

# Final Program

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## HEAT EXCHANGER GASKETS RADIAL SHEAR TESTING

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### ABSTRACT

Due to the high incidence of leaks in Shell and Tube Heat Exchangers that are in thermal cycling service, there have been studies of the suitability of gasket styles for this kind of application. This paper researches several gasket styles in a test rig developed to simulate the radial shear caused by the differential thermal expansion of the flanges in a Heat Exchanger.

### INTRODUCTION

In the last few years there have been studies to determine the suitability of different gasket styles for Shell and Tube Heat Exchanger services. The major concern has been the gasket ability to tolerate the differential thermal growth between flanges, an intrinsic characteristic of Heat Exchangers which, by design, are built to transfer heat between fluids in the process industry.

In our previous papers of Double Jacketed [1] gaskets we studied the finish [2] and the sealability [3] in flanges with and without nubbins. For these studies a test rig that simulates typical Heat Exchanger [4] flanges was specially designed and built. As a result of these studies, the welding of partition bars and eliminating nubbins were shown to be major improvements in reducing leaks in many applications. However, these studies were performed at a steady state room temperature. This is not typical of field conditions in processes where there is a constant variation of the media temperature, either caused by constant adjustments to process conditions or thermal cycling from plant startups and shutdowns. The mating flanges in a Heat Exchanger are subject to a temperature differential causing variation in the thermal growth of the flanges as shown in Figure 1. This differential growth is

primarily caused by the mating flanges having a different amount of mass, which causes the flange with less mass to grow faster than the heavier one. The differential growth is also aggravated if the flanges are made of dissimilar metal alloys. For a gasket to maintain its seal for its intended service life, it must be able to resist the shear effect caused by this differential growth.

To simulate this condition the École Polytechnique of the University of Montreal, Canada developed the Radial Shear Tightness Test [5], known as RaST and studied several gaskets styles available at the time. However, the RaST was disassembled and sent to Europe and is no longer available for gasket testing and development.

To test and develop new gaskets the Teadit Test Rig used in previous studies was modified to simulate the radial shear caused by the differential thermal growth of the mating flanges.

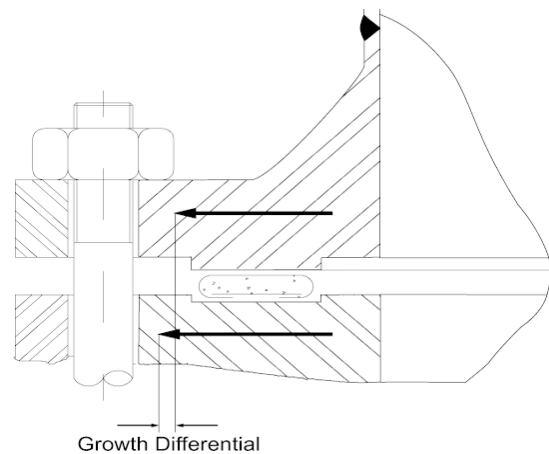


Figure 1

## TEADIT RADIAL SHEAR TEST (T-RaST)

The Teadit Radial Shear Test (T-RaST) uses a pair of “Tongue-and-Groove” flanges in a typical arrangement found in some Heat Exchangers. Figure 2 shows a picture of the T-RaST test rig and Figure 3 shows a schematic diagram of it. The upper flange assembly is water cooled and the lower one is electrically heated to generate the differential growth. Gasket dimensions are 453 mm (17.385 in) outside diameter x 427 mm (16.811 in) inside diameter x 3.2 mm (1/8 in) thick.

To measure the thermal growth between the flanges two pins are located on the outside of the gasket sealing area.

Four thermocouples are installed in each flange to control the temperature near the vicinity of the gasket sealing surface.

After the first long run, calibrated bolts were added to the T-RaST rig to evaluate gasket relaxation. The bolt load is calculated after measuring the bolt length.

As of the writing of this paper the T-RaST test rig was able to generate a test temperature of approximately 300 C (572 F) and 1.66 mm (0.065 in) of growth differential between the two flange measuring pins, or 0.83 mm (0.033 in) of radial shear across the gasket surface.

