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Fluid Sealing Association

Flange Gaskets – Glossary of terms

Glossary of sealing terms related to flanges and gaskets

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Flange Gaskets – Glossary of terms

Glossary of sealing terms related to flanges and gaskets

This document is a major update of ESA publication 008/97(*Glossary of sealing Terms – Flanges and Gaskets*)

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The **European Sealing Association** is a pan-European trade association, established in 1992 and representing a strong majority of the fluid sealing industry in Europe. Member Companies are involved in the manufacture and supply of sealing materials, crucial components in the safe containment of fluids during processing and use.

The **Fluid Sealing Association** is an international trade association, founded in 1933. Members are involved in the production and marketing of virtually every kind of fluid sealing device available today. FSA membership includes a number of companies in Europe and Central and South America, but is most heavily concentrated in North America. FSA Members account for almost 90% of the manufacturing capacity for fluid sealing devices in the NASFTA market.

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Contents

1. Introduction

This document is the first revision of ESA Publication n°. 008/97, “Glossary of sealing terms”, reflecting the development of new European and International standards for flange and gasket sealing technology.

The document has been prepared for use by original equipment manufacturers, engineering contractors and end users. The Glossary aims to provide the reader with a comprehensive background to terms used in describing aspects of sealing terminology, allowing the user access to technical considerations involved in safe and reliable sealing. Where the classification of a sealing term is unknown, refer initially to the **Alphabetical Index**, which provides a listing of all terms, including those used colloquially. The remaining sections of this document provide the following information:

Section 2. (page 6) ***Brief description of terms***, deals with each of the sealing terms in concise form, in ***English, French, German, Italian*** and ***Spanish***. The section is in alphabetical order according to the ***Term English***.

Section 3. (page 15) ***Detailed descriptions***, gives a more extensive technical description of appropriate terms in alphabetical order.

Section 4. (page 46) ***History of European norms and gasket parameters***, which gives information on flange calculations and the determination of the required gasket parameters

Section 5. (page 48) ***Typical flange and gasket layouts***, gives information on the most common types employed in the process industries.

Section 6. (page 50) ***Relevant units and conversion factors***, provides relationships between appropriate units.

Section 7. (page 55) ***Relevant standards***, describes the current national and international standards which are involved in sealing technology.

Section 8. (page 57) ***Standards issuing organisations and other relevant bodies***, gives details about the key groups involved in establishing standards which may have an impact on the European Union.

Section 9. (page 60) ***References and further reading***.

Section 10. (page 61) ***Common abbreviations***, gives the full description of relevant abbreviations.

Section 11. (page 62) ***Alphabetical index***, lists all terms alphabetically, including colloquial terms.

Please note that in colloquial English, a force per unit area is often referred to as ``stress'', rather than ``pressure''. Whilst this is technically incorrect, it is in common usage. Please note that in this document, the term ``pressure'' is used in such circumstances.

2. Brief description of terms

This section describes terms applied to gasket technology only. The section is listed in alphabetical order (by ***Term English***) and describes only those terms which are technically correct (for colloquial terms which are technically misleading, please refer initially to the ***Alphabetical index***, which will provide suitable cross references). Further details of the more elaborate items are available in the section entitled, ***Detailed descriptions*** (indicated by the term in ***bold italics***). Blank spaces indicate lack of equivalent term in that language:

Definition	***Term English***	***Term French***	***Term German***	***Term Italian***	***Term Spanish***
Ability of a material to resist mechanical wear	Abrasion resistance	Résistance à l'abrasion	Abriebfestigkeit	Resistenza all'abrasione	Resistencia a la abrasión
Continuation of vulcanisation after the desired cure is effected and the heat source removed	After cure	Post vulcanisation	Nachvernetzung	Post-trattamento	Post-curado
To undergo changes in physical properties over time	Ageing	Vieillissement	Alterung	Invecchiamento	Envejecimiento
Designated as 23°C (± 5°C) / 73°F(± 9°F)	Ambient temperature	Température ambiante	Umgebungstemperatur	Temperatura ambiente	Temperatura ambiente
Load generated by the bolts on gasket during assembly	Assembly load	Effort/ force D'assemblage	Einbauschraubenkraft	Carico per assemblaggio	Carga de apriete
Pressure generated on gasket during assembly	***Assembly pressure***	***Contrainte d'assemblage***	***Einbauflächen-pressung***	***Pressione d' assemblaggio***	***Presión de montaje***
A ring (often metallic) around the outer periphery of the sealing material, to prevent extrusion	Back-up ring	Bague anti-extrusion	Äußere Einfassung, Äußerer Stützring	Anello antiestrusione	Anillo anti-extrusión
Gasket material manufactured by a paper-making process	Beater addition product	Technique papetière	Beater Material	Fibra cartacea per guarnizioni	Producto tipo beater addition
Washer with a slightly conical section, which acts as a spring when compressed axially	Belleville washer	Rondelle ressort	Tellerfeder	Rondella a molla	Arandela Belleville
A substance (usually organic) used to bond the components of a gasket material into a matrix	Binder	Agglomérant, liant	Binder, Bindemittel	Legante, agglomerante, colla	Ligante
Flange with no bore, used to provide a sealed closure to a flanged opening	Blank flange, blind flange	Bride pleine	Blindflansch	Flangia cieca	Brida ciega
Threaded fastener used to secure the members of a flange joint together and to apply compressive force to flange	Bolt	Boulonnerie	Bolzen, Schraube	Perno, bullone	Tornillo
Means of applying compressive pressure to the gasket	Bolt load	Contrainte d'assise	Schraubenkraft	Carico sul bullone	Carga de los tornillos sobre la junta

Definition	***Term English***	***Term French***	***Term German***	***Term Italian***	***Term Spanish***
Tension (tensile stress) created in a bolt by assembly preloads and/or thermal expansion, service conditions etc	Bolt tension	Contrainte dans le bouon	Bolzenspannung, Schraubenspannung	Tensione del bullone	Tensión en el tornillo
A machine with two or more heavy rolls, which may be internally heated or cooled, used for the manufacture of compressed sheeting materials	Calender, \`sheeter'	Calandre	Kalander	Calandra	Calandra
	Centering ring (*see* Guide ring)				
An alpha-numeric designation related to a combination of mechanical and dimensional characteristics of a component of a pipework system. It comprises the word \`CLASS', followed by a dimensionless whole number and is used to identify ranges of related components in a number of different standards (for example, EN 1759)	Class	Class	Class	Classe	Clase
Gasket material, primarily containing fibres, rubber and fillers, manufactured on a calender under high load	Compressed fibre sheet, calendered sheet	Joint calandré, Feuille calandrée	Kalandrierte Faserstoffplatte	Foglio calandrato	Plancha de fibra comprimida
Percentage reduction of thickness under a compressive pressure, applied at a constant rate, at room temperature	***Compressibility***	***Compressibilité par rapport à l'épaisseur, Compressibilité***	***Kompressibilität, Kaltstauchwert***	***Comprimibilità***	***Compresibilidad***
Residual deformation of a gasket after it has been subjected to, and then released from a specified compressive pressure, over a defined time and at a given temperature	***Compression Set***	***Déformation permanente, Déformation rémanante à la compression***	***Bleibende Verformung, Druckverformungs-rest***	***Deformazione permanente***	***Deformación remanente***
Property of gasket material to swell to a defined extent when in contact with the retained fluid, to provide additional sealing pressure	***Controlled swell***	***Gonflement controlé***	***Kontrollierte Quellung***	***Dilatazione controllata***	***Hinchamien-to controlado***
Gasket with compliant, wave-form metal core, faced usually with a sealing material	Corrugated metallic gasket	Joint ondulé	Wellringdichtung	Guarnizione metallica ondulata	Junta metálica corrugada
Percentage loss of thickness over a specified time under constant load, applied at a specified rate, at a specified temperature	***Creep deformation***	***Fluage***	***Kriechrelaxation***, ***Kriechverformung***	***Deformazione viscosa, Scorrimento plastico***	***Fluencia***

Definition	*Term English*	*Term French*	*Term German*	*Term Italian*	*Term Spanish*
Cross-linking reaction of elastomer with various chemicals, creating a matrix of greater stability	Cure	Vulcanisation	Vernetzung, Polymerisation	Indurimento per polimerizzazione	Reticulación
A designation of nominal size of components in a pipework system, defined in EN ISO 6708	DN	DN	DN	DN	DN
That part of the actual width of a gasket considered to contribute to the performance of the gasket	***Effective sealing width***	***Largeur efficace***	***effektive Dichtbreite***	***Sezione di tenuta***	***Ancho efectivo de sellado***
Partial relaxation of bolt load on tightening adjacent bolts, creating non-uniform loading	Elastic interaction	Interaction elastique	Elastische Entspannung	Interazione elastica	Interacción elástica
Property of a body to recover its original size and shape immediately after removal of the external forces which cause it to deform	Elasticity	Elasticité	Elastizität	Elasticità	Elasticidad
Generally long chain polymer molecules, which show elastic properties	Elastomer	Élastomère	Elastomer	Elastomero	Elastómero
A gasket design in which the gasket material is enclosed within an outer cover (typically PTFE) to minimise chemical degradation by the sealed fluid	Envelope gasket	Joint jacquette	umhüllte Dichtung, Hüllendichtung	Guarnizione a busta	Junta recubierta
Metallic cover around inner periphery of gasket material, to minimise chemical degradation by the sealed fluid. Depending on selection of geometry and metal, it may also improve sealability and blowout resistance	Eyelet	Joint avec insert intérieur	Bördel	Bordino interno	Refuerzo o inserción interior
The weakening or deterioration of a material caused by cyclic or continual application of stress	Fatigue	Fatigue	Materialermüdung	Affaticamento	Fatiga
Strip form sealing material wound between the metallic strip in a spiral-wound gasket	Filler	Remplissage	Füllstoff	Carica	Relleno
Basic component of a gasketed joint assembly, incorporating a substantially radially extending collar for the purpose of joining two or more items of process equipment	Flange	Bride	Flansch	Flangia	Brida
Deformation of a flange caused by imposed forces	***Flange rotation***	***Rotation des Brides***	***Flanschblattneigung***	***Deformazione della flangia***	***Rotación de la brida***

Definition	***Term English***	***Term French***	***Term German***	***Term Italian***	***Term Spanish***
A flange where the entire mating faces are flat	Flat-face flange	Faces plates	Flansch ohne Dichtleiste	Flangia piana	Brida plana
Ability of a body to deform or yield due to the action of external forces.	Flexibility	Flexibilité	Flexibilität, Biegefestigkeit	Flessibilità	Flexibilidad
Measure of the ability of the material to resist chemical attack	Fluid resistance, chemical compatibility	Compatibilité, Résistance chimique	Medienbeständigkeit	Compatibilità chimica, Resistenza al fluido	Resistencia al fluido (compatibilidad química)
A gasket which covers the entire flange surface extending beyond the bolt holes	Full-face gasket	Joint percé	Dichtung mit Schraubenlöchern	Guarnizione intera	Junta de cara completa
Deformable material (or combination of materials) intended to be clamped between flanges to prevent leakage of contained fluid	Gasket	Joint	Dichtung	Guarnizione	Junta
Gasket parameters derived from the ROTT test (ASTM standard in preparation)	***Gasket parameters a, G_b, G_s***	***ROTT test constante***	***Dichtungskennwerte a, G_b, G_s***	***Fattori delle guarnizioni a, G_b, G_s***	***Constantes de junta a, G_b, G_s***
The assembly of components (e.g flanges, bolts, gaskets) required to join two or more items of process equipment and to prevent leakage	Gasketed joint, Flanged joint	Assemblage d'étanchéité	Dichtstelle, Dichtverbindung, Flanschverbindung	Connessione flangiata	Unión embridada
Point at which the load on a gasket can be considered to react for moment calculation purposes	Gasket load reaction	Force de reaction du joint	Hebelarm der Dichtkraft a_D	Reazione al carico della guarnizione	Reacción de la junta
Effective compressive load per unit of gasket area	***Gasket pressure*** *(colloquially "Gasket stress")*	***Pression de serrage***	***Dichtungsflächen-pressung***	***Pressione sulla guarnizione***	***Presión sobre la junta***
Distance on a bolt between the inner face of a nut and the inner face of the bolt head	Grip length	Longueur de serrage	Einspannlänge	Lunghezza della presa	Longitud de agarre
An extension of a gasket for the purpose of locating it centrally on a flange	Guide ring	Centreur	Zentrierring, Außenring, Innere Stützring	Anello di centraggio	Anillo centrador
Differentiation between predominantly hard, metal-based gaskets (e.g. spiral wound) and softer or fibre-reinforced materials	*Hard* and *soft* gasket materials	Joint mou ou dur	-------	Materiali per guarnizioni morbidi e rigidi	Materiales de junta *duros* y *blandos*
Percentage reduction in thickness under constant compressive pressure at elevated temperature	Hot creep during service	Fluage en fonction de l'augmentation de temperature	Warmsetzwert, Warmverformung	Deformazione viscosa a caldo durante il servizio	Fluencia en caliente durante el servicio

Definition	***Term English***	***Term French***	***Term German***	***Term Italian***	***Term Spanish***
Relieving force caused by the pressure of the retained fluid, resulting in a reduction in gasket pressure and an increase in bolt load (see also, "***Off-loading***")	Hydrostatic end thrust	Force hydrostatic, effet de fond	Innendruckentlastung	Spinta idrostatica	Empuje hidrostático axial
The load under which the initial gasket thickness is determined during laboratory testing	Initial preload at the start of a test procedure	Effort initiale avant essai	Vorlast	Precarico iniziale prima de la proba	Precarga Inicial para ensayo
A gasket lying wholly within a ring of bolts	Inside bolt circle, (IBC) gasket	Joint inscrit	Dichtung innerhalb Schraubenkreis	Guarnizione parziale	Junta IBC
Fluid pressure applied to the joint	Internal pressure	Pression interne	Innendruck	Pressione interna	Presión interna
A gasket design in which the gasket material is enclosed totally within an outer metal cover	Jacketed gasket	Metallo plastique	Metallummantelte Dichtung, Metallumhüllte Dichtung	Guarnizione avvolta	Junta metaloplástica
Metal gasket with grooved faces, with or without resilient sealing layer on surfaces	Kammprofile gasket	Joint strié revêtu	Kammprofildichtung	Guarnizione Kammprofile	Junta Kammprofile
Quantity of fluid passing through the body and/or over the faces of a gasket per unit periphery of the gasket over a specified time	***Leakage rate***	***Débit de fuite, Taux de fuite***	***Leckagerate***	***Livello delle perdite***	***Caudal de fuga***
Reduction of thickness under specified load and temperature conditions	***Load compression characteristic***	***Courbe de compression, Courbe de ecrasement***	***Setzbetrag***	***Caratteristiche di compressione al carico***	***Curva Característica de carga de compresión***
Defined in the ASME code as the factor which provides additional load on the gasket, in order to ensure adequate sealing pressure when internal pressure is applied	***Maintenance Factor ``m"***	***Facteur ``m"***	***"m"-Faktor***	***Fattore «m»***	***Factor de mantenimiento "m"***
Maximum allowable pressure during assembly to prevent unacceptable creep or failure of the gasket material under operating conditions	Maximum assembly pressure	Pression maximale admissible	Maximal zulässige Flächenpressung im Einbauzustand	Massima pressione d' assemblaggio	Presión máxima de montaje
Maximum allowable pressure under operating conditions to prevent unacceptable creep relaxation or failure of the gasket material	***Maximum gasket pressure under operating conditions***	***Pression / contrainte maximale de serrage en service***	***Maximal zulässige Flächenpressung bei Betriebs-bedingungen***	***Massima pressione di servizio ammissibile sulla guarnizione***	***Presión máxima sobre la junta en condiciones de servicio***

