



Based on innovative solutions and adhering to the principles of sustainability:

flexible, universally resistant against chemicals, low permeation rates – with a barrier layer made of thermoplastic fluorelastomer vulcanizates.

Legislature, environmental protection, function, global utilization options, cleanliness requirements, and safety.

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Veritas

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1. Function of Fuel Hoses

Hoses installed in automotive fluid systems usually have the following functions:

- mechanical and acoustical decoupling and damping
- tolerance compensation
- self-sealing connections

In addition, there are function-relevant chemical and thermal resistance as well as, where applicable, requirements on flexibility in vehicle installation and in the event of an accident and vehicle repair.

Unique fuel-hose characteristics are defined by chemical and physical resistance against highly-heterogeneous fuels, their diffusion into the environment as well as dynamic pressure burdens on supply and return hoses. Other factors are the extreme thermal stress in the engine compartment with temperatures of up to 180°C. (N.B.: permeation is regulated by law)

2. Contemporary Technical Solutions

The focus here is on multi-layer elastomeric hoses with textile pressure-bearing layers.

These designs warrant for good mechanical/acoustical properties. However, owing to the rubber's (amorphous) structure, the diffusion rate of fuel through the hose wall, also through relatively strong thickness of the barrier layer, is relatively high, which also has unfavorable impact on the price.

In a current version of the 4-layer fuel hose, the FKM barrier layer has been substituted by semi-crystalline fluoric thermoplastics:

This fluoric thermoplastic barrier layer (THV) owing to its crystalline properties in comparison with the 4-layer elastomer hoses features significantly lower permeability and distinctly improved fuel resistance capacities in spite of reduced wall thicknesses. This again decreases manufacturing costs.

Chart 1: Fuel-Hose Characteristics

Characteristics	4-layer-FKM	Hybrid fuel hose
Sealing/Connecting	+	-
Dynamics	+	-
Acoustics	+	-
Temperature	+	-
Tolerance Compensation	+	+-
Radii	+	-
Weight	-	+
Permeation	-	+
Price	-	+

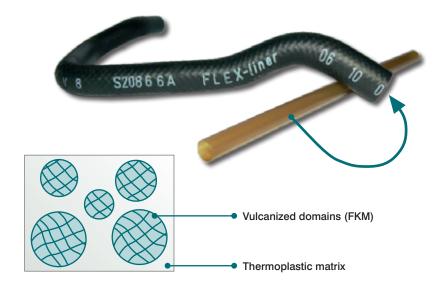
Fulfillment of requirements: + positive, - negative, +- neutral

The goal of the innovations presented here is to resolve the purported inherent incompatibility between mechanical/acoustical properties on one side and permeation characteristics on the other.

Interdisciplinary cooperation between polymer manufacturers and hose producers resulted in development of a hose design based on an innovative F-TPV (thermoplastic fluorelastomer vulcanizates), which unites in itself all positive characteristics of the 4-layer and hybrid fuel hoses respectively.

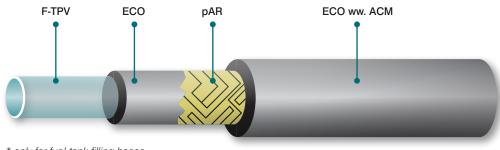
3. The Innovation 3.1 Veritas-Flex-Liner®

Fig. 1: F-TPV / Veritas-Flex-Liner®



The core element of this innovative hose concept is the permeation-optimized, thin F-TPV barrier layer (thermoplastic hose-foil extrusion), which at the same time has elastomeric properties. In all other respects, the design structure essentially is identical to the conventional hose structure described above. The use of special bonding agents integrated in the intermediate layer creates a non-separable compound after passing through the vulcanization process. Owing to accurately synchronized processes and materials, there is no need to use external bonding agents usually based on organic solvents (environmental and occupational safety issues!).

Fig. 2: Structure of Veritas-Flex-Liner®



^{*} only for fuel-tank filling hoses

Chart, 2: Characteristics of Veritas-Flex-Liner®

Burst Pressure 23°C	Cohesive Strength	Thermal Resistance	Flexibility at low Tem- peratures	Permeation	Price
240 bar	F-TPV/ ECO 35N/cm (cohesion failure)	125°C Consistent; 150°C peak	22h/-40°C ("dry") DIN 73379	≈4,0 g/100 cm² (DIN 73379, FAM B, 80°C); In comparison: FPM 4-layer hose ≈6,5 - 8,0 g/100 cm²	Price advantage

In view of global diversification of general-purpose fuels, which is essentially driven by the use of biofuels (PME, Flex Fuel etc.) with diverse admixtures, the universal chemical resistance of the innovation described above is particularly advantageous. Long-term studies with the relevant operating materials show no perceptible changes in characteristics even under adverse conditions (s. Fig. 3).

