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EXTERNAL REFERENCE / VERSION

Design Report

ITER VACUUM FLANGE USE DESIGN GUIDANCE

This document's purpose is to define the permitted design loadings and application for the ITER Style Vacuum Flange and provide sufficient information to allow mechanical engineers or designers to properly apply this protection important component (PIC), within a vacuum system.

Approval Process			
	Name	*Action*	*Affiliation*
Author	**Quinn E.**	**04 Jan 2017:signed**	**IO/DG/COO/PED/FCED/VS**
Co-Authors			
Reviewers	**Dremel M.**	**09 Jan 2017:recommended**	**IO/DG/COO/PED/FCED/VS**
Approver	**Pearce R.**	**26 Jan 2017:approved**	**IO/DG/COO/PED/FCED/VS**
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Change Log			
ITER VACUUM FLANGE USE DESIGN GUIDANCE (PA3BXP)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v1.0	Signed	15 May 2014	
v1.1	Approved	22 May 2014	Addressed comments form M Dremel and reformated using ITER template
v2.0	Signed	17 Jul 2015	Full revison of guidance note following revised FEA: Includes: Sizes: DN065, DN100, DN150, DN200, DN250 & DN300 Flanges in both Fixed and Rotatable configurations. Gives Allowable Bending Moments for flange design. Gives Allowable Shear Force for flange design. To qualify for ASME or EN13445 compliance.
v2.1	Approved	28 Aug 2015	Previous work reported in gave data only for the DN065 & DN150 flanges, further work revises these figures. The analysis method used for the first set of FEA was purely linear elastic, the second FEA round used elastic-plastic analysis to better model the rotatable flanges. This was applied consistently across the range of all flanges in the suite. This accounts for the changes in the figures from the previous version of this document and slight resizing of the rotatable flange elements that have enabled a greater allowable moment for the rotatable flange during service.
v2.2	Approved	04 Jan 2017	Addition of Tooling Clearances needed to assembly and disassemble these flange using hand tooling.

Table of Contents

1 Purpose

This document's purpose is to define the permitted design loadings and applications for the ITER Style Vacuum Flange and provide information to allow mechanical engineers and designers to properly apply this protection important component (PIC) within a vacuum system. The basis of these values results from the analysis defined by [1] and fully reported in [2].

2 Scope

This document covers the ITER Style Flange Suite for use in VQC 1 [3] systems. Six sizes are in the range DN065 to DN300. Two joint types are considered,

- Fixed Flange to Fixed Flange and,
- Fixed Flange to Rotatable Flange.

A third arrangement of either style flange assembly with a cover plate is not included. This arrangement is used to blank off a line permanently in the case of equipment not being available for installation or having been removed in some future scenario.

It is the responsibility of the engineer to ensure these flanges are suitable for the application. Reference to the Vacuum Handbook [3] should be made to ensure compliance to ITER vacuum standards.

Recommended clearances around the flange for tooling and assembly aides are given in 4.1 below.

2.1 CAD Models

CAD models of the flanges can be found in ENS Catalogue. Drawings exist and are tabulated below. Also short form document summarising the key dimensions can be found in [4]. The ENS Catalogue shall always be used as the source reference.

Table 1 Flange Assembles Covered by this Design Guidance Note:

FLANGE SIZE DN	FIXED TO FIXED	FIXED TO ROTATABLE
065	BFGFDN	QQ6HVF
100	BLZJ8N	QQ7A7Z
150	BLZK9E	QQBYPM
200	BM3LDD	QQEGCW
250	BM3ZRG	QQHTXQ
300	BM43TL	QTV5NS

2.1 Limitations

A rotatable flange cannot have a service vacuum system (SVS) interspace connection; the mating of two rotatable flanges together is not permitted when a pumped and monitored interspace is required as is the case for a VQC 1A flange joint. If a rotatable flange is directly connected to equipment then that equipment shall provide an SVS connection to allow interspace monitoring and pumping.

The values given in the Table 4 below are set as absolute maximum values for each case and shall not be exceeded.

2.2 Further Advice

Contact the ITER Vacuum Section [5] to clarify any open questions.

