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Double-jacketed gaskets for heat exchangers sealabilty behavior in flanges with and without nubbin

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ABSTRACT

Due to their large size, double-jacketed gaskets used in shell and tube heat exchangers[1] are manufactured by radial bending of pre-fabricated jacketed strip and joined by butt-welding of the metal jacket ends[2].
This paper reports the results of a study to show the sealability behavior of the butt-welded DJ gaskets and their joint resistance, when installed in flanges with and without nubbin[3] varying the seating stress.

1. INTRODUCTION

Double-jacketed gaskets are subjected to high stresses during their installation and service. A study was conducted to investigate the behavior of double-jacketed gaskets as follows:

- The resistance of the butt-welding of the gasket ring subjected to different seating stress levels.
- The resistance of the spot welding of the gasket partitions to the gasket ring.
- The effect flange nubbin upon the gasket sealability.
- The sealability effect of installing the gasket off center.

In this paper, several tests performed are presented in two parts. In the first part, the gasket ring butt-welding capacity to resist high seating compressive stress was verified. In the second part, sealability tests were performed on flanges with nubbin and without nubbin at four stress levels.
All tests were conducted at room temperature.

2. FIRST PART: GASKET WELDING RESISTANCE

The objective of this part was to verify the seating stress resistance of butt-welded test coupons when compared with coupons without welds and, at the same time, the resistance of the welds of the gasket partitions to the gasket ring.

2.1 TEST COUPONS

Test coupons were prepared, using 3.2 mm thick double-jacketed samples made of carbon steel with flexible graphite filler (CS/FG) and stainless steel with flexible graphite filler (SS/FG).
To simulate gaskets without partitions, straight test coupons were prepared with and without butt-welding joints, in two lengths, as shown in Figures 1 and 5.
To simulate gaskets with welded partition, "T" shaped test coupons were prepared in two sizes, as shown in Figures 2 and 3.
The ends of the test coupons were welded to avoid the filler extrusion and better simulate the gasket behavior.
The test coupons widths selected are the most common ones used in practice. Their length was a function of the capability of the available testing equipment.

2.2. LIQUID PENETRANT EXAMINATION

The liquid penetrant examination (abbreviated as PT) is capable of detecting discontinuities open to the surface, even when the discontinuities are generally not visible to the unaided eye.
Liquid penetrant is applied to the surface of the part, where it remains for a period of time and penetrates into the flaws. After the penetrating period, the excess penetrant remaining on the surface is removed. Then an absorbent, light-colored developer is applied to the surface. This developer acts as a blotter, drawing out a portion of the penetrant that had previously seeped into the surface openings. The inspector looks for these colored indications against the background of the developer.
Per ASME Boiler & Pressure Vessel Code[4], Section VIII, Division 1 a linear indication is one having a length greater than three times the width. A round indication is one of circular or elliptical shape with the length equal to or less than three times the width.

2.3 COMPRESSION TEST

The test coupons were compressed between two steel plates to the stress levels shown in Table 1.

Table 1 – Compression Test Coupons

Test coupons	Material	Compressive Stress MPa (psi)
51 mm length straight	CS/FG	417 (60 465)
	SS/FG	
Little "T"	SS/FG	
85 mm length straight	CS/FG	250 (36 250)
	SS/FG	
Big "T"	SS/FG	

After compression, the test coupons were visually inspected and Penetrant Liquid tested. Results are shown in Table 4.

2.4 RESULTS AND ANALYSIS

Only the Carbon Steel test coupons, butt-welded and compressed to the stress level of 417 MPa (60 465 psi) ruptured extruding the flexible graphite filler, as shown in Figures 6 and 7. However, the rupture was not at the butt-welded joint.

A few test coupons showed PT indications like small pores and cracks in the butt-welded joint. However, these indications did not change the sealability of the tested gaskets, as shown in the second part of this paper.

None of the test coupons, that simulate the gasket ring with welded partition, showed any PT indications like pores or cracks, as shown in Figure 4.

Results show that 250 MPa (36 250 psi) is a safe seating stress for the tested double-jacketed gaskets.

3. SECOND PART: SEALABILITY TESTS

This part deals with the verification of the sealability and the welding resistance of gaskets manufactured with butt-welding joint when they are installed in flanges with and without nubbin under four stress levels.

Since most heat exchangers have flanges in a vertical position, it is very difficult or almost impossible to install gaskets perfectly centered. To simulate this condition, tests were performed installing the gasket off-center.

A common installation error is to put the gasket with the double jacket overlaps facing the nubbin. This condition was also simulated.

3.1 TEST GASKETS

All gaskets tested were produced from 304 stainless steel with flexible graphite filler. The gaskets dimensions were 453 mm X 427 mm X 3.2 mm. They were made by rolling and butt welding a preformed double-jacket strip.

All gasket tested were subjected to PT examination before installation to assure they did not have any indication like cracks or porous.

