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A GUIDE TO GASKETING PRINCIPLES AND BEST PRACTICES

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The Fluid Sealing Association (FSA) is an international trade association founded in 1933. Membership today represents over 85% of the manufacturing capacity for fluid sealing devices in North America. Our membership is most heavily concentrated in North America, but also includes a number of companies in Europe, Asia and South America. Now as international trade grows throughout the world and creates a need for universally accepted standards, we have become international in scope.

ABSTRACT

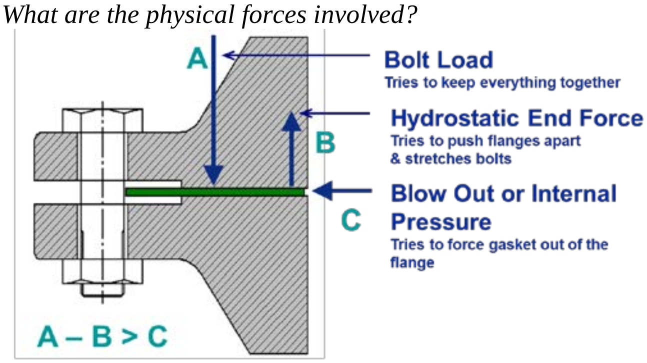
Leakage from static joints has been found to be a major contributor of emissions in many plants. With the collaboration from the world's leading gasket manufacturers, the Gasket Division of the Fluid Sealing Association has created a training presentation that will assist all personnel dealing with modern gasketing applications and issues. What may appear to be a simple and easy to install component actually requires knowledge and understanding of its working principles and characteristics. This paper will start with basic gasketing concepts and then proceed into details regarding installation & assembly. It will also address equipment and fastener considerations, material selection and common uses. Finally, field failure analysis techniques will be explained so that errors in selection or installation procedures can be corrected. As the original format of this paper is based on a digital slide presentation, the format that follows will follow that layout.

GASKETING BASICS

What is a gasket? A gasket is any deformable material that is used to create a static seal and maintain that seal under the various conditions of a mechanical assembly.

What is a seal? A seal is created by compressing the gasket material, causing it to deform and flow into the imperfections of the sealing surfaces.

What are the physical forces involved?



What is the gasket responsible for?

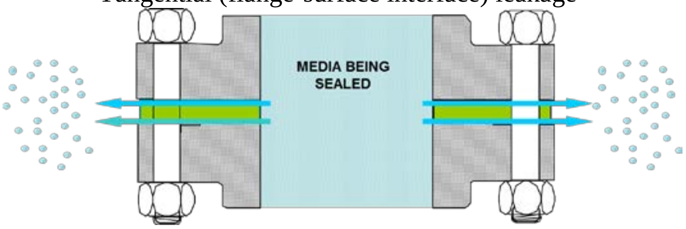
- Maintaining a seal for an indefinite period of time
- Chemically resist the fluid being sealed
- Withstand system temperatures and pressures without serious impairment
- Resist creep and crushing under load
- Must not contaminate the fluid
- Will not promote corrosion
- Be easily removed

The integrity of a bolted joint depends on:

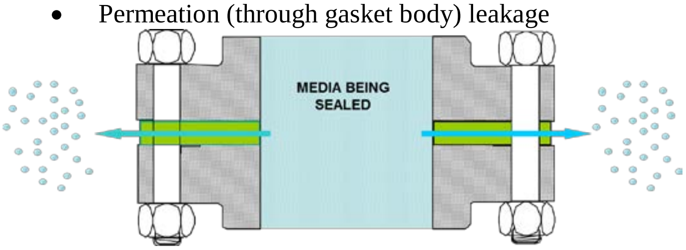
- Selection of the correct components
- Careful preparation, cleaning, and installation
- Correct bolt tightening and loading

How/where do gaskets actually leak?

- Tangential (flange-surface interface) leakage



- Permeation (through gasket body) leakage



Leaks are:

- Expensive
    - Lost production
    - Increased maintenance
    - Fines
- Dangerous
    - Health and safety concerns
- Preventable
    - Installation techniques are very important

Gaskets don't fail, joints do.