3 Definitions and Acronyms

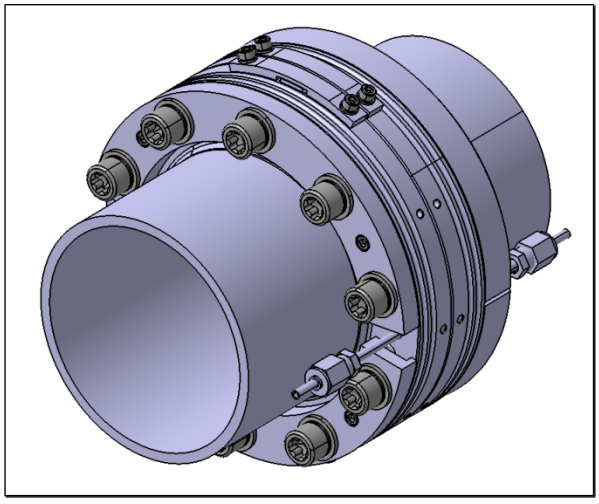
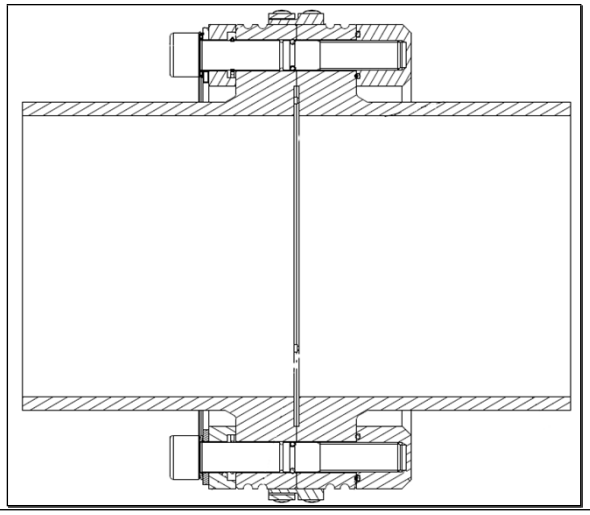
ENS	Equipment & Systems Catalogue
FEA	Finite Element Analysis
PIC	Protection Important Component
SVS	Service Vacuum System
VQC	Vacuum Quality Class

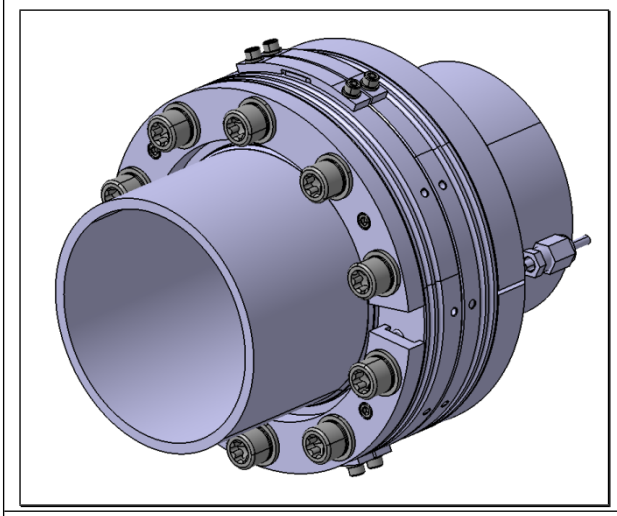
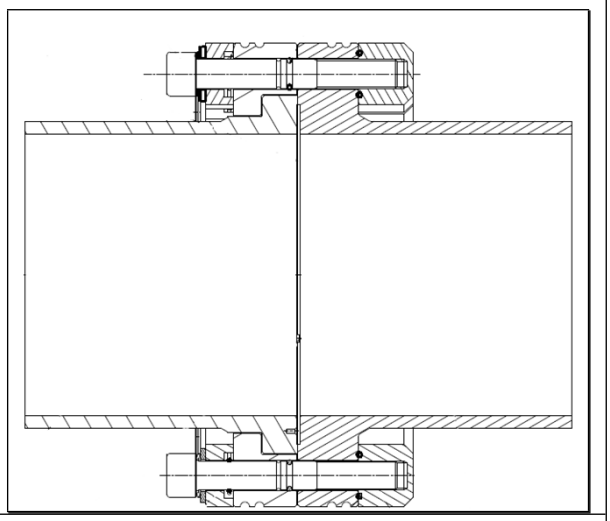
For a more complete list of ITER abbreviations refer to [6].

