HEAT EXCHANGER WORLD
CONFERENCE & EXPO
AMERICAS

2022

SOLVING DIFFICULT CASES OF THERMAL EXPANSION

Pasadena, TX
November 16, 2022
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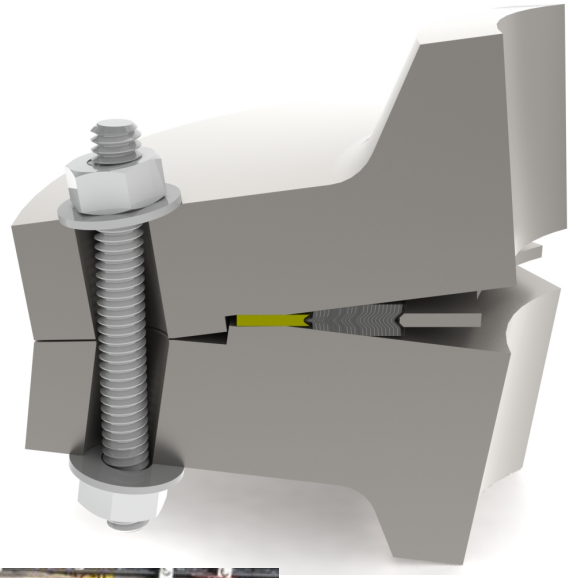
Flexitallic US, Director of Engineering

Some Phenomena are Hard to Avoid

- Bolted flange bending (flange rotation)



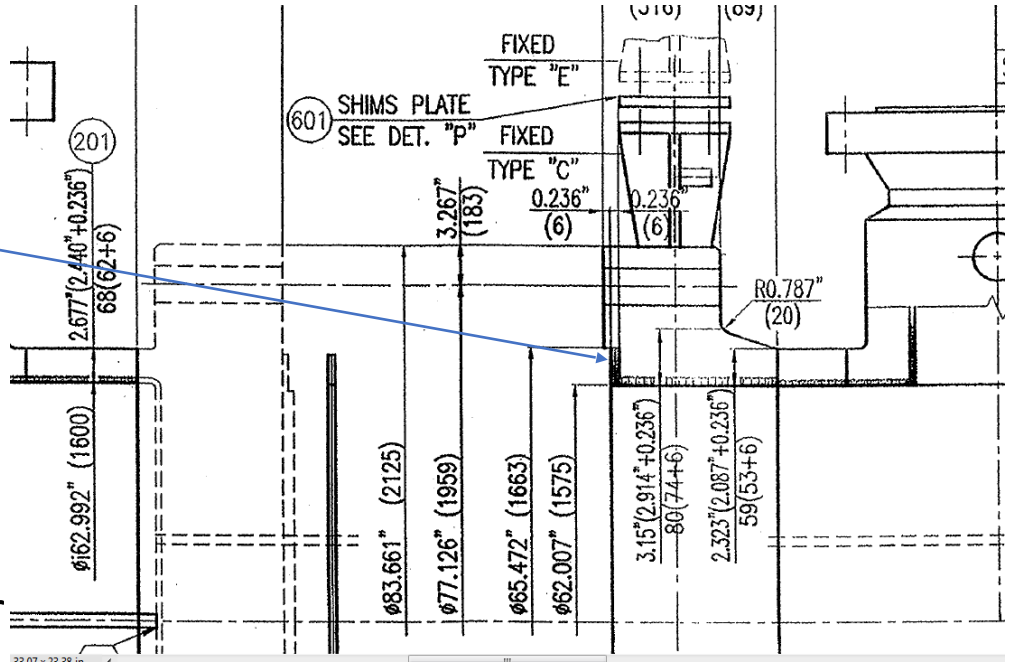
- Differential Thermal Expansion

Hydrotreater Mechanical Outage Extension

Feed/Effluent Exchanger Large Refinery, Port Arthur, TX

Exchanger information

- Shell and Tube w/ Integral Tubesheet
  - Design information:
    - 62” ID
    - Shell– 1200 psig @ 800F
    - Tube– 1445 psig @ 750F
    - New 2010
    - 2010: The distillate hydrotreater unit producing ultra low-sulfur diesel is brought on stream
    - Bolt design stress <40ksi
    - B7 Bolting

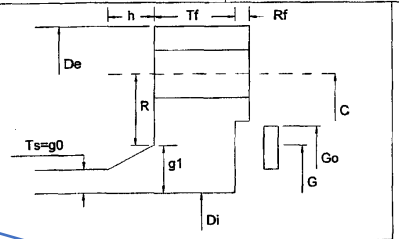


- Very Large/High Pressure Vessels
- Original gasket type Kammprofile
- 3-1/2” bolt size creating excessive stress
- Very critical joint with flammable hydrocarbons
- Leaks due to upsets while the emergency shut off valves close unexpectedly
- Bending moment a suspect (although thick flanges)
- Had to use Furmanite rings to continue the operation, but was not successful

