Elastomers in Pumps and Mechanical Seals

API 610 11th Edition
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Agenda

- Elastomers – Brief Overview
  - Choices
  - Advantages
  - Types & Comparisons
- Elastomers – Production
  - Fillers & Additives
  - Curing
- Elastomers – Structure and Property Comparison
- Perfluoroelastomers
  - History
  - Property Comparison
  - Advantages
- Perfluoroelastomers – Case Histories
- Perfluoroelastomers – Next Generation
- Summary

Elastomer Choice

Elastomer choice in any sealing scenario is dependent upon the following application parameters:

- Service Media - Media incompatibility can cause swell, hardness change and physical property deterioration
- Service Temperature - Different elastomers have different low and high temperature capabilities (Low temperature retraction (TR10) tests, Subjective compatibility, Compression set or other testing used to ascertain this)
- Service Pressure - High pressure applications require higher durometer O-rings and hardware changes to resist extrusion
- Installation Parameters - Different elastomers have different elongation capabilities
- Static or Dynamic Service – Dynamic seals require a tougher, more tear resistant elastomer than static seals

Consideration of the full properties are needed to best select an elastomer for a given application

Advantages of Elastomeric Seals

Elastomers make very good sealing elements, both in static and dynamic services

What makes elastomers so good as seals?

The fact that they are elastomeric, the more you squeeze them, the more sealing force you get from them.

Often termed "super-cooled" liquids, elastomers act as hydraulic extensions of the media to be sealed.

They are also relatively soft, and hence compliant to the mating surfaces of the hardware.

Less reliant on high cost fine polished surface finishes.

Easier to install, more damage tolerant.

They are relatively easy to mould into the shapes needed to make seals, "O" rings, Bellows, Gaskets etc. Hence they are relatively cheap to produce.

From a material point of view they can be compatible with many different media. They often have lower permeability than other sealing materials, which can lead to lower fugitive emissions

With adjustments in compound formulation the physical properties can be changed to give the optimum material for the application.

What is an Elastomer?

An **elastomer** is defined as:

"Any polymer having the elastic properties of natural rubber"

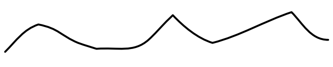
A **Polymer** is defined as:

"A substance formed by the linkage of numerous natural or synthetic compounds (monomers). They are usually of high molecular weight and composed of one (polymer), two (copolymer), three (terpolymer) or more repeated units."

There are three basic polymer molecular structures:

- Linear Molecules

  Like Polytetrafluoroethylene (PTFE) or High Density Polyethylene (HDPE)

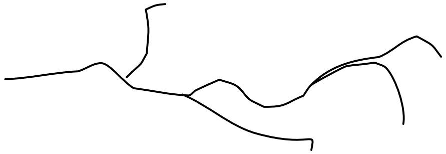


- Branched Molecules

  Like Nitriles (NBR) or Ethylene Propylene Diene (EPDM)

  Most elastomers start as branched molecules.

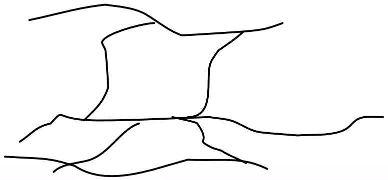
  The branches are often termed "pendant fractions".



- Networked

  Like Phenol Formaldehyde (PF)

  Thermoset plastics and elastomers have this structure



Elastomer Types

The elements which make up the monomers (repeat units) are formed from chains of atoms from organic elements of the periodic table:

Carbon, Oxygen, Silicon, Nitrogen, Sulphur, Phosphorous

Attached to the chain are atoms of Hydrogen or halogens such as Fluorine or Chlorine.

It is how these elements are mixed together that define the physical and chemical properties of the elastomer.

The polymers which are used to produce elastomers are wide and varied. Here are a few of the more common elastomers and their ASTM abbreviations:

- **NBR** Acrylonitrile-butadiene rubber
- **HNBR** Hydrogenated Nitrile
- **EPR** Ethylene-propylene
- **EPDM** Ethylene-propylene Diene Monomer
- **CR** Chloroprene / Neoprene rubber
- **FKM** Fluorocarbon
- **FEPM** Tetrafluoroethylene propylene (Aflas / Fluoraz)
- **FVMQ** Fluorosilicone
- **FFKM** Perfluoroelastomer

Elastomers Property Comparison

Properties	NBR	HNBR	EPDM	CR	FKM	FEPM	FFKM
Typ Min Temperature	-59ºC (-74ºF)	-40ºC (-40ºF)	-54ºC (-65ºF)	-54ºC (-65ºF)	-40ºC (-40ºF)	0ºC (+32ºF)	-30ºC (-22ºF)
Typ Max Temperature	135ºC (275ºF)	150ºC (302ºF)	150ºC (302ºF)	121ºC (250ºF)	232ºC (450ºF)	260ºC (500ºF)	324ºC (615ºF)
Abrasion Resistance	G	G	G/E	G	G	G	P
Acid Resistance	F	E	G	F/G	E	E	E
Chemical Resistance	F	G	G	F/G	E	E	E
(Freons) Refrigerants	F/G	F/G	F	E	G/E	P	F
Heat Resistance	G	E	E	F	E	E	E
Oil Resistance	E	E	P	F/G	E	F	E
Ozone Resistance	P	G	E	G/E	E	E	E
Comp. Set Resistance	G/E	G/E	G/E	F	G/E	G	G
Solvent Resistance	P	P	F/G	P	G	F/G	E
Tear Resistance	F/G	F/G	G/E	F/G	F	F	P
Tensile Strength	G/E	E	G/E	G	G/E	G/E	F/G
Water/Steam <150ºC	F/G	E	E	F	F/G	G	G/E
Water/Steam >150ºC	P	P	F	P	P	G	G/E

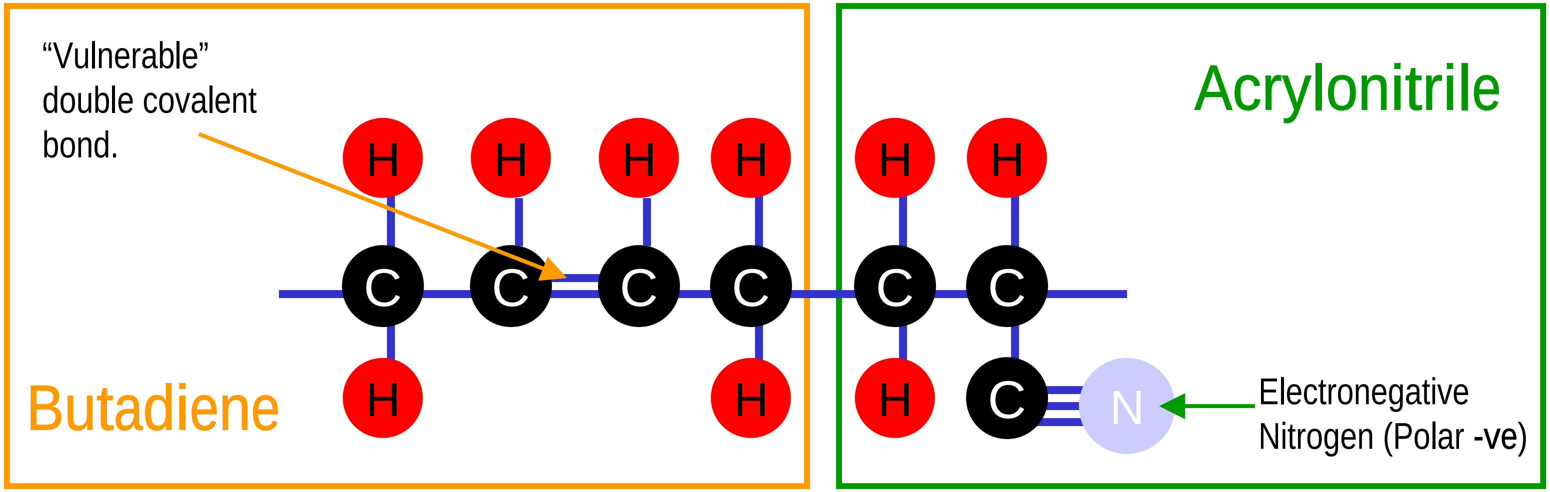
Legend: **E**=Excellent, **G**=Good, **F**=Fair, **P**=Poor

Skip Types

Nitrile (NBR) – Elastomers

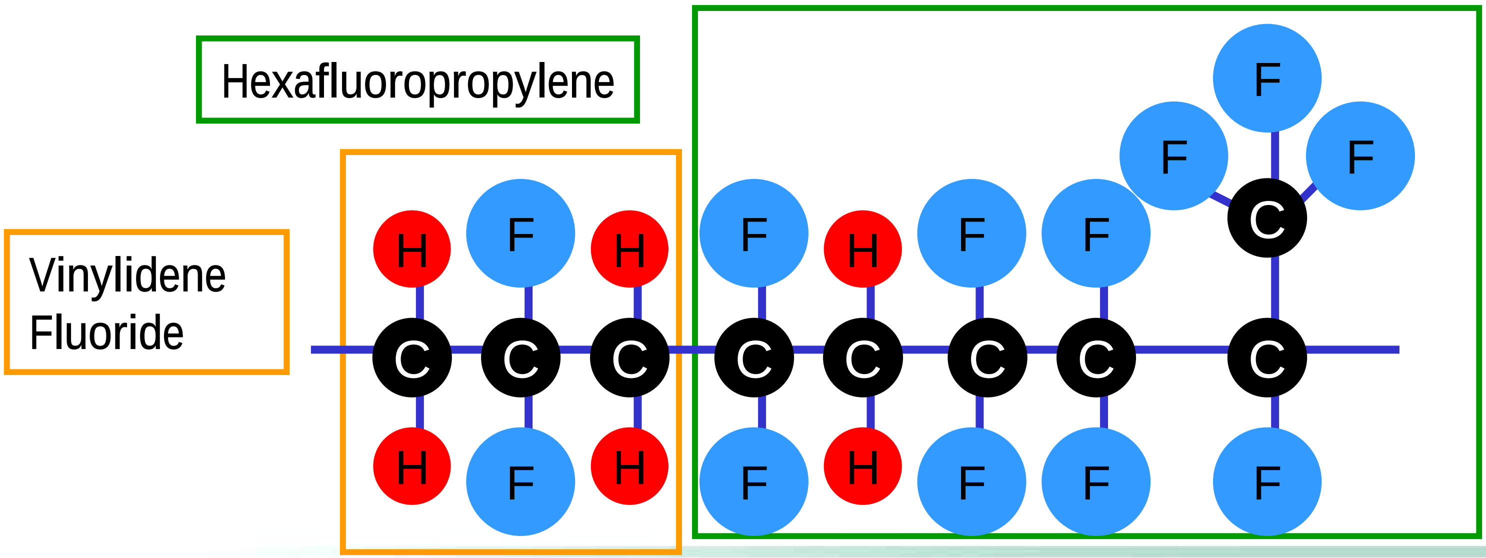
This is the most widely used general purpose elastomer.

