated weather resistant steel shall be kept free of contamination such as oil, grease, paint, concrete and asphalt.

3 (04/21) Wax or grease markers shall not be used to mark surfaces of weather resistant steels.

1810.4 (08/14) **Galvanic coupling (AEN)**

1810.5 (04/21) **Hot dip galvanizing (18/1)**

1 (04/21) The preparation of surfaces prior to hot dip galvanizing shall be as given in Series 1900.

1810.6 (04/21) **Sealing of spaces (18/1) (19/1)**

1 (04/21) The internal treatment system to be provided to enclosed spaces that are to be sealed by welding or provided with internal protective treatment shall be as stated in contract specific Appendix 19/1.

2 (04/21) All internal spaces which have been identified as being hermetically sealed in contract specific Appendix 18/1 shall have all joints, whether welded, mechanically fastened or bonded, leak tested prior to application of the external protective coating; see BS EN 1779. The bubble emission technique in accordance with BS EN 1593 shall be used.

3 (04/21) Where spaces are to be fully enclosed by sealing welds to prevent the ingress of moisture, weld imperfections involving surface breaking voids otherwise permitted under the welding specification shall be sealed using an appropriate weld repair.

1810.7 (08/14) **Surfaces in contact with concrete (18/1)**

1 (08/14) When formwork is in contact with the outer surfaces of the steelwork the embedded length shall be measured from the junction between the concrete, the formwork and the steelwork.

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1810.8 (08/14) **Inaccessible surfaces**

1 (08/14) Faying surfaces and surfaces beneath washers in connections other than slip resistant connections that are to be painted shall be treated in accordance with Series 1900.

2 (08/14) In uncoated weather resisting steels, faying surfaces and surfaces beneath washers in connections other than slip resistant connections shall be cleaned to grade St2 to BS EN ISO 8501-1 immediately prior to the connection being made.

1810.9 (08/14) **Repairs after cutting or welding (18/1)**

1 (04/21) Protective treatment on edges and adjacent surfaces which have been damaged by cutting or after welding shall be restored in accordance with the original specification.

2 (04/21) Coatings on precoated constituent products that have been damaged by welding shall be restored in accordance with contract specific Appendix 18/1

1810.10 (04/21) **Cleaning of stainless steel components (AEN) (18/1)**

1811 (08/14) Geometrical Tolerances

1811.1 (08/14) **Tolerance types (18/1)**

1 (04/21) Where full contact end bearing is specified, see BS EN 1090-2:2018, Table B.19, special tolerances are required. The maximum gap between the two surfaces shall be limited to 0.5mm. In the case of fitted web stiffeners, the gap shall also be limited to a maximum of 0.25mm over 60% of the fitted area.

1811.2 (08/14) **Essential tolerances**

1811.2.1 (08/14) **General (AEN)**

1811.2.2 (08/14) **Manufacturing tolerances**

1811.2.2.1 (08/14) **Rolled sections (AEN)**

1811.2.2.2 (08/14) **Welded sections(AEN)**

1811.2.2.3 (08/14) **Cold formed sections (AEN)**

1811.2.2.4 (08/14) **Stiffened plating (AEN)**

1811.2.2.5 (04/21) **Shells (18/1)**

1 (04/21) The scope of dimensional checking for dimple measurements shall be as given in contract specific Appendix 18/1. See BS EN 1090-2:2018, Table B.11.

1811.2.3 (08/14) **Erection tolerances**

1811.2.3.1 (08/14) **Reference system (AEN)**

1811.2.3.2 (04/21) **Foundation bolts and other supports (AEN) (18/1)**

1811.2.3.3 (08/14) **Column bases (AEN)**

1811.2.3.4 (08/14) **Columns (AEN)**

1811.2.3.5 (08/14) **Full contact bearing (AEN)**

1811.3 (08/14) **Functional tolerances**

1811.3.1 (08/14) **General (AEN)**

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1811.3.2 (08/14) **Tabulated values**

1 (04/21) Functional tolerance class 1 shall be adopted, except in the following cases from BS EN 1090-2:2018 where class 2 shall be adopted:

a) Table B.1, No 1 to No 6 at bearing and bearing stiffener locations; and

b) Table B.6, No 3 and No 4.

1811.3.3 (08/14) **Alternative criteria (AEN) (18/1)**

1812 (08/14) Inspection, Testing and Correction

1812.1 (08/14) **General (AEN)**

1812.2 (08/14) **Constituent products and components**

1812.2.1 (08/14) **Constituent products (18/1)**

1 (04/21) Proprietary products not covered by the European or International standards references in BS EN 1090-2:2018 shall be subject to specific testing as stated in contract specific Appendix 18/1.

2 (04/21) Mechanical fasteners, see BS EN 1090-2:2018, 5.6, shall be verified by the constructor to show that they conform to the requirements of the product standard to which they have been manufactured; see 1800.5.2 (1). Reports of the verification undertaken shall be prepared. The reports shall be treated as execution records and shall form part of the execution documentation; see 1804.2.2 and 1804.2.4. The verification shall include the following requirements:

a) evidence of certification of the quality of the mechanical fasteners such as the manufacturer's declaration of performance under a CE/UK marking, manufacturer's certificates, and test reports from manufacturers or suppliers shall be obtained;

b) mechanical fastener documentation shall be reviewed to confirm authenticity, relevance, accuracy and completeness; and

c) inspection and sample testing of the mechanical fasteners in accordance with BS EN ISO 3269 shall be undertaken, to confirm that the dimensional characteristics and mechanical, physical and functional properties comply with the product standard to which the mechanical fasteners have been manufactured.

