

RAISING THE BAR

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WHY THE NEW DIRECTION?

The never ending pursuit to increase the life expectancy of **elastomeric** seals that are constantly challenged by; elevated operating pressures, increasing flow rates, protracted throttling, harsher chemicals, looming **explosive decompression**, diminishing lubricity, potential **spiral failure**, mounting abrasion, broader thermal excursions, impending **compression set** failure and pugnacious steam, is the central developmental mission here at DuraSeat (OMG it's our name).

Indeed all seals, see Graphic 1, are confronted by this daunting list of challenges: static orings to a lesser extent dynamic orings especially those that rotate & reciprocate to a greater degree, but by far, the valve seat trim pays the ultimate economic toll for the above endlessly mounting burdens.

That's why when I first heard (late 2001) about Dupont's, then developmental APA (**Advanced Polymer Architecture**) fluoroelastomers, I paid attention and filed this info away in the back of my mind.

This now proprietary technology has demonstrated its value to be indeed as important & significant to the Double Block & Bleed seat as I envisioned. I'm excited to share the following information with you so that together we can make our users' future life better, while getting a leg up on the competition.

HOW DID WE GET HERE?

In about 1740 the first Western explorer to observe the collection of "Latex" a white, tacky, aqueous suspension with about 35% **hydrocarbon polymer** occurring naturally in some species of plants such as the Hevea tree (botanical function of the hydrocarbon is unknown) reported that this substance had commercial potential. Thirty years later, about 1770, in England when a sample of this Latex milk was treated to make a gum some observed how good it erased pencil marks hence the name "**Rubber**" was coined.

The Latex gum remained substantially useless, since in warm climates the heat of summer would revert the gum back to thick milky tree sap, until, sixty nine years later, Charles Goodyear made the "great discovery" in the winter of 1839. For four long years he had tried blending various chemicals into his gum in an attempt to stabilize the substance, to no avail, on a cold February day, he laid a piece of sulfur treated gum on a pot belly stove during a presentation he was making. Afterward, he picked up the piece of rubber, and much to his astonishment, he had stumbled upon, the substance he had envisioned.

Three years later in 1842 after perfecting the process the term “**Vulcanization**”, named after Vulcan the Roman God of Fire, was coined to describe the transformational process of Latex to cured Natural Rubber. With the advent of this breakthrough technology the rubber industry was born, providing tires just in time for the explosion of the motor vehicle industry in the 1890s.

The overwhelming demand for natural rubber fostered the need for the synthetic rubber industry. By 1930 the world’s first synthetic rubber plant opened in Buna, Germany for which “Buna-n” (AcryloNitrileButadiene Rubber; NBR) was named. In as little as twenty years (1950) synthetic rubber consumption in the US increased from nothing to equal that of natural rubber.

Meanwhile, in 1955 another issue was resolved, the original Chemlock rubber to metal concurrent vulcanization bonding (bonding to a substrate during the curing process) agent was patented. The goal of the bond agent is to cause a chemical reaction initiating an **atomic** attraction between the rubber and the substrate during vulcanization whose resultant chemical bond strength is superior to the strength of the rubber. Thus the higher the tensile strength of the rubber, the greater the bond strength can be.

WHICH IS THE BEST RUBBER FOR US AND WHY?

By 1957 there were natural and synthetic rubber seal materials available for most commercial industries. The Oil and Gas industry welcomed a newcomer DuPont’s Viton that year. Based on toughness, thermal capabilities, petrochemical resistance and bond-ability this **fluoroelastomer** quickly proved to be superior alternative to other elastomers as explained below and as shown in Graphic 2:

1. Higher **Molecular Weight** (the sum of the atomic weights of the atoms in a molecule) provides the rubber with the necessary strength and toughness required by the oil patch and pipelines.
2. High Density ([g/cc] or **specific gravity**) delivers added support required for seal toughness.
3. High Viscosity gum (Mooney) further conveys strength and toughness to the elastomer.
4. High **Dissociation** Energy (the process by which a chemical combination breaks up as a result of added heat or chemical attack [jewel/mole]) between carbon and fluorine imparts immensely improved heat and chemical resistance.
5. Complete **Saturation** is the state in which all available valence bonds of an atom are attached to other atoms. This imparts vastly improved chemical resistance.
6. Replacing some hydrocarbon compounds’ hydrogen atoms with **fluorine** atoms creates **fluorocarbon polymers** including fluoroelastomers. Such polymers are thermally stable and resistant to solvents and chemicals. Thus the high ratio of fluorine to hydrogen on the polymer backbone imparts heat and chemical resistance.