3.2 TESTS STANDS

Two test stands were used, one with a nubbin and the other without a nubbin. Both were made with a pair of flanges with twenty 1 inch diameter bolts, as shown in Figures 8 and 13.

3.3 TEST PROCEDURE

The test procedure for both test stands was as follows:

- Clean all residues from bolts, nuts and flange raised faces.
- Clean and lubricate nuts and bolts. All nuts must turn freely by hand. Any combination of bolt / nut that did not meet this criterion was discarded.
- Install gasket and hand tighten all bolts.
- Tighten bolts using the star pattern increasing the torque as shown in Table 2.
- After achieving the target torque, continue tightening until no further bolt turning.
- Wait 30 minutes for the gasket creep and if necessary re-tighten the bolts.
- Pressurize with Nitrogen at 40 bar (590 psi) and close the inlet valve.
- Record the pressure drop for 4 hours. If the pressure gauge did not show any drop after 4 hours, record as "no leak".
- Open the inlet valve to vent the test stand until there is no gas pressure.
- Increase the torque to the next level using steps as per Table 2
- Repeat the pressurization and record steps as above.

Table 2 – Torque and tightening steps

Tightening torque (N.m)	Tightening steps (N.m)
0 to 40	5
40 to 150	10
150 to 220	20
220 to 300	20
300 to 520	30
520 to 850	30

3.4 SEALABILITY TESTS

All gaskets were tested at four levels of compressive stress as shown in Table 3. The stress levels selected for the sealability test were higher than the minimum per the ASME Boiler & Pressure Vessel Code, Section VIII, Appendix 2 and lower that the maximum to avoid crushing the gasket plus two intermediate stress levels.

Table 3 – Gasket Stress

Gasket Stress	
MPa	**psi**
54	7 800
74	10 700
128	18 500
209	30 300

The gaskets were tested as shown in the Table 5.

After the sealing test the gasket butt-welded joints were visually checked and penetrant liquid inspected.

3.5 RESULTS AND ANALYSIS

The sealability test results are shown in Tables 5 and 6 and Figures 18 through 22.

As shown in Table 5 there is a larger difference between the maximum and minimum leakage for gaskets installed in flanges with nubbin (Figures 15 and 17) if compared with gaskets installed in flanges without nubbin (Figure 14), which sealed better.

The Table 6 shows the results of the PT examination after the sealability test and the average leakage of the gaskets with PT indications. Comparing these values with respective values of average leakage of Table 5, there is no increase in leakage for gaskets with PT indications, except for the gasket with a linear indication of 3mm, which was installed off center with the groove and overlap towards the nubbin. The small PT indications were not detrimental to the gasket sealability, as shown by the results of the leakage of the gaskets with PT indications, that were less than the general average for gaskets installed in "flanges with nubbin, centered with groove, overlap opposite nubbin" (Table 5).

Comparing the values of Figures 18 through 22 the flanges with nubbin have a higher leakage than flanges without nubbin for the lower values of seating stress. At higher seating stresses this difference is less except for gaskets installed per Figure 15 as shown in Figure 22. These results show that the nubbin did not increase the gasket sealability and that the erroneous installation with the overlap towards the nubbin showed the worse results

The off-center installation of the gasket did not show a significant influence upon its sealability in flanges without nubbin. However, there is a better sealability for the gaskets installed off-center in flanges with nubbin.

Higher seating stresses reduce the problems associated with the installation, as shown in all charts for the 209 MPa (30 300 psi).

4. CONCLUSIONS

Double-jacketed gaskets manufactured with butt-welded joints and pass ribs, spot welded to the gasket ring, can be installed under compression stresses of 250 MPa, (36 250 psi) without causing damage to the welds. The additional cost to machining flanges with nubbin can be eliminated increasing the sealing efficiency.

An off-center installation of the gasket did not influence its sealability in flanges without nubbin.

The butt-welding of the gasket rings was not detrimental to the gasket sealability.

5. LITERATURE

1. Standards of the Tubular Exchanger Manufacturers Association. Eighth Edition, Tarrytown, NY, USA.
2. The Influence of the Gasket Finish on the Sealability of Double Jacketed Gaskets used in Heat Exchangers – J. C. Veiga, N. Kavanagh, PVP Volume 405, Analysis of Bolted Joints 2000, The ASME Pressure and Piping Conference 2000, Seattle, Washington, USA.
3. Industrial Gaskets, 3rd Edition, 2003 - José Carlos Veiga – Teadit Ind. Com. Ltda., Rio de Janeiro, Brasil
4. ASME Boiler & Pressure Code VIII – Division 1 Section VIII.

