Natural Rubber : Agromanagement and Crop Processing
Editors : P.J. George and C. Kuruvilla Jacob

Chapter 22

Crepe rubbers

Baby Kuriakose and K. Mariamma George

1. INTRODUCTION

Sheet and crepe rubbers were the two marketable forms of dry natural rubber before the introduction of technically specified rubber (TSR). Crepe rubbers are processed from fresh latex coagulum, field coagulum or cuttings of RSS. When any of these materials,

after necessary preliminary treatments, is passed through a set of crepe making machines, crinkly, lace-like rubber is obtained. This, when dried, is called crepe rubber. Processing into crepe rubber was one of the methods to upgrade low quality field coagulum materials such as earth scrap, shell scrap, tree lace, *etc.* Very often, materials selected from different types of field coagulum are blended in appropriate proportions to make crepe rubber of a desired quality. Thorough soaking, agitation, cleaning and machining are required to produce good quality crepe from field coagulum materials. Processing of low quality field coagulum into crepe rubber is now being replaced by TSR, since this yields a better quality material.

Crepe rubbers are classified into latex crepe and field coagulum crepe, depending on the starting material used. The latex crepe is of better quality compared with that from field coagulum.

2. LATEX CREPE

Pale latex crepe (PLC) and sole crepe are the latex grade crepe. These are produced from latex selected specially under strictly controlled conditions and hence are of premium quality. Different grades of PLC are used for high quality products such as pharmaceutical articles, light coloured and transparent goods, adhesives, tapes, tubings and derivatives such as chlorinated rubber. Sole crepe is used primarily for the production of translucent shoe soling materials. It also finds application in products such as adhesives, tapes, pharmaceutical articles, *etc.* Sole crepe is marketed in different sizes and thicknesses.

2.1 Pale latex crepe

2.1.1 Choice of latex

Latex to be used for the production of PLC and sole crepe shall be free from yellow pigments as far as possible. The coagulum shall not undergo discolouration and the rubber shall be sufficiently hard even after the addition of the required quantity of bleaching agent to get maximum whiteness. Therefore, latex has to be collected from clones which are identified on the basis of characters such as the extent of yellow pigment in latex, tendency of the coagulum for discolouration, viscosity of the rubber obtained, *etc.* (Peries, 1970). Other factors such as climatic conditions, tapping system, application of stimulants, *etc.* affect the above characteristics only to a limited extent. Yellow colouring matter in latex has been identified as carotenoid pigments. Latex from clones like RRIM 605 and RRIM 700 contains higher concentration of yellow pigments and has a deep yellow colour whereas clones like PB 5/51, RRIM 501 and Tjir 1 give latex of only light yellow colour. White latex from clones like PB 86 and RRIM 600 is more suitable for production of PLC and sole crepe. If yellow latex is used for production of latex crepe, it shall be blended with white latex and shall not exceed 20 per cent of the total quantity of the latex processed. Latex coagulum from clones such as PB 86, Gl 1, Tjir 1, RRIM 501, RRIM 600, RRIM 701 and RRII 105 are less susceptible to discolouration due to enzymic action. The Mooney viscosity of rubber from different clones varies over a wide range of 50 to 100. Harder rubber is more suitable for preparing latex crepe since more quantity of bleaching agent can be used in this case. Latex from clones like Gl 1, RRIM 501, RRIM 701, RRIM 707

and PB 186 gives soft rubber which does not permit the use of sufficient quantity of bleaching agent. Such latex, when used, shall be blended with latices which give comparatively harder rubbers. Thus, proper selection of latex is an important factor in the production of good quality PLC and sole crepe.

2.1.2 Addition of anticoagulant

Latex which shows a tendency to precoagulate shall be treated with anticoagulants like sodium sulphite or ammonia. Sodium sulphite is preferred for latex crepe production. The quantity used is about 0.05 per cent on latex by weight. A stock solution is prepared by dissolving 500 g of the chemical in 10 L of purified water, 200 ml of this stock solution is sufficient to treat about 20 L of field latex. Formalin is not used as an anticoagulant when latex is to be processed into pale crepe or sole crepe since it activates enzymic discolouration. Ammonia, if used, shall be less than 0.03 per cent since excess quantity results in serious darkening of the coagulum.

