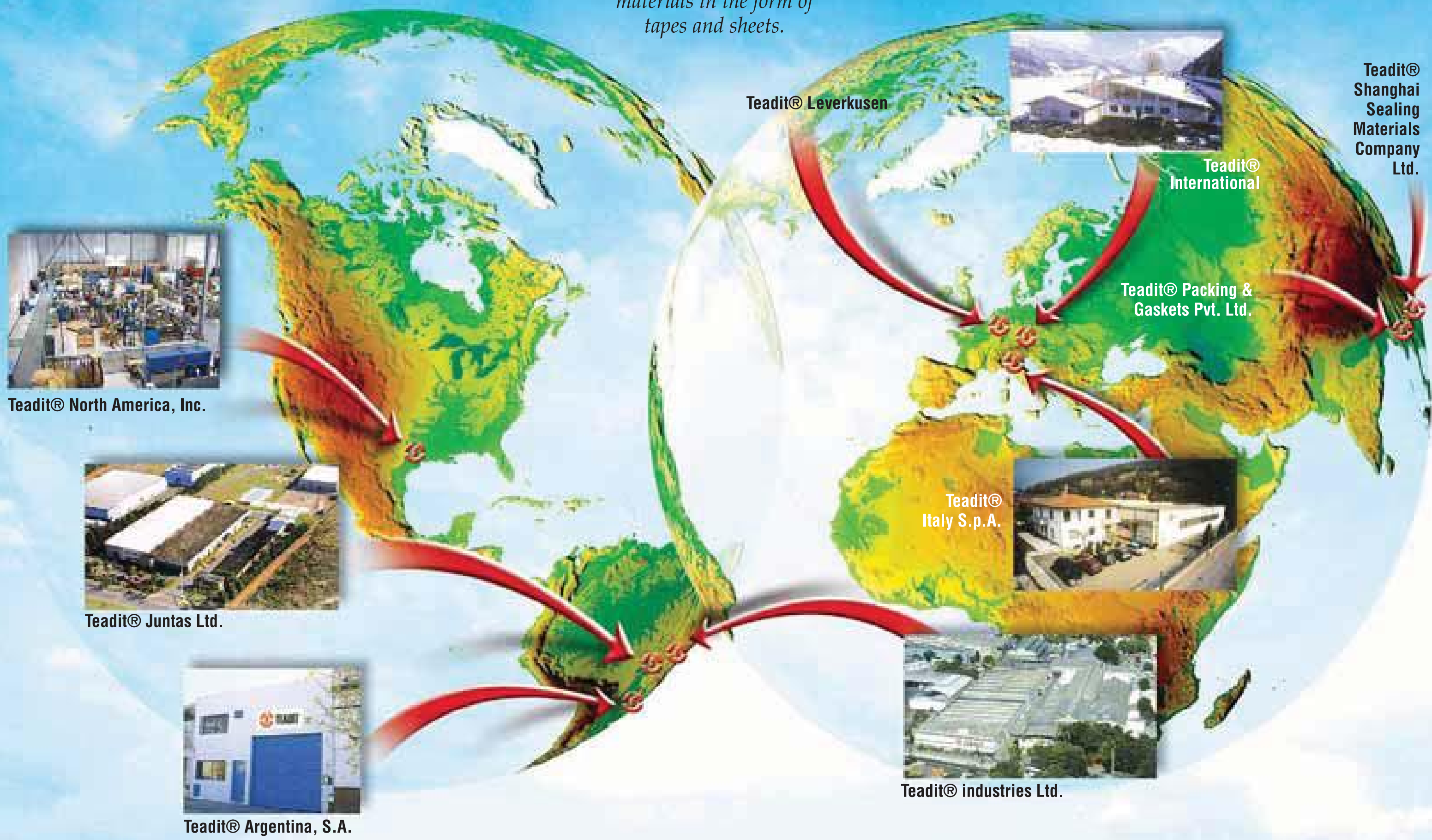
About the Teadit Group

With plants and operations worldwide, the Teadit Group serves industrial fluid sealing requirements with a complete range of products and technical services. In business for more than 50 years, the company is vertically integrated from the basic development of yarns and filaments used in the manufacture of its products, to the installation of its products in the field. Teadit is a world leader in the development and manufacture of compression packings, gasket sheet materials, metal gaskets, textiles, metal bellows, expansion joints and expanded PTFE joint sealant materials in the form of tapes and sheets.



Customer Base Served by Teadit

- Pulp & Paper
- Petrochemical
- Oil & Gas
- Refining
- Mining
- Pharmaceutical
- Automotive
- Food & Beverage
- Water & Wastewater Treatment

TEADIT WORLDWIDE

TEADIT GROUP

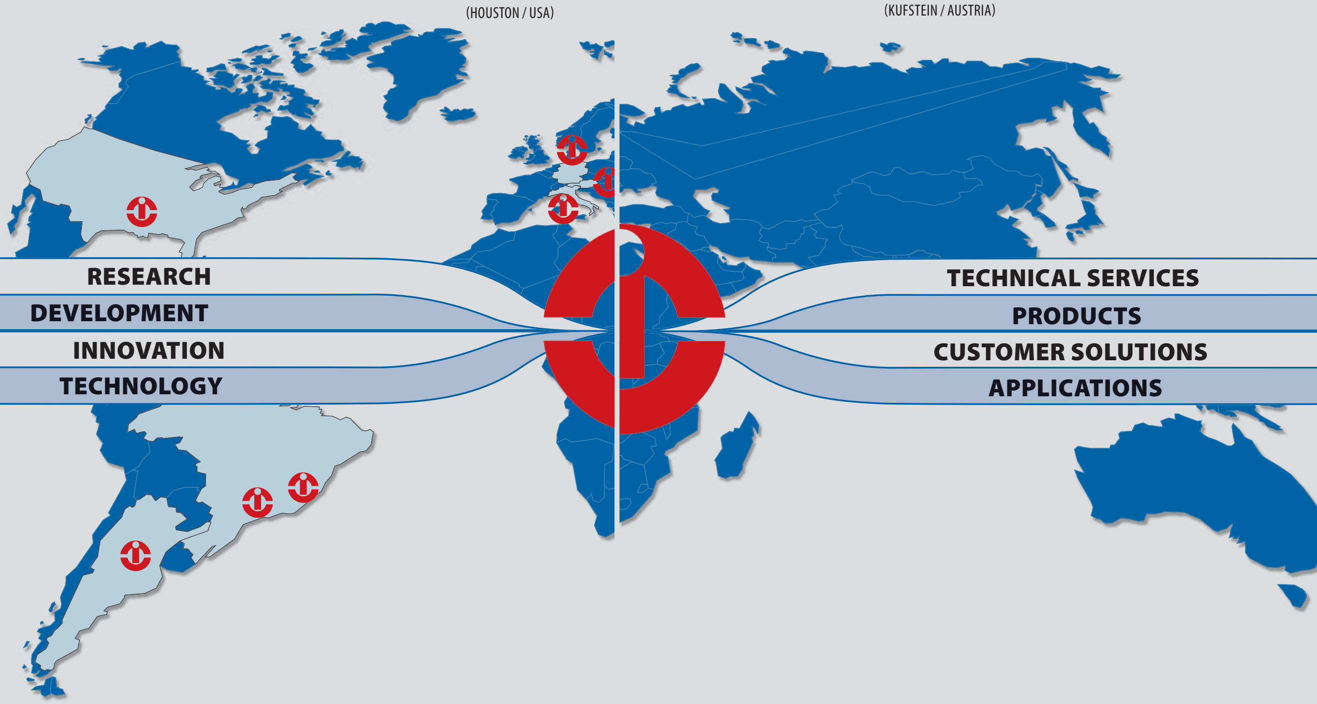
With plants and operations worldwide, the Teadit Group serves industrial fluid sealing requirements with a complete range of products and technical services.

In business for more than 50 years, the company is vertically integrated from the basic development of yarns and filaments used in the manufacture of its products, to the installation of its products in the field. Teadit is a world leader in the development and manufacture of compression packings, gasket sheet materials, metal gaskets, textiles, metal bellows, expansion joints and expanded PTFE joint sealant materials in the form of tapes and sheets.

TEADIT NORTH AMERICA
(HOUSTON / USA)

TEADIT INTERNATIONAL
(KUFSTEIN / AUSTRIA)

TEADIT ITALY
(PARATICO / ITALY)



TEADIT ARGENTINA
(BUENOS AIRES / ARGENTINA)

TEADIT JUNTAS
(CAMPINAS / BRAZIL)

TEADIT INDUSTRIA E COMERCIO
(RIO DE JANEIRO / BRAZIL)

More than 700,000 square feet of plant, laboratory, office and warehouse space. More than 1000 employees, worldwide. Teadit products are distributed to more than sixty countries on five continents.

PRODUCTS

Teadit is a vertically integrated manufacturer using highest quality raw materials to assure the best performance of the equipment and the environmental protection.

Teadit offers a complete and broad range of solutions for fluid sealing and thermal insulation to meet the demand of numerous industrial applications.

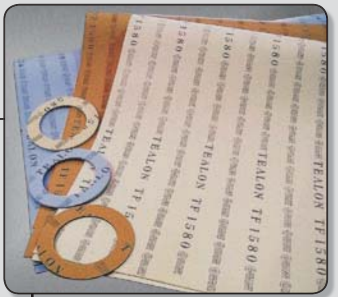
Compressed Non-Asbestos Gasket Sheets

Mechanical Packings

Metal Gaskets

Metallic and Non-Metallic Expansion Joints

Expanded PTFE Products

Industrial Textiles

PTFE Gasket Sheets - TEALON

Metal Bellows

Thermal Insulation Millboard

Flexible Graphite Products

MANUFACTURING

Teadit has state-of-the-art manufacturing facilities worldwide. All plants operate under ISO 9001 certification and employ the latest technologies in its processes.

Visitors often remark about the cleanliness of the plants and the apparent attention to worker's safety. Careful consideration and implementation is given to environmental concerns.

Braided Packing Plant

Electronic Warping Machine

Autolever Draw Frame
Fiber Alignment

Rapier Loom with Load Cell Warp Control

Gasket Sheet Plant

Computer Controlled Gasket Cutting

Autoclave

Spiral-Wound Gasket Manufacturing Cell

Dental Floss Production

RESEARCH & DEVELOPMENT


Image Analyser

Each Teadit manufacturing facility operates a laboratory with testing devices and procedures relative to its specific products.

These laboratories are peripheral to the primary R&D facility, located in Rio de Janeiro, where very sophisticated equipment is utilized by highly trained product development engineers and technicians.

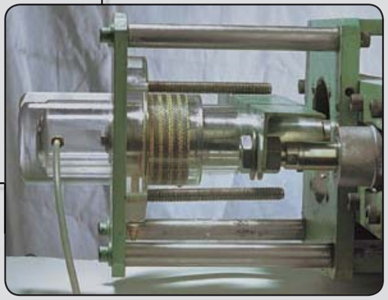
There are new materials and products under continuous development, products that will improve performance and offer practical solutions to the most difficult fluid sealing problems.


Lab Mixer


Automated R&D Process Control


Mass Spectrometer


Positive Metal Identification (PMI)


Packing Testing Station


Infrared Spectrometer


Gasket Test Bench

TECHNICAL FIELD SERVICES

- Valve Stem Packing Extraction and Replacement
- Packing Installation
- Gasket Installation
- Field Fabrication of Gaskets
- Expansion Joint Installation
- Leakage Trouble-Shooting
- Product Training Seminars
- Gasket Bolting Calculations Software
- Product / Application Literature

Fugitive Emissions Monitoring

Training and Seminars

Controlled Torque
Gasket Installation

Valve Stem Packing Extraction

In-Plant Service Center

Teadit has developed the Service Center concept which is a mobile plant installed on customer premises to manufacture special gaskets, remove and repack valves and rotating equipment and install expansion joints. Prior to the turnaround Teadit engineers do plant surveys to determine the needs and prepare the specifications.

Services performed are carefully recorded, daily and a final complete report are presented to the customer for follow-up and analysis.

CERTIFICATES

DET NORSKE VERITAS
CERTIFICADO DE SISTEMA DA QUALIDADE
TEADIT JUNTAS LTDA.

TEADIT JUNTAS - CAMPINAS / BRAZIL

DET NORSKE VERITAS
MANAGEMENT SYSTEM CERTIFICATE
TEADIT INDÚSTRIA E COMÉRCIO LTDA.

TEADIT IND. E COM. - RIO DE JANEIRO / BRAZIL

Memberships and Associations

ESA - European Sealing Association

FSA - Fluid Sealing Association

Quality Statement

The Teadit Group is comprised of Total Quality Management companies and is committed to 100% customer satisfaction through innovative product development, cost effective manufacturing, finished goods inventory and efficient customer service. All performed by empowered employees committed to continuous improvement.

The Teadit Group manufacturing plants operate under ISO 9001 certification. Please see the display of current certificates on this page.

DET NORSKE VERITAS
QUALITY MANAGEMENT SYSTEM CERTIFICATE
TEADIT ITALIA S.p.A.
SINCERT

TEADIT ITALY - PARATICO / ITALY

CERTIFICATE
ISO 9001 : 2000

TEADIT INTERNATIONAL - KUFSTEIN / AUSTRIA

Industrial Gasket Handbook
Gasket Bolting Calculation Software

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TEADIT®

Solutions with Quality

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June 2007

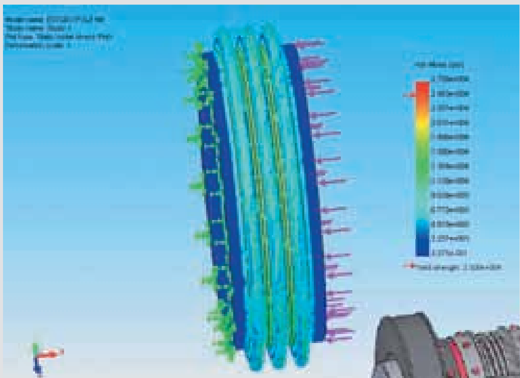
Metallic and Non-Metallic Expansion Joints

TEADIT®

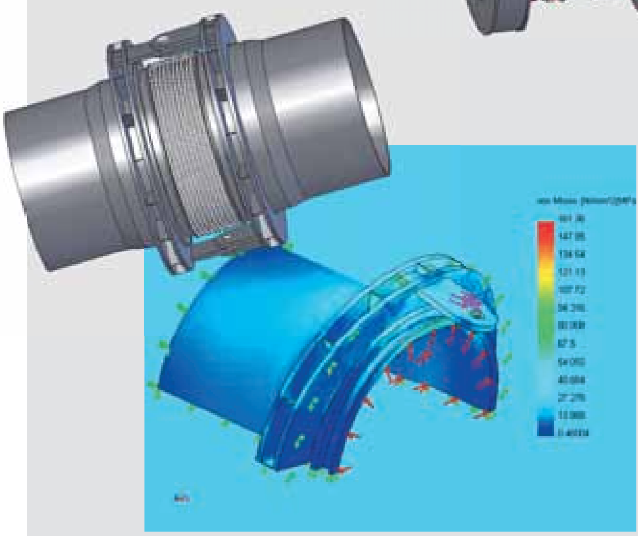
Design Technology

Teadit employs updated technology to develop their products. Advanced software allows creating 3D models to design the expansion joints and their hardware.

Besides the simulation of different operational conditions, it is possible to analyze the interaction between the several expansion joints components, to do mechanical and thermal studies, to simulate operational conditions and validate the design.



FEA – Finite Element Analysis.



The expansion joint design is improved to achieve high performance and life.

The expansion joints are designed to solve the pipes thermal expansion, in the hardest operational conditions. Designed with proper flexibility, avoid fluid head losses and energy, reducing the implementation and assembling costs, with high quality level and safety.

Teadit manufacture a wide range of different expansion joints, including the types: axial, universal, hinged, gimbal and pressure balanced, following the standards EJMA and ASME, under surveillance of specialized engineers and technicians.

Universal Rectangular Expansion Joint

Application:
Cooper Smelting Plant

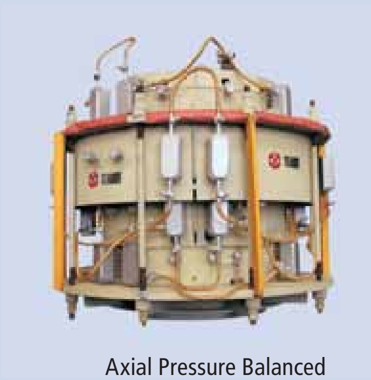
Gimbal Expansion Joint

Application:
"Tuyere Stock" Steel Mill Blast Furnace.

Universal Expansion Joint

Application:
Steel Mill Hot Air Blow Line.

Metallic Expansion Joints


Axial Pressure Balanced Expansion Joint, with Hot Blanket


Universal Pressure Balanced Expansion Joint


Universal Expansion Joint with tie rods

Gimbal Expansion Joint

Application:
Refinery UFCC

Universal Pressure Balanced Expansion Joint

Application:
Steel Mill

Universal Expansion Joints with Tie Rods

Application:
Carbon Black Plant
Tail Gas

Pressure Balanced Expansion Joint

Application:
Refinery UFCC Riser

Axial Expansion Joint with Tie Rods

Application:
Steel Mill Blast Furnace
Gas Line

Hinged Expansion Joint

Application:
Iron Ore Mining
Hot Air Line

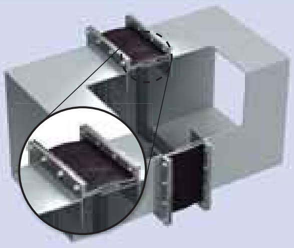
Non-Metallic Expansion Joints

Developed to be used in extreme operational conditions and manufactured in rectangular or circular shapes. The non-metallic expansion joint are designed to absorb thermal expansion from air and process gases ducts.

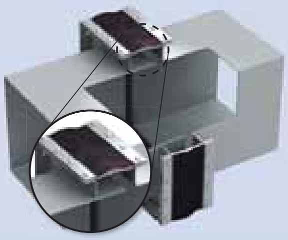
They are frequently used in boiler, gas turbines, furnace and burners. Application in several industries: cement, petrochemicals, pulp & paper, refining, etc.

FRAME STYLES

Flanged U Belt



Flat Belt



COMPOSITE FABRIC BELT TYPES

Quality Type

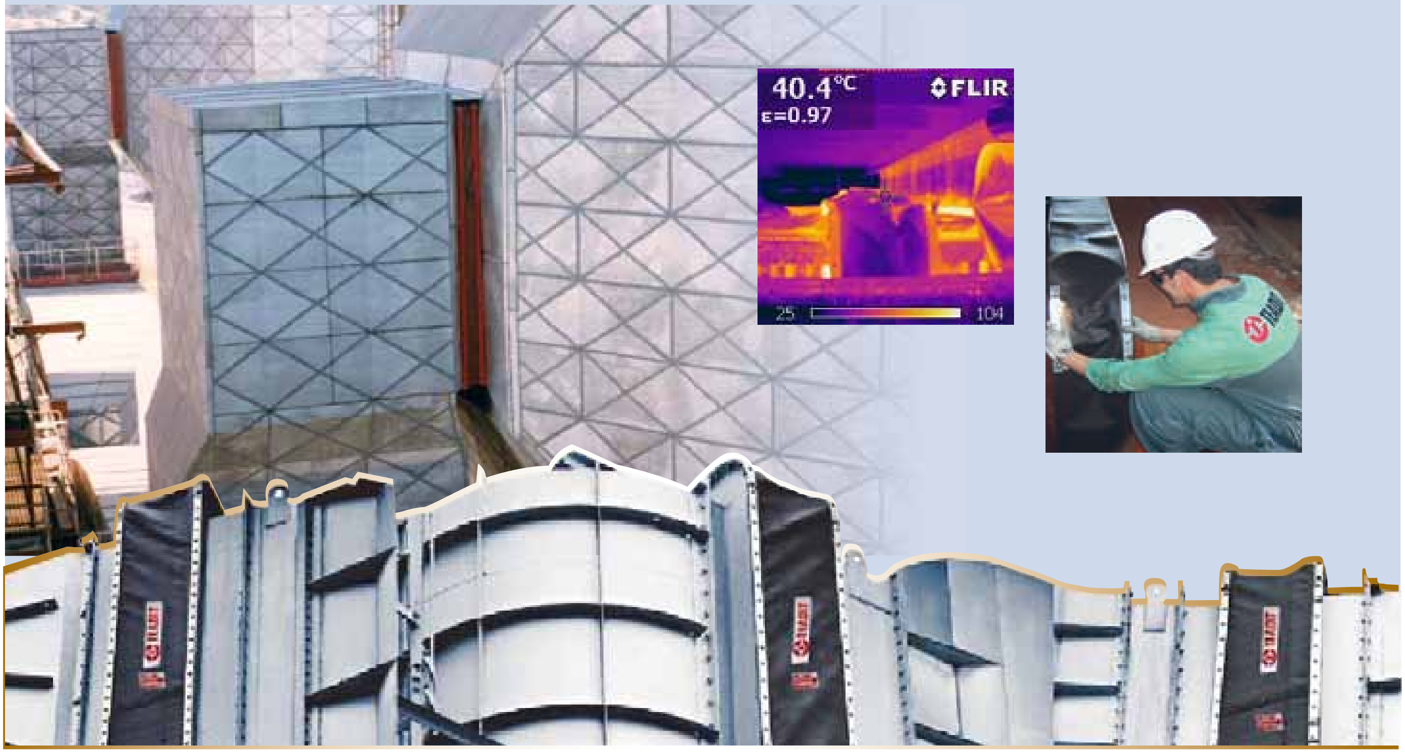
Silicone Coated Fiberglass Fabric

Premium Type

PTFE Impregnated Fiberglass Fabric with PTFE Film Sealing

SERVICE LIMITS

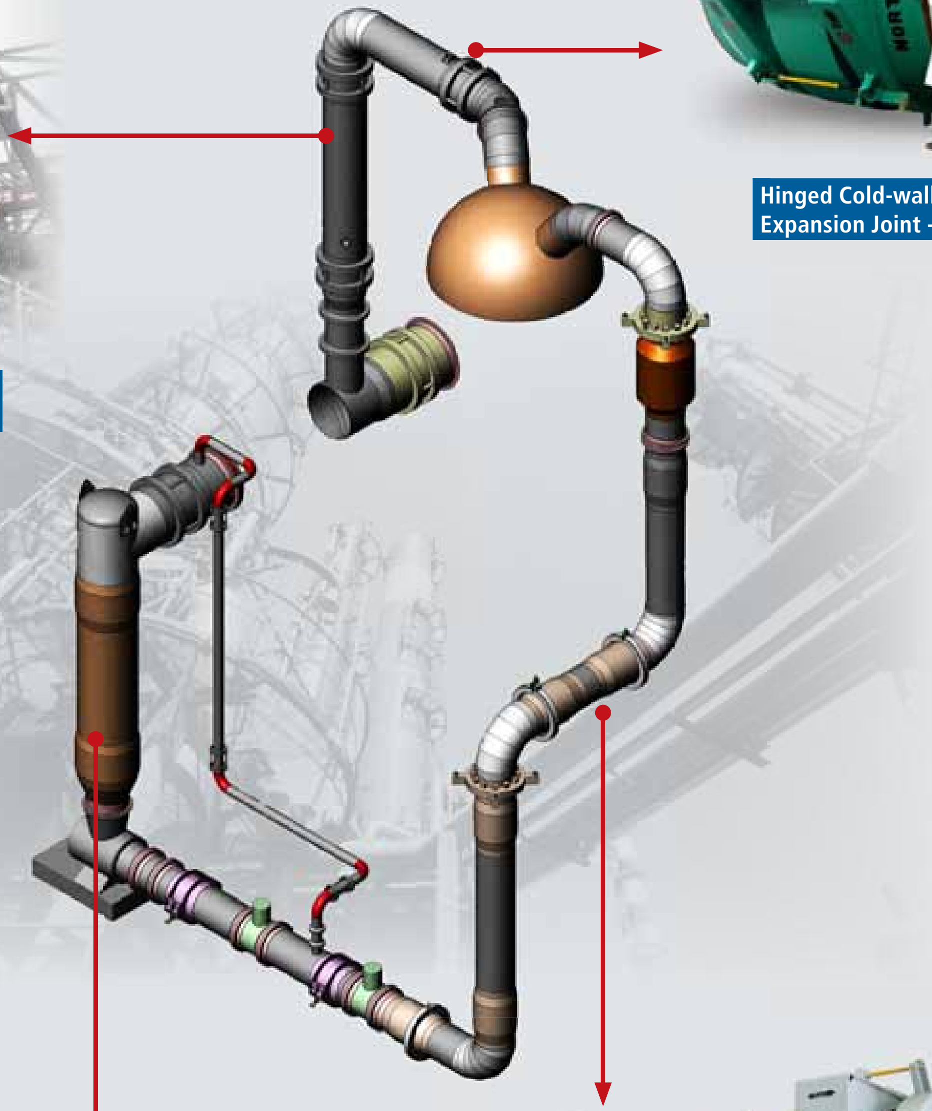
Non-metallic expansion joints have applications up to 0.4 bar pressure and temperature of 1200°C. Specifically developed for each operational conditions including heavy acid attack.



TEADIT® Refining Expansion Joints

Gimbal Cold-wall Expansion Joint - ID 64 in

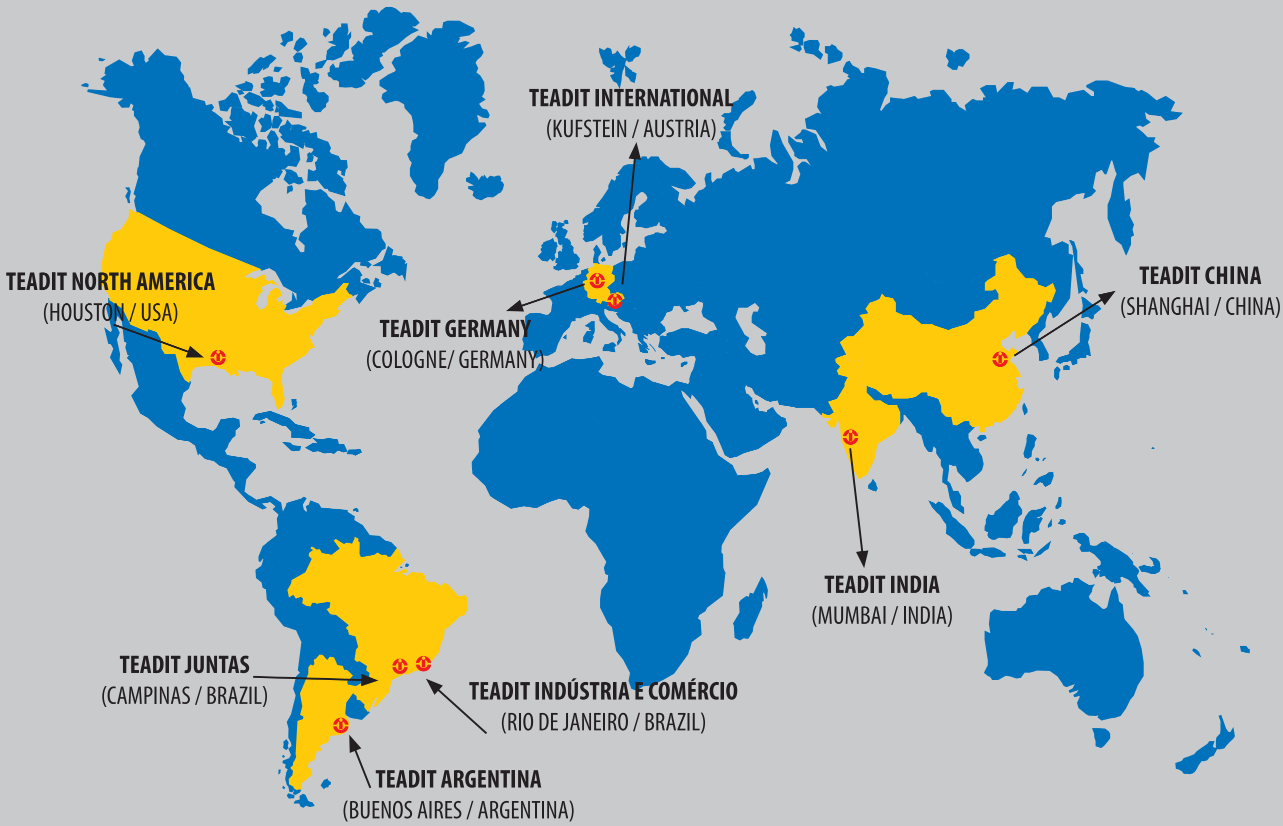
Hinged Cold-wall Expansion Joint - ID 64 in



Gimbal Universal Hot-wall Expansion Joint - ID 120 in / 50 ton

Double Gimbal Hot-wall Expansion Joint - ID 66 in / 35 ton

TEADIT WORLDWIDE



COMPANY ISO 9001

With more than 50 years of industrial experience, TEADIT® stands for competence, quality and innovation. Our extensive product range plus the flexibility to react competently and quickly to customers' wishes have made us one of the market leaders. At TEADIT® numerous manufacturing plants and sales agencies guarantee availability of the complete product range as well as competent service in every area of technology. Baked by sophisticated technology and constantly growing know-how, TEADIT® counts as one of the market leaders for stuffing box packings, expanded PTFE, sheet jointings, metallic and non-metallic gaskets, expansion joints, yarns and textiles.

Our Products

MECHANICAL PACKINGS • COMPRESSED SHEETS • YARNS AND TECHNICAL TEXTILES • PTFE GASKETING PRODUCTS

METALLIC AND NON-METALLIC GASKETS • METALLIC EXPANSION JOINTS • NON-METALLIC EXPANSION JOINTS

TEADIT®

Solutions with Quality

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Campinas, SP - Brazil - Av. Mercedes Benz, 390 - CEP 13054-750
Phone: (55-19) 3765-6501 - Fax: (55-19) 3225-5614 - E-mail: juntas@teadit.com.br

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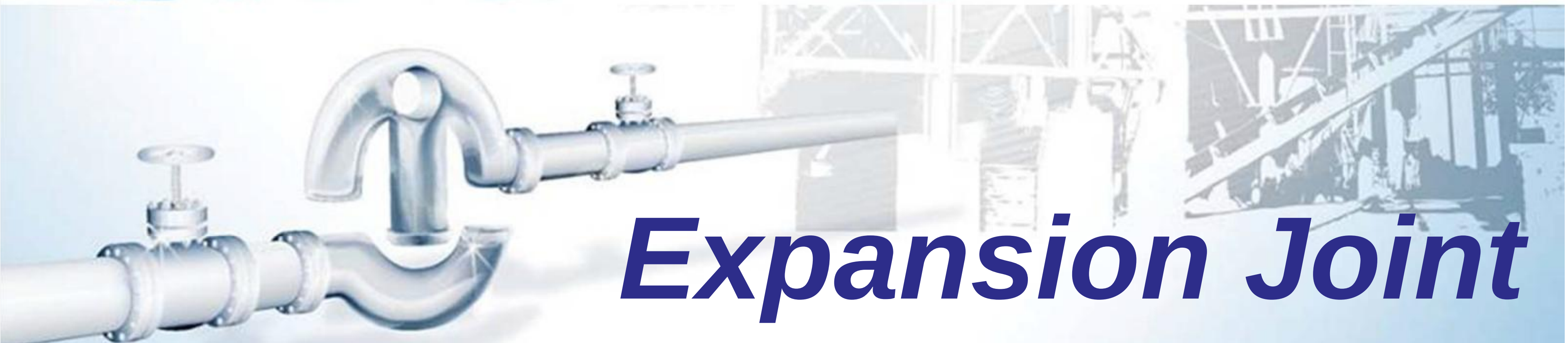


Expansion Joint Capabilities

TEADIT®

Expansion Joints

Styles

- **Metallic Bellows**
- **Fabric Expansion Joints**
- **Axial**
- **Universal**
- **Hinged**
- **Gimbal**
- **Pressure Balanced**

Bellows up to 6 meters ID

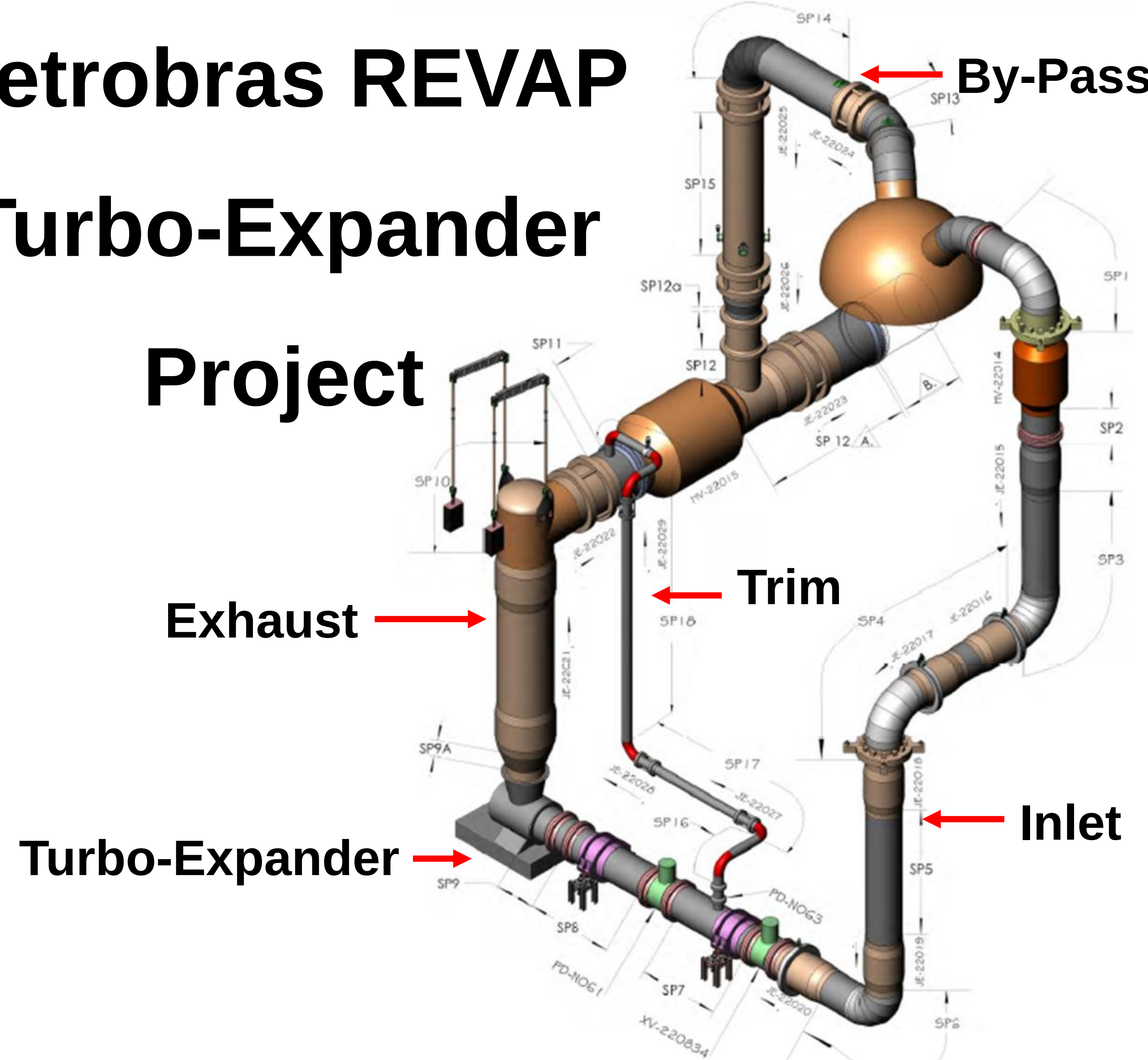
TEADIT

Bellows Thickness

up to ½ inch

Fabrication Capability

Petrobras REVAP Turbo-Expander Project



Gimbal
Hot-Wall
ID: 66 in
L: 118 in
W: 16 ton

Design

Temperature: 1350 F
Pressure: 3.6 bar (53 psi)

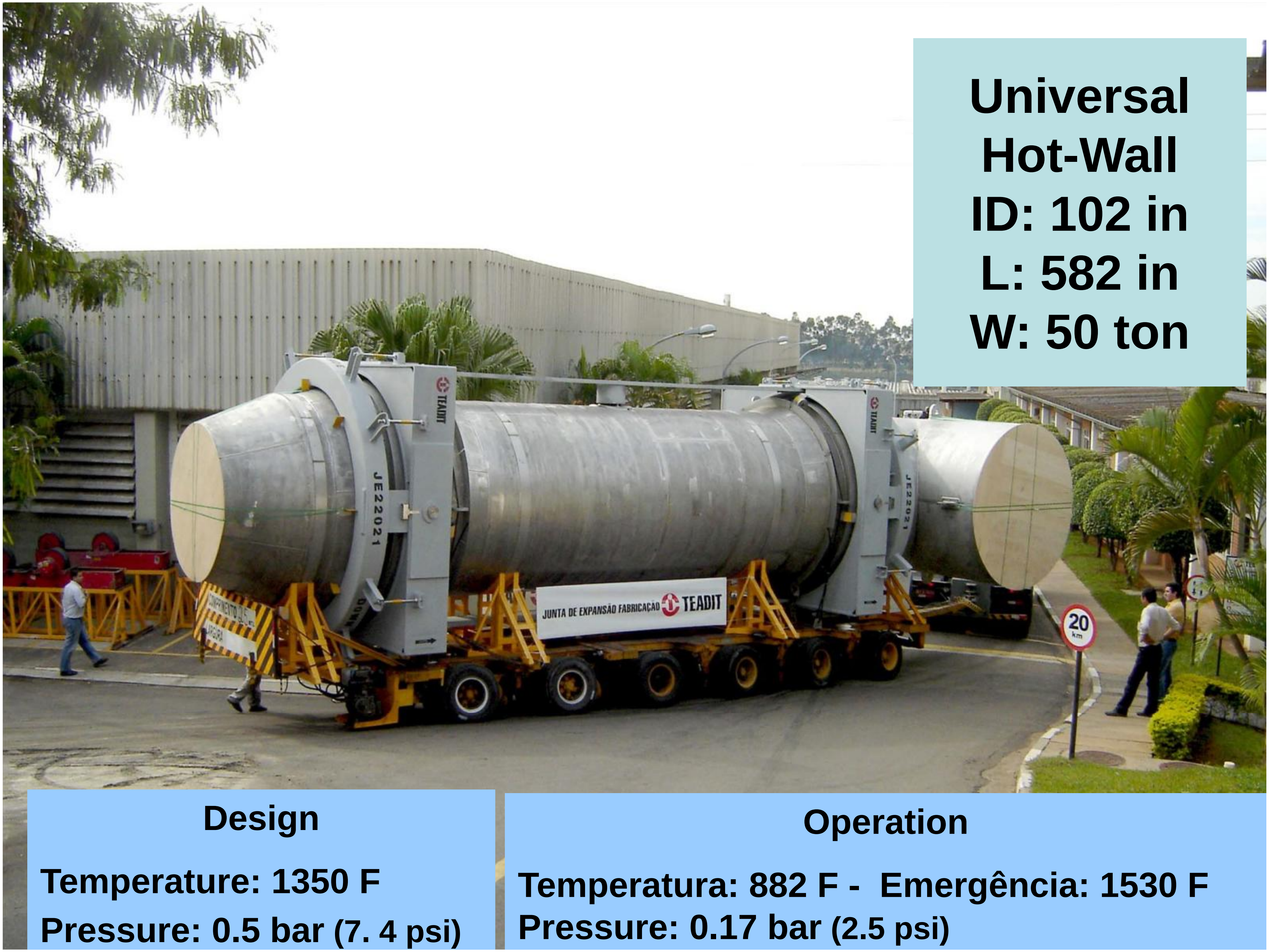
Operation

Temperature: 1200 F - Emergêncy: 1800F
Pressure: 2.3 bar (34 psi)

Double Gimbal
Hot-Wall
ID: 66 in
L: 300 in
W: 35 ton

Hinged Hot-Wall
ID: 66 in
L: 118 in
W: 11 ton

Gimbal
Hot-Wall
ID: 66 in
L: 118 in
W: 16 ton



Universal Hot-Wall
ID: 102 in
L: 582 in
W: 50 ton

Design

Temperature: 1350 F
Pressure: 0.5 bar (7. 4 psi)

Operation

Temperatura: 882 F - Emergência: 1530 F
Pressure: 0.17 bar (2.5 psi)

Hingwed
Hot-Wall
ID: 102 in
L: 110 in
W: 13 ton

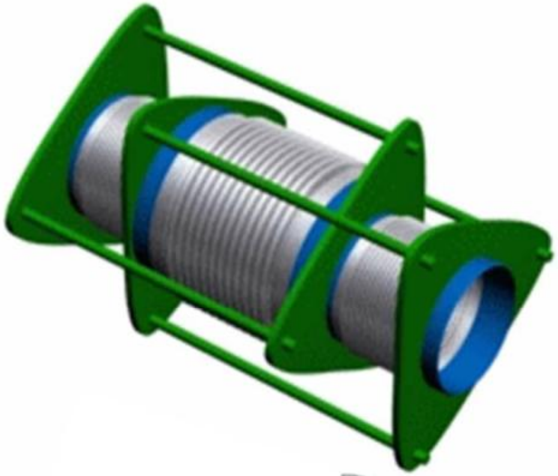
Axial
Cold-Wall
ID: 66 in
L: 100 in
W: 22 ton

Gimbal Cold-Wall
ID: 64 in
L: 80 in
W: 14 ton

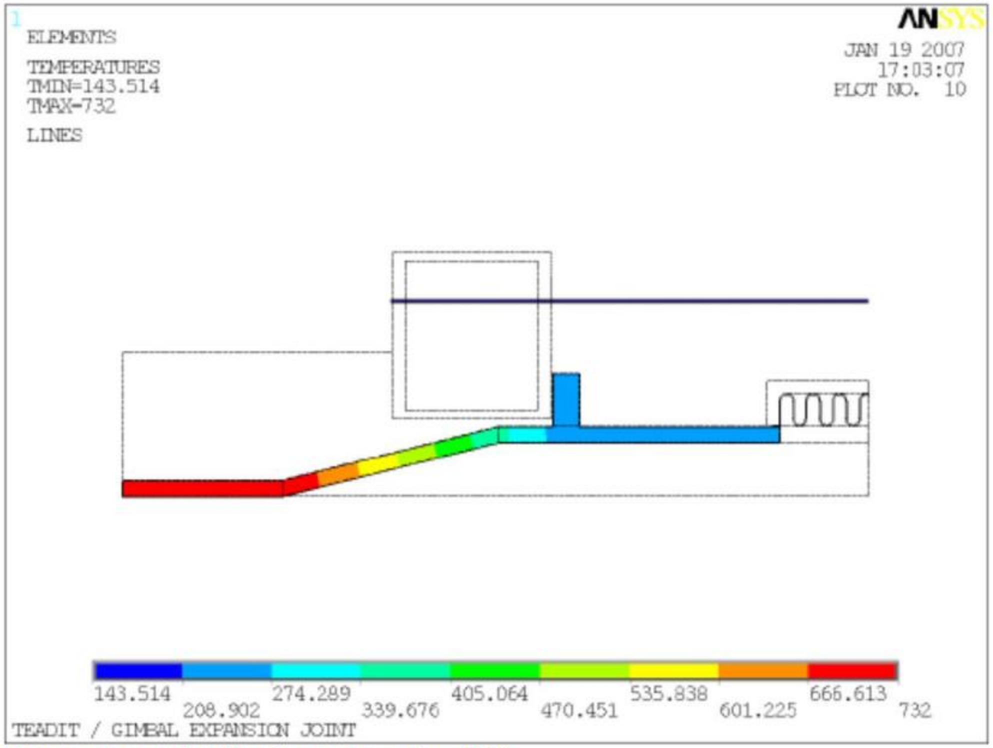
Hinged Cold-Wall
ID: 64 in
L: 80 in
W: 12 ton

Cold Wall Joints – Refractory Lining

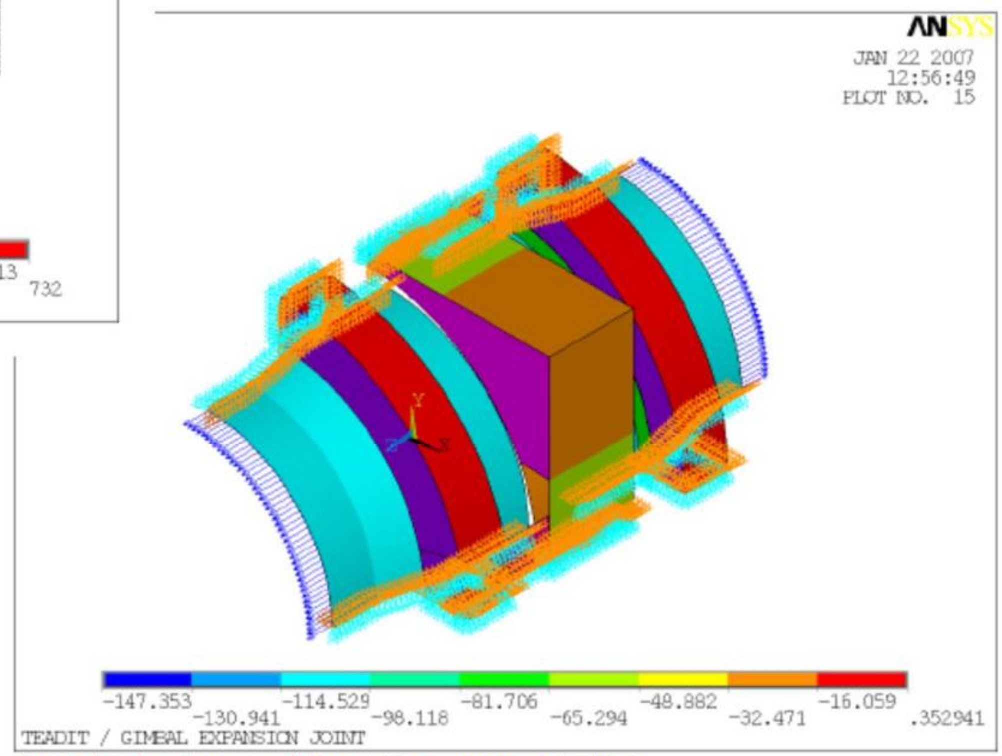
Pressure Balanced



Finite Element Design



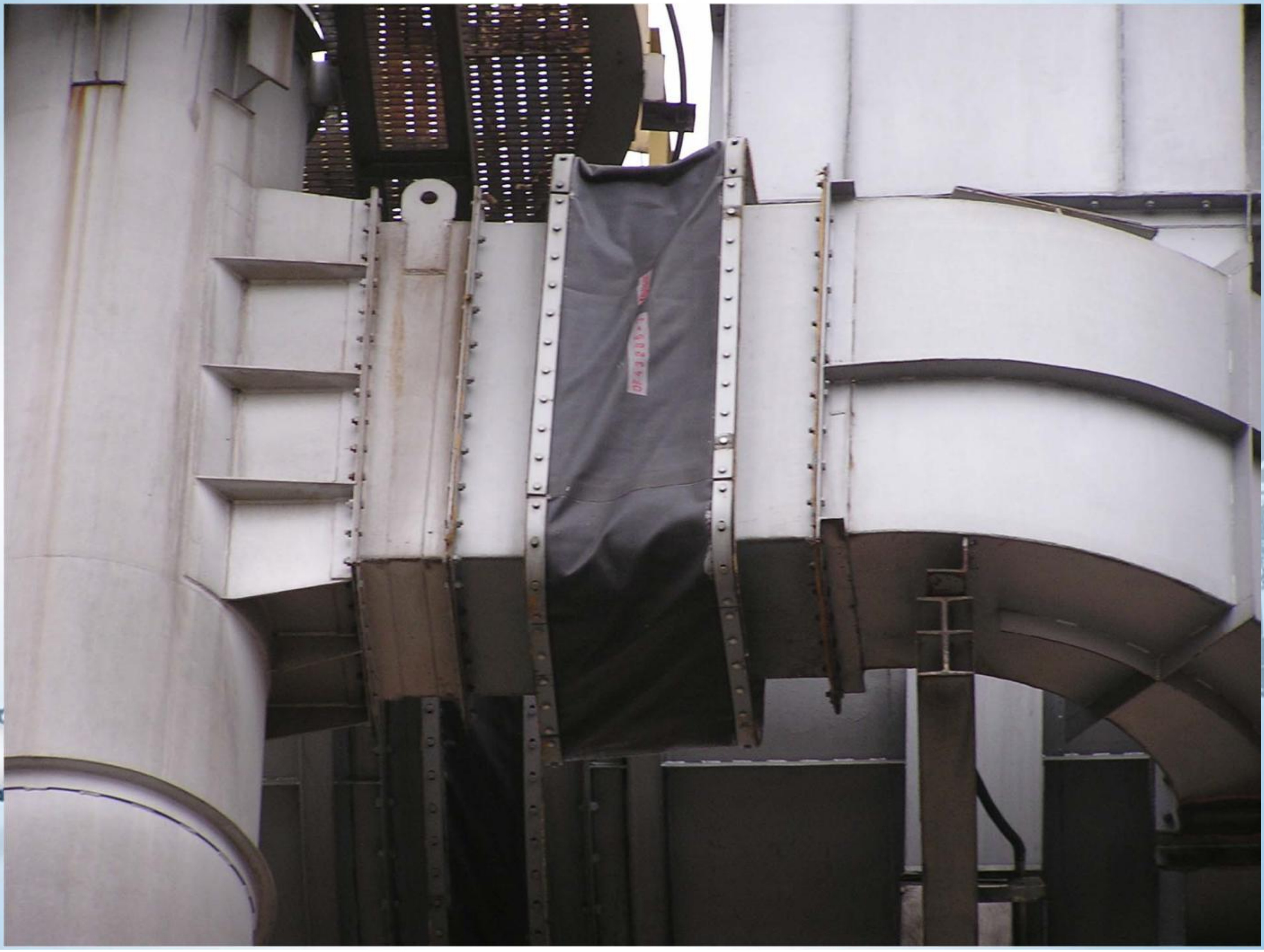
Temperature distribution on the pipe (ºC)



Model / Boundary conditions / Pressure load (MPa)

Pressure and Movement Test

Flue Duct Expansion Joints



Flue Duct Expansion Joints

- Media pH 0 to14
- Temperature up to 1200 ºC 2200 F
- Circular, rectangular, square, etc
- Vibration insulation
- Duct misalignment
- Large movements

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Expansion Joint Capabilities

TEADIT®

Proceedings of the ASME 2009 Pressure Vessels and Piping Division Conference
PVP2009
July 26-30, 2009, Prague, Czech Republic

PVP2009-77828

ANALYSIS OF FCC EXPANSION JOINTS MOVEMENT TEST

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ABSTRACT

The Turboexpander is an equipment that works under very critical conditions requiring very low allowable nozzle forces and moments. A solution to minimize the piping loads transmitted to the equipment is the use of expansion joints. A usual piping stress analysis normally is not enough to guarantee the turboexpander reliability.

This paper shows the results obtained in a movement test realized on metallic bellows expansion joints (EJ) used in a turboexpander piping system. The EJ were designed according to the expansion joints manufacturer association code (EJMA), the diameters range from 457 to 2,898 mm, the material of the bellows is Inconel 625 LCF and the shell materials are “killed” carbon steel, for refractory lined EJ or stainless steel 304H.

A special test device was developed to apply the design movements on the EJ at the factory. A digital dynamometer was used for data acquisition and the tests were performed on 16 expansion joints of two distinct types: hinged and gimbal. The EJ were pressurized with water during the test. The reactions and corresponding displacements for each step of the test were recorded during loading and unloading.

INTRODUCTION

Expansion joints (EJ) are commonly used in the petroleum industry. The Turboexpander, typical equipment in industrial plants, require the use of expansion joints in its system because of the lower allowable nozzle loads. There is a strong relation between the EJ correct function and the system reliability.

Therefore, it was necessary to develop an EJ movement test for use after complete construction of the expansion joint. With this test it is possible to anticipate EJ construction problems in time to mitigate an action.

This paper presents the results of a shop test which verifies the existence of internal construction interference, the friction between hardware components and obtains a comparison between the actual EJ behavior during the movement and the project values (behavior), according to EJMA standard (Expansion Joints Manufacturers Association) [1].

TURBOEXPANDER

The Turboexpander is the equipment responsible for the generation of electric energy produced from the hot gases regenerator effluent of the fluid catalytic cracking unit (FCC). These gases have operating temperatures ranging from 650 °C to 760 °C and internal pressures about 3.0 kgf/cm^2. With the intention to optimize the energy consumption within the refineries some new projects of turboexpander are in progress.

Due to service severity, the turboexpander piping system is, normally, of austenitic stainless steel 304H, material that presents high cost in its use, and requires, at least, wall thicknesses of 25 mm, to attempt the project requirements. Moreover, the piping layout shall attempt several prerequisites to guarantee the maximum efficiency and reliability of the turboexpander, since the equipment nozzles have tight stress limits.

In order to minimize the piping layout and to attempt those prerequisites, expansion joints must be used. During the turboexpander system basic project is determined the best route for the ducts connected to the turboexpander and are verified its flexibility. The loads transmitted to the machine nozzles are also verified as they cannot exceed the values established by the

Machine Code [2] or supplied limits. In Fig. 1, a schematically drawing of a turboexpander ideal inlet duct arrangement can be observed.

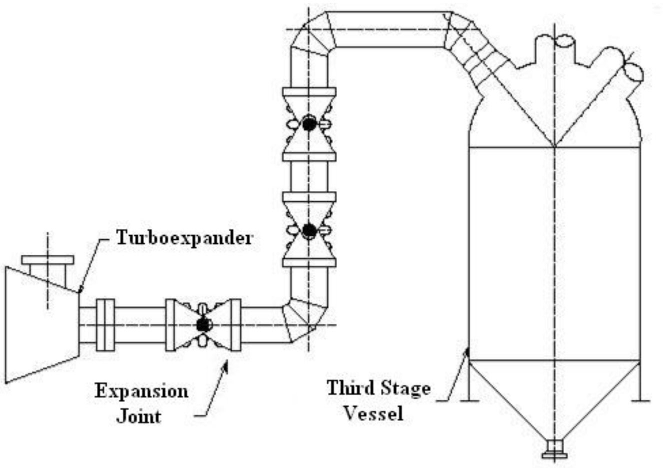


Fig. 1. Schematically drawn of a turboexpander inlet line ideal lay-out [3].

EXPANSION JOINTS

An expansion joint (EJ) is a flexible device capable of absorbing, with small reactions, the movements imposed in a pressurized piping system [4]. Usually, pipes movements originated from thermal expansion, equipment movement, vibration and pressure pulsation. The restriction to these movements generates stresses and reactions in the piping system and its connections.

EJ are commonly used for the following [5]:

• Systems whose available space is insufficient to have a pipe route with adequate flexibility;

• Low responsibility Services (condensed, low pressure vapor, hot water, among others), when the EJ represent an economic alternative in comparison to a non-linear layout;

• Piping with large diameters (above of 20”) or of expensive material, where there is an economic interest in a shorter runs;

• Piping where service requirements dictate linear and short runs;

• Piping that is subject to excessive vibrations, or linked to equipments where allowable stresses are very small.

The EJ are usually classified by the bellows material, which can be metallic, not-metallic (composite), elastomeric or in PTFE [6]. The metallic EJ are used for work in high temperature and pressure, non-metallic for low pressures and high temperatures and elastomeric or PTFE for water systems and some types of high pressure chemical products and temperatures limited by bellows material. For the project referenced in this paper, the approach was metallic joints.

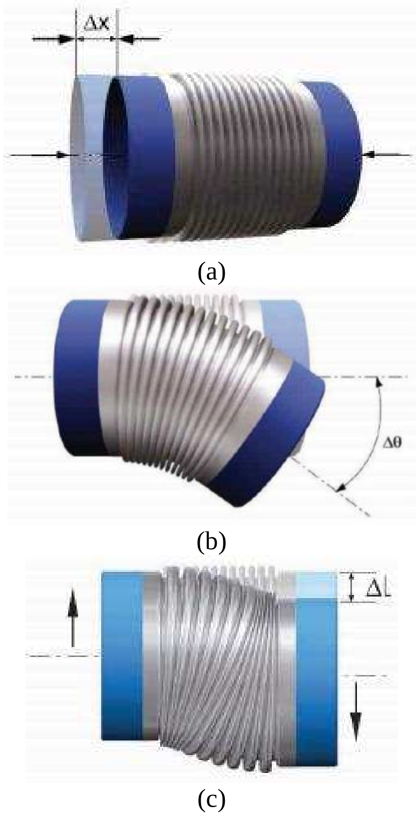


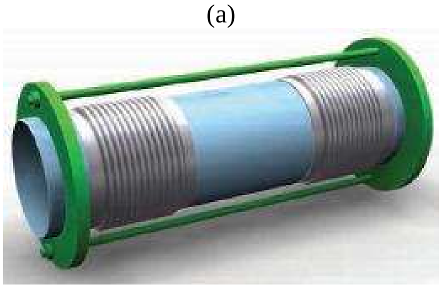
Fig. 2. Movement types of an expansion joints. (a) Axial, (b) angular and (c) lateral.

The main component of a metallic expansion joint is the bellows, formed mechanically or hydraulically from a thin-walled tube, contains only longitudinal welds. The bellows exhibits significant flexibility, behaving like a spring which deforms under low stress. It is manufactured from one or more plies and composed of a single or multiple convolutions of a suitable material. Special care should be taken in the material selection for metallic bellows due to the modest thickness of the metal which is subjected to high stresses and strains and possible corrosion attack. Use of a more corrosion resistant, stronger, or exotic material than specified pipe materials are often required [7].

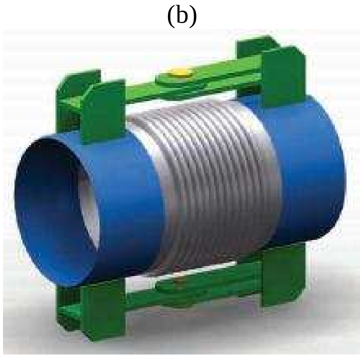
Moreover, for the appropriate bellows functioning, the expansion joint is composed of structural components (hardware), whose main functions are to support the proper weight of the components, to resist the axial loads due the internal pressure (pressure thrust), to limit undesirable movements and to protect the bellows from overloads [6].

Four types of basic movements can be applied to the bellows. Three of them are presented in Figure 2: axial, lateral and angular. The fourth movement is torsion and must be avoided; since the bellows exhibit unstable behavior under twist torsion.

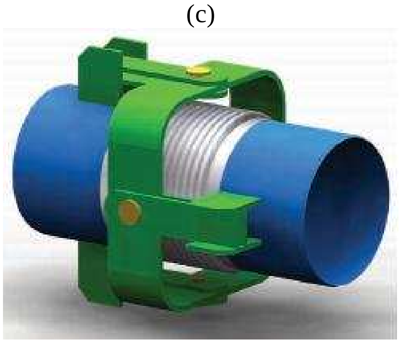
(a)



(b)



(c)



(d)

Fig. 3. Expansion joints types. (a) Axial, (b) tied universal, (c) hinged, (d) gimbal.

When it is compressed, the bellows resist the movement in the same way as a spring. The bellows spring constant depends on its geometry and the material's properties.

The simpler expansion joint is the axial type that only consists of one bellows, used to absorb tension or compression movements. For absorbing the axial movements, they transmit through the system the loads of pressure thrust due to internal pressure that can be large. Thus, a high value of loads will be transmitted all the way to the equipment nozzles connected to the pipe system. Therefore, simple axial EJ are not commonly used in pipe systems connected to critical equipment.

Universal expansion joint is the EJ type when two bellows are used together. This configuration allow the system to absorb axial, lateral and angular movements, greater than in the axial type. As in the simple EJ axial type, the pressure thrust effect must be considered. To minimize this effect rigid rods are introduced which, however, restrict the axial movements.

A hinged expansion joints allows the rotation in only one plan, and because of the hardware they do not transmit pressure thrust force through the system. Hinged expansion joints are normally displaced in sets of two or three to better absorb the system movement.

Finally, gimbal expansion joint is capable of absorbing rotation in all planes and, as in the hinged type, it does not transmit pressure thrust force nor torsion to the pipe system. Thus, hinged or gimbal expansion joints are preferred to be utilized in a Turboexpander systems.

Figure 3 presents the types of EJ, just explained: (a) axial, (b) Tied universal, (c) hinged, (d) gimbal.

As the stress limits in the turboexpander nozzle are low metallic expansion joints are introduced in the pipe system layout. The hinged and/or gimbal type shall be used rather than the others. After the type of EJ are defined, additional criteria must be specified such as length, bellows material, expansion joint type and stiffness factors. The calculation of these coefficients is carried out on the basis of EJMA [2] criteria. The bellows convolutions amount and thickness as well as the number, height and pitch of its corrugations are estimated for the design project. This estimation will be the initial reference for the selection and scope of supply for the expansion joints project.

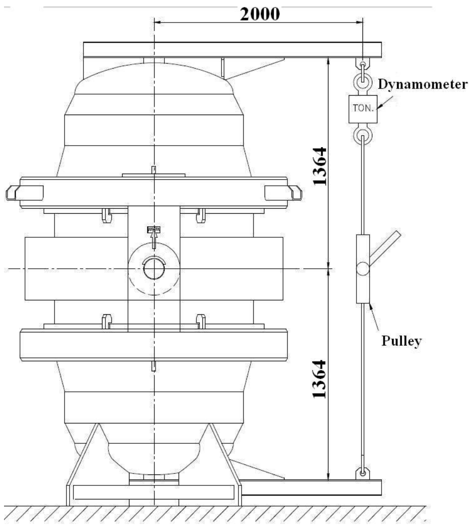
TEST DEVICE

A test mechanism was developed to realize the experiment in the hinged and gimbal expansion joints. The test consists of positioning the EJ on a support system on the vertical position; both ends closed by welded heads with a beam "I" welded to the top head extending past the center point by 2,000 mm to be used as a pivot arm (Fig.4), chains, pulley and a digital dynamometer to show the load value. The influence of the angle of the crowbar arm in the EJ reactions value was evaluated; however it did not have significant influence in the results.

The used dynamometer, Fig. 5 (a), have load capacity up to 10 tons. During the test, the given angle was verified with a device fastened to the EJ, shown on Fig. 5 (b). The application of the load was provided by a hand operator (Fig. 5 (c)).

The tests was carried out for 13 EJ, being 5 of the hinged type and 8 of the gimbal type. Table 1 lists each EJ by equipment number with corresponding pipe diameters and design characteristics.

The EJ will be installed in the turboexpander system of a Petrobras FCC unit, the EJ will be used in the inlet and outlet portions of the system. The tests were carried out moving each EJ until the design angle shown in the Table 1 was reached.

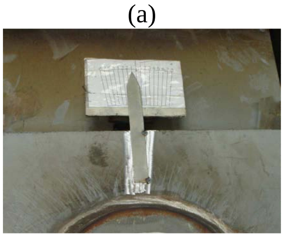


(a)

(b)

Fig. 4. Expansion joint in the test position (unit in mm). (a) Schematic draw of the test device and (b) Test device build of.

(a)



(b)

(c)

Fig. 5. Test Device. (a) Dynamometer used during the test, (b) angle measurement device and (c) Load application.

Table 1. EJ´s characteristics.

Number	Type	Movement	Design angle (˚)	ID (mm)
15	Gimbal	Angular	1.7	1930
16			6.2	
17				
18	Hinged		4.6	
19			7.9	
20	Gimbal		3.3	
22	Hinged		1.0	2910
24			1.0	1910
25			1.4	
26	Gimbal		0.5	
27			1.1	610
28				
29				

The corresponding reactions of each step of the movement during the loading (increasing angle) and unloading process (decreasing angle) were registered.

Each loading and unloading test was carried through on three conditions of applied pressure: design, operating and no-pressure (atmospheric pressure).Water was used to pressurize the system. All the tests were carried out at ambient temperature. The design and operating pressures correspondents to each one of the EJ are presented in Table 2.

In the loading process, the pulley was set gradually in motion, and the EJ angular movement was from the neutral position. In the unloading process, the pulley was gradually set free so that the EJ could return to the neutral position because of the spring reaction (Fig. 6).

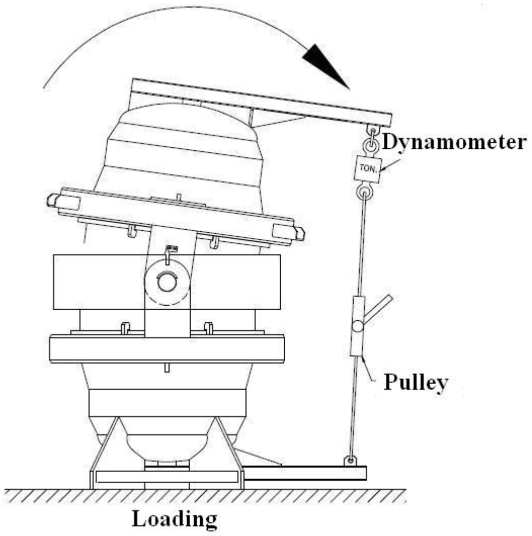
Figure 7 (a) and (b) shows one of the inspected EJ during the loading test. Observing the top of the EJ it is possible to see an angle from the EJ's movement.

Table 2. EJ operating and design characteristics: temperature and pressure.

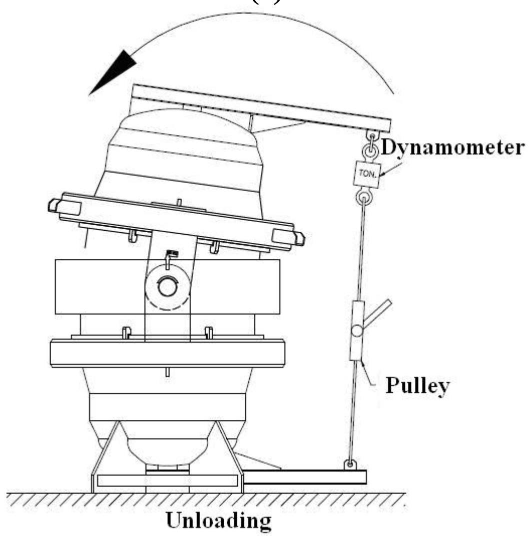
		Pressure (kgf/cm^2)	
Number	Temperature (˚C)	Design	Operation
15	450	3.6	2.3
16	450	3.6	2.3
17	450	3.6	2.3
18	450	3.6	2.3
19	450	3.6	2.3
20	450	3.6	2.3
22	450	0.5	0.2
24	450	3.6	2.3
25	450	3.6	2.3
26	450	3.6	2.3
27	450	3.6	2.3
28	450	3.6	2.3
29	450	3.6	2.3

ANALYSIS OF THE TEST RESULTS

Figure 8, 9 and 10, presented on Annex A, shows the applied moments and the corresponding rotation movement for the design, operating and non-pressure cases respectively. The test was performed in steps of 0.5º up to design angle for each of the expansion joints. Using linear regression a tendency line was created and the corresponding equation is presented for each expansion joint.



(a)



(b)

Fig. 6. Loading and unloading schematic drawing.

For the tests under pressure the expansion joints required an initial load to initiate the movement.

Table 3 shows the results obtained in the movement test for expansion joint JE-22020 movement test. The bending moment is proportional to the increase in pressure.

Table 3 – Initial bending moment on JE-22020.

Test Pressure (kgf/cm^2)	Initial Moment (kgf*m)
3.6	840
2.3	496
0	~0

The initial load can be explained by the friction forces on the structural component surfaces of the expansion joints such as hinges, pins and arms.

(a)

(b)

Fig. 7. Images from the EJ during the tests.

The inclination of such curves represents the bending stiffening factor of the expansion joint. The average values for each test condition are summarized in Table 4.

Reviewing Table 4, in most cases, the stiffness factors increases as the pressure condition increases. This confirms the pressure stiffening effect.

In some cases (EJ-22015, -16 and -22) the operating pressure test shows greater stiffness values than design values, while in expansion joints -27 and -29 the operating pressure stiffness value is lower than the non-pressure value. Since the data acquisition is not precise, these differences are possible the result of reading error or approximation. Some reading points may influence the deviation on the linearization used to determine the average stiffening factors. Besides these differences, the forces for each conditions tested are fully consistent with the internal pressure increase, as can be seen on Fig. 8, 9 and 10 (Annex A).

Table 4. Bending stiffness theoretical and test results.

EJ	Stiffness Factors (kgf/m*deg)			
	Movement Test			Theoretical
	Design	Operating	No Pressure	
JE-22015	1338	1361	1176	1150
JE-22016	997	1022	812	
JE-22017	1026	1006	818	
JE-22018	1147	1107	844	
JE-22019	1320	1172	879	
JE-22020	1116	1025	900	
JE-22022	1655	1714	1666	2108
JE-22024	1145	1157	1094	1116
JE-22025	1266	1250	1063	
JE-22026	1180	1154	1085	
JE-22027	140	109	135	92
JE-22028	125	103	102	
JE-22029	144	98	175	

The last column of Table 4 shows the theoretical cold stiffness factor calculated by EJMA code [1]. From this table it is possible to see that there are differences among the theoretical stiffness factor and those obtained from the movement test, these differences can affect the behavior of industrial systems.

The significant differences on Stiffness Factor, between the theoretical and the actual results obtained from the tests, occurred on EJ JE-22015 and -19 that presents values 16.4% and 14.8% higher than the theoretical ones. These differences become extremely high for the small diameter EJ: JE-22027, -28 and -29.

In the small expansion joints, since the design movements are very low (1.1º), only three readings were performed (0.5°, 1.0° and 1.5°), increasing the susceptibility to mathematical deviations.

Expansion joints JE-22015 and -19 are identical to EJ -20 and -18 respectively, but the stiffness factors are 20% greater on -15 in comparison to -20 for the design case, while for EJ -19 and -18 the difference is 15% for the design case.

Expansion joints JE-22015, -16, -17, -19 and -20 have the same theoretical bending stiffness, due to the fact that bellow design is the same. But, as we can see in Table 1, there are different hardware details involved, which would justify the difference in the values found for the stiffness factor.

CONCLUSIONS

This article presented the results achieved in the metal bellows expansion joint movement tests performed at the factory. A total of 13 expansion joints were tested, 5 of then were hinged and 8 were gimbal type.

The objective of the movement test was to check if there was any internal interference in the expansion joints final assembly that could limit the amount of movement that should be absorbed. In addition, it was possible to check if the real bending stiffness factors were close to those determined by the theoretical calculation by EJMA [2]. This is all important information since the turboexpander allowable nozzle loads are quite small.

The tests confirmed the importance of the pressure stiffening effect, and emphasize the necessity of finding out a better way to include this effect on bellows stiffening calculation and on the piping system simulation (flexibility analysis).

The friction forces are quite considerable and are directly related to normal force applied on the hinged pins. These pins are metal to metal contact without any special treatment, except for the hardcoating applied in some cases. This is especially important when stainless steel pins are required, to avoid the galling effect. In all tests, both carbon steel and stainless steel pins with or without hardcoating produced the similar behavior.

This pin friction effect as well as any other friction effect regarding expansion joint hardware is usually neglected in piping stress simulation. Since there is no reference in EJMA Code to this effect, there is no formal method to calculate or to simulate it. The tests showed that this value can be a higher value during the very first time the expansion joint is being moved in comparison to the subsequent movements. Dust, oxide or moisture can cause the system reactions to be higher. A friction reduction device is recommended, as well as some protection to avoid corrosion, dust and other undesirable components that could prevent the smooth movement of the expansion joint hardware.

The tests confirmed that the mechanisms (hinges), the inner sleeve, the insulation blankets and the anchor do not have interference which would prevent the correct performance of the expansion joints.

The test is quite simple and can be performed several times in a few hours. The device required to perform the test can be build in an ordinary factory facility.

Considering the advantage of confirm before installation that the EJ can properly absorb the design movements and since the tests have low complexity, perform the tests became a good practice in critical EJ systems, in order to avoid surprises during field operation.

Finally, there is another aspect that should be emphasized: the pressure stiffening effect can not be neglected when determining the bellows stiffness factors. Even though there is a quite linear behavior in most of the cases; there is an important initial force normally not considered in piping stress analysis; this extra load may result in damage to the internal parts of turboexpander systems or any other rotating machine.

ACKNOWLEDGMENTS

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ANNEX A

RESULTS FROM EXPANSION JOINTS MOVEMENT TESTS

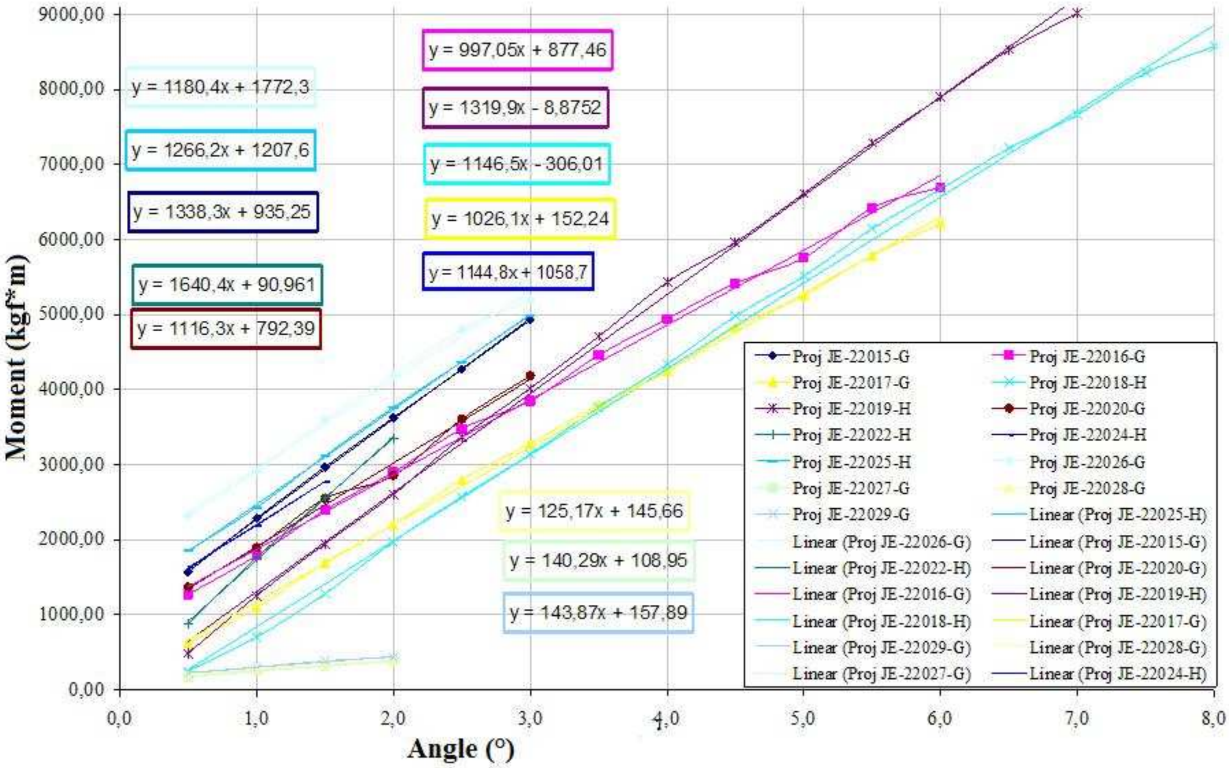

Fig. 8. Applied moment on each expansion joint – Design load condition.

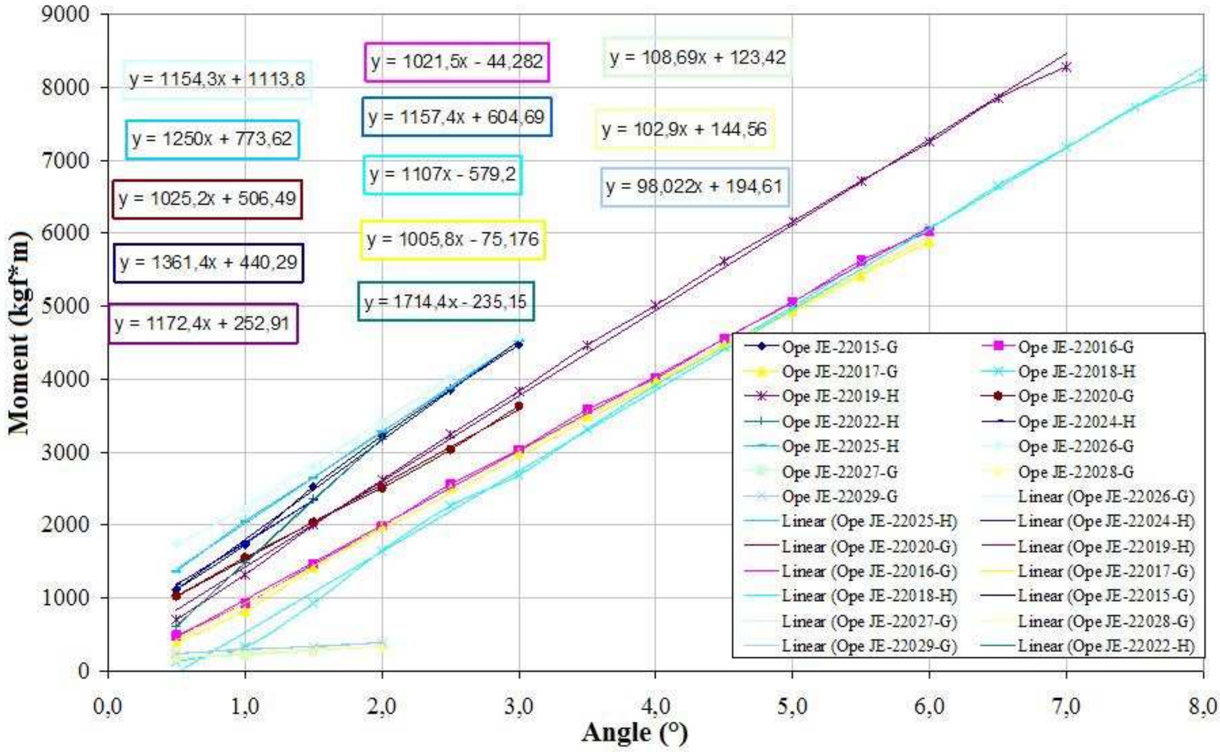

Fig. 9. Applied moment on each expansion joint – Operating load condition.

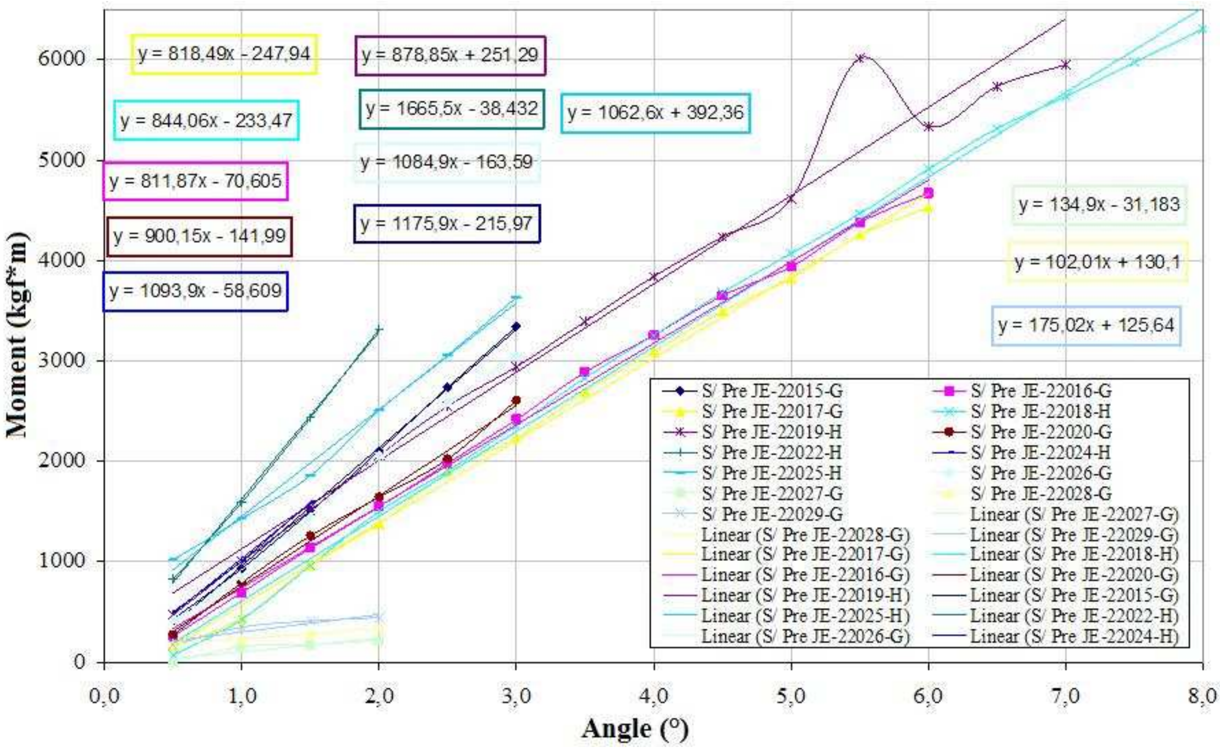

Fig. 10. Applied moment on each expansion joint – Non-pressure load condition.

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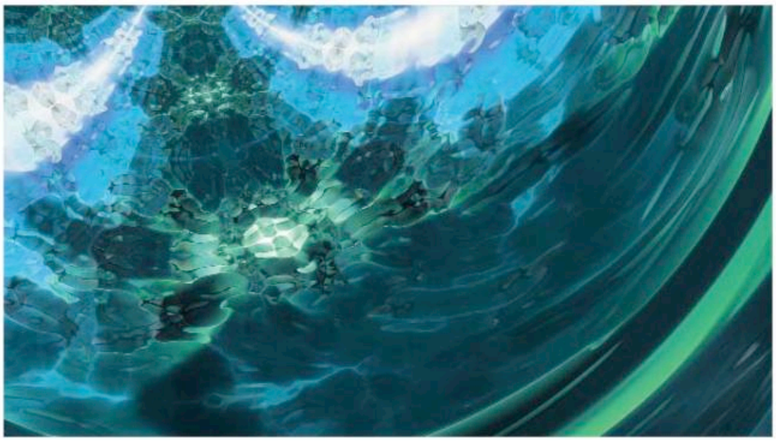

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DETERMINATION OF GIMBAL AND HINGED EXPANSION JOINTS REACTION MOMENTS

Proceedings of the ASME 2010 Pressure Vessel & Piping Division / K-PVP Conference
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DETERMINATION OF GIMBAL AND HINGED EXPANSION JOINTS REACTION MOMENTS

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ABSTRACT

This paper proposes a method to estimate the actual reaction loads in gimbal and hinged metal bellows expansion joints. Friction and some media pressure forces, which are not considered in current EJMA Standard calculations, are added to bellows spring rate to estimate the expansion joint movement reaction moment. The proposed calculation method is based upon pressure and movement tests of large size expansion joints.
Keywords: Expansion joint reaction loads, EJMA

NOMENCLATURE

Ac	= Partial differential area
Ad	= Differential area
Aeff	= Effective bellows area
C_R	= Correction factor
D	= Bellows inside diameter
Fb	= Force due to the differential area
Fe	= External forces (weight, etc)
Fp	= Tf + Fe = Total transversal force in the pin
L	= Half the bellows length
Ma	= Actual moment calculated from expansion joint tests
Marm	= Moment due to hinges friction
Mav	= Total moment in a EJ with angular movement
Mb	= Bellows angular moment due to bellows spring rate
Mejt	= Theoretical moment in a expansion joint
Mlpf	= Moment due to the lateral pressure force
Mpf	= Moment due to pin friction
Ms	= Moment due to inner sleeve seal friction
P	= Pressure
R	= D / 2
Tf	= Aeff . P = pressure thrust force calculated per EJMA equations
d	= Pin diameter
kα	= Bellows angular spring rate
α	= Movement angle
μp	= Pin friction coefficient

INTRODUCTION

Expansion joints are used by the industry in process piping and ducts to compensate the thermal expansion and provide the proper pipe flexibility. A pipe line is considered flexible if the pipe stresses and the equipment connection loads are lower than an acceptable level.

The ASME Process Piping code B31.3 [1] establishes the rules and values for the maximum allowable stresses in a process piping system. In addition, rotating equipment like steam turbines (Fig. 1), compressors, pumps and turbo-expanders, have the maximum allowable nozzle loads specified by the manufacturer or by an industry specific standard such as the NEMA SM23 [2] for steam turbines and turbo-expanders.

In a paper by the authors [3] metal bellows expansion joints actual reaction forces were compared with the theoretical values as per standards of the Expansion Joint Manufactures Association (EJMA) [4] equations. Since

EJMA does not consider effects like friction and components interference there is a discrepancy in the calculations that can show an increase in the actual pipe stresses and equipment nozzle loads.

This Paper presents a series of equations, based upon 13 large gimbal (Fig. 2) and hinged (Fig. 3) expansion joints pressure and movements tests, that take into account the loads not considered by the EJMA calculations. These equations can be used to estimate with higher precision the reaction forces in piping systems with metal bellows expansion joints.

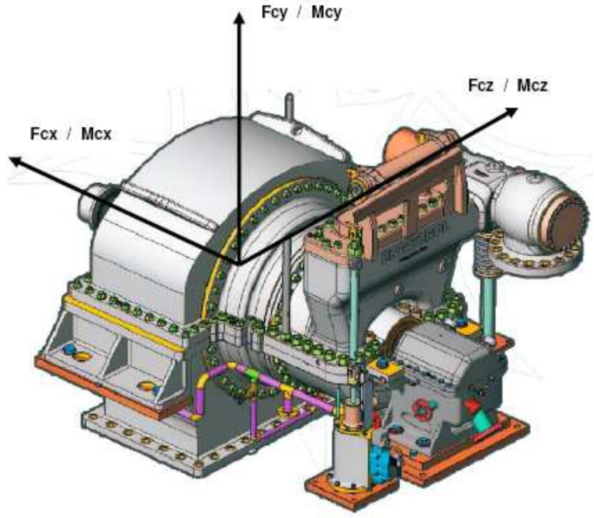


FIG. 1 - STEAM TURBINE

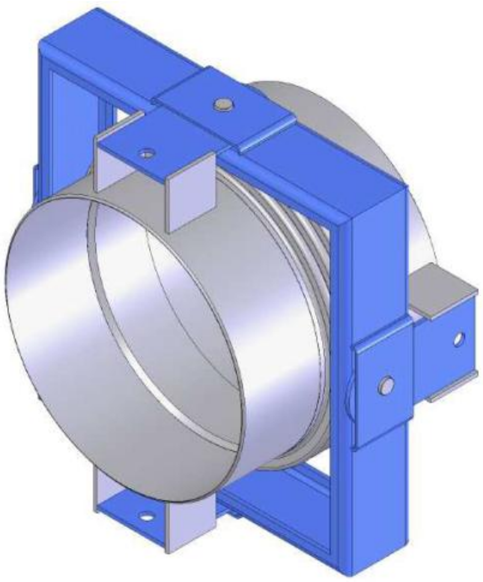


FIG. 2 – GIMBAL EXPANSION JOINT

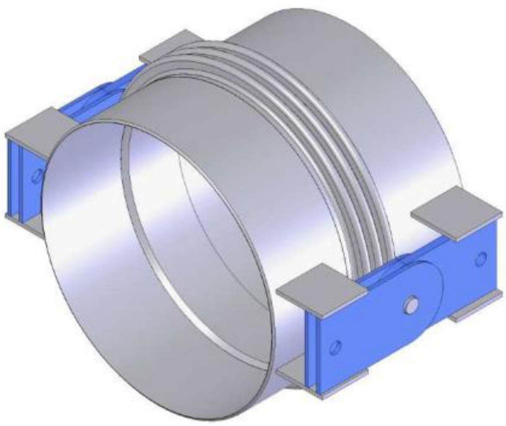


FIG. 3 – HINGED EXPANSION JOINT

EXPANSION JOINT REACTION FORCES

The media pressure and the movement acting in a gimbal or hinged expansion joints causes reaction loads calculated according to EJMA equations. The source of these reaction loads may be attributed to the following effects:

- Bellows spring effect: a metal bellows acts like a spring when it is flexed by the piping movement (Fig. 4).