MT-COMP Rev.3.1.3

1926 Villa & Bonaldi
Ricengo - Italy

Project: 7012 Date: 19-10-2007
Item: 43E-502 A/B Sh. 16 of 163
Calculation Code: ASME VIII-1 A.2006 Par. App.2-App.S
Calcul.Datasheet : Flange shell-tubesheet



Material
Shell: SA 387 22 CL2-K21590
Flange: SA 336 F22 CL3-K21590
Bolts: A 193 B7-A194 2H-G41400
Lining: AISI 347
Gasket: SS 304 Camprofile
Flange facing: FLAT-FLAT
Bolts series: TEMA Tab.D5

(Flange 1)

DESIGN CONDITIONS

P	- Pressure	1538.	Psi	De	- Flange outside diam.	83.661	in
Pe	- External pressure	15.	Psi	C	- Bolts circle diam.	77.126	in
T	- Temperature	800.	Fahr	Go	- Gasket outside diam.	65.354	in
Ci	- Internal corrosion	-	in	Tf	- Flange thickness	12.205	in
Ce	- External corrosion	-	in	g0	- Hub lower thickness	2.323	in
Pli	- Internal lining	0.236	in	g1	- Hub higher thickness	3.15	in
Di	- Shell inside diam.	62.008	in	h	- Hub length	3.504	in
Ts	- Shell thickness	2.323	in	Cfg	- Flange corr. (gask.face)	-	in
fv	- Shell all.stress	19300.29	Psi	Pfg	- Weld deposit (gask.face)	0.236	in
fvo	- Shell all.stress (amb)	21405.21	Psi	ff	- Flange allow.stress	19300.29	Psi
Tb	- Bolts temperature	800.	Fahr	ffo	- Flange allow.stress(amb)	21405.21	Psi
Nb	- Bolts number	32		Ng	- Gasket width	1.299	in
An	- Bolt area	8.749	in2	w	- Nubbin width	-	in
Db	- Bolts nom.diameter	3.5	in	m	- Gasket m factor	3.	
fb	- Bolts allow.stress	23000.	Psi	y	- Gasket y factor	12500.	Psi
fbo	- Bolts allow.stress (amb)	23000.	Psi	Rf	- Riser thickness	0.236	in
Nr	- Rib width	-	in				
rl	- Rib length	-	in	m'	- Rib gasket m factor	-	
				y'	- Rib gasket y factor	-	Psi
F	- Radial load	-	Lbf	M	- Bending moment	-	Lb.in
Hri	- Gasket ring height (int.)	-	in	Hre	- Gasket ring height (ext.)	-	in

Bolts area check

bo = .5*Ng = 0.65 b = .5 * $bo^{1/2}$ =0.403 G = Go - 2*Hre - 2*b = 64.548
bor = .5*Nr = - br = bor = -
Pldi = 16*M/(π*G^3) - 4*F/(π*G^2) = - Plde = 16*M/(π*G^3) + 4*F/(π*G^2) = -
Peqi = Max[P, (P+Pldi)] = 1538. Peqe = Max[Pe, (Pe+Plde)] = 15.
H = .25*π*G^2*Peqi =5033013. Hp = 2*P*[π*b*G*m + br*rl*m'] = 754135.3
Wm1 = H + Hp = 5787148. Am1 = Wm1 / fb = 251.608
Wm0 = π*b*G*y + br*rl*y' = 1021531. Am0 = Wm0 / fbo = 44.413
Am = MAX(Am1, Am0) = 251.608 Ab = Nb * An = 279.968 ≥ **Am**

