

**Äärikud ja nende ühendused. Tihendiga ümaräärikutega liidete projekteerimisreeglid. Osa 1: Arvutusmeetod**

**Flanges and their joints - Design rules for gasketed circular flange connections - Part 1: Calculation**

## EESTI STANDARDI EESSÕNA

## NATIONAL FOREWORD

|                                                                                                                     |                                                                                                                                    |
|---------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|
| See Eesti standard EVS-EN 1591-1:2014 sisaldab Euroopa standardi EN 1591-1:2013 inglisekeelset teksti.              | This Estonian standard EVS-EN 1591-1:2014 consists of the English text of the European standard EN 1591-1:2013.                    |
| Standard on jõustunud sellekohase teate avaldamisega EVS Teatajas.                                                  | This standard has been endorsed with a notification published in the official bulletin of the Estonian Centre for Standardisation. |
| Euroopa standardimisorganisatsioonid on teinud Euroopa standardi rahvuslikele liikmetele kättesaadavaks 18.12.2013. | Date of Availability of the European standard is 18.12.2013.                                                                       |
| Standard on kättesaadav Eesti Standardikeskusest.                                                                   | The standard is available from the Estonian Centre for Standardisation.                                                            |

Tagasisidet standardi sisu kohta on võimalik edastada, kasutades EVS-i veebilehel asuvat tagasiside vormi või saates e-kirja meiliaadressile [standardiosakond@evs.ee](mailto:standardiosakond@evs.ee).

ICS 23.040.60

### Standardite reprodutseerimise ja levitamise õigus kuulub Eesti Standardikeskusele

Andmete paljundamine, taastekitamine, kopeerimine, salvestamine elektroonsesse süsteemi või edastamine ükskõik millises vormis või millisel teel ilma Eesti Standardikeskuse kirjaliku loata on keelatud.

Kui Teil on küsimusi standardite autorikaitse kohta, võtke palun ühendust Eesti Standardikeskusega:  
Aru 10, 10317 Tallinn, Eesti; [www.evs.ee](http://www.evs.ee); telefon 605 5050; e-post [info@evs.ee](mailto:info@evs.ee)

### The right to reproduce and distribute standards belongs to the Estonian Centre for Standardisation

No part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying, without a written permission from the Estonian Centre for Standardisation.

If you have any questions about copyright, please contact Estonian Centre for Standardisation:  
Aru 10, 10317 Tallinn, Estonia; [www.evs.ee](http://www.evs.ee); phone 605 5050; e-mail [info@evs.ee](mailto:info@evs.ee)

English Version

## Flanges and their joints - Design rules for gasketed circular flange connections - Part 1: Calculation

Brides et leurs assemblages - Règles de calcul des assemblages à brides circulaires avec joint - Partie 1: Méthode de calcul

Flansche und ihre Verbindungen - Regeln für die Auslegung von Flanschverbindungen mit runden Flanschen - Teil 1: Berechnung

This European Standard was approved by CEN on 12 October 2013.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.



