Materials, Properties and Testing of Sealing Profiles

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We have covered in Whitepapers elsewhere the various general considerations in design and specification of a sealing profile - such as material types and likely usage as well as structure of the profile and the extrusion process itself – in this paper more detailed information is offered regarding the various materials used, their properties and the various national and international testing methods and standards relevant to sealing profiles - and as such a tabular format is used where appropriate. This covers:

- Comparative features of common rubber/synthetic rubber materials
- Comparative vulcanisate properties of NR and other SR's
- Fluid immersion national and international test methods
- Brittleness temperature of some Engineering Elastomers
- Compression set
- Determination of hardness
- Heat resistance and aging
- Tensile properties
- Specific gravity and density

Comparative chart of material features

Headings	**Natural Rubber**	**SBR**	**Neoprene**	**Nitrile**	**EPDM**	**Silicone**	**Viton**
Chemical name	Poly-isoprene	Styrene butadiene	Poly-chloroprene	Acrylo-nitrile-Butadiene	Ethylene-propylene Dieneterpolymer	Poly-siloxane	Fluorinated hydrocarbon
SAE 1200 & ASTM D-2000 Designation	AA	AA, BA	BC, BE	BF, BG, BK	BA, CA	FC, FE, GE	HK
ASTM D-1418 Designation	NR	SBR	CR	NBR	EPDM	VMQ	FKM
Minimum temperature	-55C (-67F)	-55C (-67F)	-40C (-40F)	40C (-40F)	-55C (-67F)	-65C (-85F)	40C (-40F)
Maximum temperature	50C (122F)	70C (158F)	100C (212F)	100C (212F)	120C (275F)	225C (437F)	225C (437F)
Usual shelf life	3 to 5 years	3 to 5 years	5 to 10 years	5 to 10 years	5 to 10 years	Up to 20 years	Up to 20 years
Advantages	1) Outstanding elasticity 2) Good flexibility at low temperatures	1) Very good flexibility at low temperatures	1) Good resistance to flame 2) Very good resistance to weather, ozone, and natural ageing 3) Very good resistance to alkalis and acids	1) Very good resistance to oils and fuel 2) Superior resistance to petroleum-based hydraulic fluids 3) Wide range of operating temperatures 4) Very good resistance to alkalis and acids	1) Excellent heat, ozone and sunlight resistance 2) Very good flexibility at low temperatures 3) Good resistance to alkalis, acids and solvents 4) Superior resistance to water and steam	1) Flexible at extreme temperatures 2) Low compression set 3) Excellent ultra-violet, weather and ozone resistance 4) Inert, odourless, tasteless and non-toxic	1) Excellent resistance to a wide variety of oils, fuel, solvents and acids at high temperatures 2) Very good impermeability to gases and steam 3) Very good weather, ozone and sunlight resistance
Restrictions	1) Poor heat, ozone and sunlight resistance 2) Very little resistance to	1) Poor heat, ozone and sunlight resistance 2) Very little resistance to	1) Poor to low resistance to aromatic solvents 2) Limited capacities at low	1) Low resistance to ozone, sunlight and natural ageing 2) Poor resistance to	1) Poor resistance to oils, fuels and to hydrocarbon solvents	1) Poor abrasion and tear resistance 2) Poor resistance to solvents, alkalis	1) Will be severely attacked by some solvents such as esters, ethers and acetates

	oils, fuel and to hydrocarbon solvents	oils, fuel and to hydrocarbon solvents	temperatures	polar solvents		and acids	
Legend: E= Excellent, VG = Very good, G = Good, F= Fair, P = Poor							
Tensile strength	E	F - G	VG	VG	F - G	VG	VG
Ultimate elongation	VG - E	G	G	G	G	VG - E	F - G
Compression set	G	G	F - G	G	G	VG - E	VG - E
Heat resistance	F	F - G	F - G	G	VG - E	E	E
Resistance to flame	P	P	G	P	P	F - G	VG - E
Resilience	E	F - G	VG	F - G	G	G	F
Abrasion resistance	E	VG - E	VG - E	VG - E	VG - E	P - F	F - G
Water resistance	E	VG - E	G	VG - E	E	VG - E	G
Acids	F - G	F - G	G	G	G	F	G
Alcohol	G	G	VG	F - G	F - G	G	F - G
Animal & vegetable oils	F	F	G	VG	G	G	E
Oils & Fuels	P	P	F - G	G - E	P	P - F	E
Hydrocaarbon solvents	P	P	G	E	P	P - F	E
Oxygenic solvents	G	G	P - F	P	VG	F	P