Definition	Term English	Term French	Term German	Term Italian	Term Spanish
Minimum pressure required on assembling the gasket in the flange to achieve the desired level of sealing under operating conditions See Section 3, ***Principal forces on the flanged joint***	Minimum assembly pressure	Pression / contrainte minimale d'assemblage	Mindestflächen-pressung im Einbauzustand	Minima pressione d'assemblaggio	Presión mínima de montaje
Minimum pressure required on gasket to remain within leakage class under operating conditions See Section 3, ***Principal forces on the flanged joint***	Minimum gasket pressure under operating conditions	Pression / contrainte minimal de serrage en service	Mindestflächen-pressung im Betriebszustand	Minima pressione sulla guarnizione durante il funzionamento	Presión mínima sobre la junta en condiciones de servicio
Defined in the ASME code as the pressure over the contact area of the gasket required to provide a sealed joint, with no internal pressure in the joint	Minimum seating pressure "y"-factor (yield factor)	Facteur-"y", Pression d'assise	Vorverformungs-pressung, "y"-Faktor	Minima pressione d'alloggiamento Fattore «y»	Presión mínima de asentamiento (factor "y")
	Modulus of elasticity (*see* Secant or unloading modulus of elasticity)				
An alpha-numeric designation of size for components of a pipework system	Nominal pipe size (NPS/DN)	Diametre nominal du tube	Nominaler Durchmesser (des Rohres)	Dimensioni nominali della tubazione (NPS)	Diámetro nominal de la tubería
Reduction of gasket load after assembly caused by for example bending moments or hydrostatic end thrust	***Off-loading***	***Desserrage***	***Entlastung***	***Discarico***	***Descarga***
Pressure retained on the gasket under operating conditions (the situation after initial tightening when the flange has been pressurised, is at operational temperature, and creep and other relaxation mechanisms have occurred) See Section 3, ***Principal forces on a flanged joint***	Operational gasket pressure	Pression / contrainte residuelle en service	Flächenpressung unter Betriebsbedingungen	Pressione di servizio sulla guarnizione	Presión sobre la junta en servicio
A seal (often referred to as a packing or moulded ring in the USA), usually elastomeric or hollow metal, of circular cross section, confined in a groove	O-ring	Joint torique	O-Ring	O-ring	Junta tórica
A measure of the ease with which a fluid can pass through a gasket material	***Permeability***	***Perméabilité***	***Durchlässigkeit***	***Permeabilità***	***Permeabilidad***
Tables defining pipe thickness in relation to nominal bore and process pressure, according to ASME and ISO standard	Pipe schedules	Epaisseur du tuyau	Rohrdiagramm	Diagrammi delle tubazioni	Schedules de tuberías

Definition	***Term English***	***Term French***	***Term German***	***Term Italian***	***Term Spanish***
Alpha-numeric designation related to mechanical and dimensional characteristics of a component of a pipework system. It comprises of the letters ``PN'', followed by a number. Used to identify ranges of related components in a number of standards (e.g. EN 1092) and is defined in EN 1333	PN	PN, Pression nominale	PN	PN	PN
Difference between the theoretical and actual density of a material (as a result of small voids or interstices within the material matrix)	Porosity	Porosité	Porosität	Porosità	Porosidad
Load per unit area on a body	Pressure	Pression	Pressung	Pressione	Presión
The maximum, safe, static, tensile load which can be placed on a fastener without causing it to yield. It is an absolute value, sometimes defined as force (N), or pressure (MPa)	Proof load	Contrainte maximale autorisée	Zugelassene Belastung	Carico di prova	Carga de prueba
The rating of a flange manufactured from a specified material, indicating the allowable pressure (non-shock) at which it may operate at a specific temperature (e.g. see tables in EN 1092 and EN 1759)	p/T rating	Pression température associées	P/T-Rating, Druck/Temperatur Beziehung	Classificazione di p/T (pressione/ temperatura)	Índice p/T
Numerical value resulting from the multiplication of the internal pressure by the temperature of the fluid being sealed. Provides only a *rough* guide for limiting gasket usage and consequently the ESA recommends that this term should NOT be used	PT value	Relation pression température PT, (indication grossière pour l'utilisation du joint)	PT Wert	Valore di PT	Valor PT
A flange which makes contact with its mating joint member only in the region where the gasket is located. The faces of the flange do not make contact with each other at the bolt circle	Raised-face flange	Bride à faces surélevées	Flansch mit Dichtleiste	Flangia con piano sollevato	Brida con resalte
Increase of thickness over the compressed thickness, once the compressive load has been removed	***Recovery***	***Reprise élastique***	***Rückfederung***	***Recupero elastico***	***Recuperación***
Material (such as fibre or metal) within the gasket matrix, which imparts increased strength or other desirable properties	Reinforcement	Renforcement	Materialverstärkung	Materiale di rinforzo	Refuerzo

Definition	***Term English***	***Term French***	***Term German***	***Term Italian***	***Term Spanish***
Surface pressure remaining on a gasket after service for a given time	***Residual stress***	***Contrainte résiduelle***	***Druckstandfestigkeit***	***Tensione residua***	***Compresión remanente***
Room temperature operational tightness test. See also ***Gasket factors derived for the ROTT test***	ROTT	ROTT	ROTT	ROTT	ROTT
A flange system in which both flanges are grooved to accept a ring-joint gasket	Ring type joint flange	Bride RTJ	RTJ-Flansch	Flangia con sede interna	Brida RTJ
A gasket machined from metal (usually oval or octagonal in cross-section) and used in conjunction with ring-joint flanges	Ring type joint gasket	Joint métallique pour bride RTJ	RTJ-Dichtung	Guarnizione interna metallica	Junta metálica para brida (RTJ)
Ability of a gasket material to prevent flow of fluid through its body and between the gasket / flange interfaces	***Sealability***	***Étanchéité***	***Dichtfähigkeit, Dichtheit***	***Capacità di tenuta***	***Estanqueidad***
Ratio between stress and strain during unloading, a parameter used in current flange calculations	Secant or unloading modulus of elasticity	Module élastique	Ersatz-Elastizitätsmodul	Modulo di elasticità	Módulo de elasticidad
Application of a sealant bead onto the gasket surface for seal enhancement	Selective area coating	Traitement de surface du joint	Teilbeschichtung	Trattamento area di tenuta	Cordon de sellado
Gasket design which uses internal fluid pressure to create or increase the contact pressure	Self-energising gasket	Joint autoclave	Selbstdichtende Dichtung	Guarnizione autoserrante	Junta autoapretante
A method by which selective area coating can be applied and / or to add a company brand	Silk screen printing	Sérigraphie	Siebdruck	Serigrafia	Serigrafía
A gasket design which is formed by winding spring-like metal, usually ``V''-shaped, and a suitable filler material into a spiral	Spiral-wound gasket	Joint spiralé	Spiraldichtung, Spiralring-dichtung	Guarnizione a spirale	Junta espirometálica
The ``stiffness'' of a bolt, defined as the load generated, divided by its elongation after tensioning	Spring constant	Rigidité de la boulonnnerie	Federkonstante	Costante elastica	Constante de elasticidad
Ability of a body to resist deformation due to the action of external forces. Reciprocal of elasticity	Stiffness	Rigidité	Steifigkeit	Rigidità	Rigidez
Change in dimensions or shape of a body due to applied force or stress	Strain	Deformation	Deformation, Verformung	Deformazione	Deformación

Definition	***Term English***	***Term French***	***Term German***	***Term Italian***	***Term Spanish***
Load per unit area on a body	Stress	Contrainte	Spannung	Sforzo	Esfuerzo
A common form of cracking in which an electrolyte encourages the growth of a crack in a bolt under stress	Stress corrosion cracking	Corrosion sous tension	Spannungsriß-korrosion	Formazione di cricche per corrosion elettrolitica sotto sforzo	Corrosión bajo tensión
Loss of stress at a constant gasket thickness as a function of time, after application of a specified compressive load at a specified rate, at constant temperature	***Stress relaxation***	***Relaxation***	***Spannungs-relaxation***	***Rilassamento sotto sforzo***	***Relajación***
Fastener which is threaded at both ends	Stud	Goujon	Gewindebolzen, Gewindestange	Prigioniero	Esparrago
Fine irregularities of the flange surface finish	***Surface roughness***	***Rugosité***	***Rautiefe***	***Ruvidità superficiale***	***Rugosidad Superficial***
Breaking tensile force divided by the original cross-sectional area	Tensile strength	Résistance à la rupture	Bruchspannung, Zugfestigkeit	Resistenza alla trazione	Resistencia a la tracción
Specific leakage rate range	***Tightness Class***	Classe d'étanchéité	***Dichtheitsklasse***	Classe di tenuta	Clase de Estanqueidad
Mathematical relationship between the measured specific leakage rate and the internal fluid pressure causing it	***Tightness Parameter T_p***	***Classe d'etanchéité T_p***	***Dichtheitsparameter T_p***	Parametro di tenuta T_p	Parámetro de Estanqueidad T_p
A flange system in which one flange is provided with an annular tongue and the other with a complimentary groove to accept it	Tongue and groove flange	Bride à double emboitement	Nut und Feder Flansch	Flangia con connessione a linguetta e cava	Brida de doble acoplamiento
Cross-linking reaction of elastomer with sulphur or other agents, creating a matrix of greater stability	Vulcanisation	Vulcanisation	Vulkanisation	Vulcanizzazione	Vulcanización
Gasket design which consists of two metal rings welded first to the flanges and then to each other	Weld gasket	Joint soudé	Schweißdichtung	Guarnizione saldata	Junta soldada

3. Detailed descriptions

In this section, the more complex sealing terms are given an extended technical description and listed in alphabetical order. Related terms which have their own entries in this section are indicated in ***bold italics***. Please note that colloquial or ambiguous terms are shown in *italics*.

Notation

The following symbols apply throughout these descriptions:

Symbol	***Definition***
F	Force
h	Thickness (height)
λ	Leakage rate
$L_{0.01}$–$L_{1.0}$	Tightness classes (according to EN 13555)
p	Internal (process) pressure
σ	Compressive pressure (applied to gasket)
T1–T5	Tightness classes (according to PVRC)
T_p	Tightness parameter

3.1. Assembly pressure

Definition: Pressure generated on gasket during assembly

Unit:
N/mm^2 – metric
MPa – SI
psi – imperial

Colloquial terms:
Assembly stress
Sealing stress
Sealing pressure

Related terms:
Gasket pressure
Minimum assembly pressure
Maximum assembly pressure

Standards:
EN 13555 (Symbol Q_A)
EN 1591-1 (Symbol Q_A)
EN 1591-2 (Symbol Q_A)

Purpose: Q_A will be limited by either the maximum bolt load available, the maximum flange loading that can be permitted or the maximum gasket loading, Q_{SMAX} that can be withstood. Q_A should be as high as possible to reach lowest emissions and highest residual gasket pressure.

The ***assembly pressure*** is the pressure required to be applied onto the gasket surface to ensure that:

- the gasket is safely clamped between the flange surfaces
- unevenness, unparallelities and distortions are levelled out or equalised
- under operational conditions the required level of sealing is achieved by sufficient compression of the gasket

Normally, in industrial flanges the pressure is generated by bolts which are torqued. By this they transfer their tension as a force to the flanges and further to the *effective area* of the gasket. The total forces of each bolt related to the effective area of the gasket is the ***assembly pressure***.

There are also alternatives to bolts for the generation of assembly pressure. For example, special clamping devices are available, although the pressure generated is generally low. These systems are therefore only suitable for light flanges and *soft gaskets*. Furthermore, screwed pipe connections are also available.

3.2. <u>Blow-out safety</u>

Definition: Requirement for a joint to ensure that the gasket cannot be blown or forced out of place, or allow excessive leakage, under specified service conditions.

Unit: Typically classified in terms of leakage rates, mg/(s m), cm^3/min, ml/min

Related terms: ***Leakage rate***
Internal pressure

Standards: VDI 2200
Hot Blow-out Test (PVRC HOBT)

Purpose: In common understanding the aim of the *blow-out resistance* is to avoid sudden leakage through seal burst at a certain internal pressure.

A complete gasket or part of a gasket shall not be blown or forced out of a flange joint due to the influence of the following factors: insufficient gasket pressure, excessive tensile stresses or gasket creep and the associated relaxation.
Service medium shall not escape between gasket and flange as a result of insufficient gasket stress.
Specific leakage limits shall not be exceeded because of unduly high permeability, relaxation, or chemical attack on the sealing material during operation.

Comments: *Blow-out safety* (=blow-out resistance) is one of the key requirements for sealing materials. It is an important consideration particularly when handling hazardous or dangerous media.

No gasket blow-outs are likely to occur if the flange/gasket design calculations are accurate, the gaskets are selected to match the application concerned, the equipment is correctly assembled and suitable operation conditions are used. Defective gaskets not considered.

3.3. Compressibility

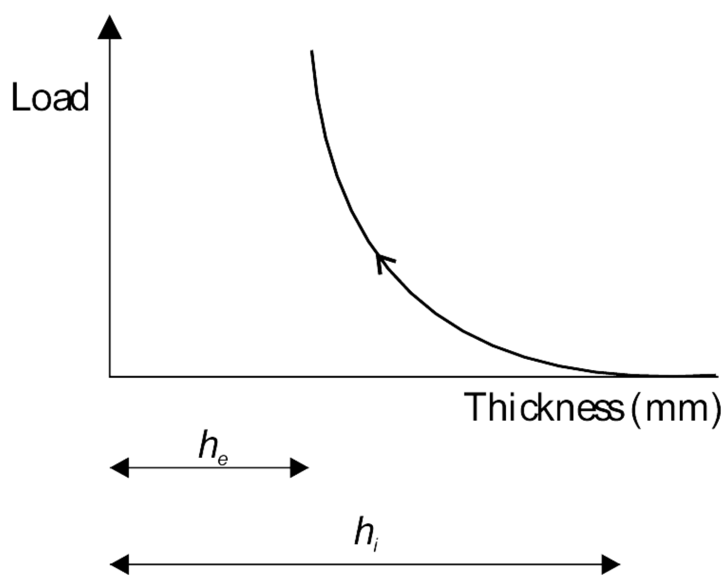
Definition: Percentage reduction of thickness under a compressive pressure, applied at a constant rate, at room temperature

Unit: %

Related terms: ***Compression set***
Creep deformation
Elasticity
Recovery

Standards: ASTM F 36
BS 7531
DIN 28090–2

Purpose: ***Compressibility*** is one of the primary parameters for the characterisation of gasket materials. It gives the basis to measure its elastic and plastic deformation properties, and an indication of the ability of the material to conform to the flange surface irregularities.



For ASTM and BS calculations, ***Compressibility*** is expressed as:

Compressibility (%) = $100 [(h_i – h_e) / h_i]$

where h_i = initial thickness under pre-load
h_e = thickness after compression

For DIN calculations, the following formula applies for the Compressive creep test:

$\varepsilon_{KSW} = 100 [(h_{D2} – h_{D3}) / h_{D1}]$

where ε_{KSW} = relative compressibility (also referred to as Compression modulus *sic*)
h_{D1} = initial thickness
h_{D2} = thickness under pre-load
h_{D3} = thickness under applied load

Comments: ***Compressibility*** gives an indication of the ability of a gasket material to conform to the flange surface irregularities. The higher the ***compressibility***, the more readily it will fill surface irregularities.