EUROPEAN COMMITTEE FOR STANDARDIZATION  
COMITÉ EUROPÉEN DE NORMALISATION  
EUROPÄISCHES KOMITEE FÜR NORMUNG

**CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels**

# Contents

Page

|                                                                                         |    |
|-----------------------------------------------------------------------------------------|----|
| Foreword.....                                                                           | 5  |
| 1 Scope .....                                                                           | 7  |
| 2 Normative references .....                                                            | 7  |
| 3 Notation .....                                                                        | 7  |
| 3.1 Use of figures .....                                                                | 7  |
| 3.2 Subscripts and special marks .....                                                  | 7  |
| 3.2.1 Subscripts .....                                                                  | 7  |
| 3.2.2 Special marks .....                                                               | 9  |
| 3.3 Symbols .....                                                                       | 9  |
| 3.4 Terminology .....                                                                   | 14 |
| 3.4.1 Flanges .....                                                                     | 14 |
| 3.4.2 Loading .....                                                                     | 14 |
| 3.4.3 Load conditions .....                                                             | 14 |
| 3.4.4 Compliances .....                                                                 | 14 |
| 4 Requirements for use of the calculation method .....                                  | 22 |
| 4.1 General .....                                                                       | 22 |
| 4.2 Geometry .....                                                                      | 22 |
| 4.3 Material .....                                                                      | 23 |
| 4.4 Loads .....                                                                         | 23 |
| 5 Checking the assembly for a specified initial tightening bolt force (or torque) ..... | 23 |
| 6 Calculation parameters .....                                                          | 24 |
| 6.1 General .....                                                                       | 24 |
| 6.2 Flange parameters .....                                                             | 24 |
| 6.2.1 General .....                                                                     | 24 |
| 6.2.2 Flange ring .....                                                                 | 25 |
| 6.2.3 Connected shell .....                                                             | 26 |
| 6.2.4 Flexibility-related flange parameters .....                                       | 27 |
| 6.3 Bolt and washer parameters .....                                                    | 28 |
| 6.3.1 General .....                                                                     | 28 |
| 6.3.2 Effective cross-section area of bolts .....                                       | 28 |
| 6.3.3 Flexibility modulus of bolts .....                                                | 28 |
| 6.3.4 Geometric parameters for washers and contact surfaces .....                       | 28 |
| 6.3.5 Flexibility modulus of washers .....                                              | 29 |
| 6.4 Gasket parameters .....                                                             | 29 |
| 6.4.1 General .....                                                                     | 29 |
| 6.4.2 Theoretical dimensions .....                                                      | 29 |
| 6.4.3 Effective dimensions .....                                                        | 29 |
| 6.4.4 Axial flexibility modulus of gasket .....                                         | 30 |
| 6.4.5 Lever arms .....                                                                  | 32 |
| 7 Forces .....                                                                          | 33 |
| 7.1 General .....                                                                       | 33 |
| 7.2 Applied loads .....                                                                 | 33 |
| 7.2.1 Assembly condition ( $I = 0$ ) .....                                              | 33 |
| 7.2.2 Subsequent conditions ( $I = 1, 2, \dots$ ) .....                                 | 33 |
| 7.3 Compliance of the joint .....                                                       | 34 |
| 7.4 Minimum forces necessary for the gasket .....                                       | 35 |
| 7.4.1 Assembly condition ( $I = 0$ ) .....                                              | 35 |
| 7.4.2 Subsequent conditions ( $I = 1, 2, \dots$ ) .....                                 | 35 |
| 7.5 Internal forces in assembly condition ( $I = 0$ ) .....                             | 35 |
| 7.5.1 Required forces .....                                                             | 35 |