3 (04/21) Mechanical fasteners supplied for use in the works shall be suitability tested by the constructor in accordance with the relevant standard for the fasteners selected. This testing is in addition to the requirements of 1800.5.2 (1) or 1812.2.1 (2) as appropriate. For each inspection lot of mechanical fasteners, three fasteners shall be selected at random and tested in accordance with the suitability test related to the product standard to which the mechanical fasteners have been manufactured. The mechanical fasteners that are subjected to the suitability testing shall be discarded following testing. In the event of a mechanical fastener not meeting the requirements of the suitability test, all mechanical fasteners in the associated inspection lot shall be discarded. The suitability testing shall be reported in accordance with the relevant standard for the fasteners selected. The reports shall be treated as execution records and shall form part of the execution documentation; see 1804.2.2 and 1804.2.4.

4 (04/21) Structural steel products, see BS EN 1090-2:2018, 5.3, shall be verified by the constructor to show that they conform to the requirements of the product standard to which they have been manufactured; see 1800.5.3 (1). Reports of the verification undertaken shall be prepared. The reports shall be treated as execution records and shall form part of the execution documentation; see 1804.2.2 and 1804.2.4. The verification shall include the following requirements:

a) evidence of certification of the quality of the structural steel product such as the manufacturer's declaration of performance under a CE/UK marking, manufacturer's certificates, and test reports from manufacturers or suppliers shall be obtained;

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b) structural steel product documentation shall be reviewed to confirm authenticity, relevance, accuracy and completeness; and

c) inspection and sample testing of a structural steel product shall be undertaken where manufacturer's or supplier's test reports confirming compliance with product standard requirements are not reviewed or are reviewed but are not found to be authentic, relevant, accurate or complete. The inspection and sample testing shall be to confirm that the dimensions, chemical composition and mechanical properties comply with the product standard to which the structural steel product has been manufactured.

5 (04/21) Steel castings shall be verified by the constructor in accordance with the specific testing requirements and acceptance levels given in Table 18/3.

(04/21) **Table 18/3 Specific testing requirements and acceptance levels for steel castings**

BS EN 1090-2:2018, 5.4 Item	Testing Requirement	QSC				
		F56	F71	F90	F112	F140
a) Visual inspection	% of lot	100				
b) Destructive tests	Test piece type	Product Sample				
c) Non-destructive tests	6) MT % of lot	20	100	100	100	100
	7) UT % of lot	20	50	100	100	100
	7) RT % of lot	20	20	50	100	100
Acceptance Criteria	MT severity level SM	2	2	1	NP[A)]	NP[A)]
	MT severity level LM/AM	3	2	1	NP[A)]	NP[A)]
	UT severity level	2	1	1	NP[A)]	NP[A)]
	RT severity level[B)]	3	2	1	NP[A)]	NP[A)]

[A)] NP = no indications permitted
[B)] In accordance with BS EN 12681

1812.2.2 (08/14) **Components (AEN)**

1812.2.3 (08/14) **Non-conforming products**

1 (04/21) Records of testing undertaken to prove product conformity shall be treated as execution records and shall form part of the execution documentation; see 1804.2.2 and 1804.2.4.

1812.3 (08/14) **Manufacturing: geometrical dimensions of manufactured components**

1 (04/21) The inspection plan shall identify all dimensions which could be at risk of non-conformity. Checks shall be made during execution and action taken to correct any non-conformity at the earliest opportunity. All such dimensions shall be checked before the steelwork is dispatched to site. Components in the neighbourhood of site connections shall be re-checked once the connections are complete.

2 (04/21) If the correction of a nonconformity is not practicable, proposed modifications to the steel structure to compensate for the nonconformity shall be submitted to and approved by the Overseeing Organisation in advance of implementation.

3 (04/21) Repair of local dents in the surface of hollow sections by means of welded cover plates shall only be undertaken if approved by the Overseeing Organisation in advance of implementation.

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1812.4 (08/14) **Welding**

1812.4.1 (04/21) **General (AEN)**

1812.4.2 (04/21) **Inspection after welding**

1812.4.2.1 (08/14) **Timing (AEN)**

1812.4.2.2 (04/21) **Type testing (AEN)**

1812.4.2.3 (04/21) **Routine inspection and testing**

1 (04/21) The selection of EXC in BS EN 1090-2:2018, Table 24 for the extent of their routine FPC inspection shall be determined by the manufacturer according to the nature of their work in normal production. It shall be not less than that required for EXC3 or for the project specific inspections required in 1812.4.2.4 (2) to (6), whichever is the greater.

2 (04/21) Any FPC inspections undertaken on a specific structure which conform to Table 18/4, providing that the acceptance criteria in 1812.4.2.5 and 1812.4.2.6 are fully met, are permitted to be included and documented as part of the specific inspection required in 1812.4.2.4 (2) to (6).

1812.4.2.4 (04/21) **Project specific inspection and testing**

1 (04/21) All welded joints shall be subject to specific inspection, as permitted for EXC1/2/3.