- Pressure thrust: as a flexible element the media pressure creates a pressure thrust force (Fig. 5) that acts on expansion joint hinges.

In addition to these loads, other loads may be attributed to reactions as defined bellow:

- Hinges pin friction: as the expansion joints move, there is friction force acting on the hinge pins (Fig. 6). This force is due to the pressure thrust, joint weight and external forces.

- Lateral pressure force: in a rotated bellows the difference between expanded and contracted sides generates a lateral force

- Hinges Arm friction: the rubbing effect of the arms (Fig. 6) creates a friction force that opposite to their rotation.

- Sleeve Seal friction: expansion joints with inner sleeves may have a seal to hold inside bellows insulation. The seal creates a force which opposes the angular movement as shown in Fig. 7.

The forces acting on the expansion joint create an angular moment which can be expressed as follows:

$$Mav = Mb + Mpf + Mlpf + Marm + Ms \qquad (1)$$

In the following paragraphs each reaction moment is analyzed.

FIG. 4 – SPRING EFFECT

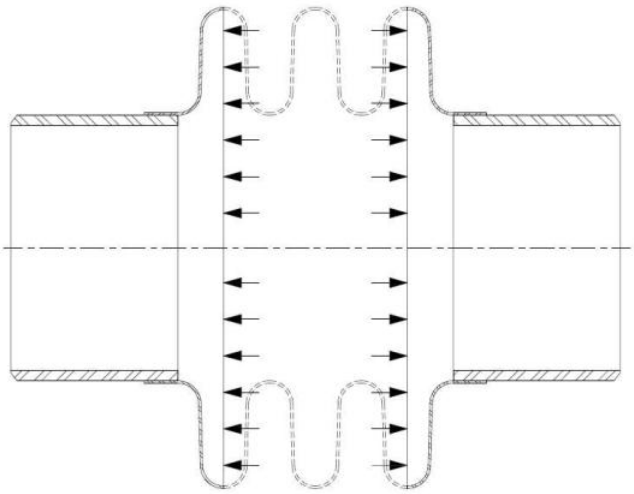


FIG. 5 – THRUST PRESSURE

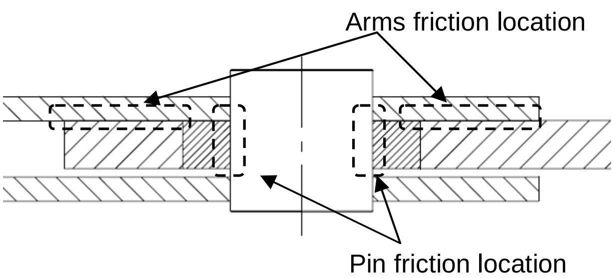


FIG. 6 – HINGED PIN / ARMS FRICTION

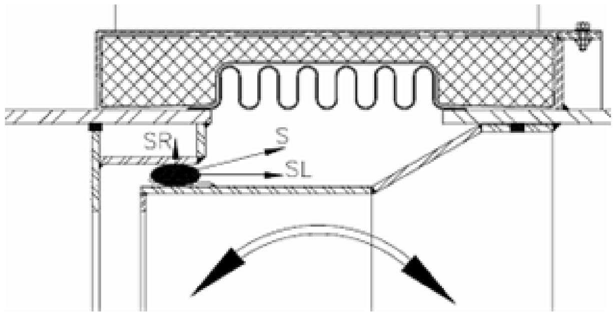


FIG. 7 – INNER SLEEVE SEAL FRICTION

MOMENT DUE TO BELLOWS SPRING RATE

The standard EJMA (Expansion Joint Manufacturers Association), state the spring rate calculation considering only the bellows spring effect.

$$Mb = \alpha * k\alpha \qquad (2)$$

MOMENT DUE TO PIN FRICTION

The pressure thrust force acting on an expansion joint hinge can reach very high values. For examples, in one of the joints tested, during the preparation of this paper, it reached 112 ton (248000 lbf) at its maximum test pressure. Consequently, it is necessary to account accurately and reduce the hinge pin friction.

An expansion joint, installed in a process piping to compensate thermal growth, is under a low frequency movement. A process which starts-up and stays for long periods at a steady-state, once the process temperature has been reached and hinges will not move.

In Fig. 8, see the sketch of the angular movement and the pin friction moment, due to the pin load.

The hinges pin moment can be written as:

$$Mpf = Fp * \mu p * d/2 \qquad (3)$$

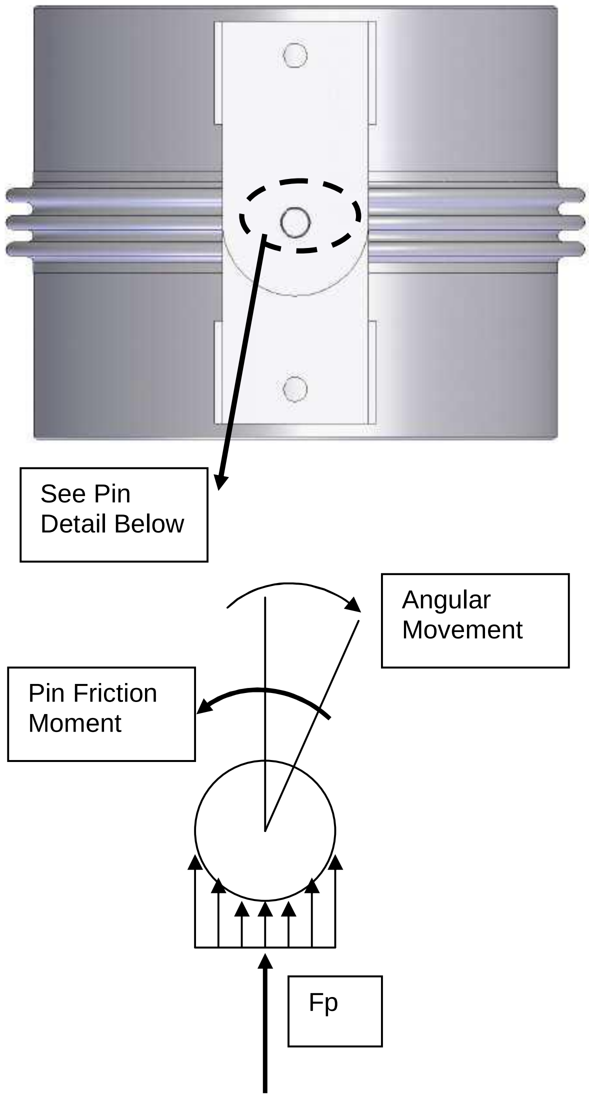


FIG. 8 – PIN FRICTION MOMENT

The pin static friction coefficient value "μp" depends of several conditions, like materials, hardness, surface finishing, presence of dirty and others. The most part of expansion joints applications use some steel pin straight in contact with the arms steel or with a metal sleeve, not using any lubricant and usually, in this condition the "μp" value is from 0.25 to 0.9 and this values can change due to environmental conditions. The choice of the proper pin and arm or sleeve metal must be carefully studied during the expansion joint design.

It is not part of this paper to analyze pin and sleeve materials. Further studies are necessary to evaluate the best choices. The focus of this paper is to show the importance of pin/sleeve friction loads.

If the hinges pin and sleeves are not properly hardened, the pressure thrust force may create a galling effect at their contact surface, increasing the moment necessary to move the joint. To avoid galling the pins can be hardened or adopt some other solution. In the expansion joints tested, for this paper, the pins were hardened using stellite, with grinding surface finishing. In order to check the friction coefficient of stellite x stellite, it was developed a test using different contact pressures, considering that the media pressure would cause a pin contact pressure from 47 MPa to 73 MPa (6.8 ksi to 10.5 ksi). Table 1 shows the stellite friction test results. For this study we considered a friction coefficient of 0.14.

TABLE 1 – STELLITE FRICTION TEST

Contact pressure – MPa (ksi)	Friction Coefficient
21 (3.0)	0.14
52 (7.5)	0.14
66 (9.6)	0.13
85 (12.3)	0.13
99 (14.4)	0.13
114 (16.5)	0.13

MOMENT DUE TO THE LATERAL PRESSURE FORCE

As shown in Fig. 9, as the expansion joint rotates, one side of the bellows expands and the opposite side contracts. The difference between the expanded and contracted areas (Fig.10) will generate a force in the opposite direction of the rotation. The moment due to the differential area can be written as follows:

$$Mlpf = Fb * L / 2 \quad (4)$$

The force due to the differential area can be written as:

$$Fb = P * Ad \quad (5)$$

Figure 11 shows an angular sector equals to half of the total rotation angle α. A side view (X-X) of this sector is shown in Fig. 12. The shaded portions are the differential areas between the expanded and contracted sides of the rotated bellows.

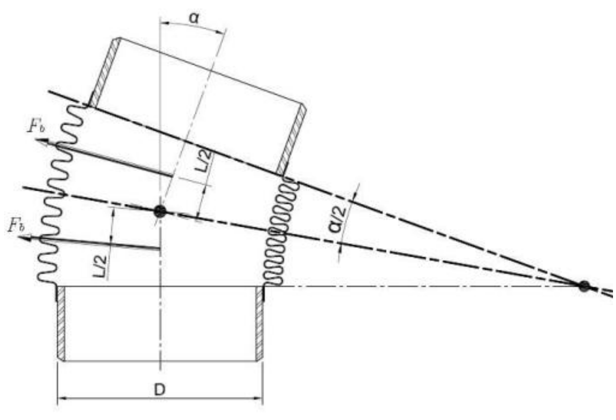


FIG. 9 – LATERAL PRESSURE FORCE

FIG. 10 – BELLOWS SIDES AREA DIFFERENCES, UNDER ANGULAR MOVEMENT

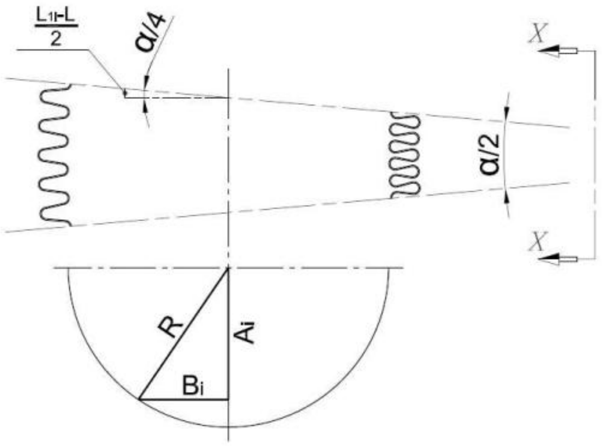


FIG. 11 – BELLOWS ANGULAR SECTOR

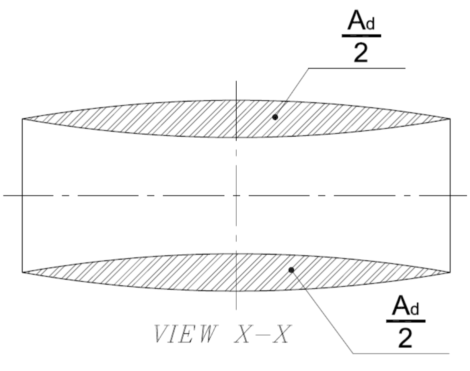


FIG. 12 – BELLOWS ANGULAR VIEW X-X

As shown in Fig. 13, it was considered a partial area, from the total differential area, to calculate in an easiest way. So the equation is:

$$Ad = 8 * Ac \tag{6}$$

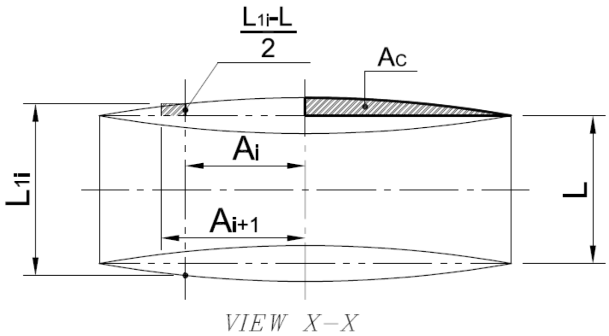


FIG. 13 – DIFFERENTIAL AREAS

Considering the radius R in the view XX divided in "n" equal parts, the partial differential area can be calculated as follows:

$$Ac = \sum_{i=0}^{n-1} \left(\left(\frac{L1_i - L}{2} \right) * \left(A_{i+1} - A_i \right) \right) \tag{7}$$

In this study, it was adopted a division in 10 equal parts, so the equation becomes:

$$Ac = \sum_{i=0}^{9} \left(\left(\frac{L1_i - L}{2} \right) * \left(A_{i+1} - A_i \right) \right) \tag{8}$$

$$\left(\frac{L1_i - L}{2} \right) = B_i * \tan\left(\frac{\alpha}{4} \right) \tag{9}$$

$$B_i = \left(R^2 - A_i^2 \right)^{0.5} \tag{10}$$

So the equation becomes:

$$Ac = \sum_{i=0}^{9} \left(\left(R^2 - A_i^2 \right)^{0.5} * \tan\left(\frac{\alpha}{4} \right) * \left(A_{i+1} - A_i \right) \right) \tag{11}$$

Table 2 shows values of the differential areas Ad for the diameters and movements of this paper.

TABLE 2 – BELLOWS SIDES AREA DIFFERENCES

ID mm (in)	1650 (65)	1900 (75)	1930 (76)
α (°)	Ad (cm²)		
1	196,3	262,4	268,5
1,5	294,4	393,7	402,8
2	392,5	524,9	537,1
2,5	490,7	656,1	671,4
3	588,8	787,4	805,6
3,5	687,0	918,6	939,9
4	785,2	1049,9	1074,2
4,5	883,3	1181,2	1208,6
5	981,5	1312,4	1342,9

MOMENT DUE TO HINGES FRICTION

The friction between hinges will increase the moment required to move the expansion joint. This friction can not be accurately accounted for. Bending due to welding thermal stresses can reduce the gap between arms increasing their rubbing.

MOMENT DUE TO INNER SLEEVE SEAL

The expansion joints, with internal refractory insulation, may be fitted with a metal seal between sleeves as shown in Fig. 14. This seal usually is a steel wire braid with steel mesh filler.

If the seal is aligned with the hinge pin, it will slide between the internal sleeves when the expansion joint is subjected to an angular movement as shown in Fig. 14. If the seal is not aligned it will slide as well as compress with the joint rotation as shown in Fig. 15. Both the sliding movement and the seal compression will generate a force, and consequently, a moment that can not be accurately calculated.

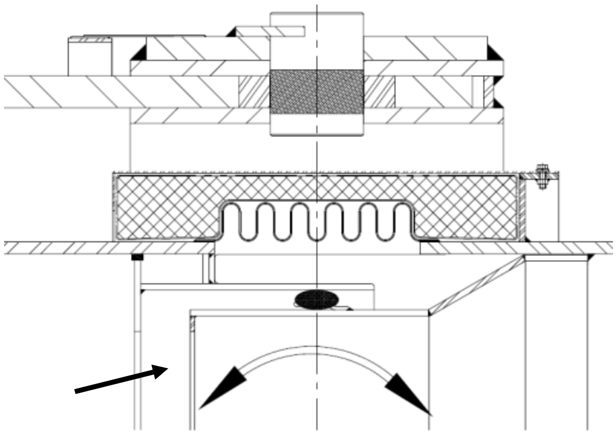


FIG. 14 – SLEEVE SEAL CENTERED

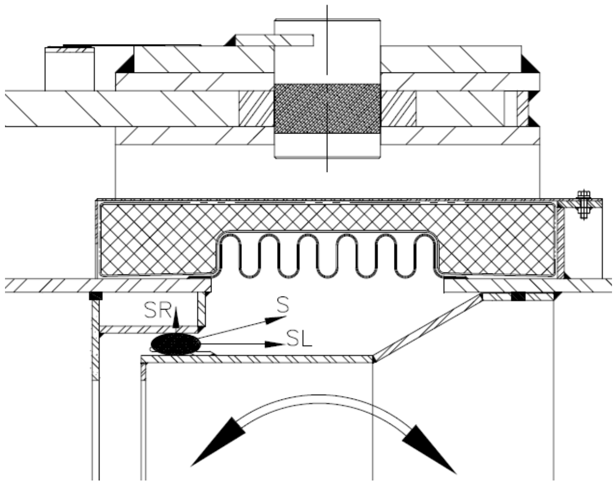


FIG. 15 – SLEEVE SEAL NOT CENTERED

ANALYSIS OF LARGE EXPANSION JOINTS TEST RESULTS

Pressure and movement tests were performed by the authors [3] with 13 large expansion joints. A summary of the test results are shown in Fig. 18 to 23. The actual moment values (black lines) are larger than the values calculated by the EJMA equations (green lines). Figure 16 shows a picture of a joint being tested and Fig. 17 shows a schematic drawing of the test device.

The force on hinges is affected by the weight of the test device and its value was excluded from calculations. The actual values can be as high as 3 times when compared with the EJMA equations results. Angles in the 1 to 2 degrees range increase the error. This difference can result large errors in the pipe flexibility analysis.

To minimize this error, at the piping design time, the actual values were compared with the theoretical values in order to define a correction factor (C_R) to account for the uncertainties.

We have seen that is possible to calculate moment due to bellows spring rate (Mb), media pressure (Mlpf) and pin friction (Mpf), so the eq. (1) in theory can be calculated and becomes as eq. (12).

$$Mavt = Mb + Mlpf + Mpf \qquad (12)$$

The value of C_R can be used as a correction factor to adjust the Eq. (12) in order to have values closer to the actual expanded joint.

FIG. 16 – MOVEMENT TEST

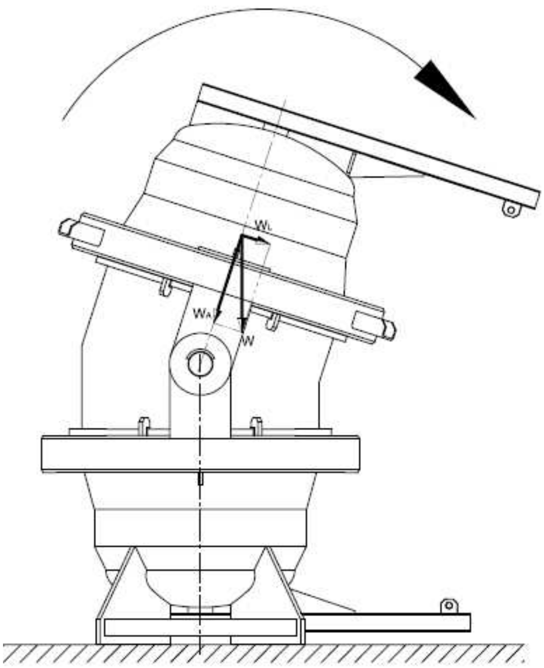


FIG. 17 – MOVEMENT TEST

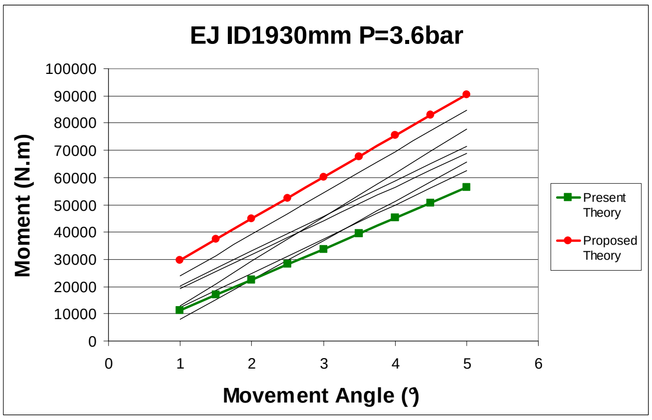


FIG. 18 – TEST RESULT 1 VS. THEORY

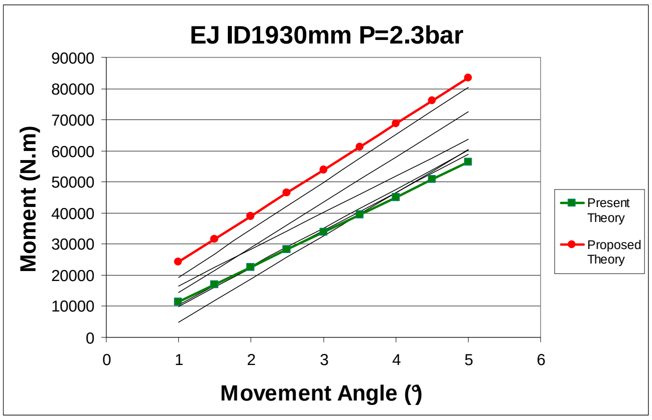


FIG. 19 – TEST RESULT 2 VS. THEORY

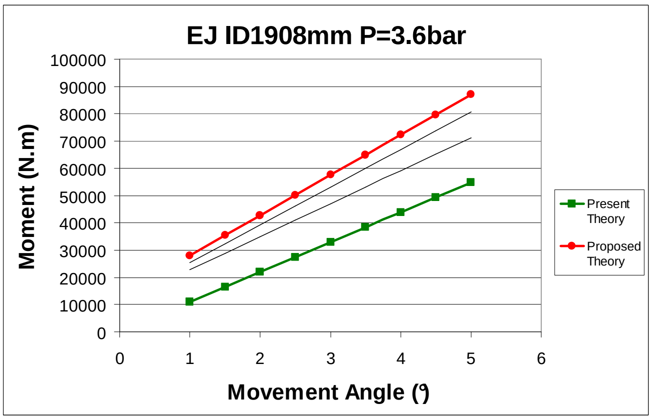


FIG. 20 – TEST RESULT 3 VS. THEORY

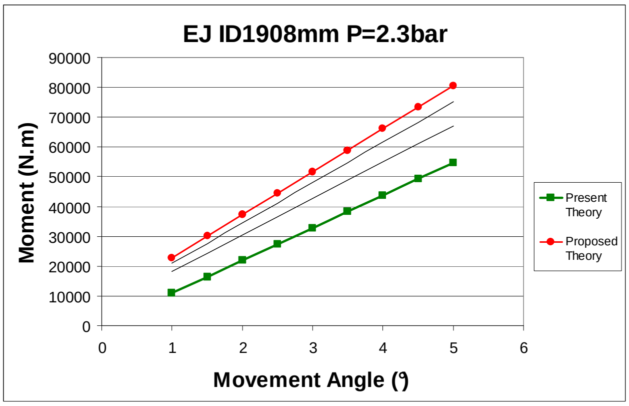


FIG. 21 – TEST RESULT 4 VS. THEORY

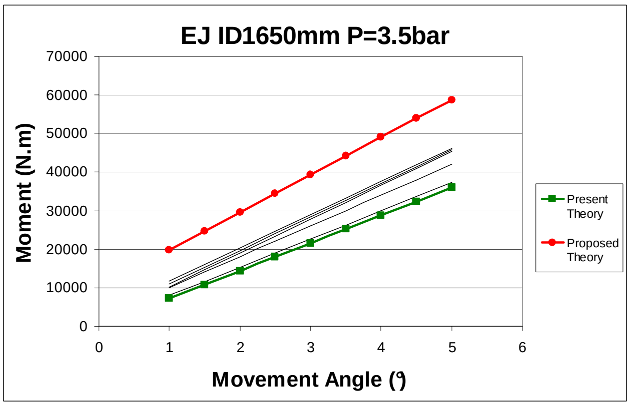


FIG. 22 – TEST RESULT 5 VS. THEORY

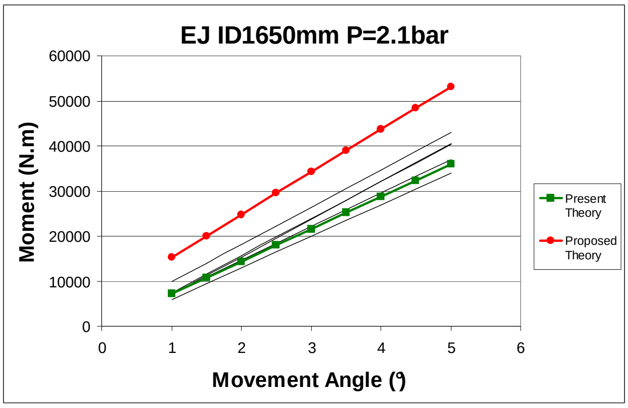


FIG. 23 – TEST RESULT 6 VS. THEORY

Thus, the ratio of actual value and Mavt is defined as moment Ratio (M_R) shown in Eq. (13).

$$M_R = Ma / Mavt \quad (13)$$

The moment ratios calculated using Eq.(13) are shown in Tables 3 and 4, for test pressures of 2.2 bar and 3.5 bar respectively. These values were feed into the Statgraphics Centurion software [5] to determine the best probability distribution for the data.

TABLE 3 - M_R IN TEST PRESSURE 2.2bar

	Angle (degree)								
Run	**1**	**1,5**	**2**	**2,5**	**3**	**3,5**	**4**	**4,5**	**5**
1	1,00	1,07	1,12	1,15	1,17	1,18	1,20	1,21	1,21
2	0,54	0,66	0,74	0,79	0,82	0,85	0,87	0,89	0,91
3	0,52	0,64	0,72	0,77	0,81	0,83	0,86	0,87	0,89
4	-	-	0,61	0,70	0,76	0,81	0,85	0,89	0,91
5	0,75	0,86	0,93	0,98	1,02	1,04	1,06	1,08	1,09
6	0,86	0,89	0,91	0,93	0,94	0,95	0,95	0,96	0,96
7	1,01	1,02	1,03	1,04	1,04	1,04	1,05	1,05	1,05
8	1,15	1,16	1,16	1,17	1,17	1,17	1,17	1,17	1,17
9	0,81	0,88	0,92	0,95	0,97	0,99	1,00	1,01	1,02
10	0,49	0,59	0,66	0,70	0,73	0,76	0,78	0,79	0,80
11	0,59	0,69	0,75	0,79	0,81	0,84	0,85	0,87	0,88
12	0,61	0,73	0,80	0,84	0,88	0,90	0,92	0,94	0,95
13	0,58	0,70	0,78	0,83	0,87	0,90	0,92	0,94	0,96

TABLE 4 - M_R IN TEST PRESSURE 3.5bar

	Angle (degree)								
Run	**1**	**1,5**	**2**	**2,5**	**3**	**3,5**	**4**	**4,5**	**5**
1	1,01	1,06	1,10	1,12	1,14	1,15	1,16	1,17	1,18
2	0,82	0,86	0,89	0,91	0,92	0,94	0,94	0,95	0,96
3	0,52	0,63	0,70	0,75	0,78	0,81	0,84	0,85	0,87
4	-	0,51	0,63	0,71	0,77	0,82	0,86	0,89	0,91
5	0,55	0,71	0,82	0,90	0,95	1,00	1,03	1,06	1,08
6	0,86	0,90	0,93	0,95	0,96	0,97	0,98	0,99	1,00
7	1,02	1,02	1,03	1,03	1,03	1,03	1,03	1,03	1,03
8	1,14	1,15	1,15	1,16	1,16	1,16	1,16	1,16	1,17
9	0,75	0,82	0,87	0,90	0,93	0,95	0,96	0,98	0,99
10	0,51	0,59	0,65	0,69	0,73	0,75	0,77	0,79	0,80
11	0,64	0,72	0,77	0,81	0,83	0,86	0,87	0,89	0,90
12	0,70	0,78	0,84	0,88	0,91	0,93	0,95	0,97	0,98
13	0,65	0,75	0,81	0,86	0,89	0,92	0,94	0,96	0,97

According to box-and-whisker plot for each pressure test, shown in Fig. 24, the variability is similar within each sample. The mean comparison shows the same behavior of variability, as shown in Fig. 25. It means that pressure does not have influence on $M_{R;}$ consequently all data can be used to determine the probability distribution.

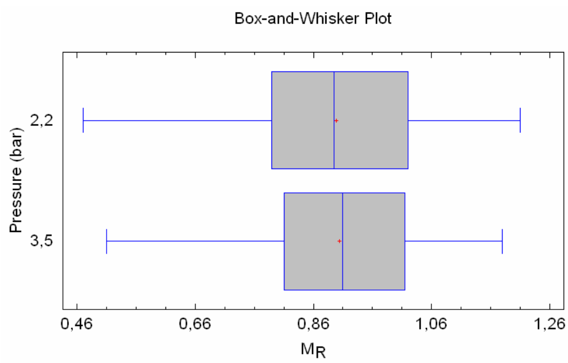


FIG. 24 – BOX AND WHISKER PLOT

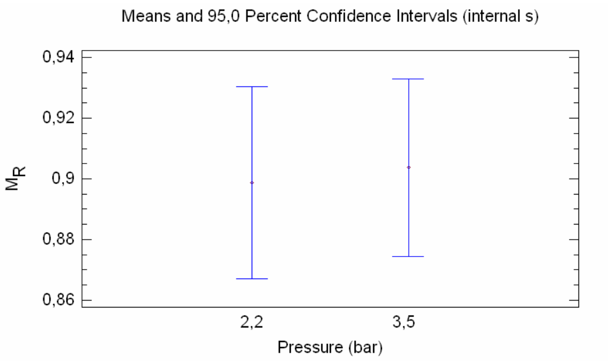


FIG. 25 – MEANS CONFIDENCE INTERVALS

A distribution fitting procedure was performed to find a probability that provides a suitable model for the experimental data in order to determine M_R tolerance limits. From this procedure, experimental data of M_R can be adequately modeled by Weibull, as shown in Fig. 26, which compare frequency histogram to the estimated probability density according Weibull distribution.

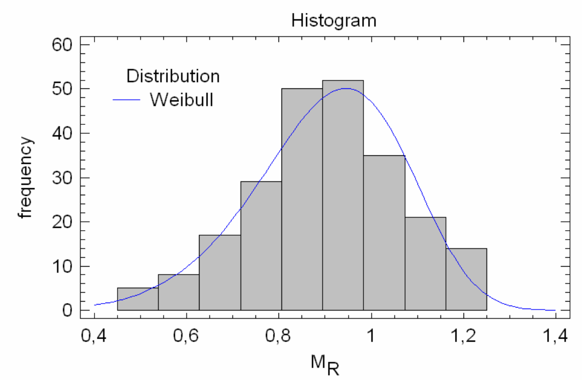


FIG. 26 - M_R HISTOGRAM VS. WEIBULL DISTRIBUTION

Table 5 shows the calculated M_R and its respective probability obtained from the fitted Weibull distribution.

TABLE 5 - M_R VALUES PROBABILITIES

M_R	Probability, %
1.15	95.0
1.19	97.5
1.23	99.0
1.26	99,5
1.31	99.9

The values shown in Table 5 can be used as a correction factor (C_R). The selection of the M_R value, used as C_R, will depend upon how critical the application is. Thus the expansion joint estimated moment can be expressed as in Eq. (14) below.

$$Mejt=Mavt^{*}\ C_R \qquad (14)$$

For example, the respective M_R value of a probability of 99.5% is 1.26. Using this number as C_R, the Mejt calculated from Eq. (14) is plotted, in red lines, against the joint actual test results, as shown in Fig. 18 to 23.

CONCLUSION

Based upon test values it is possible to improve the EJMA reaction moment, represented by Eq. (2), which is considering just the bellows spring effect, by adding the friction and pressure forces effects with a correction factor. So, it is suggested to use Eq. (15), to calculate the angular moment for gimbal and hinged expansion joints, due to angular rotation.

$$Mejt=(Mb + Mlpf + Mpf)^{*}\ C_R \qquad (15)$$

Using this equation at the design time will prevent an underestimation of the expansion joints reaction loads, which are critical in rotating equipment like turbines and turbo-expanders.

Additional studies are necessary to evaluate the C_R variation according to the pin/sleeve different materials and environment exposure.

REFERENCES

[1] ASME B31.3 – 2006 Process Piping, chapter II and appendix A, ASME Code for Pressure Piping, B31, New York, NY, USA.

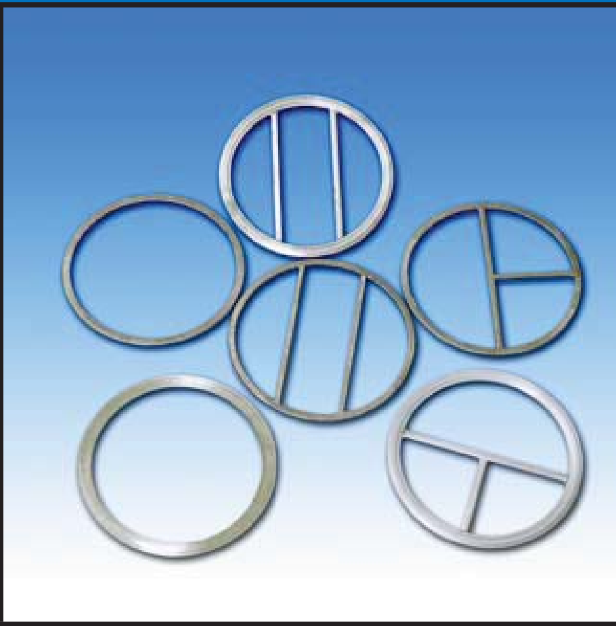
[2] NEMA SM23 – 1991(R1997, R2002), Steam Turbines for Mechanical Drive Service, section 8.4, Steam Piping Systems, NEMA Standards, Rosslyn, VA, USA .

[3] Veiga J.C., Medeiros J., Veiga J.L.B.C., PVP2009-77828, "Analysis of FCC Expansion Joints Movement Test", 2009 ASME Pressure Vessel and Piping Conference , Prague, Czech Republic.

[4] EJMA – 2008, 9th edition, section 4, Standards of the Expansion Joint Manufacturers Association, Inc., Terrytown, NY, USA.

[5] Statgraphics Centurion XV - 2006, version 15.2.00 – Edition Profissional, StatPoint Technologies, Inc., Warrenton, VA, USA.

Metallic Gaskets



TEADIT®

Utilized for Extreme Conditions

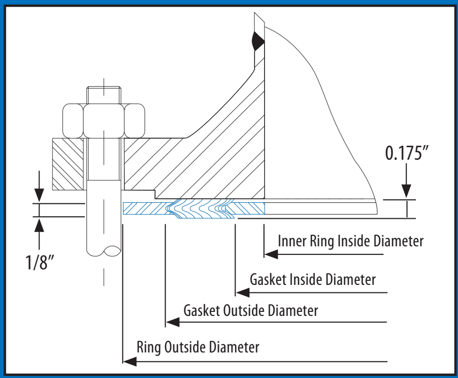
Gaskets per ASME B16.20 have the winding with an external guide on the centering ring. This solid metallic ring centralizes the gasket on the flange surface, limits the compression and reinforces the gasket.

Several countries developed dimensional standards for this style of gasket. On March 30th, 1993 the American Society of Mechanical Engineers (ASME) and the American National Standards Institute (ANSI) issued a new edition of the ASME B16.20. This edition includes spiral wound gaskets specifications and dimensions previously covered by the API 601 which will no longer be published by the American Petroleum Institute (API). ASME B16.20 was most recently updated in 2007, adding new inner ring requirements and metrication of units.

The ASME B16.20 (API 601) standard is one of the most used, worldwide. Gaskets manufactured following the recommendations of the ASME B16.20 are produced in large quantities. They are low priced compared with other gaskets of equivalent performance. When specifying a metallic gasket they should be the first design option. The use of another type of metal gasket should only be recommended if required by the specific application conditions.

The ASME B16.20 gaskets were designed for use in ASME B16.5 flanges or ASME 16.47 (API 605 and MSS SP-44). Therefore, when ordering a spiral wound gasket for these flanges, dimensions are not necessary. It is enough to inform materials for the metallic strip and filler, which should be compatible with the fluid to be sealed, the outer and inner ring metal, the nominal diameter and the pressure class of the flange. In charts below, are the dimensions for ASME B16.20 gaskets. The outerrings are color coded on the outer with a solid color to indicate the metallic winding strip and stripes indicating the filler.

Metalic Strip		Filler Color Coding	
Material	Color	Material	Color
AISI 304	Yellow		
AISI 316	Green	PTFE	White
AISI 347	Blue	Flexible Graphite	Gray
AISI 321	Turquoise	Mica-Graphite	Pink
Monel	Orange		
Nickel	Red		
Carbon Steel	Silver		
Inconel	Gold		

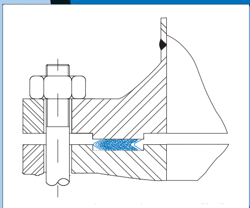


Nominal	Gasket Outside Diameter			Gasket Inside Diameter							Ring Outside Diameter							Inner Ring Inside Diameter						
	150 300 400 600		900 1500 2500	150	300	400	600	900	1500	2500	150	300	400	600	900	1500	2500	150	300	400	600	900	1500	2500
1/2	1.25			0.75	0.75		0.75		0.75	0.75	1.88	2.13		2.13		2.50	2.75	0.56	0.56		0.56		0.56	0.56
3/4	1.56			1.00	1.00		1.00	use	1.00	1.00	2.25	2.63		2.63	use	2.75	3.00	0.81	0.81		0.81	use	0.81	0.81
1	1.88			1.25	1.25	use	1.25		1.25	1.25	2.63	2.88	use	2.88		3.13	3.38	1.06	1.06	use	1.06		1.06	1.06
1 1/4	2.38			1.88	1.88		1.88	1500	1.56	1.56	3.00	3.25		3.25	1500	3.50	4.13	1.50	1.50		1.50	1500	1.31	1.31
1 1/2	2.75			2.13	2.13	600	2.13	psi	1.88	1.88	3.38	3.75	600	3.75	psi	3.88	4.63	1.75	1.75	600	1.75	psi	1.63	1.63
2	3.38			2.75	2.75	psi	2.75		2.31	2.31	4.13	4.38	psi	4.38		5.63	5.75	2.19	2.19	psi	2.19		2.06	2.06
2 1/2	3.88			3.25	3.25		3.25		2.75	2.75	4.88	5.13		5.13		6.50	6.63	2.62	2.62		2.62		2.50	2.50
3	4.75			4.00	4.00		4.00	3.75	3.63	3.63	5.38	5.88		5.88	6.63	6.88	7.75	3.19	3.19		3.19	3.10	3.10	3.10
4	5.88			5.00	5.00	4.75	4.75	4.75	4.63	4.63	6.88	7.13	7.00	7.63	8.13	8.25	9.25	4.19	4.19	4.04	4.04	4.04	3.85	3.85
5	7.00			6.13	6.13	5.81	5.81	5.81	5.63	5.63	7.75	8.50	8.38	9.50	9.75	10.00	11.00	5.19	5.19	5.05	5.05	5.05	4.90	4.90
6	8.25			7.19	7.19	6.88	6.88	6.88	6.75	6.75	8.75	9.88	9.75	10.50	11.38	11.13	12.50	6.19	6.19	6.10	6.10	6.10	5.80	5.80
8	10.38		10.13	9.19	9.19	8.88	8.88	8.75	8.50	8.50	11.00	12.13	12.00	12.63	14.13	13.88	15.25	8.50	8.50	8.10	8.10	7.75	7.75	7.75
10	12.50		12.25	11.31	11.31	10.81	10.81	10.88	10.50	10.63	13.38	14.25	14.13	15.75	17.13	17.13	18.75	10.56	10.56	10.05	10.05	9.69	9.69	9.69
12	14.75		14.50	13.38	13.38	12.88	12.88	12.75	12.75	12.50	16.13	16.63	16.50	18.00	19.63	20.50	21.63	12.50	12.50	12.10	12.10	11.50	11.50	11.50
14	16.00		15.75	14.63	14.63	14.25	14.25	14.00	14.25		17.75	19.13	19.00	19.38	20.50	22.75		13.75	13.75	13.50	13.50	12.63	12.63	
16	18.25		18.00	16.63	16.63	16.25	16.25	16.25	16.00		20.25	21.25	21.13	22.25	22.63	25.25		15.75	15.75	15.35	15.35	14.75	14.50	
18	20.75		20.50	18.69	18.69	18.50	18.50	18.25	18.25		21.63	23.50	23.38	24.13	25.13	27.75		17.69	17.69	17.25	17.25	16.75	16.75	
20	22.75		22.50	20.69	20.69	20.50	20.50	20.50	20.25		23.88	25.75	25.50	26.88	27.50	29.75		19.69	19.69	19.25	19.25	19.00	18.75	
24	27.00		26.75	24.75	24.75	24.75	24.75	24.75	24.25		28.25	30.50	30.25	31.13	33.00	35.50		23.75	23.75	23.25	23.25	23.25	22.75	

Dimensions in inches.

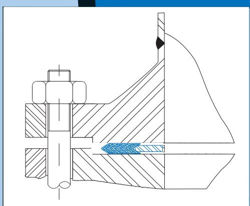
GASKETS

Spiral wound gaskets
Types and Profiles



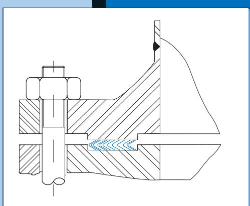
911

This is the simplest style of spiral wound gasket, consisting of a circular winding without guide or inner rings. Spiral wound gaskets Style 911 are mainly used in tongue and groove or male and female flanges. They are also used in equipment with space and weight limitations. Special flange machining may be necessary (contact Teadit Technical Dept).



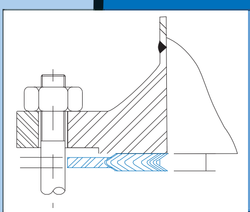
911M

A style 911-M gasket is a sealing winding with an inner ring. The purpose of this ring is to fill out the space between the flanges, avoiding turbulence in the flow of the fluid or as a protection against corrosion or erosion. It is also used as a compression limit.



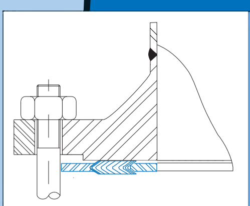
911T

Double jacketed bars are welded into the winding. They are used in shell and tube heat exchangers with several passes. The bars are manufactured in the same material and are welded to the winding. The thickness of the bar is normally a little less than the winding to reduce the seating force of the gasket. Style 911-T has a better sealability than conventional heat exchanger double-jacketed gaskets. However a specially machined groove with an appropriate compression stop is needed for 911-T.



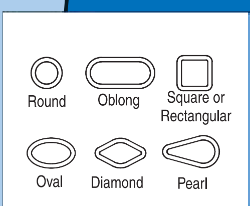
913

The construction of this gasket is circular metal windings with an outer guide ring. The sealing element is made of the specified metal and soft sealing material. The standard pipe size gaskets are made to the ASME B16.20 (see also style 913M). These gaskets are used in a very wide variety of applications.



913M

The 913M is the standard spiral wound gasket with an inner ring. The purpose of this ring is to fill out the space between the flanges, avoiding turbulence in the flow of the fluid or as a protection against corrosion or erosion. It is also used as a compression limit. Gaskets with PTFE filler have a tendency to inward buckle thus the use of an inner ring is required by ASME B16.20. Inner rings are also required with ASME standard spiral wound gaskets with flexible graphite fillers unless the purchaser specifies otherwise. Some sizes and pressure class require inner rings regardless of filler material.



914

Style 914 spiral wound gaskets are windings in non-circular forms like oval, rectangular and square with rounded corners, diamond, oblong or pear shaped. Style 914 gaskets are used in boiler handholes and manholes, equipment, engine head-gaskets and exhaust systems. Inner rings should also be used for many of these applications.

HEAT EXCHANGERS

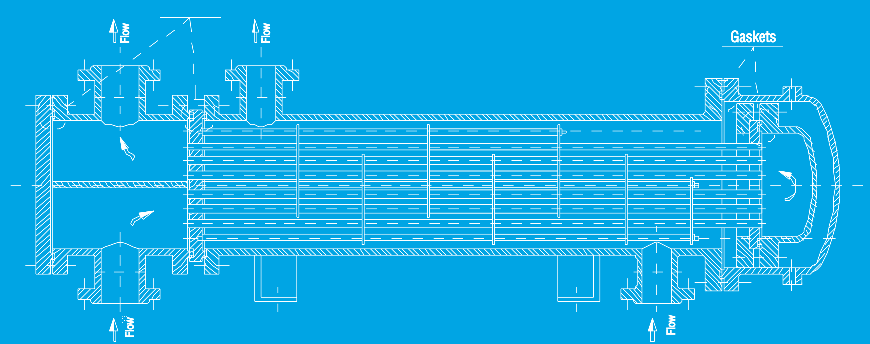
Gaskets for Heat Exchangers

There are several types of Heat Exchangers, some of them so incorporated in our life style that we hardly notice them, like car radiators or home heating units. All of them transfer heat from one fluid to the other, cooling (radiator) or heating (home heating), according to the process needs.

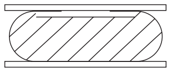
In industry, there are several types of Heat Exchangers, some have specific names like radiators, boilers, chillers, etc. However, when we refer to a Heat Exchanger generically, we may be referring to any of them. However, the term Heat Exchanger, in most process industries is referred to as the "Shell and Tube Heat Exchanger". As the name implies, it is equipment that has a "shell" and a bundle of " tubes". One of the fluids flows inside the shell and outside the tubes and the

The great majority of the Shell and Tube Heat Exchangers are manufactured following the recommendations of the "Standards of the Tubular Exchanger Manufactures Association TEMA", which sets the guidelines for design, construction, testing, installation and maintenance of this equipment.

Design

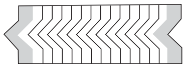


Style 927 Metalbest



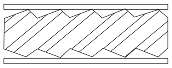
Double Jacket with Graphite Facing

Style 911 Metalflex



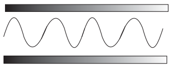
Spiral Wound

Style 942 Camprofile



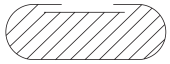
Solid Metal with specified facing material

Style 905 Metalbest



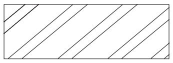
Corrugated metal core graphite facing material

Style 923

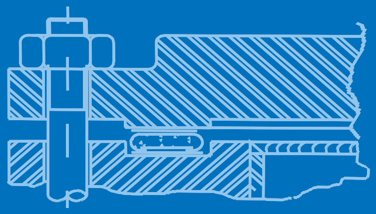


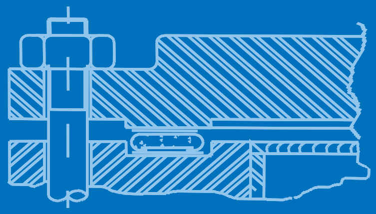
Double Jacket

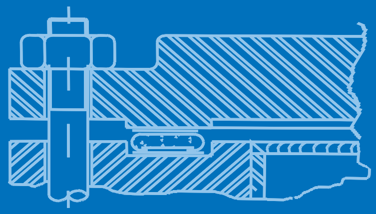
Style 940



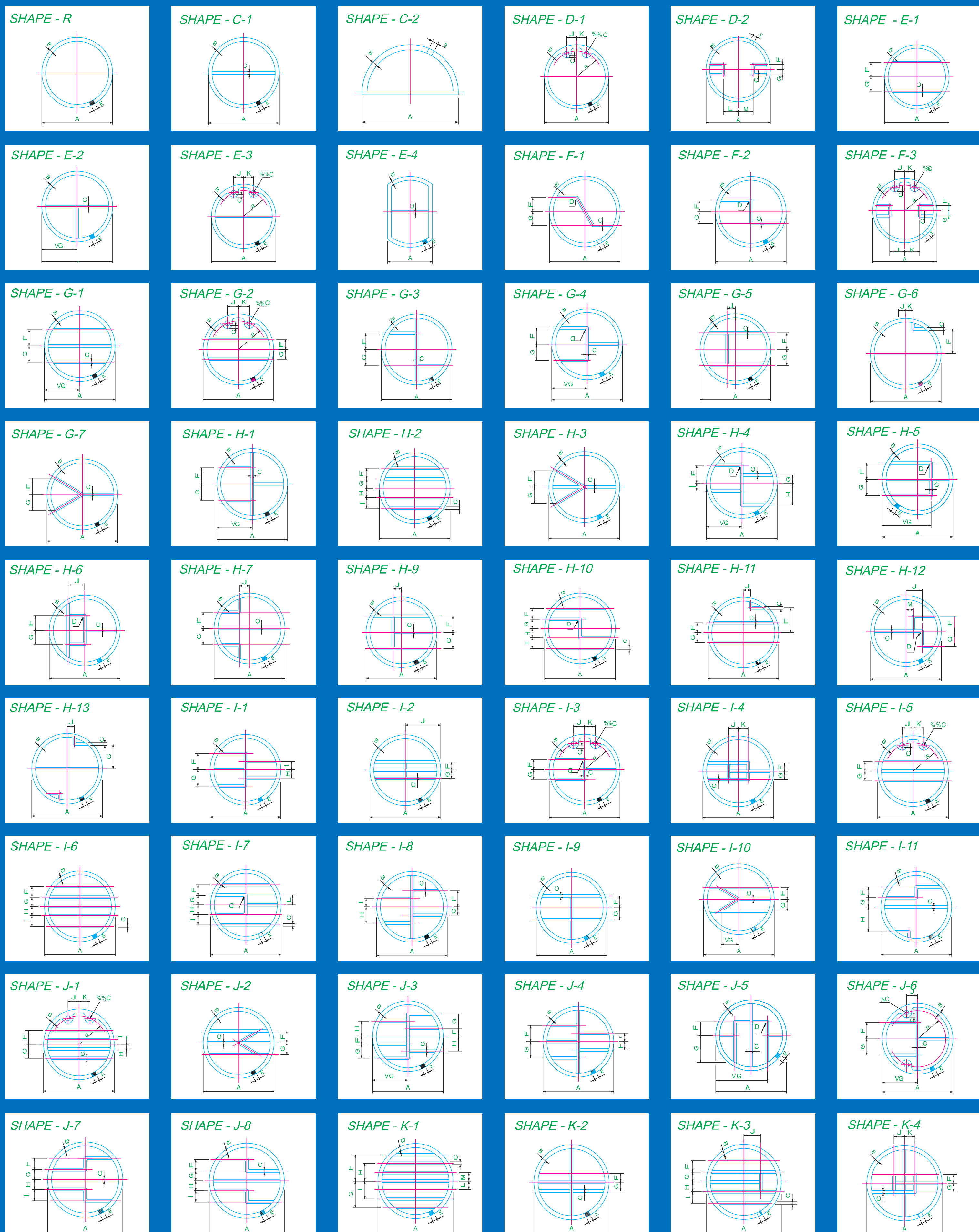
Solid Metal







Gaskets for Heat Exchangers



905 Metalbest

PROFILE OF OUR NEW 905 METALBEST

Corrugated metal gaskets with Flexible Graphite facings, style 905 Metalbest, have gained popularity in the marketplace in Class 150 and 300 ASME B16.5 flanges due to their ability to seal at low bolt loads. Style 905 Matalbest gaskets have been fire tested and approved according the requirements of the PVRC Fire Tightness Test (FITT) procedure and have been sealability tested per ROTT procedure.

One of the most frequent uses of Style 905 Metalbest Gaskets are in shell and Tube Heat Exchangers, due to their ability to avoid mechanical shearing problems associated other gasket types in heavy thermal cycling applications. The standard core material is 316L Stainless Steel and the covering layer is Flexible Graphite. Other alloys are available upon request. The gasket tickness before seating is approximately 0.085 in (2.2 mm), for heat exchanger applications, and the other dimensions and shapes are per application.

Technical Specification

Graphite Purity	99.5%
Core Material	SS316
Maximum Temperature	850ºF (450ºC)
Minimun Temperature	-328ºF (-200ºC)
Maximum pressure	1450psi (100bar)Pasad

Excellent Gas Tightness Results

Tested and passed FITT (Fire Tightness Test) at CETIM (France)

ROTT Results Available upon Request

The standard material for the metal core is 316L Stainless Steel. Other alloys are available upon request.

Set/2010

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www.teadit.com

905 MetalBest, 905-C (Corrugated Metal/Graphite faced)

Style **905 Metalbest** is a corrugated gasket style 900 metal core with flexible graphite facings (see figure below). It combines the sealing properties of the Flexible Graphite with the extrusion resistance of the corrugated metal core. It is designed to maintain a positive seal through thermal cycling and shock load conditions. These gaskets have passed an industry fire test, a relative indicator of the gasket's ability to resist fire conditions.

STYLE 905 METALBEST GASKETS FOR ASME B16.5 FLANGES

Style 905 Metalbest gaskets meet the Fugitive Emissions requirements, have been fire tested and approved according the requirements of the PVRC Fire Tightness Test (FITT) procedure and have been sealability tested per ROTT procedure.

The standard material for the metal core is 316L Stainless Steel. Other alloys are available upon request.

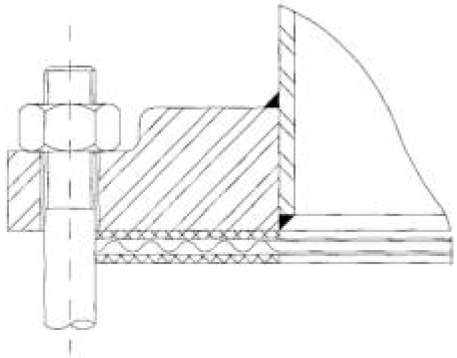
STYLE 905 METALBEST GASKETS FOR HEAT EXCHANGERS

One of the most frequent uses of Style 905 Metalbest Gaskets are in Shell and Tube Heat Exchangers, due to their ability of to avoid mechanical shearing problems associated other gasket types in heavy thermal cycling applications. Teadit style **905-C** is a 905 Metalbest made specifically to a major refiner's specifications, for this purpose. The standard core material is 316L Stainless Steel and the covering layer is Flexible Graphite. Other alloys are available upon request. The gasket thickness before seating is 0.085 in (2.2 mm) and the other dimensions and shapes are per application.

For customers requiring expanded PTFE facing material instead of graphite, style **905-ePTFE** is available in thicknesses as required.

905 Metalbest PVRC Gasket Constants:

- Gb: 90 psi
- a: 0.547
- Gs: 0.388 psi



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905-ePTFE Product Specification

Style **905-ePTFE** is a corrugated gasket style 900 metal core with expanded PTFE facings (see figure below). It combines the sealing properties of the PTFE with the extrusion resistance of the corrugated metal core. It is designed to maintain a positive seal through cycling for many chemical applications.

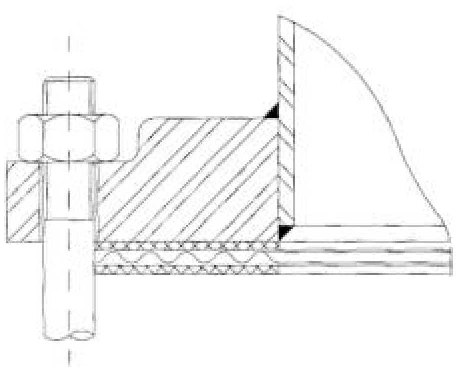
STYLE 905-ePTFE GASKETS FOR ASME B16.5 FLANGES

The gasket type can be made to ring or full faced dimesions.The typical material for the metal core is 316L Stainless Steel. Other alloys are available upon request.

STYLE 905-ePTFE GASKETS FOR HEAT EXCHANGERS

One of the uses of Style 905-ePTFE gaskets are in shell and tube heat exchangers,
The gasket thickness before seating is 0.085 in (2.2 mm) unless otherwise specified, and the other dimensions and shapes are per application.

Temperature limit: 500 F (260 C)
Pressure Limit: Generally used for 150# and 300# class flange ratings.



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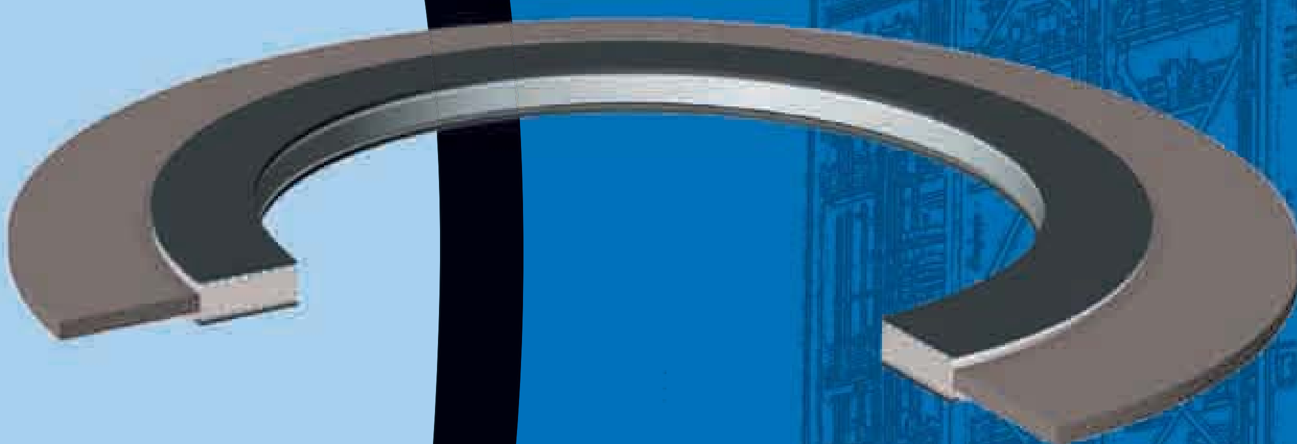
CAMPROFILE GASKETS



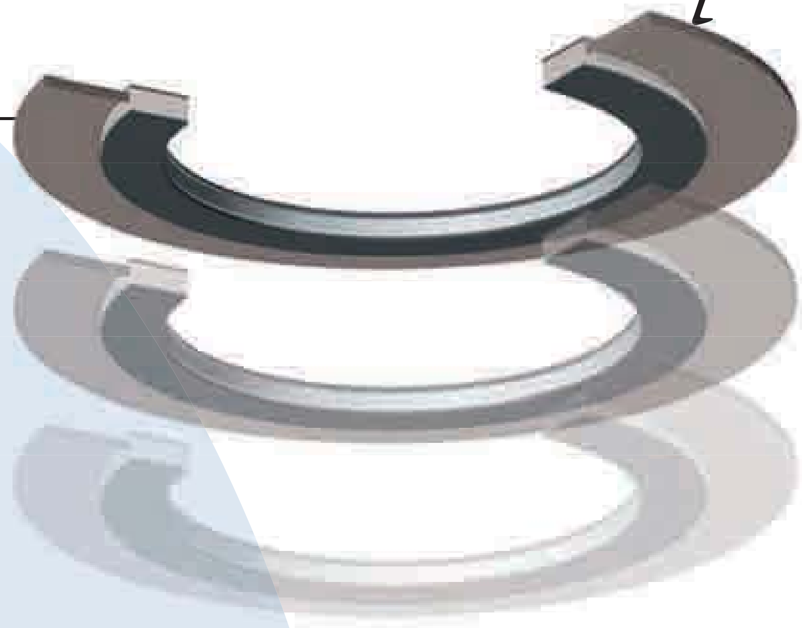
TEADIT®

Introduction

Teadit® Camprofile gaskets offer outstanding flexibility and recovery, assuring seal integrity under pressure and temperature fluctuations, flange rotation, bolt stress relaxation and creep.

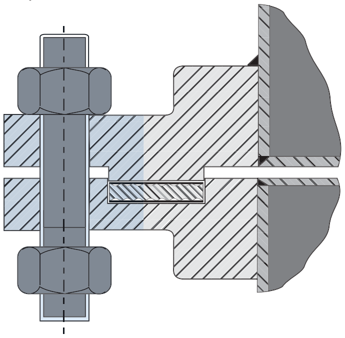
Teadit® Camprofile gaskets are used by the chemical and petrochemical industry, as well as in power stations and refineries, on both standard pipework and special applications, e.g. shell and tube heat exchangers, etc. Camprofile gaskets are constructed from a precision serrated metallic core with soft facing materials - flexible graphite or expanded PTFE - bonded to either side.

Depending on the kind of metal used, TEADIT® Camprofile gaskets can be used for all media from pH 0 to 14.



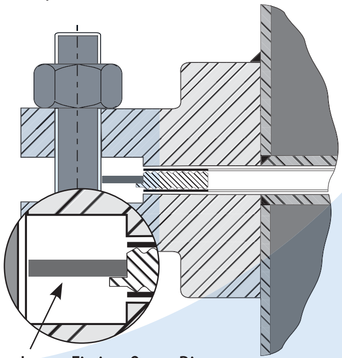
Camprofiles Gaskets Styles

Style 942



Designed to be used in most male/ female and tongue and groove flanges in heat exchangers.

Style 946



Designed to be used in raised faced flanges like ASME B16.5 or ASME B16.47.
The loose fitting outer ring allow the thermal expansion of the serrated core.

Facing Material Limits*

Material	Temperature - F (°C) min	Temperature - F (°C) max	Pressure psi (bar)
Graflex®	-400 (-240)	850 (455)	5 000 (345)
Expanded PTFE	-400 (-240)	500 (260)	1 500 (100)

*The Pressure and Temperature range is related to the range of each component. The service range is the governing limit for the metal and covering combination selected. For example a Teadit 942 camprofile with a carbon steel core and Graflex® covering has the following limits:

Maximum pressure:
5,000 psi (345 bar)

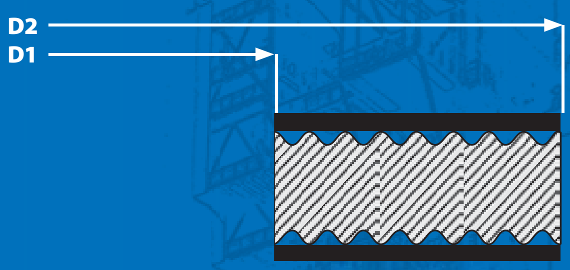
Temperature range:
-40 F to 850 F (-40°C to 455°C)

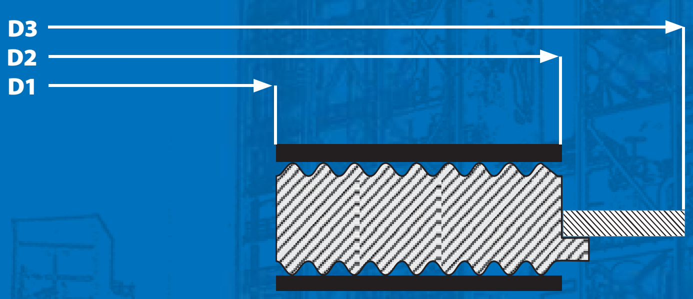
Teadit Camprofile gaskets have the following characteristics:

- Operating pressure up to 5,000 psi (250 bar).
- Maximum temperature up to 850 F (455°C).
- Wide range of service.
- Less susceptible to flange imperfections than conventional flat metal gaskets. The thin Flexible Graphite or Expanded PTFE core fills up the flange irregularities and prevents the serrated finish from damaging the flanges.

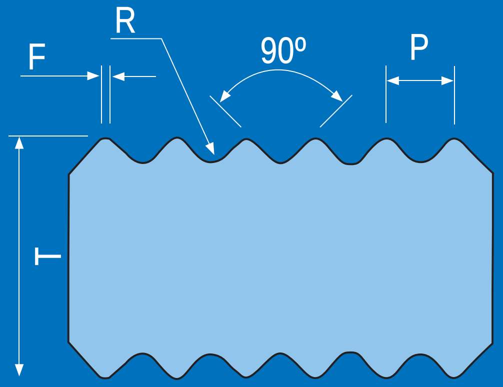
Dimensions

NPS	Serrated Metal Ring (inch)		(D3) Centering Ring Outside Diameter (inch)						
	(D1) Inside Diameter	(D2) Outside Diameter	Pressure Class						
			150	300	400	600	900	1500	2500
1/2	0.91	1.31	1.88	2.13	2.13	2.13	2.50	2.50	2.75
3/4	1.13	1.56	2.25	2.63	2.63	2.63	2.75	2.75	3.00
1	1.44	1.87	2.63	2.88	2.88	2.88	3.13	3.13	3.38
1 1/4	1.75	2.37	3.00	3.25	3.25	3.25	3.50	3.50	4.13
1 1/2	2.06	2.75	3.38	3.75	3.75	3.75	3.88	3.88	4.63
2	2.75	3.50	4.13	4.38	4.38	4.38	5.63	5.63	5.75
2 1/2	3.25	4.00	4.88	5.13	5.13	5.13	6.50	6.50	6.63
3	3.87	4.88	5.38	5.88	5.88	5.88	6.63	6.88	7.75
3 1/2	4.37	5.38	6.38	6.50	6.38	6.38	7.50	7.38	-----
4	4.87	6.06	6.88	7.13	7.00	7.63	8.13	8.25	9.25
5	5.94	7.19	7.75	8.50	8.38	9.50	9.75	10.00	11.00
6	7.00	8.37	8.75	9.88	9.75	10.50	11.38	11.13	12.50
8	9.00	10.50	11.00	12.13	12.00	12.63	14.13	13.88	15.25
10	11.13	12.63	13.38	14.25	14.13	15.75	17.13	17.13	18.75
12	13.37	14.87	16.13	16.63	16.50	18.00	19.63	20.50	21.63
14	14.63	16.13	17.75	19.13	19.00	19.38	20.50	22.75	-----
16	16.63	18.38	20.25	21.25	21.13	22.25	22.63	25.25	-----
18	18.87	20.87	21.63	23.50	23.38	24.13	25.13	27.75	-----
20	20.87	22.87	23.88	25.75	25.50	26.88	27.50	29.75	-----
24	24.88	26.87	28.25	30.50	30.25	31.13	33.00	35.50	-----





Tolerances



P: 0.04 inch	
T: 0.117 to 0.131 inch for Style 942	
T: 0.110 to 0.157 inch for Style 946	
Serrated Metal Ring Inside Diameter (D1) NPS ½ to NPS 8: ± 0.03 inch NPS 10 to NPS 24: ± 0.06 inch	
Serrated Metal Ring Outside Diameter (D2) NPS ½ to NPS 8: ± 0.03 inch NPS 10 to NPS 24: ± 0.06 inch	
Centering Ring Outside Diameter (D3) for all sizes: ± 0.03 inch	
Thickness Covering Layer: 0.020 inch	
Typical Thickness for Loose Fit Centering Ring: 0.03 to 0.06 inch	

Notes:

1. The groove angle shall be approximately 90 degrees.
2. F and R have a function of the pitch, depth, and angle of groove.

TEADIT®

Metalflex Styles - 911, 911M, 911T, 914

DESCRIPTION
Teadit Metalflex® 911 Spiral-wound gaskets are made of a preformed metallic strip and a soft filler material (PTFE or graphite), wound together under pressure. The metal strip holds the filler, resulting in excellent mechanical resistance, resilience and recovery.

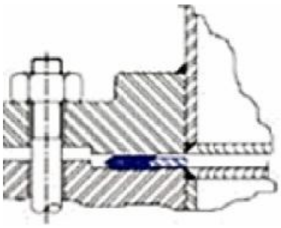
CONSTRUCTION
This spiral wound is constructed with a metallic winding and a filler element. The winding is manufactured from metal in a complicated form of a spiral, in assembly with a filler material. The metallic Winding, of special profile, provides excellent resistance, compensating the changes in operational conditions such as: variations of pressure and temperature, vibrations, thermal shocks, etc. The filler materials fill the irregularities of the flanges.

APPLICATION / SERVICE
For applications with high temperature variations (thermal cycling), and/or pressure variations, and/or flange rotation problems etc., gaskets with adequate residual stress (stress retention), flexibility and recovery are needed. TEADIT spiral-wound gaskets have been designed to meet these demanding requirements. The flanges should be designed to provide compression limitation to the gasket's optimum compressed thickness (Please contact Teadit Technical Department for details).

MATERIAL PROPERTIES	
Filler Material	**Max. Temperature**
Mica Graphite	232°C (450 °F)
Flexible Graphite	450°C (842 °F)
PTFE	260°C (500 °F)

General Note: Pressure Construction may be specified from 150 to 2500 class.

Teadit Metalflex® 911-M

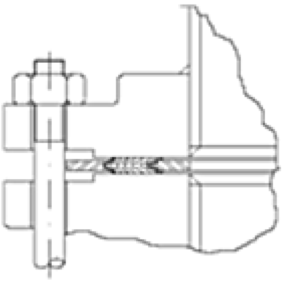


DESCRIPTION
Developed basically for the same application as the Metalflex® 911, but specifically for elevated vacuum, pressures and temperatures, this Metalflex® 911-M is a modified 911 with an internal ring that fills the space between the flanges, avoiding turbulence in the flow of the fluid or as a protection against corrosion or erosion. It is also used as a compression limit.

Second, gaskets with PTFE and flexible graphite filler have a tendency to inward buckle thus the use of an inner ring is recommended.

CONSTRUCTION, APPLICATION/SERVICE, MATERIAL PROPERTIES
See **Teadit Metalflex®911**

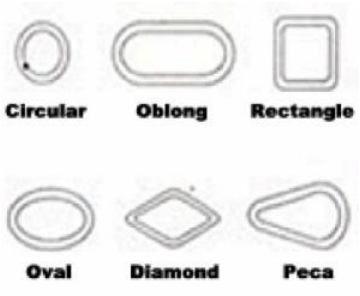
Teadit Metalflex® 911-T



DESCRIPTION
Double Jacketed bars are welded into the winding of a Metalflex® 911 developed for shell and tube heat exchangers with several passes.The bars are manufactured in the same material and are plasma or spot welded to the winding. When used in a properly designed groove, Metalflex® 911-T generally provide good sealability. In many other cases the addition of solid metal inner and outer rings (913MT) are recommended.

CONSTRUCTION, APPLICATION/SERVICE, MATERIAL PROPERTIES
See **Teadit Metalflex®911**

Teadit Metalflex® 914



DESCRIPTION
Style Metalflex® 914 spiral wound gaskets are windings in non-circular forms like oval, rectangular and square with rounded corners, diamond, oblong or pear shaped.

CONSTRUCTION, MATERIAL PROPERTIES
See **Teadit Metalflex®911**

APPLICATION/SERVICE
Teadit Metalflex® 914 spiral wound gaskets are used in boiler handholes and manholes, equipment, engine head-gaskets and exhaust systems.

Note: The addition of solid metal inner rings is recommended for some applications to avoid crushing or pinching on the gasket ID.

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Spiral Wound Gasket - 913, 913M, 913-CMP, 913-RJ, Teadit Metalflex Styles

DESCRIPTION
Teadit Metalflex® 913 Spiral-wound gaskets are made of a preformed metallic strip and a soft filler material wound together under pressure, with an outer guide ring.

CONSTRUCTION
Style 913 is constructed with a metallic guide ring, metallic winding and a filler element. The winding is manufactured from metal in a complicated form of a spiral, in assembly with a filler material. The filler materials fill the irregularities of the flanges. Its external guide ring has the function of centering the gasket in the flanges and gives the sealing elements additional resistance to the flow pressure and excessive bolt torque.

APPLICATION / SERVICE
For applications with high temperature variations (thermal cycling), and/or pressure variations, and/or flange rotation problems etc., gaskets with adequate residual stress (stress retention) and flexibility are needed. TEADIT spiral-wound gaskets have been designed to meet these demanding requirements.

MATERIAL PROPERTIES

Filler Material	Max. Temperature
Mica Graphite	232°C (450 °F)
Flexible Graphite	450°C (842 °F)
PTFE	260°C (500 °F)

Pressures available from 150 to 2500 class as specified.

Teadit Metalflex® 913-M

DESCRIPTION Teadit Metalflex® 913M is a 913 with an internal solid ring that fills the space between the flanges. Gaskets with PTFE and flexible graphite filler have a tendency to inward buckle thus the use of an inner ring is recommended. ASME B16.20 requires the use of the inner ring with PTFE fillers and some sizes with all other fillers. It requires inner rings for all flexible graphite filled unless the purchaser specifies otherwise. Inner rings also avoid turbulence in the flow of the fluid or help provide protection against corrosion or erosion.

CONSTRUCTION, APPLICATION/SERVICE, MATERIAL PROPERTIES
See **Teadit Metalflex® 913**

The Spiral Wound **Teadit Metalflex® 913-M** for flanges ASME B16.5 follows rigorously the specifications from ASME B16.20. For some special applications, PTFE inner rings or composite grooved metal/expanded PTFE type can be offered such as **Teadit 913-CMP** with an ePTFE/Monel Camprofile Inner Ring for HF service.

Teadit Metalflex® 913-RJ/913M-RJ

The 913-RJ is a specially sized spiral wound, designed to be a replacement item in ring joint flanges for maintenance purposes, when ring joint gaskets may no longer be practical. They are not for original designs. The outer ring bridges the ring groove, placing the winding (and inner ring if style 913M-RJ) between the groove ID and the flange bore. Teadit provides "typical" dimensions for these items. However the user must assure that the winding (and inner ring if applicable) does not protrude into the flange bore, which may vary. Proper movement is needed in the piping to compress the spiral wound. Please contact Teadit's Technical Department for assistance.

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Jacketed Gaskets

DESCRIPTION
A Jacketed Gasket is comprised of a soft pliable core inside a metallic jacket.

METALLIC JACKET
Almost any metal or alloy found in sheet form can be used as a jacket; its choice must take into consideration the fluid to be sealed. The metallic jacket is 0.016 in (0.4 mm) to 0.020 in (0.5 mm) thick.

FILLER
The standard filler material is Flexible Graphite. Other fillers like ceramic, PTFE or another metal (corrugated, flat, or serrated) can be used.

STYLES AND APPLICATIONS

STYLE 920 The style 920 is a round single jacket gasket. Used in applications where the seating stress and width are limited. It can be manufactured in circular or oval shape. The maximum gasket width is 1/4 (6.4 mm) and the standard thickness is 3/32 in (2.4 mm).

STYLE 923 The style 923 is a flat double jacket gasket. Its most typical applications are in Heat Exchangers. ASME B 16.20 shows the gasket dimensions for ANSI B 16.5 flanges. The standard thickness is 1/8 in (3.2 mm). This style is also used in large size reactors in chemical plants. Another important use is for flanges in the large, low pressure ducting in Steel Mill Blast Furnaces. To compensate for distortions and irregularities of these flanges gaskets have the thickness from 5/32 in (4 mm) to 1/4 in (6 mm).

STYLE 926 Similar to style 923 but the metallic jacket is corrugated. The corrugations act as a labyrinth.

STYLE 929 Similar to style 926 with a grooved metallic filler. Used in applications where it is necessary to have a gasket without non-metallic materials, temperature limits and chemical resistance depend upon of the metal only.

DESIGN
The following recommendations are based on successful practical applications: Gaskets

confined by the inside and outside diameters:Gasket inside diameter = groove inside diameter plus 1/16 in (1.6 mm).

- Gasket outside diameter = groove outside diameter less 1/16 in (1.6 mm).

Gaskets confined by outside diameter:

- Gasket inside diameter = flange inside diameter plus a minimum of 1/8 in (3.2 mm).
- Gasket outside diameter = groove outside diameter less 1/16 in (1.6 mm).

Non confined gaskets:

- Gasket inside diameter = flange inside diameter plus 1/8 in (3.2 mm).
- Gasket outside diameter = bolt circle diameter less bolt diameter.

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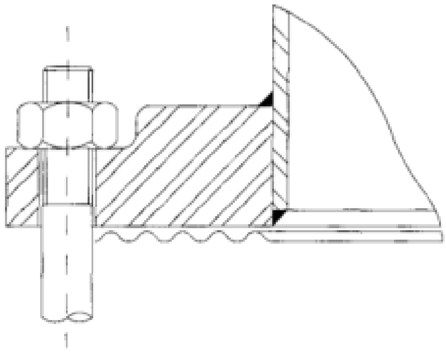
sales@teadit.com

Solid Metal Gaskets - 900, 940



Corrugated Metal

Style 900 is a corrugated metal gasket. They are used in low pressure applications where there are limitations of weight and space. The thickness of the sheet should be 0.010 in (0.25 mm) to 0.04 in (1 mm) depending on the metal and number of corrugations. Due to the thickness of the sheet, the force required to seat the gasket is greatly reduced when compared with gasket styles 940 and 941. A minimum of 3 corrugations is necessary to obtain satisfactory sealing. A small flat area on the inside and outside diameters of the gasket is recommended to increase its mechanical strength. The corrugation pitch can vary between 0.045 in (1.1 mm) to 1/4 in (6.4 mm). The total thickness of the gasket is 40% to 50% of the corrugation pitch. The metal used determines the service temperature limit. Maximum service pressure: 500 psi.

Flat Metal

Style 940 is a metallic gasket that has a smooth sealing surface and can be manufactured practically in any shape. Their typical applications are in valves, heat exchangers, hydraulic presses and tongue and groove flanges. The strong points are mechanical and chemical attack resistance and they can be used in elevated temperature and pressure service. The width of the gasket sealing surface should be at least equal to 1.5 times its thickness. These gaskets depending upon their material have high maximum seating stress.

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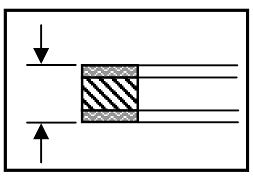
TEADIT

Graphite Faced Fin-Fan Exchanger Plug Gaskets

Sealing the hundreds of plugs on the typical Fin-Fan exchanger has become more and more problematic as emission requirements have gotten increasingly stringent. To address this issue **Teadit North America** now offers a graphite-faced plug gasket that ensures that the end-user will be able to attain the level of sealability required. This gasket utilizes the standard soft iron



OEM plug gasket, and adds a layer of 0.015" thick, 70-lb density graphite to each surface. The result is a stable, high-temperature gasket that is easy to install and easy to seal. It not only prevents leakage, but also helps minimize down-time and helps eliminate thread galling, as it provides a gas-tight seal at lower installation torques.

Core Material: OEM provided 1/16" soft iron or carbon steel. (Manufacturers thickness tolerance +/-.003")

Graphite Facings: 0.015" thick, oxidation-resistant APX2 Graphite, 70-lb density.

Resultant Thickness: Nominal 0.090"

Dimensional Tolerances: +/- .010"

Temperature Rating: 900F

Minimum Recommended Seating Stress: 10,000-psi

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North America

Suggested Torque Values for Use with Teadit Spiral wound 913M (with inner & outer rings)/Standard ASME B16.5 Raised Face Pipe Flanges

For Use with ASTM A193 B7 Bolting or equal yield strength bolt material.

Gasket to be per ASME B16.20 and used with appropriate flange bore size per the B16.20 tables. If no inner ring is used, gasket may buckle on the ID. Use Correct size, New, bolts/studs, nuts, washers (multiply torques by 0.70 for PTFE coated bolting). Lubricate on bolt threads and nut faces with compatible antiseize*. This Chart gives the torque value for the final pass. After hand tightening, torquing must follow a cross bolting sequence as exampled in Annex 12.1 of Teadit's "Industrial Gaskets" 3rd editon by Jose Veiga. There shall be 3 complete passes (30%, 60%,100% of final pass torque). Once final torque is achieved, a minimum of 2 clockwise passes to be applied until there is no further nut rotation.

Class 150

Nominal Pipe Size	Torque FT. LB.
1/2	40
3/4	60
1	60
1 1/4	60
1 1/2	60
2	120
2 1/2	120
3	125
3 1/2	120
4	115
5	200
6	200
8	225
10	320
12	320
14	500
16	405
18	650
20	595
24	835

Class 300

Nominal Pipe Size	Torque FT. LB.
1/2	40
3/4	65
1	90
1 1/4	105
1 1/2	170
2	90
2 1/2	115
3	160
3 1/2	200
4	200
5	200
6	200
8	320
10	500
12	710
14	535
16	835
18	835
20	835
24	1200

*Charts based on nut factor approximately 0.17

Flange stress limitations were considered per Warren Brown and David Reeves, An Update on Selecting the Optimum Bolt Assembly Stress for Piping Flanges, (Advanced Draft for presentation at 2007 ASME PVP Conference), Table 2.This assumes A-105 or stainless steel weld necks w/ pipe walls as listed by the document. Other arrangements may require further evaluation. Spiral wound gasket dimensions were used for the flange stress analysis. Not suitable for flange materials with elongation at failure less than 20%.

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North America

Suggested Torque Values for Use with Teadit Spiral wound 913M (with inner & outer rings)/Standard ASME B16.5 Raised Face Pipe Flanges

For Use with ASTM A193 B7 Bolting or equal yield strength bolt material.

Gasket to be per ASME B16.20 and used with appropriate flange bore size per the 16.20 tables. If no inner ring is used, gasket may buckle on the ID. Use Correct size, New, bolts/studs, nuts, washers (multiply torques by 0.70 for PTFE coated bolting). Lubricate on bolt threads and nut faces with compatible antiseize*. This Chart gives the torque value for the final pass. After hand tightening, torquing must follow a cross bolting sequence as exampled in Annex 12.1 of Teadit's "Industrial Gaskets" 3rd editon by Jose Veiga. There shall be 3 complete passes (30%, 60%,100% of final pass torque). Once final torque is achieved, a minimum of 2 clockwise passes to be applied until there is no further nut rotation.

Class 400

Nominal Pipe Size	Torque FT. LB.
1/2	No flanges
3/4	No flanges
1	No flanges
1 1/4	No flanges
1 1/2	No flanges
2	No flanges
2 1/2	No flanges
3	No flanges
3 1/2	No flanges
4	320
5	320
6	320
8	500
10	620
12	875
14	875
16	1200
18	1200
20	1400
24	2600

Class 600

Nominal Pipe Size	Torque FT. LB.
1/2	40
3/4	60
1	85
1 1/4	85
1 1/2	160
2	85
2 1/2	160
3	180
3 1/2	300
4	330
5	470
6	470
8	650
10	875
12	875
14	1020
16	1335
18	1900
20	1900
24	3000

*Charts based on nut factor approximately 0.17

Flange stress limitations were considered per Warren Brown and David Reeves, An Update on Selecting the Optimum Bolt Assembly Stress for Piping Flanges, (Advanced Draft for presentation at 2007 ASME PVP Conference), Table 2. This assumes A-105 or stainless steel weld necks with pipe walls listed by the document. Other arrangements may require further evaluation. Spiral wound gasket dimensions were used for the flange stress analysis. Not suitable for flange materials with elongation at failure less than 20%.

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North America

Suggested Torque Values for Use with Teadit Spiral wound 913M (with inner & outer rings)/Standard ASME B16.5 Raised Face Pipe Flanges

For Use with ASTM A193 B7 Bolting or equal yield strength bolt material.
Gasket to be per ASME B16.20 and used with appropriate flange bore size per the B16.20 tables. If no inner ring is used, gasket may buckle on the ID.
Use Correct size, New, bolts/studs, nuts, washers (multiply torques by 0.70 for PTFE coated bolting). Lubricate on bolt threads and nut faces with compatible antiseize*. This Chart gives the torque value for the final pass. After hand tightening, torquing must follow a cross bolting sequence as exampled in Annex 12.1 of Teadit's "Industrial Gaskets" 3rd editon by Jose Veiga. There shall be 3 complete passes (30%, 60%,100% of final pass torque). Once final torque is achieved, a minimum of 2 clockwise passes to be applied until there is no further nut rotation.

Class 900

Nominal Pipe Size	Torque FT. LB.
1/2	No Flanges
3/4	No Flanges
1	No Flanges
1 1/4	No Flanges
1 1/2	No Flanges
2	No Flanges
2 1/2	No Flanges
3	265
4	500
5	840
6	590
8	950
10	950
12	1130
14	1330
16	1830
18	3000
20	3000
24	5000

Class 1500

Nominal Pipe Size	Torque FT. LB.
1/2	80
3/4	100
1	160
1 1/4	200
1 1/2	275
2	200
2 1/2	300
3	400
4	650
5	1000
6	900
8	1400
10	2400
12	2500
14	3200
16	4500
18	6000
20	7730
24	12750

*Charts based on nut factor approximately 0.17
Flange stress limitations were considered per Warren Brown and David Reeves, An Update on Selecting the Optimum Bolt Assembly Stress for Piping Flanges, (Advanced Draft for presentation at 2007 ASME PVP Conference), Table 2. This assumes A-105 or stainless steel weld necks with pipe walls as listed by the document. Other arrangements may require further evaluation. Spiral wound gasket dimensions were used for the flange stress analysis. Not suitable for flange materials with elongation at failure less than 20%.

TEADIT

North America

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Suggested Torque Values for Use with Teadit Spiral wound 913M (with inner & outer rings)/Standard ASME B16.5 Raised Face Pipe Flanges

For Use with ASTM A193 B7 Bolting or equal yield strength bolt material.

Gasket to be per ASME B16.20 and used with appropriate flange bore size per the B16.20 tables. If no inner ring is used, gasket may buckle on the ID. Use Correct size, New, bolts/studs, nuts, washers (multiply torques by 0.70 for PTFE coated bolting). Lubricate on bolt threads and nut faces with compatible antiseize*. This Chart gives the torque value for the final pass. After hand tightening, torquing must follow a cross bolting sequence as exampled in Annex 12.1 of Teadit's "Industrial Gaskets" 3rd editon by Jose Veiga. There shall be 3 complete passes (30%, 60%,100% of final pass torque). Once final torque is achieved, a minimum of 2 clockwise passes to be applied until there is no further nut rotation.

Class 2500

Nominal Pipe Size	Torque FT. LB.
1/2	85
3/4	85
1	125
1 1/4	220
1 1/2	320
2	220
2 1/2	320
3	450
4	750
5	1300
6	2000
8	2000
10	3500
12	5000

*Chart based on nut factor approximately 0.17

Flange stress limitations were considered per Warren Brown and David Reeves, An Update on Selecting the Optimum Bolt Assembly Stress for Piping Flanges, (Advanced Draft for presentation at 2007 ASME PVP Conference), Table 2. This assumes A-105 or stainless steel weld necks with pipe walls as listed by the document. Other arrangements may require further evaluation. Spiral wound gasket dimensions were used for the flange stress analysis. Not suitable for flange materials with elongation at failure less than 20%.

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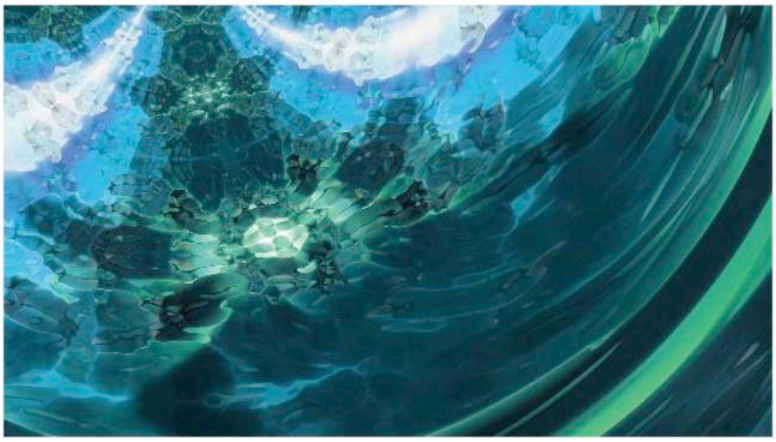

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SPIRAL WOUND VERSUS FLEXIBLE GRAPHITE FACED SARRATED METAL PIPE FLANGE GASKETS IN THERMAL CYCLING AND PRESSURE COMPARATIVE TESTING

Proceedings of the ASME 2010 Pressure Vessel and Piping Division Conference
PVP2010
July 18-22, 2010, Bellevue, Washington, USA

PVP2010-25966

SPIRAL WOUND VERSUS FLEXIBLE GRAPHITE FACED SERRATED METAL PIPE FLANGE GASKETS IN THERMAL CYCLING AND PRESSURE COMPARATIVE TESTING

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ABSTRACT

Spiral Wound gaskets have been successfully used in ASME B16.5 pipe flanges. However, in the last few years, to increase the reliability and safety, there has been a trend to replace them by graphite faced serrated metal gaskets. These are assumed to be better in terms of relaxation and installation. This paper shows a comparison between these two gasket styles. Relaxation and leak tests were performed using standard studs and flanges to simulate actual field conditions.

