Wonderful Institute for
Sustainable Engineering

Materials of Construction

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Materials of Construction

Materials of Construction refer to the materials used for equipment and facilities of chemical processes, comprising production, handling, transportation, and storage

Primary considerations for material determination are chemical compatibility, operating conditions, and process requirements

The selection of appropriate materials includes assessment of safety, economic costs, and process/product quality

Materials of Construction

This is a comprehensive topic

This safety meeting will give an overview of the topic: types of materials, chemical and process compatibility, and how to select appropriate materials of construction

The focus will be on laboratory experiments and processes

Terms

- Material = what equipment is made of
- Medium = process fluids, solids

Considerations

Health and Safety	Economics	Process/Product Quality

• Human and Environment
  • Toxic materials
  • Harsh conditions
• Consider both catastrophic hazards and long-term exposure
	• Initial costs
	  • Equipment
	  • Installation
	• Long term costs
	  • Maintenance
	  • Replace/repair
	  • Mitigation
		• Process requirements
		  • Desired chemicals in use
		  • Operating conditions
		• Product
		  • Quality
		  • Contaminants

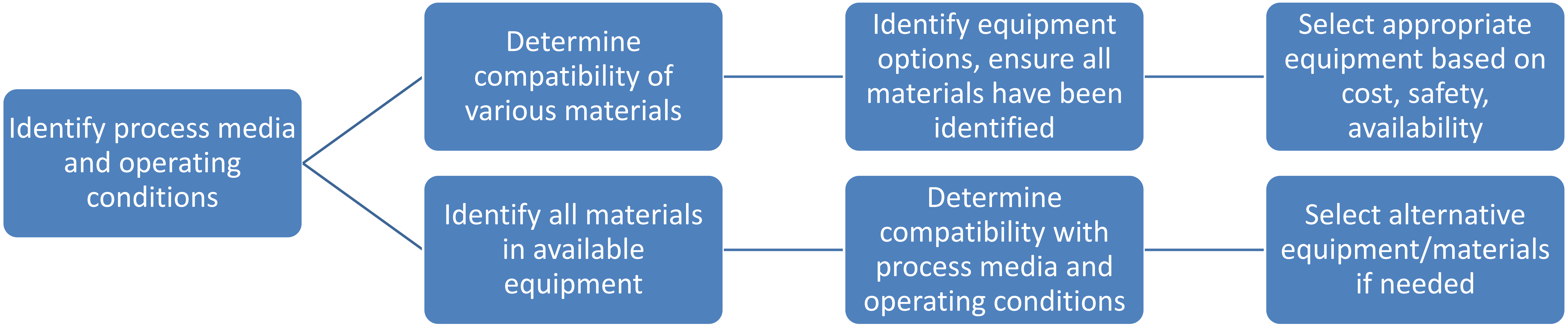
Challenges

- Materials want to return to most stable form – not always the most useful form
- Identifying all materials of construction present
- In a laboratory environment
  - Flexible process systems are preferable since work can change quickly
  - New mediums or processes in extreme conditions with unknown compatibility are tested
- Availability of data can be limited

Selecting MOCs

Process is different depending on whether equipment is already available or needs to be purchased.

In laboratory environments, equipment is often repurposed for new experiments



Material Identification and Classification

1. Material Classification

Materials behave very differently depending on their inherent characteristics

2. Material Identification

Identify all materials used in a process – not always obvious

Material Classification

There are four major classifications for the materials used for structures and components

Materials can belong in more than one category

Metals
- Ferrous Alloys
- Aluminum Alloys
- Nickel Alloys
- Copper Alloys
- Titanium Alloys

Polymers
- Thermoplastic
- Thermosetting
- Elastomers

Ceramics
- Glass
- Cement
- Clay
- Refractories
- Abrasives

Composites
- Particulate
- Fibrous
- Laminated

Metals

- Composition
  - Ferrous Alloys
    - Most common – abundant, easy to produce, versatile, inexpensive
    - Low corrosion resistance
  - Other Alloys
    - Aluminum, Nickel, Copper, Titanium are the most common
    - Vary in cost and properties – usually used when ferrous alloys are not compatible
- The alloying ingredient may be a factor affecting corrosion, impurities, etc.
- How the metal is processed can affect corrosion

Ferrous Alloys

- Base Element = Iron
  - Advantages: abundant, easy to produce, versatility
  - Disadvantage: low corrosion resistance
- Carbon Steel
  - Iron with carbon (<2%)
  - Used for machine parts, sheet metal, wire, axles, gears
- Cast Iron
  - Iron with carbon (>2%)
  - Suitable for casting
- Low-Alloy Steel
  - Less than 8-10% total alloying ingredients
  - Used for pipes, vehicles, structural steel, pressure vessels, rail lines
- Stainless Steel
  - Austenitic – best corrosion resistance and mechanical properties
  - Ferritic – good corrosion resistance, less expensive
  - Martensitic – strongest, lower corrosion resistance
  - Used for industrial equipment, surgical instruments,

- 304 SS
- 310 SS
- 316 SS

Stainless Steel

- AISI 4140
- AISI 4340
- AISI 6150
- AISI 8620

Low-Alloy Steel

- Low-carbon
- Medium-carbon
- High-carbon

Carbon Steel

- ASTM A159
- ASTM A536

Cast Iron

Other Alloys

- Can be more corrosion resistant, usually more expensive than ferrous alloys
- Aluminum
  - Lightweight, corrosion resistant
  - Alloying elements include: copper, manganese, silicon, magnesium, zinc
- Nickel
  - High temperature and corrosion resistance
  - Alloying elements include: copper, chromium, and iron
- Copper
  - Electrically conductive, good corrosion resistance, easy to form and cast
  - Alloying elements: zinc, tin, nickel, aluminum, beryllium
- Titanium
  - Light, strong, extremely corrosion resistant, high cost
  - Alloying elements: aluminum, tin, vanadium

- Pure
- 3000 series
- 5000 series
- 6000 series

Aluminum

- Hastelloy C-276
- Inconel
- Monel

Nickel

- Brass
- Bronze

Copper

- Pure
- Ti 6Al 4V (grade 5)
- Ti 3Al 2.5V (grade 9)

Titanium

Metal Alloy Identification

- Unified Alloy Numbering System (UNS)
  - Reduces confusion involved in labeling of commercial alloys
  - Proprietary alloys are assigned numbers by the AA, AISI, ASTM, and SAE
    - Aluminum Association (AA)
    - American Iron and Steel (AISI)
    - American National Standards Institute (ANSI)
    - American Society for Testing and Materials (ASTM)
    - Society of Automotive Engineers (SAE)
    - American Society of Mechanical Engineers (ASME)
    - International Organization for Standardization (ISO)
- Example:
  - SAE = 316 SS
  - ASTM = A479
  - UNS = S31600
- Note: Other numbering systems may be used in different countries