The ***compressibility*** of a structure is a function of various parameters:

- nature of the constituents
- geometry of the structure
- rate of application of the compressive force
- temperature
- isotropy of the structure

For the ***compressibility*** values to be reproducible, the parameters must be identical

Note that there is no direct equivalent to a compressibility factor in EN 13555

3.4. Compression set

Definition: Residual deformation of a gasket after it has been subjected to, and then released from a specified compressive pressure, over a defined time at a given temperature.

Unit: %

Colloquial term: *Permanent set*

Related terms: ***Compressibility***
Recovery

Standards:

ASTM D 395	– Method A	Compression set under constant force
	– Method B	Compression set under constant deflection
BS 903 Part A	– Compression set after strain. This standard previously included compression set after constant stress, but this was deleted in 1974	
DIN 53517	– Testing of Elastomers ; determination of residual stress under constant deflection at low temperatures	
ISO 815	– Compression set under constant deflection at normal and high temperatures	

Purpose: ***Compression set*** indicates the permanent deformation which remains after relieving the load. It is caused by ***creep deformation*** and ***stress relaxation*** of the gasket material which has been subjected to compression load, temperature and medium, over time. The actual value depends on the material composition, the temperature, and the nature and duration of the pressure. Similar changes occur on enbrittlement or ageing.

Compression set may be calculated from the following formulae. Compression set under constant force (ASTM Method A) is the procedure used most commonly in the industry, in which the following formula applies:

Compression set by Method A = $100\ [(h_I - h_F) / h_I]$

Compression set under constant deflection (ASTM Method B) includes a compression limiter and the following formula applies:

Compression set by Method B = $100\ [(h_I - h_F) / (h_I - h_s)]$

where h_I = initial specimen thickness
h_F = final specimen thickness (after testing)
h_s = limiter thickness

The above tests are carried out usually in air. Alternatively, a test in specified media (oil, steam etc) can be used to indicate additional influences (swelling, shrinking etc.) of the contact medium on the gasket material.

Comments A gasket material should be soft and flexible to fill all irregularities of the flange surface, while it must also be elastic to ensure long term sealing. In cases of high compression on an elastomer there will be both elastic deformation and plastic flow, resulting in a permanent deformation and therefore a decrease in the recovery after release.

Typically, ***compression set*** is used for long term rubber characterisation.

3.5. Controlled swell

Definition: Property of a gasket material to swell to a defined extent when in contact with the retained fluid, to provide additional sealing pressure

Unit: %

Colloquial term: *Swell*

Related terms: Thickness change after fluid immersion
Weight change after fluid immersion
Fluid resistance

Standards: ASTM F 104
ASTM F 146
DIN 3535, Part 5

Test procedures: ASTM F 146
DIN 3535, Part 5

Purpose: ***Controlled swell*** means a degree of swelling, high enough to help in containing the fluid, but not too high as to degrade the elastomeric binder and cause the gasket to fail.
Controlled swell provides a self-sealing effect for flanges with low or unequal surface pressure.

Comments This effect is desirable in certain applications, such as those with readily deformable flange material by which the original surface pressure becomes too low to provide a satisfactory seal. The gasket material will swell to fill any space originally filled by the gasket upon initial installation. A controlled swell material should not be degraded by the fluid with which it is in contact. For a given swell, it is desirable to have a low increase in weight (caused by absorption of the fluid).

Gasket materials are often designed to enhance sealing by swelling in service. Such a material is able to compensate for differences in gasket pressure between bolts, such as in lightweight, pressed metal flanges with widely spaced bolts.

Swell is measured as the increase in thickness after immersion in a fluid. Normally this is tested in ASTM fluids (such as Oil N$^{o.}$ 3, Fuel B, etc., which are defined in ASTM D 471). Note however that “Oil N$^{o.}$ 3” has now been replaced in the ASTM standards with IRM 903. Thickness increase percentages for materials categorised as “controlled swell” normally range from 20% to 70% thickness increase in ASTM Oil N$^{o.}$ 3 or ASTM Fuel B, but can be “swellable” in any fluid (such as water).

3.6. **Creep deformation**

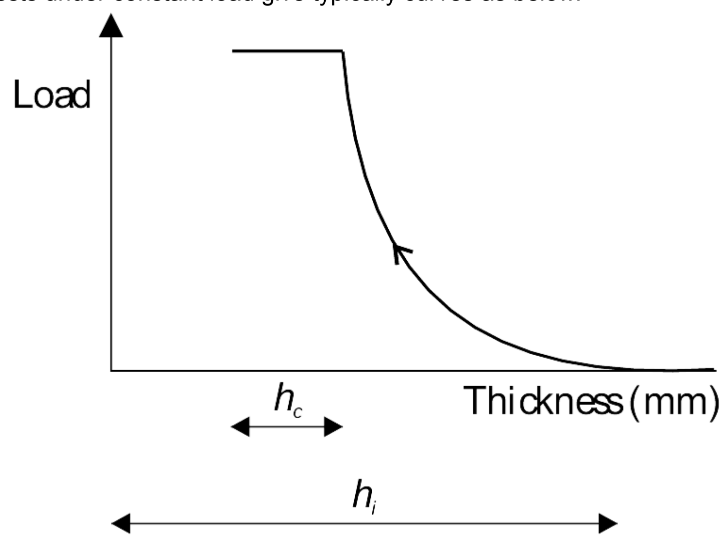
Definition: Percentage loss of thickness over a specified time under constant load, applied at a specified rate, at a specified temperature

Unit: %

Related terms: ***Stress relaxation***
Compression set

Standards: DIN 28090-2

Purpose: ***Creep deformation*** gives an indication of the effect of time on the deformation behaviour of gasket materials. Compression and relaxation tests under constant load give typically curves as below:



Creep deformation (%) = 100 [h_e / h_i]

where:
h_i = initial thickness of sample
h_c = change of thickness under constant load at a given temperature over time

Comments: ***Creep deformation*** of a structure is a function of various parameters:
- nature of the constituents
- geometry of the structure
- rate of application of the compressive force
- time
- temperature
- isotropy of the structure

Tests such as ASTM F 38 do not measure creep alone, since both ***creep deformation*** and ***stress relaxation*** are measured simultaneously.

3.7. Effective sealing width

Definition: That part of the actual width of a gasket which is considered to contribute to the performance of the gasket

Unit:
mm – metric
inch – imperial

Colloquial term: *Effective gasket width*

Standards:
AD 2000 B7
ASME Boiler and Pressure Vessel Code, Section VIII
BS 5500
EN 1591
EN 13445
NF E 29-001

Purpose: For circular gaskets, the ***effective sealing width*** is the part of the radial width of the gasket which is considered in calculations of the forces necessary to seat the gasket and achieve a defined level of sealing.

3.8. Emissions

Definition: The release of process fluid into the atmosphere (land, water or air).

Units: Typically classified in terms of g/h (mass over time). Some more qualitative measurement systems use ppm (parts per million), although in reality this is a measure of concentration.

Related term: ***Leakage rate***

Legislation: EU **Directive 96/61** on Integrated Pollution Prevention and Control (IPPC Directive)

Purpose: The purpose of the Directive is to achieve integrated prevention and control of pollution arising from certain industrial activities, which have been classified as key sources of potential pollution.

The IPPC Directive became mandatory in October 2007, applying to specific sectors of industry considered by the European Commission to be the greatest potential sources of industrial pollution.

The Directive provides an integrated approach for a potential pollutant across all media which might be affected. All industrial installations covered by the legislation must be authorised to operate through a permitting system, based upon the principle of best available techniques (**BAT**). This must take into account the industrial sector economics, the technical characteristics of the installation, its geographical location and local environmental conditions. These factors vary throughout Europe, so it is anticipated that significant differences will emerge in the emission limits and BAT applied by the Member States. The Directive recognises this fact, and sets out a procedure for the exchange of information on BAT and emission limits, through a series of so-called BAT Reference (**BREF**) notes, developed by experts from the industrial sectors involved. In view of this, the **European IPPC Bureau** was established at the Joint Research Centre in Seville, to assist information exchange on BAT and publish the BREF notes. In total, 33 BREF notes have been published and already a number are under review for updating. The BREF's may be downloaded from the European IPPC Bureau website at: http://eippcb.jrc.es/

Importantly, the IPPC Directive is the fundamental “umbrella” legislation across the EU, requiring EU Member States to transpose the regulations into national legislation. For example, in Germany the TA-Luft is the main item of national legislation for environmental protection; recent updates have included amendments which have been transposed from the IPPC Directive. In addition, a number of national “guidelines” have been introduced (such as VDI 2200 and 2440) to provide guidance on the implementation of TA-Luft for specific facilities.

It is important to recognise that a large proportion of industrial emissions are those **anticipated** from the processes themselves, under the control of the plant operator, and will not be considered in detail here. However, a significant portion of industrial emissions occurs through **unanticipated** or spurious leaks in process systems, often referred to as "fugitive emissions". This is an area where sealing technology can play a major role and has been a prime focus of attention for the European Sealing Association (ESA).

In the development of their own BREF notes, the industry sectors covered by the IPPC regime focussed on items of major pollution potential, usually process derived and with little relevance to sealing. As a result, a number of the early BREF notes had only limited information regarding BAT for sealing technologies. Such inadequacies may provide incomplete advice on BAT, especially in relation to sealing technologies.

Consequently, on its own initiative, the ESA has developed a “horizontal” BAT guidance note on sealing technology, as a guideline specifically for industries which fall under the IPPC regulations. For an industrial sector not covered directly by the IPPC Directive, the sealing industry took a lead in developing this BAT guidance note voluntarily. It is pleasing to report that sections of the ESA document have been incorporated into subsequent BREF notes as appropriate.

The **ESA Sealing Technology BAT guidance notes** document is available from the ESA website at www.europeansealing.com

3.9. Fire safety

Definition: Valves (and flange joints) must be able to withstand a fire for a short duration.

Unit: mg/(s m), cm^3/min, ml/min, l/h

Related terms: ***Leakage rate***
Temperature

Standards:

ISO 10497	]	
BS 6755-2	]	- flame temperature tests
API 607	]	
API 6FB	]	
DVGW VP 401		- oven temperature test

Purpose: In case of fire a valve or flange joint must withstand the fire for a short time. The time to extinguish most fires in the chemical and petrochemical industry is less than 30 minutes. Therefore 30 minutes are the accepted duration for *fire-safe* tests.

Comments: An early flange joint failure caused by a fire can quickly end in a disaster. Therefore, plant operators must consider the aspect of fire resistance in selection of the sealing material.

All "*fire-safe"* test standards relate to the testing of valves only.

The common principle of the testing standards is that a locked valve filled with water and under pressure is exposed to open flames for 30 minutes. The test temperatures during this procedure are 750°C-1000°C (1382°F – 1832°F, **ISO 10497**), 780°C-980°C (1400°F – 1800°F, **BS6755**) and 760°C-980°C (1400°F – 1800°F, **API 607**). During these standardised test procedures these temperatures do not necessarily represent the temperature experienced by the gasket.

DVGW VP 401 represents a high temperature service test rather than a disaster test, because it relies upon the valve to be heated in an oven to 650°C (343°F).

A valve is regarded as *"fire-safe"* if defined sealability requirements are achieved, both for the through-valve-seat leakage and external leakage.

Testing standards mentioned can also be used for flange joints as a universal fire-safe minimum requirement - provided that the material for flanges, bolts and seals is reliably fire resistant, thermally stable, and adequately heat-resistant.

Standard	Tested element	Heating medium	Temperature of heating medium	Temperature of Calorimeter / body of valve / flange	Test duration	Test medium	Pressure of medium	Leakage test after cooling down
ISO 10497	Valves	Flame	750°C-1000°C (1382°F – 1832°F) within 2 minutes	650°C (343°F) within 15 minutes	30 min (including 15 min. heating up period)	H_2O	2 bar (29psi) for valves rated: PN10, PN 16, PN25, PN40, class150, class 300 (for all others 75% of cold working pressure)	Yes
BS 6755-2	Valves	Flame	760°C-980°C (1400°F – 1800°F) within 2 minutes	650°C (343°F) within 15 minutes	30 min (including 15 min. heating up period)	H_2O	For PN and Class ratings: 12 to 317 bar (174 to 4600psi) For other valves: 75% of cold working pressure	Yes
API 6FA	Valves	Flame	760°C-980°C (1400°F – 1800°F) within 2 minutes	650°C (343°F) within 15 minutes	30 min (including 15 min. heating up period)	H_2O	14 to 1034 bar (203 to 15000psi) (class dependent)	Yes
API 607	Soft-seated quarter-turn valves	Flame	760°C-980°C (1400°F – 1800°F) within 2 minutes	650°C (343°F) within 15 minutes	30 min (including 15 min. heating up period)	H_2O	2 bar (29psi) (for class 600 and more: 75% of cold working pressure)	Yes
DVGW VP 401	Joint DIN 3376-1: DN25 and DIN 3376-2: DN25	Hot Oven	Dependent upon the capacity of hot oven – the joint/flange must be heated to 650°C (343°F) in 15 min.	650°C (343°F) within 15 minutes	30 min (after reaching 650°C (343°F))	N_2	0.1 to 1 bar (105 to 15psi)	No
DVGW VP 401	Flange EN 1092-1: DN25 PN16	Hot Oven		650°C (343°F) within 15 minutes	30 min (after reaching 650°C (343°F))	N_2	5 bar (73psi)	No

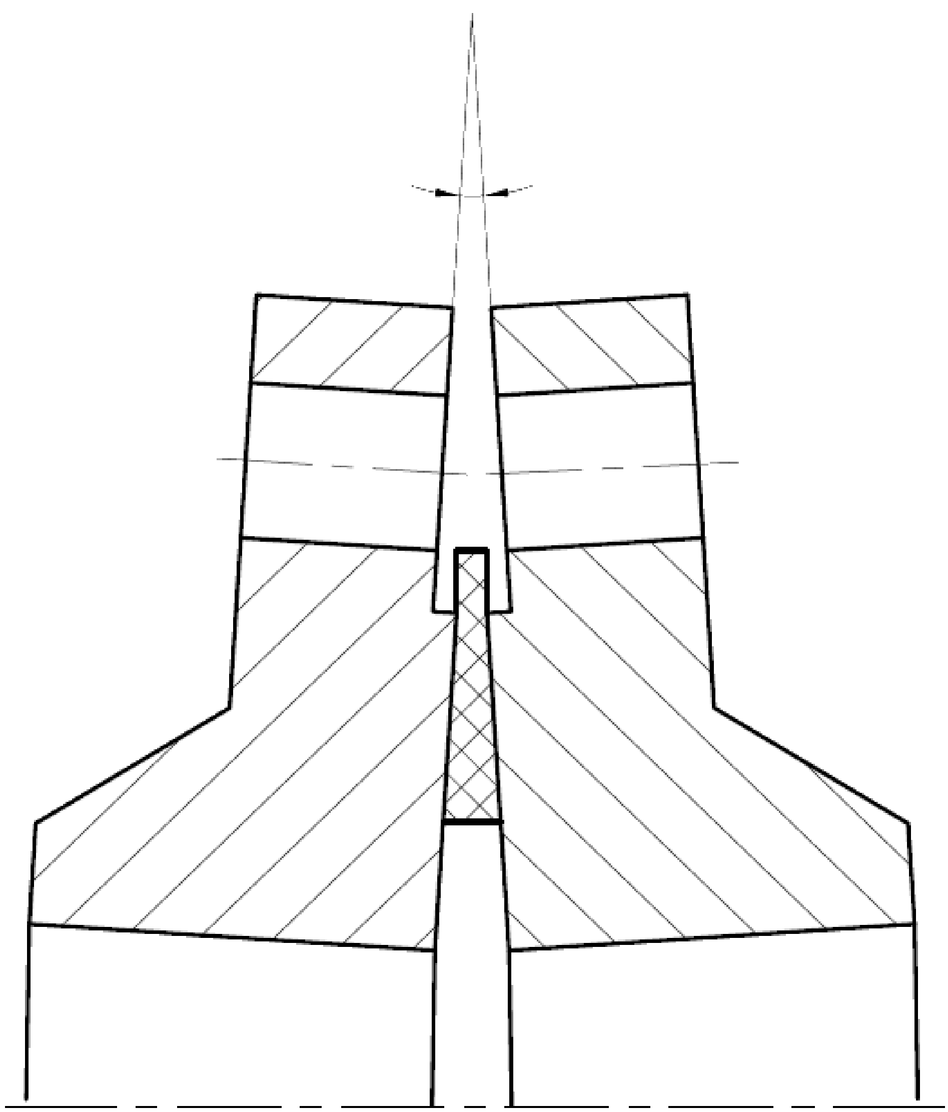
3.10. **Flange rotation**

Definition: Deformation of a flange caused by imposed forces

Colloquial term: *Flange bending*
Flange bowing
Flange deformation

Standards: ASME Boiler and Pressure Vessel Code, Section VIII
EN 1591

Purpose: ***Flange rotation*** should be minimised to guarantee good sealability generally, since it tends to reduce the pressure on the inner region of the gasket, which tends to reduce the ***effective sealing width***. Occasionally, ***flange rotation*** can improve sealing.