INTRODUCTION

Spiral Wound Gaskets (SW) are widely used by industry in process piping and equipment. Most of these gaskets are produced according to ASME B16.20 – 2007 Metallic Gaskets for Pipe Flanges [1]. Correctly produced and installed SWs are very reliable gaskets, they have been successfully used in high pressure and temperature as well as in difficult applications such as vacuum and lines subjected to vibration.

Field reports, articles and test methods [2 - 6] have shown that SW Gaskets without inner rings have a tendency to inward buckle, being a major source of gasket leaks. The inward buckling can not be detected during the gasket installation so it is not possible to be sure that it did not occur. The ASME B16.20 in its latest issue has addressed the problem recommending the use of inner rings for all sizes and in some cases making it mandatory. Another problem associated with SW Gaskets is the “unwinding” of larger gaskets. If not properly handled during transportation and installation large gaskets (mainly above 10 inches NPS) can easily disassembly. However, SW Gaskets are easy to find in the market at very competitive prices when compared with other gasket styles of similar performance. Due to its wide use by the industry they have been subjected to several studies of performance, installation and manufacturing [7 - 12].

Graphite Faced Serrated Metal Gaskets, also known as KAM gaskets have been used successfully in equipment such as heat exchangers and reactors. In applications subject to radial shear its performance is outstanding, as demonstrated in laboratories tests and field applications [13, 14].

In the last few years there has been a trend toward the use of KAM Gaskets in Piping Flanges for new projects or as replacement of SW Gaskets in existing installations. This trend is due to the fact that KAM Gaskets are more tolerant to handling and installation abuse. However, we did not find published studies of their comparative performance with SW Gaskets.

This study provides comparative sealing and relaxation performance between SW and KAM Gaskets installed in ASME (ANSI) pipe flanges. To simulate the actual field conditions the installation was done using industrial tooling like Hydraulic or Lever torque wrenches. Thermal cycling and hydrostatic tests were performed to evaluate and compare the performance of the tested gaskets.

TEST GASKETS

The study was done with standard pipe flange gaskets as shown in Figure 1. The gasket (a) is a SW and the (b) is a KAM.

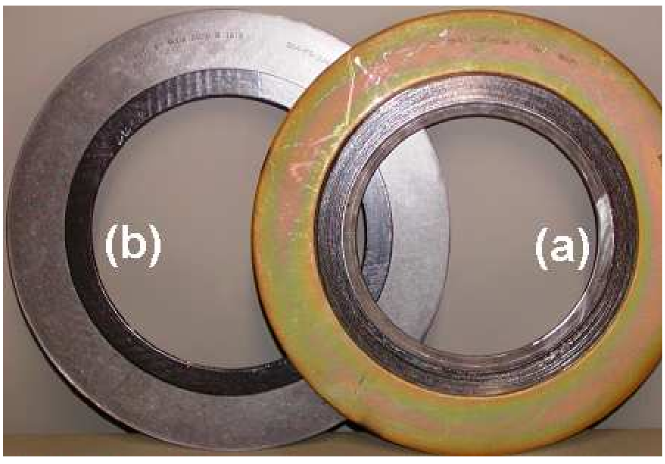

FIGURE 1: SW (A) AND KAM (B) GASKETS

All SW Gaskets tested were with AISI 304 Stainless Steel and Graphite filler windings, Carbon Steel outer rings and Stainless Steel inner rings, dimensions according the ASME B16.20 Standard. A schematic view of the SW gasket is shown in Figure 2.

FIGURE 2: SW GASKET

All KAM Gaskets tested were with AISI 304 Stainless Steel core and Graphite facings, Stainless Steel outer rings, dimensions according to the FSA-MG-502-05 - Serrated Metal Gaskets with Covering Layers [15]. A schematic view of the KAM gasket is shown in Figure 3.

FIGURE 3: KAM GASKET

TEST RIGS

This study was performed with ASTM A105 cast steel flanges, dimensions per ASME B16.5 - Pipe Flanges and Flanged Fittings [16] according to Table 1. All Flange Facings were Raised Face 3.2 µm (125 µin) Figure 4 shows the 6 inches – Class 900 test rig arrangement. The Target Torque was set at 50% of the Yield Strength of the ASTM A193 – B7 bolts used in all flange sets.

TABLE 1: Gasket Seating Stress

Nominal Diameter	Pressure Class	Gasket Stress KAM MPa (psi)	Gasket Stress SW MPa (psi)
2	300	178 (25800)	216 (31300)
3	150	47 (6800)	63 (9100)
6	900	208 (30200)	210 (30450)

Heating elements are installed on the flange necks. Thermal insulation with ceramic fiber felt and a Fiber Glass tape wound over to protect it and provide additional insulation.

Thermocouples and pressure transducers were installed inside the flanges for temperature and pressure control and recording.

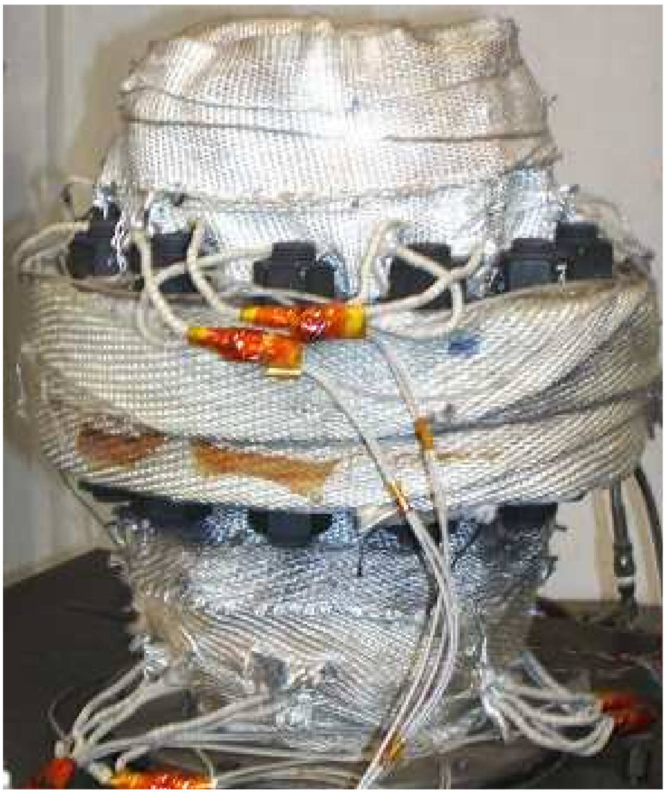

FIGURE 4: 6" 900# TEST RIG

All bolts materials were ASTM SA-193-B7 with machined ends to allow a precise bolt elongation measurement. The elongation was used to calculate the bolt load. All dimensions were measured at room temperature. Figure 5 shows how the bolt elongation was measured and Figure 6 the calculated versus actual length for a 1.1/4 x 8 in long bolt. This comparison was done to validate the measurement method.

FIGURE 5: 3" 150# BOLT MEASUREMENT

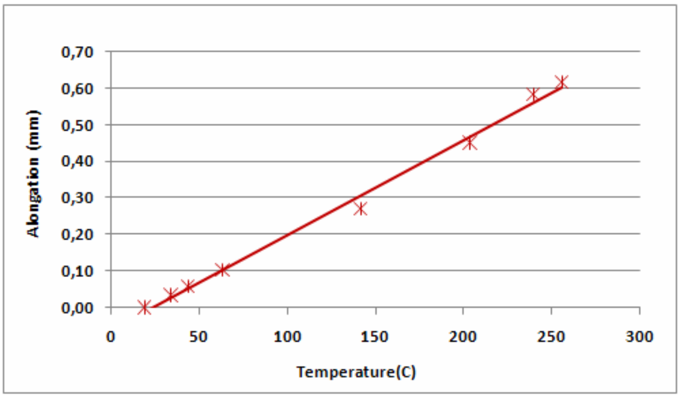

FIGURE 6: ASTM SA-193-B7 BOLT

TEST PROTOCOL

The Test Protocol was designed to reproduce actual Field Conditions which includes a hydrostatic test before start-up, pressure and thermal cycling. Most high temperature tests were with Steam. Helium was used only to confirm the tightness observed during the Steam cycles. The Steam leak rate was calculated by Pressure Decay. Helium leaks were evaluated sniffing with a Mass Spectrometer.

The Bolt Tightening was done following the ASME PCC-1 [17], the target torque was set to 50% of the Yield Strength of the ASTM SA193-B7 bolts. In a previous PVP Paper [18] the Authors have shown that re-torquing Compressed Non-Asbestos gaskets during the start-up, when flange temperature is between 120C (248F) and 200C (392F), reduces the long term bolt load relaxation. Authos field experience with metal gaskets also indicates the same behavior. To investigate this practice, experiments were performed with a retightening when flanges reached 150C (302F).

Bolts were cleaned and lubricated with Molykote 1000 prior to a new test.

Thermal cycles with saturated steam at 662°F (350°C) were performed daily. Hydrostatic tests, with 1.5 times of the maximum working pressure of the flange material, were performed after installation, between the 5th and 6th cycles and at the end of the test.

A summary of the Test Protocol is as follows:

1 - Install gasket;
2 - Tighten bolts with 3 cross pattern rounds followed by rotational pattern until nuts do not turn;
3 - Measure and record bolt length;
4 - Perform hydrostatic test with 1.5 times the maximum flange working pressure;
5 - Turn heat on for 12 hours;
6 - Monitor temperature and pressure;
7 - Turn heat off;
8 - When flanges reach room temperature measure and record bolt length;
9- Repeat steps 5 to 8 for 5 times;
10- Repeat step 4;
11 - Repeat steps 5 to 8 for 5 times;
12 – Repeat step 4 and finish test.

For start-up with Hot-Torque an additional step of re-tightening with 100% of the target torque was performed when flanges reached 150C (302F).

SW TEST RESULTS WITH FLANGE 6 IN - CLASS 900

Steam Tests were performed with the following parameters:
- Steam Test Pressure: 113 bar (1639 psi)
- Hydrostatic Test Pressure: 230 bar (3335 psi)
- Thermal Cycle Maximum Temperature: 350C (662F)

The chart in Figure 7 shows the Average Bolt Load and the Figure 8 the Remaining bolt load as a percentage of initial bolt load. The fluctuation of the load value is due to the temperature variation of the bolts.

No pressure decay was observed for the duration of the tests, indicating a good sealing behavior. One of the gaskets was cycled for 10 times and another for 3 times to confirm the results of the first sample.

The Red Line represents the Hydrostatic Test Pressure Force and the Blue Line the Steam Test Pressure. If the average bolt load falls below or close to the hydrostatic or steam pressure, it is possible to have a leak. It can be observed in Figure 7 that even with an about 20% Bolt Load Loss there is still a safety margin of about 4 times.

To investigate the good field results of re-torquing during the initial heating, two additional Steam tests were performed. As shown in Figures 9 and 10. Both were run for 10 cycles.

It can be observed that re-torquing at the start up eliminates bolt load loss. Both tests also indicate that even though the torque value set in the Hydraulic Torque Wrenches was not changed the actual bolt load increased. Anti-seize testing at TTRL in Canada [19] and by some end users have shown that the lubricity in anti-size lubricant changes, usually with a reduction of the Coefficient of Friction due to the temperature effect on the lubricant. This investigation is beyond the scope of this paper.

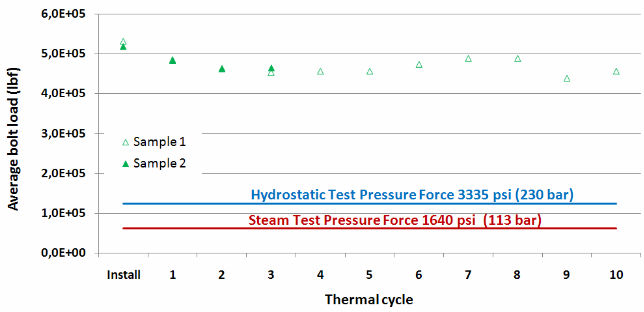

FIGURE 7: SW - 6" 900# - 350 C (662F)

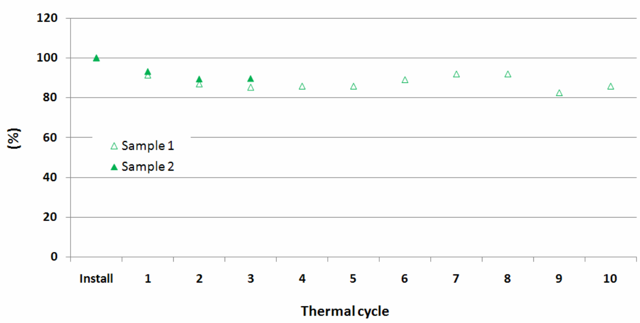

FIGURE 8: SW 6" 900# - REMAINING % OF INITIAL LOAD

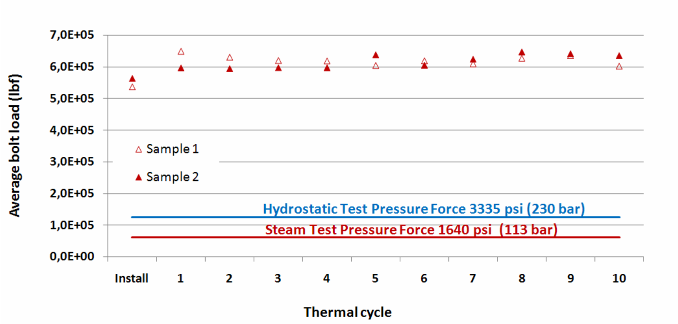

FIGURE 9: SW - 6" 900# - 350C (662F) - WITH RETORQUE DURING HEATING

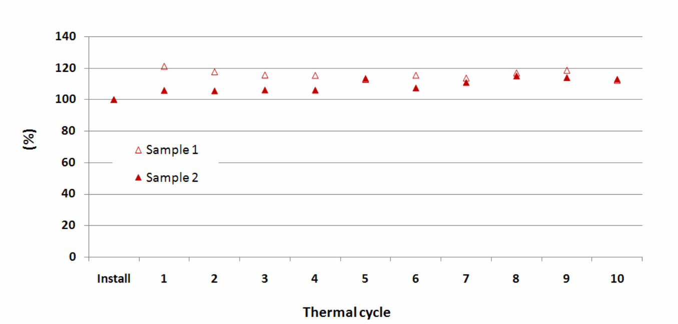

FIGURE 10: SW 6" 900# - REMAINING % OF INITIAL LOAD

A Helium leak test was performed to confirm the sealability of the SW Gasket as shown in Figure 11. The leak rate was evaluated with a Mass Spectrometer Sniffer probe. The value of 2E-8 mbar-l/sec confirmed the Steam test results.

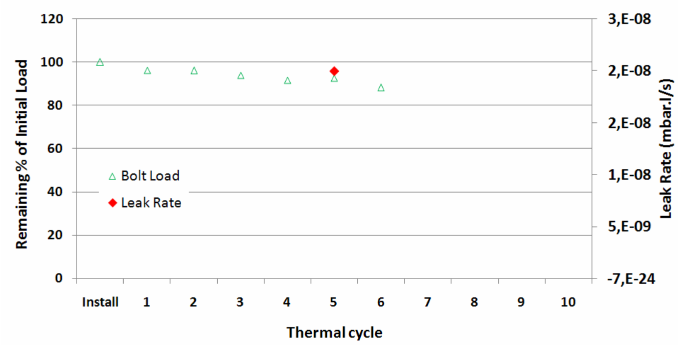

FIGURE 11: SW WITH HELIUM GAS - 6" 900# - 350C (662F)

KAM TEST RESULTS WITH FLANGE 6 IN - CLASS 900

Steam Tests were performed with the following parameters:

- Steam Test Pressure: 113 bar (1639 psi)
- Hydrostatic Test Pressure: 230 bar (3335 psi)
- Thermal Cycle Maximum Temperature: 350C (662F)

The chart in Figure 12 shows the Average Bolt Load and the Figure 13 the Bolt Load Loss as percent of the initial load. The fluctuation of the load value is due to the temperature variation of the bolts.

No pressure decay was observed during the duration of the tests, indicating a good sealing behavior.

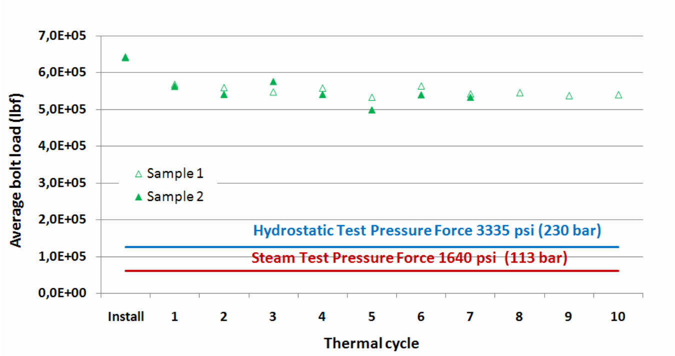

FIGURE 12: KAM 6" 900# - 350C (662F)

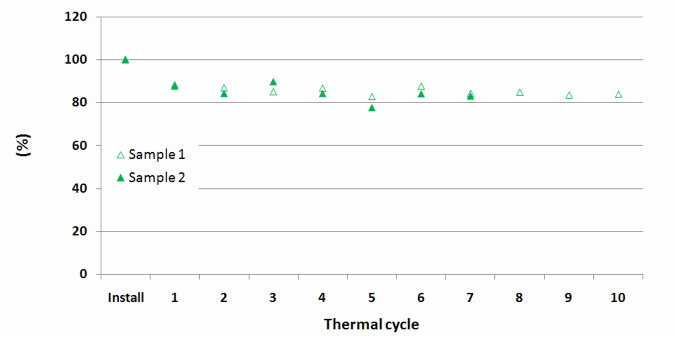

FIGURE 13: KAM 6" 900# - REMAINING % OF INITIAL LOAD

To compare with the SW Gaskets tests were also performed with re-torque during the start-up. Results are shown in Figures 14 and 15.

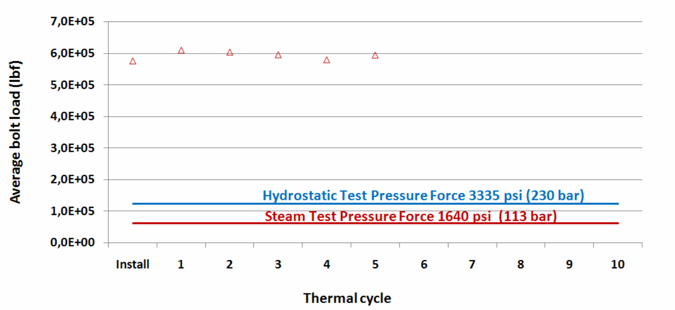

FIGURE 14: KAM 6" 900# - 350C (662F) - WITH RETORQUE DURING HEATING

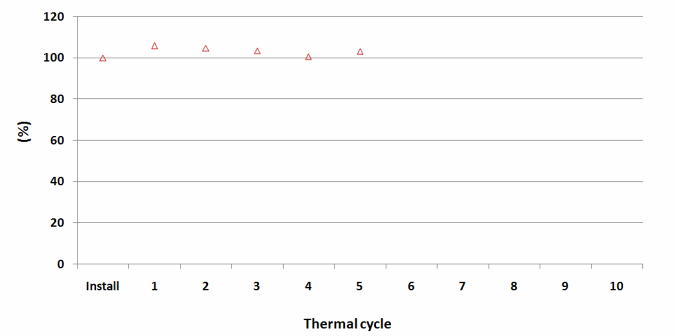

FIGURE 15: KAM 6" 900# - REMAINING % OF INITIAL LOAD

Comparing the Steam Test Pressure Force against the Bolt Load the KAM Gaskets showed a safety margin of about 5 times.

To confirm the KAM Gasket sealability a Helium leak test was performed as shown if Figure 16. The value of 4E-6 mbar-l/sec confirmed the Steam test results.

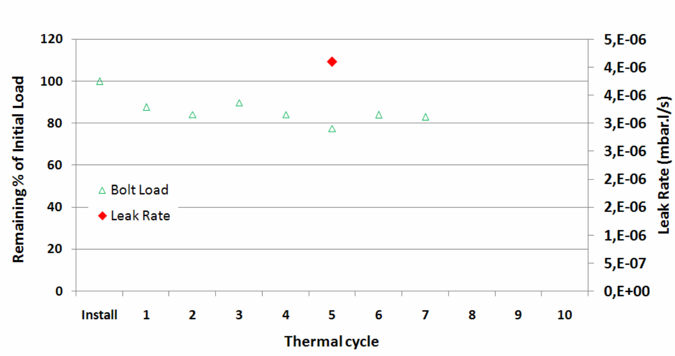

FIGURE 16: KAM WITH HELIUM GAS - 6" 900# - 350C (662F)

SW X KAM GASKETS 6 IN-CLASS 900 COMPARISON

The Bolt Load Loss as percent of the initial load for SW and KAM Gaskets in the 6 in – Class 900 comparison is shown in Figure 17. It can be observed that both gasket styles have a very similar behavior. After an initial 20% loss the Load stays constant after the third thermal cycle. Since the Leak Rates had also the same behavior there was no noticeable difference between the tested gaskets for this flange size.

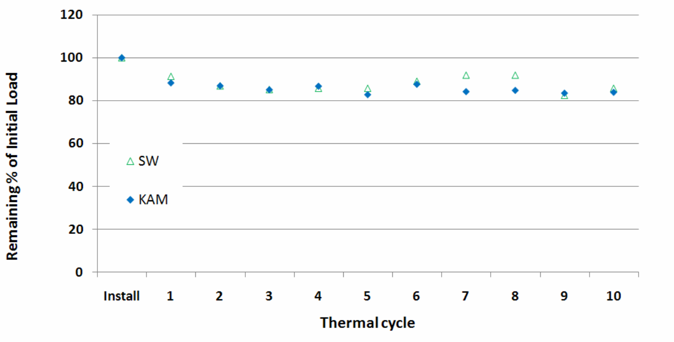

FIGURE 17: SW X KAM - 6" 900# - 350C (662F)

SW TEST RESULTS WITH FLANGE 3 IN - CLASS 150

After analyzing the results of the 6 in class 900 flanges, a series of tests were carried out in a 3 inches class 150 Test Rig to investigate the influence of the flange size behavior. The 3 inche – class 150 test rig is shown in Figure 18.

Steam Tests were performed with the following parameters:

- Steam Test Pressure: 14 bar (203 psi)
- Hydrostatic Test Pressure: 30 bar (435 psi)
- Thermal Cycle Maximum Temperature: 200C (392F)

FIGURE 18: 3” 150# TEST RIG

The chart in Figure 19 shows the Average Bolt Load and the Figure 20 the Bolt Load Loss as percent of the initial load. The fluctuation of the load value is due to the temperature variation of the bolts.

The Red Line represents the Hydrostatic Test Pressure Force and the Blue Line the Steam Test Pressure. It can be observed that even with about 20% Bolt Load Loss, there is still a safety margin of 7 times the maximum operating pressure for this temperature.

No pressure decay was observed for the duration of the tests, indicating a good sealing behavior.

Tests with start up re-torque were also performed as shown in figures 21 and 22.

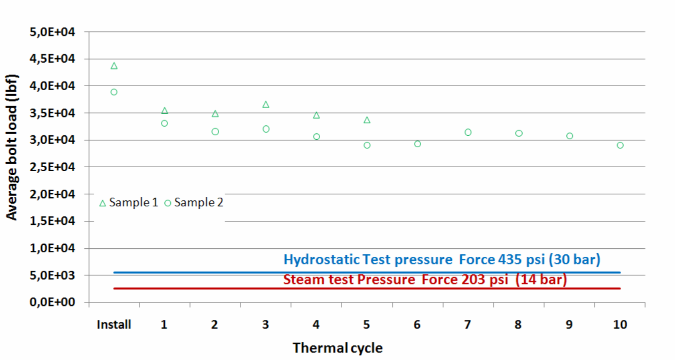

FIGURE 19: SW 3" 150# 200C (392F)

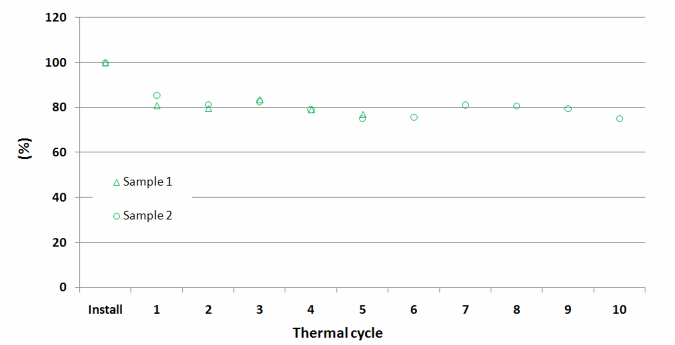

FIGURE 20: SW 3” 150# - REMAINING % OF INITIAL LOAD

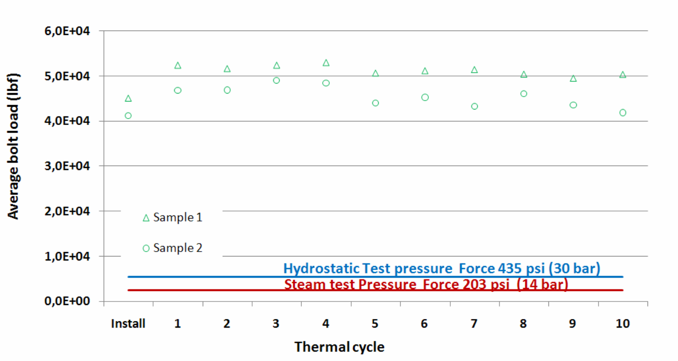

FIGURE 21: SW 3" 150# 200C (392F) - WITH RETORQUE DURING HEATING

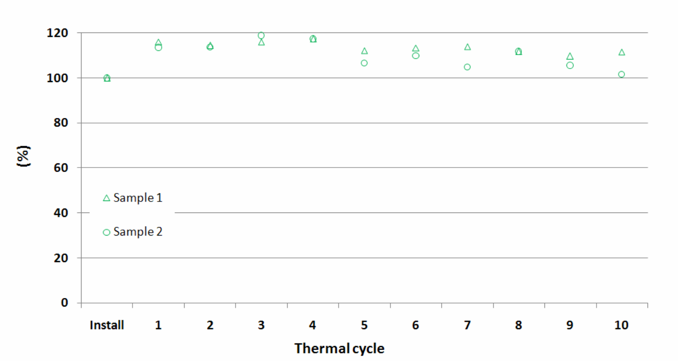

FIGURE 22: SW 3" 150# - REMAINING % OF INITIAL LOAD

KAM TEST RESULTS WITH FLANGE 3 IN - CLASS 150

The same 3 inches class 150 comparison was performed for KAM Gaskets. The test parameters were as follows:

- Steam Test Pressure: 14 bar (203 psi)
- Hydrostatic Test Pressure: 30 bar (435 psi)
- Thermal Cycle Maximum Temperature: 200C (392F)

The chart in Figure 23 shows the Average Bolt Load and the Figure 24 the Bolt Load Loss as percent of the initial load. The fluctuation of the load value is due to the temperature variation of the bolts.

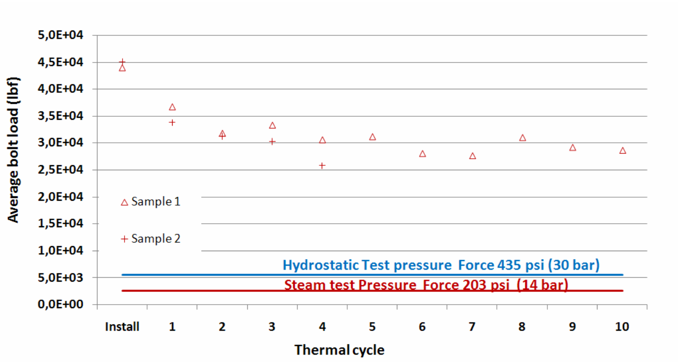

FIGURE 23: KAM 3" 150# 200C (392F)

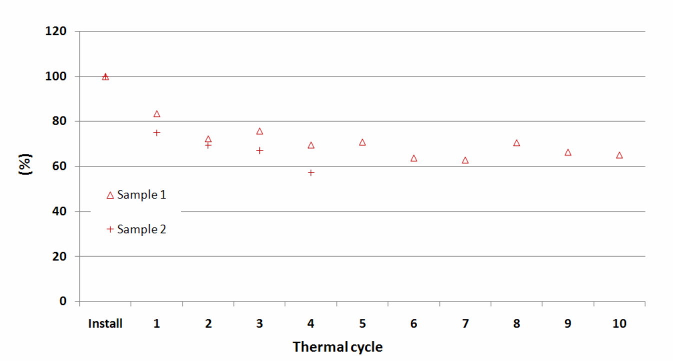

FIGURE 24: KAM 3" 150# - REMAINING % OF INITIAL LOAD

To compare with the SW Gaskets tests were also performed with re-torque during the start-up. Results are shown in Figures 25 and 26.

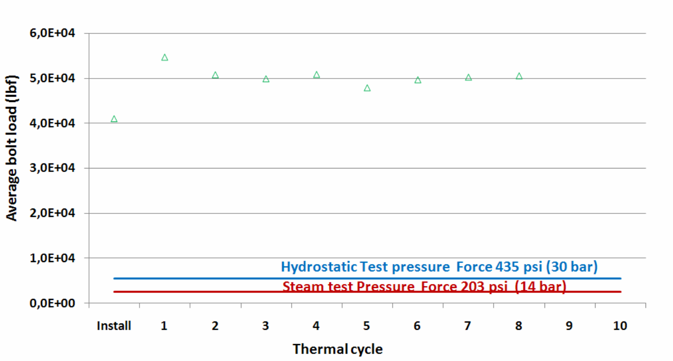

FIGURE 25: KAM 3" 150# 200C (392F) - WITH RETORQUE DURING HEATING

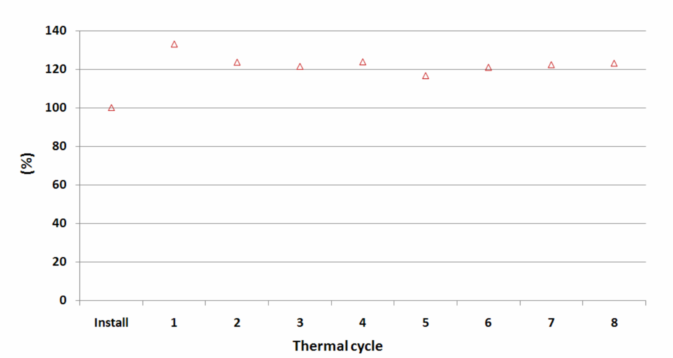

FIGURE 26: KAM 3" 150# - REMAINING % OF INITIAL LOAD

SW X KAM GASKETS 3 IN-CLASS 150 COMPARISON

Figures 27 and 28 show a comparison between SW and KAM Gaskets in 3 inch-Class 150 flanges. The same behavior of the larger flange can be observed. Both gasket styles had no leak during tests and comparable bolt load loss. For this flange set, the SW Gasket that was cycle tested had a relaxation of 5% less than the KAM Gasket. Due to time constraints, only one test per gasket style was performed so it is not possible to assure that this behavior is a trend.

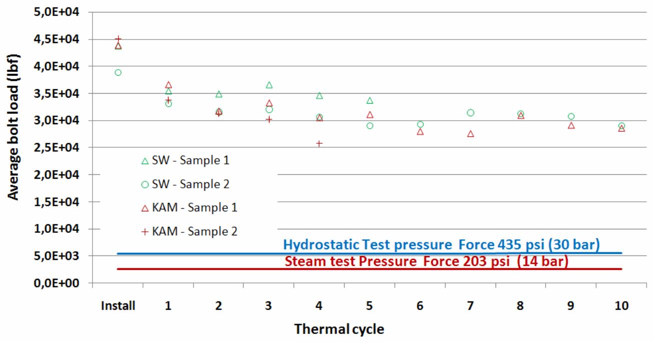

FIGURE 27: SW X KAM 3" 150# 200C (392F)

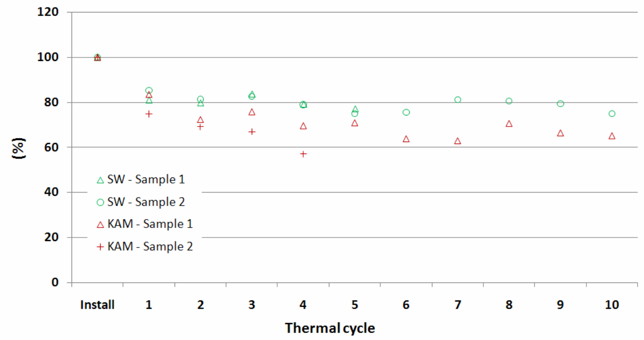

FIGURE 28: SW X KAM 3" 150# - REMAINING % OF INITIAL LOAD

SW TEST RESULTS WITH FLANGE 2 IN - CLASS 300

Steam Tests were performed with the following parameters:

- Steam Test Pressure: 14 bar (203 psi)
- Hydrostatic Test Pressure: 77 bar (1116 psi)
- Thermal Cycle Maximum Temperature: 200C (392F)

The chart in Figure 29 shows the Average Bolt Load and the Figure 30 the Bolt Load Loss as percent of the initial load. The fluctuation of the load value is due to the temperature variation of the bolts.

This flange set showed a higher bolt load loss than others. The relaxation which was less than 40% for both 6 inch-class 900 and 3 inch-class 150 reached 50% for one of the tested gaskets. Additional tests have to be performed to confirm this trend. However, even with this high relaxation the safety margin was about 5 times the test pressure.

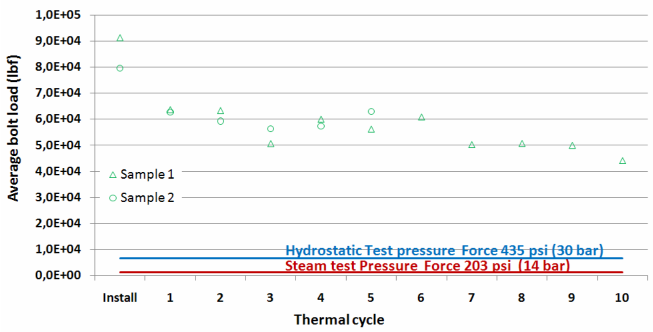

FIGURE 29: SW 2" 300# - 200C (392F)

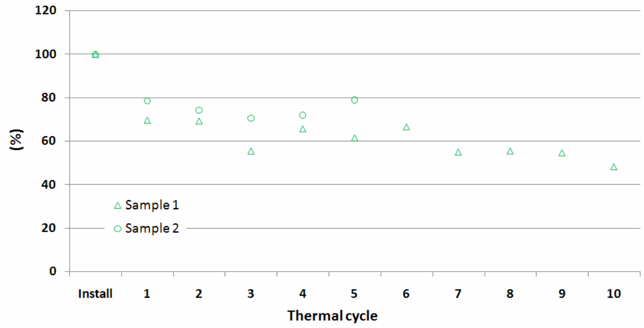

FIGURE 30: SW 2” 300# - REMAINING % OF INITIAL LOAD

KAM TEST RESULTS WITH FLANGE 2 IN - CLASS 300

The same test parameters were used for the KAM Gaskets which showed the same trend of higher bolt load loss as the SW gasket as compared with larger diameter flanges.

The chart in Figure 31 shows the Average Bolt Load and the Figure 32 the Bolt Load Loss as percent of the initial load. The fluctuation of the load value is due to the temperature variation of the bolts.

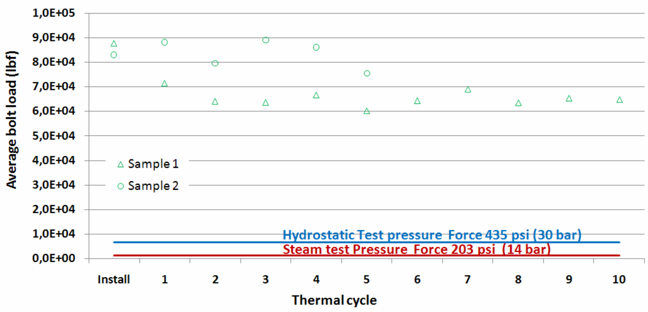

FIGURE 31: KAM 2" 300# - 200C (392F)

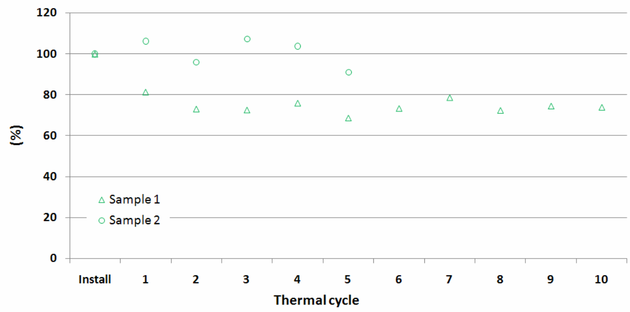

FIGURE 32: KAM 2” 300# - Remaining % of Initial Load

SW X KAM GASKETS 2 IN-CLASS 300 COMPARISON

Figures 33 and 34 shows a comparison between SW and KAM gaskets in the 2 inch-class 300 flange set. The higher bolt load loss can be observed for both gasket styles as compared with the larger flange sizes used for these tests. This behavior suggests this is a characteristic of the flange. To assure this trend it is necessary to perform further comparative tests including other flange sizes of similar size. This investigation is beyond the scope of this paper.

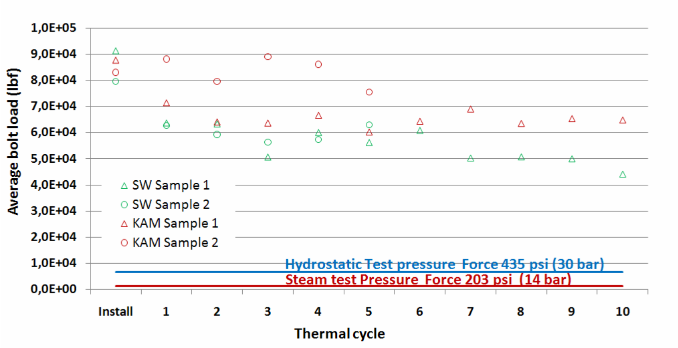

FIGURE 33: SW x KAM - 2" 300# - 200C (392F)

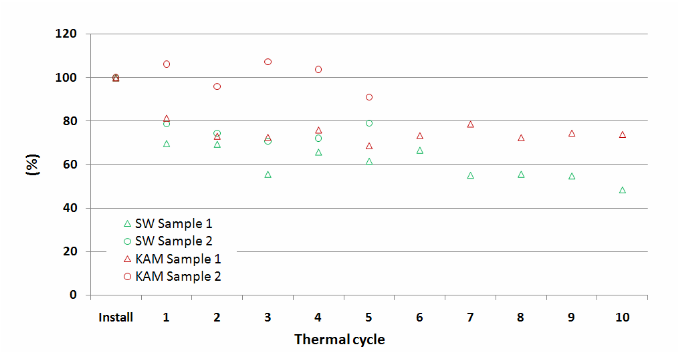

FIGURE 34: SW X KAM 2" 300# - REMAINING % OF INITIAL LOAD

INSTALLATION EFFECT

With purpose to compare the susceptibility of gaskets to installation mistakes, tests were performed in the 6 inch-class 900 applying 100% of the target torque in a clockwise direction as shown in Figure 35. For both gasket styles there were no steam leaks

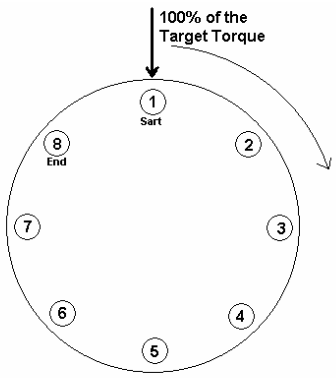

FIGURE 35: BOLT FLANGE TIGHTENING SEQUENCE

CONCLUSION

From this series of tests it is not possible to affirm that one gasket style has a remarkably better performance than the other. There were no steam leaks and the Helium tests showed a comparable leak rate. The bolt load loss also comparable for all flange size tested. On initial installation, a SW will crush down in the range .030 to .075 inches (.762 to 1.905 mm) where a KAM will crush .022 to .027 inches (.559 to .686 mm). This makes the tightening pattern more critical for the SW in order to maintain correct flange alignment and even gasket stresses. This difference in crush also results in KAM's loading much quicker. There can be wide variations between SW manufacturers in how far their SW's will crush as B16.20 provides no guidance as to winding density. SW gaskets can be a better choice in some application where the winding provide additional protection of the graphite. This can include higher temperature applications where the windings have been shown to reduce graphite oxidation, and where the gasket might be susceptible to mechanical damage during installation, like flange pairs that can only be spread wide enough to slide in the gasket. KAM's have been show in certain field applications to provide a more reliable seal, especially when compared against SW gaskets where the winding density is so low that the sealing surfaces contact one or both guide rings. There are also differences in gasket stress, for any given stud stress, for every flange size and class. This is because the sealing area will be different for both gasket types. The gaskets will also have differences in the maximum and minimum recommended stress requirements, which can impact which one is selected. The choice of whether to use a SW or a KAM Gasket style will have to take into account these factors, as well as other factors like availability, cost, etc.

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Proceedings of PVP2005
2005 ASME Pressure Vessels and Piping Division Conference
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PVP2005-71023

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

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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

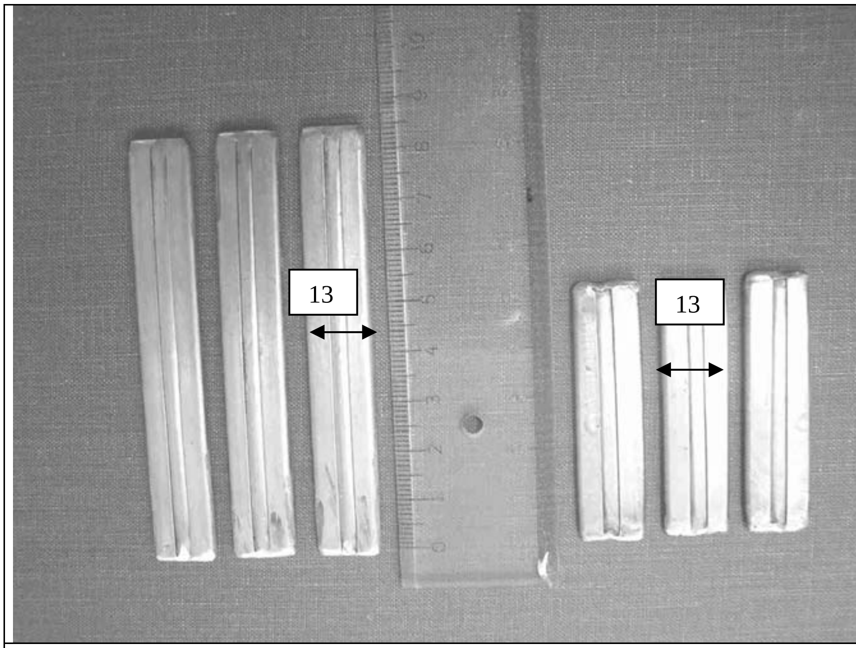

Figure 1 – Straight Test Coupons without butt-welded joint

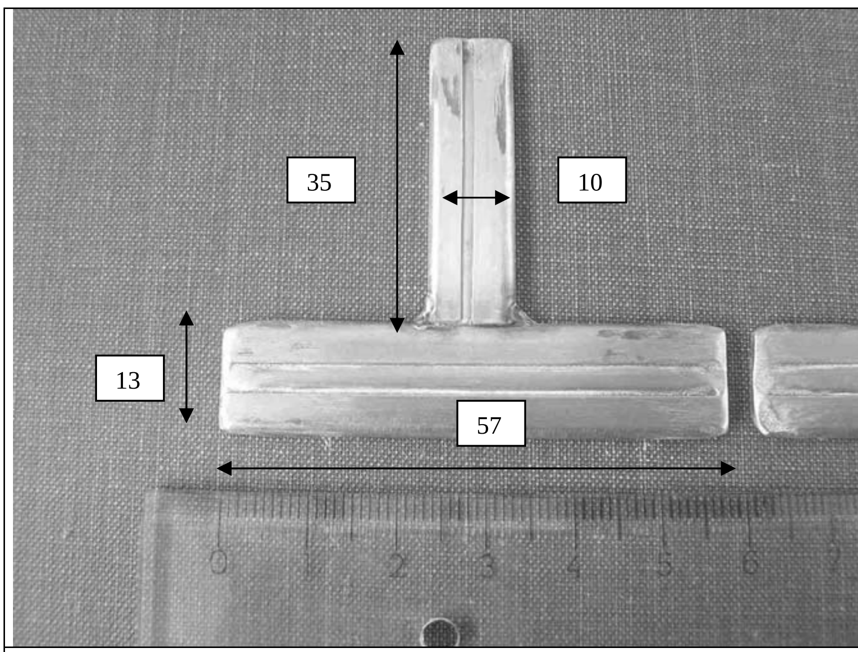

Figure 2 – Big "T" Test Coupons

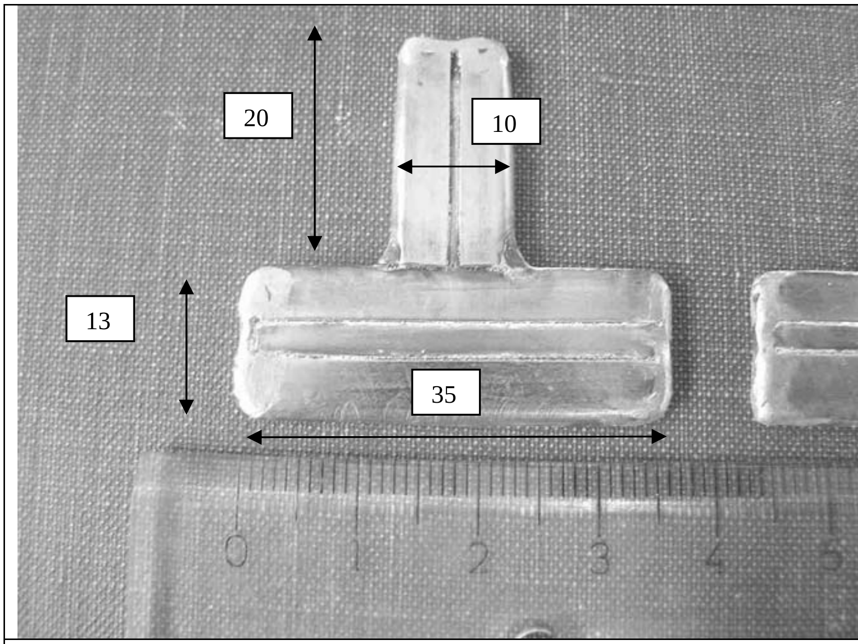

Figure 3 – Little " T " Test Coupons

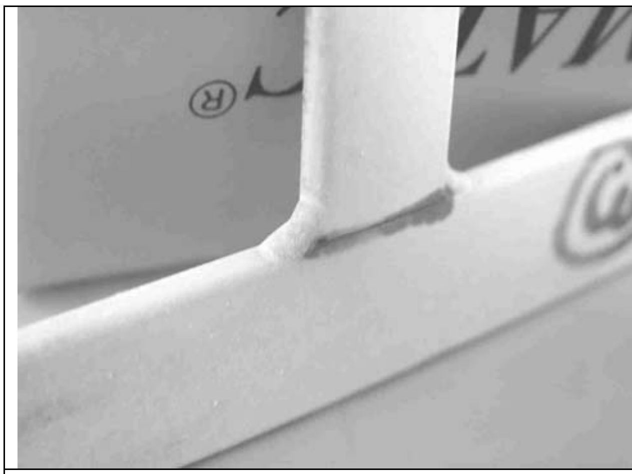

Figure 4 – Penetrant test after compression

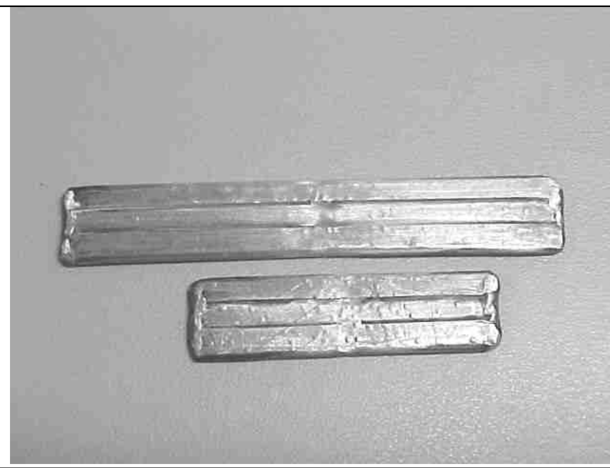

Figure 5 – Straight test coupons with butt-welded joint

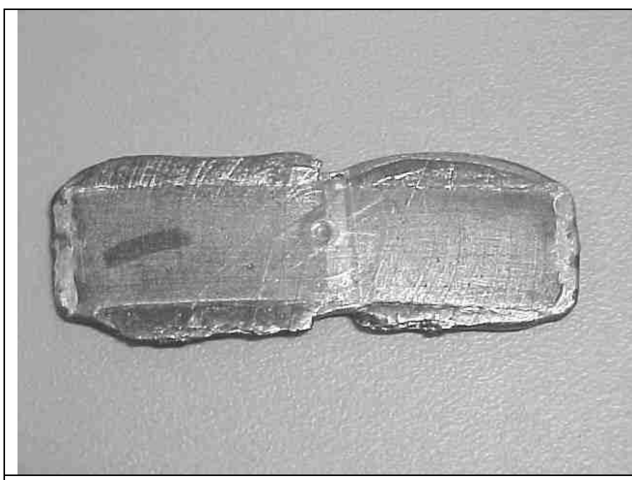

Figure 6 – CS jacket rupture

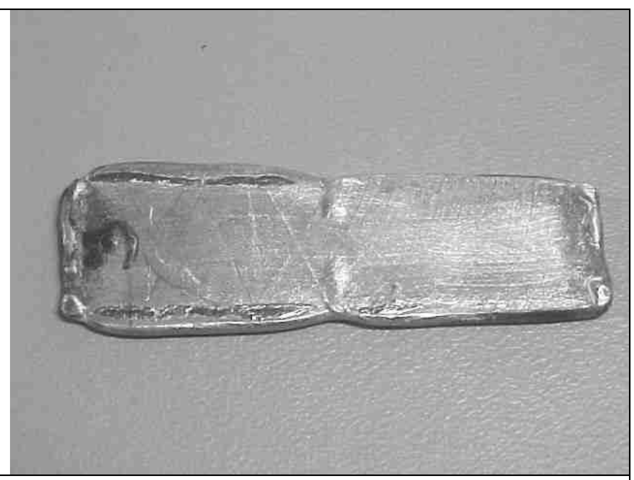

Figure 7 – CS jacket rupture


Figure 8 – Sealability test stands

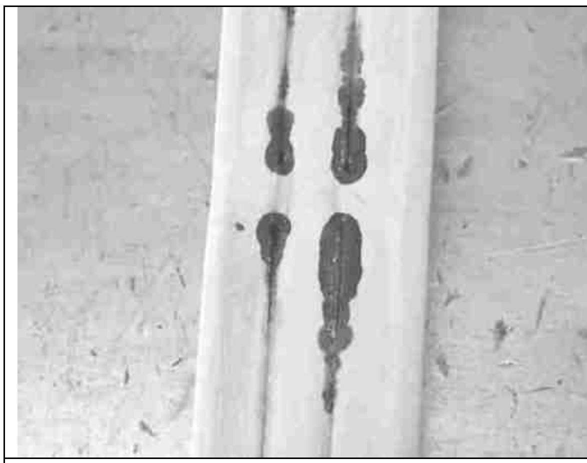
Figure 9 – Round indication in PT

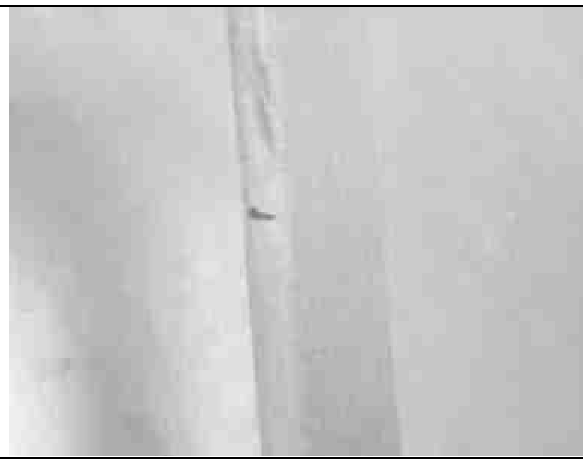
Figure 10 – Linear indication in PT

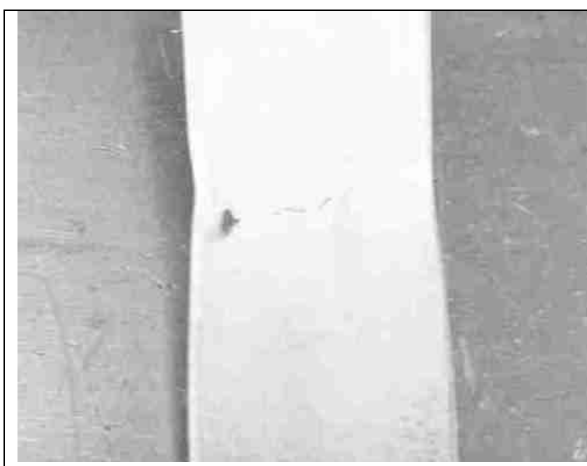
Figure 11 – Round indication in PT

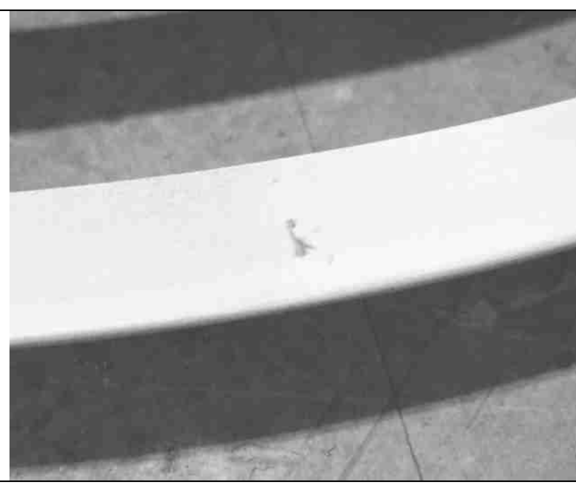
Figure 12 – Linear indication in PT

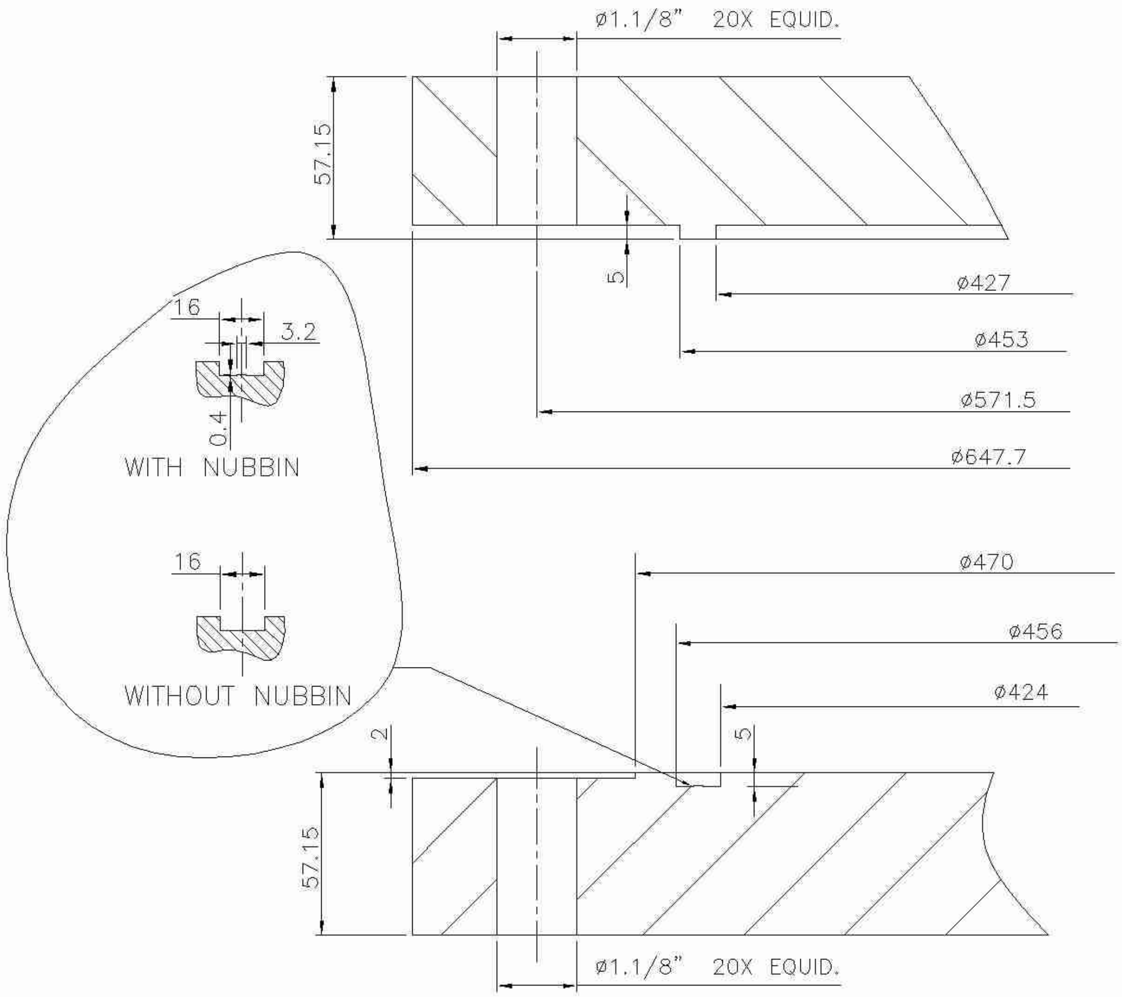

Figure 13 – Test flanges with nubbin and without nubbin.

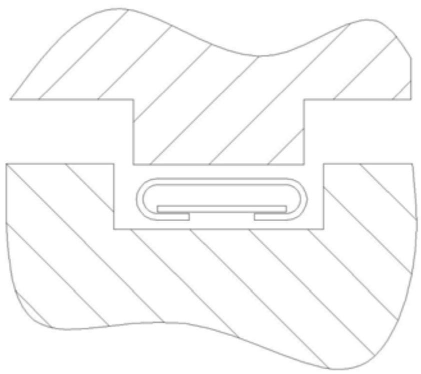

Figure 14 – Flange without nubbin, gasket centered with groove. Overlap opposite male.

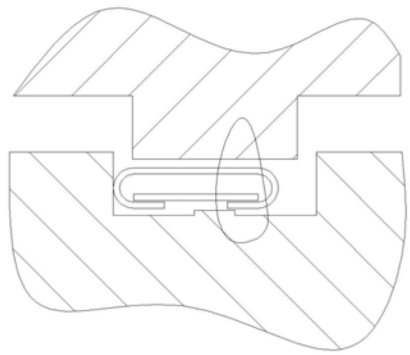

Figure 15 – Flange with nubbin, gasket not centered with groove. Ov

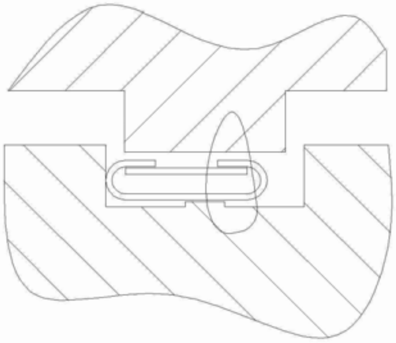

Figure 16 – Flange with nubbin, gasket not centered with groove. Overlap opposite nubbin.

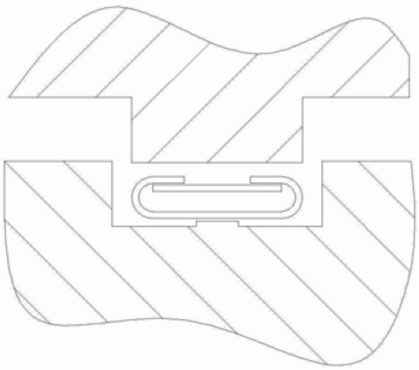

Figure 17 – Flange with nubbin, gasket centered with groove. Overlap opposite nubbin.

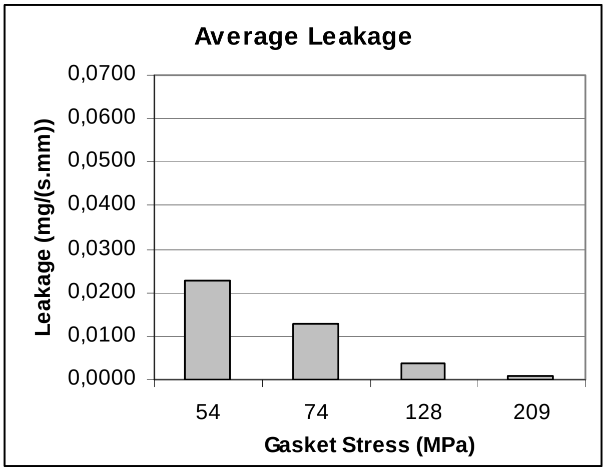

Figure 18 – Flange without nubbin, gasket centered with groove. Overlap opposite male.

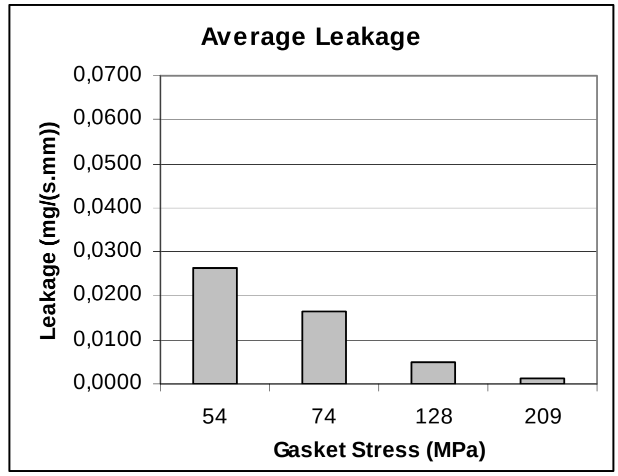

Figure 19 – Flange without nubbin, gasket not centered with groove. Overlap opposite male.

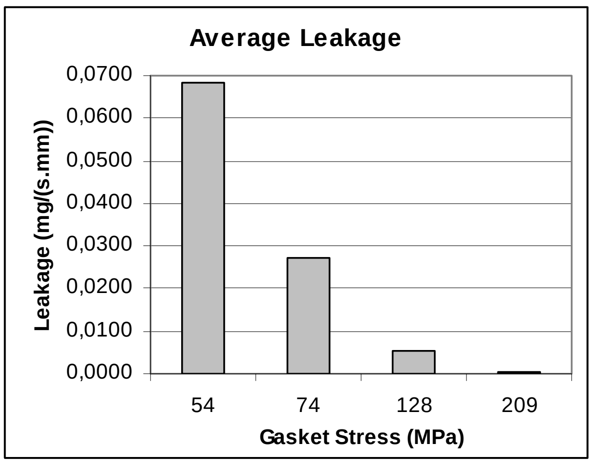

Figure 20 - Flange with nubbin, gasket centered with groove. Overlap opposite nubbin.

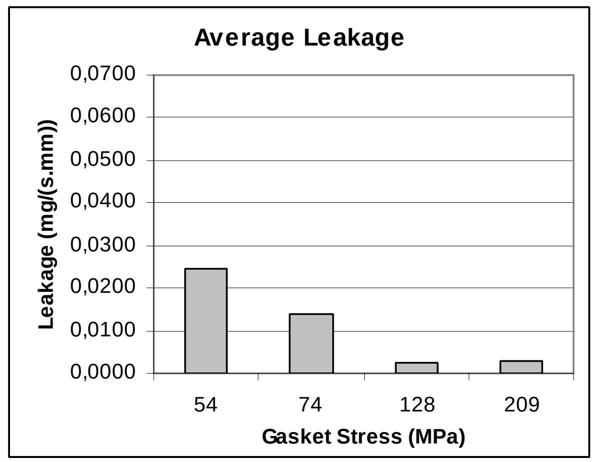

Figure 21 - Flange with nubbin, gasket not centered with groove. Overlap opposite nubbin.

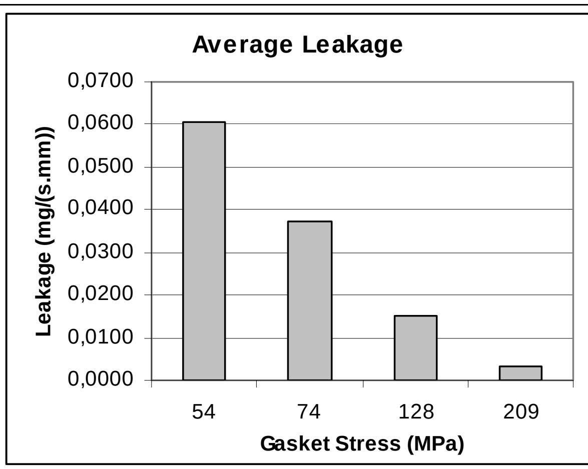

Figure 22 - Flange with nubbin, gasket not centered with groove. Overlap towards nubbin.

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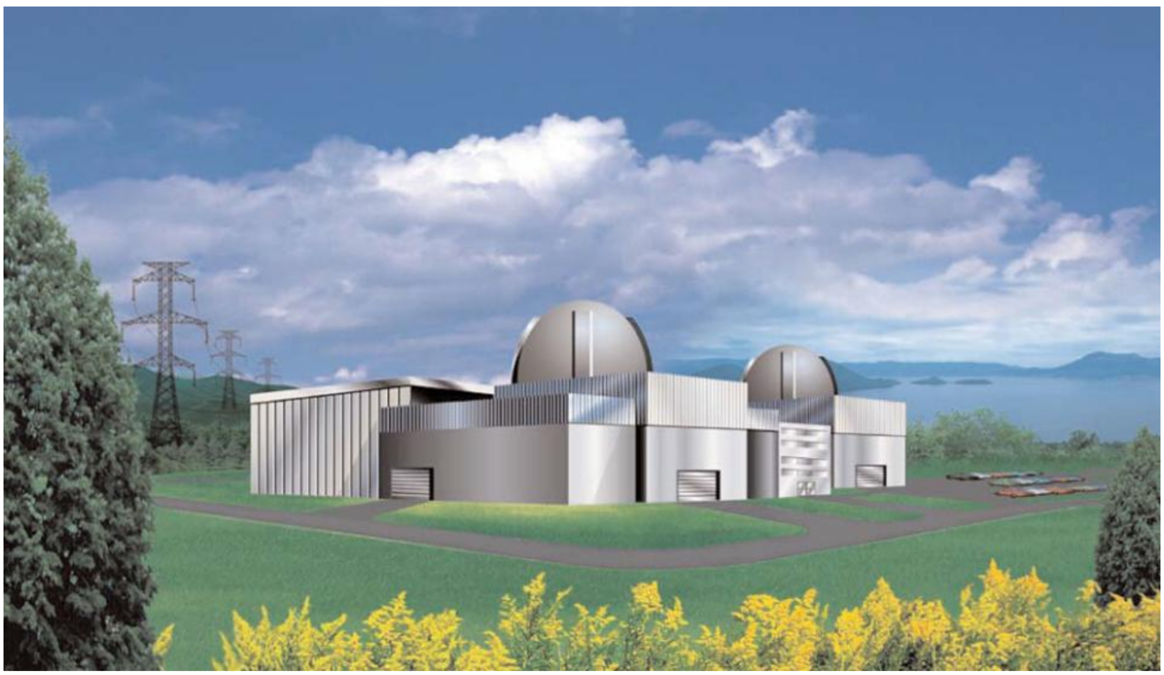

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HEAT EXCHANGER GASKETS RADIAL SHEAR TESTING

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ABSTRACT

Due to the high incidence of leaks in Shell and Tube Heat Exchanges 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.

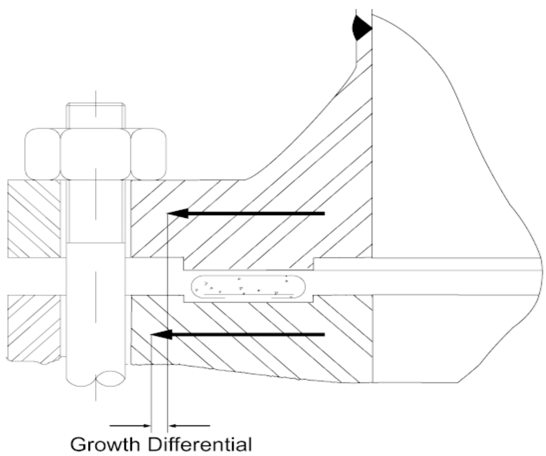

Figure 1

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.

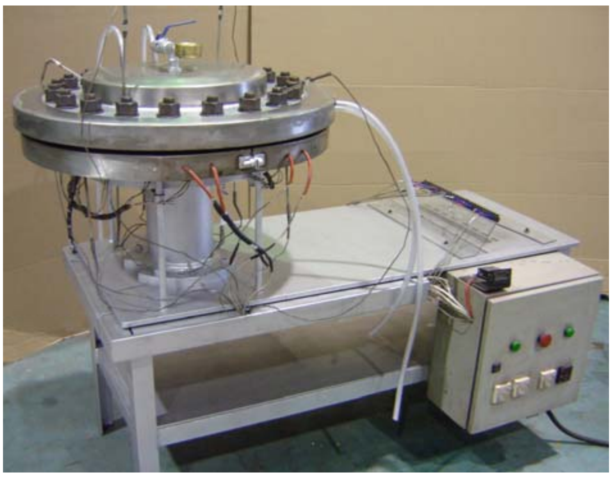

Figure 2

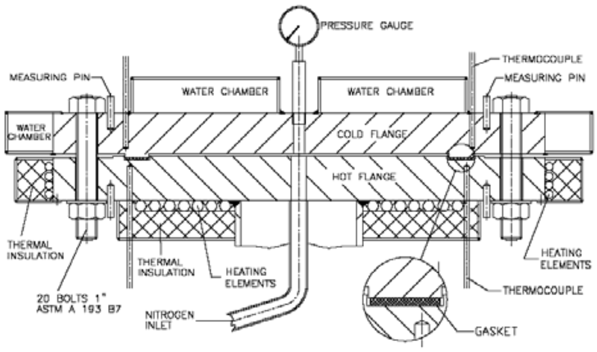

Figure 3

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.

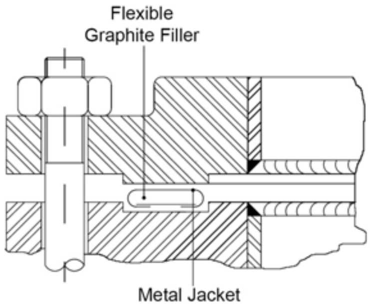

Figure 4

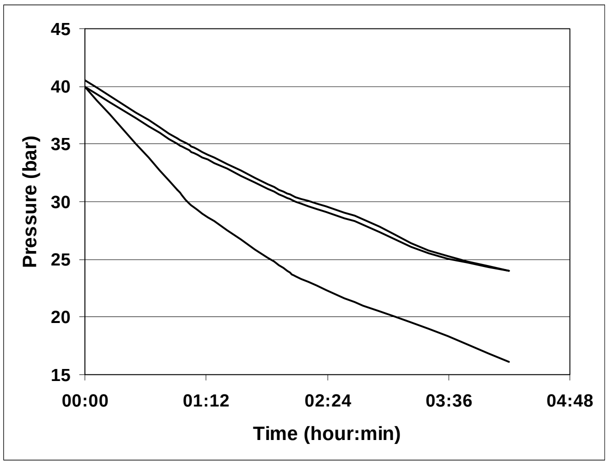

Figure 5

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.

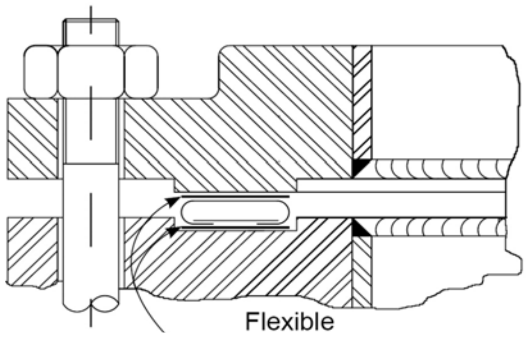

Figure 6

Figure 7

Figure 8

Figure 9

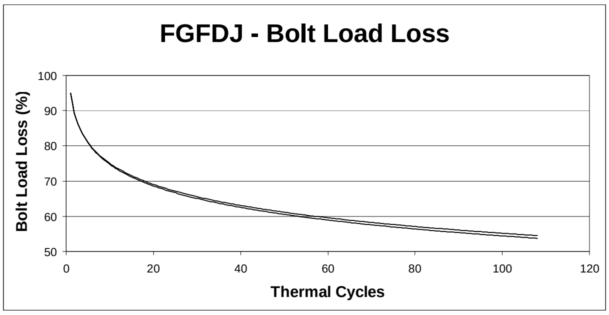

Figure 10

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.

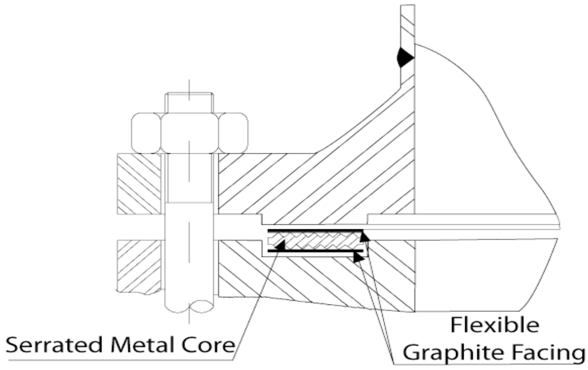

Figure 11

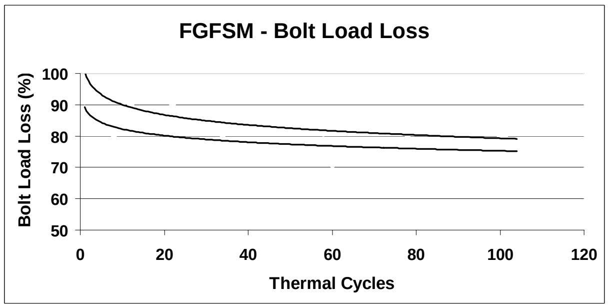

Figure 12

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.

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Proceedings of the ASME 2009 Pressure Vessels and Piping Division Conference
PVP2009
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SUPERHEATED STEAM TEST RIG FOR COMPRESSED NON-ASBESTOS GASKETS EVALUATION

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ABSTRACT

This paper presents a Superheated Steam Test Rig and a Test Procedure for Compressed Non-Asbestos (CNA) Gaskets qualification. The Test Rig is a versatile assembly that can use different flange sizes and heating systems. It simulates a Superheated Steam Boiler with a water feed pump, pressurized water tank, pressure relief valve, condenser and the flange pair acting as the Steam generation unit. Heating can be provided by an oven or heating element bands. The Test Protocol enables the evaluation of the gasket performance in Superheated Steam in severe operational conditions like high pressure and temperature with thermal cycling. Different types of non-asbestos compressed gaskets were tested monitoring the leak rate and bolt load at each thermal cycle.

1. INTRODUCTION

With the increased concern for safety, environmental and cost issues, the non-metallic gasket producers focus efforts to develop new materials while improving quality and the production process. As there is a vast diversity of gasket materials in the marketplace, it is difficult for users to specify the correct product because most of the properties shown in data sheets are not related to the performance in an actual application. These properties are evaluated following ASTM International (ASTM) procedures which were developed for material comparison or quality control purposes [1, 2, 3, 4].

The authors have published a paper [5] with a procedure to determine the maximum continuous service temperature of CNA gasket sheets. This procedure also does not address actual field conditions.

Steam service is part of almost every major industrial process. The Fluid Sealing Association (FSA) has developed a standard test method for testing non-metallic gaskets in Saturated Steam [6]. This test method has also been adopted by ASTM as a standard procedure [7]. It provides a means of assessing the performance of various non-metallic gaskets; it is particularly useful for non-asbestos gasket materials. This standard procedure is limited to Saturated Steam up to 295°C (563°F). According to Figure 1 [8, 9], it is possible to observe that there are a significant number of applications where Superheated Steam is required. These applications include higher thermal efficiency equipment and/or when water droplets can cause severe erosion in equipment like steam turbines.

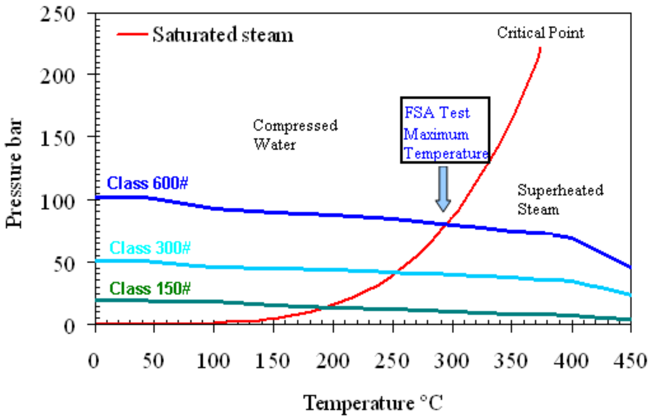

Figure 1 - ASME B16.5 Pressure-Temperature Ratings for ASTM A105 Flanges and the Saturated Steam Curve

Additionally, it is commonly recognized that most industry flanges are 150 and 300 psi rating class designations. Following ASME PCC1 guidelines [10], the seating stresses for 150, 300 and 600 psi bolted flange joint systems were calculated for ASTM SA-193-B7 low-alloy steel bolts, with 50 ksi bolt stress, as shown in Figure 2.

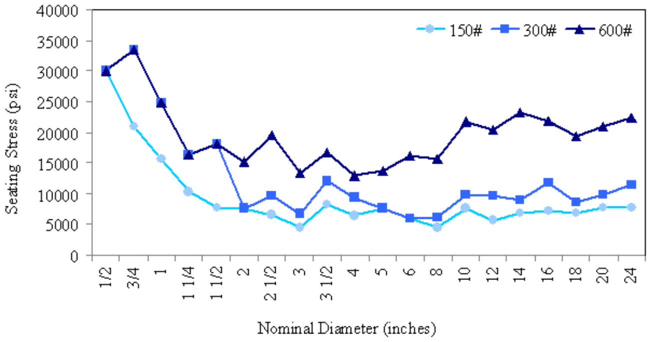

Figure 2 – Gasket Seating Stress for 150, 300 and 600 psi Flanges

The results demonstrate the following:

(a) 600 psi rating class has a higher seating stress than lower classes, and

(b) 150 and 300 psi bolted flanges sizes 2, 3, 6 and 8 inches of nominal diameter have gasket seating stress close to 5,000 psi.

The comparison between the values presented above and the gasket load recommended by FSA/ASTM test procedure (11,000 psi for 2" class 600 flanges) indicates that it may not reproduce the actual field applications where 150 and 300 psi bolted flanges with 2, 3, 6 and 8 inches are used.

An observation carried out within several industries in Brazil showed that most of gasket failures occur with 2, 3, 6 and 8" nominal diameter flanges. These failures occur at the re-start of a line which has experienced thermal cycles.

In many industrial processes, it is necessary to shut-down a steam line frequently. During process re-start, the system is pressurized quickly; however the temperature does not increase at the same rate. Since most of flange connections are not insulated, there is a temperature gradient on it; consequently, during operation the bolts are colder than flanges. When the line cools down the flange thermal contraction is greater than the bolts, reducing the gasket stress. At the re-start of the line the gasket is at its lowest load value.

In order to reproduce the field conditions in the laboratory, a Superheated Steam Test Rig (SSTR) was developed. This device enables to test CNA materials with Superheated Steam. The laboratory results were compared with field performance of the gaskets for validation of the new rig.

To reproduce common field installation practice in Brazil, the following installation conditions were purposely used in this study:

- The use of lubricating grease on the gasket surface;
- No retorque as recommended by the ASME PCC-1;
- Use of 3.2 mm (1/8 in) thick gaskets regardless of flange dimensions or media pressure.

These practices combined with the low gasket stress can lead to a low performance and ultimately a gasket blow-out.

2. TEST RIG DESCRIPTION

Field conditions simulated by the test rig:

- High temperature.
- Successive thermal cycles.
- Superheated Steam media.
- Internal pressure increase before the temperature increase.
- Bolt load consistent with class 150 psi flanges.

To simulate those conditions a test rig was developed with the following characteristics (Figures 3 and 4):

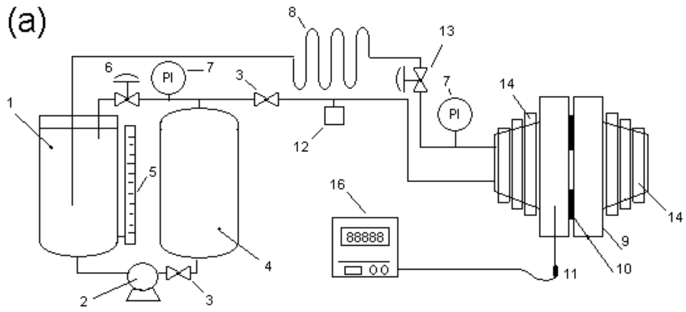

Figure 3 - Schematic of the Superheated Steam Test Rig with heating element tapes.

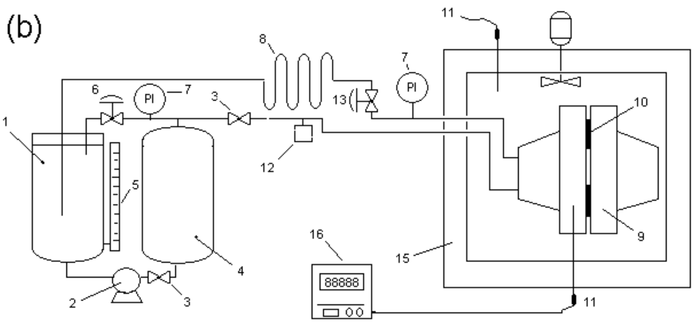

Figure 4 - Schematic of the Superheated Steam Test Rig with oven heating.

Test rig components:

1- Water Vessel.
2- Water Feed Pump.
3- Check Valve.
4- Pressure Vessel.
5- Calibrated Glass Sight Gauge.
6- Pressure Regulator.
7- Pressure Gauge.
8- Condenser.
9- Flange Set.
10- Test Gasket.
11- Temperature Sensor.
12- Pressure Controller
13- Relief Valve.
14- Heating Tapes.
15- Oven
16- Temperature Controller.

- A pair of NPS 6 class 150 cast steel fixture made from two RF weld neck flanges with surface finish of 6.4µm (250 µin). The flange set is the Superheated Steam generator (Figure 5). As shown in Figure 2, it has one of the lowest gasket seating stresses.

Figure 5 - Flange set cast steel 6 in class

- A water supply system with a Feed Pump and Pressure Vessel connected to the flange set like a boiler-water feed system. This system is equipped with a Steam Pressure Regulator to control the water feed keeping the Steam pressure stable. A picture of the water supply system is shown in Figure 6.

Figure 6 - Water supply system with water feed pump, pressure vessel and Steam condenser.

- A condenser to collect the excess Steam generated at the flange set (item 8).

- Two types of heating systems can be used:
  - Heating Tapes on the neck of the flange (Figure 7) that better simulate the heating in field.
  - Oven heating (Figure 8), which is easier to be used than Heating Tapes

- The leak rate is monitored by:
  - High leakage: Determined by the water level in the calibrated glass sight gauge.
  - Low leakage: Determined by the pressure decay method.

Figure 7 - Tape Heating SSTR

Figure 8 - Oven Heating SSTR

3. EXPERIMENTAL

3.1. Test Sequence

The following test sequence was taken on this study:
3.1.1. SSTR Method Test Validation.
3.1.2. Comparison between Oven Heating and Tape Heating.
3.1.3. Comparison between FSA/ASTM and SSTR Test Methods.
3.1.4. Comparison between the SSTR Test Method and the Field Gasket Performance.
3.1.5. Other Evaluations.

3.2. Test Procedure

3.2.1. Center the gasket into the flange face.
3.2.2. Install the calibrated bolts, washers and nuts finger tight.
3.2.3. Record bolt lengths before tightening.
3.2.4. Using a calibrated torque wrench, torque bolts according to the ASME PPC-1 [9] cross pattern. Gasket seating stress: 34 MPa (5000 psi);
3.2.5. Measure and record bolt elongations at room temperature.
3.2.6. Perform a hydrostatic test at room temperature and set pressure;
3.2.7. Start a heating cycle keeping the pressure constant at the set value. The excess pressure is released by the pressure relief valve as the system heats up.
3.2.8. Maintain the set test pressure and temperature for 8 hours.
3.2.9. Record the leak rate after the system has reached the set pressure and temperature and just before a cool down.
3.2.10. Record the leak rate just before starting the cool down phase (after 8 hours of heating).
3.2.11. Perform ten (10) daily cycles repeating steps 3.2.5 though 3.2.11.
3.2.12. The test is completed if one of following condition is reached:
- The gasket fails a hydrostatic test;
- The gasket blows-out;
- The leak rate during the hot phase is higher than the capacity of the water feed pump to replace the lost Superheated Steam;
- Ten cycles are completed successfully.

4. RESULTS AND DISCUSSION

4.1. SSTR Method Test Validation

The purpose of this sequence was to verify if SSTR Test Method was capable of producing different results for three styles of compressed non-asbestos fiber gasket sheets that are available in the market, as shown at Table 1. The test condition used in this evaluation was Superheated Steam at 300°C (572 °F) and 30 bar (435 psi).
The criteria used to select the materials were as follows:
- a product not suitable for the test condition, so a failure was expected;
- a product with application limits close to the test condition;
- a product considered suitable for test condition, so no failure was expected.

Table 1: Samples of Non-Asbestos Fiber Sheet

Material	Composition	Max. Temperature
Style A	Organic Fiber/NBR	220°C (428°F)
Style B	Synthetic Fiber/NBR	280°C (536°F)
Style C	Inorganic Fiber/NBR	400°C (752°F)

The *Style A* test result is shown in Figure 9. The test duration was 6 days. The Superheated Steam leakage in the 5º cycle was already excessive at $5x10^{-2}$ mg/s.m, when the blow-out occurred (Figure 10) and the test was aborted. The bolt load decreased continuously during each thermal cycle. As expected this product had the lowest performance of the three products selected to validate the test.