- **Elements**: Carbon, Hydrogen, Nitrogen. Polymer makeup:
  - Copolymer of butadiene and acrylonitrile. Acrylonitrile content determines hydrocarbon resistance, low temperature flexibility and other properties *(High ACN content low swell in oils and poor low temp flexibility)*
- Strengths:
  - Exhibits good compression set, tear and abrasion resistance
- Recommended for:
  - Petroleum based fluids, water, silicone fluids, ethylene glycols
- Not Recommended for:
  - Phosphate ester, halogenated hydrocarbons, ketones, acids, brake fluids, ozone and H_2S



Fluorocarbon, Viton® A (FKM)

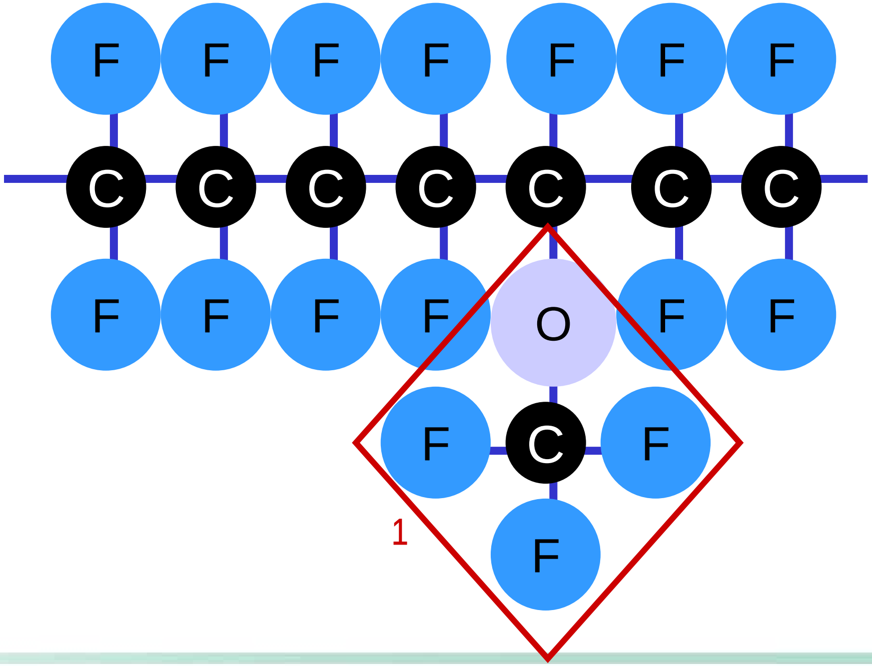
- Elements: Carbon, Hydrogen, Fluorine. Polymer makeup:
  - Based upon the monomers Vinylidene Fluoride (VDF), Hexafluoropropylene (HFP), **(PMVE, TFE Also)**
  - Variations of each monomer give different chemical resistance and physical properties and FKM grades
- Strengths:
  - Excellent high temperature resistance with good chemical resistance and compression set properties
- Recommended for:
  - Petroleum, diester and silicate ester fluids, acids, halogenated hydrocarbons
- Not Recommended for:
  - Phosphate ester, amines, ketones, steam, anhydrous ammonia, and selected acids



Perfluoroelastomers (FFKM)

- Elements: Carbon, Fluorine, Oxygen. Polymer makeup:
  - Completely fluorinated polymer with no reactive hydrogen made from three monomers, the principal being TFE
- Strengths:
  - Excellent high temperature resistance, excellent chemical resistance and compression set properties
- Recommended for:
  - Virtually all media due to its chemical inertness and high temperatures due to its polymer structure

- **Not Recommended for**:
  - PERFLUORINATED SOLVENTS AND ALKALI METALS



Fully fluorinated structure

1. Branched group varies by manufacturer

Producing an Elastomer

Once you have chosen your elastomer compound, you first have to produce a gum or resin, of the monomers. These are produced via many different chemical reactions in large vats.

Other compounding ingredients need to be mixed, with the elastomer, to make it effective for both operation and manufacture. These could include:

- Fillers: Carbon black, Non-black materials
- Curing agents
- Processing aids such as lubricants

These are then processed with tight controls on temperature, time and power consumption:

Mixed → Milled → Preformed → Moulded

Following this some materials are “Post-Processed” in an oven to complete the cure cycle.

Skip to Curing

Elastomers – Fillers & Additives

An elastomer is a compound which comprises a base, polymer or copolymer, with the addition of other additives used to achieve the desired properties of the elastomer. These are added in parts per hundred or phr with the base polymer being 100.

Typical additives include:

Elastomers / Base Polymer
Curatives (Vulcanising Agents)
Accelerator
Activator or Retarders
Antidegradant (Antioxidents, Antiozonants, Protective Waxes)
Processing Aid (Peptizers, Lubricants, Release Agents)
Filler (Carbon Blacks, Non-Black Materials)
Plasticiser, Softners, and Tackifiers
Colour Pigments
Special Purpose Materials (Blowing Agents, Reodorants, etc.)

Elastomers – Fillers & Additives

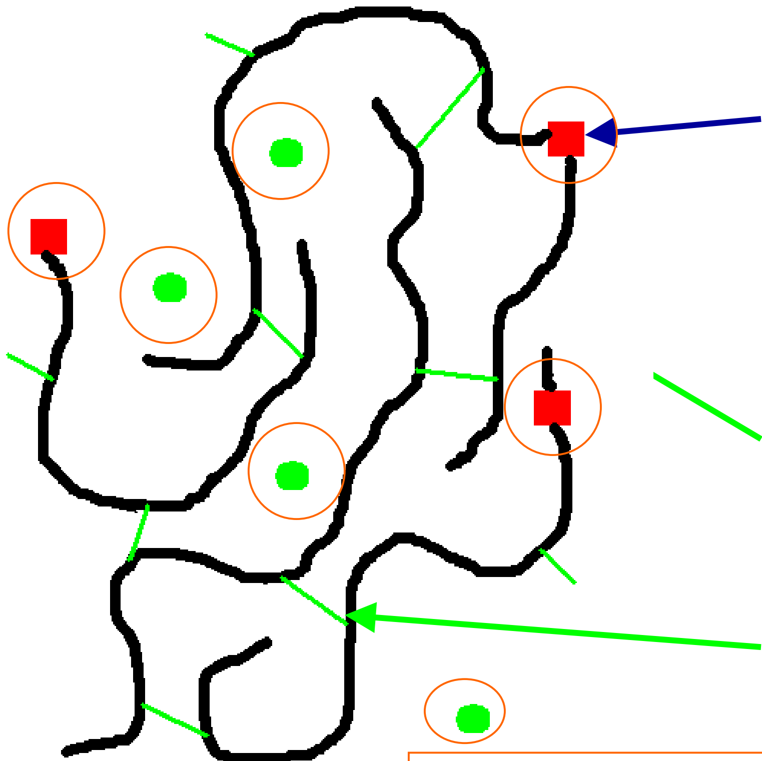
So what properties can be changed in elastomers?

An elastomers properties can be affected by compounding, in order of the decreasing dependence on the compound they are:

- Modulus and Hardness
- Resistance to Abrasion
- Tear Strength
- Tensile Strength
- Bonding
- Elasticity
- Electrical Properties
- Resistance to Light
- Weathering and Ozone Resistance
- Thermal Expansion

Elastomers - Curing

What happens to the elastomeric structure during Curing?



The raw material which is used as the basic ingredient for the elastomer gum consists of a long chain of “mers”, known as the “polymer”.

In this polymer chain are the sites which the polymer chemist will use to cross link the material.

Additives called activators are often added to “activate” these sites. With some polymers this is not needed.

The vulcanising or curing agent which was dispersed into the polymer matrix during compounding can then act on these sites when the preform elastomer is subjected to heat and pressure during moulding.

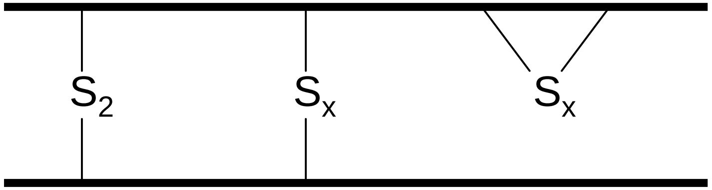
The curing agent then “neutralises” the sites on the polymer chain and a cross link is formed. This happens millions and millions of times in each batch of elastomer compound.

Care must be taken to ensure the correct amount of additives are used and that they are dispersed as evenly as possible. If this does not happen then it can have serious effect on the material in service.

Elastomers Cure Agents

Sulphur Cure Systems

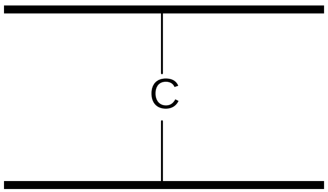
Used in elastomers with unsaturated bonds in the backbone chains or pendant fractions e.g. NBR, EPDM.