Comments: As a general rule, this can present more of a problem with DIN flanges rather than ANSI flanges.

3.11. Gasket factors derived from EN 13555 for use with EN 1591

Standard: EN 13555

Purpose: In the framework of the 97/23/CE PED Directive governing pressure equipment design, the EN 1591-1 standard gives the calculation method for gasketed circular flanged connections and this calculation requires certain gasket parameters. EN 13555 provides the test procedures to allow the generation of those gasket parameters required by the EN 1591-1 design equations.

This calculation method is also the basis of Annex G of EN 13445-3 giving design rules alternative to those of Chapter 11 (similar to ASME Code, Section VIII).

Test procedures: Loading and unloading compression tests combined with leakage tests as per EN 13555

Comments: The EN 13555 generated parameters represent a marked improvement over the empirical **m** and **y** gasket factors of ASME Code, Section VIII. However, obtained through room temperature measurements, they ignore the influence of one important operational parameter, that of temperature.

Loading and Unloading to Simulate Off-loading in Service: The test methods of EN 13555 include both loading and unloading cycles to simulate service conditions. In service the gasket will be loaded during the gasket tightening stages of the flange assembly process but then, as the pipe line is pressurised, the gasket surface pressure will reduce due to the hydrostatic end thrust created by the pressurised fluid in the pipeline. Later, during service, there will be further changes to the gasket surface pressure, most of which also lead to reductions.

So the test methods of EN 13555 include unloading cycles to allow the effect of off-loading in service to be determined.

Definitions:

Q_{smax} maximum gasket surface pressure that may be imposed on the gasket at the indicated temperatures without collapse or compressive failure of the gasket

$Q_{min\ (L)}$ minimum gasket surface pressure on assembly required at ambient temperature in order to seat the gasket into the flange facing roughness and close the internal leakage channels so that the tightness class is to the required level *L* for the internal test pressure.

Tightness class L_N tightness classes are defined in the Table in terms of specific leak rates. Additional, better tightness classes can be introduced as required by continuing the series

Tightness classes	$L_{1,0}$	$L_{0,1}$	$L_{0,01}$
Specific leak rates (mg s $^{-1}$ m $^{-1}$)	≤ 1,0	≤ 0,1	≤ 0,01

The specific leak rate shall be obtained by dividing the measured leak rate by the arithmetic mean of the inner and outer gasket peripheries subjected to surface from the flange facings, $\pi/2\ (D_s + d_s)$.

$Q_{smin\ (L)}$ minimum gasket surface pressure required under the service pressure conditions, (i.e.) after off loading and at the service temperature, so that the required tightness class *L* is maintained for the internal test pressure.

P_{QR} a factor to allow for the effect on the imposed load of the relaxation of the gasket between the completion of bolt up and after long term experience of the service temperature.

E_G the unloading moduli determined from the thickness recovery of the gasket between the initial compression surface pressure and unloading to a third of this initial surface pressure.

Units: All above parameters expressed in MPa, except for:
Tightness classes expressed in mg s $^{-1}$ m $^{-1}$ and P_{QR} is a dimensionless ratio

3.12. **Gasket factors derived from the ROTT test**

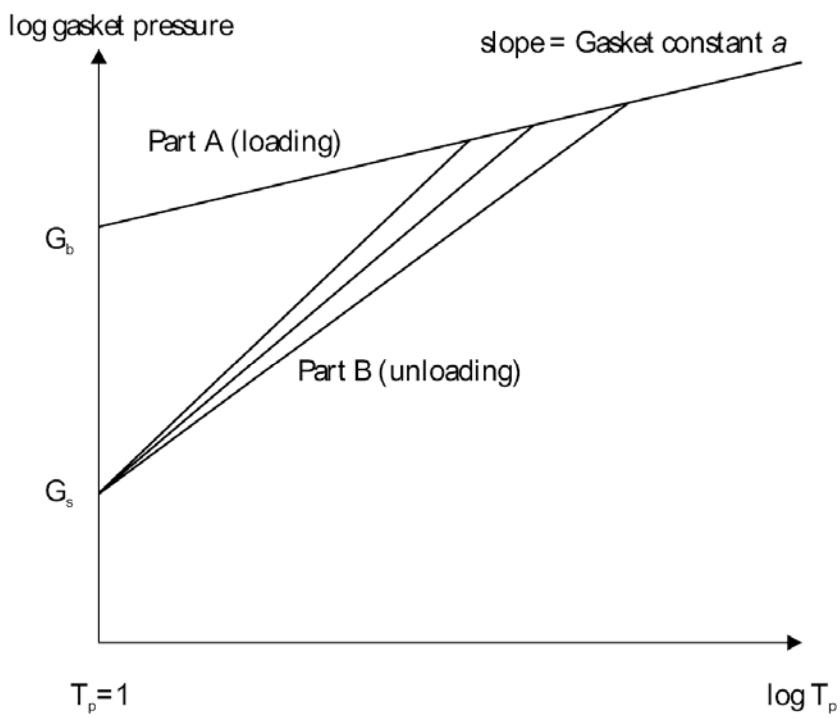
Definitions: **a** Slope of gasket seating curve (also known as slope of Part A)
G_b Gasket pressure required to achieve T_p = 1 on assembly, according to ROTT test
G_s Intercept of the unloading lines with the line T_p = 1

Units: **a** Dimensionless
G_b, G_s MPa – SI unit
psi – imperial

Standard: ASTM standard being written (ROTT – still in draft)

Test procedure: ROTT (still in draft)

Purpose: Factors which are intended to provide a more reliable basis for calculation of assembly pressure than the traditional "y" and "m" values (published in the ASME code), used in the ASME flange calculation



Comments: These constants are generated from data which is collected by the test procedure known as ROTT (Room temperature operational tightness test).

Equivalent factors for CEN calculation methods are generated from parallel test procedures, which also are obtained through room temperature measurements , thus omitting the influence of one important operational parameter, that of temperature.

In general, the ESA recommends the use of EN 13555 gasket data for calculations with EN1591 where applicable.

3.13. **Gasket factors “m” and “y”**

Definition: “m” is defined in the ASME code as the factor which provides the tension in the flange fastening, in order to obtain sealing pressure when internal pressure is applied

“y” is defined in the ASME code as the minimum seating pressure

Unit: “m” - dimensionless
“y” - psi

Colloquial terms: “m” - Maintenance factor
“y” - Yield factor

Standards: ASME Boiler and Pressure Vessel Code, Section VIII
ASTM F586 (withdrawn in 1998)
BS 3915
BS 5500
EN 13445 - Unfired pressure vessels

Purpose: Used in part of the calculation to ensure that the joint has a sufficient bolt area and gasket pressure for safe operation.

In order to ensure a tight joint, as the *internal pressure* increases, and after allowance for the *hydrostatic end thrus*t, a compressive pressure expressed as a multiple (m) of the internal pressure has to be maintained.

Comments: The maintenance factor “m” was established before tightness classes were developed. As a result of the uncertainties in the determination of this parameter, the ESA recommends that the procedures given in EN 13555 and EN 1591 should be used in preference.

According to the ASME code, “y” is the pressure to seat the gasket in the flange and does not take account of the internal pressure which has to be contained in the service application. The y-factor is an empirical estimate only.

3.14. Gasket pressure

Definition: Effective compressive load per unit of gasket area

Unit: N/mm^2 - metric
MPa - SI
psi - imperial

Colloquial terms: *Gasket load* (the total load on the gasket, not per unit area)
Gasket stress (the effect of the applied pressure in the gasket). In colloquial English, a force per unit area on a body is often referred to as “stress” rather than “pressure”. Although this is perhaps technically wrong, it is in common usage. In this document, “pressure” is used in such circumstances.

Related term *Gasket compressive stress* Q, as defined by EN 1591, corresponds to the concept of ***gasket pressure*** and is expressed by the formula:

$$Q = F_G / A_G$$

where F_G = “gasket force”
A_G = “gasket area”

(includes references to *effective gasket area*, A_{Ge} and *theoretical gasket area*, A_{Gt})

Standards: EN 13555
EN 1591-1

Purpose: ***Gasket pressure*** is the effective load applied to the gasket surface per unit of effective gasket area under operating conditions, and can be determined with the above formula, using:

$$F_G = F_{DV} - F_i$$

where F_{DV} is the force applied to the gasket on installation
F_i is the force due to the internal pressure (hydrostatic end thrust)

The *nominal gasket pressure* must be maintained between the *minimum gasket pressure under operating conditions* and the ***maximum gasket pressure under operating conditions*** (which should not be exceeded in order to prevent gasket collapse or creep).

Usually, gasket pressure is measured only when carrying out gasket tests on equipment fitted with rigid plates.

3.15. <u>Leakage rate</u>

Definition: Quantity of fluid passing through the body and/or over the faces of a gasket per unit periphery of the gasket over a specified time

Unit: mg/(s m)

Colloquial term: Leak rate
Gasket leak
Flange leak
Mass leak rate

Related terms: ***Emissions***
Permeability
Sealability
TA-Luft
Tightness class
Tightness parameter

Standards: EN 13555 - Gasket parameters and test procedures relevant to the design rules for gasketed circular flange connections
ASTM F 37 - Test method for sealability of gasket material
ASTM F 112 - Test method for sealability of envelope gaskets
ASTM F 2378 - Test method for sealability of sheet, composite and solid form-in place gasket materials
BS 7531
DIN 28090–2
EPA Method 21 - for the measurement of emission in ppm

Purpose: To measure the total quantity of fluid lost over the face and through the body of the gasket.

Comments: ***Leakage rate*** is profoundly influenced by working conditions such as media, pressure, temperature, surface pressure. It is usually measured under a specific gasket load and specific fluid pressure. For a given set of application conditions, the lower the leakage rate, the better the fluid is retained by the gasket material.

As a general guideline, increasing internal pressure gives higher leakage rates. Increasing surface pressure results in lower leakage rates. Increasing molecular size gives lower leakage rates. Increasing temperature gives lower leakage rates for some gasket materials, although towards the end of the service life for some of these materials, the leakage rate is likely to increase.

Low leakage rate is equivalent to good sealability and low permeability. ***Leakage rate*** and ***sealability*** describe a similar concept, but are expressed in opposite terms.

Tests according to BS 7531 measure permeability (through the body) only , due to the presence of foils which exclude leakage over the surfaces.

Note that PVRC leakage rates are measured in mg/(s mm), whereas leakage rates for EN 13555 are measured in mg/(s m). For the definitions of specific leakage rates according to EN13555 and PVRC, please refer to ***Tightness class*** and ***Tightness parameter***, respectively.

3.16. Load compression characteristic

Definition: Reduction of thickness under specified load and temperature conditions

Unit: mm - metric
inch - imperial

Colloquial term: *Gasket deflection* (used primarily in the USA)

Standards: EN 13555
DIN 28090–2, Section 9.1

Purpose: There is no absolute, theoretical value for the reduction of thickness under specified load and temperature conditions. Since the purpose of obtaining the compression curve can be multiple, different parameters need to be considered in the course of testing. The main ones are:

- the pressure on the gasket
- the temperature
- the rates of pressure and temperature increase

The purpose of the compression testing can be to obtain the modulus of elasticity, the maximum surface pressure, or simply the thickness loss at ambient or elevated temperatures.

Comment: A series of ***Load compression characteristics*** can be represented graphically as a compression curve, which is supplied often by manufacturers

3.17. Maximum gasket pressure under operating conditions

Definition: Maximum gasket surface pressure Q_{Smax} which may be imposed on the gasket at the indicated temperatures without collapse or compressive failure of the gasket

Note: Q_{Smax} has to be verified by conducting a EN13555-test for P_{QR} at the same temperature and surface pressure as for the Q_{Smax} test.

Unit:
N/mm^2 – metric
MPa – SI
psi – imperial

Colloquial terms:
Maximum seating stress under operating conditions
Maximum service gasket stress
Maximum surface pressure under operating conditions
Maximum surface stress under operating conditions

Standards:
EN 13555
EN 1591-1
EN 1591-2

Test procedures: EN 13555, Sections 5.1 and 8.4 - cyclic compression test

Purpose: The ***maximum gasket pressure under operating conditions*** is the maximum allowable (surface) pressure which can be applied on the effective gasket area under service conditions (operating temperature) to avoid unacceptable deformation and / or destruction of the gasket.

The ***maximum gasket pressure under operating conditions*** is needed for the calculation of flanged joints. It determines the maximum bolt load under operating conditions.