Gasket overloading

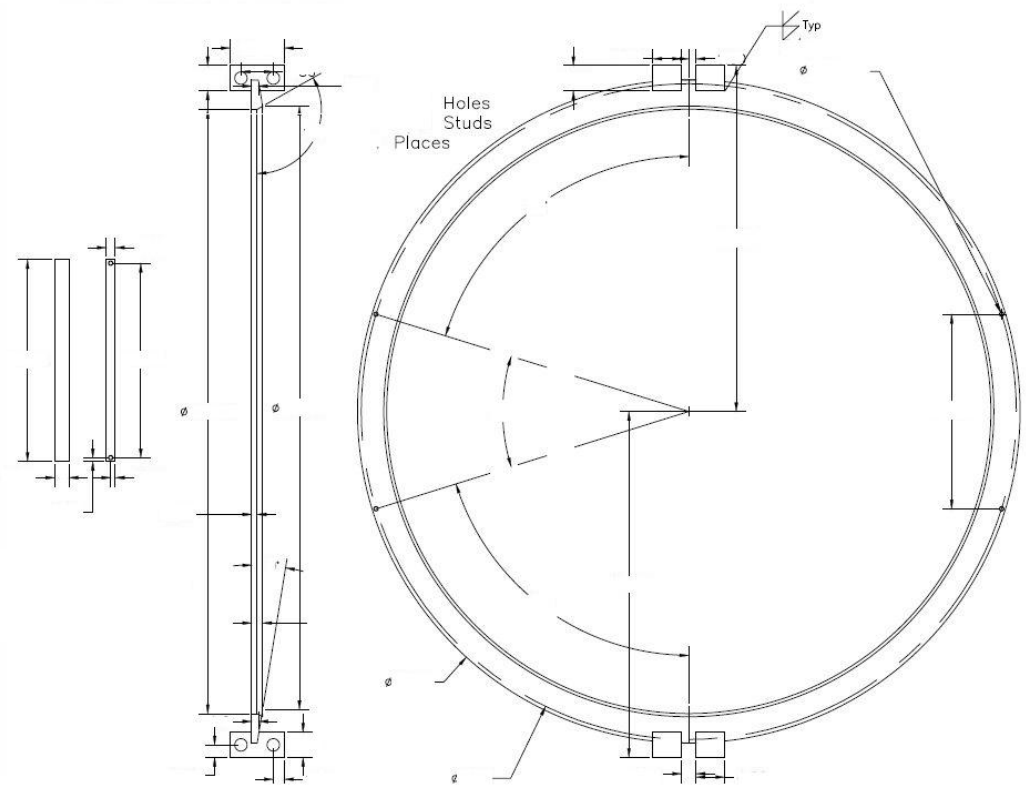
Sbo = fbo = 23000. N1 = Ab*Sbo / (2*π*G*y) = 1.27
N2 = (.785*G^2*Pe + Ab*fb) / (2*π*G*y) =1.28 Nmin = MAX(N1, N2) = 1.28 ≤ **Ng**

Service gasket

- Original fabrication gasket
  - Service gasket since 2010 –
  - Gasket installed and hydro-tested at factory
  - Kammprofile 4mm core, 0.5mm graphite both sides
  - 321SS core with graphite face
  - Leaks during thermal cycle events

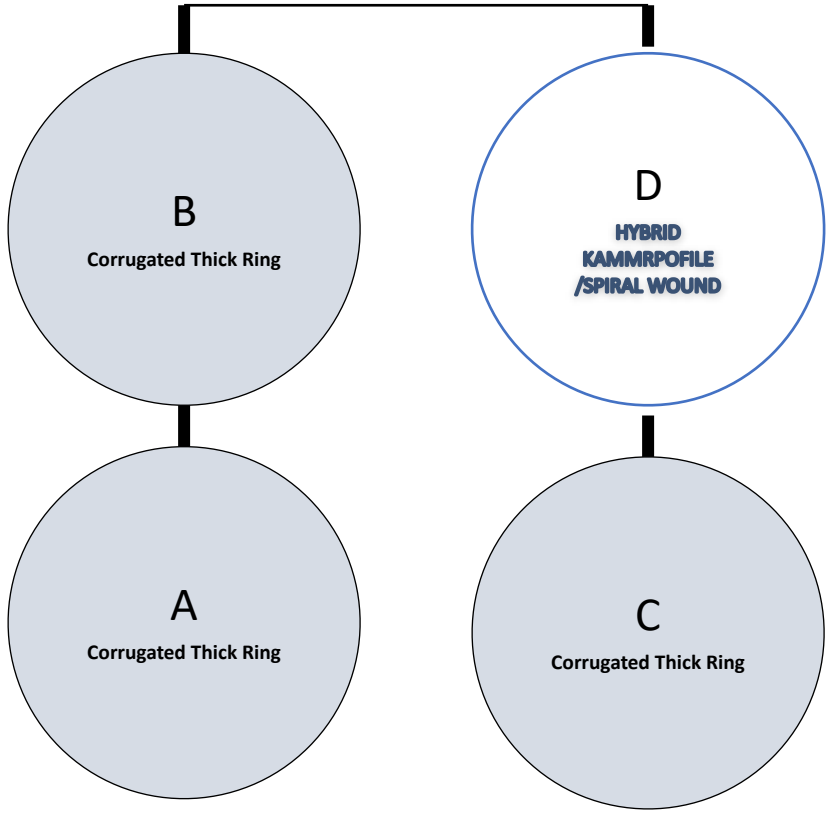
Events after start up

- Exchanger girth flange develops leak after thermal cycling event
  - First attempt to stop leak was by torquing
    - Torquing is unsuccessful
    - Bolts were initially tensioned and bolt nuts are dry
    - Difficult to torque accurately considering no lubrication and size of bolts
  - Leaking girth flange is clamped
    - Clamp is marginally successful
    - Clamp requires periodic re-pumps
    - Clamp leaks after thermal events or feed rate changes