MORE DEVELOPMENT WAS STILL REQUIRED!

This new Viton fluoroelastomer, now known as Viton A, was indeed a helpful major step in the development of elastomers in its' day. An indication of just how much Viton A helped is to compare our industry's compatibility ratings from Graphic 2 to the available polymers of that day; NR @ 14%, EPDM @ 24%, NBR @ 41% and Viton A @ 58%. So as you can see, like any technical advancement indeed we had made progress, but there was still more work to be done. Some examples of these developmental roadblocks still to be challenged and vanquished over the next 45 years are discussed below:

1. Carbon Dioxide, Hydrogen Sulfide and other contaminants are often found in natural gas and liquid hydrocarbon streams. CO₂ combined with water creates corrosive carbonic acid, it also reduces the BTU value of the gas, thus reducing its marketability. H₂S is a dangerously toxic and tremendously corrosive gas which requires treatment.
2. The Amine Sweetening Process (H₂S is considered to be sour thus the term sweetening) removes these contaminants rendering the products suitable for market and transportation. Both H₂S and Amines aggressively attack all elastomers of this time including this new Viton A. Aflas* would have worked if available at that time.
3. With regard to the CO₂ there is an elastomeric explosive decompression risk. Some media under pressure permeates rubber substantially. During sudden depressurization the expanding gas can rupture the host seal causing failure. This phenomenon is overcome by proper compounding, the technology was evolving at that time and is used widely now.
4. Butadiene the 37th highest volume chemical, a suspected carcinogen, used to produce synthetic **elastomers** such as nitrile, neoprene and ABS resins. None of the early synthetic or natural rubbers were compatible with butadiene.
5. Acrylonitrile the 39th most popular chemical, a carcinogen, used to produce acrylic fibers, ABS plastics, nitrile rubber etcetera. All of the early rubbers were incompatible with acrylonitrile.
6. Steam is widely used in a variety of petrochemical processes one of the most important is in the production of hydrogen by the steam-hydrocarbon gas process known as reforming also it is used in steam cracking of gas oil and naphtha. All elastomers had difficulty with steam especially in the early days.
7. MTBE (Methyl Tertiary Butyl Ether), a gasoline octane booster, had not been marketed as such at that time. A special type of NBR copolymer mixture high in acrylonitrile and lower in butadiene monomers (see graphic 2) would have been required during this era. This high ACN Nitrile** (MaxNitrile) would not have been available for MTBE at that time. Nothing else would have worked, especially, Viton A.

8. Methanol the 22nd highest volume chemical, a small highly polar solvent, employs an unusual arrangement of molecular charges which encourages ionization thus, in a solution, it promotes emulsion and detergent action. Had Methanol been offered up as an octane enhancer / fuel extender during this time it would have enjoyed limited elastomeric compatibility, only EPDM***, none with Viton A.
9. MEK, methyl ethyl ketone, is an aggressive polar solvent that is used for a variety of purposes. We at DuraSeat use it to strip our competitors' old seat trim from their cores. All Elastomers of this time would swell in MEK > 200% except EPDM***.
10. Anhydrous (void of water) Ammonia, the 5th most popular chemical, alone or in compound is used frequently in the agricultural industry as a fertilizer. Back in the day EPDM*** would have been the only suitable elastomer for anhydrous ammonia.
11. Acetone, the 44th highest volume chemical produced in the US, a polar solvent, is used, amongst other uses, as fingernail polish remover. It used to only be compatible with EPDM***.
12. *Aflas in 2) above is an issue in and of itself as a result of limited fluid resistance. Multi-product pipelines transport just that, multiple products one after another. Most of these products are solvent based, Aflas is not compatible with the vast majority, we'll discuss why later.
13. **High ACN Nitrile (MaxNitrile) as in 7) above is an issue in and of itself as a result of limited compatibility. Thus High ACN Nitrile is simply not versatile enough for most pipelines. Multi-media pipelines require broad fluid resistance which is not demonstrated by any nitrile, MaxNitrle, or HNBR.
14. ***EPDM in the above 8), 9), 10) and 11) developmental roadblocks is an issue in and of itself. Multi-product pipelines transport as the name implies multiple products in succession. Most of these products are fuels, oils, solvents, aromatics and the list goes on. Thus EPDM with its' disdain for hydrocarbons is simply not versatile enough for most pipelines.
15. The original Viton Xtreme ETP could have potentially eliminated the issues in 12), 13) and 14) above if the chemical compatibility was slightly better and the bond-ability issue was overcome.
16. Strength has always been an issue in throttling high pressure differentials, especially in ANSI 600# and 900# applications. The seat trim elastomer by design and circumstance must be structurally self-supporting therefore two of its' physical properties namely Tensile and Modulus strengths both need to be substantially greater than the maximum applied load (MWP). None of the earlier elastomers could demonstrate these material physical properties.

