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**CRACKING FURNACE GASKET SELECTION – A KEY FACTOR IN FURNACE
LIFE EXTENSION**

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Abstract: Flanges on ethylene cracking furnaces are necessary for proper maintenance, and offer specific challenges in terms of leakage avoidance and safety assurance. On cracking furnaces, any gasket failure will require a cold shutdown for repair. As both radiant coil and refractory service life are strongly impacted by hot-cold cycling, avoidance of gasket failure events can be key to maintenance minimization and furnace life extension.

The steam cracking process normally takes hydrocarbon feed from roughly 120°F to above 1,600°F. The thermal expansion of the heating surface requires provisions to absorb the resulting movement which may result in significant stress on joints. In addition, the furnace operation is cyclic in terms of thermal cycling as well as oxidation/reduction cycling due to the intermittent decoking operation.

The subject paper reviews the common flange types and locations on a cracking furnace and front end piping and outlines important considerations for gasket specification/selection. Suggested gasket solutions for each location are presented, which consider the fluid, the operating conditions, code requirements and safety related issues.

Key Factors to Consider

Process Conditions

Temperature and pressure are obvious factors that will impact gasket selection as well as choice of joint configuration, flange type and rating. However, other process fluid and exposure factors should also be considered in the gasket selection procedure.

Temperature Cycling

Any furnace related gasket service will be subjected to hot/cold cycling, with the number of cycles a function of the requirements for shutdown and restart. In the case of a cracking furnace, it should be an operations goal to minimize the number of unnecessary shutdown events, not only from the perspective of lost production but also because of the detrimental impact on radiant coil creep.

Oxidation/Reduction Cycling

A cracking furnace run length and associated decoking cycle will expose certain gaskets to alternating reducing atmosphere (cracking reaction produces a H₂ rich hydrocarbon-steam cracked gas mixture) followed by an oxidizing atmosphere (steam air decoking of the radiant coil). This may result in gasket degradation if the gasket material is not resistant to oxidation, e.g. graphite based.

Fluid Contaminants

Certain components that may be present in the fluid being handled may impact flange, piping, and gasket integrity. Compounds which may form strong acids or bases as a result of reaction or phase change, such as sulfur, chloride, or sodium should be considered during material selection.

Pyrophoric Fluid

Leakage of any fluid which is above its auto ignition temperature will result in spontaneous ignition upon contact with air, irrespective of any ignition source or spark. Many of the flange joints near the radiant coil of a cracking furnace are handling mixtures which are above their auto ignition temperatures. Thus any leakage resulting from joint failure will be a serious safety issue, a fugitive emission, as well as a maintenance issue. Auto ignition temperatures of common cracking furnace feed and product molecules are listed in Table 1.

Table 1 (1)

Auto Ignition Temperature	°F	°C
Hydrogen	932	500
Methane	1,076	580
Ethane	959	515
Ethylene	914	490
Propane	878	470
Propylene	856	458
n-Butane	761	405
Naphtha	1,022	550
Gas Oil	637	336

Personnel Exposure

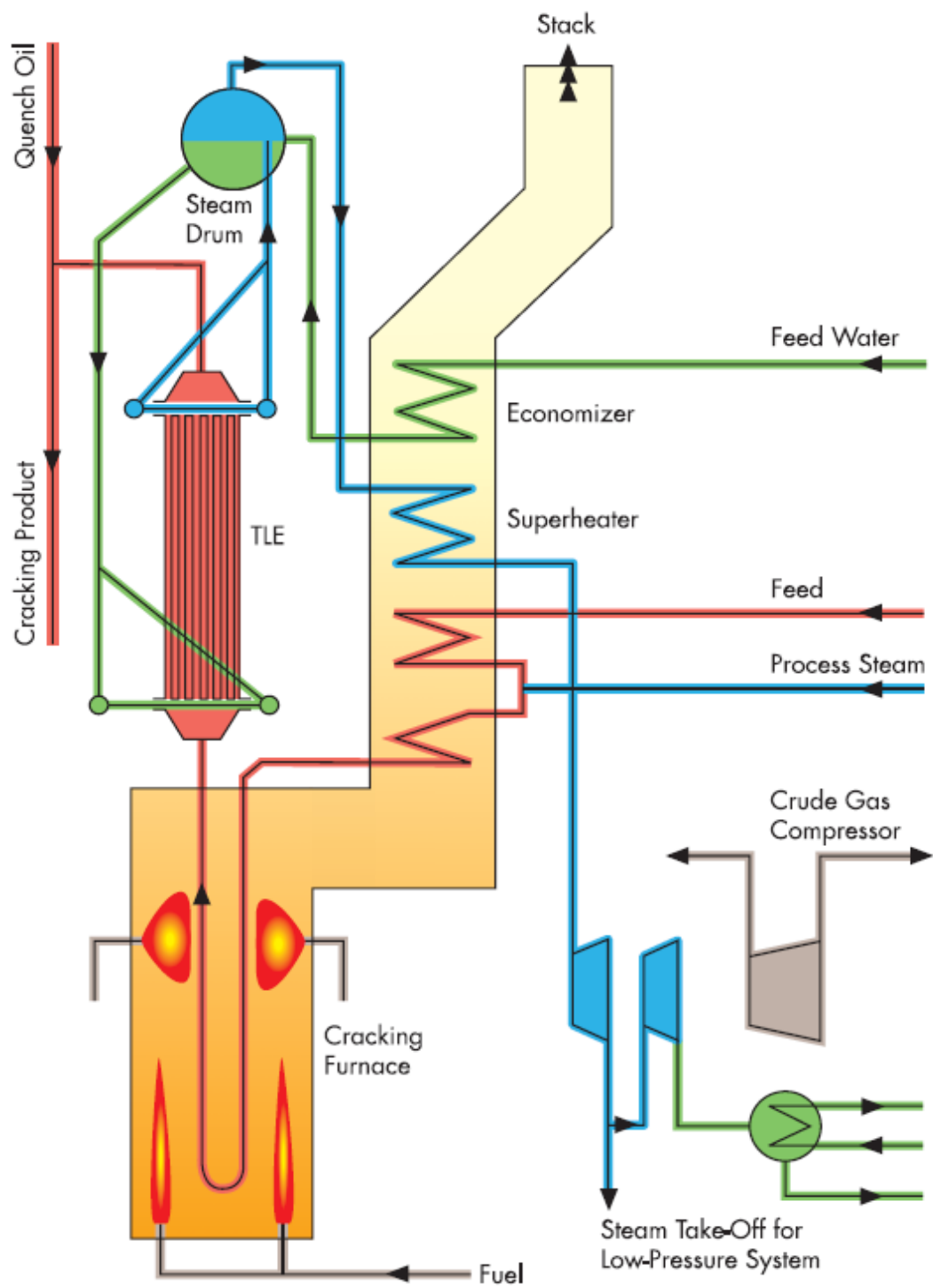
All flanged joints are normally accessible for maintenance purposes, but certain flanges are located in areas of frequent personnel traffic. This factor should be considered when selecting suitable gaskets.