- Low bolting torques (inadvertently or by design)
- Excessive bolt loads (no torque control)
- Weak fastening materials
- Inadequate lubrication of fasteners
- Poor flange design and weak materials
- Uneven compression
- Poor gasket cutting and/or storage
- Uncontrolled installation practices

Hardware considerations - flanges:

- Type (RF, FF, T&G, RTJ)
- Class (ASME, ANSI, DIN, BS, ISO, API, AWWA)
- New or Used?
- Surface Condition (Roughness, Tool Marks)
- Surface Flatness
- Surface Finish (according to gasket manufacturer's recommendations)
- Material (Metallurgy, Polymer, Coatings)

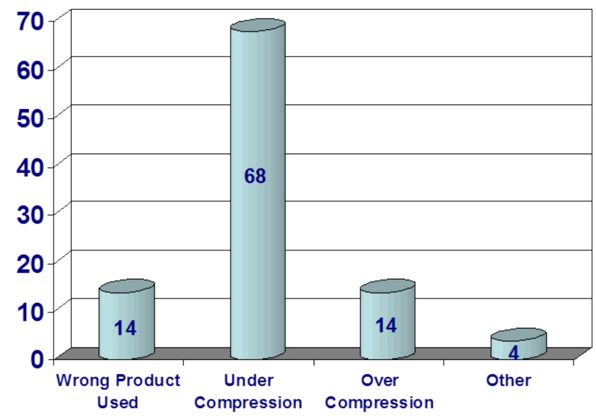
Hardware considerations – fasteners:

- Material/Grade
- Strength Rating
- New (recommended) vs Used (common)
- Clean, inspect, and replace anything defective
- Anti-corrosion Coatings
- Use hardened steel washers
- Lubrication

INSTALLATION AND ASSEMBLY

Approximately 75-85% (taken from FSA Sealing Sense, January 2008. Pumps and Systems Magazine) of all bolted flange joint failures relate to uncontrolled gasket installation and joint assembly practices.

Failure analysis of 100 gaskets:



Gasket installation procedures: A guide to successful gasket installation

Successfully sealing a flanged connection is dependent upon all components of a well-designed flange system working well together. This installation overview provides guidance to maintenance operators, engineers, and fitters, to ensure successful gasket installation and assembly of bolted flange connections. It is intended to complement other plant-approved installation procedures

Specific tools are required for cleaning and tensioning the fasteners. Additionally, always use standard safety equipment and follow good safety practices.

- Calibrated torque wrench, hydraulic, or other tensioner
- Wire brush (brass if possible)
- Helmet
- Safety goggles
- Lubricant
- Other plant-specified equipment

1a. Clean

- Remove all foreign material and debris from:
    - Seating surfaces
    - Fasteners (bolts or studs)
    - Nuts
    - Washers
- Use plant-specified dust control procedures

1b. Examine

- Examine fasteners (bolts or studs), nuts, and washers for defects such as burrs or cracks
- Examine flange surfaces for warping, radial scores, heavy tool marks, or anything prohibiting proper

gasket seating
- Replace components if found to be defective. If in doubt, seek advice.

2. Align flanges
- Align flange faces and bolt holes without using excessive force
- Report any misalignment

3. Install gasket
- Ensure gasket is the specified size and material
- Examine the gasket to ensure it is free of defects
- Carefully insert the gasket between the flanges
- Make sure the gasket is centered between the flanges
- Do not use jointing compounds or release agents on the gasket or seating surfaces unless specified by the gasket manufacturer
- Bring flanges together, ensuring the gasket isn't pinched or damaged

4a. Lubricate load-bearing surfaces
- Use only specified or approved lubricants
- Liberally apply lubricant uniformly to all thread, nut, and washer load-bearing surfaces
- Ensure lubricant doesn't contaminate either flange or gasket face

4b. Install and tighten fasteners
- Always use proper tools: calibrated torque wrench or other controlled tensioning device
- Consult your gasket manufacturer for guidance on torque specifications
- Always torque in a cross bolt tightening pattern
- Tighten the nuts in multiple steps in a cross pattern
  - Step 1: Tighten all nuts initially by hand (Larger bolts may require a small hand wrench.)
  - Step 2: Torque each nut to approximately 30% of full torque
  - Step 3: Torque each nut to approximately 60% of full torque
  - Step 4: Torque each nut to full torque, again using the cross bolt tightening pattern. (Large diameter flanges may require additional tightening passes.)
  - Step 5: Apply at least one final full torque to all nuts in a clockwise direction until all torque is uniform. (Large diameter flanges may require additional tightening passes.)