2.1.3 Sieving and bulking

Latex shall be sieved through 40- and 60-mesh sieves to remove suspended impurities. Latex from different fields are blended in rectangular bulking tanks, which may be of aluminium or brickwork lined inside with porcelain tiles. The volume of the tank shall be sufficient to accommodate the volume of latex, solutions of chemicals and water for diluting the latex. The depth of the tank shall not be more than 125 cm so as to facilitate quicker settling of the denser impurities. The width of the tank shall not be more than 180 cm as it may be difficult to mix the latex properly. The floor of the tank shall have a slope with the back side about 7.5 cm lower than the front and be fitted with a separate tap at the base to remove the sediments. The outlet for latex on the front side of the tank shall be slightly above the bottom level. A mechanical stirrer with a speed of about 15 rpm may also be fitted to the tank.

2.1.4 Standardization of latex

The dry rubber content (DRC) of latex in the bulking tank is determined as per standard procedures and the latex is diluted to a standard DRC of 25 per cent. Water used for diluting latex shall be free from copper and manganese and shall not contain more than 150 ppm of dissolved solids, 20 ppm of suspended solids and 2 ppm of iron. Since high calcium levels in water results in poor lamination of sole crepe plies, calcium content in water shall also be checked and maintained below 15 ppm.

2.1.5 Addition of chemicals

Sodium bisulphite or sodium metabisulphite is used to prevent enzymic darkening of the coagulum. The exact quantity of the chemical to be used depends on the type of latex to be processed. The usual dosage is 0.5 per cent on DRC and is added to latex as a five per cent solution. Sodium bisulphite decomposes gradually on keeping and for good results, a fresh solution has to be prepared just before use. Boric acid in the range of 0.05 to 1.0 per cent on DRC of latex in place of sodium bisulphite can also control discolouration to some extent (Nadarajah and De Silva, 1983).

2.1.6 Coagulation tanks

Latex, after dilution and addition of the chemicals, is stirred well and kept undisturbed for about 15 to 30 min to allow settling of denser impurities. It is then transferred to coagulation tank without disturbing the sediments. The coagulation tank may be of aluminium or brickwork with glazed tiles inside. The usual size of the tank is 3.0 x 1.0 x 0.6 m. The tank is fitted with a wooden frame at the top which facilitates insertion of aluminium partition plates at intervals of 7.5 cm. The depth of latex loaded in the coagulation tank shall be such that the width of the coagulum obtained is slightly less than the width of crepe making roller. If the width of the roller is 70 cm, the width of the coagulum may be around 60 cm.

2.1.7 Removal of pigments

Removal of naturally occurring yellow pigments is done by fractional coagulation or by bleaching or by a combination of the two, depending on the type of latex, cost and availability of bleaching agent, extent of whiteness required, *etc.*

2.1.7.1 Fractional coagulation

Fractional coagulation is the preferential coagulation of colouring materials present in latex along with a small portion of rubber. In certain cases, if latex, after bulking and dilution is agitated thoroughly for about 20 to 30 min and then allowed to remain for some time, the yellow colouring materials separate out forming a clot, which is removed by straining through a 60 mesh sieve. But usually it is necessary to add a small quantity of coagulant to separate the fraction containing the yellow pigments. Acetic acid or oxalic acid can be used for this purpose. Formic acid is not generally used since it is stronger. The quantity of coagulant varies depending on the nature of latex, type of anticoagulant used, climatic conditions and storage time between tapping and processing. The quantity of acetic acid to be used varies between 0.625 to 1.1 ml per kg dry rubber if the anticoagulant used is sodium sulphite. When ammonia is used as the anticoagulant, higher quantity of the acid is required. The acid is to be diluted to one per cent before adding to the latex. In the case of oxalic acid, the quantity is 0.625 g per kg dry rubber, to be added as a two per cent solution.

After adding the acid, latex is thoroughly stirred and allowed to remain undisturbed for about 1 to 2 h and then sieved through 60 mesh to remove the yellow fraction. The quantity removed in this fraction may come to about 10 to 15 per cent of the total dry rubber by weight. In case latex contains more yellow pigments, gelled rubber and non-rubber materials, the quantity of the first fraction will be much higher. Thus, fractional coagulation has the disadvantage that the process is time consuming and is effective in converting only part of the crop into first quality crepe, the remaining being converted into lower grades.