Table 4 – Compression test results

Description	Number of Coupons Tested	Material	Compressive Stress MPa (psi)	Results visual and PT inspection after compression
Big "T" - Figure 2	3	SS/FG	250 (36250)	No indication as shown in Figure 4.
Little "T"- Figure 3	3	SS/FG	417 (60 465)	No indication.
85mm length straight without butt-weld joint	4	SS/FG	250 (36250)	No indication.
85mm length straight with butt-weld joint	4	SS/FG	250 (36250)	One coupon with linear 2 mm indication; two coupons with round 1 mm indications and one without indication.
85mm length straight without butt-weld joint	4	CS/FG	250 (36250)	No indication.
85mm length straight with butt-weld joint	4	CS/FG	250 (36250)	One coupon without indication; two coupons with linear 2mm indications and one coupon with round 1 mm indication, as shown in Figure 9.
51mm length straight without butt-weld joint	4	SS/FG	417 (60 465)	No indication.
51mm length straight with butt-weld joint	4	SS/FG	417 (60 465)	Two coupons without indication; one coupon with linear 2mm indication and one coupon with linear 1.5mm indication. See Figure 10.
51mm length straight without butt-weld joint	4	CS/FG	417 (60 465)	No indication.
51mm length straight with butt-weld joint	7	CS/FG	417 (60 465)	Six coupons metal jacket ruptured, as shown in Figures 6 and 7, and one coupon with a 4 mm liner and 2 mm round indications as shown in Figure 11.

Table 5 – Sealability test results

Description	Figure Number	Number of Gaskets Tested	Gasket Stress MPa	Maximum Leakage mg/(s.mm)	Minimum Leakage mg/(s.mm)	Average Leakage mg/(s.mm)
Flange without nubbin, gasket centered with groove. Overlap opposite male.	14	5	54	0.0274	0.0174	0.0226
			74	0.0161	0.0074	0.0128
			128	0.0062	0.0017	0.0039
			209	0.0012	0.0000	0.0007
Flange without nubbin, gasket not centered with groove. Overlap opposite male.	-	5	54	0.0352	0.0164	0.0265
			74	0.0219	0.0092	0.0165
			128	0.0065	0.0020	0.0050
			209	0.0022	0.0000	0.0013
Flange with nubbin, gasket centered with groove. Overlap opposite nubbin.	17	5	54	0.1354	0.0222	0.0682
			74	0.0459	0.0113	0.0272
			128	0.0096	0.0017	0.0052
			209	0.0010	0.0000	0.0004
Flange with nubbin, gasket not centered with groove. Overlap opposite nubbin.	16	3	54	0.0280	0.0183	0.0248
			74	0.0154	0.0115	0.0137
			128	0.0031	0.0021	0.0026
			209	0.0075	0.0000	0.0029
Flange with nubbin, gasket not centered with groove. Overlap towards nubbin.	15	4	54	0.0794	0.0397	0.0604
			74	0.0472	0.0291	0.0371
			128	0.0246	0.0062	0.0151
			209	0.0079	0.0009	0.0031

Table 6 – Penetrant test results

Description	Number of Gaskets Tested	Gasket Stress MPa	Results visual and PT inspection after test	Average Leakage between gaskets with PT indication (mg/(s.mm))
Flange without nubbin, gasket centered with groove. Overlap opposite male.	5	54	One gasket with linear indication of 1,5mm. Two gaskets with round indication of maximum 1mm.	0.0229
		74		0.0131
		128		0.0030
		209		0.0004
Flange without nubbin, gasket not centered with groove. Overlap opposite male.	5	54	No indication.	
		74		
		128		
		209		
Flange with nubbin, gasket centered with groove. Overlap opposite nubbin.	5	54	One gasket with linear indication of 2mm. One gasket with round indication of 1mm.	0.0272
		74		0.0128
		128		0.0022
		209		0.0000
Flange with nubbin, gasket not centered with groove. Overlap opposite nubbin.	3	54	No indication.	
		74		
		128		
		209		
Flange with nubbin, gasket not centered with groove. Overlap towards nubbin.	4	54	One gasket with linear indication of 3mm as shown in Figure 12.	0.0794
		74		0.0472
		128		0.0246
		209		0.0028