Fire Exposure

As fires in and around the cracking furnaces may be anticipated, the proper gasket selection for fuel piping should take into account fire resistance. NFPA 54 National Fuel Gas Code outlines requirements for gasket performance that include fire exposure. However, this code normally applies only to fuel gas piping inside occupied buildings. In the absence of code requirements, application of fire-safe ratings such as API or PVRC FITT to gasket selection on cracking furnaces becomes a matter of corporate or plant safety policy.

Code Requirements

Hydrocarbon piping and furnace coils are usually designed to ASME B31.3 piping code or the equivalent European or Japanese codes, and gaskets in those lines should conform to the applicable code. Modern cracking furnace design will typically incorporate a 1,200 to 1,800 psig (80-120 bar) steam system integrated into the waste heat recovery. The bolted flange joints and gaskets must comply with the applicable ASME and boiler code requirements.



Ethylene Cracking Furnace Schematic (2)

Gasket Selection

Although a gasket may be a very small component of a cracking furnace, proper gasket selection and installation means the difference between continuous operation or joint failure leading to downtime and lost productivity while possibly compromising the safety of plant personnel. The gasket is only one component of a bolted joint that includes the flanges, fasteners, installation procedure, tools for assembly, and a human factor. Proper gasket selection is the first step to eliminating leaks and eventual unplanned outages due to joint failure. A severe incident can start with one gasket leak and can ultimately cost a plant operator millions in lost production and rehabilitation costs.

Flanged joints on cracking furnaces can be grouped into three categories with similar requirements: process, steam and fuel streams. Process streams are those handling fluids associated with the cracking feed or effluent, including dilution steam, as this "dirty steam" stream normally has organic and inorganic impurities far in excess of the streams associated with steam generation. Similar considerations apply to gasket selection for the process, steam and fuel streams of a cracking furnace.

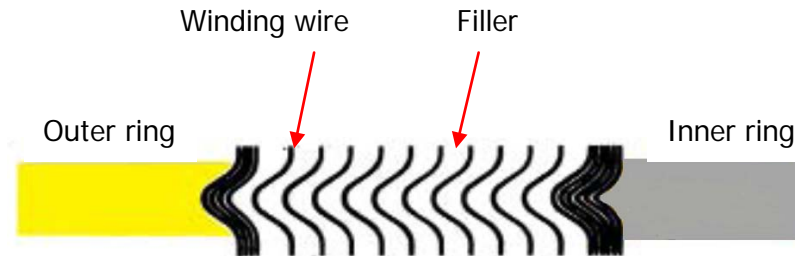
PROCESS: Hydrocarbon Feed Inlet

For liquid crackers, this stream is normally a virgin naphtha or gas oil with significant organic sulfur. The temperature is normally low ($< 120^{\circ}\text{F}$) and the pressure elevated to account for the furnace pressure drop but not to a point where a RF Class 150 flange cannot meet the requirements. Hot/Cold cycling is negligible and oxidation/reduction cycling is not present, as the decoking air stream is normally introduced further downstream to reduce the pressure required. The fluid is a liquid far below the auto ignition temperature, and the flange location is normally at the highest point on the furnace far away from fire exposure or any regular personnel traffic.