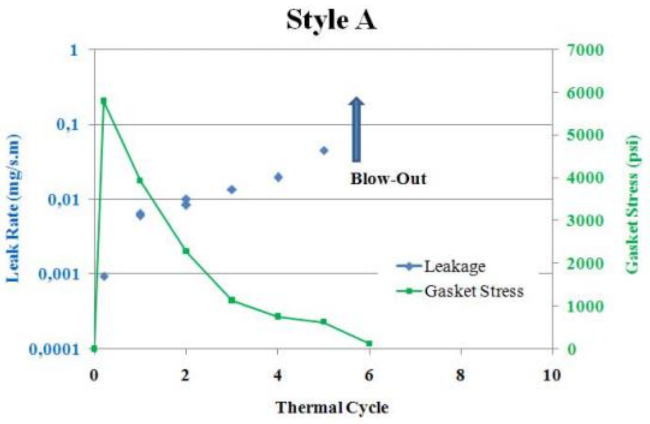

Figure 9 - *Style A* - 300°C (572 °F) & 30 bar (435 psi)

Figure 10 - Blow-out failure of *Style A*

The result for the second product – *Style B* – is shown in Figure 11. The test duration was 8 days, when the gasket failed a hydrostatic test. The leakage of the Superheated Steam had been stable at about $1x10^{-3}$ mg/s.m**.** The bolt load decreased continuously during each thermal cycle. As expected, the performance of *Style B* was better than *Style A.*

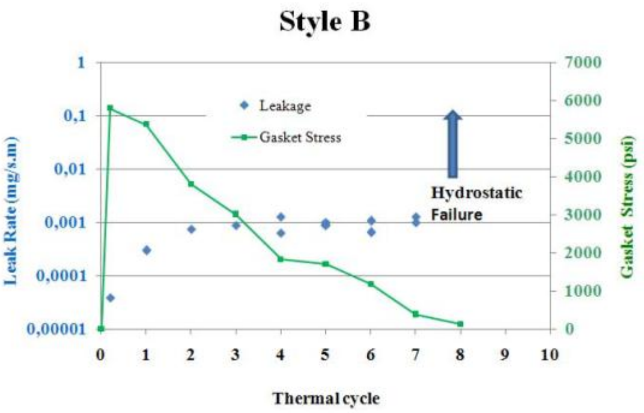

Figure 11 - *Style B* - 300°C (572 °F) & 30 bar (435 psi)

The test result for the third product – *Style C* – is shown in Figure 12. The test duration was 10 days. The leak rate of the Superheated Steam was approximately 2.4 x 10^{-4} mg/s.m. After the 10^{th} cycle an additional hydrostatic test was successfully performed. The bolt load decreased continuously during each thermal cycle, but at a lower rate than the other styles tested. As expected for the product, there was no failure and the leak rate remained stable for the test duration.

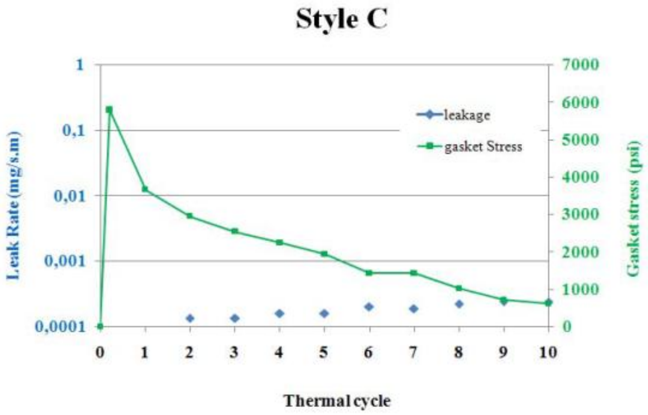

Figure 12 - *Style C* - 300°C (572 °F) & 30 bar (435 psi)

4.2. Comparison between Oven Heating and Tape Heating

The purpose of this test sequence was to verify the influence of the heating in an oven compared to tape heating. The sample used was *Style C* and the test condition was Superheated Steam at 400°C (752°F) & 12 bar (174psi). Ten daily cycles were carried out.

Heating the flange set with tapes wrapped around the flange welding neck is a better simulation of the field conditions where the heat comes from inside, as opposed to oven heating, where it comes from the outside. In order to demonstrate this behavior, temperature measurements were taken as shown in Figure 13. When the flange temperature (T1) in the gasket vicinity was stable at 400°C (752°F) bolt temperature (T2) was 325°C (617°F). This temperature differential causes a linear thermal expansion of the flanges 6.2 x10^{-2} mm (2.4 x 10^{-3} in) larger than the bolts. Consequently the bolts are stretched during the heat–up increasing the gasket stress. This additional bolt stretching does not occur when Oven Heating is used, because there is no temperature differential between bolts and flanges.

The results of Heating Tapes and Oven Heating are shown in Figures 14 and 15, respectively. The following observations were verified:

(a) The leak rate of *Style C* for the both tests was high and increased during each thermal cycle. These results were expected since *Style C* was tested close to its temperature limit.

(b) The bolt load loss was higher with Oven Heating than with Tape Heating. This behavior is in accordance with temperature measurement during the test (Figure 13).

Even though Tape Heating is a better simulation of actual conditions, Oven Heating is more convenient and, being more severe, provides us a "worst case scenario".

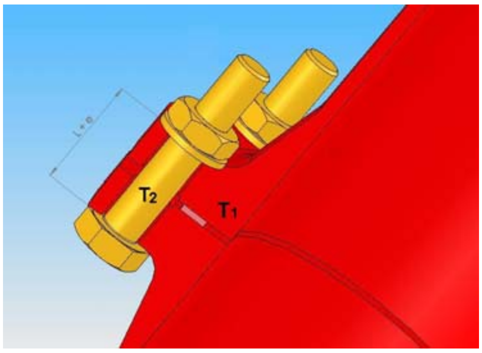

Figure 13 - Temperatures indications.

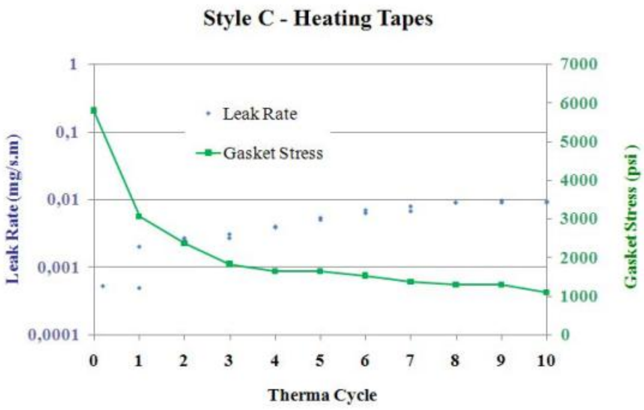

Figure 14 - *Style C* tested using Heating Tapes

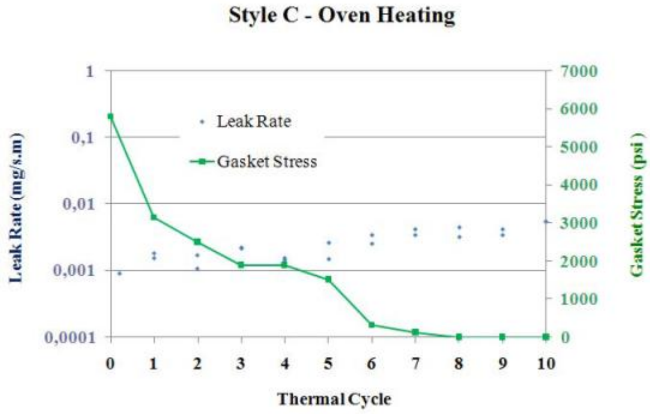

Figure 15 - *Style C* tested in an Oven

4.3. Comparison between FSA/ASTM and SSTR Test Methods.

The objective of this sequence was to compare the current FSA/ASTM Standard Test Method with the SSTR. The CNA sample tested is a product available in the market but not recommended for the test condition, consequently a failure was expected. The Table 2 shows the material composition and its temperature limit.

Table 2: Sample of Non-Asbestos Fiber Sheet

Material	Composition	Max. Temperature
Style D	Organic Fiber/NBR	200°C (392°F)

Since FSA/ASTM standard uses saturated Steam as media, the temperature used was the same for the both tests. However, in order to generate Superheated Steam, the SSTR test was run at a lower pressure. This difference results in two test conditions, as described bellow:

- FSA/ASTM standard method: 10 thermal cycles, Saturated Steam at 250°C (482°F), consequently the pressure is 40bar (580psi).
- SSTR test method: 10 thermal cycles, Superheated Steam at 250°C (482°F) and 30bar (435psi).

The leakage rates for both tests are shown in Figure 16 with the following results:

- The 12 grams water loss result of the FSA/ASTM indicates that *Style D* is adequate for Steam at 250°C (482°F).
- The *Style D* in SSTR with a 10 bar (145 psi) lower test pressure than the FSA/ASTM failed the hydrostatic test at the 5° cycle.

Although *Style D* had failed, the SSTR test was continued for research purposes. It was observed a continuously increase of leakage rate confirming that *Style D* is not suitable for application with Steam at 250°C (482°F).

The main differences between the SSTR and the FSA/ASTM procedures are the SSTR uses lower gasket seating stress and the hydrostatic test at the beginning of each thermal cycle. The SSTR gasket seating stress is 34 MPa (5000 psi) as opposed to 76 MPa (11000 psi) for the FSA/ASTM test. As described in the Introduction of this paper 76 MPa (11000 psi) is not realistic to most class 150 psi flanges, leading to a wrong application compatibility conclusion.

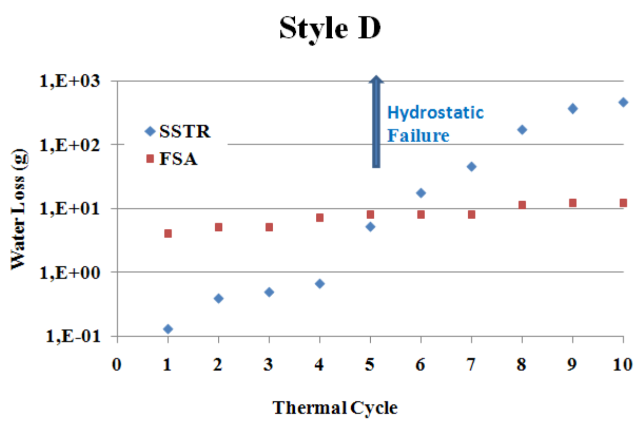

Figure 16 - Comparison between FSA/ASTM Test Procedures

4.4. Comparison between SSTR Test Method and Field Gasket Performance.

As shown in Figure 12, the compressed non-asbestos *Style C* SSTR test result indicates that it can be used in Superheated Steam at 300°C (572°F) up to 30 bar (435 psi). In order to validate the laboratory results, field performance evaluations were carried out in the five major Biofuel Plants located in Brazil.

The renewable energy sources remains high on the agenda of environmentally sustainable developments, these new Plants in addition of Biofuel productions, have also streamlined their process using the combustion of the waste process biomass for electrical energy generation.

These Biofuel Plants are an evolution of old sugar mills and, until just recently, used asbestos gaskets. There are no installations procedures like ASME - PCC-1 here and flanges are not always built in accordance with ASME or EN standards. The surface finishes are not regular and most of them are not thermally insulated. In order to assure that the tested material would meet these conditions, the gaskets were installed following common plant practices such as:

- Grease used on gasket surface to make it easy for its removal;
- No torque wrench used;
- No retorque was applied.

As no torque wrench is used, there is no assurance of correct gasket seating stress which can contribute to an excessive leak or gasket blow-out.

The criteria used to select the field application were:

- Test *Style C* in application with pressure and temperature as close as possible to a previous SSTR test, so a correlation could be established.
- Locations where *Style B* had failed. For these applications a spiral wound gasket (SWG) was being used. However, the Plant Management would like to have the flexibility offered with a CNA gasket sheet.

The Table 3 shows the Field Test conditions where *Style C* was tested. Each plant installed their gaskets using their procedures. "Torque Control" and "Re-tightening" were not applied.

Table 3: Superheated Steam Field Test Conditions

Plant	Number of Gaskets	Temperature	Pressure (psi)
A	6	300 °C (572°F)	21bar (305psi)
B	13	300 °C (572°F)	21bar (305psi)
C	6	330 °C (626°F)	22bar (319psi)
D	16	320 °C (608°F)	21bar (305psi)
	2	310 °C (590°F)	10bar (145psi)
E	4	280 °C (536°F)	21bar (305psi)

All gaskets were installed in March, 2008. At the time that this paper was prepared (February, 2009), they were still in operation without failures. The field test results showed satisfactory correlation between actual application and the SSTR laboratory simulations.

4.5- Other Evaluations

Different from the FSA/ASTM procedure, the proposed SSTR does not use saturated Steam which is limited to the water critical point (374°C or 705 °F). Tests at higher temperatures and pressure are possible and limited only by the mechanical and temperature limits of the flange set and the heating system.

Once the rig was developed, a series of tests were carried out for research purposes and to evaluate the rig capability. Sealability is the most important property of the gasket, because it determines its ability to seal. For this purpose, two styles of compressed non-asbestos fiber gaskets sheet of 3,2mm ($^1/_8$ in) from distinct manufacturers were used. Table 4 shows the composition and temperature limits for each style.

Table 4: Sample of Non-Asbestos Fiber Sheet

Manufacturer	Material	Composition	Maximum Temperature
A	*Style E*	Inorganic Fiber/NBR	400°C 752°F
B	*Style F*	Inorganic Fiber/NBR Wire reinforced	400°C 752°F

The first SSTR experiment was carried out with Superheated Steam at 400°C (752°F) and 12bar (174psi), with 10 daily thermal cycles. According to results, shown in Figure 17, it is possible to verify that:

- The performance of *Style E* was satisfactory since its leakage rate remained at low level and no leaks were observed during hydrostatic test.
- Different behavior was observed for *Style F* as its leak rate increased during each thermal cycle and it failed the hydrostatic test at the 8th cycle.

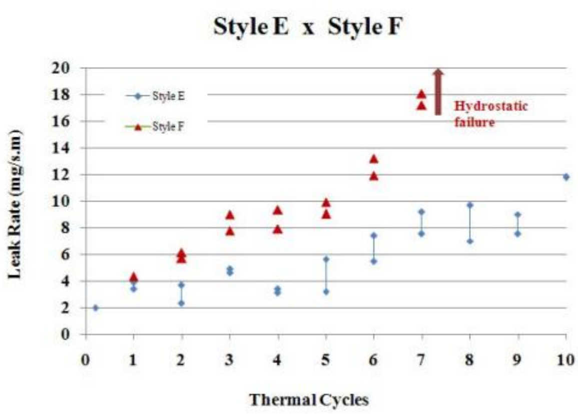

Figure 17 - 400°C (752°F) &12 bar (174psi)

The Second SSTR experiment was with Superheated Steam at 400°C (752°F) but the pressure was increased to 35bar (507psi) without daily thermal cycles.

The leak rates for each style are shown in Figure 18. The test results indicate that both styles failed at this test level. *Style E* had a blow-out on the 6th day (Figure 19) and the sealing performance of *Style F* was substantially reduced as its leakage increased sharply during the 4th day, consequently the test had to be aborted because the leakage rate was higher than the capacity of the water feed pump.

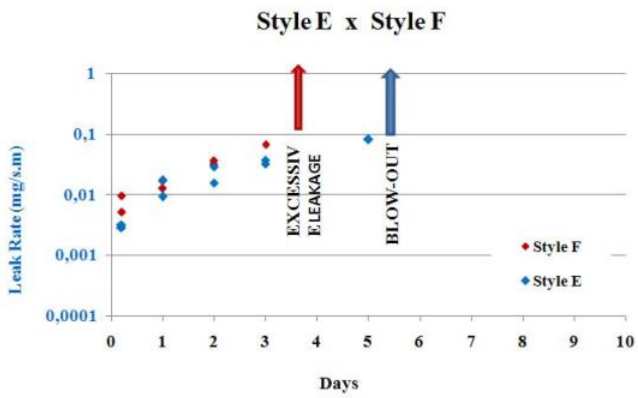

Figure 18 - Comparison at 400°C (752°F) & 35 bar (507psi)

Figure 19 - Blowout of *Style E*

5. CONCLUSIONS

The Superheated Steam Test Rig (SSTR) was developed to meet the need to have a Steam Service Test Method which reproduces the field gasket conditions. The experimental tests showed that:

- The SSTR was successfully developed and a good correlation with field application results was also established.
- It was possible to reproduce in the laboratory Superheated Steam service conditions enabling an economical way to test, compare and develop new products for this application.

- Using Superheated Steam as test media, the SSTR is not restricted by the Saturated Steam pressure x temperature values. Temperatures above the Water Critical Point can be simulated.

- Specific operating conditions of P and T can be easily simulated by just changing the temperature and pressure settings of the rig. The P x T values or charts usually informed by product manufactures can be developed. Other conditions such as thermal cycles or continuous service are also easy to be reproduced.

- The SSTR can also be used to study the temperature influence on non-asbestos gasket degradation and/or service lifetime prediction. However, these studies were not the purpose of this paper.

- Since SSTR uses commercially available flanges, actual field conditions like flange rotation and low bolt load are reproduced. In addition, using a set of standard flanges makes it easy and inexpensive to test other flange configurations, like tongue and groove, male-female or other sealing surface finishes.

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Tealon TF1570

DESCRIPTION

TEALON TF1570 is a structured PTFE - Gasket - Sheet manufactured by a unique process which provides a high level of fibrillation to overcome the creep relaxation and cold flow problems associated with normal (skived or molded) PTFE sheets. This style is produced from virgin PTFE resin filled with hollow glass micro spheres.

APPLICATION / SERVICE

TEALON TF1570 is suitable for service with a wide variety of aggressive fluids, including hydrocarbons, acids, solvents, water, steam, hydrogen-peroxide, refrigerants, etc. The high compressibility of this style makes it particularly suitable for use with stress sensitive and/or fragile flanged joints, e.g. glass, ceramics, plastic, etc. The gasket material was tested to be in conformance per FDA requirement Method 21 CFR177.2260

AVAILABILITY

TEALON TF1570 is available in sheets of 59” x 59” (1500mm x 1500mm) with a thickness of 1/16” or 1/8”.

SERVICE LIMITS		
Type	**Description**	**Value**
Temperature	Minimum	-350°F (-210°C)
	Maximum	500°F (260°C)
Pressure	Maximum	800 psig (55 bar)
Color	blue	
pH		0-14
P x T* max		350,000 (12,000)**
		250,000 (8,600)***

* P x T = psig x °F (bar x °C)
** Based on 1.5mm sheet thickness
*** Based on 3.0mm sheet thickness

TYPICAL PHYSICAL PROPERTIES

ASTM Test Method*	Property	Value
ASTM F36 A	Compressability Range (%)	30-50
ASTM F36 A	Recovery (%)	30
ASTM 152	Tensile Strength (MPa)	14
ASTM D792	Specific Gravity (g/cm^3)	1.70
ASTM F38	Creep Relaxation (%)	40
ASTM F37 A	Sealability (ml/h @ .7 bar)	0.12
DIN 3535	Sealability (cm^3/min)	<.015

*ASTM tests are based on 0.80mm sheet thickness and DIN test is based on 1.50mm sheet thickness

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Properties and application parameters shown throughout this datasheet are typical. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury. Specifications are subject to change without notice. This edition supersedes all previous issues.

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Tealon TF1580

DESCRIPTION

Tealon TF1580 is a structured PTFE Gasket Sheet manufactured by a unique process which provides a high fibrillation level to overcome the creep relaxation and cold flow problem associated with skived PTFE sheets. This style is produced with virgin PTFE resin filled with Barium Sulfate.

APPLICATION / SERVICE

Tealon TF1580 It is suitable for services with general service in wide variety of fluids, strong caustics, moderate acids, chlorine, gases, water, steam, hydrocarbons, hydrogen and aluminum flouride. The gasket material was tested to be in conformance per FDA CFR177.2260

TF1580 is listed by Chlorine Institute Pamphlet 95.

AVAILABILITY

Tealon TF1580 is available in sheets of 59” x 59” (1500mm x 1500mm) with a thickness of 1/16” or 1/8”.

SERVICE LIMITS		
Type	**Description**	**Value**
Temperature	Minimum	-350°F (-210°C)
	Maximum	500°F (260°C)
Pressure	Maximum	1200 psi (83 bar)
Color	off-white	
pH		0-14
P x T* max		350,000 (12,000)**
		250,000 (8,600)***

* P x T = psig x °F (bar x °C)
** Based on 1.5mm sheet thickness
*** Based on 3.0mm sheet thickness

TYPICAL PHYSICAL PROPERTIES		
ASTM Test Method*	**Property**	**Value**
ASTM F 36A	Compressibility Range @ 5000 psi	4-10
ASTM F 36A	Recovery (%)	40
ASTM 152	Tensile Strength (MPa)	14
ASTM D 792	Specific Gravity (g/cm^3)	2.90
ASTM F 38	Creep Relaxation	11
ASTM F 37A	Sealability (ml/h @ .7 bar)	0.04
DIN 3535	Sealability (cm^3/min)	<.015

*ASTM tests are based on .80mm sheet thickness and DIN test is based on 1.50mm sheet thickness.

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Tealon TF1590

DESCRIPTION

Tealon TF1590 is a restructured PTFE Gasket Sheet manufactured by a unique process which provides a high fibrillation level to overcome the creep relaxation and cold flow problem associated with skived PTFE sheets. This style is produced with virgin PTFE resin filled with Silica.

APPLICATION / SERVICE

Tealon TF1590 is suitable for services with high pressures and temperature, especially in chemical processing and hydrocarbon plants in strong acids (except hydrofluoric), solvents, hydrocarbons, water, steam, and chlorine.The gasket material was tested to be in conformance per FDA CFR177.2260

TF1590 is listed by Chlorine Institute Pamphlet 95.

AVAILABILITY

Tealon TF1590 is available in sheets of 59” x 59” (1500mm x 1500mm) with a thickness of 1/16” or 1/8”.

SERVICE LIMITS

Type	Description	Value
Temperature	Minimum	-350°F (-210°C)
	Maximum	500°F (260°C)
Pressure	Maximum	1200 psig (83 bar)
Color	fawn	
pH Range	0-14	
P x T max*		350,000 (12,000)**
		250,000 (8,600)***

* P x T = psig x °F (bar x °C)

** Based on 1.5mm sheet thickness

*** Based on 3.0mm sheet thickness

TYPICAL PHYSICAL PROPERTIES		
ASTM Test Method	**Property**	**Value**
ASTM F 36A	Compressibility @ 5000 psi	7-12
ASTM F 36A	Recovery (%)	40
ASTM 152	Tensile Strength (MPa)	14
ASTM D 792	Specific Gravity (g/cm^3)	2.10
ASTM F 38	Creep Relaxation (%)	18
ASTM F 37A	Sealability (ml/h @ .7 bar)	0.2
DIN 3535	Sealability (cm^3/min)	< 0.015

*ASTM tests are based on .80mm sheet thickness and DIN test is based on 1.50mm sheet thickness

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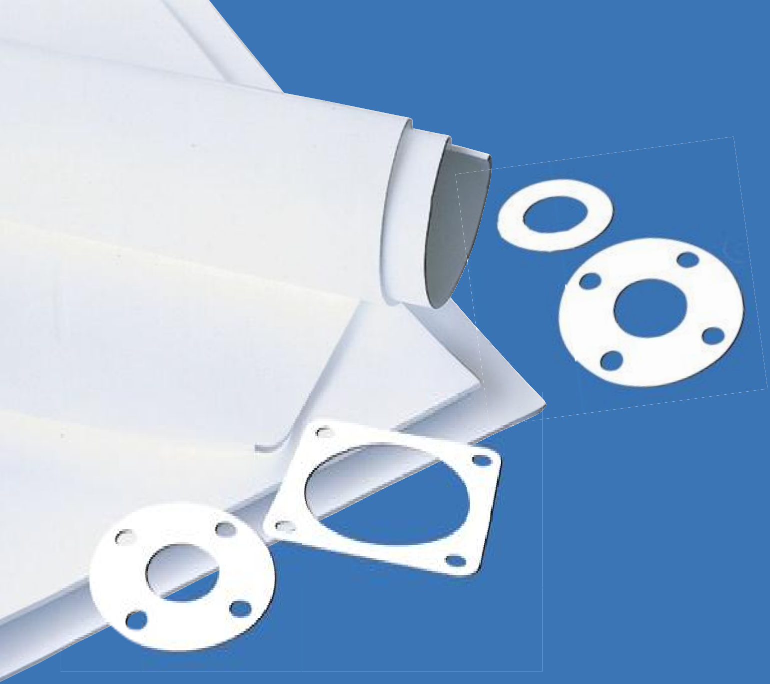

TF 1560
PTFE Gasket Sheet

DESCRIPTION:

TF 1560 is a structured PTFE - Gasket - Sheet manufactured by a unique process, which provides a high level of fibrillation to overcome the creep relaxation and cold flow problems associated with normal (skived or molded) PTFE sheets.
This style is produced from virgin PTFE resin without fillers or additives.

APPLICATION / SERVICE:

Due to the product's low permeability it is recommended for application where media permeation through the gasket is not acceptable.
TF 1560 is quick and simple to install. The gasket can be removed easily after use and without residue.

- ✓ Restructured without filler
- ✓ Better creep properties
- ✓ Better torque retention
- ✓ Low porosity PTFE resin
- ✓ High sealability

COMPANY ISO 9001

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FIELD TEST:

BUTADIENE APPLICATION

Problem Description

The Monomer is polymerizing on the gasket ID eventually blocking the line and swelling the gasket. Gaskets had to be replaced after only a few cycles to avoid leaks and to eliminate the risk of explosion.

Service Conditions

- Hydrogen peroxide 70%, butadiene and ethanol steam.
- Temperature: ambient to 145 ^{0}C (293 ^{0}F).
- Pressure: vacuum to 30 bar (427psi).
- 4 temperature and pressure cycles per day.

Conclusion

The Skived gasket showed Popcorn and high polymerization inside the gasket, with reduction of the inside diameter after 12 cycles. After 180 cycles TF 1560 showed low polymerization, non-reduction of the internal diameter.
Figure 1 shows the Skived gasket after 12 cycles.
Figure 2 shows the TF 1560 gasket after 180 cycles.

Figure 1

Figure 2

STYRENE APPLICATION

Problem Description

The Monomer is polymerizing on the gasket ID eventually blocking the line and swelling the gasket. Gaskets had to replaced after a few days.

Service Conditions

- Styrene + Chloride acid.
- Temperature: 90 ^{0}C (194 ^{0}F).
- Pressure: 2 bar (29psi).

Conclusion

- **Skived :** Normal life time – between 60, 90 days with polymerize inside the gasket
- **TF1560 :** Installed since august of 2006, without problems.

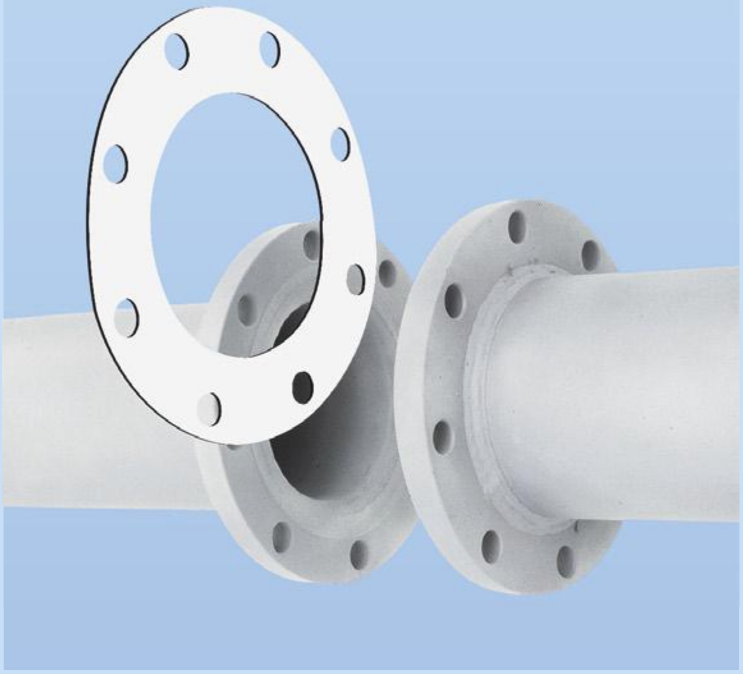
Figures 3 shows the Skived gasket in service for less than one week.

Figure 3

Typical Physical Properties	Typical Results
Density - ASTM F1315 - g/cm^3	2.15
Compressibility - ASTM F36A - %	10
Recovery - ASTM F36A - % minimum	60
Creep Relaxation - ASTM F38 - %	60
Sealability - DIN 52913 - cm^3/min	< 0.015
Sealability - ASTM F37A - ml/h - 0,7 bar	< 0.1
pH	0 - 14

Typical values based on 2.0 mm sheet thickness.

Availability	**Sizes:** 1000 x 1000 mm **Thickness:** 1.5 , 2.0 and 3.0 mm
Limit Temperature	**Minimum:** -240^0 C / -464^{0}F **Maximum:** 260^0 C / 500^{0}F
Pressure	**Maximum**: 50 (bar) / 725 (psi)
Color	white-translucent



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	TEALON			Competitor 1			Competitor 2		
Nominal Thickness (mm)	Thickness (mm)	Dielectric Strength (kV/mm)	(volts/mil)	Thickness (mm)	Dielectric Strength (kV/mm)	(volts/mil)	Thickness (mm)	Dielectric Strength (kV/mm)	(volts/mil)
0.8	0.9	**27.1**	**688**	- -	*** 11**	**279**	- -	**22.7**	*** 577**
1.5	1.58	**22.2**	**564**	1.74	**17.1**	**434**	1.57	**18.9**	**479**
3.2	3.19	**NA** (See note 2)	**NA** (See note 2)	3.33	**NA** (See note 2)	**NA** (See note 2)			
0.8	0.85	**27.8**	**707**	- -	*** 17,7**	**450**	- -	**19.7**	*** 500**
1.5	1.57	**25.6**	**649**	1.60	**14.0**	**355**	1.56	**12.9**	**328**
3.2	3.14	**NA** (See note 2)	**NA** (See note 2)	3.26	**13.6**	**346**			
0.8	0.88	**13.0**	**329**	- -	*** 6,1**	**155**	- -	**12.0**	*** 305**
1.5	1.59	**18.5**	**469**	1.65	**12.0**	**305**	1.58	**12.9**	**328**
3.2	3.18	**8.0**	**291**	3	**9.6**	**244.0**			

White area is TF 1580
Fawn area is TF1590
Blue Area is TF 1570

Note 1:(*) data sheet values.
Note 2: exceeds 50 kV, which is the equipment capability.

"Restructured Filled PTFE Gasket Sheets" Test Comparisons

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New York, NY, USA

“Restructured Filled PTFE Gasket Sheets” Test Comparisons

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Keywords:
PTFE Gasket Sheets
PTFE Gaskets
Filled PTFE Sheet
Restructured PTFE
Structured PTFE

Abstract:
To maintain a good seal, gasket materials must exhibit dimensional stability and resistance to temperature, pressure and chemical media. Conventional PTFE gasket materials have an outstanding chemical resistance but lack dimensional stability. Under pressure and temperature, conventional PTFE materials creep and flow. After a short period in service, gaskets made conventionally, from pure PTFE, are unable to maintain the high loads and as a result, lose thickness due to creep relaxation. Re-tightening is often necessary to keep the joint leak free. Several alternatives are used to reduce this problem. In this paper, several PTFE gaskets sheets available in the marketplace are compared. Tests like temperature cycle, torque retention, creep relaxation and compressibility have been performed and the results analyzed. From the results, it is shown that “Structured PTFE Filled Sheets” exhibit the best balance of the desired properties.

1. Introduction

PTFE gaskets are used in applications where it is necessary to achieve a high chemical resistance. PTFE has distinct physical properties to meet the needs of each application. As with any fluid sealing material there is overlap. Several materials can be used successfully in the same application. In this paper, several PTFE gaskets types available in the marketplace are compared. Tests, which included temperature cycle, torque retention, creep relaxation and compressibility, were performed and the results analyzed.

2. Molded Sintered PTFE Sheet

Molded Sintered PTFE sheets were the first products introduced in the market. Manufactured from virgin or reprocessed PTFE resin, without fillers, which is first molded, then compressed and sintered. As with any plastic product the PTFE exhibits a creep characteristic when subjected to a compression force. This characteristic is very detrimental to the gasket performance since it requires frequent retightening to avoid and reduce leaks. Creep behavior is increased dramatically with an increase in temperature. The main advantages of molded PTFE are low cost, ample market availability and high chemical resistance.

3. Skived PTFE Sheet

Skived PTFE (sPTFE) is manufactured from virgin or reprocessed PTFE resin without fillers, by skiving a sintered PTFE billet. This process was developed to overcome the manufacturing deficiencies of the Molded Process. However its products have the same creep behavior problems. Shown in Figure 1 (with magnification of 100 times).

4. Molded or Skived Filled PTFE Sheet

To reduce the creep behavior of Molded or Skived PTFE sheet materials mineral fillers or fibers are added. However, due to the manufacturing process (molding or skiving) this reduction is not enough to produce a long-term effective seal. Figure 2 shows the microstructure of a Filled Skived PTFE sheet with a magnification of 100 times. Visible are the silica filler particles in the PTFE matrix.

5. Expanded PTFE

Before sintering, hot expansion of the PTFE gives it the ability to overcome creep. Gasket products expanded in one direction (cords or tapes) or bi-axially (sheets) can be produced. Figure 3 shows a one direction PTFE structure and Figure 4 shows a bi-axially oriented structure. Expanded PTFE (ePTFE) has a high chemical resistance and exhibits a very high compressibility ideal for use with fragile or glass lined flanges. Most Expanded PTFE products in the market do not have fillers. Its main drawback is the handling and installation of large gaskets or installation when it is not possible to separate the flanges. It is often used as a replacement for the Hollow Glass Micro-Spheres (Figure 5) sheet with the advantage of a higher chemical resistance; Glass Micro-Spheres are attached by Caustic Soda. However, in the case where gaskets are installed in a long line with several flanges in series, installation problems can occur due to the reduced gasket thickness after seating. The total length of the piping may not be enough to compensate.

6. Restructured Filled PTFE Sheet

To reduce the creep a new manufacturing process was developed to produce filled PTFE sheets. The material is subjected to a lamination process before sintering, creating a highly fibrillated structure. Creep at both room and high temperature is substantially reduced. To meet the chemical service needs several mineral or artificial fillers are used, such as Barite, Mineral and Synthetic Silica, Barium Sulphate or Hollow Glass Micro-Spheres. Each filler has a specific service application but there may be overlap in many of these applications. This process is referred as rPTFE. Figure 5 shows rPTFE filled with hollow glass micro-spheres with magnification of 100 times. The micro-spheres can clearly be seen inserted in the fibrillated PTFE matrix. Figure 6 shows a rPTFE filled with Barite with magnification of 100 times and Figure 7 the same product enlarged 500 times. Figure 8 shows a grain of Silica inserted in the fibrillated PTFE structure with magnification of 100 times.

7. Tests Performed

Several tests were performed to evaluate the properties of each of material. The materials tested are identified throughout this paper as follows:

- First digit: P denotes a PTFE sheet
- Second digit: type of sheet
  - R - restructured PTFE with filler
  - F – skived filled
  - V – skived virgin
- Third digit: type of filler.
  - B: barite
  - S: silica
  - G: hollow glass micro-spheres
  - F: fiber glass
- Fourth and fifth digit: manufacturer

Examples:
PRB11 – restructured sheet with barite, manufacturer 11.
PFG19 – reinforced sheet with glass micro-spheres, manufacturer 19.

7.1. Temperature Cycling

All temperature cycling test were performed using standard ASME B16.5 flanges. After installation of the gasket, heat is applied. When the temperature reaches 250ºC (482ºF) the system is pressurized with Nitrogen. After stabilizing the temperature, the heat is turned off until it reaches 28ºC (82.4ºF) when it is turned on again. This cycle is repeated 3 times. The pressure decay is monitored and reported. Figures 9 and 10 show the comparison between hollow-glass spheres filled rPTFE and sPTFE. Due to the higher creep relaxation; the sPTFE gasket lost about 63% of the initial N_2 pressure. On the other hand, the rPTFE lost less than 1%. Figure 10 shows the reduction of the gasket stress of the skived material (PGV) compared with the rPTFE (PRG1). This reduction is the cause of the higher leak rate for the PVG product.

7.2. Deformation under stress

Gasket specimens are compressed between two pre-heated smooth platens for one minute. Figure 11 shows pictures of the gaskets after the test. The temperature is 260^{o}C (500^{o}F) and the gasket stress is 10 MPa (1500 psi). The skived PTFE gasket deforms loosing its shape. This very simple test shows clearly the higher creep resistance of the rPTFE as compared with the sPTFE

7.3. Creep at High Temperature

This test is performed following the DIN 28090-2 procedure. The test apparatus is shown in Figure 43. For PTFE products, compression modulus at room temperature (eksw) and at elevated temperature (ewsw/t) should not exceed 20% and 50% respectively. And elevated temperature test is performed at 150ºC (302ºF) for 16 hours. Figures 12 through 15 show the behavior at room temperature and Figures 16 through 19 at high temperature. Figures 20 show the average values at room temperature and Figure 21 at elevated temperature. The products filled with hollow glass micro-spheres show higher compressibility than others. This material is designed for fragile flanges where this characteristic is required to assure the proper gasket seating. The less dense structure of this product can also be seen in Figure 5. Comparing, the sPTFE with rPTFE the former has higher compressibility. At 150ºC (302ºF) the creep for the sPTFE is about 50%, this value is very high than rPTFE results. This test confirms the findings of the Temperature Cycling described earlier in this paper. It can also be noticed that the Silica filler gives the best resistance to creep at high temperature.

7.4. Stress relaxation

This test follows the DIN 52913 procedure. The test apparatus is shown in Figure 44. Sample material is installed with a seating stress of 50 MPa (7251 psi) and the temperature is raised to 150ºC (302ºF). After 16 hours the remaining gasket stress is measured. Figures 22 through 25 show rPTFE results. Figure 26 shows the comparison of the average values for sPTFE and rPTFE. It can be noticed that the diverse rPTFE products have a similar behavior for each kind of filler, and they exhibit lower stress relaxation than the sPTFE products.

7.5. Sealability ASTM

Using ASTM F37 B procedure the test sample is seated with 7 MPa (1000 psi) and tested with isooctane at 0.7 bar (9.8 psi). The testing apparatus is shown in Figure 46. Results are show in Figures 27 through 31. Regardless of the filler, rPTFE products have a higher sealability than the sPTFE. In addition the Barite filled rPTFE showed the best results.

7.6. Compressibility and Recovery

This test follows the ASTM F36 procedure. The compressibility is the change in thickness when a seating stress of 14.5 MPa (5000 psi) is applied on the material. The recovery is how much it recovers when this load is removed. Both are expressed as a percentage of the initial thickness. Figures 32 through 37 show the test results. The charts show that the materials can be separated as either being of high or low compressibility. If the filler is hollow glass micro-spheres, no mater if it is skived or restructured, the compressibility and recovery are high. For other fillers, the compressibility is lower and the recovery is high, if taken as a percentage. However, if analyzed as an absolute value it is very low. Considering the average values both sPTFE and rPTFE have a similar behavior.

7.7. Sealability DIN

This test follows the DIN 3535 part 4 procedure. This standard is used to qualify Gaskets for use with gas valves, appliances and pipe work. At 32 MPa (4641 psi) gasket stress is applied and the leak rate measured with Nitrogen at 40 bar (580 psi). To qualify for this application the leak rate must be less than 0.1 mg/sec.m. The test apparatus is shown in Figure 45. All rPTFE products show a leak rate that qualifies for this service. On the other hand, skived/molded products may not qualify, as shown in Figures 38 to 42.

8. Scanning Electron Microscope (SEM)

To examine the morphology by the SEM analysis, specimens were fractured and gold coated. Figures 47 through 51 show two different morphologies; Virgin or Filled Skived PTFE exhibit fine fibrils (Figures 47 and 48) on the other hand Restructured PTFE (Figures 49 through 51) show larger fibrils in addition to the fine ones. This difference in morphology explains the better mechanical properties of rPTFE sheets.

9. Conclusions

Fibrillations of the PTFE matrix during the manufacturing processes along with the fillers increase the mechanical properties especially at high temperatures, overcoming the most undesirable property of PTFE based gaskets which is the high temperature creep relaxation.

It was shown different fillers meet the demands of the application such as high compressibility for fragile flanges or high mechanical strength for higher pressures.

The test results described throughout this paper clearly show better performance of the restructured filled PTFE gasket sheets for maintaining a good seal when compared with both filled and unfilled skived products.

TEALON* DATA BOOK

SUMMARY

This book was prepared to introduce the Tealon Structured PTFE Gasket Sheets. It provides information like characteristics, design data and comparison with other products. The book is divided in four sections.

Section I contains a description of the most common PTFE Gasket Sheets, their main characteristics, advantages and limitations. Also in this Section there is a comparison between the Tealon, Gylon** and a generic PTFE skived sheet. This comparison verifies that both Tealon and Gylon exhibit a similar behavior, and yield comparable results, which are far superior to PTFE skived sheet.

The Section II contains the basic technical data for TF1570, TF1580 and TF1590. The Data Sheets contain all basic design criteria such as maximum pressure and temperature in addition to all other information needed for application recommendations and media compatibility. The MSDS provide all information for handling the materials.

Section III contains the European approvals:

- TA-Luft for fugitive emissions.
- BAM for oxygen service.
- DVGW for gas service.

Section IV contains the TTRL and CETIM Test Reports for the Gasket Constants and Hot Blow Out. The Pressure Vessel Research Council (PVRC) Gasket Constants will be used in the forthcoming new ASME Pressure Vessel and Boiler Code rules for flange and gasket design. The values were generated using the new ASME Draft 10 Room Temperature Tightness Test (ROTT) procedure. The Hot Blow Out Test (HOBT2) uses a TTRL procedure developed in collaboration with the PVRC to determine the gasket resistance to blow out, prove the quality of product in operative conditions.

For further information please contact a Teadit office near you. We will be glad to analyze your specific requirements.

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** Gylon is a trademark of Garlock Sealing Technologies

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Styles of PTFE Sheets

PTFE gaskets are used in services where it is necessary to have a high chemical resistance. There are materials with distinct physical properties to meet the needs of each application. As with any fluid sealing material there is some overlapping between each other. Several materials can be used successfully in the same application. The most popular materials, with specific applications, characteristics and advantages are discussed in the following paragraphs.

1. Molded Sintered PTFE Sheet

The Molded Sintered PTFE sheets were the first products introduced in the market. They are manufactured from virgin or reprocessed PTFE resin, without fillers, in a process of molding, compressing and sintering. As any plastic product the PTFE exhibits a characteristic of creep when subjected a compression force. This characteristic is very detrimental to the gasket performance since it requires frequent retightening of the gasket to avoid or reduce leaks. This creep behavior is increased with the temperature. The main advantages are the low cost, ample market availability and high chemical resistance.

2. Skived PTFE Sheet

They are manufactured from virgin or reprocessed PTFE resin, without fillers, in a process of skiving a sintered PTFE billet. This process was developed to overcome manufacturing deficiencies of the Molded Process, however its products have the same creep behavior problems.

3. Molded or Skived Filled PTFE Sheet

To reduce the creep behavior of Molded or Skived PTFE sheets mineral fillers or fibers are added. However, due to the manufacturing process (molding or skiving) this reduction is not enough to produce a long-term effective seal. Picture 1 shows the microstructure of a Filled Skived PTFE sheet enlarged 500 times. Visible in the picture, are Silica filler particles in the PTFE matrix without any fibrillation.

Picture 1

STYLES OF PTFE SHEETS

4. Structured Filled PTFE Sheet

To reduce the creep a new manufacturing process was developed to produce Filled PTFE sheets. The material is subjected to a lamination before sintering, creating a highly fibrillated structure. Creep at both room and high temperature is substantially reduced. The first material in the market using this technology was Gylon. To meet the chemical service needs several mineral or artificial fillers are used, like Barite, Mineral and Synthetic Silica, Barium Sulphate or Hollow Glass Micro-Spheres. Each filler has an specific service application but there is a major overlapping of all of them for normal applications. The attached tables show the most known filled PTFE gasket sheets and its main characteristics as informed by the manufactures in their literature. Tables are organized by filler as follows:

- **Barite**: mineral used to produce sheets for strong caustic service. It is also considered FDA compliant. It seems to be the most commonly used sheet, it has a wide range of service applications including mild acids and general chemical products. Being white (no dye) it has the preference when product contamination is an issue. Picture 2 shows the microstructure of a Barite filled PTFE sheet enlarged 100 times. The filler particles are seen as well as the PTFE fibrillation in several directions. This fibrillation gives this type of material its superior creep properties. Tealon TF1580 is barite filled.

Picture 2

- **Mineral Silica**: used to produce sheets for strong acidic service. Is also used as a general service sheet since it has a broad range of applications including mild caustic solutions. It is normally supplied dyed (fawn). It has a microstructure similar to the Barite filled material as shown in Picture 3. Tealon TF1590 is silica filled.

Picture 3

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STYLES OF PTFE SHEETS

- **Hollow Glass Micro-Spheres**: this filler produces a sheet with a high compressibility for use with fragile or glass lined flanges replacing PTFE envelope gaskets. It is not recommended for either strong caustic or acid service. The most common color is blue dyed. Picture 3 shows a microstructure of this material, the spheres are clearly seen in the PTFE fibrillated structure. Tealon TF1570 is hollow glass micro-spheres filled.

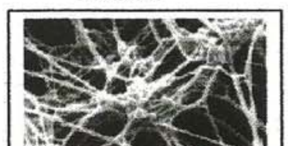
Picture 4

- **Synthetic Silica**: it is used by some manufactures as a substitute for Glass Micro-spheres since it yields sheets with compressibility closer to it.

5. Expanded PTFE

Hot expansion before sintering PTFE gives it the ability to overcome creep. Gasket products expanded in one direction (cords or tapes) or bi-axially (sheets) can be produced. Picture 5 shows a one direction PTFE structure and Picture 6 shows a bi-axially oriented structure. Expanded PTFE has a high chemical resistance; it also exhibit a very high compressibility and is ideal for use with fragile or glass lined flanges. Most Expanded PTFE products in the market do not have fillers. Its main drawback is the handling and installation of large gaskets or when it is not possible to separate the flanges. It is often used as a replacement for the Hollow Glass Micro- Spheres sheet with the advantage of a higher chemical resistance; the Glass Micro-Spheres are attached by Caustic Soda.

Picture 5



Picture 6

5. Pressure Loss with Thermal Cycling

a. Test Description

Gaskets made of Tealon* TF1570, Gylon[1] 3504 and PTFE Skived Sheet were tested using the Teadit 50T Test Bench. A description of the Test Bench is located in Appendix 1. The objective of the test is to compare the pressure loss (leak rate) of both gaskets when they are thermally cycled.

The Test Protocol used is as follows:

- Install the gasket with a seating stress of 35 MPa (5000 psi).
- Wait 30 minutes for the initial relaxation and increase the seating stress again to 35 MPa (5000 psi).
- Increase the temperature to 200° C (392° F).
- Pressurize the Test Bench with 42 bar (600 psi). The gas inlet is then closed for the remaining of the test.
- The temperature is kept constant at 200° C (392° F) for 4 hours.
- Turn the heating system off and let the Test Bench cool down.
- When the temperature reaches 30° C (86° F) it is increased to 200° C (392° F).
- The temperature is kept constant at 200° C (392° F) for 30 minutes.
- This cycle is repeated 2 times.
- The pressure, temperature and seating stress are recorded throughout the test.

b. Results

The following figures show the pressure and seating stress decay for the tested materials.

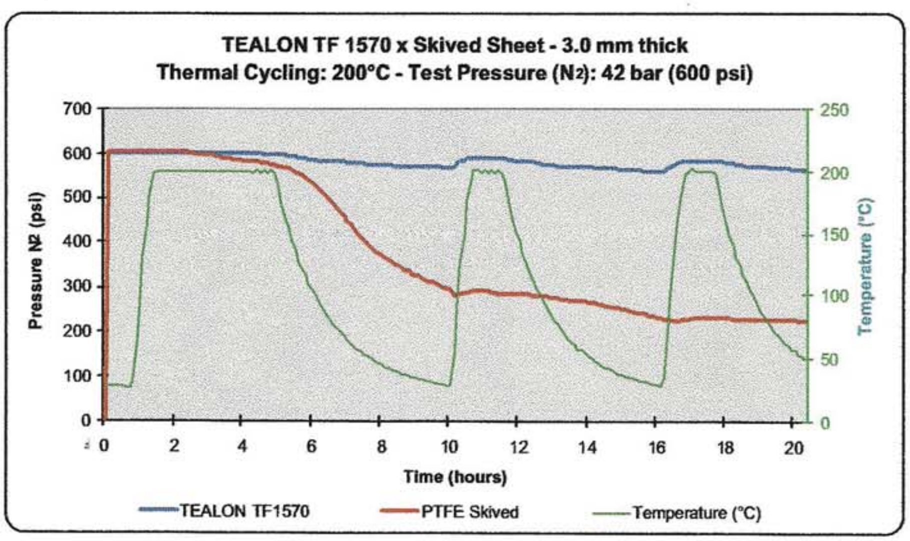


Figure 12

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TEALON*
PERFORMANCE TESTS

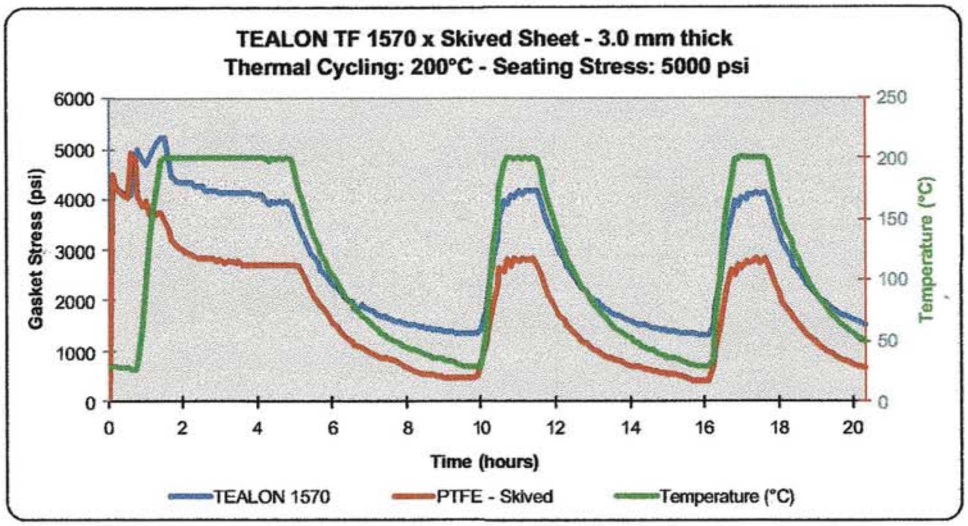

Figure 13

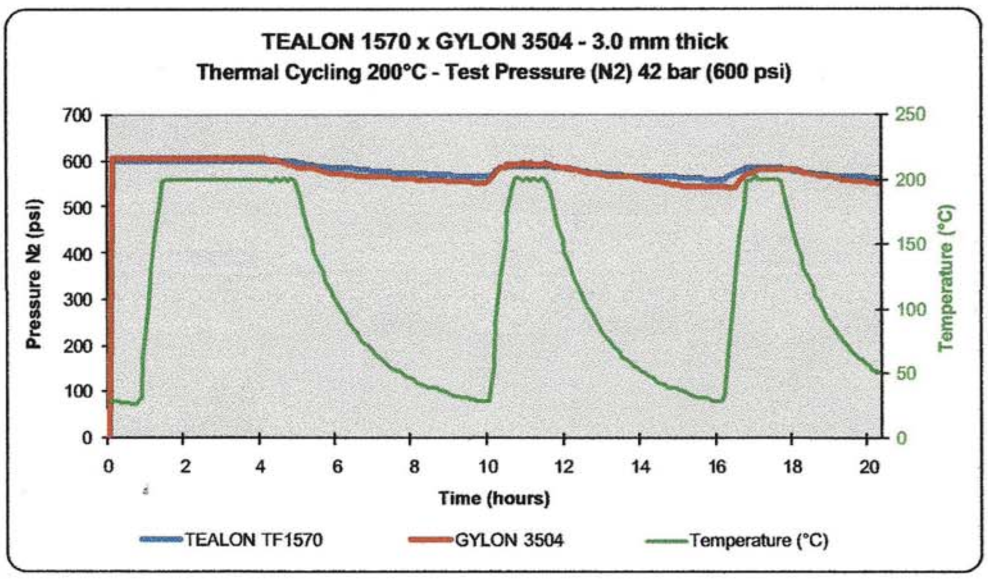

Figure 14

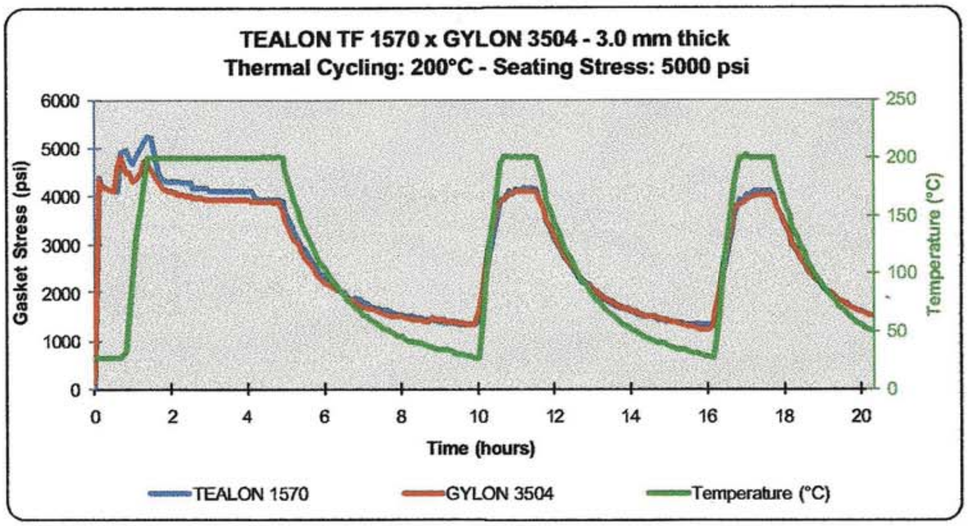

Figure 15

c. Conclusions

This test is a good example of the difference between a skived sheet and restructured PTFE sheets like Tealon* and Gylon[1]. As shown in Figure 13, the PTFE Skived Sheet loses 44% of its initial seating stress as the gaskets thermocycle. This loss of seating stress is the cause of the higher pressure loss for the PTFE Skived Sheet gasket and is typical for this kind of product. Restructured PTFE products like Tealon* and Gylon[1], due to its fibrillated structure, have a better retention of the initial seating stress and maintain a higher sealability.

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TEADIT 24B & 24BB EXPANDED PTFE GASKET TAPE

24B

DESCRIPTION

TEADIT 24B is a multi-purpose gasket material manufactured from 100% expanded PTFE fluorocarbon material, supplied as a continuous low density tape with a self-adhesive backing strip. It is soft and spongy, permitting it to conform easily to all surface irregularities and to compress to a thin ribbon under pressure.

APPLICATIONS

TEADIT 24B is recommended as a gasket tape in steel, glass lined, PVC and fiber glass pipe flanges, fume ducts, concrete lids, heat exchangers, fiberglass reinforced plastic plastic, pump housing flanges, stream vessel flanges, manhole and manhole covers, ceramic joints, ventilation ducts, hydraulic and pneumatic systems, water supply systems and turbine cases.

SERVICE LIMITS

pH range:	0-14
Temperature Limits:	-450˚/+600˚F
Pressure Limit:	3000 psi

PHYSICAL PROPERTIES

Density:	39 lbs./cu. ft., 0.63g./cm3
Elongation:	120%
Matrix Tensile Strength:	4260 PSI
Creep Relaxation (ASTMF38):	51%
Sealability (ASTM F37A):	0.1 ml/hr.

SERVICE LIMITS

Flange Size	Width
For Pipe Sizes Up to 1/2" dia.	1/8"
3/4" to 1-1/2"	3/16'
2" to 4"	1/4"
5" to 8"	3/8"
10" to 16"	1/22'
18" to 24'	5/8"
24" to 48"	3/4'
48" and above	1"

CHEMICAL RESISTANCE

Because TEADIT 24B is manufactured from 100% PTFE, it is and inert material which can be used in many applications against corrosive environments, except molten alkali metals and elemental fluorine. 24B will not contaminate media and can be used in food and drug equipment applications.

24BB

DESCRIPTION

24BB Tape is manufactured from 100% expanded PTFE fluorocarbon material. It is supplied as a continuous, low density tape with (and without) a self-adhesive backingstrip. It is available in a wide variety of thicknesses and widths.

APPLICATIONS

TEADIT 24BB is recommended as a gasket tape in steel, glass lined, PVC and fiber glass pipe flanges, fume ducts, concrete lids, heat exchangers, fiberglass reinforced plastic plastic, pump housing flanges, stream vessel flanges, manhole and manhole covers, ceramic joints, ventilation ducts, hydraulic and pneumatic systems, water supply systems and turbine cases.

SERVICE LIMITS

Pressure Limits	2900 PSI
Temperature Limits	
Minimum	-450˚F
Maximum	600˚F
pH Range	pH 0-14 except molten alkali and elemental fluorine
FDA/USDA	Meets requirements

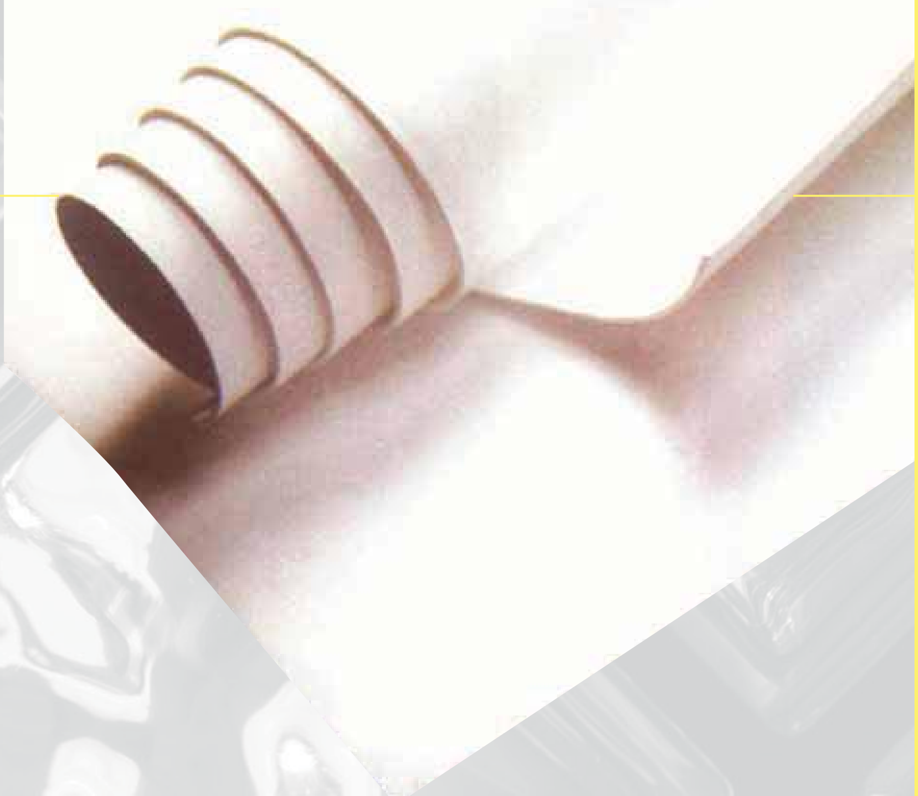
PHYSICAL PROPERTIES

Specific Gravity	0.75
% compressibility (ASTM F-36)	68%
% recovery (ASTM F-36)	12%
Sealability (m/hr leakage) (ASTM F-37B)	0.00 (Fuel A) 0.02 (Nitrogen)
% creep relaxation (ASTM F-38)	32% @ 212˚F 16% @ 73˚F

STANDARD SIZES FEET / ROLL

Thickness		WIDTH 1/2"	3/4"	1"	2"	4"	6"	8"
.020"	(1.5 mm)	100	100	100	100	-	-	-
.040"	(1.0 mm)	50	50	50	50	50	50	50
1/16"	(1.5 mm)	25	25	25	25	25	25	25
1/8"	(3.0 mm)	25	25	25	25	25	25	25

Special roll sizes are available on request with or without adhesive.



QUIMFLEX SH EXPANDED PTFE GASKET MATERIAL

Quimflex SH gasket sheet is made from 100% expanded PTFE by means of a proprietary manufacturing process that produces a highly fibrillated structure with equal tensile strength in all directions.

The characteristics of Quimflex SH sheet are significantly different from conventional PTFE. This expanded sheet is much more flexible than regular PTFE sheet and thus conforms easily to irregular and rough surfaces. In addition, the expanded sheet is easier to compress and minimize creep and cold flow.

SHEET DIMENSIONS	
Sheet Size:	60″ x 60″ (1524 mm x 1524 mm)
Thickness:	1/64″ (.5 mm), 1/4″ (6.0 mm)
Thickness Tolerance:	+/- 10%

SERVICE LIMITS	
Pressure Limits:	Full vacuum to 3000 psi
Temperature Limits:	-450˚F to +600˚F
pH Range:	pH 0-14 except molten alkali metals and elemental flourine
FDA/USDA	Meets requirements

PHYSICAL PROPERTIES	SH
Specific Gravity:	0.85
% compressibility (ASTM F-36):	68%
% recovery (ASTM F-36):	12%
Sealability (m/hr leakage9 (ASTM F-37B):	0.00 (Fuel A) 0.02 (Nitrogen)
% creep relaxation (ASTM F-38):	32 @ 212˚ F 16 @ 73˚ F

QUIMFLEX SH 100% Expanded PTFE Sheet

CONSTRUCTION

Quimflex SH gasket sheet is manufactured by expanding 100% virgin PTFE using a proprietary process that produces a uniform and highly fibrillated microstructure with equal tensile strength in all directions. The resulting product exhibits characteristics significantly different than conventional PTFE sheet. This style is much softer and more flexible than regular PTFE sheet and thus conforms easily to irregular and rough surfaces. In addition, the material is easier to compress and minimizes creep and cold flow.

APPLICATION / SERVICE:

TEADIT Quimflex SH gasket material complies to FDA regulations for food contact and EU 1935/2004
Quimflex SH is an all purpose gasket sheet that can replace all other types of PTFE sheet. It will seal all aggressive chemicals over the entire 0-14 pH range except for molten alkali metals and elemental fluorine. Made from 100% virgin PTFE, it not only resists chemical attack, but it will not contaminate or discolor end products. These industries currently use expanded PTFE sheet:

- Distillers
- Pharmaceutical
- Iron and Steel manufacturing
- Petrochemical
- General Chemical
- Pulp and Paper
- Food and Beverage
- Power Generation
- Marine

SERVICE LIMITS

Type	Description	Value
Temperature	Minimum	-450°F (-268°C)
	Maximum	500°F (260°C) Continuous. Short Periods up to 600 F (315 C)
Color	White	
pH		0-14 (except molten alkali metals and elemental fluorine)
Available Sheet Sizes	Thicknesses	1/32", 1/16", 3/32", 1/8", 3/16", 1/4"
	Sheet Size	60" x 60"

TYPICAL PHYSICAL PROPERTIES		
ASTM Test Method	**Property**	**Value**
F37	Sealability: ASTM Fuel A (isoctane): • Gasket load, 500 psi (3.5 N/mm^2) • Internal Pressure, 9.8 psi (0.7 bar) Nitrogen: • Gasket load, 500 psi (20.7 N/mm^2)	 0.0 ml/hr 0.16 ml/hr
F36	Compressability	68%
F36	Recovery	12%
F38	Creep Relaxation	32% at 212°F 16% at 73° F
F495	Ignition Loss	30%
F146	Weight Increase After 5 Hour Immersion • ASTM Fuel IRM 903 @ + 300°F (+150° C) • ASTM Fuel A @ + 70-85°F (+21-29°C) • ASTM Fuel B @ + 70-85°F (+21-29°C)	 -
F146	Thickness Increase After 5 Hour Immersion • ASTM Fuel IRM 903 @ + 300°F (+150° C) • ASTM Fuel A @ + 70-85°F (+21-29°C) • ASTM Fuel B @ + 70-85°F (+21-29°C)	 -
F 152	Tensile Strength Across Grain • 1/16" thick • 1/16" thick	 1600 psi(11 N/mm2) 1600 psi (11 N/mm2)
DIN 3535 Part 4	Gas Permeability • Nitrogen: • Internal pressure: • Gasket Load:	- 580 psi (40 bar) 4640 psi (32 N/mm^2)
-	Density	53 lb/ft^3(.85 gm/cc)

Properties and application parameters shown throughout this datasheet are typical. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury. Specifications are subject to change without notice. This edition supersedes all previous issues.

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TEADIT 24SH

Description:

TEADIT **24SH** is a large gasket sheet produced from 100% pure, multi-directionally expanded PTFE (Polytetrafluorethylen).

Advantages:

- Universally employable gasket sheet for all applications. It is suitable for all types of flanges, nearly all media, a wide temperature range and even for applications with the toughest demands on purity. It is inherently clean and non-toxic.
- The compressed gasket of multi-directionally expanded PTFE has exceptional mechanical strength which enables operation with less creep at higher temperatures than other types of PTFE sheets.
- The excellent malleability of TEADIT **24SH** makes repairing of small damages and/or irregularities of the sealing area (flange surface) unnecessary.
- Gaskets cut from TEADIT **24SH** are dimensionally stable, i.e. they do not get wider when compressed. This allows narrow flange faces to be sealed safely, i.e. without causing turbulences in the flow of the media.
- TEADIT **24SH** is quick and simple to install. The used gasket can be removed quickly, easily and without residue.

Approvals:

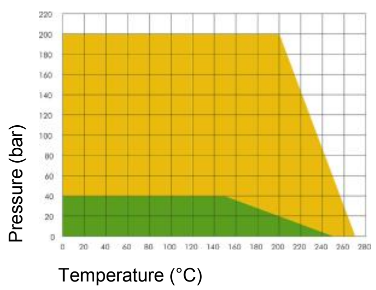
- TA-Luft
- Blow-Out-Test VDI 2200
- FDA / ISEGA
- USP Plastic Class
- Germanischer Lloyd Approval
- BAM

Properties:

- Colour: white
- Size: 1500mm x 1500mm
- Thickness: from 0.5 mm up to 6 mm
- Temperature range: -240°C up to +270°C for short periods up to 315°C
- Chemical resistance: chemically inert against all substances (pH 0-14), including the most aggressive acids and lyes. The only exceptions are molten alkali metals and elemental fluorine at high temperature and pressure.
- Operating pressure: from vacuum up to 200 bar
- Aging: TEADIT **24SH** is not subject to aging or weathering. It can be stored indefinitely.
- Safety: TEADIT **24SH** complies to FDA regulations for food, is physiologically harmless and is also suitable for oxygen applications.

P x T diagramm:

The P x T diagram above indicates the service limits considering the simultaneous influence of pressure and temperature (chemical suitability assumed). The green area represents the normal service limits, while the orange coloured area shows the maximum application limits.



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TEADIT 24SH

TEADIT 24 SH			
property	**test method**	**nominal value**	**parameters**
density [g/cm^3]	ASTM D 792	0.9	
compressibility [%]	ASTM F 36	45	σ = 34 MPa
recovery [%]	ASTM F 36	14	σ = 34 MPa
compressibility ε KSW [%]	DIN 28090 - 2	41	σ = 20 MPa
recovery ε KSW [%]	DIN 28090 - 2	10	σ = 20 MPa
tensile strength [MPa]	DIN 52910	29	room temperature
stress retention [MPa]	DIN 52913	15	30 N/mm^2 , 150℃,16h
Q min 0,01 [MPa]	EN 13555	23	HE 40 bar
Q smin 0,01 [MPa]	EN 13555	< 10	HE 40 bar
Q min 0,001 [MPa]	EN 13555	31	HE 40 bar
Q smin 0,001 [MPa]	EN 13555	< 10	HE 40 bar
Q crit	EN 13555	> 240	room temperature
Q smax	EN 13555	> 240	room temperature
specific leakage rate L [mbar • l / (s • m)]	VDI 2440 / TA LUFT	2.6 • 10^{-7}	He,1 bar, 30 MPa

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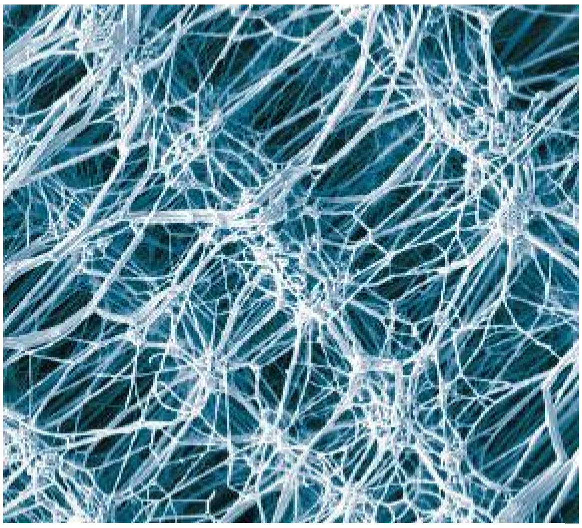
Product Information Rev.: 09/26/03

Expanded PTFE Sheet TEADIT Quimflex HD

TEADIT Quimflex HD is a large gasket sheet produced from 100% pure, multi-directionally expanded PTFE (Polytetrafluorethylen). TEADIT Quimflex HD has a higher rigidity compared to other expanded PTFE sheets.

Properties:

- **Color**: white
- **Size**:59 x 59 inches
  Thickness: from 0.020 up to 0.25 in
- **Temperature range:** -400°F up to +500°F for short periods up to 600°F
- **Chemical resistance:** chemically inert against all substances (pH 0-14), including the most aggressive acids and lyes. The only exceptions are molten alkali metals and elemental fluorine at high temperature and pressure.
- **Operating pressure:** from vacuum up to 2900 psi
- **Aging:** is not subject to aging or weathering. It can be stored indefinitely.
- FDA: Complies to FDA regulations for food service.



The highly fibrillated microstructure of multi-directionally expanded PTFE results in a gasket material with a unique combination of excellent malleability and high tensile strength.

Advantages:

- Universally employable gasket sheet for all applications. It is suitable for all types of flanges, nearly all media, a wide temperature range and even for applications with the toughest demands on purity. It is inherently clean and non-toxic.
- The compressed gasket of multi-directionally expanded PTFE has exceptional mechanical strength which enables operation with less creep at higher temperatures than other types of PTFE sheets.
- The excellent malleability of Quimflex HD makes repairing of small damages and/or irregularities of the sealing area (flange surface) unnecessary.
- Gaskets cut from Quimflex-HD are dimensionally stable, i.e. they do not get wider when compressed. This allows narrow flange faces to be sealed safely, i.e. without causing turbulences in the flow of the media.
- Is quick and simple to install. The used gasket can be removed quickly, easily and without residue.
- Has an improved rigidity compared to other expanded PTFE sheets resulting in easier installation, especially for large flanges

Approvals:

- **FDA:** conforms to the FDA's Perfluorcarbon regulation

Property	Test Method	Nominal Value	Parameters
Compressibility [%]	ASTM F 36 A	35	σ = 4,900 psi
Recovery [%]	ASTM F 36 A	17	σ = 4,900 psi
Compressibility [%]	DIN 28090 - 2	33	σ = 2,900 psi
Recovery [%]	DIN 28090 - 2	10	σ = 2,900 psi
Tensile strength [MPa]	DIN 52910	33	Room temperature
Stess retention [MPa]	DIN 52913	14	4,350 psi, 300°F, 16h
"m" Design value		2	
"y" Design value		2,800 psi	

Product information

02/120110

TEADIT 25 BI

Material properties:

TEADIT 25 BI is a multidirectionally expanded gasket-tape, produced from 100% pure PTFE (Polytetrafluorethylen). The whole production process is subject to strictest quality control, registered under ISO 9001.

Application areas:

TEADIT 25 BI – due to its excellent malleability and adaptability – is particularly well suited to compensate for irregularities or damages on the sealing areas, as well as for all stress-sensitive joints.
A special manufacturing process results in almost equal tensile strength in both the longitudinal and cross direction. As a result of this, the material does not change its width under compression. This is in stark contrast to normal expanded PTFE tapes! **TEADIT 25 BI,** because of this property, is extremely well suited as a gasket material for narrow sealing areas and in all applications where a defined gasket width (under load) is required. Typical applications are enamelled and glass flanges, heat exchangers, large flanges and containers, pressure vessels, suction filters and strainers, etc.

Technical data:

- Thermal stability: from –240°C up to +260°C; up to 310°C for short periods
- Chemical resistance: chemically inert against most substances (pH 0 – 14), including the most aggressive acids and lyes. The only exceptions are molten alkali metals and elemental fluorine at high temperatures and pressures.
- Ageing: **TEADIT 25 BI** does not age and can be stored indefinitely. (Please note: adhesive tape has a limited shelf life)
- Pressure: from vacuum up to 200 bar
- Minimum stress to seal Qmin/L (EN 13555 HE, 40 bar):
  L[mg/s*m] 10^{-2} Qmin/L [MPa] = 23
  L[mg/s*m] 10^{-3} Qmin/L [MPa] = 31
- Maximal applicable gasket stress Qsmax = 130 MPa (acc. EN 13555)
- Colour: white
- Recovery: 10 % (ASTM F36)
- Compressibility: 70 % (ASTM F36)

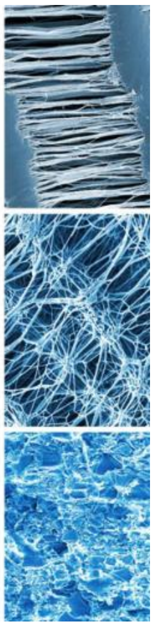
Advantages:

- quick and simple installation, no cutting or punching necessary
- the used gasket can be easily removed without leaving any deposits on the sealing areas
- excellent malleability makes the repair of minor damages and irregularities unnecessary
- extremely versatile because of exceptionally good chemical and thermal stability
- there is less danger of choosing the wrong gasket material because **TEADIT 25 BI** can be used for most applications within the plant
- longer gasket life (less downtime)
- no material waste
- low stock cost, unlimited shelf life has endless shelf life)

Approvals:

- FDA / ISEGA
- TA-Luft
- FMPA

NO WAY THROUGH



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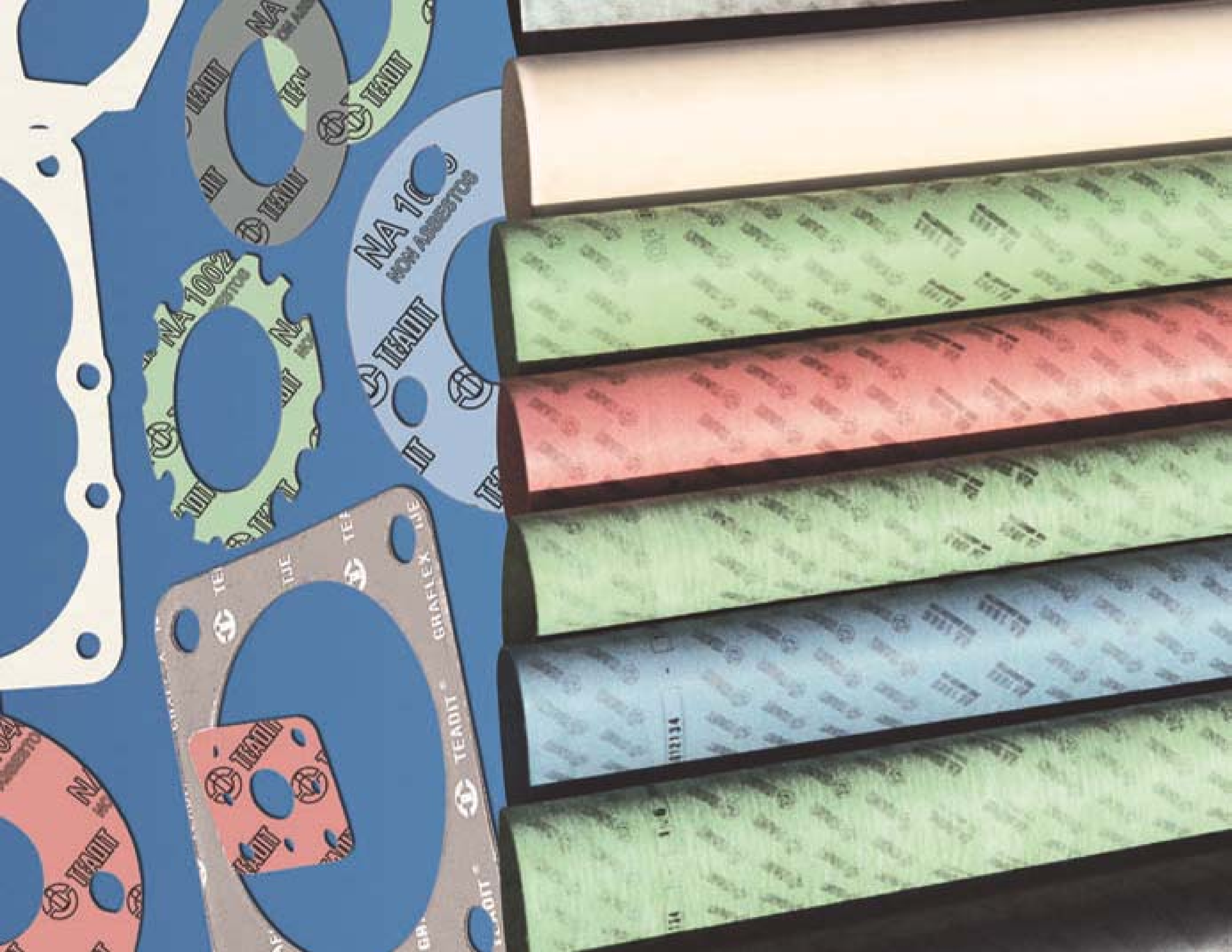


NA 1002
NON ASBESTOS
TEADIT
GRAFLEX

TEADIT®

G A S K E T

NBR, CARBON FIBER SHEET NA-1100

Color: Black
NA-1100 is manufactured from carbon fibers and graphite, bonded with NitrileRubber.
Service: For applications up to 900° F. This sheet enables plants to use only one gasket material and avoid the confusion of needing several different sheets or gasket styles in the plant. This sheet cuts very clean and easily. NA-1100 is suitable for sealing hot oils, fuels, coolants, solvents, gases, water and steam.

Temperature Limits Maximum:	840° F (450° C)
Continuous Maximum:	518° F (270° C)
Pressure limits (Vacuum) Maximum:	1900 psi (130 bar)
Continuous Maximum:	1000 psi (70 bar)

ASTM Line Call Out F104F713130M5

NBR, ARAMID FIBER NA-1001

Color: Green or White or Blue
NA-1001 gasketing is a material formulated for services in most static sealing applications as a universal replacement gasket. NA-1001 is manufactured through the hot calender process under rigorous quality control standards. Its fiber content is aramid, bound by Nitrile rubber (NBR).
Service: NA-1001 is suitable against air, water, brine, steam, organic and weak inorganic acids, concentrated and diluted alkalies, chemicals, petroleum and petroleum derivatives, synthetic oils, animal fats, vegetable oils, aromatic, aliphatic and chlorinated solvents and refrigerants.

Temperature Limits Maximum:	750° F (400° C)
Continuous Maximum:	460° F (240° C)
Pressure limits (Vacuum) Maximum:	1595 psi (110 bar)
Continuous Maximum:	725 psi (50 bar)

ASTM Line Call Out F104F712120E22M5

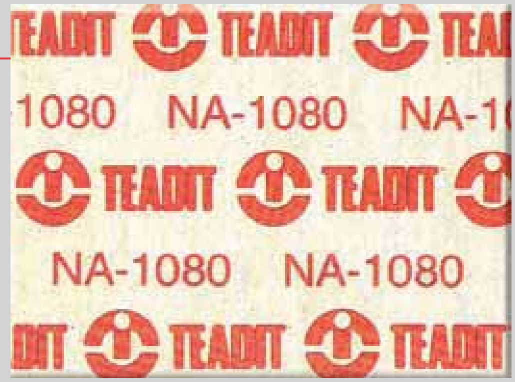
NBR, ARAMID FIBER WITH WIRE MESH NA-1000M

Color: Black, Graphited both sides
NA-1000M is an excellent sheet packing for use in gasket manufacturing to seal most fluids in the industry. NA-1000M is manufactured through the hot calender process under rigorous quality control standards, with synthetic fibers, bound with nitrile rubber (NBR) and reinforced with wire. NA-1000M is very pliable and flexible. NA-1000M is ideally suited for applications with fluctuating temperatures and pressures.
Service: Air, water, brine, steam, organic and weak inorganic acids, concentrated and diluted alkalies, chemicals, petroleum derivatives, synthetic oils, animal fats, vegetable oils, aromatic and aliphatic solvents, chlorinated solvents and cooling fluids.

Temperature Limits Maximum:	720° F (380° C)
Continuous Maximum:	390° F (200° C)
Pressure limits (Vacuum) Maximum:	1450 psi (100 bar)
Continuous Maximum:	580 psi (40 bar)

ASTM Line Call Out F104ASTM713230E23M6

M A T E R I A L S



NA-1080 SBR, ARAMID FIBER

Service: It has numerous applications in the process industries handling media like: mild acids and alkalies, water, brine, saturated steam, air, industrial gases, general chemicals and neutral solutions.
Construction: Style NA-1080 is a compressed gasket material produced from a combination of Aramid Fiber, Inorganic Fillers and bonded with Styrene-Butadiene Rubber (SBR).

Temperature Limits Maximum:	716° F (380° C)
Continuous Maximum:	490° F (270° C)
Pressure limits (Vacuum) Maximum:	1015 psi (70 bar)
Continuous Maximum:	725 psi (50 bar)

ASTM Line Call Out F104F712940E44M5

NA-1081 NBR, ARAMID FIBER

Service: It has numerous applications in the process industries handling media like: mild acids and alkalies, water, hydrocarbons, oils, gasoline, steam, air, industrial gases, general chemicals and neutral solutions.
Construction: Style NA-1081 is a compressed gasket material produced from a combination of Aramid Fiber, Inorganic Fillers and bonded with Nitrile Rubber (NBR).

Temperature Limits Maximum:	752° F (400° C)
Continuous Maximum:	500° F (260° C)
Pressure limits (Vacuum) Maximum:	1595 psi (110 bar)
Continuous Maximum:	725 psi (50 bar)

ASTM Line Call Out F104F712220E23M5

PRODUCT DATA FOR GASKET MATERIALS

ASTM	ASTM Method	NA 1100	NA 1000M	NA 1001	NA 1080	NA 1081
Density, g/cm^3	--	1.7	2.18	1.83	1.94	2.0
% Ignition Loss @ 1472°F	F-495	38	32	29	26	23
Tensile Strength, across grain psi	F-152	1900	3500	1900	1990	1915
% Compressibility @ 5000psi	F-36A	15	15	9	10	8
% Recovery, Minimum	F-36A	56	50	55	58	59
Sealability (ml/hr. Leakage) @ 2000 psi gasket load)	F-37A	0.5	1.1	0.6	0.5	0.5
Creep Relaxation @ 212°F, %	F-38	23	43	31	20	20

TEADIT®

NA1001 - Compressed Sheet with Aramid Fibers/NBR Binder

CONSTRUCTION

Style NA1001 is a compressed non-asbestos sheet gasket material produced from a combination of aramid and other synthetic fibers and bonded with nitrile rubber (NBR). It is manufactured through the hot calendar process under rigorous quality control standards that are registered under ISO-9001 certification.

APPLICATION / SERVICE

Style NA1001 is a very good general service gasket material that has numerous applications in the process industries and in the water and wastewater industry. It is also commonly used in equipment such as valves and pumps. Style NA1001 is suitable for service handling the following general media categories:

- Mild inorganic acids
- Diluted alkalis
- Aliphatic solvents
- Synthetic oils
- General chemicals
- Mild organic acids
- Water
- Industrial gases
- Vegetable oils
- Neutral solutions
- Refrigerants
- Brine
- Animal oils
- Petroleum and Derivatives
- Air

SERVICE LIMITS

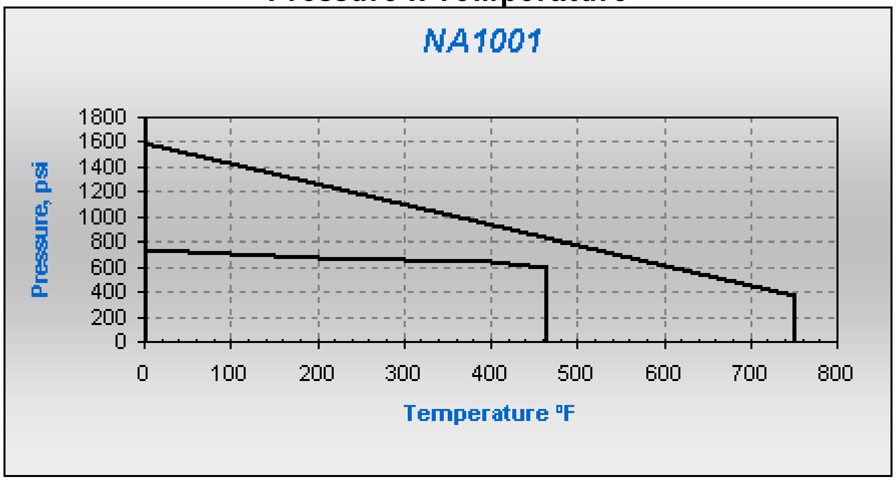
Type	Description	Value
Temperature Limits	Maximum	750°F (400°C)
	Continuous Max	460°F (240°C)
Pressure Limits	Maximum	1595 psi (110 bar)
	Continuous Max	725 psi (50 bar)
ASTM Line Call Out F104	F712120E22M5	
Color	Green, White, Or Blue	
Available Sheet Sizes	Thickness	1/64", 1/32", 1/16", 3/32", 1/8"
	Sheet Sizes	59" x 63"
		59" x 126"
		118" x 126"

TYPICAL PHYSICAL PROPERTIES

ASTM Test Method	Property	Value
-	Density	109 lb/ft^3 (1.75 gm/cc)
F36	Compressibility	7-17%
F36	Recovery	min 45%
F38	Tensile Strength Across Grain	1670 psi (11.5 N/mm2)
F495	Ignition Loss	max 34%
F146	Thickness Increase After 5 Hour Immersion	
	• ASTM IRM 903 @300°F (150°C)	max 12%
	• ASTM Fuel B @77°F (25°C)	max 10%

F146	Weight Increase After 5 Hour Immersion	
	• ASTM IRM 903 @300°F (150°C)	max 15%
	• ASTM Fuel B @77°F (25°C)	max 15%
F38	Creep Relaxation	25%
	Torque Retention (DIN 52913)	28 N/mm^2
F37	Sealability at 1000 psi	0.25 ml/h

Pressure x Temperature



The P x T graph shown above indicates the service limits for this sheet considering pressure and temperature simultaneously...(Tests were performed with nitrogen on 1.6mm thick sheet). The "normal" curve represents the common usage area for this sheet while the "maximum" curve indicates the maximum limits. For applications near or above the "maximum" curve, contact TEADIT.

Properties and application parameters shown throughout this datasheet are typical. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury. Specifications are subject to change without notice. This edition supersedes all previous issues.

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TEADIT®

NA1076 - Compressed Sheet with Aramid Fibers/Neoprene Binder

CONSTRUCTION

Style NA1076 is a compressed non-asbestos sheet gasket material produced from a combination of aramid and other synthetic fibers and bonded with neoprene rubber (CR). It is manufactured through the hot calender process under rigorous quality control standards that are registered under ISO-9001 certification.

APPLICATION / SERVICE

Style NA1076 sheet is a good all purpose sheet that is specifically formulated to handle a broad range of refrigerants. In addition, Style 1076 is suitable for services handling water, saturated steam, oils, fuels, mild acids and alkalies.

