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*Incorporating Corrigenda Nos. 1 and 2*



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# **Guide to methods for assessing the acceptability of flaws in metallic structures**

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## Contents

Foreword	<i>viii</i>
Introduction	1
1	Scope 4
2	Normative references 4
3	Symbols and definitions 5
4	Types of flaw 24
5	General guidance on assessment 25
6	Information required for assessment 27
7	Assessment for fracture resistance 35
8	Assessment for fatigue 70
9	Assessment of flaws under creep and creep/fatigue conditions 108
10	Assessment for other modes of failure 132

### Annexes

Annex A (normative)	Evaluation under mode I, II and III loads 139
Annex B (informative)	Assessment procedures for tubular joints in offshore structures 144
Annex C (normative)	Fracture assessment procedures for pressure vessels and pipelines 151
Annex D (normative)	Stress due to misalignment 155
Annex E (normative)	Flaw recharacterization 161
Annex F (normative)	Procedures for leak-before-break (LbB) assessment 162
Annex G (normative)	The assessment of locally thinned areas (LTAs) 187
Annex H (normative)	Reporting of fracture, fatigue or creep assessments 199
Annex I (informative)	The significance of strength mis-match on the fracture behaviour of welded joints 202
Annex J (informative)	Use of Charpy V-notch impact tests to estimate fracture toughness 210
Annex K (informative)	Probabilistic assessment 215
Annex L (informative)	Fracture toughness determination for welds 230
Annex M (normative)	Stress intensity factor solutions 240
Annex N (informative)	Allowance for constraint effects 295
Annex O (informative)	Consideration of proof testing and warm prestressing 333
Annex P (normative)	Compendium of reference stress and limit load solutions for homogeneous and strength mis-matched structures 340
Annex Q (normative)	Residual stress distributions in as-welded joints 383
Annex R (normative)	Determination of plasticity interaction effects with combined primary and secondary loading 404
Annex S (normative)	Information for making high temperature crack growth assessments 409
Annex T (informative)	Guidance on the use of NDT with ECA 422
Annex U (informative)	Worked examples in fatigue assessment using the quality category approach 439
Bibliography	446

### List of figures

Figure 1	– Example of integrity management procedure for flaws 2
Figure 2	– Linearization of stress distributions 31
Figure 3	– Schematic representation of stress distribution across section 34
Figure 4	– Procedure for resolving flaws normal to principal stress 35
Figure 5	– General flowchart for fracture assessment 36
Figure 6	– Flowchart for Option 1 fracture assessment 37
Figure 7	– Flowchart for Option 2 fracture assessment 38
Figure 8	– Flowchart for Option 3 fracture assessment 39
Figure 9	– Flowchart for flaw characterization 41
Figure 10	– Definitions of flaw dimensions 42

Figure 11 – Flaw alignment rules for non-coplanar flaws	43
Figure 12 – Flaw interaction rules for coplanar flaws	44
Figure 13 – De-rating values for yield/proof strength and tensile strength at temperatures above room temperature in C-Mn steels and duplex stainless steels (DSS): (not applicable to 13% Cr steels) from DNV OS F101 [6]	47
Figure 14 – Ductile tearing assessment	66
Figure 15 – Example of non-unique solutions	68
Figure 16 – Schematic crack growth relationships	77
Figure 17 – Recommended fatigue crack growth laws	77
Figure 18 – Quality category <i>S-N</i> curves	84
Figure 19 – Quality category approach: assessment of surface flaws in plates under axial loading	89
Figure 20 – Quality category approach: assessment of surface flaws in flat material (no weld toe or other stress raiser) in bending	91
Figure 21 – Quality category approach: assessment of embedded flaws in axially loaded joints	93
Figure 22 – Quality category approach: assessment of weld toe flaws in axially loaded joints	95
Figure 23 – Quality category approach: assessment of weld toe flaws in joints loaded in bending	101
Figure 24 – Determination of temperature $T_c$ at which 0.2% creep strain is accumulated at a stress level equal to the proof strength	112
Figure 25 – Insignificant creep curves for austenitic steels	113
Figure 26 – Insignificant creep curves for ferritic steels	113
Figure 27 – Schematic behaviour of crack subjected to steady loading at elevated temperature	115
Figure 28 – Schematic representation of crack propagation and failure conditions	116
Figure 29 – Flowchart for overall creep assessment procedure	117
Figure 30 – Schematic diagrams of typical relationships between crack velocity and stress intensity factor during SCC	134
Figure 31 – Types of corrosion fatigue crack growth behaviour	136
Figure A.1 – Definitions of loading modes	139
Figure B.1 – Assessment method for fatigue crack growth in tubular joints	145
Figure E.1 – Rules for recharacterization of flaws	161
Figure F.1 – The leak-before-break diagram	162
Figure F.2 – Flow charts for LbB procedures	165
Figure F.3 – Example characterization of a complex flaw	170
Figure F.4 – Schematic flaw profiles at breakthrough	172
Figure F.5 – Development of flaw shapes for sub-critical growth of surface flaws	175
Figure F.6 – Development of flaw shapes for sub-critical growth of through-wall flaws	175
Figure F.7 – Recommended re-characterization of flaws at breakthrough subjected to ductile tearing loading	176
Figure G.1 – Flow chart of assessment procedure	189
Figure G.2 – Dimensions of an LTA	190
Figure G.3 – Dimensions of a bend	192
Figure G.4 – Dimensions of a sphere and vessel end	193
Figure G.5 – Interaction between LTAs	195
Figure I.1 – Idealized weld geometry – the parent and weld metals have yield strengths of $\sigma_Y^W$ and $\sigma_Y^P$ respectively	204
Figure I.2 – Idealized definition of mis-match ratio, $M$ , and construction of the equivalent stress-strain curve (weighted average of the other two curves)	205
Figure J.1 – Flowchart for selecting an appropriate correlation for estimating fracture toughness from Charpy data	211
Figure M.1 – Through-thickness flaw geometry	243