TIME FOR MORE FLUOROELASTOMER BREAKTHROUGHS?!

Before we go much further in improving our understanding of our upcoming newly discovered seal materials we need to grasp at least some basic fluoroelastomer science.

Firstly let's establish that the major performance dissimilarities, namely heat and fluid resistance, in the following more recently developed fluoroelastomers is determined by the **copolymer's monomeric** make up.

Some familiar commercial names for these newer fluoroelastomeric copolymers include four ASTM D1418 monomeric family Types of Viton: Viton A FKM Type 1; Viton B, F, GF, and GF-S all FKM Type 2; Viton GLT, GLT-S, GFLT, GFLT-S all FKM Type 3; and Viton Xtreme ETP and ETP-S both FKM Type 5; one family type for both Aflas and Fluoraz FEPM Type 4; and one family type for both Chemraz and Kalrez FFKM.

All of these copolymers are created from a set of 6 monomer building blocks. 3 of these are straight **chain** monomers while 3 are [bulky **chain**] monomers designated in this paper by [square brackets]. Let's identify these 6 monomers.

| | | | | |
|----|--------------------------------|--------|------------------------|--------------------------------------|
| 1. | Vinyl Dene Fluoride | VDF | Straight chain monomer | $\text{CH}_2=\text{CF}_2$ |
| 2. | [Hexa Fluoro Propylene] | [HFP] | [Bulky chain] monomer | $\text{CF}_3\text{CF}=\text{CF}_2$ |
| 3. | Tetra Fluoro Ethylene | TFE | Straight chain monomer | $\text{CFOCF}=\text{CF}_2$ |
| 4. | [Perfluoro Methyl Vinyl Ether] | [PMVE] | [Bulky chain] monomer | $\text{CF}_3\text{CF}=\text{CF}_2$ |
| 5. | Ethylene | E | Straight chain monomer | $\text{CH}_2=\text{CH}_2$ |
| 6. | [Propylene] | [P] | [Bulky chain] monomer | $\text{CH}_2\text{CH}_2=\text{CH}_2$ |

These previously mentioned fluoroelastomeric copolymers are made up of two or more of these monomer families. One or more of these monomers in the copolymer are straight chain, which tend to crystallize if too long. A monomer with a [bulky chain] is incorporated at intervals to break up the crystallization tendency and produce a substantially **amorphous** elastomer. Only one [bulky chain] monomer can be used with each copolymer. So a dipolymer will employ two monomers, one straight chain and one [bulky chain]. While a terpolymer would use three monomers consisting of two straight chain and one [bulky chain].

FLUOROELASTOMERS REQUIRE A CURATIVE TO BECOME A COPOLYMER!

In addition to inherent differences between the various types and families of fluoroelastomers, a number of compounding variables have major effects on the physical property characteristics of the final vulcanizates. One very important variable is the **crosslinking** or **curing** system that is used to vulcanize the elastomer. The curative(s) determine cross link density which establishes elastomeric properties like compression set resistance and influences **tensile** and **modulus** strength.

