

Compact flanged connections

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Foreword	2
Introduction	2
1 Scope	4
2 Normative and informative references	4
2.1 Normative references	4
2.2 Informative references	4
3 Terms, definitions and abbreviations	5
3.1 Definitions	5
3.2 Abbreviations	6
4 Fundamental design requirements	6
4.1 General	6
4.2 Materials	7
4.3 Strength	7
4.4 Corrosion resistance	8
4.5 Temperature	8
4.6 Leakage	8
4.7 Information requirements for supplier specific CFC	8
4.8 Designation and marking	8
5 Product standard	9
5.1 General	9
5.2 Normative references used in Clause 5	9
5.3 General description of flange design and features	10
5.4 Standard components	11
5.5 Designation	13
5.6 General requirements	13
5.7 Dimensions	14
5.8 Weights of flanges	14
5.9 Flange faces	15
5.10 Surface finish	15
5.11 Tolerances	16
5.12 Marking	16
5.13 IX seal ring	16
5.14 Handling, installation and assembly	18
Annex A (Normative) Flange dimensions and weights	27
Annex B (Normative) Seals dimensions and weights	59
Annex C (Normative) Bolt dimensions and weights	64
Annex D (Normative) Pressure temperature ratings	70
Annex E (Informative) Materials	72
Annex F (Informative) Metric bolting	74
Annex G (Informative) Statement of compliance	76
Annex H (Normative) Integral flange angle selection	77
Bibliography	86

Foreword

The NORSOK standards are developed by the Norwegian petroleum industry to ensure adequate safety, value adding and cost effectiveness for petroleum industry developments and operations. Furthermore, NORSOK standards are, as far as, possible intended to replace oil company specifications and serve as references in the authorities regulations.

The NORSOK standards are normally based on recognised international standards, adding the provisions deemed necessary to fill the broad needs of the Norwegian petroleum industry. Where relevant, NORSOK standards will be used to provide the Norwegian industry input to the international standardisation process. Subject to development and publication of international standards, the relevant NORSOK standard will be withdrawn.

The NORSOK standards are developed according to the consensus principle generally applicable for most standards work and according to established procedures defined in NORSOK A-001.

The NORSOK standards are prepared and published with support by The Norwegian Oil Industry Association (OLF), The Federation of Norwegian Industry, Norwegian Shipowners' Association and The Petroleum Safety Authority Norway.

NORSOK standards are administered and published by Standards Norway.

Attention is drawn to the possibility that some of the elements of this NORSOK standard may be the subject of patent rights. Queries about patent rights may be directed to Standards Norway.

This NORSOK standard is based on common principles utilized by VERAX¹⁾, Vector International AS and Off.N.Galperti SpA.

The CFC as described in Clause 5 is based upon the SPO¹⁾ compact flange developed by Vector International AS.

Annex A, B, C, D and H are normative for products according to Clause 5, whilst Annex E, F and G are informative.

Experience from the first edition of this NORSOK standard has revealed a need of the following improvements, which have been incorporated into the second edition:

- Requirements in order to improve documentation of mechanical properties in 4.2.
- Nickel alloys added for flanges, see 5.6.1.
- More specific guidelines to alignment in 5.14.7 including shear force capacity of seal ring.
- Improved design of blind flange in A.3 in order to improve sealing with a rigid interface.
- Design of integral flanges in A.4 in order to make them more feasible with all type of valves and equipment nozzle designs.
- Orifice spacers for monitoring of flow rate have been added to Clause 5, see A.7.
- Reducing threaded flanges for instrument connections have been added to Clause 5, see A.8.
- An informative bibliography has been added.

Introduction

This NORSOK standard is developed to provide an industry standard for a CFC which is an alternative to conventional flanges as specified in ASME standards, European Standard and International Standard, with reduced weight and smaller overall dimensions. In addition leak tightness reliability is increased by its inherent design features and make up procedures. The CFC may also be an alternative to other types of clamp and hub type mechanical connectors.

¹⁾ VERAX, SPO, CFS and GC - Compact Flanges are trade names of products supplied by VERAX, Vector International AS and Off.N.Galperti SpA. This information is given for the convenience of users of this NORSOK standard and does not constitute an endorsement by NORSOK of the products named. Equivalent products may be used if they can be shown to lead to the same results.

The use of load carrying sealing elements, traditionally referred to as "gaskets", will normally violate the fundamental requirements of this NORSOK standard.

It is claimed that compliance with this NORSOK standard may involve the use of a patent concerning the product given in Clause 5. However, the holder of this patent right – Patent no. NO177160 – has accepted free use of the flange configurations within the application limits contained in Clause 5.

1 Scope

This NORSOK standard provides general design and manufacturing requirements for CFCs used for joining equipment, valves, piping and other piping components. A specific and complete CFC product standard is included in Clause 5.

2 Normative and informative references

The following standards include provisions and guidelines which, through reference in this text, constitute provisions and guidelines of this NORSOK standard. Latest issue of the references shall be used unless otherwise agreed. Other recognized standards may be used provided it can be shown that they meet the requirements of the referenced standards.

2.1 Normative references

ASME B1.1,	Unified Inch Screw Threads (UN and UNR Thread Form)
ASME B16.5,	Pipe Flanges and Flanged Fittings
ASME B16.20,	Metallic Gaskets For Pipe Flanges: Ring Joint Spiral Wound And Jacketed
ASME B16.25,	Butt welding ends
ASME B16.34,	Valves - Flanged, Threaded and Welding End
ASME B18.2.2,	Square and Hex Nuts (Inch Series)
ASME B1.20.1	Pipe Threads, General Purpose (Inch)
ASME B31.3,	Process Piping
ASME B36.10M,	Welded and Seamless Wrought Steel Pipe
ASME B36.19M,	Stainless Steel Pipe
ASME VIII Div. 2,	Boiler and Pressure Vessel Code – Alternative Rules
ASTM A193,	Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-temperature Service
EN 1092-1:2001,	Flanges and their joints - Circular flanges for pipes, valves, fittings and accessories, PN designated - Part 1: Steel flanges
EN 1779:1999,	Non-destructive testing - Leak testing - Criteria for method and technique selection
EN 13480 (all parts),	Metallic industrial piping -
ISO 2768-1,	General tolerances - Part 1: Tolerances for linear and angular dimensions without individual tolerance indications
ISO 4200,	Plain end steel tubes, welded and seamless. General tables of dimensions and masses per unit length.
ISO 4287,	Geometrical product specification (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters
ISO 4288,	Geometric Product Specification (GPS) — Surface texture — Profile method: Rules and procedures for the assessment of surface texture
ISO 5167-1,	Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full – Part 1: General principles and requirements
ISO 5167-2,	Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full – Part 2: Orifice plates
ISO 14313,	Petroleum and natural gas industries – Pipeline transportation systems – Pipeline valves

2.2 Informative references

API Spec 5L,	Specification for Line Pipe
ASTM A105,	Standard Specification for Carbon Steel Forgings for Piping Applications
ASTM A182,	Standard Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
ASTM A216,	Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service
ASTM A240,	Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
ASTM A320,	Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for Low-Temperature Service
ASTM A350,	Standard Specification for Carbon and Low-Alloy Steel Forgings, Requiring Notch Toughness Testing for Piping Components

ASTM A351,	Standard Specification for Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure-Containing Parts
ASTM A352,	Standard Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service
ASTM 494,	Standard Specification for Castings, Nickel and Nickel Alloy
ASTM A516,	Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service
ASTM A638,	Standard Specification for Precipitation Hardening Iron Base Superalloy Bars, Forgings, and Forging Stock for High-Temperature Service
ASTM A694,	Standard Specification for Carbon and Alloy Steel Forgings for Pipe Flanges, Fittings, Valves, and Parts for High-Pressure Transmission Service
ASTM A705,	Standard Specification for Age-Hardening Stainless Steel Forgings
ASTM A790,	Standard Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Pipe
ASTM A928,	Standard Specification for Ferritic/Austenitic (Duplex) Stainless Steel Pipe Electric Fusion Welded with Addition of Filler Metal
ASTM A995,	Standard Specification for Castings, Austenitic-Ferritic (Duplex) Stainless Steel, for Pressure-Containing Parts
ASTM B443,	Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) and Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219)* Plate, Sheet, and Strip
ASTM B564,	Standard Specification for Nickel Alloy Forgings
EN 1591-1,	Flanges and their joints - Design rules for gasketed circular flange connections - Part 1: Calculation method
EN 10025 (all parts),	Hot rolled products of structural steels -
NORSOK M-630,	Material data sheets for piping

3 Terms, definitions and abbreviations

For the purposes of this NORSOK standard, the following terms, definitions and abbreviations apply.

