FUNCTIONAL PRODUCTS INC.
Innovative Chemistry for Lubricants

Viscosity Modifiers

QMS Certified to ISO 9001:2015 (With Design) REACH and GHS Compliant

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FUNCTIONAL PRODUCTS INC.

Since 1985, Functional Products Inc. has been a leading supplier of innovative polymer additives for lubricants and grease.

Functional Products Inc. manufactures market general components as well as unique, tailor-made additive solutions through development projects with clients. FPI produces over 300 standard or custom products from one drum to tanker batches.

All clients – from small blenders to multi-national corporations – receive world-class support on the necessary technologies, formulations, and regulations from experts on staff to succeed on their projects.

FPI's headquarters, offices, labs, and production are located in Macedonia, Ohio, USA. For global sales and warehousing, contact **sales@functionalproducts.com** or refer to page 2 of the **Applications Chart**.

Mission Statement

"Functional Products Inc. is committed to providing our customers with quality products and services that meet or exceed their expectations through the use of continuous improvement."

FPI is proud to maintain an ISO 9001:2015 (with design) quality management system and complies with all REACH and CLP regulations, including the Globally Harmonized System (GHS) for labeling.

Health and Safety

The product descriptions, labels, and datasheets (TDS) are not intended to take the place of a Safety Data Sheet (SDS).

SDS are available online or requested at: **sds@functionalproducts.com**

Viscosity Modifiers

Viscosity modifiers, or "VM", are a diverse range of different polymers which allow formulators to control the viscosity behavior of lubricants.

Viscosity modifiers may also be called or include:

- **"Viscosity index improvers"** or **"VI improvers"** when the VM provides a substantial increase to the viscosity at 100°C. This reduces the thinning of oil at high temperatures and improve the viscosity index (VI). Medium to high molecular weight polymethacrylates and olefin copolymers are examples.

- **"Thickeners"** when only viscosity at 40°C for an ISO grade or viscosity at 100°C for an SAE grade are desired without considering VI. Low molecular weight polybutenes are an example. This term can also include heavy petroleum cuts like bright stock.

- **"Synthetic base stocks"** for low to medium molecular weight polymers with excellent shear stability and strong thickening efficiency. High viscosity metallocene PAO (mPAO), liquid ethylene-propylene oligomers (EPO), and shear stable polymethacrylates are examples.

Excellence in Lubrication

Functional Products Inc. is an active member or participant in the following professional technical organizations:

STLE • ILMA • NLGI • ELGI • NLGI-IC • CLGI • K-STLE • AOCS •UEIL • Lube Expo

and supporter of university programs in lubrication and tribology.

Functional Products Inc. has received best technical paper awards at:

ELGI (Paris, 2011) NLGI (Coeur d'Alene, 2018)
NLGI-IC (Amritsar, 2018) CLGI (Wuyishan, 2011)

Functional Products Inc. was noted as an 'HPM Valuable Contributor' for the NLGI High Performance Multiuse Grease Specification (2020).

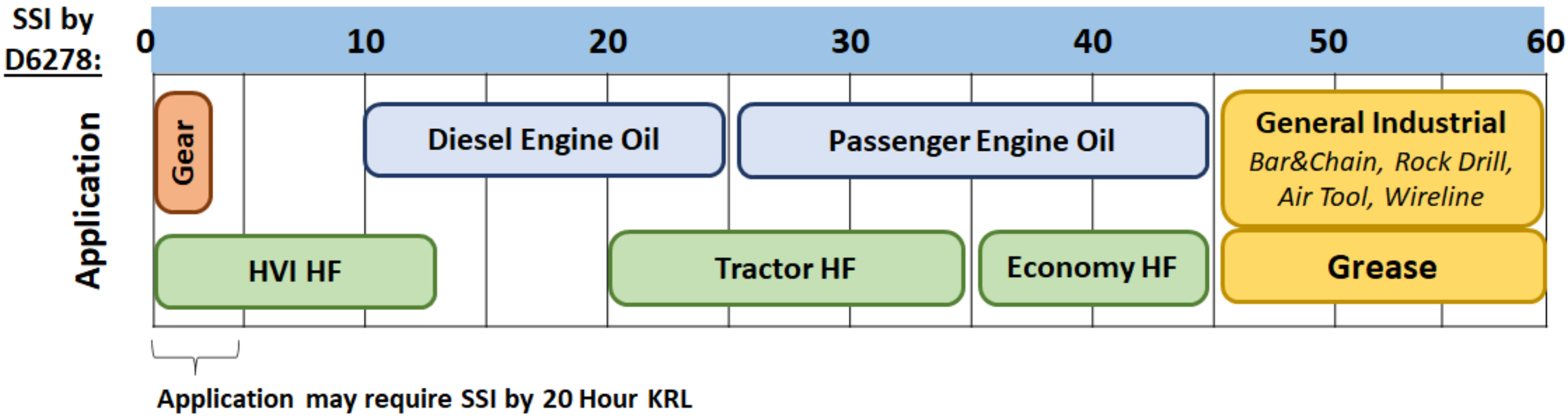
Scientists from FPI authored the chapter "Tackifiers and Antimisting Additives" in *Lubricant Additives: Chemistry and Applications*, 2nd ed. (2009) and 3rd ed. (2017), edited by Leslie R. Rudnick; and helped edit the *NLGI Lubricating Grease Guide*, 7th ed. (2022).