2 (04/21) The scope of specific inspection for each joint shall be 100% visual and in accordance with the extent and methods of supplementary non-destructive testing (NDT) given in Table 18/4, Table 18/5 and Table 18/6, according to the required QSC.

3 (04/21) Table 18/4 specifies the minimum proportions of welded joints subjected to specific supplementary NDT for shop welds in steel grades up to and including S355 and QSC F56, which represent the most common conditions. The percentages in Table 18/4 shall be applied to the number of joints tested up to weld lengths of one metre in any joint. For joints with weld lengths exceeding one metre, the percentage shall be applied to the proportion of weld in every joint.

4 (04/21) Where other conditions than those assumed in Table 18/4 apply, the minimum proportions of welded joints to be subjected to specific supplementary NDT shall be increased (or decreased) by one or more levels in accordance with Table 18/5. This shall be done by applying the next highest (or lowest) proportion using the following sequence of seven increasing levels of proportion: 0%, 2%, 5%, 10%, 20%, 50%, 100%. See Table 18/5, footnote [B)].

5 (04/21) If adjustments are made according to more than one condition in Table 18/5, the net number of levels shall be used, after adding and/or subtracting the number of levels given for each condition. See Table 18/5, footnote [C)].

6 (04/21) For QSC F71 and above for shop welds in steel grades up to and including S355, the minimum proportions of welded joints which shall be subjected to supplementary NDT are specified in Table 18/6. For other conditions, the proportion tested in Table 18/6 shall be adjusted in accordance with Table 18/5 as described in 1812.4.2.4 (4) and (5) for Table 18/4.

7 (04/21) For the proportion of inspection and testing of welds made by an EWP, see 1807.3 (2) g).

8 (04/21) For approval of NDT procedures for welds made by an EWP, see 1807.3 (2) h).

1812.4.2.5 (04/21) **Visual inspection of welds**

1 (04/21) The criteria for final acceptance without the need for remedial action shall be in accordance with Table 18/7 and Table 18/8, according to the required QSC. These criteria shall apply irrespective of those used for FPC.

1812.4.2.6 (04/21) **Supplementary NDT methods**

1 (04/21) The criteria for final acceptance without the need for remedial action shall be in accordance with Table 18/9 for magnetic particle and penetrant testing and Table 18/10 for ultrasonic and radiographic testing, according to the required QSC. These criteria shall apply irrespective of those used for FPC.

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1812.4.2.7 (04/21) **Correction of welds**

1 (04/21) Repairs by welding shall be carried out as required for EXC2/3/4.

1812.4.3 (08/14) **Inspection and testing of welded shear studs for composite steel and concrete structures**

1 (04/21) Production tests shall be carried out in accordance with BS EN ISO 14555 before the beginning of welding operations and repeated after every 5000 welds for each combination of stud diameter, parent material and type of equipment that is used.

2 (04/21) Simplified production tests shall be carried out as required by BS EN ISO 14555, and at a minimum rate of one test (comprising three studs) after every 100 welds on each piece of steelwork, with a minimum of one test (comprising three studs) per piece. The direction of the bend test shall be such that the bent stud shall not interfere with other elements of the works.

3 (04/21) Production surveillance in accordance with BS EN ISO 14555 shall include the testing of every stud on a production piece of steelwork by striking the side of the head of the stud with a 2kg hammer. The weld shall be deemed to be acceptable if there is a clear ring tone due to the striking. Any stud deemed to be unacceptable as a result of this test shall be tested as part of the testing described in 1812.4.3 (2).

4 (04/21) All stud shear connectors shall be aligned to within 4° from the normal to the plate to which the studs are welded. The length of each stud after welding (LAW) shall be within +1.5mm and -2mm of the manufacturer's specified nominal LAW.

5 (04/21) The production surveillance records in accordance with BS EN ISO 14555 shall be treated as execution records and shall form part of the execution documentation; see 1804.2.2 and 1804.2.4.

1812.4.4 (08/14) **Production tests on welding**

1 (04/21) Production tests conforming to the requirements for EXC3/4 shall be carried out.

2 (04/21) Specific production tests shall be conducted on run-off coupon plates in accordance with Table 18/11, according to the required QSC, and shall apply to all parts of the structure. Where the use of run-off coupon plates is not practicable, e.g. in the case of circumferential butt welds in tubular members, the production tests shall be conducted at the same time on separate coupon plates. The coupon material shall be from the same batch with the same weld preparation and orientation relative to the rolling direction(s) as in the production joint. The same welding equipment and welder/welding operator shall be used.

3 (04/21) For the production testing of welds made by an EWP, see 1807.3 (2) i).

1812.4.5 (04/21) **Inspection and testing of welding of reinforcing steel**

1 (04/21) Inspection and testing of welded joints involving reinforcing steel shall be carried out in accordance with BS EN ISO 17660-1, irrespective of whether a joint is nominally classified as ‘load’ or ‘non-load’ bearing.

2 (04/21) Project specific inspection and testing of welded joints involving reinforcing steel shall be carried out in accordance with 1812.4.2.4.