3.1 Definitions

3.1.1

can

verbal form used for statements of possibility and capability, whether material, physical or casual

3.1.2

class

CL

ASME pressure class (ASME B16.5 and ASME B16.34)

3.1.3

compact flanged connection

CFC

non-gasketed bolted static pipe connection including two flanges and where the bolt loads are transferred through metal to metal contact between the flange faces

3.1.4

gasket

barrier to prevent the passage of fluids, which does transmit all loads between flanges, as shown in EN 1591-1, Figure 3

3.1.5

may

verbal form used to indicate a course of action permissible within the limits of this NORSOK standard

3.1.6

purchaser

individual or organisation that buys the pipe connection on behalf of the user and/or operator or for its own use

3.1.7**seal**

component providing a barrier to prevent the passage of fluids, transmitting no significant loads between the flanges

3.1.8**shall**

verbal form used to indicate requirements strictly to be followed in order to conform to this NORSOK standard and from which no deviation is permitted, unless accepted by all involved parties

3.1.9**should**

verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required

3.1.10**supplier**

individual or organisation that takes the responsibility for the supply of the pipe connection and its conformance with this NORSOK standard

3.2 Abbreviations

API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BL	blind flange
CFC	compact flanged connection
CL	class
DN	nominal pipe diameter (mm)
EN	European Standard
ID	internal diameter
IF	integral flange (as part of some other equipment or component)
ISO	International Organisation for Standardisation
IX	special metallic seal ring applied in Clause 5
LB	line blinds (including PS and PB)
NCF5	NORSOK compact flange according to Clause 5
NPS	nominal pipe size (inch)
OD	outer diameter
OS	orifice spacer
PB	paddle blank
PN	nominal pressure (bar)
PS	paddle spacer
PTFE	polytetrafluoroethylene (Teflon®)
RI	rigid interface
RT	reducing threaded flange
WN	weld neck

4 Fundamental design requirements**4.1 General**

This clause specifies the minimum design requirements CFCs shall fulfil in order to be compliant with this NORSOK standard.

Supplier specific CFCs may refer to this NORSOK standard when additional requirements to the minimum requirements specified in this NORSOK standard are agreed between purchaser and supplier. The intention is to allow alternative designs to the products supplied in accordance with Clause 5.

A specific and complete CFC dimensional standard ranging from DN 15 to DN 1200 in pressure classes CL 150 to CL 2500 (maximum DN 600 for CL 2500) is included in Clause 5.

CFCs shall comply with the requirements in the piping or pressure vessel code agreed between the supplier and the purchaser.

CFCs shall

- be designed for face-to-face make-up for transfer of the bolt loading through the flange faces,
- be designed so that a static mode is maintained in the bolted joint up to a specified static mode pressure defined by the purchaser. Static mode is maintained as long as the difference between maximum and minimum nominal load sustained by the bolts in the joint does not exceed 5 % of minimum guaranteed yield load when measured from zero to static mode pressure at room temperature, and at minimum required bolt preload. The static mode pressure shall be at least equal to or greater than hydrostatic test pressure.

4.2 Materials

Flanges covered by this NORSOK standard shall be made from raw material products as listed in Table 1.

Forged bar material shall be certified with all required testing in position T/3 in both the longitudinal and the transverse direction (T = outside diameter).

The hot isostatic pressed process is an acceptable alternative to forging.

Cast flanges, integral or loose, shall be non-destructive tested to comply with casting factor used in calculations to determine performance.

Test samples for certification testing required by the material standard shall be taken from the flange ring transverse to the dominant grain flow direction or alternatively in both axial (weld neck) and tangential (flange ring) direction relative to internal bore.

No repair welding shall be permitted without prior approval of the purchaser.

Any welding shall be carried out in accordance with a written procedure.

4.3 Strength

CFCs shall generally have a level of structural safety that is comparable to that of the connecting pipe or piping component. CFCs shall be designed against the following possible modes of failure, as appropriate:

- gross plastic deformation (excessive yielding);
- leak tightness;
- fatigue failure.

Furthermore, considerations shall be given to maximum and minimum assembly bolt preload and possible loss of bolt preload during operation due to combination of minimum assembly bolt load, pressure, external loads and thermal effects. Minimum assembly bolt load shall be determined based on assessment of accuracy of bolt preload method, short-term and long-term bolt relaxation.

Sufficient resistance against the relevant failure modes shall be demonstrated by a calculation method, which has been validated by testing. This testing shall also verify the static mode as defined by 4.1, by applying a relevant pressure and external load test. When the internal pressure is gradually increased, it shall be demonstrated by measurement of force or elongation of the bolts, that the above requirement is met up to the specified strength pressure

The calculation methods or experimental testing method shall provide sufficient safety margins consistent, where applicable, with the requirements in the piping or pressure vessel code agreed between the supplier and the purchaser. Calculation or testing shall demonstrate that shakedown is achieved at a load level defined as the ultimate capacity. Two cycles of maximum tensile or bending load is sufficient for this purpose.

Calculations shall be made for design conditions that include pressure, external loads, assembly loads, thermal effects and tightness. Design conditions include assembly (bolt-up) condition, hydrostatic test condition and operating conditions. Calculations shall be performed using dimensions of the flange joint in

the corroded and the un-corroded condition, and the more severe case shall control. Corrosion shall be considered on all exposed surfaces.

Stresses resulting from bolt pre-loading shall be regarded as secondary stresses during testing and operation.

Nominal design stress for bolts shall be determined by the same rule as used for nominal design stress of flanges and shells, e.g. same safety factor on yield stress. Bolt materials shall be selected with due consideration to creep and relaxation.

4.4 Corrosion resistance

A CFC shall either be designed, or materials shall be selected, so that main sealing areas can not be subject to corrosion. Corrosion allowance on internally or externally exposed surfaces shall be specified by the purchaser.

4.5 Temperature

The purchaser shall specify the actual temperature range for the application.

4.6 Leakage

The maximum leakage for correctly assembled connections may be specified by the supplier according to EN 1779, and shall be expressed as leakage rate in units of gas throughput ($\text{Pa}\cdot\text{m}^3/\text{s}$) for a specific gas, i.e. helium at room temperature and at max working pressure conditions. The circumferential length for this leakage shall also be specified. It is the responsibility of the supplier to verify that this leakage is not exceeded for the specified design conditions.

Default testing method shall be according to EN 1779. The purchaser may specify other test methods.