Processing

- Processing Metals
  - Wrought/Forged= shaped using compressive force; heated and worked with tools
  - Machining = cutting, drilling, and shaping using tools
  - Cast = formed (melted, poured into mold, cooled)

Polymers

- Thermoplastics
  - Softens and melts with heat, returns to solid form when cooled
- Thermosetting
  - Do not melt with heat, degrades before melting
  - Higher strength, hardness, and dimensional stability than thermoplastics
- Elastomers
  - Elastic polymers
  - Used for seals, adhesives, hoses, belts, flexible parts

Thermoplastics

- PE
- PVC
- PS
- PET
- Nylon
- PMMA
- PTFE

Thermosets

- Epoxy Resins
- Polyurethane
- Polyester
- Silicon
- Melamine

Elastomers

- Natural Rubber
- Nitrile Rubber
- Butyl Rubber
- EPDM
- Silicon Rubber
- FKM
- Neoprene

Ceramics

- Crystalline, inorganic materials
  - May have some metallic elements as well
- Heat, corrosion, and wear resistant, chemically inert, high melting temperature, low electrical and thermal conductivity
- Brittle, hard, high compressive strength, low shear strength
- Ceramic materials may be in more than one category
- Types:
  - Glass
    - Amorphous solid, often transparent, chemically inert
  - Cement
    - Typically inorganic binder that sets and hardens
  - Clay
    - Material made from clay minerals – hydrous aluminum phyllosilicates
  - Refractory
    - Resistant to heat and thermal shock, chemically inert
  - Abrasives
    - Typically hard minerals or synthetic mineral analogs

Glass

- Silicate
- Soda-lime
- Borosilicate
- Aluminosilicate

Cement

- Portland
- Silicecious
- Slag

Clay Products

- Porcelain
- Terra Cotta
- Brick

Refractory

- Fire Brick
- Silicon Carbide
- Corundum

Abrasive

- Silicon carbide
- Aluminum oxide
- Silica sand

Composites

- One or more mutually insoluble materials are mixed or bonded together to improve properties
- Can be natural or synthetic
  - Wood is a natural composite (cellulose embedded in lignan)
- Embedded material
  - Particulate
  - Fibrous
- Laminated – layered, can use adhesive or not

Particulate

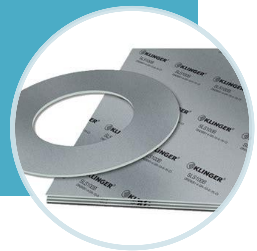
- Carbon filled rubber
- Graphite filled PTFE
- Concrete

Fibrous

- Fiberglass
- Carbon fiber reinforced polymers

Laminated

- Graphite composite laminates
- Composite wood flooring



Identifying MOCs in Use

- Wetted surfaces or wetted parts
  - The parts, surfaces, and/or components that are exposed to or in direct contact with the process medium and operating conditions
- Note that non-wetted surfaces and parts may still be exposed to some operating conditions!
- When analyzing for MOC, consider including surfaces and parts with potential exposure (leaks, sampling, start-up and shut-down, etc.)

Diaphragm is not obvious from external inspection

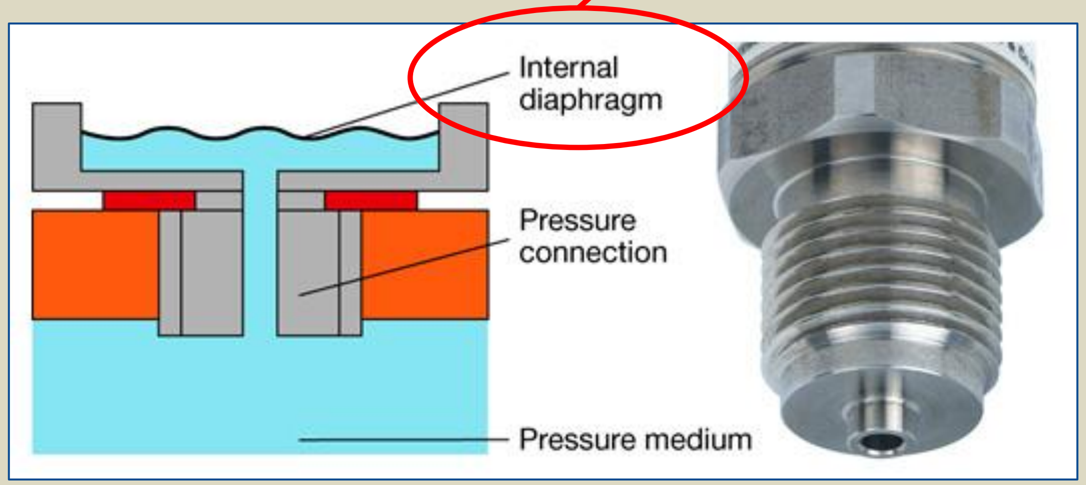


Diagram showing typical wetted parts of a pressure sensor

WIKA USA

Identifying MOCs in Use

External Components

- Visual inspection can help identify external components
  - Non-wetted surfaces and parts may still be exposed to some operating conditions
  - Consider how often external/non-wetted components are in contact with process medium
    - Often
    - Occasional
    - Accidental

Internal Components

- Internal components may not be readily apparent through visual inspection
  - Some internal components can be found during disassembly, but not all!
- Common visible internal components include:
    - Gaskets
    - O-rings
    - Seals
    - Diaphragms
- Materials/Components used during assembly are obvious, but must be considered
  - Glue
  - Lubricants
  - Thread Seals (PTFE tape, etc.)
  - Paint
  - Etc.

Identifying MOCs in Use

Best Source: Manufacturer Information

- Specification Sheets
- Catalogs
- Contact company if needed

Example: Swagelok Ball Valve 40G Series

- Non-wetted components
- Wetted component materials
  - 316 SS – A276 and A479
  - Powdered metal 300 series SS
  - Modified PTFE
  - Silicone-based lubricant
- Note that modifications with different materials are offered, be sure to check part number!