- Figure M.2 – Edge flaw geometry 243
- Figure M.3 – Surface flaw 244
- Figure M.4 – Elliptical integral as a function of  $a/2c$  used for the calculation of  $K_I$  for surface and embedded flaws 246
- Figure M.5 – Stress intensity magnification factor  $M_m$  for surface flaws in tension 246
- Figure M.6 – Stress intensity magnification factor  $M_b$  for surface flaws in bending 249
- Figure M.7 – Extended flaw geometry 250
- Figure M.8 – Embedded flaw 251
- Figure M.9 – Stress intensity magnification factor  $M_m$  for embedded flaws in tension (at point nearest material surface) 252
- Figure M.10 – Stress intensity magnification factor  $M_b$  for embedded flaws in bending 253
- Figure M.11 – Corner flaw geometry 254
- Figure M.12 – Corner flaw at hole geometry 256
- Figure M.13 – Through-thickness flaw in cylinder oriented axially 260
- Figure M.14 – Internal surface flaw in cylinder oriented axially 265
- Figure M.15 – Extended internal surface flaw in cylinder orientated axially 267
- Figure M.16 – External surface flaw in cylinder oriented axially 268
- Figure M.17 – Extended axial external surface flaw in cylinder 269
- Figure M.18 – Through-thickness flaw in cylinder oriented circumferentially 271
- Figure M.19 – Internal surface flaw in cylinder oriented circumferentially 276
- Figure M.20 – Fully circumferential internal surface flaw in cylinder 278
- Figure M.21 – Fully circumferential external surface flaw in cylinder 279
- Figure M.22 – Through-thickness flaw in spherical shell 282
- Figure M.23 – Flaws in bars and bolts 283
- Figure M.24 – Fully circumferential flaw in a round bar 286
- Figure M.25 – Welded joint geometries 288
- Figure M.26 – Transverse load-carrying cruciform joint 289
- Figure N.1 – Schematic showing curve fitting of low constraint test data to obtain  $a$  and  $k$  301
- Figure N.2 – Modifications to the Option 1 failure assessment curve for various values of the material parameters,  $a$ ,  $k$ , and constraint levels,  $\beta$  ( $< 0$ ), using Equation N.23 with  $k = 3$ . For  $a = 0$  or  $\beta = 0$  the curves reduce to the Option 1 curve 303
- Figure N.3 – FAD analysis for (a) fracture initiation and (b) ductile tearing 304
- Figure O.1 – Schematic illustration of a proof test argument (following [3]) 335
- Figure O.2 – Typical warm prestress cycles 337
- Figure P.1 – Double edge cracked plate under tension 346
- Figure P.2 – Extended embedded flaw in a plate 348
- Figure P.3 – Circumferential internal and external surface flaws in thick-walled cylinders under combined tension and bending 358
- Figure P.4 – T and Y joints under a) axial load, b) in-plane and out-of-plane bending 362
- Figure P.5 – K-joints under a) axial load and b) in-plane and out-of-plane bending 363
- Figure P.6 – X and DT joints under a) axial load and b) in-plane and out-of-plane bending 364
- Figure P.7 – Classification of plasticity deformation patterns for mis-matched structures, [367] 365
- Figure P.8 – Centre cracked plate under tension  $\psi = (W - a)/h$  369
- Figure P.9 – Double edge cracked plate under tension 373
- Figure P.10 – Single edge cracked plate under pure bending 377
- Figure P.11 – Fully circumferential internal flaws in thin-walled pipes/cylinders under tension 379