4.7 Information requirements for supplier specific CFC

A supplier specific product standard shall be documented by the following items of information:

- general description of suppliers CFC design and features;
- necessary design and verification documentation required by applicable code reference;
- dimensions in mm:
 - overall dimensions;
 - welding neck configuration;
 - pipe wall thickness.
- weight of complete CFC in kg;
- temperature coverage;
- maximum allowable pressure at ambient temperature;
- pressure/temperature (P/T) dependency;
- maximum hydrostatic test pressure in bar;
- load carrying capacity:
 - bending moment in kNm;
 - axial load in kN;
 - static mode pressure at ambient temperature in bar.
- maximum guaranteed leakage rate;
- handling procedures;
- welding and assembly procedures;
- maintenance procedures.

4.8 Designation and marking

4.8.1 Designation

In line with EN 1092-1, the following shall designate the flanges in accordance with this NORSOK standard. The designation elements shall be separated by a slash. The number of characters is not fixed.

- NORSOK standard identification: NCF4 or NCF5 to identify clause in this NORSOK standard;
- flange type abbreviation according to Table 1;

- type of flange facing according to Clause 5 or supplier specific notation;
- nominal flange size;
- pressure class designation (PN, CL or rated pressure);
- pipe dimensions:
 - for standard pipes, the wall thickness in mm to one decimal accuracy;
 - for non-standard pipes, the pipe bore and wall thickness.
- material designation.

See 5.5 for typical examples.

4.8.2 Marking

All flanges, other than integral flanges shall be marked with the suppliers trade mark followed by the flange designation and material charge (cast) identification, see below. All elements shall be separated by a slash. The number of characters is not fixed. Flanges that are identical for several pressure classes shall be marked with the highest pressure class.

- Supplier's name or trade mark.
- Designation according to 4.8.1.
- Cast number of melt identification or suitable quality control number traceable to the cast number.

See 5.12 for typical examples.

5 Product standard

5.1 General

This clause gives a product standard for CFCs that meets the requirements of Clause 4. This product standard is in accordance with ASME VIII Div.2, Appendix 4 and Appendix 6, and has been developed for use in process piping, see ASME B31.3 and EN 13480 (all parts). Additional requirements may be relevant for other applications, e.g. subsea and pipeline risers in the oil and gas industry.

This clause specifies detailed manufacturing requirements for circular steel flanged connections in class designations CL 150 (PN 20) to CL 1500 (PN 260) for nominal sizes from DN 15 (NPS ½) to DN 1200 (NPS 48) and CL 2500 (PN 420) for nominal sizes from DN 15 (NPS ½) to DN 600 (NPS 24). NPS is in accordance with ASME B36.10M and ASME B36.19M.

This clause covers welding neck flanges, WN, blind flanges, BL, spacers, PS, and spacer blinds, PB, valve/equipment integral flanges, IF, orifice spacers, OS, reducing threaded flanges, RT and rigid interfaces, RI.

This clause covers the temperature range from -101 °C to +250 °C.

This clause contains

- flange dimensions and material requirements,
- seal ring dimensions and material requirements for steel seal rings,
- bolting dimensions and material requirements,
- weights of all flange standard components,
- structural capacity equations,
- installation and assembly instructions, maintenance,
- necessary information for manufacturing of flanges and seal components; tolerances, surface finishing and marking.

5.2 Normative references used in Clause 5

ASME B1.1,	Unified Inch Screw Threads (UN and UNR Thread Form)
ASME B1.20.1,	Pipe Threads, General Purpose (Inch)
ASME B16.5,	Pipe Flanges and Flanged Fittings
ASME B16.20,	Metallic Gaskets For Pipe Flanges: Ring Joint Spiral Wound And Jacketed
ASME B16.25,	Butt welding ends

ASME B16.34,	Valves - Flanged, Threaded and Welding End
ASME B18.2.2,	Square and Hex Nuts (Inch Series)
ASME B31.3,	Process Piping
ASME B36.10M,	Welded and Seamless Wrought Steel Pipe
ASME B36.19M,	Stainless Steel Pipe
ASME VIII Div. 2,	Boiler and Pressure Vessel Code – Alternative Rules
ASTM A193,	Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-temperature Service
EN 13480 (all parts),	Metallic industrial piping
ISO 2768-1,	General tolerances - Part 1: Tolerances for linear and angular dimensions without individual tolerance indications
ISO 4287,	Geometrical product specification (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters
ISO 4288,	Geometric Product Specification (GPS) — Surface texture — Profile method: Rules and procedures for the assessment of surface texture
ISO 4200,	Plain end steel tubes, welded and seamless. General tables of dimensions and masses per unit length.
ISO 5167-1,	Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full – Part 1: General principles and requirements
ISO 5167-2,	Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full – Part 2: Orifice plates
ISO 14313,	Petroleum and natural gas industries – Pipeline transportation systems – Pipeline valves

5.3 General description of flange design and features

Figure 1 shows the NCF5 and its seal system.

The flange face includes a slightly convex bevel with the highest point, called the heel, adjacent to the bore and a small outer wedge around the outer diameter of the flange. The NCF5 is made up by tightening/tensioning the flange bolting which pulls the two connector halves together.

For the IX seal ring, axial forces are exerted on the taper of the metal seal ring and translated into a radial sealing force. Furthermore with increased pre-load, the bevel is closed and face to face contact is achieved at the outer wedge while most of the bolt pre-load is transferred as compressive forces between the flange faces at the heel, see Figure 1. The arrows in the figure indicate the applied forces/pressure and the contact forces after make-up and during normal operation.

The principle design of the flange face includes two independent seals. The first seal is created by application of seal seating stress at the flange heel. However, an undamaged flange heel may not seal at any extreme load condition, but the heel contact will be maintained for pressure values up to 1,8 times the flange rating at room temperature. This requirement is only applicable when the WN thickness fulfils the code requirement for minimum pipe wall thickness for the actual material. This pressure will also represent the static mode pressure. The flange also remains in contact along its outer circumference at the flange faces for all allowable load levels. The main seal is the IX seal ring. The seal ring force is provided by the elastic stored energy in the stressed seal ring. Any heel leakage will give internal pressure acting on the seal ring inside intensifying the sealing action.

The design aims at preventing exposure to oxygen and other corrosive agents. Thus, this prevents corrosion of the flange faces, the stressed length of the bolts and the seal ring.

The back face of the flange in the made-up position is parallel to the flange face in order to prevent bending of the bolts in the assembled condition.