Disulfidic Link | Polysufidic where x>3 | Cyclic Sulphur Link

Peroxide Cure Systems

Used in elastomers with cure sites capable of reacting with peroxides either in the backbone chains or pendant fractions e.g. NBR, EPDM, FKM or FFKM

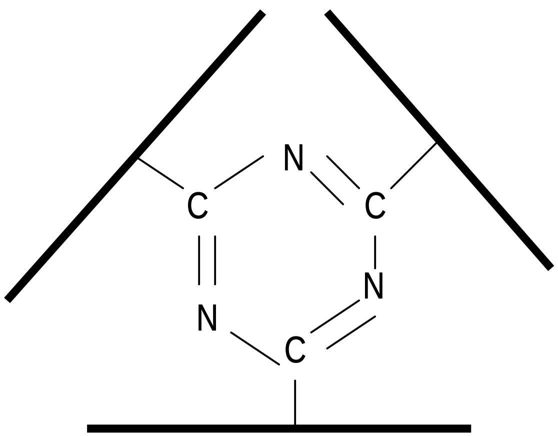


C-C Cross Link

Triazine Cure Systems

Used in elastomers with cure sites capable of generating triazine bonds FKM or FFKM.

Note: Three bonds off of the triazine ring



1,3,5-Triazine Link

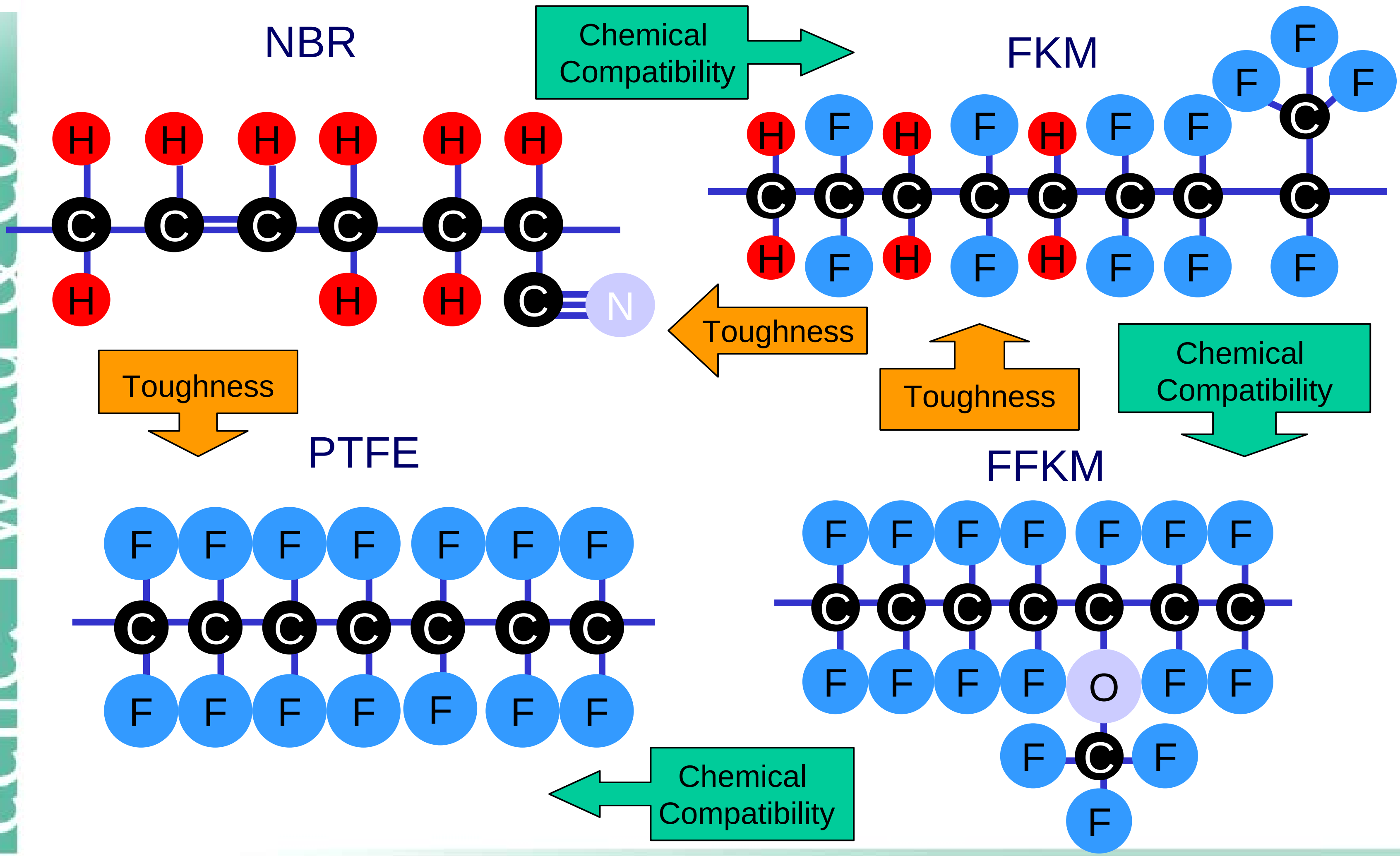
Elastomers - Bonds

As we know elastomers are made up of lots of atoms joined together by Covalent bonds. These atoms are from a small group of elements. The **Bond Dissociation Temperature** (T_{diss}) and **Activation Energy** (E_{diss}) needed to break the bonds between various atoms has an influence on the maximum service temperature of the elastomer. Here are some typical covalent bonds with their T_{diss} and E_{diss} values.

Chemical Bond (Break)	T_{diss} (°C (°F))	E_{diss} (kJ/mol)
— N = | C <	~500 (932)	615
— CF_2 — | — CF_2 —	500 (932)	400
— Si — O — | — CF_2 —	500 (932)	400
— CH_2 — | — CH_2 —	400 (752)	320
— CH_2 — | — CH_2 — C = C —	390 (734)	300
— C — S — | — S — C —	~380 (716)	300
— C — Sx — | — C —	~160 (320)	120

So now we can see why differently cured elastomers yield good high temperature properties.

Elastomers Structure Comparison



Elastomers Property Comparison

Properties	NBR (S)	NBR (P)		FKM (B)	FKM (GF)	FKM (GLT)	FKM (A)
Typ Min Temperature	-59ºC (-74ºF)	-59ºC (-74ºF)		-13ºC (9ºF)	-2ºC (28ºF)	-40ºC (-40ºF)	-17ºC (-1ºF)
Typ Max Temperature	135ºC (275ºF)	135ºC (275ºF)		232ºC (450ºF)	232ºC (450ºF)	232ºC (450ºF)	232ºC (450ºF)
Abrasion Resistance	G	F		F	G	F	G
Acid Resistance	F	F		E	E	E	E
Chemical Resistance	F	F		G	E	F	F
(Freons) Refrigerants	F/G	F/G		F	F	P	P
Heat Resistance	G	G/E		G/E	E	F	F
Oil Resistance	E	E		G	E	F/G	F
Ozone Resistance	P	P		E	E	E	E
Comp. Set Resistance	G	E		F	P	G	G
Solvent Resistance	P	P		F/G	F/G	F/G	F/G
Tear Resistance	G	F		G	G	F	F
Tensile Strength	G/E	G/E		G	E	G	F
Water/Steam <150ºC	F	G		G	G/E	G	G
Water/Steam >150ºC	P	P		F	G	F	F

Legend: **E**=Excellent, **G**=Good, **F**=Fair,**P**=Poor

Note: The above rankings are based on NBR to NBR and Viton to Viton not across material types

Perfluoroelastomers History

1970's Dupont used its PTFE (Teflon) experience and developed the first Perfluoroelastomer Kalrez®

1980's Greene, Tweed Developed Chemraz ®

Originally – Peroxide Cure systems with Universal Chemical resistance – "Low" Maximum Temperature 232°C (450°F), Moderate Steam Resistance, Low Durability. Used mainly in the chemical industry.

1990's Greene, Tweed developed specific Semiconductor Grades for high purity and plasma resistance and the market for Perfluoroelastomers "took off"

1998 Greene, Tweed developed materials which expanded the temperature and physical limits of Perfluoroelastomers

Still Peroxide Universal Chemical – "Medium" Maximum Temperature (260°C),, Excellent Steam Resistance, Better durability through tougher physicals

2000's Greene, Tweed developed materials which expanded the temperature limits even more.

"New" Triazine cure system which limited Universal Chemical compatibility– "High" Maximum Temperature 324°C (615°F). However these had no Steam Resistance, medium durability.