1812.5 (08/14) **Mechanical fastening**

1812.5.1 (08/14) **Inspection of non-preloaded bolted connections (AEN) (18/1)**

1812.5.2 (08/14) **Inspection and testing of preloaded bolted connections**

1812.5.2.1 (04/21) **General (AEN) (18/1)**

1812.5.2.2 (04/21) **Inspection of friction surfaces (AEN)**

1812.5.2.3 (04/21) **Inspection before tightening**

1 (08/14) The tightening procedure shall be checked as required for EXC2/3/4.

1812.5.2.4 (04/21) **Inspection during and after tightening**

1 (08/14) Inspection during and after tightening shall be as required for EXC2/3/4.

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2 (04/21) In BS EN 1090-2:2018, 12.5.2.4 c), the number of bolt assemblies inspected overall in a structure shall conform to the requirements for EXC3/4.

3 (04/21) The part turn method shall conform to the requirements of BS EN 1090-2:2018, 12.5.2.4 c) 2) i).

4 (04/21) In BS EN 1090-2:2018, 12.5.2.4 d) the sampling plan shall conform to the requirements for EXC2/3.

5 (04/21) Bolting assemblies shall be checked for overtightening.

6 (04/21) For the part turn method, the inspection and testing requirements of BS EN 1090-2:2018, 12.5.2.6 shall apply except as follows:

a) the first step shall be checked as required for EXC3/4 but using the same torque conditions as given in Table 18/1; and

b) for inspection after the second step, rotation angle values given for the combined method shall be replaced with:

i) 0° (in lieu of 15°); and

ii) 60° (in lieu of 30°).

1812.5.2.5 (04/21) **Torque method**

1 (04/21) Inspection of tightening by the torque method shall conform to the requirements for EXC3/4 in BS EN 1090-2:2018, Table 25.

1812.5.2.6 (04/21) **Combined method**

1 (08/14) For the combined method, checking of the first step shall conform to the requirements for EXC3/4.

1812.5.2.7 (04/21) **HRC method**

1 (04/21) For the HRC method, checking of the first tightening step shall conform to the requirements for EXC2/3/4.

1812.5.2.8 (04/21) **Direction tension indicator method (AEN)**

1812.5.3 (04/21) **Inspection and repairs of solid rivets for hot riveting**

1812.5.3.1 (08/14) **Inspection**

1 (04/21) The sequential sampling plan shall conform to the requirements for EXC2/3.

1812.5.3.2 (08/14) **Repairs (AEN)**

1812.5.4 (04/21) **Special fasteners and fastening methods**

1812.5.4.1 (04/21) **General (AEN) (18/1)**

1812.5.4.2 (04/21) **Other mechanical fasteners (AEN)**

1812.6 (08/14) **Surface treatment and corrosion protection (AEN)**

1812.7 (08/14) **Erection**

1812.7.1 (08/14) **Inspection of trial erection (18/1)**

1 (04/21) In addition to the checks that are stated in contract specific Appendix 18/1, the following checks shall be carried out during trial erection, where applicable.

a) dimensions critical to assembly to other parts of the structure;

b) overall horizontal and vertical alignment and twist;

c) evidence of correct re-establishment of alignment of units in staged trial erection;

d) temperature differentials in box girders;

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e) fit-up of bolted joints and site welding preparations;

f) alignment of bolt holes; and

g) identification marks of members and their orientation, including packer plates.

1812.7.2 (08/14) **Inspection of the erected structure (AEN)**

1812.7.3 (08/14) **Survey of geometrical position of connection nodes**

1812.7.3.1 (04/21) **Survey methods and accuracy (18/1)**

1 (04/21) The survey of the completed structure shall conform to the requirements for EXC3/4. This shall include recording of dimensional checks at acceptance of the structure. Records of the survey including records of dimensional checks shall be treated as execution records and shall form part of the execution documentation; see 1804.2.2 and 1804.2.4.

2 (04/21) For components comprising weather resistant steels, residual material thickness monitoring locations shall be established, and initial measurements of residual material thickness shall be taken on completion of the construction works, as stated in contract specific Appendix 18/1. Details of the monitoring locations and the material thickness measurements shall be recorded. The records shall be treated as execution records and shall form part of the execution documentation; see 1804.2.2 and 1804.2.4.

1812.7.3.2 (08/14) **System of measurement (AEN)**

1812.7.3.3 (08/14) **Reference points and levels (AEN)**

1812.7.3.4 (08/14) **Location and frequency (18/1)**

1 (08/14) Account shall be taken of the deflection effects due to temporary equipment supported by or supporting the erected structure, and any non-steelwork dead weight which is in place at the time of measurement of the positional accuracy of the steelwork.

1812.7.3.5 (08/14) **Acceptance criteria (AEN)**

1812.7.3.6 (08/14) **Definition of nonconformity (AEN) (18/1)**

1812.7.3.7 (08/14) **Action on nonconformity (AEN)**

1812.7.4 (08/14) **Other acceptance tests (AEN) (18/1)**

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(04/21) **Table 18/4 Minimum extent of supplementary NDT of shop welds in steel grades up to and including S355 and QSC F56**

Weld type	Orientation [A]	Thickness (t) or throat (a) [B] mm	Proportion of joints tested %	
			Magnetic particle (MT) or penetrant testing (PT)	Ultrasonic testing (UT) [C]
Butt	Transverse	$t < 8$ $8 \leq t \leq 20$ $t > 20$	100 20 50	Not applicable 50 [D] 100
	Longitudinal	$t < 8$ $8 \leq t \leq 20$ $t > 20$	50 5 10	Not applicable 0 10
Fillet	Transverse	$t \leq 20$	5	No requirement
		$t > 20$, $a \leq 10$	10	0[F]
		$t > 20$, $10 < a \leq 15$	20	5[F]
		$t > 20$, $a > 15$	20	10[F]
	Longitudinal	As per transverse fillet but reduced by 2 levels [E]		

[A] Transverse applies to all welds orientated within 60° of the longitudinal axis of members, except for connection zones where all orientations are deemed to be transverse. Connection zones are all locations within 200 mm of a main structural connection, loading point or support position.