Extensive field work done at Chevron’s El Segundo Refinery [6] has shown that most exchangers will generate between 0.254 mm (0.010 in) and 1.016 mm (0.040 in) of radial shear between mating flanges during initial heating, with total shear values as high as 6.35 mm (0.25 in) recorded for Coke drum flanges over each cyclic cycle.

The gasket stress is 215 MPa (31 000 psi) with a bolt load of 390 MPa (57 000 psi), which is a value within the normal range for Heat Exchanger applications.

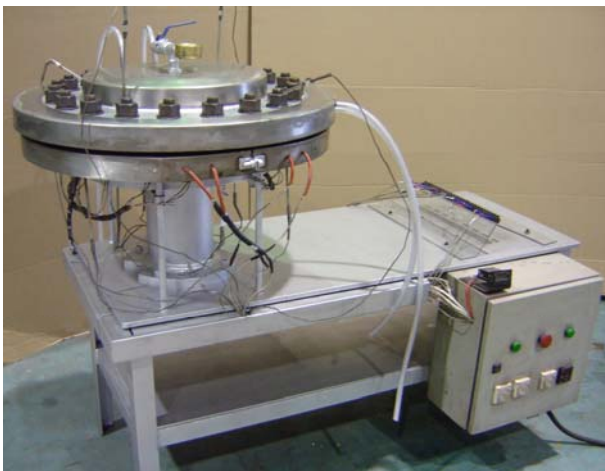


Figure 2

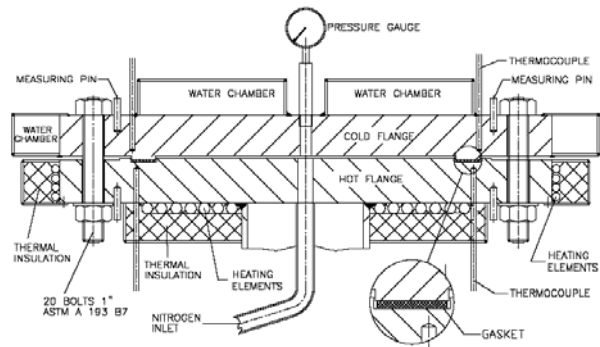


Figure 3

## GASKET TESTING

### INSTALLATION AND TEST PROCEDURE

The gaskets were installed and tested per the following procedure:

1. Measure unloaded bolt lengths.
  2. Measure bolt loaded with 390 MPa (57 000 psi) lengths.
  3. Install gasket and torque bolts in four steps using the star pattern up to the final torque. Keep tightening until there is no further nut rotation.
  4. Open the water flow valve.
  5. After 30 minutes retighten all bolts. Wait another 30 minutes and retighten again.
  6. Measure and record the initial bolt lengths.
  7. Pressurize the gas chamber with Nitrogen at 40 bar (590 psi).
  8. Close the Nitrogen inlet valve and record the pressure drop after four hours.
  9. Measure and record the bolt lengths.
  10. Record upper and lower flanges temperature.
  11. Record the distance between measuring pins on both flanges.
  12. Purge the Nitrogen from the gas chamber.
  13. Turn the heating system on with a set point of 300C (572 F) on the lower flange.
  14. When the lower flange reaches 300 C (572 F) record the temperature of the thermocouples near the gasket sealing area and the distance between measuring pins on both flanges.
  15. Turn the heating system off and wait until the lower flange reaches room temperature.
  16. Measure and record bolt lengths.
  17. After repeating steps 13 through 15 for about 15 cycles and repeat steps 7 through 9, leak test and measure and record bolt length.
  18. Repeat steps 7 through 16 for 100 thermal cycles.
- Note: measuring bolt length was introduced after the first Flexible Graphite faced Double Jacketed gasket test.

## DOUBLE JACKETED GASKETS

The first gasket to be tested was a 304 Stainless Steel Flexible Graphite filled Double Jacketed gasket as shown in Figure 4. Even though this kind of gasket had been tested at the École Polytechnique RaST it was tested again to establish a correlation between the test rigs and the field experience.