Recommended Gasket

The recommended gasket selection in this case could be based mainly on economics. A spiral wound gasket (SWG) with an outer ring will provide blow out resistance and enough resiliency to respond to joint relaxation. Thermal cycling is negligible and requires no additional recovery; therefore a 304SS winding wire is standard for this application with carbon steel flanges. For the filler material, graphite is an excellent sealing material, compatible with hydrocarbons and suitable for the low temperatures. "Inner rings for flexible graphite-filled spiral-wound gaskets shall be furnished unless the purchaser specifies otherwise." ⁽³⁾ (Inner rings for large diameters and high pressures are still mandatory for all filler materials.) Inner rings provide multiple advantages including significant benefits to sealing as well as eliminating the problem of buckling. In general, inner ring metallurgy is chosen to match the winding wire.

Less expensive filler materials are available (chlorite graphite type or similar), but they can easily be mistaken for graphite. Most plants decide that the *minimal cost advantage* is not worth the risk of accidentally installing a material with lower chemical and temperature resistance.



Spiral wound gasket with inner and outer ring

For gas crackers, the Hydrocarbon Feed stream will be a low molecular weight alkane, typically ethane or propane which may have trace sulfur added to inhibit the coking rate. The pressure and temperature will be in the same range as for a liquid feed. The vapor is still far below the auto ignition temperature and the gasket selection would follow the same criteria.

PROCESS: Dilution Steam Inlet

At this point, Dilution Steam is mixed with the partially vaporized liquid feed or the preheated vapor feed. Hot/Cold cycling will apply but operating and ambient temperatures will remain below 250°F. Two phase flow at these locations may result in some level of vibration/mechanical cycling. Oxidation/Reduction cycling will likely be present as the decoking air stream is normally introduced to the dilution steam flow prior to the mix point.

The fluid is still below the auto ignition temperature and the flange location is normally at an intermediate point on the convection section away from fire exposure or any regular personnel traffic.

Recommended Gasket

The typical gasket choice is a graphite filled spiral wound (conveniently the same as mentioned above). One significant advantage to standardizing gasket material is inventory consolidation and reducing risk of the wrong gasket being put in service – a common mistake when many different types are in the warehouse.

PROCESS: External Crossovers

The fully preheated mix is transferred from the convection coils to the radiant section coils via external crossovers which are normally constructed from 300 series stainless alloy. The normal process temperature will be in the range of 1,100 to 1,250°F and the mix will consist of steam and hydrocarbon components far above the auto ignition temperature.

Thermal cycling between ambient and process temperature will occur at every cold shutdown of the furnace, and oxidation/reduction cycling will occur at the end of every furnace run and associated decoking cycle. Sulfur will be present in dilute concentration.

The crossover flanges are usually located at the arch level, accessible from platforms such that movement of the crossover piping can be monitored and instrumentation on the crossovers can be serviced. Instrumentation such as thermowells and pressure transmitters may also have flanges associated with them. Crossover movement and mechanical stress on joints can be significant, as the flexibility in the crossover piping usually must absorb the movement of the radiant inlet associated with the thermal growth of the radiant coil tubes.

Recommended Gasket

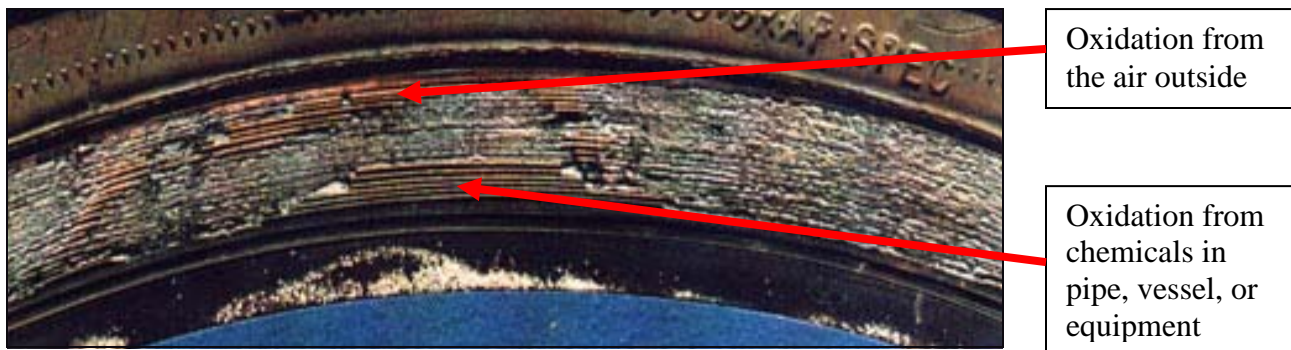
All these factors combine to make joint sealing and gasket selection especially challenging for any flanges required in external crossover piping. Leakage from crossover flanges will smoke immediately and pose a hazard to personnel as well as other critical equipment at the arch level, e.g. TLE's.

Gasket selection should be mindful of the elevated temperature, thermal cycling, as well as risk and tolerance for leakage. The risk of fire, product loss, process shutdown, and personnel safety should drive gasket selection. The best choice is a spiral wound gasket with an inorganic filler material with good sealing properties, along with an extremely resilient winding wire. A common example of such winding wire is Heat Treated Inconel X-750. The best example of such a filler material available today is one using specially formulated combinations of different types of exfoliated vermiculite. (4) Going forward, this filler material will be referred to as 'exfoliated vermiculite'.