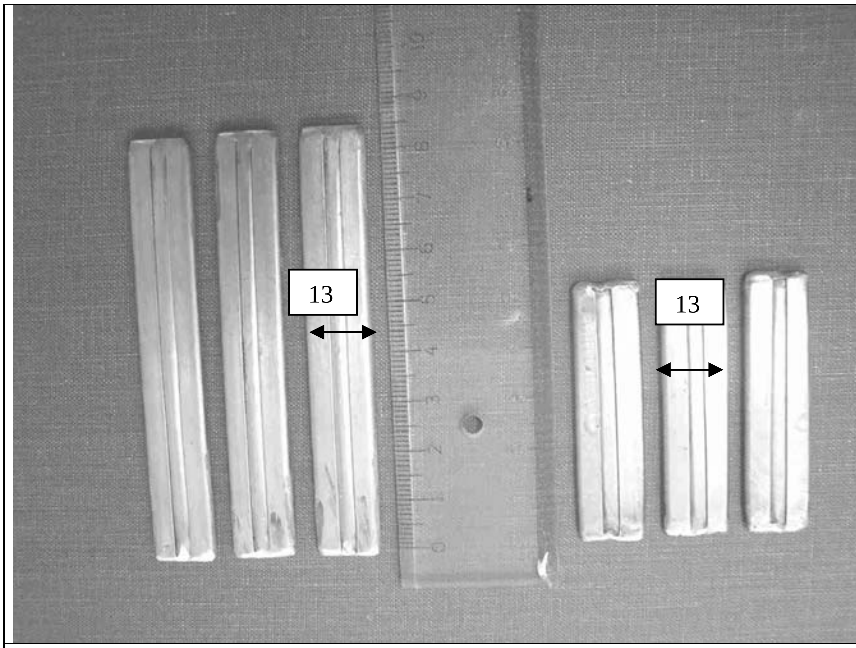

Figure 1 – Straight Test Coupons without butt-welded joint

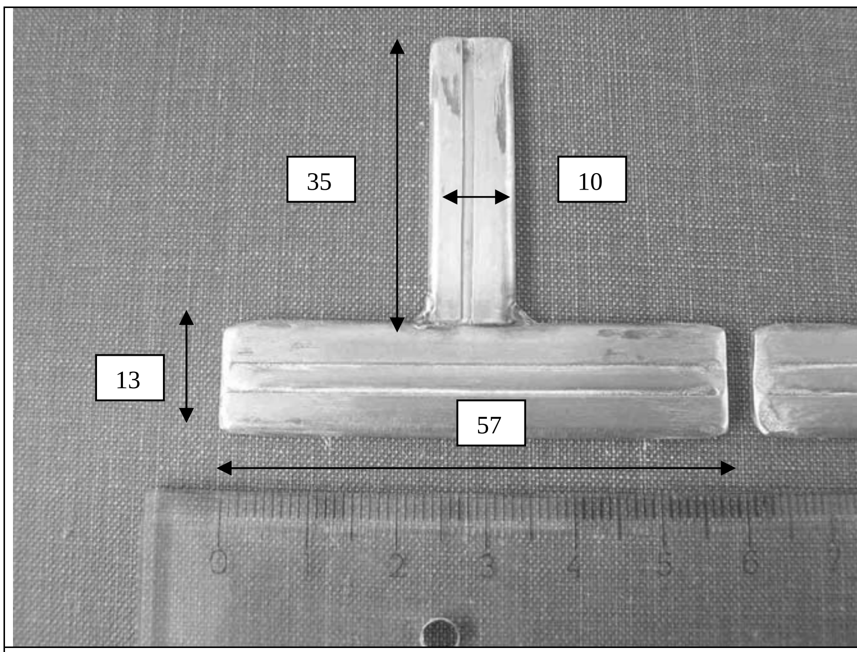

Figure 2 – Big "T" Test Coupons

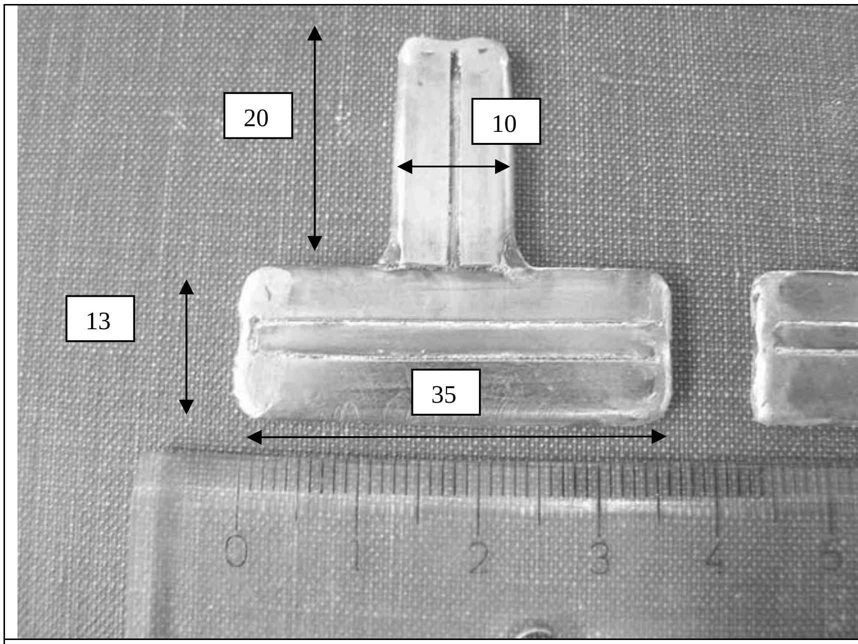