Gasket Options

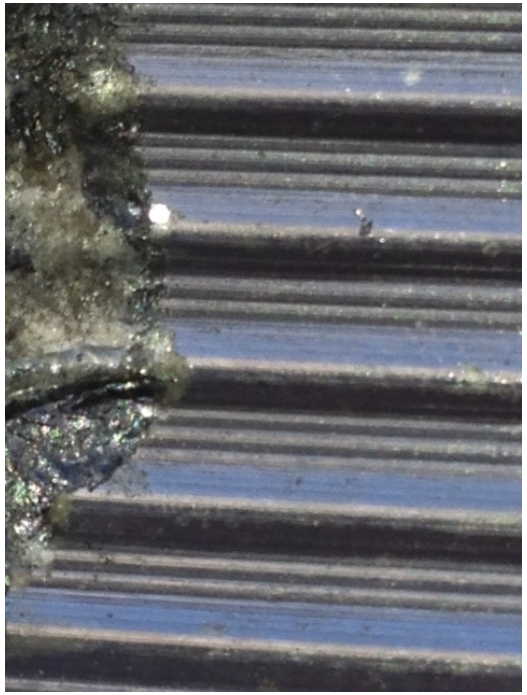
- Two gasket designs are installed during outage to test performance.
  - (1) Hybrid - Kammprofile inner-ring, spiral wound outer-graphite filler
  - (3) Thick Corrugated Ring with – Mica/Graphite/Mica (Picked to achieve some saving as the hybrid gasket was more expensive



Gasket Options

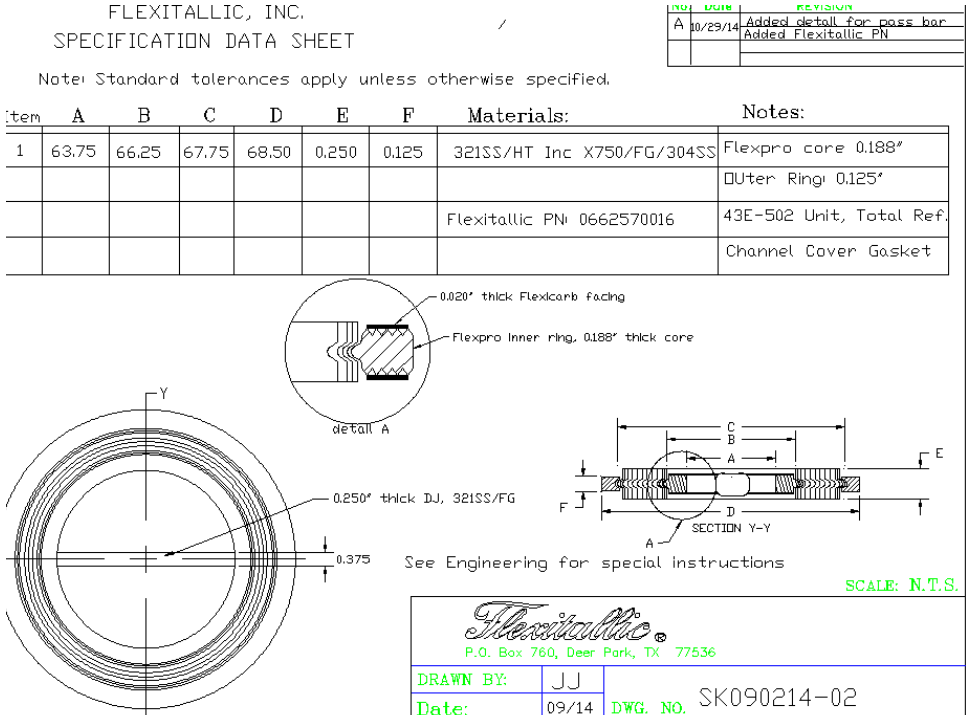
Experienced “blow-out” of thick corrugated gasket during hydro-test.