Figure P.12 – Centre through-thickness flaws in clad plates under tension [372], [373]	380
Figure P.13 – Through-thickness flaw in a clad plate with repair weld	382
Figure Q.1 – Components of longitudinal residual stress distribution for plate butt welds and pipe axial seam welds (austenitic steel)	385
Figure Q.2 – Components of transverse stress distribution for plate butt welds and axial seam welds (austenitic and ferritic steels)	386
Figure Q.3 – Components of longitudinal stress distribution for pipe butt welds (ferritic and austenitic steels)	387
Figure Q.4 – Components of transverse stress distribution for pipe butt welds (ferritic steels)	388
Figure Q.5 – Components of longitudinal stress distribution for plate to plate T-butt welds (ferritic steels)	392
Figure Q.6 – Components of transverse stress distribution for plate to plate T-butt welds (austenitic and ferritic steels)	394
Figure Q.7 – Components of longitudinal stress distribution for tubular T-butt welds (ferritic steels)	395
Figure Q.8 – Components of transverse stress distribution for tubular T-butt welds (ferritic steels)	396
Figure Q.9 – Residual stress profile for repair welds (transverse and longitudinal)	398
Figure Q.10 – Finite surface crack in an infinite width plate	399
Figure Q.11 – Extended surface flaw in an infinite width plate	403
Figure R.1 – Non-dimensional stress intensity factors for through-thickness flaws with through-wall self-balancing stress distributions	407
Figure S.1 – General form of a creep curve defining the average and secondary creep strain rates	411
Figure S.2 – Derivation of strain versus time curves from iso-strain curves	412
Figure T.1 – Assessment of flaw tolerance using ECA	426
Figure T.2 – Assessment of detected flaw	427
Figure U.1 – Butt weld containing embedded flaw	439
Figure U.2 – Derivation of actual quality category for a flaw	440
Figure U.3 – Fillet weld containing a surface flaw	441
Figure U.4 – Obtaining the required quality category	442
Figure U.5 – Obtaining the quality category for the flaw	443

#### List of tables

Table 1 – Symbols	5
Table 2 – Coefficient of variation (COV) for tensile properties for ferritic steels	46
Table 3 – Elastic modulus	46
Table 4 – Guidance for determining whether yielding is continuous or discontinuous	49
Table 5 – Minimum of three equivalent (MOTE)	56
Table 6 – Values of $k_{0.90}$ at the lower 20th percentile for the one sided tolerance limit for a normal distribution	56
Table 7 – Limits for slag inclusions and porosity	68
Table 8 – Procedure for assessment of known flaws	70
Table 9 – Stress ranges used in fatigue assessments	75
Table 10 – Recommended fatigue crack growth laws for steels in air	78
Table 11 – Recommended fatigue crack growth laws for steels in a marine environment	79
Table 12 – Recommended fatigue crack growth threshold, $\Delta K_0$ , values for assessing welded joints	81
Table 13 – Details of quality category <i>S-N</i> curves	83
Table 14 – Minimum values of $\Delta\sigma_j$ for assessing non-planar flaws and shape imperfections	105
Table 15 – Limits for non-planar flaws in as welded steel and aluminium alloy weldments	106