Elastomers Property Comparison

Properties	"Low" Temp FFKM (P)	"Medium" Temp FFKM (P)	"High" Temp FFKM (T)
Typ Min Temperature	-30ºC (-22ºF)	-20ºC (-4ºF)	-18ºC (0ºF)
Typ Max Temperature	232ºC (450ºF)	260ºC (500ºF)	324ºC (615ºF)
Abrasion Resistance	P	G	F
Acid Resistance	E	E	E
Amine Resistance	E	E	P
(Freons) Refrigerants	F	F	F
Heat Resistance	E	E	E
Oil Resistance	E	E	E
Ozone Resistance	G	G	E
Comp. Set Resistance	G	G/E	E
Solvent Resistance	E	E	E
Tear Resistance	P	G	F
Tensile Strength	G/E	E	G/E
Water/Steam <150ºC	E	E	G
Water/Steam >150ºC	G	G/E	P
Legend: **E**=Excellent, **G**=Good, **F**=Fair, **P**=Poor			

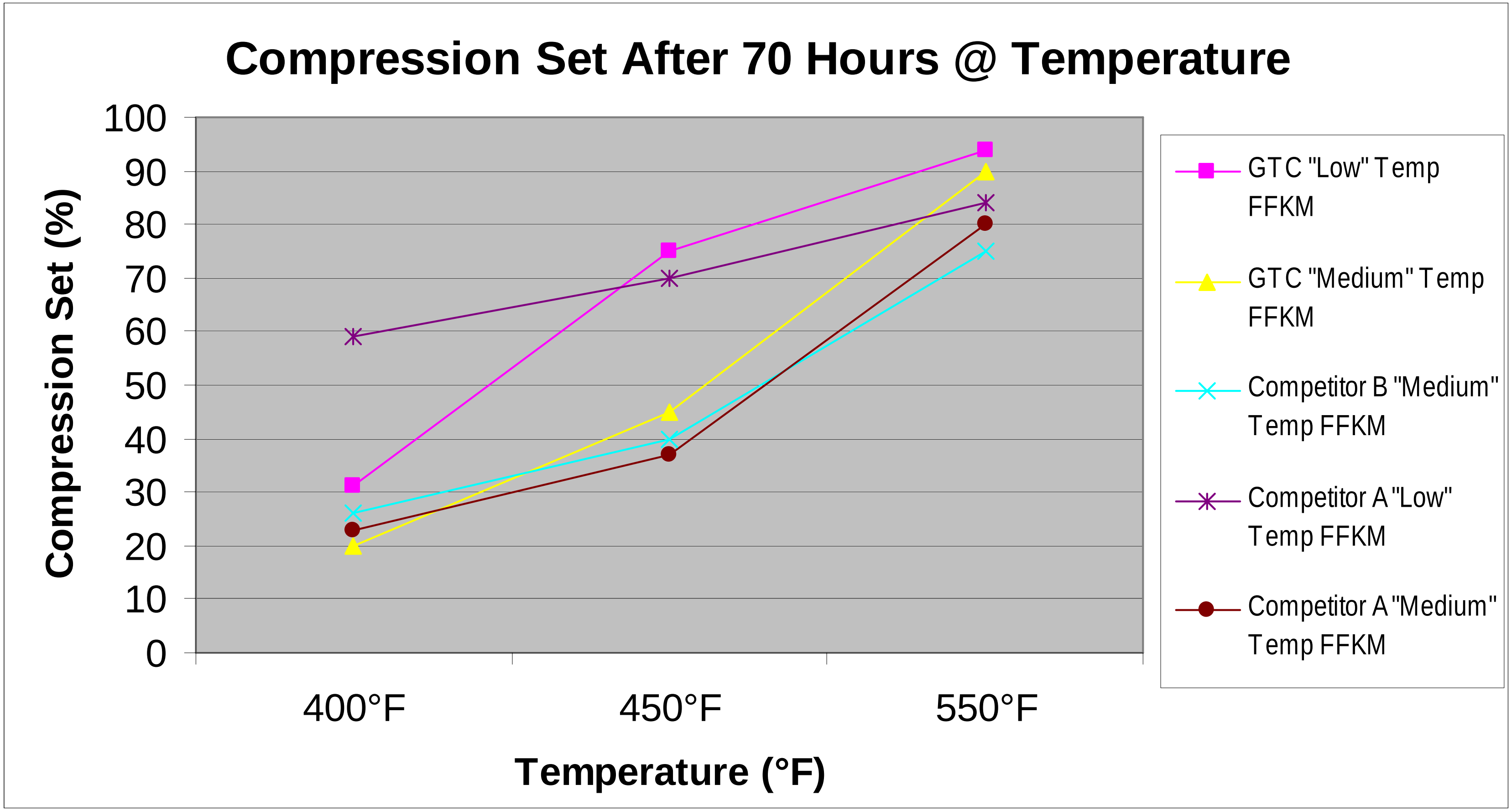
Note: The above rankings are based on FFKM to FFKM not across material types

Perfluoroelastomer Properties

PROPERTIES	GTC "Low" Temp FFKM	GTC "Medium" Temp FFKM	GTC "High" Temp FFKM
TR10	-14^{o}C (+6^{o}F)	-7^{o}C (+19^{o}F)	-7^{o}C (+20^{o}F)
HARDNESS (SHORE A)	75	80	80
TENSILE STRENGTH (psi)	1750	2150	1830
ELONGATION (%)	140	130	135
50% MODULUS (psi)	450	420	360
100% MODULUS (psi)	1150	1310	1090