These gaskets performed poorly at room temperature as shown by the drop in pressure in the Figure 5 chart. Three gaskets were tested to assure that the bad results were consistent. The average leak rate for the three gaskets was 21 mg/(sec-m). Due to these poor levels of performance it was decided that it was not worth doing thermal cycling tests on this kind of gasket.

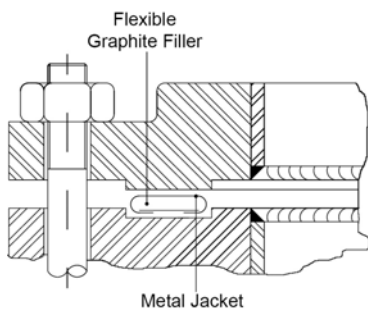


Figure 4

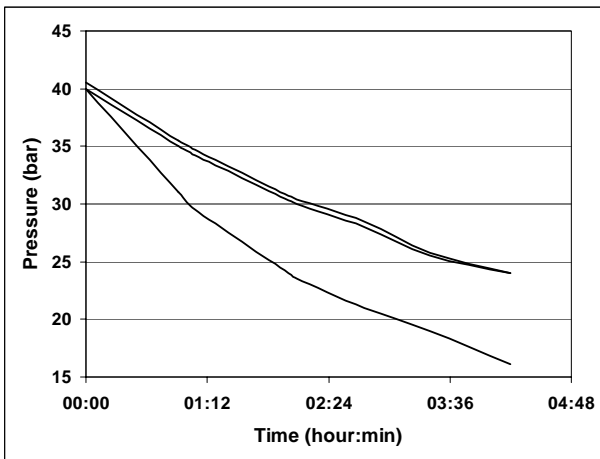


Figure 5

## FLEXIBLE GRAPHITE FACED DOUBLE JACKETED GASKETS

Since Flexible Graphite faced Double Jacketed (FGFDJ) gaskets as shown in Figure 6 are very common in Heat Exchanger applications, it was decided to test them first. Three gaskets were tested.

The initial results of the first gasket tested were very good, no leaks at room temperature and after 65 thermal cycles. However, when the rig was opened the radial shear effect was clearly visible. The overlapping metal was pushed away by the shear effect as shown in Figure 7 and 8.

The break-off torque was only 20% of the initial value indicating a major bolt load loss caused by gasket degradation.

Three more gaskets were tested increasing the number of thermal cycles to 100.

Due to the high torque loss with the first gasket tested it was decided to measure the bolt load using calibrated bolts. The bolt length is measured at room temperature using a micrometer.

The results for the second and third gaskets were very similar. The shear effect of the flange movement on the gasket sealing surface is clearly visible as shown in Figure 9.

The bolt load chart in Figure 10 shows a continuous load loss. At the end of 100 cycles the bolts had only 55% of their initial load. This chart is an average of all bolts.

In spite of the bolt load loss there was no noticeable leak during the pressure tests for both gaskets.

The Flexible Graphite facing is an improvement for short term sealability but does not solve the susceptibility of the Double Jacketed gaskets to Radial Shear, confirming the results of previous papers.

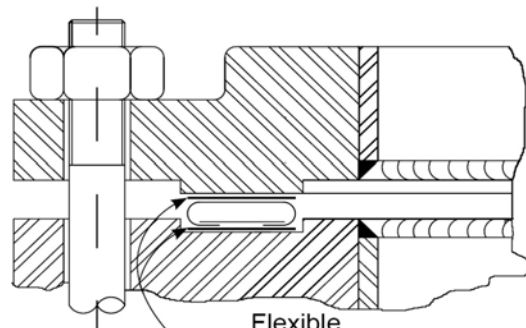


Figure 6



Figure 7



Figure 8



Figure 9

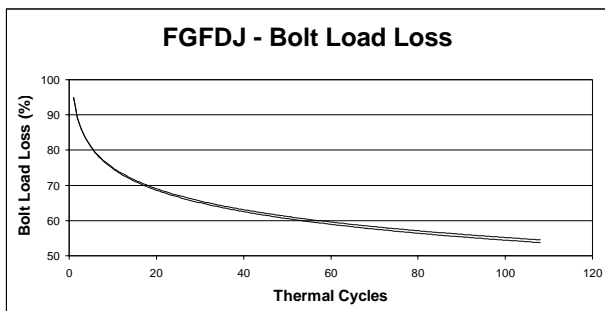


Figure 10

### Flexible Graphite Faced Serrated Metal Gaskets

Due to the problems encountered in the field with Double Jacketed Gaskets [6], the Flexible Graphite Faced Serrated Metal (FGFSM) Gaskets (Figure 11) have been used as a replacement. It was decided to test these to confirm if the field results could be duplicated in the test rig. Two gaskets were tested with similar results.