Vermiculite is an inorganic phyllosilicate mineral with extreme temperature (1800°F +) and chemical resistance. Exfoliated vermiculite is fire safe, maintains its integrity and sealability at extreme temperatures, and will not oxidize at high temperatures due to its inorganic structure.

Graphite Oxidation

The recommendation for an inorganic sealing material is to avoid the main pitfall of graphite – that of oxidation. When graphite is exposed to oxygen from the external air or internal process gases (steam, air, CO, CO₂, etc), the oxygen reacts with the carbon in graphite and produces carbon dioxide. Upon discovery, the graphite is simply missing from the gasket. It seems to have *disappeared*.



A spiral wound gasket (with an inner and outer ring) shows visible oxidation of graphite filler from outside air and internal chemicals where it is missing between the winding wire.

Oxidation means there is volume loss to the sealing element of the gasket. Too much volume loss leads to lost bolt load and resultant gasket load. End users should always inspect gaskets upon removal, and look for signs of oxidation indicated by missing graphite. It is important to catch it prior to a major joint failure, or eliminate the risk entirely by using a material that is not susceptible to oxidation but capable of producing a gas tight seal.

Note that graphite's rate of oxidation is highly dependent on the concentration of oxygen, the temperature, tightness of the joint (bolt load and resultant gasket load especially after relaxation at high temperatures), gasket type (sheet versus semi-metallic) and quality of graphite (impurities accelerate oxidation while inhibitors may decelerate it). Variation in each of these contributing factors makes oxidation very difficult to predict and furthermore, a maximum temperature limit on graphite very difficult to assign.

Not including extreme oxidizers like NO_x gas, examples of oxidized graphite in gaskets have been found below 700°F . The development of inhibited grades of graphite has improved graphite's ability to withstand oxidation but has not eliminated it. Different manufacturers employ different methods and produce different grades – each having a different resistance to oxidation. Although improvements continue to be researched and employed, the best inhibited graphite typically adds 100 degrees or less additional temperature resistance to that of its standard graphite counterpart.

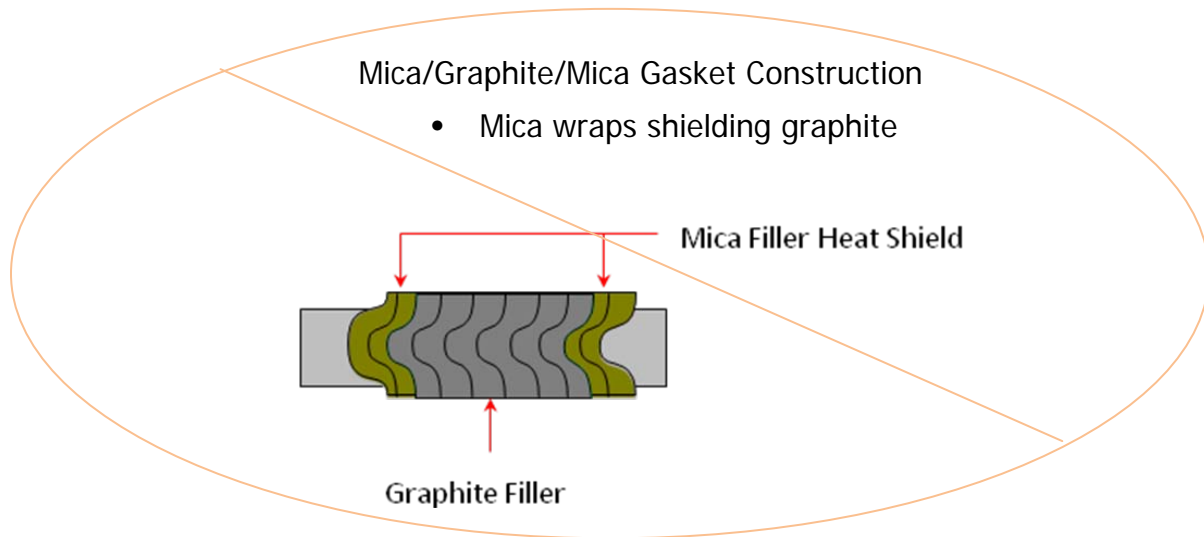
End user specs and drafts of upcoming industry standards suggest maximum long term operating temperature of even the best super-inhibited graphite to be 850°F , with the poorest being limited to 575°F . If interested in a test for graphite quality, Fluid Sealing Association procedure FSA-G-604-07⁽⁵⁾ can indicate graphite quality through Thermo Gravimetric Analysis.