Comparative vulcanisate properties of NR and other SR's

Properties	**Rubber**																
	NR	**IR**	**SBR**	**BR**	**NBR**	**ACM**	**CR**	**ECO**	**CSM**	**FKM**	**(X)IIR's**	**EPDM**	**EAM**	**PYMQ**	**TM**	**SBS**	**AU**
Tensile strength	1	2	5	6	5	6	3	4	5	5	4	5	5	6	6	3	1
Tensile strength with reinforcing fillers	1	2	2	4	2	3	2	3	3	3	3	3	3	4	4	1	1
Maximum elongation	1	1	2	3	2	4	2	3	3	3	2	3	3	4	4	1	2
Abrasion resistance with reinforcing fillers	4	4	3	1	2	4	3	3	3	4	4	3	2	5	5	5	1
Tear resistance	2	2	3	5	3	3	2	3	3	4	3	3	3	5	4	3	1
Rebound	2	2	3	1	3	4	3	3	4	5	6	3	3	3	5	4	3
Low temperature flexibility	2	2	3	2	3	5	3	3	5	5	2	2	4	1	4	2	4
Heat resistance	5	5	4	4	3	2	3	2	3	1	3	2	2	1	5	6	5
Oxidative resistance	4	4	3	2	3	2	2	1	2	1	2	1	1	1	1	5	1
UV resistance	4	4	3	3	3	2	2	1	2	1	2	1	1	1	1	5	1
Weather and ozone resistance	4	4	4	3	3	2	2	1	2	1	2	1	1	1	1	5	1
Oil resistance	6	6	5	6	1	1	2	1	2	1	6	4	4	1	1	6	1
Motor fuel resistance	6	6	6	6	2	3	3	1	2	1	6	5	5	6	1	6	1
Acid resistance	3	3	3	3	4	5	2	2	2	1	2	1	3	5	6	2	6
Alkali resistance	3	3	3	3	4	5	2	2	2	4	2	1	3	5	6	2	6
Flame resistance	6	6	6	6	6	6	2	2	3	3	6	6	6	6	6	6	6
Electrical resistivity	1	1	2	2	5	5	4	4	4	4	2	2	3	1	4	2	4
Gas permeation	5	5	4	4	2	3	3	1	3	3	1	4	2	6	1	4	1
Compression set – 40C	3	3	3	3	3	5	5	5	6	6	5	4	6	3	5	4	5
+ 20C	2	2	3	3	2	3	3	2	5	4	4	3	5	2	4	3	3
+ 100C	6	6	5	5	3	5	4	2	6	3	2	2	1	1	4	6	5

Legend: 1=excellent, 6+insufficient

Fluid immersion

NATIONAL AND INTERNATIONAL TEST METHODS
BS 903: Part A16:1987 & ISO 1817 'Method for the determination of the effect of liquids'
ASTM D471 'Rubber property - effect of liquids'
The action of a liquid on a rubber will generally result in [a] absorption of the liquid by the rubber [b] extraction of soluble ingredients from the rubber [c] a chemical reaction with the rubber.

The rate at which absorption takes place will depend upon the thickness of the rubber and the temperature of the liquid. The resistance of the rubbers to liquids depends on [a] the compatibility of the liquid with the rubber [b] the state of cure [c] the amount of contact i.e.> immersion or splash contact only.
The effect of a liquid can be measured by the change in properties such as tensile strength, hardness, volume and weight.

Brittleness

Brittleness temperature of some Engineering Elastomers (Classification after ISO / TR 8461) [3,851a]

Low temperature Flexibility	Rubber
-75C	Q
-55C	NR, IR, BR, CR, SBR, (X)IIR, EP(D)M, CM, CSM, FVMQ, PNF
-40C	ECO, NBR, EP(D)M, CSM, FKM, AU, EU
-25C	ACM, NBR, OT, FKM
-10C	ACM, CO, FKM, TM, NBR

NATIONAL AND INTERNATIONAL TEST METHODS
BS 903: Part A6:1992 & ISO 815:1991 'Method for the determination of compression set at ambient, elevated or low temperature'
ASTM D395 'Rubber property - Compression set'
This test measures the residual deformation of a rubber test piece after a compression period at a given test temperature. Typical test times would be 24, 72 &168 hours at temperatures of 23, 70, 100, 150C etc. The compression is normally 25% of the initial thickness. At the end of the test time the samples are released and allowed to recover for 30 minutes at room temperature before the final thickness is measured

The result is calculated as % compression set = $\frac{\text{Deformation [set]}}{\text{Compression}} \times 100$

Compression set and, in a similar manner, stress relaxation, can be influenced to a considerable extent by the crosslinking structure and the compunding (choice of cross linking systems, fillers etc.) as well as the vulcanisation time.