4 One-Piece Instrumentation Ball Valves—40G Series and 40 Series

Materials of Construction

40G Series

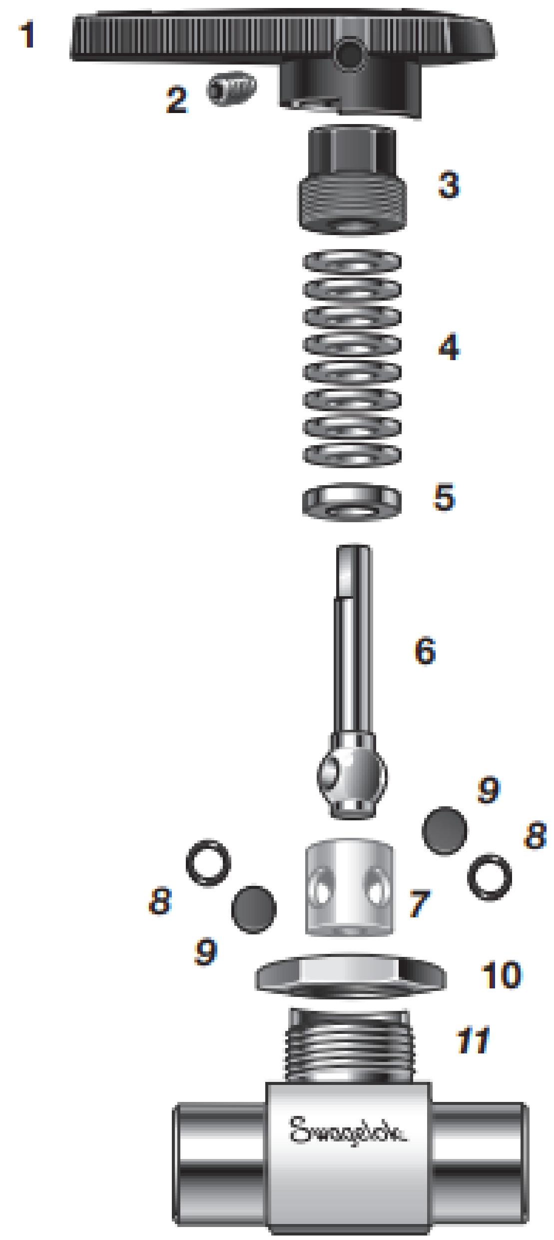
Component	Stainless Steel Valve Body Material Material Grade/ASTM Specification
1 Handle	Nylon with powdered metal 300 series SS insert
2 Set screw	S17400/A564
3 Packing bolt	Powdered metal 300 series SS
4 Springs①	S17700/A693
5 Gland	Powdered metal 300 series SS
6 Ball stem	*316 SS/A276*
7 Packing	*Modified PTFE/D1710 type 1, Grade 1, Class B or UHMWPE/D4020*
8 Side rings	*Powdered metal 300 series SS/B783②*
9 Side discs	
10 Panel nut	Powdered metal 300 series SS/B783
11 Body③	*316 SS/A276 and A479*
Wetted lubricant	*Silicone-based*
Nonwetted lubricant	Molybdenum disulfide with hydrocarbon binder coating

Wetted components listed in *italics*.

① 41G and 42G series: 8 springs; 43G series: 6 springs.

② B783 specification not available on 41G and 42G series; standard on 43G series.

③ Bodies with VCO® end connections and modified PTFE packing have fluorocarbon FKM O-rings; bodies with VCO end connections and UHMWPE packing have ethylene propylene O-rings.



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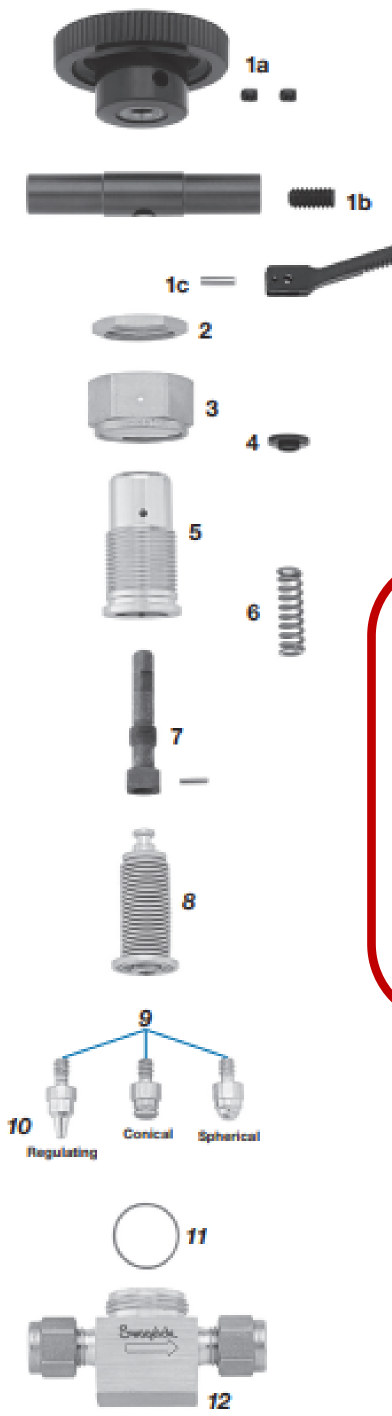
Example: [Swagelok Bellows Valve SS-4BK]

- Check part number!
    - SS-4BK has the conical stem tip
- Non-wetted components
- Wetted component materials
    - 316 SS /A479
    - 320 SS /A269
    - Silver-plated 316 SS/A580
    - PCTFE
    - Fluorinated-based lubricant
- Other models with different stem tips have different materials