Ineffective Alternatives

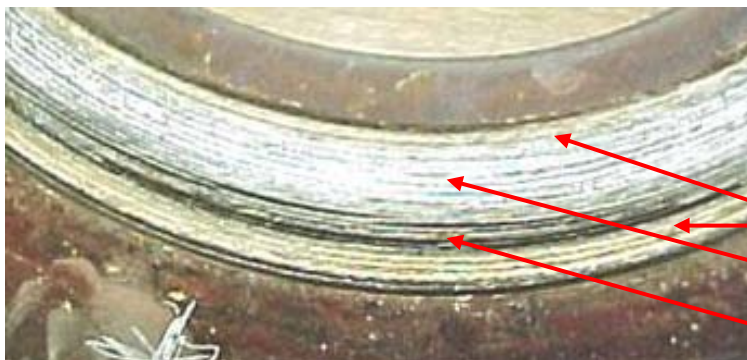
Being able to resist oxidation is not a sealing material's only requirement. If a material can be used in extreme temperatures but cannot produce a gas tight seal, there is little value in it. Prior to the availability of a sealing material made of exfoliated vermiculite, manufacturers were required to use high temperature materials like mica or ceramic. Unfortunately, they are very poor sealing materials and easily permeated. Attempts to use

them as an oxygen barrier around graphite may delay the oxidation process but it will not prevent it. Oxygen permeates the material and still oxidizes the graphite.

The tendency of graphite filler to oxidize through a mica heat shield has been shown in multiple real world examples since the 1990's. The typical construction of such a spiral wound gasket has wraps of mica filler on the ID and OD with graphite between.



Oxidation Example 1



Ethylene Furnace Application

- 5" spiral with inner ring
- Mica/graphite/mica filler
- 1,100°F
- 12 months

Photo illustrates an ethylene manufacturer's furnace gasket where graphite oxidized through the mica after 12 months at 1,100°F.

Successful Application 1

This plant began using exfoliated vermiculite filled spiral wounds in 2003 to eliminate oxidation at this flange and others.

Product:	Exfoliated vermiculite SWG
Temperature:	Range 1,100°F to 1,250°F
Pressure:	20 psig
Since:	February 2003

Oxidation Example 2

Beginning in late 2005, a Japanese ethylene producer began researching alternative sealing materials to asbestos following the country's legislative ban of the material. Statistical analysis of mica/graphite/mica spiral wounds showed significant leakage after relatively short periods of service, as shown in the excerpt of test results in Table 2. Upon investigation of the gaskets in leaky joints, the graphite was found to be all or mostly "disappeared".

Conditions of sealing included:

- Normal Operation: Hydrocarbon gas, Steam; 1,110°F; Maximum pressure 51 psig
- At Decoking: Air, Steam; 1,020°F; Maximum pressure 18 psig

Table 2. Ethylene producer tests mica/graphite/mica performance

Gasket Type: Spiral wound, mica/graphite/mica	Period of Operation	
	3.7 months	5.8 months
Qty ON TEST at start of operation	22	25
Qty LEAKING at end of operation	6	15

Successful Application 2

All gaskets were eventually replaced with exfoliated vermiculite filled spiral wounds to eliminate the oxidation related leaks and were found to be "superior in sealing quality and long endurance".

Product:	Exfoliated vermiculite SWG
Temperature:	Up to 1,110°F
Pressure:	51 psig maximum
Since:	November 2005

Exfoliated Vermiculite

In the case of vermiculite (and graphite for that matter), the exfoliation process of the natural flake is key to generating good sealability and low porosity. Unlike mica, vermiculite can be exfoliated. Unlike graphite, vermiculite will not oxidize. Exfoliated vermiculite has been used as a sealing material with tremendous success since 1997 and is now in tens of thousands of joints replacing poor sealing materials or those that suffer from oxidation.



Vermiculite Flake



Exfoliated Vermiculite Flake

Heat Treated Inconel X-750 Winding Wire

Extreme thermal cycling causes differential thermal expansion and contraction of components in a bolted joint. It is difficult for the gasket to compensate for fluctuating load conditions, and sometimes extra resiliency must be built into the joint. A special heat treated (HT) Inconel X-750 winding wire has been developed in conjunction with the nuclear industry to ensure that joint integrity is maintained during thermal cycles. Heat treating must be specified in order for the precipitation hardening process to be performed by the manufacturer. (6)

Testing from a nuclear OEM & a nuclear power producer shows that heat treated Inconel X-750 has twice the usable recovery over 316L Stainless Steel (refer to Table 3). Usable recovery is different from overall recovery. A gasket's ability to spring-back/recover while still compressed in a bolted joint, or its usable recovery, is more significant than how much it recovers after disassembly. The HT Inconel X-750 material has been used in cycling applications since the early '80s with remarkable success.

Table 3. Test results showing usable recovery of different winding wire in SWGs.

Winding Material	316L SS	Heat Treated Inconel X-750
Initial Thickness	0.178"	0.179"
Compressed Thickness	0.122"	0.121"
Total Springback	0.011"	0.013"
Springback to Leakage (2500 psig test press.)	0.0038"	0.0078"

HT Inc X-750 has twice the usable recovery over 316LSS.

Full Scale Test Results (Averaged) on Reactor Coolant Pump Gaskets (40-5/8 x 42 x .175)

Successful Application 3

An ethylene manufacturer discovered vermiculite's resistance to oxidation and the resiliency of heat treated Inconel X-750 after a test application and has been using them both in spiral wound gaskets in their external crossovers since September 2002.