Viscosity Modifier Selection

This brochure features industrial viscosity modifiers mainly for petroleum based lubricants and greases. VMs for biobased or incidental food contact (NSF H1) are described in the **Biobased** and **Food Grade** brochures from Functional Products Inc.

The key selection factor in starting development work with a viscosity modifier is to select any appropriate shear stability index or "SSI" based on how aggressive the mechanical shearing of the working environment is. Heavily loaded, high speed gears can damage large polymers while engine oils or general purpose industrial lubricants do not experience high pressure shearing.

The recommended SSI rating of the viscosity modifier varies with the severity of the application:



Viscosity modifiers in this brochure are indexed by their SSI by ASTM D6278 but may include the SSI by 20 Hour KRL for severe applications like industrial gear, automotive gear, ATF, and HVLP HVI hydraulic fluids.

Terms and abbreviations in this brochure:

Form – Solid polymer is available in bale, pellet, or flake form.

SSI – "Shear Stability Index", a measure of how mechanical shearing damages the polymer and reduces viscosity.

ASTM D6278 – Diesel injector or Kurt-Orbahn shear. Mild shearing comparable to engine oil conditions.

20 Hour KRL – CEC L-45-A-99 or "tapered roller bearing" test. Severe shearing comparable to gear oils.

Chemistry – Type of polymer based on the monomers used.

OCP – Olefin Copolymer. Copolymers of different olefins: ethylene, propylene, butylene, etc.

Styrene OCP – Olefin copolymers with some styrene content for improved performance.

PMA – Polymethacrylates. Copolymers of methacrylate esters which are tuned by changing the esters.

EPO – Ethylene propylene oligomers. Low molecular weight, liquid copolymers of ethylene and propylene.

PAO – Low viscosity polyalphaolefins. Group IV base fluids up to ISO 68.

mPAO – Metallocene PAO. High molecular weight PAO prepared up to 300 cSt at 100°C.

Base Oil – Type of diluent oil used to prepare solubilized viscosity modifiers in liquid form.

% Ethylene – wt% ethylene content in the polymer.

Thickening Efficiency – Viscosity at 100°C of 150SN Group I oil with 10wt% (for liquids) or 1wt% (for solids) of product.

Treat for 1000 cSt – wt% polymer required to obtain 1000 cSt at 100°C in 100N Group II oil.

Olefin Copolymers (OCP)

Olefin copolymers are a diverse group of polymers with medium to high molecular weight which are best suited for medium to low shear applications. These applications include: engine or crankcase oil, tractor fluids, hydraulic fluids, pneumatic oils, greases, rust preventatives, and general purpose industrial lubricants. OCPs are a cost effective replacement for heavy petroleum oils and provide both improved low temperature fluidity and greater high temperature viscosity.

Functional Products Inc. offers material in both liquid and solid form. Contact us for custom diluent oils, viscosity grades, and more as required for your production capabilities or the end application.

Availability and packaging options for solid polymers may vary by location.

Solubilized Olefin Copolymers in Liquid Form

High quality OCP pre-dissolved in highly refined petroleum oil is the fastest and easiest way to add VM to a batch.