Knowing this, just like Charles Goodyear stuck with rubber development discovering 'vulcanization' and the curative 'sulfur' for Latex, DuPont kept their eye on the ball pursuing better curatives for existing and newly discovered families of Viton fluoroelastomers. There are 3 basic curative types created over time with various enhancements, here are some notable milestones:

- 1957: **Diamine** curatives crosslinked the dipolymer Viton A. Together they exhibit slow curing, low compression set resistance, excellent bonds and high hot tensile strength.
- 1970: **Bisphenol** AF mixed in with Viton A became the first precompund gum with built in curative called Viton E60c. It exhibits fast cures, excellent scorch safety and good compression set resistance.
- 1976: Efficient **Peroxide** curing was introduced along with a new family of terpolymers Viton GLT, later GFLT and GF. Providing enhanced resistance to aggressive automotive oils, steam and acids.
- 1987: Improved **Bisphenol** with additional precompunds and the introduction of another new terpolymer family Viton B, F. Demonstrating still faster cures, improved mold release and better compression set resistance.
- 2002: A series of Peroxide cured types of Viton made with Advanced Polymer Architecture were introduced. These polymers, designated as APA polymers by having an "S" suffix on the product name, incorporate: 1) a **dual cure system**, implementing a **curative** and a **coagent**, providing the most thorough crosslink density ever while delivering vastly improved physical properties 2) a proprietary **cure site monomer** which provides improved chemical resistance especially to small polar molecules 3) and an improved molecular positioning of the cure site monomer along the polymer chain providing a crosslink network typical of a much higher molecular weight polymer improving steam resistance.

FLUROELASTOMERS REQUIRE HEAT, PRESSURE, TIME & ADDITIVES TO BECOME USEFUL ENGINEERING MATERIALS!

To prevent voids and improve material properties Oxides are incorporated which work with all three curatives as acid acceptors to absorb the reaction byproducts released such as steam, acid, fluorine and other gases.

Reinforcing fillers such as carbon blacks, minerals and fibers in cooperation with curatives, coagents, bond agents and cure site monomers enhance physical properties such as modulus, tensile strength, compression set resistance, tear strength and bond strength.

Heat, pressure, press cure time, curatives to a greater degree, coagents to a lesser degree, fillers and cure site monomers create initial cross links establishing elastomeric bond, press cure shape, and press cure properties.

Oven heat treating over extended time, curatives to a minimal degree, coagents to a greater degree and cure site monomers further enhance the cross link density formed and thus determine the ultimate physical properties.

SPAGHETTI MODELS MAY HELP WITH VISUALIZING THE SCIENCE!?

Let's use pasta to illustrate a dipolymer. In order to render the pasta's behavior amorphous in nature it must be cooked. The spaghetti noodles represent a straight chain monomer and bowtie noodles represent a [bulky chain] monomer. Put this pan of noodles on a plate, push it around, it would not maintain or return to any predetermined shape (amorphous). Now drench these noodles in Jello (the 'curative', any flavor :) place it now into a mold and refrigerate till thoroughly set (vulcanized). When demolded the "tie points" caused by the "cross linking" Jello, now causes the spaghetti and bowtie noodles to rebound or return to its original (molded) shape after a load (stress) is applied and then removed.

In order to further demonstrate the various APA curative systems lets add another different curative (coagent) beside Jello say pudding now imagine that it would improve physical properties which would improve chewiness, let's say that's a good thing. Also let's say that the smell of the refrigerator permeates easily through the mixture and travels through the end of the strand of spaghetti and spoils our concoction. So let's add another curative (cure site monomer) say taffy that binds only the ends of the spaghetti to itself preventing refrigerator gases from working along the axis of the noodles.

MAJOR CHARACTERISTICS OF THESE FLUROELASTOMER FAMILIES ARE DESCRIBED IN THE FOLLOWING SECTION:

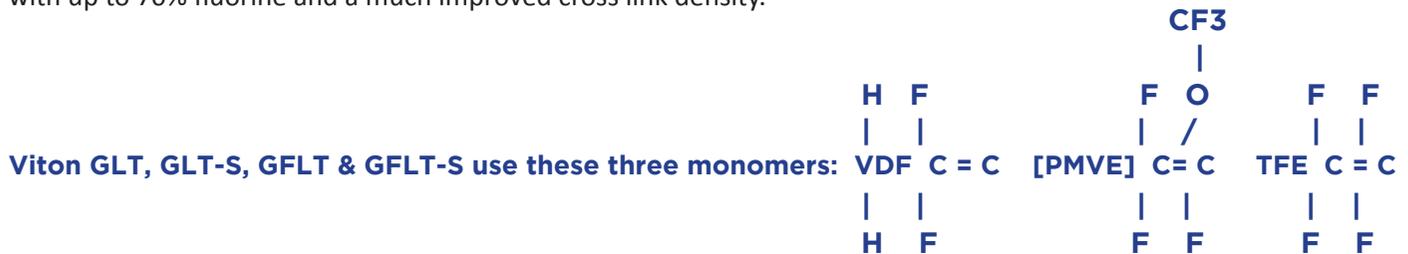
We finally have enough basic knowledge to proceed and appreciate our previously mentioned fluoroelastomers .