[B] t = the nominal maximum parent metal thickness in the joint; and
a = the nominal fillet weld throat dimension (including any specified penetration).

[C] Testing conditions to BS EN ISO 17640 shall be as follows: Level B, evaluation level DAC –14 dB.

[D] 100% for single sided butt where there is no access to root side.

[E] See 1812.4.2.4(4) and (5) for definition of change in level.

[F] The main purpose of these inspections is to provide assurance that there are no systematic embedded imperfections which are either not permitted, such as solidification or HAZ cracking, lamellar tearing etc, or which would also contribute to a resulting loss of required cross section in the weld throat or leg (fusion boundary) zones, such as LORP, LOSWF, laminations, etc

(04/21) **Table 18/5 Adjustments in proportions of supplementary NDT for conditions other than those covered by Table 18/4 and Table 18/6**

Condition	Change in level [A] [B] [C]
Site welded joints	+1
Automatic and robotic welded joints [D]	−1
Standard proprietary products manufactured on a mass production basis [D]	−1
Steel grades above S355 and below S500	+1
Steel grades S500 and above	+2
QSC F36 (relative to F56)	−1
After a non-conformance with acceptance criteria in Table 18/9 or Table 18/10, applicable to all joints of similar type tested in the same production batch; to be maintained until the cause has been identified and rectified and defects eliminated.	+2 (minimum, depending on degree of severity of non-conformance)

[A] See 1812.4.2.4(4) and (5) for definition of change in level.

[B] If the proportion in Table 18/4 is say 20%, an increase of one level according to this table would change the proportion to 50% and a decrease of one level to 10%.

[C] Where more than one condition exists, if the proportion in Table 18/4 is say 100% and the adjustments according to this table are -1, -1 and +1 level respectively, the net adjustment would be -1 level, which would result in a final proportion of 50%.

[D] Not applicable to transverse butt welds of F90 and above.

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(04/21) **Table 18/6 Minimum extent of supplementary NDT of shop welds in steel grades up to and including S355 and QSCs F71 to F140**

Weld type	Orientation [A]	Thickness (t) or throat (a) [B] mm	Proportion of joints tested according to QSC %								
			Magnetic particle (MT) or penetrant testing (PT)			Ultrasonic testing (UT) [C]			Radiographic testing (RT) [D]		
			F71	F90	F112 and F140	F71	F90	F112 and F140	F90	F112	F140
Butt	Transverse	t <8	100	100	100	Not applicable	20[F]	100[F]	20	100	100[E]
		8 ≤ t ≤ 20	50	100	100	100	100	100[F]	0	20	100[E]
		t > 20	100	100	100	100	100	100[F]	0	50	100[E]
	Longitudinal	t < 8	100	100	100	Not applicable	20[F]	100[F]	10	50	100
		8 ≤ t ≤ 20	20	50	100	10	20	100[F]	0	10	100
		t > 20	20	50	100	10	20	100[F]	0	10	100
Fillet	Transverse	t ≤ 20	20	100	100	No requirement	No requirement	No requirement	No requirement		
		t > 20, a ≤ 10	50	100	100	10	20	20			
		t > 20, 10 < a ≤ 15	100	100	100	20	50	50			
		t > 20, a > 15	100	100	100	50	100	100			
	Longitudinal	As per longitudinal butt weld									

[A] and [B] As per Table 18/4, footnotes [A] and [B].

[C] Testing conditions to BS EN ISO 17640 shall be as follows:

- QSCs F71 and F90: testing level B, evaluation level DAC −14dB;
- QSC F112: testing level C, evaluation level DAC −17dB;
- QSC F140: testing level C, evaluation level DAC −20dB; and
- transverse indication scans required for longitudinal welds.

Where phased array technique is to be used, the principles of BS EN ISO 13588 shall be applied. Testing level D shall apply where the test procedures, the equipment and the operator's competency shall be subject to independent validation for suitability for assessment of Table 18/10 requirements.

[D] Applies to in-line butt welds only. BS EN 17636 test class B shall be used. RT not required if phased array technique used for UT.

[E] Not relevant for designs based on Table 8.3 in BS EN 1993-1-9:2005.

[F] Phased array required if RT not used.