4 Operational Conditions

Category		Internal Pressure [kPa Absolute]	External Pressure [kPa Absolute]	Temperature [°C]	Leak Rate [$Pa.m^{-3}s^{-1}$]
I	Normal	0 – 200	100	0 – 120	$<1x10^{-10}$
II					
III	Emergency	0 – 200	260	0 – 200	$<1x10^{-1}$
IV	Faulted				

Table 2 General Flange Arrangement and Free Body Diagrams for the ITER Flange

	
GENERIC ASSEMBLY DN150 Fixed to Fixed	SECTION VIEW: Fixed to Fixed

	
GENERAL VIEW Fixed to Rotatable Assembly DN150	SECTIONAL VIEW Fixed to Rotatable Assembly DN150

3.1 Design Codes

These ITER flanges have been optimised to comply with three design codes:

- ASME B31.3 M [7]
- EN 13445 [8]
- RCC-MR [9]

The allowable moments and shear forces given in Table 4 may be used in designs that use the above codes.

3.2 Configurations

Two configurations are given for the Flange Assemblies:

1. Flange configures for ASME code compliance.
2. Flange configured for EN13445/ RCC-MR code compliance.

The difference is in the bolting used for the main flange bolts

3.2.1 ASME Configuration

Bolts shall be in Grade B21 SA540 Class 1

3.2.2 EN13445/RCC-MR Configuration

Bolts shall be in Grade 1.6580+QT to EN10269

3.3 Comment on the Table Values

Presented in the table below, using two significant figures, are the recommend maximum values for Allowable Bending Moment and Allowable Shear Force for the load categories. These are given for as the maximum value allowable under each category. The assumption is made that the flanges will be baked to 200°C. This is limiting case for the allowable bending moment.

In the table below the maximum allowable moment for VQC 1A leak rate is given for normal operation category I & II conditions. Generally this moment is limited by the sealing performance requirement. In the case of the DN065 the factored[1] mechanical limit of the model representing the ultimate failure of the flange assembly is reached at the same load hence the coincidence of the maximum moments for the category III & IV and the normal operating category.

For category III & IV conditions sealing performance will be maintained to at least a containment level of $1x10^{-1}$ $Pa.m^{-3}s^{-1}$.

It has been demonstrated by test that the sealing performance is robust. For a DN150 Rotatable to Fixed flange assembly its sealing performance to VQC 1A leak rate was maintained up to a quasi-static applied moment of 6.2kN.m [10]. This exceeded the VQC 1A design allowable value of 2.8 kN.m by more than 120%.

4 Assembly of Flanges

Assembly of the flanges is to done to the assembly procedure for ITER style flanges [11].

4.1 Tooling Clearances needed for assembly

The following tooling clearances are required for assembly of these flanges. The assumption is made that normal tooling is used with torque wenches for the final tightening sequences. In all cases a standard ergonomic data coupled with experience has been used [12], a hand width of 110mm with a glove worn was chosen.

[1] In the design code a factor of 2.5 or 2.4 (depending on the code), is applied to ensure the mechanical collapse load is not reached.