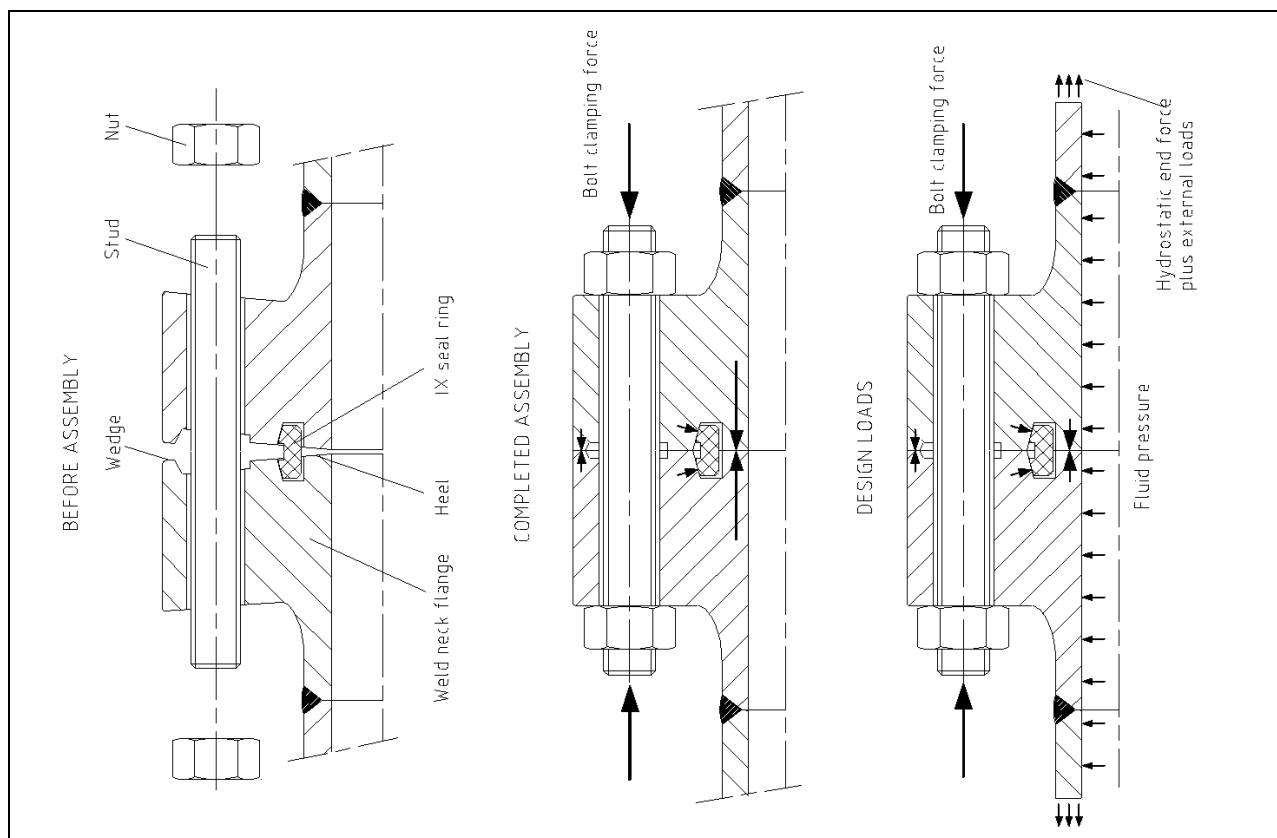


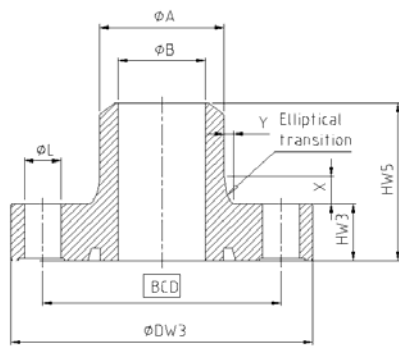
Figure 1 – How the NCF5 works

5.4 Standard components

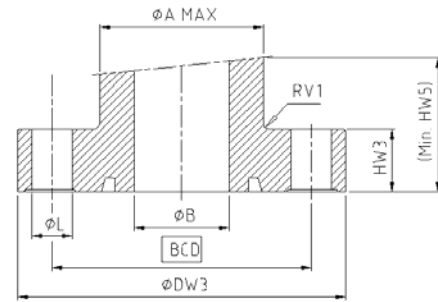
The types of flanges specified in this subclause are given in Table 1 and Figure 2 showing the flange types with the relevant designations.

Table 1 – Types of flanges and accepted raw material forms for manufacture

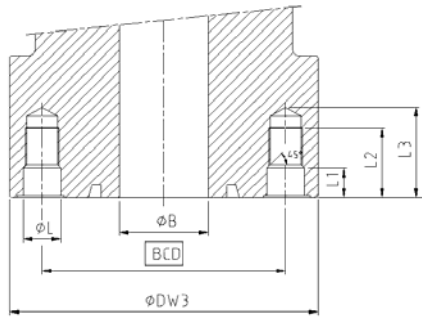
Type abbreviation	Description	Raw material product forms
WN	Weld neck flange	Forging or Forged bar
BL	Blind flange	Plate, Forging or Forged bar
IF	Integral flange as part of some other equipment or component	Forging, Forged bar or Casting
RI	Rigid interface as part of some other equipment or component	Plate, Forging or Casting
PB	Paddle blank	Plate, Forging or Forged bar
PS	Paddle spacer	Plate, Forging or Forged bar
OS	Orifice spacer	Plate, Forging or Forged bar
RT	Reducing threaded flange	Forging or Forged bar



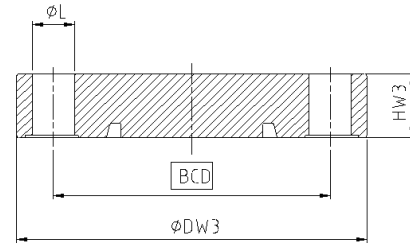
WELD NECK



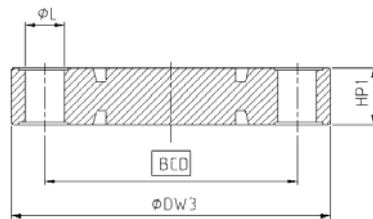
INTEGRAL



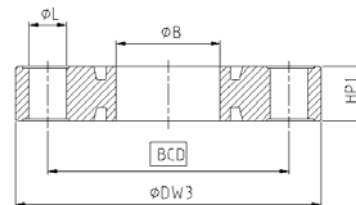
RIGID INTERFACE



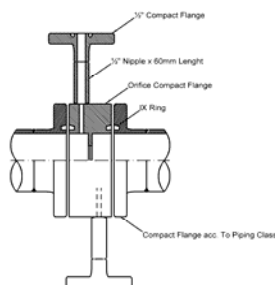
BLIND



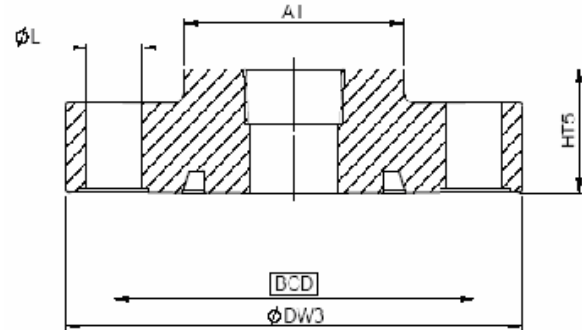
PADDLE BLANK



PADDLE SPACER



ORIFICE SPACER



REDUCING THREADED

Figure 2 – Components in the NCF5 standard

5.5 Designation

The flange designations shall be according to 4.8.1.

Examples of designation are given below:

Example 1

Designation of WN flange in CL 600 with IX groove, nominal size DN 250 with pipe schedule 40S, i.e. 9,3 mm wall thickness and material A182F51 (duplex):

NCF5/WN/IX/DN250/CL600/9.3/A182F51

Example 2

For designation of a BL flange in CL 2500 with IX groove, nominal size DN 200 and with material A516 grade 70 (low temperature carbon steel):

NCF5/BL/IX/DN200/CL2500/A516gr70

Example 3

Designation of a RT flange in CL900 with IX groove, nominal size DN 25, threaded outlet not specified (DN 15 NPT is default, see A.8), and with material A182F316 (stainless steel):

NCF5/RT/IX/DN25/CL900/DN15NPT/A182F316

5.6 General requirements

Requirements herein are additional to those listed in 4.2.

5.6.1 Flange material

The NCF5 covers flanges made of steel and nickel alloys. It is assumed that the flange material has a Young's modulus in the range 190 000 MPa to 210 000 MPa at room temperature. Minimum specified yield strength for flanges to this NORSOK standard is at room temperature 205 MPa. For lower strength materials, the flange size, the bolt pre-tension force and flange face angle shall be determined based on the actual design requirements. The principles of Clause 4 shall then be utilised.

Stainless steel overlay welding of flange faces and seal groove is not considered necessary when interfacing carbon steel and stainless steel flanges.