Product:	Exfoliated vermiculite SWG, HT Inc X-750 winding
Temperature:	1,300°F maximum
Pressure:	30 psig
Since:	September 2002

PROCESS: Radiant Outlet / TLE Inlet

The cracked gas must pass from the radiant coil to the quench in a manner so as to minimize residence time at temperature, and thus avoid secondary reactions that can degrade olefin yields. At the same time, flanges are desirable at the radiant coil/TLE transition for cleaning, inspection and other maintenance related purposes, such as coil repair or replacement. The TLE will normally have a removable "inlet cone" that is flanged at both ends.



The inlet flange of the cone is normally directly coupled to the radiant coil outlet while the upper "body flange", also known as the "girth flange", is bolted to the inlet channel. Both flanges are under considerable mechanical stress, as they are supporting the dead weight of some portion of the radiant coil.

While the pressure at the coil outlet is kept as low as possible, normally 10 – 20 psig, the coil outlet temperature required for the cracking reaction will be in the range of 1500 – 1650°F necessitating the use of bulky flanges.

Internal refractory lining can be used at both the inlet flange and the body flange to reduce the operating temperature of the joint significantly below the flowing process temperature.

Transfer Line Exchanger Inlet Cone (2)

The cracked gas will be high in steam and H_2 and will thus normally be a reducing atmosphere. However, the intermittent decoking will expose the radiant outlet flange to a steam air mix and high temperature oxidizing atmosphere that may also see erosive coke fines. Also consider that even though the internal media may be reducing, exposure to the outside air can still cause oxidation. Sulfur will be present in both modes, predominantly in the form of H_2S .

Thermal cycling will be over an extreme range (ambient to 1650°F), and radiant outlet and associated flanges on the TLE inlet cone and body flange can also be large diameter joints, further complicating the gasket sealing requirements.

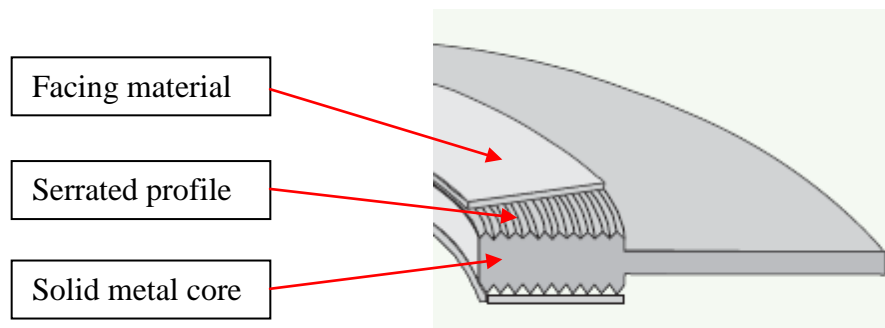
Recommended Gasket

These are the most difficult sealing applications on a cracking furnace. Critical joints require special focus on not only the gasket and process conditions but also on installation. Even the best gasket will still leak if not installed with an evenly distributed, adequate level of load. The following items are critical along with the gasket: bolt tightening sequence, uniform and adequate bolt stretch, fastener condition, and using tools with high level of accuracy. For some guidance in this area refer to *ASME PCC-1-2010: Guidelines for Pressure Boundary Bolted Flange Joint Assembly*.

Proper gaskets in this service would use exfoliated vermiculite, due to the extreme temperature requirements. A spiral wound gasket with heat treated Inconel X-750 winding wire is an ideal choice for extreme thermal cycling.

On flanges where available bolt load is limited, a kammprofile (serrated solid metal with a facing material) can be a useful alternative. The minimum required seating stress is less than half that of a spiral wound gasket. Therefore, it allows for sealing on non-standard flanges where bolting is inadequate to seal or maintain a seal with a spiral wound gasket. Kammprofiles do not respond as well as heat treated Inconel X-750 in cycling but because they require less seating stress than a spiral, many have found success with them in cycling applications especially with a higher initial load applied at assembly.

The kammprofile's solid metal core also eliminates some common pitfalls of a SWG. They do not buckle. They do not spring apart. Handleability is greatly improved especially on large diameters where spirals tend to come apart from flexing, poor handling, or when trying to install in flanges with poor accessibility. Kammprofiles do not require a compression stop and essentially cannot be crushed. They are advantageous on narrow flange widths where an inner ring cannot be accommodated with a spiral. (Kammprofiles inherently do not require an inner ring.) They are also less sensitive to bolt up inconsistencies.



Cross-section of kammprofile style gasket

Successful Application 4

Beginning in November 2005, BASF Port Arthur converted all TLE inlet and outlet cone gaskets to kammprofiles faced with exfoliated vermiculite after a successful in-service test.

Product:	Exfoliated vermiculite kammprofile
Temperature:	1,500°F
Pressure:	65 psig
Since:	November 2005

Successful Application 5

Beginning September 2002, this ethylene producer converted all inlet flanges to the primary TLEs to exfoliated vermiculite filled spirals with heat treated Inconel X-750 winding wire. The prior gaskets using graphite filler oxidized after 6 months in service, causing flash fires, downtime, and lost productivity costing "millions".