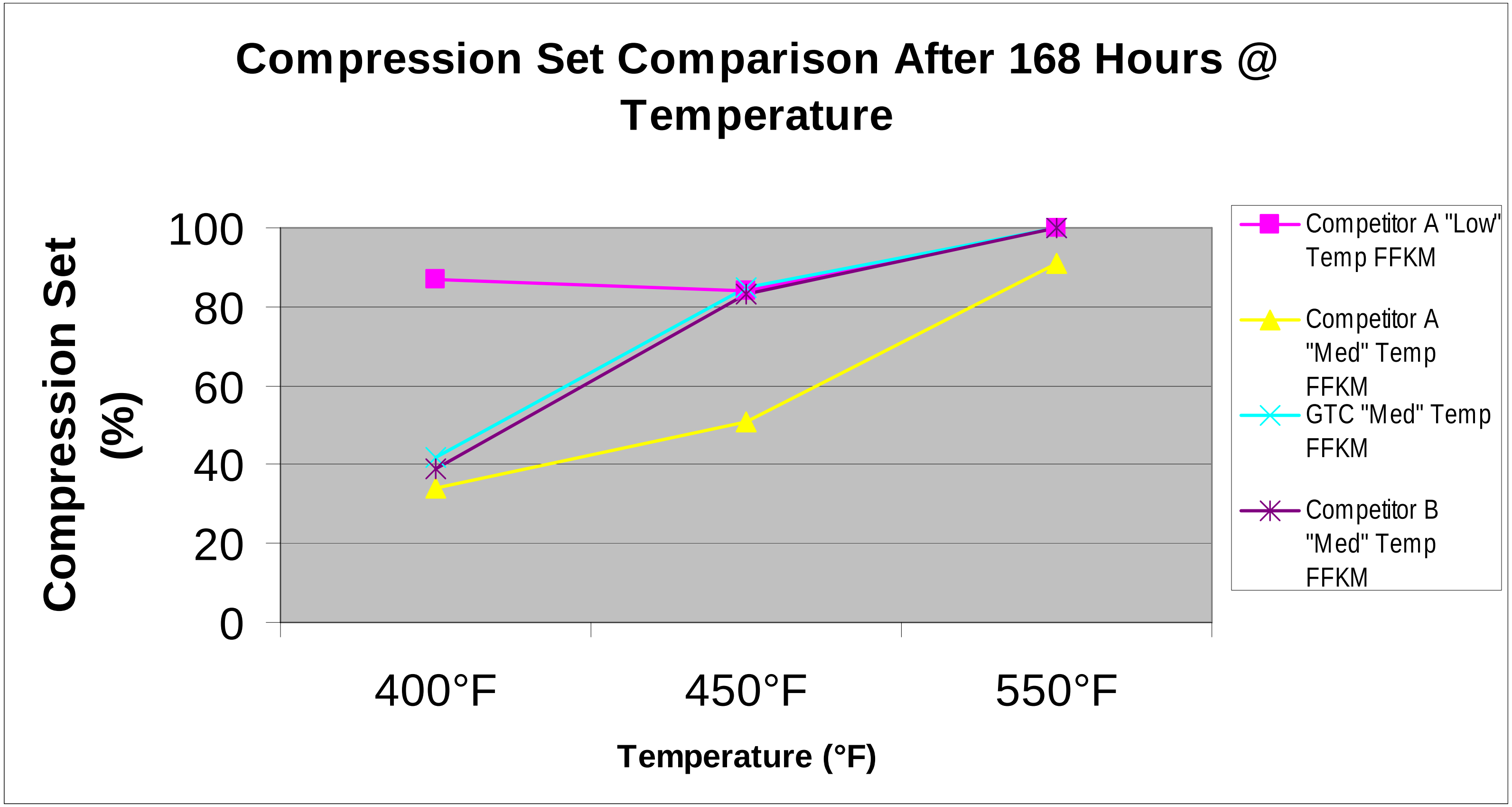
Skip to FFKM Adv

Comparative Compression Set - 70 Hours @ Elevated Temperatures



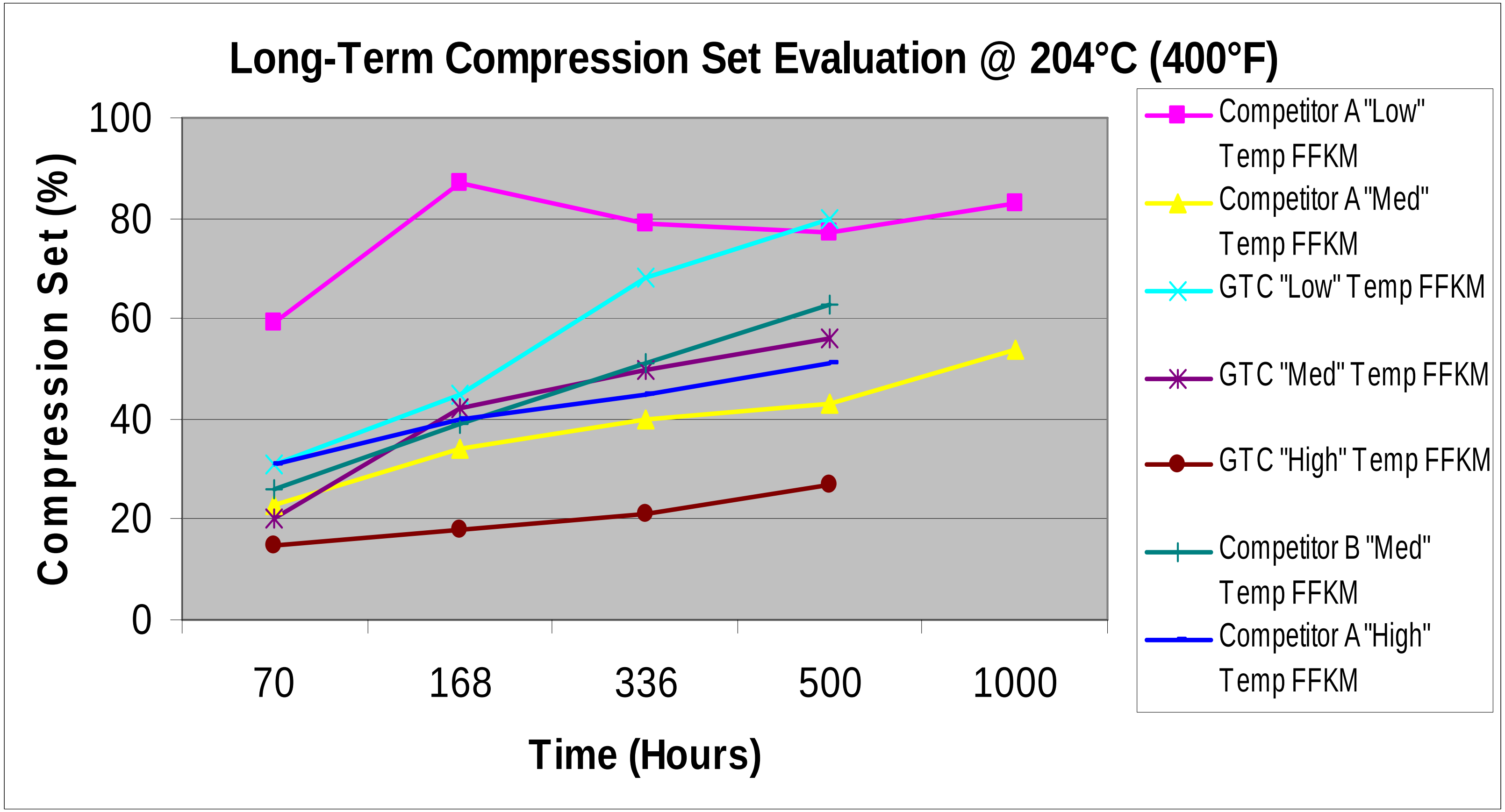
Data Sources:
- **Greene Tweed Rubber Lab, Kulpsville, PA, and independent testing**
- **Note: All tests performed in accordance with ASTM D1414 on -214 Size O-rings**

Comparative Compression Set - 168 Hours @ Elevated Temperatures



Data Sources:
- **Greene Tweed Rubber Lab, Kulpsville, PA, and independent testing**
- **Note: All tests performed in accordance with ASTM D1414 on -214 Size O-rings**
- **GTC "Low" Temp FFKM not included due to 100% compression set due to being above the recommended max temperature**

Comparative Compression Set – Long-Term @ 204°C (400°F)



Data Sources:

- **Greene Tweed Rubber Lab, Kulpsville, PA, and independent testing**
- **Note: All tests performed in accordance with ASTM D1414 on -214 Size O-rings**

Advantages of Perfluorelastomer Seals

Compared to other elastomers:

a.Perfluoroelastomers have Universal Chemical Compatibility

Whatever media is in the system, used to clean the system or intermediates in reactions are more likely to be compatible with FFKM.

b.Broad temperature capability

Especially in the high >200°C range. Reactivities of media at low temperatures <20 °C often mean other none FFKM materials could often be used.

Perfluoroelastomers however have to be used with the following points in mind:

They have a high coefficient of thermal expansion, typically 300xe^{-6} /°C compared to NBR or FKM which are typically 130xe^{-6} and 215xe^{-6} /°C.

Their lower physical properties can cause problems with tensile failure at high temperatures due to excessive stretch or high squeeze.

<u>Correct specification and hardware design becomes more critical with FFKM materials</u>

Skip to Next Gen

Perfluoroelastomer Case Histories

The following slides outline:

a. A list of examples from one refinery with API – 610 pumps utilising API-682 sealing systems, with temperatures in support of those listed in the "tutorial" section C:3 of API-682 3rd Edition.

    a. Those which could be covered by "Low" Temp FFKM materials are shaded Yellow

    b. Those which could be covered by "Med" Temp materials are shaded Blue

    c. Those which could be covered by "High" Temp materials are shaded Red

b. Examples of the Mechanical Seal locations where "High" Temp FFKM materials have replaced other sealing materials at high temperatures some of which even exceed the temperatures listed in the "tutorial" section C:3 of API-682 3rd Edition.

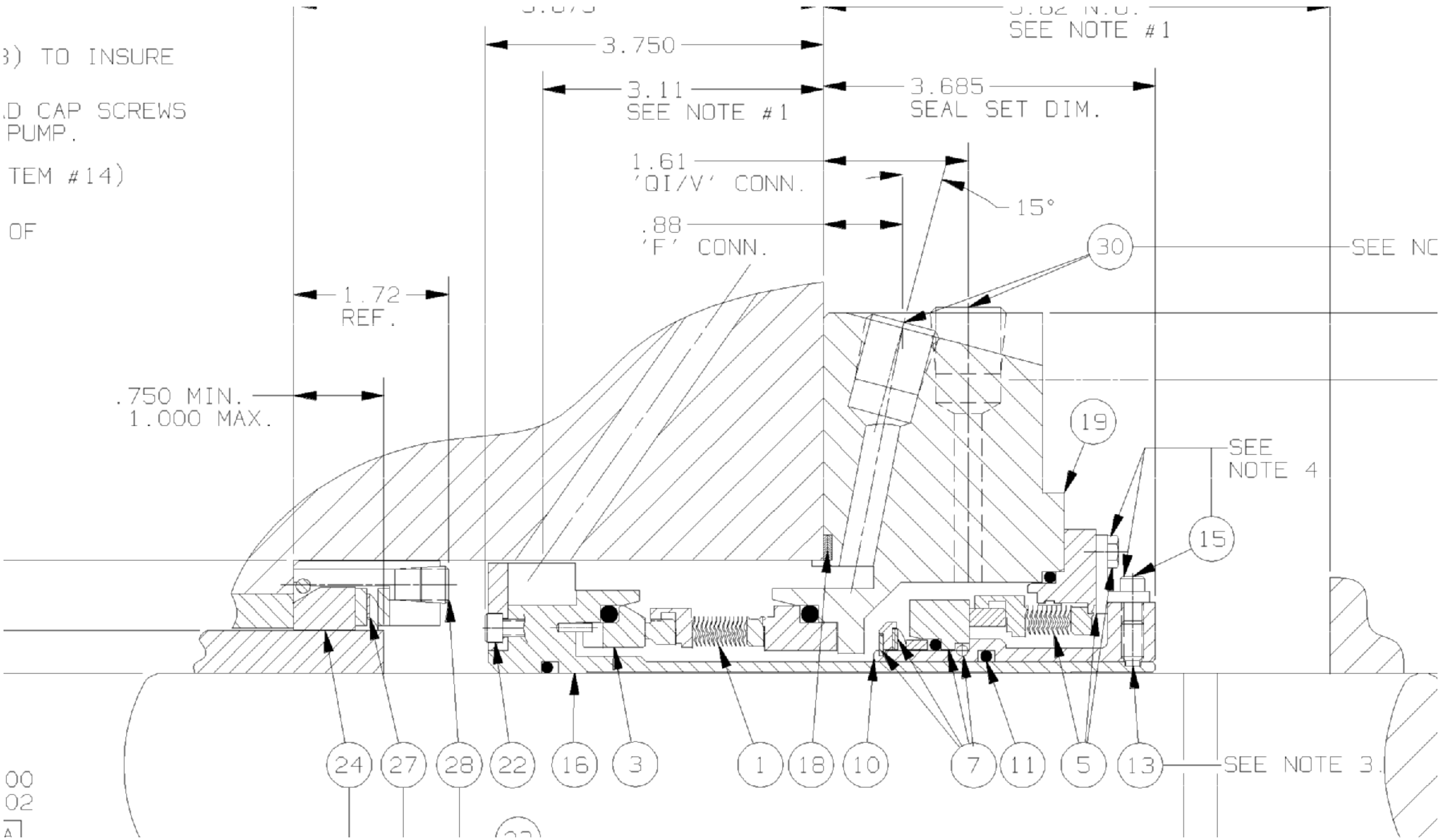
PUMP MAKE	MODEL	SIZE	SPEED	FLUSH	TEMP	GRAVITY	PROCESS FLUID
INGERSOLL RAND	J	14X12X19	3560	23	325	0.727	TOLUENE & XYLENE
INGERSOLL RAND	J	14X12X19	3570	23	325	0.727	TOLUENE & XYLENE
BINGHAM	CDA	8X10X14C	3500	21	325	0.729	TOLUENE & XYLENE
BINGHAM	CDA	8X10X14C	3560	21	325	0.729	TOLUENE & XYLENE
BINGHAM	CAP 8	3X6X14	3560	21	357	0.801	SPLITTER BOTTOM LIQUID
WORTHINGTON	8 HN 194	10X8	1770	11	388	0.696	HYDROCARBONS
WORTHINGTON	8 HN 194	10X8	1770	11	388	0.696	HYDROCARBONS
BINGHAM	CDA	10X14X20-1/2	1780	21	390	0.675	EXTRACT TO C-5330
BINGHAM	CDA	10X14X20-1/2	1780	21	390	0.675	EXTRACT TO C-5330
GOULDS	3620 L	8X10-17	3560	21	400	0.723	TOLUENE
GOULDS	3620 L	8X10-17	3570	21	400	0.723	TOLUENE
SUNDYNE	LMV 801	3X2X4.919	3560	23	420	0.873	HEAVY REFORMATE
SUNDYNE	LMV 801	3X2X4.919	3560	23	420	0.873	HEAVY REFORMATE
BINGHAM	CAP 8	8X10X21B	1760	21	425	0.663	XYLENES SOLUTION
BINGHAM	CAP 8	8X10X21B	1760	21	425	0.663	XYLENES SOLUTION
BINGHAM	CDA	8X10X18A	3560	21	425	0.66	XYLENES, MIXED FEED
BINGHAM	CDA	8X10X18	3560	21	425	0.66	XYLENES, MIXED FEED
GOULDS	3620	14X16-22A	1180	21	450	0.72	EXTRACT LIQUID
GOULDS	3620	14X16-22A	1180	21	450	0.72	EXTRACT LIQUID
INGERSOLL DRESSER	JD	18X12X17	1780	21	465	0.641	RAFFINATE LIQUID
INGERSOLL DRESSER	JD	18X12X17	1780	21	465	0.641	RAFFINATE LIQUID
INGERSOLL DRESSER	JD	18X12X17	1780	21	465	0.641	RAFFINATE LIQUID
BINGHAM	CD	16X20X34	1180	21	503	0.64	RERUN COLUMN BOTTOMS
BINGHAM	CD	16X20X34	1180	21	503	0.64	RERUN COLUMN BOTTOMS

Graphoil Seals replaced with HT FFKM

- **Customer:** Gulf Coast Refiner
- **Applications:** Metal Bellows Seals
- **Media / Units:** Paraxylene and Benzene
- **Temperature:** up to 262°C (503°F)
- **Background:** Customer originally specified Graphoil secondary seals. Leakage occurred on a number seals shortly after start up due to poor sealing compression between the Graphoil and the shaft sleeve.
- **Outcome:** Seal vendor and customer began replacing the Graphoil with HT FFKM. The seal leaks were stopped. Approximately 55 mechanical seal have been retrofitted with the "High" Temp FFKM and have running successfully for 4 years.