|         |                                                                                                                                                                           |    |
|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| 7.5.2   | Accounting for bolt-load scatter at assembly .....                                                                                                                        | 36 |
| 7.6     | Internal forces in subsequent conditions ( $l = 1, 2, \dots$ ) .....                                                                                                      | 37 |
| 8       | Load limits .....                                                                                                                                                         | 38 |
| 8.1     | General .....                                                                                                                                                             | 38 |
| 8.2     | Bolts .....                                                                                                                                                               | 38 |
| 8.3     | Gasket .....                                                                                                                                                              | 39 |
| 8.4     | Integral flange and collar .....                                                                                                                                          | 39 |
| 8.5     | Blank flange .....                                                                                                                                                        | 41 |
| 8.6     | Loose flange with collar .....                                                                                                                                            | 42 |
| Annex A | (informative) Dimensions of standard metric bolts .....                                                                                                                   | 43 |
| Annex B | (informative) Tightening .....                                                                                                                                            | 44 |
| B.1     | Scatter of initial bolt load of a single bolt — Indicative values $\varepsilon_{1-}$ and $\varepsilon_{1+}$ for a single bolt .....                                       | 44 |
| B.2     | Scatter for the global load of all the bolts .....                                                                                                                        | 44 |
| B.3     | Manual uncontrolled tightening .....                                                                                                                                      | 45 |
| B.4     | Assembly using torque wrench .....                                                                                                                                        | 45 |
| B.5     | Assembly using bolt tensioner .....                                                                                                                                       | 46 |
| Annex C | (informative) Flange rotations .....                                                                                                                                      | 48 |
| C.1     | General .....                                                                                                                                                             | 48 |
| C.2     | Use of flange rotation .....                                                                                                                                              | 48 |
| C.3     | Calculation of flange rotations .....                                                                                                                                     | 48 |
| Annex D | (informative) Use of the calculation method .....                                                                                                                         | 50 |
| D.1     | Calculation method principle .....                                                                                                                                        | 50 |
| D.2     | Mechanical model .....                                                                                                                                                    | 51 |
| D.3     | Required checks .....                                                                                                                                                     | 52 |
| D.4     | Calculation sequence .....                                                                                                                                                | 52 |
| Annex E | (informative) Gasket/flange face friction coefficients examples .....                                                                                                     | 54 |
| Annex F | (normative) Determination of $\Delta_{eGc,l}$ based on a given $P_{QR}$ .....                                                                                             | 55 |
| F.1     | Determination of the deflection occurring during a $P_{QR}$ test .....                                                                                                    | 55 |
| F.2     | Determination of the deflection to be taken into account in the calculation .....                                                                                         | 56 |
| Annex G | (informative) Sealing gasket parameter when no leakage rate is specified .....                                                                                            | 57 |
| Annex H | (informative) Alternative calculation procedure taking into account the plastic deformation of the gasket in subsequent load conditions procedures (after assembly) ..... | 58 |
| H.1     | Introduction .....                                                                                                                                                        | 58 |
| H.2     | Calculation procedure .....                                                                                                                                               | 58 |
| H.2.1   | General description .....                                                                                                                                                 | 58 |
| H.2.2   | No additional plastic deformation .....                                                                                                                                   | 59 |
| H.2.3   | Additional plastic deformation .....                                                                                                                                      | 59 |
| H.3     | Flat gaskets .....                                                                                                                                                        | 59 |
| H.3.1   | Flat gaskets with small or median deformations .....                                                                                                                      | 59 |
| H.3.2   | Flat gaskets with greater deformations .....                                                                                                                              | 61 |
| H.4     | Metal gaskets with curved surfaces (Figures 3b, c, e, f) .....                                                                                                            | 62 |
| H.5     | Metal gaskets with octagonal section (Figure 3d) .....                                                                                                                    | 62 |
| Annex I | (informative) Available, incomplete models for conversion of the leakage rates in different conditions (based on certain flow models) .....                               | 63 |
| I.1     | Introduction and warning .....                                                                                                                                            | 63 |
| I.2     | Flow theory fundamentals .....                                                                                                                                            | 63 |
| I.2.1   | Transport modes .....                                                                                                                                                     | 63 |
| I.2.2   | Case of gases .....                                                                                                                                                       | 64 |
| I.2.3   | Case of liquids: Parallel capillary model .....                                                                                                                           | 65 |
| I.3     | Factors of influence on the leakage rate of gaskets and gasketed joints .....                                                                                             | 65 |
| I.3.1   | List of identified factors .....                                                                                                                                          | 65 |
| I.3.2   | Limits and restriction of the proposed models .....                                                                                                                       | 65 |
| I.3.3   | Dependence on pressure .....                                                                                                                                              | 66 |
| I.3.4   | Dependence on temperature .....                                                                                                                                           | 67 |

|                        |                                                                                                                          |    |
|------------------------|--------------------------------------------------------------------------------------------------------------------------|----|
| I.3.5                  | Dependence on the type of fluid .....                                                                                    | 68 |
| I.3.6                  | Influence of the gasket thickness .....                                                                                  | 68 |
| I.3.7                  | Influence of gasket width .....                                                                                          | 69 |
| I.3.8                  | Influence of gasket stress .....                                                                                         | 69 |
| I.3.9                  | Influence of other factors .....                                                                                         | 69 |
| I.3.10                 | Conclusion on the factors of influence .....                                                                             | 70 |
| I.4                    | Practical application for EN 1591-1 calculations .....                                                                   | 70 |
| I.4.1                  | General .....                                                                                                            | 70 |
| I.4.2                  | Determination of a trend for the leakage rate for the flange connection in “actual” from<br>“reference” conditions ..... | 71 |
| I.4.3                  | Determination of a trend for the leakage rate for the flange connection in “reference”<br>from “actual” conditions ..... | 72 |
| Annex ZA (informative) | Relationship between this European Standard and the Essential<br>Requirements of EU Directive 97/23/EC .....             | 74 |
| Bibliography           | .....                                                                                                                    | 75 |

## Foreword

This document (EN 1591-1:2013) has been prepared by Technical Committee CEN/TC 74 “Flanges and their joints”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2014, and conflicting national standards shall be withdrawn at the latest by June 2014.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 1591-1:2001+A1:2009.