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(04/21) **Table 18/7 Weld acceptance criteria for visual inspection (all dimensions in mm)**

Main criterion	Imperfection type [A]		Dimensional parameter [B]		Joint type	Weld type	Acceptance limits [B, C] according to QSC [ ] applies to longitudinal welds only [D]		Remedial action in event of non-conformance [E]
	Description	BS EN ISO 6520-1 ref no.	Symbol	BS EN ISO 5817 ref no.			F56 (For F36, see [F])	F71 to F140	
Overall joint geometry	Weld location error	—	Dr	—	All	Fillet	Dr ± 10 [±10]	As per F56	Refer to welding co-ordinator for remedial action
	Incorrect weld type	—	Dr	—	All	All	NP [NP]	As per F56	Refer to welding co-ordinator for remedial action
	Inadequate weld length	—	Dr	—	All	All	Dr −0 [−5]	As per F56	Add extra weld length
	Linear misalignment	5071, 5072	h	3.1	In line butt	Butt	h ≤ 0.2t [0.3t] h ≤ 4 [5]	See Table 18/8	Remove existing weld, realign joint, remake preparations and check with MT or PT, reweld to AWPS, check with UT
		507	h	—	Cruciform	All	h ≤ 0.4t [0.4t] h ≤ 6 [6]	See Table 18/8	
	Angular misalignment	508	β	—	In line butt	Butt	β ≤ 2° [3°]	See Table 18/8	Correct using approved procedure, check with MT or PT
	Root gap G)	617	h	3.2	Lap, tee, cruciform	Fillet	h ≤ 2 [3]	See Table 18/8	Refer to welding co-ordinator for remedial action
	Excess weld dimensions	502, 503, 504, 512, 5214	h	1.9, 1.10, 1.11, 1.16, 1.21	All	All	NL[B] [NL][B]	As per F56	Correct by grinding if any functional limits are required [B]
Surface notches	Crack	100 to 106	—	1.1, 1.2	All	All	NP [NP]	As per F56	Remove imperfections by grinding to approved excavation shape, check with PT, reweld to AWPS, refer to welding co-ordinator to determine cause
	Lack of fusion	401, 506	—	1.5, 1.13	All	All	NP [NP]	As per F56	
	Lack of penetration (unspecified)	402	h	1.6	All	Single sided butt	NP [h ≤ 0.1t] [h ≤ 1]	As per F56 [NP]	
	Large cavities	2015, 2016, 202, 510	—	2.6 2.7, 1.15	All	Butt	NP [NP]	As per F56	

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Main criterion	Imperfection type [A]		Dimensional parameter [B]		Joint type	Weld type	Acceptance limits [B], [C] according to QSC [ ] applies to longitudinal welds only [D]		Remedial action in event of non-conformance [E]
	Description	BS EN ISO 6520-1 ref no.	Symbol	BS EN ISO 5817 ref no.			F56 (For F36, see [F])	F71 to F140	
Surfaces notches - continued	Undercut, under fill etc.	501, 509, 511, 515, 517	h	1.7, 1.8, 1.14, 1.17, 1.19	All	All	$h \leq 0.5$ [1]	See Table 18/8	Remove by grinding, repair to AWPS
	Pore	2017	d	1.3	All	All	$d \leq 2$ [2]	See Table 18/8	Remove to depth of 3 mm, repair to AWPS
	Toe angle	5051	α	1.12	All	All	$\alpha \geq 90°$ [90°]	See Table 18/8	Correct with high speed rotary burr or reweld to AWPS
	Damage	601, 603 to 606	—	1.22	All	All	NP [NP]	As per F56	Grind out to smooth profile, repair by AWPS if $h > 1$
Loss of cross-section	Insufficient weld throat, a [H]	5213	h	1.20	Tee, lap, cruciform	Fillet	NP [G] [$h \leq 0.1a$] [G] [$h \leq 1$] [G]	As per F56	Increase size using same AWPS
	Insufficient leg length, z [H]	521	h	—	Tee, lap, cruciform	Fillet	NP [G] [$h \leq 0.1z$] [G] [$h \leq 2$] [G]	As per F56	
	Multiple con-forming surface imperfections	201, 202, 501, 509, 511, 515, 5213	h, l, d, l_p	4.2, 4.1	All	All	See [I] [See [I]]	As per F56	Increase cross sectional area using methods above, depending on imperfection type
Surface condition	Deposits	602, 613, 614, 615	—	1.23	All	All	Not permitted for various surface conditions [J]	See Table 18/8	Remove by grinding or blast cleaning

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Main criterion	Imperfection type [A]		Dimensional parameter [B]		Joint type	Weld type	Acceptance limits [B], [C] according to QSC [ ] applies to longitudinal welds only [D]		Remedial action in event of non-conformance [E]
	Description	BS EN ISO 6520-1 ref no.	Symbol	BS EN ISO 5817 ref no.			F56 (For F36, see [F])	F71 to F140	

[A] The three digit BS EN ISO 6520-1 designation is deemed to include all four digit sub-categories.

[B] Symbols are as defined by BS EN ISO 5817 or BS EN ISO 6520-1.
Dr = the dimension (or weld type) specified on the drawings. NP = not permitted. NL = no limits specified for FFP; functional limits shall apply where specified for a particular application.

[C] Where more than one limit is given for an imperfection for a given QSC and weld orientation, all limits shall apply.

[D] Longitudinal welds are those not deemed to be "transverse"; see Table 18/4 footnote [A].

[E] AWPS = approved welding procedure specification for repair, qualified in accordance with 1807.4.1

[F] For joints in any orientation to F36, the imperfection limits given for longitudinal welds [ ] for F56 are applicable.