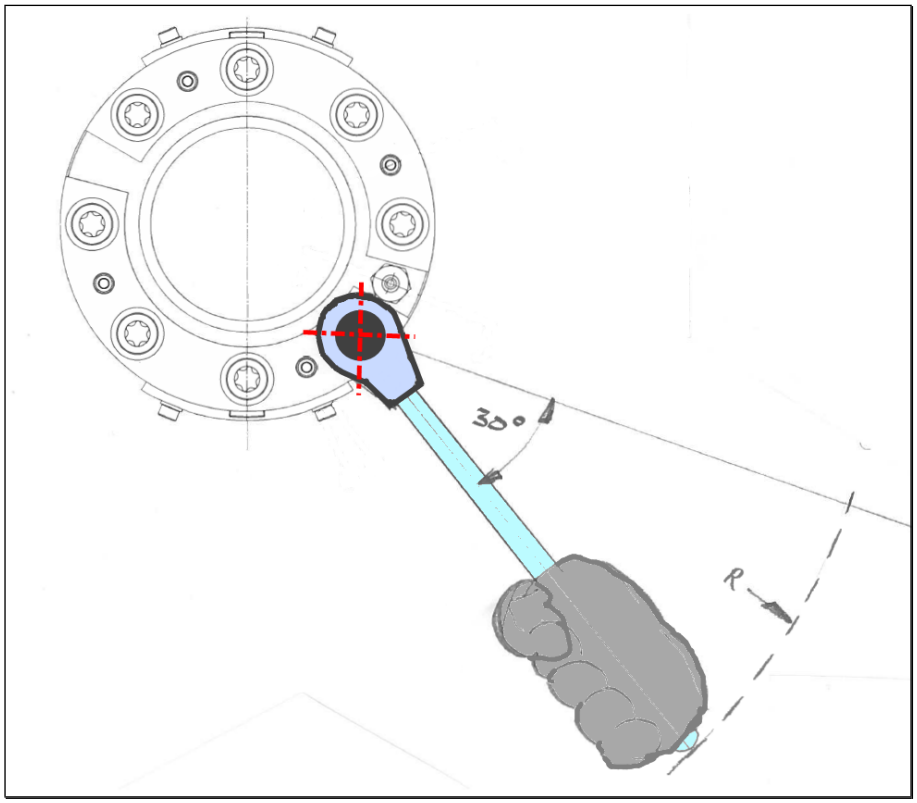


Figure 1 Radial Clearance Needed for Tooling

Table 3 Table of Dimensions [mm]- see Figure 1 & Figure 2.

Flange Size Any Type, Fixed, Rotatable or Blind cover	Main Bolt Size	A Bolt is fully loosened from flange	B Bolt is fully tightened in flange	C Tool Bit minimum length	D Engagement clearance	R Radial Clearance needed with 30° minimum cranking angle
DN65	M12	175	122	62	5	500
DN100	M14	180	124	64	5	500
DN150 & DN200	M16	185	125	65	5	500
DN250 & DN300	M16	195	125	65	5	500

