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ANNEX 1

A1.1 Antioxidants

There are chemicals which can delay the aging process of rubber and increases the durability of the product and such product are called protective chemicals or protective agents.

Major portions of these chemicals are categorized under antioxidants. These chemicals are good against oxygen attack to prevent polymer deterioration.

6PPD is generally recognized as the most effective and widely used all purpose antioxidant. In addition to oxygen protection, it imparts a high degree of protection against flex cracking.

Specification of antioxidant 6PPD is given as follows:

% of Ash Content (max)	0.2 (ASTM D 4574)
Melting point (min) °C	44 (ASTM D 1519)
% of Active Ingredient (min)	97 (ASTM D 4937)
% of Heat loss (max)	0.5 (ASTM D 4571)

The other antioxidant used during the study is SKF and its specification is given below.

% of Ash Content (max)	1 (Bayer 17 B)
% Evaporation loss	0.5 (Bayer 18 A)
Melting point (C)	105

Kraft lignin is experimented as third antioxidant. Among various natural polymers lignin is one of the richest natural polymers in the biosphere. It is a natural phenolic polymer composing up to one third of the material found in plant cell walls. Lignin is available mostly in abundant and renewable resources such as trees, plants and

agricultural crops and shown antioxidant properties while keeping non-toxic and extremely versatile in performance. The advantages are obvious lignin as an antioxidant has important potential in tire industrial applications. Therefore kraft lignin was selected as the natural antioxidant for this research.

Lignin is identified as amorphous polymer, it composed of three different cinnamyl alcohol monomers, such as p-coumaryl alcohol, coniferyl alcohol, and Sinapyl alcohol in varying compositions. The diversity in both monomer content and chemical bonds makes the determination of the exact chemical structure of each isolated lignin extremely difficult.

A1.2 Natural rubber

NR is selected as base polymer since it provides intended properties for tread compounds, these properties can be listed as T.S , green tackiness and tear resistance. Micro structure of polymer is supported to achieve these tasks as polymer molecules tend to crystalline at low temperature and also during stretching. Natural rubber was sourced from one specific supplier of Sri Lanka. Principal intension of this action is to control viscosity of the base polymer.

Mooney viscosity [ML(1+4) at 100 °C]	75 +/-15
% Dirt content by mass (Max.)	0.05 (ISO249)
% of Volatile material by mass (Max.)	0.8 (ISO248)
% of Nitrogen content (Max)	0.6 (ISO1656)
% of Ash by mass (Max.)	0.5 (ISO 247)
Initial Wallace Plasticity (Po) * Range (Min.)	30 (ISO 2007)
Plastic Retention Index (PRL) (Min.)	70 (ISO 2930)

A1.3 Carbon black

Carbon black is the organic filler widely used worldwide. Filler with high surface area (Particle size up to 50 nm) is used to obtain required physical property of tread compounds.

N220 carbon black from Phillip India was selected as reinforcing filler and material specification is described below.

DBP absorption (cm ³ /100g)	110 - 120 (ASTM D 2414)
Iodine adsorption number (g/Kg)	118 – 126 (ASTM D 1510)
Nitrogen adsorption (m ² /gm)	119 (ASTM D 4028)
STSA surface area (m ² /gm)	106 (ASTM D5816)
Compressed DBP absorption (ml/100/g)	98 (ASTM D3493)
Tint strength, % ITRB	116 (ASTM D3265)
Pore density (gm/Lit)	320-370 (ASTM D1513)
Moisture (%)	1.2 Max. (ASTM1509)
Pellet hardness (gf)	15-45 Avg. (ASTM 5230)

A1.4 Activator

Zinc oxide, (inorganic activator) and stearic acid, (organic activator) will be formulated in almost all type of recipe. They are known as activators to accelerators. Activators are activating the process of cross linking formation and produce uniform state of cure in the compound. Modules of the rubber vulcanizates is improved by activators.

High purity Zinc oxide is used for the study. It is known that tracers of metals such as Copper, Manganese, and Ferrous can be present as impurity in Zinc oxide. These metals can cause degradation of polymer. This interference may lead to affect final results of the study.

Zinc oxide used for the study complies with following specification.

% of Moisture (Max)	0.5 (D 280)
% of Pbo (Max)	0.15 (D4075)
% of Purity (Min)	99.5 (D 3280)
% of Sieve Residue (max) 45 Micron (325 mesh)	0.25 (D 4315)
% of Loss on Ignition (Max)	0.6

A1.5 Stearic acid

Rubber grade stearic acid is not pure compound of stearic acid but it is normally a mixture of stearic acid (60%) Pulmitic acid (20%) and oleic acid (20%)

Steric Acid used for the study carries following specification:

Acid Value (mg, KOH/g)	190-215
Iodine Value (Max) (g, 100g)	5
% of Fatty acid C18 (Min)	32

A1.6 Rubber processing oil (Low PAH oils)

In recent years the carcinogenicity of poly cyclic aromatic hydrocarbons comes to be regarded as important. Oils containing 3% or more of polycyclic aromatic compounds (PCA) are obliged to indicate that they are toxic and there is a trend towards regulation of their use. Accordingly, it becomes an urgent task to reduce the content of PCA in rubber process oil to less than 3% these oils are called Low PAH oils.

Kinematic viscosity @ 100 °C	20-32 (ASTM D 445)
Aniline point °C	86-94 (ASTM D611)
Density @ 15.0 cg/ml	0.930-0.950 (ASTM D 1298)
Benzo (a) pyrene (BaP) (Max. ppm)	1
Sum 8 PAH's (Max. ppm)	10
Flash Point (Min.), °C	210 (ASTM D 92)

A1.7 Sulphur

Sulphur is commonly used because of its easy availability and affordable price. Tire industry consumes almost 80% of elastomers and all tires worldwide conventionally getting cured with Sulphur accelerator system.

% of Sieve Residue (325mesh), (Max.)	10 (D 4572-89)
% of Moisture (Max.)	0.5 (2 Hrs @ 105 C)
% of Purity (Min.)	99.5

A1.8 Retarder (Pre vulcanization inhibitor, PVI)

Faster the accelerator, higher is the productivity but it has some disadvantage in processing as well. With faster accelerators the cross linking process may begin in the heat history during the milling and mixing etc. and is often termed premature vulcanization. Precise weighing of this chemical is very important as it is used fairly low amount.

% of Active ingredient content (Min)	95
% of Ash Content (Max.)	0.2
% Drying loss (Heat loss)	0.4 2 hrs /105 °C
Melting point °C	88
% of Volatile matter (Max.)	0.5 Bayer K 234

A1.9 Accelerator

There are wide varieties of accelerators available to the rubber compounds. Sulphenamide is types of accelerators are widely used for tread compounds.

MOR is used as an accelerator and its specification is described below.

% Moisture content (Max.)	0.5 (ASTM D 4571)
% Purity (Max.)	96 (ASTM D 4936)
% Insoluble methanol (Max)	0.5 (ASTM D 4934)
% Ash content (Max.)	0.3 (ASTM 4574)
% Volatile matter (Max.)	0.3 (ASTM D 4571 (15-23))
% Free amine (Max.)	0.4 (ASTM D 4936)
Melting point (C)	75-90