Figure 3 – Little “ T “ Test Coupons

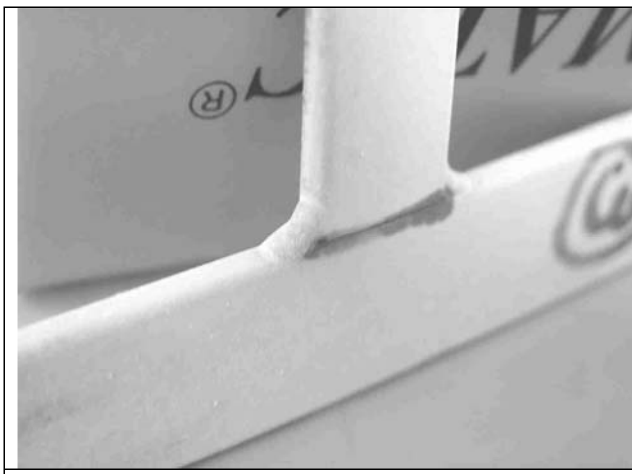
Figure 4 – Penetrant test after compression

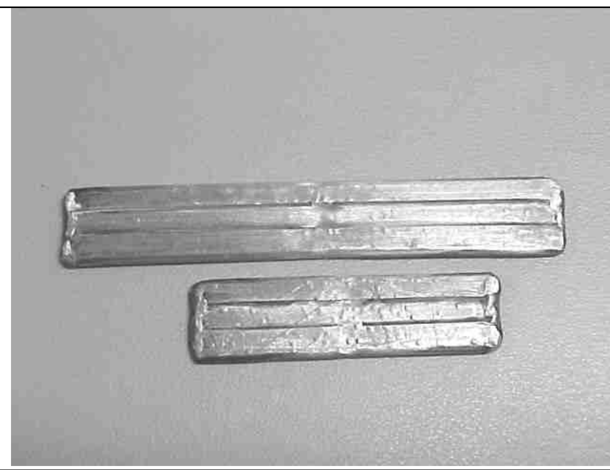
Figure 5 – Straight test coupons with butt-welded joint