3.18. Off-loading

Definition: The reduction of surface pressure on a gasket after assembly

Related terms: ***Principal forces on a flanged joint***
Gasket factors derived from EN 13555 for use with EN 1591

Comments: After the assembly of a bolted connection the surface pressure on the gasket will reduce for a variety of reasons. There are two general causes for the loss of surface pressure:

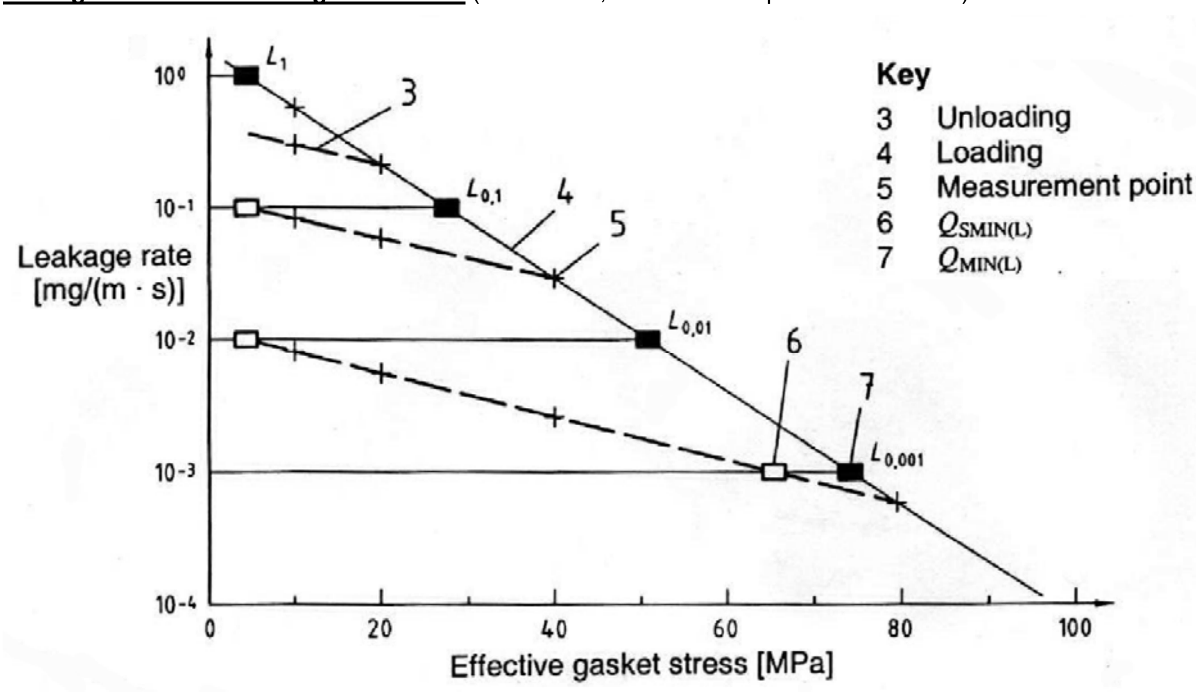
- ***internal*** causes, which result from changes experienced by the gasket (for instance, creep and weight loss at temperature)
- ***external*** causes, which are known collectively as "***off-loading***" effects

The ***off-loading*** effect which is always present once the pipeline is in service is the opening force created by the hydrostatic pressure of the fluid being sealed. Other ***off-loading*** mechanisms are the forces created by the pipeline and the consequence of thermal transients.

The consequence of ***off-loading*** for a particular gasket type or style is assessed during the sealing test in EN 13555 by the series of unloading sequences after each loading sequence of that test.

In this respect, those gaskets which suffer the least increase in the leakage rate during the unloading sequences are regarded as the better ones.

Leakage rate as a factor of gasket stress (in this case, for an internal pressure of 40 bar)



Original diagram extracted from EN 13555, with thanks and acknowledgement to CEN

3.19. **Oxygen service**

Definition: Requirement for sealing materials to be used safely in oxygen or oxygen-enriched fluid service

Unit: -

Related terms: compatibility with oxygen

Standards: ASTM D25-12
ASTM G63
ASTM G86
EN 1797
VDI 2200

Purpose: Materials and equipment, which is used in oxygen service has to meet stringent requirements. They must offer high ignition temperatures and no reactivity with oxygen under service conditions.

No reaction with oxygen (burning) of the gasket or parts of the gasket within the flange connection must be assured to prevent the escape of process media because of gasket damage.

As liquid oxygen is cryogenic, this has also to be considered in service duties of materials and equipment.

Comments: To ensure these requirements, they have to withstand an impact stress test in liquid oxygen with a minimum force of 125 Nm and a flammability test at demanded service temperature (details from ASTM D25-12)
Tests are conducted by BAM in Berlin, which provides subsequently certificates of compliance for the materials

3.20. <u>Permeability</u>

Definition: A measure of the ease with which a fluid can pass through a gasket material

Unit: ml/s – SI
cm^3/min – metric
mg/(s m)

Related terms: ***Leakage rate***
Sealability

Standards: BS 7531
DIN 3535-6

Purpose: To determine the maximum fluid passage through the body of a gasket only as opposed to total leakage which will include the interfacial leakage. This parameter is more significant in the case of gaseous rather than liquid fluids.

Comments: When a gasket shows low permeability, it has a low level of fluid loss through the body of the gasket material over time. This is not necessarily equivalent to good ***sealability***, or low ***leakage rate***.

3.21. <u>Principal forces on a flanged joint</u>

Definition: The key sealing concepts in gasket and flange interactions

Related terms: ***Assembly pressure***
Gasket factors derived from EN 13555 for use with EN 1591
Off-loading
Stress relaxation

Comments: When a gasket is placed in a flange and the bolts are tightened a surface pressure is created on the gasket due to the stretching of the bolts during the tightening operation. As soon as the tightening operation is completed then various factors, some more important than others, lead to the reduction of that surface pressure.

In order to create a seal that in service will have a leakage rate below a required level then the gasket surface pressure at the end of the bolt tightening process, the **assembly pressure {a}** must be sufficiently greater than the **minimum assembly pressure** to ensure that after all of the gasket surface pressure loss mechanisms have occurred that the **operational surface pressure {b}** on the gasket (also known as the **residual surface pressure**) remains above the required **minimum gasket pressure under operating conditions {c}**

The major factors which reduce the stress are:

Creep & relaxation effects collectively known as **stress relaxation {d}**

Off-loading {e} due to the end thrust created by the pressure of the service fluid to be sealed

So the minimum assembly pressure can be related to the required minimum gasket surface pressure under service conditions by :

$$[\mathbf{a} - \mathbf{e}]\,\mathbf{d} > \mathbf{c}$$

3.22. **Recovery**

Definition: Increase of thickness over the compressed thickness, once the compressive load has been removed

Unit: %

Related terms: ***Compressibility***
Compression set
Creep deformation
Elasticity
Resiliency
EN 13555 Secant modulus E_G

Standards: ASTM F 36
DIN 28090-2 Section 9.2.1: Compressive creep test - percentage creep relaxation at room temperature

ASTM F 36 expresses recovery with the following formula:

$$\textbf{\textit{Recovery}}\ (\%) = 100\ [(h_d - h_e) / (h_i - h_e)]$$

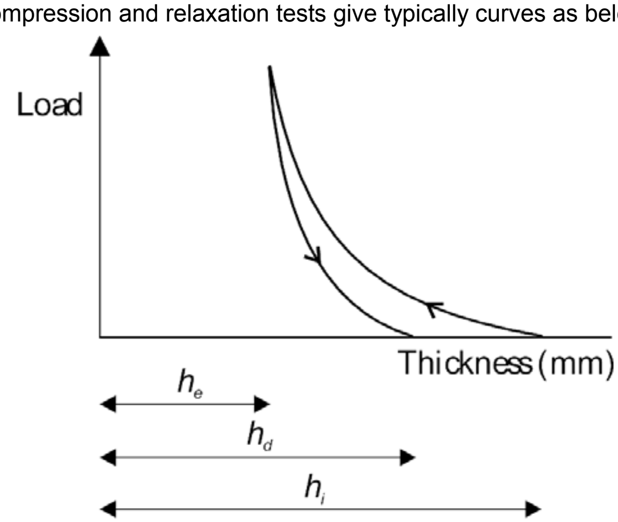
where h_i = initial thickness of sample
h_e = thickness at the end of compression
h_d = thickness after recovery

DIN 28090–2 expresses recovery with the following formula:

$$\varepsilon_{KRW} = 100\ [(h_{D4} - h_{D3}) / h_{D1}]$$

where ε_{KRW} = percentage creep relaxation
h_{D1} = initial thickness
h_{D3} = thickness under applied load
h_{D4} = thickness after load has been reduced to pre-load

Purpose: ***Recovery*** is one of the primary parameters for the characterisation of gasket materials. It gives the measure of its elastic deformation properties and an indication of the ability of the material to compensate for the stress relaxation and/or thermal expansion of the bolts. Compression and relaxation tests give typically curves as below:



Comments: Recovery of a structure is a function of various parameters:
- nature of the constituents
- geometry of the structure
- rate of application and release of the compressive force
- temperature
- isotropy of the structure

The ASTM value should be used in conjunction with the compressibility value.

3.23. Residual stress

Definition: Stress remaining in a gasket after service for a given time

Unit: N/mm^2 – metric
MPa – SI
psi – imperial

Colloquial terms: Stress retention
Residual pressure

Related term: Operational gasket pressure
Stress relaxation
Creep relaxation
EN 13555 P_{QR} , the ratio of gasket surface stress after and before relaxation

Standards: BS 7531 (and previously BS 1832)
DIN 52913
EN 13555
ASTM F38

Note that the outputs from specified test methods are as follows:
ASTM F 38: percentage stress loss
DIN 52913: remaining stress
BS 7531: remaining stress
EN 13555: ratio of stress after and before relaxation

The test methods defined by the procedures can strictly be considered as a combination of ***creep deformation*** and ***stress relaxation***.

BS 7531 is tested with an initial surface pressure of 40 MPa, while the DIN 52913 is tested with an initial surface pressure of 50 MPa. Hence, the two standards are not entirely comparable.

Purpose: The stress retained test result is an index of the ability of the material to retain the load generated by bolt tensioning and therefore, of the likely in-service reliability of the material.

The values quoted as ***residual stress*** refer to the stress retained in a test gasket when loaded under specified conditions of initial surface pressure, temperature, time and test rig rigidity.

The higher the ***residual stress***, the better the load bearing capacity of the gasket material. The thinner the gasket material after the initial load has been applied, the better the load bearing capacity.

Comments: ***Residual stress*** is the output from a test designed to characterise the load bearing property of a gasket material.

3.24. **Sealability**

Definition: Ability of a gasket material to prevent flow of fluid through the body and/or over the surfaces

Related terms: ***Leakage rate***
Permeability

Standards: EN 13555 (Symbols Q_{min} and Q_{Smin})
ASTM draft ROTT-test (Symbols G_b, a, G_s)

Purpose: A generic term.

Comments: ***Sealability*** is very much influenced by the media and surface pressure. Usually, the leakage rate of an ASTM reference fluid (defined in ASTM D 471) through and/or over the surfaces of a material, is used to define the sealability of that material. A material which has little fluid loss during the test period is said to have "good sealability". Due to this, ***leakage rate*** and ***sealability*** appear to be one and the same. However, this is not the case. ***Leakage rate*** and ***sealability*** are antonyms, although they are commonly interchanged with the same meaning!

For a given set of conditions, the smaller the quantity of fluid lost with time, the better the ***sealability*** of the gasket material.

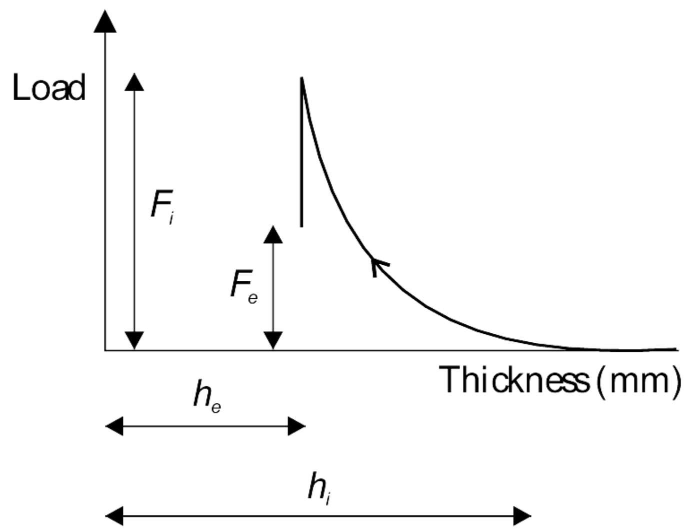
3.25. **Stress relaxation**

Definition: Loss of stress at a constant gasket thickness as a function of time, after application of a specified compressive load at a specified rate, at constant temperature. (This definition uses colloquial English, whereas to be consistent with the terminology of this document, the word "stress" should be replaced by the word "pressure")

Unit: %

Related terms: ***Compression set***
Creep deformation
Residual stress

Purpose: ***Stress relaxation*** gives an indication of the effect of time on the mechanical behaviour of gasket materials. Compression and relaxation tests under constant thickness give typically curves as indicated below:



Stress relaxation (%) = 100 [(F_i-F_e) / F_i]

where F_i = specified test pressure
F_e = pressure remaining under constant thickness over specified period

Comments: ***Stress relaxation*** of a structure is a function of various parameters:

- nature of the constituents
- geometry of the structure
- rate of application of compressive force
- time
- temperature
- isotropy of the structure

The term ***stress relaxation*** is often used incorrectly to describe ***residual stress***, which is measured by test procedures, such as BS 7531, DIN 52913, EN 13555 and ASTM F38, as a combination of ***creep deformation*** and ***stress relaxation***.

3.26. Surface roughness

Definition: Fine irregularities of the flange surface finish.

Units: Ra (in µm or µin)
R_Z

Related term: *Surface finish*
Surface texture

Standards: EN 1092 Flanges and their joints. PN designated.
EN 1759 Flanges and their joints. Class-designated.
EN 10049 Measurement of roughness average. Ra and peak count RPc on metallic flat products
EN ISO 4287:2000 Geometrical product specification (GPS). Surface texture. Profile method. Terms, definitions and surface texture parameters
ISO 7005-1. Metallic flanges. Part 1. Steel flanges

Purpose: ***Surface roughness*** is often represented by the symbol R_a, although it is not the sole criterion for defining a suitable surface. Irregularities in the flange surfaces will affect the capacity of a gasket to conform to the flange surface profile and close leak-paths. They will also affect the friction values necessary to keep the gasket in position.

Comments: The flange surface finish can have a significant effect on gasket performance. It should not be assumed that a smoother finish will provide superior results, nor the converse. This has been a matter of contentious debate at a number of ISO and CEN technical committees. When preparing the CEN flange standards EN 1092 (for PN) and EN 1759 (for Class), consideration was given to general dimensional tolerance proposals from various national bodies, and the consensus opinion was formulated. These two standards (for flanges in various metals) provide recommendations for R_a and R_Z values of surface finish.

As a *general* guideline, it is recommended that smooth surfaces on the flange faces should be used for low temperature work, while rough surfaces on the flange faces should be used for elevated temperature work.

3.27. **Tightness class**

Definition: Maximum acceptable specific leakage rate for particular applications

Units: mg/(s m)

Related term: ***Tightness parameter***. Although closely related to ***Tightness class***, these two terms are not synonymous.

Standards : EN 13555

Purpose: ***Tightness class*** defines a specific leakage rate, usually expressed as the mass flow (mg/s) per metre of the mean perimeter of the gasket.

Comments: The ***Tightness class*** is a specific value within the overall concept being promulgated by the ASTM and EN, but its use in general design work is only just beginning. Both ASTM and EN use the same term to describe specific leakage rates, although with different notations and values. ASTM classes are indicated by the letter "T", and EN classes by the letter "L".

Tightness class within EN 13555 provides specific leakage rate values:

Tightness class	Specific leakage rate, mg/(s m)
$L_{1.0}$	≤ 1.0
$L_{0.1}$	≤ 0.1
$L_{0.01}$	≤ 0.01

Series can be extended as required.

In reality, the EN ***Tightness classes*** are ranked according to the leakage rate, such that as leakage rises, so EN ***Tightness class*** increases. The opposite is true with the ASTM ***Tightness classes***, where the higher the ***Tightness class***, the lower the leakage.

