ASME Code Qualification of ConFlat Flanges

Overview

ConFlat (CF) flanges or their equivalent are available from a number of vacuum supply companies (i.e. MDC Vacuum, Kurt J. Lesker Co., NorCal, etc.). They have been designed for vacuum service only. It has been standard practice at a number of facilities, Jefferson Lab being one, however, to use these fittings as pressure fittings where high purity and extremely cold (<4.5K) (non permanent or semi permanent) connections are required. Figure 1 gives a cutaway view of a typical CF connection. The all metal leak tight seal is achieved by extruding the gasket between the opposing conical sealing (knife) edges. This causes the gasket material to flow against the capture rings. The extruded gasket material fills small imperfections in the sealing surfaces and provides a reliable leak tight seal. It is commonly thought that the actual sealing surfaces are the knife edges. We will assume, however, that they are the outer capture rings.

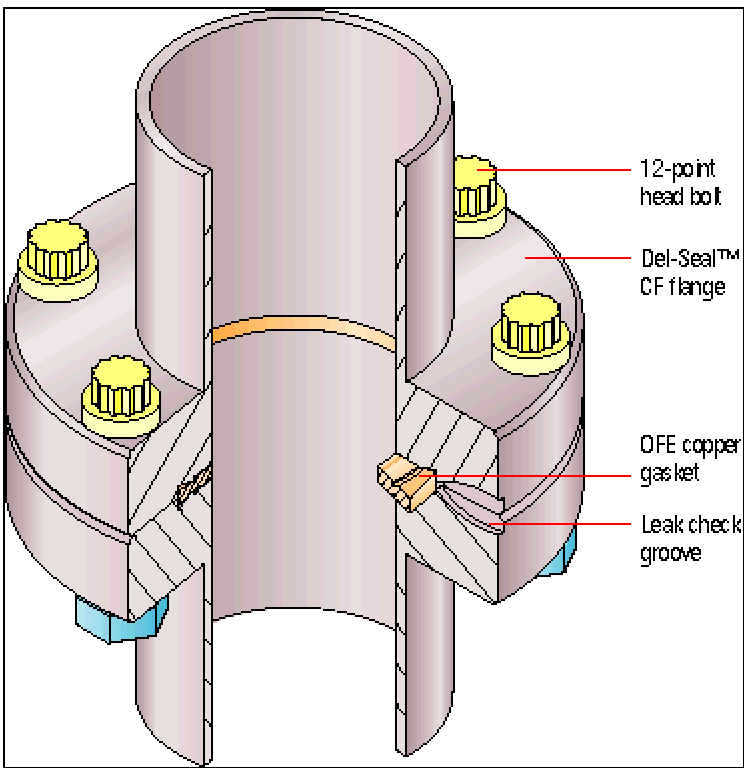

Figure 1: Cutaway view of CF assembly. From MDC Vacuum Catalog.

The purpose of this technical note is to qualify as much as possible the CF flange connection for use in ASME (B31.3 and Section VIII Div. 1) coded pressure systems and components. Pressure design of flanges and blanks is covered in Appendix 2 of the ASME Boiler and Pressure Vessel Code Section VIII Div. 1. Other necessary information is contained in Appendix S of the same code. The B31.3 code, for process piping, (Section 304.5) refers to this section of the B&PV code for flange design.

UG-34 Eq (2) of Section VIII gives the required minimum thickness for a blank flange or flat cover as

$$t = d\sqrt{CP/SE + 1.9Wh_g/SEd} \quad (1)$$

where

C is a constant determined by flange geometry. Using sketch (k) it is 0.3

d is the mean gasket diameter

P is the pressure loads

W is the gasket seating bolt load

E is a casting factor

h_g is the

A slight modification of this equation should be used. The pressure seal should be taken as the gasket OD. The gasket seating moment arm h_g is determined as the radial distance from the bolt circle to the knife edge. The first term in the radical considers on the pressure load. The second term considers only the moment from the bolt load. Thus, the minimum thickness of the CF flange is given by

$$t = \sqrt{CPd_g^2/SE + 1.9Wh_g d_k/SE} \quad (2)$$

where

d_k is the knife edge diameter

d_g is the gasket ring diameter

An expression for stress can easily be derived from the above equation for a given thickness. The standard CF flange available from MDC can be supplied with a certificate of conformance. This states that the material is SST 304. From Table 1A in Section II of the ASME B&PV code, the maximum allowable stress for SST 304 plate is 20 ksi.