Dipolymers of VDF with [HFP] in about 80/20 mole ratio comprise the highest volume fluoroelastomers family. Originally cured with Diamene now readily cured with Bisphenol. Its 66% fluorine content yields excellent properties over a useful temperature range. These dipolymers are particularly useful for oring seals with good compression set resistance.



TFE may be added to the above replacing part of VDF in the dipolymer with [HFP] creating a new terpolymer which displays better fluid resistance with some sacrifice in low-temperature flexibility. Up to about 30% TFE may be incorporated without imparting excessive crystallinity. Viton B & F terpolymers offer 67%-69% fluorine and are cured with Bisphenol. Viton's cured with Peroxide incorporate a "G" in the prefix of the "type" code thus Viton GF & GF-S terpolymers are cured with Peroxide. These types display higher fluorine content in the range of 69%-70% and lower VDF levels. Viton GF-S also contains cure-site monomers to allow Peroxide initiated free radical curing and a dual cure system with up to 70% fluorine and a much improved cross link density.



Specialty terpolymers with monomers of VDF, [PMVE] & TFE have better low temperature flexibility than the [HFP] family described above. Cure site monomers must be incorporated to allow effective cross linking of these Peroxide cured polymers, usually by free radical cure systems. Products based on these compositions are becoming more important in automotive fuel systems sealing applications and low temp pipeline service, since good sealing performance is possible down to -50F. Fluorine contents vary from 64%-68% respectively. Additionally a dual cure systems is incorporated in the GFLT-S to enhance the crosslink density.



A terpolymer of E, [PMVE] & TFE, replacing VDF with E in above, with cure site monomers allowing Peroxide curing has excellent base resistance and fair low temperature characteristics. This specialty material is finding use in fluid environments where enhanced resistance to base, ketones, methanol, MTBE, ammonia and amines. It has been offered for use in oil seals for automotive power trains and multimedia pipelines. The ETP-S version incorporates a dual cure system providing Kalrez like chemical compatibility ratings and the best physical properties ever. Fluorine content is 67% to 73.5%.



This dipolymer is made of about 75% TFE & 25% [P] monomers. It demonstrates good base (7.1-14ph caustic and corrosive solutions) resistance but unlike the various Viton families it has poor resistance to solvents and petroleum products. It is Peroxide cured with the lowest fluorine content for fluoroelastomers of 55%-60% thus the narrow chemical resistance spectrum.



Perfluorolastomers are completely Fluoronated Fluoroelastomers demonstrating the highest possible content of 74% fluorine. This means that all of the Hydrogen atoms have been replaced with fluorine atoms. Thus these Perfluoroelastomers demonstrate the highest heat and broadest chemical resistance of all elastomers.

AND FINALLY HERE WE ARE!

In review referring to Graphic 2 one notes that the three seal materials with the most improved fluid compatibility and most importantly, elimination of our last 16 roadblocks as outlined on pages 4 & 5 namely CO₂, H₂S, Amines, Butadiene, Acrylonitrile, Steam, MTBE, Methanol, MEK, Anhydrous Ammonia, Acetone, Aflas, High ACN Nitrile(MaxNitrle), EPDM, Viton Xtreme ETP and Strength.

Selecting these three APA polymers as DuraSeat’s new line of elastomers as of May 2013 for our trim materials we are proud to introduce:

VITONGF-S: OUR NEW, BEST STANDARD MATERIAL BONDED INTO ANYONES SEAT, EVER!

Viton GF-S with monomers VDF[HFP]TFE is a next generation peroxide cured 69%-70% fluorine flueroeleastomer based on new Advanced Polymer Architecture. Compared to the original VitonGF, Viton GF-S exhibits improved fluid resistance in aromatic hydrocarbons, alcohols, polar solvents, steam and acids.