2.1.7.2 Bleaching

In this process, a chemical, which preferentially reacts with the colouring materials present in latex and removes the colour, is used. Xylyl mercaptan which was available in the trade name RPA No.3, was the most widely used bleaching agent, but production

of this chemical was stopped due to health reasons. An alternative bleaching agent, tolyl mercaptan, was found suitable in the manufacture of high quality crepe rubber (Karunaratne, 1979; Tillekeratne *et al.*, 1984). However, due to the non-ionic nature, it is insoluble in water but a 35 per cent ready to use solution in a petroleum oil is available. It is volatile with a characteristic foul odour and is injurious to health.

To overcome these, the thiol content of tolyl mercaptan was converted to an alkali metal salt of sodium/potassium (Karunaratne, 1983) and is marketed under the trade name Nexobleech New Formula. It has hardly any smell, does not emit any harmful vapour and is water soluble and easily mixes with latex in any proportion. It reduces magnesium and calcium ions by forming soluble salts and hence storage discolouration is minimal (Karunaratne, 1984). It is used as a five per cent aqueous solution and the quantity required varies from 1.9 to 2.5 L per batch of latex containing 100 kg dry rubber. Paratertiary-butylthiophenol is also reported to be effective for bleaching (Karunaratne, 1983). The bleaching action of the above chemicals is reported to be effected through oxidized carotene of xanthophyll and other oxygenated forms of carotene and not through carotene itself (Tillekeratne *et al.*, 1984). The bleaching method has the advantage that the whole latex can be converted into first quality crepe and that the process is quicker than fractional coagulation method. But the higher cost of the bleaching agent and its harmful effect on rubber, when used in excess quantity, limit the application of this method.

Better colour can be obtained if the bleaching agent is added after fractional coagulation. In this case, since the second fraction contains only lower concentration of the colouring materials, the quantity of bleaching agent required is much less.

2.1.8 Coagulation

Latex, after fractional coagulation and/or bleaching, is coagulated using formic or oxalic acid. Normally, 3.3 to 4.4 ml of formic acid per kg dry rubber is sufficient. The acid is to be diluted to one per cent before use. If oxalic acid is used, the quantity varies between 5.6 and 7.5 g per kg dry rubber and is added to latex as a two per cent aqueous solution. Use of oxalic acid gives better colour and retention of colour during storage (Nadarajah and Muthukuda 1974). Latex is stirred well after adding the coagulant and the froth removed. Partition plates are then inserted and the tank covered. The coagulum obtained has to be milled in crepe making machines within 24 h.

2.1.9 Crepe making

The minimum essential set of crepe making machines for production of PLC consists of a coarse macerator, an intermediate macerator and a set of smooth rollers. But, for economic reasons it is better to have a battery of machines consisting of two coarse macerators, one intermediate macerator and three sets of plain rollers. The size of the rollers depends on the width of the pale crepe to be produced. For producing sole crepe of 30 cm width, the finished pale crepe shall be 40 cm wide to give allowance for shrinkage during drying and for edge cutting. In such a case, the width of the rollers shall be 75 cm. For sole crepe of 50 cm width, the rollers shall be of 95 cm width. The diameter of the roller is usually 35 cm. The rollers are made of either cast iron or an alloy of cast iron with