After 100 cycles there was no pressure loss indicating no noticeable leak. As shown in Figure 12 the bolt load slowly dropped over the first 40 thermal cycles, remaining at the 75% to 80% range after that point. The average break-off torque was 66% of the initial value.

The tested gasket confirmed that with serrations machined with depth and pitch in such way that the Flexible Graphite facing is not carried away by the flange shear movement. Figure 13 shows the gasket after being removed from the T-RaST rig. It can be seen that the

Flexible Graphite is completely facing the metal core, which never touches the flange surface.

Figure 14 shows the Flexible Graphite facing being lifted from the metal core. The seating stress increases the Graphite density creating a film that acts as a lubricant between the metal core and the flange.

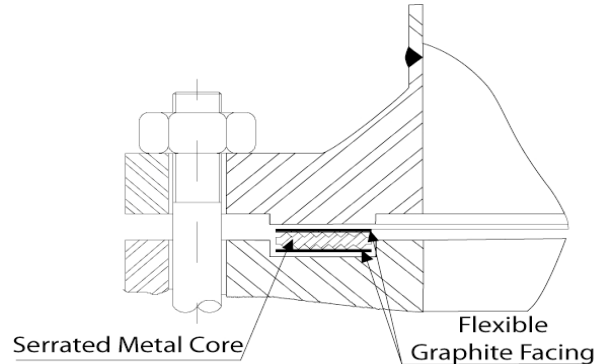


Figure 11

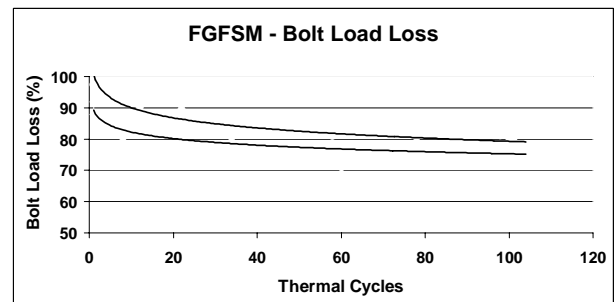


Figure 12



Figure 13



Figure 14

## Conclusions

Double Jacketed gaskets are subjected to degradation if used in applications that are susceptible to radial shear conditions. The tests confirmed their poor performance and facing them with Flexible Graphite only improved their short term sealability. They still showed signs of major gasket degradation caused by the flange differential growth. The testing has shown that these gaskets are not a good choice for Heat Exchanger service even though they have been used extensively.

Testing has also shown that a properly designed Flexible Graphite faced Serrated Metal gaskets is a better choice for Heat Exchanger applications than Double Jacketed gaskets. The T-RaST test results showed no leaks and an acceptable bolt load loss after 100 thermal cycles.

The Teadit Radial Shear Test rig (T-RaST) proved that it is possible to build a simple and easy to operate test device that reproduces the operating conditions of Heat Exchange flanges in the field. It can be a very efficient tool to develop and qualify gaskets for critical applications that are susceptible to radial shear conditions.

## Future Work

Testing has been scheduled to test Flexible Graphite Corrugated Metal gaskets to confirm their good results in the field.

Time saving installation procedures can also be developed with this test rig simulating conditions that are closer to actual gasket applications.

Being an easy and economical to operate rig, the T-RaST can be used for many types of gasket developments. It simulates actual Pressure Vessel

conditions like flange rotation and thermal effects, which can not be done with a test rig that used a hydraulic press with flat platens at room temperature.

## References

- [1] - *Industrial Gaskets*, 3rd Edition, 2003 - José Carlos Veiga – Teadit Ind. Com. Ltda., Rio de Janeiro, Brasil.
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