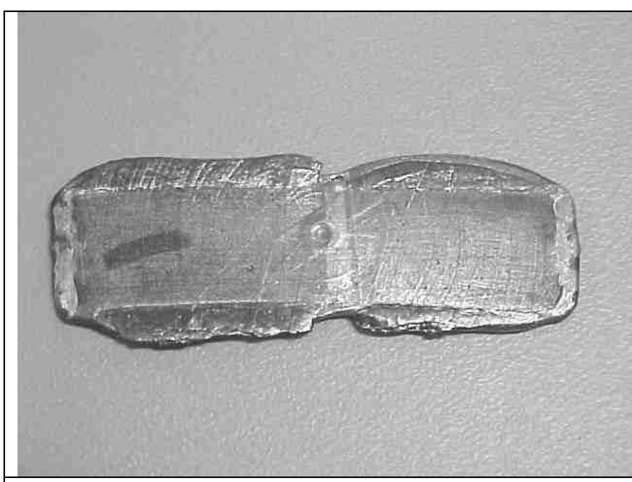
Figure 6 – CS jacket rupture

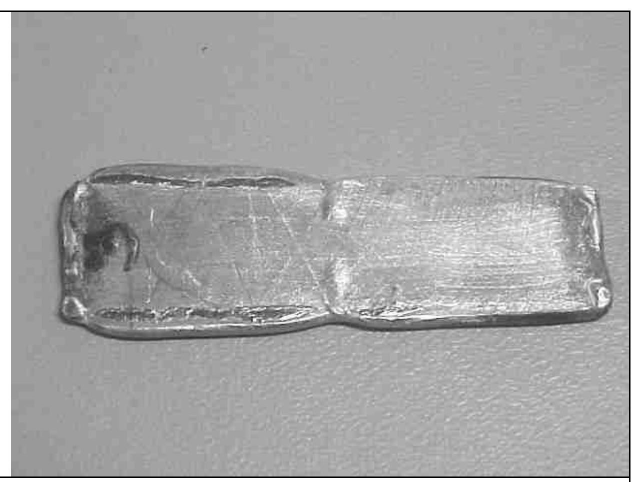
Figure 7 – CS jacket rupture

Figure 8 – Sealability test stands

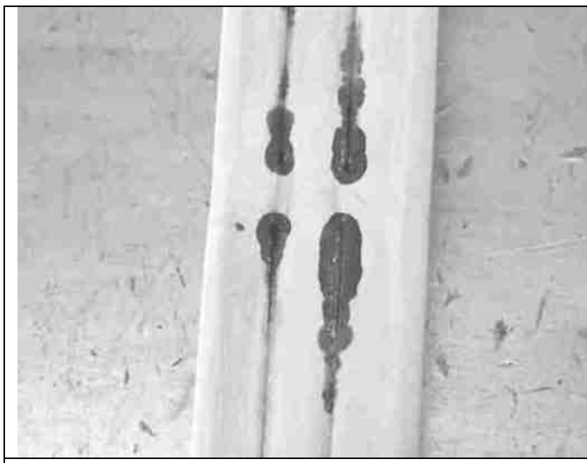

Figure 9 – Round indication in PT

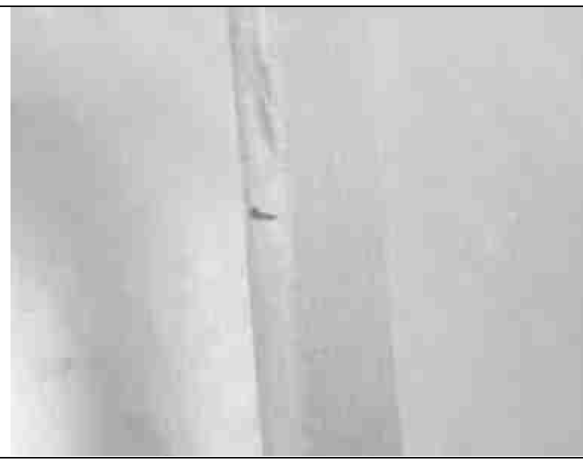

Figure 10 – Linear indication in PT

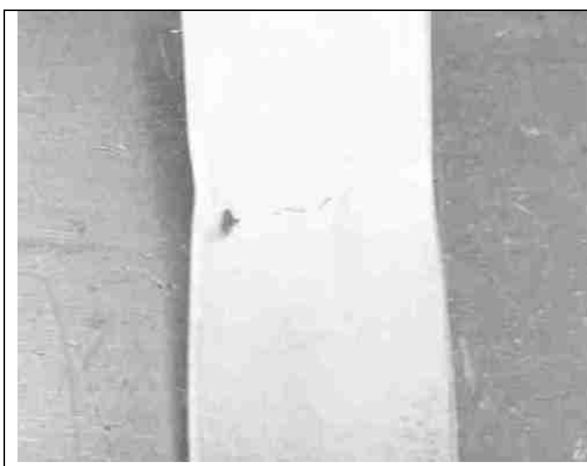

Figure 11 – Round indication in PT

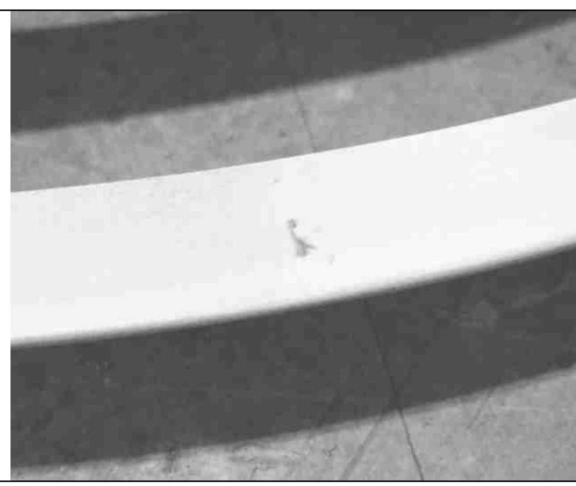

Figure 12 – Linear indication in PT

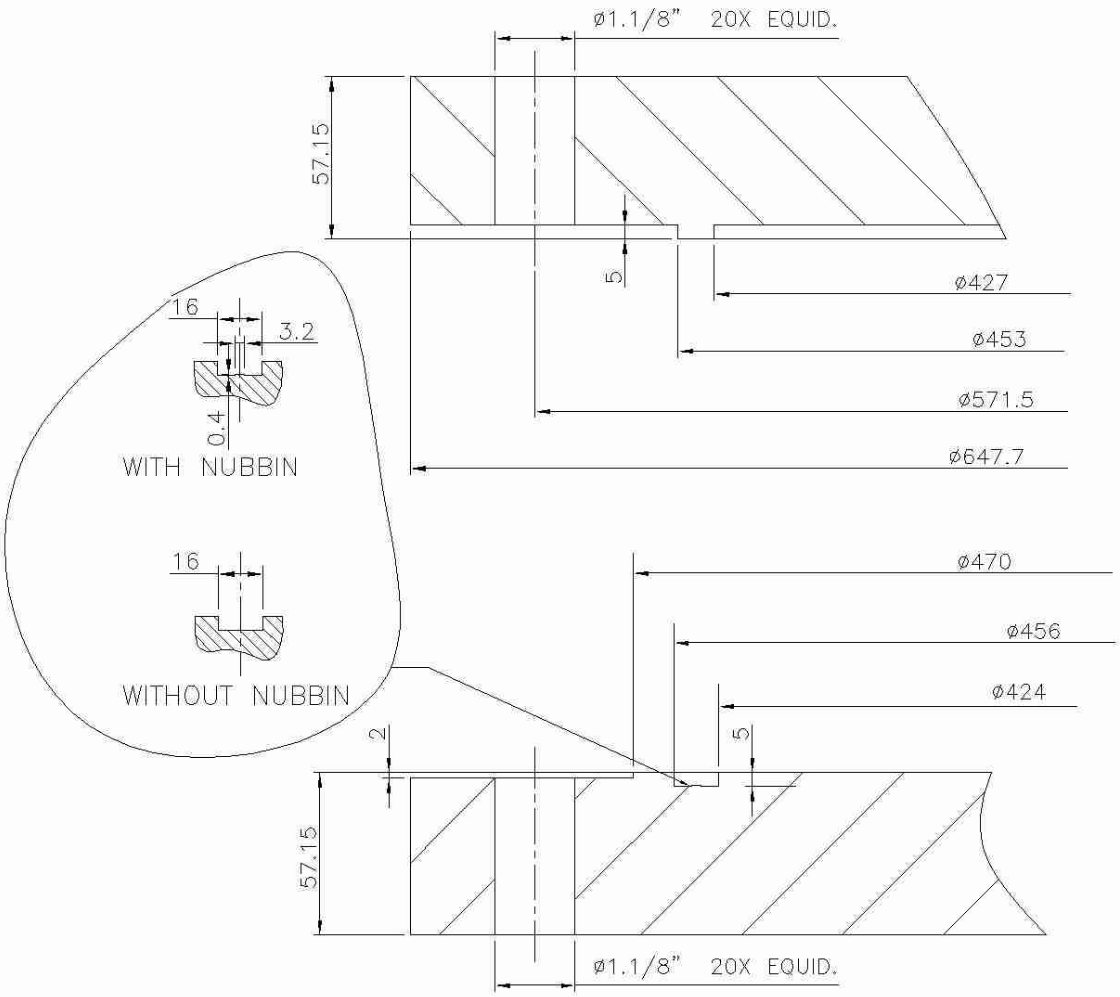