[G] Where a root gap h has been observed in a tee, cruciform or corner joint, the nominal required fillet weld dimensions, as measured with a weld gauge, shall be increased as follows, unless compensating penetration beyond the root has been proven: minimum required throat size a + 0.7h; minimum required leg length z + h (on affected leg only). See also [H].

[H] Both a and z measurements shall be checked, irrespective of which has been specified on the drawings. They are related as follows:

Angle between fusion faces	120°	110°	100°	90°	80°	70°	60°	See also [G]
z/a	2.0	1.74	1.56	1.41	1.31	1.22	1.15	

[I] All permitted imperfections resulting in loss of cross-section shall be summed and assessed as follows:

$\Sigma hl + \Sigma 0.5dt \leq 4.5t$ or $[\leq 9t]$. Σhl shall include subsurface imperfections assuming h = 3; see Table 18/10, footnote [K]. Measurement length l_p = 100 mm. For fillet welds "a" shall be substituted for "t".

[J] Not permitted if surface is to receive corrosion protection except as allowed by 1810.2, or on uncoated steels conforming to BS EN 10025-5 and BS EN 10088-1. See 1807.5.16.

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(04/21) **Table 18/8 Weld acceptance criteria for visual inspection for QSCs F71 to F140 where limits differ from those for F56 in Table 18/7 (all dimensions in mm)**

Imperfection type [A]		Acceptance limits according to QSC [B, C] [ ] applies to longitudinal welds only [D]								Remedial action in event of non-conformance
		F71		F90		F112		F140		
Linear misalignment	In-line butt	$h \leq 0.15t$ $h \leq 4$	[0.2t] [5]	$h \leq 0.1t$ $h \leq 3$	[0.2t] [4]	$h \leq 0.05t$ $h \leq 3$	[0.2t] [4]	$h \leq 0.05t$ $h \leq 3$	[0.2 t] [4]	As per Table 18/7
	Cruciform	$h \leq 0.3t$ $h \leq 5$	[0.4t] [6]	$h \leq 0.2t$ $h \leq 4$	[0.4t] [6]	$h \leq 0.1t$ $h \leq 3$	[0.3t] [5]	$h \leq 0.1t$ $h \leq 3$	[0.2t] [3]	
Angular misalignment		$\beta \leq 2°$	[3°]	$\beta \leq 1.5°$	[2°]	$\beta \leq 1°$	[2°]	$\beta \leq 0.5°$	[2°]	As per Table 18/7
Root gap [E]		$h \leq 2$	[2]	$h \leq 2$	[2]	$h \leq 1$	[1]	$h \leq 0.5$	[0.5]	As per Table 18/7
Undercut, underfill		$h \leq 0.3$	[$h \leq 1$]	NP	[$h \leq 1$]	NP	[$h \leq 0.5$]	NP	[$h \leq 0.5$]	As per Table 18/7
Porosity		$d \leq 1.5$	[1.5]	$d \leq 1$	[1]	NP	[NP]	NP	[NP]	As per Table 18/7
Toe angle		$\alpha \geq 110°$	[90°]	$\alpha \geq 150°$	[90°]	$\alpha \geq 165°$	[110°]	$\alpha \geq 175°$	[110°]	As per Table 18/7
Deposits		Not permitted for various surface conditions [I]		NP	[NP]	NP	[NP]	NP	[NP]	See [F]
Variation in root or cap longitudinal profile [B]		$\Delta h \leq 3$ [G]	[$\Delta h \leq 3$]	$\Delta h \leq 2$ [G]	[$\Delta h \leq 2$]	$\Delta h \leq 1$ [G]	[$\Delta h \leq 1$]	$\Delta h \leq 0.5$ [G]	[$\Delta h \leq 0.5$]	See [H]

[A] Imperfection types as designated in Table 18/7, footnote [A].

[B] Symbols are as defined by BS EN ISO 5817 or BS EN ISO 6520-1.
NP = not permitted. Δh = the maximum variation in cap or root profile measured along weld axis over any length of 3 mm.

[C] Where more than one limit is given for an imperfection for a given QSC and weld orientation, all limits shall apply.

[D] Longitudinal welds are those not deemed to be "transverse"; see Table 18/4, footnote [A].

[E] Correct fillet weld sizes as per Table 18/7, footnote [G].

[F] For F112 and above, remove with high speed rotary burr.

[G] Transverse welds outside connection zones are exempt from this restriction; see Table 18/4, footnote [A].

[H] Correct by tapering slope to shallower angle or repair to AWPS.

[I] Not permitted if surface is to receive corrosion protection except as allowed by 1810.2, or on uncoated steels conforming to BS EN 10025-5 and BS EN 10088-1. See 1807.5.16.

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(04/21) **Table 18/9 Weld acceptance criteria for magnetic particle and penetrant testing**

Imperfection type	**Acceptance standards**	**Indication pattern**	**Acceptance limits according to QSC [A] [ ] applies to longitudinal welds with longitudinal linear indications only [B]**						**Remedial actions in event of non-conformance [C]**
			F56 (For F36, see [D])		**F71**		**F90 to F140**		
Surface notches identified in Table 18/7 and Table 18/8	BS EN ISO 23278 and BS EN ISO 23277	Isolated	Level 2	[Level 3]	Level 1	[Level 2]	NP	[NP]	Remove by high speed burr machining with machining marks in longitudinal direction. Repair to AWPS if non-conformance with Table 18/7 and Table 18/8 depth requirements (h).
		Grouped [E]	NP	[NP]	NP	[NP]	NP	[NP]	

[A] NP = not permitted.