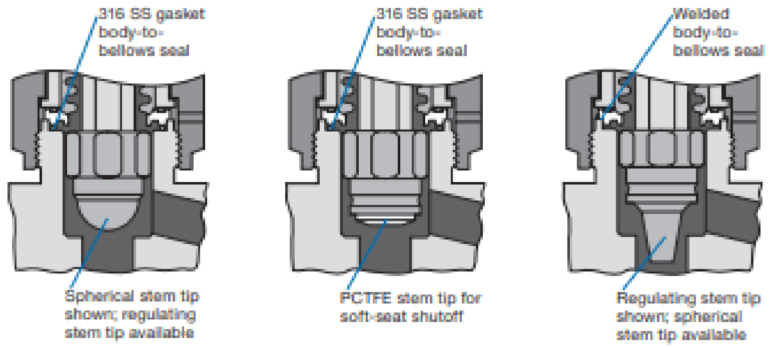
Materials of Construction



Component		Series	Valve Body Materials: Brass[1]	Valve Body Materials: 316 SS	Valve Body Materials: Alloy 400[2]
			Material Grade/ASTM Specification		
1a	Handle	4BG, 4BRG, 4BK, 4BW, 4BRW	Green phenolic[2]		
	Set screws	4BG, 4BRG, 4BK, 4BW, 4BRW	Alloy steel/ANSI 18.3[2]		
1b	Handle	6BG, 8BG, 6BK, 8BK, 6BW, 8BW	Green anodized aluminum 2024-T4/B211		—
	Set screw	6BG, 8BG, 6BK, 8BK, 6BW, 8BW	Alloy steel/ANSI 18.3		—
1c	Handle	4BKT	Black nylon		
	Handle pin	4BKT	302 SS		
2	Panel mount nut	All	Brass/B16	316 SS/B783	
3	Bonnet nut	All except 4BKT	Brass/B16	Silver-plated 316 SS/A479[2]	
		4BKT	Silver-plated brass/B16		
4	Washer	4BKT	Nylon		
5	Bonnet	All	Brass/B16	316 SS/A479	
6	Spring	4BKT	S17700/AMS 5678		
7	Actuator	All except 4BKT	416 SS/A582		
		4BKT	303 SS/A582		
	Actuator pin	All	420 SS		
8	*Stem*	*All*	*316 SS/A479*		*Alloy 400/B164*
	Bellows	*All*	*321 SS/A269*		*Alloy 400/B165*
	Weld ring	*All*	*316 SS/A479*		*Alloy 400/B164*
9	*Stem adapter*	*All*	*316 SS/A479*		*Alloy 400/B164*
10	*Stem tip*	*4BRG, 4BRW*	*Chrome-plated 316 SS/A479 (regulating)*		—
		4BK, 6BK, 8BK, 4BKT	*PCTFE (conical)[2]*		
		4BG, 6BG, 8BG, 4BW, 6BW, 8BW	*Cobalt-based alloy (spherical)*		*Alloy K-500/AMS 4676 (conical)[2]*
11	*Gasket*	*4BG, 6BG, 8BG, 4BRG*	*PTFE-coated 316 SS/A580*	*Silver-plated 316 SS/A580*	*Silver-plated alloy 400/AMS 4730[2]*
		4BK, 6BK, 8BK, 4BKT	*PTFE-coated 316 SS/A580*		*PTFE-coated alloy 400/AMS 4730[2]*
12	*Body*	*All*	*Brass/B16*	*316 SS/A479*	*Alloy 400/B164*
Wetted lubricant		*4BG, 6BG, 8BG, 4BW, 6BW, 8BW*	*Fluorinated-based (spherical stem tip, pneumatically actuated valves)*		—
Nonwetted lubricant		All	Molybdenum disulfide-based		

Wetted components listed in *italics*.
Additional stem tip options available. See **Options**, page 10.
[1] Valves with welded body-to-bellows seal (4BRW, 4BW, 6BW, 8BW) not available in brass.
[2] Alloy 400 only available for 4BG, 4BK, 4BKT, and 4BW series.

Gasket Seal — **BG Series**, **BK Series**
Welded Seal — **BW Series**



Swagelok

Identifying MOCs in Use

Best Source: Manufacturer Information

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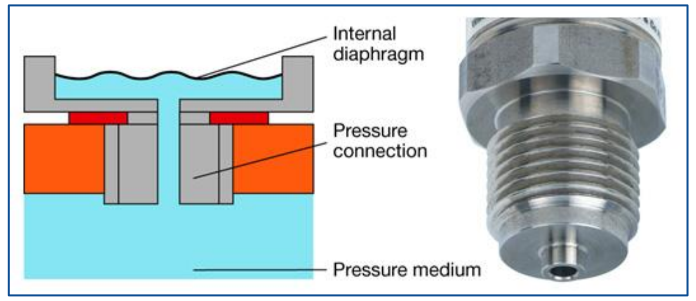


Example: WIKA Pressure Sensor

- Materials depend on configuration
  - Pressure range ≤ 600 bar
  - Connection = G 1 B Flush
- Non-wetted components
- Wetted component materials
  - 316Ti
  - Seal material depends on temp range chosen
- Note that modifications with different materials are offered, be sure to check part number!

Material			
Material (wetted)			
Flush process connections	Measuring ranges ≤ 25 bar [≤ 400 psi]	G 1 B flush	316Ti
		G 1 B hygienic	316L
	Measuring ranges ≤ 600 bar [≤ 8.700 psi]	G ½ B flush	316Ti
Process connections with pressure port	Measuring ranges ≤ 25 bar [≤ 400 psi]	Permissible temperatu-re range ≥ -20 °C ... ≤ 80°C [≥ -4 ... ≤ 176 °F]	316Ti
	Measuring ranges ≤ 25 bar [≤ 400 psi]	Permissible temperatu-re range < -20 °C ... > 80°C [< -4 ... > 176 °F]	316L and 316Ti
	Measuring ranges ≥ 40 bar [≥ 500 psi]	Permissible temperatu-re range < -20 °C ... > 80°C [< -4 ... > 176 °F]	316L and 316Ti and S13800
	Measuring ranges ≥ 40 und ≤ 1.050 bar [≥ 500 und ≤ 15.000 psi]	-	316Ti and S13800
	Measuring ranges > 1.050 bar [> 15.000 psi]	-	S13800
Seal	→ See table „Process connection"		

Thread	Max. measuring range in bar [psi]	Overpressure limit in bar [psi]	Permissible tempera-ture ranges in °C [°F] for ignition protection type Ex ia	Seal
Flush				
G ½ B	600 [8,000]	1,200 [17,500]	-20 ... +80 [-4 ... +176]	NBR
			-15 ... +80 [+5 ... +176]	FKM/FPM
		600 [8,700]	-15 ... +150 [+5 ... +302]	FKM/FPM
		1,200 [17,500]	-20 ... +80 [-4 ... +176]	FFKM
			-20 ... +150 [-4 ... +302]	FFKM
		800 [11,600]	-20 ... +80 [-4 ... +176]	EPDM
		[illegible]	[illegible]	[illegible]
G 1 B	1,6 [30]	4.8 [69]	-20 ... +80 [-4 ... +176]	NBR
			-15 ... +80 [+5 ... +176]	FKM/FPM
			-20 ... +80 [-4 ... +176]	EPDM
			-15 ... +150 [+5 ... +302]	FKM/FPM
			-20 ... +150 [-4 ... +302]	EPDM
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Material Degradation

Must be understood to determine appropriate materials for a process

Material Degradation

- Material Degradation Mechanisms are the fundamental processes that lead to the deterioration of material properties over time, impacting their performance and lifespan
- There are four primary degradation mechanisms
  - Corrosion
  - Wear
  - Mechanical Failure
  - Thermal

Corrosion

- Corrosion
  - Previously, was only discussed with regards to metals but is now used to describe a specific type of degradation in all types of materials.
  - "Corrosion is defined as an irreversible interfacial reaction between a material (such as metal, ceramic, or polymer) and its surroundings that causes the material to either dissolve into or be consumed by an environmental component"
- Metal Corrosion is the electrochemical oxidation of a refined metal to a metal oxide
  - Most prevalent material degradation mechanism
- Non-metal Corrosion is typically dissolution or a chemical reaction
  - Many possible mechanisms
  - Generally less understood than metal corrosion

Metal Corrosion

- Metal Corrosion is the electrochemical oxidation of a refined metal to a metal oxide
  - Most prevalent material degradation mechanism
  - Presence of water and air (oxygen) promote corrosion
- Oxide formation can result in a protective layer. Disruption of this layer can induce further corrosion
- Types
  - General
  - Galvanic = two dissimilar metals are in electrical contact in the presence of a aqueous solution that causes general corrosion of both metal
  - Crevice = driving force in difference in oxygen concentration in crevice, stagnant fluid
  - Intergranular = corrosion along grain boundaries
  - Dealloying = selective leaching of one element from an alloy
  - Stress corrosion cracking = stress in a corrosive environment when stress alone isn't a problem
  - Liquid-metal corrosion = Liquid metals can corrode other metals
  - Hydrogen embrittlement = loss of ductility due to hydrogen absorption in metal
- Other compounding factors
  - Temperature and heat transfer rates, pressure, pH, cavitation, mechanical stresses, microbes, presence of trace impurities, aeriation, stream velocity, presence of other metals, etc.