The major changes in comparison with the previous edition include:

- correction of load ratio calculation for blind flanges;
- integration of spacers (washers);
- modification of bolt load ratio calculation;
- integration of lateral forces and torsion moments applied on the bolted joint;
- integration of an alternative calculation method (more precise) for the determination of the gasket effective width (informative annex);
- integration of the possibility to handle gasket creep/relaxation behaviour through additional deflection;
- integration of an informative annex concerning leakage rates conversions;
- integration of the possibility to check a bolted flange connection for a specified initial bolt load value;
- integration of the possibility to perform a calculation even when no tightness requirement is defined through basic gasket parameters (Annex G).

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For relationship with EU Directive(s), see informative Annex ZA, which is an integral part of this document.

EN 1591 consists of several parts:

- EN 1591-1, *Flanges and their joints — Design rules for gasketed circular flange connections — Part 1: Calculation*
- EN 1591-2, *Flanges and their joints — Design rules for gasketed circular flange connections — Part 2: Gasket parameters*
- CEN/TS 1591-3, *Flanges and their joints — Design rules for gasketed circular flange connections — Part 3: Calculation method for metal to metal contact type flanged joint*
- EN 1591-4, *Flanges and their joints — Part 4: Qualification of personnel competency in the assembly of the bolted connections of critical service pressurized systems*

- CEN/TR 1591-5, *Flanges and their joints — Design rules for gasketed circular flange connections — Part 5: Calculation method for full face gasketed joints*

The calculation method satisfies both leak tightness and strength criteria. The behaviour of the complete flanges-bolts-gasket system is considered. Parameters taken into account include not only basic ones such as:

- fluid pressure;
- material strength values of flanges, bolts and gaskets;
- gasket compression factors;
- nominal bolt load;

but also:

- possible scatter due to bolting up procedure;
- changes in gasket force due to deformation of all components of the joint;
- influence of connected shell or pipe;
- effect of external axial and lateral forces and torsion and bending moments;
- effect of temperature difference between bolts and flange ring.

The use of this calculation method is particularly useful for joints where the bolt load is monitored when bolting up. The greater the precision of this, the more benefit can be gained from application of the calculation method.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

## 1 Scope

This European Standard defines a calculation method for bolted, gasketed, circular flange joints. Its purpose is to ensure structural integrity and control of leak tightness. It uses gasket parameters based on definitions and test methods specified in EN 13555.

The calculation method is not applicable to joints with a metallic contact out of the sealing face or to joints whose rigidity varies appreciably across gasket width. For gaskets in incompressible materials, which permit large deformations, the results given by the calculation method can be excessively conservative (i.e. required bolting load too high, allowable pressure of the fluid too low, required flange thickness too large, etc.).

## 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.

EN 13555:2004, *Flanges and their joints — Gasket parameters and test procedures relevant to the design rules for gasketed circular flange connections*

## 3 Notation

### 3.1 Use of figures

Figure 1 to Figure 14 illustrate the notation corresponding to the geometric parameters. They only show principles and are not intended to be practical designs. They do not illustrate all possible flange types for which the calculation method is valid.

NOTE For standard flange types, e.g. as shown in EN 1092 or EN 1759, the relevant figures are the following:

|         |                |
|---------|----------------|
| Type 01 | Figure 10      |
| Type 02 | Figure 12      |
| Type 04 | Figure 12      |
| Type 05 | Figure 11      |
| Type 07 | Figure 12      |
| Type 11 | Figure 6       |
| Type 12 | Figure 13      |
| Type 13 | Figure 14      |
| Type 21 | Figures 6 to 9 |

### 3.2 Subscripts and special marks

#### 3.2.1 Subscripts

*A* – Additional ( $F_A$ ,  $M_A$ )

*B* – Bolt