Skip to Next Gen

Graphoil Seals replaced with HT FFKM

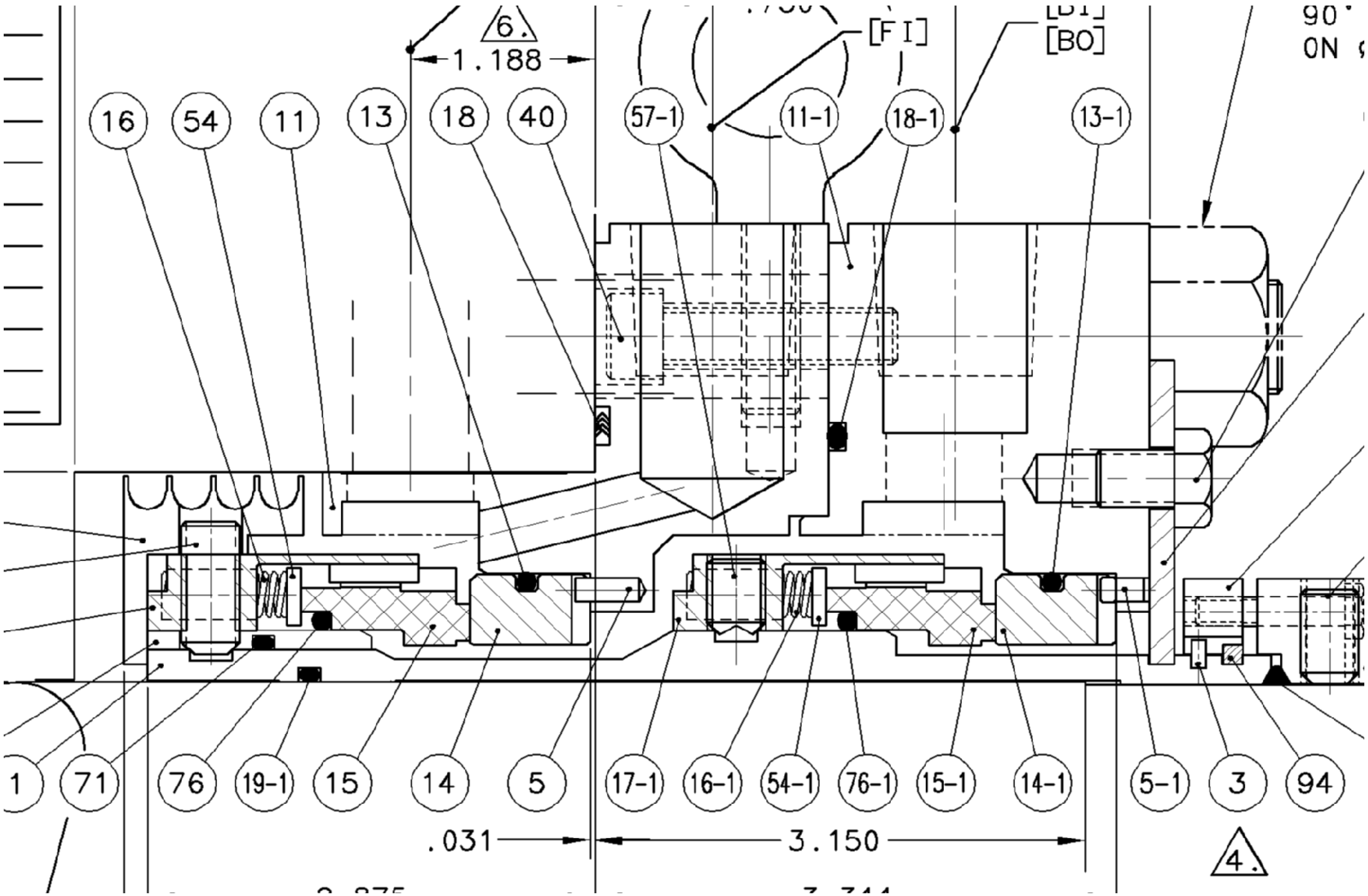


Pusher Seals Specified with HT FFKM

- Customer: Gulf Coast Refinery
- Application: Pusher Seal (Single & Double)
- Media / Units: Naptha / Heavy HC / LSG
- Temperature: up to 343°C (650°F)
- **Background:** Mechanical seals were originally specified with "High" Temp FFKM . Over 50 applications have been in place without failure for 3 years.

Skip to Next Gen

Pusher Seals Specified with HT FFKMs



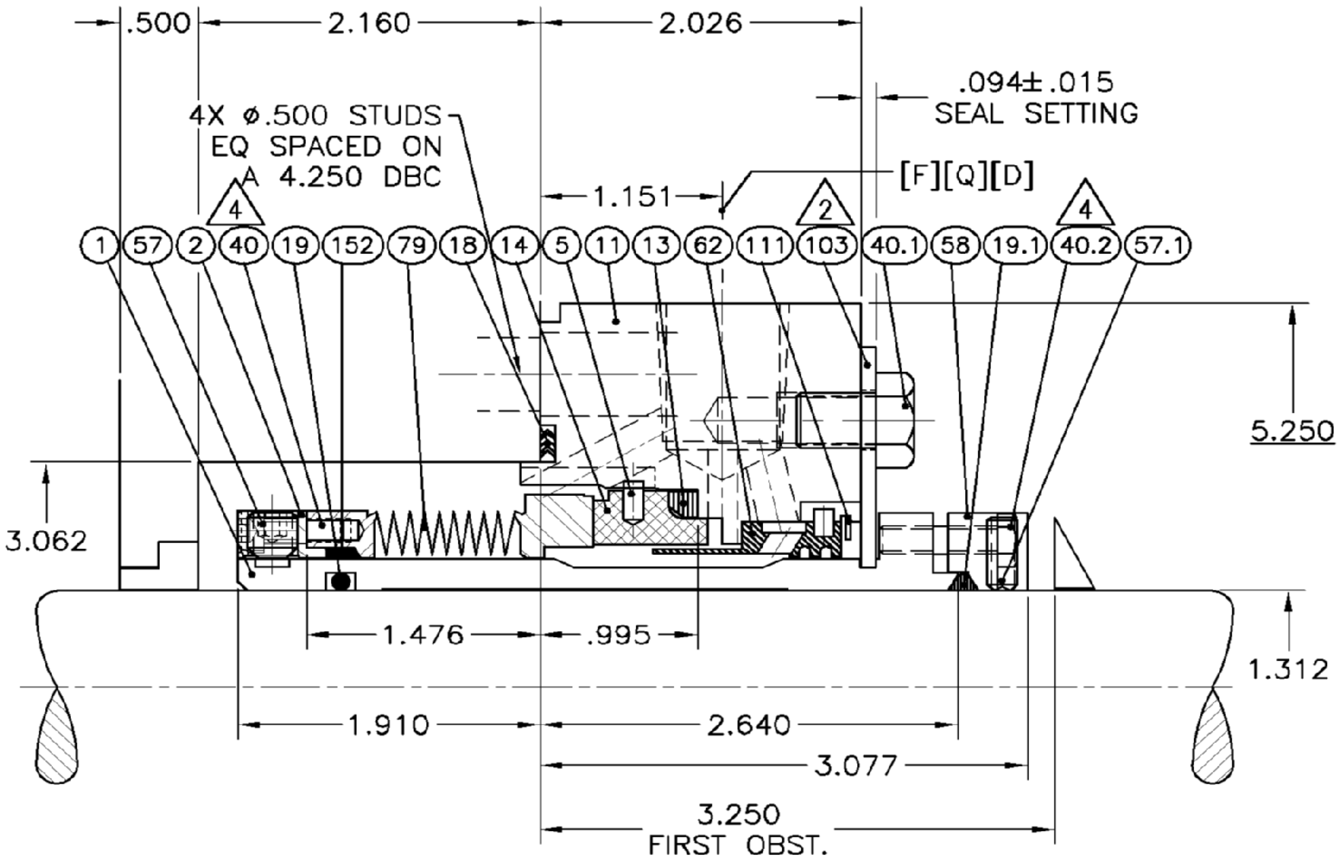
HT FFKM in Mechanical Seals & Sundyne Pumps

- **Customer:** Southern Refinery
- **Applications:** Mechanical Seals & Sundyne pumps
- **Media:** Dimethyl2, 6-Naphthalene Dicarboxylate
- **Temperature:** up to 343°C (650°F)
- **Background:** Customer experimented first with one mechanical seal using HT FFKM at 650F, 1,500psi and 3,500 rpm. This was considered the toughest application in the unit. The test was considered a success after running for 2 years when the seal was disassembled and the o-rings were found to be in "like new" condition. The customer has since upgraded approximately 45 mechanicals and 18 Sundyne pumps with "High" Temp FFKM . These applications have been running successfully ranging from 2 to 5 years.