Annex E gives references to material standards for forged flanges listed by ASME B31.3.

5.6.2 Bolting

It is a design requirement to use bolts of the minimum strength as to ASTM A193 gr.B7.

Imperial standard bolts threaded at both ends or full length may be used. Heavy hex nuts (ASME B18.2.2) shall be used. Threads shall be coarse series, CL 2A (ASME B1.1), and nuts shall be coarse series, CL 2B. The specified tolerances shall be met after galvanising or other surface treatment. Nominal diameters of 1 in and smaller shall be coarse thread series (UNC); nominal diameters of 1½ in and larger shall be of the 8 thread series (8 UN).

Metric bolting may be used if specified by the purchaser. This may affect assembly and bolt preloading procedures. Annex F describes which metric bolts to choose for replacing the listed imperial bolts.

5.6.3 Bolt dimensions and weights

Dimensions and weights of bolts and nuts can be found in Annex C. This annex also describes dimensions of washers/sleeves where this should be used in order to control bolting load during assembly.

5.6.4 Seals

The NCF5 uses a steel seal ring (IX).

The IX seal ring dimensions, design characteristics and typical materials used are given in 5.13.

5.6.5 Pressure/temperature ratings

Generally flanges covered by NCF5 shall be designated as one of the given classes in Table 2

Table 2 – Pressure class designation and ASME rating ceiling values to ASME B16.5

Pressure class		Class abbreviation	Nominal pressure		ASME pressure rating ceiling values	
					psig	barg
Class	150	CL 150	PN	20	290	20,0
Class	300	CL 300	PN	50	750	51,7
Class	600	CL 600	PN	110	1500	103,4
Class	900	CL 900	PN	150	2250	155,2
Class	1500	CL 1500	PN	260	3750	258,6
Class	2500	CL 2500	PN	420	6250	431,0

Flanges covered by a class of Clause 5 will stand the maximum rating of the corresponding ASME B16.5 class over the temperature range covered by NCF5. This corresponds to a utilization factor of 0,5 according to Annex D, which gives a method for determining the external load capacity for flanged connections.

For integral cast flanges also some design codes use the concept of “casting factors”. The yield strength should in such cases be multiplied by the relevant casting factor before used in the capacity equations

5.7 Dimensions

5.7.1 Range of nominal sizes

A summary of the DN's applicable to each rating class is given in Table 3.

5.7.2 Weld neck (WN) dimensions

The minimum outside diameter of the WN of WN flange is equal to the nominal outside diameter of the pipe. The maximum bore is equal to the specified nominal bore. This assures that the minimum WN thickness is equal to or larger than the wall thickness of the connected pipe.

5.7.3 Flange dimensions

Dimensions of the flanges shall be in accordance with the information given in Annex A (see Table 3 for an overview).

5.7.4 Welding end preparation

Details for the weld preparation for WN flanges are given in ASME B16.25. Other welding end preparations can be agreed between supplier and purchaser.

5.7.5 Bolt holes

All bolt holes shall be equally spaced on the bolt circle diameter. Bolt holes on integral flanges shall straddle the horizontal or vertical lines, see Figure 8.

5.8 Weights of flanges

Calculated weights of flanges are based on nominal dimensions given in Annex A and density equal to 7,85 kg/dm³.

NOTE The SI unit system specifies “N” (Newton) as unit for force (weight is a force). However, in this NORSOK standard “kg” is used as unit for weight.

Table 3 – Overview of sizes and rating class (CL)

DN	NPS	CL 150	CL 300	CL 600	CL 900	CL 1500	CL 2500
15	½	Equal to CL 300	•	Equal to CL 2500	Equal to CL 2500	Equal to CL 2500	•
20	¾		•				•
25	1		•				•
40	1 ½		•				•
50	2		•	Equal to CL 1500	Equal to CL 1500	•	•
65	2 ½		•			•	•
80	3		•	Equal to CL 900	•	•	•
100	4		•		•	•	•
125	5		•		•	•	•
150	6		•	•	•	•	•
200	8	•	•	•	•	•	•
250	10	•	•	•	•	•	•
300	12	•	•	•	•	•	•
350	14	•	•	•	•	•	•
400	16	•	•	•	•	•	•
450	18	•	•	•	•	•	•
500	20	•	•	•	•	•	•
550	22	•	•	•	•	•	•
600	24	•	•	•	•	•	•
650	26	•	•	•	•	•	
700	28	•	•	•	•	•	
750	30	•	•	•	•	•	
800	32	•	•	•	•	•	
850	34	•	•	•	•	•	
900	36	•	•	•	•	•	
950	38	•	•	•	•	•	
1000	40	•	•	•	•	•	
1050	42	•	•	•	•	•	
1100	44	•	•	•	•	•	
1150	46	•	•	•	•	•	
1200	48	•	•	•	•	•	

NOTE "Equal to CL xxxx" means that the dimensions are equal for the referred pressure class, the flange shall then be marked with the higher pressure class, see 5.12.

5.9 Flange faces

This clause includes grooves for IX-type flange facings. Flange face dimensions are given together with all other flange dimensions in Annex A.

5.10 Surface finish

The flange surfaces shall be machined to comply with the requirements of Table 4 below, see ISO 4287. A sample of at least 10 % of the batch shall be checked by methods defined in ISO 4288.

Table 4 – Surface finish for flanges

Location	R _a min. μm	R _a max. μm
OD surface of IX groove	-	0,8
Flange heel face	-	0,8
Flange face general and IX groove	-	1,6
Bolt holes	-	12,5
All other surfaces	-	6,3

5.11 Tolerances

Tolerances on dimensions of flanges shall be as given in Annex A, Table A.12. Medium tolerances to ISO 2768-1 shall be used for non specified tolerances.

5.12 Marking

5.12.1 General

The flange marking shall be according to 4.8.2.

The example below is for a DN 250 WN flange CL 600 for a pipe wall thickness of 9,3 mm. The material is ASTM A182 F51 (duplex SS) and the heat number is F1245.

Example for a supplier by the name of XXX:

XXX/NCF5/WN/IX/DN250/CL600/9.3/A182F51/F1245

5.12.2 Stamping

Where steel stamps are used, the marking shall be positioned on the rim of the flange. Care should be taken to ensure that steel stamp markings are not liable to cause cracks in the flange material, i.e. use soft nose stamps.

5.13 IX seal ring

The IX seal ring design exists in one size per DN covering all pressure classes in Clause 5.

5.13.1 Designation

The IX seal ring is designated as described below. The designation elements shall be separated by "/" (slash). The number of characters is not fixed.

- Standard identification - NCF5.
- Type - and ring size - IX and the appropriate DN.
- Material designation.

Example:

Designation of an IX seal ring for DN 250 and material A182F51 (Duplex):

NCF5/IX250/A182F51

5.13.2 Typical seal ring materials

Typical minimum yield stress and ultimate stress for the seal ring material shall at maximum design temperature be 300 MPa and 360 MPa, respectively, in order to allow for reasonably elastic spring-back.

Lower strength may be used, but is not recommended. The user is responsible for selecting a seal ring material which is suitable for the service medium and the design temperature conditions. Seal ring materials are commonly chosen to be compatible with the flange material, i.e. duplex seal ring in duplex flange.

For in service use, Table 5 gives a guideline for seal ring selection.

Annex E gives references to seal ring material specifications that may be used.

5.13.3 Dimensions

Metallic IX seal rings shall have dimensions and tolerances as specified in Annex B. Medium tolerances to ISO 2768-1 shall be used for non specified tolerances. Figure B.2 gives nomenclature used in Table B.2 and Table B.3.