Features:

- Replaces Viton B, GF, Nitrile and HSN
- Exhibits excellent physical properties providing throttle resistance for 150#, 300#, 600# and even 900# ANSI class applications with outstanding compression set resistance
- Exhibits improved heat, fluids, and low temperature resistance compared to VitonGF
- Adds fluid compatibility for CO₂, butadiene, methanol and steam compared to VitonGF

VITON GFLT-S: OUR NEW LOW TEMP & BROADEST FLUID RESISTANCE MATERIAL BONDED INTO ANYONE'S SEAT, EVER!!

Viton GFLT-S with monomers VDF[PMVE]TFE is a next generation fluoroelastomer with a 67%-68% fluorine, peroxide-cured, low temperature fluoroelastomer utilizing the latest technology from DuPont, Advanced Polymer Architecture (APA).

Features:

- Replaces Viton GLT, GFLT, low temp nitrile, low temp HNBR
- Improved low temperature properties compared to Viton GFLT
- Excellent physical properties providing throttle resistance for 150#, 300#, 600# and even 900# ANSI class applications with outstanding compression set resistance
- Heat, fluids and low temperature down to -50F resistance is superior to Viton GLT and GFLT
- Adds fluid resistance to CO₂, butadiene, methanol and steam over Viton GFLT

VITON XTREME ETP-S: OUR NEW & BROADEST FLUID RESISTANCE MATERIAL EVER BONDED INTO ANYONES SEAT, EVER!!!

Viton Extreme ETP-S with monomers E[PMVE]TFE is an optimized Advanced Polymer Architecture compound exhibiting resistant to hydrocarbons and small polar molecules such as methanol and even ketones and it is not chemically attacked by amines. Low temperature properties also improved.

Features:

- Replaces Aflas, MaxNitrile, EPDM and Viton Xtreme ETP
- Higher physical properties providing throttle resistance for 150#, 300#, 600# and even 900# ANSI class applications with outstanding compression set resistance
- Heat, fluids and low temperature resistance superior to Viton Xtreme ETP
- Adds fluid resistance to CO₂, H₂S, amine, butadiene, acrylonitrile, methanol, steam, MTBE, MEK, anhydrous ammonia and acetone

GLOSSARY

Advanced Polymer Architecture is a series of peroxide cured types of Viton. These polymers, designated as APA polymers have an "S" suffix on the product name, they incorporate: 1) a **dual cure** system, implementing a **curative** and a **coagent**, providing the most thorough crosslink density ever while delivering vastly improved physical properties 2) a proprietary **cure site monomer** which provides improved chemical resistance especially to small polar molecules 3) and an improved molecular positioning of the cure site monomer along the polymer chain providing a crosslink network typical of a much higher molecular weight polymer improving steam resistance.

Amorphous materials are noncrystalline with geometrically random molecular structures they also demonstrate no well-defined melting point. All liquids are amorphous, some materials that appear to be solid are considered to be high viscosity liquids such as glass, plastics and rubber.

Atom is the smallest unit of an element which combines with the same or different elements to form **molecules**.

Bisphenol cure system is used primarily with Viton A precompounds to cross link VDF[HFP] monomers, it is also used to cross link Viton B and F terpolymers VDF[HFP] TFE.

Chains, usually, are a series of carbon **atoms** connected by chemical bonds which constitutes the structural configuration of a **compound**.

Compound is a substance composed of two or more elements in chemical combination. The resultant properties are far different than those of the elements. Such as hydrogen and oxygen both gases combine to make water a liquid.

Cross-linking is the attachment of two **chains of polymer molecules** with chemical bonds. The addition of chemicals and heat or radiation can artificially effect this.

Curative is an agent that effects a change in a material, along with heat and pressure, to make it suitable for use. In APA polymers the curative, peroxide, which controls the rate of the cure, it does so mostly during the press cure shape and set process.

Cure Site in a polymer chain that can be activated to allow additional crosslinks during heat treat.

Cure Site Monomer is a monomer with a reactive group, ordinarily incorporated in elastomer chains as free radicals at low levels, capable of undergoing crosslinking reactions at curing temperatures

Curing is the conversion of raw product to a useful condition usually with heat and chemicals.

Coagent is an agent that effects a change in a material, along with heat and a **curative**, to make it more suitable for use. In an APA polymer the coagent controls the final state of the cure, it does so mostly during the heat treat process

Compression Set or permanent set is the permanent distortion of a seal after withstanding a long term load at elevated temperature (% unrecovered deflection).