Shaft Sleeve Seal – Metal Bellows Seals

- **Customer:** Gulf Coast Refinery
- **Application:** Mechanical Seals, Shaft seal
- **Media:** Various Hydrocarbons
- **Temperature:** up to 315°C (600°F)
- **Background:** Pump user was experiencing "gunk" build up underneath the shaft sleeve. This created problems removing the seal from the pump during change outs. Mechanical seal OEM addressed the problem by machining an o-ring groove on the inbound side of the shaft sleeve (see drawing next slide). HT FFKM was installed in this o-ring groove. Customer is very happy with the results. This practice has been in place for just over 2 years.

Shaft Sleeve Seal – Metal Bellows Seals



Perfluoroelastomer Recommendations

The following two slides outline the minimum recommendations that Greene, Tweed would make to API and Industry on Perfluoroelastomer use in the rotating equipment arena:

Perfluoroelastomers have come a long way since the data on sealing materials contained in API-610 and API-682 was originally incorporated.

Pefluoroelastomers should be considered in three family groups (as of Jan 2006):

- Universal Chemical Compatibility
  - Limited Thermal 232°C (450°F) and Limited Steam capability
- Universal Chemical Compatibility – Steam Resistance
  - Medium Thermal capability 260°C (500°F), High Steam capability
- Limited (Amine) Chemical Compatibility
  - High Thermal capability 324°C (615°F), No Steam capability

Perfluoroelastomer Recommendations

Guidance notes on the application of Perfluoroelastomers in API documentation should also contain:

High Thermal Expansion Coefficients of Perfluoroelastomer materials, when compared to NBR and FKM materials in the standards and the problems associated with excessive gland fill at high temperatures. (Increased compression set, stress rupture)

Problems of low physical properties, when compared to NBR and FKM materials in the standards and the tear problems associated with high percentages >3% of stretch, at high temperatures. (Gow-Joule effect)

General Note:

Perfluoroelastomers and sealing components made from them require as much knowledge on materials as those required for metallurgy, recognised training of those people involved in material selection of polymeric components is advised.

Perfluoroelastomers Next Generation

Perfluoroelastomer suppliers are working on bridging the gap by combining:

- The Universal media compatibility of “Medium” temperature FFKM’s with their good steam resistance and physical properties
- With improved high temperature capability of the “High” temperature FFKM’s

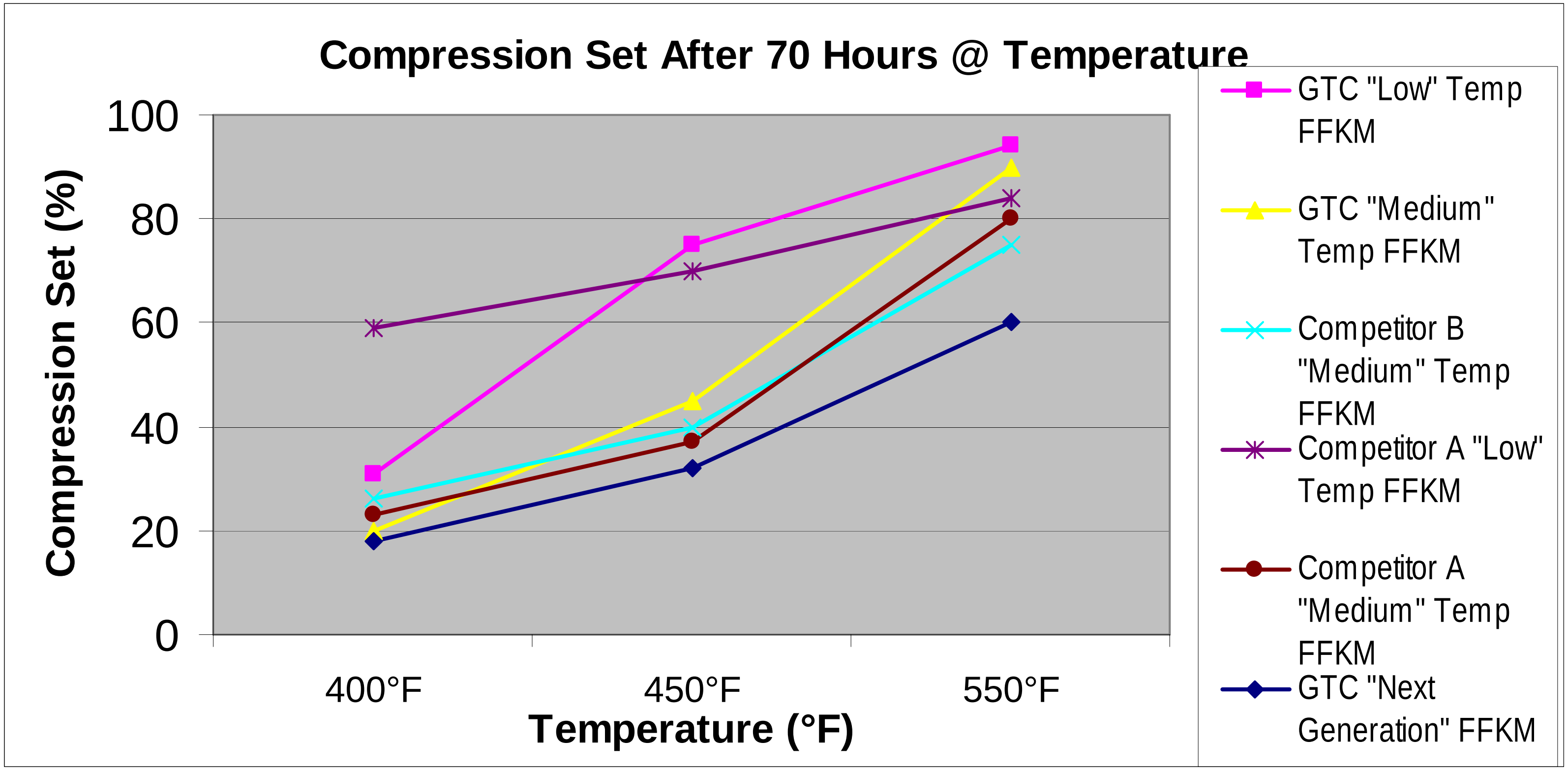
The “Next Generation” of Perfluoroelastomers will provide even greater flexibility in design and compatibility, with improved reliability in arduous applications

The following slides show how Greene, Tweed’s “Next Generation” Perfluoroelastomer improves upon current grades of FFKM in:

- Compression Set
- Chemical (Acid and Amine) Resistance
- Steam Resistance

Skip to Chem Comp

Comparative Compression Set - 70 Hours @ Elevated Temperatures

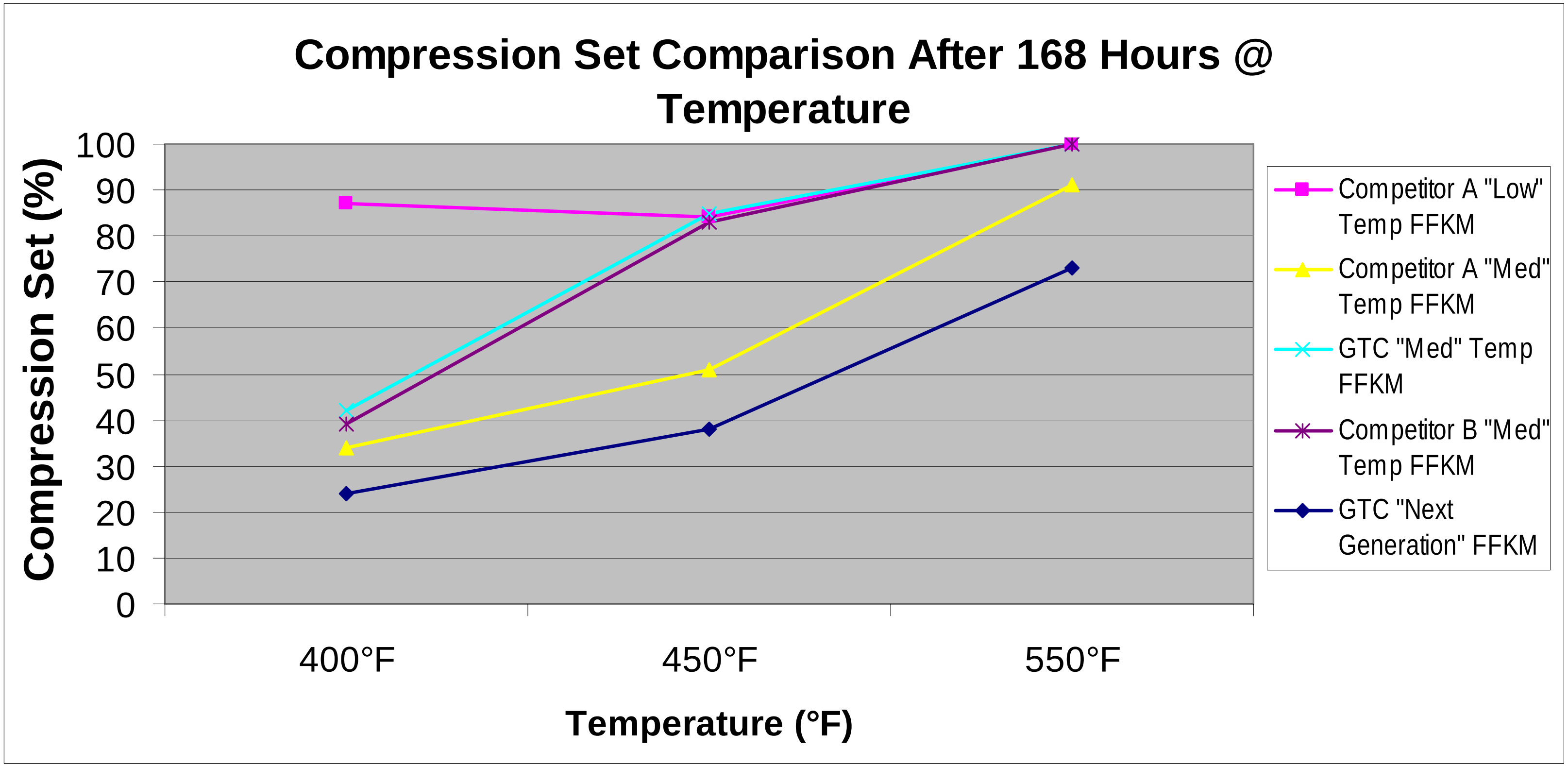


<u>Data Sources:</u>

•Greene Tweed Rubber Lab, Kulpsville, PA, and independent testing

•Note: All tests performed in accordance with ASTM D1414 on -214 Size O-rings

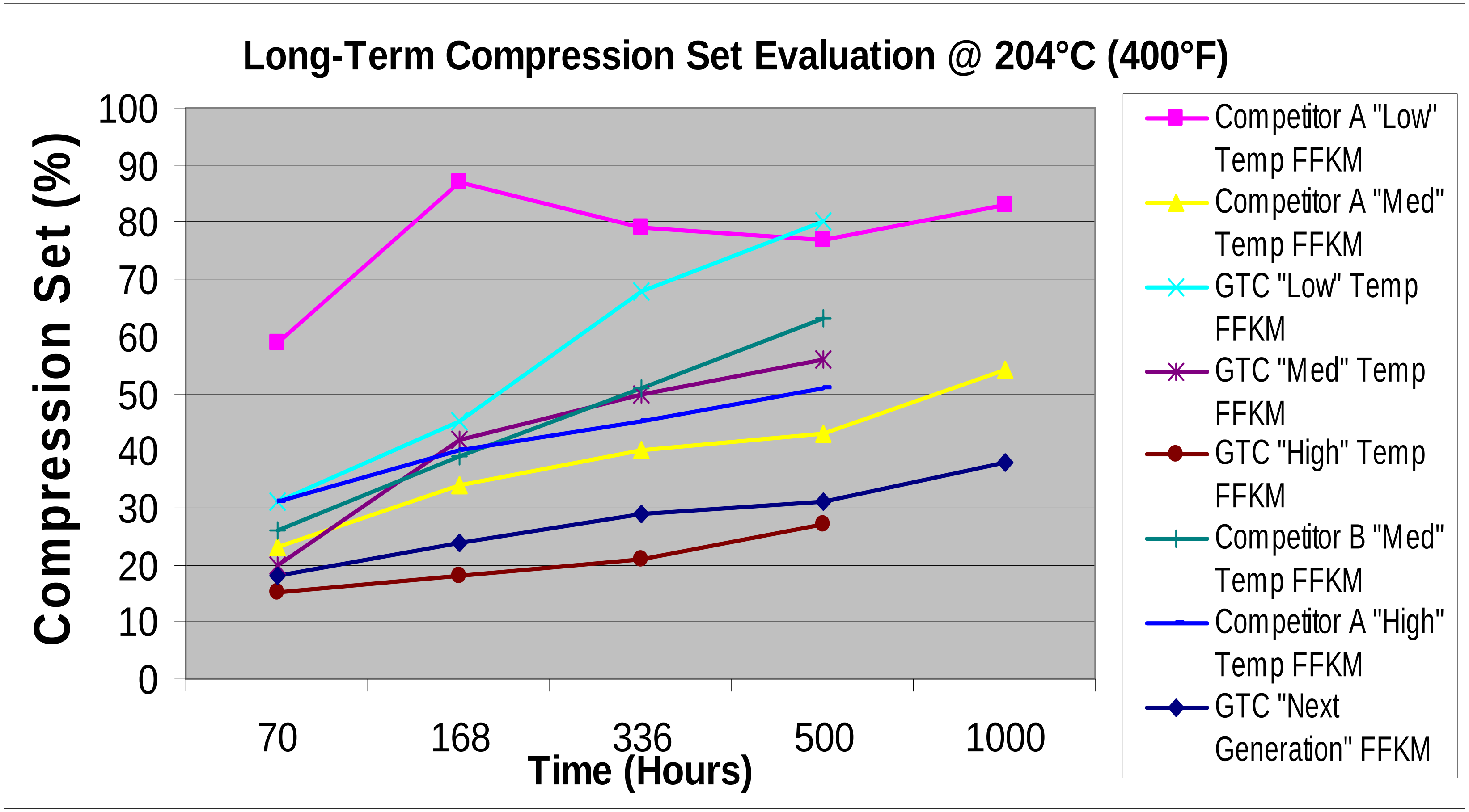
Comparative Compression Set - 168 Hours @ Elevated Temperatures



Data Sources:

- **Greene Tweed Rubber Lab, Kulpsville, PA, and independent testing**
- **Note: All tests performed in accordance with ASTM D1414 on -214 Size O-rings**
- **GTC "Low" Temp FFKM not included due to 100% compression set due to being above the recommended max temperature**

Comparative Compression Set – Long-Term @ 204°C (400°F)



Data Sources:

•**Greene Tweed Rubber Lab, Kulpsville, PA, and independent testing**

•**Note: All tests performed in accordance with ASTM D1414 on -214 Size O-rings**

GTC Perfluoroelastomer - Acid Soak Data 168 Hours @ 66°C (150°F)

Nitric Acid - 168 Hours @ 66°C (150°F)			
	GTC "Low" Temp FFKM	GTC "Med" Temp FFKM	GTC "Next Generation" FFKM
Volume Change	9.9	6.6	3.4
Tensile Change	-8.1	-14.5	-57.2
Elongation Change	64.6	29.3	50.6
Harness Change	-5	-3	-6

Sulfuric Acid - 168 Hours @ 66°C (150°F)			
	GTC "Low" Temp FFKM	GTC "Med" Temp FFKM	GTC "Next Generation" FFKM
Volume Change	-0.1	-0.3	-1.6
Tensile Change	14.8	2.5	13.9
Elongation Change	-5.4	-5.5	5.1
Harness Change	1	2	1

Acetic Acid - 168 Hours @ 66°C (150°F)			
	GTC "Low" Temp FFKM	GTC "Med" Temp FFKM	GTC "Next Generation" FFKM
Volume Change	5.7	3.5	3.2
Tensile Change	23.2	2.4	-1
Elongation Change	21.1	8.8	12.7
Harness Change	-2	0	-2

Skip to Properties

GTC Perfluoroelastomer - Amines Data
168 Hours @ Temperature

Dipropylamine - 168 Hours @ 21°C (70°F)			
	GTC "Low" Temp FFKM	GTC "Med" Temp FFKM	GTC "Next Generation" FFKM
Volume Change	1.5	-0.5	-0.9
Tensile Change	10.9	-1.5	4
Elongation Change	15.7	4.1	0
Harness Change	-2	0	-2

Dipropylamine - 168 Hours @ 93°C (200°F)			
	GTC "Low" Temp FFKM	GTC "Med" Temp FFKM	GTC "Next Generation" FFKM
Volume Change	4.3	3.1	4.5
Tensile Change	-5.4	-7.8	-25.1
Elongation Change	5.4	15	24
Harness Change	-2	-1	-2

GTC Perfluoroelastomer - Steam Data 168 Hours at 232°C (450°F) & "High Temp"

Steam - 168 Hours @ 232°C (450°F)			
	GTC "Low" Temp FFKM	GTC "Med" Temp FFKM	GTC "Next Generation" FFKM
Volume Change	19.7	2.8	6
Tensile Change	-52.3	-60.7	-68
Elongation Change	26	20	32
Harness Change	-10	-19	-3

Steam - 168 Hours @ "High Temperatures"			
	GTC "Next Generation" FFKM 260°C (500°F)	GTC "Next Generation" FFKM 290°C (550°F)	GTC "Next Generation" FFKM 315°C (600°F)
Volume Change	6.51	9.51	10.66
Tensile Change	-68.4	-68.9	-77.1
Elongation Change	23.1	48.6	39.9
Harness Change	-6	-8	-8

Elastomers Property Comparison

Properties	"Low" Temp FFKM (P)	"Medium" Temp FFKM (P)	"High" Temp FFKM (T)	"New Generation" FFKM (P)
Typ Min Temperature	-30ºC (-22ºF)	-20ºC (-4ºF)	-18ºC (0ºF)	-12ºC (+10ºF)
Typ Max Temperature	232ºC (450ºF)	260ºC (500ºF)	324ºC (615ºF)	316ºC (600ºF)
Abrasion Resistance	P	G	F	G
Acid Resistance	E	E	E	E
Amine Resistance	E	E	P	G
(Freons) Refrigerants	F	F	F	F
Heat Resistance	E	E	E	E
Oil Resistance	E	E	E	E
Ozone Resistance	G	G	E	G
Comp. Set Resistance	G	G/E	E	E
Solvent Resistance	E	E	E	E
Tear Resistance	P	G	F	G
Tensile Strength	G/E	E	G/E	E
Water/Steam <150ºC	E	E	G	E
Water/Steam >150ºC	G	G/E	P	E

Legend: **E**=Excellent, **G**=Good, **F**=Fair, **P**=Poor

Note: The above rankings are based on FFKM to FFKM not across material types

Perfluoroelastomer Recommendations

Pefluoroelastomers could be considered in four family groups (as of Sept 2006):

Universal Chemical Compatibility

Limited Thermal 232°C (450°F) and Limited Steam capability

Universal Chemical Compatibility

Medium Thermal capability 260°C (500°F) , High Steam capability

Limited (Amine) Chemical Compatibility

High Thermal capability 324°C (615°F) , No Steam capability

Next Generation Perfluoroelastomer Universal Chemical Compatibility

High Thermal capability 316°C (600°F) , High Steam capability