Fluoroelastomers

Fluoroelastomers are a class of synthetic rubber which provide extraordinary levels of resistance to chemicals, oil and heat, while providing useful service life above 200°C. The outstanding heat stability and excellent oil resistance of these materials are due to the high ratio of fluorine to hydrogen, the strength of the carbon-fluorine bond, and the absence of unsaturation. Fluoroelastomers are referred to generically as FKM polymers per the nomenclature noted in ASTM D1418. In the SAE J200 / ASTM D2000 classification system for rubber materials, fluoroelastomers are documented as a “HK” material, and can be found in the HK section of this specification.

BACKGROUND

The original fluoroelastomer was a copolymer of hexafluoropropylene (HFP) and vinylidene fluoride (VF_2). It was developed by the DuPont Company in 1957 in response to high performance sealing needs in the aerospace industry. To provide even greater thermal stability and solvent resistance, tetrafluoroethylene (TFE) containing fluoroelastomer terpolymers were introduced in 1959 and in the mid to late 1960’s lower viscosity versions of FKMs were introduced A breakthrough in crosslinking occurred with the introduction of the bisphenol cure system in the 1970’s. This bisphenol cure system offered much improved heat and compression set resistance with better scorch safety and faster cure speed. In the late 70’s and early 80’s fluoroelastomers with improved low temperature flexibility were introduced by using perfluoromethylvinyl ether (PMVE) in place of HFP. These polymers require a peroxide cure. The latest FKM polymers have a much broader fluids resistance profile than standard fluoroelastomers, and are able to withstand strong bases and ketones as well as aromatic hydrocarbons, oils, acids, and steam.

APPLICATIONS

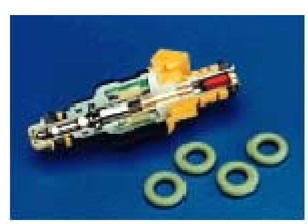
Fluoroelastomers are used in a wide variety of high-performance applications. FKM provides premium, long-term reliability even in harsh environments. A partial listing of current end use applications include:

Aerospace
1. O-ring seals in fuels, lubricants, and hydraulic systems
2. Manifold gaskets
3. Fuel tank bladders
4. Firewall seals
5. Engine lube siphon hose
6. Clips for jet engines
7. Tire valve stem seals

Automotive
1. Shaft seals
2. Valve stem seals
3. Fuel Injector O-rings
4. Fuel hoses
5. In tank and quick connect fuel system seals
6. Gaskets (valve & manifold)
7. Balls for check valves
8. Lathe cut gaskets

Industrial
1. Hydraulic o-ring seals
2. Check valve balls
3. Military flare binders
4. Diaphragms
5. Electrical connectors
6. Flue duct exp. joints
7. Valve liners
8. Roll covers
9. Sheet stock / cut gaskets


Fuel hose lined with FKM


FKM O-rings and seals for fuel injectors

PRODUCERS

There has been significant developmental activity in the past decade related to the end-use application and new product development of FKMs. This has resulted in a large portfolio of intellectual assets (patents) which continues to grow. Major producers of FKM include:

Producer	Product Tradename
DuPont Dow elastomers, L.L.C	Viton® fluoroelastomer
Dyneon	Dyneon® fluoroelastomer
Ausimont	Tecnoflon® fluoroelastomer
Daikin	Daiel® fluoroelastomer

ATTRIBUTES OF FKM

Fluoroelastomers are a family of fluoropolymer rubbers, not a single entity. Fluoroelastomers can be classified by their fluorine content, 66%, 68%, & 70% respectively. Fluoroelastomers having higher fluorine content have increasing fluids resistance derived from increasing fluorine levels. Peroxide cured fluoroelastomers have inherently better water, steam, and acid resistance.

Since one of the primary attributes of fluoroelastomers is its fluids resistance, it is necessary to define the capability of each type of FKM to various environments.

Types of Fluoroelastomers
Differences in Fluids Resistance & Low Temperature Capability

Fluid or environment	Type Of Fluoroelastomer(a)							
	A 66% fluorine copolymer)	**B** 68% fluorine terpolymer)	**F** 70% fluorine terpolymer)	**GBL** 66% fluorine terpolymer)	**GF** 70% fluorine terpolymer)	**GLT** 64% fluorine low temp. terpolymer)	**GFLT** 67% fluorine low temp. terpolymer)	**ETP** 67% fluorine non-VF2 terpolymer)
	Cure System							
	Bisphenol			**Peroxide**				
Aliphatic Hydrocarbons, Process fluids, chemicals	1	1	1	1	1	1	1	1
Aromatic Hydrocarbons (toluene, etc.), Process fluids, chemicals	2	1	1	1	1	2	1	1
Automotive & Aviation Fuels (pure hydrocarbons - no alcohol))	1	1	1	1	1	1	1	1
Automotive fuels containing legal levels (5-15%) of alcohols & ethers (methanol, ethanol, MTBE, TAME)	2	1	1	1	1	2	1	1
Automotive / methanol fuels blends up too 100% methanol (flex fuels)	NR	2	1	2	1	NR	1	1
Engine lubricating oils (SE-SF grades)	2	1	1	1	1	1	1	1
Engine lubricating oils (SG-SH grades)	3	2	2	1	1	1	1	1
Acid (H_2SO_4, HNO_3), hot water, and steam	3	2	2	1	1	1	1	1
Strong base, high pH, caustic, amines	NR	NR	NR	NR	NR	NR	NR	1-2
Low molecular weight carbonyls – 100% concentration (MTBE, MEK, MIBK, etc.)	NR	NR	NR	NR	NR	NR	NR	1-2
Low temperature sealing capability TR-10 test results	**-17°C**	**-14°C**	**-7°C**	**-15°C**	**-6°C**	**-30°C**	**-24°C**	**-11°C**

a = naming convention used by one of the major suppliers of fluoroelastomers
1 = Excellent, minimal volume swell 2 = Very Good, small volume swell 3 = Good, moderate volume swell
NR = Not Recommended, excessive volume swell or change in physical properties

CHEMISTRY AND MANUFACTURING PROCESS

Fluoroelastomers are generally made in an emulsion polymerization process. Fluoro-monomers such as HFP, VF2, and TFE are fed to a reactor under elevated temperature and pressure along with surfactants and other additives. Once the polymerization is complete the latex is removed, the polymer coagulated and washed, and the polymer is dried and packaged for use.

The main fluoroelastomer compositions are shown below:

Copolymer fluoroelastomer:

$-(CF_2-CF)-(CH_2-CF_2)-$
|
CF_3

Terpolymer fluoroelastomer:

$-(CF_2-CF)-(CH_2-CF_2)-(CF_2-CF_2)$ - TFE level can be varied for different fluorine contents
|
CF_3

Improved Low Temperature Fluoroelastomer Terpolymer:

$-(CF_2-CF)-(CH_2-CF_2)-(CF_2-CF_2)$ - HFP replaced with fluoro-ether
|
$O-CF_3$

Non-VF_2 Fluoroelastomer Terpolymer:

$-(CF_2-CF)-(CH_2-CH_2)-(CF_2-CF_2)$ - VF_2 replaced with ethylene, imparts base / amine resistance
|
$O-CF_3$

CONCLUSIONS

Fluoroelastomers are a high value in use class of synthetic rubber which provide extraordinary levels of resistance to chemicals, oil and heat, and service life above 200°C. Fluoroelastomers can be fabricated into seals, o-rings, and hoses for a variety of high performance applications in the automotive, aerospace, and petrochemical industries.