Product	Viscosity, at 100°C	SSI, ASTM D6278	Chemistry	Base Oil	Thickening Efficiency, 10wt%
V-160	1000	22	OCP	Paraffinic	11.0 cSt
V-166	1200	35	OCP	Paraffinic	11.4 cSt
V-158	1200	45	OCP	Paraffinic	11.9 cSt
V-158F	1400	50	OCP	Paraffinic	12.1 cSt
V-201L	4500	60	OCP	Paraffinic	12.3 cSt

Solid Form Olefin Copolymers

OCP in bale (block), pellet, or flake form offers the best economics but requires the time and energy to process.

Product	Form	SSI, ASTM D6278	Chemistry	% Ethylene	Thickening Efficiency	Treat for 1000 cSt
V-100	Bale	22	OCP	45 – 55%	11.0 cSt	9.8 wt%
V-125	Bale	24	OCP	45 – 55%	9.7 cSt	11.3 wt%
V-255	Pellet	25	OCP	12 – 18%	10.5 cSt	13.0 wt%
V-135	Bale	35	OCP	45 – 55%	11.9 cSt	8.3 wt%
V-101	Bale	45	OCP	45 – 55%	13.0 cSt	9.0 wt%
V-113	Bale	50	OCP	50 – 60%	14.6 cSt	6.6 wt%
V-201	Pellet	60	OCP	60 – 70%	21.0 cSt	5.4 wt%

Styrene Olefin Copolymers

The use of styrene in Styrene OCPs like **FUNCTIONAL V-711** enables lower molecular weight copolymer in solid form, increases the viscosity index improvement, and allow excellent performance at low temperature. The flake form dissolves readily. **FUNCTIONAL V-4316** is a high molecular weight liquid viscosity modifier which offers excellent benefit as a VM for industrial lubricants and greases.

Product	Form	SSI, ASTM D6278	Chemistry	Thickening Efficiency
V-711	Flake	7	Styrene OCP	9.8 cSt
V-4316	Liquid	60	Styrene OCP	11.0 cSt

Polymethacrylates (PMA)

FUNCTIONAL M Series viscosity modifiers are polymethacrylate copolymers which offer greatly improved shear stability, viscosity index improvement, and low temperature fluidity versus olefin copolymer (OCP) viscosity modifiers. Olefin copolymers typically have SSI from 20 – 60 by ASTM D6278 diesel injector shear; polymethacrylates can achieve SSI as low as 0 by ASTM D6278 and require the more aggressive 20 Hour KRL (CEC L-45-A-99) test to exhibit shearing of viscosity.

FUNCTIONAL MH-2000, **MH-4500**, and **MH-7000** are highly recommended starting points.

For PMA pour point depressants, see the **Industrial Additives** brochure from Functional Products Inc.

Product	**Viscosity,** at 100°C	**SSI,** ASTM D6278	**SSI,** 20 Hour KRL	**Thickening Efficiency,** 10wt%	**Key Applications**
MG-1000	1050	0	15	9.8 cSt	Gear oil and HF in (PAO)
MG-3000	550	0	20	11.0 cSt	Gear oil and HF in Group I-III
MH-2000	1050	1	35	9.7 cSt	Economy gear oil
MH-4500	1550	15	65	13.0 cSt	Hydraulic fluid
MH-7000	1550	36	N/A	14.6 cSt	High VI industrial, engine oil

Dispersant Polymethacrylates

For Enhanced Varnish and Sludge Control

FUNCTIONAL MD polymethacrylates include a small percentage (<1%) of nitrogen functionality to greatly reduce deposits formed from high temperature and oxidation. **FUNCTIONAL MD** products are often used in clutch or transmission fluids for tractor, automotive, and racing where high heat and wear is generated.

Product	**Viscosity,** at 100°C	**SSI,** ASTM D6278	**SSI,** 20 Hour KRL	**Thickening Efficiency,** 10wt%	**Key Applications / Notes**
MD-8004	950	40	N/A	16.9 cSt	Tractor hydraulic

High Viscosity Synthetic Base Stocks

Synthetic base stocks are defined here as shear stable polymers meeting or exceeding the 15% viscosity loss by DIN 51350-6 (also known as 20 Hour KRL or CEC L-45-A-99) for applications like HVLP high VI hydraulic fluid or OEM gear oils. These high viscosity options are able to effectively thicken low viscosity fluids with minimal shear loss in severe duty applications.