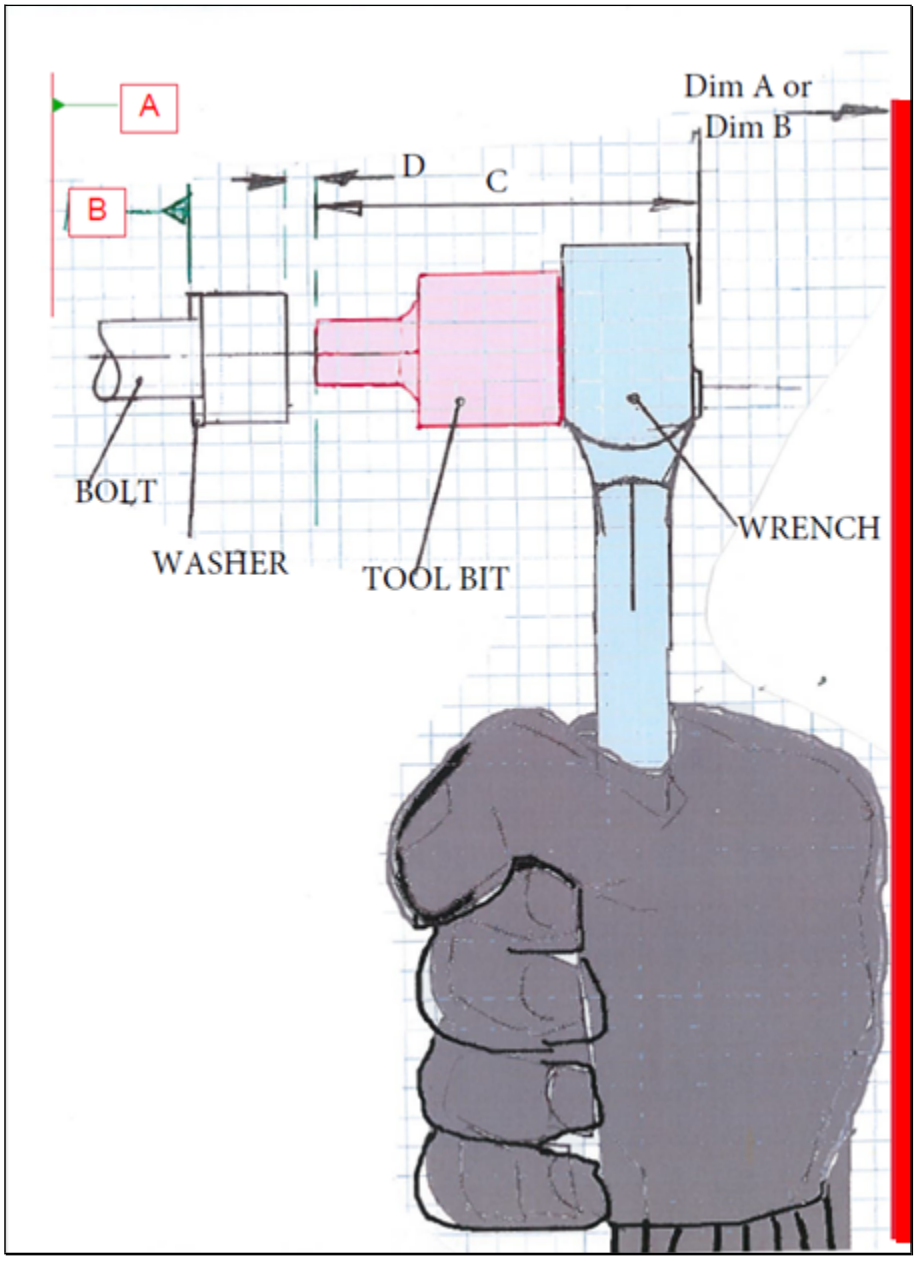


Figure 2 Clearance Dimensions for Tooling on Flanges

5 Design Guidance Allowables

5.1 Bending Moment and Shear Force Allowables for Design Purposes

Table 4 Maximum Allowable Moments & Shear Forces

FLANGE SIZE (Drawing IDM Ref)	Bolt Torque Assumes μ = 0.2 **[Nm]**	ASSEMBLY. TYPE	Max Allowable MOMENT **[kN.m] CAT I & II**	Max Allowable MOMENT **[kN.m] CAT III & IV**	Max Allowable SHEAR FORCE F **[kN]**
DN065	**76**	FIXED / FIXED	1.0	1.0	**20**
DN065R		FIXED / ROTATABLE	1.0	1.0	
DN100	**135**	FIXED / FIXED	2.3	2.3	**25**
DN100R		FIXED / ROTATABLE	1.5	2.9	
DN150	**186**	FIXED / FIXED	3.3	7.5	**38**
DN150R		FIXED / ROTATABLE	2.8	7.5	
DN200	**186**	FIXED / FIXED	4.0	11	**49**
DN200R		FIXED / ROTATABLE	3.8	11	
DN250	**186**	FIXED / FIXED	7.6	19	**62**
DN250R		FIXED / ROTATABLE	5.7	19	
DN300	**186**	FIXED / FIXED	9.5	24	**75**
DN300R		FIXED / ROTATABLE	17	24	

5.2 Seal Specification

Below the seal part number are given to be used with each Flange Size for VQC 1A applications. The use of any other seal not in this list will not qualify the flange assembly for VQC 1A use.

Table 5 Twin Torus HND229 All Metal Seals suitable for VQC 1A ITER Style Flange [13]

Size	Ref. Number	Description
DN65	**211439**	HELICOFLEX HND 229 DRG 111-0081957 REP 1
DN100	**224803**	HELICOFLEX HND 229 DRG 111-0081957 REP 2
DN150	**211440**	HELICOFLEX HND 229 DRG 111-0081957 REP 3
DN200	**224804**	HELICOFLEX HND 229 DRG 111-0081957 REP 4
DN250	**224805**	HELICOFLEX HND 229 DRG 111-0081957 REP 5
DN300	**224806**	HELICOFLEX HND 229 DRG 111-0081957 REP 6

These seals are available from **Technetics Group**

6 References

1 Technical Specification for Design Optimization of the ITER Double Metal Seal, Conceptual Bolted Flanges Suite BJHRXQ v1.8
2 Design Optimization of the ITER Double Metal Seal, Conceptual Bolted Flanges suite. QYLFAG
3 ITER Vacuum Handbook 2EZ9UM v2.3
4 ITER Style Flange Basic Dimensions, QQ5BDA v2.0
5 Vacuum Section. ITER HQ: 13067 St Paul Lez Durance, France.
6 ITER Abbreviations ITER_D_2MU6W5 v1.15
7 ASME B31.3M (ASME VIII DIV 2 PART 5)
8 EN 13445 -3 (ANNEX C)
9 RCC-MR (RCC-MRx)
10 DN150R TEST RESULTS REPORT QYU7TP_v1.1
11 ITER Style Flanges Instruction for Assembly RF27FL
12 A. Mital, W. Karwowski, 1991, Work Space, Equipment and Tool Design, Amsterdam Elsevier Science, ISBN 0-444-87441-0 edited by, table 16 page 202
13 Technetics Drawing 111-0081957 Rev D 16/FEB/2015 R79YB4