5.13.4 Weights

Annex B gives calculated weights of seal rings based on nominal dimensions and density equal to 7,85 kg/dm³.

Table 5 – Seal ring selection

Flange material	Service temperature	Seal ring material	Seal ring PTFE colour
Carbon steel	-50°C to +250°C	Carbon steel CS360LT or low alloy steels, e.g. AISI 4140	Blue
Stainless steel	-50°C to +250°C	22Cr Duplex	Yellow
Stainless steel	-50°C to +250°C	17/4-PH	Orange
Stainless steel	-101°C to +250°C	Nickel alloys such as Alloy 625 or similar	Black

NOTE 1 For testing purposes at ambient temperature, a carbon steel ring can be used for all flange materials.

NOTE 2 Listed seal ring materials may be less resistant to corrosion than the stainless steel of the flanges, and this is justified by the low probability of corrosion due to the stressed contact between heel areas of the mating flanges, and due to the seal at the outer circumference of the flanges preventing ingress of moisture and water.

5.13.5 Surface finish

All seal ring surfaces shall be machined finished with maximum surface roughness in accordance with Table 6, see ISO 4287.

Table 6 – Surface finish for seal rings

Location	R _a max. µm
Sealing faces	0,8
All other surfaces	6,3

5.13.6 Inspection and testing

No special requirements regarding hardness are required for the IX seal ring as opposed to standard ring-joint gaskets to ASME B16.20.

There is no requirement for Charpy impact testing of seal ring materials.

5.13.7 Coating

Seal rings shall be coated with 10 µm to 30 µm PTFE coating. The colour of the coating shall follow the requirements of Table 5.

5.13.8 Marking

5.13.8.1 General

All seal rings shall be marked with the suppliers trade mark followed by the seal ring designation and material charge (cast) identification, i.e. as follows:

1. suppliers name;
2. designation;
3. cast number of melt identification or suitable quality control number traceable to the cast number, e.g. F1245.

Example (XXX supplier):

XXX NCF5/IX250/A182F51/F1245

Stamping or other suitable marking shall be positioned on inner diameter of the ring.

5.13.8.2 Stamping

Where steel stamps are used, care should be taken to ensure that the sealing faces are not damaged.

5.14 Handling, installation and assembly

5.14.1 General

This information serves as a guide during handling, welding and assembly of NCF5. In addition, it contains procedures for preload qualification.

NOTE: All NCF5 products shall be supplied without any damages and scratches, i.e. 5.14.7 applies to damages occurred on sites for fabrication and installation of piping only.

5.14.2 Protection

Flanges shall be supplied with suitable protection of the flange face, such as plywood boards or plastic caps. They should not be removed prior to field assembly to minimise the likelihood of accidental damage - except for inspection, welding and stress relieving of the weld area. Seal rings should be stored in its original packing until final installation. Careful handling is of the utmost importance.

5.14.3 Flange handling

Flanges shall not be lifted by slinging through the bore of the flange, as this may damage the seal surface and the bevelled end. It is preferable to lift using the bolt holes or other suitable lifting points.

5.14.4 Welding

Protect the flange sealing faces with an inhibitor to prevent oxidation during pre-heating and stress relieving.

Ensure that the sealing faces are protected from scratching and weld splatter. The alignment tolerances are similar as for conventional ASME/ANSI flanges. If flanges welded to the pipe spools are not to be assembled immediately, coat the sealing faces with grease or another type of preservative.

5.14.5 Painting

If the flange is to be shot-blasted and painted, then it is imperative that the plywood board or protective cap is left on preferably also sealed off by strong adhesive tape to prevent damage to the sealing faces. No contact areas should be painted in order to avoid loss of bolt preload. This includes flange faces and nut bearing areas.

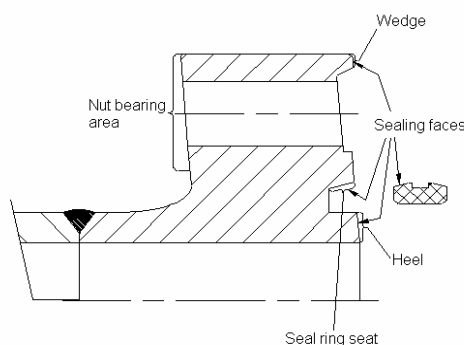


Figure 3 – Flange areas to be protected

5.14.6 Procedure personnel and equipment for assembly

For flanged connections, which rely on axial compression to activate the seal and to ensure a static mode of action, the capacity depends directly on the bolt pre-stress achieved. Bolt preloading procedures and personnel shall be qualified according to 5.14.11. Ensure use of skilled workmen and correct equipment. Final preload tools should be well maintained and should have accuracy within $\pm 2\%$ of the torque or tension to be applied, see Table 8.

5.14.7 Preparation before final preloading

Clean and check

Use a nonabrasive soft cloth to clean all components with solvent to remove grease, preservation and dirt. Special care should be taken on sealing faces and contact areas. Check that all components are of correct material and size.

Inspection and repair, see Figure 3 and Figure 4, and Table 7

Examine all sealing surfaces for mechanical damage and rust. The sealing faces rely on a good surface finish. These surfaces should therefore be free from leak path scratches, damage marks and other surface irregularities. Use a suitable light source and run the fingertip over seal surfaces to detect dents and gouges. Polish off any small scratches on the heel, seal ring and seal ring seat with fine emery cloth in the circumferential direction only. Polish at least one third of the circumference to ensure a uniform blending of the re-work area. Lateral polishing is unacceptable. Larger flange damages may require flange face re-machining.

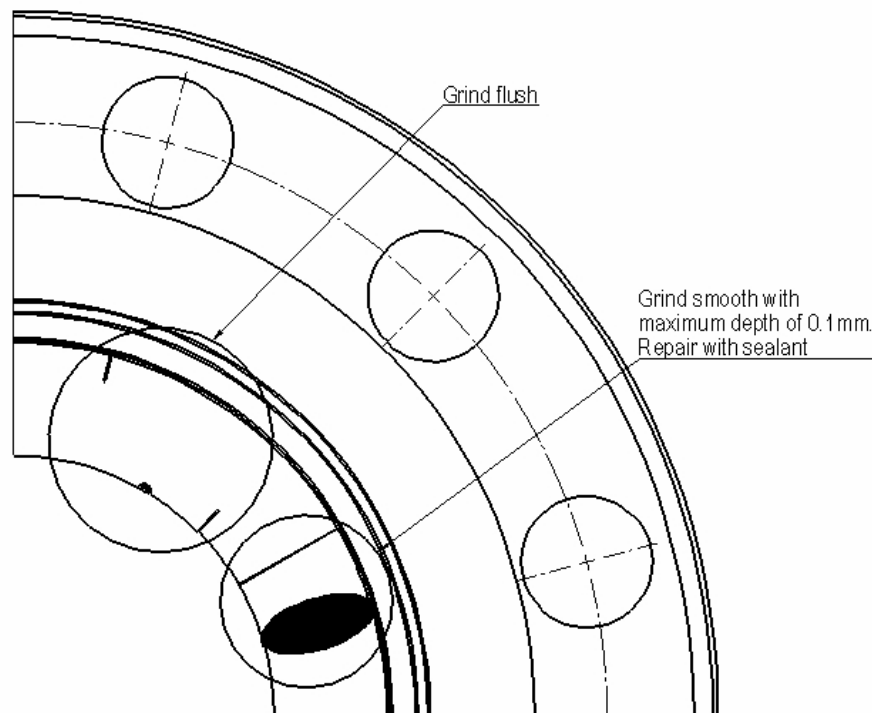


Figure 4 – Repair of heel

Table 7 – Damage repair guide

Damage and location	Remedy
Scratch or dent at the heel, covering less than $\frac{3}{4}$ of the heel width.	Grind with fine emery paper to the required depth. Finish with emery paper grade 240.
Scratch or dent at the heel, covering $\frac{3}{4}$ or more of the heel width.	Grind with fine emery paper to the required depth. Finish with emery paper grade 240. The depth after grinding should be maximum 0,1 mm. "Repair" large scratches with a suitable sealant (gasket eliminator).
Small scratch in seal ring seat location.	Grind with fine emery paper. Finish with emery paper grade 240.
Outer wedge.	Remove any burr standing proud of the surface by grinding/filing.
Seal ring sealing faces.	Replace seal ring.