Product:	Exfoliated vermiculite SWG, HT Inc X-750 winding
Temperature:	Approximately 1,650°F
Pressure:	30 psig
Since:	September 2002

Successful Application 6

One particular ethylene producer was plagued with weekly fires due to graphite oxidation and extreme thermal variation across the flange face because the TLE was without refractory lining. After several iterations of gasket metallurgy and filler materials including ceramic and mica, the final construction was a carrier ring of an exotic alloy with HT Inconel X-750 winding wire and exfoliated vermiculite filler for the spiral wound. This design is employed on 10 furnaces.

Product:	Exfoliated vermiculite SWG, HT Inc X-750 winding
Temperature:	1545°F process; 1,650°F decoke

Pressure: 65 psig
Since: 2003

PROCESS: Effluent Transfer Line Piping

The cracked effluent will pass to the main transfer line and quench sections of the plant at low pressure via large diameter piping. The temperature cycling of this effluent piping between the End-of-Run (EOR), Start-of-Run (SOR), decoking, and ambient startup will be very significant. The thermal expansion and associated movement of this large piping will result in significant stresses. Layout, stress and support design for the effluent piping involves some of the most difficult and sophisticated engineering in an ethylene plant.

The effluent piping will see oxidation/reduction cycling because of the decoking operation and sulfur will be present in the effluent, mainly in the form of H₂S. The fluid will be above the auto ignition temperature at any point upstream of the oil quench for liquid crackers. For gas crackers, the TLE outlet temperatures will normally be in a range below the associated auto ignition temperature.

Recommended Gasket

Because of the large diameter flanges involved, the difficult service conditions, and the extreme fouling nature of the fluid, kammprofile gaskets are favored for these applications. Condensation of heavy tars at the inside surface of effluent piping and associated joints will cause coke formation at the inside gasket sealing surface. To prevent or reduce coke formation, kammprofile inner diameters can be designed to the flange bore as long as there is enough bolt load to adequately seal the additional gasket area. Consult your gasket manufacturer for the best design.

As the transfer line will normally be a large diameter piping system spanning the entire heater row and flowing to the compressor house, use of a fire safe gasket such as graphite or vermiculite should be considered to avoid loss of containment and de-inventory of the hot section in case of an external fire. Vermiculite is inherently fire safe ⁽⁷⁾ due to its inorganic composition and is certified to API 607 ⁽⁸⁾ (1,200°F exposure for 30 minutes).

FUEL: Fuel Gas Piping

Fuel to fire the cracking furnaces is normally made up of a H₂/methane mix recovered from the cracked gas during fractionation. It will normally be returned to the furnaces at ambient temperature and roughly 50 psig in the fuel header. Since NFPA 54 applies only to furnaces and boilers located inside buildings, cracking furnaces are not normally required to

comply with the National Fuel Gas Code. However, NFPA 54 encourages the use of fire resistant gaskets in fuel distribution piping to address the potential risk of flange leakage feeding methane to a fire in the area containing the fuel piping.

Recommended Gasket

As the operating conditions of the fuel piping are not severe – low temperature and pressure, no thermal cycling, no oxidizing or reducing service, below the auto ignition temperature – a low cost spiral wound gasket is normally specified. If external fire exposure is judged to be a significant factor or concern, selection of a fire-safe material per API or PVRC FITT is recommended, i.e. graphite or vermiculite.

STEAM: High Temperature Steam, Boiler Feed Water Piping

Certain plants, usually those designed for very heavy feed, may superheat the Dilution Steam to a very high temperature in a separate coil, and then inject it. Not all steam in an ethylene plant is clean deaerated steam and some steam services can also be oxidizing.

Exfoliated vermiculite gaskets have replaced graphite in hundreds of steam flanges beginning at temperatures as low as 600°F and covering industries from refining to power generation to pharmaceutical. Among the dozens of documented successful applications, two for the ethylene industry are listed below.

Successful Application 7

This refining and petrochemical end user installs exfoliated vermiculite kammprofiles or spiral wounds throughout their plant in applications exceeding 750°F. In their ethylene manufacturing units, they have been using exfoliated vermiculite faced kammprofiles in their dilution steam injection flanges since early 2002.

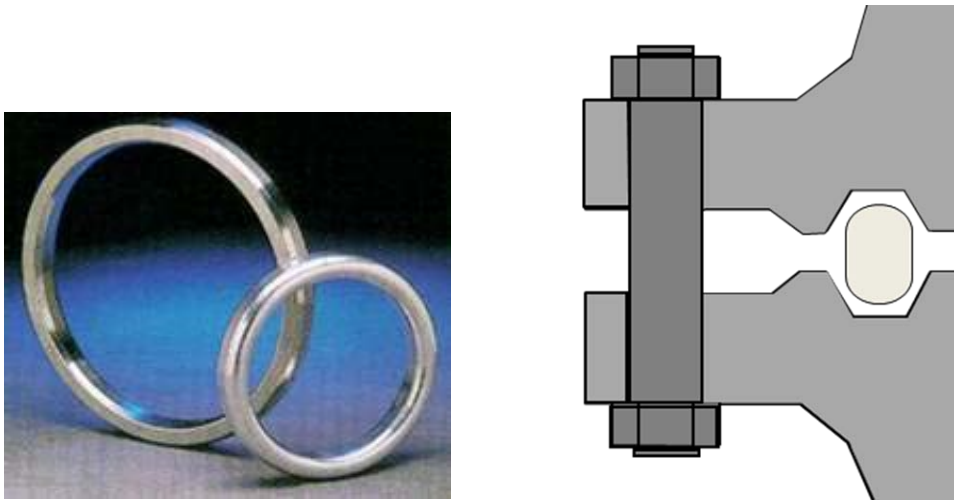
Product:	Exfoliated vermiculite kammprofile
Temperature:	1,000 – 1,100 °F
Pressure:	25 – 60 psig
Media:	Superheated Steam
Since:	Early 2002