Fig. 3a: Changes in Tensile Strength F-TPV (Soaking fuel 60°C/diesel and RME 125°C): [N/mm²]

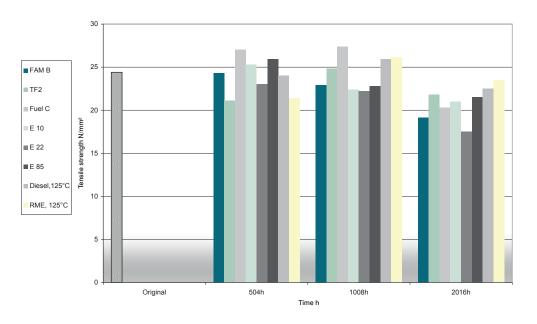
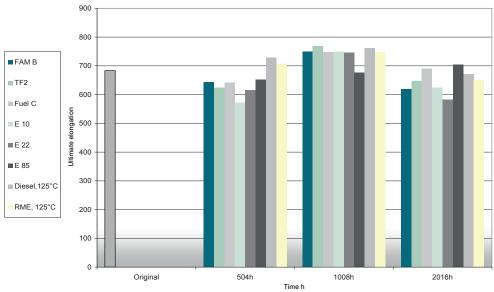


Fig. 3b: Changes in Ultimate Elongation F-TPV (Soaking fuel 60°C/diesel and RME 125°C): [%]



Diverse strict permeation requirements (LEV II, Euro V, etc.) on the conduit system are also met. The particular flexibility based on the relatively low modulus and the elastomer character of the barrier layer allows placement in tight radii and thus meets the need for adaptation to more complex and confined installation conditions.

Fig. 4: Extreme Geometries; Pre-bent Hose



The Veritas-Flex-Liner® also features considerable innovation potential as relates to economic and ecological aspects. In comparison with barrier layers based on fluorelastomers, the layer thickness of the new hose version is reduced relatively by a factor 4, which leads to significant cost savings and weight reductions (density \approx 2g/cm³). This also decreases the direct burden on raw-material and energy resources. This in context with the avoidance of solvents in hose production, recycling of extrusion scrap as well as optimized permeation capacities (reduction of emissions) contributes directly to product-related environmental protection.

Chart 3: Comparison of Fuel Hoses vs. Veritas-Flex-Liner®

Characteristics	4-layer-FKM	Hybrid hose	Veritas-Flex-Liner®
Sealing/Connecting	+	-	+
Dynamics	+	_	+
Acoustics	+	-	+
Temperature	+	_	+
Tolerance	+	+-	+
Radii	+	_	+
Weight	-	+	+
Permeation	-	+	+
Price	-	+	+

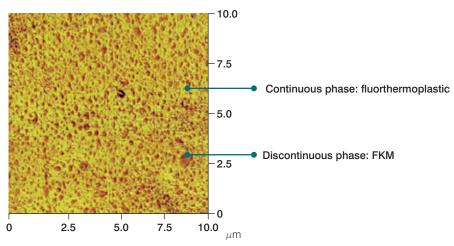
Fulfillment of requirements: + positive, - negative, +- neutral

3.2 F-TPV

The new Fluor-TPV concept is the access to a new and unique product group: thermoplastic fluorelastomer vulcanizates.

The intent of this invention was to combine the low permeation rates and thermoplastic processing features of fluor plastics with the characteristic properties of an elastomer. F-TPV combines these properties in a single product group. This is achieved by dispersing a defined share of FKM in a continuous fluorthermoplast phase followed by dynamic cross-linking in the blending process.

Fig. 5: AFM Image (Atomic Force Microscopy) F-TPV



The resulting advantages essentially consist of optimization of permeation and chemical resistance against standard fuels while maintaining elastomer properties, thermoplastic processability, excellent bonding to other elastomers (FKM, NBR, ECO) as well as low-temperature characteristics.

These products are primarily used for barrier liners in fuel conduits and for other aggressive substances and materials, e.g. blowby gases, exhaust-gas recycling and diesel particle filters.

Chart 4: Sealing Load F-TPV - Determination of Compression set (6 mm test specimen)

Conditions*	FKM**	F-TPV	THV
22h/23°C in %	28	49	80
22h/60°C in %	32	54	100
22h/100°C in %	35	59	100

Scale: (good) 0 ... 100 (poor)

* 25% deformation acc. to DIN-73379 ** Fluorelastomer, bisphenol cross-linking

Fig. 6: Specimen Carrier to Determine Compression Set



3.3 VeriConflex®

An innovative conductive hose structure named VeriConflex® was developed on the basis of the Veritas-Flex-Liner®:

Owing to the chosen technical solution to realize conductivity by way of four extremely thin conductive F-TPV strips arranged along the circumference of the interior of the F-TPV inner tube, this is achieved without any loss of mechanical properties while at the same time maintaining the excellent permeation characteristics.