5. Retightening
- *Caution:* consult your gasket manufacturer for guidance and recommendations on re-tightening
- *Do not* re-torque elastomer-based, asbestos-free gaskets after they have been exposed to elevated temperatures unless otherwise specified
- Re-torque fasteners exposed to aggressive thermal cycling
- All retorquing should be performed at ambient temperature and atmospheric pressure
- Consult with the gasket manufacturer for specific recommendations on retightening under "hot" conditions

Gasket installation summary:
- Clean and inspect all load bearing surfaces for defects
- Follow some sort of assembly and torquing procedure (eg. ASME PCC-1)
- Use a cross-pattern torqueing procedure
- Consult the gasket manufacturer for material specific recommendations

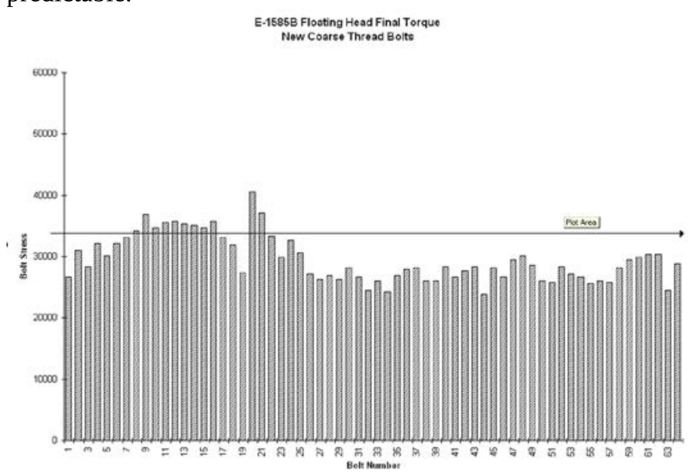
FASTENERS

Because a tight bolted flange connection is directly dependent on the fasteners…
- Use new bolts every time
- Use the strongest bolt every time
- Use proper lubrication every time
- Consider the flange (yield) strength every time

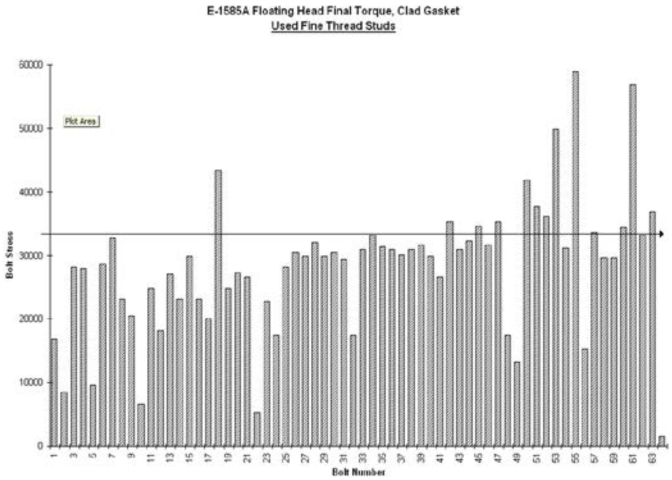
What is the function of a bolt/fastener?
- To hold things together
- To transfer load

You must also take into consideration:
- The overall purpose of the fastener
- Thickness and material of the material being joined
- The configuration of the overall joint
- The operating environment
- The type of loading

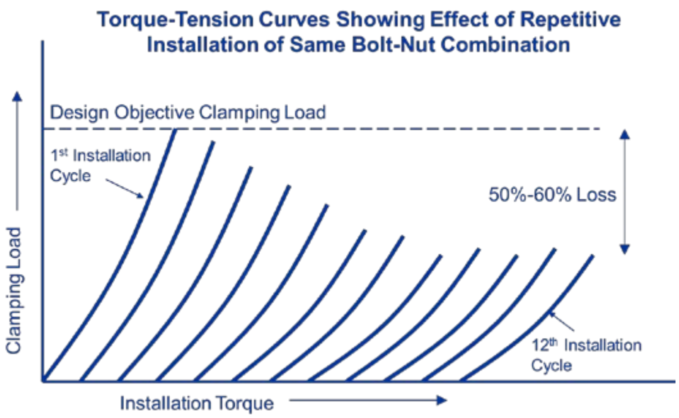
The following graph depicts the evenness of the bolt stress or strain that creates and maintains the compression on the gasket. Since these bolts are new, their performance is even and predictable.



Due to previous torquing and the effects that temperature can have on even the strongest bolting materials, the following graph depicts the tremendous differences in bolt stress among used bolts, even when installed properly.