Table 16 – Limits for non-planar flaws in steel weldments stress relieved by PWHT	106
Table 17 – Acceptance levels for misalignment expressed in terms of stress magnification factor, $k_m$	107
Table 18 – Acceptance levels for weld toe undercut in material thicknesses from 10 mm to 40 mm	107
Table 19 – Temperature below which creep is negligible in 200,000 h	112
Table D.1 – Formulae for calculating the bending stress due to misalignment in butt joints	156
Table D.2 – Formulae for calculating the bending stress due to misalignment in cruciform joints	159
Table F.1 – Guidance on selection of assessment sites around a pipe system	164
Table F.2 – Advice on growth of surface flaws [160]	173
Table F.3 – Advice on growth of through-wall defects [160]	174
Table F.4 – Crack opening area methods for simple geometries and loading	177
Table F.5 – Summary of short wave length surface roughness values [208]	181
Table F.6 – Particulates in primary system water	186
Table K.1 – Uncertainties in Paris parameter $A$	219
Table K.2 – Uncertainties in Paris parameter $A$ for the two stage model	220
Table K.3 – Target failure probability (events/year)	221
Table K.4 – Recommended partial factors for different combinations of target reliability and variability of input data based on failure on the FAD	222
Table M.1 a) – $M_1$ for axial through-thickness in cylinders: membrane loading	261
Table M.1 b) – $M_2$ for axial through-thickness flaws in cylinders: membrane loading	262
Table M.1 c) – $M_3$ for axial through-thickness flaws in cylinders: bending loading	263
Table M.1 d) – $M_4$ for axial through-thickness flaws in cylinders: bending loading	264
Table M.2 – $M_m$ and $M_b$ for axial internal surface flaw in cylinder	266
Table M.3 – $M_m$ and $M_b$ for extended axial internal surface flaw in cylinder	267
Table M.4 – $M_m$ and $M_b$ for axial external surface flaw in cylinder	268
Table M.5 – $M_m$ and $M_b$ for extended axial external surface flaw in cylinder	269
Table M.6a) – $M_1$ for circumferential through-thickness flaws in cylinders: membrane loading	272
Table M.6b) – $M_2$ for circumferential through-thickness flaws in cylinders: membrane loading	273
Table M.6c) – $M_3$ for circumferential through-thickness flaws in cylinders: bending loading	274
Table M.6d) – $M_4$ for circumferential through-thickness flaws in cylinders: bending loading	275
Table M.7 – $M_m$ and $M_b$ for circumferential internal surface flaw in cylinder	277
Table M.8 – $M_m$ and $M_b$ for extended circumferential internal surface flaw in cylindrical shell	278
Table M.9 – Influence coefficients at points A and B for an equatorial through-thickness flaw in a sphere	280
Table M.10 – $M_m$ for semi-elliptical flaw in a round bar under tension loading	284
Table M.11 – $M_b$ for semi-elliptical flaw in a round bar under bending loading	284
Table M.12 – Values of $v$ and $w$ for axial and bending loading	289
Table N.1 – Polynomial coefficients defining $\beta_T$ for CCT [326 to 328]	306
Table N.2 – Polynomial coefficients defining $\beta_T$ for CCBT	306
Table N.3 – Polynomial coefficients defining $\beta_T$ for DECT [311], [326], [328]	307
Table N.4 – Polynomial coefficients defining $\beta_T$ for SECT	307
Table N.5 – Polynomial coefficients defining $\beta_T$ for SEB [311, 326, 328]	308
Table N.6 – Polynomial coefficients defining $\beta_T$ for 3PB	308
Table N.7 – Polynomial coefficients defining $\beta_T$ for SCT [329]	309
Table N.8 – Polynomial coefficients defining $\beta_T$ for SCB [329]	310