SERVICE LIMITS

Type	Description	Value
Temperature Limits	Minimum/Maximum	-40°F (-40°C)/700 F (370 C)
	Continuous Max.	392°F (200 C)
Pressure Limits		Vacuum to 725 psi (50 bar)
ASTM Line Call Out	ASTM F104-F712120-B4E99M9	
Color	Black	
Available Sheet Sizes	Thickness	1/64", 1/32", 1/16", 3/32", 1/8"
	Sheet Sizes	59" x 63"
		59" x 126"

TYPICAL PHYSICAL PROPERTIES*

ASTM Test Method	Property	Value
F 36	Compressibility	7-17%
F 36	Recovery	46%
F 38	Creep relaxation	20%
F146	Weight Increase After 5 Hour Immersion	
	• ASTM Fuel B @77°F (25°C)	<_20%
	Thickness Increase After 5 Hour Immersion	
	• ASTM IRM 903 @ 300°F (150°C)	<_30%
	• ASTM Fuel B @77°F (25°C)	<_20%
	Tensile Strength Across Grain	1740 psi
	Density	106 lb/ft^3 (1.70 gm/cc)

*This data is a general guide for selection of materials and does not constitute specification limits. It should not be used as the sole means of specifying a material for an application.

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TEADIT®

NA1080 - Compressed Sheet with Aramid Fibers/SBR Binder

CONSTRUCTION

Style NA1080 is a compressed non-asbestos sheet gasket material produced from a combination of Aramid Fiber, Inorganic Fillers and bonded with Styrene-Butadiene Rubber (SBR). It is manufactured under rigorous quality control standards that are registered under ISO-9001 certification.

APPLICATION / SERVICE

Style NA1080 has numerous applications in the process industries handling media like: mild acids and alkalis, water, brine, saturated steam, air, industrial gases, general chemicals, neutral solutions.

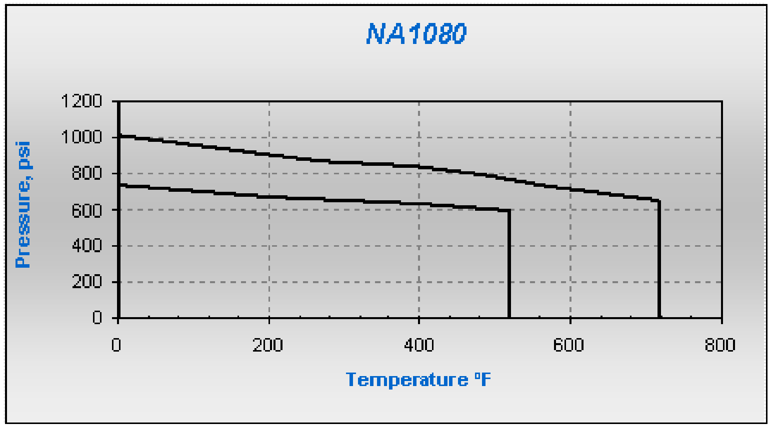
SERVICE LIMITS

Type	Description	Value
Temperature Limits	Maximum	716°F (380°C)
	Continuous Max	490°F (270°C)
Pressure Limits	Maximum	1015 psi (70 bar)
	Continuous Max	725 psi (50 bar)
ASTM Line Call Out F104	F712940E44M5	
Color	Off White	
Available Sheet Sizes	Thickness	From 1/64" (0.4mm) to 1/8" (3.2mm)
	Sheet Sizes	59" (1500mm) x 63" (1600mm)
		59" (1500mm) x 126" (3200mm)

TYPICAL PHYSICAL PROPERTIES

ASTM Test Method	Property	Value
-	Density	122 lb/ft^3 (1.96 g/cc)
F36	Compressibility	7-17%
F36	Recovery	min 45%
F152	Tensile Strength	2030 psi (14 MPa)
F495	Ignition Loss	max 28%
F146	Thickness Increase After 5 Hour Immersion	
	• ASTM oil IRM 903 @300°F (150°C)	max 40%
	• ASTM Fuel B @ 77ºF (25ºC)	max 20%
F146	Weight Increase After 5 Hour Immersion	
	• ASTM oil IRM 903 @300°F (150°C)	max 30%
	• ASTM Fuel B @ 77ºF (25ºC)	max 30%
F38	Creep relaxation	22%
	Torque Retention (DIN 52913)	37 N/mm^2
F37	Sealability at 1000 psi	0.25 ml/h

Pressure x Temperature



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NA1081 - Compressed Sheet with Kevlar® Fibers / NBR Binder

CONSTRUCTION
Style NA1081 is a compressed non-asbestos sheet gasket material produced from a combination of DuPont Kevlar®, Inorganic Fillers and bonded with Nitrile Rubber (NBR). It is manufactured under rigorous quality control standards that are registered under ISO-9001 certification.

APPLICATION / SERVICE
Style NA1081 has numerous applications in the process industries handling media like: mild acids and alkalis, water, hydrocarbons, oils, gasoline, steam, air, industrial gases, general chemicals, neutral solutions.

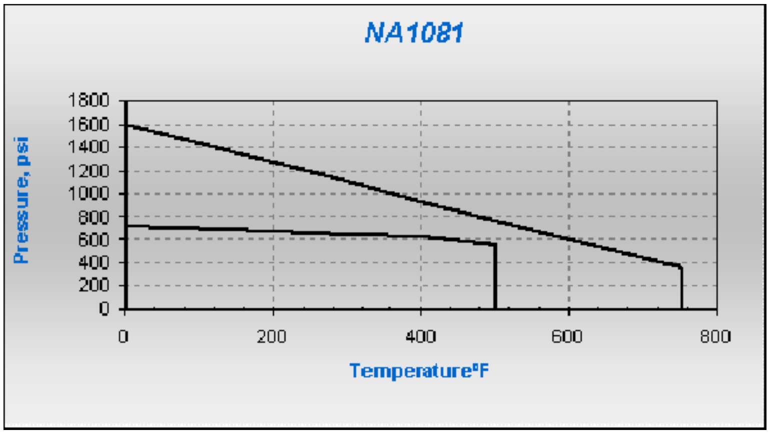
SERVICE LIMITS

Type	Description	Value
Temperature Limits	Maximum	752°F (400°C)
	Continuous Max	500°F (260°C)
Pressure Limits	Maximum	1595 psi (110 bar)
	Continuous Max	725 psi (50 bar)
ASTM Line Call Out F104	F712220E23M5	
Color	Blue	
Available Sheet Sizes	Thickness	From 1/64' (0.4mm) to 1/8' (3.2mm)
	Sheet Sizes	59' (1500mm) x 63' (1600mm)
		59' (1500mm) x 126' (3200mm)

TYPICAL PHYSICAL PROPERTIES

ASTM Test Method	Property	Value
	Density	119.5 lb/ft^3 (1.92 g/cc)
F36	Compressibility	7-17%
F36	Recovery	min 50%
F152	Tensile Strength	1820 psi (12.5 MPa)
F495	Ignition Loss	max 26%
F146	Thickness Increase After 5 Hour Immersion	
	• ASTM oil IRM 903 @300°F (150°C)	max 15%
	• ASTM Fuel B @77ºF (25ºC)	max 15%
F146	Weight Increase After 5 Hour Immersion	
	• ASTM oil IRM 903 @300°F (150°C)	max 15%
	• ASTM Fuel B @77ºF (25ºC)	max 15%
F38	Creep relaxation	22%
	Torque Retention (DIN 52913)	37 N/mm^2
F37	Sealability at 1000 psi	0.2 ml/h

Pressure x Temperature



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NA1085 - Compressed Sheet with Aramid Fibers/Hypalon Binder

CONSTRUCTION

Style NA1085 is a compressed non-asbestos sheet gasket material produced from aramid fibers and bonded with Hypalon® rubber. It is manufactured through the hot calendar process under rigorous quality control standards that are registered under ISO-9001 certification.

APPLICATION / SERVICE

Style NA1085 is a severe service non-asbestos sheet that is specifically formulated to provide an effective seal against most acids in the process industries. This style is suitable for service handling the following general media categories:

- Water
- Brine
- Saturated Steam
- Air
- Industrial gases
- Oxygenated Solvents
- Neutral solutions
- Refrigerants
- General chemicals
- Diluted alkalis

SERVICE LIMITS

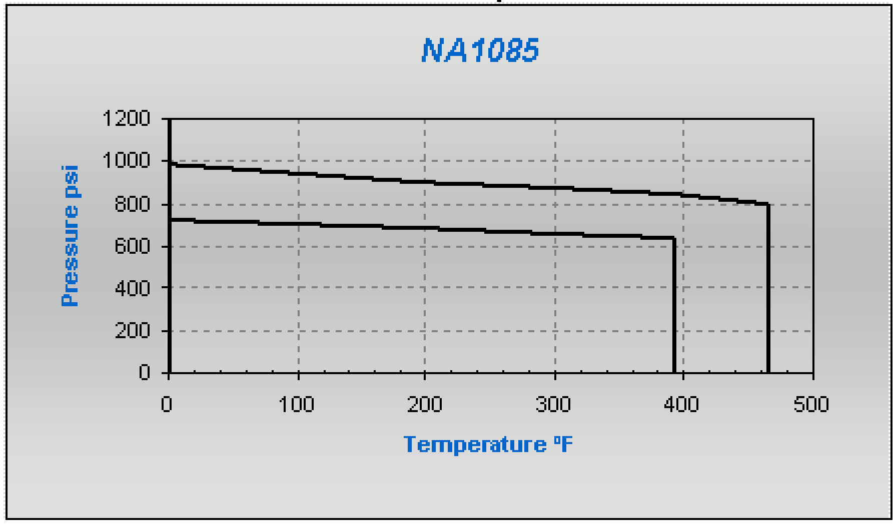
Type	Description	Value
Temperature Limits	Maximum	464°F (240°C)
	Continuous Max	362°F (200°C)
Pressure Limits	Maximum	1015 psi (70 bar)
	Continuous Max	725 psi (50 bar)
ASTM Line Call Out F104	F712000E00M5	
Color	Cobalt Blue	
Available Sheet Sizes	Thickness	1/64", 1/32", 1/16", 3/32", 1/8"
	Sheet Sizes	59" x 63"
		59" x 126"

TYPICAL PHYSICAL PROPERTIES

ASTM Test Method	Property	Value
-	Density	106 lb/ft^3 (1.7 gm/cc)
F36	Compressibility	5-15%
F36	Recovery	min 40%
F152	Tensile Strength	2030 psi (14 N/mm^2)
F495	Ignition Loss	max 37%
F38	Creep relaxation	26%

	Torque Retention (DIN 52913)	28 N/mm^2
F37	Sealability at 1000 psi	0.2 ml/h

Pressure x Temperature



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TEADIT®

NA1090 - Compressed Sheet with Inorganic Fibers / NBR Binder

CONSTRUCTION

Style NA1090 is a Compressed Non-Asbestos sheet gasket material produced from inorganic fibers, reinforced fillers and bonded with nitrile rubber (NBR). It is manufactured through the hot calendar process under rigorous quality control standards that are registered under ISO-9001.

APPLICATION / SERVICE

NA1090 is a general purpose Compressed Non-Asbestos sheet gasket material suitable for services with the following general media categories:

• Mild inorganic acids • Water • Industrial gases • Vegetable oils • Neutral solutions	• Mild organic acids • Brine • Animal oils • Petrol and Derivatives • Air	• Diluted alkalis • Steam • Synthetic oils • General chemicals

SERVICE LIMITS

Type	Description	Value
Temperature Limits	Maximum	750°F (400°C)
	Continuous Max	480°F (250°C)
Pressure Limits	Maximum	1560 psi (110 bar)
	Continuous Max	1140 psi (80 bar)
ASTM Line Call Cut F104	F712290E33M4	
Color		Black
Available Sheet Sizes	Thickness	1/64”, 1/32”, 1/16”, 3/32”, 1/8”
	Sheet Sizes	59” x 63” 59" x 126"

TYPICAL PHYSICAL PROPERTIES

ASTM Test Method	Property	Value
ASTM F1315	Density	96 lb/ft^3 (1,54g/cc)
ASTM F36A	Compressibility	7-17%
ASTM F36A	Recovery	min 45%
ASTM F152	Tensile Strength	1450 psi (10N/mm^2)
ASTM F495	Ignition loss	max 37%
ASTM F146	Thickness Increase	
	• ASTM Oil IRM903, 5h/300ºF (150ºC)	max 20%
	• Fuel B, 5h/77ºF (25ºC)	max 15%
ASTM F146	Weight Increase	
	• ASTM Oil IRM903, 5h/300ºF (150ºC)	max 25%
	• Fuel B, 5h/77ºF (25ºC	max 20%
ASTM F38	Creep Relaxation	23%
DIN 52913	Torque Retention	40 N/mm^2
ASTM F37A	Sealability at 1000 psi	0,3 mL/h

Note: ASTM values for 0.8mm and DIN values for 2.0 mm thick sheets

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TEADIT®

NA1092 – Compressed Sheet with Aramid Fibers/ Graphite / NBR

CONSTRUCTION

Style NA1092 is a Compressed Non-Asbestos sheet gasket material produced from aramid fiber, graphite, reinforced fillers and bonded with nitrile rubber (NBR). It is manufactured through the hot calendar process under rigorous quality control standards that are registered under ISO-9001.

APPLICATION / SERVICE

NA1092 NA1092 is suitable for services with the following general media categories

• Mild inorganic acids • Water • Industrial gases • Vegetable oils • Neutral solutions	• Mild organic acids • Brine • Animal oils • Petrol and Derivatives • Air	• Diluted alkalis • Steam • Synthetic oils • General chemicals

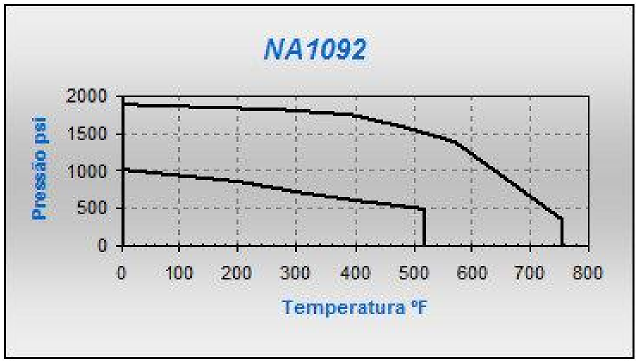
SERVICE LIMITS

Type	Description	Value
Temperature Limits	Maximum	750°F (400°C)
	Continuous Max	518°F (270°C)
Pressure Limits	Maximum	1885 psi (130 bar)
	Continuous Max	1015 psi (70 bar)
ASTM Line Call Cut F104	F7713130E43M5	
Color		Black
Available Sheet Sizes	Thickness	1/64", 1/32", 1/16", 3/32", 1/8"
	Sheet Sizes	59" x 63" 59" x 126"

TYPICAL PHYSICAL PROPERTIES

ASTM Test Method	Property	Value
ASTM F1315	Density	100 lb/ft^3 (1,6g/cc)
ASTM F36A	Compressibility	10-20%
ASTM F36A	Recovery	min 37%
ASTM F152	Tensile Strength	1740 psi (12N/mm^2)
ASTM F146	Thickness Increase	
	• ASTM Oil IRM903, 5h/300ºF (150ºC)	max 15%
	• Fuel B, 5h/77ºF (25ºC)	max 15%
ASTM F146	Weight Increase	
	• ASTM Oil IRM903, 5h/300ºF (150ºC)	max 25%
	• Fuel B, 5h/77ºF (25ºC	max 30%

Note: ASTM values for 0.8mm thick sheets



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NA1100 - Compressed Sheet with Carbon Fibers / NBR Binder

CONSTRUCTION

Style NA1100 is a compressed non-asbestos sheet gasket material produced from carbon fibers and graphite, bonded with nitrile rubber (NBR). It is manufactured through the hot calendar process under rigorous quality control standards that are registered under ISO-9001 certification.

APPLICATION / SERVICE

Style NA1100 is a premium grade, multi-service gasket sheet, designed to handle the extremes of pressure and temperature, and it cuts very easily and cleanly. The versatility of this sheet enables a plant to standardize on one sheet for a multitude of applications and avoid the confusion of having to choose from several different sheets. NA1100 is suitable for service handling the following general media categories:

- Mild inorganic acids
- Diluted alkalis
- Saturated steam
- Synthetic oils
- General chemicals
- Aliphatic solvents
- Mild organic acids
- Water
- Industrial gases
- Vegetable oils
- Neutral solutions
- Air
- Brine
- Animal oils
- Petroleum and Derivatives
- Refrigerants

SERVICE LIMITS

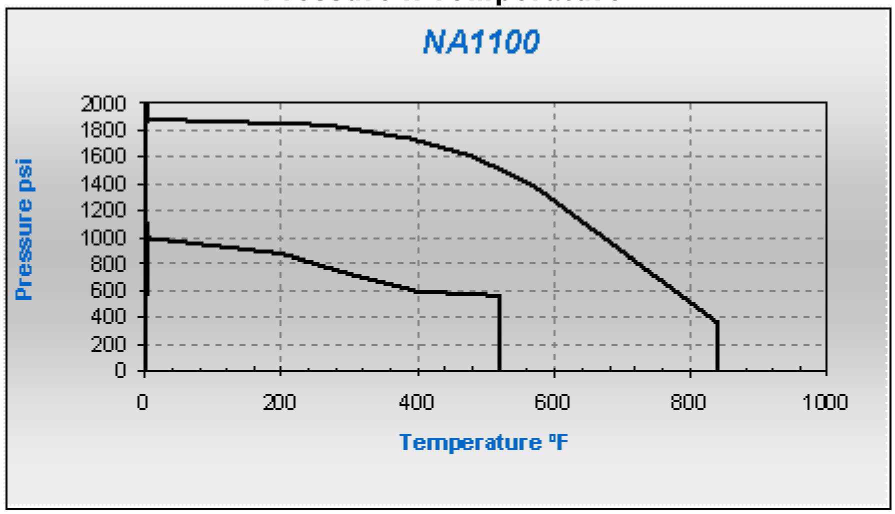
Type	Description	Value
Temperature Limits	Maximum	840°F (450°C)
	Continuous Max	518°F (270°C)
Pressure Limits	Maximum	1900 psi (130 bar)
	Continuous Max	1000 psi (70 bar)
ASTM Line Call Out F104	F712120E23M6	
Color	Black	
Available Sheet Sizes	Thicknesses	1/64", 1/32", 1/16", 3/32", 1/8"
	Sheet Sizes	59" x 63"
		59" x 126"
		118" x 126"

TYPICAL PHYSICAL PROPERTIES

ASTM Test Method	Property	Value
-	Density	106 lb/ft^3 (1.7 gg/cc)
F36	Compressibility	5-15%
F36	Recovery	min 50%
F152	Tensile Strength Across Grain	2175 psi (15 N/mm^2)
F495	Ignition Loss	max 50%

F146	Thickness Increase After 5 Hour Immersion	
	• ASTM IRM 903 @300°F (150°C)	max 15%
	• ASTM Fuel B @77°F (25°C)	max 15%
F146	Weight Increase After 5 Hour Immersion	
	• ASTM IRM 903 @300°F (150°C)	max 15%
	• ASTM Fuel B @77°F (25°C)	max 15%
F38	Creep relaxation	22%
	Torque Retention (DIN 52913)	35 N/mm^2
F37	Sealability at 1000 psi	0.2 ml/h

Pressure x Temperature



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NA1000M - Compressed Sheet with Aramid Fibers/Metal/NBR Binder

CONSTRUCTION

Style NA1000M is a compressed non-asbestos sheet gasket material produced from aramid fibers, reinforced with a woven wire mesh and bonded with nitrile rubber (NBR). The sheet is graphited on both sides. Style NA1000M is manufactured through the hot calendar process under rigorous quality control standards that are registered under ISO-9001 certification.

APPLICATION / SERVICE

Style NA1000M is a premium service gasket material that is ideally suited for applications with fluctuating pressures and temperatures. It has a broad range of applications in the process industries and in the water and wastewater industry. It is also commonly used in equipment such as pumps and valves. Style NA1000M is suitable for service handling that following general media categories:

- Mild inorganic acids
- Mild organic acids
- Aliphatic Solvents
- Diluted alkalis
- Water
- Brine
- Air
- Industrial Gases
- Animal Oils
- Synthetic oils
- Vegetable Oils
- Petroleum and Derivatives

SERVICE LIMITS

Type	Description	Value
Temperature Limits	Maximum	720°F (380°C)
	Continuous Max	390°F (200°C)
Pressure Limits	Maximum	1450 psi (100 bar)
	Continuous Max	580 psi (40 bar)
ASTM Line Call Out F104	ASTM 713230E23M6	
Color	Black	
Available Sheet Sizes	Thickness	1/32", 1/16", 3/32", 1/8"
	Sheet Sizes	59" x 63"
		59" x 126"

TYPICAL PHYSICAL PROPERTIES

ASTM Test Method	Property	Value
-	Density	118 lb/ft^3 (1.9 g/cm)
F36	Compressibility	10-20%
F36	Recovery	min 40%
F152	Tensile Strength Across Grain	2680 psi (18.5 N/mm$^{2)}$
F495	Ignition Loss	max 37%
F146	Thickness Increase After 5 Hour Immersion	
	• ASTM IRM 903 @300°F (150°C)	max 20%

	• ASTM Fuel B @77°F (25°C)	max 15%
F146	Weight Increase After 5 Hour Immersion	
	• ASTM IRM 903 @300°F (150°C)	max 20%
	• ASTM Fuel B @77°F (25°C)	max 15%
F38	Creep relaxation	-
	Torque Retention (DIN 52913)	-
F37	Sealability at 1000 psi	-

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ISO 9001 COMPANY

Compressed Sheet

NA1122

THE SOLUTION FOR STEAM APPLICATIONS

APPLICATIONS

Teadit style NA1122 was developed to have superior thermal stability in order to replace compressed asbestos gasket sheets in thermal cycling applications. It is specifically recommended for saturated and superheated steam applications. It is also suitable for sealing petroleum derivates, ethanol, chemical products and general services. Field tests have proven the results found in our laboratories and have confirmed the higher performance of the NA1122 compressed sheet.

CONSTRUCTION

Teadit style NA1122 is a compressed non-asbestos sheet gasket material produced from a combination of inorganic fibers and special fillers, bonded with nitrile rubber (NBR). It is manufactured through the hot calendar process under rigorous quality control standards that are registered under ISO-9001 certification. Teadit style NA1122 is also available wire reinforced. Sheet size: 59 x 63 in or 59 x 126 in. Thickness ranging from 1/64” to 1/4”. Color: black.

APPLICATION LIMITS

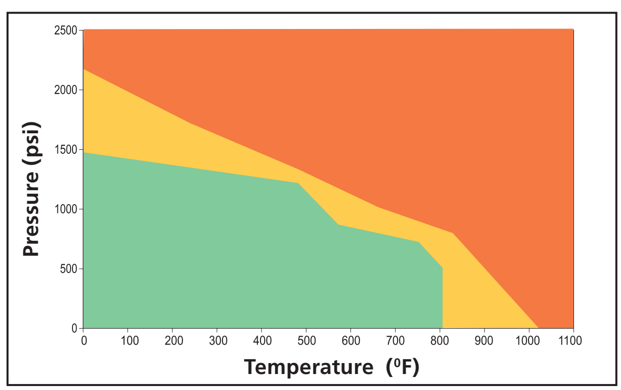
Consult P x T diagram as well as its chemical compatibility chart.

Service Limits

Temperature	Continuous: **806º F**
	Peak: **1022º F**
Pressure	Continuous: **1480 psi**
	Peak: **2177 psi**

- ✓ ***Thermal Stability***
- ✓ ***Incomparable Sealability***
- ✓ ***Recommended for Thermal Cycles***
- ✓ ***Asbestos Free***

P x T Diagram



General Suitability — Consultation is recommended — Technical consultation is mandatory

For applications near or above the “peak” curve, contact Teadit.

TEADIT®

Compressed Sheet NA1122

Overcoming Limits

The product was submitted to the following laboratory tests:

1. SEALABILITY TEST UNDER HIGH TEMPERATURES AND PRESSURES (SUPERHEATED STEAM)

Teadit style NA1122 reached its target of work above 800º F and 1480 psi without leakage.
See temperature x pressure chart.

TEST CONDITIONS

- Superheated steam
- Temperature: up to 800° F
- Pressure: up to 1480 psi
- Flanges ANSI RF 2 in 600 psi

TEMPERATURE X PRESSURE

Temperature (°F)	Pressure (psi)
Ambient	1480
210	1350
390	1270
570	870
750	667
800	550

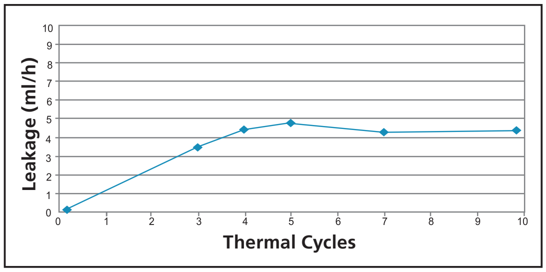
2. THERMAL CYCLING TEST (SUPERHEATED STEAM)

Teadit style NA1122 was submitted to numerous thermal cycles (more than 10 daily cycles) with seating stress of 5800 psi, increasing the temperature up to 800° F.

TEST CONDITIONS

- Superheated steam
- Temperature: 800° F
- Internal Pressure: 174 psi
- Flanges ANSI RF 6 in 150 psi

CYCLING X SEALABILITY



Final Results

Field tests as well as laboratory tests confirmed that, even under severe application conditions, Teadit style NA1122 has exceptional performance without leakage.

TYPICAL PHYSICAL PROPERTIES

Tests are based on 1.6 mm sheet thickness

Density	ASTM F1315	1.6 g/cm³
After 1 hour at 210º F		
Compressibility	ASTM F36A	7-17 %
Recovery	ASTM F36A	40 % min.
Tensile Strength	ASTM F152	9 MPa
Torque Retention	DIN52913	43 MPa

Thickness Increase	ASTM F146	
• ASTM Oil IRM 903, 5h / 300º F		15 % max.
• Fuel B, 5h / 77° F		15 % max.
Weight Increase	ASTM F146	
• ASTM Oil IRM 903, 5h / 300º F		30 % max.
• Fuel B, 5h / 77° F		20 % max.

TEADIT®
Solutions with Quality

Mar/09

TEADIT	**Superheated Steam Test** Reference: Teadit NA1122 vs. Garlock ST-706 Mar/09

1. Scope:

Compare the performance of gasket materials Teadit NA1122 and Garlock ST-706 when subjected to steam with high pressures, temperatures and thermal cycling.

2. Materials Tested:

- Teadit – NA1122 – 3,2 mm
- Garlock – ST-706 – 3,2 mm

3. Summary of Test Method:

A set of 6 in class 150 cast steel fixture made from two RF weld neck flanges with surface finish of 6.4µm (250 µin) was the superheated steam generator (Figure 1). A water supply system with a feed pump and pressure vessel connected to the flange set like a boiler-water feed system. This system is equipped with a steam pressure regulator to control the water feed keeping the steam pressure stable. Ten thermal cycles were performed and the leak rate was measured in each hot phase. After each thermal cycle, the gasket stress was measured and one hydrostatic test was performed.

Figure 1 – A set of 6 in class 150 cast steel fixture made from two RF weld neck flanges.

4. Test Conditions:

- ✓ Gasket Stress: 40 MPa (5800 psi)
- ✓ Torque of Bolts: 219 N m (159 lb ft)
- ✓ Tightening Sequence: 1-5-3-7 – 2-6-4-8 ASME PCC-1
- ✓ Tightening method: Electronic Torque Wrench
- ✓ Test Media: Superheated Steam.
- ✓ Temperature: Thermal cycles of 400°C
- ✓ Internal Pressure: 12 bar (174 psi)
- ✓ Gasket Stress control: Bolt Length
- ✓ Leak Rate Control: Pressure Loss.

Teadit Indústria e Comércio Ltda.
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3.2. Test Procedure

3.2.1. Center the gasket into the flange face.
3.2.2. Install the calibrated bolts, washers and nuts finger tight.
3.2.3. Record bolt lengths before tightening.
3.2.4. Using a calibrated torque wrench, torque bolts according to the ASME PPC-1 [9] cross pattern. Gasket seating stress: 34 MPa (5000 psi);
3.2.5. Measure and record bolt elongations at room temperature.
3.2.6. Perform a hydrostatic test at room temperature and set pressure;
3.2.7. Start a heating cycle keeping the pressure constant at the set value. The excess pressure is released by the pressure relief valve as the system heats up.
3.2.8. Maintain the set test pressure and temperature for 8 hours.
3.2.9. Record the leak rate after the system has reached the set pressure and temperature and just before a cool down.
3.2.10. Record the leak rate just before starting the cool down phase (after 8 hours of heating).
3.2.11. Perform ten (10) daily cycles repeating steps 3.2.5 though 3.2.11.
3.2.12. The test is completed if one of following condition is reached:
- The gasket fails a hydrostatic test;
- The gasket blows-out;
- The leak rate during the hot phase is higher than the capacity of the water feed pump to replace the lost Superheated Steam;
- Ten cycles are completed successfully.

5 - Results:

Teadit NA1122 - The test result is shown in Figure 2 and 3. The test duration was 10 days. The leak rate of the Superheated Steam was stable at about 1.0 x 10^{-2} mg/s.m. After each thermal cycle a hydrostatic test was successfully performed. The material completed the test procedure without fail.

Garlock ST-706 - The result is shown in Figure 2 and 3. The material failed the hydrostatic test after the first thermal cycle. The testing was continued for research purposes and aborted after the sixth cycle due to the continuous failures at each hydrostatic test and increase of the leak rate.

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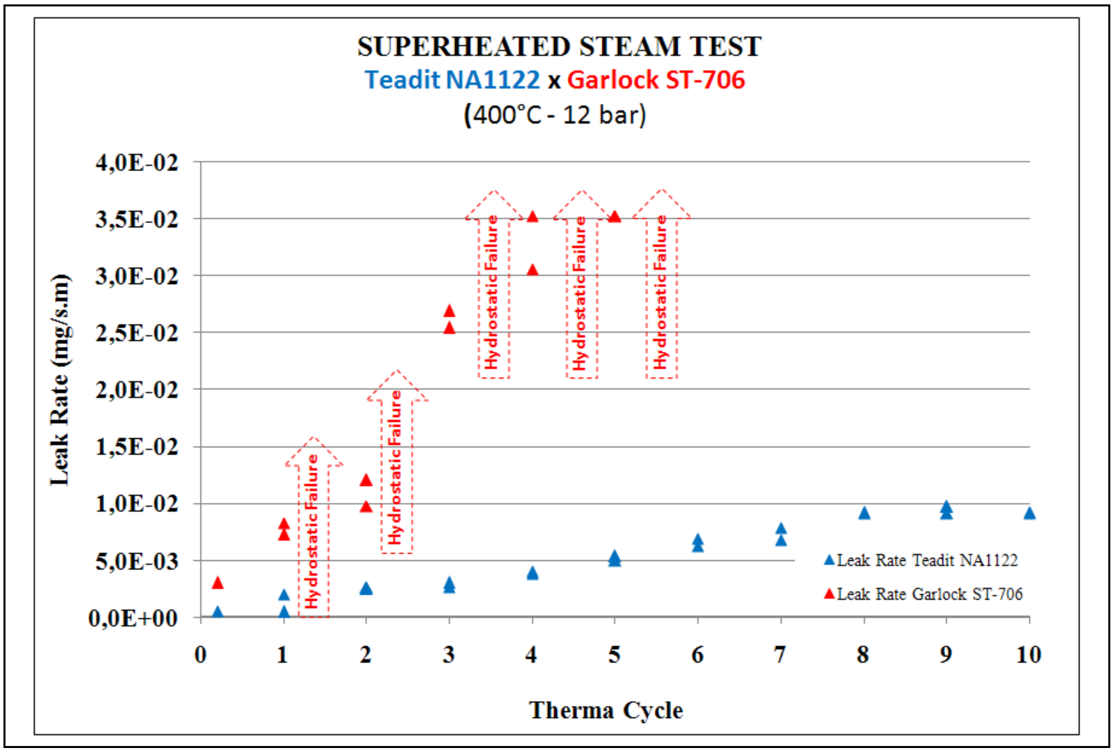


Figure 2: NA1122 x ST-706

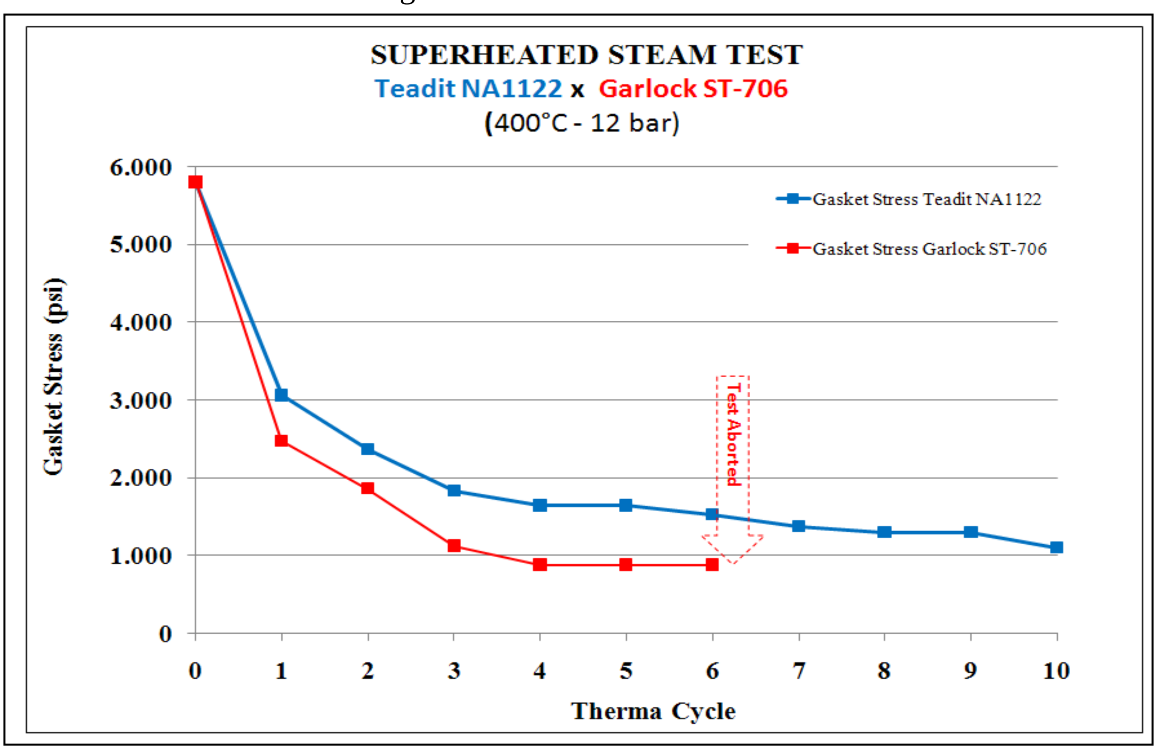


Figure 3: NA1122 x ST-706

TEADIT	**Superheated Steam Test** Reference: Teadit NA1122 vs. Garlock ST-706 Mar/09

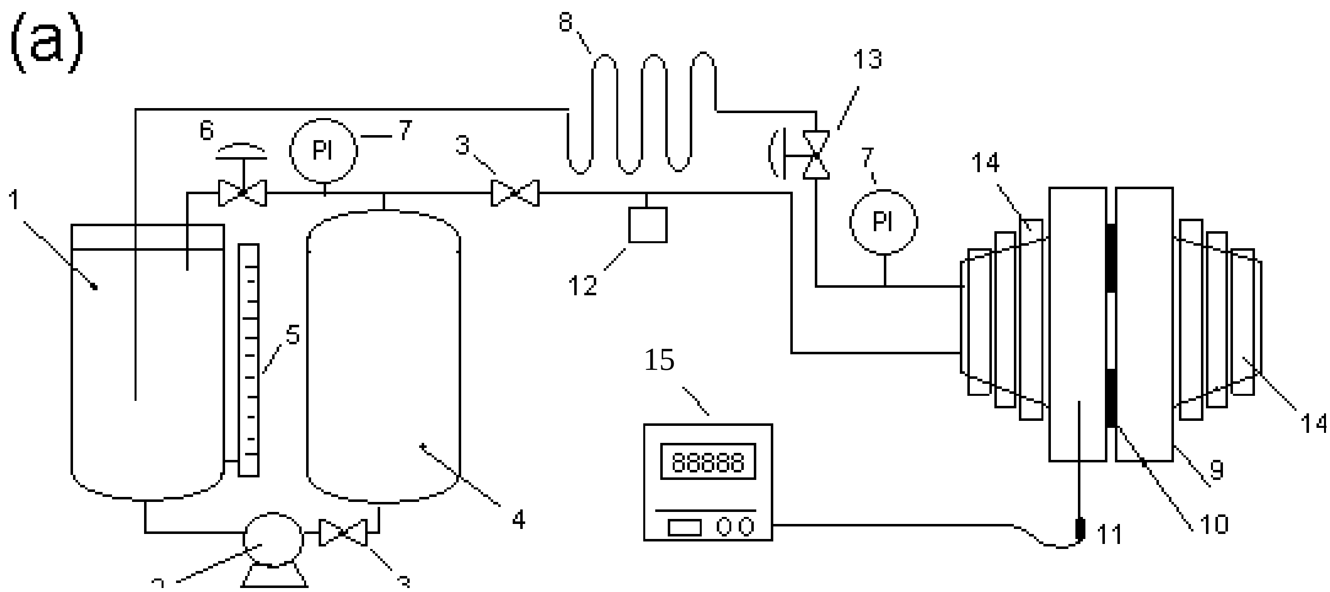
Figure 4: Teadit NA1122 after test.

Figure 6: Teadit NA1122 after disassembled.

Figure 5: Garlock ST-706 after test.

Figure 6: Garlock ST-706 after disassembled.

6 – **Schematic of the Superheated Steam Test Rig**



Test rig components:

1- Water Vessel.
2- Water Feed Pump.
3- Check Valve.
4- Pressure Vessel.
5- Calibrated Glass Sight Gauge.
6- Pressure Regulator.
7- Pressure Gauge.
8- Condenser.
9- Flange Set.
10- Test Gasket.
11- Temperature Sensor.
12- Pressure Controller
13- Relief Valve.
14- Heating Tapes.
15- Temperature Controller

" M & Y " Factors

COMPRESSED NON-ASBESTOS	Thickness (mm)	" m " (no units)	" y " (psi)
NA 1001	1.6	2	3500
	3.2	2	3500
NA 1040	1.6	2.5	3500
	3.2	3.2	3000
NA 1081	1.6	2.2	4000
	3.2	2.2	4000
NA 1082	1.6	2	3500
	3.2	2	4000
NA 1085	1.6	2.5	2500
	3.2	6.8	3500
NA 1100	1.6	2.9	3500
	3.2	4.1	3500
NA 1122	1.6	3	6000
	3.2	3	6000
NA 1076	1.6	5	5500
	3.2	4	6500
NA 1092	1.6	2.9	4000
	3.2	4.5	5000
NA 1000(1)	1.6	7.0	5000
	3.2	11.0	7000
TEALON			
TF 1570	1.5	2	1500
	3.0	2	1500
TF 1580	1.5	2	1800
	3.0	2	1500
TF 1590	1.5	4.4	2500
	3.0	3.5	2000

NOTES:

NOTE (1): Liquid Test. General Note:Properties and application parameters shown throughout this datasheet are typical. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury. Specifications are subject to change without notice. This edition supersedes all previous issues. Dec. 2010 REV.

Dielectric properties of Teadit NA Sheet		
Material	**KV/mm**	**V/Mil**
NA 1000	11	279
NA 1001	19	483
NA 1030	19	483
NA 1040	16	406
NA 1085	12	305
NA 1060 / NA 1020 / NA 1080	18	457
NA 1081	16	406

Note: Test based on 1/16" material

Silicone Rubber (SI)

Silicone rubber offers excellent resistance to the aging process, being unaffected by sunlight or ozone. For that reason it is often used in hot air. It has little mechanical resistance. It does not resist aliphatic and aromatic hydrocarbons or steam.

Typical Properties

Thickness (Inches)	Width (Inches)	Durometer Hardness Shore A±5	Tensile	Elongation	Temp	Finish
1/16 thru 1/4	36 & 48	50	1080	350	-40° F to 400° F	Smooth
1/16 thru 1/4	36 & 48	60	1130	300	-40° F to 400° F	Smooth

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Fluoroelastomer (FKM)

FKM fluorelastomer offers excellent resistance to strong acids, oils, gasoline, chlorate solvents and aliphatic and aromatic hydrocarbons. Not recommended for use with aminos, esters, ketones and steam.

			Typical Properties			
Grade	**Thickness (Inches)**	**Width (Inches)**	**Durometer Hardness Shore A±5**	**Tensile**	**Elongation**	**Temp**
A	1/16 thru 1/4	36 & 48	75	1650	165	-18°C to 204°C (400°F)

"Commercial Grade" FKM also available

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Chloroprene Rubber (CR)

(CHLOROPRENE - CR)

Has excellent resistance to oils, ozone, sunlight and aging. Low permeability to gases. Recommended for use with gasoline and non-aromatic solvents. It offers little resistance to strong oxidants and to aromatic and chlorate hydrocarbons.

Typical Properties

Thickness (Inches)	Width (Inches)	Durometer Hardness Shore A ±5	Tensile	Elongation	Temp	Finish
1/16 thru 1	36 & 48	40	800	350	-20°F to +170°F	Smooth
1/16 thru 2 1/32 thru 2	36 & 48 72	50	800	300	-20°F to +170°F	Smooth
1/16, 1/8, 1/4		60	900	300	-20°F to +170°F	Smooth
1/16 thru 2	36 & 48	70	1000	200	-20°F to +170°F	Smooth
1/16 thru 2	36 & 48	80	1000	100	-20°F to +170°F	Smooth

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Red Rubber (SBR)

(STYRENE-BUTADIENE - SBR)

SBR rubber commonly called "synthetic rubber" was developed as an alternative to the natural rubber. Recommended for service in cold and hot water, air, steam and some weak acids. It should not be used with strong acids, oils, grease and chlorates. It offers little resistance to ozone and to the majority of hydrocarbons.

Typical Properties

Thickness (Inches)	Width (Inches)	Durometer Hardness Shore A ±5	Tensile	Elongation	Temp	Finish
1/32 thru 1/4	36, 48	75	400	150	-20°F to +170°F	Smooth†

*Also available in black on request.
†Also available in fabric finish upon request

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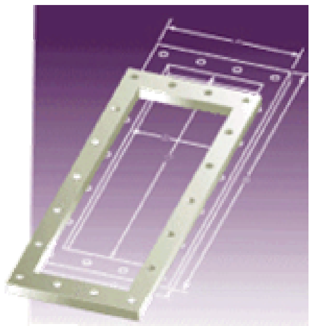

Natural Rubber (NR)

Natural Rubber

Typical Properties

Thickness (Inches)	Width (Inches)	Durometer Hardness Shore A±5	Tensile	Elongation	Temp	Finish	
				BLACK			
1/16 thru 1	36 & 48	40	800	350	-20°F to +170°F	*Smooth	
1/32 thru 1	36 & 48	50	800	300	-20°F to +170°F	*Smooth	
1/32 thru 1	36 & 48	60	900	300	-20°F to +170°F	*Smooth	
1/32 thru 1	36 & 48	70	1000	200	-20°F to +170°F	*Smooth	
1/16 thru 1	36	80	1000	100	-20°F to +170°F	*Smooth	
				WHITE			
1/16 thru 1/4	36 & 48	60	1000	350	-25°F to +180°F	Smooth	FDA Approved Non-Toxic Ingredients Non-Allergenic Non-Marking Good oil resistance

*Also available in Matte Finish.

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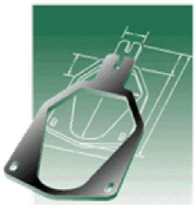

Ethylene-Propylene (EPDM) Rubber

EPDM rubber has good resistance to ozone, steam, strong acids and alkali. Not recommended for use with solvents and aromatic hydrocarbons.

Typical Properties

Thickness (Inches)	Width (Inches)	Durometer Hardness Shore A ±5	Tensile	Elongation	Temp	Finish
1/16 thru 1/4	36 & 48	40 50 60	800	300 300 250	-40°F to +212°F	Smooth

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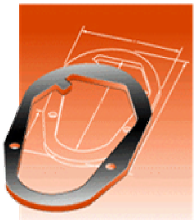
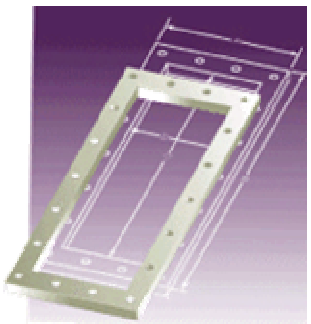


Nitrile Rubber (NBR) Black or White

NBR rubber is also know as Buna-N. It offers good resistance to oils, and alipahatic hydrocarbons and gasoline. Little resistance to strong oxidant agents, chlorate hydrocarbons, ketones and esters.



Typical Properties

Thickness (Inches)	Width (Inches)	Durometer Hardness Shore A±5	Tensile	Elongation	Temp	Finish	
				BLACK			
1/16 thru 1	36 & 48	40	800	350	-20°F to +170°F	*Smooth	
1/32 thru 1	36 & 48	50	800	300	-20°F to +170°F	*Smooth	
1/32 thru 1	36 & 48	60	900	300	-20°F to +170°F	*Smooth	
1/32 thru 1	36 & 48	70	1000	200	-20°F to +170°F	*Smooth	
1/16 thru 1	36	80	1000	100	-20°F to +170°F	*Smooth	
				WHITE			
1/16 thru 1/4	36 & 48	60	1000	350	-25°F to +180°F	Smooth	Available as FDA Approved Non-Toxic Ingredients Non-Allergenic Non-Marking Good oil resistance

*Also available in Matte Finish.

Nov 2010 REV.

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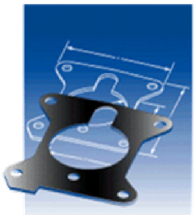
Hypalon® Rubber



Hypalon®, similar to Neoprene rubber, offers excellent resistance to ozone, sunlight, chemical products and good resistance to oils.

Typical Properties

Thickness (Inches)	Width (Inches)	Durometer Hardness Shore A ±5	Tensile	Elongation	Temp	Finish
1/16 thru 1/4	36 & 48	65	400	350	-40° F to 275° F	Smooth

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Product: Garlock IFG5500	
SE: 033/05	**Analyst:** DFC/GMS
Project: 7.0442-30	**Date:** 17th February 2005
Analysis: Composition	

1. SCOPE

Characterize Garlock IFG5500 material and compare it to TEADIT NA1090.

2. METHOD

The material composition was identified by Infrared Spectroscopy, Microscopy and Thermogravimetric analyses.

Thermogravimetric analysis was also used to make determinations about thermal stability.

3. RESULTS

According to the results of Infrared Spectroscopy (Figure1), Microscopy (Figure 2) and Thermogravimetric analysis (Figure 3) the composition of both materials were determined as shown in Table 1.

Table 1 – Raw Materials

Garlock IFG5500	NA1090
NBR	NBR
ARAMID	ARAMID
INORGANIC FILLER	INORGANIC FILLER

Figure 1- Infrared Spectroscopy

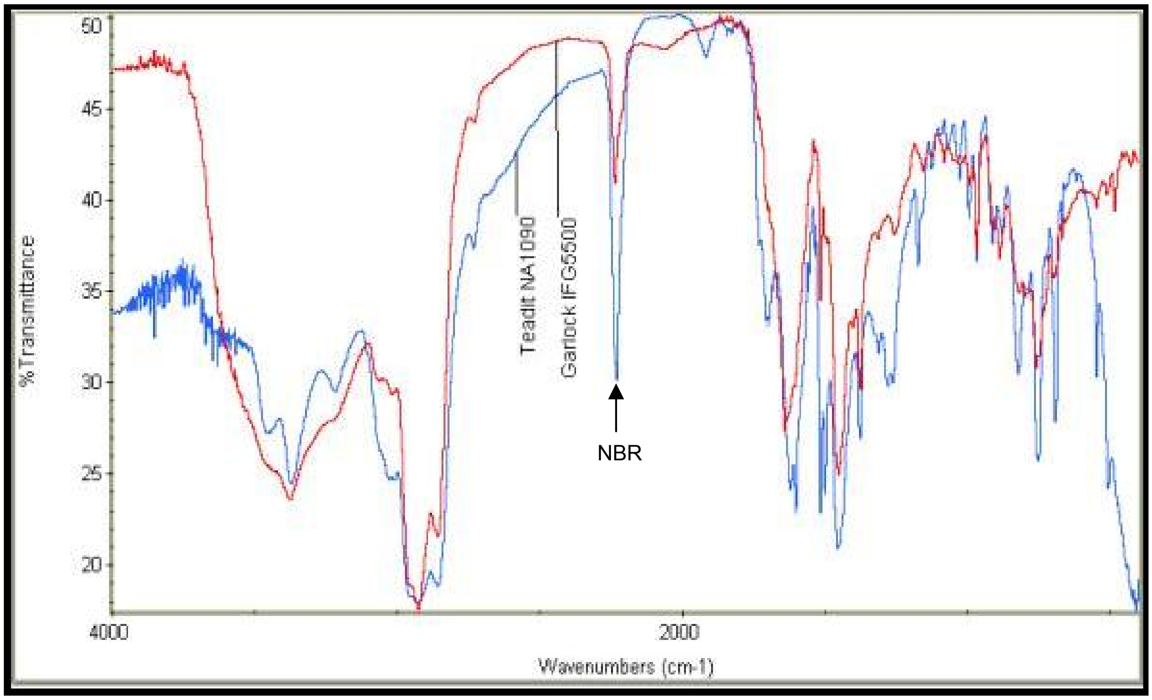
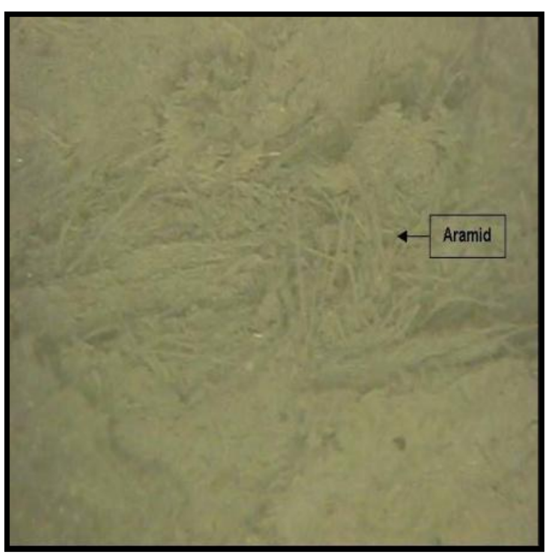


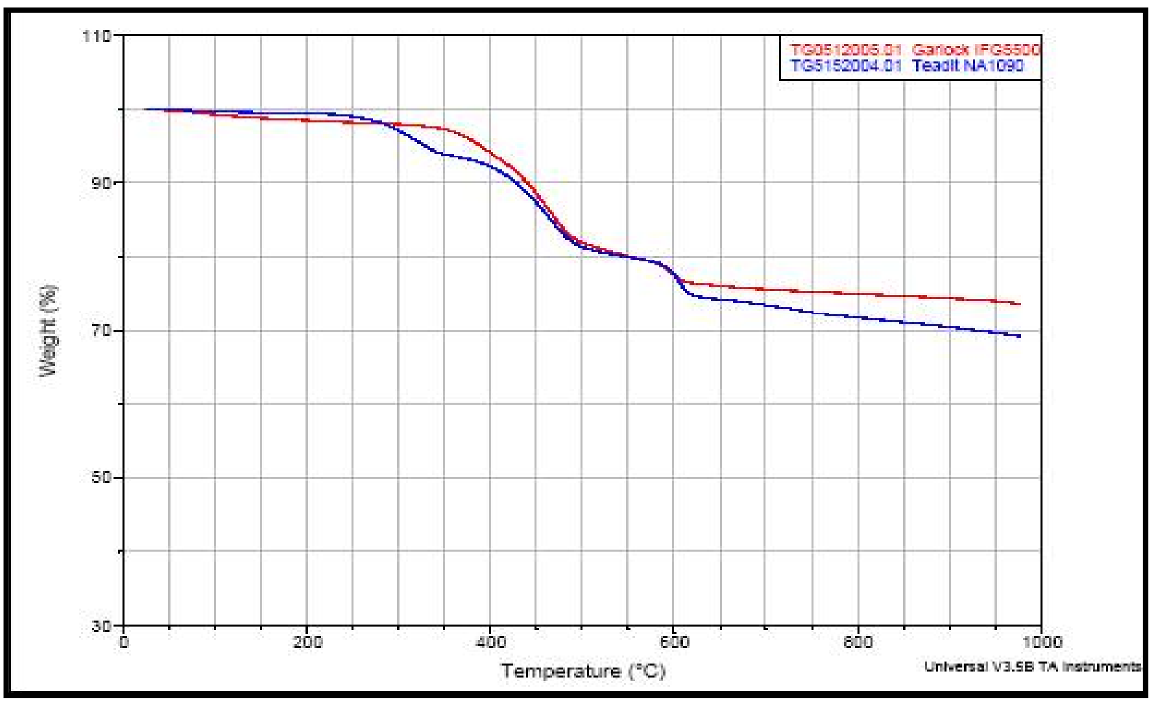
Figure 2 – Garlock IFG5500: Microscopy



(a) As received

(b) After 600ºC/1h

Figure 3 –Thermogravimetric analysis



The typical values of physical properties for Garlock IFG5500 and TEADIT NA1090 are present in Table 2.

Table 2 – Physical properties

	Garlock IFG5500		**NA1090**	
Reference	www.garlock.com	Test result	Technical data	Test Result
Compressibility (%)	7 – 17	10	7 – 17	11
Recovery (%)	Min 50	63	Min 45	62
Tensile Strength (N/mm^2)	1500	1195	1140	1400
IRM-903 (150ºC/5h)				
Thickness increase (%)	0 – 15	6	Max 20	5
Fuel-B (Room Temp. /5h)				
Thickness Increase (%)	0 – 15	6	Max 15	5
Weight Increase (%)	Max 15	14	Max 20	12
Sealability 500 psi, F37 (ml/h)	0,2	1,2	1,0	0,9
Sealability 1000 psi, F37 (ml/h)	---	0,2	0,35	0,3
Creep ASTM (%)	---	35	34	30

4. CONCLUSION

The product Garlock IFG5500 presents a composition similar to TEADIT NA1090.

Garlock IFG5500 and TEADIT NA1090 have equivalent thermal stability.

The physical properties of Garlock IFG5500 are close to TEADIT characteristics as well.

There are no significant differences between Garlock IFG5500 and TEADIT NA1090 materials.

Final Program

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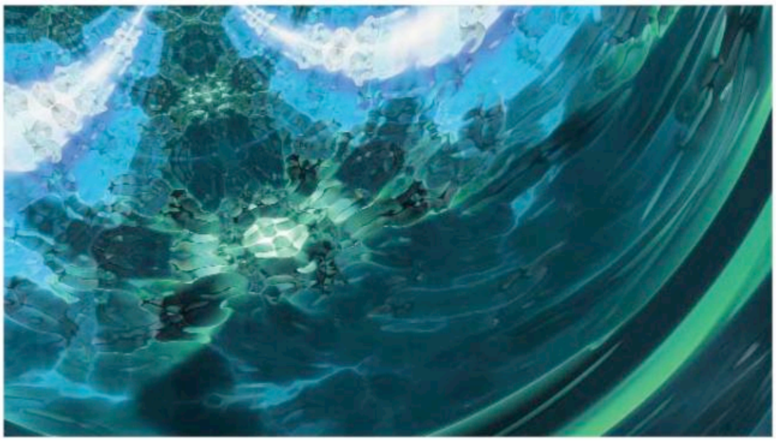

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EVALUATION OF PIPE FLANGE GASKETS RELAXATION

Proceedings of the ASME 2010 Pressure Vessels & Piping Division / K-PVP Conference
PVP2010
July 18-22, 2010, Bellevue, Washington, USA

PVP2010-25961

EVALUATION OF PIPE FLANGE GASKETS RELAXATION

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ABSTRACT

Relaxation is a characteristic observed in any gasket type, being affected by a series of factors, such as composition, manufacturing process, temperature, etc. Therefore the relaxation of the gasket cannot be treated in a generic way. This paper presents a test protocol, based upon an existing test standard, as well as actual relaxation results for spiral wound gasket and compressed non-asbestos, the most used gaskets in pipe flanges. The objective is to have data to allow a better evaluation of the gasket relaxation behavior in order to determine the additional bolt pre-load to compensate for it.

INTRODUCTION

Gasket relaxation is frequent cause of piping joint leakage. To reduce its effects it is a common practice in the field to increase the stud preload. However, ASME Section VIII, Division 1, Appendix 2 [1], bolting calculation does not take relaxation into consideration. ASME Post Construction Committee (PCC-1) [2] has introduced the concept of an extra load on the studs in order to compensate, among other factors, the gasket relaxation. Although this guideline did it in a linear way, i.e., it recommended the same level of load equivalent to 50% of stud yield limit whatever is the application. But this approach does not consider that there are others variables related in this process which can interfere in the final result. Therefore, the effectiveness of this recommendation is limited. At the time of writing this paper a revision of the ASME PCC-1 was being discussed. This revision proposes a range for the stud load from 40 up to 70% of bolt yield limit depending on the application, flange type, etc.

Over time many studies were undertaken in order to better understand the gasket relaxation process [3-6].

This paper presents a test model where gasket relaxation is evaluated based in the following elements: Gasket seating stress, temperature, thickness and time. The studies were performed in a test rig and protocol based upon standard DIN 28090-2 [7], which is part of the standard EN 13555 [8]. The test rig was set up to better reproduce actual gasket behavior in a pipe flange. This test model does not simulate internal pressure, thermal cycles and joint external forces.

The purpose of this paper is to determine the relaxation as a function of the gasket thickness reduction. Assuming that all the reduction in gasket thickness will be transferred to the studs, this data will be equivalent to the total of stud elongation reduction. Bending flange effects are out of the scope. With this test data available it is possible to estimate how much of additional elongation will be needed in the studs in order to compensate the gasket relaxation effects.

Petrobrás, a Brazilian corporation of petroleum and energy, is working in the development of a gasket bolting software. Since there is no data available about gasket relaxation, Petrobrás plans to include the results of this study in its calculation method as an additional variable to increase initial preload and assure long term joint sealability.

Materials chosen for this evaluation, Compressed Non-Asbestos fiber gasket sheet (CNA) and Spiral Wound Gasket (SWG), are widely employed in the industry usually in ASME B16.5 [9] flanges. Petrobrás criteria to specify these gaskets in accordance with its standard N-2797 [10] are showed below:

CNA

Composition: NBR rubber + Aramid fiber
Flange: class 150 psi
Thickness: 1.6 mm (1/16") and 3.2 mm (1/8")
Media: Utilities

SWG

Composition: Stainless Steel strip + Flexible Graphite filler
Flange: class 150, 300 and 600 psi
Thickness: 4.45 mm (0.175")
Media: Steam and Hydrocarbon

TEST RIG DESCRIPTION

Figure 1 shows a sketch of the test rig proposed by standard DIN 28090-2.

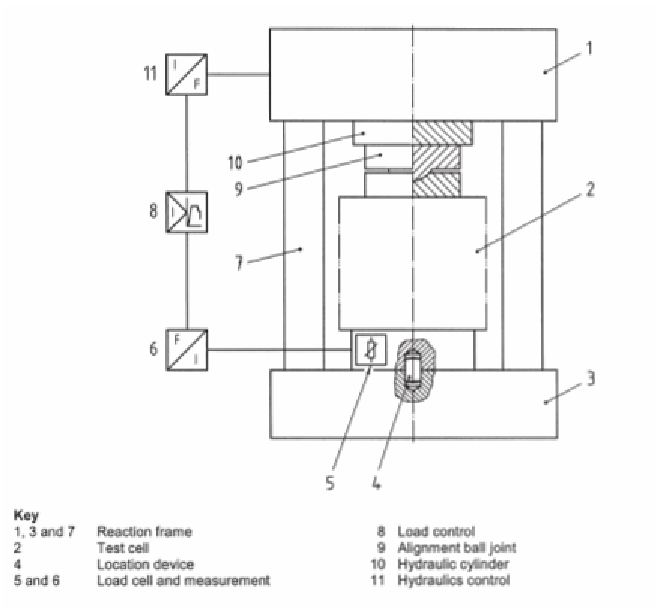


FIGURE 1

Figure 2 shows test rig used for this paper.

FIGURE 2

The standard DIN 28090-2 defines a hydraulic tightening for the test rig. However, for this paper to better simulate an actual flange installation a mechanical device was used. In a hydraulic rig the seating stress is constant as the gasket reduces in thickness. In a mechanical rig behavior is similar to an actual flange where the gasket load is reduced as it relaxes. Furthermore Table 1 highlights some important differences concerning the behavior of a gasket in a pipe flange and in the test rig.

TABLE 1

	Test rig	Pipe flange
Heating	From the outside Stud is not heated	From inside Studs are heated
Gasket load	Flat Platens No bending effect Stud compression	Standard flanges Bending effect Stud elongation
Stud	One centered stud	Several studs around the gasket

These differences make the gasket seating stress and consequently its thickness reduction higher in the test rig than in an actual pipe flange, especially for hot tests. Because of this, the results for CNA up to 150º C (302º F) and for SWG up to 200º C (392º F) were considered.

TEST PARAMETERS

Gasket material and identification:

- Style A CNA NBR rubber + Aramid fiber
- Style B CNA NBR rubber + Carbon fiber
- Style C CNA NBR rubber + Inorganic fiber
- Style D SWG SS strip + Flexible Graphite filler

CNA styles B and C, even though not used by Petrobrás, were included in the evaluation since they are representative in the industry.

Specimen size:

- 55 x 75 mm (2.1” x 3.0”) (CNA)
- NPS 2 class 300 (SWG)

Some users, including Petrobrás, specifies SWG with outer ring for flanges up to NPS 6” and both outer and inner rings for flanges from NPS 8” and up. But for the tests were used SWG with outer and inner rings following the last revision of the standard ASME B16.20 [11], which recommends this configuration for any NPS size and pressure class flange.

Thickness:

CNA

- 1.6 mm (1/16”)
- 3.2 mm (1/8”)

SWG

- 4.45 mm (0.175”)

Temperature:

CNA

- Room Temperature (RT)
- 100º C (212º F)
- 150º C (302º F)

SWG

- Room Temperature (RT)
- 100º C (212º F)
- 200º C (392º F)

Gasket seating stress:

CNA

- 50 MPa (7250 psi)

SWG

- 50 MPa (7250 psi)
- 207 MPa (30000 psi)

TEST PROCEDURE

Test procedure showed below follows the steps recommended by standard DIN 28090-2.

1. Record initial specimen thickness (h_{D1}).
2. Apply a preload (F_v) of 1MPa (145 psi) for one minute and record the specimen thickness (h_{D2}).
3. Increase load over the specimens until the value specified (F_w) is achieved and record the specimen thickness (h_{D3}).
4. Reduce the load to (F_v) and record the specimen thickness (h_{D4}).
5. Repeat step 3 and record the specimen thickness (h_{D5}).
6. For hot test, heat at a uniform rate (5º C/min) up to final temperature.
7. Record the specimen thickness after 16 hours (h_{D6}).
8. Reduce load and cool down the test rig.

Thickness (h_{D5}) is always recorded at room temperature and thickness (h_{D6}) is recorded at test temperature.

RESULTS

Relaxation (R) was defined as the thickness reduction in millimeter between values (h_{D5}) and (h_{D6})

$$R = h_{D5} - h_{D6} \quad \text{(mm)} \qquad (1)$$

To analyze the results 4 charts were plotted:

- Figure 3 CNA 1.6 mm (1/16")
- Figure 4 CNA 3.2 mm (1/8")
- Figure 5 SWG 50 MPa (7250 psi)
- Figure 6 SWG 207 MPa (30000 psi)

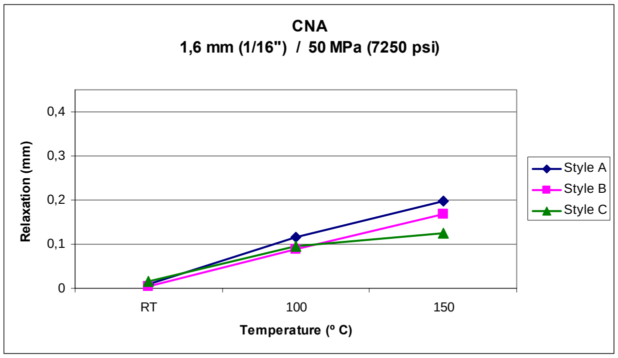


FIGURE 3

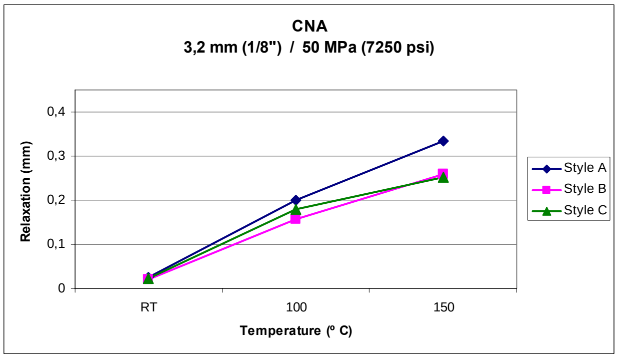
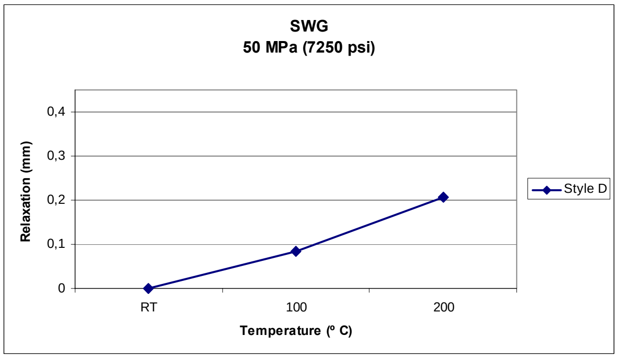


FIGURE 4



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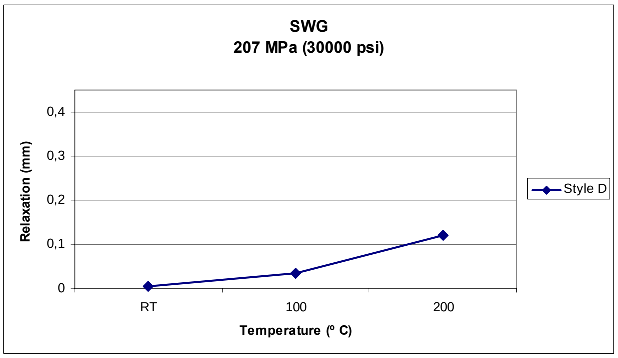

FIGURE 6

The tests results showed in Figures 3 and 4 indicate that there is a relation between CNA thickness and the relaxation observed. The relaxation increases as the CNA thickness increases.

The tests results showed in Figures 5 and 6 indicate that there is a relation between SWG seating stress applied and the relaxation observed. Relaxation reduces as seating stress increases. For its constructive features, thickness is less relevant for SWG.

DISCUSSION

ASME Section VIII, Division 1, Appendix 2 describes bolting calculation method and define minimum tightening taking into account internal pressure, temperature, factors m and y, flange surface type and gasket dimensions. But for each flange size, there is a specific value of effective stud length, which is described in ASME PCC-1 as the distance between mid-thickness of the nuts. Therefore, this is another variable that can affect joint sealing performance, since the relation between gasket reduction thickness and effective stud length in not constant. As per ASME bolting calculation method, maximum stud allowable stress in order to have minimum torque is about 25% of its yield limit (S_y). Assuming the proposed revision of the standard ASME PCC-1, maximum torque is equivalent to 70% of stud yield limit (S_y). Thus, effective stud elongation (Ee) can be understood as the range of these two limits. The value of Ee represents what is available to compensate gasket relaxation as well as embedment, tightening method precision, thermal expansion and all the others variables related to flange tightening loss.

$$Ee = 0.7S_y - 0.25S_y \qquad (2)$$

Figures 7 and 8 show the variation of effective stud elongation (Ee) in accordance with the pressure class and NPS for some ASME B16.5 flanges, based on the above criteria using ASTM SA-193-B7 studs.

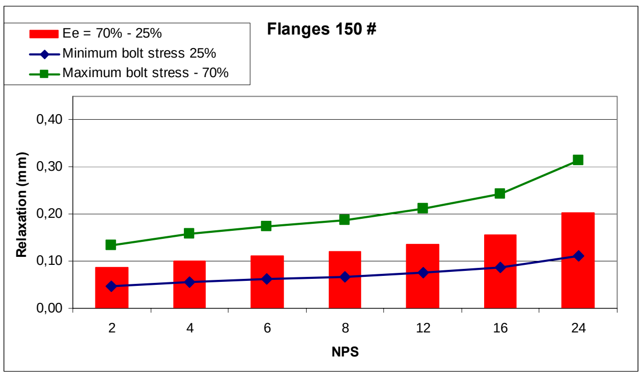

FIGURE 7

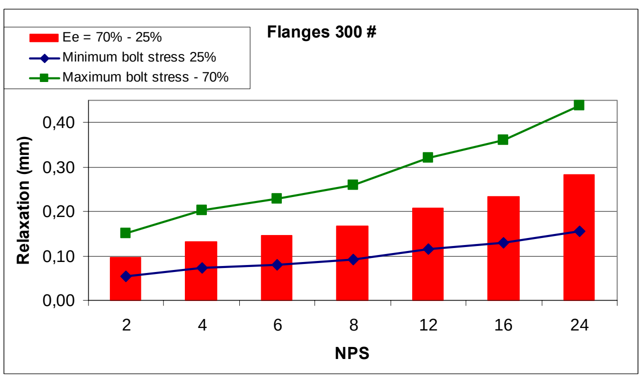

FIGURE 8

Field good practices recommend CNA gasket 1,6 mm (1/16") for smaller flanges and CNA gasket 3,2 mm (1/8") for larger flanges. This criteria was established taking as reference possible flatness problems in flanges of bigger NPS. Moreover a thicker gasket is also recommended to compensate surface irregularities typically observed in older flanges.
Petrobrás standard N-2797 specifies CNA gasket thickness, as below:

– Flanges NPS ≤ 10" - 1,6 mm (1/16")
– Flanges NPS ≥ 12" - 3,2 mm (1/8")

Nevertheless when the relaxation test results for CNA gaskets are associated to the Ee showed in Figures 7 and 8, it becomes clear that the above mentioned criteria to define CNA gasket thickness can generate some distortions.

Figures 9 and 10 show examples comparing Ee for some flanges and relaxation of style A.

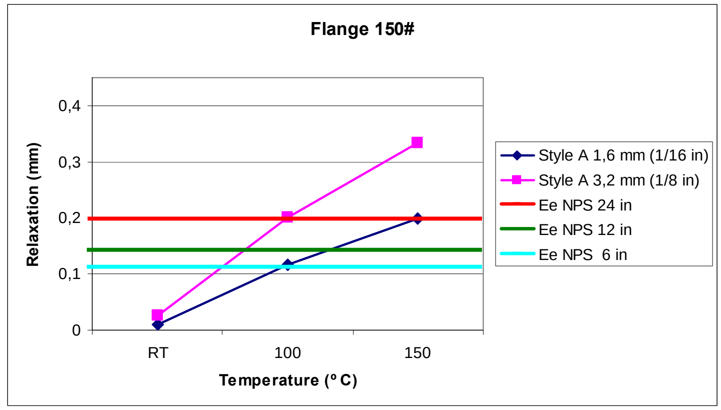

FIGURE 9

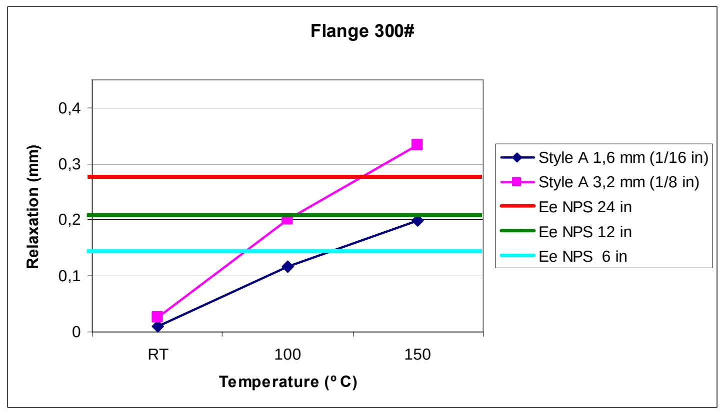

FIGURE 10

The charts indicate that depending on gasket temperature and thickness, Ee for some flanges size cannot be enough to compensate CNA gasket relaxation effects. Therefore the test results suggest that the CNA gasket thickness specification must also consider operation temperature as well as Ee for each NPS and flange pressure class. Additionally other thickness should be evaluated to improve joint sealing performance. Further studies came to similar conclusions:

Veiga et al. [3] relaxation investigation showed that the temperature has an important contribution to relaxation of this type of gasket.

A steam test performed with CNA equivalent to style A also presented by Veiga et al. [12] showed a dramatic level of relaxation in a flange NPS 6 class 150. Figure 11 shows a chart summarizing the test which included the following variables:

– Thermal cycles: one per day
– Hydrostatic test: one per day
– Temperature: 300°C (572 °F)
– Pressure: 30 bar (435 psi)
– Sample thickness: 3.2 mm (1/8")

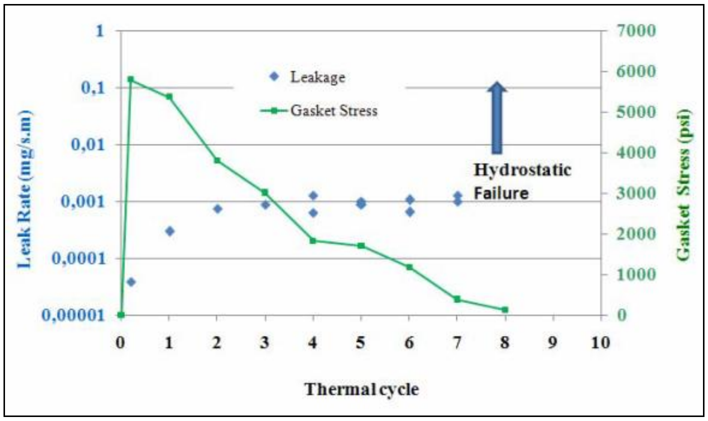

FIGURE 11

Figures 12 and 13 show a correlation between relaxation tests results for SWG and the Ee showed in Figures 7 and 8.

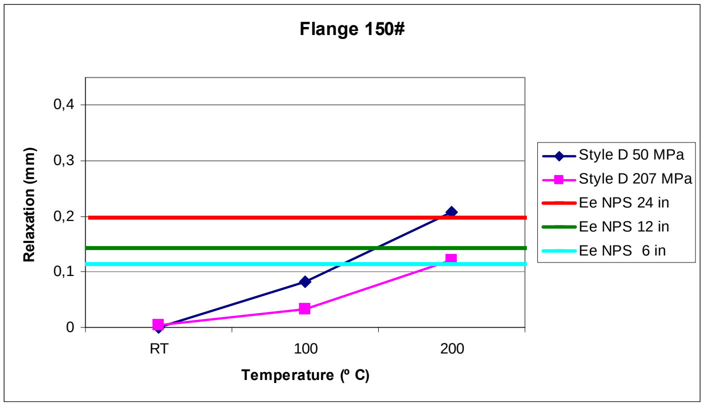

FIGURE 12

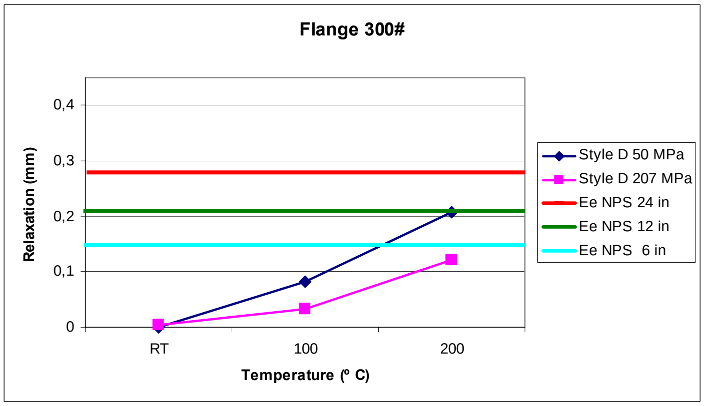

FIGURE 13

The charts indicate that depending on gasket temperature and seating stress, Ee for some flanges size cannot be enough to compensate SWG relaxation effects. Therefore the test results suggest that application of SWG must consider seating stress and operation temperature as well as Ee for each NPS and flange class. A minimum seating stress per flange size should be evaluated to improve joint sealing performance.
The proposed revision of standard ASME PCC-1 recommends the highest allowable seating stress for assembly of a pipe flange. The results shown in Figures 12 and 13 confirm that this recommendation improves SWG reliability.

CONCLUSION

It is possible to determine the relaxation and compensate its effects by increasing stud preload.

There is a correlation between CNA gasket thickness and its level of relaxation. The relaxation increases as the CNA thickness increases. Specification of CNA gasket thickness must be considered for a better sealing performance.

There is a correlation between SWG seating stress and its level of relaxation. The relaxation reduces as seating stress increases. Specification of SWG seating stress must be considered for a better sealing performance.

The proposed revision of ASME PCC-1 suggests, if manufacturer data is not available, a relaxation reference equal to 30%. But it was observed in these tests that relaxation cannot be treated in a linear way.

Further tests have to be carried out with standard flanges to establish a correlation with the test rig used for this paper.

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ANALYSIS OF BOLTED JOINTS

Edited by
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DETERMINATION OF CRITICAL TEMPERATURE OF COMPRESSED NON-ASBESTOS FIBER SHEET GASKETS

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ABSTRACT

Temperature and pressure limits of compressed non-asbestos gaskets have always been of interest to end users, as well as the gasket industry. Since flanges up to class 300 cover the majority of industrial applications of compressed fiber gaskets, a proposed procedure has been developed to clearly document the effect that temperature has on leak rate of the gasket at the maximum internal flange pressure. Different types of non-asbestos compressed gaskets were tested and results showed that for each material, there is a critical temperature after which leakage increases significantly.

1. INTRODUCTION

Resistance to the operating conditions may determine effectiveness of any gasket material. To ensure proper sealing a gasket has to create a seal, which can be maintained under operating conditions during the service life. It has to be resistant to chemical attacks and must withstand the temperature and pressure changes. In addition, the gasket should not contaminate the media or promote corrosion [1,2].

Temperature influences the ability of gasket materials to create and maintain a seal and also has an effect on the mechanical behavior of the flanges. As temperature is a significant factor, which directly affects the tightness in a gasketed joint, it is important to know the temperature limit of the gasket material [1,2].

In this study a procedure has been developed to determine the critical temperature of compressed non-asbestos gasket sheets used in ASME B16.5 flanges up to class 300 [3] which comprise the majority of industrial applications.

2. EXPERIMENTAL

Material: Four styles of Non-Asbestos Fiber Sheets 1/16in thick were tested. Table 1 shows the materials composition. The gasket dimensions are 60.4mm ($2^3/_8$") ID and 111.25mm ($4^3/_8$") OD.

Apparatus: Teadit 300 Test Bench was used for Sealability Tests. This Test Unit is composed of three ASME B16.5 standard flanges (Figure 1) each equipped with a heating element inside, an outside insulation and a digital temperature controller. Once the gasket is installed the system is connected to a computer for data acquisition and control. The Teadit 300 has the following main characteristics:

- Flange: ASME B16.5 NPS 2 class 300, Raised Face, welding neck
- Maximum Pressure: 740 psi (51bar) at room temperature.
- Maximum Temperature: 752°F (400°C)

Table 1. Samples of Non-Asbestos Fiber Sheet

Material	Fiber	Rubber
Sample #1	Carbon	Nitrile Rubber (NBR)
Sample #2	Aramid	Nitrile Rubber (NBR)
Sample #3	Aramid	Styrene Butadiene Rubber (SBR)
Sample #4	Aramid	Ethylene Propylene Diene Methylene Terpolymer (EPDM)

Figure 1. Teadit 300 Test Bench - ASME B16.5 Standard Flanges

Test Procedure: The test procedure is based on the temperature limit after which the gasket material is no longer able to maintain a seal. Excessive temperature may cause physical damage to the gasket material and consequently an increase of leakage would be observed. The test parameters are as follows:

- Test pressure is according to the maximum temperature of flange material according to the ASMEB16.5 class 300 pressure-temperature rating [3]
- Sealed media: Nitrogen
- Gasket stress: 11600psi (80MPa)
- Temperature: The initial temperature test were defined as following: sample#1: 250°C (482°F); sample#2: 150°C (302°F); sample#3: 180°C (356°F) and sample#4: 150°C (302°F).
- Test duration: 120 hours for each temperature. The gasket specimen was replaced for new one after 120 hours testing

A summary of the procedure is as follow:

a) Installation of the gasket specimen with gasket seating stress of 80 MPa (11600psi) using bolting procedure designed to achieve a uniform gasket stress distribution in the flange: Ensure that the flange assembly has been cleaned and that the exposed surfaces of the flanges are free of all residues from previous tests. Clean and lubricate bolt threads, nuts and washers. Using a calibrated torque wrench, torque the bolts using cross pattern in three increments.

b) After 4 hours, re-torque the bolts to 80 MPa (11600psi).

c) Heat up the fixture until gasket test temperature is reached. After the temperature is stabilized, the fixture is pressurized with Nitrogen.

d) Record temperature and gasket leak rates using the according pressure decay method for 120 hours [4].

e) Repeat steps (a) to (d), using a new gasket specimen, for others test temperatures.

3. Results and Discussion

Average leak rates as a function of temperature for all samples are shown in Table 2 and Figures 2 through 5. According to these results, it could be verified that there is a temperature where an increase of leak rate was observed.

Table 2. Leak rate Results (mg/s.mm)

T °C (°F)	Flange #1	Flange #2	Flange #3	Average
Sample #1				
250 (482)	4E-06	4E-05		2E-05
280 (536)	1E-05	2E-05		2E-05
300 (572)	3E-03	1E-04		2E-03
320 (608)	1E-02	1E-02		1E-02
Sample #2				
150 (302)	3E-06	2E-06	8E-06	4E-06
250 (482)	2E-06	1E-05	5E-05	2E-05
260 (500)	2E-06	8E-06	1E-05	7E-06
280 (536)	2E-04	3E-03	3E-04	1E-03
Sample #3				
180 (356)	2E-06	6E-06	6E-06	5E-06
250 (482)	6E-07	2E-06	6E-07	1E-06
280 (536)	1E-05	4E-06	1E-05	8E-06
290 (554)	3E-05	1E-05	2E-04	8E-05
Sample #4				
150 (302)	2E-06	1E-06	5E-07	1E-06
200 (392)	5E-06	2E-06	9E-07	3E-06
230 (446)	5E-05	2E-05	9E-06	3E-05
250 (482)	4E-04	2E-04	2E-04	3E-04

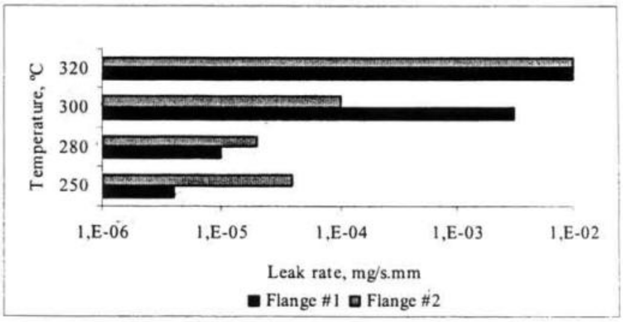

Figure 2. Average leak rate as a function of temperature of sample#1

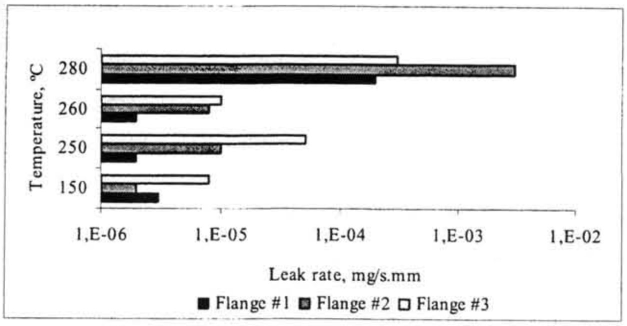

Figure 3. Average leak rate as a function of temperature of sample#2

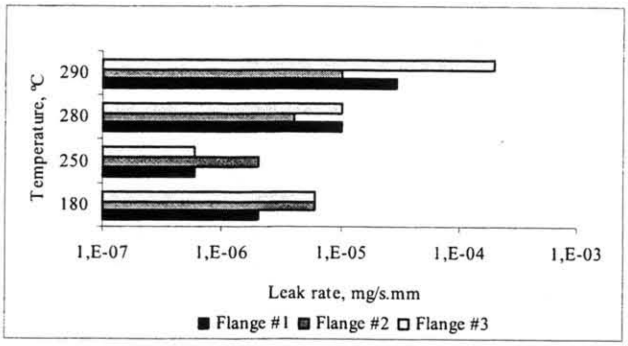

Figure 4. Average leak rate as a function of temperature of sample#3

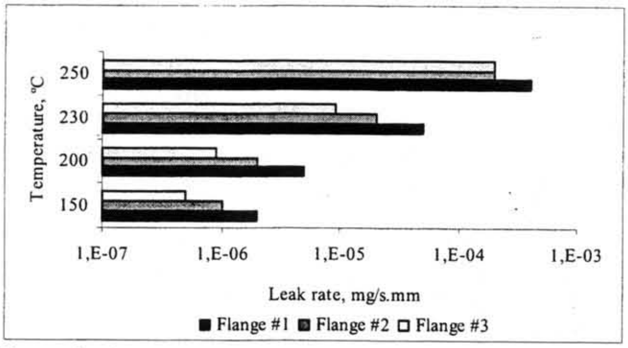

Figure 5. Average leak rate as a function of temperature of sample#4

From Figure 2, it was possible to verify that there is no major difference of average leak rate when the temperature was increased from 250°C (482°F) to 280°C (536°F) but when it was changed from 280°C (536°F) to 300°C (572°F) a significant increase of average leak rate was observed. According to this behavior, it could be verified that gasket performance degradation starts to occur when the test temperature was close to 300°C (572°F); therefore the critical temperature range of sample #1 could be 280 to 300°C (536 to 572°F).

Similar behavior was observed for other samples. Figures 3 and 4 show the charts of sample #2 and sample #3, respectively. It could be verified that the average leak rate increased 100 times when test temperature increased from the range critical temperature occurs 260°C (500°F) to 280°C (536°F) for the sample #2 and 10 times when temperature increased from 280°C (536°F) to 290°C (554°F) for the sample #3.

Figure 5 shows the charts of sample#4. It could be observed that the average leak rate at 230°C (446°F) is higher than respective values of 200°C (392°F) and 150°C (302°F).

Therefore, using the same criteria of sample #1, the critical temperature range of sample #2, #3 and #4 could be: 260 to 280°C (50 to 536°F); 280 to 290°C (536 to 554°F) and 200 to 230°C (302 to 446°F), respectively.

Since tests were performed in laboratory conditions, it would be expected that field conditions could affect results.

4. Conclusion

Test results clearly showed that it is possible to determine a critical temperature range for CNA sheets. All products tested showed that above a very well defined temperature level, the gasket sealability degraded, increasing the leak rate up to 100 times.

The critical temperature range for all samples could be established, as summarized bellow:

- Sample #1: 280 to 300°C (536 to 572°F)
- Sample #2: 260 to 280°C (500 to 536°F)
- Sample #3: 280 to 290°C (536 to 554°F)
- Sample #4: 200 to 230°C (302 to 446°F)

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AN EXPERIMENTAL INVESTIGATION OF THE FACTORS THAT CONTRIBUTE TO THE CREEP- RELAXATION OF COMPRESSED NON-ASBESTOS GASKETS.