Product	Chemistry	Viscosity, at 40°C	Viscosity, at 100°C	Viscosity Index	SSI, 20 Hour KRL	Flash Pt., D92 COC	Density, lb/gal	Color, D1500
V-731	EPO	19000	1100	270	10	280°C	7.1	0.5
V-732	EPO	40000	2000	290	15	290°C	7.1	0.5
MB-1010	PMA	44000	900	170	15	200°C	7.8	1.0
V-705	Polyolefin	37000	6500	510	4	220°C	7.5	<0.5

FUNCTIONAL V-731 and V-732

Industrial Ethylene Propylene Oligomers

FUNCTIONAL V-731 and **V-732** are low molecular weight copolymers (“oligomers”) of ethylene and propylene in liquid form. Ethylene propylene oligomer (or “EPO”) viscosity modifiers offer the best thermal, oxidative, and hydrolytic stability versus other synthetic base stocks including metallocene PAOs.

FUNCTIONAL MB-1010

Polymethacrylate Base Stock

FUNCTIONAL MB-1010 is a high viscosity synthetic base stock which has been tailored for improved thickening efficiency, high VI improvement, and low temperature fluidity in PAOs for applications like full synthetic 75W automotive gear oils. **FUNCTIONAL MB-1010** contains polar ester functional groups and can improve the solubility of synthetic formulations versus EPO or mPAO thickeners.

FUNCTIONAL V-705

Low Temperature High Performance Base Stock

Proprietary polyolefin **FUNCTIONAL V-705** is ideally suited for low temperature, high VI hydraulic fluids in paraffinic oil. **FUNCTIONAL V-705** in Group III paraffinic oil can exceed the low temperature performance of full PAO/mPAO formulas. **FUNCTIONAL V-705** provides highly shear stable thickening without negligible effect on low temperature fluidity in tests like Brookfield viscosity (ASTM D2983) or pour point (ASTM D97).

FUNCTIONAL V-705 is not recommended for the extreme temperatures and oxidative stress of industrial and automotive gear oils.

Guidelines for Handling and Blending

Handling High Viscosity Additives

SAFETY – Consult safety data sheet before any transferring operation and wear appropriate PPE for both the physical hazards of heating and pressurized fluids/equipment and any chemical hazards associated with the product. When working with heated surfaces or liquids, the ASTM C 1055 standard suggests temperatures of 100°F/40°C can cause immediate pain with skin damage after long-term exposure while temperatures of 140°F/60°C can cause immediate damage to skin upon contact.

Drums and tote unloading – Drums can be warmed to facilitate pouring or pumping with a hot room, drum oven, or individual heating jackets. Totes should be warmed in a hot room or drum oven but heating jackets should be avoided to prevent melting of the plastic container. Inspect containers for residual product before proper disposal.

Storage – High viscosity synthetic base stocks may be transferred to large heated storage tanks for ease of use in production. Long-term storage is recommended at 100-160°F (40-70°C). Nitrogen blanketing is ideal. Use the lowest temperature possible to achieve acceptable pumpability to minimize product oxidation and discoloration. Avoid localized hot spots above 300°F (150°C) by restricting boiler and steam jacket pressure to 50 psi or less.
Check storage tank regularly for discoloration or changes to viscosity. Circulate tank once per day.

Blending with Viscosity Modifiers

Lubricants – Blending high viscosity materials should occur at 100-140°F (40-60°C). Add base oils in order from lowest to highest viscosity followed by viscosity modifiers (or VI improvers), additives and packages, and finally tackifiers. Allow 30 minutes of continuous mixing between each different component to ensure equal mixing and avoid possible incompatibilities. Once all components have been added proceed with QC and oil adjustments to reach target viscosity. Mixing speed should be regulated to avoid aerating the product and ideally to minimize disturbances to the surface which will reduce oxidation and discoloration.

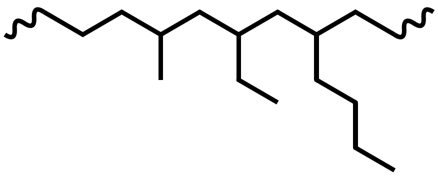
Lubricants with solid polymer – If dissolving solid polymers then it is recommended to add 0.1wt% of a process antioxidant such as BHT and heat the base oils to 176-212°F (80-100°C). Grind bales to ¼" pieces or chop into 1" slides and add to tank manually or through a conveyor or blower system. Allow 8-16 hours for polymers to dissolve with higher concentrations of higher MW polymers requiring the longest time. Adjust times and temperatures as needed but always confirm a process change at small scale in the lab first.