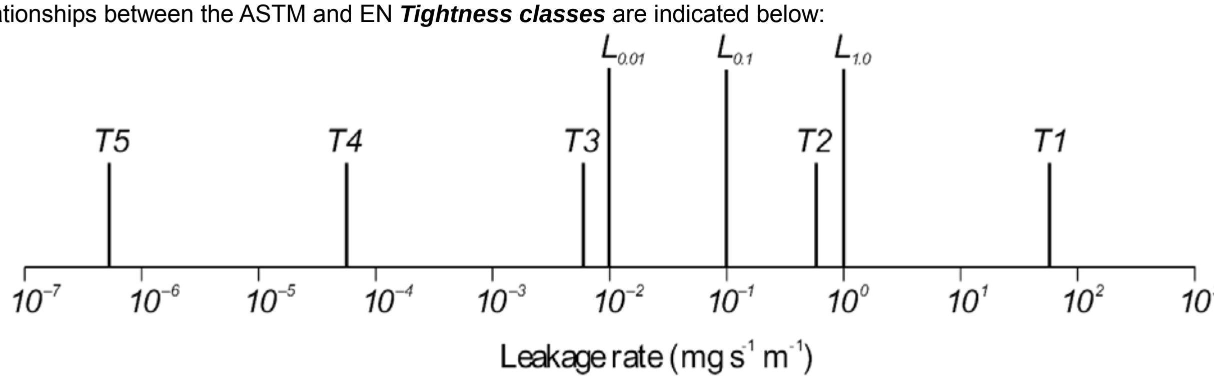
The ASTM ***Tightness classes*** are derived as:

T1 Economy = Flange leakage rate of 2×10^{-1} mg/(s mm)
T2 Standard = Flange leakage rate of 2×10^{-3} mg/(s mm)
T3 Tight = Flange leakage rate of 2×10^{-5} mg/(s mm)

while two further -"tighter"- classes are added occasionally:

T4 = Flange leakage rate of 2×10^{-7} mg/(s mm)
T5 = Flange leakage rate of 2×10^{-9} mg/(s mm)

The relationships between the ASTM and EN ***Tightness classes*** are indicated below:



(adapted from Dr Hans Kockelmann, MPA Stuttgart)

3.28. Tightness parameter

Definition: Mathematical relationship between the measured specific leakage rate and the internal fluid pressure causing it

A dimensionless sealability measure which is proportional to pressure and inversely proportional to the square root of leak rate. More precisely, Tp is the pressure relative to the atmospheric pressure required to cause a Helium leak of 1 mg/s for a 150 mm OD gasket.

$$T_p = \frac{P \quad (Lrm^*)^{0.5}}{P^* \quad (Lrm)^{0.5}}$$

where

T_p = Tightness parameter

P = Internal pressure (MPa or psig)

P^* = Reference pressure = atmospheric pressure (0.101325 MPa or 14.69 psia)

Lrm = Measured leakage rate in mg/s

Lrm^* = Reference leakage rate = 1 mg/s for a 150mm outside gasket diameter

Note 1: the pressure, P* and the associated leakage rate, are reference values to define non-dimensional T_p

Note 2: the exponent (0.5) shown in the above formula may need to vary for differing fluids, for example it may change between gas and liquid states

Standard: ASTM Standard being written (ROTT - still in draft)

Note that ASTM leakage rates are measured in mg/s, whereas leakage rates for EN 13555 are measured in mg/(s m), normalised on the mean circumference of the gasket.

Related term: ***Tightness class***

Purpose: The ***Tightness parameter*** for a given gasket allows manipulation of the leakage rate and internal pressure values, in order to predict the leakage rate under different operating conditions. T_p was developed so that at a given state, the same tightness value may be obtained whether leakage is measured at any pressure of fluid. A higher value of T_p means a tighter joint, and since T_p is proportional to pressure and inversely proportional to the square root of the leak rate, a joint which is 10 times tighter will leak 100 times less.

Tightness parameter is non-dimensional and provides the following advantages:

- the value of T_p is the same, irrespective of whether pressures are noted in psi or MPa, or whether leakages are measured in mass/time or volume/time
- T_p combines the effect of internal pressure P, and leakage L, according to the above equation, by condensing the two parameters into one
- T_p can be used for all gasket assemblies, independent of gasket material
- for a given gasket, the same T_p can apply for different combinations of surface pressure, internal pressure and leakage rate.
- as a simple rule: high T_p represents a tight connection
low T_p indicates high leakage
- the plot of T_p against gasket pressure in log-log scale gives easy access to the ***gasket factors derived for the PVRC ROTT test***

4. History of European norms and gasket parameters

	DIN 2505 (1964)	**AD 2000 B7** (2000)	**DIN E 2505** (1990)	**DIN 28090** Part 1 (1995) replaced by **EN 13555** in Feb 2005	**EN 1591** Parts 1 and 2 (2007)	**EN 13555** (2005)	Conceptual relationship
Approx date of initial introduction	1964	1977	1990	1995	1994	1998	
Parameters for assembly pressure	k_0K_D	k_0K_D	σ_{VU}	$\sigma_{VU/L}$	$Q_{min(L)}$	$Q_{min(L)}$	$\sigma_{VU} \approx Q_{min(L)} \approx k_0K_D / b_D$
Minimum gasket pressure in service	k1	k_1	σ_{BU} $m = \sigma_{BU} / p$	$\sigma_{BU/L}$	$Q_{Smin(L)}$	$Q_{Smin(L)}$	$\sigma_{BU} \approx Q_{Smin(L)}$ $m = k1 / b_D$
Maximum allowed gasket pressure during assembly	V		σ_{VO}	σ_{VO}	Q_{SMax}	Q_{SMax}	$\sigma_{VO} \approx Q_{Max} \approx V^* k_0K_D / b_D$
Maximum allowed gasket pressure in service	$k_2K_{D\nu}$	$k_0K_{D\nu}$	σ_{BO}	σ_{BO}	Q_{SMax}	Q_{SMax}	$\sigma_{BO} \approx Q_{SMax} \approx k_2K_{D\nu} / b_D$
Unloading modulus	E_D		E_D	$E_{D/\nu}$	E_0 , K_1	E_G	$E_D \approx E_0 + K_1 * Q$
Rheological properties			$- I\Delta V$	Δh_D	g_C	P_{QR} , Δe_G	$\Delta h_D \approx \Delta V$

The parameters on each line are not exactly equivalent, but relate to a common concept.

For DIN 2505 (1964) and for AD 2000 B7 (2000) test methods for measuring these parameters do not exist.

DIN 28090-1 (1995) supplied the parameters for calculation in DIN E 2505 (1990).

EN 13555 supplies the test procedures for the derivation of the parameters required by EN 1591

4.1. Calculations of the gasket in a flange connection

Calculations of the flange connection are provided in order to obtain the constructions features of bolts and flanges. Those calculations starts with a determination of a tension force on bolts. That force is connected with dimensions, material (which is described by the gasket parameters), working conditions and sometimes a tightness class. Those calculations are provided according to different calculations standards. The most popular ones in Europe are EN 1591-1, EN 13445, EN 13480, AD 2000, ASME s.VIII and EN 286-1 (effectively the same as the ASME)

EN 1591-1, EN 13445, EN 13480 are harmonised to PED (97/23/WE),
EN 286-1 is harmonised to SPV 87/404/WE

Generally different calculations standards do not use equivalent parameters and also give different results.

Calculation methods comparison table

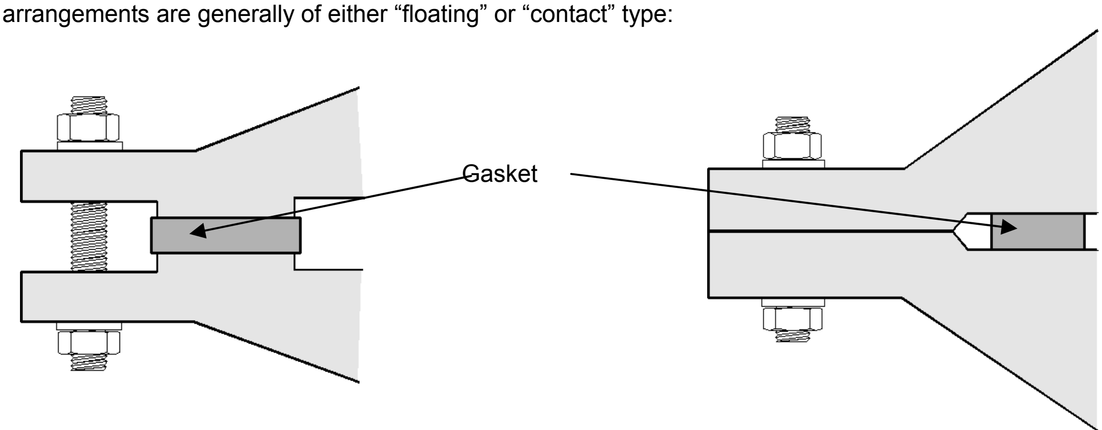
Feature	ASME S.VIII	AD 2000	EN 1591-1
Circular flange shape	✓	✓	✓
Other flange shape (oval, rectangular)		✓	
Gasket style - inside bolt circle (IBC)	✓	✓	✓
Gasket style - full face (FF)		✓	
Split flanges	✓	✓	
Reverse flanges	✓	✓	✓
Flange rotations calculation		(recommendation only)	✓
Pressure internal	✓	✓	✓
Pressure external	✓		✓
External moments and forces		✓	✓
Determination of flange connection deformation			✓
Blind bolts holes			✓
Influence of assembly method			✓
Gasket stress optimization		✓	✓
Contemporary gasket parameters included in standard	✓	✓	(EN 1591-2)
Maximum gasket pressure control			✓
Gasket creep			✓
Gasket efficient width calculation	(2-step reduction)		✓
Possibility of gasket centering ring contact with flanges			✓
Self energising gasket	✓		
Welded gasket		✓	

5. Typical flange and gasket layouts

There are many arrangements of flanges and gaskets in common use. This section aims to highlight the key types of flanges employed for piping and connections in the process industries. While detailed discussion of flange design is beyond the scope of this document, it is valuable to at least outline some of the major types which are to be found in industrial installations.

Although the majority of flange materials are metallic, some applications call for non-metallic flanges, such as reinforced plastic, glass, or glass-lined steel. Non-metallic flanges tend to be used for applications which require a greater chemical inertness. Generally, these flanges are less robust and dictate a softer gasket material, able to be seated under lower gasket pressure. Operating temperatures and pressures are usually less severe.

Flange arrangements are generally of either “floating” or “contact” type:



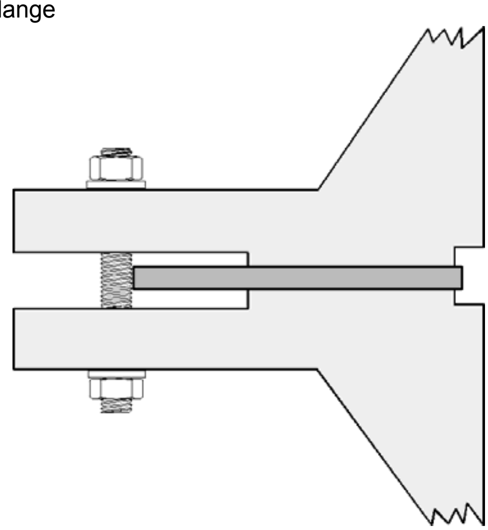
Floating arrangement

Contact arrangement

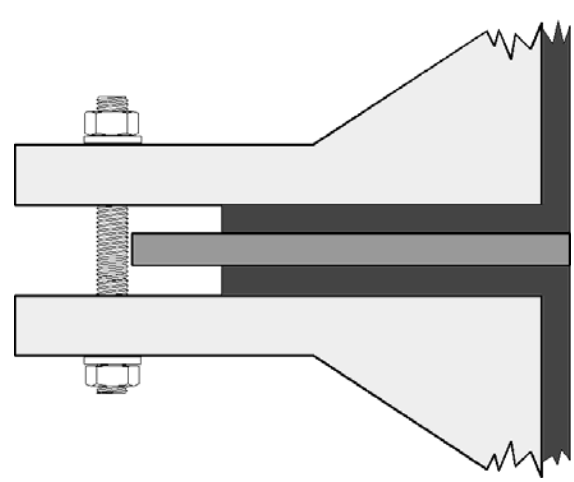
5.1. Common systems

Raised face flanges are in common usage in pipework systems. The flange contact surfaces are raised, although the gasket is non-confined. Generally, the outside diameter of the gasket is equal to the bolt circle diameter, less the diameter of the bolts. This represents the inside bolt circle (IBC) gasket (also referred to as a “ring” gasket in the USA). In this case, the bolts act to centralise the gasket, allowing easy installation and removal of the gasket, without having to separate the complete flange system. Similar to the raised face flange is the ***lapped joint*** arrangement. This connection is used when the process requires a more inert piping system (possibly alloys, plastic or glass), but where the flange itself may be made from a less exotic material:

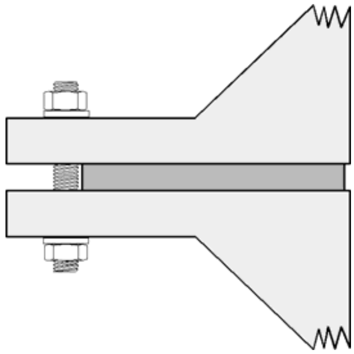
Raised face flange



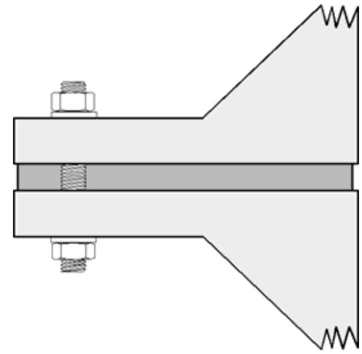
Lapped joint



Flat face flanges are normally used where the flange material is made of relatively fragile materials. In this case, the gasket is non-confined and is relatively easy to install and remove:

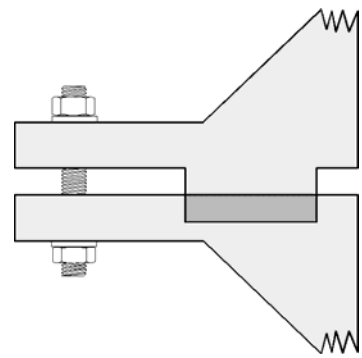


Flat face flange with IBC gasket

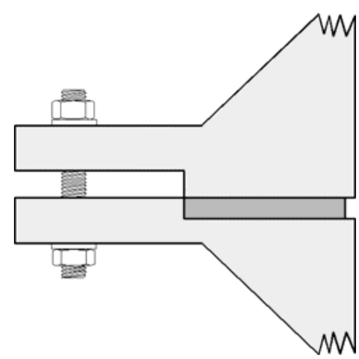


Flat face flange with full face gasket

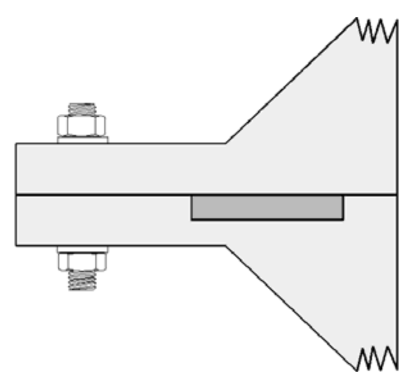
Tongue and groove flange, with a totally confined gasket. The groove depth is equal to or greater than the tongue height. Normally, the gasket has the same width as the tongue. In this arrangement it is necessary to separate the flanges completely in order to change the gasket. This flange system exerts high seating pressure on the gasket and is not usually recommended for soft gasket types:



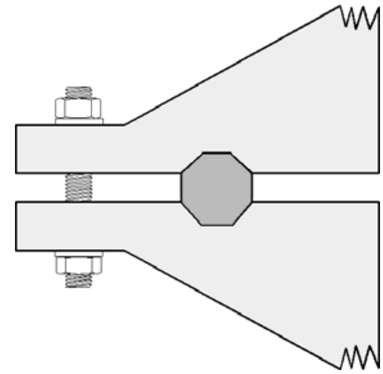
Male and female flanges (also known as ***spigot flanges***) contain a semi-confined gasket, and may be in a variety of forms. The depth of the female flange is equal to or less than the height of the male, in order to avoid the possibility of direct contact between the flange faces when the gasket is compressed. The flange system must be separated in order to change the gasket:



Flat face and groove flange arrangement, with totally confined gasket. The external face of one of the flanges is plain (flat) and the other has a groove where the gasket is installed. These designs are used in applications where the distance between the flanges must be precise. When the gasket is seated, the flanges are usually in contact with each other. Only resilient gaskets should be used in this system:



Ring joint flange arrangement (also known as ***API Ring***), in which both flanges have channels to accept the ring joint gasket, which is usually made of solid metal. The gaskets involved are often referred to as ***RTJ*** or ***ring type joint*** gaskets:



6. Relevant units and conversion factors

The International System of Units (Le Système International d'Unités, or SI units) was first adopted by the 11th General Conference of Weights and Measures in 1960. This list is not exhaustive, and more details of the SI system can be found in publications such as ISO 31, ISO 1000, DIN 1301, BS 5555, BS 5775.