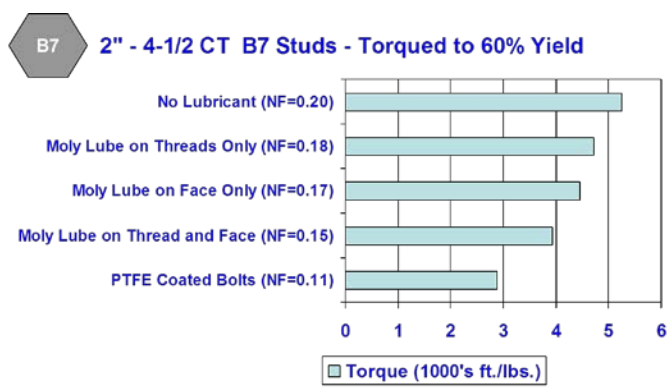
Another factor often overlooked is that the installation-torque value normally specified for a bolt-nut combination is essentially valid only for the initial assembly of the fastener. Continued use of the same bolt-nut assembly tends to alter and change the coefficient of friction properties of the nut, resulting in lower preload in the bolt after as few as five installations. This graph illustrates this effect with data from other tests showing that preload loss for the same fastener combination can range as much as 30 to 60% after 10 installations. The following graph has been adapted from "The Standard Handbook of Fastening and Joining" Robert O. Parmley Editor-in-Chief. ed1996.



Why use stronger bolts? Here are the yield values (we never recommend over 80% of total yield as a safety factor) and the corresponding torque values for 5 common ¾-10 bolting materials. You can clearly see that standard stainless steel bolts (B8 Class I) are a problem. We typically recommend Grade B7 and Grade 8 bolts and studs with their corresponding nuts and hardened flat washers. If there is a corrosive atmosphere, then ptfe coated B7 or B8 Class II materials are recommended. Another reason for using the ptfe coated materials is that the ptfe acts as a lubricant.

Size	Grade	80% Yield Strength*, psi	Torque, ft-lbs
¾" - 10	Grade 5 HHCS	73,600	307
	Grade B7	84,000	351
	Grade 8 HHCS	104,000	434
	Grade B8 Class I SS	24,000	100
	Grade B8 Class II SS	80,000	334

As much as 60% - 70% of the bolt stress can be lost due to friction between the bolts, nuts, washers, and load bearing surfaces. We refer to this sum of friction values as “nut factor” (NF) when calculating recommended assembly torque values. All of these surfaces should be well lubricated. This slide depicts the different torque values needed to obtain 60% yield of the same B7 stud with differing lubrication areas. If you do not lubricate properly, even if torque wrenches are used, you are guessing at the load being applied to the gasket. It is also important to note that when using PTFE coated bolts, it is critical to follow the recommended torque values for such.



Fasteners summary: Fastener materials are some of the least expensive items that are purchased, yet they are absolutely critical in how our gaskets perform. And when there is a leaking flange, the gasket, not the bolts, almost always gets the blame. Failure analysis has proven that poor installation and poor fasteners are responsible for more than 75% of leaks. Gaskets will perform only as good as the fasteners and the method of installation. Gaskets don’t fail…joints do. It’s a system → bolts-gasket-flange.

MATERIAL SELECTION

Considerations:

- Application requirements and restrictions
- Environmental compliance and considerations
- Financial requirements and restrictions
- Material group/class considerations

Application requirements and restrictions:

- Tightness – allowable leakage rate
- Temperature – max/min/continuous, thermal cycling
- Media – gas, liquid, steam, alkalis, acids, ultra-pure, FDA, oxygen
- Pressure – min/max, constant, surges
- Hardware – flange design, flange material, new/old, RF, FF, available gasket load
- Size – 3” and 8” Class 150 loading issues, large diameter flatness

Environmental compliance and considerations: Environmental requirements and restrictions are more important these days than ever before. If your company is not bound by legislation it can often be bound by internal protocols such as ISO 14000, BS 7750, and EMAS (Eco-Management and Audit Scheme) or even public groups.

- Clean Air Act – EPA
- IPPC Directive – BREF documents
- OSHA
- TA Luft
- Kyoto
- End-user qualification requirements
- Action groups
- Publicity

Note: IPPC Directive (Integrated Pollution Prevention and Control): The IPPC Directive has been in place for over 10 years and the Commission has undertaken a 2 year review with all stakeholders to examine how it, and the related legislation on industrial emissions, can be improved to offer the highest level of protection for the environment and human health while simplifying the existing legislation and cutting unnecessary administrative costs. BREF documents are Best available techniques REFerence documents

Financial requirements and restrictions: There are many financial requirements and restrictions to consider and many of these involve inputs from several departments. It is always beneficial to consider long-term costs when selecting any material but there are times where immediate financial constraints overrule this approach.