Non-Metal Corrosion

- Non-metal corrosion is dissolution or another chemical reactions
    - Varies significantly by material type
    - Includes hydrolysis, photo degradation, microbial attack, and other types of reactions
- Polymers
    - Chemical degradation
        - Photochemical degradation = cleavage of polymer chains due to exposure to UV and visible light
        - Thermo-oxidative degradations = the thermal decomposition of polymers at elevated temperatures
        - Hydrolytic degradation = hydrolysis of polymers in the presence of water
        - Polyesters and polyamides are most susceptible.
    - Biological degradation involves the breakdown of materials by microorganisms, such as bacteria and fungi
        - Primary: microorganisms secrete enzymes that cleave polymer chains
        - Secondary: smaller molecular fragments further metabolized by microorganisms
        - Polyesters and polyurethanes are most susceptible
    - Degradation mechanism is influenced by
        - Polymer structure (crystallinity, crosslinking, polymer type, etc.)
        - Environmental conditions (temperature, light exposure, oxygen, moisture, presence of microorganisms)

Non-Metal Corrosion

- Ceramics
  - In general, have excellent corrosion resistance.
    - Many ceramics are oxidizes, so oxidation is not an issue
    - Non-oxide ceramics (borides, nitrides, carbides) form oxide layers, which can be protective. Water vapor can increase oxidation rate, which can be a problem.
  - Can be susceptible to acids, bases, slag, and chemical reducing agents.
    - Depends on specific composition of the ceramic
    - Tends to be in extreme conditions
      - Hydroflouric acid is corrosive to most ceramics
      - Temperature and strong alkaline or acidic environments, super heated water can also be a problem
  - Glass
    - Dissolution = breaking of Si-O bonds → alkaline environments
    - Leaching = release of alkali or alkali-earth ions → acidic environments,
    - Glass corrosion can be seen as dullness (formation of layers of corrosion products on surface), iridescence (metal oxides from ion leaching in the corrosion product layers), pitting (due to dissolution in alkaline environments)
    - Generally very slow unless conditions are extreme

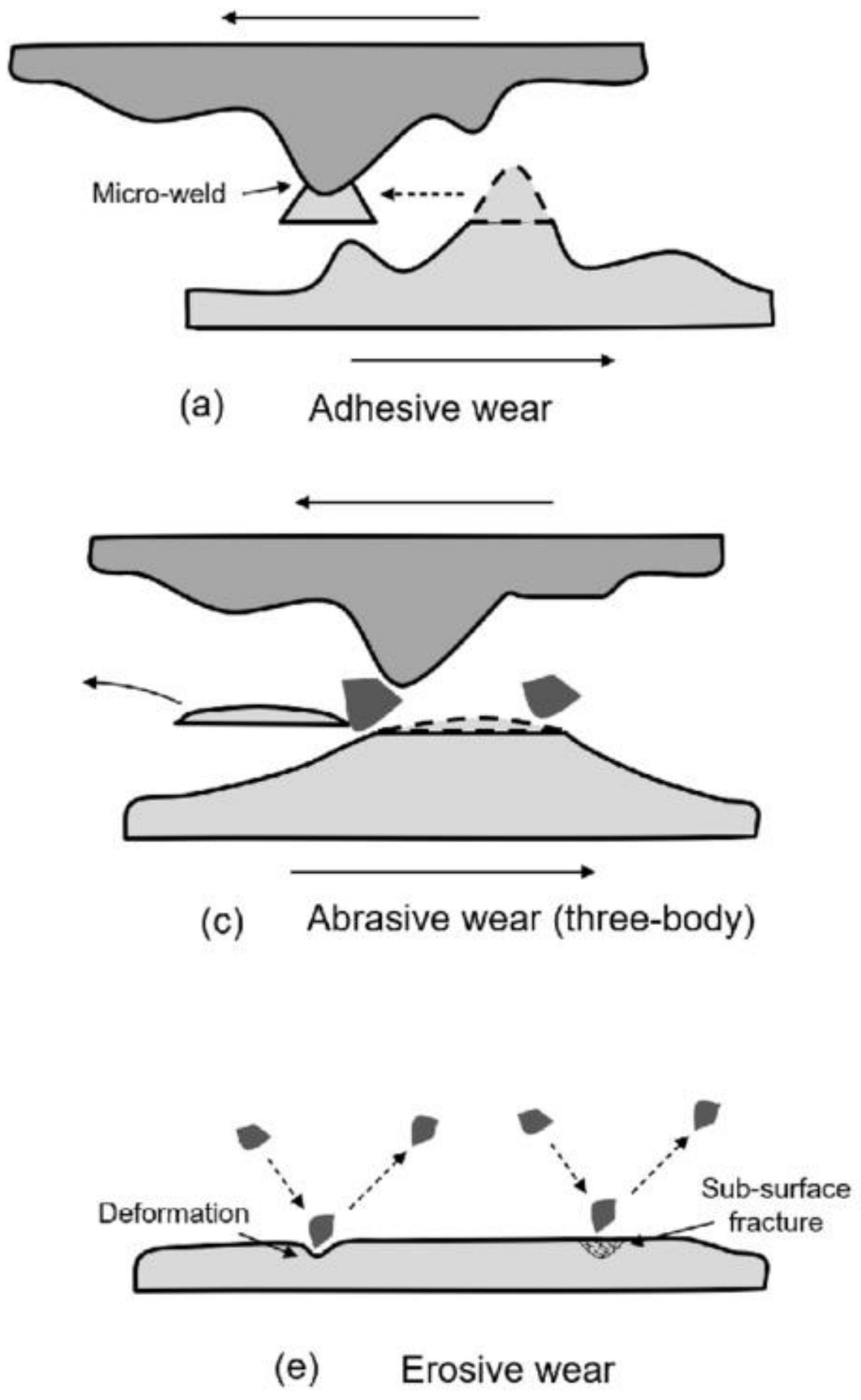
Non-Metal Corrosion

- Composites
  - Delimitation and failure at the component interface may cause significant problems under fatigue or impact pressures
  - Interfacial corrosion is accelerated by poor adhesion or moisture intrusion at the contact.
  - Must consider corrosion possibilities for each component.