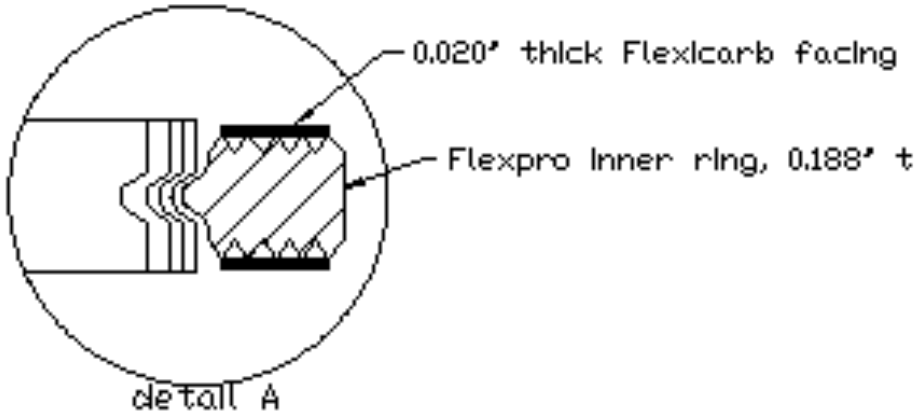
- Gasket would seep water during ramp up of hydro-test pressure
- Seeps were stopped by re-torquing
- Additional torquing possibly rotated flanges causing them to become nearly metal bound
  - Possibly rotated flanges unload the corrugated gasket
- Gasket “blows out” prior to reaching full hydro-test pressure
  - Post mortem revealed gasket filler material separated (slipped) from core and damages (dents) to core are observed



Initial Solution

- **Special Kammprofile inner/SW outer**
- **The inner 0.188” thick Flexpro to act as torque stop**
- **The outer SW with HT inconel X750 will not be unloaded due to excessive bolt load**
- **The thin (0.125”) outer ring will NOT act as stop**
- **Not heard from them for a couple of months**
- **Suddenly ordered super rush delivery of 8 sets**
- **It turned out that they had used another type gasket which blew out during the hydro test, causing major cost and delay in start up, requiring emergency order for our gaskets**

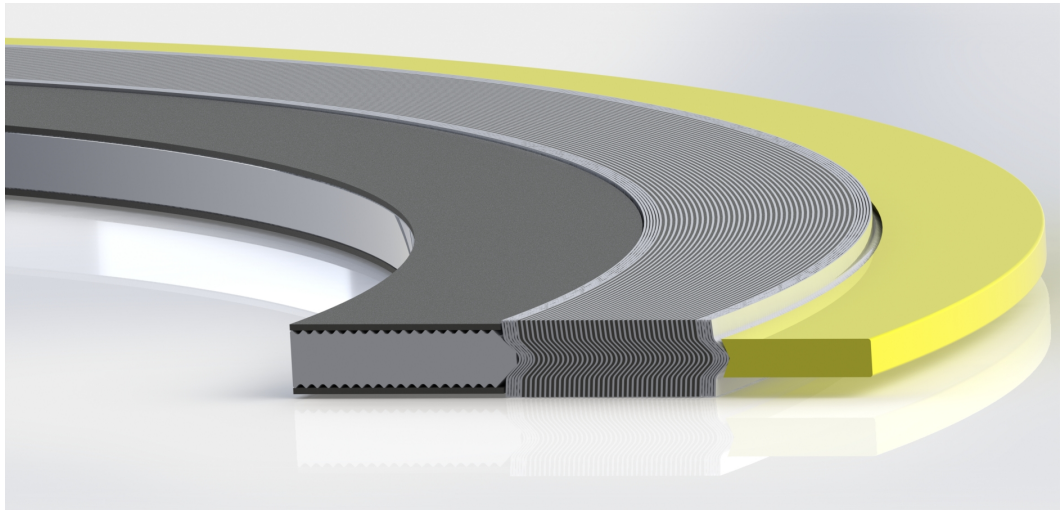




Gasket Options

Hybrid Gasket passed hydro-test.