- Gasketing products come in various quality grades, types, and price ranges. As most things in life, the more the product costs, the better it performs and the longer it lasts (not always, but more often than not).
- Many end-user companies have supply contracts that are set on specific financial parameters. This may limit the type of material that can be used due to its cost.
- One factor not often considered is lost production costs. If a lower quality/cost material is used solely for financial reasons, a premature failure or frequent replacements may end up costing significantly more than what a premium material may have cost from the onset.
- Similarly, repeat installation and replacement costs more money than what is typically realized.

Material group/class considerations:

- Chemical Compatibility
- Thermal Stability
- Blow-Out Resistance
- Gas Permeability
- Conformability to Surface Imperfections
- Torque Retention
- Creep Relaxation
- Non-contamination and Particulation
- FDA and other Regulatory Compliance

Now you must enter the gasketing world: Many people don’t realize the vast array of gasketing materials available. This is a fairly comprehensive list of material groups that are common. When you combine this list with the number of manufacturers producing them and the number of styles in each group from each manufacturer, you literally end up with multiple thousands of gasketing choices available to you. It becomes a little overwhelming.

- Asbestos
- Non-Asbestos
- Elastomers
- Carbon Fiber
- Flexible Graphite
- PTFE
- Filled PTFE
- Miscellaneous (paper, cork, etc.)
- Expanded PTFE
- Microcellular PTFE
- O-Rings
- Envelope Gaskets
- Spiral Wound
- Metal Reinforced
- Corrugated Metal Core
- Ring Joints
- Form-in-Place

So how do you choose which gasket is right for you?

- On your own, the right choice is very complicated
- Groups, discussion boards
- Gasket Manufacturer’s sites
- Equipment Manufacturer’s sites
- Trade Associations
- Internal specifications
- Supplier/engineering contracts
- History

On your own, overwhelming is probably an understatement. There are simply too many inputs of information available that someone would have to consider. So then how do you make the best selection?

In order to choose the right material

- Get the manufacturer’s involved
    - They are the technical experts and do not want to see misapplications of their material
    - The FSA has a data sheet that can be completed and submitted to the manufacturer for a complete analysis of your application
    - They can provide you with recommendations based on similar applications with other users

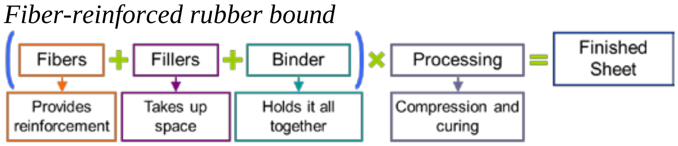
- o …but, they can only make recommendations based on the accuracy and completeness of the information you provide

COMMON INDUSTRIAL GASKET MATERIALS

Homogeneous rubber sheet

- Many types of elastomeric polymers
    - o NBR, SBR, EPDM, FKM, FFKM
- Inorganic and/or carbon fillers used to reinforce and increase tensile strength
    - o Required for the integrity of the product
- Finished sheets come in a variety of hardness expressed by the Shore A hardness scale
    - o The lower the number the softer the material
- Media compatibility depends on polymer type and fillers
- Rubber sheet compound constituents vary
    - o NBR sheet from manufacturer "A" may not be the same as from manufacturer "B"
- Ideal as full face gaskets with flat faced flanges
    - o Low compression, low load to obtain a seal
- Can be crushed in a raised face flanges
- Prevalent in water systems

Fiber-reinforced rubber bound



- Many types of reinforcing fibers being used
- NBR and SBR rubber are most common binders
- Vast mixology of additional fillers
- Wide range of compressibility and recovery
- Coatings for anti-stick properties
- Anti-swell and swell technologies
- Wide array of media compatibility
- Generally limited to Class 150 and 300 systems
- Gasket factors vary
- Torque requirements are specific
- Original flange design can limit use

PTFE (virgin, filled, expanded)

- Excellent sealability characteristics
- Withstands aggressive chemicals
- Various fillers and processes to reduce gasket creep
- Conforms well to flange/surface irregularities
- Very good for bolt stress limited systems
- Very easy to cut and handle
- Generally limited to Class 150 and 300 systems
- Gasket creep can be a concern
- Typically limited to 500°F continuous

Flexible Graphite (homogeneous, laminated)

- Very good for high temperatures
- Purity levels can be controlled for specific applications
- Metallic cores improve robustness
- Very good media compatibility
- Highly compressible and conformable to imperfect surface conditions
- Must be careful of oxidizing environments
- Impurities can cause quick deterioration
- Can cause media contamination through particulation
- Graphite is easily marked and damaged