Figure 13 – Test flanges with nubbin and without nubbin.

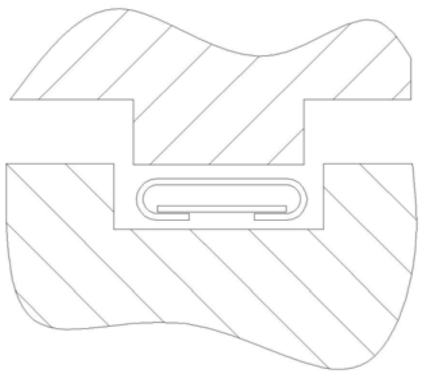

Figure 14 – Flange without nubbin, gasket centered with groove. Overlap opposite male.

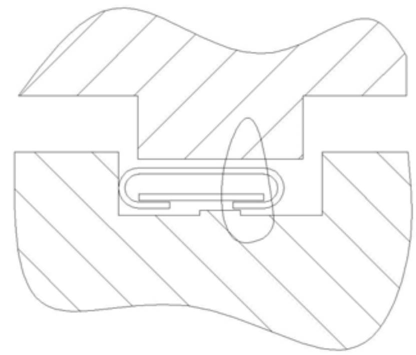

Figure 15 – Flange with nubbin, gasket not centered with groove. Ov

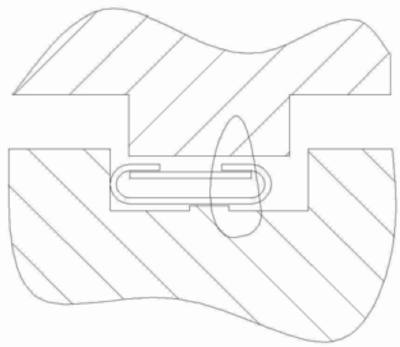

Figure 16 – Flange with nubbin, gasket not centered with groove. Overlap opposite nubbin.

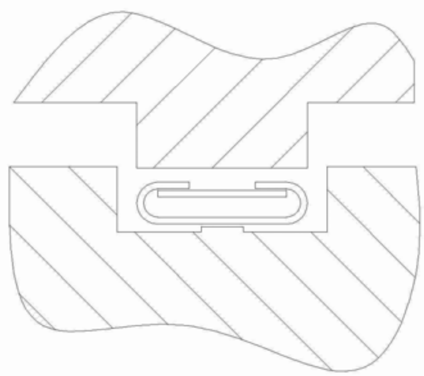

Figure 17 – Flange with nubbin, gasket centered with groove. Overlap opposite nubbin.