nickel-chromium-molybdenum. Stainless steel or other types of steel which develops a highly polished and shiny surface shall not be used for crepe making rollers. The rollers are to be provided with suitable bearings for smooth and efficient functioning. Individual drive to the mill is found to be more economical than back shaft drive. The speed ratio of the macerator may be 18/21 whereas that of the finishing rollers could vary from 19/31 to 17/32. Higher speed differential for the finishing rollers is necessary to get the close texture of thin pale crepe. The machine shall not be allowed to run without rubber between the rollers, unless they are well separated. Wear of the rollers makes a crepe thick at the centre and thin at the edges which may lead to poor lamination and uneven thickness of the final crepe. The life of the rollers depends on the nature of the material and the care taken while operating. Cast iron rollers need regrooving after the production of every 1000 t of crepe. Groove recutting can be done only up to the stage when the diameter of the roller reaches 25 to 28 cm. The machine shall be set in such a way that minimum number of passes is given to get the required thickness and cleanliness to the final crepe. Handling of the coagulum through each machine (Plate 64. a) depends on the nature of the coagulum. The nip settings of the rollers are to be adjusted in such a way that the thickness of the final crepe obtained is 0.95 to 1.00 mm (Plate 64. b). Sufficient quantity of water shall be used while machining the coagulum to wash out the serum and other non-rubber materials. Details of the crepe making battery for PLC/sole crepe production (Morris, 1964) are given in Table 1.

Table 1. Details of crepe making battery for PLC/sole crepe production

Machine no.	Type of machine	Roll width (cm)	Gear ratio	No. of passes	No. of operators	Crepe thickness (mm)
1.	Macerator *	75	23/27	8	2	9.0 - 12.0
2.	Macerator *	75	23/27	6	1	4.0 - 6.0
3.	Intermediate macerator**	75	19/31	2	1	1.0 - 2.0
4.	Smooth roller	75	19/31	1	1	1.3 - 1.4
5.	Smooth roller	75	19/31	1	1	1.1 - 1.2
6.	Smooth roller	75	19/31	1	2	0.9 - 1.0

* 3.2 x 3.2 mm diamond grooved; ** 0.4 x 0.4 mm diamond grooved

2.1.10 Drying

Moisture content of the thin crepe reaching the drying chamber is in the range of 7 to 12 per cent (Tharmalingam *et al.*, 1977) which has to be reduced to less than 0.2 per cent before inspection and grading. Drying of crepe is done either in air drying sheds or in heated drying chambers. The drying sheds are of two- or three-tier construction and crepe are hung on reapers of 3.8 to 5.0 cm diameter (Plate 64. c). The reapers are of wood or bamboo and are spaced 10 cm apart. The chamber shall be provided with sufficient number of roof vents or exhaust fans and louvres to facilitate an upward air draught. The crepe at the bottom tier shall be hung 1.2 m above the floor and all the

tiers of the drying shed shall be loaded simultaneously so that wet crepe is never hung over partially dried crepe. The drying time depends on the atmospheric conditions and varies from 7 to 10 days. The drying capacity of this type of drying shed is about 5.6 kg per m^3.

In drying chamber, hot air at 33 to 35°C is circulated. The conventional heating equipment to provide warm air to the drying chamber consists of a boiler and a set of radiators. Steam generated is passed through radiators over which air is blown. The air, which gets heated, is trapped into the drying chamber. Usually firewood is used as fuel for the boiler. In this case, maintenance of a steady temperature within the chamber is dependent on the firing rate which is manually controlled. Inadequate and irregular firing can cause undue delay in drying and may affect quality of the produce. Modern drying chambers have electrical heaters to supply warm air and have the advantage that the temperature inside the chamber can be controlled thermostatically. In a drier of 4100 kg capacity, 16 to 22 numbers of finned air heaters of 1 kW rating are required. A simple air heater arrangement which extracts heat from the flue gases prior to discharge from the chimney has been reported to improve the efficiency (Walpita *et al.*, 1984a). Use of solar energy and application of partial vacuum are found to reduce the drying time of latex crepe considerably (Walpita *et al.*, 1984b; Tillekeratne *et al.*, 1995).

2.2 Sole crepe

The dried PLC is spooled off the hangers and kept on racks. These are then spread on the inspection table and any speck of impurities, discoloured parts, *etc.* remaining on the surface are removed and the crepe cut into the required length. Requisite number of pieces of pale crepe are placed on the building table. Each piece is lightly stretched, placed one above the other and pressed down with the palm or with a hand-operated roller to avoid wrinkles. The weight shall be about 20 per cent more than the weight of sole crepe to be made from it. This is then placed on a metal-topped laminating table and heated by circulating hot water. The temperature of the table shall be 45°C and each built up pad shall be placed on the table for 1 min, turned over and again placed for another minute. The built up pad is then taken to the laminator which consists of two heavy plain rollers for smooth sole crepe production and another set with the top roller grooved horizontally for corrugated sole crepe production. The speed of the laminating rollers shall be in the range of 10 to 12 rpm. The warmed pad is passed through the laminator rollers, the nip of which has been adjusted properly, to get smooth sole crepe of exact thickness. For corrugated sole crepe, one pass through the smooth laminating rollers and another pass through the grooved one is necessary. If proper ply adhesion is obtained, it is difficult to split the plies apart. After lamination, the pads are covered and kept for about 24 h before they are cut into two pieces of 0.9 x 0.3 m size sole crepe using a guillotine-type cutter. For wider crepe, the pad is cut into 1.0 x 0.5 m.