Inspect bolt threads and nut bearing area to verify that there is no evidence of galling or other damage. The surface shall be completely intact. If any sign of damage, discard and replace.

IX seal ring – Installation and check for stand-off

When the seal ring is placed in the groove by hand, it should rock slightly in the groove, i.e. the ring should be unable to firmly contact the groove bottom. If this is not the case the seal will need replacing.

Use a pull up cord as shown on Figure 7 when installing the IX ring between flanges in horizontal piping, and remove the cord when the ring has entered the flange grooves on each side.

Use of lubrication and sealant

Assembly of compact flanges does not require use of lubricants or sealants if flange sealing surfaces are undamaged. On repeated assembling operations it is recommended to lubricate sealing surfaces by applying a layer of thin oil. If flange sealing surfaces have been damaged, a layer of a suitable sealant should be applied to ensure tightness, see Figure 4 and Table 7.

Lubricate

The nut thread and nut bearing surfaces on the flange should be lubricated in accordance to the qualified procedure when torque is used to achieve the final preload.

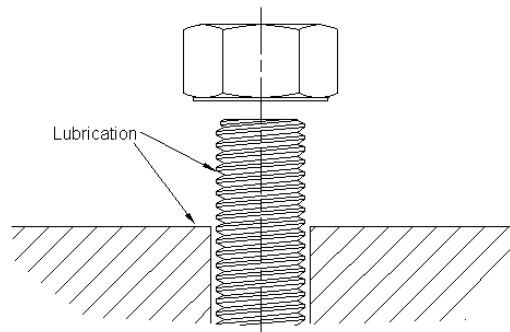
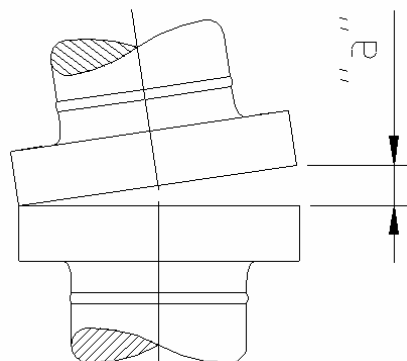


Figure 5 – Thread lubrication



Alignment of facings, "a", shall not be more than 3mm or 10mm per meter flange diameter, whichever is the greater.

Figure 6 – Flange assembly alignment

Alignment

With the seal ring in the groove of one of the flanges (parallel standoff), bring the other flange into alignment, see Figure 6. The load to bring into alignment shall not exceed the maximum load given in the section below. The shear load capacity of the IX seal ring is given in Annex B.3. The bolt holes should be positioned so that the bolts can be moved easily.

Fitting

The stud shall protrude one to two threads from the nut on the side where the tool is not used. Loosely assemble the studs and nuts. As the flanges are drawn together by the tightening of the bolts, the IX ring will provide the final alignment of the flange prior to full make-up of the joint.

Tighten the bolts using a spanner in a criss-cross pattern, such that the seal ring standoff is closed and there is face-to-face contact at the heel. Typically 10 % of final bolt tightening torque should be sufficient, see Table 8 for non-restrained pipe-work. However, if misalignment will require a higher load in order to bring the flange heels together, do as follows:

Step 1: Pull flanges together without the seal ring, and measure applied force when flange heels are touching around the whole circumference. Acceptance limit: No bolt shall be loaded more than 15 % of the target preload in Table 8.

Step 2: Release and insert the seal ring. Pull flanges together. If closing of the gap between the flanges at the outer rim is impossible within the target preload values of Table 8, this is cause to reject the alignment.

If final preload is not applied immediately, it is preferably to seal off the flange faces with adhesive tape to avoid foreign particles to enter the gap between the flange faces.

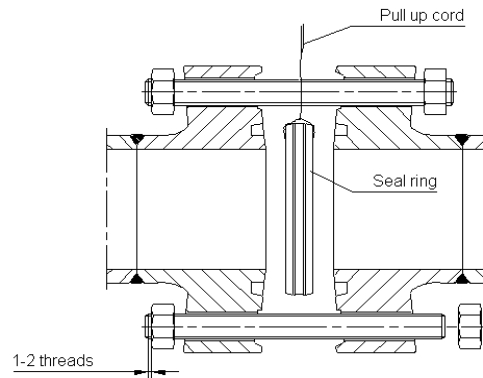


Figure 7 – Seal ring installation

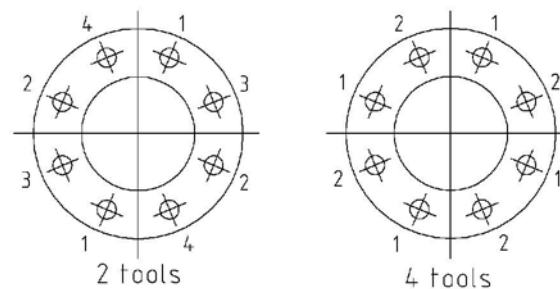


Figure 8 – Bolt pre-loading sequence

5.14.8 Final pre-loading procedure

Tighten bolts in a diagonal sequence as illustrated in Figure 8. The bolt preload shall be applied in suitable steps. Especially when using only one tool the preload used in the first step shall not be greater than 30 % of the total preload. Start with the bolt where the flanges have the largest gap.

Tighten bolts to 100 % of the applied tension or torque values given in Table 8 for imperial standard bolting, and see Annex F for metric bolts. The flanges are stronger than the bolts and can not be overloaded by the bolts. Continue torque or tensioning the bolts until the nuts can not be turned with the preset max load value from the tool. Check that the flange gap at the flange outside diameter is closed all around the circumference of the connection.

If closing of the gap at the outer rim was just achieved at the target value of Table 8 due to misalignment, it is recommended to increase the final pre-load to 5 % above the target value of Table 8.

5.14.9 Maintenance

NCF5 connections do not require special maintenance if correctly assembled. Seal ring may be reused if they have sufficient standoff, see 5.14.7, and are free from defects. Minor rust, burrs or scratches on sealing faces shall be removed, see 5.14.7, *Inspection and repair*.

5.14.10 Disassembly

Before disassembling compact flanged connections, verify that all pressure has been bled from the line. As a safeguard, the bolting should be slackened (1/6 turn first time) gradually in a criss-cross sequence enabling a controlled release of fluid. Then remove the bolting completely. Once the flange is fully disassembled and inspected, it is advisable to re-apply suitable surface protection and protection on the flange faces and seal ring.

When disassembling the flanges, great care should be exercised to avoid damaging the outer diameter seal. Hence, the use of standard flange spreaders should be avoided. However, such tools may be used if suitable jacking brackets are welded to the flange diameter. Spreader tools designed for use in the bolt holes may be used.