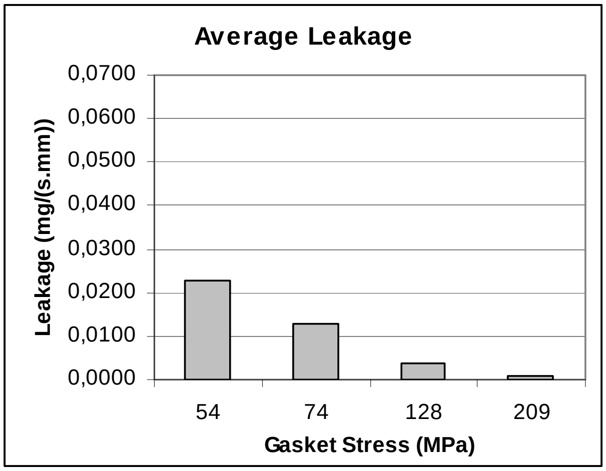

Figure 18 – Flange without nubbin, gasket centered with groove. Overlap opposite male.

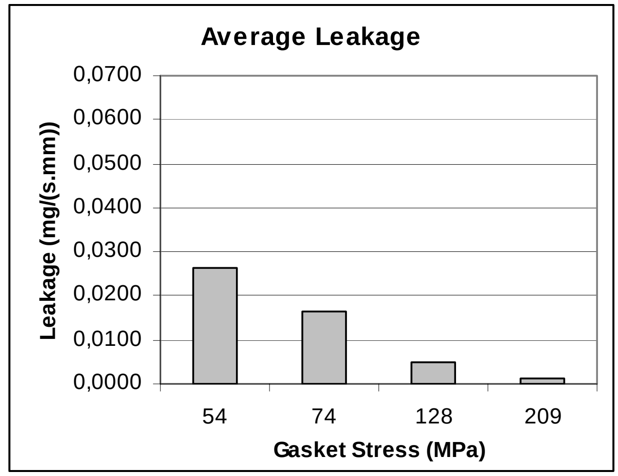

Figure 19 – Flange without nubbin, gasket not centered with groove. Overlap opposite male.

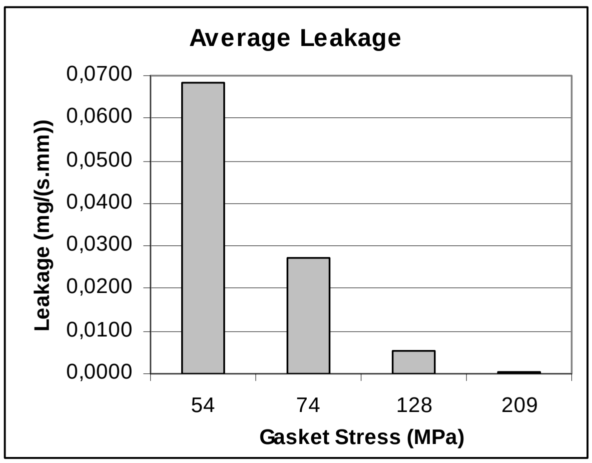

Figure 20 - Flange with nubbin, gasket centered with groove. Overlap opposite nubbin.

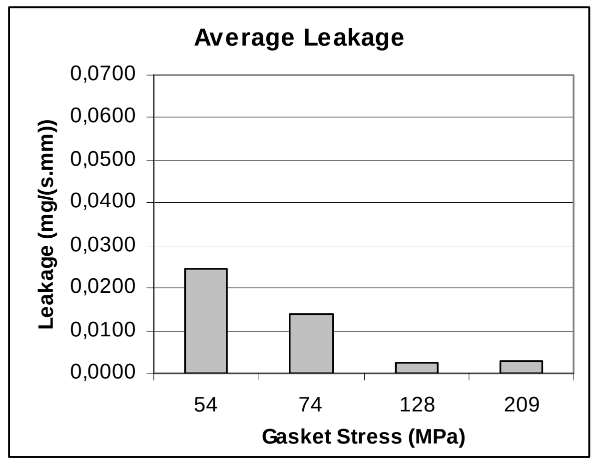

Figure 21 - Flange with nubbin, gasket not centered with groove. Overlap opposite nubbin.

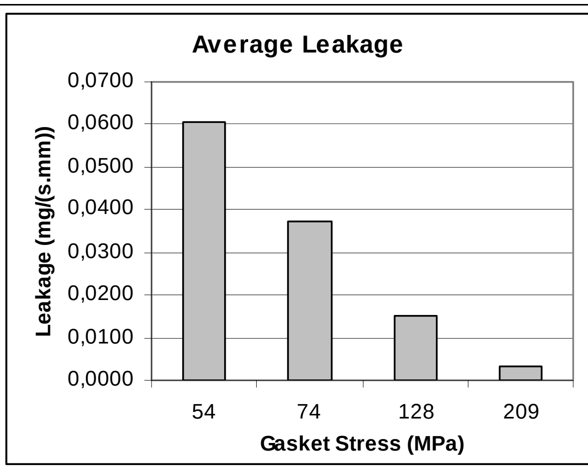

Figure 22 - Flange with nubbin, gasket not centered with groove. Overlap towards nubbin.