Tank and Mixer Design – Functional Products recommends an upright mixing tank equipped with external steam jacket, side baffles, top-mounted paddle mixer, and center drain to ensure the most thorough blending of high viscosity liquids into other base oils and additives. Consult Functional Products Inc. for a generic tank schematic or how to adapt an existing tank.

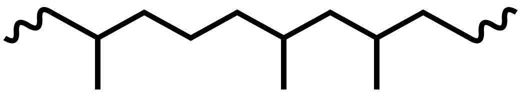
Mixing by recirculating with a pump is not recommended and may produce areas of poorly mixed lubricant with higher or lower viscosity than expected. The use of heating, tank baffles, and a tank eductor nozzle may greatly improve recirculation mixing performance when mixing capabilities are limited.

Ultrasonic homogenizers or disintegrators are not recommended unless specifically optimized to preserve the integrity of the polymers and avoid excessive shearing damage. Blenders should check for discoloration and accelerated oxidation during long blend times. Default settings on homogenizers may not be optimal for lubricant blending.

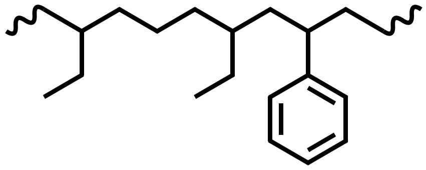
Visual Guide to Viscosity Modifiers and Base Stocks



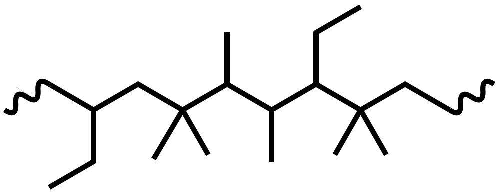
Olefin Copolymer (OCP)
Copolymer of ethylene propylene, and other olefins; high MW



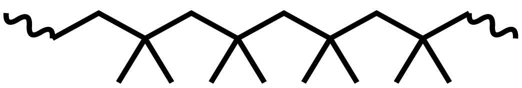
Ethylene-Propylene Oligomer (EPO)
Liquid copolymer of ethylene and propylene; low MW



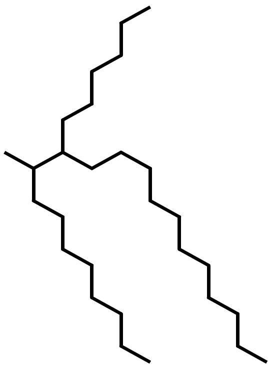
Styrene Olefin Copolymer
Same as OCP with up to 35% styrene by weight low to medium MW



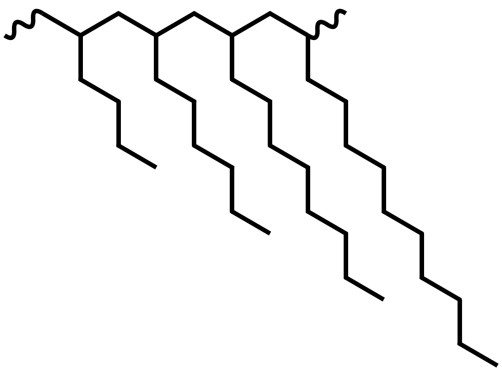
Polybutylene Copolymer (PB)
Copolymer of 1-butene, 2-butene, and isobutene; low MW



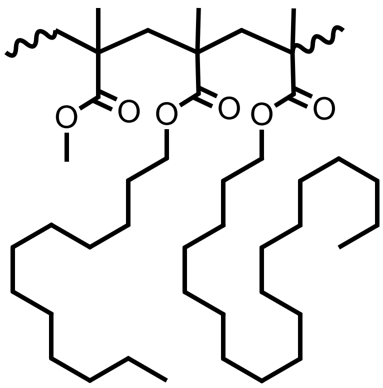
Polyisobutylene (PIB)
Ideal polymer of isobutene; low to very high MW



Conventional Polyalphaolefin (PAO)
Semi comb-like structure using metal halide initiator; distilled, low MW



Metallocene Polyalphaolefin (mPAO)
Ideal comb-like structure using organometallic catalyst; high MW



Polymethacrylate (PMA)
Mixture of short, medium, and long fatty esters; medium to high MW