- Hybrid gasket does not seep water during hydro-test ramp up
- Additional torquing is not required during hydro-test
- Any rotation of flanges do not cause unloading of the gasket as the inner gasket acts as compression stop



Cost of the hydro test failure

Maintenance cost to change the gasket that failed hydro test

- $2,000,000

Lost production due to extended shut down time to replace gaskets

- $750,000

Total of

- $2,750,000

Other options

Problems with the Kamprofile gaskets used in Reactors of a prominent Refinery at 770 F

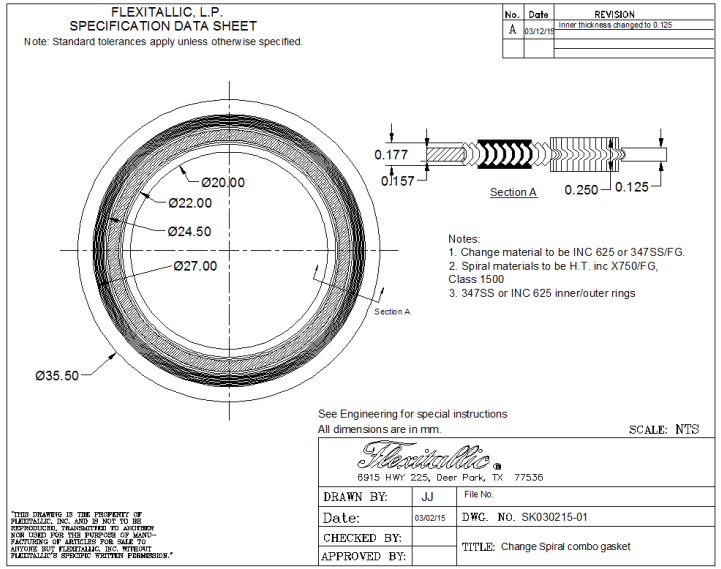
➢ Flanges: 24”, Class 1500 with dissimilar materials, Radial Shear, Cycling, possibility of flange Rotation
➢ Calculated radial shear: .020” (.010” allowable)

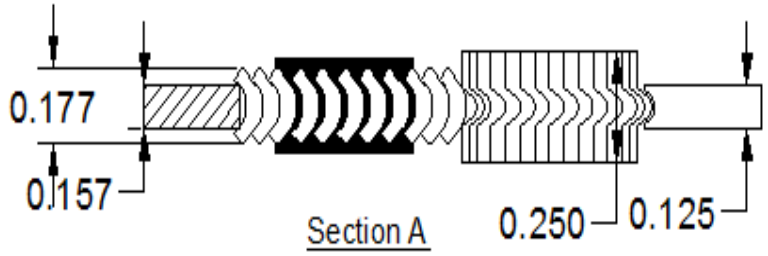
✓ Solution:
A Hybrid gasket using Change inner and SWG with HT inconel X750 winding outer gasket

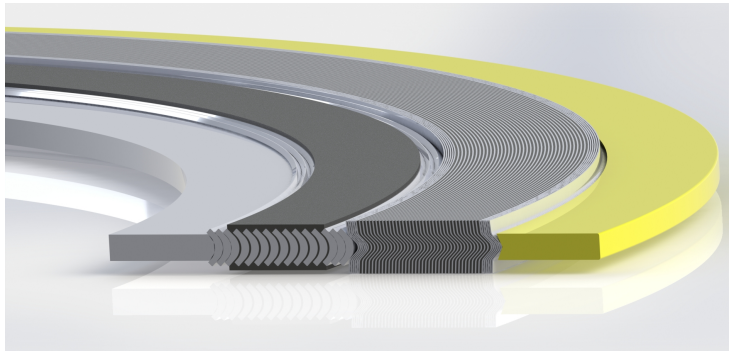
The more rigid inner Change gasket acts as compression stop for the outer SWG with H T inconel X750

The outer ring is thin so it does not create flange rotation causing any unloading of the gaskets

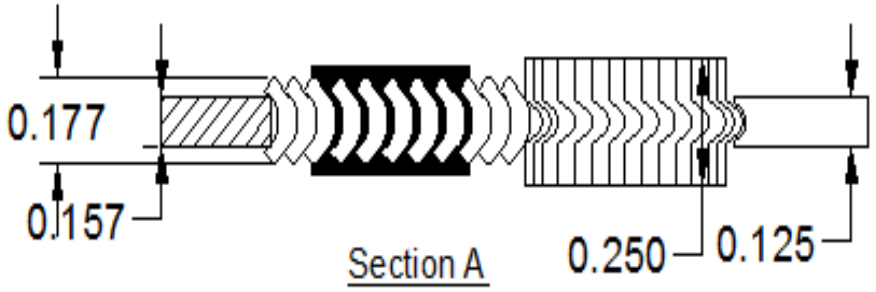
Both the Change and the SWG are suitable for Radial Shear inherent in this application