2.3 Defects

The common defects occurring in PLC and sole crepe are listed in Table 2.

Table 2. The causes for common defects of PLC and sole crepe

Defect	Causes
Fungal spots	Action of various microorganisms on the non-rubber constitutents presents on crepe surfaces under moist condition which develop due to use of excess sodium bisulphite, coagulation of latex at higher DRC, storage of the coagulum or macerated crepe for long period, drying of the crepe in badly ventilated air drying sheds, blanketing the crepe before it is quite dry, blanketing on wet rollers, *etc.*
Brown discolouration	Presence of iron in water, inadequate preservation of latex in the field, use of deteriorated sodium bisulphite, exposure of the rubber to direct sunlight during or after drying
Grey or dark colour	Contamination with iron compounds, carbon particles or oil from the bearings of rollers
White spots	Thicker lumps of coagulum or adulteration with starch or similar non-rubber materials
White streaks	Improper blending of latex, improper dilution and mixing of sodium bisulphite and bleaching agent
Tackiness	Contamination with copper, mainly from the roller bearings, direct exposure of the crepe to sunlight, higher temperature in the drying chamber
Poor lamination strength	Use of worn out rollers, lower temperature of the lamination table, high calcium content in water

3. FIELD COAGULUM CREPE

Among the various field coagulum materials, cup lump and tree lace are collected on every tapping day. Hence the crepe rubber produced from these, mainly estate brown crepe (EBC), will be of better quality if processed without storing for long periods. Earth scrap, bark scrap, smoked and dried cup lump, *etc.* are of lower quality materials and hence the crepe processed from these will be of poor quality. Different grades of field coagulum crepe are used in appropriate proportions in blends with other forms of natural rubber to make products such as tyres, footwear, retreads, mechanical goods, extruded items, *etc.*

3.1 Types

The crepe prepared from field coagulum materials falls into five types.

3.1.1 Estate brown crepe

These are prepared from cup lumps and other grades of scrap. Bark scrap can also be used after cleaning and removing the bark. Earth scrap and smoked scrap are not used for the production of EBC.

3.1.2 Thin brown crepe

Thin brown crepe and remilled crepe are manufactured from wet slabs, unsmoked sheets and other high grade scrap. Bark scrap is used only after cleaning and separating the bark. Earth scrap and smoked scrap are not used.

3.1.3 Thick blanket crepe

Crepe of this category is manufactured from wet slabs, unsmoked sheets or other high grade scrap. Pre-cleaned bark scrap is also used, but use of earth scrap is not permitted.

3.1.4 Flat bark crepe

This is prepared from all types of field coagulum grade including earth scrap.

3.1.5 Pure smoked blanket crepe

This type of crepe is also available in the market and is prepared exclusively from RSS cuttings.

3.2 Processing

3.2.1 Soaking

Depending on the type of crepe to be manufactured, suitable field coagulum is selected and soaked in water for at least one day. In certain cases, the field coagulum is soaked in 0.5 per cent solution of oxalic acid or phosphoric acid for a few hours to improve quality. Phosphoric acid treatment improves plasticity retention index (PRI) of raw rubber and ageing properties of the vulcanizates to a considerable extent (Watson, 1969). Addition of a detergent to soaking water helps to remove the impurities at a faster rate (Peries, 1970). Care should be taken to see that the scrap is properly submerged during soaking. While handling very low quality field coagulum, the soaked material is passed through scrap washers to remove foreign materials. This process helps to reduce the number of passes to be given in the crepe making machines and hence to increase the output.