Fig. 7: VeriConflex® Structure

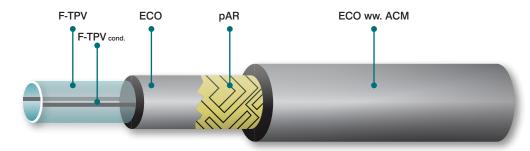


Chart 5: Functional Properties of F-TPV (cond)

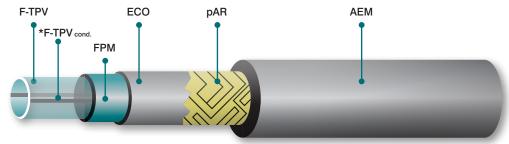
Property	F-TPV	F-TPVcond
Tensile strength [MPa]	28,0	26,5
Elongation [%]	>500	>250
Module 100%	15,0	17,5
Cohesive strength [N/mm]	32,0	25,0
Surface resistivity [Ω]	>1012	<10 ⁶ *
Decay-Time [s] **	0,04	

^{*} No conductivity loss after temperature exposure or fuel swelling

3.4 Veritas-XZ-Liner® and VeriPentaflex®

The Veritas-XZ-Liner® is the product of the consistent technical advancement of the new hose concept to meet maximum permeation requirements. An additional second barrier layer made of a special enriched fluorelastomer compound reduces hydrocarbon emissions to a minimum.

Fig. 8: Veritas-XZ-Liner® / *VeriPentaflex® Structure



^{** 5}KV, MIL-B-81705B

4. Permeation

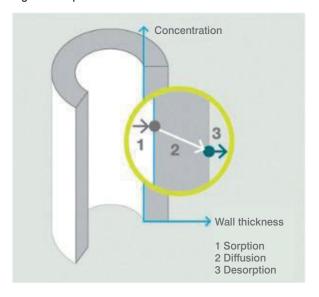
Chart 6: Shed Test Results

	Veritas-XZ-Liner® + VeriPentaflex®	Veritas-Flex-Liner® + VeriConflex®	4-layer FPM
60°C	240	504	1610
40°C	52	117	406
18,3°C	10	27	85
CARB-cycles	23	66	216

Sizes: 7.3 x 3.5

CARB Phase III, mg/(m*d)

Fig. 9: Principle of Permeation



5 Cleanliness

Owing to their thermoplastic inner surfaces, which are very smooth in comparison with elastomer inner tubes, all hoses of the entire Veritas-Flex-Liner®-family have only very low or zero inclination to adhesion of particles of any kind. As a consequence, any particles intruding into the hose during the manufacturing process may very conveniently be flushed out in a washing process following vulcanization.

This is further backed by the specific extrusion process for both hose types characterized by online extrusion with support mandrel (tool) and inner hose tube. As a consequence, there is absolutely zero contaminant ingress already in this early manufacturing stage.

For dimensions Di < 10 mm, this positive feature can be further augmented by a new vulcanization process (pre-bent hoses) applicable only to this hose generation in order to manufacture a high-purity product - as compared to conventional fuel hoses with FKM inner tube. This is possible due to a virtual self-contained system in benthose production: the manufacturing process progresses entirely without any contact between shaping tools and uncured material and without applying any production auxiliaries such as separating agents, etc.

This manufacturing process is currently in the prototype phase; small-series industrialization is planned for 2016.

In keeping with the policy "where there is no contaminant ingress, there is no need for contaminant removal", Veritas AG is creating products which will meet and surpass the exacting cleanliness requirements on fuel conduits in the automotive industry.

6. Summary

The intent of our innovation was/is to combine the elastomeric characteristics of rubber with the diffusion-tightness and economic advantages of a hybrid hose (rubber/ thermoplast).

For this purpose, we needed to develop a material with elastomer characteristics and capable of being processed in thermoplastic applications.

The solution was found in form of an F-TPV (thermoplastic fluorelastomer vulcanizate). The F-TPV is formed in a continuous phase of a fluorthermoplast, into which an FKM is dispersed (discontinuous phase). The continuous fluoropolymer phase provides for thermoplastic processing and the good barrier characteristics while the FKM contributes the elastomer properties.

This innovative barrier layer was integrated in a 4-layer rubber hose consisting of an ECO intermediate layer, a p-aramid pressure bearer and an ECO/ACM surface layer. The Veritas-Flex-Liner® and VeriConflex® products thus in unique form combine typical elastomer properties with semi-crystalline characteristics inherent to thermoplastics. Other advantages are:

- · Self-sealing connections
- Maximum dynamic resilience
- Acoustic damping
- Flexibility
- · Low fuel permeation
- · High universal fuel resistance

- Resistance against blowby gas, exhaust-gas condensate, organic and inorganic acids, urea
- Optional compliance with strict cleanliness requirements
- Conductivity*
- Optional flame-proof versions
- Reliable material supply
- Cost savings
- Low weight

Chart 7: Veritas-Flex-Liner® and VeriConflex® Characteristics

Chart. 7. Ventas-Fiex-Line	and venconnex characteristics
	Veritas-Flex-Liner®, VeriConflex®, Veritas-XZ-Liner® and VeriPentaflex®
Sealing/Connecting	+
Dynamics	+
Acoustics	+
Temperature	+
Tolerance Compensation	+
Radii	+
Weight	+
Permeation	+
Cleanliness	+
Conductivity	+*
Price	+

Fulfillment of requirements: + positive, - negative, +- neutral

^{*} only for VeriConflex® and VeriPentaflex®

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Veritas-Flex-Liner®, VeriConflex®, Veritas-XZ-Liner® and VeriPentaflex® The new fuel hose generation engineered by Veritas AG