Table N.9 – Polynomial coefficients defining $\beta_T$ for CISLCCT [326], [330]	311
Table N.10 – Polynomial coefficients defining $\beta_T$ for CISSCCBT [331]	312
Table N.11 – Polynomial coefficients defining $\beta_T$ for CISSCCT [331]	313
Table N.12 – $a$ and $k$ defined with respect to $T/\sigma_Y$ for $n = 5$	315
Table N.13 – $a$ and $k$ defined with respect to $T/\sigma_Y$ for $n = 6$	316
Table N.14 – $a$ and $k$ defined with respect to $T/\sigma_Y$ for $n = 7$	316
Table N.15 – $a$ and $k$ defined with respect to $T/\sigma_Y$ for $n = 8$	317
Table N.16 – $a$ and $k$ defined with respect to $T/\sigma_Y$ for $n = 9$	317
Table N.17 – $a$ and $k$ defined with respect to $T/\sigma_Y$ for $n = 10$	318
Table N.18 – $a$ and $k$ defined with respect to $T/\sigma_Y$ for $n = 11$	318
Table N.19 – $a$ and $k$ defined with respect to $T/\sigma_Y$ for $n = 12$	319
Table N.20 – $a$ and $k$ defined with respect to $T/\sigma_Y$ for $n = 13$	319
Table N.21 – $a$ and $k$ defined with respect to $T/\sigma_Y$ for $n = 14$	320
Table N.22 – $a$ and $k$ defined with respect to $T/\sigma_Y$ for $n = 15$	320
Table N.23 – $a$ and $k$ defined with respect to $T/\sigma_Y$ for $n = 16$	321
Table N.24 – $a$ and $k$ defined with respect to $T/\sigma_Y$ for $n = 17$	321
Table N.25 – $a$ and $k$ defined with respect to $T/\sigma_Y$ for $n = 18$	322
Table N.26 – $a$ and $k$ defined with respect to $T/\sigma_Y$ for $n = 19$	322
Table N.27 – $a$ and $k$ defined with respect to $T/\sigma_Y$ for $n = 20$	323
Table N.28 – $a$ and $k$ defined with respect to $Q$ for $n = 5$	324
Table N.29 – $a$ and $k$ defined with respect to $Q$ for $n = 6$	325
Table N.30 – $a$ and $k$ defined with respect to $Q$ for $n = 7$	325
Table N.31 – $a$ and $k$ defined with respect to $Q$ for $n = 8$	326
Table N.32 – $a$ and $k$ defined with respect to $Q$ for $n = 9$	326
Table N.33 – $a$ and $k$ defined with respect to $Q$ for $n = 10$	327
Table N.34 – $a$ and $k$ defined with respect to $Q$ for $n = 11$	327
Table N.35 – $a$ and $k$ defined with respect to $Q$ for $n = 12$	328
Table N.36 – $a$ and $k$ defined with respect to $Q$ for $n = 13$	328
Table N.37 – $a$ and $k$ defined with respect to $Q$ for $n = 14$	329
Table N.38 – $a$ and $k$ defined with respect to $Q$ for $n = 15$	329
Table N.39 – $a$ and $k$ defined with respect to $Q$ for $n = 16$	330
Table N.40 – $a$ and $k$ defined with respect to $Q$ for $n = 17$	330
Table N.41 – $a$ and $k$ defined with respect to $Q$ for $n = 18$	331
Table N.42 – $a$ and $k$ defined with respect to $Q$ for $n = 19$	331
Table N.43 – $a$ and $k$ defined with respect to $Q$ for $n = 20$	332
Table P.1 – Calculation of bending stresses as functions of moments	342
Table P.2 – Values of $\chi$ for bending loading	359
Table P.3 – Coefficient $Q_u$ for various joint design classifications	361
Table Q.0 – Validity ranges for as-welded residual stress distributions in ferritic steels	383
Table Q.1 – Components of longitudinal stress and $K_{sb}^{max}$ for plate butt welds and pipe axial seam welds (austenitic steel)	385
Table Q.2 – Components of transverse stress and $K_{sb}^{max}$ for plate butt welds and axial seam welds (austenitic and ferritic steels)	386
Table Q.3 – Components of longitudinal stress and $K_{sb}^{max}$ for pipe butt welds (ferritic and austenitic steels)	387
Table Q.4 – Components of transverse stress and $K_{sb}^{max}$ for pipe butt welds (ferritic steel)	391
Table Q.5 – Components of transverse stresses and $K_{sb}^{max}$ for pipe butt welds (austenitic steel)	391
Table Q.6 – Components of longitudinal stress and $K_{sb}^{max}$ for plate to plate T-butt welds (ferritic steels)	393
Table Q.7 – Components of transverse stress and $K_{sb}^{max}$ for plate to plate T-butt welds (ferritic and austenitic steels) and longitudinal stress and $K_{sb}^{max}$ for plate to plate T-butt welds (austenitic steels)	394
Table Q.8 – Components of longitudinal stress and $K_{sb}^{max}$ for tubular T-butt welds (ferritic steels)	395

Table Q.9 – Components of transverse stress and $K_{sb}^{max}$ for tubular T-butt welds (ferritic steels)	397
Table Q.10 – Components of transverse and longitudinal stress distribution for repair welds (ferritic and austenitic steels)	398
Table Q.11 – Geometry functions for a finite surface flaw in an infinite width plate – deepest point of the flaw	400
Table Q.12 – Geometry functions for a finite surface flaw in an infinite width plate – intersection of flaw with free surface	401
Table Q.13 – Geometry functions for an extended surface flaw in an infinite width plate	403
Table S.1 – Mean uniaxial creep properties for different steels for short (<10 000 h) and long term tests	413
Table S.2 – Constants used to derive creep crack growth rates in mm/h and $C^*$ in $MPamh^{-1}$	415
Table T.1 – Examples of inspection capabilities for sub-surface flaws	429
Table T.2 – Examples of inspection capabilities for back surface flaws	429
Table T.3 – Examples of inspection capabilities for flaws at the accessible surface	430
Table T.4 – Capabilities for detection and length measurement of surface-breaking flaws by MPI ([416])	435
Table T.5 – Flaw detection capability for liquid penetrant testing [444, 445]	436

### Summary of pages

This document comprises a front cover, an inside front cover, pages i to x, pages 1 to 478, an inside back cover and a back cover.

## Foreword

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 31 December 2013. It was prepared by Technical Committee WEE/37 *Acceptance levels for flaws in welds*. A list of organizations represented on this committee can be obtained on request to its secretary.

### Supersession

BS 7910:2013+A1:2015 supersedes BS 7910:2013, which is withdrawn.

### Information about this document

The start and finish of text introduced or altered by Amendment No. 1 is indicated in the text by tags  $\boxed{A_1}$  and  $\langle A_1 \rangle$ . Minor editorial changes are not tagged.