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ABSTRACT
The adequate tightness of flanged joints contributes to maintaining safe working conditions in numerous equipment and industrial installations. The new sealing technologies and materials can require more careful selection, handling and installation than previous asbestos equivalents. Many research studies have been conducted to understand and improve the assembly bolt load of piping joints in order to minimize the likelihood of leakage. The selection of the bolt load must consider many factors, such as: minimum gasket stress to achieve a seal; the maximum stress that will damage the joint components and the amount of gasket stress lost to creep-relaxation under room temperature and service condition. It is well known that the bolt load decrease to some degree after the initial assembly due to creep-relaxation characteristics of the gasket. ASME PCC-1 recommends restoring the gasket load, after a minimum 4 hours, due to short-term creep-relation.
This paper intends to investigate factors which may influence the creep-relaxation characteristic of the compressed non-asbestos gasket. In order to reproduce real field condition, ASME B16.5 class 300lbs flanges were used in this experimental investigation.

1. INTRODUCTION

1.1 BACKGROUND

Bolted flange connections for piping and pressure vessels loose bolt load over time given the effects of the operating temperature and pressure. This loss of bolt load may result in a leak of a connection that has been operating successfully for some time [1]. The creep relaxation of gaskets is a well know phenomena and it has been subjected to innumerous studies [2-4] however, the current ASME Code [5] does not give a specific procedure to assure that the problem is addressed properly at the design, installation and pressure testing of the joint.
In 2001 ASME issued the PCC-1 -2000 Guidelines for Pressure Boundary Bolted Flange Joint Assembly [6] partially addressing the issue by recommending to tighten the bolts using a standard percent of bolt material yield, which is approximately twice the design stress at room temperature.
Most gasket manufactures and end-users recommend re-tighten the bolts some time after gasket installation in order to compensate for short term creep relaxation. Both ASME PCC-1 and the FSA Gasket Installation Guidelines recommend waiting 4 hours before re-tightening [6-7].
A chart to properly select the bolt load has been presented by Brown and Reeves [8]. This chart is showed in Figure 1 and clearly addresses the problem. In order to keep the joint tight it is necessary to install the gasket with an initial stress Y% which is higher than the minimum X% required to seal.
This Y% stress has to compensate for the uncertainties of the tightening method, stress loss due to thermal loading, load loss due to the internal pressure and any external loading, and the creep of the gasket over time. The stress Y% must also be less than the maximum permissible for the gasket material, bolts and flanges in order to avoid damaging any of them.

1.2 METALLIC GASKETS FIELD EXPERIENCE

Field studies conducted by Chevron Refining Technology in the *El Segundo Refinery* have determined that there is a long term relaxation of corrugated metal gaskets with flexible graphite covering. Figure 2 shows the average stud load loss over an 18 month long period of a critical Heat Exchanger application. It can be seen that after the bolt-up and before system start-up there was a loss of 30% of the initial stud load. The stud load was hot-torqued and after 18 months in service there was a 55% stud load loss. The chart also shows a continuous load loss that explains why it is common to observe in the field that gaskets performing well for a period of time and without any apparent cause start to leak. To reduce the likelihood of a leak, an assembly and bolt-up procedure [10] has been developed and adopted successfully in Chevron Refineries. This procedure requires a re-torque of the bolts when the Heat Exchanger is between 250°F (121°C) to 400°F (204°C). Brown RAST [9] study of gaskets for heat exchanger has confirmed the field results. The gasket comparison of this study was performed after a 300°F (150°C) hot-torquing

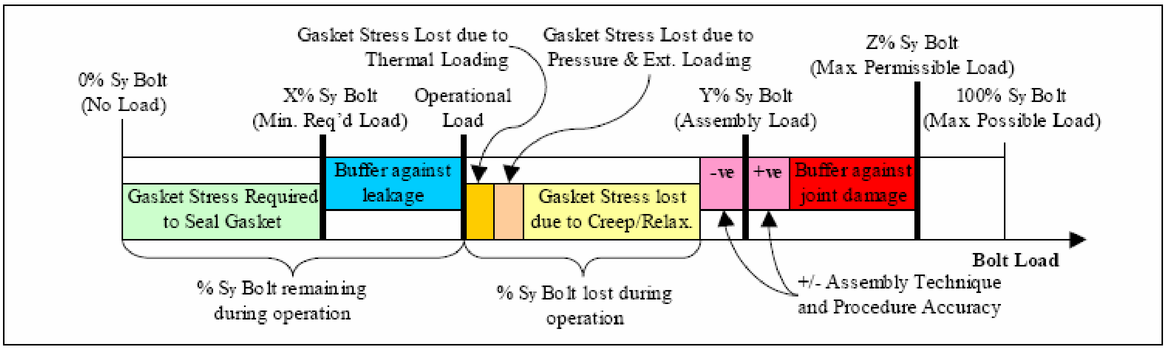

Figure 1 – Bolt Assembly Load Selection Criteria [8]

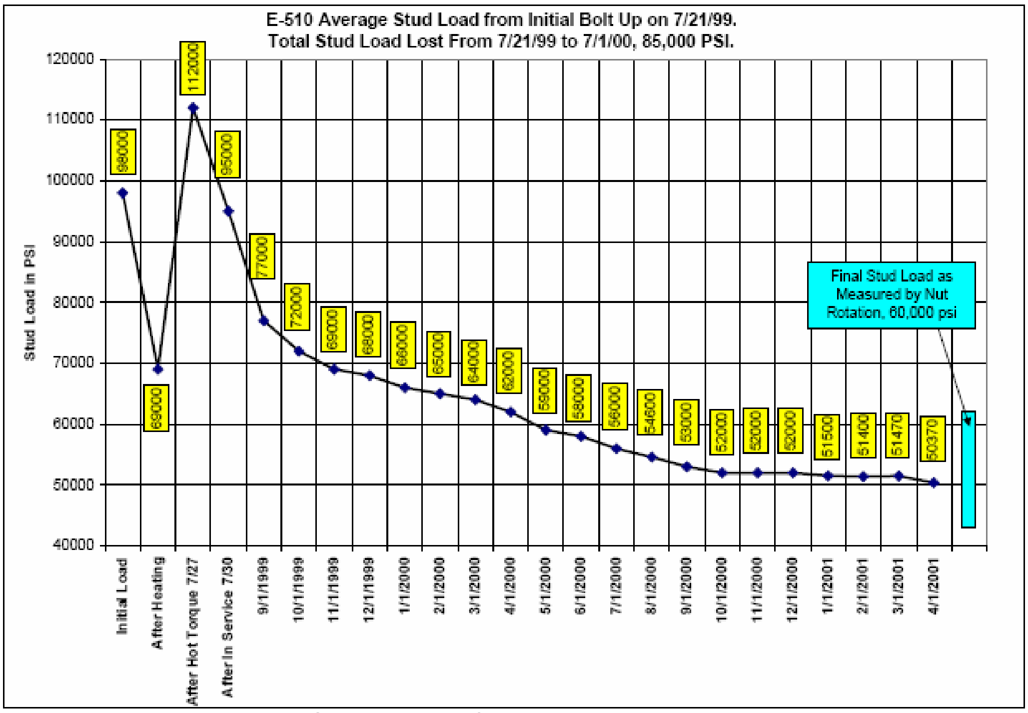

Figure 2 – Stud Load Lost from 7/21/00 to 7/01/00; 85,000psi

1.3 OBJECTIVE OF THIS PAPER

Gasket manufactures, as well as the FSA Gasket Installation Guidelines, recommend not to use Hot-Torquing especially for elastomeric based gaskets as they have a tendency to harden when subjected to high temperatures. The preferred way of reducing the bolt load relaxation is re-tightening the bolts sometime after the installation and before start-up. However, the Heat Exchanger Gasket results indicate that hot-torquing reduces significantly the possibility of a long term gasket failure.

This paper intends to investigate factors which may influence the creep-relaxation characteristic of the compressed non-asbestos gasket like the effects of temperature, gasket load and the tightening of the bolts before and after heating the flanges. The objective is to minimize the yellow area in Figure 1, with the aim of assuring a leak free joint for the duration of the service life. In order to reproduce the real working condition, ASME B16.5 class 300lbs flanges were used in this experimental investigation

2. EXPERIMENTAL

The gasket creep-relaxation was investigated focusing on the influence of temperature and gasket load. The effects of the re-tightening procedure was measured, named here as "*Room Temperature Torquing*", when re-torquing is applied 4 hours after the gasket is installed at room temperature according PCC-1-2000 recommendation [6] and "*Hot-Torquing*" when the torquing is applied 4 hours after heat is applied. The 2^2 Factorial Design (Table 1) with two experimental factors (Temperature and Gasket Load) at two levels (low (-1) and high (+1)) was used to study if experimental factors have influence on the response variable, considering both types of re-tightening procedures.

Table 1 - Experimental run according Complete Factorial Design

Run	Temperature, °F (°C)		Gasket Load, psi (MPa)	
1	-1	77 (25)	-1	7250 (50)
2	-1	77 (25)	+1	20300 (140)
3	+1	392 (200)	-1	7250 (50)
4	+1	392 (200)	+1	20300 (140)
Central point	0	234 (112)	0	13775 (95)

The temperature and gasket load values adopted were based on recommended working conditions; therefore the following criteria was used:

- ✓ The temperature should be lower than maximum temperature recommendation of respective compressed non-asbestos gasket [11] or be lower than 400°F, which is the limit recommended for Hot-Torquing according to Chevron Procedure [10] since in this temperature the stud and nut friction factor increase substantially as the lubricant burns off.

- ✓ The Gasket Load must be higher than the minimum required to seal [5,12].

The Response Variable is named here as "*Torque Retention*", and it is defined as percent of the Gasket Load Loss. The analyses of the experiment were done using the software Statgraphics Plus version 5.

Material: Three styles of Non-Asbestos Fiber Sheet 1/16in were tested. Table 2 shows the composition of each one. The gasket tested was a ring type, size 2 inches class 300, $2^3/_8$" (60.4mm) ID and $4^3/_8$" (111.25mm) OD.

Table 2 - Samples of Non-Asbestos Fiber Sheet

Material	Manufacturer	Fiber	Rubber
Sample #1	A	Carbon Fiber	NBR
Sample #2	B	Aramid Fiber	NBR
Sample #3	A	Aramid Fiber	SBR

Heating: The flanges were heated from room to test temperature in one hour. The heat rate is shown at Table 3. Heating is by electrical cartridge heaters inside the flanges to simulate actual field conditions.

Table 3 – Heat Rate Test

Temperature, °F (°C)	°F/min	°C/min
392 (200)	6.5	3.3
234 (112)	3.9	1.9

Apparatus: A pressure vessel composed by two ASME B16.5 Standard Flanges with a heating cartridge inside, outside insulation and a digital controller was used for the test. Calibrated 5/8 inches bolts (ASTM A193 B7) with tempered washer GRB 5/8 were used to measure the bolt load.

Test Procedure:

1. Ensure the flange assembly has been cleaned
2. Ensure the bolts, nuts, washers are not damaged and the nuts can be freely assembled on the bolts.
3. Clean bolt, nuts and washers with an organic solvent. Lubricate them with molybdenum disulfide anti-seize
4. Cut standard ASME 2 inches class 300 ring gaskets.
5. Center the gasket on the raised face of weld neck flange.
6. Torque the bolt according ASME PCC-1 [6] tightening in three increments of 20, 50 and 100%.
7. Re-tightening procedures:
7.1 Room Temperature Torquing: After 4 hours, re-tightening the bolts and then raise the temperature to set test condition.
7.2 Hot-torquing: turn the heating on, after 4 hours re-tightening the bolts.
8. Measure the bolt load every 2 hours
9. After 12 hours, cool down the flanges to room temperature.

3. RESULTS AND DISCUSSION

3.1 FACTORIAL DESIGN ANALYSES

The Complete Factorial Design analyses for all samples are shown in attachments 1 to 6. Each analysis shows:

• ANOVA Table: In general, the purpose of ANOVA is yield values that can be tested in order to determine whether a significant influence exists between investigated factors (in this case, they are Temperature, Gasket Load and their interactions) and variable response (Torque Retention). As a result, P-value lower than 0.05 means that the respective factor has a significant influence on Torque Retention.

• The Estimated Effects Table and Pareto Chart: They show the factors in decreasing order of importance regarding the *Torque Retention* influence;

• Main Effects and Interaction Plots: They shown if the investigated factors have a positive or negative effect on the *Torque Retention;*

• Equation Model Regression: A regression equation (Figure 3) which has been fitted to the data is presented. This model can be used to generate the predicted values of the Torque Retention, considering the studied limits.

Torque Retention (%) = A + A1*Temperature + A2*Gasket Load + A3*Temperature*Gasket Load

A: All experiments average
Ai: Regression coefficients associeted to the factor *i*

Figure 3 – Regression Equation model Example

The presented analysis shows that, independent of the tested material and the re-tightening procedure, the main factor that contributes to gasket creep-relaxation is the Temperature. For an example, according to the Figure 4, which shows the ANOVA Table for Sample #1 tested after "*Room Temperature Torquing*", the P-value of Temperature factor is 0.000. Comparing this value with the other P-values it is possible to see how strong the temperature influence is. The same results can be verified through Pareto Chart (Figure 5). A similar result was observed for the other materials tested.

Analysis of Variance for Torque Retention

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
A: Temperature	4236,6	1	4236,6	1316,03	0,0000
B: Gasket Load	27,0112	1	27,0112	8,39	0,0231
AB	5,28125	1	5,28125	1,64	0,2411
blocks	3,10083	1	3,10083	0,96	0,3591
Total error	22,5346	7	3,21923		
Total (corr.)	4294,53	11			

R-squared = 99,4753 percent
R-squared (adjusted for d.f.) = 99,2785 percent
Standard Error of Est. = 1,79422
Mean absolute error = 1,18958
Durbin-Watson statistic = 1,40369 (P=0,1254)
Lag 1 residual autocorrelation = 0,198881

Figure 4 – ANOVA Table – Sample #1 at *Room Temperature Torquing Procedure*

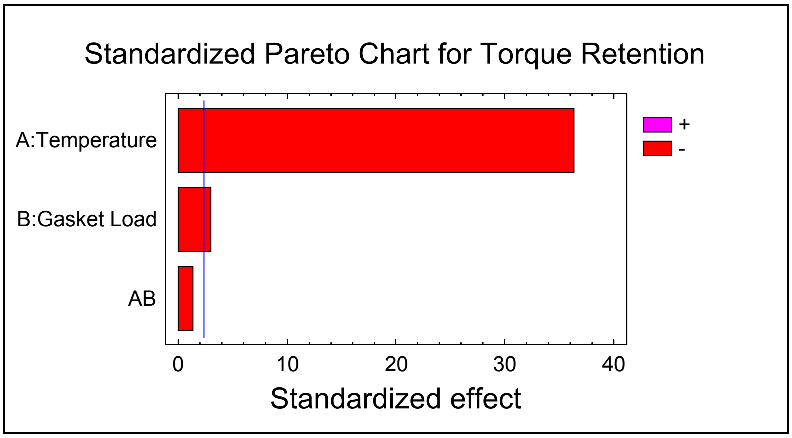

Figure 5 – Pareto Chart – Sample #1 at *Room Temperature Torquing Procedure*

According to the Main Effects Plots, Temperature has a negative effect on the *Torque Retention*; as a consequence Torque retention decreases as the Temperature is increased. Figure 6 shows this chart for Sample #1 as an example.

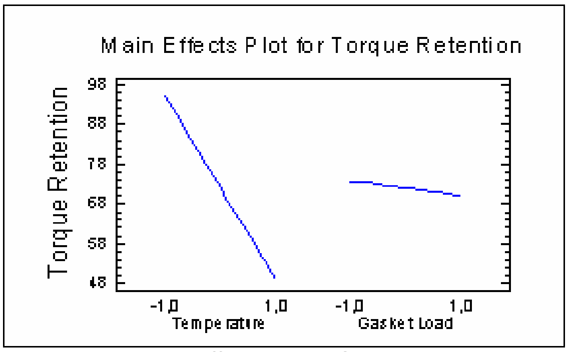

Figure 6 – Main Effects Plot – Sample #1 at *Room Temperature Torquing Procedure*

The Temperature influence is more perceptible when comparing *Room Temperature Torquing* and *Hot-Torquing* results. As an example, Figure 7 shows the Pareto's Charts for Sample #3 for both types of re-tightening procedures.

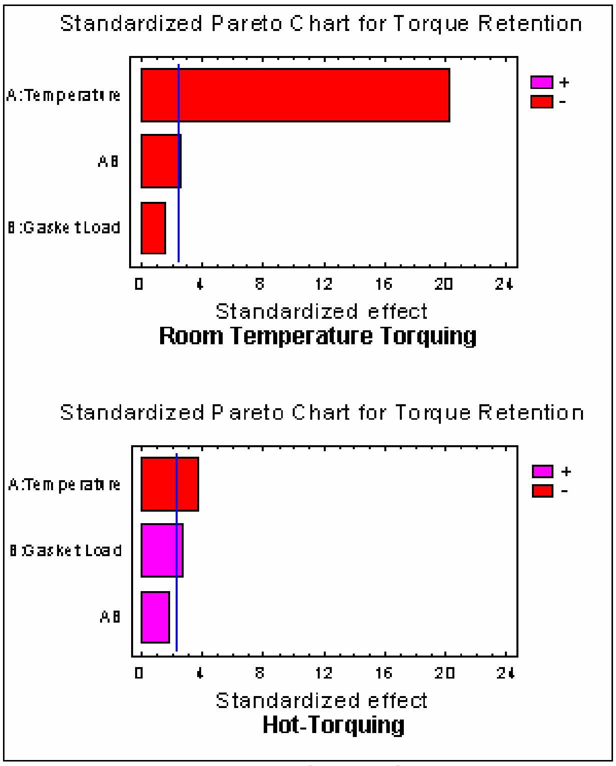

Figure 7 – Pareto Chart at Sample #3

3.2 RE-TITGHTENING COMPARISON

Figures 8 and 9 show *Room Temperature Torquing* and *Hot-Torquing* Estimated Response Surfaces for sample #1. Based on these charts, it is possible to observe when the *Hot-Torquing* was applied, the Estimated Response Surface is nearly parallel to the Temperature and Gasket Load plane, but on the other hand, when *Room Temperature Torquing* was used, a significant reduction of *Torque Retention* was observed as the Temperature increases. The same conclusion was observed for sample #2 (Figures 10 and 11) and for sample #3 (Figures 12 and 13).

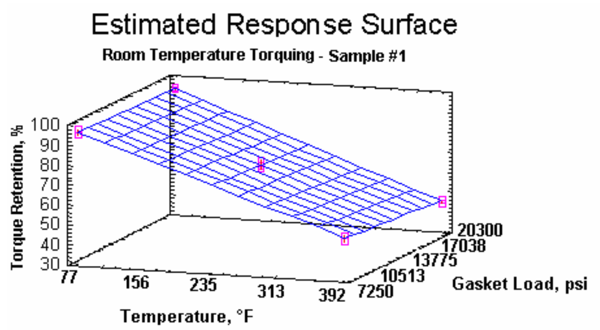

Figure 8 – Estimated Response Surface for Sample #1; Room Temperature Torquing

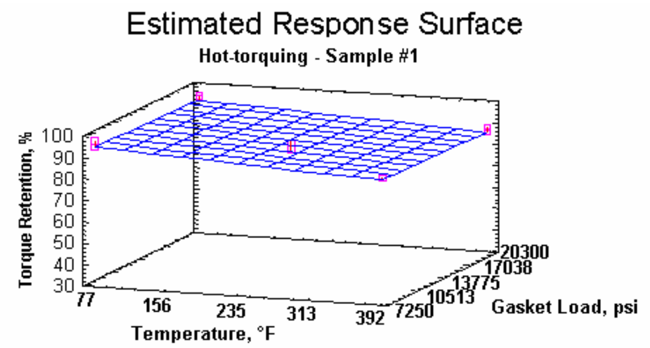

Figure 9 – Estimated Response Surface for Sample #1; Hot-Torquing

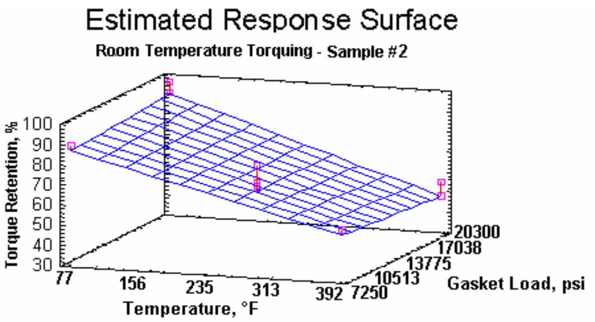

Figure 10 – Estimated Response Surface for Sample #2; Room Temperature Torquing

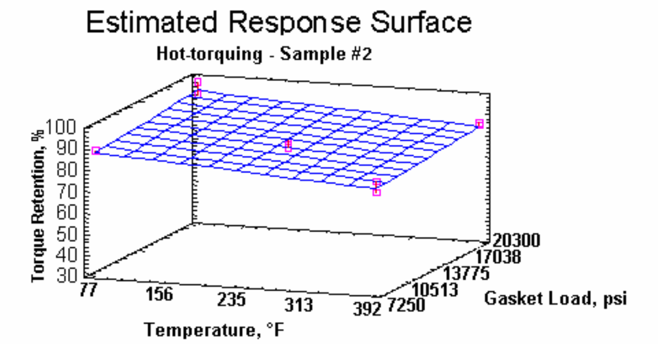

Figure 11 – Estimated Response Surface for Sample #2; Hot-Torquing

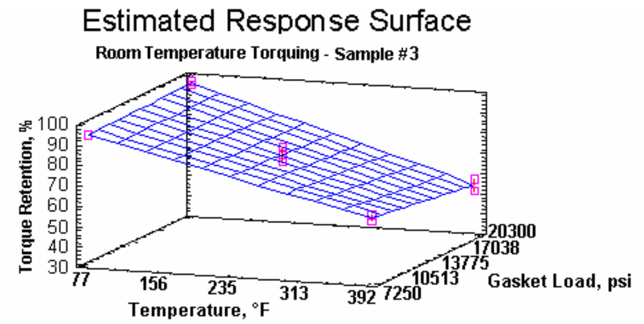

Figure 12 – Estimated Response Surface for Sample #3; Room Temperature Torquing

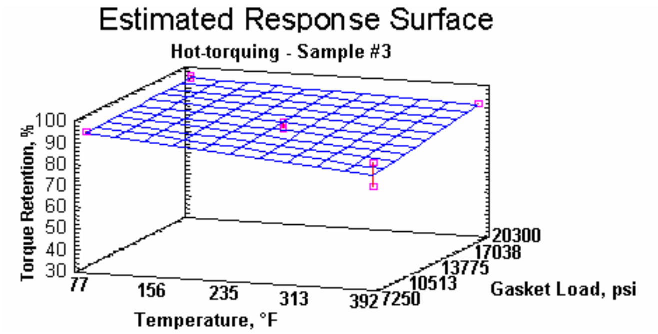

Figure 13 – Estimated Response Surface for Sample #3; Hot-Torquing

These results show that the re-tightening procedure has a significant influence on the *Torque Retention* and it suggests that *Hot-Torquing* could be more effectively used in compressed non-asbestos gasket installation since it minimizes the gasket creep-relaxation.

The lower performance of the *Room Temperature Torquing* procedure, when compared to *Hot-Torquing* results, can be explained by the fact that Temperature is the most important factor that contributes negatively to gasket creep-relaxation. Thus, re-torquing at room temperature can restore only short-term creep relaxation due to room temperature gasket relaxation, but, on the other hand, the Hot-Torque procedure can restore the more pronounced effect of creep relaxation due to temperature.

Similar conclusion regarding *Hot-Torquing* was observed in the tested with corrugated metal gaskets with flexible graphite covering conducted by Chevron [10].

3.3 PREDICTION OF TORQUE RETENTION

To test the prediction of the regression equation obtained by Experimental Design, extra tests were carried out according to the Table 3.

Table 3 - Extra Test Condition

Material	Re-tightening procedure	Temperature	Gasket Load
Sample #1	Hot-Torquing	356°F (180°C)	12180psi (84 MPa)
Sample #2	Room Temperature Torquing	356°F (180°C)	10150psi (70 Mpa)
Sample #3	Hot-Torquing	302°F (150°C)	14500psi (100 Mpa)

The Torque Retention Predictions, as shown in Table 4, suggest that regression equations can be used as a tool to estimate a gasket creep relaxation, as the test results are in accordance with respective predicted values.

Table 4 - Estimation Result using Statgraphics Plus version 5 (95%CL) for Torque Retention (%)

Regression Equation		**Test Results**
Fitted value	**Forecast**	
Sample #1 - Hot-Torquing		
88	82 – 94	84; 85
Sample #2 - Room Temperature Torquing		
56	41 – 71	46; 65
Sample #3 - Hot-Torquing		
90	83 – 97	83; 86

Note: CL: Confidence Level

The results presented suggest that Regression Equations obtained by Experimental Data can be used in order to predict the yellow area [8] in the Bolt Load Chart for a specific gasket. Thus, test criteria and procedures must be discussed and developed with the purpose of assuring applicability.

4. Conclusion

Based on the 2^2 Factorial Design Analyses, the most important experimental factor which contributes to gasket creep-relaxation is Temperature.

Hot-Torquing is a procedure that contributes to restoring stud load loss due to gasket creep relaxation; it can be used to minimize the yellow area of the Bolt Load Chart.

Although the results show *Hot-Torquing* as a recommended re-tightening procedure for compressed non-asbestos gasket fiber, it is important to call attention to the fact that elastomeric based gaskets have a tendency to harden when they are subjected to elevated temperatures. It means that a *Hot-Torque* procedure must be developed in order to guarantee safe installation and long life service time.

Experiments can be used to produce a model for gasket creep-relaxation prediction; however Field Test must be carried out in order to validate the equation.

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[2]. Nagy, A.; "*Time dependent characteristics of gaskets at Flange Joints*", 1997, International Journal of Pressure Vessel & Piping

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ANALYZE EXPERIMENT – ATTACHMENT 01
SAMPLE # 1 – ROOM TEMPERATURE TORQUING

Analysis of Variance for Torque Retention

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
A:Temperature	4236,6	1	4236,6	1316,03	0,0000
B:Gasket Load	27,0112	1	27,0112	8,39	0,0231
AB	5,28125	1	5,28125	1,64	0,2411
blocks	3,10083	1	3,10083	0,96	0,3591
Total error	22,5346	7	3,21923		
Total (corr.)	4294,53	11			

R-squared = 99,4753 percent
R-squared (adjusted for d.f.) = 99,2785 percent
Standard Error of Est. = 1,79422
Mean absolute error = 1,18958
Durbin-Watson statistic = 1,40369 (P=0,1254)
Lag 1 residual autocorrelation = 0,198881

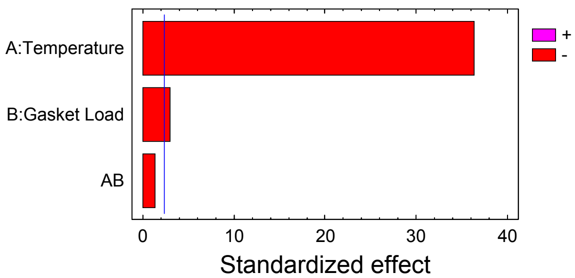
File name: D:\Meus documentos\sample#1.sfx

Estimated effects for Torque Retention

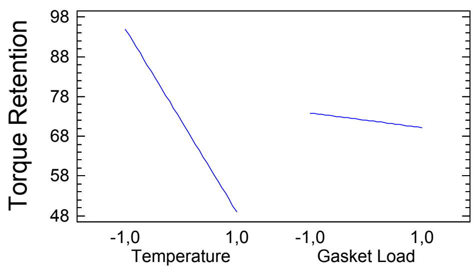
Effect		Estimate		Std. error
average	=	72,0083	+/-	0,517947
A:Temperature	=	-46,025	+/-	1,26871
B:Gasket Load	=	-3,675	+/-	1,26871
AB	=	-1,625	+/-	1,26871
block	=	1,01667	+/-	1,03589

Standard errors are based on total error with 7 d.f.

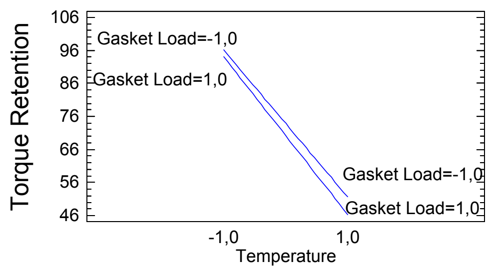
Standardized Pareto Chart for Torque Retention



Main Effects Plot for Torque Retention



Interaction Plot for Torque Retention



Torque Retention = 72,0083 - 23,0125*Temperature - 1,8375*Gasket Load
- 0,8125*Temperature*Gasket Load

Torque Retention (%)

Temperature (°C) = (X – 112,5) / 87,5   25°C ≤ X ≤ 200°C
Gasket Load (MPa) = (Y – 95) / 45   50 MPa ≤ Y ≤ 140 MPa

ANALYZE EXPERIMENT – ATTACHMENT 02
SAMPLE # 1 – HOT-TORQUING

Analysis of Variance for Torque Retention

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
A:Temperature	86,4612	1	86,4612	16,67	0,0035
B:Gasket Load	5,95125	1	5,95125	1,15	0,3153
blocks	6,16333	1	6,16333	1,19	0,3073
Total error	41,4808	8	5,1851		
Total (corr.)	140,057	11			

R-squared = 70,3828 percent
R-squared (adjusted for d.f.) = 63,8012 percent
Standard Error of Est. = 2,27708
Mean absolute error = 1,60556
Durbin-Watson statistic = 1,51993 (P=0,1392)
Lag 1 residual autocorrelation = 0,164979

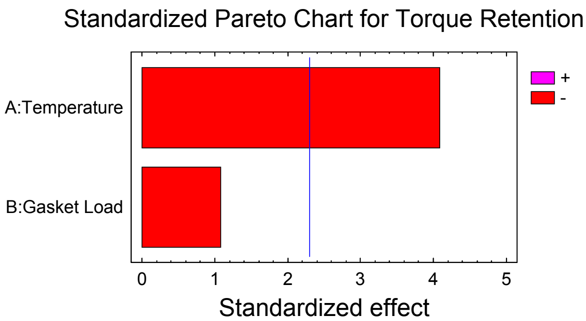
Analysis Summary

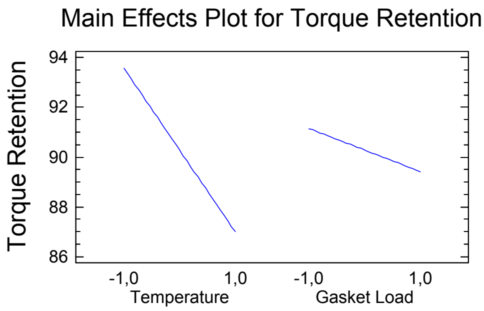
File name: D:\Meus documentos\sample#1.sfx

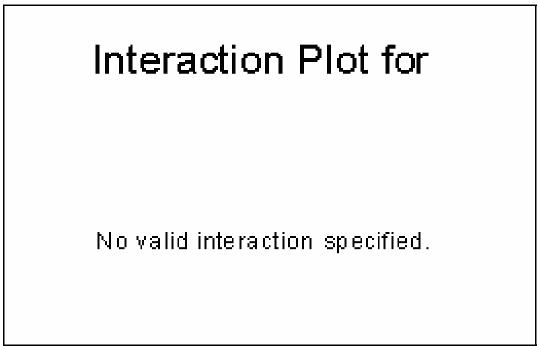
Estimated effects for Torque Retention

```
average        = 90,2833 +/- 0,657337
A:Temperature  = -6,575  +/- 1,61014
B:Gasket Load  = -1,725  +/- 1,61014
block          = 1,43333 +/- 1,31467
```

Standard errors are based on total error with 8 d.f.







Torque Retention = 90,2833 - 3,2875*Temperature - 0,8625*Gasket Load

Torque Retention (%)

Temperature (°C) = (X – 112,5) / 87,5   25°C ≤ X ≤ 200°C
Gasket Load (MPa) = (Y – 95) / 45   50 MPa ≤ Y ≤ 140 MPa

ANALYZE EXPERIMENT – ATTACHMENT 03
SAMPLE # 2 – ROOM TEMPERATURE TORQUING

Analysis of Variance for Torque Retention

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
A:Temperature	2823,76	1	2823,76	81,83	0,0000
AB	36,5512	1	36,5512	1,06	0,3335
blocks	53,7633	1	53,7633	1,56	0,2473
Total error	276,071	8	34,5089		
Total (corr.)	3190,15	11			

R-squared = 91,3461 percent
R-squared (adjusted for d.f.) = 89,4231 percent
Standard Error of Est. = 5,87442
Mean absolute error = 3,93889
Durbin-Watson statistic = 1,70308 (P=0,1770)
Lag 1 residual autocorrelation = 0,110692

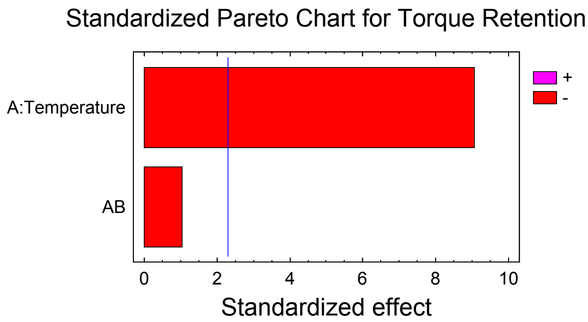
Analysis Summary

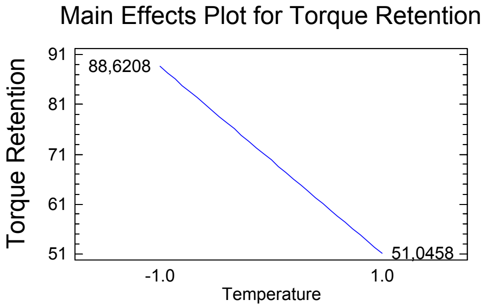
File name: D:\Meus documentos\sample#2.sfx

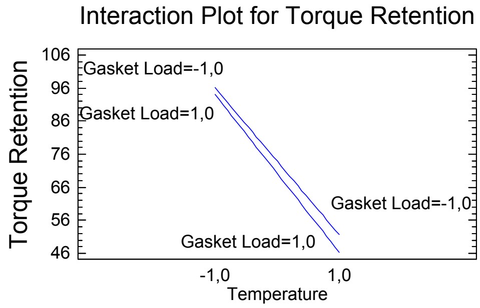
Estimated effects for Torque Retention

```
average        = 69,8333 +/- 1,6958
A:Temperature  = -37,575 +/- 4,15384
AB             = -4,275  +/- 4,15384
block          = 4,23333 +/- 3,3916
```

Standard errors are based on total error with 8 d.f.







Torque Retention = 69,8333 - 18,7875*Temperature - 2,1375*Temperature*Gasket Load

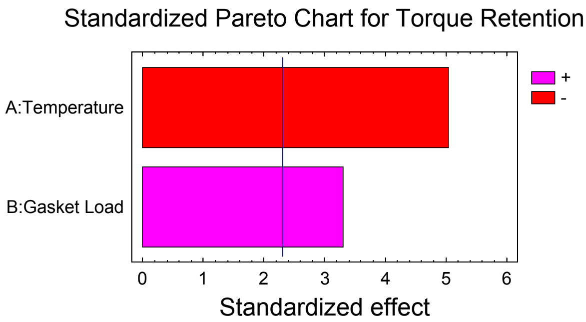
Torque Retention (%)

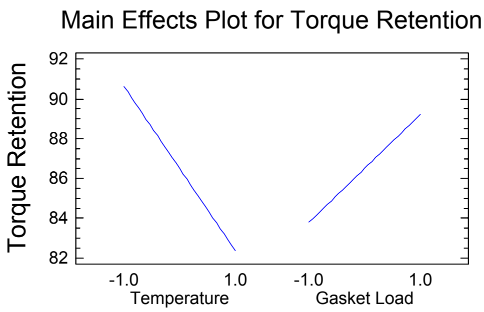
Temperature (°C) = (X – 112,5) / 87,5   25°C ≤ X ≤ 200°C
Gasket Load (MPa) = (Y – 95) / 45   50 MPa ≤ Y ≤ 140 MPa

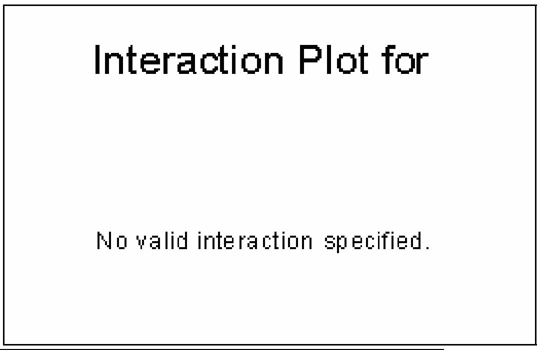
ANALYZE EXPERIMENT – ATTACHMENT 04
SAMPLE # 2 – HOT-TORQUING

```
Analysis of Variance for Torque Retention
--------------------------------------------------------------------------------
Source                   Sum of Squares     Df     Mean Square    F-Ratio    P-Value
--------------------------------------------------------------------------------
A:Temperature                 136,951        1         136,951      25,35     0,0010
B:Gasket Load                 58,8612        1         58,8612      10,90     0,0108
blocks                        15,4133        1         15,4133       2,85     0,1297
Total error                   43,2142        8         5,40177
--------------------------------------------------------------------------------
Total (corr.)                  254,44       11

R-squared = 83,016 percent
R-squared (adjusted for d.f.) = 79,2417 percent
Standard Error of Est. = 2,32417
Mean absolute error = 1,5875
Durbin-Watson statistic = 1,1511 (P=0,0354)
Lag 1 residual autocorrelation = 0,244461
```

```
Analysis Summary
----------------
File name: D:\Meus documentos\sample#2.sfx

Estimated effects for Torque Retention
----------------------------------------------------------
average        = 86,5     +/- 0,67093
A:Temperature = -8,275   +/- 1,64344
B:Gasket Load = 5,425    +/- 1,64344
block         = 2,26667 +/- 1,34186
----------------------------------------------------------
Standard errors are based on total error with 8 d.f.
```








```
Torque Retention = 86,5 - 4,1375*Temperature + 2,7125*Gasket Load
```

Torque Retention (%)

Temperature (°C) = (X – 112,5) / 87,5   25°C ≤ X ≤ 200°C
Gasket Load (MPa) = (Y – 95) / 45   50 MPa ≤ Y ≤ 140 MPa

ANALYZE EXPERIMENT – ATTACHMENT 05
SAMPLE # 3 – ROOM TEMPERATURE TORQUING

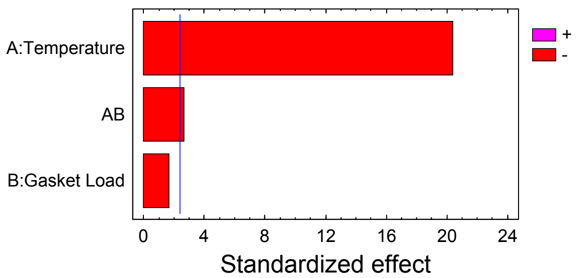
Analysis of Variance for Torque Retention

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
A:Temperature	2679,12	1	2679,12	413,96	0,0000
B:Gasket Load	17,405	1	17,405	2,69	0,1450
AB	44,18	1	44,18	6,83	0,0348
blocks	3,10083	1	3,10083	0,48	0,5111
Total error	45,3033	7	6,4719		
Total (corr.)	2789,11	11			

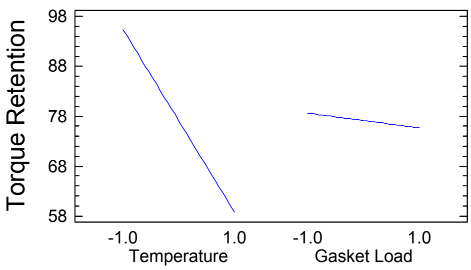
R-squared = 98,3757 percent
R-squared (adjusted for d.f.) = 97,7666 percent
Standard Error of Est. = 2,54399
Mean absolute error = 1,45833
Durbin-Watson statistic = 2,82024 (P=0,0593)
Lag 1 residual autocorrelation = -0,414748

```
Analysis Summary
----------------
File name: D:\Meus documentos\sample#3.sfx

Estimated effects for Torque Retention
----------------------------------------------------
average        = 77,1417 +/- 0,734388
A:Temperature  = -36,6   +/- 1,79888
B:Gasket Load  = -2,95   +/- 1,79888
AB             = -4,7    +/- 1,79888
block          = 1,01667 +/- 1,46878
----------------------------------------------------
Standard errors are based on total error with 7 d.f.
```

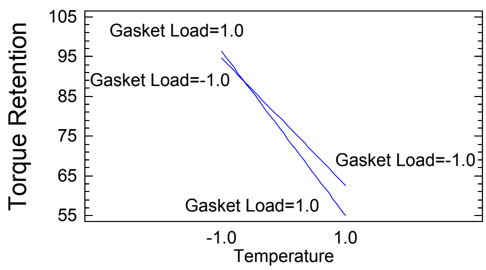
Standardized Pareto Chart for Torque Retention



Main Effects Plot for Torque Retention



Interaction Plot for Torque Retention



Torque Retention = 77,1417 - 18,3*Temperature - 1,475*Gasket Load - 2,35*Temperature*Gasket Load

Torque Retention (%)

Temperature (°C) = (X – 112,5) / 87,5	25°C ≤ X ≤ 200°C
Gasket Load (MPa) = (Y – 95) / 45	50 MPa ≤ Y ≤ 140 MPa

ANALYZE EXPERIMENT – ATTACHMENT 06
SAMPLE # 3 – HOT-TORQUING

Analysis of Variance for Torque Retention

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
A:Temperature	111,005	1	111,005	14,04	0,0072
B:Gasket Load	57,245	1	57,245	7,24	0,0311
AB	25,92	1	25,92	3,28	0,1132
blocks	17,28	1	17,28	2,18	0,1829
Total error	55,36	7	7,90857		
Total (corr.)	266,81	11			

R-squared = 79,2512 percent
R-squared (adjusted for d.f.) = 71,4703 percent
Standard Error of Est. = 2,81222
Mean absolute error = 1,7
Durbin-Watson statistic = 2,37893 (P=0,2206)
Lag 1 residual autocorrelation = -0,220737

Analysis Summary

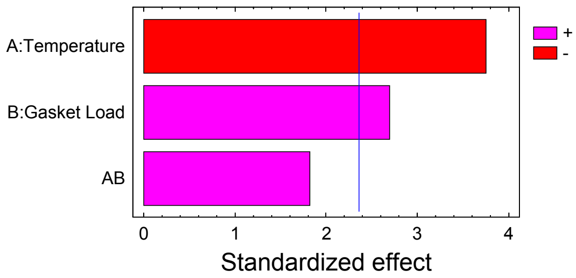
File name: D:\Meus documentos\sample#3.sfx

Estimated effects for Torque Retention

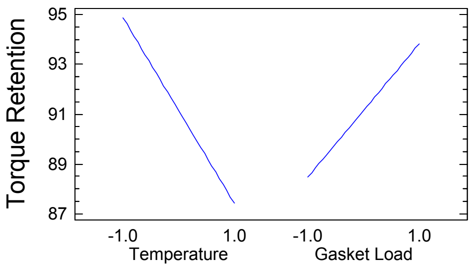
```
average         = 91,15 +/- 0,811817
A:Temperature   = -7,45 +/- 1,98854
B:Gasket Load   = 5,35  +/- 1,98854
AB              = 3,6   +/- 1,98854
block           = 2,4   +/- 1,62363
```

Standard errors are based on total error with 7 d.f.

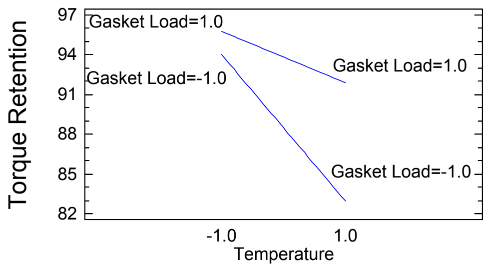
Standardized Pareto Chart for Torque Retention



Main Effects Plot for Torque Retention



Interaction Plot for Torque Retention



Torque Retention = 91,15 - 3,725*Temperature + 2,675*Gasket Load + 1,8*Temperature*Gasket Load

Torque Retention (%)

Temperature (°C) = (X – 112,5) / 87,5   25°C ≤ X ≤ 200°C
Gasket Load (MPa) = (Y – 95) / 45   50 MPa ≤ Y ≤ 140 MPa

FLEXIBLE GRAPHITE

Teadit's flexible graphite sheet is made from pure graphite with no fibers, binders or other additives. Flexible graphite gaskets offer excellent sealing capabilities under extreme conditions with a longer life and less maintenance. They have proven to be a superior replacement for asbestos gaskets in a wide range of services.

Because of its versatility and flexibility, flexible graphite is becoming the most popular fluid sealing material in use today. It is being used extensively in the chemical, automotive and pump and valve industries; new applications are being identified daily.

PHYSICAL PROPERTIES (VALUES SHOWN ARE TYPICAL AND DO NOT REPRESENT CERTIFICATION).

Bulk Density:	62 and 70 lbs/cu. ft. std.	compressibility: 45-60%
Tensile Strength:	800 psi	Recovery: 20-40%
Ash content:	4% max. (standard)	Melting Point: Sublimates at 6600˚F
Leachable chlorides:	50 ppm max.	Temperature Range:
Leachable Flourides:	50 ppm max.	Inert or Reducing atmospheres: to 5400˚F
		Oxidizing atmospheres: to 700˚F

FLEXIBLE GRAPHITE SHEET

2660 HOMOGENEOUS

2661 STAINLESS STEEL FOIL REINFORCED

2662 WIRE REINFORCED

2663 TANGED STAINLESS STEEL REINFORCED

Flexible Graphite Sheets are available as homogeneous, laminated, or reinforced. All sheets can be easily cut using conventional steel rule dies, utility knives or other simple gasket cutting equipment.

Standard Sizes: 39.4" x 39.4", 60" x 60"   Standard Thickness: 1/64", 1/32", 1/16", 1/8", 1/4"

FLEXIBLE GRAPHITE TAPE

Available as tape packing or gasket tape in rolls up to 300 ft. long in standard widths of 1/4", 1/2", 3/4", 1", 1-1/4", 1-1/2"
Tape can be furnished smooth or corrugated; with or without adhesive backing.

2550 (Tape packing) universal stuffing box packing for pumps and values. The packing is formed in place in the stuffing box from standard width tape.

2551 (Gasket Tape) adhesive backed tape used as a form-in-place gasket, thread sealant, and for wrapping jacketed and other difficult-to-seal gaskets. Used to rejuvenate spiral wound gaskets in emergency situations.

2550/2551 Crinkled Flexible Graphite Tape

CONSTRUCTION

Styles 2550 and 2551 crinkled flexible graphite tape are made from high purity graphite with no fibers, binders or other additives. Style 2550 crinkled tape is typically used as a stuffing box packing for pumps and valves. Style 2551 is the same as 2550 except that it is furnished with a self-adhesive backing strip to facilitate installation as a form-in-place gasket, thread sealant, or for facing jacketed and other difficult-to-seal gaskets.

APPLICATION / SERVICE

Styles 2550 and 2551 Flexible graphite covers a broad range of sealing applications. It handles most chemicals in the 0 - 14 pH range at cryogenic and elevated temperatures, and from vacuum to extreme pressures. It is used extensively in the chemical, automotive and pump and valve industries.

SERVICE LIMITS		
Type	**Description**	**Value**
Temperature	Minimum	-320°F (-200°C)
	Maximum	
	• In air	840°F (450°C)
	• In steam	1200°F (650°C)
	• In reducing or inert media	5400°F (3000°C)
Pressure	Static	2000 psi (137 bar)
pH		0-14
Typical Properties	Carbon Content	98% minimum
	Leachable Chlorides	50 ppm maximum
	Total sulfur	100 ppm maximum

STANDARD PACKAGING*		
Tape Thicknes	**Tape Width**	**Spool Length**
.015	1/4", 3/8", 1/2", 3/4", 1", 1-1/4", 1-1/8" 1-3/4", 2"	1/4" thru 1-1/8"...50' 1/4" thru 1-1/8"...100'

*other thicknesses, widths, and spool lengths are available on special order

Properties and application parameters shown throughout this datasheet are typical. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury. Specifications are subject to change without notice. This edition supersedes all previous issues.

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2660 Homogeneous Flexible Graphite Sheet

CONSTRUCTION

Style 2660 flexible graphite sheet is made from exfoliated graphite flake which is compressed into foil by a carefully controlled calendering process. In this process, the expanded flake particles are mechanically locked together without the use of fibers, binders or other additives. Sheets of foil are then adhesive bonded and laminated to the required thickness.

APPLICATION / SERVICE

Style 2660 flexible graphite sheet has pressure-temperature sealability capabilities that are far superior to all asbestos reinforced and non-asbestos reinforced sheet products. It is resistant to chemical attack by virtually all organic and inorganic fluids with the exception of concentrated, highly oxidizing acids.

Gaskets cut from Style 2660 flexible graphite sheet seal with low to moderate bolt loads and because of very low creep relaxation, re-torquing is rarely required. Flexible graphite conforms to irregular flange sealing surfaces and readily flows into flange irregularities enabling it to seal both smooth and coarse surface finishes.

SERVICE LIMITS

Type	Description	Value
Temperature Limits:	Minimum	-328°F (-200°C)
	Maximum	
	• In air	840°F (450°C)
	• In steam	1200°F (650°C)
	• In reducing or inert media	5400°F (3000°C)
Pressure Limits:		2000 psi (140 bar)
Typical Properties:	Compressibility	45% (Tested under 5000 psi)
	Recovery	20% (Tested under 5000 psi)
	Creep Relaxation	5%
	Tensile Strength	650 psi
	Compressive Strength	35, 000 psi
	Density	62.4 lbs/ft^3
	Carbon Content	98% minimum
	Total sulfur	1200 ppm maximum
	Leachable Chlorides	50 ppm maximum
Available Sheet Sizes:	Thickness	1/64", 1/32", 1/16", 1/8"
	Sheet Sizes	39.4" x 39.4"
	NOTE: Rolls, 108' long, are available in 1/64" and 1/32" thicknesses.	

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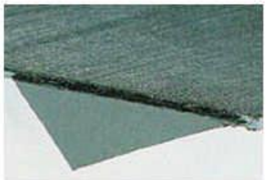

2661 Stainless Steel Flexible Graphite Sheet Foil Inserted

CONSTRUCTION

Style 2661 is a flexible graphite sheet reinforced with a 316ss foil, .002” thick. The flexible graphite sheet is made from exfoliated graphite flake which is compressed into foil by a carefully controlled calendaring process. In this process, the expanded flake particles are mechanically locked together without the use of fibers, binders or other additives. Sheets of foil are then adhesive bonded and laminated to the required thickness with the 316ss foil core in the center.

APPLICATION / SERVICE

Style 2661 flexible graphite sheet has pressure-temperature sealability capabilities that are far superior to all asbestos reinforced and non-asbestos reinforced sheet products. It is resistant to chemical attack by virtually all organic and inorganic fluids with the exception of concentrated, highly oxidizing acids.

Gaskets cut from Style 2661 flexible graphite sheet seal with low to moderate bolt loads and because of very low creep relaxation, re-torquing is rarely required. Flexible graphite conforms to irregular flange sealing surfaces and readily flows into flange irregularities enabling it to seal both smooth and coarse surface finishes.

SERVICE LIMITS

Type	Description	Value
Temperature Limits:	Minimum	-328°F (-200°C)
	Maximum	
	• In air	840°F (450°C)
	• In steam	1200°F (650°C)
	• In reducing or inert media	5400°F (3000°C)
Pressure Limits:		2000 psi (140 bar)
Typical Properties:	Compressibility	35% (Tested under 5000 psi)
	Recovery	18% (Tested under 5000 psi)
	Creep Relaxation	12%
	Tensile Strength	5000 psi
	Compressive Strength	35,000 psi
	Density	62.4 lbs/ft^3
	Carbon Content	98% minimum
	Total sulfur	1200 ppm maximum
	Leachable Chlorides	50 ppm maximum
Available Sheet Sizes:	Thickness	1/32", 1/16", 1/8"
	Sheet Sizes	39.4" x 39.4"

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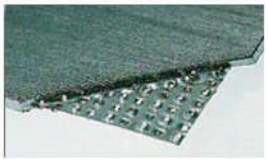

2663 Flexible Graphite Sheet 316ss Tang Inserted

CONSTRUCTION

Style 2663 is a flexible graphite sheet reinforced with a 316ss tanged core, .005” thick. The flexible graphite sheet is made from exfoliated graphite flake which is compressed into foil by a carefully controlled calendering process. In this process, the expanded flake particles are mechanically locked together without the use of fibers, binders or other additives. Sheets of foil are then adhesive bonded and laminated to the required thickness with the 316ss tanged core in the center.

APPLICATION / SERVICE

Style 2663 flexible graphite sheet has pressure-temperature sealability capabilities that are far superior to all asbestos reinforced and non-asbestos reinforced sheet products. It is resistant to chemical attack by virtually all organic and inorganic fluids with the exception of concentrated, highly oxidizing acids.

Gaskets cut from Style 2663 flexible graphite sheet seal with low to moderate bolt loads and because of very low creep relaxation, re-torquing is rarely required. Flexible graphite conforms to irregular flange sealing surfaces and readily flows into flange irregularities enabling it to seal both smooth and coarse surface finishes.

SERVICE LIMITS

Type	Description	Value
Temperature Limits:	Minimum	-328°F (-200°C)
	Maximum	
	• In air	840°F (450°C)
	• In steam	1200°F (650°C)
	• In reducing or inert media	5400°F (3000°C)
Pressure Limits:		2000 psi (140 bar)
Typical Properties:	Compressibility	35% (Tested under 5000 psi)
	Recovery	18% (Tested under 5000 psi)
	Creep Relaxation	10%
	Tensile Strength	5000 psi
	Compressive Strength	35,000 psi
	Density	62.4 lbs/ft^3
	Carbon Content	98% minimum
	Total Sulfur	1200 ppm maximum
	Leachable Chlorides	50 ppm maximum
Available Sheet Sizes:	Thickness	1/32", 1/16", 1/8"
	Sheet Sizes	39.4" x 39.4"

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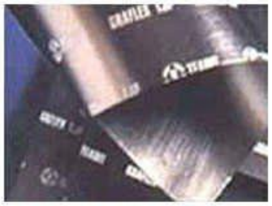

2664 Flexible Graphite Mylar Film Inserted

CONSTRUCTION

Style 2664 is a flexible graphite sheet reinforced with Mylar film, .0005" thick. The flexible graphite sheet is made from exfoliated graphite flake which is compressed into foil by a carefully controlled calendering process. In this process, the expanded flake particles are mechanically locked together without the use of fibers, binders or other additives. Sheets of foil are then adhesive bonded and laminated to the required thickness with the Mylar film in the center.

APPLICATION / SERVICE

Style 2664 flexible graphite sheet has pressure-temperature sealability capabilities that are far superior to all asbestos reinforced and non-asbestos reinforced sheet products. It is resistant to chemical attack by virtually all organic and inorganic fluids with the exception of concentrated, highly oxidizing acids.

Gaskets cut from Style 2664 flexible graphite sheet seal with low to moderate bolt loads and because of very low creep relaxation, re-torquing is rarely required. Flexible graphite conforms to irregular flange sealing surfaces and readily flows into flange irregularities enabling it to seal both smooth and coarse surface finishes.

SERVICE LIMITS

Type	Description	Value
Temperature Limits:	Minimum	-328°F (-200°C)
	Maximum	
	• In air	840°F (450°C)
	• In steam	1200°F (650°C)
	• In reducing or inert media	5400°F (3000°C)
Pressure Limits:		2000 psi (140 bar)
Typical Properties:	Compressibility	40% (Tested under 5000 psi)
	Recovery	18% (Tested under 5000 psi)
	Creep Relaxation	5%
	Tensile Strength	650 psi
	Compressive Strength	35,000 psi
	Density	62.4 lbs/ft³
	Carbon Content	98% minimum
	Total Sulfur	1200 ppm maximum
	Leachable Chlorides	50 ppm maximum
Available Sheet Sizes:	Thickness	1/32", 1/16", 1/8"
	Sheet Sizes	39.4" x 39.4"

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2550/2551 Crinkled Flexible Graphite Tape

CONSTRUCTION

Styles 2550 and 2551 crinkled flexible graphite tape are made from high purity graphite with no fibers, binders or other additives. Style 2550 crinkled tape is typically used as a stuffing box packing for pumps and valves. Style 2551 is the same as 2550 except that it is furnished with a self-adhesive backing strip to facilitate installation as a form-in-place gasket, thread sealant, or for facing jacketed and other difficult-to-seal gaskets.

APPLICATION / SERVICE

Styles 2550 and 2551 Flexible graphite covers a broad range of sealing applications. It handles most chemicals in the 0 - 14 pH range at cryogenic and elevated temperatures, and from vacuum to extreme pressures. It is used extensively in the chemical, automotive and pump and valve industries.

SERVICE LIMITS		
Type	**Description**	**Value**
Temperature	Minimum	-320°F (-200°C)
	Maximum	
	• In air	840°F (450°C)
	• In steam	1200°F (650°C)
	• In reducing or inert media	5400°F (3000°C)
Pressure	Static	2000 psi (137 bar)
pH		0-14
Typical Properties	Carbon Content	98% minimum
	Leachable Chlorides	50 ppm maximum
	Total sulfur	100 ppm maximum

STANDARD PACKAGING*		
Tape Thicknes	**Tape Width**	**Spool Length**
.015	1/4”, 3/8”, 1/2”, 3/4”, 1”, 1-1/4”, 1-1/8” 1-3/4”, 2”	1/4" thru 1-1/8"...50' 1/4" thru 1-1/8"...100'

*other thicknesses, widths, and spool lengths are available on special order

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M & Y Values for Flexible Graphite Gasketing Products

	m	y (psi)
Style 2660	1.5	900
Style 2661	2	1,000
Style 2662	2	2,800
Style 2663	2	2,800
Style 2664	1.5	900

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Dec. 2010 REV.

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TEADIT®

Outstanding
Valve Stem Packings
for Petroleum and Chemical Process Industry

TEADIT® 010-ELE (Extremely Low Emissions)
Combo Set Valve Stem Packings for Extreme Emission Control

Teadit® Style Packings for sealing Valve Stems: 2235 - 2236 - 2222

COMBO SET

TEADIT® 010-ELE

Extremely Low Emissions

TEADIT® 010-ELE COMBO SET has an excellent sealability for applications where a rigid control of fugitive emissions is required due to hazardousness of fluids or risks involved.

TEADIT® 010-ELE COMBO SET combines 4 rings of ***"Packing A"*** plus one ring of ***"Packing B"***, following the arrangement ***"A-A-B-A-A"***. This provides incomparable performance in the control of fugitive emissions. Laboratory tests by internationally recognized authorities in the field confirm the impressive results. It's high temperature flexible graphite and Inconel® filament jacket affords mechanical stability while the advanced construction provides the best leakage control and high integrity in hydrocarbon and steam services.

TEADIT® 010-ELE COMBO SET is self-lubricating, non-hardening, dimensionally stable and resistant to gases and fluids as well as heat, pressure and chemicals.

KEY FEATURES

- ***Certified Low-Leakage Packing Technology***
- ***Extreme Emission Control***
- ***Fire Safe***
- ***Definitive Combo Set in Valve Sealing***

Specifications

Temperature:	-240ºC (-400ºF) to 650ºC (1,200ºF) steam 455ºC (850ºF) atmosphere
pH range:	0 - 14
Pressure:	To 310 bar (4,500 psi)

Packing B *Packing A*

TYPICAL TEADIT® 010-ELE ARRANGEMENT

THE GOAL ACHIEVED

Maximum 10PPMv in 5000 cycles, as can be seen in the approval of the product in Yarmouth Research and Technology LLC by the strict Chevron method testing.

Fugitive Emission Test Report

ChevronTexaco Test Standard

Performed for

Teadit North America

www.teadit.com

010-ELE Combo Set

Project Number: 210202
Start Date: September 22, 2010

Performed by

YARMOUTH RESEARCH AND TECHNOLOGY, LLC

434 Walnut Hill Road
North Yarmouth, ME 04097 USA
(207) 829-5359
info@yarmouthresearch.com
www.yarmouthresearch.com

Fugitive Emissions

Complete report available upon to request.
See on back page report summary.

Exceeds TA-Luft requirement

amtec

AMTEC Messtechnischer Service GmbH

CERTIFICATE

In accordance with the VDI Guideline 2440 (edition November 2000) the compliance with the tightness criteria of the type of packing set

TEADIT 2236
consisting of 5 packing rings

of the packing manufacturer

TEADIT
Rosenheimer Str. 10, A-6330 Kufstein/Tirol

was verified in a first-time test under the following test conditions:

predeformation:	1x 75	MPa
prestress:	60	MPa
geometry:	56x40x40	mm
temperature of packing:	300	°C
number of stem cycles:	5000	
stroke:	40	mm
test pressure (absolute):	40	bar
test medium:	Helium	
period of leakage measurement:	24	h

The leak rate measured with the Helium leak detector at the end of the period of the leakage measurement was

1.5 · 10[illegible] mbar · l/(m · s).

therefore the packing set is in compliance with the tightness criteria of VDI 2440 of **1.0·10[illegible] mbar · l/(m · s)** for tests at a temperature higher than 250 °C and can be regarded as a high-grade sealing system for the purposes of TA-Luft.

This certificate is only valid in combination with the test report 3020351A

Lauffen, September 10, 2010

amtec Messtechnischer Service GmbH

Dipl. Ing. F. Herkert

TA-Luft

PACKING
2236

PROPERTIES

TEADIT® PACKING 2236 is self-lubricating, non-hardening, dimensionally stable and resistant to gases and fluids as well as heat, pressure and chemicals. It's high temperature flexible graphite and Inconel® filament jacket affords mechanical stability while the advanced construction provides leakage control and high integrity in steam service.

Due to it's physical properties and ability to minimize friction, **TEADIT® STYLE 2236** is ideal for valves and can be used within a broad range of applications.

Packing 2236 - Specifications

Temperature:	-240ºC (-400ºF) to 650ºC (1,200ºF) steam 455ºC (850ºF) atmosphere
pH range:	0 - 14 (except strong oxidizers)
Pressure:	To 450 bar (6,500 psi)

KEY FEATURES

- *Certified Low-Leakage Packing Technology*
- *TA-Luft aproved*
- *Suitable to VOC and VHAP emissions regulations*
- *Environment friendly valve stem packing with supreme emissions control*

Highly Suitable for services with

Fugitive Emissions

PACKING

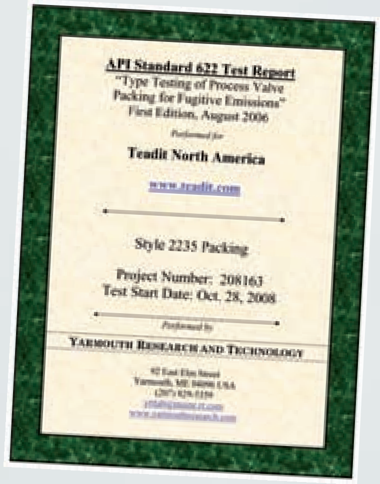
2235

TEADIT® PACKING 2235 is ideal for valves and can be used within a broad range of applications. It is well suited for power plants, refineries, petrochemical industry, and chemical processing as well as sealing applications in steam at high pressure and temperature. It is self-lubricating, non-hardening, dimensionally stable and resistant to gases and fluids as well as heat, pressure and chemicals.

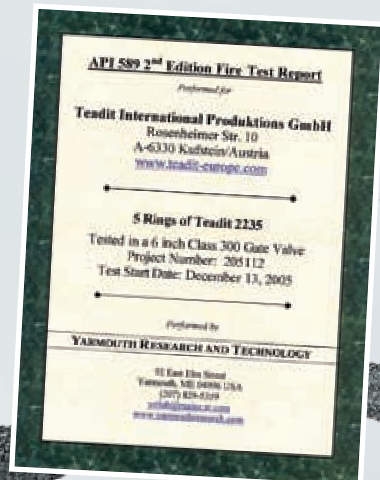
KEY FEATURES

- *Certified Low-Leakage Packing Technology*
- *Superior performance for high temperature steam service*
- *Excellent sealing, thermal and pressure properties contribute to the reduction of "fugitive emissions"*
- *Fire Safe*
- *Suitable for steam, hydrocarbon and chemical processing services*

Approval for Fire Test and Fugitive Emissions


API Standard 622 Test Report
"Type Testing of Process Valve Packing for Fugitive Emissions"
First Edition, August 2006
Teadit North America
Style 2235 Packing
Project Number: 208163
Test Start Date: Oct. 28, 2008
Yarmouth Research and Technology

Fugitive Emissions


API 589 2nd Edition Fire Test Report
Teadit International Produktions GmbH
Rosenheimer Str. 10
A-6330 Kufstein/Austria
5 Rings of Teadit 2235
Tested in a 6 inch Class 300 Gate Valve
Project Number: 205112
Test Start Date: December 13, 2005
Yarmouth Research and Technology

Fire Test

Packing 2235 - Specifications

Temperature:	-240ºC (-400ºF) to 650ºC (1,200ºF) steam 455ºC (850ºF) atmosphere
pH range:	0 - 14 (except strong oxidizers)
Pressure:	To 450 bar (6,500 psi)

Highly Suitable for services with

High Pressure and Temperature

PACKING
2222

PROPERTIES

TEADIT® PACKING 2222 stands out for its characteristic of compatibility with most industrial fluids except in the presence of oxidizing agents. Ideal for severe services in high-temperature and pressure valves, it is indicated for hydrocarbons, steam, water, gases, chemicals, synthetic and mineral oils.

Packing 2222 - Specifications

Temperature:	-240ºC (-400ºF) to 650ºC (1,200ºF) steam 455ºC (850ºF) atmosphere
pH range:	0 - 14 (except strong oxidizers)
Pressure:	To 275 bar (4,000 psi) without end rings

KEY FEATURES

» Superior performance

» Heat, pressure and chemically resistant

Approval for Fire Safe

Approval for TEADIT® 010-ELE Combo Set

Extreme Emission Control – Maximum 10ppmv in 5,000 cycles

Yarmouth Research and Technology, LLC

PROJECT SUMMARY

Customer: Teadit North America — **Start Date:** 22-Sep-10
Packing Manufacturer: Teadit — **Project #:** 210202
Packing Description: Teadit 020-ELE Combo Set

Test Fixture: 4" C1300 Velan Gate Valve

Manufacturer's Recommended Packing Torque:	35	ft-lb
Stem Diameter:	0.999	inches
Bore Diameter:	1.510	inches
Number of Handwheel Turns During Cycling:	11.5	(each direction)
Stem Travel During Cycling:	4.1	inches
Cycling Speed:	43	RPM
Cycling Rate:	75	seconds per cycle
Maximum Allowable Leakage:	500	PPMv (stem static)
Maximum Allowable Handwheel Torque:	83	ft-lb (based on 200lb pull force)
Test Pressure:	600	psig
Test Media:	99% Methane	

RESULTS

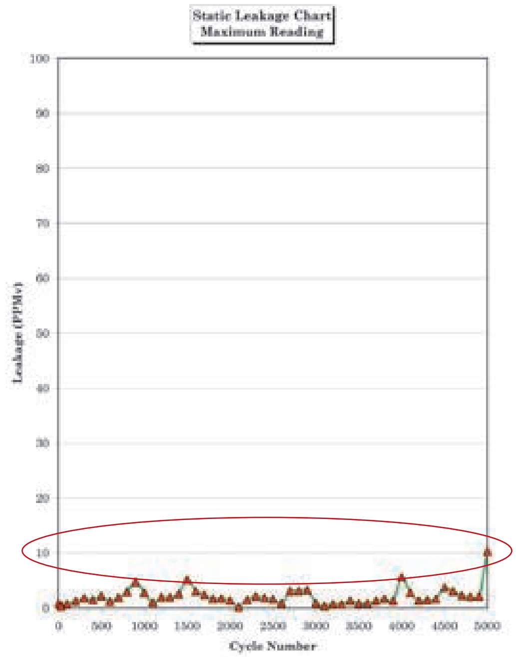
Reason for Test Completion:	5000 cycles completed
Number of Mechanical Cycles Completed:	5000
Number of Thermal Cycles Completed:	10
Number of Packing Adjustments Required:	0

	Stem Seal Leakage Readings (PPMv)				*Opening*	*Closing*
	Static		*Dynamic*		*Torque*	*Torque*
	Avg.	*Max.*	*Avg.*	*Max.*	*(ft-lb)*	*(ft-lb)*
Average:	2	2	2	3	15	20
Maximum:	9	10	19	28	18	25

Witness [signature]

STATE OF MAINE — MATTHEW J WASIELEWSKI — No. 7437 — LICENSED — PROFESSIONAL ENGINEER

Yarmouth Research and Technology, LLC



CONCLUSION: TEADIT® 010 ELE COMBO SET successfully completed test **without any packing adjustments** throughout the 5,000 mechanical cycles and maintained leakage below 10 PPMv.

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TEADIT® North America, INC
Houston - Texas
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TEADIT®

COMPANY ISO 9001

TÜV SÜD ISO 9001

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Cologne (Germany), Houston (USA), Rio de Janeiro (Brazil), Campinas (Brazil),
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Oct/10

AMTEC Meßtechnischer Service GmbH
Hoher Steg 13
74348 Lauffen
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Internet: www.amtec.de

CERTIFICATE

No. 30203501E/FH/10.09.10

In accordance with the VDI Guideline 2440 (edition November 2000) the compliance with the tightness criteria of the type of packing set

TEADIT 2236
consisting of 5 packing rings

of the packing manufacturer

TEADIT
Rosenheimer Str. 10, A-6330 Kufstein/Tirol

was verified in a first-time test under the following test conditions:

predeformation:	1x 75	MPa
prestress:	60	MPa
geometrie:	56x40x40	mm
temperature of packing:	300	°C
number of stem cycles:	5000	
stroke:	40	mm
test pressure (absolute):	40	bar
test medium:	Helium	
period of leakage measurement:	24	h

The leak rate measured with the Helium leak detector at the end of the period of the leakage measurement was

$1.5 \cdot 10^{-3}$ mbar · l/(m · s),

therefore the packing set is in compliance with the tightness criteria of VDI 2440 of **$1.0 \cdot 10^{-2}$ mbar · l/(m · s)** for tests at a temperature higher than 250 °C.

This certificate is only valid in combination with the test report 3020351/-

Lauffen, September 10, 2010.

amtec Meßtechnischer Service GmbH

Dipl. Ing. F. Herkert

Fire Test Report

ANSI/API Standard 607, Sixth Edition, 2010

ISO 10497:2010

Performed for

TEADIT North America, Inc.

www.TEADIT.com

Style 2236 Packing

Tested in a 6 inch Class 300 Gate Valve

Project Number: 210229

February 7, 2011

Performed by

YARMOUTH RESEARCH AND TECHNOLOGY, LLC

434 Walnut Hill Road
North Yarmouth, ME 04097 USA
(207) 829-5359
info@yarmouthresearch.com
www.yarmouthresearch.com

Yarmouth Research and Technology, LLC

Customer:	TEADIT North America, Inc.	**Date:**	2/7/2011
Specification:	ANSI/API Standard 607,Sixth Edition, 2010		
	ISO 10497-5:2010		
Product Description:	Style 2233 Packing		
Project Number:	PN210229		
Comments:	Test conducted in 6 inch Cl300 gate valve		
	Packing nuts torqued to 35 ft-lb at start of test.		
Yarmouth Engineer:	Matthew J. Wasielewski, P.E.		
Equipment Confirmed to be in Calibration to NIST Standards:	Yes		

Burn and Cool Down Test

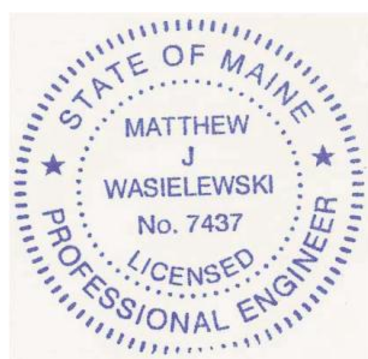
Burn Start Time:	11:21:00	
Average Pressure During Burn:	571	psig
External Leak Rate During Burn/Cool Down:	0.5	ml/min
Allowable External Leak Rate:	600	ml/min
Amount of Time of Avg. Cal. Blocks > 650 deg. C:	20.5	minutes
Were Test Conditions Within Compliance?	Yes	
Were the Valve Leakages Below the Allowables?	Yes	

Operational Test

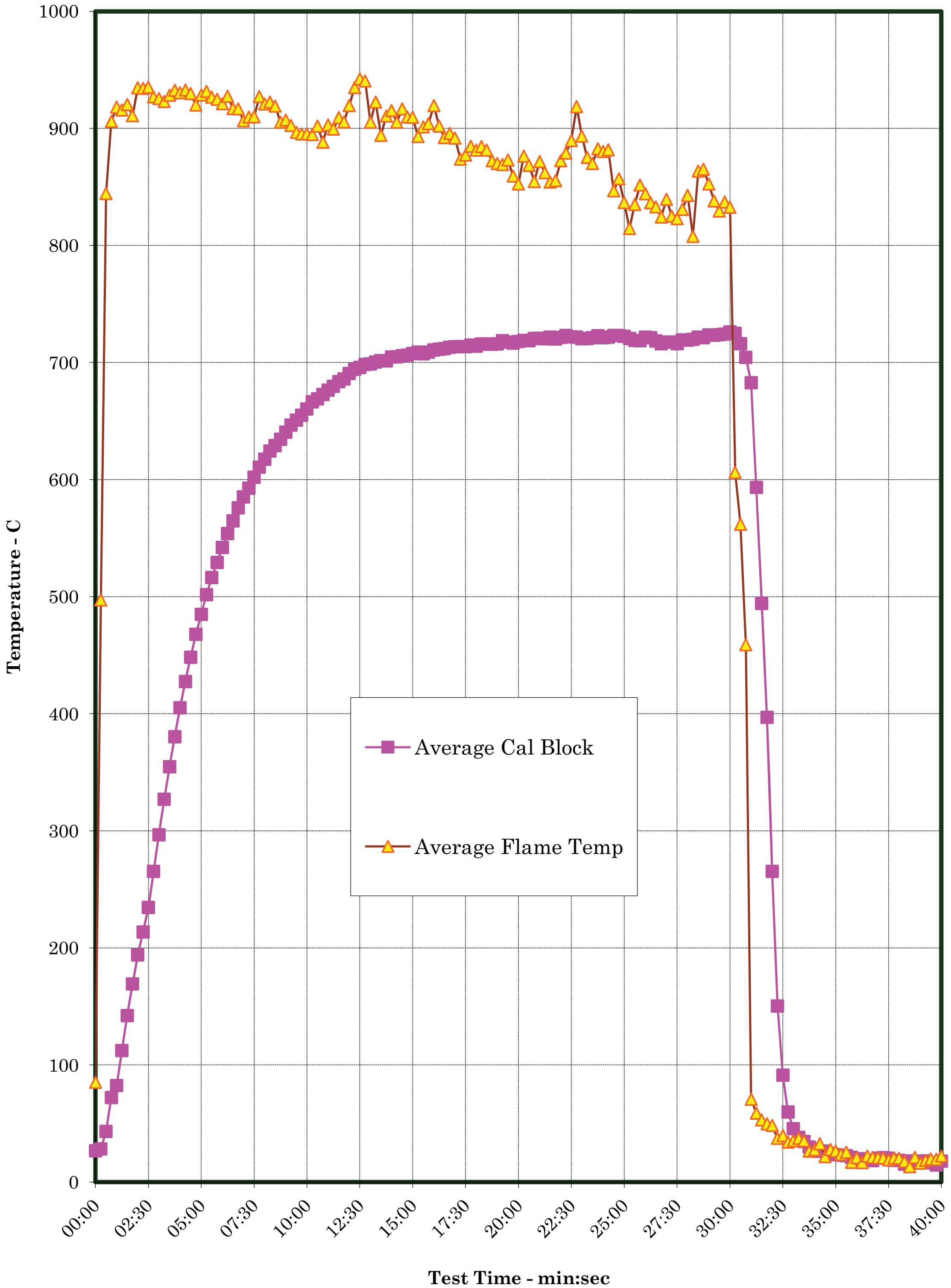
Did Valve Unseat and Open Fully?:	Yes	
Average Pressure During Test:	561	psig
External Leak Rate After Operating:	24.4	ml/min
Allowable External Leak Rate:	150	ml/min
Was the Leakage Below the Allowable?	Yes	

Valve Pass or Fail the Test Standard?	**PASS**

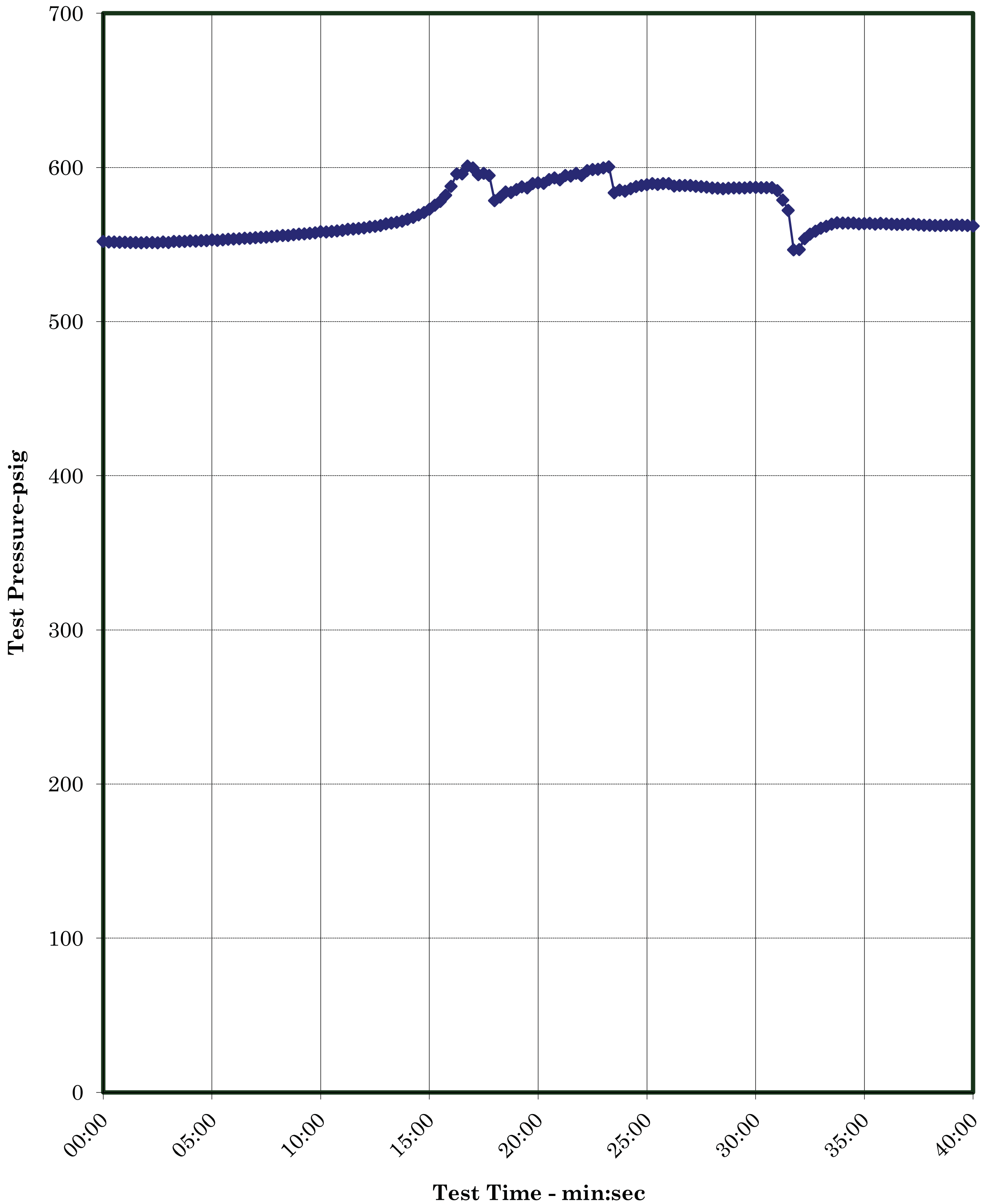
Witnesses



Temperature verses Time Chart



Pressure verses Time Chart



Packing Prior to Test

Valve During Burn.

Teadit® 2236 valve packing is self-lubricating, non-hardening, dimensionally stable and resistant to gases and fluids as well as heat, pressure and chemicals. It's high temperature flexible graphite and Inconel® filament jacket affords mechanical stability while the advanced construction provides leakage control and high integrity in steam service.

Application Areas
Due to it's physical properties and ability to minimize friction, Teadit® Style 2236 is ideal for valves and can be used within a broad range of applications.

Key Features
» Certified Low-Leakage Packing Technology
» TA-Luft approved
» Suitable to VOC and VHAP emissions regulations
» Environment friendly valve stem packing with supreme emissions control

SERVICE LIMITS		
Type	**Description**	**Value**
Temperature	Minimum	-400°F (-240°C)
	Maximum*	
	• steam	1200°F (650°C)*
	• atmosphere	850°F (455°C)*
Pressure	Valve	6500 psi (450 bar)
pH		0-14 (except strong oxidizers)

APPROXIMATE YIELDS (+/- 10%)			
Size	**Feet/Pound**	**Size**	**Feet/Pound**
1/8"	87.5	1/2"	5.4
3/16"	38.2	9/16"	4.3
1/4"	21.6	5/8"	3.5
5/16"	14.0	3/4"	2.4
3/8"	9.7	7/8"	1.8
7/16"	7.1	1"	1.4

*Consult Teadit Engineering for all applications above 600°F (315°C) in order to optimize the packing solution.

Properties and application parameters shown throughout this datasheet are typical. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury. Specifications are subject to change without notice. This edition supersedes all previous issues.

Fugitive Emission Test Report

ChevronTexaco Test Standard

Performed for

Teadit North America

www.teadit.com

Teadit Style 2236 Braided Graphite Packing

Project Number: 210202
Start Date: November 1, 2010

Performed by

YARMOUTH RESEARCH AND TECHNOLOGY, LLC

434 Walnut Hill Road
North Yarmouth, ME 04097 USA
(207) 829-5359
info@yarmouthresearch.com
www.yarmouthresearch.com

Yarmouth Research and Technology, LLC

PROJECT SUMMARY

Customer:	Teadit North America	**Start Date:**	1-Nov-10
Packing Manufacturer:	Teadit	**Project #:**	210202
Packing Description:	Teadit GAX 2236		
	5 rings cut from spool		
Test Fixture:	4" Cl300 Velan Gate Valve		

Manufacturer's Recommended Packing Torque:	56	ft-lb
Stem Diameter:	1.000	inches
Bore Diameter:	1.510	inches
Number of Handwheel Turns During Cycling:	11.5	(each direction)
Stem Travel During Cycling:	4.1	inches
Cycling Speed:	43	RPM
Cycling Rate:	75	seconds per cycle

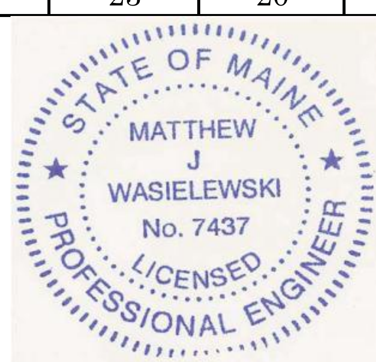
Maximum Allowable Leakage:	500	PPMv (stem static)
Maximum Allowable Handwheel Torque:	83	ft-lb (based on 200lb pull force)
Test Pressure:	600	psig
Test Media:	99% Methane	

RESULTS

Reason for Test Completion:	5000 cycles completed
Number of Mechanical Cycles Completed:	5000
Number of Thermal Cycles Completed:	10
Number of Packing Adjustments Required:	0

	Stem Seal Leakage Readings (PPMv)				***Opening***	***Closing***
	Static		***Dynamic***		***Torque***	***Torque***
	Avg.	***Max.***	***Avg.***	***Max.***	***(ft-lb)***	***(ft-lb)***
Average:	4	4	4	6	18	23
Maximum:	19	20	18	23	20	25

Witness



Yarmouth Research and Technology, LLC

Customer: Teadit North America | **Start Date:** 1-Nov-10
Packing Manufacturer: Teadit | **Project #:** 210202
Packing Description: Teadit GAX 2236

Test Fixture: 4" Cl300 Velan Gate Valve

Test Results: The average and maximum leakage results shown below were calculated from 60 readings measured during a minute duration.
Opening and closing torques are performed against the test pressure.
See data sheets for more detailed information.