Wear

- Wear
  - Gradual damage of a material surface due to motion against another surface
  - Common mechanisms:
    - Adhesive wear between two locally bonded surfaces
    - Abrasive wear between a solid surface and hard material
    - Erosive wear between a solid surface and a fluid or free particles

Wear Schematic



Mechanical Failure

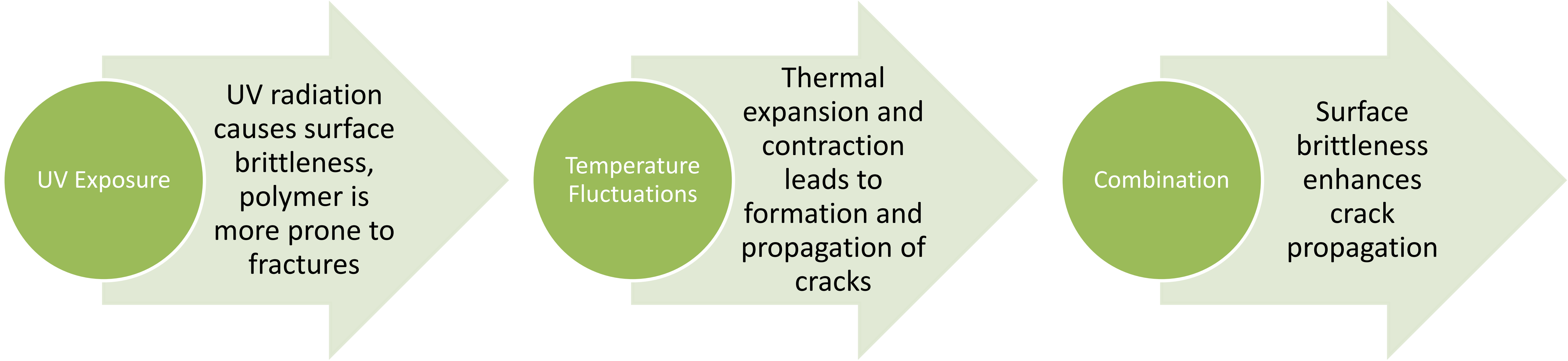
- Fatigue
  - Occurs when materials are subjected to repeated cycles of stress or strain
  - Even low stress, when repeated, can lead to cracks and failure
- Creep Rupture
  - Occurs when materials are subjected to a constant load over time
- Fractures
  - Occurs due to impacts or excessive stress

Thermal

- Thermal
  - Excessive heat or cold can alter material structure and properties
  - Temperature fluctuations results in expansion and contraction of materials

Compounding Affects

POLYMERS



Determination of Materials of Construction

1. Chemical Compatibility
2. Operating Conditions
3. Process Requirements

Chemical Compatibility

- Corrosion is determined by material and process medium compatibility
  - Operating conditions must be considered!
- The best method for determining chemical compatibility is well-documented experience in an identical process unit [Perry's 8th – Chapter 25.2]
  - Not always possible, especially in a laboratory environment
  - Other sources, in order of preference:
    1. Pilot units
    2. Corrosion coupon tests (pilot or bench scale units)
    3. Laboratory corrosion coupon tests in actual process fluids
    4. Corrosion coupon tests in synthetic solutions
    5. Documented material compatibility
       - Note: often for short-term exposure, not always available

Chemical Compatibility

- Corrosion metal coupon test procedure
  - Coupon preparation
    - Engrave with ID code
    - Clean
    - Weigh
  - Immerse coupon in test solution
    - Set operating conditions (temperature, pressure)
    - Leave at operating conditions for set time (30, 60, 90 days)
  - Measure coupon
    - Remove from test solution
    - Remove residual solution and loose corrosion material
    - Clean and dry coupon
    - Weigh coupon
  - Corrosion rate is determined by change in mass
- This method can be used for other types of materials
- Other methods are used for specific types of corrosion as well

Chemical Compatibility

- Documented material compatibility charts available
- Drawbacks
  - Limited chemicals
  - Chemical mixtures generally not included
  - Limited conditions
    - Temperature
    - Pressure
    - Time
- Good to check, but more information is often needed

Operating Conditions

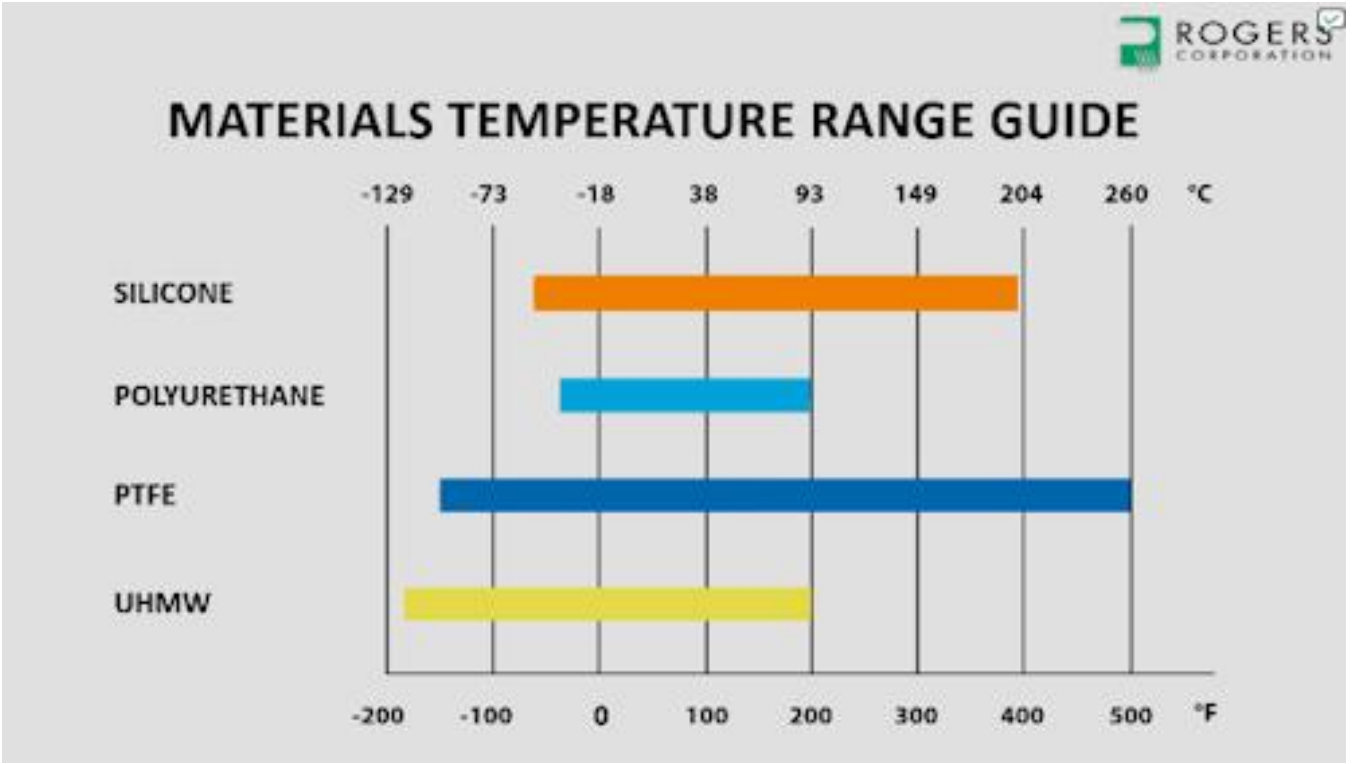
- Operating Conditions include:
  - Temperature
  - Pressure
  - Other
    - Fluid Velocity
    - Vibrations
    - Light Exposure
    - Other Mechanical Stresses