Semi-metallic: spiral wound gaskets

- Wide range of temperature and pressure limits
- Density profile can be varied to accommodate available bolt loads
- Inner rings are now recommended by ASME B16.20
- Improves performance and eliminates inward buckling issues
- Various filler materials available to satisfy temperature and media compatibility requirements
- Wide array of metallurgy available
- Common marking system makes identification easy
- Inward buckling can be an issue with no inner ring
- Required seating stress is typically high
- Large sizes must be carefully handled as they can be bulky and heavy
- Design tolerances can allow for sealing element separation from the carrier ring

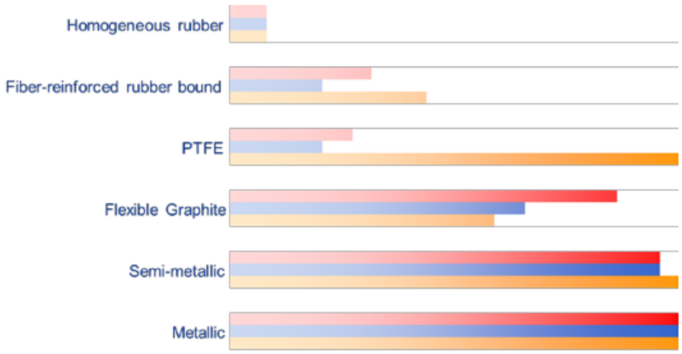
Semi-metallic: Serrated Metal Core with Soft Facing Material (Kammprofile)

- Robust design good for high and cycling temperature and pressures
- Excellent sealing characteristics
- Good in low available stress applications
- Metallurgy and facing options allow vast media sealing capabilities
- Good bolt torque retention
- Design provides low creep results
- Can be refaced

Metallic: Ring Type Joints (RTJ)

- Typically used for very high pressure and temperature applications
- Standard designs/dimensions to ASME B16.20 and API Specification 6A
- Requires very robust specialized flanges
- Flange surface finish is very important
- RTJ metal hardness in critical

A general guide to product capabilities: The following charte is intended to bring all the previous information together in a very general format. It is by no means to scale or all inclusive. The 3 scales indicate temperature (top bar)), pressure (middle bar) and chemical resistance (bottom bar). The scale moves from low/weak at the left to high/aggressive on the right. It should be noted that in order to achieve any maximum rating, the appropriate components within any given product type must be selected. This makes it very important to get to know your manufacturer.



In order to make the best choice and avoid misapplication, provide as much information as possible to your gasket manufacturer.

- General application description/type
- Temperature (minimum, maximum, continuous)
- Pressure (minimum, maximum, normal)
- Thermal cycling (yes/no, range)
- Vibration (yes/no, frequency)
- Pressure stability (stable, intermittent, +/-)
- Installation setting (new, existing)
- Media being sealed (pH, concentration, specific gravity)
- Media state (liquid, gas, mixed)
- Suspended particulates (yes/no, size)
- Flanges (new/old, RF/FF, surface finish, groove type, class)
- Fasteners (material, grade, diameter, number, washers)

FIELD ANALYSIS AND TROUBLESHOOTING

Before doing anything in the field, make safety a number one priority!

- **Is the equipment hot?**
- **Is the equipment under pressure?**
- **What is the media being sealed?**
- **Wear goggles and other protective items.**
- **Wear a safety helmet.**
- **Follow plant safety procedures at all times, including elevated locations.**

Field analysis requires some detective work:

- Verify gasketing material in the joint
- Verify system media
- Verify temperature and pressure
- Determine if pressure or temperature spikes are possible
- Determine bolt grade, torque method, torque level, lubrication, etc.
- Inspect seating surface of the gasket
- Check the impressions left by the flange on the gasket
- Check for gasket treatments or coatings
- Check for chemical attack
- Measure gasket thickness all the way around seating area (I.D. and O.D.) and compare variations

Important note: Most full face flanges do not allow for adequate gasket compression on full face gaskets. Use caution and consult your gasket manufacturer for assistance.

SUMMARY

The integrity of a bolted joint depends on

- Selection of the correct components
- Careful preparation, cleaning, and installation
- Correct bolt tightening and loading

Contrary to common belief, gaskets rarely fail.

When dealing with gaskets **ALWAYS** consult with the manufacturer and leverage their expertise.

For more information on everything sealing, please visit www.fluidsealing.com