Table 8 – Final bolt tension and torque values

Stud bolt size in	Target residual preload ^{a c} kN	Applied tension with tension tool ^{b c} kN	Applied torque with torque tool and lubricant $\mu=0,12^d$ Nm
1/2-UNC	44		98
5/8-UNC	71		192
3/4-UNC	106	134	341
7/8-UNC	147	186	544
1-UNC	193	244	816
1 1/8-8UN	255	323	1194
1 1/4-8UN	325	412	1671
1 3/8-8UN	405	512	2261
1 1/2-8UN	492	623	2989
1 5/8-8UN	589	745	3840
1 3/4-8UN	693	878	4859
1 7/8-8UN	807	1022	6020
2-8UN	929	1177	7351
2 1/4-8UN	1199	1519	10610
2 1/2-8UN	1503	1904	14665
2 3/4-8UN	1667	2111	17766
3-8UN	2004	2539	23240
3 1/4-8UN	2373	3006	29736
3 1/2-8UN	2773	3512	37258
3 3/4-8UN	3204	4058	46046
4-8UN	3666	4643	56008
NOTE Bolting material: ASTM A193 gr.B7, ASTM A193 gr.B16 and ASTM A320, gr.L7 and gr.L43			
a	Target minimum pre-stress is 75 % of yield such that a minimum of 70 % is achieved due to uncertainties in the make-up procedure. Bolt root diameter used.		
b	The applied tension is equivalent to 95 % of yield in bolt in order to ensure that a minimum of 75 % of yield (target residual value) is left when preload is transferred from the tension tool to nut.		
c	Washers may be necessary for some flanges to achieve sufficient residual bolt load with tension tool.		
d	Torque tests with a specified lubrication procedure shall be performed to determine the appropriate coefficient of friction. Full filling of threads with lubricant is recommended.		

5.14.11 Bolt tensioning qualification procedure

5.14.11.1 General

This clause describes procedures for qualification of bolt preloading with hydraulic tensioning or hydraulic torque methods. The target minimum prestress should be 75 % of yield such that a minimum of 70 % prestress is achieved after losses due to time dependent strains (relaxation). However, the target value should be lower for bolts of higher strength than required in 5.6.2, and also lower for some metric bolts, see Annex F. This procedure applies to bolt sizes above 1/2 in or M12. Standard spanners used by trained

personnel may be used for smaller sizes, i.e. no special procedure is necessary. However, the personnel shall be trained to recognize suitable torque according to yield strength properties of the bolts, and the requirements of 5.14.7 apply.

The requirement for skilled operators is a very important aspect, which often is neglected. The complete assembly of tool and torque/tension measurement instrument shall be calibrated together and have a calibration traceable to a recognised international standard. Finally in order to achieve good accuracy and repeatability operators shall be technically qualified and experienced in assessing surface conditions, lubricant application and tool performance.

5.14.11.2 Torque preloading

5.14.11.2.1 Background

Preloading by torque is achieved by applying a measured torque to a bolt and nut with a controlled lubrication. For bolts of moderate length the required torque is with good accuracy given by the following expression:

$$T = \frac{F_p}{2} \left(\mu_n \times d_n + 1.155 \times \mu_t \times d_t + \frac{p}{\pi} \right)$$

where	T	=	torque applied to the bolt
	F _p	=	required bolt preload
	μ _n	=	coefficient of friction of nut bearing surface
	d _n	=	effective contact diameter of nut face (average between width of cross flats and diameter of bolt hole)
	μ _t	=	coefficient of friction of threads
	d _t	=	effective (mean) contact diameter of threads
	p	=	thread pitch

The nut and thread friction is set equal to μ in Table 8, i.e. μ = μ_n = μ_t. It is seen that the coefficients of friction are of dominant importance to the achieved preload. The coefficients of friction are sensitive to a number of factors:

- bolt/nut material;
- bolt surface coating;
- type;
- amount;
- condition;
- method of application;
- contamination;
- temperature of the lubrication of the bolt threads and nut bearing surface;
- hardness of all parts;
- surface finish;
- speed with which the nut is tightened;
- the fit between threads and thread tolerances.

Consistent application of bolt lubrication is vital in maintaining the consistency of induced bolt stresses at assembly with torque methods. Change of lubrication will change friction coefficient and hence the required torque.

5.14.11.2.2 Equipment

Use the following equipment:

1. a torque wrench with a current calibration certificate or, a hydraulic torque tool with a pressure gauge of class 1.6 or with better accuracy and with a calibration certificate;
2. a hollow load cell with a capacity at least equal to the yield strength of the bolt. The capacity should desirably not exceed twice the yield capacity of the bolt. The load cell shall have a valid (not more than 12

month old) calibration certificate traceable to a recognised national standard from an accredited laboratory;

3. two solid steel backing plates with one hole in each to suit the bolts;
4. suitable bolt lubricant such as a MoS₂ lubricant supplied in a closed container such as an aerosol or a tube or box;
5. five sets of bolts with nuts for calibration test.

5.14.11.2.3 Calibration and qualification

The following procedure shall be followed:

1. place load cell between reaction plates, enter bolt and nuts and pull hand tight after lubricating according to lubrication procedure. Centre the bolt on the load cell;
2. apply specified torque value;
3. record bolt force achieved;
4. repeat steps 2. and 3. with the remaining bolt sets;
5. calculate the mean tensile load achieved;
6. calculate the standard deviation of the tensile load achieved;
7. calculate the minimum bolt tension as the mean value less one standard deviation and check to see that this exceeds the minimum bolt load specified;
8. calculate the maximum bolt load as the mean plus one standard deviation and the corresponding axial bolt stress as well as the shear stress due to the applied torque. Check that the equivalent von Mises stress does not exceed the yield strength of the bolts;
9. if the checks in 7. or 8. are not satisfied revise the specified bolt torque or the lubrication procedure or chose a new lubricant and repeat the same procedure using new bolts and nuts until satisfied.

5.14.11.2.4 Lubrication procedure

The purpose of this lubrication procedure is to apply bolt lubrication as consistently as possible without contaminating the lubricant. Apply lubricant in a manner that can easily be repeated giving a consistent amount of lubricant. To achieve this it is recommended that the threads shall be filled with lubricant.

5.14.11.3 Hydraulic tension preloading

5.14.11.3.1 Background

Any bolt tensioner exhibits a load transfer loss as the bolt load is transferred from the bolt tensioner to the nuts. The bolt load loss is a direct loss of stud elongation, this due to many different factors, such as thread deflections, radial expansion of the nut and "Bedding in" of the nut into the flange. Extra load shall be applied so the bolt will relax down to the required load on load transfer. The load transfer loss can be calculated as:

$$\Delta = 0,9 \, d/l$$

where Δ = fraction of the initially applied pre stress lost in transfer
 d = nominal bolt diameter
 l = clear bolt length between engaged threads

If the bearing surface is flexible this shall be allowed for by calculating the equivalent effective bolt length. The d/l ratio should not exceed 0,222 which corresponds to a load transfer loss of 0,20. The bolt length may have to be increased by using washers for some flanges. Refer to tables in Annex C for details.

5.14.11.3.2 Equipment

The following equipment is required:

- a hydraulic tensioner;
- an electronic load cell with a valid calibration from an accredited laboratory traceable to a recognised national standard;
- two solid steel backing plates;
- five bolts with nuts.

5.14.11.3.3 Qualification and calibration

The following procedure shall be followed:

1. place the load cell between the reaction plates, insert bolt and attach nuts;
2. install bolt tensioner and apply estimated initial tensile load;
3. make transfer and record achieved pre-load;
4. repeat step 1. to step 3. for all five bolts;
5. calculate the mean tensile load achieved;

6. calculate the standard deviation of the tensile load achieved;
7. calculate the minimum bolt tension as the mean value less one standard deviation and check to see that this exceeds the minimum bolt load specified;
8. calculate the maximum bolt tension as the mean value plus one standard deviation and check to see that this is lower than the maximum bolt load specified.