Cycle Number	*Temp (F)*	*Stem Seal Leakage Readings (PPMv) Static Avg.*	*Static Max.*	*Dynamic Avg.*	*Dynamic Max.*	*Packing Retorque See Note*	*Opening Torque (ft-lb)*	*Closing Torque (ft-lb)*
0	Ambient	1	1	3	8		20	25
30	145	1	1	2	2	**0**	20	25
31	145	2	2	2	2		20	25
100	320	3	3	3	3		20	25
200	500	6	6	6	7		20	25
300	500	4	5	5	6		20	25
400	320	3	4	3	4		20	25
500	Ambient	2	2	2	3		20	25
600	320	5	5	5	6		20	25
700	500	3	3	3	3		20	25
800	500	3	3	3	3		20	25
900	320	2	2	2	2		20	25
1000	Ambient	3	4	4	5		20	25
1100	320	2	2	2	2		20	25
1200	500	2	2	2	2		20	25
1300	500	2	2	2	2		20	25
1400	320	3	3	3	3		20	25
1500	Ambient	4	4	4	4		20	25
1600	320	4	4	4	4		20	25
1700	500	3	3	3	3		20	25
1800	500	3	3	3	3		20	25
1900	320	2	2	2	2		20	25
2000	Ambient	6	7	6	7		20	25
2100	320	3	3	4	4		20	25
2200	500	2	2	2	2		20	25
2300	500	2	2	2	2		20	25
2400	320	1	1	1	1		20	25
2500	Ambient	1	2	4	9		20	25
2600	320	2	2	2	3		20	25
2700	500	2	2	2	3		15	20
2800	500	1	2	2	2		15	20

2900	320	1	1	1	3		15	20
3000	Ambient	4	5	5	9		15	20
3100	320	2	2	2	3		15	20
3200	500	1	1	1	1		15	20
3300	500	2	2	2	2		15	20
3400	320	2	2	2	3		15	20
3500	Ambient	1	1	1	2		15	20
3600	320	3	3	3	4		15	20
3700	500	1	1	2	3		15	20
3800	500	3	4	3	4		15	20
3900	320	2	2	2	3		15	20
4000	Ambient	1	2	2	4		15	20
4100	320	3	4	6	9		15	20
4200	500	4	5	6	8		15	20
4300	500	9	9	8	11		15	20
4400	320	9	10	8	12		15	20
4500	Ambient	10	11	12	14		15	20
4600	320	11	12	18	23		15	20
4700	500	19	20	16	21		15	20
4800	500	11	13	15	22		15	25
4900	320	7	8	6	12		15	25
5000	Ambient	4	6	8	15		15	25
Averages ->		**4**	**4**	**4**	**6**		**18**	**23**
Maximums ->		**19**	**20**	**18**	**23**		**20**	**25**

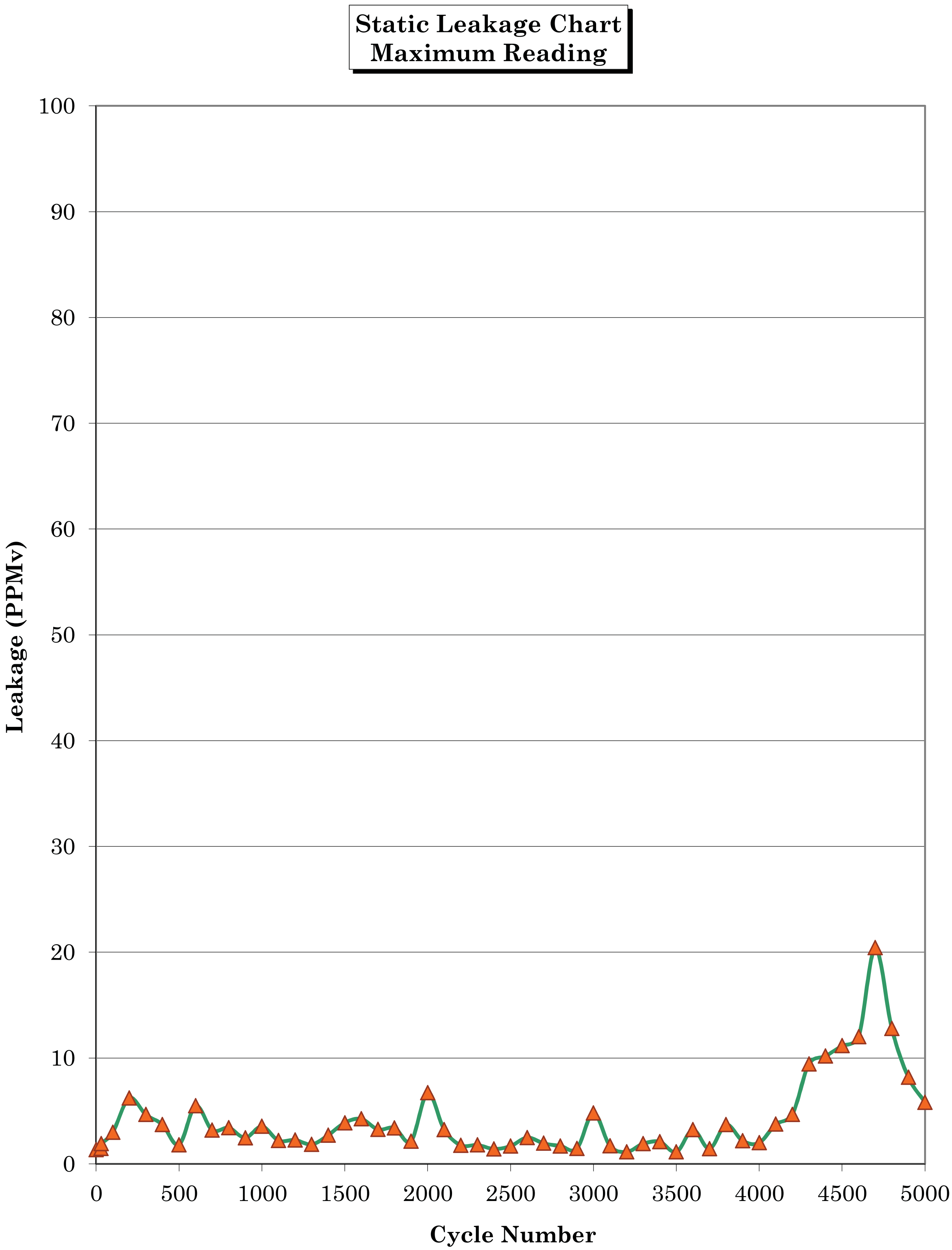
Packing Retorque Notes:

	Static Leakage PPMv	*Before Adjustment*				*After Adjustment*		
		Nut Torque		*Opening*	*Closing*	*Nut Torque*		*Gland*
		Top	*Bottom*	*Torque*	*Torque*	*Top*	*Bottom*	*Height*
0	1	55	55	20	25	56	56	0.58
1								
2								

Bonnet Gasket Leakage at Start: (PPMv)	0	***Avg.***	0	***Max.***
Packing Nut Torque at End of Test: (ft-lb)	35	***<-top***	40	***<-bottom***

Test Notes:

Yarmouth Research and Technology, LLC



Yarmouth Research and Technology, LLC

Customer:	Teadit North America	**Start Date:**	1-Nov-10
Packing Manufacturer:	Teadit	**Project #:**	210202
Packing Description:	Teadit GAX 2236		
Test Fixture:	4" Cl300 Velan Gate Valve		

Test Results: The average and maximum leakage results shown below were calculated from 60 readings measured during a minute duration.
Opening and closing torques are performed against the test pressure.
See data sheets for more detailed information.

Original PPMv values converted to mg/sec based on a methane density of .66 mg/ml and a sampling rate of 1000 ml/min.

		Stem Seal Leakage Readings (mg/sec)				***Packing***	***Opening***	***Closing***
Cycle	***Temp***	***Static***		***Dynamic***		***Retorque***	***Torque***	***Torque***
Number	***(F)***	***Avg.***	***Max.***	***Avg.***	***Max.***	***See Note***	***(ft-lb)***	***(ft-lb)***
0	Ambient	9.1E-06	1.5E-05	3.0E-05	8.9E-05		20	25
30	145	1.5E-05	1.6E-05	1.7E-05	1.9E-05	**0**	20	25
31	145	1.7E-05	2.1E-05	1.8E-05	2.1E-05		20	25
100	320	3.1E-05	3.3E-05	3.2E-05	3.5E-05		20	25
200	500	6.4E-05	6.8E-05	6.7E-05	8.1E-05		20	25
300	500	4.9E-05	5.1E-05	5.5E-05	6.2E-05		20	25
400	320	3.5E-05	4.1E-05	3.5E-05	4.0E-05		20	25
500	Ambient	1.9E-05	2.0E-05	2.4E-05	3.8E-05		20	25
600	320	5.9E-05	6.0E-05	6.0E-05	6.1E-05		20	25
700	500	3.4E-05	3.5E-05	3.2E-05	3.3E-05		20	25
800	500	3.6E-05	3.7E-05	3.6E-05	3.8E-05		20	25
900	320	2.6E-05	2.7E-05	2.2E-05	2.4E-05		20	25
1000	Ambient	3.3E-05	3.9E-05	4.5E-05	5.4E-05		20	25
1100	320	2.3E-05	2.4E-05	2.4E-05	2.5E-05		20	25
1200	500	2.4E-05	2.5E-05	2.4E-05	2.5E-05		20	25
1300	500	1.9E-05	2.0E-05	1.8E-05	2.0E-05		20	25
1400	320	2.9E-05	3.0E-05	3.0E-05	3.1E-05		20	25
1500	Ambient	4.0E-05	4.3E-05	4.3E-05	4.5E-05		20	25
1600	320	4.1E-05	4.7E-05	4.5E-05	4.7E-05		20	25
1700	500	3.3E-05	3.6E-05	3.4E-05	3.7E-05		20	25
1800	500	3.6E-05	3.7E-05	3.3E-05	3.8E-05		20	25
1900	320	2.3E-05	2.4E-05	2.4E-05	2.7E-05		20	25
2000	Ambient	7.0E-05	7.4E-05	6.8E-05	7.2E-05		20	25
2100	320	3.4E-05	3.5E-05	4.0E-05	4.1E-05		20	25
2200	500	1.9E-05	1.9E-05	1.9E-05	2.1E-05		20	25
2300	500	1.9E-05	2.0E-05	1.8E-05	1.9E-05		20	25
2400	320	1.5E-05	1.5E-05	1.4E-05	1.5E-05		20	25
2500	Ambient	1.5E-05	1.8E-05	4.9E-05	1.0E-04		20	25
2600	320	2.5E-05	2.7E-05	2.2E-05	2.9E-05		20	25

2700	500	1.9E-05	2.1E-05	2.1E-05	2.9E-05		15	20
2800	500	1.6E-05	1.8E-05	1.7E-05	2.4E-05		15	20
2900	320	1.5E-05	1.6E-05	1.6E-05	3.0E-05		15	20
3000	Ambient	4.6E-05	5.3E-05	5.5E-05	9.8E-05		15	20
3100	320	1.7E-05	1.9E-05	2.0E-05	3.4E-05		15	20
3200	500	1.0E-05	1.2E-05	1.2E-05	1.3E-05		15	20
3300	500	1.9E-05	2.1E-05	1.8E-05	2.3E-05		15	20
3400	320	2.1E-05	2.3E-05	2.4E-05	3.2E-05		15	20
3500	Ambient	1.2E-05	1.2E-05	9.9E-06	1.7E-05		15	20
3600	320	3.4E-05	3.5E-05	3.8E-05	3.9E-05		15	20
3700	500	1.4E-05	1.6E-05	1.7E-05	3.3E-05		15	20
3800	500	3.6E-05	4.1E-05	3.4E-05	4.9E-05		15	20
3900	320	2.0E-05	2.4E-05	2.2E-05	3.5E-05		15	20
4000	Ambient	1.6E-05	2.2E-05	2.4E-05	4.2E-05		15	20
4100	320	3.8E-05	4.1E-05	7.0E-05	9.8E-05		15	20
4200	500	4.3E-05	5.1E-05	6.9E-05	9.3E-05		15	20
4300	500	1.0E-04	1.0E-04	9.3E-05	1.2E-04		15	20
4400	320	1.0E-04	1.1E-04	9.1E-05	1.3E-04		15	20
4500	Ambient	1.1E-04	1.2E-04	1.3E-04	1.5E-04		15	20
4600	320	1.2E-04	1.3E-04	2.0E-04	2.5E-04		15	20
4700	500	2.1E-04	2.2E-04	1.7E-04	2.3E-04		15	20
4800	500	1.2E-04	1.4E-04	1.6E-04	2.5E-04		15	25
4900	320	7.8E-05	9.0E-05	6.7E-05	1.3E-04		15	25
5000	Ambient	4.7E-05	6.4E-05	8.6E-05	1.6E-04		15	25
Averages ->		**4.1E-05**	**4.5E-05**	**4.6E-05**	**6.2E-05**		**18**	**23**
Maximums ->		**2.1E-04**	**2.2E-04**	**2.0E-04**	**2.5E-04**		**20**	**25**

Packing Retorque Notes:

	Static Leakage mg/sec	*Before Adjustment*				*After Adjustment*		
		Nut Torque ft-lb		*Opening*	*Closing*	*Nut Torque*		*Gland*
		Top	*Bottom*	*Torque*	*Torque*	*Top*	*Bottom*	*Height*
0	1.6E-05	55	55	20	25	56	56	0.58
1								
2								

Bonnet Gasket Leakage at Start: (PPMv)	0	***Avg.***	0	***Max.***
Packing Nut Torque at End of Test: (ft-lb)	35	***<-top***	40	***<-bottom***

Test Notes:

DIMENSIONAL INFORMATION

Manufacturer's Information

Packing Description:	Teadit GAX 2236	
	5 rings cut from spool by Yarmouth	
Valve Manufacturer:	4 inch Class 300 Velan Gate Valve	
Valve Product Code:	133-8	
Test Start Date:	1-Nov-10	
Is the stem rising rotating, or rising?:	Rising	
Packing - OEM or Repack:	Repack	
Packing Supplier:	Teadit	
Initial Packing Torque or Packing Instructions:	56	ft-lb

Photographs - Before Repacking

Valve As Received:	Yes	
Bonnet, Stem, Handwheel, Gland:	Yes	
Yoke Mechanism:	Yes	

Valve Dimensional Information

Gland stud size:	5/8	inches
Gland Stud Threads per inch:	11	
Gland Height as Received:	-	inches
Number of Handwheel Turns to Open:	12.5	
Stem Travel:	4.5	inches
Calculated Pitch of Stem Threads:	0.36	

Re-pack Information

Stem Diameter:	0.999	inches
Gland Follower OD:	1.497	inches
Gland Follower Height:	1.055	inches
Bore Depth:	1.433	inches
Calculated Packing Cross-section:	0.25	inches
Cross-section of Packing Used:	0.250	inches
Number of Packing Rings Installed:	5	
Nominal Uncompressed Packing Height:	1.250	inches
Packing Nut Torque Specified:	56	ft-lb
Gland Follower Height After Compression:	0.580	inches
% Compression Calculated:	23.4%	
Ease of Cutting Packing:	OK with blade	

Photographs - During Repacking

Packing Spool Information:	Yes
Packing Rings Cut:	Yes

Yarmouth Research and Technology, LLC

Pre-Test Information

Stem Threads, Yoke and Gland Studs Lubed?:	Yes	
Closing Torque with 0 Pressure After Retorquing:	20	ft-lb
Opening Torque with 0 Pressure After Retorquing:	20	ft-lb
Handwheel Outside Radius:	5	inches
Maximum Allowable Handwheel Pull:	200	pounds
Calculated Maximum Allowable Handwheel Torque:	83.3	ft-lb

Test Parameters

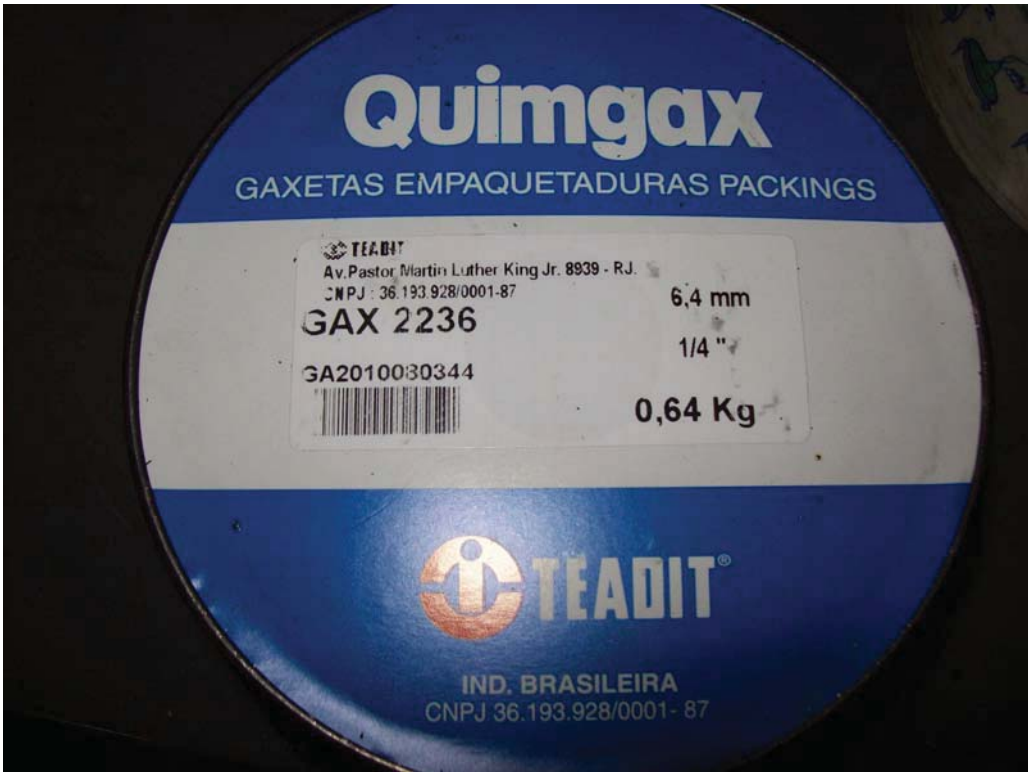
Actuator Speed:	43	RPM
# of Handle Turns During Cycling:	11.5	
Stroke Length:	4.14	
Time to Open Valve:	16.0	
Time to Close Valve:	16.0	
Total Time to Complete One Cycle:	75	seconds

Post Test Measurements

Closing Torque with 0 Pressure:	20	ft-lb
Opening Torque with 0 Pressure:	20	ft-lb
Packing extrusion between shaft and follower:	0.25	inches
Stem Diameter Above Packing:	1.000	inches
Stem Diameter Center of Packing:	1.000	inches
Stem Circularity (min. Diam):	0.0005	inches
Stem Taper (min. Diam):	0.0005	inches
Stem Side to Side Play:	0.020	inches
Stem Straightness:	0.000	inches
Stem Surface Finish:	12	Ra
Follower ID:	1.041	inches
Follower OD:	1.497	inches
Follower Height:	1.055	inches
Stuffing Box Diameter:	1.510	inches
Stuffing Box Depth:	1.433	inches
Stuffing Box Finish (estimated w/comparator):	16	Ra
Bottom Bore Diameter:	1.044	inches

Calculations

Clearance Between Bottom Bore and Stem:	0.044	inches
Clearance Between Follower and Stem:	0.041	inches
Clearance Between Follower and Bore:	0.013	inches
Packing Compression After Retorque:	23%	
After Hot Torque:	23%	
After First Adjustment, (if required):		
At End of Test:	23%	



Packing Material – Rings cut and installed by Matt Wasielewski, Yarmouth

Test Setup
(date code on photos – DD/MM/YYYY)

Packing After Test
Grease on stem from yoke nut grease required for cycling.

(date code on photos – MM/DD/YYYY)

API Standard 622 Test Report

"Type Testing of Process Valve
Packing for Fugitive Emissions"
Second Edition, 2011

Performed for

Teadit North America

www.teadit-na.com

Teadit Style 2236 Graphite Packing

Project Number: 211142
Test Start Date: June 8, 2011

Performed by

YARMOUTH RESEARCH AND TECHNOLOGY, LLC

434 Walnut Hill Road
North Yarmouth, ME 04097 USA
(207) 829-5359
info@yarmouthresearch.com
www.yarmouthresearch.com

Yarmouth Research and Technology, LLC

API 622 PROJECT SUMMARY

Customer:	Teadit North America	**Start Date:**	8-Jun-11
		Project #:	211142

Packing Information

Packing Description:	Teadit Style 2236	
	Rings cut from spool and installed by Yarmouth	
	Test conducted in test fixture.(1)	
Source of Sample:	Customer	
Packing Cross Section:	1/4 inch	nominal
Packing Free Ht:	1.375	inches - measured

Test Conditions

Specification:	API 622, 2nd Edition, 2011			
Test Media:	99% Methane	**Test Pressure:**	600	psig
Recommended Packing Nut Torque:			57	ft-lb
Maximum Allowable Leakage:			100	PPMv
Stem Linear Travel During Cycling:			4.0	inches
Cycling Rate:			45	seconds per cycle

Dimensions (inches)

Stem Diameter:	1.000	**Bore Diameter:**	1.500
Follower Height:	1.015	**Bore Depth:**	1.250
Gland Ht at Start:	0.658	**% Compression:**	35%
Gland Ht at End:	0.658	**% Compression:**	35%
Gland Bolt Diameter:	5/8		

Results

Average Test Pressure:	600	psig
Number of Mechanical Cycles Completed:	1510	
Number of Thermal Cycles Completed:	5	
Number of Packing Adjustments Required:	0	
Cycle Number(s) of Packing Adjustments:	n/a	
Average Leakage Throughout Test:	2	PPMv
Maximum Leakage Throughout Test:	22	PPMv

Witness

Matthew J Wasielewski, PE

President, Yarmouth Research

Yarmouth Research and Technology, LLC

Customer: Teadit North America **Start Date:** 8-Jun-11

Project #: 211142

Packing Description: Teadit Style 2236

Rings cut from spool and installed by Yarmouth

Cycle Number	Inside Temp (F)	Bonnet Temp - (F)	Pressure (psig)	Stem Seal Leakage (PPMv) Avg.	Stem Seal Leakage (PPMv) Max.	Packing Retorque See Note
0	65	63	606	1	1	
50	66	70	600	0	0	
100	69	77	601	1	1	
150	71	80	606	0	1	
150	491	498	604	3	3	
200	497	496	597	2	3	
250	502	493	601	0	0	
300	503	495	601	0	1	
300	94	80	595	1	1	
350	84	83	598	1	1	
400	82	83	599	1	1	
450	78	80	598	0	0	
450	507	499	602	0	1	
500	502	499	600	1	1	
550	502	503	602	1	1	
600	497	499	598	0	0	
600	86	81	604	1	1	
650	85	84	599	1	1	
700	85	87	600	1	1	
750	85	90	601	1	2	
750	504	500	600	2	2	
800	500	500	604	2	2	
850	502	500	601	1	1	
900	503	499	600	1	1	
900	69	70	596	1	1	
950	73	76	602	2	2	
1000	75	81	597	1	1	
1050	78	85	603	0	1	
1050	509	499	600	2	3	
1100	510	499	599	1	2	
1150	508	500	601	1	1	
1200	505	499	597	1	1	
1200	91	85	603	2	2	
1250	92	92	604	2	2	
1300	90	95	598	7	7	

1350	91	94	599	21	22	
1350	502	499	602	4	5	
1400	506	499	598	4	4	
1450	507	499	607	4	4	
1500	508	499	601	8	8	
1500	89	80	599	2	2	
1510	86	81	595	4	4	
		Averages ->	**600**	**2**	**2**	
		Maximums ->	**607**	**21**	**22**	

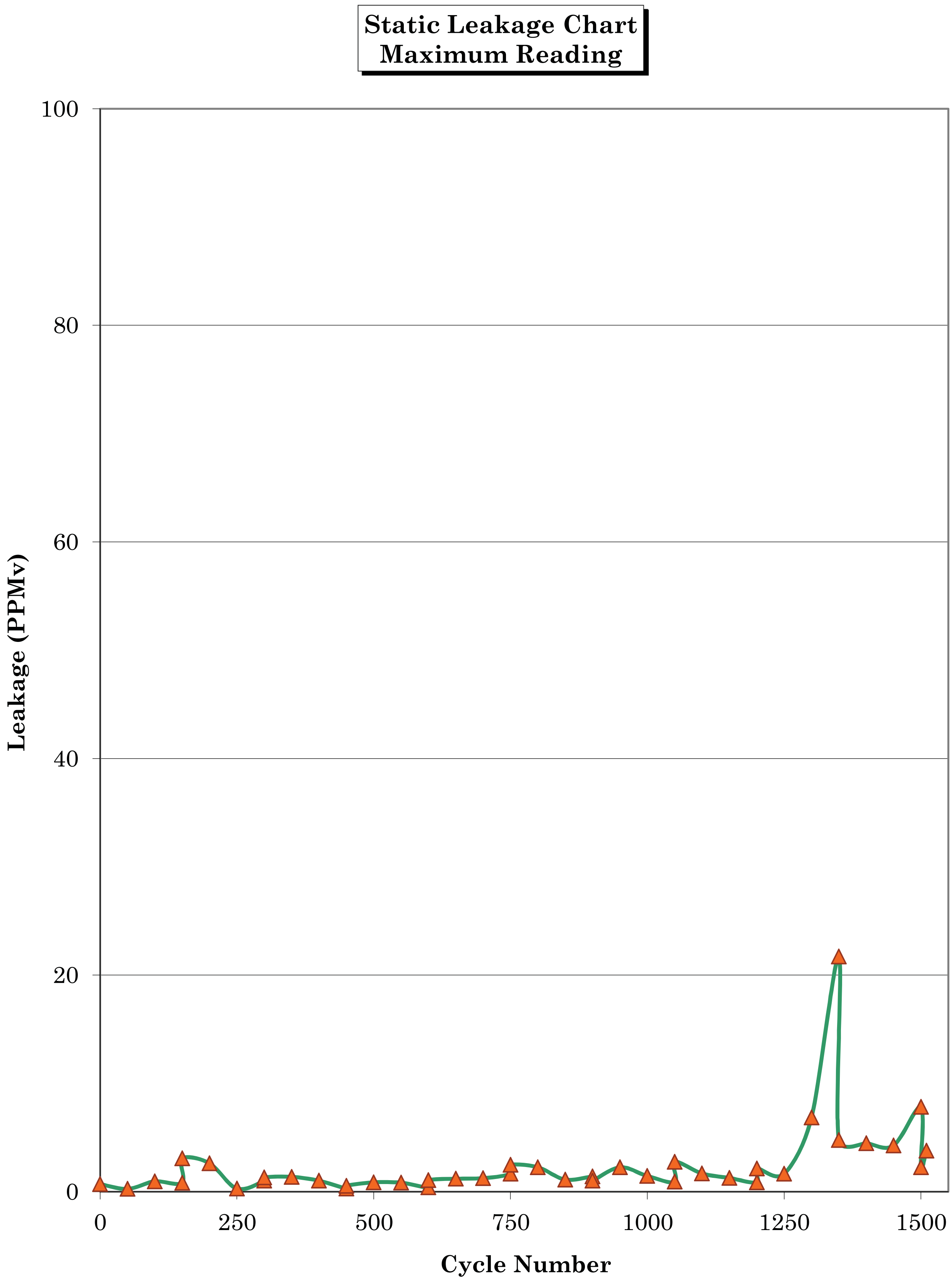
Packing Retorque Notes:

	Before Adjustment		***After Adjustment***			
	Nut Torque		***Nut Torque***		***Number of Flats***	***Gland Height***
	Side 1	***Side 2***	***Side 1***	***Side 2***		
1						
2						

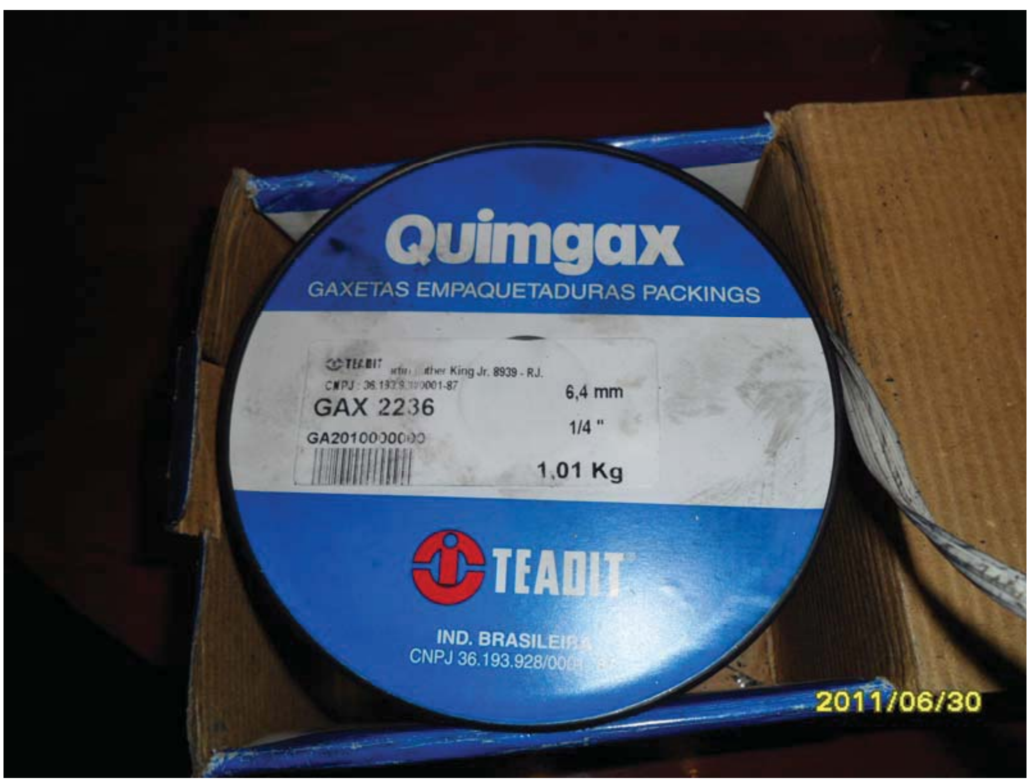
Nut Torque at End of Test: (ft-lb)	35	***<-Side 1***	40	***<-Side 2***

Test Notes:

Test Results: The average and maximum leakage results shown below were calculated from 60 readings measured during a minute duration.
See data sheets for more detailed information.


Static Leakage Chart
Maximum Reading
100
80
60
40
20
0
Leakage (PPMv)
0
250
500
750
1000
1250
1500
Cycle Number

PHOTOGRAPHS



Test fixture setup

.

Packing rings after test

Fluid Sealing Solutions from Teadit

"Certified Low-Leaking Valve Packing Technology"

2236 & 010-ELE Packing

Warranty of < 50 PPMv

For 10 Years or 5000 Cycles

TEADIT

Teadit's Commitment to Assist Our Valued Customers with Lowering Valve Fugitive Emissions

Utilizing trained valve installation technicians and certified low-leaking valve packing technology provides you the benefit of a packing with a warranty.

2236 Warranty Registration Card

Certified Installer's Name______________________________________

Date Installed__________________

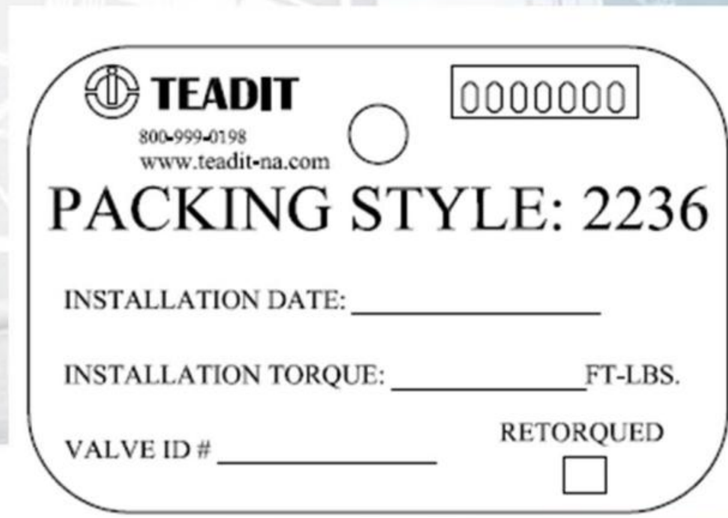
Valve ID#______________________
____

The information provided on this card will be entered into a database maintained by Teadit North America. The information should be referenced for any warranty claims for the 2236 product.

Tag #____

Valve Description (s)____
____

Example of Warranty Registration Card for <50 PPMv for 10 year or 5000 cycles



Example of Valve Tag Provided with Packing

Teadit's Commitment to Assist Our Valued Customers with Lowering Valve Fugitive Emissions

Teadit iPhone & iPad App to determine appropriate installation torque. Free download from App Store.

TEADIT

Product: Teadit 2236 **SE:** - **Project:** - **Analysis:** API standard 622	**Analyst:** DFC/NYC **Date:** 30th December 2010

1. SCOPE

To characterize Teadit 2236 packing, according to API standard 622 – "Type testing of process valve packing for fugitive emissions".

2. METHODOLOGY

Teadit 2236 packing was analyzed based on API standard 622, however some adjustments were necessary to do it in Teadit laboratory.

The following properties were determined:

- Corrosion test: Packing sample was tied to a graphite yarn and immerged in NaCl 1M solution. A steel bar was immerged in the same solution and electrically connected to the packing. The electric potential difference was recorded.
- Weight loss: according to API 622
- Density: according API 622
- Lubricant content
  - PTFE content: according EPA 9056A[1], tested in the external laboratory - Analytical Solutions.
  - Wet lubricant: according API 622
- Leachables
  - Chloride: according EPA 9056A, tested in the external laboratory - Analytical Solutions.
  - Fluoride: according EPA 9056A, tested in the external laboratory - Analytical Solutions.

[1] EPA 9056A – "Determination of inorganic anions by ion chromatography"

3. RESULTS

Figure 1 shows the corrosion test result.

Table 1 presents weight loss after 1 hour in each temperature. The other properties are resumed in table 2.

Figure 1 – Corrosion test

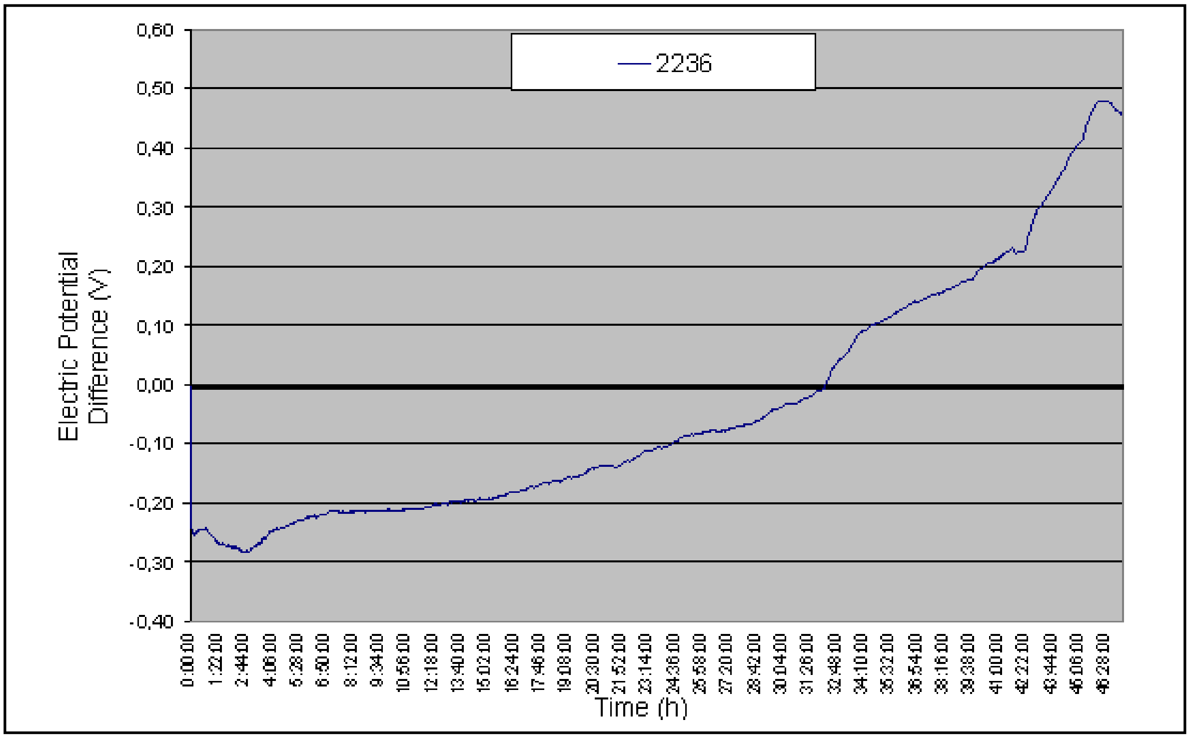


Table 1 – Weight loss

Temperature ºC (ºF) /1hour	Weight loss (%)
150 (300)	0.06
260 (500)	0.5
300 (570)	0.5
340 (645)	0.2
380 (720)	0.1
420 (790)	0.2
460 (860)	0.2
500 (930)	4.4
540 (1000)	7.3

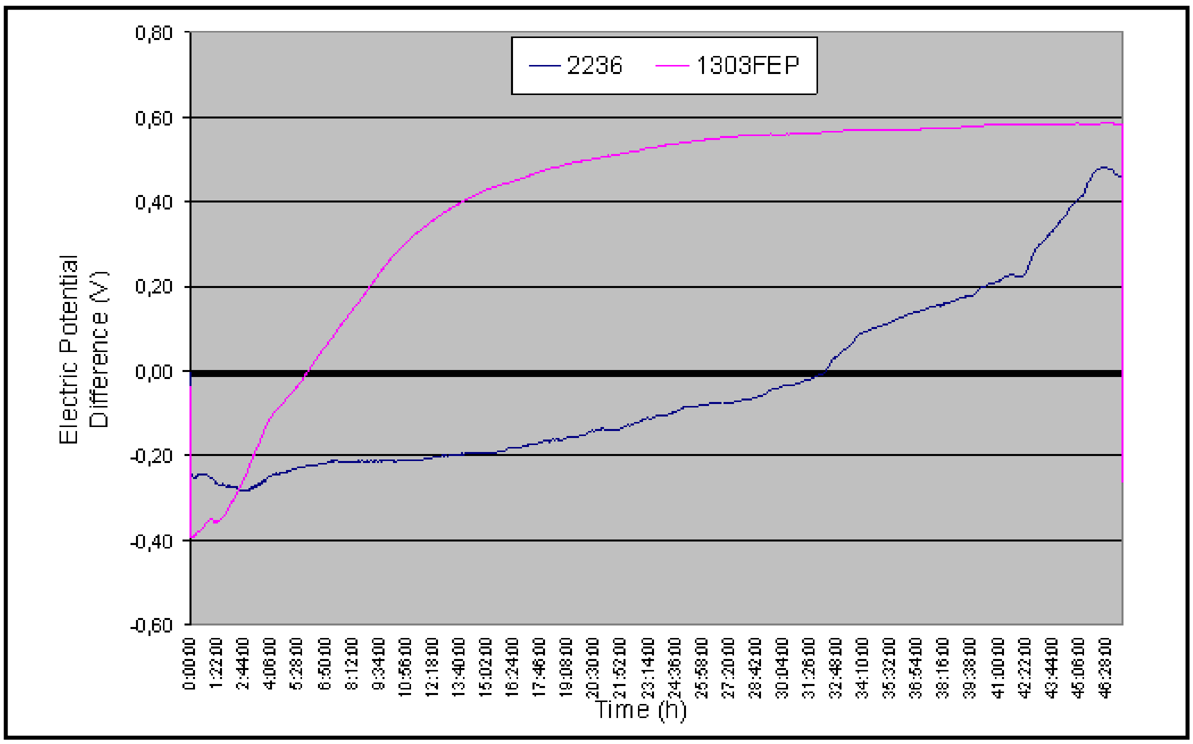
Table 2 –Property

Property	Unit	2236
Density	g/cm^3	1.68
PTFE content	%	N.D.
Wet lubricant	%	0.58
Chloride	ppm	6.7
Fluoride	ppm	N.D.

N.D. → Not Detected (quantification limit = 0,020 ppm)

Appendix – Complementary tests

1 – Corrosion test: Comparative between Teadit 2236 and Garlock 1303FEP



2 – Others inorganic anions quantified in Analytical solutions laboratory

Anions	ppm
Nitrite	N.D.
Bromide	0.064
Nitrate	N.D.
Sulfate	3.76
Phosphate	19.46
Acetate	N.D.
Chlorite	N.D.
Bromate	N.D.

Teadit

2235 Fugitive Emission Valve Packing

- Superior containment of fugitive emissions
- Low friction design
- Compatible with a variety of medias
- Complete range of sizes available

2235 Packing

Teadit Style 2235 packing is composed of layers of flexible graphite tape plied into compact strands; with each filament reinforced with an Inconel® wire jacket. These individual strands are then square braided to form a dense yet malleable packing. Outwardly it is then impregnated with lubricating agents to reduce stem friction.

Teadit Style 2235 Packing was developed to operate in valve applications that are designed for hydrocarbons and steam at high pressure. Style 2235 packing is an ideal solution for containment of fugitive emissions in extreme applications found in refineries, petrochemical plants, and thermal electricity generation stations.

Operating Parameters

Designed for most chemical and gas applications, Style 2235 is also suitable for service in steam applications

Temperature	Min/Max	Steam
(°C)	-240 / 450	650
(°F)	-464 / 842	1202

Static Pressure: 6500 psi

pH: 0-14

Benefits:

Mechanical and thermal stability. Thermally conductive vs. heat, pressure and chemicals. Extrusion-proof, minimal weight loss, easy to handle and install.

The packing is supplied with a corrosion inhibitor.

Style 2235 is not designed for applications that contain high oxidizing agents.

Yarmouth Fugitive Emission Packing Test Report

This test protocol is designed to be the standard by which all valve and valve packing systems will be evaluated by a major North American Refinery. The objective of the test is to allow direct comparisons between packing and valve manufacturers so that the best performing products can be selected.

Basic Test Parameters

• Test Media	Methane Gas
• Test Pressure	600 psig
• Test Temp.	500 °F at the stuffing box
• Heating Rate	70°F to 350°F, 115°F per hour 350°F to 500°F, 83°F an hour
• Time for open/close cycle	60 seconds, 15 second rest between cycles
• Number of cycles	5,000 fully open to fully close, or until 500 ppmv is reached a third time
• Number of cycles per day	500
• Test Valve	ANSI Class 300, API 600, NPS 4, Carbon Steel Gate Valve
• Leak Detection Method	EPA Method 21
• Max. Emission (ppm)	500PPMv static with data provided on dynamic measurement
• Leak detection frequency	Every 100 cycles after valve has set for 2 minutes (static) and upon resumption of cycling (dynamic)
• Torque to open and close	Every 100 cycles, either by hand or electronically
• Minimum number of Tests	Two for each valve manufacturer, one on the Valve's OEM packing, one on an approved spool required to evaluate a packing or packing system

A maximum of 3 gland adjustments (re-torque) are allowed to maintain a leakage rate of less than 500 PPMv over the 5000 mechanical cycles and 10 thermal cycles.

Yarmouth Results

TEADIT

Teadit Style 2235 meets the requirement of the Fugitive Emission Qualification Test Procedure

Yarmouth Research and Technology

DATA SUMMARY

Customer: Teadit N.A.		**Start Date:** 6-Feb-08
Contact: Calvin Gillis		
Packing Description: 5 rings of Style 2235		
1/4" cross section, cut and installed by Yarmouth		
Test Valve: 4 inch Class 300 Velan Gate Valve		**Project #:** 207111

Manufacturer's Recommended Packing Torque:	33	ft-lb
Stem Diameter:	0.999	inches
Bore Diameter:	1.507	inches
Number of Handwheel Turns During Cycling:	10.3	(each direction)
Stem Travel During Cycling:	3.4	inches
Cycling Speed:	43	RPM
Cycling Rate:	75	seconds per cycle
Maximum Allowable Leakage:	500	PPMv (stem static)
Maximum Allowable Handwheel Torque:	83	ft-lb (based on 200lb pull force)
Test Pressure:	600	psig
Test Media:	99% Methane	

Does the packing meet the requirement of no more than 3 gland adjustments to maintain leakage less than 500 PPMv over 5000 mechanical cycles and 10 thermal cycles?	YES

STATE OF MAINE
MATTHEW J WASIELEWSKI
No. 7437
LICENSED
PROFESSIONAL ENGINEER

Witness [signature]

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No. 908 Li An Road
Minhang District
Shanghai 2001
China

2235 Valve Stem Packing

The latest TEADIT packing, style 2235, is composed of layers of flexible graphite tape plie
strands; each filament is reinforced with an Inconel* wire jacket. The strands are then sq
dense yet malleable packing. Outwardly it is then impregnated with lubricating agents wh
friction.

PROPERTIES
Teadit **style 2235** is self-lubricating, non-hardening, dimensionally stable and resistant t
well as heat, pressure and chemicals. The Inconel* filament jacket affords mechanical sta
advanced construction provides leakage control and high integrity in steam service.

APPLICATION AREAS
Due to it's physical properties and ability to minimize friction, 2235 is ideal for valves anc
broad range of applications. It is well suited for power plants, refineries, petrochemical in
processing as well as sealing applications in steam at high pressure and temperature.

APPLICATION MEDIA

Designed for steam applications, Teadit style 2235 can also be used with most chemicals.

Temperature	Min / Max
(°C)	-240 450
(°F)	-400 842

Static Pressure: 6500 psi

pH: 0-14

BENEFITS

Mechanical and thermal stability. Thermally conductive vs. heat, pressure and chemicals. minimal weight loss, easy to handle and install.

The packing is supplied with a corrosion inhibitor.

Not suitable for:
Highly oxidizing agents.

Approximate FT/Lb Yields (plus/minus 10%) :

1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4
93	40.2	22.6	14.9	10.3	7.6	5.8	4.6	3.7	3	2.6

* Inconel is a registered trademark of Intemational Co.

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PVP2009
July 26-30, 2009, Prague, Czech Republic

PVP2009-77467

THE INFLUENCE OF DIFFERENT BRAIDED PACKING MATERIALS AND NUMBER OF RINGS ON STEM TORQUE AND SEALABILITY

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Carlos D. Girão
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21530-012 Brazil

ABSTRACT

This paper introduces a test device and a protocol that simulates packing performance in different size valve stuffing boxes and stems. This test device enables measurement of braided packing compression, relaxation, axial force at the bottom of the stuffing box, the torque generated upon stem turning and the influence of the number of packing rings on stem torque. It also enables comparisons between different braiding yarns materials, impregnations and correlations with seating stress, stem torque and sealability. Test results showing these comparisons and correlations are reported.

INTRODUCTION

The number and size of braided packing rings used in valves varies widely from one valve manufacturer to another. Standards are not very clear regarding this subject. For instance API 600 / ISO 10434 [1] states that that the nominal depth of the packing box shall accommodate a minimum of five uncompressed packing rings with the packing width dependent on the sizes of the stem diameter. API 602 / ISO 15761[2] specifies the minimum uncompressed total height of the installed packing regardless of the packing width. And MSS SP 120 [3] shows a packing depth of 4W or 5W, which is the equivalent of 4 or 5 square packing rings, with cross-sections varying according to the stem diameter.

Laboratory and subsequent field tests performed with different packing styles, valves and media showed that, as for gaskets, it is possible to have an installation seating stress procedures for packing valves [10]. However, these studies did not investigate the effect of the installation stress on the stem torque.

Some test standards, such as Chevron Texaco's [4], establish a maximum turning torque on the valve hand wheel. Ideally, testing should predict the stem torque, while avoiding the common situation where the valve hand wheel is not able to turn, thereby allowing the sizing of actuators. It was decided to investigate the possibility of correlating the installation stress with the friction force holding the stem, the influence of the number of packing rings installed and the consequence on sealability.

TEST RIG

A test rig that simulates a stuffing box and a stem was developed to perform the studies as shown in Figures 1 and 2. This rig has a load cell at the bottom of the stuffing box that measures the residual force at the bottom of the last packing ring. It is equipped with two gauge bolts that indicate the force being applied on the packing by the gland follower. A torque meter fastened to the stem measures the force necessary to turn it.

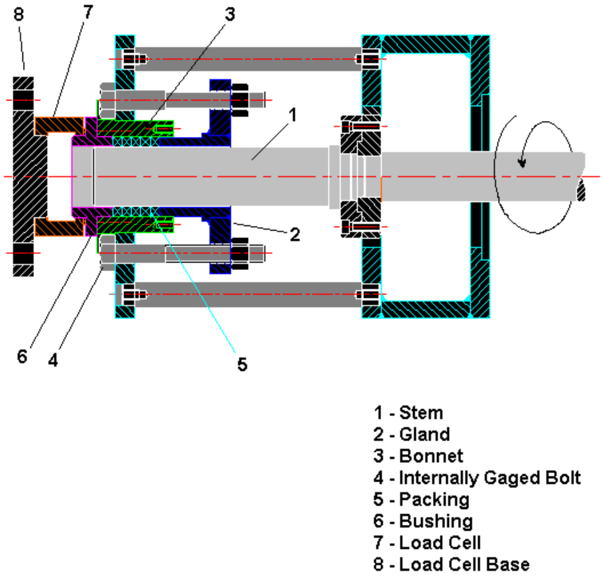

FIGURE 1 – TEST RIG SCHEME

The gauged bolts and the load cell are connected to a graphic register that records the packing axial relaxation over the time.

FIGURE 2 – TEST RIG

The stem has a surface finish (R_a) of 0,8µm (32µin) and the stuffing box a surface finish (R_a) of 3,2µm (125µin). These values meet the requirements of surface finish for valves under API 600 [1], API 602 [2] and MSS SP 120 [3].

TEST PROCEDURE

A test procedure was developed to analyze the different packing behavior when subjected to several loads. This procedure enables an evaluation of the torque needed to turn a stem as a function of the axial stress and a quick observation of packing relaxation. An approximation of the axial stress distribution can also be determined following this protocol. Packings were tested as described below:

- The Rig is cleaned to assure that the stem and the stuffing box are free from any unwanted material/dust.
- Random loads are applied on a metal bushing to assure the load cell and the gauged bolts are correctly calibrated.
- The packing rings are installed and an initial load of 1MPa (145psi) is applied to seat the packing rings.
- The height of the packing set is recorded.
- The desired load is applied to the packing and the load on the last ring registered. The packing is allowed to relax for ten minutes and the loads on the gauged bolts and on the load cell are recorded. The desired load is re-applied and both readings are once again registered.
- The height of the packing set is recorded.
- The stem torque is then measured using a torque meter. Four readings are made with a half-turn of the stem each. The first reading records the static torque while the three subsequent readings record the dynamic torque.
- After the two complete stem turns, the readings on the gauged bolts and on the load cell are registered.
- This procedure was repeated with two, four, five and seven packing rings.

PACKINGS TESTED

The tests were performed for each of the packing styles described below, and their dynamic properties registered.

Style A - Flexible Graphite Yarn reinforced with an Inconel® wire mesh.
Style B - Flexible Graphite Yarn reinforced with an Inconel® wire.
Style C - Carbon and Flexible Graphite Yarn with Graphite impregnation
Style D – Expanded PTFE filled with Barium Sulphate.

TEST RESULTS
Torque x Axial Stress

In order to analyze the packing materials effect on the force to turn a valve hand wheel, eight graphs were plotted. The friction force necessary to turn the stem as a function of the gland stress and the number of packing rings, is shown on Figures 3 through 10. The torque value used to calculate the friction force was either static or dynamic, whichever had the higher value. The stem for the 6.4mm (1/4in) cross-section packings had a diameter of 25.4mm (1in) and for the 7.9mm (5/16in), 50.8mm (2in).

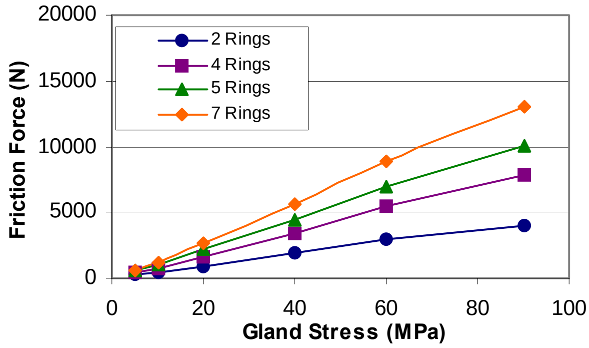

FIGURE 3 – FRICTION FORCE X AXIAL STRESS: STYLE A – 6.4mm

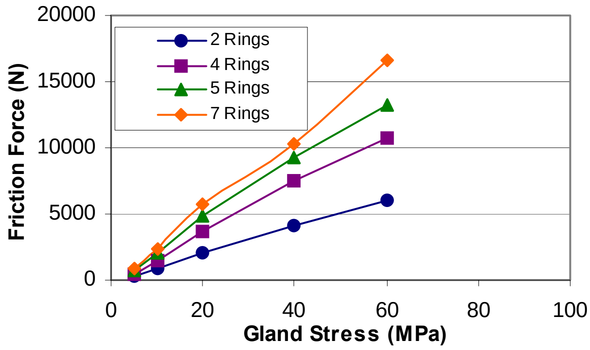

FIGURE 4 – FRICTION FORCE X AXIAL STRESS: STYLE A – 7.9mm

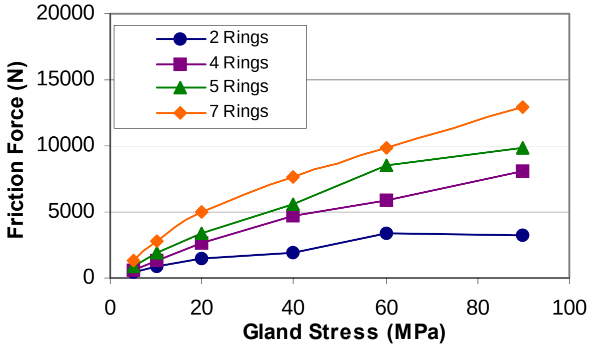

FIGURE 5 – FRICTION FORCE X AXIAL STRESS: STYLE B – 6.4mm

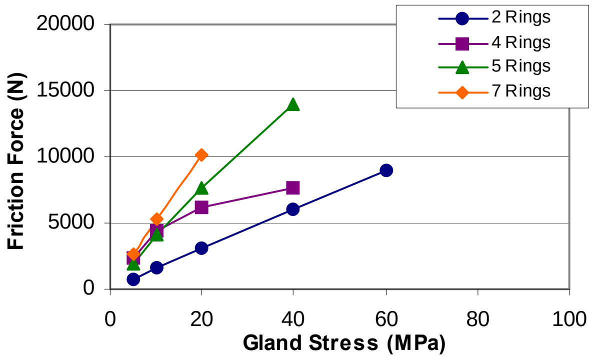

FIGURE 6 – FRICTION FORCE X AXIAL STRESS: STYLE B – 7.9mm

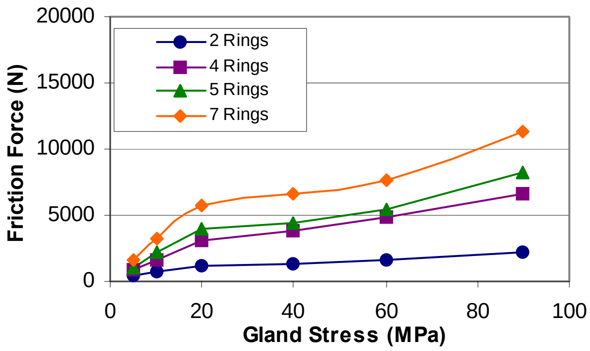

FIGURE 7 – FRICTION FORCE X AXIAL STRESS: STYLE C – 6.4mm

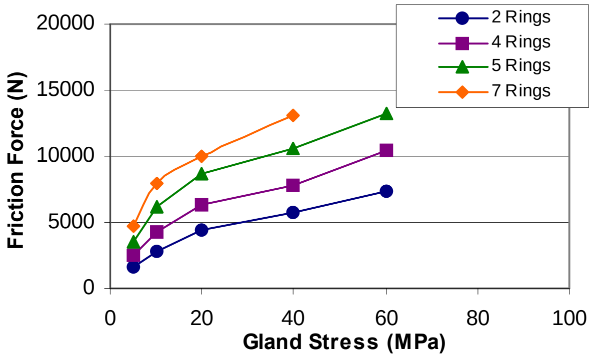

FIGURE 8 – FRICTION FORCE X AXIAL STRESS: STYLE C – 7.9mm

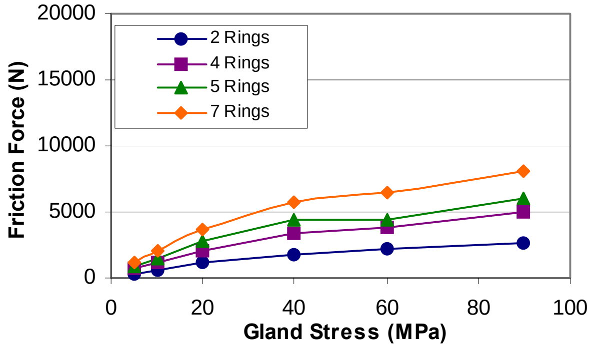

FIGURE 9 – FRICTION FORCE X AXIAL STRESS: STYLE D – 6.4mm

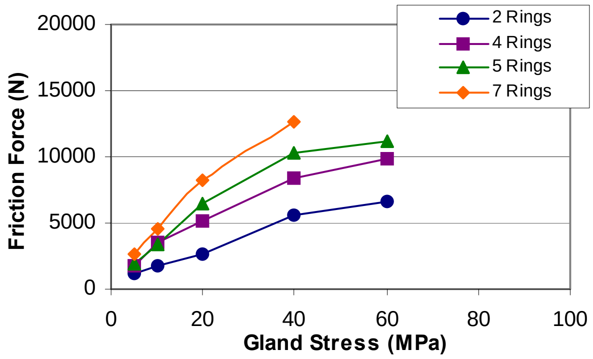

FIGURE 10 – FRICTION FORCE X AXIAL STRESS: STYLE D – 7.9mm

The graphs show that there is an increase in the friction force (force that opposes movement) as more packing rings are added. The higher the friction force, the harder it will be to operate the valve.

The effect of composition on packing behavior can also be analyzed from these graphs. Both packings constructed from Flexible Graphite Yarn reinforced with Inconel® had similar results. These packings generated a much higher friction force than the packing made with Expanded PTFE Yarn filled with Barium Sulphate.

It is also possible to observe, that the packings behave differently under low and high gland stresses. On Style C, for instance, where this difference can be seen more clearly, the packing behavior to 20MPa (2900psi) is completely different from its behavior under higher stresses. This difference in tendencies is illustrated in Figure 11 by the blue and red lines.

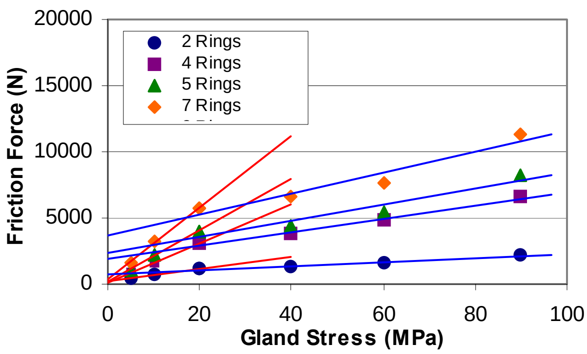

FIGURE 11 – TENDENCIES: STYLE C – 6.4mm

After analyzing these results it is important to reintroduce the concept of minimum seating stress, $S_{min(0,01)}$. Minimum seating stress is the pressure applied by the valve gland, σ_0, to seat the packing so it fills all the voids between the stem and the stuffing box. These values were determined [10] experimentally using five rings with 6.4mm (1/4in) cross-section and the results are shown in Table 1.

TABLE 1 – $S_{min(0,01)}$ VALUES

	$S_{min(0,01)}$	
Packing Style	**MPa**	**psi**
A	55	7975
B	35	5075
C	20	2900
D	25	3625

The minimum seating stress of each packing style is indicated on the following charts by a red vertical line.

Notice that the minimum seating stress for Style C is 20MPa. There is a direct correlation between the minimum seating stress and the changes in the packing behavior. Once the minimum seating stress is reached, the packing stress starts to show a linear tendency that can be described by the equation of a straight line

For $\sigma_0 > S_{min(0,01)}$

$$F_{ri} = m\sigma_0 + b \qquad (1)$$

where σ_0 is the installation stress, F_{ri} is the friction force, m is the slope of the line and b, the y-intercept.

Even though this equation closely models the packing behavior it is not conveniently predict the friction force as a function of the gland stress. To use this equation it would be necessary to experimentally determine m and b for all packings cross-section as well as for the different number of packing rings used. Throughout this paper, a more efficient mathematical model will be proposed.

Residual Axial Stress at the Bottom of the Stuffing Box

The test rig enables the measurement of the residual axial stress at the bottom of the stuffing box. This information is critical since it indicates how much of the axial stress applied on the top of the first packing ring is actually reaching the bottom of the last ring. “To ensure effective sealing at the bottom of the stuffing box, the radial stress exerted by the bottom ring must be greater than the media pressure” [13].

The percentages of the applied gland stress that reaches the bottom of the stuffing box, ξ, for the different packings and for different number of packing rings are shown in figures 12 through 19:

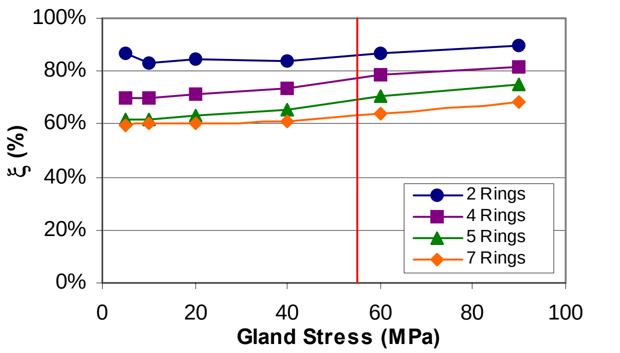

FIGURE 12 – RESIDUAL AXIAL STRESS ON THE BOTTOM RING: STYLE A – 6.4mm

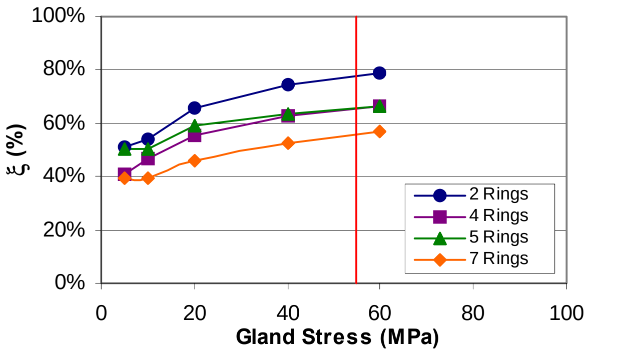

FIGURE 13 – RESIDUAL AXIAL STRESS ON THE BOTTOM RING: STYLE A – 7.9mm

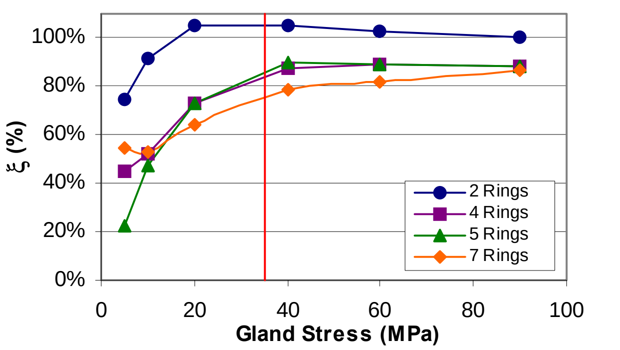

FIGURE 14 – RESIDUAL AXIAL STRESS ON THE BOTTOM RING: STYLE B – 6.4mm

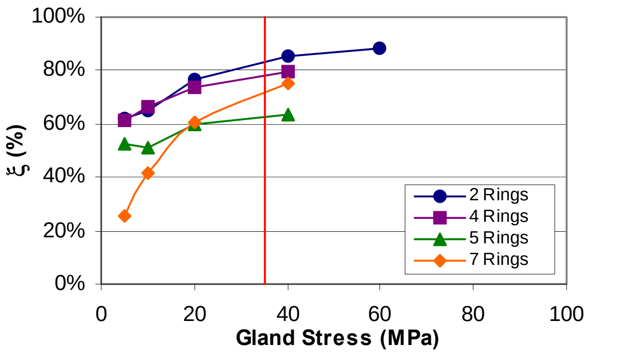

FIGURE 15 – RESIDUAL AXIAL STRESS ON THE BOTTOM RING: STYLE B – 7.9mm

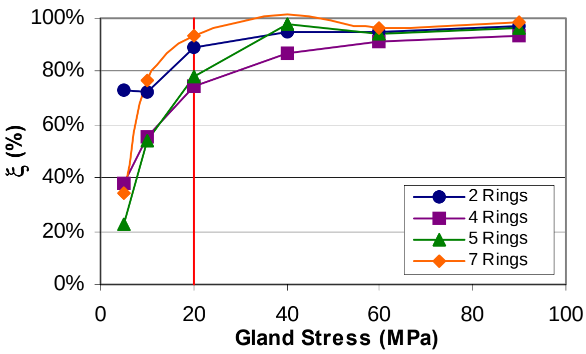

FIGURE 16 – RESIDUAL AXIAL STRESS ON THE BOTTOM RING: STYLE C – 6.4mm

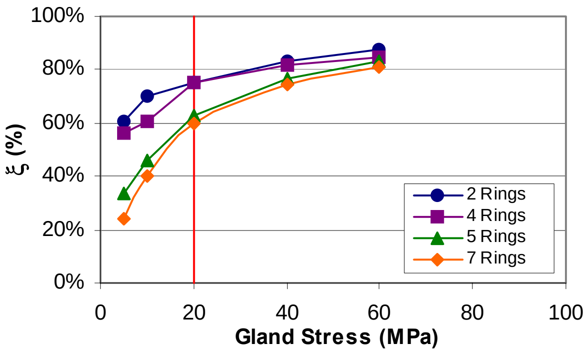

FIGURE 17 – RESIDUAL AXIAL STRESS ON THE BOTTOM RING: STYLE C – 7.9mm

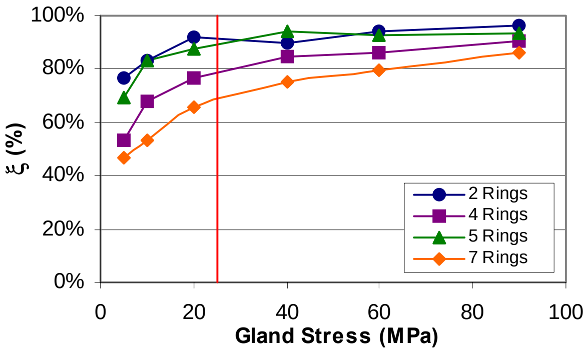

FIGURE 18 – RESIDUAL AXIAL STRESS ON THE BOTTOM RING: STYLE D – 6.4mm

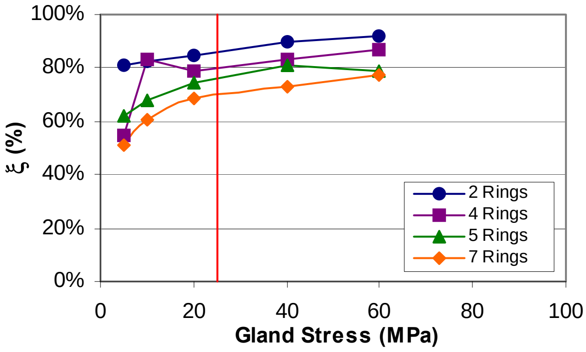

FIGURE 19 – RESIDUAL AXIAL STRESS ON THE BOTTOM RING: STYLE D – 7.9mm

The relationship between the number of packing rings and the amount of the applied gland stress transferred to the bottom of the stuffing box decreases as the gland stress increases. Under high stresses (above the minimum seating stress) all four packings studied showed very little difference on the amount of the gland stress that reached the bottom of the stuffing box for two and seven rings.

It is usual to find in traditional literature [13, 14] the picture on Figure 20, where the first few packing rings apply most of the radial force.

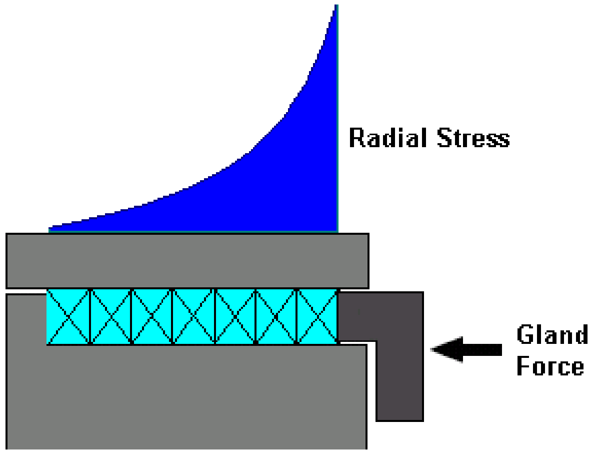

FIGURE 20 – RADIAL STRESS DISTRIBUTION

The radial stress distribution is directly proportional to the axial stress distribution [11]. The tests performed show that the amount of axial stress reaching the bottom of the stuffing box is only slightly less than that at the gland. Therefore, the radial distribution on the picture above is not true for valve applications, where for stresses above the minimum seating stress, more than 50% of the applied gland stress reached the bottom of the stuffing box. In some cases, more than 90% of the gland stress reached the bottom.

The behavior shown on figure 20 might be true under low stresses, however the study of packings under gland pressures below the minimum seating stress is not within the scope of this project.

Packing Relaxation

The packing relaxation as a percentage of the initial stress, ε, was also measured over a period of ten minutes. The rig enables a continuous measurement of the gland stress and the stress on the bottom of the stuffing box. The results for the four packings studied, using five rings with a cross-section of 6.4mm (1/4in) are shown below (Figures 21 and 22).

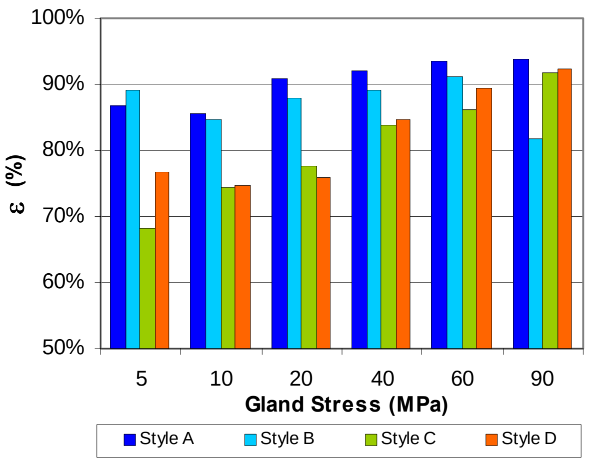

FIGURE 21 –RELAXATION AT GLAND

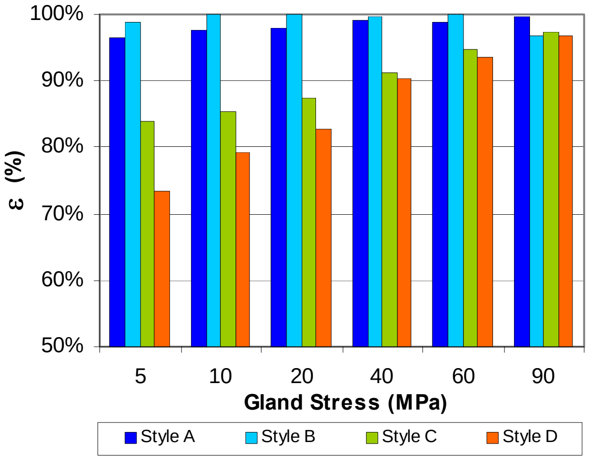

FIGURE 22 RELAXATION AT THE BOTTOM OF THE STUFFING BOX

Over the ten minutes period that the packings were allowed to relax, the decrease on the stress was higher close to the gland follower than at bottom of the stuffing box.

It was also observed that, over the relaxation period, packings under higher installation stresses relaxed less than packings with lower installation stresses.

In order to verify if the ten minutes period was a reasonable relaxation time, a four-day relaxation test was performed with five ring of Style D under an initial gland stress of 60MPa (8700psi) as shown in Figure 23.

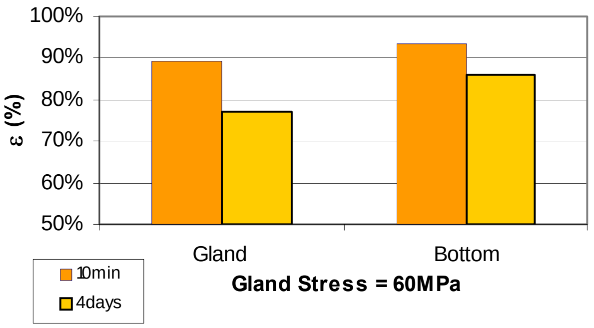

FIGURE 23 – COMPARISON BETWEEN 10 MIN AND 4 DAYS RELAXATION PERIODS

The results showed that the relaxation for the packing tested in four days was not much higher than the initial relaxation over the ten minutes period.

Prediction of Friction Force on the Stem

The torque, τ, measured at the stem on the rig can be described as the friction force, F_{ri}, generated by contact between the packing and the stem, times the stem radius, r.

$$\tau = F_{ri} \cdot r \quad (2)$$

The friction force, by definition, is the force that opposes motion when the surface of one object comes into contact with the surface of another. This force is given as the product between the resultant normal force, F_N, and the mean coefficient of friction, μ.

$$F_{ri} = \mu \cdot F_N \quad (3)$$

The normal force is the resultant of the radial forces. A reasonable approximation is to treat this resultant as the sum of the radial forces applied by each packing ring

$$F_N = \sum_{i=1}^{N} q_i \cdot A_i \quad (4)$$

where N is the total number of rings, q is the radial stress and A is the contact area between the packing and the stem. This area is given by the circumference of the stem, times the height of the packing set after it has been compressed. With an increase in the number of the packing rings, the area will increase and, as a consequence, the friction force will also increase as shown on Figures 3 thorough 10.

Knowing that the lateral deformation factor, K, which is ratio of the radial stress over the axial stress, σ, is constant [11]

$$\mathrm{K} = \frac{q_i}{\sigma_i} \quad (5)$$

the normal force can then be expressed as:

$$F_N = \sum_{i=1}^{N} \mathrm{K} \cdot \sigma_i \cdot A_i \quad (6)$$

and the formula for the torque on a stem with radius equals r can be re-written as

$$\tau = r \cdot \mathrm{K} \cdot \mu \cdot \sum_{i=1}^{N} \sigma_i \cdot A_i \quad (7)$$

The test results show a considerable variation in the coefficient of friction with the applied stress for different packing materials. A more accurate mathematical description would include μ inside the sum sign, however, one of the main objectives of this work is to experimentally determine this coefficient as well as the lateral deformation factor, K, allowing a prediction of the stem torque as a function of the applied gland stress.

For practical purposes equation (7) can be written as

$$\lambda = \mu \cdot \mathrm{K} = \frac{\tau}{r \cdot \sum_{i=1}^{N} \sigma_i \cdot A_i} \tag{8}$$

where λ is the friction-deformation factor, which is the combination of the coefficient of friction and the lateral deformation factor.

The above equation gives a friction-deformation factor that is close to the real value. This real value is difficult to be used in service since it is necessary to know the axial stress distribution along the packing rings, σ_i. A good approximation to equation (8) was determined experimentally (9) with the test rig using the value of the stress on the bottom of the stuffing box, σ_N.

$$\lambda = \frac{2\tau}{r \cdot A \cdot (\sigma_0 + \sigma_N)} \tag{9}$$

An actual friction-deformation factor, λ_A, that could be used to predict the friction force on the stem as a function of the applied gland stress, σ_0, can also be determined experimentally.

$$\lambda_A = \frac{\lambda}{2} \cdot (1 + \xi) \tag{10}$$

Notice that on the limit where 100% of the stress applied reaches the bottom of the stuffing box $\xi = 1$, $\lambda_A = \lambda$.

The friction-deformation factors for the packings in study are expressed in the figures below:

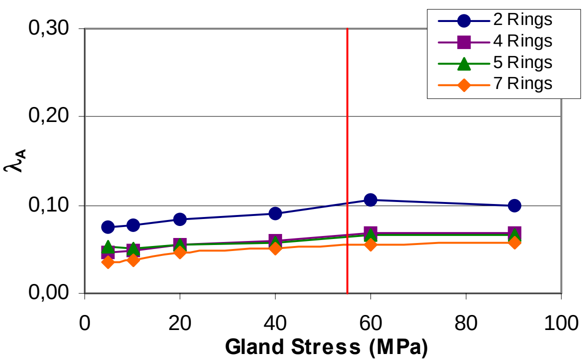

FIGURE 24 – FRICTION-DEFORMATION FACTOR: STYLE A – 6.4mm

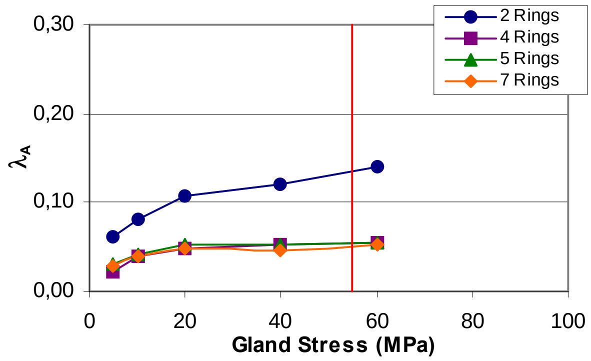

FIGURE 25 – FRICTION-DEFORMATION FACTOR: STYLE A – 7.9mm

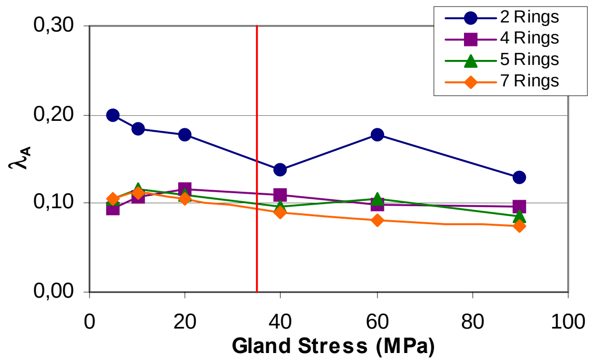

FIGURE 26 – FRICTION-DEFORMATION FACTOR: STYLE B – 6.4mm

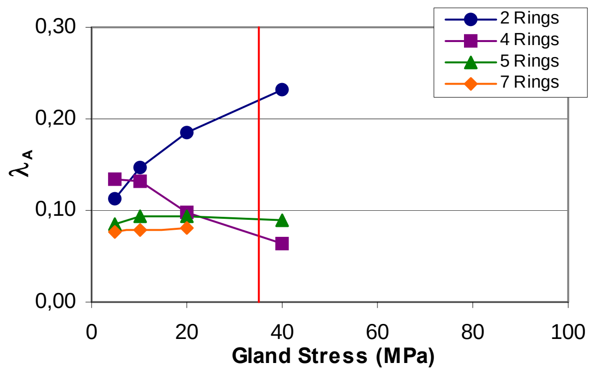

FIGURE 27 – FRICTION-DEFORMATION FACTOR: STYLE B – 7.9mm

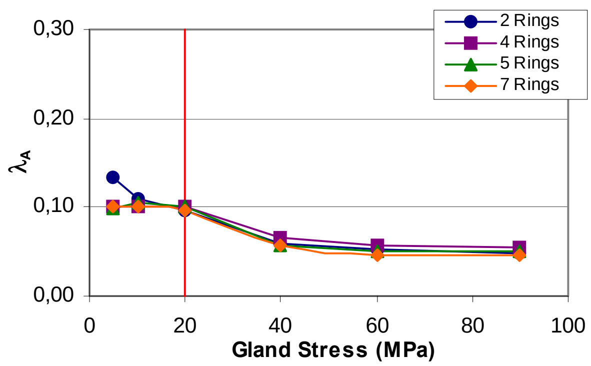

FIGURE 28 – FRICTION-DEFORMATION FACTOR: STYLE C – 6.4mm

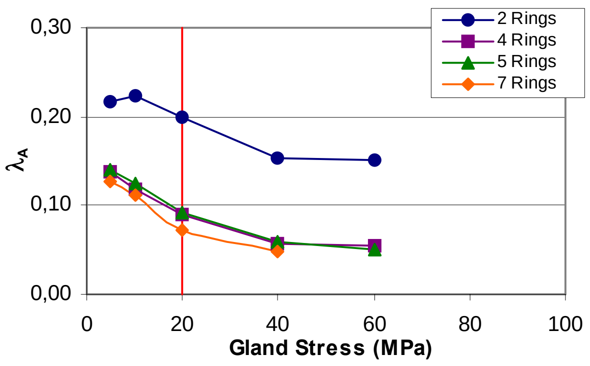

FIGURE 29 – FRICTION-DEFORMATION FACTOR: STYLE C – 7.9mm

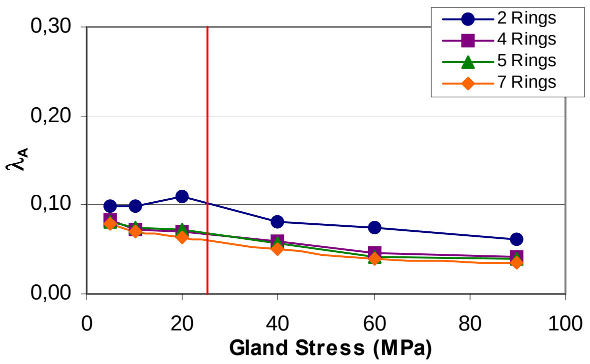

FIGURE 30 – FRICTION-DEFORMATION FACTOR: STYLE D – 6.4mm

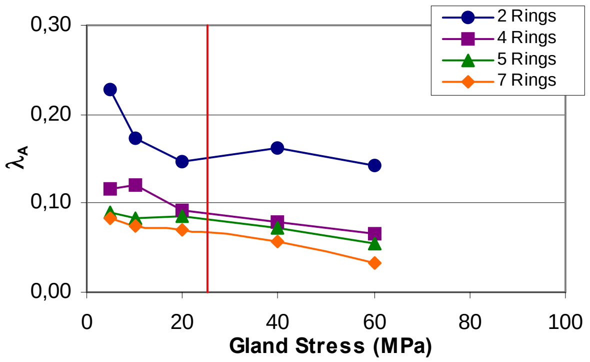

FIGURE 31 – FRICTION-DEFORMATION FACTOR: STYLE D – 7.9mm

The figures above show that after a certain applied stress, the value of the friction-deformation factor stabilizes, becoming a constant.

The torque for the 7.9mm (5/16in) cross-section packings under a gland stress above 60MPa (8700psi) and, on certain cases, 40MPa (5800psi) could not be measured due to equipment limitations.

The packings studied here had their minimum seating stress values used as a start up point on the choice of the friction-deformation factor shown on Table 2.

TABLE 2 – AVERAGE FRICTION-DEFORMATION FACTORS

	λ_A		
Packing Style	**4 Rings**	**5 Rings**	**7 Rings**
A	0.06	0.06	0.05
B	0.10	0.09	0.08
C	0.06	0.05	0.05
D	0.05	0.05	0.04

The values found for two rings were not used for the determination of λ_A, since all standards studied [1,2,3] do not considerer this option. Packing Style C showed two ranges for the friction-deformation factor which are: 0.06 to 0.10 from its minimum seating stress to 40MPa (5800psi) and 0.05 to 0.06 from 40MPa (5800psi) to 90MPa (13050psi) when it stabilizes.

To validate the λ_A, the maximum and minimum values found experimentally were applied to the formula below and the results compared with the actual values.

$$\tau_A = r \cdot \lambda_A \cdot \sigma_0 \cdot A \qquad (11)$$

Figure 32 shows the relationship between the predicted torque and the torque measured experimentally for Style A packing, with cross-section of 6.4mm. A λ_A of 0.06 was used for four and five rings and 0,05 for seven rings.

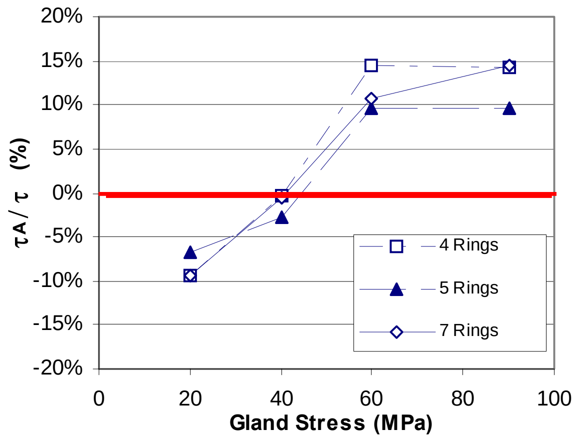

FIGURE 32 – λ_A VALIDATION: STYLE A – 6.4mm

Based on the results obtained, the experimentally found friction-deformation factor proved to be a good tool to predict the friction force on the stem as a function of the gland stress.

SEALABILITY

The influence of the number of packing rings on sealability was also investigated. The minimum seating stress calculated on the previous paper [10] for five packing rings was now applied for two and seven rings. It was found that for the four packings studied, the leak rate was equal or less than 0.001mbar-l/sec of He under a pressure of 7bar (102psi).

CONLUSIONS

The sealability tests shows that once the minimum seating stress is applied no matter how many rings are used, two, four, five or seven, the established leakage criterion is met. The tests conducted with the developed rig shows that there is a reasonable increase in the friction force with the increase on the number of packing rings. This leads to the conclusion that the best relationship between the number of rings in a valve and sealability is the use of the lowest number of rings that meets the valve manufacturer's standard requirements. API 600 [1], for instance, states that the stuffing box height should fit at least five uncompressed rings.

The test rig enabled the measurement of the stress that reaches the bottom of the stuffing box. Results showed that there are reasonable differences on the ability to transfer forces from one material to another. However, above the minimum seating stress most of the applied stress reaches the bottom of the stuffing box.

Laboratory tests performed with different packing styles showed that it is possible to determine a factor that allows the prediction of the friction force on a stem as a function of the applied gland stress and the packing contact area. They presented, as well, the friction force profile on stems as a function of the gland stress.

The test rig also showed that in a ten-minute relaxation process, the decrease in the packing stress is higher close to the gland follower than at bottom of the stuffing box. This relaxation decreases as the applied gland stress increases. These results show that there is a need to re-tighten the gland bolts after the installation stress is applied and before process start-up.

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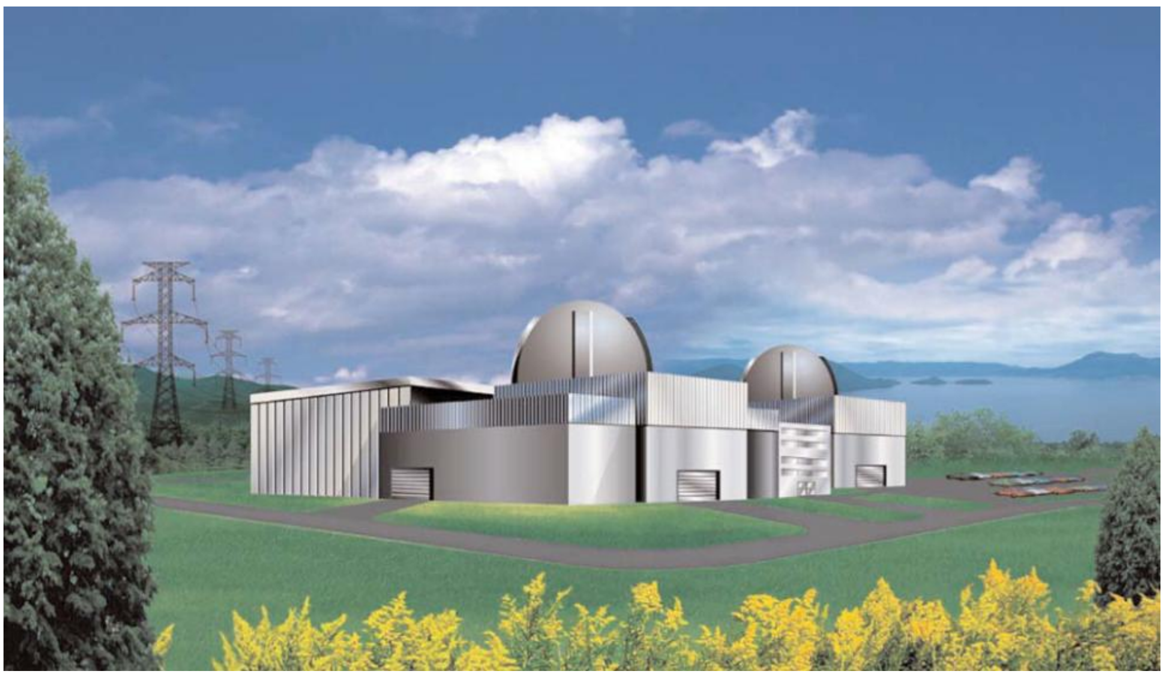

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VALVE PACKINGS SEATING STRESS

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ABSTRACT

This paper studies the seating stress required to assure the sealability in valve stems used in high pressure steam service. A test device that simulates the valve stuffing box and a test protocol are proposed. Actual field tests conducted according to a procedure developed from the laboratory tests are also reported.

INTRODUCTION

Traditionally braided packings used in valves are installed without controlling the seating stress. Standard organizations like the American Petroleum Institute (API) do not have packing installation procedures [1, 2] as part of their valve standards or as a separate document. Packings are usually installed by tightening the gland bolts to the point where heavy resistance to wrenching is felt. Then, the valve stem is turned back and forth to determine ease of turning. The main concern is to avoid torque down to the point where the stem will not turn. This procedure is highly dependent on the skill of the installation personnel. It does not assure a uniform seating stress from one operator to the other; a very common situation in plant shut-downs when hundreds or thousands of valves must be repacked in a very short period of time. It can easily be observed in the field that for the same valve and packing size and style the torque to open or close the valve varies significantly indicating that the packing stress is not the same.