Test Procedure

Materials

The following is a list of the tools and materials used to assemble the CF test joints.

1. Torque wrenches
   1.1. Kobalt 3/8 drive (Ser#1001500784)
   1.2. KD ¼ drive (Ser#991135747)
2. Snap-On torque tester (Ser # 0699800012) calibrated.
3. Transducer Techniques load cell Model THC-7.5K-S Serial # 114657
4. Test flanges were supplied by MDC vacuum
5. Gaskets (both OFHC copper and aluminum) were supplied by Kurt J. Lesker Co.
6. Loctite 51609 anti-seize
7. Bolting hardware (18-8 SST nuts and bolts no washers were used)
   7.1. 1.33" nominal flange hardware from Kurt J. Lesker Co.

7.2. 2.75" and 2.125" flange hardware from Kurt J. Lesker Co. (1/4-28 x 1.25 12pt)
7.3. 13.25" flange hardware from York Bolt (3/8-24 x 3.5 HHCS)
7.4. All other flanges (5/16-24 x 3.5 12pt) from Kurt J. Lesker Co.

Torque wrench calibration

It is recognized that there will be significant error in the actual bolt torque for an individual technician using a given torque wrench. In an effort to minimize this error and quantify it, the technician performing all assembly work and torque wrench calibration/force measurements was kept constant. Both torque wrenches are "snap" type. The assembly technician and torque wrenches were checked for consistency using the Snap-On torque tester at multiple torque settings. Table A1 in Appendix A summarizes the measurements made to check the consistency of the small ¼ inch drive KD torque wrench and technician. Measurements were made at 10, 20, 30, 40, and 68 inch pounds. Similar measurements were also taken with the Kobalt 3/8 in drive torque wrench at larger values of torque. These data are shown in Table A2.

While it is necessary to understand the consistency of the actual torque, it is most important to know the actual force (bolt load) relative to a given torque setting. The total bolt load will be required in the analysis of the flange and fastener stress. It is common practice to determine the force on a bolt assembly using the standard equation for fastener torque τ

$$\tau = kFD \quad (3)$$

Where

k is a coefficient determined by friction geometry etc.

F is the bolt load force

D is the nominal outer diameter of the fastener

The coefficient k is nominally taken as 0.2 in many conditions and Machinery's Handbook suggests 0.18 for lubricated assemblies. For our case, however, it is proper to measure the value of k where possible. Indeed it is even better to measure the absolute force applied by the fastener for a given torque setting. The load cell was used to determine the actual force applied by a given fastener for a given toque setting. Figure xxx shows the technique. Measurements were performed with both torque wrenches at several torque settings. These data are summarized in Table A3. Accounting for torque consistency and load cell error, the data indicate that a conservative error for absolute force applied is 10%.

CF test assemblies

The test assemblies were made by assembling two blank CF flanges with a copper gasket (from Lesker) and, when available, aluminum gaskets (from Lesker). The flanges were tightened using the cross flange pattern recommended in the MDC catalog until the flanges were visibly close to "metal to metal". At this point, the fasteners were torqued in a clockwise pattern until the flange faces were visibly "metal to metal". This is the standard practice of many of the technicians at Jefferson Lab. No washers were used on any assembly. In all cases, a backing wrench was applied to the nut and the torque wrench was applied to the bolt head (see Figure xxx).

The torque was incrementally increased in 5 inch lb steps when using the smaller KD wrench and in 1 ft lb steps when using the Kobalt wrench. The fasteners were tightened at a given torque setting in repeated patterns until no rotation was felt. If needed the torque setting was increased and the tightening pattern repeated. The final torque setting was recorded. In the case of the smaller flange sizes, many assemblies were measured. In all cases (with the exception of the aluminum seals), at least 2 assemblies were measured. No measurable deviation in torque required to complete the assembly was found at any flange size, thus it is felt that more test assemblies are unnecessary. Assemblies using “plate nuts” (Ref 1) were also tested.

After the initial gasket crushing assembly, the bolts were loosened to less than finger tight and retightened following the same procedure above so that the flanges were again “metal to metal”. This was done to determine the gasket sealing torque. This is the final gasket seating torque required to maintain a leak tight connection. The final gasket seating torque values were also recorded.

Results

The torque values required to make each CF connection are summarized in Table xxx. The 1.33 and 2.75 (aluminum gasket only) inch CF joints were assembled using the KD torque wrench. All other assemblies were performed with the Kobalt torque wrench.