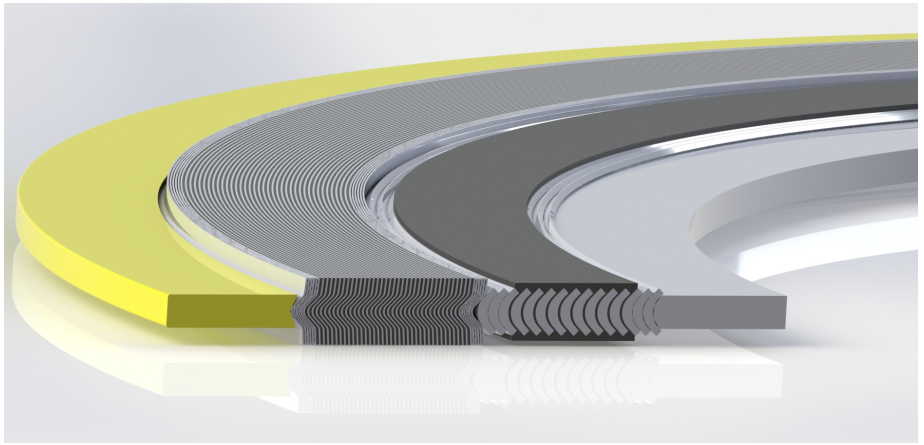






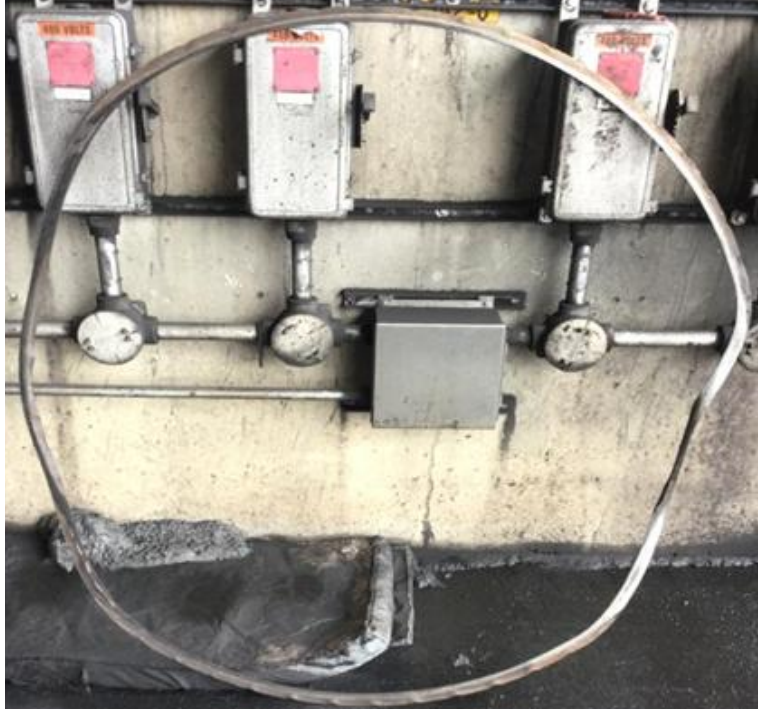
Other options





Bottom Unheading Valve- Coker

- Relatively new drums (6 each)
- Original gasket type Corrugated Metal Gasket
- Gaskets were deformed badly, and blew out in short time
- Gasket was upgraded to Grooved metal “Kammprofile”
- Kammprofile last a little longer, but deformed after a while as well
- No room for a thick Carrier Ring type we had success with in the past
- Use of tabs with holes or full-face not possible due to space limitations (not all bolts could be removed)
- Severe constant thermal cycles simply would ruin the gaskets in time possibly due to the extremely high radial forces
- They did an FEA thermal analysis showing hot spots and cold spots causing the gasket to be pulled inward
- We used Shear Plates strong enough to be higher than the friction forces pulling the gasket