Successful Application 8

Since September 2002, this Ethylene manufacturer in the Gulf Coast has been using exfoliated vermiculite gasket material in their dilution steam injection flanges. They started with spiral wounds and on occasion switch to kammprofiles on larger flanges where better handleability is desired.

Product: Exfoliated vermiculite SWG and kammprofile
Media: Superheated Steam
Since: September 2002

Modern cracking furnace designs will typically incorporate 1,500 to 1,800 psig (100 – 125 bar) steam loops in the waste heat recovery section of the furnace convection surface. Steam piping can be designed to either B31.1 or B31.3 codes, and flanges in these services are historically Ring Type Joints (RTJ). However, before deciding whether to use RTJ flanges, it's important to recognize that they may be problematic over time and alternatives are available.



Octagonal and Oval RTJ gaskets and an Oval RTJ gasket in a flat bottom groove

RTJ gaskets are for high pressure and high temperature services but they have no recovery and are therefore not good for cyclic conditions. An extremely high level of stress is required to compress and seal a ring joint gasket which can be associated with certain risks.

When an RTJ is bolted up, a very high surface stress is generated between the RTJ gasket and the flange groove. This stress causes plastic deformation – permanent deformation of the metal. The RTJ gasket hardness increases due to the work hardening after it is compressed. The difference in initial hardness between the flange and gasket should be 15-20 Brinell. If an RTJ gasket is reused (a common mistake in the field), it eventually becomes harder than the flange causing cracking and permanent damage to the flange, typically in the groove itself. RTJ gaskets should never be reused. If this flange and gasket design is chosen, this point must be stressed.

Depending on material selection (of the piping, flange, and gasket components) and if a corrosive environment is present (Chlorides, Hydroxides, Sulphides, Hydrogen, etc), the RTJ groove might be susceptible to stress corrosion cracking or hydrogen embrittlement due to the extreme loads present. Material selection is important to preventing this.

One way to reduce the high stresses that influence corrosion is to use a spiral wound or kammprofile which are manufactured for flanges up to Class 2500 and are able to handle the pressure associated with those flange ratings. Octagonal RTJs can also be made with a serrated profile and layered with soft facing material in the area that contacts the flange to help reduce localized stresses. This design is known as a Kamm-ORJ. As opposed to graphite, vermiculite is non-conductive and can be used as the facing material if chloride-related corrosion is a concern.

Improved Assembly

Gasket selection is a key first step to eliminating downtime and extending furnace runtime and overall life. Unfortunately, even if a gasket is chosen properly, a poor installation will still cause the joint to leak. Even bolt load and sufficient gasket stress are mandatory for achieving a leak free joint. On all bolted connections, critical joints in particular, it is important to stress proper installation (uniform gasket stress by utilizing a proper tightening sequence) and adequate gasket stress. Note that achieving minimum pre-load is not always enough. High temperature joints will see extensive bolt relaxation causing a reduction in bolt stress and ultimately reduced gasket stress. Adequate preload must be applied to overcome these. As long as the gasket, bolts and flanges are not over-stressed, higher gasket stress means a tighter joint with lower emissions.

Increasing the accuracy of the tools being used will reduce the chance of leaks. Unfortunately, the most common tools in a plant are also the most inaccurate – hand and impact wrenches. On critical joints, consider upgrading to hydraulic torquing, tensioning, or (at minimum) ultrasonics to check bolt stretch. For guidance on improving assembly, refer to *ASME PCC-1-2010 Guidelines for Pressure Boundary Bolted Flange Joint Assembly*.

References:

- (1) Data from The Engineering ToolBox, www.engineeringtoolbox.com*
- (2) Graphics courtesy of Alstom Power Energy Recovery GmbH*
- (3) Per Paragraph 3.2.5 of ASME Standard B16.20 - 2007 Metallic Gaskets for Pipe Flanges: Ring-Joint, Spiral-Wound, and Jacketed*
- (4) Developed by Flexitallic® under the trade name Thermiculite™*
- (5) Fluid Sealing Association STANDARD FSA-G-604-07 Oxidation Test Standard for Flexible Graphite Gasket Materials*
- (6) Developed in conjunction with Flexitallic®*
- (7) API 607 Fire Test reports are for Thermiculite™ and available upon request from Flexitallic®*
- (8) API Standard 607 Fire Test for Quarter-turn Valves and Valves Equipped with Nonmetallic Seats. Thermiculite™ tested to the 4th Edition.*