[B] Longitudinal welds are those not deemed to be "transverse"; see Table 18/4, footnote [A].

[C] AWPS = Approved welding procedure specification for repair, qualified in accordance with 1807.4.1.

[D] For joints in any orientation to F36, the imperfection limits given for longitudinal welds [ ] for F56 are applicable.

[E] "Grouped" shall be deemed to apply to any indications separated by less than 2.5 mm.

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(04/21) **Table 18/10 Weld acceptance criteria for ultrasonic testing with limited optional radiographic testing (all dimensions in mm)**

Imperfection type [A]		Dimensional parameter [B]		Location in cross-section or throat	Acceptance limits according to QSC [B, C] [ ] applies to longitudinal welds only [D]										Remedial action in event of non-conformance [E]
					F56 (For F36, see [F])		F71		F90		F112		F140		
Description	BS EN ISO 6520-1, ref no.	Symbol	BS EN ISO 5817 ref no.												
Cracks	100 to 106	—	2.1, 2.2	Full depth	NP [H]	[NP] [H]	NP [H]	[NP] [H]	NP [H]	[NP] [H]	NP [I]	[NP] [I]	NP [J]	[NP] [J]	Refer to welding co-ordinator to determine cause. Remove by grinding to approved excavation shape. Check with MT or PT. Reweld to AWPS.
Pores [G], inclusions [G], cavities [G], lack of fusion, lack of penetration	2011, 2014, 2015, 2016, 202, 203 301 to 304, 401, 402	h, l	2.3, 2.5, 2.6 to 2.13	Within 6 mm of any surface	$h \le 3$ $l \le 10$	[3] [20]	$h \le 3$ $l \le 5$	[3] [10]	NP [H] NP [H]	[h ≤ 3] [l ≤ 5]	NP [I] NP [I]	[NP] [I] [NP] [I]	NP [J] NP [J]	[NP] [J] [NP] [J]	
				Deeper than 6 mm from any surface	$h \le 3$ $l \le 1.5t$	[3] [3t]	$h \le 3$ $l \le 10$	[3] [1.5t]	$h \le 3$ $l \le 5$	[3] [20]	NP [H] NP [H]	[h ≤ 3] [l ≤ 5]	NP [I] NP [I]	[NP] [I] [NP] [I]	
		h, l, l_p, H, L	4.2	Full depth	$\sum l \le 1.5t$ [K] $l_p = 100$ $H \ge 6$ $L \ge 10$	[3t] [J] [100] [6] [10]	$\sum l \le 1.5t$ [K] $l_p = 100$ $H \ge 6$ $L \ge 10$	[3t] [K] [100] [6] [10]	$\sum l \le 1.5t$ [K] $l_p = 100$ $H \ge 6$ $L \ge 10$	[3t] [K] [100] [6] [10]	NP NP NP NP	[∑l ≤ 1.5t] [K] [l_p = 100] [H ≥ 6] [L ≥ 10]	NP NP NP NP	[NP] [NP] [NP] [NP]	
Uniformly distributed or clustered porosity	2012, 2013	—	2.3, 2.4,	Full depth	Not permitted if obstructs detection or evaluation of imperfections above								NP [L]	[NP] [L]	

[A] Imperfection types as designated in Table 18/7, footnote [A].

[B] Symbols are as defined by BS EN ISO 5817.
NP = not permitted. H = the clear gap between adjacent imperfections measured in through thickness direction. L = the gap between ends of adjacent imperfections measured along weld axis.

[C] Where more than one limit is given for an imperfection for a given QSC and weld orientation, all limits shall apply. If surface breaking imperfections are detected by UT, the criteria given in Table 18/7, Table 18/8 and Table 18/9 apply.

[D] Longitudinal welds are those not deemed to be "transverse"; see Table 18/4, footnote [A].

[E] AWPS = Approved welding procedure specification for repair, qualified in accordance with 1807.4.1.

[F] For joints in any orientation to F36, the imperfection limits given for longitudinal welds [ ] for F56 are applicable.

[G] Use of radiographic testing is permitted to assist in interpretation of these imperfections.

[H] Rejection level DAC −14dB.

[I] Rejection level DAC −17dB.

[J] Rejection level DAC −20dB.

[K] If permitted surface imperfections resulting in loss of cross-section also exist, the criteria in Table 18/7, footnote [I] also apply.

[L] Also, not permitted when checked by radiographic testing.

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(04/21) **Table 18/11 Specific production tests on run-off coupon plates**

Weld type	QSC	Material grades	Test type	Testing rate
In-line transverse butt weld in tension	F56 and above	S355 to S460 ML, NL S460 to S690 Q S420 to S690 QL, QL1	Charpys Tensile Tensile and Charpys	1 in 10 1 in 5 1 in 5
	F90 and above	All	UT+3 macros [A)]	1 in 5
Longitudinal butt or fillet	F90	All	UT + 3 macros[B)]	1 in 20
	F112 and above	All	UT + 3 macros[B)]	1 in 5

[A)] These tests are additional to those described in the rows above.

[B)] A tack weld shall be included in the coupon plate if used in production and at least one macro shall be taken at each end of the tack weld

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