Temperature

- There are no set guidelines for what is considered high, low, or extreme temperatures
  - Varies by material
- Based on material availability, common use:
  - Cryogenic < 150 ˚C
  - Cold = -150 ˚C to 0 ˚C
  - Ambient = close to room temperature
  - High temperature = 50 ˚C - 260 ˚C
  - Extreme temperature > 260 ˚C
- Consider
  - Minimum and maximum operating temperatures
  - Short term/intermittent temperatures may cause material failure
    - Chemical reactions, corrosion can increase temperature

Temperature Extremes

- High temperatures
  - High temperature = 50 ˚C - 260 ˚C
    - Polymers can be used
    - Must determine which polymer
  - Extreme temperature > 260 ˚C
    - Polymers can not be used
    - Can be difficult to find materials
- Cryogenics is "the science that addresses the production and effects of very low temperatures"
  - Measurements – platinum resistance thermometer can be used down to 20K (-253 ˚C)
  - Electrical resistance of metals is affected at low temperatures
- Volume expansion can be an issue for high and low temperatures



What You Need to Know About Temperature and Why It's Essential in Elastomeric Material Design

Pressure

- High and low pressures can affect material properties and chemical reactions
- Potential Dangers
  - Explosion Risk
    - Flammable gas and liquids, dusts
    - Corrosion can produces gases
  - Equipment Failure
    - Include valves, seals, pipes in MOC analysis
  - Measurement Accuracy
    - Improper measurements can lead to over or under pressurization
- Material properties can be affect
  - Polymers – pressure changes can shift glass transition temperatures
  - Glass – choice of glass is extremely important
  - Metals – processing can affect pressure rating

Pressure Vessels

- Pressure Vessel Failures
  - Corrosive environments
  - Material defects
  - Material degradation
    - Wear, fatigue, sudden shock
  - Improper operation or maintenance
  - Thermal stress
    - Low or high temperatures
  - Poor design
  - Poor construction

Stainless Steel

- Stainless Steel
  - Pressure rating decreases with increasing temperature
  - Above 427 ˚C, there is a permanent reduction in pressure rating
- Must consider ALL operating conditions and how they affect each other

SERIES 40 GAGE RATING (PSI)

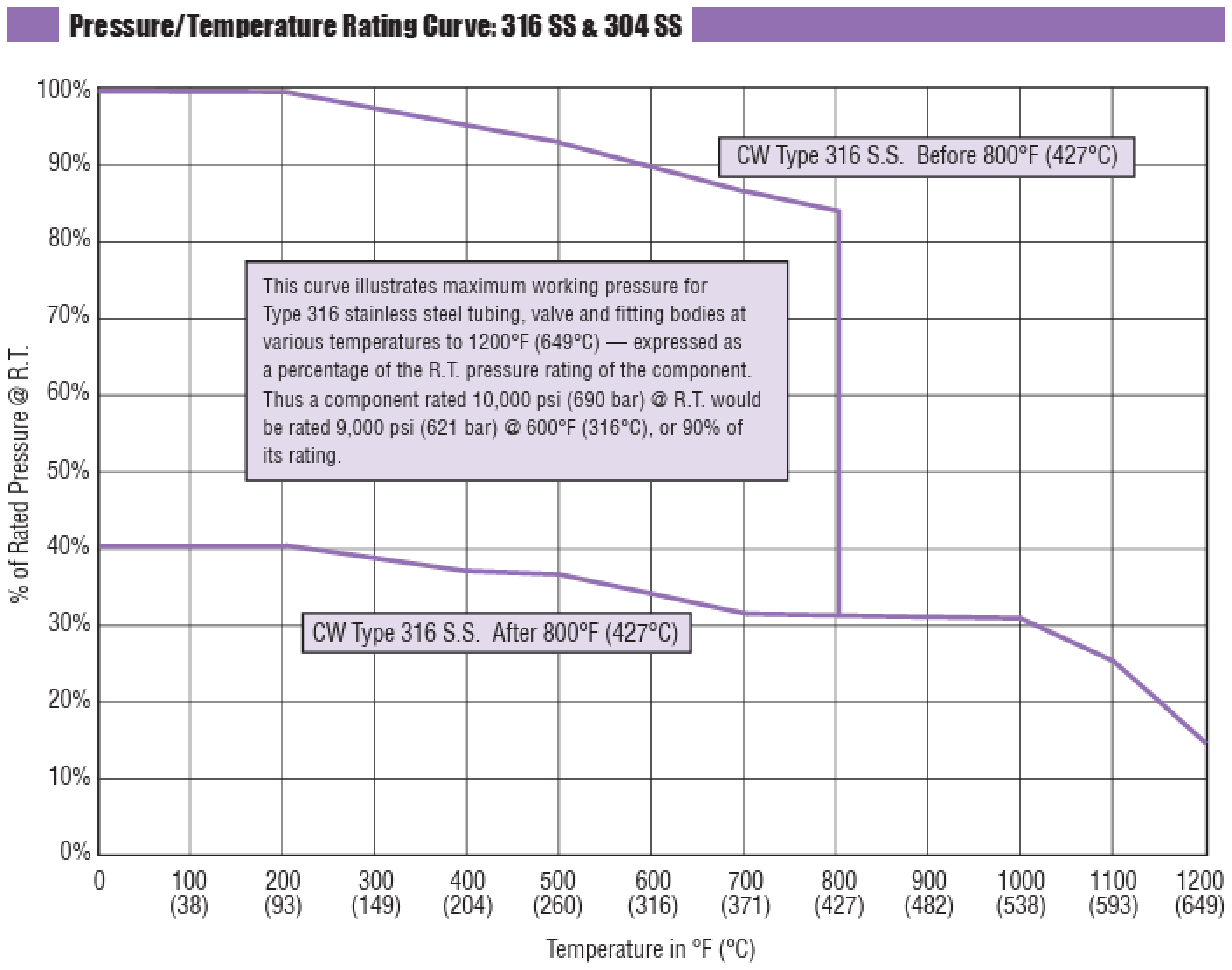
SERIES 40		
Temperature °F	°C	CS & 316SS
100	38	5000
200	93	4685
300	149	4370
400	204	4055
500	260	3740
600	316	3425
For temperatures above 600˚F (316˚C) Aluminosilicate Glass must be used		
700	371	3110
800	427	2795