Nominal Flange Size (in)	Torque Cu (in lb)	Torque Al (in lb)
1.33	40	31
2.125	163.2	n/a
2.75	163.2	67
3.375	197.5	142
4.5	217.7	142
4.625	190.4	n/a
6	217.7	163.2
8	246.8	146.8
10	260	163.2
13.25	330	n/a

Table 1: Torque values required to make CF assemblies "metal to metal"

Analysis

Flanges

The actual force required to make the CF seal was determined from the final torque wrench setting and the data in Table A3. It is clear from equation (2) that an expression for stress in the flange may easily be derived. Table xxx shows the final bolt loads for copper gasket assemblies.

Fasteners

Appendix A

This appendix contains the torque wrench consistency and calibration data.

Table A2 : Torque consistency data for 1/4 inch drive KD torque wrench all data are in inch pounds

Torque Setting (in-lb)	10	20	30	40	68
Data	12.7	24	32	40.1	66.1
	12.7	22	29.4	39.9	66.9
	13.9	19.2	29.1	39.6	66
	13.9	20.8	28.4	38.5	67
	11.1	19.3	29.4	40.4	67.7
	11.6	20.3			66.9
	12.1				
	11.1				
	12.6				
	11.1				
	10.6				
Average	12.12727	20.93333	29.66	39.7	66.76667
Std dev	1.137621	1.823915	1.370401	0.731437	0.631401

Table A3: Torque consistency data for 3/8 inch drive Kobalt torque wrench all data are in inch pounds

Torque Setting (ft-lb)	**10**	**11**	**12**	**13**	**15**	**16**	**17**	**18**	**19**	**20**
										.
Data (in-lb)	117	131	142	168	182	191	219	236	243	250
	121	131	144	162	182	196	215		247	256
	115.2	138	146	162	189	195	217		247	260
	117.2	140	138	159	178.3	198	212		247	252
	117.2	142	146.6	161.7	194	196	212		243	245
		140		150	179	195	209		243	241
				151	188				243	252
				148						
				150						
				156						
				157						
Average	117.5	137	143.3	156.8	184.6	195	214	236	245	251
Std deviation	2.119	4.8	3.48	6.423	5.829	2.3	3.7		2.1	6.4

Table A3: Torque wrench setting to absolute force calibration data

				Torque wrench setting to force calibration Excitation voltage is 10V 2mV per V full scale (7500 lb) Kobalt wrench					
Torque setting (ft lb)	Torque Setting (in-lb)	Actual torque (in-lb)	Error Torque (in-lb)	Load Cell readout (mV)	Fastener OD (in)	Force (lb)	Coefficient K	Error K	Error Force (lb)
10	120	118	2	5.35	0.313	2006.25	0.19	0.01	112.0501604
11	132	137	5	5.81	0.313	2178.75	0.20	0.01	134.479561
12	144	143	3	6.34	0.313	2377.5	0.19	0.01	133.3982048
13	156	157	6	6.77	0.313	2538.75	0.20	0.01	161.0098237
14	168	168	0	7.57	0.313	2838.75	0.19	0.01	150.1375589
15	180	185	6	7.95	0.313	2981.25	0.20	0.01	178.7758102
16	192	195	2	8.76	0.313	3285	0.19	0.01	176.4593824
17	204	214	4	9.75	0.313	3656.25	0.19	0.01	207.1244576
18	216	236	0	10.45	0.313	3918.75	0.19	0.01	203.6701817
19	228	245	2	10.86	0.313	4072.5	0.19	0.01	214.4773258
20	240	251	6	11.77	0.313	4413.75	0.18	0.01	264.8551591
21	252	252	0	12.28	0.313	4605	0.17	0.01	263.3922946
22	264	264	0	12.74	0.313	4777.5	0.18	0.01	270.6087294
25	300	300	0	13.66	0.313	5122.5	0.19	0.01	273.7707319
27	324	324	0	14.36	0.313	5385	0.19	0.01	280.1371736
27	324	324	0	9.16	0.375	3435	0.25	0.01	136.5651042
KD wrench									
	20	21	2	0.87	0.313	326.25	0.21	0.02	44.40902721
	30	30	1	1.41	0.313	528.75	0.18	0.01	34.08049604
	40	40	1	1.91	0.313	716.25	0.18	0.01	43.95591393
	50	50	0	2.47	0.313	926.25	0.17	0.01	53.70698531
	68	67	1	3.41	0.313	1278.75	0.17	0.01	78.73891481