3.2.2 Crepe making

For the production of crepe rubber from field coagulum, the minimum set of machinery required consists of a macerator, crepe roller and one finishing machine. A crepe making battery, with three machines having roller size of 60 x 30 cm, can produce about 500 kg of dry crepe rubber per shift of 8 h (Kumaran *et al.*, 1979). For higher output and for making fine-textured crepe, additional crepe rollers and smooth rollers are required. The number of passes through various machines depends on the nature of the material to be processed. Normally, when scrap washer is used, 10 to 15 passes through the macerator (Plate 64. d), five passes through the crepe roller and two passes through the finishing rolls are given for the manufacture of lower grade crepe. The nip setting of the smooth rollers is adjusted in such a way that the final crepe has a thickness of 2 to 3 mm. Sufficient quantity of water shall be passed over the crepe while machining to remove dirt and non-rubber constituents.

3.2.3 Drying

The wet crepe obtained after machining is dried in air, shade or heated drying chambers. Inside the drying sheds, the crepe is hung on reapers made of wood or bamboo up to a height of 2 to 3 m from the floor. The reapers are usually spaced at about 10 cm from centre to centre. The drying shed is provided with air inlets at the bottom and ventilators at the top which can be closed or opened. In air drying sheds, it takes about 7 to 10 days for drying the crepe during summer, but in rainy season, it may be more. In heated drying chambers, the drying temperature may be in the range of 65 to 70°C

and the period of drying may vary from a few hours to one day, depending on the thickness of the crepe. The dried crepe is taken out from the drying shed, graded and packed.

3.3 Defects

The common defects occurring in crepe produced from field coagulum are listed in Table 3.

Table 3. The causes for common defects in field coagulum crepe

Defect	Causes
Mould growth	Improper washing during machining, inadequate drying, storage of the dried crepe in humid conditions
Greenish and tacky streaks	Contamination with copper or brass from worn out bushes or bearings of the rollers
Rust stains	Contamination from the surface of rollers
Tackiness on the surface	Exposure of the crepe to direct sunlight, contamination with copper or brass, grease from the roller bearings, high temperature in the drying chambers
Uneven thickness	Use of worn out rollers
Coloured spots	Action of various types of microorganisms on the non-rubber constituents present on the surface, high thickness of the crepe and storage of wet crepe for longer period before drying
Discolouration	Use of impure water for dilution, presence of rust on roller surfaces, overheating of crepe in the drying chamber, contamination with grease from the bearings
Dirt and sand	Improper milling and washing of crepe

4. GRADING AND PACKING

4.1 Grading

Grading of PLC and sole crepe is done by examining factors such as colour, presence of streaks, strength of lamination, uniformity in thickness, presence of dirt and variation from the weight specified. Grading of crepe (Plate 64. e) is done as per the standards of quality and packing for natural rubber grades, prescribed in the Green Book (IRQPC, 1979). The descriptions of grades and guidelines for grading are given below.

4.1.1 Pale crepe

The grades must be produced from the fresh coagulum of natural rubber latex under conditions where all processes are carefully and uniformly controlled. The rubber is milled to produce crepe in thickness corresponding approximately to the pieces in the samples of thick and thin pale crepe, respectively.

No.1 X Thick pale crepe / No.1 X Thin pale crepe

Deliveries must consist of dry, firm rubber of very light uniform colour.

Discolouration, sour or foul odours, regardless of cause, dust, specks, sand or other foreign matter, oil or other stains, or any evidence of oxidation or heat is not permissible.

No master or official international sample has been established for 1 X thin pale crepe.

No.1 Thick pale crepe / No.1 Thin pale crepe

Deliveries must consist of dry, firm rubber of light colour with very slight variation in shade permissible.

Discolouration, sour or foul odours, regardless of cause, dust, specks, sand or other foreign matter, oil or other stains, or any evidence of oxidation or heat is not permissible.

No.2 Thick pale crepe / No.2 Thin pale crepe

Deliveries must consist of dry, firm rubber, slightly darker than No.1 thick or thin pale crepe with slight variation in shade permissible.

Slightly mottled rubber, of the degree shown in the sample will not be objected to, provided this condition does not exist in more than 10 per cent of the number of bales included in the delivery, lot or tender as determined by the number of bales inspected.