Text introduced or altered by Corrigenda Nos. 1 and 2, respectively is indicated in the text by tags  $\boxed{C_1}$   $\langle C_1 \rangle$  and  $\boxed{C_2}$   $\langle C_2 \rangle$ . Minor editorial changes are not tagged.

This is a full revision of the standard, and introduces the following principal changes that reflect advances in structural integrity technology, in particular elements of the European FITNET procedure [1] and [2] and the UK nuclear industry's R6 procedure [3].

- In Clause 7 the fracture assessment "Levels" 1-3 have been replaced by "Options" 1-3 and the definitions changed substantially so that the new hierarchy of Options is in line with that used in the R6 procedure. The Level I fracture assessment procedure and the simplified implementation thereof (given in Annex N of BS 7910:2005) have been deleted.
- Annex S of BS 7910:2005 on appropriate numerical integration techniques for fatigue life estimation has been deleted.
- Annex U of BS 7910:2005, which gave worked examples to demonstrate high temperature assessment, has been deleted.
- Crack driving force is expressed in terms of  $K_I$  only. The materials toughness,  $K_{mat}$ , can be derived from  $K_{Ic}$ , CTOD or  $J$ -integral or Charpy test data.
- A procedure for incorporating weld strength mis-match has been included in Annex I for selected geometries.
- A procedure for incorporating crack tip constraint effects has been included in Annex N.
- New rules for flaw interaction criteria have been introduced in Clause 7.
- Clause 8, Clause 9 and Clause 10 have been rewritten to take into account new sources of information on environmental fatigue crack growth, creep crack growth and environmentally assisted cracking (EAC).
- Annex P now includes reference stress solutions and limit load solutions for both homogeneous and strength mis-matched structures.
- A new informative annex on the reliability of various non-destructive testing (NDT) techniques has been added as Annex T.
- Annex Q has been rewritten to facilitate the use of non-linear stress distributions for residual stress fields.
- The corrosion assessment annex (Annex G) has been renamed *Assessment of locally thinned areas (LTAs)* and substantially expanded to cover geometries other than straight pipes, e.g. elbows and spheres.

**Use of this document**

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

As a guide this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification or a code of practice and claims of compliance cannot be made to it.

**Presentational conventions**

The guidance in this standard is presented in roman (i.e. upright) type. Any recommendations are expressed in sentences in which the principal auxiliary verb is "should".

*Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.*

**Contractual and legal considerations**

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

**Compliance with a British Standard cannot confer immunity from legal obligations.**



## Introduction

Where it is necessary to examine critically the integrity of new or existing structures by the use of non-destructive testing (NDT) methods, acceptance levels are required for any flaws that might be revealed. These often already exist as quality control levels (for example in a construction code); however, in this British Standard the derivation of acceptance levels for flaws is based upon the principle of fitness-for-service.

By this principle a structure is considered to be adequate for its purpose, provided the conditions to cause failure are not reached. A distinction has to be made between acceptance based on quality control and acceptance based on fitness-for-service.