6.1. *SI units*

Quantity	Name of unit	Symbol	Expressed in terms of other SI units
Energy (work)	joule	J	$J = N.m = kg.m^2.s^{-2}$
Force	newton	N	$N = kg.m.s^{-2}$
Length	meter	m	
Mass	kilogram	kg	
Pressure	pascal	Pa	$Pa = N.m^{-2} = MN.mm^{-2}$
Power	watt	W	$W = kg.m^2.s^{-3}$
Temperature (thermodynamic)	kelvin	K	$K = {}^oC + 273.15$
Time	second	s	

6.2. *Multiples of SI units*

The multiples are expressed by orders of magnitude, which are given as a prefix to the SI unit:

Prefix name	Prefix symbol	Factor by which the primary unit is multiplied	
exa	E	10^{18}	1 000 000 000 000 000 000
peta	P	10^{15}	1 000 000 000 000 000
tera	T	10^{12}	1 000 000 000 000
giga	G	10^{9}	1 000 000 000
mega	M	10^{6}	1 000 000
kilo	k	10^{3}	1 000
hecto	h	10^{2}	100
deca	da	10^{1}	10
deci	d	10^{-1}	0.1
centi	c	10^{-2}	0.01
milli	m	10^{-3}	0.001
micro	µ	10^{-6}	0.000 001
nano	n	10^{-9}	0.000 000 001
pico	p	10^{-12}	0.000 000 000 001
femto	f	10^{-15}	0.000 000 000 000 001
atto	a	10^{-18}	0.000 000 000 000 000 001

As an example, the multiple unit MPa (megaPascal = 10^6 Pa) is often used when referring to pressure in fluid systems, such as those in the process industries.

6.3. ***Units of common usage in sealing technology***

The following list covers **non-SI units** which are used regularly in connection with sealing terminology, and gives equivalent conversions into SI units (and other units where appropriate). The list is in alphabetical order (for conversion factors for SI units, please refer to ***Section 8.4***):

Unit	SI equivalent		Other non-SI unit equivalents				Various other units or conversions
			bar	*kp.cm^{-2}*	*N.mm^{-2}*	*psi*	
1 at	0.1013	MPa	1.013 bar	1.033 kp.cm^{-2}	0.1013 N.mm^{-2}	14.695 psi	
1 bar	0.1	MPa			0.10 N.mm^{-2}	14.504 psi	0.987 atmospheres
°C	–273.15	K					
°F							(°C x 1.8) + 32
1 ft (foot)	0.305	m					
1 in (inch)	0.025	m					
1 in^2	645.2	mm^2					
1 kgf	9.81	N					2.2046 lbf
1 kg/cm^2	0.098	MPa	0.981 bar	1 kp.cm^{-2}	0.098 N.mm^{-2}	14.223 psi	
1 N/mm^2	1	MPa	10.0 bar	10.197 kp.cm^{-2}	1 N.mm^{-2}	145.038 psi	
1 lb (pound)	4.45	N					0.4536 kp
1 lbf. ft	1.355	N.m					
1 lbf.in	0.113	N.m					
1 mm Hg	0.133322	kPa					
1 psi	6.895	kPa	0.0689 bar	0.0703 kp.cm^{-2}	0.00689 N.mm^{-2}		

6.4. ***Conversion factors (SI units)***

Quantity	SI unit	Non-SI unit	Conversions
Acceleration	$m.s^{-2}$	$ft.s^{-2}$	1 $m.s^{-2}$ = 3.281 $ft.s^{-2}$ 1 $ft.s^{-2}$ = 0.305 $m.s^{-2}$
	9.806 $m.s^{-2}$	32.174 $ft.s^{-2}$	= Standard acceleration of gravity
Area	ha (hectare)	acre	1 ha = 10, 000 m^2 = 2.471 acres = 3.86 x 10^{-3} $mile^2$ 1 acre = 0.405 ha = 4046.86 m^2
	m^2	ft^2	1 m^2 = 10.764 ft^2 1 ft^2 = 9.290 x 10^{-2} m^2
	m^2	in^2	1 m^2 = 1.550 x 10^3 in^2 1 mm^2 = 1.550 x 10^{-3} in^2 1 in^2 = 6.452 x 10^{-4} m^2 = 645.2 mm^2
	m^2	$mile^2$	1 m^2 = 3.861 x 10^{-7} $mile^2$ 1 $mile^2$ = 2.589 x 10^6 m^2 = 259 ha
	m^2	yd^2	1 m^2 = 1.196 yd^2 1 yd^2 = 0.836 m^2
Density	$kg.m^{-3}$	$lb.ft^{-3}$	1 $kg.m^{-3}$ = 6.243 x 10^{-2} $lb.ft^{-3}$ 1 $lb.ft^{-3}$ = 16.018 $kg.m^{-3}$
	$kg.m^{-3}$	$lb.gal^{-1}$	1 $lb.gal^{-1}$ = 0.099 $kg.dm^{-3}$
	$kg.m^{-3}$	$lb.in^{-3}$	1 $lb.in^{-3}$ = 27.679 $g.cm^{-3}$
Energy (work)	J	Btu	1 J = 9.478 x 10^{-4} Btu 1 Btu = 1.055 x 10^3 J
	J	ft.lbf	1 J = 0.738 ft.lbf 1 ft.lbf = 1.356 J
	J	kcal	1 J = 2.390 x 10^{-4} kcal 1 kcal = 4.19 x 10^3 J
	J	kgf.m	1 J = 0.102 kgf.m 1 kgf.m = 9.810 J
	J	kWh	1 J = 2.778 x 10^{-7} kWh 1 kWh = 3.6 x 10^6 J
Force	N	kgf	1 N = 0.102 kgf 1 kgf = 9.81 N = 2.205 lbf
	N	lbf	1 N = 0.225 lbf 1 lbf = 4.448 N
	N	tonf	1 N = 1.003 x 10^{-4} tonf 1 tonf = 9964 N
Length	m	ft	1 m = 3.281 ft 1 ft = 0.305 m
	m	in (1”)	1 m = 39.37 in 1 in = 0.025 m
	m	mile	1 m = 6.214 x 10^{-4} mile 1 mile = 1.609 x 10^3 m
	m	milli-inch (“thou”)	1 “thou” = 25.4 μm
	m	yd	1 m = 1.094 yd 1 yd = 0.914 m

Quantity	SI unit	Non-SI unit	Conversions
Mass	kg	cwt	1 kg = 1.968 x 10^{-2} cwt 1 cwt = 50.802 kg
	kg	oz	1 kg = 35.274 oz 1 oz = 28.349 g
	kg	pound (lb)	1 kg = 2.203 lb 1 lb = 0.454 kg
	kg	ton	1 kg = 9.842 x 10^{-4} ton 1 ton = 1.016 x 10^{3} kg = 1.016 tonne 1 tonne (= 1 metric tonne) = 1000 kg
Moment of force (torque)	N.m	kgf.m	1 N.m = 0.102 kgf.m 1 kgf.m = 9.807 N.m
	N.m	ozf.in	1N.m. = 141.612 ozf.in 1 ozf.in = 7061.55 µN.m
	N.m	lbf.ft	1 N.m = 0.738 lbf.ft 1 lbf.ft = 1.356 N.m
	N.m	lbf.in	1 N.m = 8.85 lbf.in 1 lbf.in = 0.113 N.m
	N.m	tonf.ft	1 kN.m = 0.329 tonf.ft 1 tonf.ft = 3.037 kN.m
Moment of inertia	kg.m^2	oz.in^2	1 kg.m^2 = 5.464 x 10^3 oz.in^2 1 oz.in^2 = 1.829 x 10^{-5} kg.m^2
	kg.m^2	lb.ft^2	1 kg.m^2 = 23.730 lb.ft^2 1 lb.ft^2 = 0.042 kg.m^2
	kg.m^2	lb.in^2	1 kg.m^2 = 3.417 x 10^3 lb.in^2 1 lb.in^2 = 2.926 x 10^{-4} kg.m^2
Power	W	ft.lbf.s^{-1}	1 W = 0.738 ft.lbf.s^{-1} 1 ft.lbf.s^{-1} = 1.356 W
	W	hp	1 W = 1.341 x 10^{-3} hp 1 hp = 7.457 x 10^2 W
	W	kgf.m.s^{-1}	1 W = 0.102 kgf.m.s^{-1} 1 kgf.m.s^{-1} = 9.81 W
Pressure	Pa	bar	10^6 Pa = 1 MPa = 10 bar = 1 N.mm^{-2} 1 bar = 0.10 MPa = 14.504 psi
	Pa	ft H_2O (feet of water)	1 kPa = 0.335 ft H_2O 1 ft H_2O = 2.989 kPa
	Pa	in Hg (inch of mercury)	1 kPa = 0.295 in Hg 1 in Hg = 3.386 kPa
	Pa	kgf.m^{-2}	1 Pa = 0.102 kgf.m^{-2} 1 kgf.m^{-2} = 9.81 Pa
	Pa	kp.cm^{-2}	1 MPa = 10.194 kp.cm^{-2} 1 kp.cm^{-2} = 0.0981 MPa = 0.981 bar = 14.223 psi
	Pa	N.mm^{-2}	1 MPa = 1 N.mm^{-2} = 1 MN.m^{-2} = 10.197 kp.cm^{-2}
	Pa	lbf. ft^{-2}	1 kPa = 20.885 lbf. ft^{-2} 1 lbf. ft^{-2} = 47.880 Pa
	Pa	psi (lbf.in^{-2})	1 Pa = 1.450 x 10^{-4} lbf.in^{-2} 1 lbf.in^{-2} = 6.895 kPa = 0.0703 kp.cm^{-2} = 0.0689 bar
	Pa	ton.in^{-2}	1 MPa = 6.477 x 10^{-2} ton.in^{-2} 1 ton.in^{-2} = 15.44 MPa = 15.44 N.mm^{-2}
	1.013 x 10^5 Pa	14.696 lbf.in^{-2}	Standard atmosphere = 1.013 bar = 1.033 kp.cm^{-2}

Quantity	SI unit	Non-SI unit	Conversions
Rate of flow (volumetric)	$m^3.s^{-1}$	$ft^3.s^{-1}$ (cusec)	1 $m^3.s^{-1}$ = 35.314 $ft^3.s^{-1}$ 1 $ft^3.s^{-1}$ = 0.028 $m^3.s^{-1}$ = 28.317 $dm^3.s^{-1}$
	$m^3.s^{-1}$	imperial $gal.h^{-1}$	1 $m^3.s^{-1}$ = 7.919 x 10^5 imp $gal.h^{-1}$ 1 imp $gal.h^{-1}$ = 1.263 x 10^{-6} $m^3.s^{-1}$ = 4.546 $dm^3.h^{-1}$
	$m^3.s^{-1}$	$in^3.min^{-1}$	1 $m^3.s^{-1}$ = 3.661 x 10^6 $in^3.min^{-1}$ 1 $in^3.min^{-1}$ = 2.731 x 10^{-7} $m^3.s^{-1}$
	$m^3.s^{-1}$	US gal. min^{-1}	1 $m^3.s^{-1}$ = 1.585 x 10^4 US gal. min^{-1} 1 US gal. min^{-1} = 6.309 x 10^{-5} $m^3.s^{-1}$
Temperature	K	^oC	K = ^oC + 273.15 ^oC = K –273.15
		^oF	^oC = (^oF –32) x 0.556 ^oF = (^oC x 1.8) + 32
Velocity	$m.s^{-1}$	$ft.s^{-1}$	1 $m.s^{-1}$ = 3.281 $ft.s^{-1}$ 1 $ft.s^{-1}$ = 0.305 $m.s^{-1}$
	$m.s^{-1}$	$km.h^{-1}$	1 $m.s^{-1}$ = 3.6 $km.h^{-1}$ 1 $km.h^{-1}$ = 0.278 $m.s^{-1}$
	$m.s^{-1}$	$mile.h^{-1}$	1 $m.s^{-1}$ = 2.237 $mile.h^{-1}$ 1 $mile.h^{-1}$ = 0.447 $m.s^{-1}$ = 1.467 $ft.s^{-1}$
Viscosity (dynamic)	Pa.s	P (poise)	1 Pa.s = 10 P 1 P = 0.1 Pa.s
	Pa.s	$lbf.s.ft^{-2}$	1 Pa.s = 2.089 x 10^{-2} $lbf.s.ft^{-2}$ 1 $lbf.s.ft^{-2}$ = 47.880 Pa.s
Viscosity (kinematic)	$m^2.s^{-1}$	$ft^2.s^{-1}$	1 $m^2.s^{-1}$ = 10.764 $ft^2.s^{-1}$ 1 $ft^2.s^{-1}$ = 9.290 x 10^{-2} $m^2.s^{-1}$
	$m^2.s^{-1}$	$in^2.s^{-1}$	1 $in^2.s^{-1}$ = 6.452 $cm^2.s^{-1}$ = 645.16 cSt
	$m^2.s^{-1}$	St (stokes)	1 $m^2.s^{-1}$ = 10^4 St 1 St = 10^{-4} $m^2.s^{-1}$
Volume (capacity)	m^3	ft^3	1 m^3 = 35.315 ft^3 1 ft^3 = 0.028 m^3
	m^3	imperial fl oz	1 fl oz = 28.413 cm^3
	m^3	imperial gal	1 m^3 = 2.199 x 10^2 imp gal 1 imp gal = 4.546 x 10^{-3} m^3
	m^3	imperial pt (pint)	1 pt = 0.568 dm^3
	m^3	in^3	1 m^3 = 6.102 x 10^4 in^3 1 in^3 = 1.639 x 10^{-5} m^3
	m^3	litre (L)	1 L = 10^{-3} m^3 = 0.220 imp gal = 0.264 US gal
	m^3	US gal	1 m^3 = 2.642 x 10^2 US gal 1 US gal = 3.785 x 10^{-3} m^3

7. Relevant Standards

Standards mentioned below are not exhaustive, but rather a selection of the most relevant documents:

International

ISO 31	
ISO 37	Stress–strain
ISO 175	Determination of behaviour with respect to liquids
ISO 468	Surface roughness—parameters, values and general rules for specifying requirements
ISO 815	Compression (Permanent) set at ambient and elevated temperatures
ISO 1000	
ISO 1399	Permeability to gases at constant volume
ISO 1653	Compression (Permanent) set at low temperature
ISO 1817	Resistance to liquids
ISO 2528	Permeability to water vapour
ISO 2782	Permeability to gases at constant pressure
ISO 2955	
ISO 3384	Stress relaxation
ISO 4014	Hexagonal bolts with shank
ISO 4032	Hexagonal nuts
ISO 4287	Surface texture
ISO 6179	Permeability to volatile liquids
ISO 6708	Definition of DN
ISO 6914	Stress relaxation of elastomers
ISO 7005	Metallic flanges
ISO 7483	Dimensions of gaskets for ISO 7005 flanges
ISO 8013	Creep (strain relaxation)
ISO 10497	Fire safety