Saturated Steam Rating 1500 WSP

SERIES 40 GAGE RATING (BarG)

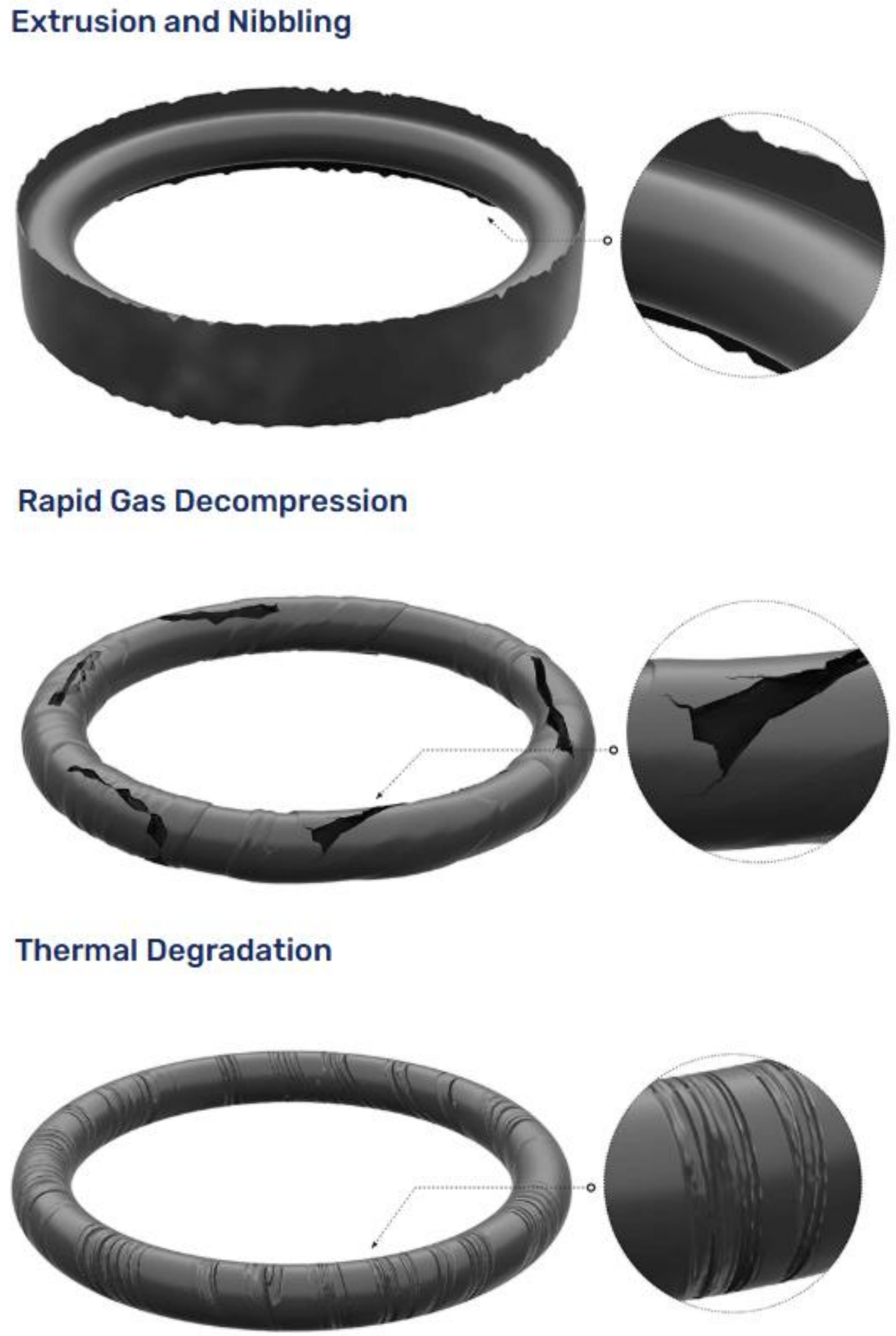
SERIES 40		
Temperature °F	°C	CS & 316SS
100	38	344.7
200	93	323.0
300	149	301.3
400	204	279.6
500	260	257.9
600	316	236.1
For temperatures above 600˚F (316˚C) Aluminosilicate Glass must be used		
700	371	214.4
800	427	192.7

Saturated Steam Rating 1500 WSP



O-Rings

- O-Rings can fail for many reasons
  - Abrasion
  - Chemical Degradation
  - Chemical Swelling
  - Compression Set
  - Damage
  - Extrusion
  - Outgassing
  - Rapid Gas Decompression
  - Spiral Failure
  - Thermal Degradation
  - UV Degradations



Process Requirements

- Other things to consider
  - Contaminants
    - Product purity
    - Environmental release
  - Operator use
  - Maintenance and repair
    - Cost
    - Downtime
    - Required expertise

Examples

Learn from past mistakes

KU Examples

O-Ring Degradation

- Supercritical CO_2 in pressure vessel
- O-ring failure
- Material listed as compatible with CO_2
- $SCCO_2$ can have different properties than CO_2
- $SCCO_2$ shows significant expansion – rapid gas decompression

KU Examples

Aluminum corrosion

- Galinstan used in differential pressure transducer
- Galinstan migrated to areas not intended
- Aluminum level gauge corroded

KU Examples

Silver Nitrate and Copper

- Silver nitrate aqueous solutions in a pressure vessel
- Copper induces silver precipitation
- Leak of solution onto copper gauze used for insulated heated lines
- Upgraded system – avoided all copper containing materials (brass, lubricants with copper)

Conclusions

- Know your process!
  - Types of materials have different benefits and drawbacks
  - Chemical compatibility is important, but not the only factor
  - Operating conditions limit appropriate materials
    - Temperature and pressure are key factors
- There are many resources
  - There may not be information on your specific combination of medium and operating conditions

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Thank you for listening!
Questions?

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