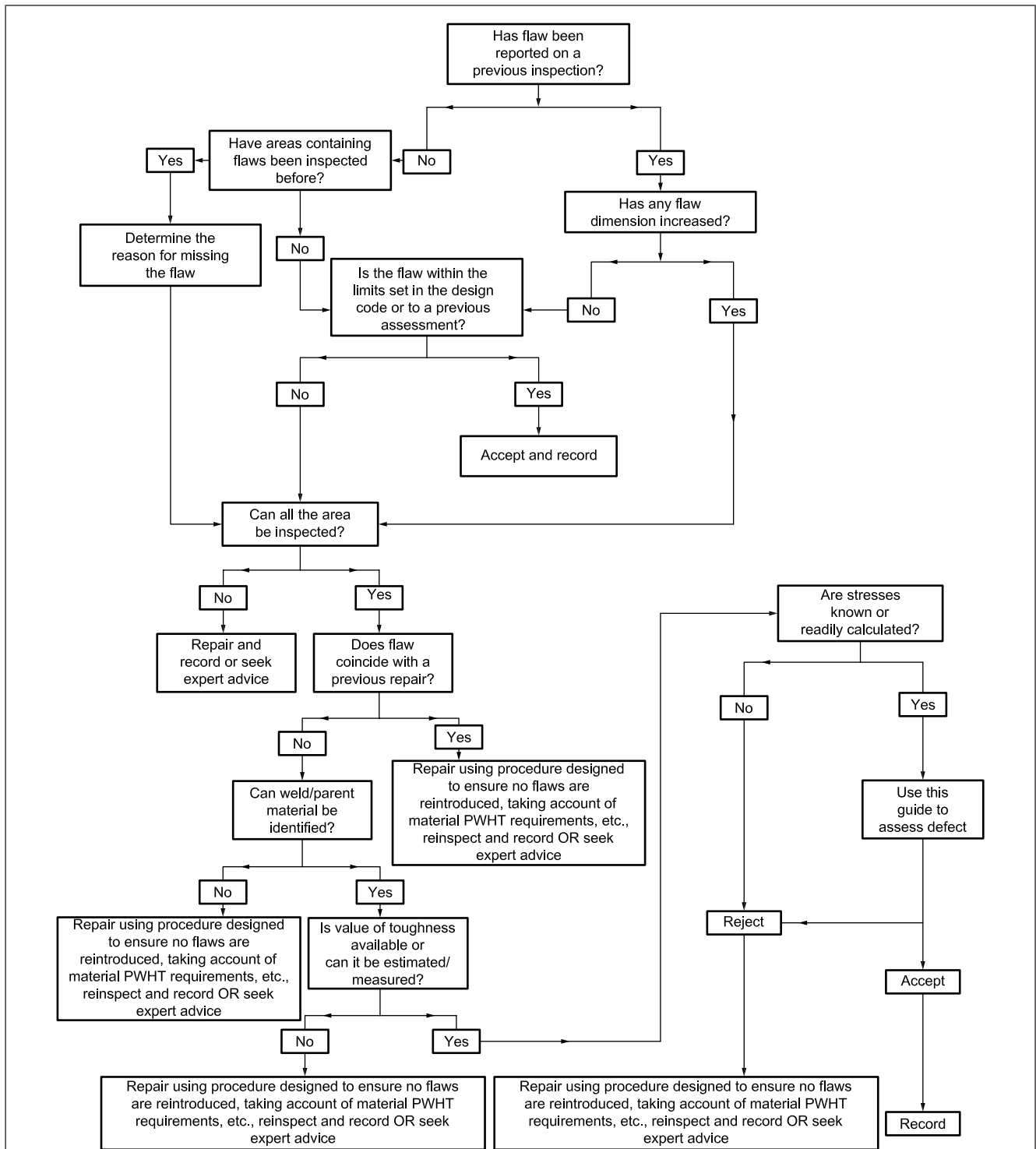
Quality control levels are usually both arbitrary and conservative, but are of considerable value in the monitoring and maintenance of quality during production. Flaws that are less severe than such quality control levels as given, for example, in current construction codes, are acceptable without further consideration. If flaws are more severe than the quality control levels, rejection is not necessarily automatic. Decisions on whether rejection, down rating and/or repairs are required may be based on fitness-for-service, either in the light of previously documented experience with similar material, stress and environmental combinations or on the basis of an engineering critical assessment (ECA) (see Figure 1). It is with the latter that this document is concerned. It is emphasized, however, that a proliferation of flaws, even if shown to be acceptable by an ECA, is regarded as indicating that quality is in need of improvement. The use of an ECA is not intended to be viewed as an alternative to good workmanship. The response to flaws not conforming to workmanship criteria needs to be the correction of the fault in the process causing the non-conformance. The methods covered by this British Standard are complementary to, and not a replacement for, good quality workmanship.

A procedure for an ECA is described throughout whereby the significance of flaws under a particular set of circumstances can be determined. All parties need to agree to its use.

It is impossible to provide a single list of flaws that are known not to cause premature failure as a large number of variables are involved as enumerated in this British Standard. Where relevant experience and data already exist it is possible to dispense with the full ECA procedure and to use authenticated previous assessments as a basis for the establishment of acceptability limits. An ECA may also be used as a basis for deferring necessary repairs to a time mutually agreeable to the contracting parties. Unsatisfactory repair of innocuous flaws can result in the substitution of more harmful and/or less readily detectable flaws.

Flaw assessment on a fitness-for-service basis requires thorough examination by NDT using techniques capable of locating and sizing flaws in critical areas. This British Standard may be used to identify such areas and to assist in optimizing the NDT procedures by identifying those aspects of flaw characterization, size and position that need to be determined. Such NDT is normally carried out after any post weld heat treatment (PWHT) and/or proof test. However, since a major objective of this British Standard is to reduce costs by eliminating unnecessary repair, careful consideration needs to be given to the level of inspection required to implement this British Standard, and to the limitations of NDT methods.

Figure 1 Example of integrity management procedure for flaws



*NOTE* If a component is rejected on the basis of a fitness-for-service analysis, downrating or retirement of the component may be considered as well as repair. Alternatively, the more advanced methods of this British Standard may be used, e.g. analyses based on leak-before-break (see Annex F) or recharacterization of flaws (see Annex E).

Where NDT has revealed the presence of flaws, the following options apply.