Hardness

NATIONAL AND INTERNATIONAL TEST METHODS
BS 903: Part 26:1995 & ISO 48:1994 'Method for the determination of hardness'
ASTM D1415 'Rubber property - International hardness'
ASTM D2240 'Rubber property - Durometer hardness'

The hardness of vulcanised rubber is normally measured in International Rubber Hardness Units [IRHD], however, sometimes American Durometer [Shore A] are used. The IRHD method of test is based on measuring the depth of indentation by a rigid ball under a dead load. The indentation depth is then converted into International Rubber Hardness Degrees on a scale of 0 [infinitely soft] to 100 [infinitely hard]. Results of any indentation test depend on the thickness of the test piece unless this is considerably greater than 8mm. Micro hardness testers are available which are useful for checking hardness of finished products to 2mm. 'Pocket hardness' gauges are used for taking measurements on line or on very large products but their accuracy is poor due to hand pressure application, Only the dead load type instruments or stand mounted Shore meters should be used for official reference.

Heat Resistance and Aging

NATIONAL AND INTERNATIONAL TEST METHODS
BS 903: Part A19:1986 & ISO 188 'Heat resistance and accelerated ageing tests'
ASTM D573 'Rubber - Deterioration in an air oven'
Heat will increase the risk of oxygen attack. When accelerated ageing tests are conducted the concentration of oxygen must be maintained by good air circulation through the oven.

Rubbers are normally assessed for ageing performance at temperatures above their normal service temperature for a short period. This will give a measure of their longer performance.

Change in physical properties are usually measured and reported as a percentage of their original values.

Heat resistance of some engineering elastomers (Classification after ISO / TR 8461, aerobic condition, Method ISO 4632/1 3 days (Retention of properties)) [3.851a]	
Heat resistance up to	**Elastomer**
100C	AU/EU, NR (IR), OT, SBR, PNR
125C	CR, NBR, X-NBR
150C	CO, ECO, EP(D)M, EVM, CM, CSM (X)-ITR, H-NBR
175C	COACM, EAM, PNF
200C	FVMQ
225C	MVQ
250C	FKM

Tensile Properties
NATIONAL AND INTERNATIONAL TEST METHODS
BS 903: Part A2:1995 & ISO 37:1994 'Method for the determination of tensile stress - strain properties'
ASTM D412 'Rubber properties in tension'
Rubbers are rarely used in tension. If very high strengths are required then fibres or cords are incorporated to improve strength in a particular direction. Tensile strength has been used in specifications to control the overall quality of the product and prevent over extension of the formulation with cheap non reinforcing extenders.

Tensile strength is normally measured at the same time as elongation at break and modulus. Test pieces are cut from moulded sheets normally in the shape of a 'dumbbell'. Sometimes orientation effects in the rubber, produced during preparation of the moulding blanks, will affect the results. If this is a possibility then two sets of samples cut at right angles to each other should be tested.

The tensile strength of a material is expressed in terms of force per unit area: - e.g. MN/m2 = mega Newtons per metre squared or Mpa mega Pascalls

Specific Gravity and Density
NATIONAL AND INTERNATIONAL TEST METHODS
BS 903: Part A1:1996 & ISO 2781:1988 'Determination of density'
ASTM D297 'Determination of density'
The Specific Gravity (SG) of a rubber is the ratio of the mass of a given volume of the rubber to the mass of an equal volume of pure water. For example: a block of rubber 100mm cubed [volume 1 litre] weighs 1.2kg. We know that 1 litre of water weighs 1kg. Therefore the block of rubber has an SG of 1.2.

$$\text{Density} = \frac{\text{weight}}{\text{volume}} = \frac{\text{kilos}}{\text{litres}} = \frac{\text{grammes}}{\text{cm3}} = \frac{\text{lbs}}{\text{cub.ft}}$$

When density is measured in kg / litre, tonnes / m3 or g/cm3 then this value is the same as SG

The specific gravity of a rubber will indicate if the recipe has been adhered to and in some cases whether the weighments are correct

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