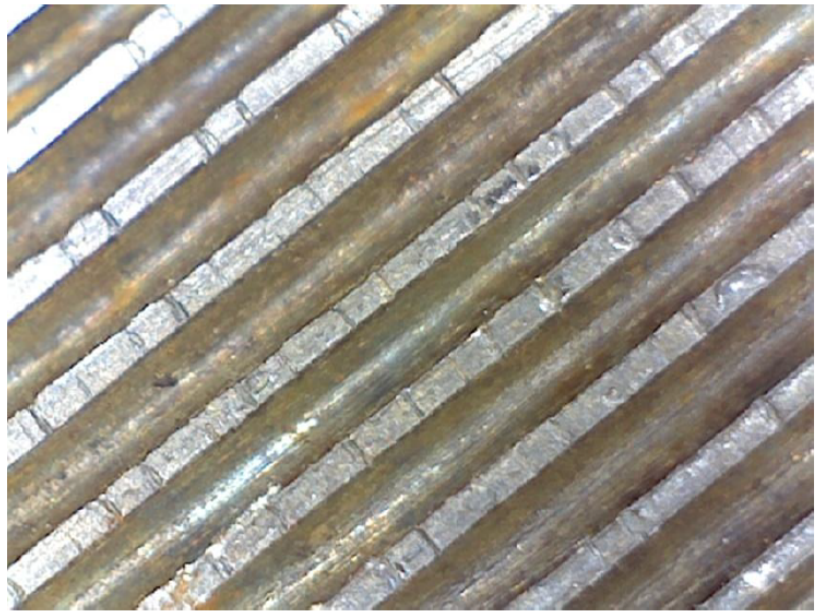
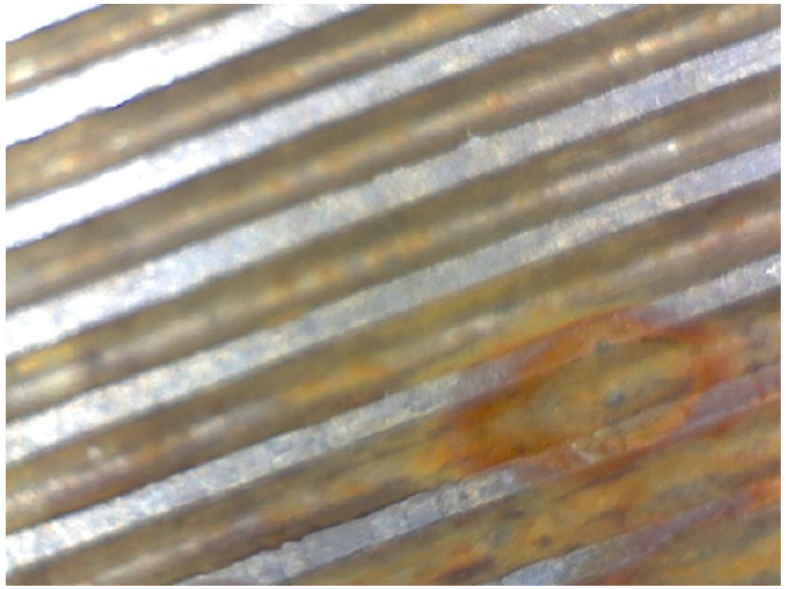


Image 312 -Gripper Marking on groove tips - Left Side (Image 2) Magnified



Img 313 - Opposite Side, portion inboard of raised face sticking into bore, opposite face from heavy carbon deposit.

✓ Solution:

Use of a GMGC gasket with Inconel 625, and FG facing

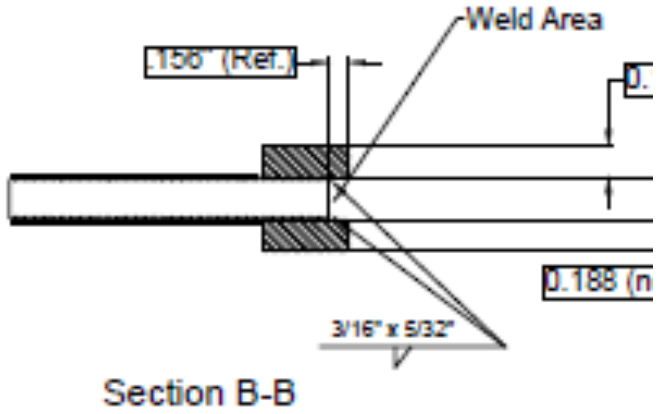
Special shear plates were welded to outer edge of the GMCG gasket all around

The size of the shear plates and weld strength were tested to make sure the strength of the welds

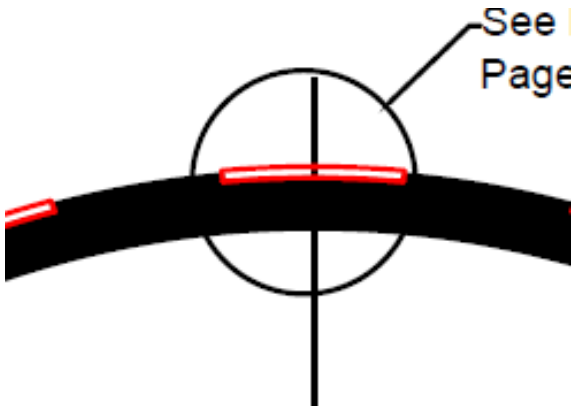
The failure mode will not be the weld breakage

The shear plates keep the gasket attached to the joint raised face as they seat between the outer edge of the raised face, and inside the bolts.

No news since the assembly in 2015 which means good news



Section B-B



Questions?