- If the flaws do not exceed the quality control levels in the appropriate application standard, no further action is required.
- If acceptance limits have already been established on the basis of an ECA for the appropriate combination of materials, fabrication procedure, welding consumables, stress and environmental factors, flaws need to be assessed on that basis.
- If no relevant documented experience exists, then an ECA based on the guidance given in this document needs to be carried out.

An ECA helps to identify the limiting conditions for failure or the limiting design conditions. It is emphasized that some aspects of an ECA are based on new concepts that could be subject to review.

The application of ECA principles means that “safe” results are obtained. The option of using appropriate safety factors has been incorporated or is inherent throughout the standard. If the accuracy of the input information employed (e.g. stress levels, material properties at the appropriate temperature, flaw size determination) is in question, appropriate additional safety factors need to be agreed. Equally a flaw is not necessarily unacceptable when it is found initially to exceed the acceptance levels that are derived from this standard. A further assessment may be made following the principles given in this standard incorporating more precise input data or analysis methods or by testing structurally relevant components.

This British Standard also gives guidance on the use of safety factors, reliability factors and probabilistic methods. These factors and methods do not constitute a full risk analysis of the component undergoing assessment as they do not quantify the consequences of a failure. Where failure of the structure under assessment could pose an unjustifiable or intolerable risk to the surrounding environment or population, a full risk analysis might be needed, with due recognition of both individual and societal risk [4].

The assessment methods given in this British Standard provide a quantitative measure of the acceptability of a flaw in a structure. They are not to be used in isolation but are to be used as part of an overall process for the management of flaws. The management of flaws is part of a wider integrity management plan for the structure or system. The management processes for flaws addresses factors such as:

- the cause of the flaw and remedial action to prevent further occurrences or growth;
- whether a previous inspection failed to detect this flaw. If so, the reasons for not detecting the flaw need to be determined. The inspection technique or assumptions about sub-critical crack growth rates might need to be reviewed;
- the previous history of the structure and whether it is consistent with the nature, location and size of the flaw;
- whether an inspection suggests that the flaw has grown and the observed growth is consistent with assumptions about loading and sub-critical crack growth rates after allowing for uncertainty in the inspection results;
- the implications for other structures of the same or similar design and whether modifications to the structure or a change in the service conditions might be required;
- whether there is a pattern of this flaw being detected in other structures of the same design.

An example algorithm for managing the assessment of flaws is shown in Figure 1. Alternative approaches may be developed.

## 1 Scope

This British Standard gives guidance and recommendations for assessing the acceptability of flaws in all types of structures and components. Although emphasis is placed on welded fabrications in ferritic and austenitic steels and aluminium alloys, the procedures may be used for analysing flaws in structures made from other metallic materials and in non-welded components or structures. The methods described are applicable at the design, fabrication and operational phases of a structure's life.

## 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ASTM E1820, *Standard test method for measurement of fracture toughness*

ASTM E1921, *Standard test method for determination of reference temperature*

BS 7448 (all parts), *Fracture mechanics toughness tests*

BS EN 583 (all parts), *Nondestructive testing – Ultrasonic examination*

BS EN 12454, *Founding – Visual examination of surface discontinuities – Steel sand castings*

BS EN 12517 (all parts), *Non-destructive testing of welds*

BS EN ISO 6892-1, *Metallic materials – Tensile testing – Part 1: Method of test at ambient temperature*

BS EN ISO 6892-2, *Metallic materials – Tensile testing – Part 2: Method of test at elevated temperature*

BS EN ISO 7539 (all parts), *Corrosion of metals and alloys – Stress corrosion testing – Preparation and use of precracked specimens for tests under constant load or constant displacement*

BS EN ISO 11666, *Non-destructive testing of welds – Ultrasonic testing – Acceptance levels*

BS EN ISO 12737, *Metallic materials – Determination of plane-strain fracture toughness*

BS EN ISO 15548 (all parts), *Non-destructive testing – Equipment for eddy current examination*

BS EN ISO 15549, *Non-destructive testing – Eddy current testing*

BS EN 17640, *Non-destructive testing of welds – Ultrasonic testing – Techniques, testing levels, and assessment*

BS EN ISO 15653, *Metallic materials – Method of test for the determination of quasistatic fracture toughness of weld*

BS EN ISO 17636-1, *Non-destructive testing of welds – Radiographic testing – Part 1: X- and gamma-ray techniques with film*

BS EN ISO 17636-2, *Non-destructive testing of welds – Radiographic testing – Part 2: X- and gamma-ray techniques with digital detectors*

BS EN ISO 17637, *Non-destructive testing of welds – Visual testing of fusion-welded joints*

BS EN ISO 17638, *Non-destructive testing of welds – Magnetic particle testing*