Copolymer is an elastomer produced by the simultaneous polymerization of two or more dissimilar monomers.

Diamine cure system used for cross linking early Viton A VDF[HFP] monomers now largely replaced with bisphenol cure system.

Dissociation is the process by which a chemical combination breaks up into simpler constituents as a result of added energy or a solvent.

Dual Cure System is a curative system used with APA polymers. It employs a curative which establishes the 'rate' of the cure while the coagent dictates the 'state' of the cure.

Elasticity is the ability of a material to recover its original shape partially or completely after a deforming force has been removed. The small amount of deformation that is not recovered is called permanent set or elongation. Glass and some metals are virtually 100% elastic, vulcanized rubber is in the range of 60%-90%.

Elastomer is a synthetic thermo-curing **high polymer** with mechanical properties similar to vulcanized natural rubber.

Explosive Decompression occurs when the sudden depressurization of seals ruptures said seals which have been immersed in certain high pressure media that permeates the rubber.

Fluorine is the most electronegative element and powerful oxidizing agent known, it forms fluorides with all elements but helium, neon and argon used in drinking water and toothpaste easily combining with calcium to harden teeth and bones.

Fluoroelastomer are elastomeric, high molecular weight, fluid and heat resistant, **fluorocarbon polymers** containing **fluorine**.

Fluorocarbons are chemical and heat resistant organic compounds analogous to hydrocarbons in which the hydrogen atoms have been replaced by fluorine.

Free Radicals is a molecular fragment having one or more unpaired electrons, usually short lived and highly reactive. In spite of their transitory existence, they are capable of initiating many kinds of chemical reactions by means of a chain reaction mechanism.

Hardness of a rubber compound effects 1) Modulus 2) Extrusion 3) Power wash resistance 4) Seal-ability. A softer compound will conform to machined surfaces easily sealing low pressures and vacuums. Higher pressures require stiffer compounds to resist extrusion and power washing due to throttling.

High Polymer is an organic macromolecule composed of a large number of monomers with molecular weights of 5,000 into the millions.

Hydrocarbons are organic compound consisting exclusively of carbon and hydrogen elements derived principally from petroleum, coal tar and plant sources.

Hydrogenation is any reaction of hydrogen with an organic compound. In the case of HNBR the hydrogenation of nitrile improves the mechanical and high temp properties of nitrile while essentially having no effect on the fluid resistance.

Macromolecule is a molecule comprised of an aggregation of hundreds or thousands of atoms. Such giant molecules are repeating chemical units called monomers linked together into **chain** structures called **polymers**.

Modulus Strength (for our purposes) is the extrapolated amount of stress required to stretch a test specimen 100%. Modulus varies with elastomer and its' compound ingredients and is usually directly proportionate to hardness. Modulus is a major design consideration for high pressure applications because it is the indicator of resistance to deformation, extrusion and power washing due to throttling.

Molecule is a chemical unit composed of one or more **atoms**.

Molecular Weight is the sum of the atomic weights of the **atoms** in a **molecule**.

Monomer is a **molecule** or **compound** usually containing carbon and of relatively low molecular weight and simple structure capable of conversion to a polymer, resin, or elastomer by combining with itself or other similar molecules or compounds.

Peroxide cure system based on **free radicals** generated by thermal decomposition of a peroxide at curing temperatures. The Viton families associated with peroxide cures all begin with a G prefix such as Viton GF.

Polymer is a **macromolecule** formed by the chemical union of five or more **monomers**.

Rubber is any of a number of natural or synthetic **vulcanized high polymers**.

Saturation is the state in which all valence bonds of a carbon atom are attached to other atoms.

Specific Gravity is the ratio of the density of a substance to a reference substance. It is an abstract dimensionless number. For solids and liquids specific gravity is numerically equal to density.

Spiral Failure occurs with reciprocating oring seals (gland ID) in association with low lubricity applications. The oring tends to stick to the shaft on one side causing rotation about its axis while stationary elsewhere. The oring will display a unique spiral failure. Use non solvent grease and 90 duro orings in order to overcome this challenge.

Tensile Strength is the amount of stress required to rupture a test specimen (psi).

Vulcanization is a physicochemical change resulting from cross-linking of the **unsaturated chain** of **polymers** with a **curative**, heat and pressure.

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