Discolouration, regardless of cause, dust, specks, sand or other foreign matter, oil or other stains, or any evidence of oxidation or heat, not permissible, other than those specified above as permissible.

No.3 Thick pale crepe / No.3 Thin pale crepe

Deliveries must consist of dry, firm rubber of yellowish colour with variation in shade permissible. Mottled and streaked rubber to the extent shown in the sample are permissible provided this condition does not exist in more than 20 per cent of the number of bales included in the delivery, lot or tender as determined by the number of bales inspected.

Discolouration, regardless of cause, dust, specks, sand or other foreign matter, oil or other stains, or any evidence of oxidation or heat is not permissible, other than those specified above as permissible.

4.1.2 Estate brown crepe

The grades are made from lump and other high grade rubber scrap generated on rubber estates. Tree bark scrap, if used, must be pre-cleaned to separate the rubber from the bark. Power wash mills are to be used in milling these grades into a form of crepe of thickness corresponding approximately to the pieces in the samples of estate thick and thin brown crepe, respectively. Use of earth scrap, smoked scrap, and wet slab is not permissible in the preparation of estate brown crepe.

No.1 X Thick brown crepe / No.1 X Thin brown crepe

Deliveries must consist of dry, clean rubber medium brown in colour.

Discolouration, regardless of cause, specks, sand, or other foreign matter, oil or other stains, or any evidence of oxidation or heat, strong sour or foul odours, not permissible.

No.2X Thick brown crepe / No.2X Thin brown crepe

Deliveries must consist of dry, clean rubber light brown in colour.

Discolouration, regardless of cause, specks, sand, or other foreign matter, oil or other stains, or any evidence of oxidation or heat, not permissible.

No.3 X Thick brown crepe / No.3 X Thin brown crepe

Deliveries must consist of dry rubber, brown to dark brown in colour.

Discolouration, regardless of cause, specks, sand, or other foreign matter, oil or other stains, or any evidence of oxidation or heat, strong sour or foul odours, not permissible, except specks of bark of the degree shown in the sample which will not be objected to.

4.1.3 Thin brown crepe (Remills)

These grades are manufactured on power wash mills from wet slab, unsmoked sheets, lump and other high grade scrap generated on estates or smallholdings. Tree bark scrap, if used, must be pre-cleaned to separate the rubber from the bark. Earth scrap and smoked scrap are not permissible in these grades. The rubber is milled to produce crepe in thickness corresponding approximately to the pieces in the sample.

No.1 Thin brown crepe

Deliveries must consist of dry, clean rubber, light brown in colour. Mottled rubber is permitted in the amount as shown in the sample.

Discolouration, regardless of cause, sludge, specks of bark, sand, dirty packing, or all other foreign matter, oil or other stains or any evidence of oxidation or heat, not permissible.

No master or official international sample has been established for this grade.

No.2 Thin brown crepe

Deliveries must consist of dry, clean rubber, light to medium brown in colour. Mottled rubber permitted in the amount as shown in the sample.

Discolouration, regardless of cause, sludge, specks of bark, sand, dirty packing, or all other foreign matter, oil or other stains or any evidence of oxidation or heat is not permissible.

No.3 Thin brown crepe

Deliveries must consist of dry, clean rubber, medium brown to medium dark brown in colour. Mottled rubber is permitted in the amount as shown in the sample.

Discolouration, regardless of cause, sludge, specks of bark, sand, dirty packing, or all other foreign matter, oil or other stains or any evidence of oxidation or heat is not permissible.

No.4 Thin brown crepe

Deliveries must consist of dry rubber, medium dark brown to dark brown in colour. Mottled rubber and small minute specks of bark of the degree shown in the sample will not be objected to.

Discolouration, regardless of cause, sludge, sand, dirty packing or all other foreign matter, oil or other stains or any evidence of oxidation or heat is not permissible.

4.1.4 Thick blanket crepe (Ambers)

These grades are manufactured on power wash mills from wet slab, unsmoked sheets, lump and other high grade scrap generated on estates or smallholdings. Tree bark scrap, if used, must be pre-cleaned to separate the rubber from the bark. Earth scrap is not permissible in these grades. The rubber is milled to produce crepe in thickness correponding approximately to the pieces in the sample.