European Union

EN 286	Simple pressure vessel
EN 764	Pressure equipment, terminology and symbols - pressure, temperature, volume
EN 1092	Metallic flanges, PN designated
EN 1333	Definition and selection of PN
EN 1514	Dimensions of gaskets for PN-designated flanges
EN 1515	Bolting for flanges
EN 1591	Design rules for gasketed circular flange connections
EN 1759	Metallic flanges, Class designated
EN ISO 6708	Definition of DN
EN 12560	Dimensions of gaskets for Class-designated flanges
EN 13445	Unfired pressure vessels
EN 13480	Metallic industrial piping
EN 13555	Gasket characteristics and test procedures relevant to EN 1591 design rules
EN 24014	Hexagonal bolts with shank – Product classes A and B
EN 24032	Hexagonal nuts, type 1 – Product classes A and B

Deutschland

AD 2000	Set of guidelines related to industrial equipment
DIN E 2505	Calculation of flange joints
DIN 2527	Blanking flanges
DIN 2635	Welding neck blanking flanges
DIN 2690	Gaskets for flanges with flat sealing faces
DIN 3535	Seals for gas supplies
DIN 3754	``it''-gasket sheet
DIN 28090	Static gaskets for flange connections
DIN 28091	Technical delivery conditions for gasket sheet
DIN 52910	Tensile testing of compressed fibre sheet
DIN 52911	Determination of the loss on ignition
DIN 52913	Compressive creep test on ``it''-gasket sheet
DIN 53122	Permeability to water vapour
DIN 53452	Testing of plastic-bending test
DIN 53504	Stress–strain
DIN 53517	Compression (Permanent) set
DIN 53521	Resistance to liquids

DIN 53532	Permeability to volatile liquids
DIN 53536	Permeability to gases
DIN 53537	Stress relaxation
DIN 53538	Resistance to liquids
VDI 2200	Guidelines for gasketed joints
VDI 2440	Guidelines for oil refineries

France

NF E 05-015	
NF E 29-001	
NF E 29-203	
NF E 29-901	
NF T 46-002	Stress–strain
NF T 46-011	Compression (Permanent) set
NF T 46-013	Resistance to liquids
NF T 46-034	Permeability to gases at constant pressure
NF T 46-037	Permeability to gases at constant volume
NF T 46-044	Stress relaxation
NF T 48-001	
NF T 48-101 to 48-109	

UK

BS F 66	Rubber bonded cork sheets
BS 903	Methods for testing of vulcanised rubber
BS 1560	Metallic flanges, Class designated
BS 1737	Jointing materials for water, town gas and low pressure steam installations (withdrawn)
BS 3381	Spiral wound gaskets for BS 1560 flanges
BS 3915	Specification for carbon and low alloy steel vessels for nuclear installations (obsolete)
BS 4249	Paper jointing and cork/paper jointing
BS 4332	Composition cork jointing
BS 4504	Metallic flanges, PN designated
BS 4865	Dimensions of various gasket materials for BS 4505 flanges
BS 5292	Jointing compounds for gases
BS 5500	Specification for fusion welded pressure vessels
BS 6956	Jointing materials and compounds
BS 7076	Dimensions of gasket materials for BS 1560 flanges
BS 7531	Specification for compressed asbestos-free fibre jointing (supersedes BS 2815)

USA

ANSI B 16	Flanges and fittings
ANSI B 46.1	Surface texture
API 601	Metallic gaskets (double-jacketed, corrugated and spiral wound)
API 605	Large diameter carbon steel flanges
ASME	Boiler and Pressure Vessel Code
ASTM F 36	Gasket materials: compressibility and recovery
ASTM F 37	Gasket materials: sealability
ASTM F 38	Gasket materials: creep relaxation
ASTM F 104	Classification system for non-metallic gasket materials
ASTM F 112	Sealability of envelope gaskets
ASTM F 145	Evaluating flat-faced gasketed joint assemblies
ASTM F 146	Fluid resistance of gasket materials
ASTM F 147	Flexibility of non-metallic gasket materials
ASTM F 152	Tension testing of non-metallic gasket materials
ASTM F 363	Corrosion testing of gaskets
ASTM D 395	Compression (Permanent) set at ambient and elevated temperatures
ASTM D 412	Stress, strain and creep
ASTM D 471	Resistance to liquids
ASTM F 495	Weight loss of gasket materials upon exposure to elevated temperatures
ASTM F 586	Leak rates versus “y” stresses and ``m'' factors for gaskets (withdrawn)
ASTM F 607	Adhesion of gasket materials to metal surfaces
ASTM F 806	Compressibility and recovery of laminated composite gasket materials
ASTM F 868	Classification of laminated composite gasket materials
ASTM D 1229	Compression (Permanent) set at low temperature
ASTM D 1390	Stress relaxation

ASTM D 1460	Resistance to liquids
ASTM D 3137	Resistance to liquids
MSS SP-44	Steel pipe-line flanges

8. Standards issuing organisations and other relevant bodies

8.1. Standards issuing organisations

Country	Name of Body	Abbreviation	Address
Austria	Österreichisches Normungsinstitut	ON	Postfach 130, Heinestraße 38, A-1021 Wien
Belgium	Institut Belge de Normalisation (Belgisch Instituut voor Normalisatie)	IBN (BIN)	Avenue de la Brabançonne 29, B-1040 Bruxelles
Bulgaria	Committee for Standardization and Metrology	CSM	21, rue du 6 Septembre, BG-1000 Sofia
Czech Republic	Czech Office for Metrology, Standards and Testing	COMST	Biskupsky dvúr 5, CS-113 47 Praha 1
Denmark	Dansk Standard	DS	Baunegaardsvej 73, DK-2900 Hellerup
Finland	Suomen Standardisoimisliitto r.y.	SFS	PO Box 116, FIN-00241 Helsinki
France	Association française de normalisation	AFNOR	Tour Europe, F-92049 Paris la Défense
Germany	Deutsches Institut für Normung e.V.	DIN	D-10772 Berlin
Greece	Ellinikos Organismos Typopiisis	ELOT	313, Acharnon Street, GR-11145 Athens
Hungary	Magyar Szabvanyugyi Hivatal	MSZH	HU-1450 Budapest 9
Iceland	Technological Institute of Iceland	STRI	Keldnaholt, IS-112 Reykjavik
Ireland	National Standards Authority of Ireland	NSAI	Glasnevin, IRL-Dublin 9
Italy	Ente Nazionale Italiano di Unificazione	UNI	Via Battistotti Sassi, 11b, I-20133 Milano MI
Luxembourg	Inspection du Travail et des Mines	ITM	Boite Postal 27, 26, rue Zithe, L-2010 Luxembourg
Netherlands	Nederlands Normalisatie-instituut	NNI	Postbus 5059, Kalfjeslaan 2, NL-2600 GB Delft
Norway	Norges Standardiseringsforbund	NSF	PO Box 353 Skøyen, N-0212 Oslo
Poland	Polski Komitet Normalizacji	PKN	ul. Elektoralna 2, PL-00-139 Warszawa
Portugal	Instituto Português da Qualidade	IPQ	Rua C, Av. dos Tres Vales, P-2825 Monte da Caparica

Country	*Name of Body*	*Abbreviation*	*Address*
Romania	Institutul Român de Standardizare	IRS	13, rue Jean-Louis Calderon, RO-70201 Bucuresti 2
Slovakia	Slovak Office of Standards, Metrology and Testing	UNMS	3, Stefanovicova, SK-81439 Bratislava
Slovenia	Slovenian Institute for Standardization	SIST	Šmartinska cesta 152, SI-1000 Ljubljana
Spain	Asociación Española de Normalización y Certificación	AENOR	Génova, 6, E-28004 Madrid
Sweden	Standardiseringskommissionen i Sverige	SIS	Box 6455, S-113 82 Stockholm
Switzerland	Schweizerische Normen-Vereinigung	SNV	Mühlebachstraße 54, CH-8008 Zürich
Turkey	Turk Standardlari Enstitusu	TSE	Necatibey Cad 112, TR-06100 Ankara Bakanliklar
United Kingdom	British Standards Institution	BSI	389, Chiswick High Road, London W4 4AL

8.2. ***Other relevant bodies*** (commonly used abbreviations in ***bold italics***)

American National Standards Institute Inc (***ANSI***),
1819 L Street, NW
Suite 600,
Washington, DC 20036,
USA
tel: +1 202 293 8020
fax: +1 202 293 9287

American Petroleum Institute (***API***),
1220 L Street, NW
Washington, DC 20005-4070,
USA
tel: +1 202 682 8000
fax: +1 202 682 8070

American Society of Mechanical Engineers (***ASME***),
Three Park Avenue,
New York 10016,
USA
tel: + 1 973 882 1167
fax: +1 973 882 1717

ASTM International (***ASTM***),
100 Bar Harbor Drive,
W. Conshohocken,
PA 19428,
USA
tel: +1 610 832 9585
fax: + 1 610 832 9555

Bundesanstalt für Materialforschung und -prüfung (***BAM***)
Unter den Eichen 87,
12205 Berlin,
Deutschland
tel: +49 3081 04-0
fax: +49 3081 12029

British Hydromechanics Research Group Ltd (***BHRG***),
Cranfield,
Bedford MK43 0AJ,
United Kingdom
tel: +44 1234 750 422
fax: +44 1234 750 074

Centre Technique des Industries Mécaniques (***CETIM***),
74, rue de la Jonelière, tel: +33 2 40 37 36 35
BP 957 -F-44076 Nantes, fax: +33 2 40 37 36 99
France

Comité Européen de Normalisation (***CEN***),
Rue de Stassart 36, tel: +32 2 550 0811
B-1050 Bruxelles, fax: + 32 2 550 0819
Belgium

European Sealing Association (***ESA***),
Tegfryn,
Tregarth, tel: +44 1248 600 250
Gwynedd LL57 4PL, fax: +44 1248 600 250
United Kingdom

Fluid Sealing Association (***FSA***),
Suite 1019,
994, Old Eagle School Road, tel: +1 610 971 4850
Wayne, fax: +1 610 971 4859
PA 19087-1802,
USA

International Standards Organisation (***ISO***),
Geneva,
Switzerland

Manufacturers' Standardization Society of the Valve and Fittings Industry (***MSS***),
127 Park Street NE,
Vienna, tel: +1 703 281 6613
VA 22180, fax: +1 703 281 6671
USA

Pressure Vessel Research Council (***PVRC***),
Box 201547, tel: + 1 216 658 3847
Shaker Heights, fax: +1 216 658 3847
OH 44120,
USA

Staatliche Materialprüfungsanstalt (***MPA***),
Universität Stuttgart, tel: +49 711 685 2578
Postfach 801140, fax: +49 711 685 2635
D-70511 Stuttgart,
Deutschland

Society of Tribologists and Lubrication Engineers (***STLE***),
840, Busse Highway, tel: +1 847 825 5536
Park Ridge, fax: +1 847 825 1456
Illinois 60068-2302,
USA

Verein Deutscher Ingenieure (***VDI***),
Postfach 10 11 39, tel: +49 211 62 14 275
D-40002 Düsseldorf, fax: +49 211 62 14 575
Deutschland

Verband Deutscher Maschinen- und Anlagenbau e.V. (***VDMA***),
Lyoner Straße 18,
Niederrad,
D-60528 Frankfurt,
Deutschland

9. References and further reading

The European Sealing Association and Fluid Sealing Association have produced a wide variety of technical publications, focused primarily on helping users to achieve and maintain good sealing performance. The documents listed below form the basis for this particular publication and are available from the ESA or FSA:

ESA Sealing Technology - BAT guidance notes, (ESA publication nº. 014/05), published 2005. Guidance notes to the best available techniques for sealing technology used in equipment on industrial installations covered by the EU IPPC Directive.
Available in English.

ESA+FSA Guidelines for safe seal usage - Flanges and Gaskets, (ESA+FSA publication nº. 009/98), a joint publication of the ESA and FSA, published September 1998.Provides solutions to the typical challenges faced by maintenance engineers and fitters responsible for pipe and equipment connections involving flanges and gaskets.
Available in the following language versions; Deutsch, English, Español, Français, Italiano.

In addition, the following **leaflet / pamphlet** provides installation guidance for engineers in the field:

FSA+ESA Gasket Installation Procedures, a joint publication of the FSA and ESA, published 2000.
Available in the following language versions; Chinese (Mandarin), Deutsch, English, Español, Français, Italiano, Nederland, Polish, Portuguese, Turkish.

10. Common Abbreviations

This section gives a listing of frequently observed abbreviated forms.

Abbreviation	Meaning	See page
AFNOR	Association française de normalisation	60
ANSI	American National Standards Institute, Inc.	61
API	American Petroleum Institute	61
ASME	American Society of Mechanical Engineers	61
ASTM	American Society for Testing and Materials (now ASTM International)	61
BAT	Best available technique	
BHRG	British Hydromechanics Research Group Ltd	61
BS	British Standard	58
BSI	British Standards Institution	61
CAF	Compressed asbestos fibre sheet *(see also "it", below)*	
CEN	Comité Européen de Normalisation	62
CETIM	Centre Technique des Industries Mécaniques	62
CMA	Chemical Manufacturers Association (USA)	
DIN	Deutsches Institut für Normung	60
DN	Designation of nominal size of components in a pipework system	9
EN	European Norm	57
EPA	Environmental Protection Agency (USA)	
ESA	European Sealing Association	3, 62
FSA	Fluid Sealing Association	3, 62
IBC	Inside bolt circle	11
ISO	International Standards Organisation	57, 62
"it"	last letters of the two words *gummi asbest* (from the German), meaning CAF or compressed asbestos fibre sheet	
LDAR	Leak detection and repair programme (as defined by the EPA)	
MACT	Maximum achievable control technology (as defined by the EPA)	
MPA	Staatliche Materialprüfungsanstalt, Universität Stuttgart	62
MPa	megaPascal (= 10^6 Pa), SI unit of pressure	53, 55
MSS	Manufacturers' Standardization Society of the Valve and Fittings Industry	62
NF	Norm française	58
NPS	Nominal pipe size	12
OEM	Original equipment manufacturer	
PN	Designation related to characteristics of a pipework system	13
ppm	parts per million (can be by weight or volume)	
ppmv	parts per million volumetric	
psi	pounds (lb) per square inch, imperial unit of pressure	53, 55
PVRC	Pressure Vessel Research Committee of the Welding Research Council (now Pressure Vessel Research Council)	33, 46, 62
ROTT	Room temperature Operational Tightness Test	14, 30, 46
RTJ	Ring type joint	14
SCC	Stress corrosion cracking	15
SI	Le Système International d'Unités	52
STLE	Society of Tribologists and Lubrication Engineers (USA)	62
VDI	Verein Deutscher Ingenieure	62
VDMA	Verband Deutscher Maschinen- und Anlagenbau e.V.	62

11. Alphabetical Index

This index provides a comprehensive listing of sealing terms, including those terms in common colloquial use. Terms shown in **bold** are provided with a ***Detailed Description***, the page number of which is indicated in **bold**. Where technically ambiguous, terms are shown in *italics*.

#In colloquial English, a force per unit area is often referred to as "*stress*", rather than "pressure". Whilst this is technically incorrect, it is in common usage. Please note that in this document, the term ``pressure'' is used in such circumstances.