As a consequence the sealability is not assured. Especially in high pressure steam service that once a leak is initiated it is very difficult to stop. The high pressure steam flow creates leak paths which are difficult or almost impossible to seal by just re-tightening the gland. In most cases when shut-down is not allowed to repack the valve, sealant has to be injected to stop the steam leak making the valve inoperable until the next plant shut-down.

Manufacturers and trade organizations like the Fluid Sealing Association (FSA) and The European Sealing Association (ESA) have published the Pump & Valve Installation Procedures [3] where there is a recommendation to "consult packing manufacturer and/or plant engineering department for guidance on torque specifications or percent of compression". However, there is no published procedure to determine the required installation torque.

In order to assure sealability and avoid the high costs of injecting sealant or having to turn-off the line and repack the valve, it was decided to investigate the possibility to develop a procedure similar to that of flange gaskets where the initial tightening is calculated to insure a minimum leak operation.

MINIMUM SEATING STRESS TEST RIG

A test rig was developed to determine the minimum seating stress to insure the packing sealability. This stress is the pressure, applied by the valve gland, required to seat the packing so it fills all the voids between the stem and the stuffing box. The test rig simulates a valve stuffing box, with a stem and a gland follower. Five rings are used in each test. Figure 1 shows a schematic diagram of the test rig.

The test gas is introduced at the bottom of the rig and leak rate is monitored at the gland with a Mass Spectrometer. For this study Helium was used however, another gas or steam can be used to simulate an actual field application.

The load is applied with a hydraulic press and the force monitored with a load cell. Figure 2 shows the rig installed in the hydraulic press and the mass spectrometer used to measure the Helium leak rate.

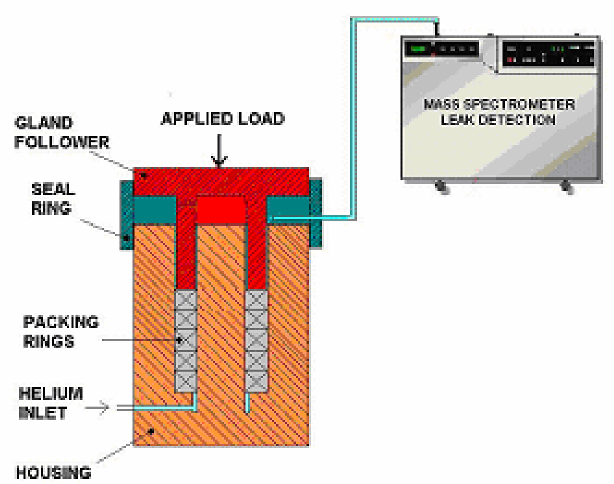


FIGURE 1 – MINUMUM SEATING STRESS TEST RIG

FIGURE 3 – TEST RIG, HYDRAULIC PRESS AND He MASS SPECTOMETER

MINIMUM SEATING STRESS TEST PROCEDURE

EN13555 defines the minimum seating stress for gaskets, $Q_{min(L)}$, as: "minimum gasket surface pressure on assembly required at ambient temperature in order to seat the gasket into the flange facing roughness and close the internal leakage channels so that the tightness class is to the required level L for the internal test procedure". Based on this concept, a similar procedure for packings was developed.

The leak rates for flange gaskets are determined in Standard DIN EN 13555[4] in tightness classes. For this study it was decided to use the $L_{0,01}$ class, which is the lower class specified. The $L_{0,01}$ corresponds to a leak rate of 0,001mg/(s-m) for Nitrogen or 0,001mbar-l/s for Helium adjusted for the packing diameter.

For the determination of the packing minimum seating stress, $S_{min(0,01)}$, the test pressure was established as 7bar (101psi) and Helium as the test media.

The following procedure was developed to determine the mechanical packing minimum seating stress $S_{min(0,01)}$. Packings with cross-section of 6,4mm (1/4") were used.

- Cut the packing rings from a spool with 45º ends
- Install the five rings with the ends 90º apart
- Install the Test Rig in the Hydraulic Press
- Apply an initial seating stress of 5MPa (725psi)
- Pressurize the Test Rig with 7bar (101psi) Helium pressure and start to monitor the leak rate.
- The seating stress is raised in 5MPa (725psi) increments and leak rates recorded.
- If the leak rate is equal or less than 0.001mbar-l/sec record the seating stress and finish the test.

PACKINGS TESTED

Two tests were performed for each of the packing styles described below, and their minimum seating stresses, $S_{min(0,01)}$ was established. Packings with cross-section of 6,4mm (1/4") were used.

Style A - Flexible Graphite Yarn reinforced with an Inconel wire mesh.

Style B - Flexible Graphite Yarn reinforced with an Inconel wire.

Style C - Carbon and Flexible Graphite Yarn with Graphite impregnation

Style D – Expanded PTFE filled with Barium Sulphate.

Figures 3, 4, 5 and 6 show the test results.

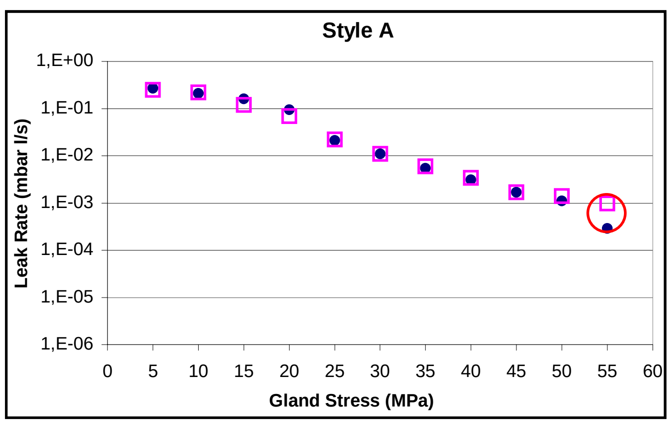


FIGURE 3 – STYLE A: LEAK RATE X PACKING STRESS

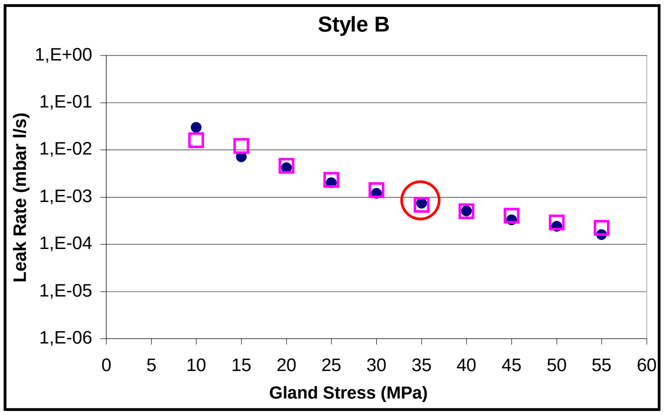


FIGURE 4 – STYLE B: LEAK RATE X PACKING STRESS

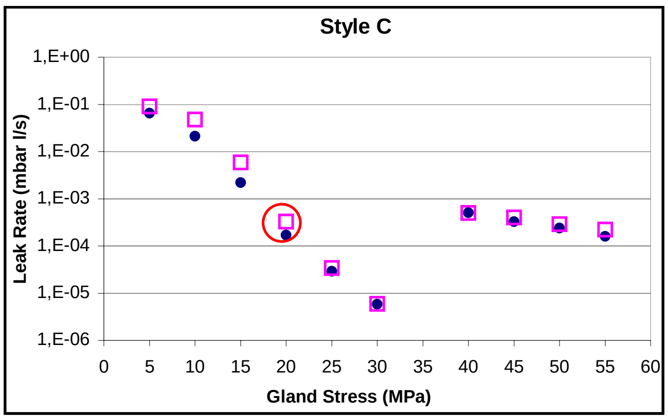


FIGURE 5 – STYLE C: LEAK RATE X PACKING STRESS

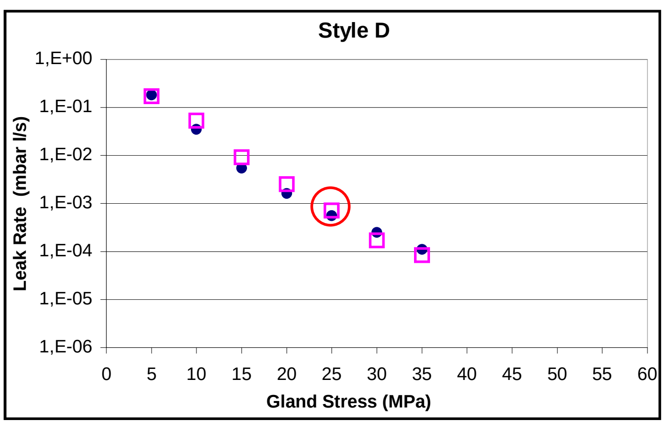


FIGURE 6 – STYLE D: LEAK RATE X PACKING STRESS

From the above graphs, the $S_{min(0,01)}$ values were determined for all four styles and are shown in Table 1.

TABLE 1 - $S_{min(0,01)}$ VALUES

	$S_{min(0,01)}$	
Packing Style	**MPa**	**psi**
A	55	7975
B	35	5075
C	20	2900
D	25	3625

PACKINGS TIGHTENING STRESS

Once the minimum seating stress was established, the next step was the determination of the installation stress.

For this test, valves mostly used in the Brazilian market were used to evaluate the stem torque. The valves were:

- Globe Valve, 3in, Class 150psi;
- Globe Valve, 8in, Class 300psi;
- Gate Valve, 4in, Class 300psi.

FIGURE 7 – TEST VALVES

The minimum seating stress ($S_{min(0,01)}$) was applied and the internal Helium pressure was increased while the packing behavior was monitored. The leak rate increased considerably as the Helium pressure reached high values. The results were not found satisfactory.

Another test consisted in keeping the leak rate constant and increasing the packing stress as the Helium pressure is increasing. This test led to packing stress values that were too high and the stem torque was not applicable under actual conditions.

The results found satisfactory were accomplished when the minimum seating stress ($S_{min(0,01)}$) was applied and raised by the same value of the test media. Figure 8 shows the leak rate when the gland pressure was increased by the same value as the Helium pressure.

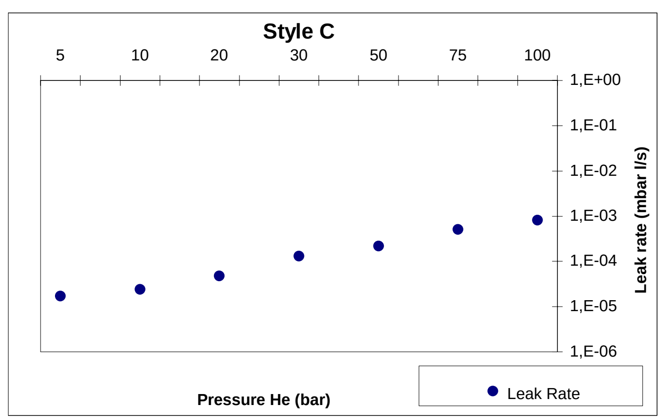


FIGURE 8 – INCREASING GLAND PRESSURE AND HELLIUM PRESSURE

The laboratory results indicated that the gland seating stress is according to the following formula:

$$S_s = S_{min(0,01)} + P$$

Where:
S_s = packing installation seating stress
$S_{min(0,01)}$ = minimum seating stress
P = media pressure

LABORATORY VALVE TESTS

In order to evaluate the effectiveness of the packing installation seating stress (S_s) a series of laboratory tests were performed on gate and control valves simulating actual field conditions. These tests included both thermal and mechanical cycles.

For the valve tests, the leak rate was monitored using a Toxic Vapor Analyzer - TVA1000 with Methane as test gas. This leak measurement method was adopted to minimize the gap between lab testing and field-testing.

GATE VALVE TESTS

The packings were tested under the following parameters:

- Test Valve: Gate Valve, 4 in, Class 300 psi.
- Packing Size: 6.4mm (1/4”)
- Number of Rings: 05
- Packing Installation Seating Stress: $S_{min(0,01)} + P$
- Test Media: Methane gas
- Media Pressure: 4,1MPa (600 psi)
- Test Temperature: 260°C (500ºF)
- Heating Rate: 21°C (70ºF) to 177°C (351ºF), 46ºC (115ºF) per hour, 177°C (351ºF) to 260°C (500ºF), 28°C (82ºF) per hour.
- N°. of Cycles: (open/close): 2000
- Max Leakage: < 500 ppmv
- Maximum Close Torque: < 160 N.m (118 lbf.ft)

FIGURE 9 – GATE VALVE TEST BENCH

The test results for the Style A packing is presented on Figure 10.

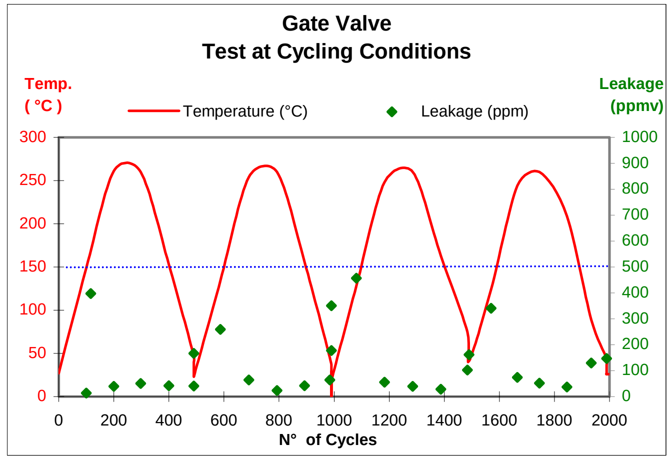


FIGURE 10 – GATE VALVE TEST RESULTS: STYLE A

The packing met the proposed criteria. The leakage did not reach 500ppmv over the 2.000 cycles being kept low during the hot phases. No re-tighten was necessary.

Packings B and C were tested as well, showing similar results.

Subsequently, the Style A packing was tested under the same protocol by an independent laboratory in the US with similar results.

CONTROL VALVE TESTS

The packings were also tested in a 2in, class 300psi control valve under a protocol that represents a demanding field application. The test consists of thermal cycles from 25ºC (77ºF) to 235ºC (455ºF) at a 7bar (102psi) constant Methane pressure, with the valve completing 180 open-close cycles an hour.

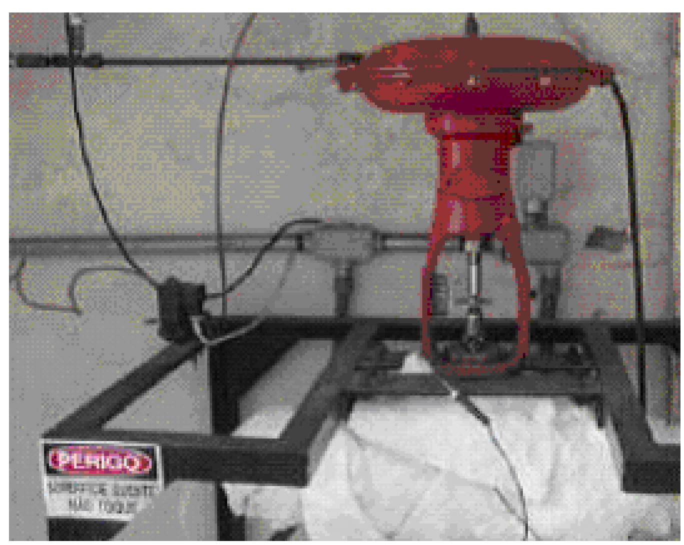


FIGURE 11 – CONTROL VALVE TEST BENCH

The packings were set with the installation seating stress (S_s) and their behavior monitored

The results for Style C with the S_s of 21MPa are shown in Figure 12.

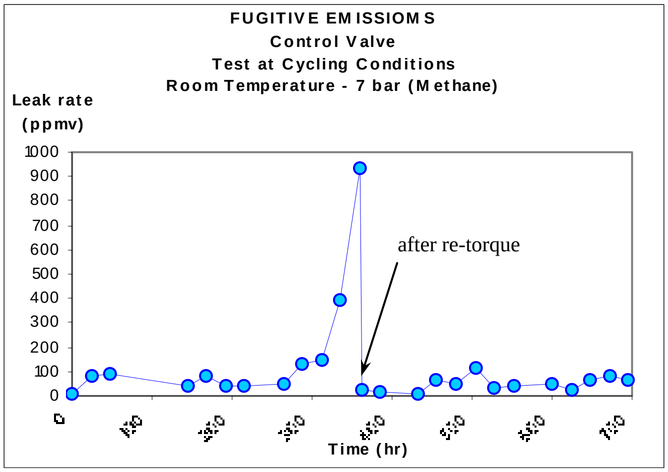


FIGURE 12 – CONTROL VALVE TEST – STYLE C WITHOUT SPRING LOAD

Due to packing wear, the seating stress decreased and after 350 hours (63.000 cycles) high leak rates were measured. The gland bolts were then re-tightened, bringing the stress on the packing to the value of the initial seating stress (S_s). Once again sealability was assured.

To guarantee that the installation seating stress (S_s) was kept constant and if its value was successful in controlling Fugitive Emissions, a new series of tests were performed using spring loads.

The results for Style C with the S_s of 21MPa are shown in Figure 13.

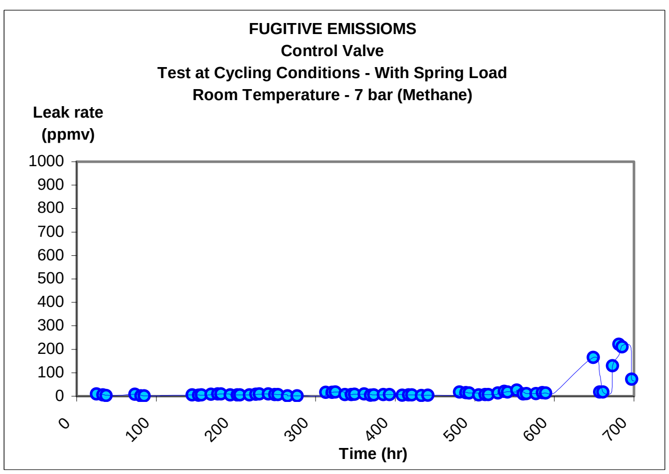


FIGURE 13 – CONTROL VALVE TEST – STYLE C WITH SPRING LOAD

The above results show that after 700 hours (126.000 cycles) the packing Style C with spring loads, maintaining the initial seating stress (S_s), kept the system leakage below 220ppmv. This was not the case when the spring loads were not used. These results were considered satisfactory. They showed that when the determined installation seating stress is maintained, the leak rates are kept at low levels.

Packing Styles A and B were not tested in the control valve since their yarns are reinforced with Inconel, and could damage the stem due to its high hardness. Inconel reinforced yarns are not suitable for applications with high mechanical cycles.

FIELD PILOT TEST

Two field tests were performed to verify if the laboratory results could be replicated in actual plant conditions. High pressure steam and hydrocarbon lines were selected for the field tests.

The steam application for the pilot test was the Copesul Steam Generation plant. This plant was chosen due to its constant history of high leaks.

Once a high steam pressure leak is initiated it is not possible to retighten or repack the valves without shutting-down the whole line. This plant presented high costs due to steam leakage as well as the several interventions to inject sealant. Up to 2.000 tons of steam was wasted every year.

FIGURE 14 – LEAKING VALVE

With the severe working condition of the plant, where valves are submitted to pressures of 140bar (2030psi) under temperatures as high as 550ºC (1022ºF), it became extremely necessary the use of a proper installation procedure of packing.

Before the installation, the old packings and/or injected seals were removed with high pressure water jet. Carbon bushings were installed at the bottom of the stuffing boxes whenever necessary to keep a maximum of six packing rings[1].

A total of 46 steam valves ranging in size from 1/2" to 16" were packed with Style A following the Pump & Valve Installation Procedures[3] with the gland stress calculated according to the formula:

$$S_s = S_{min(0,01)} + P = 69MPa$$

Where

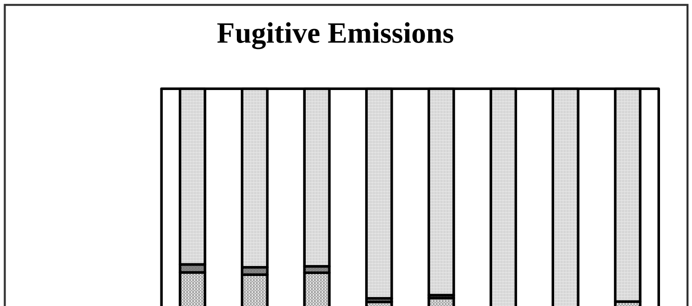
$S_{min(0,01)}$ = 55Mpa (7975psi)
P = 140bar = 14MPa (2030psi)

The packing behavior has been monitored for over 36 months until the time this paper was being edited, however the number of mechanical cycles executed by each valve was not registered due to operational conditions. In this period, no interventions were necessary, no re-torques were applied, and the old need to inject sealant was completely eliminated.

FIGURE 15 – LEAK-FREE VALVES AFTER S_S WAS APPLIED

The plant was shut down and all valves were inspected. The gland bolts were retightened to assure that all packings had the calculated installation stress (S_s) before the plant start-up. None of the packings were replaced and none of the valves showed any leaks after start-up and operation. The same installation procedure was also applied in hydrocarbon lines, with packing Style C, to control fugitive emissions. Before the application of the controlled torque, 54% of the 17.474 valves presented leakage values higher than 500ppmv. After the application of the calculated installation seating stress (S_s), 92,5% of the valves showed leak rate values under 250ppmv and a total of 94,2% under 500ppmv. The results are in Figure 16. Once re-tightened to the calculated value the fugitive emissions were back to less than 250 ppmv level

Packing Style C was used for this application.



	Angular	Butterf.	Ball	Gate	Globe	Plug	Mach	Others
<250 ppmv	242	24	820	11.176	1.574	155	7	63
>250 / <500 ppmv	11	1	29	195	23	-	-	-
>500 ppmv	54	5	181	527	104	1	-	3

FIGURE 16 – LEAKAGE x PACKED VALVES

Even though The *Minimum Seating Stress Test* was performed with 6,4mm (1/4”) cross-section packings, the concept showed to be valid for other cross sections as verified in the Field Pilot Test.

CONCLUSIONS

Laboratory and subsequent field tests performed with different packing styles, valves and media showed that, like for gaskets, it is possible to have similar installation procedures for packing valves.

The number of strokes executed by the valves on the field tests was not monitored. However, for this study, the plant past condition was taken as the basis. The improvements observed shows that it is possible to determine the minimum seating stress in laboratory tests for each packing style and an installation seating stress calculated according to a formula to assure a leak free start-up and operation.

Leak free start-up and operation generates economy, reducing product waste and eliminating expenses with the injection of sealant, besides increasing the plant personnel safety.

The calculated installation seating stress also proved to be efficient in controlling fugitive emissions, reducing air pollution and costs.

REFERENCES

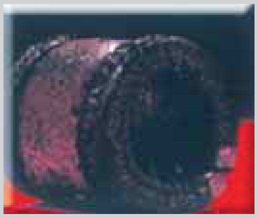
1. American Petroleum Institute – API RP 621 - Reconditioning of Metallic Gate, Globe, and Check Valves
2. American Petroleum Institute - API STD 622 - Testing of Process Valve Packing for Fugitive Emissions
3. Pump & Valve Installation Procedures, The Fluid Sealing Association/European Sealing Association, 2003
4. DIN EN 13555 – Gasket parameters and test procedures relevant to the design rules for gasketed circular flange connections.

TEADIT®

J A M P A K

Teadit's JAMPAK injectable pump and valve sealing system has been and continues to be a leading edge technology for Teadit worldwide. JAMPAK combines the unique ability to repack pumps and valves on-line with conventional packing technology. The attributes expressed give you, our customer, the ability to continue operating as new JAMPAK material is installed through our injection process.

In all, JAMPAK provides reduced operating cost, savings on energy consumption, and reduction of downtime along with a reduced need for equipment repair, rework or overhaul.



JAMPAK 20

JAMPAK 26

JAMPAK 27

JAMPAK 29

JAMPAK 20
A blend of exfoliated graphite particles and high-temperature sacrificial lubricants for extreme service applications.
Available in:
1kg (2.2lb)
5kg (11lb)
10kg (22lb)

JAMPAK 26
A non-staining, non-toxic PTFE fiber blended with FDA-approved lubricant for clean "A" food grade applications.
Available in:
1kg (2.2lb)
5kg (11lb)
10kg (22lb)

JAMPAK 27
A blend of high-performance FTFE fibers and chemically resistant lubricants.
Available in:
1kg (2.2lb)
5kg (11lb)
10kg (22lb)

JAMPAK 29
A blend of synthetic fibers and non-staining lubricants for general services.
Available in:
1kg (2.2lb)
5kg (11lb)
10kg (22lb)

JAMPAK 20 | 26 | 27 | 29

SEALANT SELECTION GUIDE

	20	26	27	29
Applications	Centrifugal pumps Rotating equipment Reciprocating equipment Valves	Centrifugal pumps Rotating equipment Reciprocating equipment Valves	Centrifugal pumps Rotating equipment Reciprocating equipment Valves	Centrifugal pumps Rotating equipment Reciprocating equipment Valves
Product Service	Chemicals Steam Petroleum fuels Hydrocarbons	Foods Potable Water Pharmaceuticals Acids Caustics	Sea water Brine Acids/Caustics Alkalis Certain Solvent	Water Sewage Brine Sea Water Mild Acids Caustics
Color	Black	White	Black	White

SERVICE LIMITS

	20	26	27	29
pH Range	0-14	0-14	0-14	2-12
Shaft Speed fpm	4000	2350	4000	2350
Maximum Temperature	260° C (500° F) 650° C (1200° F) Steam 450° C (850° F) 0^2 atm.	260° C (500° F)	260° C 500° F)	260° C 500° F)
Recommended Anti-extrusion Ring*	2001/2002	2006/2060	2007/2070	2019/2060

*Other styles of packing and other types of end rings such as cut gaskets may be substituted for end rings with varying performance. Consult factory for these recommendations.

COMPRESSION PACKINGS/NATURAL FIBER

2138

MARINE GRADE RAMIE, LUBRICATED

Service: A medium hard packing which is lubricated throughout. Extremely low frictional characteristics where minimal shaft wear is essential. Rot resistant and ideal for marine use, handling cold water, brine and cold oils. Use in stern tube, rudder posts and tail shaft liners and industrial applications where minimal shaft scoring rates are required.
Construction: Square plaited construction, paraffin treated and mineral oil lubricated throughout.

Service Limits:	pH range		6-8
	Temperature: Maximum:	212˚ F	100˚ C
	Pressure: Rotating:	218 PSI	15 BAR
	Reciprocating:	218 PSI	15 BAR
	Static:	290 PSI	20 BAR
	Shaft Speed:	1181 f/m	6 m/s

2177

RAMIE WITH GRAPHITE

Service: A medium hard packing which is lubricated and graphited throughout. Extremely low frictional characteristics where minimum shaft wear is essential. Rot resistant and ideal for marine use, handling cold water, brine and cold oils.
Construction: Square plaited construction, graphite coated and mineral oil lubricated throughout.

Service Limits:	pH range:		6-8
	Temperature: Maximum:	212˚ F	100˚ C
	Pressure: Rotating:	218 PSI	15 BAR
	Reciprocating:	218 PSI	15 BAR
	Static:	290 PSI	20 BAR
	Shaft Speed:	1181 f/m	6 m/s

2421

RAMIE IMPREGNATED WITH PTFE

Service: Stern tube and rudder post stuffing boxes in the marine field. Other applications include certain rotary and reciprocating pumps and valve stems in the paper industry.
Construction: Highest quality ramie yarn with PTFE suspensoid in a square plait construction. Additional break-in lubricant is added to minimize shaft wear and to allow for expansion during the break-in period.

Service Limits:	pH range:		5-11
	Temperature: Maximum:	266˚ F	130˚ C
	Pressure: Rotating:	290 PSI	20 BAR
	Reciprocating:	290 PSI	20 BAR
	Static:	435 PSI	30 BAR
	Shaft Speed:	1968 f/m	10 m/s

TEADIT® COMPRESSION PACKINGS/SYNTHETIC

SYNTHETIC WITH PTFE, DRY

Service: General service packing with no lubricant. Valve service and static gasket applications.
Construction: Interlock braid using carded synthetic yarns and thoroughly impregnated with PTFE suspensoid.

Service Limits:

pH Range:	2-12	
Temperature: Maximum:	446˚ F	230˚ C
Minimum:	-148˚ F	-100˚ C
Pressure: Rotating:	290 PSI	20 BAR
Reciprocating:	1160 PSI	80 BAR
Static:	1450 PSI	100 BAR
Shaft Speed:	590 f/m	3m/s

2018

SYNTHETIC WITH PTFE, LUBRICATED

Service: Excellent multi-service packing for a wide variety of uses throughout a plant. Recommended for use in steam, water, solvents, oils, most chemicals, mild acids and alkalies.
Construction: Interlock braid using carded synthetic yarns thoroughly impregnated with PTFE suspensoid. The finished packing is again coated with PTFE dispersion and a break-in lubricant is added to reduce shaft wear and eliminate glazing at start-up.

Service Limits:

pH Range:	2-12	
Temperature: Maximum:	446˚ F	230˚ C
Minimum:	-148˚ F	-100˚ C
Pressure: Rotating:	290 PSI	20 BAR
Reciprocating:	290 PSI	20 BAR
Static:	725 PSI	50 BAR
Shaft Speed:	2362 f/m	12m/s

2019

SYNTHETIC WITH GRAPHITE

Service: A dense but flexible general service packing. It ensures an excellent seal against steam, brine, oil, mild acids, and alkalies, centrifugal, oscillating and reciprocating shafts and valve plugs.
Construction: Interlock braid using carded synthetic yarns thoroughly impregnated with petroleum based lubricants and graphite finished.

Service Limits:

pH Range:	4-10	
Temperature: Maximum:	338˚ F	170˚ C
Minimum:	-148˚ F	-100˚ C
Pressure: Rotating:	290 PSI	20 BAR
Reciprocating:	290 PSI	20 BAR
Static:	725 PSI	50 BAR
Shaft Speed:	1968 f/m	10m/s

2255

NOVOLOID FIBER, PTFE IMPREGNATED

Service: A high performance packing that is well suited to applications where graphite impregnation may not be acceptable. It can handle steam, water, acids and other chemical and solvent applications. Style 2777 packing has multiple uses in chemical plants and pulp and paper mills, and is regularly used in rotating and reciprocating pumps, washer journals, liquor pumps, refiners and digesters.
Construction: Packing is an interlock braid using Novoloid fibers impregnated with PTFE. In addition, the individual fibers are lubricated using a special process that assures thorough lubrication for a longer packing life.

Service Limits:

pH Range:	1-13	
Temperature: Maximum:	482˚ F	250˚ C
Minimum:	-148˚ F	-100˚ C
Pressure: Rotating:	363 PSI	25 BAR
Reciprocating:	363 PSI	25 BAR
Static:	1160 PSI	80 BAR
Shaft Speed:	1968 f/m	10m/s

2777

COMPRESSION PACKINGS/PTFE

2005

PTFE FILAMENT, DRY

Service: A firm, highly density PTFE filament packing similar to Style 2006S but commonly used in valves or lower shaft speed applications. Recommended environments are all types of chemicals, aggressive fluids, gases and solvents, with the exception of molten alkali metals. It is especially suited for oxygen or other services where no organic materials or lubricants other than PTFE are allowed.
Construction: Interlock braid, using pure PTFE filament pretreated with PTFE dispersion.

Service Limits:	pH Range:	0-14	
	Temperature: Maximum:	536 ˚ F	280 ˚ C
	Minimum:	-328 ˚ F	-200 ˚ C
	Pressure: Rotating:	218 PSI	15 BAR
	Reciprocating:	2175 PSI	150 BAR
	Static:	3625 PSI	250 BAR
	Shaft Speed:	984 f/m	5m/s

2006S

PTFE FILAMENT LUBRICATED

Service: A pliable and soft, yet dimensionally stable packing, which has excellent lubricant and running characteristics. It is suited for high speed rotary shaft service and handles all acids, alkalies and most chemicals with the exception of molten alkali metals.
Construction: Interlock braid, using pure PTFE filament pretreated with PTFE dispersion plus a break-in lubricant to reduce the friction coefficient as well as the frictional heat created under high shaft speeds.

Service Limits:	pH Range:	0-14	
	Temperature: Maximum:	536 ˚ F	280 ˚ C
	Minimum:	-148 ˚ F	-100 ˚ C
	Pressure: Rotating:	435 PSI	30 BAR
	Reciprocating:	435 PSI	30 BAR
	Static:	1450 PSI	100 BAR
	Shaft Speed:	2362 f/m	12m/s

2006FDA

PTFE FILAMENT, FDA APPROVED

Service: For use in food and drinking water processing and handling equipment. All materials of construction are FDA approved.
Construction: Interlock braid of pure PTFE filament pretreated with a FDA approved lubricant.

Service Limits:	pH Range:	0-14	
	Temperature: Maximum:	536 ˚ F	280 ˚ C
	Minimum:	-148 ˚ F	-100 ˚ C
	Pressure: Rotating:	435 PSI	30 BAR
	Reciprocating:	435 PSI	30 BAR
	Static:	1450 PSI	100 BAR
	Shaft Speed:	2362 f/m	12m/s

24A

EXPANDED PTFE VALVE STEM PACKING

Service: Good for aggressive gases, concentrated acids, steam, water, oxygen. Also ideal for food and beverage process and pharmaceutical applications.
Construction: 100% pure PTFE; very comformable yet is a high density packing.

Service Limits:	pH Range:	0-14	
	Temperature: Maximum:	536 ˚ F	280 ˚ C
	Minimum:	-148 ˚ F	-100 ˚ C
	Pressure: Rotating:	1450 PSI	100 BAR

gPTFE FILAMENT (EG2G®)

Service: For use in pumps, valves, reciprocating and rotating shafts, mixers and agitators. Especially designed for services involving surface speeds and temperatures higher than those normally specified for packings manufactured from pure PTFE filaments. Can be used in all chemical pump applications with the exception of molten alkali metals, fluoride, oleum, fuming nitric acid, aqua regia and other strong oxidizing agents. It is also suitable against water, steam, petroleum derivatives, vegetable oils and solvents.
Construction: Interlock braid of expanded PTFE filament in which fine particles of pure graphite have been encapsulated throughout.

Service Limits:			
	pH Range:	0-14	
	Temperature: Maximum:	536 ° F	280 ° C
	Minimum:	-328 ° F	-200 ° C
	Pressure: Rotating:	508 PSI	35 BAR
	Reciprocating:	1450 PSI	100 BAR
	Static:	2900 PSI	200 BAR
	Shaft Speed:	4920 f/m	25 m/s

2007

gPTFE* (EG2G®) with ARAMID CORNERS

Service: Offers the strength of aramid fibers and the heat dissipating, low friction qualities of expanded PTFE/Graphite. Use in paper mill stock pumps, agitators and other areas where strength and good lubrication qualities are required.
Construction: Interlock braid of expanded PTFE/Graphite with aramid yarn on the corners. This prevents extrusion which may occur without the corner reinforcement.

Service Limits:			
	pH Range:	2-12	
	Temperature: Maximum:	538 ° F	280 ° C
	Minimum:	-238 ° F	-150 ° C
	Pressure: Rotating:	435 PSI	30 BAR
	Reciprocating:	725 PSI	50 BAR
	Static:	3625 PSI	250 BAR
	Shaft Speed:	2952 f/m	15 m/s

2017

gPTFE** with ARAMID CORE (EGK®)

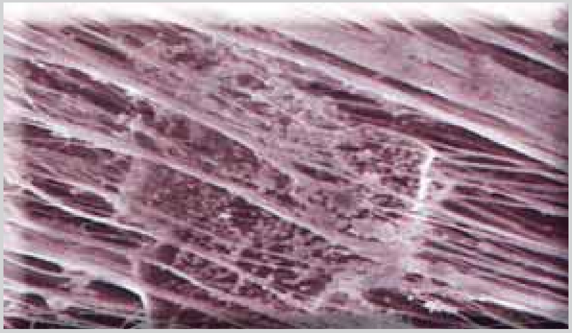
Service: For use in valves, rotary or reciprocating pumps, mixers and agitators. Its high resistance to extrusion (4 times higher than that of packings made from conventional PTFE/Graphite filaments) make Style 2070 ideal for applications against chemically aggressive fluids at high surface speeds and/or higher pressures.
Construction: Style 2070 is a packing manufactured from proprietary EGK® interlock construction. It is a multi-purpose packing formulated for services in which and outstanding chemical resistance, high mechanical strength and excellent heat transfer are required. These properties are obtained through its proprietary EGK® yarn.
(See below)

Service Limits:			
	pH Range:	0-14	
	Temperature: Maximum:	536 ° F	280 ° C
	Minimum:	-328 ° F	-200 ° C
	Pressure: Rotating:	508 PSI	35 BAR
	Reciprocating:	3625 PSI	250 BAR
	Static:	3625 PSI	250 BAR
	Shaft Speed:	4920 f/m	25 m/s

2070

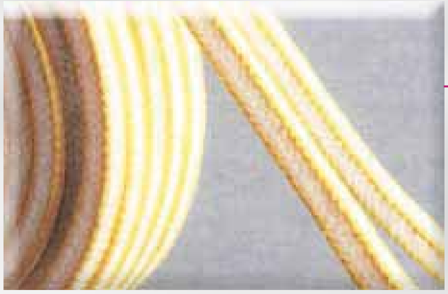
***gPTFE YARN**
A TEADIT proprietary product in which graphite particles are totally encapsulated by expanded PTFE fibers. There are no free particles of graphite on the surface of the filament and therefore no contamination can occur. The uniform distribution of graphite within the PTFE provides optimum properties of low friction and good thermal conductivity.

****gPTFE YARN**
An aramid filament core is encased in a EG2G Jacket. The aramid filament core provides the mechanical conductivity, self-lubrication and low coefficient of friction.



EG2 ELECTRON MICROPHOTOGRAPHY (2000 x). Showing a graphite particle in the PTFE matix.

COMPRESSION PACKINGS/ARAMID



2003

PTFE WITH ARAMID CORNERS

Service: Designed for high pressure reciprocating pumps, medium speed centrifugal shafts and valve stems. Especially formulated for severe service involving high pressure like those commonly found in reciprocating applications. It can be used for general service against water, steam, gases, solvents, mild acids, alkalies, chemical slurries and most abrasive liquids. The packing will not stain in pulp and paper mill applications.

Construction: Interlock braid of construction, interweaving aramid fibers on the corners and pure PTFE filaments in the body, so as to prevent extrusion and to improve resistance in higher pressure applications. Each aramid fiber is individually coated with PTFE suspensoid and teated with a break-in lubricant.

Service Limits:	pH Range:	2-12	
	Temperature: Maximum:	536 ˚ F	280 ˚ C
	Minimum:	-148 ˚ F	-100 ˚ C
	Pressure: Rotating:	435 PSI	30 BAR
	Reciprocating:	1450 PSI	100 BAR
	Static:	2610 PSI	180 BAR
	Shaft Speed:	2362 f/m	12 m/s

2004

ARAMID YARN WITH PTFE

Service: Able to withstand granular and abrasive applications. It is recommended for service in steam, slurries, petroleum derivatives, solvents, chemicals and liquified gases.

Construction: Interlock braid, using aramid filaments treated individually with PTFE suspensoid. The packing is also lubricated with a silicon-based compound for quick and easy break-in.

Service Limits:	pH Range:	2-12	
	Temperature: Maximum:	536 ˚ F	280 ˚ C
	Minimum:	-148 ˚ F	-100 ˚ C
	Pressure: Rotating:	508 PSI	35 BAR
	Reciprocating:	2900 PSI	200 BAR
	Static:	3625 PSI	250 BAR
	Shaft Speed:	2952 f/m	15 m/s

2044

SPUN ARAMID YARN WITH PTFE

Service: A durable packing able to withstand granular and abrasive applications. It is recommended for service in superheated steam, slurried, petroleum derivatives, solvents, chemicals, liquified gases, pulp and paper stocks, sugar syrups and other abrasive fluids.

Construction: Interlock braid, using spun aramid carded yarns, treated individually with PTFE suspensoid. The packing is also lubricated with a silicone-based compound for quick and easy break-in.

Service Limits:	pH Range:	2-12	
	Temperature: Maximum:	536 ˚ F	280 ˚ C
	Minimum:	-148 ˚ F	-100 ˚ C
	Pressure: Rotating:	290 PSI	20 BAR
	Reciprocating:	1160 PSI	80 BAR
	Static:	2175 PSI	150 BAR
	Shaft Speed:	2952 f/m	15 m

2060

EXPANDED PTFE YARN WITH ARAMID CORE

Service: 2060 is especially suited for applications where contamination cannot be tolerated. It's high resistance to extrusion (4 times higher than conventional PTFE packings) makes Style 2060 ideal for handling chemically aggressive fluids in high-pressure applications. It is commonly used in valves, pumps and expansion joints.

Construction: Style 2060 is an interlocked braid, utilizing TEADIT's proprietary EWK yarn and a high temperature break-in lubricant. EWK yarn totally encapsulates a high strength Aramid core in an expanded PTFE jacket. The Aramid core contributes exceptional mechanical strength and dimensional stability, while the PTFE jacket provides chemical resistance, self-lubrication and a low coefficient of friction.

Service Limits:	pH Range:	0-14	
	Temperature: Maximum:	536 ˚ F	280 ˚ C
	Minimum:	-148 ˚ F	-100 ˚ C
	Pressure: Rotating:	435 PSI	30 BAR
	Reciprocating:	2175 PSI	150 BAR
	Static:	2610 PSI	180 BAR
	Shaft Speed:	2362 f/m	12 m/s

COMPRESSION PACKINGS/CARBON & GRAPHITE

FLEXIBLE GRAPHITE

Service: Style 2000 is a multi-service packing capable of a wide variety of uses throughout a plant. Style 2000 may be used in valves, pumps, expansion joints, mixers and agittors in the hostile environments of hydrocarbon processing, pulp and paper, power generation, metal-working and other industries where effective sealing is vital.

Construction: Style 2000 is a packing manufactured from flexible graphite in a unique braid construction. It is not wire-reinforced thus minimizing shaft and stem wear.

Service Limits:			
	pH Range:	0-14	
	Temperature: Maximum:	842° F	450° C
	Steam:	1202° F	650° C
	Minimum:	-400° F	-240° C
	Pressure: Rotating:	435 PSI	30 BAR
	Reciprocating:	1450 PSI	100 BAR
	Static:	4350 PSI	300 BAR
	Shaft Speed:	3936 f/m	20 m/s

2000

GRAPHITE FIBER

Service: Severe service packing. Handles strong acids and alkali solutions except fuming nitric acid, oleum and fluorine. Handles high temperatures and extremely high shaft speeds.

Construction: Light weight graphite fiber, twisted together and interlock braided. Contains a special lubricant to provide a bearing film and prevent wicking.

Service Limits:			
	pH Range:	0-14	
	Temperature: Maximum:	842° F	450° C
	Steam:	1202° F	650° C
	Minimum:	-400° F	-240° C
	Pressure: Rotating:	435 PSI	30 BAR
	Reciprocating:	1450 PSI	100 BAR
	Static:	4350 PSI	300 BAR
	Shaft Speed:	3936 f/m	20 m/s


2001

CARBON FIBER WITH GRAPHITE PARTICLES

Service: Handles water, steam, boiler feed and aqueous solution of acids and alkalies. Seats quickly; breaks in without extensive adjustments. Use for high speed pumps, blowers, dryers, high temperature valves and furnace gasketing.

Construction: Carbon fiber interlock braided, impregnated with proprietary lubricants and graphite particles which fill voids, act as a break-in lubricant, and block leakage.

Service Limits:			
	pH Range:	0-14	
	Temperature: Maximum:	842° F	450° C
	Steam:	1112° F	600° C
	Minimum:	-400° F	-240° C
	Pressure: Rotating:	363 PSI	25 BAR
	Reciprocating:	1450 PSI	100 BAR
	Static:	2900 PSI	200 BAR
	Shaft Speed:	3936 f/m	20 m/s


2002

HIGH TEMPERATURE/HIGH PRESSURE VALVE STEM

Service: Firm, high density valve stem packing. Recommended for use in super-heated steam, most chemicals, mild acids and alkalies. Excellent choice as end rings in flexible graphite sets.

Construction: Special high temperature, high strength, rugged-duty yarn plus Inconel® wire reinforcement. Impregnated with special high temperature resistant compound with fine particles of Graphite and Molydisulfide to act as surface lubricant. Also treated with a sacrificial material to alleviate electrolytic action.

Service Limits:			
	pH Range:	2-12	
	Temperature:	1202° F	650° C
	Pressure Static:	2465 PSI	170 BAR


2214

BRAIDED PACKING

TEADIT

2000IC

FLEXIBLE GRAPHITE, WIRE REINFORCED

Service: Style 2000I packing is particularly suited for use in high temperature, high pressure steam service. In addition, it can handle most chemicals, acids and alkalies. Style 2000I is excellent for use in steam turbines, high temperature motor-actuated valves and for high pressure/high temperature valve applications in general.

Construction: Style 2000I packing is manufactured from high purity flexible graphite that is expanded and formed into a braidable yarn and then braided in a unique construction with inconel wire reinforcement. The finished product retains all the inherent of flexible graphite; while the wire reinforcement provides greater mechanical strength.

Service Limits:

pH Range:	0-14	
Temperature: Maximum:	842° F	450° C
Steam:	1202° F	650° C
Minimum:	-400° F	-240° C
Pressure: Static:	5800 PSI	400 BAR

2001I

GRAPHITE YARN, GRAPHITE FILLED, WIRE REINFORCED

Service: Style 2001I packing is particularly suited for use in high temperature, high pressure steam service. In addition, it can handle most chemicals, acids and alkalies. Style 2001I is excellent for use in steam turbines, high temperature motor-actuated valves and for high pressure, high temperature valve applications in general.

Construction: Style 2001I packing is a rugged, premium grade, low friction, high strength, proprietary graphite fiber, twisted together and interlock braided with wire reinforcement. Style 2001I is treated with pure graphite powder to provide a bearing film and protect shafts from scoring. It also acts as a blocking agent to prevent wicking. The wire reinforcement provides increased mechanical strength.

Service Limits:

pH Range:	0-14	
Temperature: Maximum:	842° F	450° C
Steam:	1202° F	650° C
Minimum:	-400° F	-240° C
Pressure: Static:	5800 PSI	400 BAR

2002I

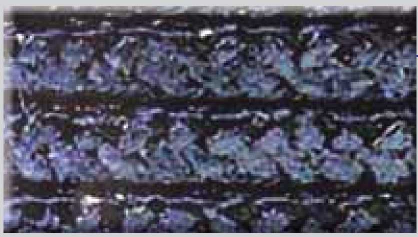
CARBON YARN, GRAPHITE FILLED, WIRE REINFORCED

Service: Style 2002I handles water, steam, boiler feed and aqueous solutions of acids and alkalis. In service, it seats quickly and does not require extensive break-in adjustments. Style 2002I is commonly used in steam turbines, high temperature motor-actuated valves and for high pressure, high temperature valve applications in general.

Construction: Style 2002I packing is manufactured form pure carbon yarn, which is interlock braided with wire reinforcement. The packing is impregnated with proprietary lubricants and graphite particles which fill voids, block leakage, and act as a break-in lubricant.

Service Limits:

pH Range:	0-14	
Temperature: Maximum:	842° F	450° C
Steam:	1112° F	600° C
Minimum:	-400° F	-240° C
Pressure: Static:	4350 PSI	300 BAR



2202

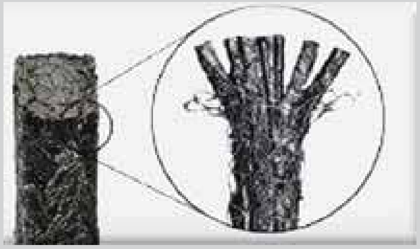
FLEXIBLE GRAPHITE WITH CARBON CORNERS

Service: This extremely versatile packing can be used in many demanding applications, both dynamic and static. Style 2202 packing is particularly suited for high temperature and high pressure service in valves, pumps, expansion joints, mixers and agitators. It can hold most chemicals in the 0-14 pH range with the exception of strong oxidizers.

Construction: Style 2202 packing is diagonally braided from pure, expanded flexible graphite, reinforced at the corners and throughout with high-quality carbon fibers. The carbon fiber reinforcement in the corners and body of the packing make it three times more resistant to extrusion and also increase the pressure handling capabilities compared to non-reinforced flexible graphite packing.

Service Limits:

pH Range:	0-14	
Temperature: Maximum:	842° F	450° C
Steam:	1112° F	600° C
Minimum:	392° F	200° C
Pressure: Rotating:	363 PSI	25 BAR
Reciprocating:	1450 PSI	100 BAR
Static:	2900 PSI	200 BAR
Shaft Speed:	3936 f/m	20 m/s



2235

FLEXIBLE GRAPHITE WITH INCONEL WIRE JACKET

Service: This packing was developed to operate in valve applications that are designed for hydrocarbons and steam at high pressures. style 2235 packing is an ideal solurtion for containment of fugitive emussions in extreme applications found in refineries, petrochemical plants, and thermal electricity generation stations.

Construction: Style 2235 packing is composed of layers of flexible graphite tape plied into compact strands; with each filament reinforced with an Inconel® wire jacket. These individual strands are then square braided to form a dense yet malleable packing. Outwardly it is then impregnated with lubricating agents to reduce stem friction.

Service Limits:

pH Range:	0-14	
Temperature: Maximum:	842° F	450° C
Steam:	1202° F	650° C
Minimum:	-464° F	-240° C
Static:	6500 PSI	

Teadit Style 2235 meets the requirement of Fugitive Emission Qualification Test Procedure as stated by Yarmouth Research and Technology.

2000 Braided Packing/Flexible Graphite Tape

CONSTRUCTION
Style 2000 packing is manufactured from high purity flexible graphite that is expanded and formed into a braidable yarn and then braided without binders or wire reinforcement. The finished product retains all the inherent benefits of flexible graphite: heat resistance, chemical inertness, low friction, self lubrication, and ready conformability.

APPLICATION / SERVICE
The outstanding properties of this style make it a truly multi-service packing capable of a wide variety of uses throughout a plant. This style may be used in valves, pumps, expansion joints, mixers and agitators in the hostile environments of hydrocarbon processing, pulp and paper, power generation, metal-working and other industries where effective sealing is vital.

SERVICE LIMITS

Type	Description	Value
Temperature Limits:	Minimum	-400°F (-240°C)
	Maximum	840°F (450°C)
	Steam	1200°F (650°C)
Pressure Limits:	Rotating	435 psi (30 bar)
	Reciprocating	1450 psi (100 bar)
	Static	4351 psi (300 bar)
Shaft Speed:		5904 fpm (30 m/s)
pH:		0-14 (except strong oxidizers)

APPROXIMATE YIELDS (+/- 10%)

Size	Feet/Pound	Size	Feet/Pound
1/8"	112	1/2"	7.4
3/16"	50	9/16"	6.1
1/4"	28.5	5/8"	4.9
5/16"	18.2	3/4"	3.6
3/8"	13.2	7/8"	2.6
7/16"	9.6	1"	2.1

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2000IC Braided Packing / Flexible Graphite, Wire Reinforced

CONSTRUCTION

Style 2000IC packing is manufactured from high purity flexible graphite that is expanded and formed into a weave-able yarn and then braided in a unique construction with wire reinforcement. The finished product retains all the inherent benefits of flexible graphite; while the wire reinforcement provides greater mechanical strength.

APPLICATION / SERVICE

Style 2000IC packing is particularly suited for use in high temperature, high pressure steam service. In addition, it can also handle most chemicals, acids and alkalis. This style is excellent for use in steam turbines, high temperature motor-actuated valves and for high pressure/high temperature valve applications in general.

SERVICE LIMITS

Type	Description	Value
Temperature	Minimum	-400°F (-240°C)
	Maximum	840°F (450°C)
	Steam	1200°F (650°C)
Pressure	Static	5800 psi (400 bar)
Shaft Speed		200 fpm (1 m/s)
pH		0-14 (except strong oxidizers)

APPROXIMATE YIELDS (+/- 10%)

Size	Feet/Pound	Size	Feet/Pound
1/8"	99.2	1/2"	8.8
3/16"	48	9/16"	6.6
1/4"	33.1	5/8"	5
5/16"	20.1	3/4"	4.1
3/8"	14.9	7/8"	3
7/16"	11.9	1"	2.3

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TEADIT®

2001 Braided Packing / Graphite Yarn, Graphite Filled

CONSTRUCTION
Style 2001 packing is a rugged premium grade, low friction, high strength, proprietary graphite fiber, twisted together and interlock braided. This style contains a special lubricant to provide a bearing film, and protect shafts from scoring. It also acts as a blocking agent to prevent wicking.

APPLICATION / SERVICE
Style 2001 packing is ideally suited for use in severe service valves and rotary shaft applications. It handles strong acids and alkali solutions except fuming nitric acid, oleum and fluorine. It can be used to seal steam, water, oil, solvents, alkalis, and acids. It is often used as end rings for packing sets utilizing softer packings that might tend to extrude. This style also handles high temperatures, extremely high shaft speeds (see Service Limits below), most strong chemicals, and reduces shaft wear.

SERVICE LIMITS

Type	Description	Value
Temperature Limits:	Minimum	-400°F (-240°C)
	Maximum	840°F (450°C)
	Steam	1200°F (650°C)
Pressure Limits:	Rotating	435 psi (30 bar)
	Reciprocating	1450 psi (100 bar)
	Static	4350 psi (300 bar)
Shaft Speed:		4000 fpm (20 m/s)
pH:		0-14 (except strong oxidizers)

APPROXIMATE YIELDS (+/- 10%)

Size	Feet/Pound	Size	Feet/Pound
1/8"	100	1/2"	9
3/16"	50	9/16"	8.1
1/4"	35	5/8"	6.7
5/16"	25	3/4"	4.5
3/8"	16.5	7/8"	3.4
7/16"	12	1"	2.6

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2002 Braided Packing / Carbon Yarn, Graphite Filled

CONSTRUCTION
Style 2002 packing is manufactured from pure carbon yarn, which is interlock braided and impregnated with proprietary lubricants and graphite particles which fill voids, block leakage, and act as a break-in lubricant. The end product has a low coefficient of friction and tends to wear more evenly than most braided packings.

APPLICATION / SERVICE
Style 2002 handles water, steam, boiler feed, and aqueous solutions of acids and alkalis. In service, it seats quickly and does not require extensive break-in adjustments. This style is commonly used for high speed pumps, blowers, dryers, high temperature valves, and furnace gasketing.

SERVICE LIMITS

Type	Description	Value
Temperature	Minimum	-400°F (-240°C)
	Maximum	
	• In air	840°F (450°C)
	• In steam	1200°F (650°C)
Pressure	Rotating	365 psi (25 bar)
	Reciprocating	1450 psi (100 bar)
Pressure	Static	4350 psi (300 bar)
Shaft Speed		4000 fpm (20 m/s)
pH		0-14 (except strong oxidizers)

APPROXIMATE YIELDS (+/- 10%)

Size	Feet/Pound	Size	Feet/Pound
1/8"	87.5	1/2"	6.8
3/16"	42.5	9/16"	5.1
1/4"	27.1	5/8"	4.4
5/16"	16.4	3/4"	3.2
3/8"	12.8	7/8"	2.2
7/16	8.6	1"	1.7

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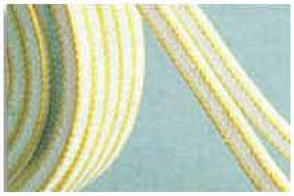

2003 Braided Packing/PTFE Yarn, Aramid Corners

CONSTRUCTION
Style 2003 is an interlock braided packing, using pure PTFE yarn, reinforced with aramid corners. The yarns are pretreated with PTFE dispersion, plus a break-in lubricant to reduce the coefficient of friction, as well as the frictional heat created by high shaft speeds.

APPLICATION / SERVICE
Style 2003 packing, with its unique combination of PTFE and aramid fibers, is dimensionally stable, non-contaminating, has excellent lubricating and running characteristics, and because of the aramid corners, is very wear resistant. It handles acids, alkalis, and a broad range of chemicals. It is well suited for service in rotary and reciprocating pumps, mixers, agitators and reactors, especially where abrasive wear is a problem.

SERVICE LIMITS

Type	Description	Value
Temperature Limits:	Minimum	-150°F (-100°C)
	Maximum	540°F (280°C)
Pressure Limits:	Rotating	435 psi (30 bar)
	Reciprocating	1450 psi (100 bar)
	Static	2600 psi (180 bar)
Shaft Speed:		2350 fpm (12 m/s)
pH:		2-12

APPROXIMATE YIELDS (+/- 10%)

Size	Feet/Pound	Size	Feet/Pound
1/8"	N/A	1/2"	5.5
3/16"	N/A	9/16"	4.4
1/4"	21.6	5/8"	3.3
5/16"	15.3	3/4"	2.5
3/8"	9.7	7/8"	2.0
7/16"	7.1	1"	1.5

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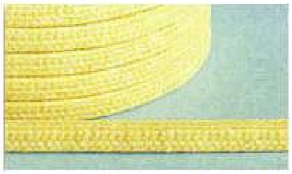
2004 Braided Packing/Aramid Yarn, PTFE Impregnated



CONSTRUCTION

Style 2004 is an interlock braided packing using aramid yarn treated with PTFE suspensoid. The packing is also lubricated with a silicon-based compound for quick and easy break-in.

APPLICATION / SERVICE

Style 2004 is an extremely durable packing able to withstand granular and abrasive applications. It is recommended for service in superheated steam, slurries, petroleum derivatives, solvents and liquified gases. It is commonly used in centrifugal, rotary and reciprocating pumps, agitators and mixers, especially in the paper, steel, petroleum and chemical industries, and in sewage treatment plants.

SERVICE LIMITS

Type	Description	Value
Temperature	Minimum	-150°F (-100°C)
	Maximum	540°F (280°C)
Pressure	Rotating	500 psi (35 bar)
	Reciprocating	2900 psi (200 bar)
	Static	3600 psi (250 bar)
Shaft Speed		2950 fpm (15 m/s)
pH		2-12

APPROXIMATE YIELDS (+/- 10%)

Size	Feet/Pound	Size	Feet/Pound
1/8"	99.2	1/2"	6.9
3/16"	49.6	9/16"	5.1
1/4"	27.1	5/8"	4.3
5/16"	17.5	3/4"	3.0
3/8"	10.6	7/8"	2.2
7/16"	8.8	1"	1.7

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2005 Braided Packing / PTFE Yarn, Dry

CONSTRUCTION

Style 2005 is a firm, high density interlock braided packing manufactured from pure PTFE filaments pretreated with PTFE dispersion, but contains no other lubricants. The PTFE dispersion provides a low friction surface finish and prevents leakage through the braid.

APPLICATION / SERVICE

Style 2005 is commonly used in valves and lower shaft speed applications. It is resistant to most chemicals, aggressive fluids, gases and solvents, with the exception of molten alkali metals.

SERVICE LIMITS

Type	Description	Value
Temperature Limits:	Minimum	-400°F (-200°C)
	Maximum	540°F (280°C)
Pressure Limits:	Rotating	290 psi (20 bar)
	Reciprocating	2150 psi (150 bar)
	Static	3600 psi (250 bar)
Shaft Speed:		984 fpm (5 m/s)
pH:		0-14

APPROXIMATE YIELDS (+/- 10%)

Size	Feet/Pound	Size	Feet/Pound
1/8"	93	1/2"	5.2
3/16"	41.3	9/16"	4.3
1/4"	21	5/8"	3.5
5/16"	13.7	3/4"	2.5
3/8"	9.8	7/8"	1.9
7/16"	7.3	1"	1.5

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2006 FDA Braided Packing / Pure PTFE Yarn, FDA Approved

CONSTRUCTION
Style 2006FDA is a firm, pliable interlock braided packing manufactured from the purest PTFE filaments. A proprietary food grade lubricant provides faster break-in and reduced shaft wear. Style 2006 FDA complies with the F.D.A. and U.S.D.A. requirements under Title 21 Food and Drugs:

Part 177.1500 - Perflourocarbon Resins
Part 178.3570 - Lubricants with Incidental Food Contact

APPLICATION / SERVICE
Style 2006FDA resists most caustic media and is commonly used in centrifical and rotary food processing equipment. It is also used in blenders, mixers, cookers, dryers and pumps.

SERVICE LIMITS

Type	Description	Value
Temperature	Minimum	-148°F (-100°C)
	Maximum	530°F (280°C)
Pressure	Rotating	290 psi (20 bar)
	Reciprocating	435 psi (30 bar)
Shaft Speed		2350 fpm (12 m/s)
pH		0-14

APPROXIMATE YIELDS (+/- 10%)

Size	Feet/Pound	Size	Feet/Pound
1/8"	78.3	1/2"	5
3/16"	35.4	9/16"	3.7
1/4"	19.8	5/8"	3.2
5/16"	11.7	3/4"	2.1
3/8"	8.3	7/8"	1.6
7/16"	6.2	1"	1.3

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2006S Braided Packing / Pure PTFE Yarn, Lubricated

CONSTRUCTION
Style 2006S is a soft and pliable interlock braided packing manufactured from pure PTFE filaments pretreated with PTFE dispersion, plus a break-in lubricant to reduce the coefficient of friction.

APPLICATION / SERVICE
Style 2006S is a dimensionally stable packing, yet relatively soft and pliable, which has excellent lubricating and running characteristics. It handles all acids, alkalis, and most chemicals, with the exception of molten alkali metals. It is suited for high speed rotary shaft service and is also commonly used on reciprocating pumps, mixers, agitators, and reactors.

NOTE: For services where lubricants other than PTFE cannot be tolerated, **Style 2005** packing is recommended…For FDA and food service applications, **Style 2006FDA** is recommended.

SERVICE LIMITS		
Type	**Description**	**Value**
Temperature	Minimum	-150°F (-100°C)
	Maximum	540°F (280°C)
Pressure	Rotating	290 psi (20 bar)
	Reciprocating	435 psi (30 bar)
Shaft Speed		2350 fpm (12 m/s)
pH		0-14

APPROXIMATE YIELDS			
Size	**Feet/Pound**	**Size**	**Feet/Pound**
1/8"	82.7	1/2"	5.4
3/16"	33.8	9/16"	4.3
1/4"	21	5/8"	3.4
5/16"	14.6	3/4"	2.4
3/8"	10	7/8"	1.9
7/16"	7.3	1"	1.5

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2007 Braided Packing / Expanded PTFE, Graphite

CONSTRUCTION

Style 2007 packing is an interlock braid, utilizing TEADIT's EG2 PTFE/graphite yarn and a high temperature break-in lubricant…EG2 yarn is formed from expanded PTFE in which fine particles of pure graphite have been encapsulated… The resulting packing combines the chemical resistance of PTFE with the heat dissipation characteristics of graphite, thus allowing much higher shaft speeds than conventional PTFE packings.

APPLICATION / SERVICE

Style 2007 is chemically inert over the entire 0-14 pH range with these exceptions: molten alkali metals, flourides, aleum, fuming nitric acid, aqua regia, and other strong oxidizing agents.

This style is an excellent general service and corrosive service packing. It is commonly used in pumps, valves, rotating and reciprocating shafts, mixers and agitators, and is especially designed for services involving surface speeds and temperatures higher than those that can be handled by pure PTFE packing.

SERVICE LIMITS

Type	Description	Value
Temperature	Minimum	-328°F (-200°C)
	Maximum	540°F (280°C)
Pressure	Rotating	500 psi (35 bar)
	Reciprocating	1450 psi (100 bar)
	Static	2900 psi (200 bar)
Shaft Speed		4900 fpm (25 m/s)
pH		0-14

APPROXIMATE YIELDS (+/- 10%)

Size	Feet/Pound	Size	Feet/Pound
1/8"	82.7	1/2"	5.5
3/16"	34.6	9/16"	4.5
1/4"	20.7	5/8"	3.5
5/16"	14	3/4"	2.4
3/8"	9.7	7/8"	1.8
7/16"	7.1	1"	1.5

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2017 Expanded PTFE/Graphite with Aramid Corners

CONSTRUCTION
Style 2017 packing is an interlock braid of TEADIT's EG2 PTFE/graphite yarn, reinforced with high strength aramid yarn corners…EG2 yarn is formed from expanded PTFE in which fine particles of graphite have been encapsulated…The resulting packing provides good chemical resistance and heat dissipation plus anti-extrusion strength.

APPLICATION / SERVICE
Style 2017 packing can handle a broad range of chemicals in the 3-11 pH range. It is used in papermill stock pumps, agitators, or any service where high strength and good lubricating qualities are needed.

SERVICE LIMITS

Type	Description	Value
Temperature Limits:	Minimum	-148°F (-100°C)
	Maximum	540°F (280°C)
Pressure Limits:	Rotating	435 psi (30 bar)
	Reciprocating	2900 psi (200 bar)
	Static	2900 psi (200 bar)
Shaft Speed:		3900 fpm (20 m/s)
pH:		2-12

APPROXIMATE YIELDS (+/- 10%)

Size	Feet/Pound	Size	Feet/Pound
1/8"	N/A	1/2"	6.0
3/16"	N/A	9/16"	4.9
1/4"	21.6	5/8"	3.9
5/16"	14.5	3/4"	2.8
3/8"	10.1	7/8"	2.1
7/16"	7.8	1"	1.7

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2018 Braided Packing / Synthetic Yarn w/ PTFE, Dry

CONSTRUCTION

Style 2018 is an interlock braid using carded synthetic yarns thoroughly impregnated with PTFE suspensoid. The finished packing is again coated with PTFE dispersion.

APPLICATION / SERVICE

Style 2018 is a good general service packing with no lubricant. It can handle a broad range of chemicals in the 3-11 pH range, and is white in color so it will not discolor flow media. This style is typically used in valves and slow speed pumps where contamination from break -in lubricants cannot be tolerated.

Style 2019 packing is a lubricated version of Style 2018

SERVICE LIMITS

Type	Description	Value
Temperature	Minimum	-150°F (-100°C)
	Maximum	450°F (230°C)
Pressure	Rotating	300 psi (20 bar)
	Reciprocating	1160 psi (80 bar)
	Static	1450 psi (100 bar)
Shaft Speed		600 fpm (3 m/s)
pH		2-12

APPROXIMATE YIELDS (+/- 10%)

Size	Feet/Pound	Size	Feet/Pound
1/8"	114.5	1/2"	8.8
3/16"	64.7	9/16"	5.2
1/4"	38.1	5/8"	4.6
5/16"	25.7	3/4"	4.1
3/8"	16.0	7/8"	3
7/16"	11.3	1"	2.2

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2019 Braided Packing / Synthetic Yarn w/ PTFE, Lubricated

CONSTRUCTION

Style 2019 is an interlock braid using carded synthetic yarns thoroughly impregnated with PTFE suspensoid. The finished packing is again coated with PTFE dispersion and a break-in lubricant is added to reduce shaft wear and eliminate glazing at start up.

APPLICATION / SERVICE

Style 2019 is an excellent multi-service packing that finds a wide variety of uses throughout a plant. It handles steam, water, solvents, oils, mild acids and alkalies, and a broad range of other chemicals. It is white in color and will not discolor the flow media. This style is recommended for use in centrifugal, rotary and reciprocating pumps and also mixers, agitators, and expansion joints.

Style 2018 packing is a non-lubricated version of Style 2019.

SERVICE LIMITS

Type	Description	Value
Temperature Limits:	Minimum	-150°F (-100°C)
	Maximum	450°F (230°C)
Pressure Limits:	Rotating	300 psi (20 bar)
	Reciprocating	1160 psi (80 bar)
	Static	1450 psi (100 bar)
Shaft Speed:		2350 fpm (12 m/s)
pH:		2-12

APPROXIMATE YIELDS (+/- 10%)

Size	Feet/Pound	Size	Feet/Pound
1/8"	78.3	1/2"	5.8
3/16"	48.1	9/16"	4.8
1/4"	23.3	5/8"	3.9
5/16"	15.3	3/4"	2.8
3/8"	10.6	7/8"	2.2
7/16"	8.6	1"	1.8

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Manufactured by an advanced method of braiding and construction, the packing Style 2020 offers excellent performance, especially in segments of equipment for pulp and paper, food, chemical, pharmaceutical and sugar and alcohol. A proprietary food grade lubricant provides faster break-in and reduced shaft wear. Style 2020 complies with the F.D.A. and U.S.D.A. requirements under Title 21 Food and Drugs:

Part 177.1500 - Perflourocarbon Resins
Part 178.3570 - Lubricants with Incidental Food Contact

Due to the technological edge of its filament that contains special additive encapsulated by pure PTFE, and his constructive feature offers excellent heat dissipation, which is usually generated by the sealing system. The result is its excellent sealability, particularly when compared with PTFE packings found in international markets.

Best packing for chemically aggressive applications and temperature gradient

High dispersion of heat, increasing product life and sealability.
Excellent chemical resistance.
Nonpolluting.
In accordance with FDA.

SERVICE LIMITS 2020		
Type	**Description**	**Value**
Temperature	Minimum	-328°F (-200°C)
	Maximum	536°F (280°C)
Pressure	Rotating	290 psi (20 bar)
	Reciprocating	435 psi (30 bar)
Shaft Speed		3920 fpm (20 m/s)
pH		0-14

APPROXIMATE YIELDS (+/- 10%)			
Size	**Feet/Pound**	**Size**	**Feet/Pound**
1/8"	78.32	1/2"	4.0
3/16"	20.7	9/16"	3.2
1/4"	16.0	5/8"	2.7
5/16"	10.5	3/4"	1.9
3/8"	7.4	7/8"	1.5
7/16"	5.5	1"	1.2

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2030 Meta-Aramid w/ PTFE and Mineral Oil

MATERIAL
TEADIT packing style 2030 is braided from meta-aramid yarn, each strand impregnated with PTFE-dispersion during the braiding process, lubricated with an inert mineral oil.

PROPERTIES
The high mechanical strength of the meta-aramid fibre, combined with the elaborate braiding process, results in a soft and pliable packing with excellent mechanical and chemical resistance. Because of the low coefficient of friction, shaft wear is largely avoided, even at high shaft speeds. No excessive heat build-up between the packing rings and the turning shaft; the packing runs cool, remains soft and flexible, resulting in longer service life.

APPLICATION AREAS
Style 2030 is recommended for all kinds of pumps, mixers, agitators, reactors, etc. for the chemical industry, pulp and paper, sewage plants, and many more.

APPLICATION MEDIA
Suitable for use with a wide variety of media in many different processes, including water, sewage, steam, solvents, chemicals, acids and caustics, as well as general service applications where a mechanically strong packing is required.

ADVANTAGES
The excellent malleability of style 2030 makes this packing very easy to handle, it installs quickly and easily. Because the packing remains soft and flexible, leakage can be adjusted to a very low level, readjustment of the gland follower is hardly necessary.

NOT SUITABLE FOR
Highly concentrated acids and caustics, alkali metals, oxygen.

Temperature (Max): 500 F (260 C)

Pressure (Max): Rotating: 500 psi (35 bar), Reciprocating: 2175 psi (150 bar), Static: 2900 psi (200 bar)

Shaft Speed (FPM) 2952 (15 m/s)

Approximate FT/LB Yields (+/- 10%):

1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	7/8
93	41.3	22.9	15	10.3	7.5	6.6	4.5	4.3	3.2	2.6	2

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2044 Braided Packing/Spun Aramid Yarn, PTFE Impregnated

CONSTRUCTION
Style 2044 is an interlock braid, using spun aramid carded yarns, treated individually with PTFE suspensoid. The packing is also lubricated with silicone based compound for quick and easy break-in. The use of spun aramid fibers produces a softer and very tough packing, but one that is less abrasive than packings braided with aramid filaments.

APPLICATION / SERVICE
Style 2044 is a durable packing able to withstand granular and abrasive applications. It is recommended for service in superheated steam, slurries, petroleum derivatives, solvents, chemicals, liquified gases, pulp and paper stocks, sugar syrups, and other abrasive fluids.

For a firmer aramid/PTFE packing, with higher pressure capabilities, see Style 2004.

SERVICE LIMITS

Type	Description	Value
Temperature	Minimum	-150°F (-100°C)
	Maximum	540°F (280°C)
Pressure	Rotating	300 psi (20 bar)
	Reciprocating	1150 psi (80 bar)
	Static	2200 psi (150 bar)
Shaft Speed		2950 fpm (15 m/s)
pH		2-12

APPROXIMATE YIELDS (+/- 10%)

Size	Feet/Pound	Size	Feet/Pound
1/8"	82.7	1/2"	6.3
3/16"	38.2	9/16"	4.6
1/4"	24.8	5/8"	4.0
5/16"	14.3	3/4"	2.9
3/8"	10.1	7/8"	2.0
7/16"	8.1	1"	1.5

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TEADIT®

2070 EGK Yarn/Expanded PTFE-Graphite Yarn with Aramid Core

CONSTRUCTION

Style 2070 packing is an interlock braid, utilizing TEADIT's patented EGK yarn and a high temperature break-in lubricant…EGK yarn totally encapsulates a high strength aramid core in an expanded PTFE/graphite jacket. The aramid core contributes exceptional mechanical strength and dimensional stability, while the PTFE/graphite jacket provides chemical resistance, heat conductivity, self lubrication and a low coefficient of friction.

APPLICATION / SERVICE

Style 2070 is a superior general service and corrosive service packing. Its high resistance to extrusion (four times higher than conventional PTFE/graphite packings) makes Style 2070 ideal for handling chemically aggressive fluids in high surface speed and high pressure applications.

SERVICE LIMITS

Type	Description	Value
Temperature	Minimum	-150°F (-100°C)
	Maximum	540°F (280°C)
Pressure	Rotating	500 psi (35 bar)
	Reciprocating	3600 psi (250 bar)
	Static	3600 psi (250 bar)
Shaft Speed		4900 fpm (25 m/s)
pH		0-14

APPROXIMATE YIELDS (+/- 10%)

Size	Feet/Pound	Size	Feet/Pound
1/8"	N/A	1/2"	5.5
3/16"	N/A	9/16"	4.4
1/4"	21.2	5/8"	3.5
5/16"	13.5	3/4"	2.5
3/8"	9	7/8"	2.0
7/16"	8.3	1"	1.5

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2103t Braided Packing / Carbon Yarn, PTFE Impregnated

CONSTRUCTION
Style 2103t packing is an interlock braid of carbon fibers which are carefully impregnated with PTFE and a special lubricant. The resulting packing is very tough, resists wear, has excellent chemical resistance and prevents contamination.

APPLICATION / SERVICE
Style 2103t packing can handle chemicals over the entire 0-14 pH range except for strong oxidizers. It is very popular in the pulp and paper industry because it is especially designed for applications involving strong caustics, acids, bleaches, slurries, and services where contamination cannot be tolerated. This style is commonly used in valves and pumps, agitators, reactors, and autoclaves.

SERVICE LIMITS

Type	Description	Value
Temperature Limits:	Minimum	-328°F (-200°C)
	Maximum	536°F (280°C)
Pressure Limits:	Rotating	362.6 psi (25 bar)
	Reciprocating	
	Static	2900 psi (200 bar)
Shaft Speed:		3000 fpm (15 m/s)
pH:		0-14 (except strong oxidizers)

APPROXIMATE YIELDS (+/- 10%)

Size	Feet/Pound	Size	Feet/Pound
1/8"	78.3	1/2"	6.6
3/16"	46.5	9/16"	5.2
1/4"	27.1	5/8"	4.2
5/16"	17.7	3/4"	2.9
3/8"	11.9	7/8"	2.2
7/16"	8.7	1"	1.7

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2138 Braided Packing / Ramie Yarn, Parraffin Impregnated

CONSTRUCTION

Style 2138 packing is braided with high quality ramie yarns in a square plait construction. The yarns are heavily impregnated throughout with paraffin and mineral oil.

APPLICATION / SERVICE

Style 2138 is a well lubricated, medium-hard packing with extremely low frictional characteristics, which assure minimal shaft wear. The ramie yarn is rot and mildew resistant, making the packing ideal for marine use, handling cold water, salt water, and cold oils. In the marine industry, it is commonly used in stern tubes, rudder posts, and tail shaft liners. This style is also used in the pulp and paper, waste/wastewater, steel and mining industries.

SERVICE LIMITS

Type	Description	Value
Temperature	Minimum	-
	Maximum	212°F (100°C)
Pressure	Rotating	217.6 psi (15 bar)
	Reciprocating	217.6 psi (15 bar)
	Static	290 psi (20°C)
Shaft Speed		1200 fpm (6 m/s)
pH		6-8

APPROXIMATE YIELDS (+/- 10%)

Size	Feet/Pound	Size	Feet/Pound
1/8"	114	5/8"	4.8
3/16"	42.6	3/4"	3.4
1/4"	33.1	7/8"	2.9
5/16"	19.1	1"	2.1
3/8"	13.5	1-1/8"	1.6
7/16"	11	1-1/4"	1.4
1/2"	8.1	1-1/2"	1.0
9/16"	7.5		

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2177 Braided Packing / Ramie Yarn, Graphited

CONSTRUCTION

Style 2177 packing is braided with high quality ramie yarns in a square plait construction. The yarns are heavily treated with a petroleum based lubricant and graphite.

APPLICATION / SERVICE

Style 2177 is a well lubricated, medium-hard packing with very low frictional characteristics, which assure minimal shaft wear. The ramie yarn is rot and mildew resistant, making the packing ideal for marine use, handling cold water, salt water, and cold oils. In the marine industry it is commonly used in stern tubes, rudder posts, and tail shaft liners. This style packing is also used in the pulp and paper, water/wastewater, and mining industries where a softer packing is desired for lower pressure hydraulic applications.

SERVICE LIMITS

Type	Description	Value
Temperature Limits:	Minimum	-
	Maximum	212°F (100°C)
Pressure Limits:	Rotating	215 psi (15 bar)
	Reciprocating	215 psi (15 bar)
	Static	290 psi (20 bar)
Shaft Speed:		1200 fpm (6 m/s)
pH:		6-8

APPROXIMATE YIELDS (+/- 10%)

Size	Feet/Pound	Size	Feet/Pound
1/8"	114	5/8"	5.7
3/16"	51	3/4"	2.8
1/4"	26	7/8"	2.3
5/16"	20	1"	1.9
3/8"	15	1-1/8"	1.7
7/16"	10	1-1/4"	1.4
1/2"	8.3	1-1/2"	1.0
9/16"	6.8		

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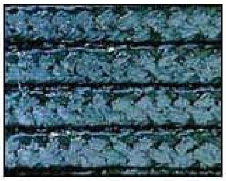

2202 Braided Packing / Flexible Graphite, Carbon Corners

CONSTRUCTION

Style 2202 packing is diagonally braided from pure, expanded flexible graphite, reinforced at the corners and throughout with high-quality carbon fibers. The carbon fiber reinforcement in the corners and body of the packing make it three times more resistant to extrusion and also increase the pressure handling capabilities compared to non-reinforced flexible graphite packing.

APPLICATION / SERVICE

Style 2202 This extremely versatile packing can be used in many demanding applications, both dynamic and static. This style packing is particularly suited for high temperature and high pressure service in valves, pumps, expansion joints, mixers and agitators. It can handle most chemicals in the 0-14 pH range with the exception of strong oxidizers.

SERVICE LIMITS

Type	Description	Value
Temperature	Minimum	-400°F (-240°C)
	Maximum	
	• In air	842°F (450°C)
	• In steam	1200°F (650°C)
Pressure	Rotating	435 psi (30 bar)
	Reciprocating	2900 psi (200 bar)
	Valve	4350 psi (300 bar)
Shaft Speed		4000 fpm (20 m/s)
pH		0-14 (except strong oxidizers)

APPROXIMATE YIELDS (+/- 10%)

Size	Feet/Pound	Size	Feet/Pound
1/8"	93	1/2"	7.4
3/16"	39.1	9/16"	5.9
1/4"	24.8	5/8"	5
5/16"	17.7	3/4"	3.8
3/8"	13.5	7/8"	2.6
7/16"	8.8	1"	2

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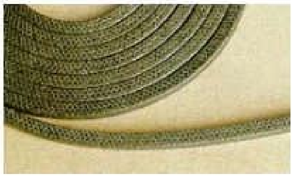

2214 High Temp, Non-Asbestos, Valve Stem Packing

CONSTRUCTION

Style 2214 is a proprietary braid-over-core construction, using a special high temperature, Inconel reinforced fiber and a non-hardening core. The packing is impregnated with a high temperature resistant compound, and coated with fine particles of graphite to act as a surface lubricant. This style is also treated with a sacrificial material to alleviate electrolytic action.

APPLICATION / SERVICE

Style 2214 is a firm, high density, non-asbestos packing. It can handle steam, most chemicals, mild acids, and alkalies. It is excellent for use in steam turbines, high temperature motor-actuated slide valves, and in high pressure/high temperature valving in general.

SERVICE LIMITS

Type	Description	Value
Temperature	Minimum	-
	Maximum	1200°F (650°C)
Pressure	Rotating	-
	Reciprocating	-
	Static	2500 psi (170 bar)
Shaft Speed		2500 fpm
pH		2-12

APPROXIMATE YIELDS (+/- 10%)

Size	Feet/Pound	Size	Feet/Pound
1/8"	110	1/2"	5.4
3/16"	45.5	9/16"	4.3
1/4"	21.5	5/8"	3
5/16"	13.7	3/4"	2.4
3/8"	9.5	7/8"	1.8
7/16"	7.1	1"	1.4

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2255 Braided Packing / Synthetic Yarn, Graphited,Lubricated

CONSTRUCTION

Style 2255 is an interlock braid using carded synthetic yarns thoroughly impregnated with a special petroleum based lubricant and graphite.

APPLICATION / SERVICE

Style 2255 is a dense, but flexible general service packing that adapts well to worn or scored shafts often found in older equipment. It assures an excellent seal against steam, brine, oil, and mild acids and alkalis. This style is well-suited for applications in rotary and centrifugal pumps and some valves.

SERVICE LIMITS

Type	Description	Value
Temperature Limits:	Minimum	-150°F (-100°C)
	Maximum	416°F (230°C)
Pressure Limits:	Rotating	300 psi (20 bar)
	Reciprocating	300 psi (20 bar)
	Static	725 psi (50 bar)
Shaft Speed:		2000 fpm (10 m/s)
pH:		4-10

APPROXIMATE YIELDS (+/- 10%)

Size	Feet/Pound	Size	Feet/Pound
1/8"	186	1/2"	7.5
3/16"	82.7	9/16"	9.5
1/4"	30.5	5/8"	7.7
5/16"	17	3/4"	3.4
3/8"	14.5	7/8"	3.3
7/16"	9.3	1"	3.0

Properties and application parameters shown throughout this datasheet are typical. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury. Specifications are subject to change without notice. This edition supersedes all previous issues.

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2421 Braided Packing / Ramie Yarn, PTFE Impregnated

CONSTRUCTION

Style 2421 packing is manufactured from the finest quality ramie yarns with PTFE suspensoid in a square plait construction. An additional break-in lubricant is added to minimize shaft wear and to allow for expansion during the break-in period.

APPLICATION / SERVICE

Style 2421 is a well lubricated, medium-hard packing with very low frictional characteristics, which assures minimal shaft wear. The ramie yarn is rot and mildew resistant, making the packing ideal for marine use, handling cold water, salt water and cold oils. In the marine industry, it is recommended for sealing stern tube and rudder post stuffing boxes. This style is also used for certain pump and valve applications in the pulp and paper, water/wastewater, and mining industries.

SERVICE LIMITS

Type	Description	Value
Temperature Limits:	Minimum	-
	Maximum	260°F (130°C)
Pressure Limits:	Rotating	300 psi (20 bar)
	Reciprocating	300 psi (20 bar)
	Static	450 psi (30 bar)
Shaft Speed:		1950 fpm (10 m/s)
pH:		5-11

APPROXIMATE YIELDS (+/- 10%)

Size	Feet/Pound	Size	Feet/Pound
1/8"	60	5/8"	4.6
3/16"	40	3/4"	2.9
1/4"	27	7/8"	2.3
5/16"	16	1"	1.8
3/8"	11	1-1/8"	1.4
7/16"	8.7	1-1/4"	1.2
1/2"	7.4	1-1/2"	0.8
9/16"	5.3		

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2777 Braided Packing / Novoloid Fiber, PTFE Impregnated

CONSTRUCTION

Style 2777 packing is an interlock braid using Novoloid fibers impregnated with PTFE. In addition, the individual fibers are lubricated using a special process that assures thorough lubrication for a longer packing life.

APPLICATION / SERVICE

Style 2777 packing is a high performance packing that is well suited to applications where graphite impregnation may not be acceptable. It can handle steam, water, acids and other chemical and solvent applications. This style has multiple uses in chemical plants and pulp and paper mills, and is regularly used in rotating and reciprocating pumps, washer journals, liquor pumps, refiners and digesters.

SERVICE LIMITS

Type	Description	Value
Temperature Limits:	Minimum	-148°F (-100°C)
	Maximum	482°F (250°C)
Pressure Limits:	Rotating	362 psi (25 bar)
	Reciprocating	725 psi (50 bar)
	Static	1450 psi (100 bar)
Shaft Speed:		2952 fpm (15 m/s)
pH:	1 - 13 (except concentrated, hot sulfuric or nitric acid)	

APPROXIMATE YIELDS (+/- 10%)

Size	Feet/Pound	Size	Feet/Pound
1/8"	N/A	1/2"	6.6
3/16"	N/A	9/16"	4.5
1/4"	21.2	5/8"	3.7
5/16"	14.5	3/4"	2.9
3/8"	10.9	7/8"	2
7/16"	7.3	1"	1.7

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TEADIT®

3070 Woven PTFE Gasket Tape

CONSTRUCTION

Style 3070 gasket tape is woven with strong PTFE yarns in a flat, tube-like construction. It is thoroughly impregnated with PTFE and can be treated with an inert lubricant (Style 3070 Wet) or furnished without the lubricant (Style 3070 Dry).

APPLICATION / SERVICE

Style 3070 gasket tape is flexible and compresses easily, and gasket extrusion is negligible. It readily conforms to flange irregularities and fills in surface voids even at low flange bolt loads. It handles virtually any chemical service with the exception of molten alkali metals, and can be used in most food processing and pharmaceutical applications. This style is recommended for sealing glass, fiberglass and metal flanges, and is commonly used for sealing tank and vessel lids.

SERVICE LIMITS

Type	Description	Value
Temperature Limits:	Minimum	-350°F
	Maximum	500°F
Pressure Limits:	Static	vacuum to 360 psi (25 bar)
pH		0-14

STANDARD PACKING

WET			DRY		
Width	Thickness (Feet per pound)		Width	Thickness (Feet per pound)	
	1/8"	1/4"		1/8"	1/4"
1/2"	20.5	-	1/2"	18.5	-
3/4"	13.5	6.7	3/4"	12.5	6.6
1"	10	5.0	1"	9.4	4.7
1-1/4"	8	4.0	1-1/4"	7.4	3.7
1-1/2"	7.6	3.8	1-1/2"	6.1	3.1
2"	-	2.5	2"	-	2.3

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STYLE 3110-I

Material composition

TEADIT style 3110I is a braided tube - folded flat to form a tape - from pure expanded, flexible graphite, reinforced with fine metal wires.

Properties

Style 3110I is a very versatile gasket material for static applications. It has excellent temperature resistance and can be used with a wide variety of media. It comes in the following cross-section: 15 x 4mm, with adhesive backing.

Application areas

Static seal for metallic and non-metallic flanges, lids, covers, hatches, reactors, autoclaves, heaters, etc.

Temperature (max) 840 F (450 C)
Pressure (max) Contact Teadit

Application media

Suitable for most media in a wide variety of processes, including steam, fuel, gases, mineral and synthetic oils, effluents, condensate, process water, etc.*

*Not suitable for oxidizing media. Properties and application parameters shown throughout this datasheet are typical. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendationsconsult TEADIT. Failure to select proper sealing products could result in property damage and/or serious personalinjury. Specifications are subject to change without notice. This edition supersedes all previous issues.

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