No.2 Thick blanket crepe (Amber)

Deliveries must consist of dry, clean rubber, light brown in colour. Mottled rubber is permitted in slight degree.

Discolouration, regardless of cause, sludge, specks of bark, sand, dirty packing, or all other foreign matter, oil or other stains or any evidence of oxidation or heat is not permissible.

No master or official international sample has been established for this grade.

No.3 Thick blanket crepe (Amber)

Deliveries must consist of dry, clean rubber, medium brown to brown in colour. Mottled rubber is permitted in the amount as shown in the sample. Discolouration, regardless of cause, sludge, specks of bark, sand, dirty packing, or all other foreign matter, oil or other stains or any evidence of oxidation or heat is not permissible

No.4 Thick blanket crepe (Amber)

Deliveries must consist of dry rubber, brown to dark brown in colour. Mottled rubber is permitted in the amount as shown in the sample.

Discolouration, regardless of cause, sludge, specks of bark, sand, dirty packing, or all other foreign matter, oil or other stains or any evidence of oxidation or heat is not permissible.

4.1.5 Flat bark crepe

This material is produced on power wash mills out of all types of scrap natural rubber in uncompounded form, including earth scrap.

Standard flat bark crepe

The rubber is dry, very dark brown to black in colour and is medium hard to soft in texture.

Sludge, cotton, sand, dirty packing and other foreign matter, except fine bark particles is not permissible.

Heated and discoloured rubber is not permissible.

Due to rapid deterioration of this grade, no master or official international sample has been established.

Hard flat bark crepe

The rubber is dry, very dark brown to black in colour and is manufactured in the form of thick, firm, comparatively tough crepe.

Sludge, cotton, sand, dirty packing and other foreign matter, except fine bark particles of the degree shown in the sample, is not permissible.

Heated and discoloured rubber is not permissible.

4.1.6 Pure smoked blanket crepe

This grade is made by milling on power wash mills smoked rubber derived exclusively from ribbed smoked sheet (including block sheets), or ribbed smoked sheet cuttings. No other type of rubber shall be used, and no non-rubber material shall be added. Rubber of this type is dry, clean, firm, tough, and retains an easily detectable smoked sheet odour.

Sludge, oil spots, heat spots, sand, dirty packing or other foreign matter (except fine bark particles of the degree shown in the sample) is not permissible.

Colour variation from brown to very dark brown is permissible.

4.2 Packing

The thickness of various types of sole crepe, specified by the consumers are 1.5, 3.2, 4.7, 6.3 and 9.5 mm and the size of laminated piece is generally 90 x 30 cm. A variation of 0.4 mm in thickness from the specified, is allowed. The sole crepe after sizing is packed in bales (Plate 64. f). The maximum weight of the crepe in each bale shall be 101.7 kg and the minimum shall be 72.6 kg, except where lower weights are specified in the buyer's contract. The crepe from field coagulum grade is also packed in bales (Plate 64. g) as specified in the Green Book.

5. POWER AND WATER REQUIREMENTS

Power requirement in crepe factories is fairly high. Common drive systems were employed earlier for a battery of crepe rollers and macerators through shafts and gear systems. Estates which were not having electric power connection were using oil engines for generating the driving force. Today all modern factories are using separate drive systems for the individual macerators and crepe rollers. This is helpful in saving power as some of the machinery which are not needed during part of the operation can be switched off without affecting the work in others. In a crepe factory having six pairs of rollers, the requirement of power is approximately 89.52 kW (120 hp) for driving the rollers alone. In some factories electric power is used for drying. Mineral oil-fired driers are also being used.

Water requirement in crepe factories processing field coagulum rubber is substantially higher than that for factories processing fresh latex coagulum. Approximately 40 to 50 L of water per kg is needed in the former whereas for PLC around 30 to 40 L per kg is adequate. Recent studies (Warnakula *et al.*, 1996; Mathew *et al.*, 1998) have shown that the recycling of waste water in PLC factories can reduce fresh water consumption and the quantity of effluent without affecting the quality of the processed rubber.

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